# Space Weather: Russian Perspectives

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Different scientific groups in Russia are successfully developing the complex of experiments and models directed to Space Weather problems. At present the complex consists of the following major parts: optics and radio observations of the Sun and a forecasting model of large solar flares; ground based monitoring of the heliospheric (neutron monitors) and geomagnetic (magnetometers) conditions; models of the geomagnetic storm forecasting; a model of galactic cosmic rays and a probabilistic model of solar energetic particles; monitoring of the radiation environment by satellites. The problems of compilation of these parts and perspectives of their future development are discussed.

## 1. INTRODUCTION

Space weather in Russia has a long history. One of the first mentions of space weather phenomena at the beginning of this century may be found in [*Ryumin*, 1925]. In this book an extremely strong magnetic storm and its destroying consequences, which impacted the ground based electric and communication systems in Russia are described. The physical nature of the phenomena is explained by the influence of a magnetic cloud from the Sun on the Earth. The fundamental studies in Russia devoted to solar-terrestrial linking were performed by *Tchijevsky* [1928]. He has shown clearly that a lot of geophysical, life and social processes on the Earth are to a certain extent connected with solar activity.

The next step in the space weather development was triggered in 60-ies by space flights. Knowledge of the near-Earth radiation environment is extremely important for radiation safety of the satellites. Studies of the high energy particles trapped in the radiation belts and cosmic rays, which can penetrate through the spacecraft shielding, showed that their fluxes have a complicated non-linear dependence on solar and magnetospheric activity. The very high energy protons originate from galactic cosmic rays (GCR), which are modulated in anti-phase with the solar cycle. The protons can be accelerated also in the solar energetic particle (SEP) events up to very high energies and, therefore, penetrate deeply into the Earth's magnetosphere. The fluxes of high energy trapped radiation vary strongly due to the geomagnetic storms and sub-storms. Shortly, the radiation environment has significant long-term variations, associated with the solar cycle and short time enhancements associated with SEP events and geomagnetic disturbances. To describe this complicated process, responsible for variations of the radiation environment, SINP MSU in 60-s initiated an activity to develop different models that permit to describing any phenomena in solar-terrestrial physics. The results of this activity were published in the form of books *"Models of the Space"* [1976] which combine the quantitative (theoretical and empirical) models of the solar activity, heliosphere, planets and moons, Earth's magnetosphere, ionosphere and atmosphere, GCR, solar energetic particles, trapped radiation and their impact on the satellite's systems and electronic equipment.

During the last decade the space weather research developed intensively due to several important reasons. The first one is the development of the International Space Station (ISS) and as a consequence, a significant increase of the number of manned space flights and duration of the astronauts' work in the space. The second reason is extensive use of high integration space electronic systems. Such micro-chips are very sensitive to both highly ionizing protons

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and to volume charge induced by high energy penetrating electrons. The space weather events in energetic particles may dramatically effect satellite electronic systems and can lead to faults in their operations and even to the loss of the satellite. The third reason is the discovery that many negative events on the ground based widely used systems (power systems, pipelines, railways and so on) at medium and high latitudes are closely connected with geomagnetic activity. Strong electric currents induced during the geomagnetic disturbances may distort the equipment in electric power systems and lead to faster erosion processes in high conductive materials of pipelines and railways. The fourth reason is expansion of radio communication systems in to space and, as a consequence, the importance of stable radio signal propagation through the ionosphere where conditions significantly depend on the solar and geomagnetic activity. The fifth reason is medical research, showing that space weather events have significant influence on human health. Fluxes of high energy particles in the stratosphere generated in strong SEP events increase the doses acquired by humans during flights onboard high altitude aircraft. Many medical tests confirm that geomagnetic field variations directly impact human health. Therefore, we can conclude that space weather defines the conditions for human activities both in space and on the Earth.

