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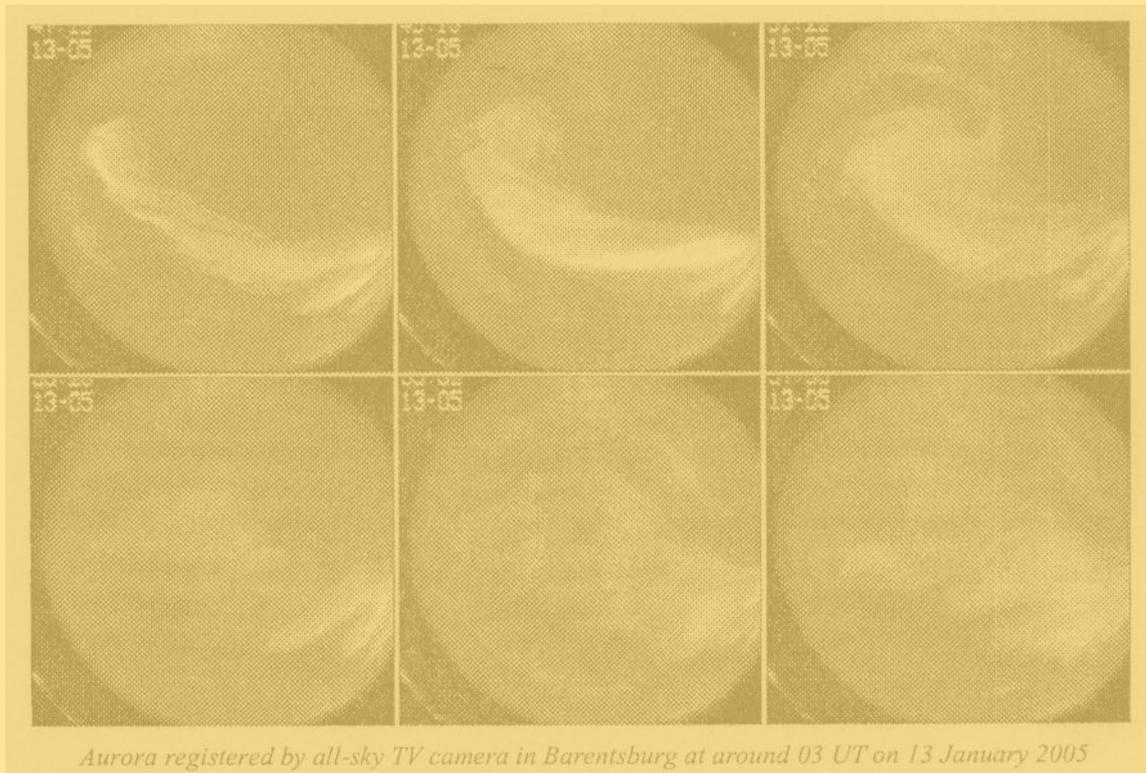
PGI -05-01-119

## **PHYSICS OF AURORAL PHENOMENA**

28<sup>th</sup> Annual Seminar

1 - 4 March 2005

Abstracts



Apatity

2005

*Russian Academy of Sciences*

KOLA SCIENCE CENTER

Polar Geophysical Institute

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The seminar is supported by the  
*Russian Foundation for Basic Research*  
grant 05-05-74002

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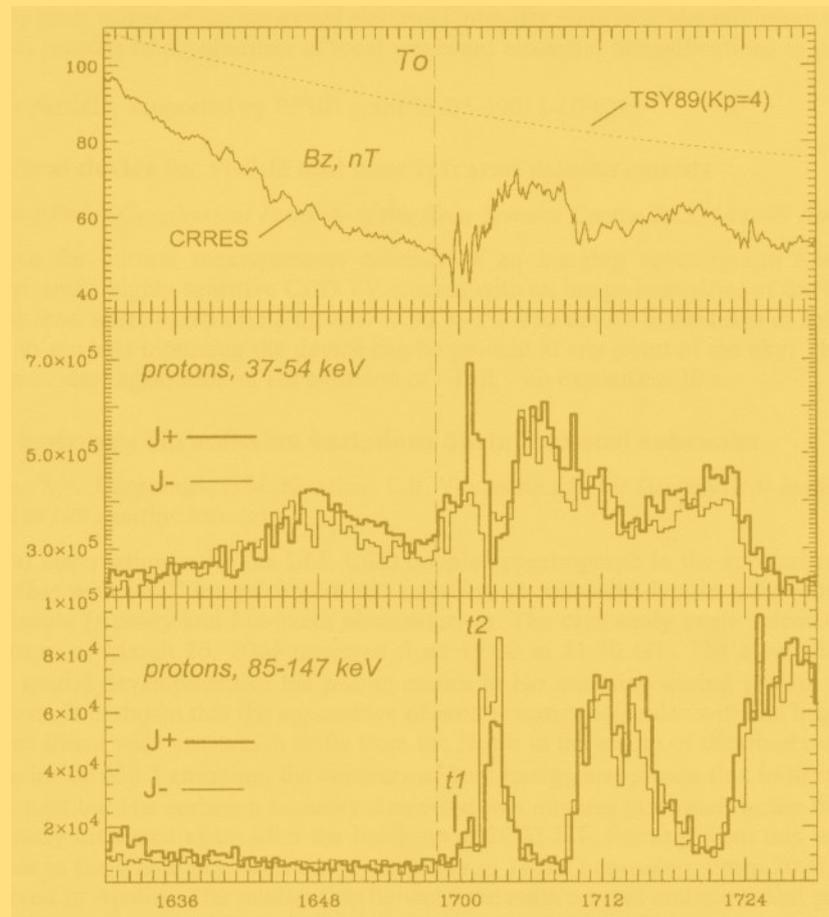
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## Geomagnetic Storms and Substorms





## **Behaviour of the geomagnetic field and aurora during the main phase of storm on November 20, 2003**

D.G. Baishev<sup>1</sup>, G.V. Borisov<sup>1</sup>, V.A. Velichko<sup>1</sup>, S.I. Solovyev<sup>1</sup>, K. Yumoto<sup>2</sup>

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All-sky camera observations at Tixie ( $\Phi'=66.0^\circ$ ,  $\Lambda'=197.5^\circ$ ,  $MLT=UT+16$ ) from 1600 to 2000 UT were used to study the relationships of hard and soft electrons, causing luminosity of discrete and diffuse auroral forms at the main phase of a severe magnetic storm of November 20, 2003. The preliminary analysis showed that compared to the previous estimates of substorm disturbances during the considered storm, the contribution of the auroral discrete forms to the summary light flux exceeds them by a factor of  $\sim 2$ .

To estimate the effect of substorms in the ASY and SYM indices, the magnetic observations of high-latitude CPMN, IMAGE, CANOPUS chain stations have been used. The total intensities of equivalent ionospheric currents were calculated from the IMAGE and CANOPUS data with using the techniques developed by Popov et al. [EPS, 2001]. The lead of the peak values of the westward electrojet intensity relative to the minimum value of the SYMH index is found. Possible reasons of peculiarities of local westward electrojet intensifications in different longitudinal sectors are discussed.

The study was partially supported by RFBR grant 03-05-39011-GFEN.

## **Optical spectral device for visible and near infrared measurements**

L.P. Borovkov (*Polar Geophysical Institute of the Kola Science Centre RAS, 184209 Apatity, Russia*)

Spectral device for auroral measurements consists of an imaging spectrograph SpectraPro-306 of the Acton Research Corp. and a highly sensitive CCD TV camera with an image intensifier of the Princeton Instruments. With Niccor fisheye lens, spectrograph field of view is  $80^\circ \times 1^\circ$ . The device is sensitive in spectral range from 500 nm to 870 nm. Due to gimbals mounting the device can be pointed at any point of the sky. Thermoelectric cooling of the CCD matrix provides registration of  $H\alpha$  emission of  $\sim 10R$  with exposition 30 s.

## **Features of hydrogen $H\alpha$ emission variations during isolated substorm**

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Optical auroral observations with the LLL CCD coupled spectrograph in the spectral range 636.0 - 657.0 nm are analyzed together with I-SIT image camera and scanning photometers data in emissions 427.8, 557.7, 630.0 nm in the Kola Peninsula (Apatity and Lovozero observatories). The case study event selected for detailed analysis is an isolated substorm of March 26, 2004 occurred from 19:30 to 21:30 UT. The scientific purpose was to study the temporal and spatial development of the proton aurora in  $H\alpha$  emission during growth and break-up phases of the auroral substorm. It is shown that the appearance of proton aurora coincides with the beginning of the growth phase, and is observed like a wide arc, which drifts from the North to the zenith of the observation point. According to the measurements in  $H\alpha$  656.3 emission, the contours of both energy and proton flux indicated an increase almost up to the break-up onset but  $H\alpha$  emission intensity decreased two minutes prior and during the break-up. Then hydrogen emission intensity increased again after the break-up at 20.23 UT. Starting from this time, the main auroral forms were rayed arcs in the whole sky, with a sharp increase in 1PGN2 emission. From 20.40 to 21.30 UT proton aurora was not observed in Apatity. The relationship between the main auroral emissions and proton emission intensities is used for estimation of temporal variations in the particle precipitation energy, which has been found to vary from several keV to 30 keV for electrons and several keV to 25 keV for protons.

## **Relationship between the parameters of the auroral bulge in the ionosphere and plasma flow reversal and total pressure decrease in the magnetotail**

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To investigate the relationship between the development of the auroral substorm and magnetotail phenomena, the data from the UV imager onboard Polar have been combined with the data from plasma and magnetic field instruments on Geotail. Some twenty events of tailward-to-Earthward plasma flow reversals in the plasma sheet are selected during intervals of auroral substorms. All reversals are associated with a reduction of the total (magnetic plus plasma) pressure. The total pressure decrease is a measure of the magnetic energy dissipation in the magnetotail, while the auroral bulge area (determined from images obtained at the LHBL passband above a certain level of luminosity) is a measure of the auroral power. It is shown that the value of the total pressure decrease is

proportional to the bulge area, that is, the auroral power is proportional to the dissipated energy in the tail. The poleward latitude of the auroral bulge determined at the moment of the flow reversal is found to be proportional to the distance from Geotail to the Earth. The tailward/earthward flows are observed when the Geotail footprint is poleward/equatorward of the auroral bulge poleward edge. These findings, as well as the fact that the average magnetic flux through the auroral bulge is equal to the average magnetic flux dissipating in the tail lobe during the substorm, are interpreted in terms of reconnection process.

### Decay of the cross-tail current due to the interchange instability

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Magnetic field lines in the cross-tail current are curvilinear. They can become interchange unstable in the regions where plasma pressure drops rapidly enough from the curvature center. At the instability nonlinear stage the plasma sheet desintegrates into hot dense filaments, alternating with cold tenuous plasma features of magnetotail lobe origin. The hot filaments tend to move away from the magnetic line curvature center, i.e. sunward. We have calculated their velocity, which at the ionospheric level appears to be  $v_h = \beta(V_A/4)(l/R)(1 + \Sigma_p/\Sigma_w)^{-1}(B_m/B_i)^{1/2}$  where  $R$  is the curvature radius,  $l$  is the length of the curvilinear segment of the magnetic field line,  $\beta$  is the ratio of plasma pressure to magnetic pressure in the magnetosphere,  $V_A$  is the Alfvén velocity magnetosphere,  $\Sigma_w = 1/(\mu_0 V_A)$  is the wave conductivity,  $\Sigma_p$  is the height-integrated Pedersen conductivity of the ionosphere,  $B_m$  and  $B_i$  are the magnetic fields in the magnetosphere and ionosphere, respectively. The hot structures move with the velocity  $v_h$  in the reference frame of the cold tenuous filaments, which footpoints move antisunward. The cold magnetic tubes eventually reconnect and collapse toward the Earth. This process is accompanied by a decrease in the magnetotail magnetic flux  $F$ . The characteristic time of plasma sheet decay due to instability development can be estimated as  $\tau = \pi r_c(1 + f_c/f_h)v_h$ , where  $r_c$  is the polar cap radius,  $f_c$  and  $f_h$  are the fractions of the cold and hot filaments in the plasma sheet boundary region. Substitution of typical quantities yields  $v_h = 0.1-1$  km/s. Assuming  $f_c = f_h$ , we obtain  $\tau = 3-30$  hours. The geomagnetic effect of the cross-tail current is  $H_{ct} \sim -F^3$ , where  $F$  is the lobe and plasma sheet magnetic flux in the nightside. Thus we obtain the recovery time of geomagnetic disturbance  $\tau_g = \tau/3 = 1-10$  hours which is consistent with the observed time of geomagnetic depression relaxation during storm recovery phase.

### Response of the northern and southern polar caps ground-based magnetic field to IMF

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IZMIRAN electrodynamic model (IZMEM) of geomagnetic variations for northern and southern polar regions was derived from a large amount of high-latitude ground-based geomagnetic data (above  $\pm 57^\circ$  corrected geomagnetic latitude) at all magnetic local times (MLT). At present, a comprehensive database of magnetic data from an array of 16 magnetic stations in Antarctica is available for analysis. We have used the data of polar stations ( $|\Phi| > 80^\circ$ ): P1, P4, P5, P6 (American AGO), Vostok, Sude (Russian stations), Scott Base (New Zealand station) and Dumont D'Urville (French observatory) to obtain a regression model where regression coefficients relate any ground-based geomagnetic field component to changes in the Interplanetary Magnetic Field (IMF) measured near the Earth's magnetosphere:

$$H = K_{By}By + K_{Bz}Bz + H_0,$$

where  $H$  is an hourly value of the geomagnetic field ( $X, Y, Z$ ) component on the Earth's surface and  $By$  and  $Bz$  are the IMF components hourly values. The period with the best data coverage (1997-1998) has been chosen for regression analysis. We have developed a new regression model and performed a comparison of new regression coefficients with those obtained from the data of Antarctic magnetic observatories and automatic magnetometers about 25 years ago (IZMEM model, the period 1978-1984). The regression coefficients  $K_{By}(\Phi, MLT)$  and  $K_{Bz}(\Phi, MLT)$  for the same latitudes of the northern and southern hemispheres have been compared as well. There are noticeable variations of  $K_{By}(\Phi, MLT)$  and  $K_{Bz}(\Phi, MLT)$  for the stations of longitudinal profile along geomagnetic latitude  $\sim 80^\circ$ : P1, P4, SBA.

This study is supported by INTAS grant No : 03-51-5359

## Statistical relationship of SAR arc dynamics to substorms and storms

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It is known that midlatitude red arcs (SAR arcs) are related to magnetic storms, which are determined by a variation in the Dst geomagnetic index. According to the mechanism of SAR arc generation proposed by Cole [1965, 1970], these arcs appear during the main phase of a magnetic storm in the process of auroral disturbance development. The Cole generalization agreed well with the results of SAR arc observations available at that time. Subsequently, after the theoretical study by Cornwell et al. [1971], it was established that SAR arcs are formed at the storm recovery phase.

At present, the concept dominates that SAR arcs are associated with the recovery phase of a magnetic storm [Kozyra et al., 1997]. However, satellite investigations performed in 1980-1990 sometimes indicated that energetic particles of the ring current penetrate into the outer plasmasphere during the main phase of a magnetic storm and/or during individual substorms [Kozyra et al., 1993, 1997]. The results of the synchronous measurements at plasmaspheric and ionospheric altitudes onboard the DE 1 and DE 2 satellites clearly showed that a SAR arc can be observed at the latitudes of the projection of the cold plasma density radial gradient inside the plasmasphere [Brace et al., 1988; Horwitz et al., 1986]. It was shown in [Ievenko, 1993, 1995, 1999] that a SAR arc appears and/or becomes brighter during the phase of substorm expansion. A SAR arc starts to form in the region of the equatorial boundary of the diffuse aurora (DA). At the recovery phase of intense substorms at SAR arc latitudes, luminosity pulsations are usually observed in the 427.8 nm  $N_2^+$  emission due to pulsating precipitations of energetic particles from the outer plasmasphere [Ievenko, 1995]. In the case of a prolonged substorm activity, a SAR arc separates from DA and moves equatorward [Ievenko, 1999].

The present paper analyzes the statistical relation of the 630.0 nm [OI] emission intensity in the SAR arc and the velocity of its equatorward motion to the geomagnetic activity indices Dst, ASYM, AL, and KP at current Dst values of up to -135 nT during weak and moderate magnetic storms. The study is based on 700 h of spectrophotometric observations of SAR arcs at the meridian of Yakutsk in 1989-2000. In particular, it has been obtained that a statistically significant positive correlation between the arc intensity ( $\log(I)$ ) and the ring current appears in the region of Dst values  $\leq -50$  nT. The dependences of  $\log(I)$  on the geomagnetic indices ASYM, AL, and Kp are significant in the data samples where the current values of Dst are  $\geq$  and  $\leq -50$  nT. This, most likely, indicates that the contribution of the asymmetric ring current arising during the phase of substorm expansion to the generation of SAR arcs is considerable. The latitudinal distribution of the observation rate of SAR arcs at the meridian of Yakutsk is normal and is mainly governed by the Dst variation. The distribution has a half-width of  $\sim 6^\circ$  with a median at the corrected geomagnetic latitude of  $\sim 55^\circ$  N ( $L = 3$ ). It is assumed that the interval of latitudes where SAR arcs are observed during weak and moderate storms is a statistical mapping of the region of L shells of the outer plasmasphere, into which the developing ring current penetrates during substorms at  $Kp = 3-5$ . The observations at the Yakutsk meridian seem to be consistent with the conclusion made by Cole [1965] that SAR arcs are associated with auroral activity at the beginning of the main phase of a magnetic storm.

## Wave signature of the recovery phase of the November 2003 superstorm

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Very large-amplitude Pc5 geomagnetic pulsations in the morning sector in the recovery phase of the huge November 2003 magnetic storm have been studied using the ground multi-point observations. The pulsations were recorded in an unusually wide range of latitudes (more than  $10^\circ$ ) with the same very strong amplitude (up to 500 nT) and with the same polarization. There were two main spectral enhancements: at  $f \sim 2$  mHz and at  $f \sim 3$  mHz. Only  $\sim 3$  mHz pick was clearly seen in the spectra of pulsating auroral radio absorption data observed by Scandinavian riometer chain. Short and localized bursts of Pi1C ( $f \sim 50-100$  mHz) geomagnetic pulsations and simultaneous short bursts of energetic electron precipitation (imaging IRIS riometers data) were observed in the morning sector. The beginning of the large-amplitude morning Pc5 activity was accompanied by a substorm onset in the evening sector. The spectra of the ULF pulsations on the ground have been compared with spectra of IMF and solar wind parameter variations, measured by ACE (240, 22, -15 Re) spacecraft. A similarity between morning Pc5 and By IMF spectra was found, but the spectra of solar wind number density variations were similar to the spectra of evening Pi3 pulsations. The Pc5 and Pi1C pulsations, as well as the bursts of auroral radio absorption, suddenly ceased when solar wind number density abruptly dropped in the end of the magnetic cloud. We suppose that  $\sim 2$  mHz Pc5 geomagnetic pulsations could be attributed to field line resonance (FLR), however,  $\sim 3$  mHz oscillations were, apparently, of non-resonance origin. Both,  $\sim 2$  and  $\sim 3$  mHz wave packets were initiated by impulsive solar wind density enhancements. The

obtained results were compared with the similar observations in the recovery phase of the October 2003 superstorm ("Halloween event").

### **Numerical modeling of auroral electrojet during geomagnetic disturbances**

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Numerical modeling of auroral electrojet behavior during geomagnetic disturbances has been performed based on the Global Self-consistent Model of Thermosphere-Ionosphere-Protonosphere system (GSM TIP) developed in WD IZMIRAN. The simulation comprises not only the traditional blocks of the model, such as the thermosphere, bottom ionosphere, F region of the ionosphere, external ionosphere and protonosphere, in which the key parameters of the near-Earth thermal plasma are calculated. A new feature is that instead of calculation of the electric fields of dynamo and magnetospheric origin, a new block is added, in which along with calculation of spatial distribution of large-scale electric field potential, the calculation of zonal current density in the ionosphere is included.

In the old version of the model the 3D current continuity equation in the ionosphere was reduced to the 2D equation by integration over the height of the current-carrying ionospheric layer with the subsequent numerical integration of the resulting elliptic - type partial derivative equation. In the new model this integration is performed along the geomagnetic field lines lying in the current-carrying layer of the ionosphere.

Within this modified model, the effect of the enhanced during geomagnetic disturbances Region 1 field-aligned current, as well as polar cap potential drop (which are model inputs), in the auroral electrojet distribution is calculated. Both quasi-stationary solutions and time evolution of the auroral electrojet during geomagnetic disturbances are obtained. It is shown that the simulation results are in a rather good qualitative and quantitative agreement with the observations.

### **An event of individual polar cap arc generation: 07.03.2002 case study**

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Though polar cap auroral arcs have been studied for many years, they are still an extremely surprising phenomena. Sunward oriented arcs appear at time intervals of positive IMF Bz, when auroral zone activity is strongly suppressed, but arc intense spatial – temporal dynamics and noticeable brightness definitely demonstrate high energy dissipation, compatible with energetics of auroral breakup. Nowadays a common viewpoint is that polar cap arcs are generated on the closed magnetic field lines crossing plasma sheet (plasma properties above arcs and in plasma sheet are identical), but this opinion contradicts some experimental data. We have analyzed a rare case of isolated individual polar cap arc generation on the basis of Barentsburg TV data, satellite imagery, and space magnetic field measurements in the solar wind and magnetotail. A polar cap arc was formed (split off) from an auroral oval arc, rapidly (with the speed of over 10 km/sec) developed northward, and then it slowly (150 m/sec) traveled through Barentsburg TV camera field of view from east to west. It is important to note that before and after the arc generation irregularities in the southern mother arc moved at different speed and in opposite direction (about 1 km/sec from west to east). So, the polar cap arc was completely separated from the oval arc. At the moment of arc generation GEOTAIL detected a fast transformation of the local magnetic field from closed configuration to the open one. Our hypothesis is that polar arc generation can be explained in the framework of disconnection process (inverse to the well-known reconnection). In other words, some local, crossing plasma sheet magnetic tubes become open, move towards magnetosphere border together with plasma sheet particles containing in them, and create polar cap aurora.

### **Some common features of auroral breakups fine structure**

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More than 60 breakups have been investigated using a new method of TV data processing together with satellite auroral images and space magnetic field data. We studied fine subvisual details of spatial and temporal dynamics of auroral arcs and surrounding diffuse luminosity both in longitudinal and latitudinal directions. Our conclusions are the following:

1. With the exception of large-scale breakups, when a substorm can spread over the whole auroral zone, auroral activations typically occupy rather small fractions of the oval. Satellite images show that the activity can cease in one place and appear in another, continuously and stochastically - looking like traveling along the oval. But TV observations demonstrate that complicated azimuthal motions of different subvisual auroral forms connect areas of aurora activations. This suggests a patchy-type reconnection pattern in the tail. That is, there usually exist not a single neutral line across the tail but several spatially limited, sequentially appearing and closely interacting ones.
2. We have found many examples of breakup stimulation by auroral structures moving from the north towards the pre-breakup region, provided the conditions formed in this region by the previous or nearby auroral activity are favorable. This finding implies that a breakup is not a result of separately taken processes setting up either in the tail reconnection region or in the near magnetosphere. A breakup is a result of close interaction between these processes, and the peculiarities of the interaction are determined both by the magnetospheric conditions existing at the moment and history of previous activity.

### **Structure and dynamics of auroral intensifications inside the double oval: Substorm of December 26, 2000**

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We present an investigation of the fine structure and dynamics of auroras observed during the substorm on December 26, 2000, when auroral distribution had a form of the double oval. Simultaneous auroral TV observations at high-latitude observatory of Barentsburg, auroral zone observatory of Lovozero and global auroral images from IMAGE spacecraft have been used.

