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Particle Acceleration in Solar Flares

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There are some theoretical arguments and numerous observations of solar flares which point out the importance of turbulence in heating of flare plasma and production of non thermal electrons and ions, which produce most of the observed flare emission and are observed as Solar Energetic Particles (SEPs). We will review these arguments and observations, among which are the recent discovery by Yohkoh satellite of distinct hard X-ray emission from the loop top region of flaring loop as well as the commonly observed foot point emission. These results have been confirmed by the higher spectral resolution observation made possible by RHESSI, which quantify the differences between the temporal and spectral characteristics of these sources. An accurate assessment of the above processes and explanation of the observations require consideration of the generation, cascade via nonlinear processes, and damping of the turbulence by the background particles which results in the heating and acceleration. We will describe recent developments in the cascade and damping of Alfvenic and fast mode turbulence and discuss some applications of the results in describing recent observations of flare radiations by RHESSI and other satellites. We will then describe how we can also address the observations of SEPs by ACE and WIND. In particular we will show that the above scenario can resolve the long standing puzzle of the extreme enhancement (relative to photospheric values) of abundance of 3He relative to 4He and possibly the observed trend of increasing enhancement with ion mass-to-charge ratio (or mass) of heavy ions.

Overview of the October-November 2003 Solar Extreme Eruptions

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Fast coronal mass ejections (CMEs), X-class flares, solar energetic particle (SEP) events, and interplanetary shocks were abundantly observed during the episode of intense solar activity in late October and early November 2003. Most of the 80 CMEs originated from three active regions (NOAA ARs 484, 486, and 488). We compare the statistical properties of these CMEs with those of the general population of CMEs observed during cycle 23. We find that (i) the 2003 October-November CMEs were fast and wide on the average and hence were very energetic, (ii) nearly 20 percent of the ultra-fast CMEs (speed >/= 2000 km/s) of cycle 23 occurred during the October-November interval, including the fastest CME of the study period (~2700 km/s on 2003 November 4 at 19:54 UT), (iii) the rate of full-halo CMEs was nearly four times the average rate during cycle 23, (iv) at least sixteen shocks were observed near the Sun, while eight of them were intercepted by spacecraft along the Sun-Earth line, (v) the CMEs were highly geoeffective: the resulting geomagnetic storms were among the most intense of cycle 23, (vi) the CMEs were associated with very large SEP events, including the largest event of cycle 23. These extreme properties were commensurate with the size and energy of the associated active regions. This study suggests that the speed of CMEs may not be much higher than ~3000 km/s, consistent with the free energy available in active regions. An important practical implication of such a speed limit is that the Sun-Earth travel times of CME-driven shocks may not be less than ~0.5 day. Two of the shocks arrived at Earth in < 20 h, the first events in ~30 years and only the 14th and 15th documented cases of such events since 1859.

Energy and Mass Transports during Extreme Events on the Sun and in the Heliosphere

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Solar and heliospheric extreme events (SEEs) are relatively rare and sporadic dissipative phenomena. Extremely weak or strong activity periods on the Sun can be not predicted well in advance with a sufficiently good accuracy because we do know in details neither their physical origins nor the chain of governing forces. The statistics of such events is poor. These events look as similar or different manifestations in the solar atmosphere from case to case depending on the situations controlled by many independent MHD and kinetic dimensionless parameters. The time scales of interest are very broad and practically span from seconds up to many years. The space scales can encompass local or even global features. We consider here several recent examples of extremely strong solar flares and coronal mass ejections (CMEs) which occurred in the 23rd solar cycle. They were driven by subphotospheric energy sources through the heat flows, bulk mass motions, and electric currents in different ways and proportions between them. Solar flares and CMEs accompany each other and share the same free energy of subphotospheric drivers. Powerful impulsive solar flares without strong CMEs can happen in deep atmospheric structures often seen as small loops. Strong CMEs without impulsive flare manifestations can arise in high coronal structures initially seen as prominences, big loops and arcades. This diversity precludes hypothetical universal scenario, which met in current literature and pretended to be valid for all flares and CMEs. In most cases both phenomena accompany each other and look as non-local energy releases. Stronger events often occupy larger volumes and appear as clusters. Sometimes, corotating and sporadic contributions coexist in space and time. Multiple energy releases can superimpose and non-linearly interact in the heliosphere. Examples of the nonlinear amplification or attenuation leading to stronger or weaker magnetic storms will be presented.

Long-Term Prediction of Solar Extreme Events Based on the General Regularities of Energetic Particle Generation by the Sun

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The SEP generation by the Sun and the SEP event occurrences in the Earth orbit are of probabilistic nature. At the same time, certain regularities inherent to SEP fluxes and events can well be inferred from the present-day experimental results, which permit also the regularities to be used in predicting the probability for SEP events (the solar extreme events, in particular) to occur.

The major regularities pertain to the SEP event distribution functions and to the relationships of the functions with solar activity.

The functions of SEP event distributions of particle fluences and peak fluxes are shown to be power laws (with exponents of about 1.3) with exponential rollover at high fluxes. An important property of the distribution function is that, if the function is divided by the sum of sunspot numbers over observation time, the resulting normalized functions prove to be the same (invariant) throughout any solar activity period. This means that the extreme events may occur during every solar activity period, even during solar activity minimum (so called "quite" Sun period). That circumstance, established in Nymmik (1999), fully justified oneself in the last solar minimum, in particular 16÷20 January 2005, when some extreme SEP events occurred.

The concept of predominant extreme event occurrences during certain solar activity phases (maximum, ascending or declining phases) has been shown not to take place.

Summary: the probability for the solar extreme events to occur within any definite period depends only on the sum of mean-monthly sunspot (Wolf) numbers throughput that same period.

Reference

Nymmik R.A., Relationships among solar activity, SEP occurrence frequency, and solar energetic particle distribution function, in: Proceedings of the 26-th ICRC V. 8, 3197-3000, 1999.

Energy Spectrum of Solar Cosmic Rays

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Energy spectrum is one of most important features of solar energetic particles (SEPs). It is connected to acceleration, propagation, and loss mechanisms, as well as time and site of particle generation and propagation. Energy spectrum is a measurable characteristic of SEPs although loaded with many signatures of above mentioned processes. It is the utmost goal of the spectrum study to disentangle and identify all factors of the spectrum formation from observational data. The relativistic protons are the SEP population most relevant for attempt to provide an insight into the SEP origin because of their prompt arrival (short time elapsed from the generation process to observation) and minor distortion by the coronal and interplanetary transport. An attempt is made to overview observational results, fitting and interpreting the SEP energy spectra according to the recent works with special emphasis on the giant event of 20 January 2005. This event clearly reveals the complexity and diversity of observational data interpretations. Theorists usually discuss one of the mechanisms (e.g., magnetic reconnection, stochastic and/or diffusive shock acceleration etc.) as a main SEP generation process. Actually, particles are subject to influence of many factors including not only acceleration mechanisms but also presence of seed population and wave-particle interactions. Main effort of this talk is directed towards revealing signatures of the acceleration and propagation processes in the SEP energy spectrum. However, it should be admitted that many questions are not answered at the moment. It is hardly possible to deduce the generation mode of solar protons only from their observed energy spectrum. Extreme solar events give a huge amount of various experimental information on the features of SEPs (ions and electrons), products of energetic particles interaction on the Sun, along with information on concomitant solar and interplanetary phenomena. These data are hoped to put some constraints on the acceleration models.

Dynamic of Electromagnetic Emission during the Period of Solar Extreme Events

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This work is devoted to study the behavior of solar emission during the period of January 2005. The analysis is based upon observations made with Radio telescopes in the out-of-town observatory NIRFI "Zimenki". Actual solar data, obtained from contemporary automatic spacecraft (e.g., SOHO, GOES) are used, as well.
We study the dynamics of centimeter and decimeter emission before main solar flares and Coronal Mass Ejections (CMEs).
The first direction is based on the effect of long-period ($T \geq 20$ min) pulsations growth during the time interval of 1-2 days before proton flares. This effect has been discovered in the solar radio emission, using specially developed equipment. The procedure of the short term forecast of powerful solar flares was proposed. The possibilities of this procedure realization with the use of routine solar observational data are examined for 4 powerful flares of January, 2005.
It was established earlier that sporadic events in solar radio emission accompanies CMEs formation. Wide band sporadic components of radio emission called microwave precursors are studied in the time interval of about 2 hours before the CMEs' registration on LASCO for the events of January, 2005.
The presence of quasi-periodic ($T \sim 7$-20 s) components in solar microwave emission just before and during the burst itself is studied. Combine analysis of emission in different frequency range is presented.

Evolution and Flare Productivity of Active Regions with Solar Extreme Events of the Current 23 Solar Cycle

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The current solar cycle under all characteristics concerns to cycles of average size. However we have an opportunity to observe solar extreme flare events in such cycles as well. First of them was observed in the beginning of April, 2001 when extreme flare activity occurred in two, carried almost on 180° of helio longitude, sunspot groups AR9393 (N20L152) and AR9415 (S22L359). But in a current solar cycle flare activity has reached the greatest concentration during 19.10 - 05.11.2003 when at once three greater and flare-active sunspot groups passed a visible disk of the sun. Solar extreme flare events are connected with sunspot groups area AR10486 (S16L286) which has developed in greater group of spots on the invisible hemisphere of the Sun. Already 23.10 in it there were flares of important X5.4/1B and X1.1/1N, and 24.10 – flare of M7.6/1N. 24-25.10 in this active region there was a first observable emergence of the powerful magnetic flux which has increased the area of sunspot group to 800 m.s.h. (Sp=2200 m.s.h.), which consequence were flares of X1.2/3B (26.10), M5.0/1F and M6.7/1F (27.10). Emergence of a new magnetic flux (27 - 28.10), increased the area of the sunspot group up to record value for a current cycle – Sp=2610 m.s.h., which led to flares of X17.3/4B 28.10 and X10/2b 29.10.
The X8.3/2B flare occurs at 2.11. The most intensive in a current cycle flare of importance X>17.5 (X28)/3B occurred at 4.11 near western limb of the sun and essential influence on geomagnetic conditions wasn't occurred, however solar proton events of class S3 and S2 were detected. The basic evolutionary characteristics of the given active region are resulted in the following table:

AR 10486 (S17L283, ПЦМ 29,3.10.03)
Sp max = 2610 m.s.h, FKC, δ;
62.56< XRI≤73.06 $X_7+M_{16}+C_{16}$; $4_1+3_2+1_7+S_{49}$;
*ПВЭ I (**59**^{h}) – 22 – 24.10 –* $X_2^{5.4}+M_6^{9.9;7.6}$;
*ПВЭ II (**59**^{h}) – 27 – 29.10 –* $X_2^{17;10}+M_4^{5;6.7}$;
*ПВЭ III (**85**^{h}) – 01 – 05.11 –* $X_2^{8.3;28}+M_6^{5.3}$.

In total for 16 days, 16 large solar flares occurred in these 3 active areas, 11 from which were X-class flares.

Solar Extreme Flare Events: Origin, Occurrence and Relation with Heliospheric Superevents

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The occurrence of extreme solar flare event in declining (more often) and in growing phases of the 11-year solar cycle likewise appears to be a usual rather than an unusual aspect of solar flare observations. The first known instances of these flare events associated with “Space Weather’s” effects and occurred on Sept. 1, 1853. In cycle 17 possible similar flare event occurred on the end of Feb. – beginning of March 1942, during the transit of an important center activity at ~ 4.8 year after maximum. In cycle 18 – Nov., 1949 (~ 2.3 y.); in cycle 19 – November, 1960 (~ 2.7 y.) and may be July, 1961 (~3.3 y.); in cycle 20 – August, 1972 (~3.7 y.); in cycle 21 – June, July, December, 1982 (~3 y.) and the end of April, 1984 (~4.8 y.), in cycle 22 – March, 1989 (~ max.), June 1991 (~2.5 y). For 8 years of development of the current solar cycle it is registered only four flares with an x-ray importance X≥10 (for example, during 1 – 15 June 1991, there was only 5 flares) and three of them were the main one during the concerned of flare activity period 19.10 – 04.11.2003 (~ 3.5 y.). Definition of SEE entirely and completely depends on those effects in Earth’s environment or in any points of a heliosphere which makes the solar active phenomenon. The history of the active phenomena observation shows, that in absolutely overwhelming majority of cases it is accompanied with powerful flare. Now terrestrial disturbances can be estimated in the following kinds of his reaction to powerful solar influence: 1. On electromagnetic shock – “electromagnetic impact”, is inherent only in solar flares, develops at the moment of realization of solar flare and is estimated on influence on an ionosphere – (R1 – 5). 2. On intensity of a stream of the charged particles (basically of protons with E> 10 MэB) - in overwhelming number of cases significant fluxes of protons are consequence of processes in solar flare event (flare) – (S1 – 5). 3. On geomagnetic indignation which develops through 1 - 4 day after solar flare events (flares, filaments ejection) which develops in reply to arrival to the Earth the disturbance structures of a solar wind from this event or passage of high-speed streams by the Earth from solar coronal holes – (G1 – 5).

Therefore it is natural to define SEE as large powerful flare events, disturbances from which influences by all three kinds it is maximum. However 2 and 3 phenomena essentially depend on localization solar flare events and at adverse, for example, solar limb localization even the most powerful flare events, consequences of his realization for environment will be expressed or only in an “electromagnetic impact” for E-limb flare event, or in R and S – for W-limb flare event.

The question of definition solar extreme flare events and their attitude to severe disturbed of space weather condition and super-events in solar cosmic rays – to the periods of long increase of level high-energy solar protons in a heliosphere is discussed. The comparative analysis of features of active areas - generators powerful flare events is lead. The opportunity of forecasting extreme flare events as result of interaction of new emerging magnetic fluxes and with already existing magnetic structures is considered.

Evolution of Morphological Features of the Eruption and Coupling of the CME Acceleration and the Flare Energy Release

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We study the initiation and development of five limb coronal mass ejections (CMEs), utilizing observations from Mauna Loa Solar Observatory (MLSO), the Solar and Heliospheric Observatory (SOHO), the Geostationary Operational Environmental Satellite (GOES) and Yohkoh. Also, we analyze the relation between kinematics of the CME and the energy release in the associated flare.
A complicate structure (prominence and bright overlying arcade) is clearly recognizable in the low corona during the pre-eruption slow-rise phase in all events. This provided measurements of kinematics of various structural elements from the very beginning of the eruption up to the post-acceleration phase which was followed up to 32 solar radii. Such events are observed only occasionally, and are of great importance for the comprehension of the nature of forces driving CMEs.

All five CME events were associated with soft X-ray flares. We found that in acceleration phase there was close temporal correlation both between the CME velocity and soft X-ray flux of the flare and between the CME acceleration and the time-derivate of the X-ray flux. These correlations indicate that the CME acceleration and the flare energy release are strongly coupled physical phenomena occurring in the corona.

Also, observations provide clear evidence that CME eruption is causing a global restructuring of the magnetic field in the inner and outer corona. Furthermore, the kinematics and morphological properties of the analyzed CMEs indicate that the dynamics of various structural elements of the erupting structure is mutually synchronized.

Solar Chromospheric Oscillations

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Oscillations of the quiet solar chromosphere with periods near the acoustic cutoff period of approximately 3 min can be excited in a gravitationally stratified medium either by: a velocity impulse representing exploding granules, or a piston that moves with periods longer than the acoustic cutoff period representing 5 min oscillations, or a piston that moves with periods shorter than the acoustic cutoff period representing the turbulent motions in the convection zone. We solve the wave equation in order to infer plausible mechanisms for the generation of 3 min waves. We found that the velocity for both impulse and long-period excitation decays in a manner similar to that observed in the $K_{2\upsilon}$ and $H_{2\upsilon}$ emission features in bright points, but the velocity for short-period excitation does not match the temporal variation of the line profiles.