Many countries announced of their own space weather activity programs over the last two years. These activities are based on existing scientific results and accomplished or future experiments (ground-based and space). Russia has many scientific Centers that have been working in the field of solar terrestrial physics for a long time. We also have several experiments in the near-Earth space. The existing potential of the Russian space weather activity permits to successfully perform space weather monitoring and forecasting: from the solar activity via interplanetary and magnetospheric perturbations to the ionosphere-atmosphere coupling. The wide network of ground-based stations created in Russia permits to perform the measurements of the solar activity, Earth's magnetic field variations, solar and ionospheric radio waves and fluxes of cosmic rays (GCR and SEP). The Russian program of near-Earth satellite experiments permits to obtain in-situ information on the magnetosphere and interplanetary medium including radiation environment, plasma characteristics, solar wind and interplanetary magnetic field properties etc. This information is vitally important for diagnostics of the interplanetary medium and Earth's magnetosphere conditions. Many theoretical and empirical models developed by Russian scientists are used successfully for description and prediction of practically any phenomena in solar-terrestrial physics. The current activity of different Russian scientific groups was partially described in [*Avdyushin et al.*, 1999] and presented on the Web-site of Russian Space Weather Initiatives (RSWI: http://alpha.npi.msu.su/RSWI/rswi.html). This paper describes the Russian space weather data resources and models. The future perspectives of RSWI activity are discussed.

## 2. SPACE WEATHER DIAGNOSTICS

### *2.1 Onground Measurements*

#### *2.1.1. Observation of the Sun*

The monitoring of the solar activity is performed in Russia in the form of radio and optical observations. IZMIRAN Solar Radio Laboratory (LaRS) supports the solar radio patrol by means of 169 MHz, 204 MHz, 3000 MHz radiometers and 45 - 270 MHZ digital spectrograph (http://helios.izmiran.troitsk.ru/lars/LARS.html). Solar radio flux in different frequency bands, spectra and solar radio bursts are measured and presented on-line. Irkutsk Radioastrophysical Observatory presents on-line information about optical and radio observations of the Sun (ftp://ssrt.iszf.irk.ru/pub/data) including bursts of solar emission at 5.7GHz (http://rao.iszf.irk.ru/bursts/stat.html). A complex of radiotelescopes in Laboratory Zimenki performs high resolution (time and angular) monitoring and patrol observations of solar radio emission with frequency from 0.1 MHz to 10 MHz (http://www.nirfi.sci-nnov.ru/english/index3e.html). Complex observations of the Sun in the optical range and in the radio waves carry out information about dynamics of active regions and flare activity including CME and filament eruption. Identification of the solar radio burst type permits to estimate the possible geomagnetic consequences of the observing solar events.

#### *2.1.2. Heliospheric cosmic ray observations*

Cosmic rays are sensitive for current global heliospheric conditions and may be used as a probe of the heliospheric disturbances. Knowledge of conditions in the inner heliosphere is extremely important because these conditions have significant influence on the CME and SEP propagation from the Sun to the Earth. High energy solar cosmic rays reach the Earth on several hours before then most intensive SEP with energies less than 100 MeV. This fact permits to estimate possible SEP flux before it arrival to the Earth's magnetosphere.

Cosmic rays are observed by the net of several Russian neutron monitors: in Moscow (IZMIRAN http://helios.izmiran.rssi.ru/cosray/main.htm), highest time resolution (10s) monitor in Apatity (PGI http://pgi.kolasc.net.ru/CosmicRay/), Yakutsk and Tixie (IKFIA http://teor.ysn.ru/rswi/graph-GIF.html). Experimental data about cosmic ray variations are loaded in the data bases presented on-line on Web-pages http://helios.izmiran.rssi.ru/cosray/main.htm (Moscow), http://pgi.kolasc.net.ru/CosmicRay/form.htm (Apatity) and http://teor.ysn.ru/imf/neutron.htm (Yakutsk and Tixie Bay). Monitoring of GCR variations and scintillation is used for short time (days) prediction of IMF disturbance [*Kozlov et al.*, 1999]. For quantitative description of GCR variations hourly index of cosmic ray activity "CR Activity Index" has been introduced [*Belov et al.*, 1999]. This index is developed directly for the purposes of diagnostic and forecasting of interplanetary perturbations and consequent geomagnetic dynamics.