It is shown that in the course of substorm development, auroral behaviour suggests an interaction between the processes occurring in the magnetospheric regions, magnetically conjugated with the poleward and equatorward edges of the double oval. It was found that 30-40 minutes prior to the substorm onset, weak subvisual structures periodically appeared poleward of the highest-latitude arc, they moved toward the equator and intensified the aurora at the polar edge of the double oval. At the same time, weak pulsating arcs registered at the Lovozero latitude moved poleward and activated the discrete auroral forms at the poleward edge of the auroral oval. In turn, 15 minutes before the substorm onset, subvisual structures emerged occasionally at the polar edge of the auroral oval, drifting from the north-east to the south-west and approaching the pre-breakup arc. Simultaneously, weak pulsating arcs split from the pre-breakup arc and drifted poleward. Their contact with the subvisual structures moving from the north is probably associated with breakup triggering at the Lovozero latitude. Just after the breakup onset, luminosity inhomogeneities moved in the west-east direction along the pre-breakup arc.

Thus, the peculiarities of the fine structure and dynamics of aurora during substorm development in the double oval may signify a close relation between the processes in the inner plasma sheet and magnetospheric midtail. Their combined interaction results in the substorm onset.

### **Characteristics of proton precipitations evaluated from ground-based PGI optical data**

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The results of coordinated optical ground-based observations of the auroral substorm on March 26, 2004 in the Kola Peninsula are described. The data of imaging spectrograph with high spectral and temporal resolution allows us by the Doppler profile of the H $\alpha$  hydrogen emission to estimate the variations of average energy of precipitating protons and the proton emission intensity. Two different populations of precipitating protons have been observed during the considered event. One was a diffuse proton precipitation that is usually observed in the evening sector of the auroral oval and located equatorward from the discrete electron precipitation. The average energy of the protons during this precipitation made  $\sim 20$ -35 keV, the energy flux  $\sim 3 \times 10^{-4}$  Joule/m<sup>2</sup>s. The other proton precipitation was detected 1-2 minutes after the breakup, during 4-5 minutes of substorm expansion into the zone of bright discrete auroral structures (N-S arcs). The average energy of the protons during this precipitation was  $\sim 60$  keV, the energy flux  $\sim 2.2 \times 10^{-3}$  Joule/m<sup>2</sup>s. An interpretation of optical observations, as well as any indirect method of diagnostics, is usually based on a theoretical model. The theoretical frameworks for proton-hydrogen atom flux transport in the Earth's atmosphere and for the excitation of hydrogen emissions are discussed.

## Polar geomagnetic pulsation response to very strong solar wind density at the initial phase of the magnetic storm (April 16, 1999)

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The multi-point ground observations including Antarctic network have been analyzed to study long period (1-5 mHz) geomagnetic pulsations generated as a response to the very dense (up to  $\sim 60 \text{ cm}^{-3}$ ) turbulent front edge of the interplanetary magnetic cloud impact with the Earth's magnetosphere. That impact led to moderate ( $Dst \sim -80 \text{ nT}$ ) magnetic storm development. The strong solar wind number density (dynamic pressure) produced a strong compression of the dayside magnetosphere in the magnetic storm initial phase with  $Dst \sim +60 \text{ nT}$ . The geostationary GOES-8, located near noon, crossed the magnetopause several times. The constructed GLAT-MLT Pc5 amplitude distribution maps indicate a dependence of local time polar Pc5 pulsation dynamics on the By IMF sign. The unusual characteristic of this storm initial phase was the Pc5 range geomagnetic pulsation excitation not only at polar cap latitudes, but inside the closed magnetosphere as well. The appearance of the latter was associated with solar wind dynamic pressure pulses.

The analysis of the magnetic Pc5 range pulsations at Antarctic and Arctic stations showed the asymmetry between the Northern and Southern polar cap location. Before and after noon the latitude spectral profile was different. The spectra of ground pulsations were not coincident with the spectra of fluctuations in the solar wind and IMF. The near-noon Pc5 pulsation spectra on the ground at the longitude of GOES-10 footprint did not exhibit a similarity with GOES-10 data. However, some Pc5 spectra likeness was found between near-noon GOES-10 data and ground observations at the stations located in the afternoon and morning sectors. At that time there were no fluctuations either in the IMF or solar wind density, IMF Bz and By being close to zero. We assume that the polar geomagnetic pulsations, observed on the ground, represent the fluctuations associated with a magnetopause hydromagnetic turbulence (Kelvin-Helmholtz instability?) as a response to the very strong solar wind dynamic pressure. The different wave packets demonstrate their different nature. The polar cap pulsations could be related to the NBZ field-aligned currents, the closed magnetosphere Pc5 pulsations might be a result of field line resonance (FLR) or cavity mode wave excitation.

This study was supported by the Grant № 03-51-5359 of INTAS and the Grant №03-05-64670 of the Russian Foundation for Basic Research.

## The problem of geomagnetic activity assessment

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Geomagnetic field disturbance scale is called geomagnetic activity and currently is described by special geomagnetic indices. Among them there are those referring to local geomagnetic disturbances (*K*-indices); those describing global geomagnetic field perturbations (*Kp*-index); indices indicating magnetic disturbance intensity caused by different current systems (*Dst*- index follows the dynamics of the magnetospheric ring current, *AE*, *AU*, *AL*-indices show auroral electrojet dynamics, *PC*-index describes the electric field over the polar caps). Being induced a long time ago, these indices are not capable of describing the real geomagnetic activity on the Earth's surface for a day, a week, a month or a year. Undoubtedly, they are capable of reflecting temporal dynamics of geomagnetic field variation amplitudes but they refer to great disturbances occurring only during one tenth of a year. Based on geomagnetic activity indices, it is impossible to find the real quantitative proportion between geomagnetic activity levels in different intervals of magnetospheric disturbances. It is difficult to quantify the geomagnetic activity either. In our view, the real geomagnetic activity is described by the total energy of geomagnetic variations distributed over the Earth's surface. The analysis of geomagnetic activity described by *Kp*-index shows that statistical maxima around equinoctial months in the annual variation of *Kp*-activity are caused by the annual variation of magnetic storm numbers. During the main phase of magnetic storms, *Kp*-index observatories fix the magnetic field of auroral electrojets shifted southward to subauroral latitudes, that provides *Kp*-index high amplitudes. These high amplitudes cause activity maxima around equinoctial months. The geomagnetic activity has been estimated based on model calculation of the energy of the large-scale geomagnetic variations using IZMEM model obtained from correlation of ground-based geomagnetic data with solar wind parameters. The annual variation of the geomagnetic activity averaged for 1996 – 2003 does not practically change during different seasons of the year. A model geomagnetic activity for different activity zones, such as the polar cap and the auroral oval, during October and November 2003 major magnetic storms is discussed.

This study is supported by INTAS grant No : 03-51-5359

## Solar wind control of magnetospheric energetics during magnetic storms

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The magnetosphere energy budget is calculated as  $Us = Uj + Uc + Udr + Ut$ , where  $Uj$  is Joule heating in the high-latitude ionosphere,  $Uc$  - power of auroral precipitation,  $Udr$  - ring current energization,  $Ut$  - plasma sheet energization. We have calculated the magnetosphere energy budget for four magnetic storms in 1998: March 10-12 ( $Dst = -116$  nT), May 02-07 ( $Dst = -205$  nT), August 26-28 ( $Dst = -205$  nT), September 24-26 ( $Dst = -207$ ). Correlation between  $Us$ ,  $Uj$ ,  $Uc$ ,  $Udr$ ,  $Ut$  and solar wind parameters are analyzed. To our knowledge, there is no adequate procedure of magnetosphere energy budget calculation yet. All known procedures are based on rough approximations and calculation results,  $Uj$ ,  $Uc$ ,  $Udr$ ,  $Ut$ ,  $Us$  may differ from real values several times, and it is impossible to estimate calculation accuracy. It is nontrivial to fix the energy input for the magnetospheric budget. As no direct means to measure the energy input are known, various solar wind-derived proxies have been developed.  $Uj$ ,  $Uc$ ,  $Udr$ ,  $Ut$ ,  $Us$  equations contain quantities which are functions of solar wind parameters. Depending on the data sets used, underlying assumptions, and time-scales under consideration, different functions have turned out to have better or worse correlation during different events or under different statistical approaches. We have analyzed the most widely used energy input function, the so-called parameter of Akasofu  $\varepsilon$ , characterizing power coming into the Earth's magnetosphere from the interplanetary medium. On the basis of correlation  $Uj$ ,  $Uc$ ,  $Udr$ ,  $Ut$ ,  $Us$  with solar wind parameters we have proposed a new function  $\varepsilon'$  similar to  $\varepsilon$ . It is established that  $\varepsilon'$  and  $\varepsilon$  have identical correlation properties with  $Uj$ ,  $Uc$ ,  $Udr$ ,  $Ut$ ,  $Us$  but  $\varepsilon'$  has more transparent physical meaning.

As known now, the geomagnetic activity is described by special geomagnetic indices, which quantify temporal scale of geomagnetic variation amplitudes only. But, in our idea, the real geomagnetic activity is described by the total energy of geomagnetic variation generated by magnetospheric and ionospheric current systems in the near-Earth space. To estimate the activity of magnetospheric current systems two following methods can be suggested: a) to estimate the energy of the magnetic field generated in the near-Earth space using the modern models of the magnetospheric currents systems such as the paraboloid model, Tsyganenko model, Maltsev model etc.; b) to estimate the magnetic energy of geomagnetic field variations on the ground from observations or model distribution of these variations (IZMEM model). Then it will be possible to introduce a geomagnetic activity index that is more precise than the classical ones and which can be used for more realistic classification of geomagnetic activity level. The energy of the ground geomagnetic variations during October and November, 2003 major magnetic storms has been estimated using the IZMEM model.

This study is supported by INTAS grant No : 03-51-5359

## Effect of substorms during a superstorm of 29-31 October, 2003

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Iyemori and Rao [Ann. Geophys., V. 14, No 6, P. 608-618, 1996] showed that magnetic storms intensify only during substorm growth phase, while at substorm expansion phase the storm enhancement is slowing down. Panasyuk et al. [Kosmicheskiye Issledovaniya, 2004, V. 42, No 5, P. 509-554], when studying the superstorm at the end of October, 2003, cast doubt on the result of Iyemori and Rao. We have examined the: same substorms as mentioned by Panasyuk et al. [2004], and shown with a one-minute resolution that the effect of Iyemori and Rao takes place for this storm as well.

## Strongly non-linear evolution of a baroclinic-type interchange perturbation in a substorm site

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Efforts of numerous studies are directed toward finding an internal magnetospheric instability that could lead to substorm onset within the inner plasma sheet. We have performed a simulation of time evolution of baroclinic interchange perturbation in the near-geosynchronous region for post-midnight MLT hours for the time period after Bz IMF northturn. It is shown that in the background field-aligned current (FAC) of  $\sim 10^{-6}$  A/m<sup>2</sup>, the non-linear regime for a small initial perturbation in  $pV^\gamma$  ( $p$  the plasma pressure,  $V$  the magnetic tube volume,  $\gamma$  the adiabatic exponent), set as a ripple somewhat inclined to azimuth, is achieved by the 6<sup>th</sup> minute. Starting from this time, the perturbation exhibits irregular deformation, developing front steepening and undulations. An interesting peculiarity in the distribution of accompanied small-scale FACs is that they are always asymmetric. Specifically, the downward FAC is strongly localised. At the non-linear stage, it reaches great local intensities (up to  $15 \times 10^{-6}$  A/m<sup>2</sup>) and has rather regular distribution. The counterpart FAC, outflowing from the ionosphere and identified in the present study with the onset arc, is always more dispersed and distorted. We present simulation results for a variety of equilibrium parameters and initial perturbations, and discuss the role of non-adiabatic processes, such as magnetic tube heating in the region of the upward FAC, in the non-linear evolution of the onset arc.

### **Reconstruction of nightside flux transfer events using Cluster data**

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A Petschek-type model of magnetic reconnection is used to describe the behaviour of nightside flux transfer events (NFTEs). Based on the Cagniard-deHoop method, we calculate the magnetic field and plasma flow time series observed by a satellite. The reconstruction of the reconnection electric field is an ill-posed inverse problem, which we treat with the method of regularisation, since the Cagniard-deHoop method yields the solution in the form of a convolution integral, which is a well-known problem in the theory of inverse problems. This method is applied to Cluster measurements on September 8, 2002, and August, 13, 2002, when a series of earthward propagating 1-min scale magnetic field and plasma flow variations, consistent with the theoretical picture of NFTEs, were observed. The techniques of estimating the satellite position with respect to the reconnection site as well as the Alfvén velocity (both are the model parameters) are presented. In order to improve the accuracy of the model, we extend the consideration for compressible plasma. The first results of theoretical modelling in the compressible case are presented.

### **An investigation of near-equatorial geomagnetic Pi2 pulsations**

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Now it is commonly accepted that Pi2 pulsations have two sources. One is a high-latitude source associated with fluctuations in electrojet intensity. The other source is a mid-latitude one driven by a global mode excited in the Earth's plasmasphere. There is observational evidence that in the near-equatorial regions the Pi2 excitation differs from that in high and mid-latitudes. In this connection, we investigated the amplitude-spectral-polarization characteristics of Pi2 pulsations using the data of near-equatorial Chinese stations. The revealed regularities in the excitation of the near-equatorial Pi2 pulsations have been used to detect a possible physical mechanism responsible for generation of these pulsations.

### **Interactive database of PGI observations with auroral scanning photometers**

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Polar Geophysical Institute has provided the observations of aurora with scanning photometers during several winter seasons since 1997. The observations at Lovozero and Barentsburg stations have been accompanied by simultaneous special campaigns for tomography reconstruction. However, the data, not converted to an available format, were not widely used in geophysical studies. Now we are revising the old data files and data calibrations, and preparing a database of daily scanograms with interactive access from INTERNET. We kindly thank all the members of the PGI staff who participated in making the equipment and providing the observations during all these years.

### **Shock structures and magnetic field behavior in the time-dependent Petschek-type model of magnetic reconnection for a moving reconnection line**

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In the time-dependent Petschek-type model of magnetic reconnection, the outflow region is bounded by shocks which propagate with the outflowing plasma in opposite directions after reconnection ceased. In general, the reconnection X-line is assumed as stationary. Various spacecraft observations in the Earth's magnetotail give rise to the assumption of a tailward directed motion of the reconnection-line. Due to these observations a model for non-steady X-line behavior as extension of the time-dependent model of Petschek magnetic reconnection is presented.

The behavior of the shock, as well as the corresponding magnetic field variations are discussed. Examining the shock structure, a strong asymmetry in the shape appears between oppositely propagating shocks, depending on the velocity of the X-line. The magnetic field inside the outflow regions also exhibits this asymmetry as follows from comparing the magnetic field inside oppositely moving outflow regions. For the magnetic field evaluated in the inflow regions, the typical bipolar behavior around each shock is maintained, but an asymmetry in the field strength appears as differs from the model with a steady X-line.

### Quantitative proof of the loading-unloading substorm scheme

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The goal of the paper is to compare the magnetotail magnetic flux  $F$  at substorm onset with the magnetic flux through the auroral bulge at substorm maximum  $F_{\text{bulge}}$ . The quantity  $F$  was calculated for 200 substorms observed by Geotail spacecraft in 1995-1998 using our empirical model, expressing the lobe magnetic field and tail radius at substorm onset via the solar wind dynamic pressure, one hour averaged merging electric field  $E_m$  and spacecraft position. It turned out that the  $F$  value depends only on the merging electric field value and so may be calculated using only  $E_m$  measurements. Thus, the computed  $F$  values were compared with the quantity  $F_{\text{bulge}}$ , calculated from Polar UVI images. The study of 40 substorms showed a good consistency between the magnetic flux stored during the substorm growth phase and the magnetic flux through the corresponding auroral bulge. We conclude:

1. The total magnetotail magnetic flux at substorm onset linearly depends on the merging solar wind electric field. An empirical formula linking  $F$  and  $E_m$  quantities is obtained.
2. For individual substorms the flux through the auroral bulge  $F_{\text{bulge}}$  is almost equal to the flux stored during the growth phase  $\Delta F$ , making  $\sim 85\%$  of its value. This result quantitatively confirms the loading - unloading substorm concept.
3. Correspondence of the quantities  $F_{\text{bulge}}$  and  $\Delta F$  confirms that the auroral bulge is the ionospheric projection of the reconnection region.

### The character of geomagnetic and auroral response to solar wind dynamic pressure variations and the dynamics of particles injected into the magnetosphere

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Variations of geomagnetic field, aurora and fluxes of injected energetic particles into the Earth's inner magnetosphere during the increase of solar wind dynamic pressure ( $P_d$ ) are studied using ground-based and satellite observations. It is shown that there exist three types of geomagnetic and auroral response to  $P_d$  variations different in velocities of azimuthal propagation of disturbance and extension of luminosity region along the auroral oval. The velocities are  $V_1 \sim 30-40$  km/s,  $V_2 \sim 10$  km/s and  $V_3 \sim 1,0$  km/s. An increase in  $P_d$  leads to an enhancement of DP2 current system, to the northward extension of the polar boundary of auroral oval in the night sector and either to simultaneous injection of energetic electrons from the evening sector to the morning one or particle drift from the midnight meridian.

It is supposed that three types of responses of auroral particle precipitation and related phenomena reflect the interaction processes of MHD-waves, surface waves at the magnetopause (compression waves) and electromagnetic waves in the ULF-range with the particles of earlier trapped magnetospheric plasma and their pitch-angular diffusion.

The study was financially supported by grant 03-05-39011 RFBR-NNSF of China.

### Auroral electrojet development and equatorward diffuse aurora boundary dynamics during magnetic storms in October-November 2003: the relation of Dst and SYM – indices

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The relationship between substorm development, low-latitude magnetic bays, SYM and Dst-indices, equatorward diffuse aurora boundary dynamics and solar wind parameter variations during magnetic storms on October 29 and 30 and November 20, 2003 has been studied. The analysis is based on the data of global high-latitude geomagnetic observations, longitudinal chains of low-latitude stations at latitudes  $\Phi \approx 10-50^\circ$  and TV observations of aurora at Zhigansk ( $\Phi \approx 61^\circ$ ).

The results suggest that the source of positive variations in the SYM-H index is intensification of the eastward electrojet during a substorm at  $\Phi' \approx 40-50^\circ$  as well as the eastward currents on the magnetopause and in the low-latitude ionosphere during the periods of enhanced solar wind dynamic pressure and DP2-current system. The source of Dst is the westward currents at  $\Phi' \approx 10-30^\circ$  in all MLT sectors with a maximum intensity in the evening sector. Therefore, SYM-H is not an analogue of Dst, which is determined by other stations with lower latitude.

It is shown that a sharp increase in Dst is accompanied by intense substorms which initial center is located at  $\Phi' \approx 55^\circ$ . H-component variations in  $\Phi' \approx 10-30^\circ$  at 17-24 MLT exhibit a rather good correlation with changes in the solar wind dynamic pressure and the latitude of equatorward boundary of the diffuse aurora and a weaker correlation with IMF Bz and Esw. The possible reasons of Dst enhancement are discussed.

The study was financially supported by grant 03-05-39011 RFBR-NNSF of China.

### **Dynamics of the storm-time ring current**

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The ring current dynamics during strong magnetic storms has been studied using the data of low-altitude satellite measurements of tens keV protons and the data on the boundaries of solar proton penetration into the magnetosphere ( $\Lambda_b$ ). A noticeable dawn-dusk asymmetry in the latitude position of  $\sim 50$  keV proton intensity maxima during the storm main phase was observed. The quasiperiodicity on the time scale of several hours is a feature of storm-time ring current particle injection. The hysteresis type behavior relative to  $D_{st}$  characterizes the dynamics of solar protons boundaries  $\Lambda_b$ . The distinction in  $\Lambda_b$  at the main and recovery storm phases, if measured relative to the same  $D_{st}$  level, may be as large as  $5^\circ$  of invariant latitude. Most probably this effect is due to the partial ring current formation during the storm main phase.

### **Critical exponents of magnetospheric dynamics**

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Magnetospheric response to solar wind fluctuations is typically accompanied by multiscale temporal and spatial auroral disturbances exhibiting broad-band self-similar statistics (Uritsky et al., 2002; 2003). Such behavior has been recently associated with self-organized criticality (SOC) of the magnetotail plasma sheet (Klimas et al., 2004). In the present study, we summarize observational signatures of SOC magnetospheric dynamics by providing an extensive set of critical exponents evaluated using high-resolution POLAR UVI images collected in the LBH-long frequency range. In particular, we present the avalanche exponents characterizing probability distributions of energetic particle precipitation events, growth and roughness exponents controlling fractal evolution of global patterns of auroral luminosity, and spreading exponents representing ensemble-averaged dynamics of auroral emission area and power output. The provided values are discussed in the context of differentiating between several alternative mechanisms of the multiscale geomagnetic response. It is shown that the measured exponents and their mutual relationships are in agreement with SOC scenario which links scale-free auroral activity to multiple localized reconnections in the tail, but seem to be inconsistent with other nonlinear effects such as MHD turbulence, low-dimensional chaos and high-dimensional stochastic evolution of extraterrestrial plasma parameters.

### **1-m irregularity flows during energetic particle precipitations**

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The STARE coherent radars are a powerful instrument for studying the auroral zone plasma irregularities and convection. Using the ion-acoustic approach (IAA, Nielsen and Schlegel, 1985) and the off-orthogonal fluid approach (Uspensky et al., 2003; 2004), one can reasonably predict the true electron drift velocities for the majority of time. However, there is a recurring atypical class of events, which is quite far outside of a careful description or study. That is the  $\sim 1$ -hour long morningside (sometimes multiple) events, when during extensive energetic particle precipitation, the ion flow measured by EISCAT becomes nearly opposite in the direction to the irregularity flow measured by STARE. We call this phenomenon the irregularity counter flow (ICF). There are two facts related to the ICF events: (a) no simple/known explanations how E-layer irregularities can run nearly opposite to  $\vec{E} \times \vec{B}$  flow and, (b) ICF events, unfortunately, cover intervals when the convection structure itself is an object of special interest and a related referring to the STARE flow signatures should be done with extra care. In the present study we describe a few such events and collect/discuss the ideas/contradictions, which can be important for understanding the ICF events.

## Electron precipitation power during substorm: DMSP F6 and F7 spacecraft observations

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Auroral boundary positions and average electron precipitation flux in different regions obtained from the observations of DMSP F6 and F7 spacecraft have been used to examine the electron precipitation power during all substorm phases. The power contribution was found for an average substorm of about 400 nT intensity in all 3-hour sectors of MLT and separately for three different auroral regions: diffuse auroral zone (DAZ), structured auroral oval precipitation (AOP) and soft diffuse precipitation (SDP) poleward of the AOP. It is shown that there is a significant increase in precipitation power both on the day and night sides of the Earth during the substorm growth phase from the quiet level of about 0.7 GW to 1.2 GW in the 09-12 MLT sector and from about 0.8 GW to 2.6 GW in the 21-24 MLT sector, respectively. On the dayside the greatest energy is allocated in the DAZ in the final stage of substorm recovery phase. In pre-noon the maximum makes about 1.8 GW. On the nightside the greatest precipitation power is registered in the AOP during the final stage of substorm expansive phase with the maximum of about 15 GW in the pre-midnight. The shape, not concerning the value, of precipitation power distribution versus MLT strongly depends on substorm phases. In the DAZ region the peak in precipitation power occurs in the 06-09 MLT sector. In the AOP region the electron precipitation is more powerful on the dayside than on the nightside, while the opposite is held in the SDP region. One hemisphere global precipitation power was found to be about 9 GW, 19 GW and 61 GW for the quiet level, in the final stage of substorm growth phase and at the end of substorm expansion, correspondingly. Our database of DMSP F6 and F7 observations makes it possible to calculate the average precipitation power for all substorm phases and any substorm intensity as determined by the AL index.