Relativistic Shock Surfing Acceleration of Ions near the Sun

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A principal possibility of ion acceleration up to relativistic energies is discovered in the magnetoacoustic shock with the isomagnetic stepwise change. It is shown that the shock surfing acceleration of solar protons up to energies of 1-10 GeV is quate reliable.

CORONAS-F observations of the Sun

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The report provides a review of observations and most important results of the CORONAS-F mission obtained for over three years in orbit (2001-2004). The observations and the related new results concern the extreme solar events, active regions and solar flares, lower corona, ultraviolet and X-ray solar radiation, and solar cosmic rays.

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Low Energy Cosmic Rays and the Disturbed Magnetosphere

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Low energy galactic cosmic rays as well as particles accelerated to high energies either at the solar surface or in the interplanetary medium have access to the atmosphere above a given position on the Earth depending upon the state of the magnetosphere. The interpretation of the cosmic ray anisotropy, deduced from the neutron monitor network, must assume the variability of the magnetospheric configuration. Along with a short review of changes of the geomagnetic cutoffs in the disturbed magnetosphere reported in the earlier papers, we present the results of computations of transmissivity function and asymptotic directions for selected points on the ground and for a low altitude polar orbiting satellite as well. The computations, based on different available models of geomagnetic field of external sources (e.g. Tsyganenko codes of the models T89c, T96_01, T01_01, T04_s available at http://nssdc.gsfc.nasa.gov/space/model/magnetos/ data-based/modeling.html), are performed for quiet time periods and for strong geomagnetic disturbances occurred in 2003 and 2004.
The implications of the results for space weather studies are discussed while comparison with the predictions by IGRF model is also presented.

Storm-Substorm Relations

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Solar wind is a mutual source of the energy for magnetic storms and magnetospheric substorms, therefore both processes certainly are related. The disagreements between researchers start with the estimation of the magnitude and the features of the mutual influence of these two processes. The problem might be divided into following parts: - influence of the substorm activity on Dst and the ring current, the distortion of the configuration of the magnetosphere during the storm-time and the adverse influence of the magnetic storms onto substorm structure and their development.

Importance of the substorm activity was supported for years by close correlation of the Dst -index and substorm indexes found both statistical and in the case studies.

The ideas of the magnetic storm partial or total independence from the substorms arrived recently based on the successful modeling of the Dst development solely from the solar wind parameters. Direct ring current particle measurements and modeling of the ring current formation offer wide variety of conclusions about the capability of the substorm injections to provide ring current carriers. Substorm injections are regarded as a obligatory part of ring current formation, as responsible only for high energy tail of the ring current protons and even as capable to slowdown Dst development.

The opinion on the importance of the substorms is strongly supported by the direct measurements the ions of the ionospheric origin in the ring current, which presumably arrived in the magnetosphere during substorms.

Dst index alone does not reflect all magnetic storm processes. During the main phase extensive transformation of the magnetospheric configuration might be regarded as a most important process while Dst grows with considerable delay. Best manifestations of the magnetosphere reconfiguration are dynamics of the solar proton penetration boundary or inner boundary of the auroral zone. There are evidences that substorm activity along with solar wind pressure enhancements are responsible for the boundary dynamics.

Therefore it is possible to conclude that substorm activity play important role in the development of the magnetic storms, although the physical mechanisms of substorm influence are not totally clear. Further studies of particles and fields dynamics during storms with sufficient temporal and spatial resolutions are required.

Comparison of the storm-substorms with the ordinary substorms shows that the similarity between their features is prevailing. The obvious causes of difference are the increased magnitude of the solar wind (convective) electric field. As a result storm-substorms have more pronounced dipolarization, longer periond of the enhanced particle invrease and so on. Long duration of the southward Bz creates such regular chain of substorms as "sawtooth" events. Earthward shift of the quasi- trapping region and, accordingly, equatorward shift of the auroral zone also lead to the certain modification of the substorm development. The only known example of special unusual storm-substorms relation was initiated by the SC impulse at the beginning of the extreme magnetic storms at the end of October 2003.

Cosmic Rays and the Processes in the Atmosphere

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The role of cosmic ray fluxes in the atmospheric processes, such as cloud and thundercloud formation, lightning production, global electric circuit operation, and global warming is considered.

The Response of the Magnetosphere in Long Period Geomagnetic Pulsations on Solar Wind Dynamic Pressure Impulses Depending on Impulse Profile.

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Regularities of geomagnetic pulsations (T ~ 200-500c), caused by the action on the magnetosphere of solar wind (SW) plasma fronts of the different nature (CME, interplanetary magnetic clouds, shock waves and tangential discontinuities) are being investigated depending on a view of dynamic pressure profile. The possibility of simultaneous excitation of the pulsations globally at the Earth's surface during initial phase of geomagnetic storms under the action of front with sharp enough pressure change is shown. The response of magnetosphere to geomagnetic pulsations with different changes of dynamic pressure of the SW is analyzed:

1) Single impulses both the positive, and the negative;
2) Sequence from two or several enough sharp and well identifiable impulses with different sign of changing of dynamic pressure on each of them;
3) Quasiperiodic oscillations of SW dynamic pressure with small enough amplitudes of pressure variation.

In the analysis of single impulses the special attention is given to the negative impulses. In the long period pulsations range impulses of both signs cause generation of a train of global long period pulsations.

In the analysis of impulses consisting of sequence of two impulses of different signs it is shown, that at the absence of change of dynamic pressure in the gap between impulses, when the time interval between them makes approximately 45-60 minutes, each of them is a source of global long period geomagnetic pulsations. Thus the following difference in behavior of central frequency of a train of generated pulsations is observed: the positive impulse is accompanied by magnification, and the negative impulse – by diminution of pulsations frequency. This behavior is explained by a model of generation of radial magnetopause oscillations, developed by the authors.

In the analysis of pulsations in the Pc5 range, observed during the crossing of multiple magnetopause the Interball 1 satellite, it has been shown, that pulsations registered at this time are not global, they were preferentially observed on the evening side of the magnetosphere and on the ground. Thus observed oscillations of geomagnetic field have the asymmetric mechanism of generation, associated with the influence of azimuthal component of interplanetary magnetic field.

Global Pc5 Oscillations in 2003 and during 22-23 Solar Cycles

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The hydromagnetic waves of the Pc5 range are generated either as the magnetosphere response to discontinuities of the solar wind, or the impulses from which excite oscillations of a magnetospheric resonator, or due to development of various hydromagnetic instabilities on the magnetopause (Kelvin-Helmgoltz and Rayleigh-Taylor instabilities, or their modifications). In the former case we deal with short-term Pc5 "trains", restricted mainly with high-latitude areas, in the second case we obtain global oscillations. Global Pc5 activity in the magnetosphere has been studied using data from satellite and on-ground worldwide network of magnetometers over a period between the maximum of 22nd solar cycle maximum and the decay phase of 23rd cycle. A number of the Pc5 intensity distribution maps are plotted to show development of hydromagnetic activity over the Earth's surface in the course of a global Pc5 event. Local time intervals preferable for the pulsation observation are revealed. Plasma and magnetic measurements in the solar wind show that global Pc5 pulsations occur against the background of very high values of the solar wind velocity. Resonance structure of the oscillations shows evident contribution of some sort of resonances to the spectrum of pulsations. Probable nature of a resonator and a source of oscillations are discussed. Energy of the hydromagnetic waves downloaded from the solar wind during a global Pc5 event exceeds the energy of a substorm. This fact allows us to suggest that the global Pc5 oscillations, excited on the magnetopause as a result of interaction of the magnetosphere with the super fast flows of the solar wind, realize the direct transfer of the solar wind energy into the magnetosphere, bypassing usual stages of accumulation and releasing of energy. Pc5 magnetic field amplitude at synchronous orbit amounts to as much as 50% of the total geomagnetic field in this region of the magnetosphere. The diversity of non-linear effects is inevitable in such a case. Very important effect is the wave acceleration of MeV electrons. In addition, other possible types of the strong wave action consequences are discussed in the report, like diamagnetic effect that weakens the magnetic barrier of magnetopause and the ponderomotive forcing, which essentially modifies plasma distribution in the magnetosphere.

On Subionosphere Source of Impulse Disturbances in Geomagnetic Field during Solar Gamma Flares

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Global geomagnetic disturbances featuring by simultaneity of worldwide registration is studied in details for magnetic storm and its structural elements particularly for preliminary impulses (PRI) of sudden storm commencement. Also global worldwide signatures are discovered for a few types of geomagnetic pulsations Pc5 which source is supposed to be related to large scale magnetosphere oscillations caused with perturbations of field aligned currents in auroral zone. This report deals with investigation of global geomagnetic disturbances of impulse nature accompanying two solar extreme events 4.11.2003 and 6.11.2004 (maximum amplitude up to 12 and 8 nT on the middle latitudes, correspondingly). These geomagnetic disturbances were taking their course against sharp variations of fluxes of hard electromagnetic radiation. In the both cases there were no jumps of solar wind pressure or drastic changes of interplanetary magnetic field. Also any substorm perturbations have not been registered.

For interpretation of observed phenomena the physical conditions favoring to appearance in polarized layer emerging on stratosphere altitudes (~20 – 40 km) due to absorption of hard flare radiation the electrical field with value close to electric discharge initiation. Such the electric discharge (stratosphere lightening) in its turn might be source of broad band emissions of different physical nature (electromagnetic, acoustical-gravitational, heat and so on.), which might lead to generation of oscillatory processes of different frequencies. In particular, acoustical wave achieving ionosphere might induce impulse of field aligned current and high-frequency turbulence on ionosphere E-layer. Presence of natural waveguides such as gravitational, atmosphere TH-waveguide, Alfven and FMS waveguides might lead to observing modulation of emerging emissions.

Basic Regimes of the Super-storm on Nov 20, 2003, and the Problem Substorms-Storm

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Driven magnetospheric disturbances arise as the result of a strengthening of the solar wind electric field IEF, which strengthens the DR-current and creates a magnetospheric storm (e.g., Rostoker et al., 1987; Akasofu et al.2001). Other type of the disturbances - substorms - arises spontaneously but also can serve as the reason of the DR-current and magnetospheric storm development (Sharma et al., 2001). Questions of interaction of the driven and spontaneous disturbances, on the one hand, and the relationship "substorms- storm" create two closely connected actual problems that both are considered in the present work.

The super-storm 20.11.03, (0-24) UT was studied by using data of ACE, WIND, and of 134 ground-based high latitude magnetometers in the northern hemisphere that were handled by the magnetogram inversion technique, MIT2 (e.g., Mishin et al., 2001). The activity level (AE), input power ε'(Poynting flux from the solar wind into the magnetosphere), total power of the magnetosphere disturbance (Q_T), and the powers consumed in the ionosphere (Q_i), and ring current (Q_{DR}) have reached values, respectively, AE~3000nT, $\varepsilon' = Q_T > 3\cdot10^{13}$ Watt, $Q_i \sim 2\cdot10^{12}$ Watt, and $Q_{DR} > 10Q_i$.

The substorms, the poorly studied rigidly driven modes, and the mode, created by the solar wind pressure pulse, are described. The ionosphere saturation mode, when the AE indexes, the values Q_T, and Q_I all did not react to strong input power growth, are described for the first time. In one of examples the saturation of an ionosphere has led to accumulation of additional magnetic energy of a tail and the subsequent jump of values Q_{DR} and Q_i.

The above modes are described in terms of powers ε', Q_T, and Q_{DR} for the first time. For the mode of a substorm, when it is the prevailing mode, the relationships $Q_T=0.5\varepsilon'$ on loading, and $Q_T>>\varepsilon'$ in the beginning of unloading, are both characteristic. For the same mode, the relationships $Q_i=Q_{DR}$, or a weak inequality $Qi>Q_{DR}$ are both typically. For the mode, which was named "rigidly driven", there corresponds the approximate equality $\varepsilon'=Q_T$ and relationships $Q_i=Q_{DR}$, or $Q_{DR}>>Q_I$ at low and high values of Q_T, respectively.

As the whole, results of the present work shed a new light on the relationship of driven and spontaneous disturbances and their energetics. New modes of the magnetospheric disturbances are described. The problem "substorms - storm" is considered in new details. The events of two types, in which predominating contributions to the DR-current power were created by driven component or by substorms, have been both described. It was found that inequality $Q_{DR}>>Q_I$ took place during the "rigidly driven" events.

Dynamics of the Ionospheric Convection Systems Observed during the Super- storm on Nov 20, 2003

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By using the magnetogram inversion technique MIT2, the ionospheric convection systems were calculated with the steps of 1 to 10 minutes for the events on Nov 20, 2003. The convection patterns are then compared with SuperDARN and Cluster in-situ electric field measurements along the orbit. It was shown that the MIT2 convection systems are changing with the observed basic regimes of the disturbance. We distinguish three types of the convection systems, respectively, for substorms (mode 1), and two other modes. Mode 2, named DSMC, is a more global one than typical substorms, and does not comprise signatures of the spontaneous expansion phase. Mode 3 is the ionospheric response to the interplanetary shock, IP. The convection system of each of these modes has its own clearly expressed signatures, which are described and discussed in terms of the probable physical scenario behind them. We discuss also the relationship of the observed convection systems and FAC systems. Some features of the magnetospheric generators of different convection systems are mentioned.

Dynamics of the Field-Aligned Current Systems and the Polar Cap Boundary Observed during the Super- Storm on Nov 20, 2003

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By using the magnetogram inversion technique MIT2 [e.g., Mishin et al., 2001, and refs therein], the systems of the field-aligned currents (FACs) were calculated with the steps of 1 to 10 minutes for the events of the super-storm during the full day of Nov 20, 2003. Basic modes of disturbances during this event were realized and they are described in terms of the FAC density spatial 2D distribution in the ionosphere.

One aspect of this study is description of the FACs density spatial distribution in the terms not only well-known Iijima-Potemras' Regions, but also in the terms of the mid-scale spatial M.N-inhomogeneities in each of these Regions. Three M.N-inhomogeneities are regularly observed in each Iijima-Potemras' Region. The value M=0, or 1, or 2 is the number of the Iijima-Potemras' Region. The value N=1, or 2, or 3 is the number of the inhomogeneity. These inhomogeneities had been overlooked in past, and were detected by [Mishin et al., 2003]. We describe them under the data of the considered events, and compare our data with appropriate data from the well-known statistic model of the FAC spatial distributions by Weimer [2001]. Models of the magnetosphere generators of the FACs, accounting for the above inhomogeneities, are briefly discussed.

The other aspect is the FACs spatial patterns for successive regimes of the magnetospheric disturbances observed in the super-storm under consideration [see Mishin et al., this issue]. The regimes differ by intensity and by a degree of a clockwise twisting of the FAC pattern. The driven mode is more global than a spontaneous substorm. Its FAC spatial pattern comprises the signatures of the rather local than global spontaneous expansion phases. Also, this pattern often comprises two current wedges, SWC1 and SWC2, which are closed in the ionosphere along the geomagnetic parallel and meridian, respectively. The response of the FAC spatial pattern on an interplanetary shock (IP) is also described.

We discuss on a conceptual level the physics of the above clockwise twisting of FACs as the consequence of the asymmetric ring current development, also the physics of the SWC2, and the nature of the FACs, created by IP.

Geomagnetic and Auroral Response to the Sharp Increase of Dynamic Solar Wind Pressure during the Magnetic Storm of November 7, 2004

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On data of global geomagnetic observations and auroral TV registration at Tixie (MLat ~66 deg, MLong~190 deg) the properties of sudden geomagnetic impulses with the onsets at 1052 UT and 1827 UT on November 7, 2004 and their manifestations in spatial-temporal dynamics of auroral luminosity in the evening (~20 MLT) and morning (~0330 MLT) sectors, respectively, are studied. Both sudden commencements (SC) have been registered at positive values of IMF Bz – the first on at Bz ~ 4-8 nT and the second impulse at Bz ~20-38 nT.