*2.1.3. Earth's magnetic field*

Geomagnetic field is measured by the magnetometers located at middle and high geomagnetic latitudes. The measured data are presented in real time from Moscow (IZMIIRAN http://helios.izmiran.troitsk.ru/cosray/magnet.htm) and Irkutsk (ISTP http://cgm.iszf.irk.ru/magnet2.htm). The data bases of the geomagnetic variations (time profiles and spectra of ultra low frequency pulsations) are presented on the web-pages http://www.izmiran.rssi.ru/magnetism/mos_data.htm, ftp://vodin.izmiran.rssi.ru/start.htm (IZMIRAN), http://pgi.kolasc.net.ru/Lovozero/ (PGI), http://cgm.iszf.irk.ru/outmag/ (ISTP). The data from the net of Russian geomagnetic observatories are combined on CD-ROM data base on ftp-server ftp://vodin.izmiran.rssi.ru/start.htm. The indexes of the geomagnetic activity are calculated and presented on-line on http://cgm.iszf.irk.ru/magnet2.htm, http://charlamp.izmiran.rssi.ru/ (local 3 hour K-indexes in Irkutsk and Moscow respectively) and on http://www.aari.nw.ru/clgmi/geophys/pc_Data_Intermagnet.html (1 min Ap index). These indexes permit to estimate current geomagnetic activity at the middle and high geomagnetic latitudes.

*2.1.4. Ionosphere*

A regular control of ionospheric conditions has been carrying out since 1978 at the Radio Astronomical Observatory "Staraya Pustyn" (http://www.nirfi.sci-nnov.ru/english/index3e.html) by the measurements of the ionosphere total electron content (TEC) and its variations using a polarimeter on the basis of 10-m steerable radiotelescope at operating frequency 290 MHz. These observations make it possible to measure the Faraday rotation angle of the polarization plane of the linearly polarized Galactic radio emission in the ionosphere and by its value to determine TEC. The accuracy of TEC determination is about 5% that is not worse than that attained with geosynchronous satellites. The methods have been developed to determine 3D spectra of ionospheric turbulence based on the analysis of amplitude and phase fluctuations of satellite signals. Temporal variations of electromagnetic emission activity in different frequency ranges as well as variations of near-earth's waveguide and resonator geometrical and electromagnetic parameters exhibit a strong dependence on solar radiations of different nature and solar wind or, in other words, they are high-sensitive indicators of Space Weather. Russia has built a network of oblique sounding stations on the basis of the national low-power chirp ionosonde by cooperative efforts with NIRFI (http://www.nirfi.sci-nnov.ru/english/index3e.html), Mari State Technical University, the Institute of Solar-Terrestrial Physics of the Siberian Branch of the RAS (http://www.iszf.irk.ru/) and IKIR of the Far Eastern Branch of the RAS. The network is used at present to conduct a large-scale investigations of the ionosphere at natural and modified conditions.

*2.2. Atmospheric Measurements*

*2.2.1. Cosmic ray monitoring*

At present the data sets on the cosmic ray fluxes in the atmosphere from ground levels up to altitudes of 30-35 km are available from the basic stratosphere stations - Murmansk (1957-1998), Moscow (1957-1998), Alma-Ata (1962-1992) and Mirny, Antarctica (1963-1998). Monthly averaged data sets are used to model the atmosphere with account for cosmic ray induced ionization effects. The correlation between cosmic ray proton fluxes with cloud area and precipitation magnitude, discovered in [*Stozhkov*, 1996], permit to assume, that global climatic changes may be caused by the variations of cosmic rays, entering the solar system from galactic space. The variations of the total cosmic ray flux, entering the terrestrial atmosphere, lead to variations of the cloud-covered, which, in turn, alters the balance between the absorbed and reflected solar emission and infra-red radiation of the Earth. The decrease of the cloud-covered area by 8% is equal to a 2% increase of the solar constant. It is expected that these processes will lead to changes in the temperature of the Earth's surface.