## Dependence of the intensity and southern boundary of H $\alpha$ hydrogen emission on the AE-index

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On the eve of the International Heliogeophysical Year (2007-2008), a statistical study of H $\alpha$  hydrogen emission relation to the AE-index of geomagnetic activity has been conducted based on the data of the patrol spectrograph, observatories Murmansk and Loparskaya. The auroral observations for the periods of both high solar activity (IGY, September-April 1958-1959, 1959-1960, 1960-1961) and low solar activity (IYQS, September-April 1963-1964, 1964-1965, 1965-1966) were used. It was shown that nearly linear dependence takes place between the mean intensity of H $\alpha$  hydrogen emission (within the interval from 0.2 kR to 1 kR) and AE-index under the relatively low values of the AE-index. The mean value of the maximum H $\alpha$  emission shift is displaced linearly southward from 64°Ф to 60°Ф) with AE-index increasing from 0 to 1000 nT. The behavior of H $\alpha$  intensity and its southern boundary versus the AE -index is the same under different solar activity.

## Комплексная классификация *Dst*-вариации

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Объектом настоящего исследования являются глобальные геомагнитные ситуации в магнитосфере. Они находят свое отражение во временной динамике характерных всплесков *Dst*-индекса. Для этого исследуются интервалы времени, когда магнитосфера взаимодействует с крупномасштабными потоками солнечной плазмы. Полагается, что источниками таких потоков являются конкретные проявления солнечной активности – вспышки, корональные дыры, активизировавшиеся волокна (протуберанцы), корональные выбросы масс и их сочетания. Принято, что исследуемые конфигурации *Dst*-вариации содержат в себе информацию об этих источниках и специфике прохождения Земли через распространяющийся от Солнца крупномасштабный плазменный поток. Таким образом, анализируется возможность классификации временной структуры *Dst*-индекса на основе параметров солнечного ветра и межпланетного магнитного поля (ММП) с привлечением сведений о солнечной активности, которая способна отразить участие в созданной структуре указанных выше источников потоков солнечной плазмы. Для этой цели применяется метод искусственных нейронных сетей (ИНС), позволяющий на основе нелинейной корреляционной обработки экспериментальных данных проводить интеллектуальное разделение входных образов на классы. Особое внимание уделяется предположениям о природе классов описывающих ситуации в солнечном ветре и ММП. В результате постановки численных экспериментов удалось выделить основные классы комплексов возмущенных параметров, отвечающих разным событиям космической погоды, каждый из которых отвечает соответствующей глобальной магнитосферной ситуации.

Работа поддержана грантом РФФИ N03-05 6513.

## Изучение связи между ионосферной конвекцией и термосферной циркуляцией в условиях магнитных бурь

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В работе исследуются количественные характеристики влияния магнитосферных источников энергии и импульса на ионосферу и термосферу во время магнитных суббурь. Геомагнитные условия в представленных в работе расчётах соответствуют магнитным бурям 6 марта 1976 ( $K_p$  индекс достигал 8 и имел два выраженных максимума), 29-31 октября 2003 и 20 ноября 2003.

Уравнения модели состоят из уравнений массопереноса и теплопереноса нейтральных и заряженных частиц и уравнения непрерывности электрического тока [1]. Уравнение потенциала электрического записывается в виде системы уравнений. Система полученных уравнений интегрируется в сферической системе координат конечно-разностным методом на прямоугольных сетках с параметрами: число узлов по высоте, кошироте и долготе – 45, 50 и 24, соответственно, шаги по времени от 10 до 30 минут.

При расчётах использовались эмпирические модели для продольных электрических токов, текущих между магнитосферой и ионосферой и для потоков авроральных электронов выпадающих из магнитосферы в ионосферу. Второстепенные параметры электронного и нейтрального газа даются из моделей IRI90 и MSIS86. Расчёты проводились в два этапа. На первом этапе вычисления выполнялись для спокойных условий до установления, а на втором - в условиях суббури. Для выявления эффектов реакции плазмы на возмущение проводился гармонический анализ ветровой системы по долготе.

Расчёты, показывают, что реакция термосферной циркуляции на магнитную суббурю происходит с некоторой временной задержкой относительно ионосферной конвекции. Эта задержка составляет 0.5 - 1 час для полярной ионосферы и становится большей с ростом кошироты, а эффекты нарушенного ионосферного динамо наиболее существенны, когда магнитная буря становится более слабой. Изучены также зависимости реакции циркуляции от интегральной амплитуды АЕ индекса и от временной структуры суббури. В частности выяснен уровень нелинейности реакции термосферной циркуляции для условий с двумя максимумами возмущения, как, например, для условий магнитной бури 6 марта 1976.

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## Применение современных Internet-технологий для организации удаленного доступа к геофизическим данным

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В работе рассмотрены вопросы структурного построения и технической реализации системы сбора, регистрации и предобработки потоков геофизических данных, разработанной для obs. Ловозеро ПГИ КНЦ РАН. Система сбора, обработки и передачи данных представляет собой трехзвенную архитектуру, включающую в себя аналого-цифровые преобразователи, сервер синхронизации и передачи данных и центральный сервер хранения и обработки данных.

*Аналого-цифровые преобразователи* (АЦП) представляют собой группу измерительных устройств, соединенных с ПК. Цифровой сигнал, поступающий от измерительного устройства на принимающий компьютер, проходит стадию первичной обработки данных, включающую в себя сглаживание сигнала. Полученные таким образом данные передаются на сервер синхронизации и передачи данных, соединенный с одним или несколько АЦП в локальную сеть.

*Сервер синхронизации и передачи данных* представляет собой программно-аппаратный комплекс, выполняющий функции синхронизации и передачи данных и включающий в себя следующие компоненты:

- *ПК*, выполняющий функцию первичного накопления данных, поступающих от АЦП и функцию передачи данных на центральный сервер хранения и обработки данных;
- *GPS-приемник*, устройство, позволяющее проводить синхронизацию системного времени с мировым временем (UTC);
- *GPRS-модуль*, устройство GPRS, позволяет организовать канал передачи данных в сети GSM на основе технологии GPRS.

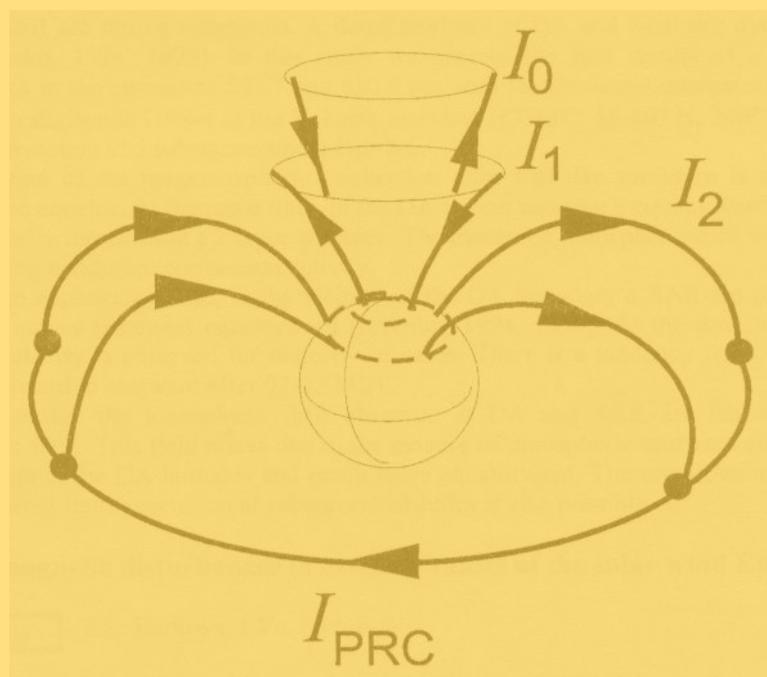
Программное обеспечение сервера делает возможным организовать на сервере центр синхронизации времени для всех АЦП, связанных с сервером в локальную сеть. Применение технологии GPRS связано с

возможностью организации канала передачи данных на расстоянии до 35 км. от базовой станции, что характерно для удаленных метеостанций и обсерваторий. Особенности данной технологии не позволяют организовывать двустороннюю передачу данных без использования специального программного обеспечения. Применение такого программного обеспечения в комплексе со специально разработанным ПО, обеспечивающим восстановление канала в случае разрыва соединения, позволяет сделать доступным сервер синхронизации и передачи данных извне, что необходимо для удаленного управления, как сервером, так и АЦП.

*Центральный сервер хранения и обработки данных* выполняет функции сбора и хранения данных, поступающих от серверов синхронизации и функцию вторичной обработки данных, что необходимо для структуризации данных с последующим размещением в единой базе данных (БД). Использование БД позволяет организовать единый центр хранения данных, поступающих от всех АЦП, входящих в систему сбора данных. Применение программного обеспечения для организации WWW-сервиса позволяет осуществлять оперативную публикацию данных, хранящихся в БД в сети Интернет.



*Fields, Currents, Particles in the magnetosphere*





## **The penetration of the magnetospheric convection electric field to subauroral latitudes as inferred from observations of the diffuse aurora, SAR arc and ionospheric drift**

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At present the attention of many researchers is focused on the phenomenon that is called a "polarization jet". It manifests during substorms as a narrow band of plasma drift in the westward direction at the height of F2 layer with the velocity up to 2 km/s and more frequently in the vicinity of the plasmapause projection. For the first time this phenomenon was detected during measurements of the ionospheric plasma drift in the evening MLT sector by "Cosmos-184" [Galperin, 1974].

At the same time, it is known that the magnetospheric convection electric field penetrates to the middle and low latitudes during intensified geomagnetic activity. The regularity of penetration of the electric field convection to plasmapause projection latitudes under  $K_p=1-5$  was shown from the measurements of ionospheric drifts by the incoherent scatter radar in Millstone Hill [Wand, 1981]. Lyatskaya and Kuznetsov [1990] found the relation of the height dynamics of regular ionization layer F2 (azimuth component of the electric field) at the middle latitudes to an increase in the IMF southern component. Ievenko et al. [2001] revealed the recurring features of the penetration of the convection electric field to plasmasphere latitudes in the dynamic of F2 layer ionization in the diffuse aurora (DA) region and SAR arc during substorms. A detail analysis of DA and SAR arc dynamics during substorms is presented in [Ievenko, 1994, 1999]. In this study we present the first results of a comparison of subauroral luminosity dynamics in the emissions 557,7 and 630,0 nm with simultaneous measurements of ionospheric drift in the F2 region with a digisonde DPS-4 at the Yakutsk meridian (CGMC: 55-60° N 200° E) during intensification of magnetospheric convection and substorms under  $K_p=2-6$ .

1). Intensification of the magnetospheric convection after IMF  $B_z$  southturn is well manifested in the DA extension toward the equator. At the same time, in the DA region and much equatorward of the DA, the ionospheric westward drift velocity increases at F2 layer altitudes. The measured ionospheric drift velocities amount to 600 m/s ( $E=30$  mV/m) during maximum convection activity.

2). At substorm expansion phase, in the vicinity of the DA boundary a SAR arc (or the red luminosity band) forms which then moves (extends) equatorward [Ievenko, 1994, 1999]. At the time, a decrease in the westward ionospheric drift velocity is observed for majority of cases. There is a tendency for a change of ionospheric drift direction from westward to eastward after 02-03 MLT.

3). We suggest that the ionospheric drift observed at DA and SAR arc latitudes can be caused by the polarization electric field. This field arises due to the closure of ionospheric eastward current to the Region 2 field-aligned currents both at the DA latitudes and much more equatorward. The contribution of DP 2 system spreading currents to polarization field generation at subauroral latitudes is also possible.

## **Relation of geomagnetic disturbances to extreme values of the solar wind $E_y$ -component**

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The effect of the azimuth component of the solar wind electric field in the geomagnetic indices AE, AP,  $K_p$ ,  $K_n$  and Dst is studied for two types of phenomena: (1) magnetic clouds and (2) high-speed streams.

It is established that for  $E_y < 12$  mV/m the AE, AP,  $K_p$ ,  $K_n$  indices are directly proportional to  $E_y$  and for  $E_y > 12$  mV/m they are inversely proportional to  $E_y$ . In opposite, the Dst index correlation to  $E_y$  always has the same sense. It is characterized by saturation in the range of great values of  $E_y$ . The peculiarities of geomagnetic activity response to changes in the interplanetary medium are related to manifestations of a specific mechanism responsible for saturation of the ionospheric electric potential in the polar cap.

It is found that magnetic clouds and high-speed streams containing azimuthal electric fields comparable in value with the southward IMF  $B_z$  cause geomagnetic disturbances of nearly the same intensity.

## **Self-similarities on small scales of aurora and location of associated SOC system**

B.V. Kozelov (*Polar Geophysical Institute, Apatity, Murmansk region*)

Recently it was found from POLAR satellite data [Uritsky et al., 2002] and from the ground-based observations [Kozelov et al., 2004] that the characteristics of the auroral intensifications on the night side of the auroral zone demonstrate extremely wide ranges of power-law distribution. On small scales the ranges are limited by several  $\text{km}^2$  in spatial domain and by  $\sim 1$  second in the temporal one. The power-law distributions are a strong support of the existence of self-organized critical (SOC) state in the magnetosphere-ionosphere plasma. Usually the SOC-like models are associated with dynamics of current sheet in the magnetosphere tail. However, small-scale auroral

## ***Fields, currents, particles in the magnetosphere***

intensifications (such as "curls") are possibly associated with the near-Earth acceleration region. The structure and location of possible SOC system are discussed.

### **Dynamics of low energetic ions and electrons near substorm onset**

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Substorm associated behavior of the low energetic particles (30 eV – 28.5 keV) near the earthward edge of the plasma sheet is examined using the CRRES observations during the late growth and early expansion phase of a substorm on March 12, 1991. Magnetic field data at CRRES and ground auroral and magnetic field observations are also used in the analysis. This event is a sequence of optical pseudo-breakups and breakup above Scandinavia near the latitude of  $\sim 62^\circ$ . The substorm develops with a chain of activations. Large expansion of the substorm begins 7 min after onset. In the substorm, the CRRES was located near the Earthward edge of the plasma sheet,  $\sim 20^\circ$  to the west from the meridian of Kilpisjarvi observatory.

In the magnetosphere at  $L \sim 6.3$ , during stretching of magnetic field lines, CRRES detected two populations of particles: (a) the Alfvén layers of low-energy (0.28- 1.88 keV) electrons, where lowest energy particles appear first, and 1- 7.31 keV ions, and (b) the outer boundary of the previously trapped electrons (7.31 – 16.5 keV) and ions (9.6-28.5 keV), where higher energy particle fluxes decrease first.

At the substorm onset an injection of electrons with the energy of 7.31-12.6 keV was observed. An injection of more energetic electrons 12.6 – 21.7 keV occurred at the moment of large expansion. Prior to a more energetic injection, two electron bursts (100 s) associated with an increase in the magnetic field fluctuations were observed. Three small bursts (100-120 s) were registered in the fluxes of ions (0.633-12.6 keV) with a quasi-period of 3-4 min. The ion bursts occurred 1-2 min before the electron bursts. We discuss a significance of these findings for substorm onset mechanism. A conclusion is made that the observations support the idea of the ballooning instability near the inner edge of the plasma sheet as a mechanism responsible for initiation of the substorm onset.

### **Auroral arcs in the regions of large-scale downward currents**

A. Kozlovsky (*Sodankylä Geophysical Observatory, Sodankylä, Finland*)

It has long been known that auroral arcs appear due to splitting of large-scale upward field-aligned currents (FAC) into narrower current sheets. In such cases, the narrow sheets of the upward FAC (carried by down-going electrons) are associated with the auroral precipitations forming arcs. However, auroral arcs can exist in the regions of downward FAC, too. In the later case, the arcs may be expected to be associated with sheets of downward currents. We suggest that this can occur due to the magnetospheric interchange instability in combination with the current sheet (Kelvin-Helmholtz) instability. As a result of these two instabilities, filaments of upward FAC and corresponding auroral structures can be embedded in a sheet of downward FAC, forming rayed auroral arc. In particular, this mechanism should be important in the morning sector where the large-scale Region 1 (R1) FAC occurs. We present the EISCAT radar and Polar satellite observations made in the vicinity of pre-noon high-latitude auroral arcs on Svalbard, which indicate that some arcs were associated with downward current sheets indeed.

### **Correspondence between ULF wave activity, field-aligned currents, UVI images, and dayside magnetospheric regions**

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We have developed a technique for studying simultaneously the ULF activity in the Pc5 frequency band, field-aligned currents (FAC), auroral images, and dayside magnetospheric regions. The FACs are derived from the Orsted satellite magnetic data, and ionospheric projections of the dayside magnetospheric regions are obtained from DMSP charged particle flux measurements. The distribution of the ULF spectral power is inferred from the Greenland coastal array of geomagnetic stations. This technique produces a latitudinal profile of the FAC distributions and ULF wave power with overlaid DMSP tracks and Polar UVI images. Various examples of the correspondence between the ULF wave activity, field-aligned currents, UVI images, and dayside magnetospheric regions are discussed.

This research was supported by grant 03-05-64670 from the Russian Foundation for Basic Research.

## **Incoherent scatter radar observations in the vicinity of dayside auroral arcs**

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A combination of EISCAT incoherent scatter radar measurements, optical and magnetometer data is used to study the plasma in and around pre-noon structured precipitation and auroral arcs. Particular attention is paid to regions of comparatively low E region density observed adjacent to arcs / structured precipitation in the EISCAT Svalbard radar field-aligned measurements. It is shown through comparison between luminosity and incoherent scatter electron density measurements that the low density regions occur due to the absence of diffuse (CPS-like) precipitation rather than to any cavity formation process. Regions of high electric field and low luminosity / conductance are observed prior to intensification of the structured precipitation. The ionospheric current is enhanced in the low conductance region, indicating that the strong electric fields do not result only from ionospheric feedback, and thus are driven by magnetospheric processes. The average energy of the precipitating electrons in the arcs and structured precipitation is according to EISCAT measurements 500 eV, and the energy spectra arc similar for the FLR and shielding cases. The average energy is thus significantly less than in the diffuse precipitation region which show CPS like energy spectra. The magnetospheric region or plasma population behind the arc formation thus appear to be related to the boundary plasma sheet (BPS) or low-latitude boundary layer (LLBL). It is suggested that the low ionospheric conductance is favorable for the arc formation process, which results in response to the dynamics of BPS /LLBL plasma in the magnetosphere.

## **The search of Region 1 field-aligned currents in the magnetosphere**

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We use two databases [Fairfield et al., 1994; Tsyganenko et al., 2003] for finding electric currents in the magnetospheric polar regions where the Region 1 field-aligned currents are presumably located. The external magnetic fields are fitted as a sum of sine and cosine of the longitude and are then averaged in spatial bins in coordinates of  $\rho$  and  $z$ , where  $\rho$  is the cylindrical distance. After smoothening and differentiating the magnetic fields we find the distribution of electric currents at distances  $3 < |z| < 10 R_E$ ,  $\rho < 10 R_E$  under various levels of geomagnetic activity.

## **Current sheets in space plasma**

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Current sheets are widely spread objects in the space plasma. They exist in the interplanetary space, in magnetospheric tails of the Earth and other planets, in the tails of comets. The current sheet magnetic field provides energy storage for solar flares and coronal mass ejection. The important features of a current sheet are plasma flow along the sheet and the normal magnetic field component. On the basis of numerical experiments, space measurements and laboratory experiments it is possible to make conclusions about current sheet generation and its dissipation, including the role of magnetic lines reconnections. The current generation in planetary and comet magnetospheres takes place in the boundary layers due to solar wind flow across the magnetic field. This current is closed in the current sheet. The  $j \times B/c$  force in the sheet determines the plasma flow along the sheet. Apparently, during steady state conditions a neutral line in the Earth tail current sheet exists in a distant tail and slow reconnection provides weak plasma flow to the Earth. At the beginning of a substorm the neutral line appears at distance of 20-30 Earth radii, In the fast reconnection set up by instability plasma inflow into the current sheet can not compensate plasma ejection along the sheet in both directions, and the current sheet becomes narrow. Current sheet decay is not associated with the instability. It occurs at the crossing of the heliospheric current sheet due to the reconnection on the sub solar neutral line.

### **Auroral activity and global interplanetary magnetic field asymmetry**

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We have studied the auroral activity as a function of the azimuthal IMF component. The variation of the auroral brightness depends on season. Mean aurora is systematically increased when IMF is directed to a certain heliospheric sector. The position of this sector changes with season. We considered the behaviour of the auroral activity versus IMF orientation in the heliographic inertial system (HGI). The obtained asymmetry in the activity distribution can particularly explain the seasonal variation of aurora.

The IMF distribution in the HGI system was also obtained. We can state the presence of a global heliospherical asymmetry in the IMF distribution. The heliosphere has a sector where the average IMF magnitude is reduced. The IMF magnitude is systematically larger when IMF is directed to the northern hemisphere.

### **Particle precipitation during SC events**

A. V. Roldugin, V. C. Roldugin, Y. P. Maltsev, and A. A. Ostapenko (*Polar Geophysical Institute, Apatity*)

The night sky TV observations during four SC events have been analyzed. A bright discrete auroral form appeared to arise equatorward of the auroral oval and to drift eastward for several minutes. Pre-existing auroral forms become brighter after SC. Geosynchronous satellites detected a decrease in the  $>2$  MeV electron flux during these events. A possible cause of the precipitation is an enlarged loss-cone of the magnetic tube during SC, so that some of the particles appear inside the loss-cone and precipitate.

### **Relativistic Electrons in the Earth's Magnetosphere, Main Geomagnetic Indices and ULF parameters**

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The splashes of energetic electron flux at the geostationary orbit during the period 1987 -1995 are analyzed and the cross-correlation of the electron flux with the main space weather parameters, such as solar and geomagnetic activity, IMF and solar wind parameters, is studied for different phases of the solar cycle. Special attention is paid to the interrelation between the electron splashes and ULF activity in space and on the ground. The ULF index indicates a high positive correlation with the electron flux for the whole period of observations. This result supports the scenario of electron acceleration up to relativistic energies by Pc5 pulsations (so-called magnetospheric cyclotron). The influence of spectral and spatial distribution of Pc5 power on the efficiency of electron acceleration is also analyzed.

### **Statistical analysis of fast flapping motions in the magnetotail observed by Geotail**

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Intense and fast flapping motions of the magnetotail current sheet are analysed based on magnetic observations from Geotail spacecraft during 2,5 years in 1996-1999. Orientation of the local normal to the current sheet was evaluated using the minimal variance analysis technique. Based on a large number ( $>1000$ ) of events we confirmed that the local current sheet normal is varied mostly in the YZ plane as consistent with kink oscillations determined previously from Cluster analysis. We show and discuss a number of new results, including the enhanced occurrence of flapping oscillations in the pre-midnight magnetotail, as well as variations of their occurrence rate, characteristic time scale, etc. with the radial distance.