It has been established that SCs propagated in azimuth and toward the pole. Two typical velocities of azimuth propagation V_1~20-40 km/s and V_2~5-10 km/s have been obtained. The first impulse propagated poleward from the MLat ~73 deg to ~ 76 deg. The second propagated from ~63 deg to ~ 75 deg. The velocity of propagation toward the pole in the postnoon-evening sector for both impulses was ~4-6 km/s.

The impulse generation has been accompanied by simultaneous brightening of auroral arc with a consequent southward extension of luminosity region in the evening hours and poleward in the morning hours with the spatial-temporal modulation of brightness of auroral luminosity with periods T~5-6 min (second SC). The enhancement of brightness and poleward extension of luminosity region were simultaneously observed with the enhancement of positive values of the geomagnetic field H-component and the shift of maximum values of ΔH poleward with the velocity ~2,2-2,6 km/s.

The onset of SC at 1827 UT led to the excitation of geomagnetic pulsations with T~2-3 min in the Pc 4 range at latitudes <= 60 deg in all temporal sectors which were registered up to 2000 UT and accompanied by wavy distortions of auroral arc at MLat~60 deg at 0330-0500 MLT.

The role of MHD wave, variations of ionospheric conductivity and field-aligned currents in generation of SC and Pc 4 pulsations is discussed.

Manifestation of Magnetosphere Fluctuations during the Large Magnetic Storm of January 21-22, 2005

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We report the results of a coordinated data analysis storm-time Pc5 event observed on the ground and also in the magnetosphere. The event took place during the main phase of the large magnetic storm on January 21-22, 2005 with SSC at 1712 UT caused by sharp increase of dynamic pressure of the solar wind (up to ~25 nPa) and drastic changes of interplanetary magnetic field (IMF). On data of high-latitude CPMN stations the variations of magnetic field during the storm were characterized by some sharp intensification (up to ~2000 nT) of westward electrojet lasted ~ 10-30 minutes. At the beginning, the maximum of intensity of westward electrojet was observed at ~ 65□ of magnetic latitude (MLAT), and was followed with the intensive bay of riometer absorption. During the intensification with onset at ~1845 UT, triggered by a very sharp jump of solar wind pressure till ~70 nPa and excursion of IMF Bz (-30 □ + 30 nT), the center of westward electrojet together with the region of energetic electron precipitations shifted to ~60□ MLAT. The electrojet weakening coincided with the excitation of Pc5 geomagnetic pulsations at the same latitude. The large amplitude pulsations were registered till 0100 UT on January 22, 2005 covering ~10□ latitude. The maximum intensity of pulsations reached ~ 400 nT. The pulsations stopped simultaneously with sharp decrease of solar wind density. The GOES 10, 12 satellites were located at the noon and evening side respectively and both registered quasi-periodic magnetic oscillations of the same period in the compressional component. A Los Alamos particle detector on board geostationary satellite observed the occurrence of energetic particle flux oscillations in the Pc5 range. Geomagnetic pulsations were followed with the VLF-emission and riometer absorption modulation. Observations of riometer absorptions at the meridian station chain showed that the regions of deep modulation of absorptions and geomagnetic pulsations maximum shifted to high latitudes in the same way. Depth of VLF-emission modulation registered at mid-latitude station Yakutsk reached 100% in a wide frequency band (till 10 kHz). Considering the characteristics of VLF-emission, we conclude that significant and long-lasting compression of magnetosphere led, probably, to moderate pitch-angle diffusion of particle into the loss cone even at the middle latitudes. It is inferred that in the present event, a modulation effects are caused by a compressional waves.

Undulations Observed by the DMSP Satellites During Magnetic Superstorms of November 2004

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DMSP satellite observations in the evening sector are used to investigate dynamics of undulations at the equatorward boundary of diffuse aurora and their relationship to the substorm/storm development and Pc5 magnetic pulsations during two successive magnetic superstorms at the beginning of November 2004. Magnetic measurements at the Yakutsk observatory (φ=62ºN, λ=129.6ºE, L=3.3) by using a new flux-gate magnetometer constructed by Magson (Germany) adding the SYM and ASY indices allowed us to instantaneously determine a magnetic activity. The first event of undulations was seen in the nighttime light images from two DMSP satellites near Yakutsk (φ~62º) at 0920-0930 UT on November 8, 2004 during the storm recovery phase (minimal value of the SYM-H index was –394 nT at 0556 UT). The observed 4 undulations had the wavelength λ~450-500 km and the amplitude A~150 km and they propagated westward with the velocity V~1 km/s. The second event of undulations was registered during 5 successive passes of three DMSP satellites in time interval from 0340 till 1030 UT on November 10, 2004 during the main phase of storm (minimal value of the SYM-H index was -282 nT at 0932 UT). In the first 2 passes the large-scale undulation with λ~600 km and A~400 km was registered at about φ~62º near Alaska and then in the sequential passes the sizes of undulations were decreased up to λ~250-300 km and A~100-150 km at about φ~60º in Far East of Russia.

All observed undulations were associated with subauroral polarization streams (SAPS) and plasma density troughs by data of the SSIES detector measurements aboard DMSP satellites. The appearance of undulations for both events near Yakutsk was accompanied by enhancements of positive values of the magnetic field H-component and Pc5 pulsations with periods ~4-8 min and ~5-7 min, respectively, registered at this station.

The behavior of undulations and fast plasma flows with concurrent Pc5 pulsations is discussed.

Bursts of solar X-rays as possible predictor of the magnetic storm in November 2004

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The geomagnetic response to optical flares of the first decade of November 2004 was detected by high-latitude stations of the northern hemisphere, which precedes the start of intensive magnetic storm on November 7. The analysis of magnetograms of ground station network has been carried out during periods of time including the famous solar flare manifestations on November 11, 2004.

The complicated coronal mass ejection belonging to “full halo” type with three brightly-expressed components with the onset 01.31UT, 02.06UT and 02.42 UT was considered as the reference point. The mean speed of disturbance distribution was approximately 950 km/sec. Probably, this very coronal mass ejection was the main source of the magnetic storm with the minimum index value of Dst 373 nT on November 8 in 07UT. The most brightly-expressed reaction of geomagnetic field variations was manifested on the day side a few minutes after the flare (02.42 UT). Dozens of minutes later ionospheric fluxes intensifies, which is typical of the known flux system formation. It is advisable to use the empiric scheme explaining the observed manifestations in the magnetic field before the storm. The hard electromagnetic radiation of Sun increases Earth ionosphere ionization. The solar flares are accompanied by hard electromagnetic radiation (ultraviolet spectrum area, X-ray radiation), which results in ionosphere conductivity increase. This leads to intensification of ionospheric currents and large-scale system currents, including longitudinal currents, which will contribute to the desired increase of magnetic field variations (H-component, Dst-variation , etc.).

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Solar Extreme Events and Great Geomagnetic Storms

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Solar extreme events having prolonged periods of large negative Bz IMF orientation produce great geomagnetic storms. Main features of great geomagnetic storm are the considerable increase of plasma pressure inside the magnetosphere, the existence of high level turbulence and the filling of magnetic flux tubes by accelerated ions of ionospheric origin. O+ ion population can be ~40% of magnetospheric ion population.

The self-consistent picture of storm time magnetospheric processes includes the analysis of plasma transport, particle acceleration, formation of storm time current systems. Theoretical analysis of the maximal possible level of plasma tube filling is presented. The analysis of plasma pressure distribution shows, that magnetic field disturbance can be connected with current systems, which were not included in modern magnetospheric current models.

Response of the Regional Ionospheric D-Layer to the 7 – 11 November 2004, Geomagnetic Storm Period

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Response of the midlatitude ionospheric D-region to geospace storms shows a complex nature. The available experimental results do not allow to detect and model many of the response features. This work is continuing the experimental studies [1, 2] of the variations of the electron density in the midlatitude ionospheric D region and the variations of the noise and the scattered signals at a frequency of 2.3 MHz performed by using the MF radar technique and encompass the interval of November 8 – 11, 2004. The data used in this study were collected with the MF radar and the fluxmeter magnetometer at the Kharkiv V. Karazin National University Radiophysical Observatory (49.5N, 36.3E). The scattered signals were sampled at 3 km intervals from the 60 – 102 km region and the magnetic fluctuations in the 1 – 1,000 s period range. The magnetic storm was associated with increases of 2 to 4 orders of magnitude in proton fluxes and of 3 to 4 orders of magnitude in electron fluxes, with a significant variation in the geomagnetic field, and with a decrease of 400 nT in the Dst index during the storm's main phase. Five optical flares (one of them was a class 3B event) and three x-ray bursts (one of them was a class X2.5 event) occurred during the observation period.

During the daytime, the electron density in the 80 to 90 km region showed the increase of 50% – 400% comparing to the undisturbed conditions. Under nighttime conditions, the scattered signals appeared intermittently over 1 – 10 min intervals, and the electron density during these intervals showed the increase up to 10^8 – 10^9 m^{-3}. These disturbances in the electron density were apparently associated with electrons and protons precipitation from the magnetosphere. Estimates of the electron fluxes based on these disturbances in the electron density provide the values of 10^8 – 10^9 m^{-2} s^{-1}, which are in good agreement with theoretical predictions and the data obtained under disturbed conditions.

During optical flares and x-ray bursts, the radio noise, the scattered signals, and the dependence of the electron density versus time and altitude show characteristic features, which distinction is discussed. The detected temporal variations in the electron density, which attain 300% – 450%, were used to calculate variations in ionization rates in the 80 – 90 km region. For instance, the electron density in the 81 – 90 km altitude range exhibited an increase by 250% – 450% during the class X2.5 event on November 11, 2004 when the ionization rate increase varied by a factor of 3 to 10.

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Regional Middle Latitude Ionospheric D-Region during 14–24 April 2002 and 27–30 May 2003 Magnetic Storms Periods

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There are presented results of experimental investigations obtained by a partial reflection (PR) technique; these are variations in PR parameters, radio noise at ~ 2 MHz and the electron density, *N*, at the middle latitude ionospheric D-region during magnetic storms occurring over periods of 14–24 April 2002 and 27–30 May 2003. Responses of the D-region to the beginning and ends of storms are investigated. Experimental investigations were carried out by means of the PR technique near Kharkiv City at the Kharkiv V.N. Karazin National University Radiophysical Observatory.

In the beginning of the magnetic storm of 27–28 May 2003, increase in the *Kp* index were synchronously accompanied by considerable increasing in the radio noise intensity, by appearing of intensives PR-signals from the height levels of $z \geq 87$ km by night, becoming units-tens of times larger. The differential absorption of PR signals increased considerably. At the same time, there were observed quasi-periodic changes in the characteristics of PR signals with their periods of more than an hour (no special features were discovered both in the reflections from the heights lower than 87 km and in the radio noise). The variance of the statistical characteristics of PR signals became several times larger. Over this period, the electron density changed quasi-periodically with about the same period, with the *N* variations being 100 – 200%. The end of the magnetic storm was accompanied by a strong disturbance in the geomagnetic field within 15.00–18/00 UT and by a small increase in the *Kp* index. Over this period and up to the magnetic storm end, quasi-periodic intensive PR signals at an ordinary component within 81–87 km were observed. The electron density at these altitudes increased by 200–400% over an hour, with both a subsequent short-time (about 20 min) recovery to the value under the undisturbed conditions and quasi-periodic variations with a period of $T \geq 60$ min before the magnetic storm end. Note that in the experiment of 31 May 2003, carried out after the magnetic storm, characteristic peculiarities – like those observed during the magnetic storm – were not discovered; *N* changes within 81–87 km corresponded to the typical undisturbed conditions.

The magnetic storm of 17–24 April 2002 was accompanied by intensive proton precipitations for tens of minutes. Though main magnetosphere-ionosphere processes occur, as a rule, at the polar latitudes, information on strong disturbances of the electron density in the middle latitude lower ionosphere, caused by the storm, is very important owing to not numerous investigations of this type. Over the periods of precipitating protons, there were periodically observed intensive PR signals within 72–78 km (the signal to noise exceeded 5). Increasing in the electron density in the lower part of the ionospheric D-region over these periods was more than 50–100 %. Changes in the ionization rate were estimated as $q/q_0 \approx 4–30$.

Assuming that increasing in the electron density were caused by the precipitation of electrons and protons over the magnetic storm period, the calculations of the energy characteristics of the particle fluxes were made by means of the experimental data. They agree well with the theoretical estimations and known data on the particle fluxes obtained experimentally during disturbances of different nature. They appeared to be $10^7–10^8$ m^{-2}c^1.

Experimental Investigation of Middle Latitude D-region Ionosphere Response to Events Related to Proton Precipitations

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The role of the proton flows precipitating in the high D-region of the ionosphere has been studied rather well. Possible effects of these flows on the middle latitude D-region of the ionosphere have been studied insufficiently: there are only episodic experimental investigations; therefore there is necessity to collect additional information in order to study this phenomenon which is important for solving both the scientific and practical problems of radio communication, radio navigations, etc.
This report deals with experimental results obtained by the partial reflection (PR) technique at middle latitude for some solar proton events over the periods of solar flares and magnetic storms. The experimental investigations were carried out by means of the complex equipment using the PR technique at the V. Karazin Kharkiv National University Radio Physical Observatory situated near Kharkiv.
For the analysis PR signal records made during 8 events of protons precipitating into the Earth ionosphere were selected from the University experimental data bank,.
The analysis of the experimental data have shown that, for the events considered, there occur typical features both in the behavior of PR signals and noise and in the height-time variations of the electron density. As a rule, the main special features of the experimental data at the time of such events are as following:

1) Appearance of intensive PR signals (the intensity of PR signals became units-tens of times larger) from the lower part of the middle latitude ionospheric D-region (z ~70-80 km) for a few tens of minutes;

2) Increasing of electron density by more than 50-150% in this height interval;

3) Decreasing of noise intensity, its dispersion and their following recovery of the typical diurnal variation.

The electron density increase at 70-81 km seems to be related to the precipitating protons having more than 10 MeV.
On the basis of a mechanism for precipitation of the high energy particles (electrons, protons), we estimate the proton flow parameters. Using the electron density magnitudes under the undisturbed N_0 - and disturbed N -conditions, there were estimated ionization rates of $q=\alpha_0 N_0^2$, $q=\alpha N^2$, where α_0 and α are the corresponding recombination coefficients. On the basis of the experimental data on changes in the electron density over the periods of precipitating protons, corresponding flows were estimated, being $\sim 10^7 m^{-2} sec^{-1}$. The calculations of the proton flows from the experimental data agree well with those theoretically known.
Using the experimental data on temporal changes in the electron density, we estimated the rate of changes in forming electrons at these heights. For instance, for the experiment of April,12, 2002 at z =75 km, q/q_0 = 5,64; for the experiment of February, 20, 2002 at z =72 km, q/q_0 = 4,0 and for the same experiment at z =78 km, q/q_0 = 26,01.

Outer Belt of Relativistic Electrons during the Solar Extreme Events of November 2004 and January 2005

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Extremely high solar activity of October-November, 2003 and November, 2004 caused a number of high-level geomagnetic disturbances. Actually, for the last 35 year only five storms were observed with amplitude of Dst-variation higher than 350 nT, and three of them, occurred just in 2003-2004 years. Thus, studying of radiation belt variations in such extreme conditions must be highly interesting.

We analyze variations of the radiation belt energetic electrons during November, 2004 – January, 2005. This time period includes two superstorms in November, 2004 and series of moderate storms during solar extreme events in January, 2005. We used charged particle data from the geosynchronous satellite Express-A2 (electrons 0.8 – 1 MeV, 4 – 6 MeV) and the satellite Meteor-3M of 1000 km altitude polar orbit (electrons >3 and >8 MeV).