*2.2.2. Arctic region observations*

A considerable part of the auroral zone and polar cap is located over Russia. We still have several operating observatories in this region. At the western part of the Polar Geophysical Institute and Kola Geophysical Center three observatories in Loparskaya, Lovozero and Apatity provide regular riometer and magnetometer observations and quasi-regular TV and photometer recordings of the aurora borealis.

Closer to the East observatories in Arhangelsk (IZMIRAN), Norilsk, (SibIzmir) and Dixon (Arctic and Antarctic Institute) continue similar regular ground-based observations. In the eastern part of the auroral and sub-auroral zone observations are provided in Yakuts, Tixie and Zhigansk by the Institute of Cosmophysical research. Riometer and magnetometer observations are available from most of the above mentioned observatories. Cosmic ray neutron monitors are in operation in Yakutsk and Tixie.

The polar cap and auroral zone are the scene of direct manifestation for magnetospheric disturbances, storms and sub-storms. On the one hand, this means, that the polar region of the ionosphere is a major scene of this activity and ground-based objects, such as oil pipe lines and electric power lines are mostly affected by strong sub-storms and magnetic storms. On the other hand, geophysical observations in the auroral region are important for magnetic activity monitoring and forecast.

### *2.3. Space Experiments*

In spite of the decrease in the number of satellite launches in Russia over the past several years, there are a number of experiments, the results of which can be used for current space weather diagnostics.

The most significant of these experiments is the 'Interball' project (http://www.iki.rssi.ru/ida.html). The launch of the 'Interball' satellites was made several years ago and the installed instruments still provide high-quality data on the fields and particles both outside and inside the Earth's magnetosphere. This project was developed for studying the different plasma processes in the surrounding space environment and consists of two pairs of space vehicles (satellite - sub-satellite) launched into orbits of up to 200 000 km (the Tail Probe) and up to 20 000 km (Auroral Probe).

The Tail Probe was launched into an ecliptic plane orbit , so that it can reach the high-altitude cusp and sub-solar magnetopause regions on the day side and the neutral sheet in the night side tail. The Auroral Probe is optimized for magnetic conjunctions between the two pairs of satellites around the midnight meridian. This permits to study the cause-and-effect relationships between the plasma processes in the tail and in the auroral particle acceleration region above the auroral oval with a high time-space resolution.

It is important to stress, that the 'Interball' project plays an important role in international cooperation in correlation analysis of plasma phenomena in the interplanetary and near-Earth environment according to data from different space probes: IMP-8, WIND, ACE, Geotail and others.

Another important national space experiment in the filed of space weather is radiation environment monitoring on orbital station (OS) 'Mir' (http://dec1.npi.msu.su/english/data/lasre/mir/mir.html). Here, a set of instruments for radiation studies (measuring both spectral and dose characteristics), which permits to estimate changes in the radiation environment at low altitudes (350-400 km) has been operating for many years. The radiation measurements on OS 'Mir' played a key role in the development of the Solar Cycle Low Altitude Model of Radiation [*Bashkirov et al.*, 1998]. Now we understand, that solar activity variations lead to significant variations in radiation intensity in the South Atlantic Anomaly region: during years of solar activity minimum (in contrast to solar activity maximum) the radiation belt particle flux intensities increase due to decrease of losses in a less denser atmosphere. Currently, in the year 2000, during the year of solar cycle maximum, minimum radiation doses are observed, the doses will increase again towards the solar cycle minimum (2006-2008).