### **Characteristics of precipitating particle fluxes in auroral torch structures**

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The results of comparison of precipitating particle fluxes on the basis of two satellite passages DMSP-F6 (30 January 1984) and DMSP-F7 (1 April 1984) in the vicinity of the auroral torch structures are presented. The footpoint of the satellite in the first case crossed the torch structure from the foot to the crest whereas in the second case the footpoint passed over the equatorward depression of diffuse auroral near the auroral structure (omega-structure). It was shown that in both cases the torch structures appeared in the region of large-scale inverted V-structures on the diffuse and discrete auroral particle precipitation boundary. In both cases discrete precipitation was

caused by the fluxes of the particles with energies close to  $\sim 1$  keV. The difference between the two cases was in the number flux of precipitating particles. The flux of electrons in the crest of the torch in the first case was about 1-2 orders higher than in the second case (in the omega-structure). A possible cause of torch development may be injection of accelerated electron cloud coming from the magnetospheric tail during the recovery phase of substorm, the particles precipitate at distance of 5-10  $R_E$ , from the Earth at the diffuse/discrete precipitation boundary. The intensification of precipitating particle flux would lead to strengthening of field-aligned current and to the heating of plasma in a certain flux tube. The heated flux tube would emerge farther tailward forming a torch structure that drifts eastward due to the large-scale electric field of magnetospheric convection directed equatorward in the morning sector. The injection of the accelerated electron clouds may be periodical, which can produce a train of torches.

### **Structure and dynamics of daytime auroral precipitation during magnetic cloud event on January 13-14, 1988**

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Meridian scanning photometer (MSP) and all-sky camera observations at Heiss Is. ( $\Phi=75.0^\circ$  N,  $\Lambda=145.2^\circ$  E and  $MLT=UT+4.7$ ) from 2200 UT on January 13 to 1200 UT on January 14 were used to examine the daytime aurora behavior during magnetic cloud event. Ion drift velocity and electron precipitation data with DMSP F7 and F8 spacecraft have been studied for comparison with auroral features. It is found that during a quiet period before SSC at 2330 UT on January 13, the auroras consisted of two different zones divided by a luminosity trough of about  $2^\circ$  in latitude. The poleward zone 1 contained faint auroral arcs. The equatorward zone 2 was located at  $68^\circ-72^\circ$  CGL and associated with 6-8 keV precipitating electrons. The zone 2 was continuously registered by MSP in 557.7 nm emission for several hours with significant variations in the intensity. A sharp enhancement in the auroral luminosity of both zones was observed just after SSC. However, the luminosity trough was filled in with bright auroras 5 min later. The zone 2 is connected with the central plasma sheet (CPS) precipitation. The boundary between CPS and BPS (boundary plasma sheet) types of precipitation occurred on the poleward fall in the auroral luminosity. The zone 2 coincided well with the broad region of the sunward ionospheric convection. The convection velocity had a maximum near the CPS-BPS boundary. Sharp small-scale peaks of the solar convection in zone 1 were in a good agreement with the location of auroral arcs. A broad distinct 630.0 nm dayside auroral band of about 1-2 kR in the intensity was observed continuously at 74-80 CGL in 06-12 UT time interval, when the northward interplanetary  $B_z$  was about 20-25 nT. Large-scale variations in the red auroral luminosity correlated very well with those in the solar wind dynamic pressure.

The study was supported by the RFBR grants 05-05-64353. The authors acknowledge the support from the Division of Physical Sciences of the Russian Academy of Sciences (program DPS-18).

### **Long-term behavior of the magnetotail stretching and dependence on interplanetary and geomagnetic conditions**

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D.A. Yahnin (*Faculty of Physics, St-Petersburg State University, St-Petersburg, Russia*)

It is known that the stretching of the magnetic field lines in the near-Earth magnetotail is characterized by the latitude of the precipitation boundary, on which the energy flux of ions with energy above 3 keV is maximum. This boundary, called  $b_{2i}$ , is routinely determined from low-orbiting DMSP satellite particle data by the Auroral Particles and Imagery Group at JHU/APL. The lower  $b_{2i}$ , the more stretched is the magnetic field. We used  $b_{2i}$  values, which are publicly available at the JHU/APL website, along with interplanetary and geomagnetic activity data from the OMNI database for years 1984-2004 (the interval spanning solar cycle 22 and most of solar cycle 23) for investigation of the long-term evolution of the magnetotail stretching. It is found that annual average of  $b_{2i}$  has pronounced variations during the two solar cycles. Maximal  $b_{2i}$  values (more dipole-like magnetosphere) are found in 1987 (near the minimum of solar cycle 22) and in 1996 (near the minimum of solar cycle 23). Minimal  $b_{2i}$  value (more stretched magnetosphere) is found in 1991 near the maximum of solar cycle 22, but in 2000 (maximum of cycle 23) the  $b_{2i}$  minimum is not distinct. In contrast to the behavior of  $b_{2i}$  during the declining phase of the preceding cycle, a strong decrease of the latitude is observed in 2002-2003. Such variations of  $b_{2i}$  are in agreement with the behavior of interplanetary parameters which also demonstrate an "anomalous" behavior in 2002-2003. The best correlation of the magnetotail stretching is found with annual average of the merging electric field. A more stretched magnetotail means more intense cross-tail current in the near-Earth region and, consequently, a higher level of geomagnetic activity. This explains the high correlation ( $|r|>0.8$ ) between annual average of  $b_{2i}$  and geomagnetic activity indices  $K_p$ , AE, and Dst. The correlation is higher than that between the indices and interplanetary parameters. It is also found that  $b_{2i}$  depends on the season. Monthly averaged  $b_{2i}$  values exhibit distinct minimum in March and October. This agrees with the well known equinox increase of geomagnetic activity.

## **Characteristics of the auroral torch-like structures as seen from the Polar spacecraft**

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Characteristics of luminosity patches at equatorial edge of the auroral oval during a prolonged interval of auroral activity are considered using the data from UV Imager onboard the Polar spacecraft. The typical size of the luminosity patch is  $n \cdot 100$  km, the life time is 10-70 minutes. These structures are observed in a wide longitudinal sector (22-04 MLT) with the occurrence peak at MLT=01. Generally, they move along the auroral zone to the East (West) in the post (pre) midnight sector. The average velocity of the movement is about 0.5 km/s. Comparison of these characteristics with features of auroral structures observed from the ground by all-sky cameras enables us to conclude that the patches seen from Polar arc images of the so-called auroral torch-like structures.

Global images from Polar enable us to connect the generation of the patches with auroral streamers propagating from poleward edge of the auroral oval to its equatorial boundary. The patches appear in the region of contact of the streamers with equatorial part of the oval. Typically, the streamers disappear after the contact, but the patches grow and start to move along the auroral zone.

## **Double Star initial results of magnetotail current sheet**

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Double Star Program (DSP) is the first Chinese space science mission. The mission, in cooperation with ESA, consists of two spacecraft with carefully designed orbits to coordinate with CLUSTER mission for important conjunctions. The first Double Star satellite, known as TC-1 which comes from Chinese abbreviation of "Explorer 1", was launched on December 29, 2003 into a nearly equatorial orbit with an apogee just about 13  $R_E$  and a perigee altitude of 570 km. The second satellite, TC-2 was launched six months later on July 24, 2004 into a polar orbit with an apogee of 7  $R_E$ . Double Star, together with CLUSTER spacecraft, enable us to make the simultaneous multi-point, multi-scale observations in many key magnetospheric regions. In this paper, we present some initial results of magnetotail current sheet from the DSP mission and we discuss the possible future studies using DSP and ground based observations.

## **Моделирование поляризационного джета с использованием самосогласованной модели движения плазмы во внутренней магнитосфере.**

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“Поляризационный джет” (PJ) - локализованная по широте (~1 град.) и MLT (~3 часа) область усиленного электрического поля в вечернем секторе внутренней магнитосферы (L~3-5), обычно наблюдающаяся во время суббурь. Скорость дрейфа плазмы в ионосфере в полосе PJ соответствует ~1-5 км/сек, что соответствует напряженности электрического поля в ионосфере 50-200 мВ/м.

Возможно, что развитие поляризационного джета вызывается усилением конвекции горячей плазмы во внутренней магнитосфере при увеличении потенциала электрического поля поперек полярной шапки.

Произведено численное моделирование нескольких “сценариев” возникновения PJ с использованием самосогласованной модели движения плазмы во внутренней магнитосфере. Самосогласованность в данном случае понимается следующим образом: движение плазмы в электрическом и магнитном полях (“поперечные” дрейфовые токи) вызывает генерацию продольных токов; продольные токи, замыкаясь через ионосферу, влияют на картину электрических полей; электрическое поле влияет на движение плазмы. Магнитное поле в данной модели полагается постоянным во времени.

Полученные результаты модельных расчетов сопоставлены с экспериментальными данными по наблюдениям поляризационного джета.

## **Активные эксперименты в космосе**

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Начало активных экспериментов в космосе связано с ядерными взрывами в атмосфере. Затем начались эксперименты с ускорителями заряженных частиц. Несколько позже - с магнитными или электрическими антеннами волн различного диапазона.

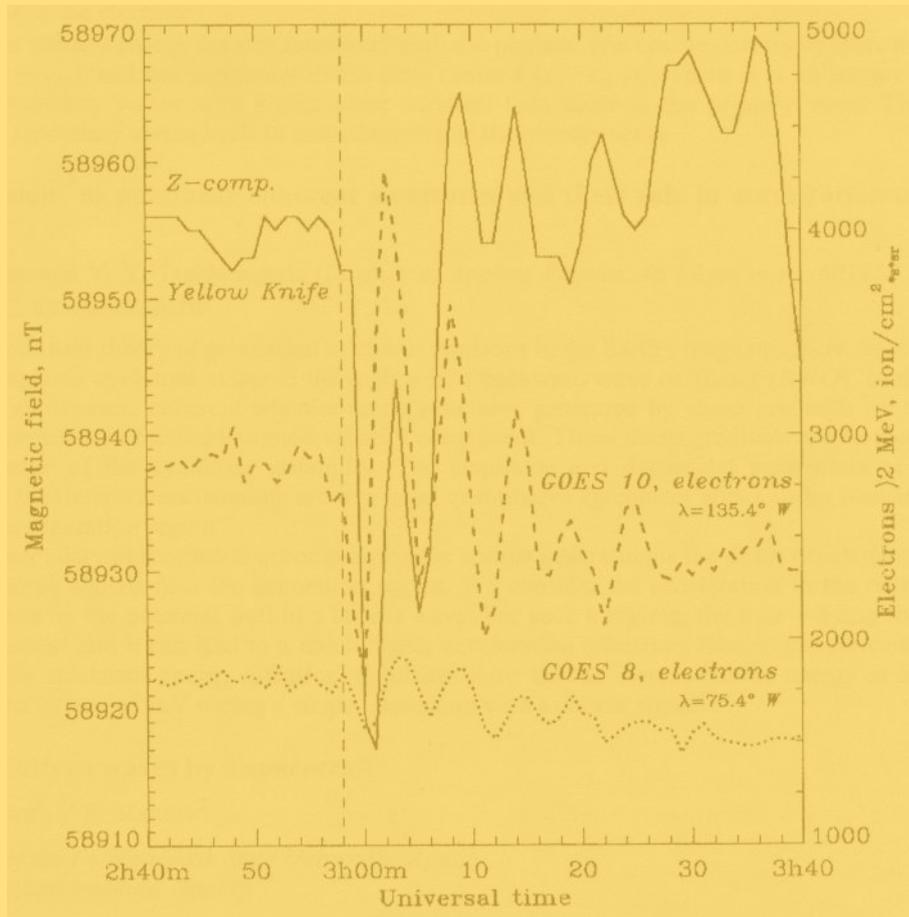
Почти одновременно начались эксперименты по изучению Альфвеновской ионизации при помощи выпуска газа. Несмотря на различные типы активных экспериментов, процессы в плазме очень похожи: нагрев

плазмы, появление электрических полей и токов, ускорение частиц, возникновение КНЧ-ОНЧ и альфвеновских волн.

В докладе будет приведена краткая история всех типов активных экспериментов, а также показаны некоторые различия в окончательных результатах при проведении активных экспериментов.



# Waves, Wave-Particle Interaction





## Damping of waves due to non-linear interaction with resonance particles

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We consider a monochromatic Langmuir wave with the potential  $\varphi = \varphi_0 \cos[k(x - v_{ph} t)]$ , where  $\varphi_0$  is the amplitude,  $k$  the wave number,  $v_{ph}$  the phase velocity. With regard to the wave, propagating in a hot plasma with velocity distribution function  $f(v)$ , electrons can be divided into two sorts: the passing ones and the trapped ones. The trapped electrons oscillate in the potential wells. If at the initial moment the derivative  $\partial f / \partial v$  in the vicinity of  $v = v_{ph}$  is negative, after half a period of the oscillations this derivative becomes positive, and, thereby, the total energy of the particles increases. Then from the energy conservation, it follows that the wave energy drops. This is the physical meaning of the Landau damping. In the next half-period the derivative  $\partial f / \partial v$  turns negative again, the particle energy falls and the wave energy grows. Such oscillations will most likely damp until a plateau in the distribution function is formed. The width of the plateau is equal to  $2v_1$  where  $v_1 = [2e(\varphi + \varphi_0)/m]^{1/2}$ ,  $e$  and  $m$  being, respectively, the charge and mass of the electron.

We examine the electric charge density associated with the plateau. The charge density appears to be  $\rho = -e f_{pl} 2v_1$ , where  $f_{pl} = f(v = v_{ph})$ , and has harmonics of the form  $\cos[m k(x - v_{ph} t)]$ , where  $m$  is an integer. These harmonics can generate secondary waves with higher wave numbers than those in the primary wave. The transmission of energy into the secondary waves leads to extra damping of the primary wave.

## Chorus emissions as nonlinear coherent structures and their role in acceleration of radiation-belt electrons

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We present a nonlinear theory of generation of chorus emissions in the Earth's magnetosphere, based on the operation of the magnetospheric cyclotron maser in the regime of a backward wave oscillator (BWO). In this regime, chorus signals appear as dynamic coherent whistler-mode structures generated by sharp gradients on the distribution of radiation-belt electrons in the field-aligned velocity component. These sharp gradients are formed self-consistently at the initial stage of the cyclotron instability. The amplitude and dynamical parameters of coherent signals, following from theoretical consideration, are in a good quantitative agreement with Cluster measurements of chorus emissions in the generation region.

An important secondary phenomenon accompanying the chorus generation is the direct acceleration of radiation-belt electrons by chorus signals near the generation region. We consider the acceleration in the regime of trapping of resonant electrons by the potential well of a chorus wave. For such a regime, the time-varying frequency of chorus elements is essential and it can lead to a much higher acceleration efficiency than in the conventional acceleration regime due to the stochastic energy diffusion. Estimates show that an increase in the energy of a resonant electron can reach several to tens of keV during a single interaction with a chorus signal.

## Radiation of Alfvén waves by a spacecraft

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Electric field  $\mathbf{E}_i = [\mathbf{v} \times \mathbf{B}]$  is induced in a body moving with the velocity  $\mathbf{v}$  across the magnetic field  $\mathbf{B}$ . With an insulator, there are no interesting effects. If the body is a conductor, there are two possibilities depending on the surrounding medium. If the body moves in vacuum, the polarization field  $\mathbf{E}_p = -\mathbf{E}_i$  arises, so that the summary electric field inside the body turns to zero. If the body (an artificial satellite, for example) is surrounded by plasma, the polarization field will propagate away from the satellite along the ambient magnetic field as a pair of Alfvén waves (so-called Alfvén wings). The Alfvén wave is a wave of field-aligned current, which is closed by transverse currents at the fronts of the Alfvén waves and inside the satellite body. The electric current flowing in the satellite is  $\mathbf{I} = [\mathbf{v} \times \mathbf{B}] a \Sigma_w / (1 + \Sigma_w / \Sigma_s)$  where  $a$  is the size of the satellite along its velocity,  $\Sigma_s$  the satellite conductivity,  $\Sigma_w = 1 / (\mu_0 V_A)$  the wave conductivity,  $V_A = B / (\mu_0 \rho)^{1/2}$  the Alfvén velocity,  $\mu_0$  the magnetic permeability of vacuum,  $\rho$  the plasma density. Assuming  $\Sigma_w \ll \Sigma_s$  we obtain  $I \approx v a (\rho / \mu_0)^{1/2}$ .

We use three-component measurements onboard Dynamics Explorer-2 satellite for studying radiated Alfvén waves. Background field-aligned currents crossed by the satellite produce the magnetic disturbance  $\delta \mathbf{B}_\perp$  transverse to the ambient magnetic field. The disturbance  $\delta B_\parallel$  along the ambient magnetic field is produced by transverse currents. These are currents flowing in the ionospheric E region as well as the currents flowing in the satellite. The

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ionospheric currents produce the large-scale  $\delta B_{\parallel}$  (with characteristic sizes  $\Delta x \gg 100$  km). We have examined it and managed to reproduce the disturbance generated by the high-latitude two-vortex current system as well as by two auroral electrojets. The small-scale disturbances  $\delta B_{\parallel}$  (with characteristic sizes  $\Delta x \approx 10$ -100 km) are produced, in our view, by varying currents in the body of the satellite. The variations of the current are  $\delta I \approx v_{\parallel} \delta \rho / (2 \sqrt{\mu_0 \rho})$ . Thus they are proportional to the plasma density variations. We found these variations to be most frequent in the auroral zone.

## **Ballooning-type instabilities and waves in the Earth's magnetosphere (review)**

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We highlight ballooning-type mechanisms for interpretation of three intriguing magnetospheric phenomena. These are: (1) hot filament extensions from the plasma sheet into the lobes and nightside polar cap arc formation; (2) destabilizing of the near-Earth tail current, accompanied by auroral arc activation prior to substorm onset; (3) flapping waves, as observed by Cluster spacecraft.

(1). Huang *et al.*, [JGR, 1987, 1989] reported about hot filaments of plasma sheet origin filling the lobes under northward IMF. On the other hand, occurrence of cold tenuous transients, observed as bubbles or streams, is well known for the plasma sheet. These features can be interpreted as due to permanent plasma exchange at the plasma sheet/lobe interface, proceeding in a filamentary manner. We present a description of this process within low-frequency ballooning (or interchange) mechanism [Ivanov *et al.*, *Geom. and Aeron.*, 1992; Golovchanskaya and Maltsev, JGR, 2003]. The near-Earth curved segment of the interface is explored, which always separates cold population of the lobe from hot plasma sheet, and, thereby, is favourable for the instability. Our treatment is closely related to the nightside originating polar cap arcs. Previously, this problem had been addressed by Rezhnev [Ann. Geophys., 1995], who treated the near-equatorial curvature of magnetic tubes. His model, relevant to the end of substorm recovery, requires a short plasma sheet surrounded by newly closed (after Bz IMF northturn) magnetic tubes containing lower pressure plasma. The difference between the two modifications of the interchange instability is discussed.

(2). Efforts of many researchers are directed toward finding an internal magnetospheric instability that could cause tail current diversion/disruption within the inner plasma sheet. By now it is generally accepted that the enhanced plasma transport to the Earth during substorm growth phase leads to a significant pressure buildup in the near- and middle tail. Therefore, the idea that destabilizing of the near-Earth tail current can be due to development of a ballooning-type instability, tending to destroy large pressure gradients, remains very popular [e.g., Swift, *Planet. Space Sci.*, 1967; Roux *et al.*, JGR, 1991; Ivanov *et al.*, *Geom. and Aeron.*, 1992; Liu, JGR, 1997]. We have performed simulation of the interchange instability driven by the longitudinal pressure gradients in a substorm site, up to the non-linear stage and onset arc formation [Mingalev and Golovchanskaya, ICS-7, 2004, *this conference*, 2005; Golovchanskaya *et al.*, ICS-7, 2004].

(3). Recently, Runov *et al.* [Geophys. Res. Lett., 2003] and Sergeev *et al.* [Geophys. Res. Lett., 2003, 2004] reported on low-frequency oscillations of the current sheet generated by some impulsive source in the center of the magnetospheric tail and propagating toward the flanks. The propagation velocity ranges from a few tens to a few hundreds of km/s, tending to increase for disturbed conditions. To interpret the finding, a number of wave modes have been invoked and then discarded, for either the group velocities or propagation directions were inconsistent with the observations. We demonstrate that the MHD ballooning-type waves, first described by Safargaleev and Maltsev [Geom. and Aeron., 1986] who termed them internal 'gravitational' waves, are a plausible candidate to interpret the flapping observations. The role of gravity is played by the centrifugal force, affecting hot plasma in a curved magnetic field. The corresponding dispersion relation was generalized for the case of high- $\beta$  plasma and large curvature, and expression for the group velocity  $v^{\text{group}}$  was derived [Golovchanskaya and Maltsev, Geophys. Res. Lett., 2005]. The component of the  $v^{\text{group}}$  in the  $\pm y_{\text{GSM}}$  directions appears to depend on the wave number across the magnetic field, half-thickness of the current sheet, and thermal velocity of ions in the neutral sheet. Its values vary from 40 km/s to 100 km/s for a quiet current sheet and from 160 km/s to 400 km/s for an active sheet, which is consistent with the observations. We have modeled propagation across the magnetic field of the MHD ballooning waves excited by a localized impulsive source. A fan-like wave structure, converging to the y-axis, has been obtained.

## **Study of non-stationary electron precipitation upon the cyclotron plasma instability in a laboratory magnetic trap**

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We present the results of experimental study of auto-oscillation regime of the cyclotron instability in nonequilibrium ECR-discharge plasma in a simple mirror machine. This study is performed in the context of laboratory modeling of non-stationary processes in space cyclotron masers. The plasma comprises two populations of electrons, one of

which (bulk plasma) has the number density  $\sim 10^{13} \text{ cm}^{-3}$  and the temperature  $\sim 300 \text{ eV}$ , and the other (energetic)-  $\sim 10^{10} \text{ cm}^{-3}$  and  $10 \text{ keV}$ , respectively. The instability occurs as quasi-periodic bursts of precipitated energetic electrons, accompanied with bursts of the electromagnetic radiation at frequencies below the electron gyrofrequency in the trap center.

Using a set of Al filters of different thickness placed in front of the energetic electrons detector (PIN diode), the energy distribution function (EDF) of the precipitated electrons has been measured. As a result, the Maxwellian EDF with temperature  $\sim 8 \text{ keV}$  has been obtained. This result is in a good agreement with the measurements of energetic-electron temperature by bremsstrahlung emission of the plasma.

By moving the PIN diode across the trap axis, we obtained the spatial distribution of precipitated energetic electrons. It has been found that the spatial structure of electron precipitation essentially depends on the value of magnetic field at the trap center, and can be non-monotonic under certain conditions. In particular, if the magnetic field corresponds to the most intense electromagnetic-wave generation upon the cyclotron instability, then the precipitation is peaked at the periphery of the chamber, with a hole observed in the center. As the magnetic field increases, the precipitation maximum approaches the center, and finally the distribution acquires a monotonic radial profile. Measurements show that the radial distribution of the bulk plasma density, unlike the energetic-electron precipitation, has a monotonic structure for all regimes. We attribute the non-uniform spatial structure of energetic electrons to the respective electromagnetic field distribution in the waves excited upon the cyclotron instability. In this respect, the proposed mechanism for the observed phenomenon has a similarity with the spatial structure formation of pulsating auroral patches .

### Excitation of transient Alfvén impulse during the onset of anomalous plasma resistance

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The efficiency of the Alfvén impulse excitation in the auroral zone of the terrestrial magnetosphere upon the onset of the anomalous field-aligned resistance has been estimated. The possibility of an additional mechanism of Pi2 generation related to the sudden occurrence of anomalous resistance layer (ARL) on auroral field lines was originally suggested by Arykov and Maltsev (1983). The impulsive disturbance excited during the onset of anomalous field-aligned resistance and electric field may signify the transition of a global magnetospheric instability into the explosive phase with a positive feedback. We consider the self-consistent problem at the excitation of anomalous resistance at the front of field-aligned current and reverse influence upon it from the induced currents. The analytical solution of the self-consistent problem has shown that during the entrance of field-aligned current front into the ARL an Alfvénic impulse is generated. The interaction of the external current with ARL also results in the delay of the current growth. The impulse duration and delay time depend on the ratio between the Alfvén damping scale and external current width. The solution obtained indicates the possibility to use the Alfvénic impulse as an indicator of distant occurrence of anomalous resistance.