As a result of each of the superstorms of 8th and 10th November 2004 (|Dst|max=373 nT and 289 nT respectively), the new radiation belts have been formed in the slot region between the inner and outer radiation belts. L-coordinates of the intensity peaks of these new belts are found to be at Lmax=2.9 and Lmax=3.1, which occurs in a good agreement with the early obtained empirical dependence |Dst|max=2.75*10^4/Lmax^4. In November-December, the new belt slowly moved earthward (the displacement ΔL~0.1 in month). This transport is in a good agreement with theory of particle diffusion under sudden impulses influence.

During a series of geomagnetic storms of average amplitude (|Dst|max~100 nT) developed as a result of the extreme solar events in January, 2005, the new belt has moved much faster and reach L~2.5. Meanwhile, the January storms themselves formed the new belts peaked at about L~4 in consistence with above empirical relationship.

Extreme Low-Latitude Auroral Oval Position in 2003-2004 Years as Inferred from meteor-3M Auroral Electron Precipitation Data

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We studied the extreme low-latitude location of the auroral electron precipitation region during the superstorms of 2003-2004: October 30, 2003 (|Dst|max=401 nT), November 20, 2003 (|Dst|max=472 nT) and November 8, 2004 (|Dst|max~373 nT). The data of 0.1-15 keV electrons measured by Meteor-3M spacecraft operating at polar orbit of about 1000 km altitude were used. Positions of the nightside auroral precipitation region in storm maximum were compared with several empirical relationships between positions of some magnetospheric plasma domains and Dst amplitude: maximum of storm-injected relativistic electron belt, westward electrojet center, equatorial boundary of night side auroral oval.
According to theory many plasma domains in the night magnetosphere are concentrated within the transition region between the plasmas of low and high pressure: trapped radiation boundary, equatorial boundary of discrete auroral forms, field-aligned currents, auroral electrojets. Most probably the peak of a storm-injected belt of relativistic electrons lies in this region too. So, all these storm-related effects may be expected to only one the same functional dependence of their L-position on the strength of a storm, i.e. |Dst|max.
The agreement between empirical dependencies of the maximum of storm-injected relativistic electron belt and nightside auroral oval low-latitude boundary on Dst-amplitude and location of auroral electron precipitation region is better than $\Delta L \sim 0.2$. Empirical relationship between position of westward electrojet center and Dst-amplitude was based in the storms of |Dst|max<250 nT and being extrapolated to the superstorms it comes to essential discrepancies with both above relationships.

Creation and Destruction of the Solar Proton Belts in the Inner Magnetosphere During Magnetic Storms

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Along with the stable inner proton belt, temporal existence of additional belt of the 1-15 MeV protons has been reported. Intensity increases and decreases were registered at L=2.5-3.5 after strong magnetic storms. As a source of this additional protons population energetic plasasheet ions and solar protons were regarded. For the explanation of the arrival of additional proton belt the model of resonant acceleration and radial particle injection was introduced, with strong electric field induced by the compression of the magnetosphere as a driver.

Our study presents experimental description and explanation of the emergence and destruction of the solar proton belts in the inner magnetosphere, based on the solar protons and ions measurements by low altitude polar orbiter Coronas-F. Time interval from October 20 to November 25 2003 have been chosen, when several magnetic storms occur. Our model does not demand resonant acceleration; it explains appearance and disappearance of solar proton belts (SPB) as a result of the magnetosphere reconfiguration.

We investigated dynamics of the boundary of solar proton penetration (PB) into the magnetosphere. Usually PB is the same for the protons with energies from 1 to 50 MeV, but in some cases during PB retreat from the Earth, part of 1 MeV proton flux remains trapped at the old position. We explain this effect by the following way.

Solar particles are on open drift orbits behind the PB and if the recovery of previously compressed magnetosphere is fast comparing with particle drift period, then part of this particle will remain on the closed trapped orbits. For example at L=3 magnetic drift of the 50 MeV and 1 MeV protons equals approximately 20s and 15 minutes. Geostationary satellites transit after the magnetosphere compression from the solar wind back to the magnetosphere lasts 5-10 minutes, and therefore 1 MeV proton belt may be created, while 50 MeV protons will not be trapped. The SPB must be destroyed during next magnetosphere compression if the PB will reach this belt position, opening particle trajectories.

Coronas-F at 500 km altitude twice a day can trace inner trapping region over the Brasilian magnetic anomaly. We use these crossings for the investigation of SPB dynamics from 20.10.03 to 25.11.03. Before the October 29-31 magnetic storms SPB was recorded on L=3.3. After SC at 0612 UT 29.10.03 PB approached the Earth to L=2.1-2.3 and destroyed this belt. Several trapping and destructions of SPB was observed during this three storm until at the end of the third main phase two consequent PB retreats create two 1 MeV proton solar belts at L=2.1 and 2.7.

On 04.11.03 moderate magnetic storm again induce PB motions, which was not deep. Both 2.1 and 2.7 SPB survived, and that PB motion create additional small amplitude SPB at L=3.5. This unique three-belt structure remains undisturbed until the next strong storm on November 20, 2003. Two outer SPB were destroyed by PB motion, but it was not deep enough to destroy the most strong L=2.1 belt. It was only shifted to L=1.9 approaching to the main inner proton belt.

Therefore experimental data confirm conclusions that additional proton belts are populated by solar cosmic rays created and destroyed by the changes of magnetosphere configuration and that energy range of trapped protons depends on the speed of the magnetosphere reconfiguration.

Unusual Strong Pc5 Geomagnetic Pulsations in the Recovery Phase of the November 2003 Superstorm

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The unusually large-amplitude Pc5 geomagnetic pulsations in the morning sector in the recovery phase of the huge November 2003 magnetic storm have been studied by using the ground multi-point observations. Two main spectral Pc5 enhancements were observed: at f ~2 mHz, which slowly increased with latitude decreasing, and at f ~3 mHz, which was latitude independent. The beginning of the large-amplitude morning Pc5 activity was accompanied by a substorms onset in the evening and midnight sectors. However, the spectra of ULF wave in the morning and evening sectors were different. The spectra of the ground ULF pulsations have been compared with spectra of IMF and solar wind parameters variations, measured at ACE (240, 22, -15 Re) spacecraft. The similarity between morning Pc5 and By IMF spectra was found, but the spectra of the solar wind number density variations were similar to the evening Pi3 pulsations. Short and localized bursts of Pi1C (f~50-100 mHz) geomagnetic pulsations and simultaneous short bursts of energetic electron precipitation (imaging IRIS riometers data) were observed in the morning sector. The Pc5 and Pi1C pulsations as well as the bursts of auroral radio absorption suddenly disappeared when the solar wind number density abruptly dropped in the end of the magnetic cloud. We suppose that ~2 mHz Pc5 geomagnetic pulsations arising could be attributed to field line resonance (FLR), however, ~3 mHz oscillation were apparently non-resonance origin. Both, ~2 and ~3 mHz wave packets were initiated by solar wind number density impulsive enhancements.

Wave Signature of the Main Phase of the November 7-8, 2004 Superstorm

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The maximum of the main phase of the November 7-8, 2004 superstorm was observed at 06-07 UT on November 8^{th}. Here we discuss the properties of the Pi2-Pi3 geomagnetic pulsations in the frequency range of 1-20 mHz, measured on the ground at 02-05 UT on November 8^{th}, just before the superstorm maximum. At that time Bz IMF was ~-40 nT, By changed from ~ -20 nT to ~ +20 nT, AE-index reached ~ 2500 nT (04.30 UT). The substorm-like night side magnetic disturbances were accompanied by strong Pi3 (2-5 mHz) and Pi2 (10-20 mHz) range geomagnetic pulsations. The dynamic spectra of the morning and evening Pi3 were compared. It was found the unusual wave polarizations in the East-West direction in the morning sector, the amplitude of X-component was much smaller than Y-component. The spectra of ground Pi3 were compared with the spectra of simultaneous fluctuations in the solar wind and interplanetary magnetic field. The computed LAT-UT diagrams of the morning Pi3 and Pi2 amplitude distribution demonstrated that the area of the intense pulsations shifted from Φ ~70-75º at 01-02 UT to Φ ~57-61º.

Geomagnetic Pulsations, Auroras and Riometer Absorption in the Late Recovery Phase of the Superstorm on November 7-9, 2004

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The November 2004 superstorm consisted of two very strong magnetic storms: on November 7-9 and on November 9-10. The interval between 18 UT on November 8th and 06 UT on November 9th represents the late recovery phase of the first strongest storm. In this time interval the Dst-index was stable but considerably high (~ -125 nT). Typically, a strom recovery phase is characterized by morning geomagnetic activity and Pc5 pulsations. However, contrary to that, the strongest magnetic disturbances were observed in the midnight sector of the Earth. We present here the results of the analysis of multi-points Scandinavian near midnight observations: geomagnetic pulsations (IMAGE magnetometer network), auroral forms (5 all-sky cameras) and particle precipitation (profile of 7 riometers, including IRIS absorption images). The strong (up to ~1000 nT) substorm-like magnetic variations, accompanied by bursts of riometer absorption (up to 5 dB) and Pi3 (2-5 mHz) and Pi2 (10-20 mHz) geomagnetic pulsations, were observed at geomagnetic latitudes higher than 60º. The LAT-UT maps of the latitude-temporal distributions of the Pi3 and Pi2 X- and Y-components were computed by the base on the dynamical spectra of pulsations. The different temporal dynamics of the occurrence and polarization of the pulsations at different latitudes are presented. It was found that each burst of Pi2 geomagnetic pulsations was occurred simultaneously with different forms of auroral brightens. Several examples of distinguished auroral forms are discussed. We also demonstrated the good agreement between the space-temporal dynamics of auroral brightens and particle precipitations, detected by IRIS imaging riometers system.

Pc5 Geomagnetic Pulsation in the Initial Phase of Magnetic Storm on April 16, 1999

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The analysis of simultaneous ULF day-time geomagnetic pulsation observations on the ground, at the geostationary satellite, and in the solar wind have been done for the initial phase of magnetic storm on April 16, 1999, characterized by a strong dynamic pressure (up to 20 nPa) of the solar wind. We compared ULF data from three latitudinal networks: near noon (West coast Greenland), morning (MACCS and CANOPUS), and evening (SAMNET and East coast Greenland). The solar wind conditions led to a sharp compression of the magnetosphere, so the geostationary satellite Goes 8 occurred near the magnetopause. Two time intervals have been distinguished: in the first one the intensive variations of all components of interplanetary magnetic field (IMF) and the solar wind density were observed, in the second one values of IMF By and Bz components were small and steady. The analysis showed that under strong the solar wind dynamic pressure, the oscillations of IMF and solar wind density may penetrate into the dayside polar cusp and be observed on the ground. The second time interval was characterized by the absence of the oscillations in the solar wind. ULF turbulence is typical for the turbulent boundary sheet (TBS), located at the boundary of dayside polar cusp. This turbulence may exit even in the absence of such waves in the solar wind. Probably, that situation we observed during the second time interval. The wave turbulence may penetrate into the magnetosphere and excite the FLR at the frequencies coincided with TBS wave ones. Contrary to our previous results, it was found that in the initial phase of this magnetic storm geomagnetic Pc5 pulsations with similar discrete spectra were observed not only in the polar cap, but in the closed magnetosphere (from polar to equator latitudes) as well.

Estimates of Long Time Detector Stability of the Worldwide Neutron Monitor Network

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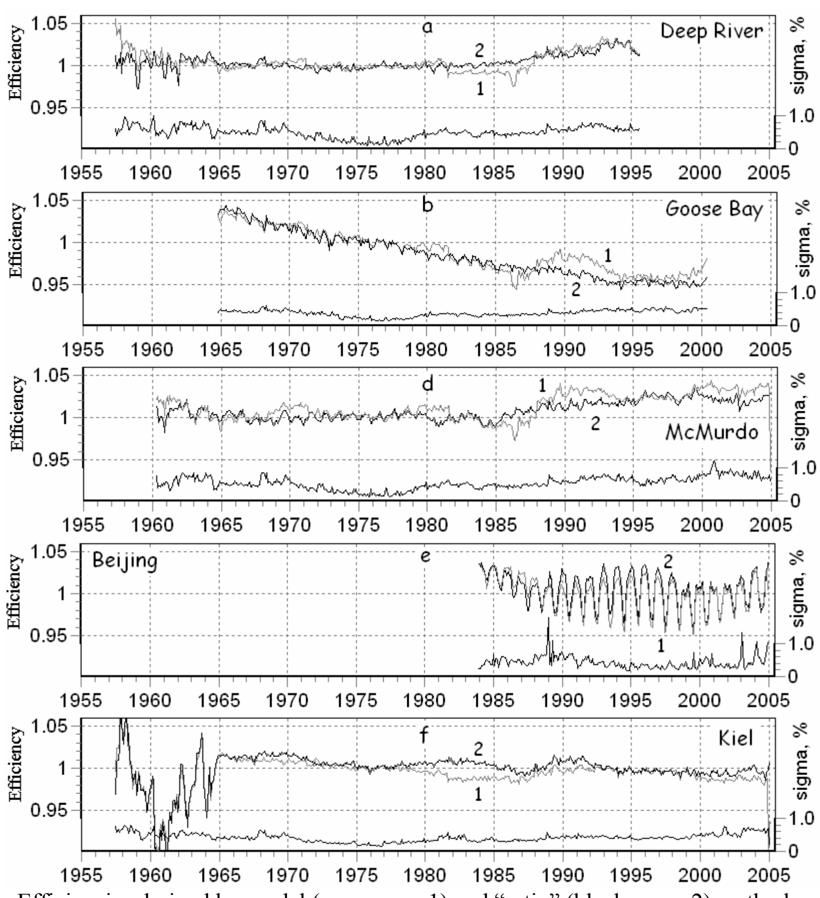
About fifty years researchers have a powerful instrument – the worldwide network of cosmic ray stations. Results of the continuous monitoring are the experimental basement for a number of research works, in particular, investigating longtime variations of cosmic rays. Therefore, a problem of the detector stability is extremely important. In this work we use two independent methods for estimates of longtime stability of the neutron monitor network performance. Different factors, which determine the detector stability, are considered. Quantitative estimates (and an accuracy of such estimates) are obtained for about 80 detectors operating in present or have being operating in the past more than one cycle of the solar activity.



Efficiencies derived by model (gray curve 1) and “ratio” (black curve 2) methods. Data are normalized to the level of 1976.

The first method uses the Cosmic Ray (CR) variation model for data analysis.

Discrepancy with the model for each station is attributed to data quality on this station. The second, independent, method of the stability estimation in the NM operating may be called as “ratio method”. In this case a set of stations with approximately identical cut off rigidities by means of specially elaborated algorithm is divided on the groups with “reliable” and “unreliable” operating stations. For a standard the group of stations is chosen which have similar CR variations and are defined as “reliable” operating. This method allows estimation of efficiency with its error for each station.

o Be-10 and C-14 Gives us Information about CR Fluxes in the Past

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A principal possibility of ion acceleration up to relativistic energies in the magnetoacoustic shock with the isomagnetic stepwise change is discovered. It is shown that the shock surfing acceleration of solar protons up to energies of 1-10 GeV is quate reliable. In the atmosphere cosmic rays produce Be-10, C-14 and other radionuclides. It is commonly supposed that the concentrations of these radionuclides (Be-10 in polar ice and C-14 in tree rings) are good proxies of cosmic ray fluxes impinging on the top of the atmosphere. But before the precipitation on the Earth's surface these elements spend several years in the atmosphere. The stirring of their concentrations over globe takes place. The analysis of 3 sets of data (2 sets of Be-10 and 1 set of C-14) shows that the correlations between them are low. Also, the relationship between cosmic ray fluxes and Be-10 concentrations in the period of 1937 - 1985 (when direct measurements of cosmic ray flux was performed) is weak. It means that the atmospheric processes, which play an essential role in the radionuclide precipitation, can violate the relationship between cosmic ray fluxes and radionuclide concentrations. We suppose that it is much more reliable to use the strong relationship of sunspot number with cosmic rays to get cosmic ray fluxes in the past. Cosmic ray fluxes in the past calculated from solar activity levels are given.