Among the projects to be launched during the next several years, we should mention the following:

- 'CORONAS-F' (http://www.izmiran.rssi.ru/projects/CORONAS/index.html) The scientific goal of this project is to carry out complex research of the powerful dynamic solar activity processes (active regions, flares, mass ejections) in a broad spectral range from radio frequencies to gamma-rays; to study solar cosmic rays accelerated in solar active phenomena besides their release conditions, propagation into the IMF and impact on the Earth's magnetosphere. Helioseismology of the Sun interior is also among the main research targets. This satellite is to be launched at the beginning of 2001 into a circular polar orbit with a ~500 km altitude
- 'Interheliozond' (http://www.izmiran.rssi.ru/projects/INTERHELIOS/) is a mission specifically designed to cover the gaps in our knowledge by exploring the inner solar system with the objectives to understand the processes, which heat the corona and accelerate the solar wind. This solar probe will orbit the Sun at 30-100 solar radii at a speed 3 times as fast as the Earth and will occupy an ideal position near the transient sources in the solar atmosphere. Interheliozond will be an important element in the future program of orbital studies of solar-terrestrial coupling, providing real-time information for the space-weather forecast.

## 3. NOWCASTING AND FORECASTING MODELS.

The main purpose of the nowcasting and forecasting models is determination of current and possible future conditions that directly influence on the equipment (space and ground based), communication systems and human health. These conditions include radiation fluxes (trapped particles and cosmic rays), geomagnetic field variations (both at high and low latitudes) and ionospheric conductivity for radio signals. Therefore the space weather models have to calculate as output parameters such quantities that reflect above described conditions.

### *3.1. Nowcasting*

Information about geoeffective solar and interplanetary events is extremely important for prediction of geomagnetic disturbances and radiation enhancement. Nowcasting models of solar and heliospheric conditions permit to define such events by means of indirect observations.

To describe the global structure of inner heliosphere the IMF sector structure is continuously restored in the form of the map of the source surface according to original programs developed in IZMIRAN (http://www.geocities.com/romashets/). The model uses current on-line experimental information about solar and interplanetary magnetic field measurements. IMF sector structure (especially sector boundary location) is extremely important for description of a structure of the heliospheric current sheet and coronal holes (associated with formation of the geoeffective corotation interaction region) and for estimation of the SEP and GCR propagation conditions.

Heliospheric disturbances may be observed by indirect method of neutron monitors. This technique is sensitive to variation of GCR that reflect the condition of high energy particle propagation in the heliosphere. Data from the world wide cosmic ray station network (> 40 stations) are processed by the special methods [*Belov et al.*, 1997] to obtain hourly means of density, spectral index of density variations and of the 3D anisotropy parameters of cosmic rays near the Earth (see 2.1.2).

Solar wind - magnetosphere coupling is described by different models. The global structure of the magnetosphere is restored from boundary conditions that associated with shape and location of the magnetopause. Three-dimensional model of the Earth dayside magnetopause is accessible online on SINP web-page http://dec1.npi.msu.su/~alla/. The model permits to calculate 3D shape and size of the dayside magnetosphere boundary in dependence on the solar wind dynamic pressure and IMF $B_y$ and $B_z$ components [*Dmitriev and Suvorova*, 2000].

Determination of the spatial structure of storm-injected relativistic electrons of outer radiation belt in dependence on the *Dst*-variation is performed by a model of *Tverskaya* [2000]. The dependence permits also to predict extreme storm-time location of some very important magnetospheric plasma domains such as extreme latitude of west electrojet center during a storm, boundary of discrete auroral forms, trapped radiation boundary and intensity maximum of symmetrised storm-time ring current [*Tverskaya*, 2000].

### *3.2. Forecasting*

RSWI web-site supports references on both long time and short time forecasting of the space weather events. Long term forecasting (months - years) is based on the empirical models of averaged values of different physical parameter depending on the solar activity. Short time forecasting (hours - days) is produced by means of dynamical empirical model applications to the current situation determined from the diagnostic of the space weather conditions.