This research is supported by the RFBR grant 04-05-64321.

### Parametric generation of the zonal structures by Alfvén waves in the Earth's ionosphere

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A novel mechanism of the Alfvén waves interaction with convective motions in the Earth's ionosphere is proposed. The model is based on the parametric excitation of convective cells by the finite amplitude Alfvén waves. Contrary to the previous studies it is shown that classical shear Alfvén waves, when dispersion effects are neglected, do not generate the electrostatic convective perturbations. It is found that the electrostatic convective cells represent vortex plasma motions (VPMS) with a very large impedance ratio. A close inspection of new dispersion relation shows that the electrostatic convective cells as well as the magnetostatic modes do not grow when the Alfvén waves are in the kinetic regime. It is found that the wave vector of the convective mode is perpendicular to that of the pump inertial Alfvén wave (IAW). The instability growth rate for the most growing mode is obtained. A comparison with the earlier obtained results is given. The theory of parametric interaction of IAW packets with large-scale convective cells in the auroral plasma cavity is developed. It is shown that in the plasma cavity where the Alfvén velocity is comparable with the speed of light the displacement current substantially reduces the parametric interaction of the IAWs with convective cells. It is shown that convective cells produced by the parametric instability can form the fine structure of the turbulent Alfvén boundary layer and can play an important role in the ionospheric plasma turbulence.

This research was partially supported by the Russian Foundation for Basic Research through the Grant No. 04-05-64657 and by the Russian Academy of Sciences through the Grant "Physics of the Atmosphere: electrical processes and radiophysical methods".

## **Generation and propagation of LHR waves in the upper ionosphere**

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Generation of LHR waves in the upper auroral ionosphere by beams of electrons and protons with energies above 1 keV and possibilities of their observation on the ground are analysed. A special attention is paid to the case of wave propagation in cavities of depleted ionospheric plasma density. The ray-tracing technique is used to study the properties of LHR wave propagation with consideration of inhomogeneity along and across the geomagnetic field. The transformation of LHR waves into whistler mode waves with the wave vector close to the direction of the geomagnetic field is analysed. These whistler waves can be registered by the ground station. Electron beams generate non-structured ELF/VLF hiss emissions while ion beams can generate a hiss with a harmonic spectral structure. In the latter case the spectrum is determined by the condition of the double resonance:  $\omega_{LHR} = n\omega_H$ , where  $\omega_{LHR}$  is the local lower-hybrid resonance frequency depending on the coordinate,  $\omega_H$  is the local gyrofrequency of energetic ions, and  $n$  is an integer. The path-integrated gain due to the joint action of generation by beams and damping along the obtained ray trajectories is calculated. The results of the theory are compared with experimental data.

## **Excitation of Pc5 pulsation in the magnetosphere by a shock wave during SC event**

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Regular electron flux oscillations with 5 min period were observed by GOES 8 and 10 satellites immediately after Sudden Commencement on 11 February 2000 at 0258 UT. Both satellites detected simultaneous magnetic pulsations with the same period. The ground-based magnetometer in Yellowknife observatory, situated near the satellite projection to the Earth along the field line, registered similar pulsations, which were in phase in Z component and in antiphase in X and Y components. A possible origin of the magnetic pulsations is an impulse enhancement of large-scale field-aligned currents after the magnetospheric compression caused by SC.

## **Police whistle type excitation of the ionospheric Alfvén resonator at middle latitudes**

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A new model for the generation of the ionospheric Alfvén resonator (IAR) at middle latitudes is developed. It is shown that the mechanism of the IAR excitation in this region is similar to the operation of the ordinary police whistle. The Earth's ionosphere wind system in this case is capable to sustain the generation of electromagnetic oscillations that can be detected by ground magnetometers. The general IAR dispersion relation describing the linear coupling of the shear Alfvén and fast magnetosonic/compressional modes is obtained. The dependence of the IAR eigenfrequencies and damping rates on the perpendicular wave number and on the ground conductivity during the day- and nighttime conditions is analyzed both analytically and numerically. In order to demonstrate the IAR excitation by neutral winds the power spectra of the geomagnetic perturbation on the ground surface are calculated. Furthermore, it is found that Kolmogorov spectra of the ionospheric turbulent neutral winds and the IAR eigenfrequencies lie in the same frequency range that makes it possible to enhance the IAR excitation. The relevance of the developed theoretical model to the ground based observations is outlined.

This research was partially supported by the Russian Foundation for Basic Research through the Grant No. 04-05-64657 and by the Russian Academy of Sciences through the Grant "Physics of the Atmosphere: electrical processes and radiophysical methods".

## **Irregular variations in simultaneous TV, IRIS and VLF observations**

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The models of VLF emission generation are based on cyclotron wave-particle interaction mechanism. According to such models the generation of waves is accompanied by a modification of electron pitch-angle distribution, that can lead to their precipitation in a loss cone. The dissipation of energetic electrons in the atmosphere is accompanied by excitation of auroral emissions at altitudes of 100-200 km, that is observed by optical instruments. If the precipitated

electrons are energetic enough to penetrate to the altitudes below 90 km, the ionization by them of atmospheric gases leads to absorption of radiowaves, that is observed by riometers. However, it is complicated to find a direct correlation of particles precipitation observed on TV and riometer with VLF emissions. Only a few papers with examples of such a correlation are known. In this paper we consider simultaneous morning time observations of VLF antenna, IRIS riometer array, and TV all-sky camera located at Kilpisjarvi and Porojarvi, Finland. We applied various transformation techniques to the original data sets to find similarities in variations seen on time scales from 1 to 60 seconds. Details of several selected events are discussed from the viewpoint of ducted VLF propagation.

### **Interplanetary suprathermal ions and spectral power of the high latitude ULF geomagnetic fluctuations**

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Long period ULF geomagnetic fluctuations (1-4 mHz) have been studied at high latitude stations of two hemispheres for two years of observations (1997-1998). It is shown that the ULF spectral power depends on the flux of keV ions in the solar wind as well as on the solar wind velocity and pressure. This dependence is partly due to the fluctuations in the IMF caused by ions with super-Alfven velocities. The geoefficiency of the ion flux in different space regions and under different IMF conditions is analyzed and possible physical mechanisms of this relation are discussed. This study is supported by INTAS grant No : 03-51-5359

### **Study of the Schumann resonance in magnetic and electric fields**

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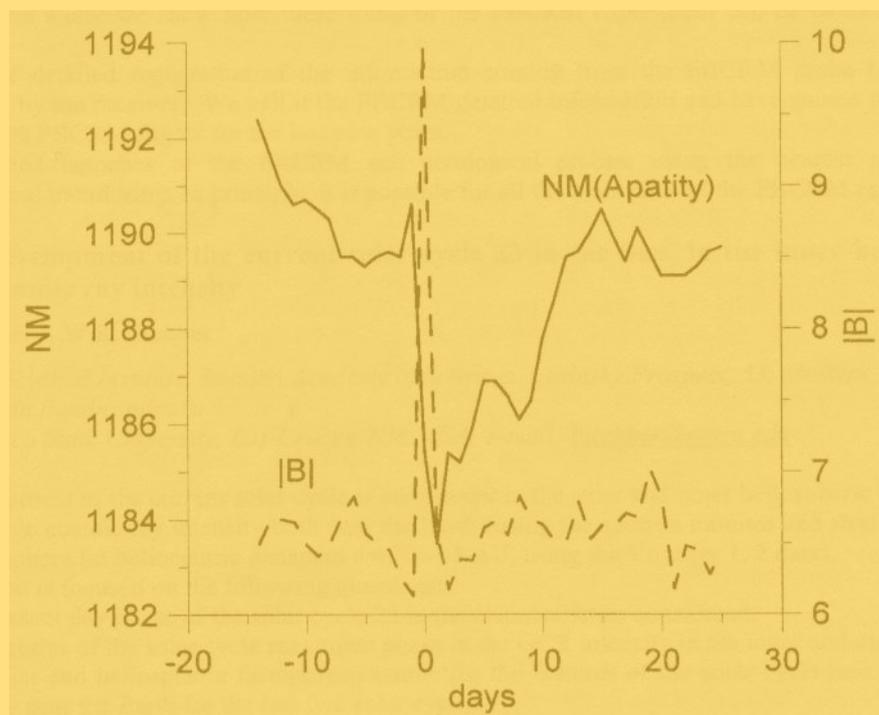
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Observations of Schumann resonances in Lovozero have been performed separately for two horizontal magnetic components and two horizontal electric components. The average frequency of the first Schumann resonance is about 7.8 Hz. It experiences a semidiurnal variation of the order of 0.2 Hz. The variations are different in different components. The frequency in the electric component slightly exceeds (by about 0.05 Hz) the frequency in the magnetic component. Sometimes very large (~1 Hz) frequency deviations, not associated with either magnetic or solar activity, are observed. We also examined the effect of the solar proton events in the frequency and amplitude of the resonances.



*The Sun, Solar Wind, Cosmic Rays*





## On possible improvements in the frequent balloon cosmic ray monitoring in the Earth's atmosphere

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The experiment on the frequent balloon cosmic ray monitoring (FBCRM) has been conducting by the Lebedev Physical Institute since 1957. The principal sites of balloon launches are the Kola Peninsula (Olenya, Apatity), the Moscow region (Dolgoprudny) and the Antarctica (Mirny). The experiment has provided some valuable findings on the behavior of galactic and solar cosmic rays, on electron precipitation and atmospheric processes. Still, there are a few flaws in the experimental procedure, which restrict the accuracy of the FBCRM data:

- 1) Finite and rather large (one minute) interval of data sampling, excluding a rejection of short but intense bursts of noise pulses, fast shifts of the frequencies, turbulence etc;
- 2) Separation of detected radio pulses into the groups of useful pulses (corresponding to the passage of ionizing particle through the omnidirectional Geiger counter or vertical telescope containing two such counters) and noise pulses, based on the only parameter (the pulse length), while neglecting its amplitude and form;
- 3) Unknown position (in the horizontal plane) and orientation of the device during the flight;
- 4) Moderate quality of pressure determination during the flight;

In the present study we show how these flaws of the FBCRM experiment can be overcome. The improvements suggest:

- 1) A more detailed registration of the information coming from the FBCRM probe (the form of each pulse detected by the receiver). We call it the FBCRM detailed information and have gained it in Dolgoprudny during over 1000 FBCRM flights for the last nine years;
- 2) Combined launches of the FBCRM and aerological probes, using the nearest meteorological station conducting aerological monitoring. In principle, it is possible for all the main sites of the FBCRM experiment.

## On the development of the current solar cycle 23 in the Sun, in the inner heliosphere and in the galactic cosmic ray intensity

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The development of the current solar cycle is considered in the solar and inner heliospheric characteristics as well as in the galactic cosmic ray intensity both near the Earth (using the neutron monitor and stratospheric data) and in the outer heliosphere (at heliocentric distances  $r = 70 - 95$  AU, using the Voyager 1, 2 data).

Our attention is focused on the following questions:

- 1) The present day phase of the solar cycle 23 in the characteristics considered;
- 2) The features of the solar cycle maximum phase in the GCR intensity in the inner and outer heliosphere;
- 3) The solar and heliospheric factors responsible for the features of the solar cycle maximum phase in the GCR intensity near the Earth for the last five solar cycles;
- 4) What can be expected in the next few years (a quiet development of the solar cycle minimum phase corresponding to the ( $A < 0$ ) phase of the 22-year (or magnetic) solar cycle or active phenomena similar to the well-known mini-cycle in 1973-1975).

## On the shock stand-off distance of interplanetary magnetic clouds

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A special subclass of interplanetary coronal mass ejections (ICMEs) are magnetic clouds (MCs). These structures are very amenable for analysis because of their high ordered magnetic fields. In a simple model MCs are modeled as locally straight cylindrical objects, with an force-free, constant  $\alpha$  magnetic field configuration (i.e.,  $\nabla \times \mathbf{B} = \alpha \mathbf{B}$ ). By a least-square fitting routine several MC parameters are obtained, as the orientation of the cylinder axis, the field

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strength at the center of the cloud, or an impact parameter of the spacecraft.

We focus then on MC which drive a shock, and which have fitted parameters in favor for this study, i.e., the MCs are intersected close to their center, orientation of the cloud axis is approximately in the ecliptic plane and directed perpendicular to the spacecraft-Sun-line, and which are not disturbed by other signatures.

A procedure is worked out to determine the influence on the magnetic field strength on the size of the sheath. This is done by a comparison with an hydrodynamic case or a cylindrical object moving in an supersonic flow. Thus, we want to figure out a prediction on the size of the sheath of MCs, and how the size of the sheath evolves with heliospheric distances.

For this study MC observations are used from Helios 1 and 2 between 0.3 and 1 AU, and from Wind spacecraft at 1 AU.

## **Magnetohydrodynamic waves within the medium separated by the plane shock wave or rotational discontinuity**

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Characteristics of small amplitude plane waves within the medium separated by the plane discontinuity into two half-spaces are analysed. The approximation of the ideal one-fluid magnetohydrodynamics (MHD) is used. The discontinuities with the nonzero mass flux across them are mainly examined. These are fast or slow shock waves and rotational discontinuities. The dispersion equation for MHD waves within each of half-spaces is obtained in the reference frame connected with the discontinuity surface. The solution of this equation permits to determine the wave vectors versus the tangential to the shock surface component of the phase velocity  $c_p$ . This value of  $c_p$  is common for all MHD waves and determined by an incident wave or spontaneous oscillations of the discontinuity surface. The analysis of the dispersion equation shows that for a given  $c_p$ , ahead or behind a discontinuity at most one diverging wave can transform to a surface wave damping when moving away from the discontinuity. The surface wave can be a fast one or, in rare cases a slow magnetoacoustic one. The entropy and Alfvén waves always remain a usual homogeneous mode. It is shown that for certain values of  $c_p$  and parameters of the discontinuity behind the front of the fast shock wave there can be four slow magnetoacoustic waves, satisfying the dispersion equation, and none of fast magnetoacoustic waves. In this case, one of the four slow magnetoacoustic waves is incident on the fast shock wave from the side of compressed medium. It is shown that its existence does not contradict the conditions of the evolutionarity of MHD shock waves. The four slow magnetoacoustic waves, satisfying the dispersion equation, can also exist from either side of a slow shock wave or rotational discontinuity. The expressions determining the polarisation of the MHD waves are derived in the reference frame connected with the discontinuity surface. This form of presentation is much more convenient in investigating the interaction of small perturbations with MHD discontinuities. It is shown that the perturbations of the velocity and magnetic field associated with the surface magnetoacoustic wave have the elliptic polarisation. Generally the planes of polarisation for the perturbations of the velocity and magnetic field are not coincident with each other.

## **The use of photosphere magnetic field evolution for solar flares prediction**

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Photospheric magnetic field evolution determines the current system that is generated in an active region in the solar corona. In the magnetic field of induced currents the accumulation of energy occurs that is released during a solar flare. Such a process is simulated through solution of 3D MHD equations. It is important to emphasize that no assumption is made about the nature of energy accumulation mechanism. The results of the simulation show that energy accumulation takes place in the magnetic field of a current sheet, which is created in the vicinity of a singular line. A potential magnetic field is obtained before the appearance of any noticeable change in the photosphere, and then it is used as an initial condition in calculation of magnetic energy accumulation above the active region due to the change in the photospheric field. Photospheric magnetic charts, obtained several days before a flare, are used as boundary conditions for photospheric magnetic field evolution. In all previous simulations for setting boundary conditions the magnetic field was extrapolated by magnetic charges of dipoles. Many important features in such a presentation can be lost. While analyzing complicated active regions with asymmetric magnetic configurations, some difficulties arise in finding the areas where the magnetic energy of a flare can be accumulated (singular lines). For the fast registration of singular lines the methods are developed, which are based on the analyses of the matrix of magnetic field gradients and its eigenvalues and search for the areas of maximal current density in complicated 3D magnetic field configurations. Some examples of numerical simulation are presented.

### **The effects of induced scattering of Alfvén waves for the solar wind acceleration**

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Analysis of energy budget of the coronal holes shows that to accelerate the fast solar wind streams one needs an energy flux of the order of  $800 \text{ erg/cm}^2 \text{ s}$ . Axford and McKenzie suggested that the energy source, necessary to accelerate the fast solar wind, is in the regions of strong magnetic field that define the boundaries of chromospheric supergranules. If the magnetic field in these regions is not strictly unipolar, then the necessary energy is released in the processes of impulsive reconnection of the magnetic field. For the plasma parameters appropriate for the coronal base such processes of impulsive reconnection are accompanied by generation of Alfvén and fast magnetosonic waves with the period of the order of 1 s.

A model for Alfvén wave evolution in the solar wind is suggested based on the kinetic equation. The induced scattering of these waves by plasma ions is considered to be a dominant mechanism of Alfvén wave dissipation. A description of wave spectra evolution in the process of wave propagation up to the distance of 187 solar radii is given.

### **The particularities of the cyclic aperiodic (quasi biennial) oscillations in the manifestations of the solar-terrestrial physics**

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Cyclic aperiodic oscillations (SAO) are the wave train with the decreasing period and amplitude. It arises on the ground of the solar convection zone in the beginning of each 11-year cycle and propagates inside and outside the sun. The SAO in the central part of the sun are registered by the neutrino flux variations with about 1.4 year delay in comparison with the SAO appearance in the photosphere according to the Wolf numbers and in the corona according to  $F_{10.7}$  indices. The SAO were accompanied by the regularities of the solar magnetic field behavior. Comparison of the temporal distribution of the SAO with the data of the paper by Ivanov and Kharshiladze (*Geomagnetism and Aeronomy*, V. 44, N 6, P. 723-733, 2004) allows one to conclude that the separated time intervals of the transformations of the solar magnetic field during the 23<sup>rd</sup> solar cycle (1996-2003), which they are made, have been well associated with the SAO. These peculiarities in the beginning of each cycle reflect the periodic oscillations of the wave train of the previous cycle on the background of the more long-term parts of the SAO of the present cycle. During the decaying phase of the current solar cycle the separated time intervals coincided with the SAO of the present cycle. The intensity of the UV solar radiation depending on the solar activity has the SAO component on the background radiation of the sun during the 11 -year cycle. Therefore, there are SAO in the terrestrial atmosphere at different heights. They are in the numbers of the red auroras, the temperatures of the thermosphere up to the lower atmosphere. They are in the phase and opposite phase according to the atmospheric heights. The sign of this correlation depends on the direction of the atmospheric circulation.

### **On the possibility of a prolonged two step production of high energy neutrons during the solar flare on 28 October 2003**

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The time profile of Tsumeb neutron monitor (NM) count rates (LAT -19.20; LONG 17.60; ALT 1240 m) during the 28 October 2003 X17.2 solar flare showed an enhancement above the background before the arrival of solar protons, which might be attributed to solar neutrons. In addition, the time profile has a second hump, coincident in time with the ground level enhancement observed by the NM network and the solar energetic particle event, but it is unlikely to be caused by the solar protons due to the large geomagnetic cutoff. Therefore, the time profile of Tsumeb NM reminds the famous event of 4 June 1991, when the evidence of a prolonged two-step injection of solar neutrons was found based on the Norikura NM, gamma ray and microwave data. This study summarizes and surveys all the relevant data available in order to check up and justify this similarity.

### **Manifestation of the Jupiter's synodic period in the solar wind parameters and ground pressure**

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Based on a large dataset (n=14038), a relation of the Jupiter's synodic period to the changes in the solar wind parameters and ground pressure has been found.

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The characteristic changes in the solar wind density and temperature, and in the ground pressure obtained by superposed epoch technique are  $\approx 0,5 \text{ cm}^{-3}$ ,  $\approx 8000^\circ\text{K}$  and 1 mb, respectively.

### **Super GLE of 20 January 2005**

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A super GLE, the second in power after the famous event of February 23, 1956, occurred on January 20, 2005. The active region 720 appeared on the solar disk on January 9 and rapidly grew in size. It produced 3 flares followed by solar proton events with energies up to 100 MeV on 15, 16, and 17 January. The effect of these flares was also a great decrease in galactic cosmic rays. The X7.1 solar flare located at N14 W61 occurred at 06.36 UT on January 25. The forrush effect of 20 % was in progress during the event onset. The increase on the neutron monitor in Apatity made 200 % and on the neutron monitor in Barentsburg 130 %. The increase on a number of other neutron monitors of the worldwide network was even stronger. In the present study the dynamics of the spectra and anisotropy of relativistic solar protons obtained by methods of optimization of the data of worldwide neutron monitor network is considered. These data are compared with the direct solar proton intensities measured in the balloon flights over Apatity.

### **Some features of relativistic proton sources on the Sun**

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Regularities in relativistic solar proton (RSP) generation and release from the Sun in the events of 22-23 solar cycles based on the data of neutron monitors, balloons and spacecraft have been studied. Overall, 10 Ground Level Enhancements (GLE) of solar cosmic rays (SCR) were analyzed. The two-peak structure of solar proton intensity profiles show existence of two distinct particle populations (components): the early, rigid and impulse-like intensity increase (prompt component, PC) and the late gradual increase with a soft energetic spectrum (delayed component, DC). The existence of two RSP populations is also confirmed by different spectral forms for the PC and DC, and by their dynamics as derived from neutron monitor data with optimization technique. It is shown that the PC spectrum has an exponential form that may be an evidence of the acceleration by the electric fields arising in magnetic reconnection in the coronal current sheets. Considering the timing of generation and release of two RSP components from the solar corona, the following scenario may be suggested. The prompt component of RSP is generated in a magnetic neutral point, which is associated with the H-alpha eruption, CME and the type II radioemission onset. The accelerated PC particles leave the corona along open field lines with diverging geometry, that results in a strong focusing of a bunch. The DC particles are originally trapped in magnetic arches in the low corona and accelerated by a stochastic mechanism related to the MHD turbulence in expanding flare plasma. Accelerated particles of the DC can be then carried out to the outer corona by an expanding CME. They are released into interplanetary space after the magnetic trap is destroyed, giving rise to a source of particles extended in time and azimuth.

### **Relativistic solar proton dynamics in the October-November, 2003 GLEs**

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By data of the worldwide neutron monitor network the ground level solar cosmic ray events of October 28 and November 2, 2003 have been studied. By the least square technique the spectra, pitch-angle distributions and anisotropy of relativistic solar protons (RSP) have been derived. The analysis of the dynamics of these parameters revealed the existence of two RSP populations (components): the prompt and delayed ones in both events. The components differ significantly in their characteristics, which may be an evidence of different sources available in the Sun. In the event of October 28, 2003 both fast and delayed components arrived at the Earth following the counter-sunward direction. Some arguments are given that the propagation of particles from the flare in the eastern part of the solar disk was in a loop-like IMF structure, formed by a preceding CME.

## **Changes in radionuclide Be-7 as related to cyclic and sporadic variations of cosmic rays**

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The variations in cosmogenic radionuclide Be-7 are studied in relation to variations in cosmic rays at the ground level and in the stratosphere. The radionuclide Be-7 is formed at the interaction of the cosmic rays with nuclei of air atoms at stratospheric heights. The data on Be-7 were taken from the daily selection of both deposits and aerosol tests and their gamma - spectrometer analysis. The variations in the cosmic ray background were studied based on neutron monitor and stratospheric measurements in balloon flights in Apatity. The data obtained for the period from 2001 to the early 2005 were analyzed. This period corresponds to the decline phase of the 23<sup>d</sup> cycle of solar activity. The correlation with long-term variations of galactic cosmic rays associated with the 11-year solar cycle as well as with sporadic events of solar cosmic rays is investigated. The effects in concentration changes of Be-7 are examined, in particular, for the superevents in solar cosmic rays in October – November, 2003 and January, 2005.