Three-Dimensional Numerical Modeling of Global Chances in Chemical Composition and Dynamics of the Atmosphere Induced by Solar Proton Fluxes during October-November 2003

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3D general circulation (GCM) and chemical global transport-photochemical middle atmosphere models have been used for simulation of ozone, wind and temperature response to one of the strongest solar proton event (SPE) of the 23rd solar cycle occurred on 28 October 2003 to investigate global response of the atmosphere to this SPE. Satellite observations of solar proton fluxes measured from the boards of GOES and CORONAS-F platforms have been used to calculate the ionization rates caused by solar energetic particles in the polar atmosphere of the Earth. It was assumed in the photochemical scheme [1] that approximately one molecule of NO and two molecules of OH are produced for each created pair of ions. In accordance with calculations the maximum of ionization rates was localized in the mesosphere (around 70-80 km). 3D photochemical simulations showed that ozone was destroyed partly in the mesosphere and stratosphere over both polar regions after SPE of 28 October 2003. The results of model runs realised with GCM showed also that SPE-induced ozone depletion leads to corresponding disturbances in temperature and dynamics mostly over high latitudes, but these effects penetrate to the lower latitudes. So, energetic solar proton flux is a simultaneous source of forcing for chemical composition and dynamics (including tides) of the atmosphere, and it possibly leads to long-term effects of global scale.

Reference

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Ground-based GeV-TeV Gamma Ray Astronomy with Air Cherenkov Telescopes

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17 m diameter MAGIC air Cherenkov imaging telescope is the largest single dish detector for very high energy (VHE) gamma rays. It is located on the Canary island of La Palma at the Roque de los Muchachos European Northern observatory at a mountain altitude of 2200 m a.s.l.. In the first time MAGIC shall measure VHE gamma rays in the sub-100 GeV energy regime. Results of observations of several sources will be shown. The design goal of MAGIC was to achieve a threshold setting of 30 GeV with classical photo multipliers and 15-20 GeV with hybrid photo diodes with GaAsP photo cathode. Application of the SiPMs that we are currently developing in two independent directions can allow one to lower the threshold setting down to < 10 GeV regime. Further lowering of the threshold setting one can expect from the coincident operation of the second MAGIC telescope that is now under construction in La Palma. Even larger diameter Cherenkov telescopes are currently under study and/or design phase. The VHE community is discussing the prospects of building an array of ultra-large reflector size for entering the 3-5 GeV energy regime. The electrons at these low energies, although largely cut by the geomagnetic field, would induce electromagnetic showers imitating gammas and thus could play the role of a strong background. The level of that background must be well understood and precisely measured for the reliable selection of the gamma ray signals.

Solar Activity Influence on the Atmospheric Airglow Emissions

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Extreme solar disturbances are the reason of strong dynamic processes in the Earth's magnetosphere and atmosphere. Middle latitude airglow emissions are sensitive to thermal and helio-geophysical conditions, including atmospheric gravity waves, vertical perturbations and conductivity, seismic activity, etc. The investigation of their variability is an effective method of studying physical and physico-chemical properties of the middle and upper Earth's atmosphere.

The nighttime airglow emissions from the upper mesosphere and lower thermosphere are dominantly produced through reactions driven by the recombination of atomic oxygen to its molecular form. Intensities of the $O(^1S)$ 5577 Å and $O(^1D)$ 6300 Å emissions have been observed at Stara Zagora, Bulgaria (42.4°N; 25.6°E) by zenith tilting photometer with 2° field of view and interenference filters. A photomultiplier of the EMI 9558 type is used as a detector. Spectral resolution for the green line is 1.5 nm and for the red line is 2.5 nm (Kanev et al, 2000). Regular observations were conducted in the period of July 2001 – May 2002 (23rd Solar Cycle maximum). Measurements during 143 nights have been used for analyzing the nocturnal, day to day and seasonal variations of the green and red oxygen line. In order to avoid the dynamical influence of tides on the daily variations, monthly mean values have been derived from averaged night intensities taken in 2 hour time interval (21-23UT).

Semiannual oscillations have been well outlined in the two emissions showing equinoctial maxima. The September – October maximum is higher than the March – April one. Strong intensity decay has been found in December. Correlation between green and red line intensities and relative sunspot number and F10.7 radioemission flux of the Sun has been investigated. Geomagnetic activity – indices D_{st} and ap during the same period has also been considered. Results are compared with the variations of $O(^1S)$ 5577 Å, measured at Sao Joao do Cariri, Brazil (7.4°S; 36.5°W), (Buriti et al., 2004) for the same time period, with the results of Givishvili et al. (1996) for long period observations and Fishkova et al. (2000).

According to Clemesha et al. (2004), airglow measurements show consistent solar cycle variations in very close synchronization with the F10.7 flux. Monthly mean values of the green line mesospheric component have been plotted against the observed values of 10.7 Solar flux and have shown periodic variation. Length of the period we obtain is nearly two times greater than that found by Midya et al. (1998) during the maximum of the 20th Solar cycle.

Data for the nocturnal variation of the green and red airglow intensities, before, during and after several Solar events in the examined period have been selected for studying geomagnetic effects on the region of photometric measurements according to Shepherd et al. (2004).

We foresee simultaneous ground based nightglow observations of the atomic oxygen green and red lines at mid-latitudes and 70 degree difference in geographic longitude – in Stara Zagora, Bulgaria and Irkutsk, Russia. Database with oxygen emission intensities will give the possibility of comparing them with satellite data and confidently identify processes and phenomena in the Earth's atmosphere and magnetosphere.

Reaction of a High-Latitude Ionosphere of the Southern Hemisphere to Solar Flash on October, 28th, 2003 according to GPS Observation

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The latest researches have shown that satellite systems can be successfully used for global and continuous monitoring of the atmosphere, as well as the ionosphere of Earth. In turn the atmosphere and the ionosphere of Earth can serve as a reliable indicator of a various sort of influence on the environment.

In October, 2003 there occurred extreme events on the Sun which surpassed by the amplitude of separate characteristics of solar activity all observed phenomena on the Sun for the last 20 years. Super-power flash, the most powerful of the earlier observed, in a X-ray range, and the most powerful coronal emission occurred on the Sun from the group of spots 486 on October, 28th. This powerful emission, prior to the flash, was directed practically towards the Earth. All the set of the experimental material obtained with the use of modern technical means from a board of satellites, as well as from solar-geophysical ground observatories, enables today to assert the solution of the problem of the forecast of solar-geophysical activity, the influence of powerful solar-geomagnetic disturbances on the Earth ionosphere and, in particular, on highly technological systems.

The observations over the behavior of key parameters of the ionosphere are necessary for studying and analysis of physical processes in the ionosphere. It facilitates the development of the empirical and semi empirical models of the ionosphere for the solution of various geophysical and radiophysical problems. The ionosondes of vertical sounding are the basic source of the information on parameters of the ionosphere. At the same time, the creation of high-precision navigating receivers allows now to use global satellite systems for the monitoring of the state of the ionosphere practically in real time. The availability of navigating receivers in Antarctica allowed tracking the influence of the solar flash on a high-altitude ionosphere of the Southern hemisphere.

The analysis of the state of the Earth ionosphere during the occurrence of the solar flash on October, 28th, has shown a significant increase in speed of change of the full electronic contents. Slightly unusual character of its change was observed for all stations and satellites at the same time, namely, during 11:02:30 AM - 11:03:00 AM UT. It is necessary to pay attention to the fact, that this change was registered 9,5 minutes prior to the flash, recorded in an optical range in 11:11:52 AM UT. The accuracy of temporary readout of the maximal amplitude of the ionospheric disturbances was defined by the discreteness of the executed measurements - 30 seconds. The form of speed change of the full electronic contents is practically identical for all azimuths of observation.

Dependence of High-Latitude and Low-Latitude Geomagnetic Disturbances on Solar Wind Parameters during the Magnetic Storm of November 7-8, 2004

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The variations of intensity and dynamics of auroral electrojets, low-latitude disturbances at latitudes ~ 10-50^0, SYM-H and Dst-indices depending on the change of solar wind dynamic pressure-Pd and IMF Bz are studied on the base of global geomagnetic observation data. It is shown that positive values of SYM-H and Dst or the decrease of their negative values correspond to the growth period of Pd.

The enhancement of magnetic field depression at latitudes Φ'~10-25^0 with the maximum ΔH in the evening sector is observed at negative values of IMF Bz and is accompanied by the enhancement of auroral electrojets in all temporal sectors and their southward shift. The western electrojet shifts up to the latitudes ≤ 55^0 and the eastern one - to the lower latitudes, and eastern electrojet is also enhanced by Φ'~75-78^0. The maximum values of Dst ~ - 400 nT correspond to the most intensity of western (eastern) electrojet in the midnight (evening) sector with a current center at the lowest latitudes. The possible sources of Dst variations are discussed.

The Magnetotail Stretching during two Successive Solar Cycles

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It is known that the stretching of the magnetic field lines in the near-Earth magnetotail is characterized by latitude of a precipitation boundary, on which the energy flux of ions with energy above 3 keV has maximum. This boundary, called as b2i, is routinely determined from low-orbiting DMSP satellite particle data by the Auroral Particles and Imagery Group at JHU/APL. The lower b2i, the more stretched is the magnetic field. We used the b2i values along with the interplanetary and geomagnetic activity data from the OMNI data set for years 1984-2004 (solar cycles 22 and 23) for investigation of the long-term evolution of the magnetotail stretching. It is found that annual average of b2i has pronounced variations during the two solar cycles. Maximal b2i values (more dipole-like magnetosphere) are found in 1987 (near the minimum of the solar cycle 22) and in 1996 (near the minimum of the solar cycle 23). Minimal b2i value (more stretched magnetosphere) is found in1991near the maximum of the solar cycle 22, but in 2000 (maximum of the cycle 23) the b2i minimum is not distinct. In contrast to behavior of b2i during the declining phase of the preceding cycle, a strong decrease of the latitude is observed in 2002-2003. Such variations of b2i are in agreement with the behavior of interplanetary parameters. The best correlation of the magnetotail stretching is found with the merging electric field. More stretched magnetotail means more intense cross-tail current and, consequently, higher level of the geomagnetic activity. This explains a high correlation ($|r|>0.8$) of annual average of b2i and geomagnetic activity indices Kp, AE, and Dst. It is also found that b2i depends on season. Monthly averaged b2i values exhibit distinct minimums in March and October. This agrees with well known equinox increase of the geomagnetic activity.

Solar Wind Ion Entry into and Ionospheric Ion Access to the Plasma Sheet during the September 24-25, 1998 Magnetic Storm

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We have used a global time-dependent magnetohydrodynamic (MHD) simulation of the magnetosphere and particle tracing calculations to determine the access of solar wind ions to the magnetosphere and the access of ionospheric O+ ions to the storm-time near-Earth plasma sheet and ring current during the September 24-25, 1998 magnetic storm. The September 24 – 25, 1998 magnetic storm began with the arrival of a sudden impulse at 23:45 UT on September 24th which abruptly increased the solar wind dynamic pressure on the nose of the magnetosphere from 2 nPa to 15 nPa. Dst reached a minimum of –207 at 1000 UT on September 25th. During this event, the TIDE instrument on board the POLAR spacecraft observed large-scale dayside ionospheric outflows in direct response to the impact of the pressure pulse on the magnetosphere. To study solar wind entry, we launched ions upstream of the bowshock at 5-minute intervals beginning one hour prior to the shock arrival and continuing throughout the main phase of the storm. Ions were launched with the solar wind streaming velocity and thermal spread measured at that time. Following the particle trajectories through detectors placed within the magnetopause current layer allowed us to gain a better understanding of the transport and acceleration of solar wind plasma during this storm. To gauge the contribution of ionospheric plasmas, we traced a large number of particle orbits from the dayside ion fountain beginning one hour prior to shock arrival and also continuing throughout the main phase of the magnetic storm, also at 5-minute intervals. The ion outflow rates were normalized with empirical models as well as in-situ observations from WIND and POLAR/TIDE. We will show a comparison of the time-varying contribution of solar wind H+ and ionospheric O+ ions to the magnetosphere during the storm, their energization in the magnetotail current sheet, and their loss from the magnetosphere.

SW1

Extreme Events and Super Storms

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As far as extreme solar cosmic ray ground level enhancements (GLEs) are concerned, the super events of February 23, 1956, September/October 1989, as well as the recent January 20, 2005 GLE rank at the top. Major criteria for classification are e.g. the peak flux and the event integrated >10 MeV total proton fluency near Earth. Among the most powerful geomagnetic storms during the solar cycles 19 - 21 were those of November 13, 1960, August 5, 1972, and February 8, 1986. On March 13, 1989, a major storm caused one third of Canada and part of upstate New York to lose electrical power. The largest storm of solar cycle 23 occurred on November 20, 2003, with a Dst index of −472 nT. But all these GLEs and geomagnetic storms are dwarfs compared to the Carrington event of September 1, 1859. Recent analyses of ice core samples indicate that this was the largest solar particle event observed in the past 500 years. The associated geomagnetic storm had an estimated Dst of about -1700nT. While in this event both the solar particle flux and the associated geomagnetic disturbance had exceptional amplitude, extreme GLEs and super storms do not always coincide. As a matter of fact, several of the major solar particle events observed at Earth occurred during large magnetic storms that were triggered by preceding solar activity that did not exceed average intensity. The paper reviews the characteristics of solar extreme events and geomagnetic super storms on the basis of selected examples and on a statistical basis. Special emphasis is given to the response of the Earth's magnetosphere. Advanced modeling techniques of geomagnetic effects on cosmic rays during major magnetic storms are illustrated.

Extreme GLE

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At a rate of roughly 15 times per solar cycle, the Sun emits cosmic rays with sufficient energy and intensity to increase radiation levels at Earth's surface, resulting in a "Ground Level Enhancement" (GLE). A coordinated array of ground-based detectors such as neutron monitors remains the state-of-the-art method for studying these extreme solar particle events.
This talk reviews the remarkably diverse physical phenomena displayed in GLE observed by *Spaceship Earth*, a multi-national network of neutron monitors arrayed across 4 continents. Among reported phenomena are:

- magnetic mirroring of GLE particles from a downstream magnetic bottleneck (Bastille Day event, July 14, 2000),
- a GLE in a CME – injection of solar cosmic rays onto both legs of a closed magnetic loop (October 22, 1989),
- relativistic solar neutrons detected prior to onset of the relativistic proton event (October 28, 2003),
- largest GLE (56X Galactic background level at South Pole) in nearly half a century – this event may have featured a rare case of wave excitation by relativistic protons, resulting in nonlinear transport phenomena (January 20, 2005).