#### *3.2.1. Long-time forecasting*

The long-time forecasting models of the solar activity and heliospheric dynamics have been developed on the base of the artificial neural network (ANN) technique in SINP MSU (http://dec1.npi.msu.su/~dalex/events/iswmc/sept99.htm). The solar activity model permits to predict monthly dynamics of yearly means sunspot number (*W*) and solar radio flux (*F10.7*) during the current XXIII solar cycle (up to 2005). The ANN model shows that current 23-d solar cycle will be similar to XX solar cycle with maximum in the autumn-winter 1999 and peak mean value *W*~110. Next solar minimum is supposed between 2006-2008.

The dynamical models of near Earth's radiation permit to describe the dynamics of three main kinds of radiation: galactic cosmic rays (GCR), solar energetic particles (SEP) and trapped radiation. The SINP MSU dynamical model of the GCR is accessible on web-page http://www.npi.msu.su/gcrf/form.html. The GCR model allow calculating differential flux of different nuclear types (from H to U) for definite parameters of the near Earth's space mission orbit (Inclination, Perigee, Apogee, Right Ascension of perigee) as a function of solar activity (*W*) and geomagnetic conditions (*Kp*-index). This model is incorporated now in the American model CREME96. Probabilistic model of solar cosmic rays (SINP MSU http://www.npi.msu.su/scrf/form.html) allows prescribe the size of the solar particles fluences and peak fluxes that are expected within a given probability, to be exceeded at a given solar activity level within a given time interval. The improved trapped radiation model based on information system SEREIS (http://dec1.npi.msu.su/~vfb/SEREIS/) is able to describe smoothed variations of energetic particles in the magnetosphere associated with local time, seasonal and solar cycle variations.

*3.2.2. Short time forecasting*

Short time forecasting of the large solar flare and solar geo-effective events (large flare, filament ejection and coronal holes) impacting on the geomagnetic and radiation condition have been developed in IZMIRAN (http:\\izmiran.rssi.ru\space\solar\forecast.html) and weekly updated. Short time large flare event forecasting is presently based on observation by the process of new magnetic flux emergencies, its evolution: the magnitude and rate of emergence, its localization and interaction with already existing magnetic fields of the active region or outside of it. Taking into account physical and geometrical parameters of the own flare and the flare active region makes possible to predict the space weather: parameters of the solar proton events, the characteristics of geomagnetic activity and other. The method has been put to successful test on Russian scientific satellites such as GRANAT, GAMMA, CORONAS-I [*Ishkov*, 1999].

The other method of short time prediction of the geoeffective solar flares is based on the statistical studies of the special radio observations in the microwave region (wavelength about 3cm) (*Kobrin, et al.*, 1997) An algorithm of the forecast procedure consists of the comparison of the mean long-period ($t$>20min) pulsation amplitude in the current series of observations and that one in a calm (nonflare) period taking into account the specific features of the equipment and observation procedure. The investigations are under way to create procedures for short time forecasting of Coronal Mass Ejection onset on the basis of registration the nonstationary processes in the lower layers of the solar atmosphere at a stage of the coronal mass ejection formation using the patrol observations of solar radio emission.

The neutron monitor technique is also used for short-term predictions of geomagnetic disturbances. This method is based on monitoring GCR variations and scintillations, which can be used for identification and short-term (days) predictions of IMF disturbances. The predictions obtained using this technique can be found at http://teor.ysn.ru/rswi/graph-GIF.html

The empirical dynamic model, developed by *Popov et al.* [1999] can be used for numerical short-term on-line predictions of energetic electron fluxes in the outer RB. The current step of modeling is the evaluation of quantitative relations between the current solar wind parameters ($n$, $V$, $B_z$, $B$ and their combinations) and current smoothed values of electron fluxes in geostationary orbit. The running average procedure is used as a smoothing filter, which resolves the fluxes of trapped and quasi-trapped electrons. It was also obtained, that the impact of $Dst$ and $V$ input parameters on the electron fluxes is practically the same. During magnetic storms the smoothed component of electron fluxes in geosynchronous orbit (energies from tens keV to 1.4 MeV) displays a distinct and stable dependence on the current $V$ and $Dst$ values. The dynamics of this component (in time and space) is similar to a certain trapped electron diffusion wave, propagating inside the magnetosphere and crossing the geosynchronous orbit.