## **Солнечная активность и космические лучи в 1973–2003 гг.**

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Проведено сопоставление характеристик солнечной активности, потоков протонов солнечных и галактических космических лучей, измеренных на искусственных спутниках Земли, шарах-зондах и нейтронных мониторах. Рассмотрены особенности их распределения в различных циклах солнечной активности. Рассчитаны частотные спектры временных рядов данных и выделены их основные периодические составляющие. Представлены характеристики вариаций чисел Вольфа, потоков, флюенсов и энергетических спектров протонов космических лучей и обсуждены возможные их причины. Определены функции, аппроксимирующие временные ряды этих данных и на основе их экстраполяции осуществлен прогноз чисел Вольфа и потоков протонов на 2005 и 2006 гг. Данные прогноза чисел Вольфа указанным методом сопоставляются с другими, выполненными используемыми в настоящее время традиционными способами. Отмечается хорошее их совпадение.

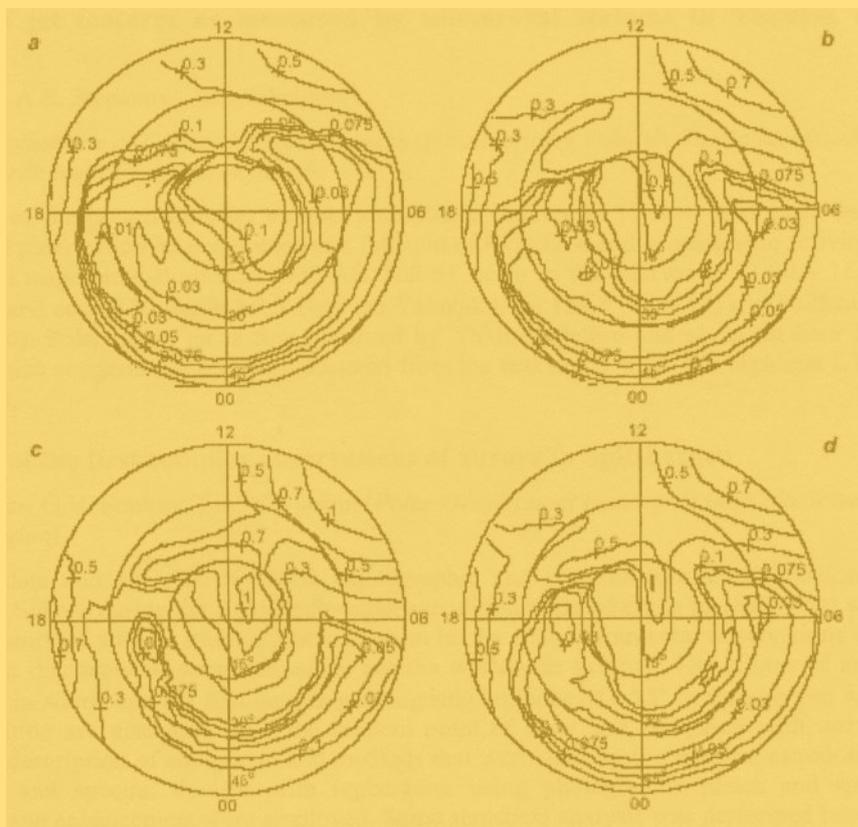
## **Характеристики полярных сияний при взаимодействии с магнитосферой Земли некоторых типов составных и изолированных потоков солнечного ветра.**

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По наземным и спутниковым наблюдениям полярных сияний исследованы спектральные характеристики и широтные вариации положения границ аврорального свечения в периоды взаимодействия с магнитосферой Земли составных потоков солнечного ветра и изолированных потоков от корональных дыр, вспышек, исчезнувших филаментов и гелиосферного токового слоя. В составных потоках солнечного ветра на орбите Земли не происходит полного перемешивания взаимодействующих потоков от разных солнечных источников. В составных потоках солнечного ветра и в авроральных возмущениях (полярные сияния) происходит последовательная смена признаков в доминировании потоков и их геоэффективности от разных солнечных источников. Исследовано 57 авроральных событий, связанных с составными потоками. Для этих событий интенсивность полярных сияний в максимуме развития аврорального возмущения достигала 2-3 балла по Международной шкале яркости полярных сияний. Из спектральных наблюдений следует, что отношения интенсивностей эмиссии 630.0 нм к эмиссии 557.7 нм в среднем составляют 0.5-1. В течение развития возмущения это отношение изменяется. В тех составных потоках, где участвуют вспышечные и волоконные потоки с очень большими значениями плотности солнечного ветра, особенно при смене знака Vz-компоненты, наблюдаются самые высокие отношения эмиссий (1-10). При переходе к доминированию потока от другого солнечного источника отношение падает до 0.2-0.5. Рассмотрено также изменение границ аврорального свечения при взаимодействии с магнитосферой Земли составных потоков типа ГТС – передняя кромка ВСП от КД, вспышечный поток – ГГС, волоконный поток – кромка ВСП от КД. Экваториальная граница в максимуме возмущений в полуночные часы распространяется до геомагнитных широт 57°- 60°, а приполюсная – выше 70°.



# *Ionosphere and Upper Atmosphere*





## **The study of the ionospheric D-layer by partial-reflection technique at middle and high latitudes in the spring of 2004**

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The observations of ionospheric effects of two solar flares in April, 2004 by partial reflection technique are presented. The investigations are conducted by using integrated measuring units located in different latitudinal regions: in Vasil'sursk near Nizhniy Novgorod (56.1°N, 46.1°E) and in Tumanny (Murmansk region, 69.0°N, 35.7°E). Quantitative estimates of the electron concentration in the polar and midlatitude D layer are obtained for the quiet conditions and during solar flares. The correlation of rapid variations in the electron concentration at heights of about 80 km at these points is found. It is shown that during solar flares the electron concentration at heights of 60-70 km follows the intensity of X-rays in the waveband of 0.5-3 Å, which is consistent with the linear law of recombination in the ionospheric D-region.

## **Polarization jet features as measured by subauroral stations in Yakutsk and Podkamennaya Tunguska**

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Observations of the polarization jet by two ionospheric stations in 1989 – 1991 have been analyzed. Statistical distribution of polarization jet occurrence as a function of local time and geomagnetic activity is given. When isolated magnetic disturbances with  $AE > 500$  nT occur in the interval of 11:00 – 16:00 UT, polarization jet band appears and covers 3 hour in MLT between Yakutsk ( $\lambda = 129.8^\circ$ ,  $L = 3.0$ ) and Podkamennaya Tunguzka ( $\lambda = 90.0^\circ$ ,  $L = 3.0$ ). Polarization jet is first observed by Yakutsk station and about an hour later by Podkamennaya Tunguzka, which suggests a source displacement from the east to the west. We highlight LT control of polarization jet occurrence.

## **The results of the first complex observations of aurora in Spitsbergen**

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We present data and analysis of visual, photographic and spectral auroral observations obtained by Russian astronomer J. Sykora during the Russian-Swedish expedition to Spitsbergen in 1899-1900 winter season and briefly survey the history of auroral studies. These seem to be the first instrumental observations of auroral spectra in the Arctic and the discovery of some emissions has the worldwide priority. The photos of aurora he made were the world second in Arctic and the first ones in geomagnetic latitudes of  $\sim 75^\circ$  in Spitsbergen Archipelago. The results of the expedition are discussed from the modern point of view and compared with our knowledge in the XXI century. The description of equipment and methods that were used by the Russian astronomers are presented. Both photographic and spectral devices with registration using photographic plates and special methods of their development and enhancement were employed. Some statistical analysis was performed based on expedition reports and diaries. This analysis shows that by means of Sykora data it was possible to discover the auroral oval or instant position of aurora distribution over the polar region. The study of the photographic samples and instant sketches of aurora demonstrated typical auroral form outlines as they are described nowadays. Spectral plates exposed for several hours to auroral lights enable to reveal not only the main auroral emissions well-known at that time but several other unidentified weak emissions, which were rediscovered and interpreted years later.

## **Global thermosphere response to the April 2002 magnetic storms**

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A study of the thermospheric effects of the geomagnetic storms of April, 17-20, 2002 has been performed within the global numerical Upper Atmosphere Model (UAM) of the Earth and empirical thermospheric model NRLMSISE-00. The calculation results are presented as global maps of latitude-longitude distribution of the basic thermospheric parameters, including the neutral temperature, concentration of atomic oxygen and molecular nitrogen, ratio

## Ionosphere and upper atmosphere

$n(O)/n(N_2)$  and velocity of the horizontal thermospheric wind at the height of 350 km. Asymmetry in the reaction of the thermosphere to the magnetic storm in the Northern and Southern hemispheres is found. Namely, within the UAM the temperature and gas composition response is the largest at the middle latitudes of the Northern hemisphere, while within the MSIS it is near the pole region of the Southern hemisphere. The time variation of the difference in the thermospheric parameters on disturbed and quiet days has been analyzed. The effect of diurnal tides in the disturbance of temperature, density and velocity of the horizontal thermospheric wind is revealed. The tides are manifested more distinctly in the temperature at middle latitudes. Their amplitudes and phases are nearly equal in both versions of the calculations, while the mean level of the disturbance is  $\sim 200$  K higher within the UAM than within the MSIS.

This study was supported by the Grant No. 05-05-97511 of Russian Foundation for Basic Research.

## New spectral peculiarities of ULF natural magnetic noise

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A new broadband spectral maximum has been detected and analyzed at frequencies of 2 - 6 Hz based on the data collected at two middle-latitude observation sites: "New Life" (Russia) and "Nurmijaervi" (Finland). This maximum appears under quiet geomagnetic conditions in 1 - 2 hours after sunset and disappears shortly after midnight as shown in Figure 1.

The following properties of this maximum are found:

- The maximum is more pronounced in the N – S component of the magnetic field at both stations;
- A correlation between the change in the maximum frequency and frequency scale of the spectral resonance structure (SRS) is indicated when both phenomena are observed simultaneously;
- The coherence coefficient between both linear components of magnetic noise at maximum frequencies increases from  $\sim 0.5$  to 0.75;
- The broad band maximum appears simultaneously at both stations but with different maximum frequency and different arbitrary amplitudes.

The new features of SRS (complicated structure at middle latitudes) are found:

- Different frequency scales in the N – S and E – W magnetic components are sometimes observed;
- A shift of the basic IAR frequencies is detected in the N – S magnetic component as compared to the E – W one, as well as strong non-equidistant resonance peaks.

The above peculiarities were mainly observed in the winter season.

The study was supported by RFBR (grant N 04-02-17333).

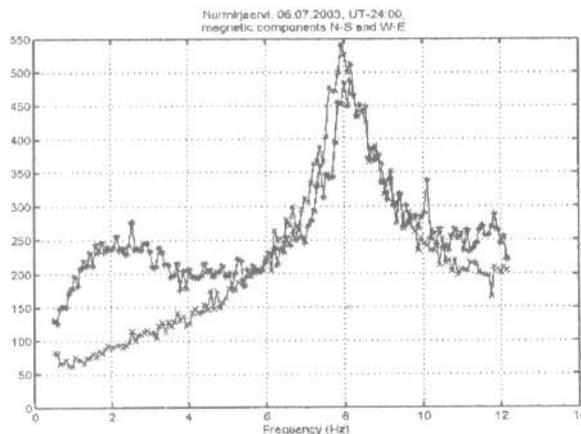


Fig. 1. An example of detection of broadband spectral maximum

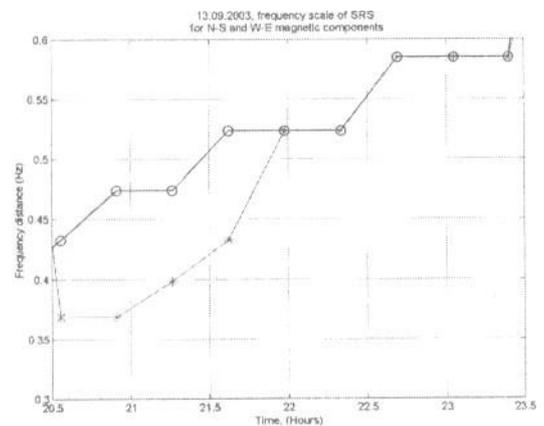


Fig. 2. An example of different frequency scales in N – S and E – W magnetic components

## **Are the World Thunderstorm Centers an Energy Source for the Mid-latitude Ionospheric Alfvén Resonator?**

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One of the most important problems of Ionospheric Alfvén Resonator (IAR) studies is a generator (or generators) of the IAR oscillations. At the first glance, electromagnetic emissions from the world thunderstorm centers exist permanently and could be an energy source for the IAR oscillations at middle latitudes. To validate this suggestion, we have compared the data of SRS IAR observations in Kamchatka with the calculated power spectra of the magnetic field generated by the World Thunderstorm Centers in the IAR frequency range. The magnitude of the magnetic field from the world thunderstorm centers has been calibrated compared to the calculated and observed values of the fundamental Shumann harmonic. Under the average thunderstorm activity the calculated and measured spectral power corresponds to the frequencies of the Shumann resonances, and the measured spectral power exceeds the calculated spectral power by 1.5 – 2 orders of magnitude at IAR frequencies. Thus, the contribution of the world thunderstorm centers to the mid-latitude electromagnetic field in the frequency range from several tenths Hz to several Hz is negligible and cannot provide the observed intensity of signal at IAR frequencies.

*Acknowledgements.* This research is performed under ISTC grant 2990.

## **Distribution of the F-spread occurrence probability in the northern and southern hemispheres for the winter solstice period**

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Global distribution (in both hemispheres, at all longitudes, for all local times) of the occurrence probability (P) of the F-spread at F2-layer maximum height has been built. About 30.000 topside ionograms obtained onboard Intercosmos-19 satellite in the period of high solar activity for two winter solstices 1979-1981 were used. The latitudinal-longitudinal variations in the F-spread occurrence probability were studied. The analysis shows that the longitudinal variations in P, in the first approximation, exhibit negative correlation with NmF2 variations both in winter and summer conditions. The amplitude of the longitudinal effect in P in the nighttime conditions reaches factor 2 in the Northern hemisphere and factor 4 in the Southern hemisphere. As a result, the longitudinal sectors stand out where P is either maximum or minimum in the broad belt of latitudes (60-120°E and 240-270°E, correspondingly, in the Southern hemisphere). In the Northern hemisphere the pattern is more complicated. Above the magnetic equator, F-spread occurrence probability for the midnight conditions is maximum (P ~ 60%) at longitudes around 330°E, and minimum (P ~ 10%) at longitudes of 180°E. The diurnal variations in P from the Intercosmos-19 data were compared with the ground observations for different latitudes. The interpretation of the found F-spread occurrence variations is given.

## **The effects of ionosphere heating experiments in the riometric absorption**

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The observations indicate that the pulses of ionosphere heating are associated with an increase of riometric absorption in the heating site. Ionization in the observation site is produced by precipitation of relatively high energy (E=10-30 keV) electrons. It seems unlikely that electrons of such energy could be generated in the ionosphere or in the magnetosphere directly in the process of ionosphere heating. It is more plausible that the observed riometric absorption is caused by an increase in the rate of precipitation prior to the experiment onset. The ionosphere - magnetosphere coupling is known to be realized by means of the Alfvén waves, characterized by magnetic field perturbations perpendicular to the background magnetic field and not changing the flux of precipitating particles. Thus, under the assumption of frozen-in conditions, the mechanism under consideration cannot explain the observed variations in the flux of precipitating particles. The interpretation of the observed modulations of precipitating fluxes can be given if we suggest a violation of the frozen-in conditions associated with inertia forces. Moreover, the proposed mechanism can explain the stabilization of the southern boundary of the westward electrojet and its intensification during heating transmitter operation.

## **Dissociative attachment processes in E-region of the ionosphere during solid-fuel rocket launches**

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The behaviour of the E-region of the ionosphere during solid-fuel rocket launches is studied taking into account the inelastic scattering of solar light on the products of solid-fuel combustion. The considered chemical processes include the reactions of combustion products and the reactions forming an ionization balance in natural conditions. Special attention is paid to peculiarities of inelastic electron-molecule collisions. The role of dissociative attachment and vibrational excitation in the interaction of thermal ionospheric electrons with HCl, H<sub>2</sub>, H<sub>2</sub>O, CO<sub>2</sub>, NO is discussed. An essential influence of dissociative attachment processes on the chemical composition of the E-region of the ionosphere after solid-fuel rocket launches is emphasized. The concentrations of 29 minor neutral constituents and 26 positive ions are calculated in the model. About 150 chemical reactions have been taken into consideration in the calculation. The results of our model calculations show that the high temperature near the rocket engine plume causes a significant variation in the electron density and an increase in the negative ion Cl<sup>-</sup> concentrations due to the dissociative attachment collisions of ionospheric electrons and HCl molecules.

## **A study of the electromagnetic drift influence on the formation or enhanced electron density regions in the night-time middle-latitude ionospheric F2-layer and in the plasmasphere**

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The influence of the electromagnetic drift on the formation of the enhanced electron density regions in the night-time middle-latitude ionospheric F2-layer and in the plasmasphere has been studied using the global numerical upper atmosphere model (UAM). It is shown that the electromagnetic drift influences the latitudinal location of the high-latitude sides of the enhanced electron density regions, moving them to lower latitudes. The displacement of these regions from the poles is proportional to the drift velocity. We have confirmed that the main cause of the night middle-latitude increases in the electron density is the thermospheric wind. The dependence of the calculated thermospheric wind and electromagnetic drift effects on initial conditions is analyzed. It is shown that they do not affect the formation of these regions.

This study was supported by the Grant No. 05-05-97511 of Russian Foundation for Basic Research.

## **Evolution of the Venus atmospheric and water environment**

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Interpretations of the Pioneer Venus mass spectrometer data on the D/H isotope ratio indicate that Venus may have had at least a water content of the order of about 0.3 % of a terrestrial ocean and even much more during and shortly after the accretion period of 1 – 300 Myr years, depending on the unknown ratio of a continuous supply of water by comets to a blown-off and impact erosion affected atmosphere. In view of the low water abundance in Venus' present atmosphere, the planet must have lost most of its water during the early period of the active young Sun. The present study uses multi-wavelength observations by the ASCA, ROSAT, EUVE, FUSE and IUE satellites of solar proxies at various ages for the investigation of how high X-ray and EUV fluxes of the young Sun have influenced the evolution of the early Venusian atmosphere. We apply for the first time a diffusive-photochemical model and investigate the heating of the young Venus thermosphere by photo-dissociation, ionization energy and due to exothermic chemical reactions, as well as cooling due to CO<sub>2</sub> IR-radiation loss. Our model yields high exospheric temperatures during the first 500 Myr, which results in dynamic blow-off and high loss for hydrogen and even high

loss rates for atomic oxygen and carbon. Furthermore, we studied also non-thermal atmospheric loss rates caused by ion-pick up and photo-chemically dissociated atomic oxygen produced by dense ionospheric layers, in Venus' early atmosphere caused by high X-ray and EUV fluxes of the young Sun. We use for our pick up ion study, estimations of minimal and maximal solar wind density and velocity parameters obtained from recent astrophysical observations of Sun-like stars with different ages.

### **Changes in the parameters of the ionospheric plasma above the pollution zones in the Euro-Arctic region**

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We have analysed the satellite measurements of low-frequency emission (0.1 ÷ 20 kHz) intensity, low energy electron fluxes and plasma temperature at satellite altitudes above the radioactive pollution zones in the seas of the Arctic Ocean, North Atlantic and Euro-Arctic region, found by means of sea water and bottom precipitation samplings.

Simultaneous characteristic changes in the ionosphere plasma parameters above the radioactive pollution zones are revealed which are coincident with the zones of intensive helium and hydrogen ion fluxes.

It is established that the radioactive pollution zones can be detected by the satellite measurements of ionosphere plasma parameters above different regions of the Earth's surface.

### **Why does not the IMF penetrate into the atmosphere of Venus?**

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One of the intriguing findings of the 1980s was zero magnetic field in the Venusian atmosphere. Venus does not possess its own magnetic field. Still, one could expect the interplanetary magnetic field penetration down the planet surface due to magnetic diffusion. The corresponding timescale, determined by the known ionospheric conductivity, should not exceed a few hours [Cloutier, JGR, Vol. 89, 2401, 1984; Phillips et al., JGR, Vol. 89, 10676, 1984]. However, the observations do not indicate a magnetic field in the lower atmosphere of Venus, the altitude of the magnetization boundary varying from ~400 km under low solar wind dynamic pressure to ~150 km under high pressure [Luhman et al., JGR, Vol. 89, 362, 1984; Krymskii and Breus, JGR, Vol. 93, 8459, 1988]. It looks like the IMF is being ejected from the Venusian atmosphere.

We hypothesize that IMF ejection is associated with an upward flux of energized ions. A similar flux of about  $10^8 \text{ cm}^{-2} \text{ s}^{-1}$ , named 'polar wind', permanently exists in the Earth's ionosphere [e.g. Banks and Holzer, JGR, Vol. 73, 6846, 1968]. The upward flux of the order of  $10^6 \text{ cm}^{-2} \text{ s}^{-1}$ , has been reported for Mars [Lundin et al., Science, Vol. 305, 1933, 2004]. It is reasonable to expect larger upward fluxes for Venus, as it is located nearer to the Sun. The ions are heated, presumably, by the solar wind and UV radiation. The upward plasma flux must prevent the IMF diffusion into the atmosphere. The estimations show that the upward velocities of plasma from tens to hundreds m/s are sufficient for ejecting the IMF from the atmosphere.

## **Seismo-Ionospheric Depression of the ULF Geomagnetic Fluctuations at Kamchatka and Japan**

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A preseismic behavior of the ULF geomagnetic fluctuations is studied at Karymshino (E158.13, N52.83), Russia, and Matsukawa (E140.94, N39.88), Japan. A depression of ULF power around the local midnight had been registered several days before violent isolated earthquakes occurred. The relative depression, i.e.  $\delta D = (D - \langle D \rangle) / \langle D \rangle$  has been analyzed, where the absolute depression is found as a sum of inversed values of spectral power densities of horizontal components  $D = 1 / P_{hh} + 1 / P_{dd}$  in a sliding window  $\pm(10 - 15)$  days. At Karymshino the most pronounced effect had been found 3 days before an earthquake in 0.5-hour vicinity of the local midnight in the frequency range 0.03-0.05 Hz. The data from Matsukawa are used to estimate the spatial scale of the effect. Its local nature has been confirmed. Thus, the analysis supports a hypothesis about the seismic origin of the observed depression of the geomagnetic field fluctuations preceding the earthquakes.

Acknowledgements. This research is supported by the ISTC grant 2990.

## **Influence of neutral spices on the artificial magnetic pulsations excitation**

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During the last decade series with the EISCAT Heating Facility have been carried out with the purpose to produce artificial magnetic pulsations in the 0.1 – 3 Hz frequency range. For several experiments the EISCAT radar provided measurement of ionospheric electric field and electron density. Numerical model of artificial pulsation excitation has been verified. The predicted amplitude of the pulsation is in accordance with the measured values, however, the model cannot not explain the sporadic nature of the artificial signals.

Variations of neutral spice density are a possible way to explain this feature. Numerical modelling shows a strong dependence of the conductivity modification on neutral density. Experiment on generation of artificial magnetic pulsations in Pc1 frequency range on November 19, 1998 is discussed in the frame of numerical simulation. A clear ionospheric response is observed during the first hour of the heating at 120-km distance by induction magnetometer but the artificial signal at the modulation frequencies has disappeared for the next hour of heating. The main ionosphere parameters do not indicate significant variations during this experimental run. The disappearance of the artificial pulsations may be related to density variations of neutral components of the ionosphere.

This study has been partly supported by INTAS (grant 01-614).

## **Generation of magnetic noise bursts during rocket launches**

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The enhancement of hydromagnetic noises in the frequency range around 1 Hz after distant rocket launches have been detected at ground-based observatories.