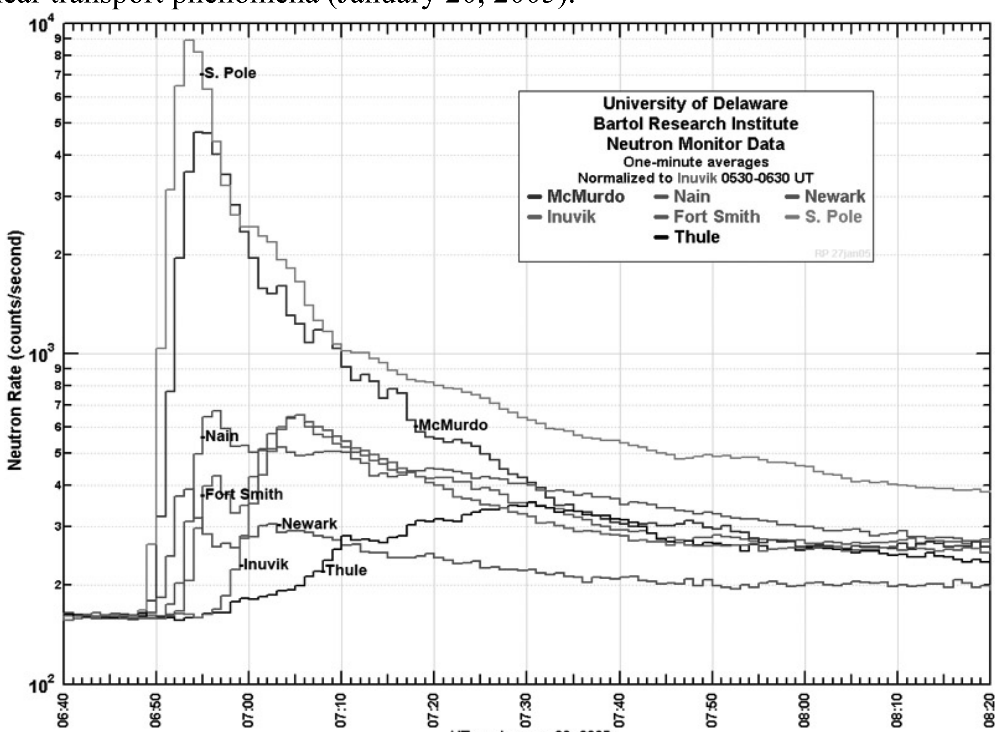

Figure 1. On January 20, 2005 the Sun emitted cosmic rays of sufficient energy and intensity to increase radiation levels on the surface of Earth. This "Ground Level Enhancement" (GLE) was especially intense at South Pole (highest peak) and McMurdo, Antarctica (second highest). In fact the McMurdo increase was the largest observed at sea level since the famous 1956 GLE, which was the largest ever recorded.

Cosmic Rays for Space Weather Tasks

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When we speak on Space Weather we are commonly meaning the radiation and electro magnetic conditions in the near Earth space. Cosmic ray variations define directly a radiation situation. Besides of this they are closely related to the second component of the space weather – to the variations of electromagnetic conditions in the interplanetary space and Earth's magnetosphere. This makes cosmic ray variation as one of the important resource for diagnosing of the space weather state and forecasting of its changes.

The following questions are discussed in this report.

- Possibility of forecasting of the long term cosmic ray variations.
- Using the ground level observations for early diagnosing and forecasting of evolving of the great proton enhancements.
- Cosmic ray anisotropy as a tool for evaluation of the interplanetary space condition.
- Relation of the Forbush effects to the interplanetary disturbances and geomagnetic storms.
- Cosmic ray density and anisotropy variations and structure of the solar wind disturbances.
- Cosmic ray behavior before the interplanetary shock arrival.
- Indices of the cosmic ray activity and their practical use.
- Cosmic rays and satellite anomalies.
- Many year data on Forbush effects and their use in forecasting of the solar activity bursts.

Cosmic ray observations till now are used out of complete volume in the space weather tasks. The main reason of such inefficiency is inaccessibility of many kinds of the cosmic ray data for an operative analysis. Fortunately, this situation is now changing fast to the better. In particularly, data from ~25 ground level cosmic ray stations now are available in real time. It gives a hope that in the nearest years we shall see more wide and effective use of the cosmic ray characteristics for space weather forecasting.

Radiation Storms in the Near Space Environment

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Russian low-orbital polar satellite Coronas-F was launched on July, 2001 and since this time several extreme solar events were observed. During some of them geomagnetic activity was very light and caused significant magnetic storms. Different phenomena such as both penetration of solar particles inside the trapping region and in polar caps and variation of electron and ions radiation belts are discussed and are compared with other experiments.

High Energy Solar Neutrons and Protons Detected in the Flare on November 28th, 1998

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One of the fundamental research subjects in astrophysics is study of acceleration mechanism of particles. The understanding of particle acceleration mechanism into high energies is very important, since it is a fundamental process of high energy phenomena extended in the universe.
The acceleration of particles can be seen everywhere in our universe. Even they are found in near our Earth. We can see such examples in the particles under thunder clouds or particles in association with aurora. If we search the phenomena beyond the Earth, we can find the process in the interplanetary space. Particles emitted from the Sun are sometimes accelerated inside the shock front in the interplanetary space. The most prominent feature of the acceleration of particles can be found at the surface of the sun. Particles are accelerated in the solar flares when the magnetic fields of the sun collides each other and make reconnection. In case a huge amount of particles are accelerated at the solar surface, they are usually transported by the interplanetary magnetic field and arrive at the Earth. Then they will attack the aeronauts who work at the international space station or sometimes they will kill the solar panel of the satellite. Therefore it is very important nowadays to predict the arrival of huge amount of energetic particles in association with solar flares.
Our final goal of research is to demonstrate the real acting model at the Sun, being based on the experimental results. One of the advantage to study the Sun from above point of view, we can see the activity of the sun in detail by using the instruments from the ground and aboard satellites. By use of X-ray telescope aboard satellites, we can see very precise movements of the magnetic filed in flares with precise time development.
In this paper by combining the data obtained by the ground based solar neutron telescope located at Tibet and the Yohkoh satellite, we would like to show when particles are accelerated into high energies at the solar surface in association with the flare on November 28th 1998. We have found new very important results by this combined data analysis that quite high energy neutrons were detected by the solar neutron telescope. If so, this must be the first evidence that solar neutrons were detected beyond 10 GeV

Space Weather Observatory on Aragats Mountain in Armenia

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Radiation and Geomagnetic storms, which are elements of Space Weather, are part of the major obstacles for Space Operations. Reliable forecasting of the arrival of these dangerous elements is of vital importance for orbiting flights and some surface industries. In addition to the fleet of space-born instruments, worldwide networks of particle detectors spread along different latitudes and longitudes, provide valuable information on the intensity and anisotropy of the variable cosmic ray fluxes.

Starting from 1996 we are developing various detectors to measure fluxes of different components of secondary cosmic rays at the Aragats research stations of the Alikhanian Physics Institute in Armenia. In 1996 we restarted our first detector - the Nor Amberd Neutron Monitor 18NM64 (2000m above sea level). A similar detector was commissioned and started to take data at the Aragats research station (3200m above sea level) in 2000. A Solar Neutron Telescope (SNT) is in operation at the Aragats station since 1997, as part of the worldwide network coordinated by the Solar-Terrestrial laboratory of the Nagoya University. In addition to the primary goal of detecting the direct neutron flux from the Sun, the SNT also has the possibility to detect muon fluxes and roughly measure the direction of the incident muons. Another monitoring system is based on the scintillation detectors of the Extensive Air Shower (EAS) surface arrays, MAKET-ANI and GAMMA, located on Mt. Aragats at 3200 m above sea level. The muon scintillation multidirectional monitor system started operation at the Nor Amberd research station in 2002. Data Acquisition (DAQ) system was modernized in 2005.

Flexible 32-bit microcontroller based electronics is designed to support the combined neutron-muon detector system and utilize the correlated information from cosmic ray secondary fluxes, including environmental parameters (temperature, pressure, magnetic field). Microcontroller based DAQ systems and high precision time synchronization of the remote installations via Global Positioning System (GPS) receivers are crucial ingredients of the new facilities on Mt. Aragats.

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The Extreme Cosmic Ray Ground Level Enhancement on January 20, 2005

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Between January 15 and 20, 2005, the solar active region NOAA AR 10720 produced five powerful solar flares. In association with this major solar activity several pronounced variations in the ground-level cosmic ray intensity were observed. After a sudden storm commencement on January 17, 2005, at 0748 UT the worldwide network of neutron monitors (NM) recorded a Forbush decrease (Fd). The neutron monitors at Jungfraujoch, Switzerland (geogr. latitude: 46.55N, geogr. longitude: 7.98E; altitude: 3570/3475 m asl; effective vertical cutoff rigidity Rc = 4.5 GV) observed a decrease in the count rate with a maximum amplitude of about -15%. Three days later, on January 20, 2005, i.e. still during the Fd, NOAA AR 10720 produced its fifth flare, a X7.1 solar burst with onset time at 0636 UT and peak time at 0952 UT. The flare position was near the west limb and therefore the Earth was well connected to the flare site along the interplanetary magnetic field lines. Less than 15 minutes after the observation of the flare onset the first relativistic solar particles arrived near Earth and a solar cosmic ray ground level enhancement (GLE) was observed by the worldwide network of NM stations. This GLE is ranked among the largest in years with gigantic count rate increases at the south polar NM stations McMurdo (almost 3000%) and South Pole (more than 5000%). The maximum count rate was reached very quickly, only ~5 minutes after the onset. This GLE exhibited a pronounced anisotropy during the initial phase of the event and a complex intensity-time profile. Some NM stations recorded a pre-increase in the count rate, some NMs a double peak. In the Jungfraujoch IGY NM 1-minute data the onset time of the GLE was at 0654 UT and reached a maximum amplitude of 11.4%. From the recordings of the Swiss cosmic ray detectors and of the worldwide network of neutron monitors, we determined the characteristics of the solar particle flux near Earth (spectral form, amplitude, pitch angle distribution). Because the ground-based cosmic ray detectors measured different and complex intensity-time profiles, the determination of the GLE parameters has proved rather difficult. The analysis includes solar wind and geomagnetic data. For the evaluation of the asymptotic directions and the cutoff rigidities of the NM locations we used the Geant4 code MAGNETOCOSMICS. Special emphasis is given to the peculiarities in the intensity-time profiles (e.g. pre-increase and double maximum of GLE). In the paper we discuss the method of analysis and present the obtained results.

Ground Level Enhancement of the Solar Cosmic Rays in January 20, 2005

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January 2005 brought an unexpectedly giant proton event towards the end of the current solar cycle. The flux of relativistic protons reached the Earth at ~ 6:49 UT on 20 January and was recorded by neutron monitors as a ground level enhancement which at southern polar stations was about several thousands of percentages. This event seems to exceed even the famous GLE05 in February 1956 by the 1-minute data. At the same time in GLE69 there was much less high energy particles than in 1956 or in September 1989 events, and majority of high latitude stations recorded effect an order less (~100-300%), and at mid-latitude stations with cut off rigidity more than 6 GV it was very small or absent at all. The first particles came from the Sun by the narrow beam from the south-west direction and had very hard spectrum with an index -0.65. In some minutes after the onset a spectrum of the solar CR jumped to become soft and during the next 5 hours its index changed only within the -3.0 - 4.0 range. The parameters of the cosmic ray energy spectrum, anisotropy, differential and integral fluxes were derived after applying anisotropic and compound models of solar cosmic ray variations to the data of about forty neutron monitors. Simultaneous maximum in broad energy range in differential fluxes of solar CR testifies the arrival of all energies at the same time in the first minutes. In the first 5-minute interval high energy particles dominated in the flux whereas just before the 7:00 UT the number of low energy particles essentially enhanced. Only in the first minutes the model selects sufficiently high upper energy, after this the modeling Eu is small and underestimated. On the other side, it is a real reflection of the small contribution of the high energy particles (>3GeV) in the observed GLE.
Anisotropy contribution dominates during the first 15-20 minutes of the effect and quickly decreases with time. However the anisotropy remains at a significant high level not less than 11 hours after the onset. The flux along the IMF force line started to dominate only some time later.

Cosmic Ray Variations during Extreme Events on November 2004.

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As it follows from the observations during the last several years the Sun reserved its main surprises in the current cycle for a descending phase. Solar activity burst in November 2004 led again to the significant sporadic variations in cosmic rays, although less in amplitude when compared to the events in October-November 2003 or in March-April 2001. Permanent releases of the solar substation, mainly from the AR10696, occurred almost every day creating interplanetary disturbances followed by shocks that caused significant short time variations in the galactic cosmic rays. Cosmic ray density and anisotropy for each hour throughout the period 6-12 November 2004 were derived from the neutron monitor network data by the global survey method. The most significant, with a magnitude of CR density decrease of 7.3% and 8.1% turn out to be the events after 3-rd and 4-th shocks. During these events the CR anisotropy revealed sharp and fast changes by the amplitude and direction. It might be explained by the quick changes in the solar wind and IMF during the disturbed period leading to the complicated structures in the interplanetary space which is reflected in the behavior of CR even with energies recorded by neutron monitors. The behavior of these parameters during Forbush effect and geomagnetic storm were analyzed in relation to the interplanetary and magnetosphere condition.

The cut off rigidity variations were evaluated for different stations (~ 40) during geomagnetic storms followed this period. Maximum changes of the cut off rigidity (dRc~0.7 GV) occurred at the latitudes corresponded to the Rc=5-6 GV, that confirms more weak perturbation of the magnetosphere in this time as compared to the storm in November 2003.

In a whole, by the perturbation level, by the number and magnitude effects in cosmic rays the situation in November 2004 gives a way only to the events in October-November 2003 and in March-April 2001 during the current solar cycle.

Forecasting and Epignoz of Galactic Cosmic Ray Variations based on Solar Activity Data

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The study of heliospheric conditions and solar-terrestrial coupling with a view to space-weather forecast is based on understanding and predicting of time variations of cosmic ray (CR) fluxes as an important element of space environment. The objective of this paper is to predict variations of CR fluxes for months and years ahead and reconstruct their behavior in the past on the basis of information available on the relationship between the modulation of galactic CR and parameters of the solar and geomagnetic activity. Such a problem can be stated and solved thanks to continuous monitoring of cosmic rays at a network of stations that have been operated for over half a century as a single multidirectional, high-precision device. We have tested the CR modulation models by density variations of 10 GV cosmic rays recorded at the ground-based network of stations.

Using the model of CR modulation in the heliosphere proposed previously, which considers a relation between long-term CR variations with parameters of the solar magnetic field calculated on the solar wind source surface, the observed CR variations were estimated with accuracy allowing their predictions. An adequate model description of CR variations can be obtained using the structural and quantitative characteristics of the solar global magnetic field, such as the tilt of the heliospheric current sheet, the calculated mean intensity of the source-surface magnetic field, and the polarity of the large-scale solar magnetic field.

It is shown that there are two possibilities: **1)** to predict CR intensity for 1-12 months by using a delay of CR variations relatively to effects of the solar activity (SA) and **2)** to predict CR intensity for the next solar cycle. For the second case predictions of global solar magnetic field characteristics are crucial. In both reliable long-term CR and SA data are necessary.

We have developed a method of forecasting CR fluxes at the Earth for the period from 1 to 12 months. The method is based on the global magnetic field characteristics calculated at the source surface using observation data from an isolated CR station available in real time. CR fluxes have been predicted for the following months and the quality of such forecast has been estimated.

CR variations for the next solar cycle are predicted by solar magnetic field data of two magnetographs (Stanford and Kitt Peak) using the statistical method. The CR behavior predicted by statistical method up to 2011 shows that the next CR maximum is to take place at the end of 2006 or beginning of 2007, according to Kitt Peak observations, and in the middle of 2006, according to Stanford data. The forecast is made taking into account the data from both observatories because of the differences in their long-term magnetic-field measurements.

The CR behavior during centuries 17-20 has been reconstructed on the basis of a model relating CR modulation to solar and geomagnetic activity indices. The behavior of cosmic rays in the past reconstructed from variations of the sunspot numbers and indices of geomagnetic activity shows that the CR modulation during the last five solar cycles was much stronger than in the previous 300 years.