For short-term predictions of the current state of ionospheric parameters and prompt correction of the ionospheric mode, a special software package was developed in NIRFI (http://www.nirfi.sci-nnov.ru/english/index3e.html). It has been shown on the basis of the experimental data obtained on the chirp sounder traces that the ionospheric model adaptation to current ionospheric conditions permits to forecast MOF on a real-time scale and with an error which is smaller by a factor of 3-5 than that of the long-term forecast method.

## 4. CONCLUSIONS

As it was shown above, in a number of space environment research fields, which are vitally important for Space Weather progress, Russia plays a key role.

These research fields include:

- ground based and atmospheric measurements of magnetic fields, cosmic rays and optic observations;
-space experiments, including deep space probes and magnetospheric satellites;
- nowcasting and forecasting modeling

We hope that our efforts in these fields will be an important part of the international space weather collaboration.

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## REFERENCES

Avdyushin S., A. Belov, A. Dmitriev, et al., Russian Space Weather Initiatives, *Proc. Workshop on Space Weather*, ESA, ESTEC, 185-198, 1999.

Belov A.V., Eroshenko E.A., Yanke V.G. Modulation effects in 1991-1994 years. *Correlated phenomena at the Sun, in the Heliosphere and in Geospace,* SP-415, ESA, ESTEC, 469-475, 1997.

Belov A.V., E.A. Eroshenko, V.G. Yanke, Indices of cosmic ray activity as reflection of situation in interplanetary medium, *Workshop on Space Weather*, ESA, ESTEC, 325-328, 1999.

Bashkirov V., Panasyuk M., Teltsov M., *Proc. of INT. Workshop on Respect to Heavy Particle Radiation*, Chiba, 151-161, 1998.

Dmitriev A.V., and A.V. Suvorova, Artificial neural network model of the dayside magnetopause: physical consequences, *Phys. Chem. Earth, 25*, 1-2, 169-172, 2000.

Gosstandart RD50-25645.152-90. Methodical Instruction. Solar Cosmic Rays. Calculation Method of temporal variations of proton energy spectra. *M. Gosstandart USSR*, 1991.

Ishkov V.N., The forecast of geoeffective solar flares: resources and restrictions (in Russian), *Izvestija RAN (ser. Phyzicheskaja), 63*, 2148-2151. 1999.

Kobrin,M.M., V.V.Pakhomov, S.D.Snegirev, V.M.Fridman, and O.A.Sheiner, An Investigation of the Relationship between Long-Period Pulsations of cm Radio Emission and Solar Proton Flare Forecasts, *Proc. of Solar-Terrestrial Prediction-V*, Jan 23-27, 1996, Hitachi, Japan, 200-205, 1997.

Kozlov V.I., Starodubtsev S.A., Markov V.V. et al., Forecast of Space Weather on the Ground-Based Radiation Monitoring, *Proceed. 26 ICRC, 7*, 406-109, 1999.

Models of the Space (in Russian), MSU, Ed. S.N. Vernov, 1976.

Popov G.V., V.I. Degtyarev, S.S. Sheshukov, and S.E. Chudnenko, The Solar Wind Control of Electron Fluxes in Geostationary Orbit During Magnetic Storms, *Radiation Measurements, 30*, 5, 679-685, 1999.

Ryumin V.V., Talking About Mignitizm (in Russian), "Petrograd", Leningrad-Moskva, pp. 173, 1925.

Stozhkov Yu., Pokrevsky P., Zullo Zh., Influence of charged particles fluxes on atmospheric precipitation (in Russian), *Geomagn. i Aeron., 36*, 4, 211-221, 1996.

Tchijevsky, A.L., Sun-spot and History, *Bulletin of the New York Academy of Sciences*, New York, 1928.

Tverskaya L.V., Diagnosing the magnetospheric plasma structures using relativistic electron data, *Phys. Chem. Earth., 25*, 1-2, 39-42, 2000

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