A theoretical model is suggested which interprets this phenomenon in terms of generation of fast compressional waves by the expanding waste products injected by rocket engine into the ionosphere and their subsequent trapping into the ionospheric magnetosonic waveguide.

### **160-min variation in the riometer absorption**

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Based on riometer measurements of space radionoise level at the frequency of 32 MHz on the Earth's surface at Tixie station, the 160-min oscillation and its 80-min mode have been found. It is shown that such oscillations can appear due to pulsations in the radionoise source itself, neutral atmosphere parameters, or particle precipitation fluxes. The possible effect of each of the above factors in space radionoise level oscillations is discussed.

### **The impulse response of ionospheric Alfvén resonator. The role of nearby thunderstorms**

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The temporal evolution of the IAR structures is analyzed. Several pulses following the initial pulse caused by a discharge are observed. The time interval between the peaks is about two seconds. A model of the IAR excited by a nearby single impulse is developed. The occurrence of several peaks in the azimuthal component is caused by the reflection of the signal from the ionospheric upper boundary. The calculated value of the time span between peaks is consistent with the observed value under typical traveling times of the Alfvén pulse from the E-layer to the reflection point in the mid-latitude ionosphere. Thus, nearby thunderstorms can provide a non-negligible contribution to the IAR power spectrum.

*Acknowledgements.* This research is performed under ISTC grant 2990.

### **The first SRS observations in the polar cap region**

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Resonance structures seen in spectra of the background electromagnetic noise in the frequency range from 0.1 to several Hz observed on the ground are believed to be a consequence of a resonator for Alfvén waves, which is suggested to exist in the upper ionosphere. It is suggested that the resonator is mainly due to specific features of the electron density altitudinal profile. These spectral resonance structures (SRS) are often observed at low latitudes and less often in the auroral zone. So far there was no information on the SRS observations from  $L > 5$ . Recently, the Polar Geophysical Institute of the Russian Academy of Sciences installed the induction coil magnetometer at the observatory of Barentsburg in Svalbard. The data from this magnetometer demonstrate that SRS can be also observed at  $L=13$ . The particle precipitation data from low-orbiting satellites as well as auroral oval models show that during the SRS observations the observatory is well poleward of the auroral oval, most likely in the polar cap. The diurnal and long-term behaviour of the SRS occurrence rate as well as dependence on the local geomagnetic activity is found in this high-latitude region to be similar to that in the auroral zone. Modelling of the ionospheric Alfvén resonator for some specific events made on the basis of the empirical EISCAT Svalbard Radar Ionosphere Model reproduces the observed SRS features.

### **The analysis of phase fluctuations of GPS signals in the polar ionosphere during storms**

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Dual frequency measurements of differential carrier phase of GPS:  $L_1$  ( $f_1=1.6$  GHz) and ( $f_2=1.2$  GHz) signals have been used for studying storm-time development of the phase of TEC fluctuations in the Antarctic region. We used GPS measurements of the International GPS service (IGS) network stations of MCM4( $78^\circ$ S,  $\Phi\sim 80^\circ$ ), CAS1( $66^\circ$ S,  $\Phi\sim 80^\circ$ ), MAV1( $67^\circ$ S,  $\Phi\sim 71^\circ$ ), DAV1 ( $68^\circ$ N,  $\Phi\sim 75^\circ$ ) for 2001. The phase fluctuations are caused by the presence of irregularities of different scale in the high latitude ionosphere. The standard GPS measurements provided by the global network are sampled with 30 s, which enables to detect the ionospheric irregularities on a scale of more than tenth of kilometer. For data analysis, the temporal variations of TEC along individual satellite passes were used. Strong TEC fluctuation as an enhancement of TEC relative to the background was detected at the polar station. The enhancement of TEC exceeded 2-10 times the background level, with the TEC increase to 10-40 TECU in the interval of about 5-10 min. The duration of such events was up to 10-20 min. They were registered during storms as well as under moderate geomagnetic activity. We interpret these structures as a manifestation of polar patches. The intensity of TEC fluctuations increases with geomagnetic activity. For 4-5 hours, satellite passes 3-5 strong and a few weak patches. As a measure of patch activity, we use the rate of TEC at a 1 min interval

(ROT). The diurnal, seasonal, latitudinal and storm-time features of polar patch occurrence are presented.

### **Magnetic storm effects in the ionosphere of East Asia**

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Ionospheric effects of a few geomagnetic storms are studied based on morphological and model analysis of the data of East Asia ionospheric stations and Irkutsk IS radar.

A comparison of ionospheric observations with the simulation results during two very strong magnetic storms of September 25, 1998 and July 15, 2000 is presented. It is found that the ionospheric response to the magnetic storms under consideration is controlled mainly by a disturbance in the composition of the neutral atmosphere. For the storm of September 25, 1998 the simulation was performed with magnetospheric inputs obtained with the Magnetogram Inversion Technique. This approach yields a smaller error than the empirical models.

The results of longitudinal ionospheric effect examination during a storm of September 25, 1998 based on the data of the ionosonds located in Siberia, Far East and Europe are presented. For the recovery phase both observations and model calculations indicate a change in ionospheric disturbance sign (from negative to positive) when moving from the east to the west. This is a combined effect of corpuscular and photo ionization. The sign of ionospheric disturbance is determined by the local time at which magnetic storm has begun.

The results of simulation of ionospheric behavior during a few geomagnetic storms that occurred in different seasons (June 7, 2003, October 13, 2003, and January 21, 2004) are presented. For the mid-latitude ionosphere it is found that the positive storms are dominated in winter, whereas the negative storms in summer. A model analysis shows a good agreement between the simulations and observations with a crucial role of neutral composition variations in fitting the calculated and observed ionospheric parameters.

### **Observations of ionospheric effects in the high latitude D-region during solar flares in April, 2004**

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The results of the lower polar ionosphere observations with a partial reflection technique during the solar flares in April, 2004 are presented. In the daylight period at heights lower than 85 km a two-layer region of enhanced electron concentration was detected. It was being observed for 40 min. The maximum electron concentration was  $(7-10) \cdot 10^2 \text{ cm}^{-3}$  in the altitude range of 64 - 70 km and  $(1.5-2.7) \cdot 10^3 \text{ cm}^{-3}$  at heights 77 - 79 km. The change in the lower ionosphere structure was accompanied by amplification in the medium radiowave absorption, impulses of space meter radio emission and generation of atmospheric waves with periods exceeding 2 minutes. The appearance of additional ionization in the lower D-region can be explained by peculiarities of the solar X-rays spectrum and high-altitude dependence of the recombination coefficient.

### **On the reaction of the lower polar ionosphere to the catastrophic earthquake in the South-East Asia on December 26, 2004**

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The behaviour of the electron concentration in the D-region of the polar ionosphere has been studied with the partial reflection technique at distance of  $\sim 7000$  km from the center of the strongest earthquake that occurred in the South-East Asia on December 26, 2004. Undulate perturbations were detected in the lower ionosphere, and the temporal/spatial characteristics of these processes were determined. It is shown, that during the series of strong earthquakes the electron concentration in the D-region of the polar ionosphere at heights over 80 km is 2-3 times higher than on the previous and subsequent days.

## **A comparison of the UAM, IRI-2001 and ISR electron density, ion and electron temperature data for the April 2002 magnetic storm events**

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The electron density, ion and electron temperatures have been calculated using the Upper Atmosphere Model (UAM) for the period of April 15-20, 2002 including the magnetic storm events. The results of modeling for three height levels close to 250, 350 and 450 km are compared with the empirical ionospheric model IRI-2001 and observations of seven incoherent scatter radars covering high, middle and low latitudes of the Northern Hemisphere. The UAM calculations of the ionospheric parameters have been performed using three versions of neutral constituents: 1) the NRLMSISE-00 neutral composition and temperature; 2) fully self-consistently with theoretical neutral composition and temperature obtained starting from NRLMSISE-00 as an initial condition; 3) the same as in 2) but starting from the steady state theoretical thermosphere solution used as an initial condition on April 15, 2002. The histograms are built to show the distinctions between all UAM versions and IRI-2001 and ISR Ne data. As a whole, the results demonstrate that the IRI-2001 reproduces the observed electron density in the most number of data points, the UAM-MSIS version has the largest difference with the ISR data and overestimates the Ne values. In most cases the ISR and IRI-2001 electron densities lie between the UAM values obtained in the first and third versions of the model calculations. Although the IRI-2001 shows the best agreement with the electron density observations, its ion and electron temperatures are underestimated as compared with both ISR and UAM values at all locations.

This study was supported by the Grant No. 05-05-97511 of Russian Foundation for Basic Research.

## **Моделирование наклонного распространения коротких радиоволн вдоль меридиональных трансавроральных радиотрасс различной длины**

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Исследуется влияние длины меридиональной трансавроральной радиотрассы на модовый состав КВ-сигналов, испускаемых находящимся в средних широтах передатчиком и достигающих приемника, находящегося на полярных широтах. При помощи расчетов, основанных на методе «пристрелки» и использующих разработанную ранее программу лучевого прослеживания траекторий КВ, синтезирована ионограмма наклонного зондирования (НЗ) для радиотрассы Москва-обс. Баренцбург и проведено ее сравнение с ионограммой НЗ, синтезированной радиотрассы Москва-Магнитный полюс северного полушария. При синтезе обеих ионограмм НЗ использовано распределение электронной концентрации, рассчитанное при помощи разработанной ранее трехмерной математической модели ионосферы и хорошо воспроизводящее в пределах геомагнитных широт 53-65° распределение электронной концентрации, полученное методом спутниковой радиотомографии. Оказалось, что длина радиотрассы существенно влияет на модовый состав КВ-сигналов, способных достичь приемника. При удлинении радиотрассы в сторону полюса происходит существенное изменение характера прохождения КВ, в частности, с ионограммы НЗ исчезают следы модов 1F2 и 2F2 и уменьшаются максимально наблюдаемые частоты, что должно приводить к ухудшению условий КВ-связи.

## **Высотное перераспределение концентрации заряженных частиц в полярной нижней ионосфере с учетом электродинамических процессов**

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Ионосфера высоких широт на высотах 100 – 150 км существенно отличается от среднелинейной ионосферы, поскольку связана с магнитосферой. Потoki частиц, электрические поля и токи, возникающие в магнитосфере, проникают в ионосферу и там влияют на образование, исчезновение и перенос заряженных частиц. В данной работе рассматривается перераспределение заряженных частиц на высотах E – F1 области ионосферы при наличии токов и динамических процессов в нейтральной атмосфере.

Решается стационарное уравнение непрерывности для заряженных частиц (положительных ионов) в предположении квазинейтральности плазмы с учетом того, что скорость ионов зависит от внешнего электрического поля, проводимости и скорости нейтральных частиц. Используя закон Ома для частично ионизированной плазмы можно показать, что наличие втекающих (вытекающих) токов вдоль силовых линий геомагнитного поля будет приводить к возникновению пространственных областей с пониженным (или повышенным) содержанием заряженных частиц. Однако, учет динамических процессов в нейтральной атмосфере может компенсировать токовые эффекты или, наоборот, усилить их.

Рассматриваются случаи малых возмущений, когда  $\Delta n \ll n_0$ , где  $\Delta n = n - n_0$ ,  $n_0$  – фоновое значение концентрации ионов в ионосфере.

Показано, что в этом случае возмущение определяется следующим выражением:

$$\Delta n = -\frac{1}{2\alpha} \left( \frac{f(z)}{\mu_0 \cdot H \cdot \Sigma_{\Pi}} \cdot j_z + \frac{v_i}{\omega_i} f(z) \cdot \operatorname{div} \left( \vec{v}_{n\perp} \right) + \frac{1}{n_0} \frac{\partial}{\partial z} (n_0 v_{nz}) + f(z) \cdot \left( \operatorname{rot} \left( \vec{v}_n \right) \right)_z \right)$$

Здесь  $\alpha$  – эффективный коэффициент рекомбинации,  $\mu_0$  – магнитная постоянная,  $H$  – напряженность магнитного поля Земли,  $\Sigma_{\Pi}$  – проводимость, проинтегрированная по высоте,  $j_z$  – компонента плотности тока вдоль оси  $z$ ,  $v_i$  – частота столкновений ионов с нейтральными частицами,  $\omega_i = \frac{\mu_0 e H}{m_i}$  – гирочастота ионов,  $e$  – заряд иона,  $m_i$  – масса иона,  $\vec{v}_n$  – скорость движения нейтральных частиц,  $\vec{v}_{n\perp}$  – горизонтальная скорость движения нейтральных частиц,  $f(z) = \frac{\omega_i v_i}{\omega_i^2 + v_i^2}$ .

Полученные численные оценки вкладов различных членов в этом выражении сопоставлены с реально наблюдаемыми величинами токов и скоростей нейтрального ветра.

## **Измерения температуры нейтральной компоненты и ветров в E-слое**

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По полученным в 2003-2005 годах данным интерферометра Фабри-Перо сделаны оценки температуры и параметров нейтрального ветра в E-слое. Разработан алгоритм аппроксимации наблюдаемого контура эмиссии 557.7 нм, который позволяет корректно решать задачу измерения температуры нейтралов в термосфере по уширению спектральной линии. Для этого используется информация, содержащаяся на всем профиле контура исследуемой эмиссии. Измеренные температуры показали изменчивость от 450 до 1200 °К при характерных значениях 500-800 °К. Сделаны предположения о связи наблюдаемых температур с состоянием авроральной активности и ее наблюдаемыми формами. Усовершенствована методика определения скорости ветра в термосфере. В данной задаче для повышения точности измерений доплеровского смещения используется режекция профиля спектральной линии. Максимальные значения измеренных скоростей достигали 400 м/с. Обнаружена долготная неоднородность поля ветров. Наблюдались случаи быстрого, квазисинхронного изменения скорости и направления ветров на значительной площади. Получение приведенных результатов стало возможным благодаря разработке новых методов оценки шумовых свойств используемых ПЗС-матриц. Обработка матриц ведется с использованием банка данных, содержащих параметры всех рабочих пикселей ПЗС.

### **Синхротронное излучение пучков электронов в среднеширотной ионосфере**

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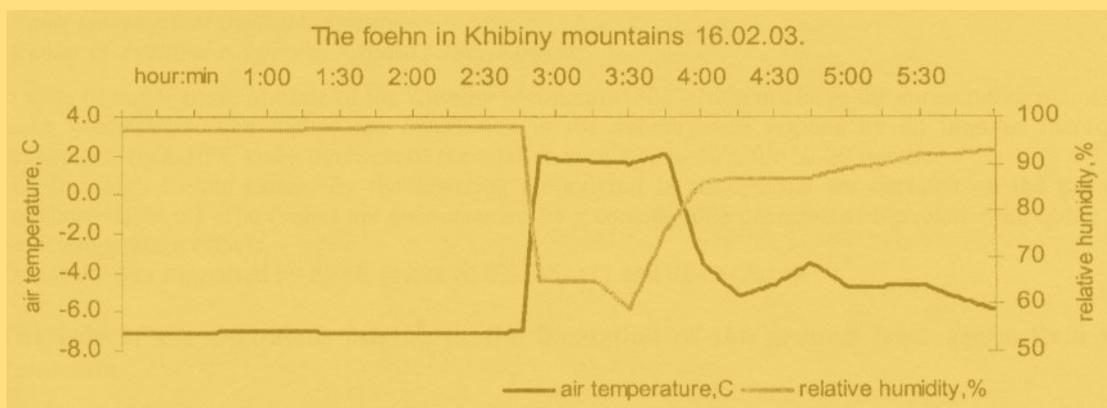
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Синхротронному излучению электронов магнитном поле Земли в последнее время уделяется значительное внимание (см. Дудник, 1999). При этом часто не конкретизируется взаимодействует ли поток частиц покрывающий значительные участки магнитного поля или мы имеем дело с локализованным пучком частиц, с основной гармоникой синхротронного излучения или с более высокими гармониками. Спектральные измерения радишумов ионосферы с частотным разрешением 100 кГц в диапазоне 90-180 МГц и временным разрешением 0.02 с. показали, что: во-первых, регистрируются всплески радиоизлучения частиц, которые можно интерпретировать как проваливающиеся в нижние слои ионосферы пучки частиц с малыми питч-углами и частотным дрейфом более 300 МГц/с; во-вторых, регистрируются пучки, которые отражаются в магнитном поле, когда их питч-угол достигает 90 градусов. В последнем случае отражения происходит в области E ионосферы, и максимум радишума имеет почти симметричную скорость частотного дрейфа. Скорости дрейфа находились в пределах 8-40 МГц/с в частотном диапазоне 90-120 МГц. Проведено моделирование пучков высыпающихся электронов и сравнение с результатами измерений.



## Low Atmosphere, Ozone





### **The ozone monitoring in the Khibiny Mountains**

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Since 2004 the ground-level ozone monitoring has been performing on the top mount Lovchorr (Khibiny, 1089 m). It is reasonable to suggest that the ozone concentrations on the top of the mount Lovchorr represent those in the free atmosphere at a given altitude. Indeed, (1) the monitoring station is outside the mixed layer or at its upper boundary during the most part of the year; (2) the size of the Khibiny mountain range is not large (30x50 km), absolute altitudes are 900-1200 m, relative altitudes are 800-1000 m. For this reason, the Khibiny Mountains do not produce a considerable disturbance in the atmospheric circulation; (3) the mount-valley circulation is absent or weak in the region, so that the ozone impoverished surface air does not rise to the upper part of the mountains and plateau.

The results of the measurements indicate the absence of the regular diurnal variations and high correlation between the ozone concentration on the top of the mount Lovchorr and conservative air characteristics (potential and equivalent-potential temperature), typical for the conditions of the free atmosphere.

This study was supported by RFFR grants № 02-0564111 and 02-05-79148

### **The foehn in the Khibiny Mountains**

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In spite of rather small altitude of the Khibiny Mountains (800 –1000 m above the surrounding plains) there are the foehn phenomena. The foehns are manifested in the submountain regions by an impulse increase in the air temperature by 8-10°C and a decrease of the relative humidity to 40% for 10-20 minute.

The free high foehns caused by the lowering air moving in anticyclone are detected on the top of the mount Lovchorr (1089 m). The foehns are accompanied by a considerable decrease of the relative humidity (to 40%) and weak temperature effects.

This study was supported by RFFR grants № 02-0564111 and 02-05-79148

### **The role of the turbulent mixing in the formation of the ground level ozone field in the Kola Peninsula**

V.I. Demin, M.I. Beloglazov (*Polar Geophysical Institute, Apatity*)

The model of the annual variations of the maximum surface ozone concentrations is constructed based on the ground-level ozone measurements in Lovozero and on the top of the mount Lovchorr (Khibiny) as well as ozone sounding data at Sodankyla (Finland). The maximum altitude of the mixed layer in the region considered and the ozone concentration at its upper boundary are input parameters. The developed model reproduces qualitatively well the main peculiarities of the observed annual variations. The maximum deviation between the observed and calculated values is less than 5 ppb. The observed maximum surface ozone concentrations are less than the ozone concentrations at the upper boundary of the mixed layer. This supports a dynamical source of the ground-level ozone in the high latitude atmosphere.

This study was supported by RFFR grants № 02-0564111 and 02-05-79148

### **The dynamical mechanisms of the formation of the surface ozone concentration anomaly on Kola Peninsula**

V.I. Demin (*Polar Geophysical Institute, Apatity*)

The content of ozone in the surface layer on Kola Peninsula is far from the maximum permissible concentration. The indications of the photochemical ozone generation in the surface layer are not found out.

The highest ozone concentrations (up to 50 ppb) are observed during the spring. During other seasons, including the periods of polar day and night, the maximal ozone concentrations are of the same order. The high concentration in winter (up to 35-40 ppb) are created during turbulent exchange strengthening at atmospheric fronts and jet streams in the boundary layer, and also by advection of unstably stratified sea air. The high concentration in summer (up to 35-40 ppb) are created in the afternoon due to unstable thermal stratification and convective mixing of air in the low troposphere when the air enriched by ozone comes into the surface layer. However, the same concentration are also created at night during strengthening of the dynamic turbulence (for example, during a cold front passage). During spring and summer the highest ozone concentrations (up to 50 ppb) are created by advection of air mass from the central Europe to Kola Peninsula. Practically synchronous changes of the ozone content in Lovozero and on plateau

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Lovchorr evidently testify advective mechanism of such increases of the ozone content.

### **Long-term changes in the quasi-stationary zonal distribution of the total ozone in Antarctic region**

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Zonal distribution of the TOMS total ozone values at the edge region of the Antarctic stratospheric polar vortex is analyzed. The time interval of August-December covering the Antarctic late winter – spring – early summer is considered. It is known that in the total ozone distribution the zonal wave number 1 is predominant and zonal asymmetry exists in the form of a quasi-stationary wave ridge (total ozone maximum) and trough (total ozone minimum), located in opposite longitudinal sectors.

We analyze the change in the zonal asymmetry during 1979-2004 using the daily TOMS data for the latitude circles of 65°S and 70°S. The five-month average zonal distributions for the total wave number are obtained. The results show that during the last 25 years the difference between the total ozone level in the wave ridge and trough increased up to ~ 80 DU, or 30% relative to the zonal mean. This anomaly indicates an increasing (decreasing) level of the surface UV-radiation in the region of ozone minimum (maximum) during Antarctic spring.

The interannual variations in the wave ridge position near the stable average longitude of about 150°E and 170°E are observed at latitudes 65°S and 70°S, respectively. The long-term eastward displacement of the wave trough exists in the longitudinal sector from 60°W to 10°E. Such a tendency could be explained theoretically by an interaction between quasi-stationary components of the zonal wave numbers 1 and 2. Geographic positioning of the quasi-stationary wave ridge and trough could be related to the asymmetry of the Antarctic continent - Antarctic Peninsula (the Weddell Sea) corresponding to the minimum, and the Ross Sea corresponding to the maximum.

### **About global temperature measurement accuracy, its stochastic disturbances, and long-term changes**

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The basic statements used as a scientific ground for the Kyoto Protocol appear to be disputable and clearly inconsistent. The suggestion of a 0.6 K global temperature increase cannot be taken as trustworthy, for such an increase is impossible to detect with the currently available measurement base; the natural variations in the mean annual global temperature exceed this value. The claim of the inevitable growth of the global temperature due to increasing emission of the greenhouse gases to the atmosphere ignores the fact of the prevailing negative feedback in the climatic system of the Earth. This feedback has been reliably established through both paleoclimatic investigations and intercomparison of the current climatic parameter variations. The referring of the observed increase in greenhouse gases amount in the atmosphere exclusively to human activity cannot be taken as valid because of the lack of reliable monitoring of such processes as atmosphere-ocean CO<sub>2</sub> exchange, lithosphere CH<sub>4</sub> emission (particularly in the marshland areas of Western Siberia), and some others. The relations between changes in the global temperature and tropical typhoon number are found.

### **Study of ozone concentration decrease in mesosphere-stratosphere during solar proton events in October 2003**

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Using one-dimensional time-dependent model we have calculated the production and loss of minor components of the middle atmosphere during solar proton precipitations in October 2003. Proton fluxes measured on the GOES-11 spacecraft have been used to estimate the rates of ion-electron pair, odd-nitrogen and odd-hydrogen production. Our calculations show that the production of odd-hydrogen causes the ozone depletion by the factor 2 and more at the altitudes higher than 55 km. The decrease in ozone concentrations at the altitudes less than 45 km and observed on POAM-3 satellite has been not obtained in our calculations with the GOES-11 data and the isotropic pitch angle distributions of solar protons.