Correlations between Variations of Cosmic Rays Spectrum and Interplanetary Medium Parameters

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According to data of ground-based and satellite observations of the cosmic rays (CR) intensity, the variations of rigidity spectrum of high-energy particles during the periods of 2003 extreme events are investigated. The parameters of CR rigidity spectrum are determined over each hour of observations, and then using these parameters the estimation is made of characteristics of heliosphere electromagnetic fields responsible for under study phenomena, as well as their comparison with the observed interplanetary medium parameters. Based on the obtained results the following scenario is proposed of CR and solar wind (SW) plasma acceleration in heliosphere. A potential difference between the pole and equator occurs in a coordinate system fixed relative to rotated source of magnetic field (sun). In case if the local emergence of magnetic field flux takes place within the source, an increasing in time electric field is produced in heliosphere and polarization drift occurs along this field. This results in particle acceleration and formation, in this connection, of current system generating the magnetic field of loop-shaped structure in heliosphere. The increasing in time magnetic field of this structure causes the particle drift into it and their acceleration due to betatron mechanism. When currents forming these structures increase up to critical values, the current circuit break can occur because of one or other instability, following by an explosive process with accelerated particle precipitation into solar atmosphere and their outflow into the interplanetary space. When accelerated particle beam propagates in inhomogeneous magnetic fields of solar corona and heliosphere it becomes polarized because the protons and electrons drift in the opposite direction that results in charge separation in a spatial inhomogeneity of accelerated particle density, so a potential difference occurs between beam boundaries along the magnetic drift trajectories. This causes the generation of increasing in time polarized electric field and as a consequence the polarized drift of background particles of SW plasma, solar corona and galactic cosmic rays (GCR) along this field, i.e. this causes particle acceleration with Larmor radius less than sizes of these structures. The current system is formed again and magnetic field is generated which accelerates particles and so on. Thus the energy exchange takes place between accelerated particles and background particles of SW plasma, solar corona and GCR as well as formation of heliosphere current structures and generation of interplanetary medium structures.

Increase of the Solar Energetic Particle Flux on January 20, 2005

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Peculiarities of the increase of E > 1 GeV particle flux during the solar flare on January 20, 2005 are studied. The amplitude of increase (~130% by the Yakutsk data) is comparable with the May 7, 1978 event and September 29, 1989 event, but it has the steeper energy spectrum. In this event the extreme anisotropy of particle flow has two peaks in the intensity maximum as in the case May 7, 1978 event. On the base of preliminary analysis of data one can explain the observed peculiarities of the event by two ways. First: the anisotropy of particle intensity can be the consequence of collimation of particle flux in IMF inhomogeneties, carried away by the solar wind. Second: such a behavior of intensity in maximum is caused by the peculiarities of particle acceleration source in the solar flare itself.

Extreme Solar Flares and the Acceleration of Particles up to Relativistic Energies at Shock Waves in Interplanetary Space

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Cosmic ray events in October-November 2003 are studied by using data of the Yakutsk detector complex and world station network, of cosmic rays. Peculiarities of observed increases are compared with characteristics of well known events in July 1959, November 1960, August 1972, October 1981 and September-October 1989. All these events have the similar scenario of development. Several major sequential solar flares from one active region generate the energetic particles and produce alternating shocks in interplanetary space. The characteristic feature is that a next shock wave moves about twice as fast as the previous one. In this case, the additional increase of relativistic particles flux observed on the Earth is caused by the acceleration of energetic particles in interplanetary space between the approaching shock fronts. In October – November 2003 three increases of energetic particles on the Earth against the background of alternating Forbush decreases are observed. In this regard, the increase of energetic particles on October 28, 2003 is of particular interest. The presence of shocks at that time essentially affects the process of diffusive particle propagation. In particular, the additional flux of relativistic particles is observed after the maximum of flare particles, which remains to be practically constant up to the arrival of a shock on the Earth. By data of in situ measurements of solar wind parameters, the passage of two shocks by the Earth with the velocities of 1000 and 1800 km/s took place. Thus, the additional flux of E>1 GeV particles is caused by the acceleration at approaching shock fronts.

An Alert System for Ground Level Enhancements

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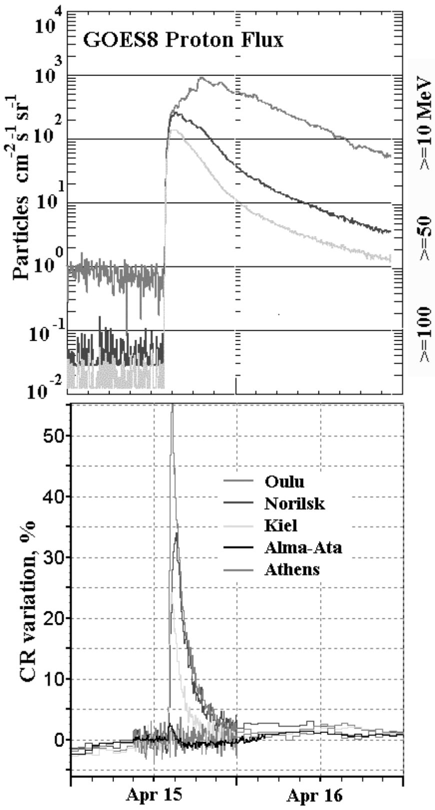

Behaviour of different energy cosmic rays during the powerful proton event in April 2001

Nowadays space is a place where many of new products of the growing electronic industry are used. Therefore now more than ever, we need a new, fast and advanced system in order to protect them in space or at the Earth's surface. In this work preliminary results of the ALERT system are discussed. The system is dedicated to searching for the onset of the solar cosmic ray ground level enhancements (GLEs) during the great proton events. Data from worldwide neutron monitor network in real time has been processed by a special program in order to produce a real time ALERT signal about start of these space weather phenomena. The onset of ground level enhancements, due to relativistic solar particles, can be registered around 20 to 30 minutes before the main part of lower energy particles responsible for a dangerous radiation came to the satellite orbits, and this can provide the advantage of forth warning. The duration of GLE is several hours, the stream of non relativistic solar particles, usually lasts one order more as it is seen in the picture.

Combining data from the neutron monitors and satellite measurements (for example, X-Ray from GOES-10 and GOES-12), using advanced and high-speed algorithms, we are able to provide a reliable alarm signal on some dangerous proton events. We use minutely data of two high latitude neutron monitors and two channels X-Ray on GOES-10 and GOES-12 to exclude a probability of the false ALERT signal. After the ALERT signal the program on a definition different parameters of relativistic solar protons is run, which allows the rigidity spectra, flux anisotropy and pitch angle distribution of the relativistic protons to be derived. Processing of the GLE data for the first 15-20 minutes is enough to define spectral characteristics by the high energy particle enhancement. Increasing precise of these parameters with following measurements we can forecast a behavior of the lower energy particle during the event that is important for preliminary estimation of the radiation dozes.

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Operative Center of the Geophysical Prognosis in IZMIRAN

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The IZMIRAN has been established about 65 years ago with one of the intentions to carry out geomagnetic prognosis. This direction was developing throughout all succeeding years, and during the last 6 years this aim became to be sufficiently feasible due to the creation of the Forecasting Center of helio-geo-physical conditions. This Center appeared as a response to the new technologies, new data in a big capacity and new requirements of the society. The Center uses extended experimental basis of IZMIRAN and all available Internet sources. The main tasks are: continuous monitoring of the processes at the Sun and near Earth environment, development of different kind of prognosis and delivering them to the users. The main production is: short term (1-6 days) prognosis of geomagnetic activity (mainly daily Ap-index and maximum Kp-index), long time (from weeks to years) prognosis, detailed forecasting on the special fixed days. Among of the main consumers it is worth to mention the Russian Space Agency, the Russian Ministry of Civil Defense, Emergencies and Disaster Relief, railway departments, a number of medical institutions, and mass media. In this work a practical activity of this Center is discussed and some examples of the real influence of geomagnetic disturbances on different sides of the human activity are also considered. The 6 year experience of this Center demonstrates the wide claiming of its prognosis, and it is believed to get more improvements in the nearest future.

Prediction of Solar Activity with the aid of Fuzzy Descriptor Models

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Among the various conditions that affect space weather, the sun-driven phenomena dominate the others. Origin of many space weather changes is the solar activity which varies in an eleven year period, called solar cycle. The solar cycle consists of a period of activity, the solar maximum, and a period of quiet, the solar minimum. There are three main observations of solar activity, sunspots, solar flares and coronal mass ejections. The sunspot number is the most useful measure of solar activity level.

The initial works of modeling the dynamics of solar cycle were just to satisfy the curiosity of human. Soon, reconstructing the sunspot time series and predicting the solar activity became an appropriate test bed for various methods. Now it has been cleared that solar activity has significant effects on earth climate, communication systems, satellites and space missions. In the past decade, several methods have been proposed to predict the solar activity in advance.

The sunspot number time series shows chaotic behavior, which leads to long time unpredictability. Following the achievements in the field of chaotic systems, several methods can be used in the prediction of sunspot numbers; namely polynomial function approximation, reconstructions using Lyapunov exponents, detecting periodicity in chaotic time series and the intelligent predictions based on neural networks and neurofuzzy models. Neural networks and neurofuzzy models which are general nonlinear function approximators have performed good performance in the prediction of chaotic time series.

On the other hand, descriptor systems describe a wider class of systems, including physical models and non-dynamic constraints. It is well known that the descriptor system is much tighter than the state-space expression for representing real independent parametric perturbations. Such systems are also known as singular systems, degenerate systems, generalized state-space systems, semi-state systems. Such systems arise in the study of robotics, optimal control, economics, large-scale interconnected systems, etc.

The fuzzy descriptor models as a generalization of the locally linear neurofuzzy models are general forms that can be trained by constructive intuitive learning algorithms. They fulfill the principle of network parsimony which results in high generalization property. Generalization is the most important aid in prediction problems. This motivates one to use the fuzzy descriptor models in the prediction of sunspot numbers, which is proposed in this paper.

This paper defines a fuzzy descriptor system whose consequent parts are represented by descriptor forms. The ordinary T-S fuzzy model is a special case of the fuzzy descriptor system. The paper proposes a new method, which is the extension of "locally linear model tree algorithm (LOLIMOT)" to fuzzy descriptor systems to adjust the parameters of such systems for modeling the problem. This method is called "generalized locally linear model tree algorithm (GLOLIMOT)". To show the advantage of this method, the performance of fuzzy descriptor system with this extended learning algorithm is compared with several neural and neurofuzzy models in the prediction of sunspot numbers. Results depict the great performance of such systems in prediction of sunspot numbers in compare of other neurofuzzy models.

Introducing a New Learning Method for Fuzzy Descriptor Systems with the Aid of Spectral Analysis to Forecast Solar Activity

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In the past two decades, researchers indicate that the physical precursor and solar dynamo techniques are preferred as practical tools for long term prediction of solar activity. But why more than 23 cycles of solar activity history should be omitted and just the empirical methods or simple autoregressive methods on the basis of observations for the latest eight cycles should be used? In this article, a method based on fuzzy descriptor systems (as a generalization of ordinary T-S neuro-fuzzy models) and singular spectrum analysis (SSA) as one of the spectral analysis is proposed to forecast some solar activity's indexes. Fuzzy descriptor model is optimized for each of the principal components obtained from singular spectrum analysis, and the multi step predicted values are recombined to make the disturbance storm time (Dst) and proton flux indexes. The proposed method is used for forecasting hourly Dst index in 2001 and daily averaged Dst index from 1957 to 2000 as well as proton flux index in 2001. The results are remarkably good in comparison to the predictions made by other methods.

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The Sunspots Roads: A Morphology-Based Sunspots Detection Method and Delaunay Triangulation Surface for Prediction

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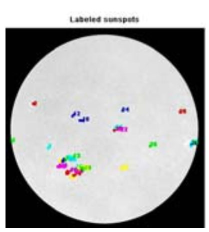
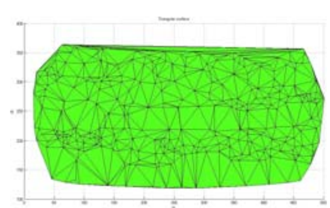
In this paper a new approach for automatic detection and identification of sunspots on the full disk solar images is presented. The technique uses morphological operators on image such as image cleaning, morphological "bottom hat" operation, image closing and H-maxima transform. Application of some filtering processes on image to enhance the contrast and remove the high frequency noises is considered. Edge detection via Sobel mask is applied to find sunspot candidates. A new transformation which is used in iris recognition strategy is utilized to map the sunspots road from Cartesian coordinates to the normalized non-concentric polar representation to analysis the sunspots trajectories. Delaunay triangulation which is a set of lines connecting each point to its natural neighbors is applied to the sunspots centers which are detected from the suggested process. The Delaunay triangulation is related to the Voronoi diagram and via this technique the surface of the connected sunspots roads is achieved for each month. By using a search mechanism that requires a triangulation of the desired points obtained by Delaunay, the prediction of the sunspots is obtained. The technique was tested on two years of full disk SOHO/MDI images. We found that the detection results are promising with a good preciseness and the sunspots location estimation is noticeable.

The pictures presented below show the results of sunspots detection and the Delaunay Triangulation Surface of the projected sunspots region.





Prediction of Geomagnetic Storms Using Neural Networks: Comparison of the Efficiency of the Satellite and Ground Based Input Parameters

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Appearance of relativistic electrons in the inner magnetosphere produces a deep negative impact on the satellite functionality. During great geomagnetic storm the region of the acceleration of relativistic electrons coincides with the lowest position of the westward electrojet center and the region of the generation of discrete forms of aurora. Different kinds of neural networks have established themselves as an effective tool in the prediction of different geomagnetic indices, including the Dst being the most important constituent for determination of the effects of Space Weather on technology infrastructure. Both the satellite and ground based data were used as an input parameters for the Dst time series forecast in the past. In this work feed-forward networks with one hidden layer have been used to forecast the Dst variation, using as input parameters the auroral electrojet indices. January-June 1981 and July-December 1985 data have been used as training data sets, July-December 1981 and January-June 1986 have been used as validation data sets, and January-December 1982, July-December 1986 and January-June 1987 have been used as test data sets. Neural networks for low activity and high activity intervals of the solar cycle have been trained and analyzed by separately. It was found that the Auroral Lower (AL) index gives substantially best results in comparison with other auroral electrojet indices, both for low and high solar activity. Changes in the neural network architecture, including the number of nodes in the input and hidden layers and the transfer functions between them lead to an improvement of a network performance up to 30%. It was found that the storm-time intervals were predicted much more accurately as quite time intervals. The majority of cross-correlation coefficients between predicted and observed strong geomagnetic storms lie between 0.8 and 0.9, which is very similar to the results, obtained previously for the solar wind input parameters. Cases of very high (more than 0.9) and low (less than 0.8) performance have been analyzed by separately, considering the impact of different solar wind parameters on the Dst forecast. A few cases of the false storm prediction have also been analyzed. In general, the results point ones more to the existence of a strong relationship between geomagnetic storms and substroms, and the knowledge of the form and weights of the transfer functions contributes to the best understanding of the physics of the substrom-storm relationship.