## Joint observations of the behaviour of polar ozone during winter 2003/2004 in the northwest sector of the Arctic

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We present ozone measurements of the Millimeter-wave spectrometers installed at the Polar Geophysical Institute in Apatity (67°N, 35°E), Russia and at the Institute of Space Physics in Kiruna (68°N, 20°E), Sweden. Besides, vertical distributions of ozone (from the Earth's surface up to the height of 25-30 km) were measured using electrochemical concentration cell (ECC) ozonesondes at the Meteorological Institute in Sodankyla (67°N, 27°E), Finland and at the Alfred Wegener Institute in Koldewey-Station (79°N, 12°E), Spitsbergen.

In this study a detailed analysis of the Arctic winter 2003/2004 is presented. Joint observations of stratospheric ozone were performed in the period from December, 2003 till May, 2004. The past ozone data (vertical distribution) at heights from 20 up to 60 km were compared to stratospheric temperature profiles. These temperature profiles were obtained from aerological or satellite measurements. Among the most interesting of the present studies one should mention the detection of a significant (30-50%) ozone decrease in the first half of April, 2004 at heights from 25 up to 40 km from measurements at all the above stations. Similar significant perturbations to the NO<sub>x</sub> (NO+NO<sub>2</sub>) and O<sub>3</sub> in the high latitude upper stratosphere are seen in the Halogen Occultation Experiment (HALOE) data during April, 2004 at 68°N.

The joint measurements 2003/2004 of ozone in the upper atmosphere (above 20 km) have shown very strongest longitudinal asymmetry in its content at high latitude.

## Unusual behaviour of ozone in the upper polar atmosphere during solar proton events in March-April 2001

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Stratospheric ozone is subject to both natural and manmade impact. At present, it is very well known that the significant fluctuations of ozone content above 20 km are connected with the atmospheric dynamics, and particularly, with the stratospheric warming and with internal gravitational waves. There is another probable reason of ozone variations as a sequence of the nitrogen oxides appearing due to cosmic rays both of solar and galactic origin.

Among various methods of stratospheric ozone measurements, there is an outstanding means of the ground-based microwave radiometry. The remote microwave observations make it possible to conduct long time middle atmosphere ozone monitoring under high time and space resolution. Besides, this method seems to be mostly efficient in the studies of the connection between solar activity and ozone variations at the Earth stratosphere and lower mesosphere.

During simultaneous microwave observation which were performed at Polar latitude {the Kola Peninsula, Apatity (67°N, 35°E)} and mid-latitude {Nizhny Novgorod (56°N, 44°E)} during winter 2000/2001 in March-April there were some solar proton events. According to the GOES-8 and GOES-10 satellite data (<http://spidr.ngdc.noaa.gov>), intense solar proton events were recorded on March 29, April 3, 9 and 12, 2001. It is necessary to note, that variations of ozone density at heights 50-60 km were more significant than above Nizhny Novgorod during proton events. By comparison of ozone fluctuations (at level 60 km) and solar activity (fluxes of energetic particles) above Apatity high positive relation was observed, and the factor of correlation was about 0.6.

Thus, experimental data show that the connection between the solar activity level and ozone content in the atmosphere is extremely complicated.

### **Titan's atmospheric winds simulated with a global 3-D non-hydrostatic circulation model**

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Saturn's largest satellite Titan is the only moon in the solar system that possesses a considerable atmosphere with a surface pressure of about 1.5 times that of the Earth. Due to the close distance from Titan to Saturn the satellite is tidally locked and has a synchronous rotation period of barely 16 days which implies that the planet belongs like Venus to the group of slowly rotating bodies with a dense atmosphere. Under such conditions, the circulation of the atmosphere is not close to geo-strophic balance like on Earth or on Mars, where pressure gradients are balanced by coriolis forces but by the centrifugal forces of an almost latitudinal circulation. Titan's atmosphere is therefore in a so-called cyclostrophic balance. Titan's atmosphere has been subject to several studies with general circulation models (GCMs) providing results that differ considerably. This may be due to the fact that the temporal evolution of the temperature is mainly governed by advective and diffusive heat transports and the radiative heating term. The latter one is strongly influenced by both the aerosol absorption properties and their spatial distribution, currently under analysis by the Huygens teams. In turn, the aerosol distribution may also be influenced by the atmospheric circulation, which implies a coupled system. The temperature distribution is used in the GCMs to derive the horizontal and vertical wind dynamics. The nowadays widely used Earth GCMs as well as GCMs developed for other planetary atmospheres are mainly based on the hydrostatic equation. As a consequence, the vertical components of the wind velocity derived from previous GCMs have values in the range of several cm/s. At the same time the observed vertical component of the wind velocity in the Earth's lower thermosphere can get up to values of 10s of m/s. This clearly shows that the existing GCMs have difficulties to correctly describe the behaviour of the vertical atmospheric winds in all regimes, especially under the disturbed conditions. We present a new approach to simulate Titan's atmosphere dynamics by using a global three-dimensional circulation model. Our approach differs from previous studies in two major respects: first, our model does not use the hydrostatic equation, i.e., all three components of the neutral gas velocity are obtained from the numerical solution of the Navier-Stokes equation, and second the global temperature field is taken as a prescribed forcing function, which implies that the model does not include the energy equation. Our model provides three-dimensional global distributions of the zonal, meridional, and vertical components of the neutral winds in Titan's atmosphere, which fit well the pre-Huygens observations.

### **Influence of GCR Forbush-decrease on atmospheric ELF-electromagnetic field**

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The results of continuous observations of atmospheric electromagnetic pulses with the frequencies 1-300 Hz (on a level 0,5) at Apatity atmospheric range of the Polar geophysical institute (67°33'N, 33°20'E) are considered. As a field sensor, the magnetic field antenna such as toroid of the 3-rd order is used. 5 cases of significant Forbush-decreases registered by the neutron monitor in Apatity (reduction of galactic cosmic rays (GCR) intensity about 4 % and more) in the period since October 2003 till November 2004 are presented. It is shown that a sharp reduction in the magnetic component of the atmospheric pulses corresponds to the beginning of GCR Forbush-decreases. We hypothesize that the reason of the found effect is a reduction in the ionization degree of the top atmospheric layers in such periods and, as a consequence, a reduction in the rate of formation of the sprites and jets, as well as ELF-signal decrease.

This work is supported by the Program of basic researches DPS of RAS "Physics of atmosphere: electrical processes, radiophysical methods of researches" and also by the RFBR (grant 02-05-641 14).

## Origin of diurnal variation of surface ozone in the Kola Peninsula and Finland

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Surface ozone concentration (SOC) at the Lovozero observatory in the Kola peninsula for 2000-2002 has been studied, including its monthly averaged diurnal variations and amplitude behavior. The geophysical station of Lovozero is located in the forest area 5 km from the Lovozero settlement. There is no industrial activity nearby. Once a minute ozone measurements are carried out with DASIBI - 1008 AH device and registered by the data collecting system together with meteorological parameters such as temperature, pressure, speed and direction of the wind, humidity, luminosity. The SOC values measured at the station represent the background values for the high-latitude atmosphere with a small level of industrial pollution. The maximum diurnal mean SOC values occur in April and reach 40 ppb, while the minimal ones are observed in August – December and equal to 15-20 ppb. The diurnal variation is at the peak at 14 – 16 local solar time. The amplitude of the diurnal variation is maximum in June - September, with the value of 10 ppb, and minimum in winter months (1 - 2 ppb, close to the estimation error). The measurements in Lovozero show that the diurnal SOC variation is great when the light intensity for the whole day is great. During low solar radiation the diurnal variation is poorly pronounced. A diurnal SOC variation may be caused by a daily change in the solar UV intensity, ozone precursor concentration, thermodynamic parameters of the atmosphere, height of the mixing layer, dry deposition rate, ozone transport velocity. The role of these factors has been investigated by numerical modeling. We use simple one-box photochemical model, which suggests that the concentrations of the trace gases are homogeneous in the mixing layer. This model presents adequately some basic characteristics of the ozone distribution in the background and polluted conditions. It describes chemical transformations of 9 trace gases: O<sub>3</sub>, NO, NO<sub>2</sub>, NO<sub>3</sub>, N<sub>2</sub>O<sub>5</sub>, HNO<sub>3</sub>, CH<sub>2</sub>O<sub>3</sub>, PAN (peroxyacetyl nitrate) and HO<sub>2</sub> in the mixing layer, where the concentrations of these gases are supposed not to change with altitude. They react with each other and with solar UV radiation by 33 reactions, presenting the basic interactions in the near-surface atmosphere. A simple model of the mixing layer typical for the middle latitude atmosphere is used. The diurnal variation of the surface ozone concentration in Lovozero is determined by the ratio of chemical sources and losses in the interactions of trace gases, and by dry deposition. The average diurnal SOC variation is mostly caused by dry deposition and destruction of ozone by nitrogen oxide at night, and by changes in both photodissociation of the nitrogen dioxide and concentration of the organic peroxy radicals (the precursors necessary for ozone generation) during daylight hours. Such factor as the amount of hydroperoxy and peroxyethyl radical formed in the atmosphere is not enough to explain the observed SOC variability. The peroxy radical concentrations, which are a necessary factor for SOC variations, should be produced by plants in the vegetation period. The contribution of a change in the mixing layer height and variability of dry deposition velocity is small and can be noticeable only in summer months. The contribution of the horizontal ozone transport into the diurnal variation does not seem to be large. The diurnal distribution of SOC at four stations in Finland has been investigated, the average SOC values and amplitude of the diurnal variations of ozone concentration being found. An increase in the amplitude of the SOC diurnal variation from the north to the south at the continental stations of Finland is revealed. A comparison with the observations in the Kola peninsula is performed. With the considered chemical model applied quantitatively to the Lovozero data, the qualitative explanation of the diurnal variations in Finland is achieved.

## About the space structure of surface ozone levels over the Russian European territory

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Surface ozone time series over the Moscow region (56 °N, 38 °E; both the city centre and a suburb area), rural area in the Penza region (54 °N, 43 °E) and Lovozero station (68 °N, 35 °E) have been compared for different periods of 2004. The results suggest that the observations of surface ozone over Moscow suburb Dolgoprudny can characterise its levels over the middle zone of the Russian European area for time intervals longer than 1 week. The western transport was observed in the movement of surface ozone fields in spring-summer period of 2004 over this area, the ozone field configuration being, on the whole, stable during some days. In the absence of long episodes with severe air pollution in the Moscow region, the levels in the city centre and nearest suburbs do not differ much. The cases of significant horizontal gradients of the surface ozone between Moscow and suburbs were mostly related to the local temperature inhomogeneity, e.g., during moving atmospheric fronts and rains. In Spring 2004 there were some periods when the surface ozone concentrations in Moscow and Kola regions (over ca. 1500 km distance) were both determined in cyclone warm sector by advection of the air masses with increased ozone levels.

## **Моделирование циркумполярных вихревых течений в земной атмосфере для январских и июльских условий**

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Исследуется формирование циркумполярных вихрей северного и южного полушарий для двух разных сезонов. Глобальные стационарные распределения нейтрального ветра в пределах высот от 0 до 120 км, рассчитываемые при помощи численной трехмерной модели горизонтального и вертикального ветра, учитывающей несферичность Земли, были получены при использовании различных планетарных распределений температуры, заданных по эмпирической модели NRLMSISE-00 для двух разных дней (16 января и 16 июля). Результаты расчетов показали, что для условий, когда в северном полушарии зима и лето, на уровнях стратосферы и мезосферы формируются циркумполярные вихри в северном и южном полушариях. В январе в северном полушарии формируется циркумполярный циклон, а в южном полушарии - циркумполярный антициклон. В июле в северном полушарии формируется циркумполярный антициклон, а в южном полушарии циркумполярный циклон. Результаты численных расчетов качественно соответствуют результатам наблюдений и подтверждают гипотезу о том, что циркумполярные вихревые движения обязаны своим происхождением горизонтальной неоднородности температуры атмосферы, в частности, градиентам температуры воздуха между экватором и полюсами. Работа выполнена при поддержке гранта РФФИ-БНТС Австрии 03-05-20003БНТС.

# *Heliobiosphere*





## Variations of geocosmic agents and the growth of microflora in human organisms

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Simultaneous appearance of pathogenic microorganisms with similar peculiarities in geographically isolated regions [1] suggests the existence of general global agents associated with solar cyclic activity and initiation of living systems transformation. Observations indicate biological connections of Ground Level Enhancements (GLE) of secondary energetic particles during the great solar proton events with the production of genetic distortions in the cell cultures [2, 3, 4]. The results of these investigations indicate that secondary cosmic rays may play an essential role in the regulation of microflora growth. A direct evidence of the connection between microflora transformation and variations in cosmic radiation was shown by Faraone [5] during experiments which had been carried out on the culture of microorganisms in the mountains, at the sea level and underground. He found that the main peaks of microflora transformation is coincident with the solar activity minimum. Therefore, it is important to understand what could be the general agent that initiates microflora growth. The growth of microflora with the patients with BA was taken as a model to study the relation to the variations of geocosmical agents. The effects of geocosmical agents on microflora have been analyzed by the Technology of System Reconstruction (TSR) [6]. It was found that the growth of pathogenic and nonpathogenic microflora is determined by different groups of geocosmical agents. The growth of pathogenic microflora shows a negative correlation with the indices of sunspots, solar wind plasma density and its variability. Positive correlation of pathogenic microflora growth rates was revealed with the neutron count on the Earth's surface, variability of modulus of the interplanetary magnetic field (IMF) and solar wind dynamic pressure, velocity and variability of the solar wind. Moreover, the neutron count and solar wind plasma density are of major importance for modulation of pathogenic microflora growth according to the analysis performed with the TSR technique. On the contrary, a negative correlation was found between the neutron counts and the growth of nonpathogenic and conditionally pathogenic microflora. The growth of mycology in human organisms exhibits a positive correlation with neutron counts and total ozone content and negative correlation with the pressure before the measurements of mycology growth rates. The data on the correlation types of microflora growth rates in the organism of BA patients are found to support in analyzing the dependence of skin microflora growth rate on the organisms. The results of this study show that the pathogenic microflora is more sensitive to the variation of geocosmical agents, especially the secondary radiation, than nonpathogenic microflora. The dependence of the epidemiological aspects on the variations of geocosmical agents and peculiarities of solar activity is discussed.

This research was supported by the Russian Foundation for Basic Research through by grant 05-04-97511\_p\_sever\_a.

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## Geomagnetic pulsations as one of the important components of heliogeophysical disturbances influence on human health

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The new heliobiological concept proposed in the beginning of the 1990s was discussed in [Breus and Rapoport, 2003]. According to this concept, the biological objects including human organism as a complicated open nonlinear system are very sensible to the influence of weak electromagnetic signals of the background level, which play a significant role in its self-organization. In the evolution processes the variations of natural electromagnetic fields represented the external signals to form the corresponding endogenic rhythms. For that reason biologic system

reaction to the heliogeomagnetic disturbances is a non-specific adaptation stress-reaction. It could be irreversible only for so-called “group of risk” people. The main “target” is the cardiovascular system. A bioefficiency of different magnetic storms even with similar intensity is different. We assume that it is a result of its different wave signature.

We present here the results of the analysis of the daily ambulance calls in Moscow in the period of solar activity maximum (1979-1981) as to the heart attacks (myocardial infarction - MI). We found the similarity between the number of monthly ambulance calls for MI in Moscow and simultaneous mortality from MI in Bulgaria. The good correlation was found between the days with anomalous great number of MI ambulance calls (later MI-events) in Moscow and previous long-lasting negative Bz IMF. The major part of MI-events was observed at a recovery phase of magnetic storm, after strong geomagnetic disturbances. Only a few MI-events occurred during the main storm phase. We have compared MI-events with the occurrence of geomagnetic Pi1 pulsations with  $T \sim 1-3$  c (similar to the men heartthrob periods). It has been found that they were observed simultaneously with high probability twice as stronger as the causal ones, in spite of the typical minimum in Pc1 occurrence during the period of the solar activity maximum. Very often (in  $\sim 80\%$  of MI-events) Pc1 pulsations were observed on previous 1-2 days. Probably, Pc1 occurrence can play a role of negative stress-reaction to the state of the cardiovascular system of certain sick human organisms.

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## **Imprints of remote past solar events in the contemporary population structure of the biota**

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The structure of any living population is strictly controlled by a number of intra biological rules and limitations. However a number of available facts are in evident contradiction with these rules, manifesting as explicit violence of biological rules of the game. The plausible causes of the deviations in expected trends and distributions in the population structure might be related to cosmic and geophysical processes. Some recently obtained examples of such phenomena are considered. Those include a domination of a definite age class in any population, and population age structure, and so-called individual annual cycle (IAC) in humans. Among other things, the age structure of populations accumulates the life history of preceding years (months, days, moments) and inevitably bears the imprints of remote past biologically significant environmental events. For that reason it could be a matter of special interest to the experts in heliobiology and researchers of solar-terrestrial links. The age structure of long-term populations of perennial herbaceous plants, cultivated in the Polar-Alpine Botanical Garden in the valley of Khibiny mountains, is considered with respect to possible significance of cosmic factors. The explicit unevenness of various start year planting subpopulations data in common plant age distribution and the relative contributions of various factors in its pattern are considered. The three points mean averaging of the data clearly reveals the pattern modulation effect by the main solar cycle in the age structure of total population over 50 years since 1930s. The data obtained, the age domination effect, and the “day of birth” effect in terms of IAC for human populations are considered based on the common paradigm of heliogeophysical factors.

## **Monitoring of biological (DNA-damaging) effects of solar UV radiation in middle and high latitudes**

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The stratospheric ozone concentration has been investigated by several methods, e.g., determinations of the ozone layer using a network of ground based spectrophotometers, of the Dobson and the Brewer types. These data indicate significant decrease of the ozone layer superimposed by much larger seasonal changes at specific geographical locations. The stratospheric ozone plays an important role in the attenuation of the short-wavelength components of the solar spectrum, thus the consequence of the decreased ozone layer is an increased UVB level. Various pyranometers measuring the biological effect of environmental UV radiation have been constructed with spectral sensitivities close to the erythema action spectrum defined by the CIE. Using these erythemally weighed broad-band

instruments to detect the tendency of UVB radiation controversial data have been found. To quantify the biological risk due to environmental UV radiation it is reasonable to weigh the solar spectrum by the spectral sensitivity of the DNA damage taking into account the high DNA-sensitivity at the short wavelength range of the solar spectrum. Various solar UV sensitive biological dosimeters have been developed e.g., polycrystalline uracil thin layer. These are usually simple biological systems or their components. Their UV sensitivity is a consequence of the DNA-damage. We show that biological dosimeters applied for long-term solar UV monitoring are promising tools for the assessment of the biological hazard. To compare solar UV induced DNA-damage between high latitudes in the Arctic regions with observations in central and southern Europe we started measurement campaigns during 2004 at facilities of the Polar Geophysical Institute of the Russian Academy of Sciences in Barentsburg/Spitsbergen (78 degrees north) and Apatity (68 degrees north). We will present the first preliminary results of these field experiments and discuss planned future experiments, which will be carried out during 2005.

This research was supported by the Russian Foundation for Basic Research through by grants 05-04-97511\_p\_sever\_a and 03-05-20003 BWTZ.

### **The assessment of regional relationship between heliogeophysical factor activity and children morbidity parameters during 11-year solar cycle in the European North region.**

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Official medical statistics of the Murmansk region indicates that the level of children morbidity in the Kola region has been increased during the last decades. It exceeds 1,3 - 1,5 times that of the Russian Federation. Sometimes Russian and foreign researchers relate this increase dynamics with the social-economical reforms in Russia started at the middle of the 1980s. But children morbidity demonstrates changeable dynamics with alternating increases and decreases every now and then. In our view, it does not seem to be associated with increasing environmental chemical pollution. For that reason we believe that this health phenomenon reflects the 11-year heliogeophysical cycle dynamics.

For this purpose an attempt has been made to find a connection between them. For the period 1994 - 2004 the two phenomena, i.e. children morbidity and heliogeophysical activity (sun-spots and cosmic rays), correlated with high statistical reliability, which confirms our hypothesis. The interrelation between some health parameters and sun-spot number has shown a synchronous dynamics at minimum and maximum of the solar cycle. As to the interrelation with cosmic rays, the correlation coefficients were opposite in sign to the health parameters dynamics.

From 1996(min) to 2000(max) the difference between the children morbidity levels was 45%. Currently a drop in children morbidity has been registered (9,7% in 2004 compared to 2000) in accordance with the tendency in sun activity and cosmic rays.

### **Monitoring of electromagnetic fluctuations from industrial sources (range geomagnetic pulsations 0.01-10 Hz)**

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Numerous experiments performed by ISTP SD RAS at Norilsk meridian have allowed us to study the morphology of geomagnetic pulsation in different latitude-longitude sectors. This knowledge was required to investigate poorly studied electromagnetic emissions of industrial origin in a large city, particularly when monitoring the environment pollution electromagnetic noise of different origin.

In this paper we present the first results of monitoring of electromagnetic emission of industrial origin registered at the Academy campus of Irkutsk city within the range of natural fluctuations of the electromagnetic field of the Earth (the frequency range 0.01-10 Hz). The monitoring was performed with standard instruments that are used for registration of geomagnetic pulsation at the ISTP SD RAS observatory, after a small upgrading.

Based on the observations, spectra and intensity of the registered signal were calculated. It has been shown that in the daytime, persistent electromagnetic noise within a broad frequency range is registered in the city, with the amplitude exceeding by 1-2 orders that of the geomagnetic fluctuations registered on the basis of the Institute observatory. It disappears after the local midnight, and appears again after 5-6 a.m. We note that the ratio of the industrial signal to the amplitude of the natural emission of the Earth increases with frequency increasing (from 7 at the frequency of 0.06 Hz to 100 at the frequency of 5 Hz). Thus, further observations should be conducted in a higher frequency band.

Our study suggests that in the large cities the electromagnetic emission of industrial origin exceeds a few times the natural background of the electromagnetic emission of the Earth.

## **Упорядоченность и стохастичность биологических систем при воздействии внешних естественных полей**

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На базе результатов 6-летнего мониторингового эксперимента ИЗМИРАН рассмотрены особенности поведения организма человека при воздействии естественных внешних полей. Высказывается предположение, что многие наблюдаемые эффекты, традиционно относимые к шумам и ошибкам эксперимента, есть проявление нелинейности и самоорганизованности биологических систем. Одним из важных направлений изучения таких эффектов может стать исследование фазовых переходов в макро-биологических системах. В общем случае поведение системы определяется симбиозом *динамики, предопределенности и случайности*. Данные нашего 6-летнего мониторингового эксперимента подтверждают, что около 20% наблюдаемого временного промежутка приходится на области стохастического поведения системы. Таким образом, для предсказания поведения биологических систем при воздействии слабых естественных полей возникает подобие принципа неопределенности в квантовой механике: необходимость выдерживать соотношение между характерными масштабами временных и пространственных характеристик, выбираемых для анализа системы. В работе [1] показано, что для каждой системы существует свой горизонт прогноза, однако, чем крупнее временной масштаб рассматриваемого явления или область пространства (что эквивалентно увеличению количества исследуемых элементарных объектов), тем точнее прогноз. Методологически для задачи прогнозирования воздействия слабых полей на организм человека это означает:

- что оптимальные предсказательные математические модели будут работать в области выявления непрямых коллективных реакций (как в случае отдаленных последствий термоядерных взрывов, рассмотренном Сахаровым)
- или на длинных временных рядах, где временной шаг модели много больше, чем характерное время переходных процессов в организме человека (работы Чижевского).

Говорить о локально точных прогнозах на длительный период, где  $t \ll T$  (например, о прогнозах на несколько месяцев с временным шагом день) *принципиально нельзя*. Пренебрежение конечностью горизонта прогноза и неправильно выбранные соотношения характерных параметров системы приводит к невоспроизводимости результатов. В качестве универсального критерия фазовых состояний биологической системы автор предлагает использовать негэнтропийный принцип Бриллюэна (с учетом свойственного для биосистем протекания процессов адаптации по правилу смешанного экстремума).

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