Real Time Prediction of Extreme Events 2005 by Singular Spectrum Analysis and Neurofuzzy Modeling

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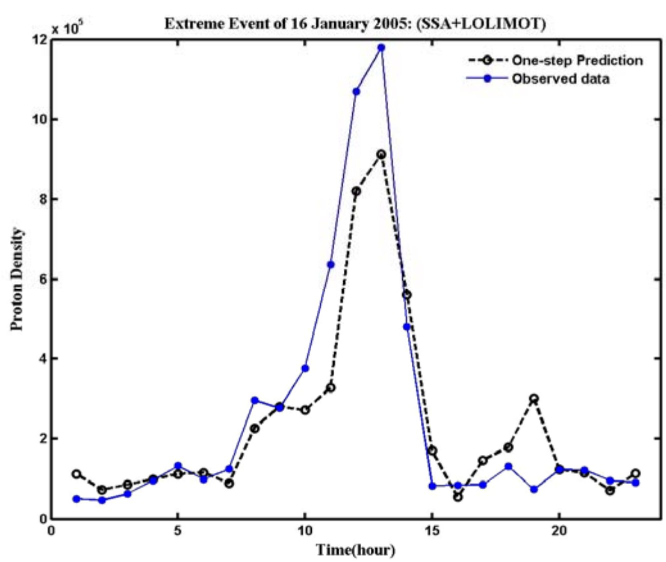
Proton density prediction of events 2005 is used as a case for studying space weather and predictability of its events. A combination of singular spectrum analysis and local linear neurofuzzy modeling with model tree learning algorithm is used for modeling and prediction of proton density data. The main time series are extracted from several time series with singular spectrum analysis and then for each newly produced time series is utilizes a locally linear neurofuzzy model for prediction of this time series. Finally after prediction of each principle component with neurofuzzy model, we recombine each of predicted principle components to obtain the predicted main series (proton density). Hourly data of October, November, September 2004 and first 15 day of January 2005 is used for modeling and 16 January 2005 for prediction. Also the data sets in 2005 prior to the events for training the model for prediction of events in this year. The prediction is without delay for prediction of maximum value of extreme event. Also the event of 7 and 15 May 2005 is predicted with our method with correlation coefficient 0.91, 0.8. In figure1, one-step prediction of proton density in 16 January 2005 with our method is depicted.



Chaotic Time Series Prediction with a Psychological Motivation

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Chaotic time series prediction has been an important challenge for forecasting techniques in recent years. In this paper, we have presented a novel model of emotional learning in prediction of a chaotic time series. The proposed method simulates the emotional learning process in human brain. The model is divided into two parts, amygdala and the orbitofrontal cortex. The amygdaloid part receives inputs from the thalamus and from cortical areas, while the orbital part receives inputs from the cortical areas and the amygdale only. The system also receives a reinforcing signal. The distinctive feature of the Brain Emotional Learning (BEL) model is that the weights of amygdala cannot decrease. In other words, the emotional learning in amygdala is monotonic (once an emotional reaction is learned, it is permanent and can not be unlearned. When needed, the Orbitofrontal Cortex (OFC) will inhibit the amygdale reaction. It is remarkable that the learning rate in amygdala is proportional to the strength of stimuli signals. Meaning the emotions are more sensitive to strong sensory inputs. This property is useful in some of the practical problems, when the large input signals are more important to be estimated or predicted. The total system works in two levels: amygdala learns to predict and react to a given reinforcement signal. This subsystem can not unlearn a connection. The orbitofrontal cortex learns to inhibit the system output when there are mismatches between predictions and actual reinforcement signals. The system output depends linearly on the action of amygdala and the inhibition by orbitofrontal cortex. The choice of external reinforcement signal provides the degrees of freedom for multi objective learning procedures. BEL has been shown to be an efficient tool of learning. . The Lueven data set is a challenging test-case for advanced forecasting techniques. We have made use of K.U. Leueven time series data to test the model in prediction criteria. The BEL based predictor inherently tends to learn the future values of Leuven data while uses the previous values of it as a time series. The reinforcement signal is defined as a combination of predicted and observed values and careful tuning of weights and learning rates. The algorithm is implemented and compared to the results which have gained by MLP and ANFIS predictors. Our proposed method can improve the prediction quality in more significant regions through trading off accuracies with less important regions.

Solar Extreme Events and Helioseismic Activity

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We study the relation between the number and intensity of earthquakes and solar activity on different time-scales. Data from the Catalogue of ancient earthquakes in the Mediterranean region covering seven centuries demonstrate a correlation between the long-term changes in the number of strong earthquakes and solar activity: there are significantly more earthquakes in the secular solar maxima than at lower solar activity. Two maxima in the number of earthquakes are observed in the 11-year solar cycle – a higher one in sunspot maximum, and a secondary one on the descending phase of the cycle. These two maxima are related to the two maxima in geomagnetic activity which are caused by the two types of drivers of solar extreme events – ones originating from open magnetic field regions (coronal holes), and others originating from closed magnetic field regions (solar flares and coronal mass ejections). The number and intensity of solar flares and coronal mass ejections is maximal in sunspot maximum, while the number of coronal holes is maximal on the declining phase of the sunspot cycle. A day-to-day study of the number and intensity of earthquakes on days of encounter of coronal mass ejections and high speed solar wind streams from coronal holes show that coronal mass ejections lead to numerous weaker earthquakes at sunspot maximum, while high speed solar wind triggers the strongest earthquakes on the descending phase of the sunspot cycle. We studied the hypothesis (Sytinskii, 1997) that the triggering mechanism for earthquake occurrence is solar induced change in atmospheric circulation expressed in large-scale reorganization of baric fields, and found that increased number of earthquakes is indeed associated with strengthening of the zonal atmospheric circulation. We therefore suggest the following possible schematic scenario of solar activity effects on seismic activity:

- Pressure pulses associated with high-speed solar wind streams or CME driven shocks compress the magnetosphere

– Auroral electrojet is strengthened
– Generated atmospheric gravity waves are transmitted downwards
– Westward zonal winds is strengthened
– Surface air pressure changes
– Pressure balance on tectonic plates is disrupted
–The earthquake is triggered when enough tension is accumulated.

Further Evidences of Two Step Acceleration of Solar Energetic Particles

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The prolonged neutral emission registered by different instruments in June 1991, till the solar extreme events (SEE) of October 2003, was a sole direct experimental fact proving that the existence of >100 MeV protons deep in the Sun during hours is possible in principle. This report will summarize further evidences based on observations of the SEE's in October 2003 and January 2005. The count rate of the Anti-Coincidence System (ACS) of SPectrometer on INTEGRAL (SPI), which is sensitive to primary γ-rays above ~100 keV as well as to charged particles and secondary γ-rays from interaction in the telescope and satellite structure, has been well above background during both events for a rather long time, which does not contradict to the possibility of prolonged solar γ-ray emission.

The time profile of Tsumeb NM on 2003 October 28 reminds the famous event of 4 June 1991, when evidence of prolonged two-step injection of solar neutrons has been found based on the Norikura NM, gamma ray and microwave data. Modeling the Tsumeb NM count rate we used the ACS count rate as a time profile of the first neutron production at the Sun and the rising and decaying exponents with characteristic time of 200 seconds starting at 11:12 UT for the second neutron production. The spectrum of solar neutrons at the Sun should been softer during the second episode. The proposed model fits rather well variations observed by the Tsumeb NM.

The first gradual enhancement of ACS counts during the event of 2005 January 20 starts at 06:43.5 UT and corresponds to the soft X-ray maximum (GOES) and the first hump of 7-20 MeV photon count rate registered by RHESSI well before the onset of solar protons. The time delay between the first γ-ray enhancement and the GLE onset suggests that the same population of protons have produced γ-rays in the solar atmosphere and propagated in the interplanetary space. The spectrum of 80-165 MeV solar protons became harder at ~07:29 UT indicating arrival of new population of protons. Assuming the proton delay of ~8 min we have the second acceleration (release) of protons at 07:21 UT. Note the second enhancement of 7-20 MeV photon count rates above the RHESSI background registered from 07:15 to 07:45 UT.

Since in both events the second acceleration of protons had a different relation between the solar γ-ray and proton (neutron) intensities, the physical conditions in the second interaction region also should be different. Temporal variations of the primary γ-ray spectrum should be studied very carefully during that time.

Multiwavelength Study of Solar Extreme Events with the SPIRIT Experiment aboard the CORONAS-F Satellite

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We report new results of investigations of the solar corona by the method of XUV imaging spectroscopy with the SPIRIT complex designed in the P.N. Lebedev Physical Institute. The experiment is carried out aboard the CORONAS-F satellite launched in July, 2001. The main feature of the experiment is a simultaneous registration of solar images in 11 independent channels which allows studying full solar disk and over-limb structures in narrow spectral bands (171, 175, 192, 285 and 304 Å) and 160 monochromatic lines in spectral bands 8.41-8.43 Å, 177-207 Å and 280-335 Å.

The investigations has been done during maximum and decay phases of 23^{rd} cycle of solar activity and allow to study solar extreme events like flares, coronal mass ejections (CME) and associated phenomena such as eruptive filaments, dimmings, coronal waves, posteruptive arcades, etc.

EUV spectra from the spectroheliogramms have been used for the determination of the distributions for the electron density and the differential emission measure (DEM) in the temperature range from 0.05 to 20 MK for various plasma structures: active regions, flares and newly described by SPIRIT “spiders”. During the flares, the flux of X-ray emission and the emission measure with the temperature $\sim 5-15$ MK increase significantly. The results of modeling of physical conditions in the emitting plasma were used for the analysis of the mechanisms of formation and dynamics of plasma structures, discovered in the X-ray full-Sun monochromatic images.

Multiwave analysis has been done with data of MgXII spectroheliometer (8.41-8.43 Å) and narrow spectral band XUV telescopes. It showed that high-temperature plasma lies in the corona above magnetic loops, exists a long time (before several day) and has complex dynamics which are not related directly to the flare activity. Simultaneous SPIRIT observations in 304 A and 175 A bands, due to their complementary temperature sensitivity ranges, are suitable to study plasmas in erupting structures at the different stages of the CME.

SW25

Magnetic Clouds and Major Geomagnetic Storms

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It is known that the most intense geomagnetic storms in both mimimum and maximum sunspot activity periods are caused by coronal mass ejections (CME's); further, from sunspot minimum to sunspot maximum the intensity of storms caused by CME's increases, however the percentage of CME's causing storms decreases. Our previous studies have shown that the most geoeffective solar drivers are not CME's in general but magnetic clouds – a subclass of CME's distinguished by the smooth rotation of the magnetic field inside the structure. We study the major geomagnetic storms (Dst<-100) during the last solar cycle and demonstrate that the solar drivers of almost all of them in both sunspot minimum and sunspot maximum periods are magnetic clouds The geoeffectiveness of CME's is determined by their velocity, magnetic field magnitude, and the presence of a prolonged period of negative Bz. Magnetic clouds, because of the magnetic field rotation, usually do have long enough periods of negative Bz. Apart from this, their average magnetic field magnitude is substantially higher than that of CME's which are not magnetic clouds. It is strongly dependent of sunspot cycle, while in CME's which are not magnetic clouds the magnetic field magnitude practically doesn't change throughout the solar cycle. The same is the dependence of the ring current index Dst of the solar cycle, while Kp geomagnetic index for disturbances caused for both CME's and magnetic clouds follows the sunspot cycle, being substantially higher for magnetic clouds.

The main factor determining whether a CME will be a magnetic cloud is the helicity (magnetic field rotation) in its source region on the Sun. Two factors determine the helicity in the solar corona: the amount of helicity transferred from the solar interior, and the surface differential rotation. The helicity transferred from the interior is proportional to the squared magnetic flux, which in maximum in sunspot minimum and minimum in sunspot maximum; this leads to solar cycle variation of the portion ot CME's which are magnetic clouds, and explains the solar cycle variation of the association of CME's to geomagnetic storms. The sign of the helicity transferred from the solar interion into the corona is independent of the solar magnetic cycle, and is always negative (corresponding to counterclockwise rotation of the magnetic structures) in the north, and positive (clockwise rotation) in the south. Emerging magnetic flux tubes carrying helical magnetic fields, are subjected to the solar differential rotation which can additionally twist or untwist the field lines, depending on the sign of helicity which it creates. This differential rotation (decreasing angular rotation velocity from the equator to the poles) together with the Coriolis force generates negative helicity in the northern solar hemisphere, and positive helisity in the southern hemisphere. Magnetic clouds carry the helicity of their source region, and have negative rotation if they originate from the northern hemisphere and positive helisity if they originate from the southern hemisphere. This hemispheric helicity rule, however, is found to hold in 70-80% of the cases. We check the helicity in the magnetic clouds – drivers of major geomagnetic storms whose source regions have been identified, and find that the hemispheric helicity rule holds in 73%. Out of the 12 cases when the hemispheric helicity rule is violated, in 10 cases the differential rotation in the source region is reversed (higher angular velocity at higher latitudes). We study the causes for this reversed rotation by comparison with other stars with known "anti-solar" rotation.

SW26

Alma-Ata High-altitude Neutron Monitor and Space Weather Tasks

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For prediction of space weather it is very important to know the level and variations of galactic cosmic rays (GCR) and possible additional flux of solar cosmic rays observed at the Earth by means of neutron monitors. The Alma-Ata high altitude neutron monitor (3340 m) has a favourable location and very good statistics (~1200 counts per second) to detect different cosmic ray effects conditioned by the space weather. This work is directed toward the experimental and theoretical investigation of the ground level solar enhancements (GLE) of cosmic rays by neutron monitors. Relativistic protons (>1 GeV) are generated in powerful flares more often than they are observed at the Earth. Especially it concerns to observation at average latitudes. Although recorded magnitudes of ground level enhancements are usually very small at these geomagnetic latitudes the high statistical accuracy of the 18-tube NM-64 Alma-Ata neutron monitor, located at 3340 m altitude, make possible detection of these events at this point. In addition, the possible solar particles contribution into general flux of galactic cosmic rays registered by means of Alma-Ata high altitude neutron monitor has been investigated in those events, when it is difficult to notice visually GLE events. In that work we used the information criterion to find out it. The information criterion was the measure of the deviation of entropy from its maximum value.

Solar and Heliospheric Disturbances Resulted in Magnetic Storm of November, 2004

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The main data on observations of the Sun, interplanetary medium, and magnetosphere, obtained before and during the strongest magnetic storm of November 08, 2004 (*Dst*= –373 nT), are presented in the work. These events were observed in year after the series of the strongest solar flares (including flares of class > X17) and the magnetic storm with *Dst* = –401 and – 472 nT during October - November 2003 (see Veselovsky et al., Cosmic Research, N5, 2004 http://www.iki.rssi.ru/people/vcr2004.pdf, and Yermolaev et al., Geomagnetism and Aeronomy, N1, 2005, http://solarwind.cosmos.ru/pdf/gma.zip, 10.6 MB). Although the number and power of the flares were much smaller during the period under study, the magnetic storm was one of the strongest for the entire period of observation of the *Dst* index and was apparently caused by the interaction of frequently occurred coronal mass ejections in the interplanetary space, as a result of which the region of interaction is compressed and the southern IMF component increased to less than –45 nT. Preliminary version of discussed data and our analysis are accepted for publication in Russian journal "Geomagnetism and Aeronomy" N6, 2005 (see http://solarwind.cosmos.ru/txt/nov04_text3.doc, 10,5 MB, in Russian).

Geoeffectiveness of Solar and Interplanetary Events

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In the literature of the solar-terrestrial relations there are different estimations of storm effectiveness of solar and interplanetary events - from 30 up to 100%. Different results arise due to differences in the methods used to analyze the data: (1) the direction in which the events are compared, (2) the pair of compared events and (3) the methods of the event classifications. We selected papers using (1) the analysis on direct and back tracing of events, and (2) solar (coronal flares and CMEs), interplanetary (magnetic clouds and ejecta) and geomagnetic disturbances (storms on Dst and Kp indices). The classifications of magnetic storms by the Kp and Dst indices, the solar flare classifications by optical and X-ray observations, and the classifications of different geoeffective interplanetary events are compared and discussed. Taking into account this selection, all published results on the geoeffectiveness agree to each other in each subset: "CME to Storms" - 40-50%, "CME to MC, Ejecta" - 60-80%, "MC, Ejecta to Storm" - 50-80%, "Storm to MC, Ejecta" – 30-70%, "MC, Ejecta to CME" – 50-80%, "Storm to CME" - 80-100%, "Flare to Storms" - 30-40% and "Storms to Flare" – 50-80%. Higher values of correlations were obtained by back tracing, that is, by method, in which they were defined as the probability of finding candidates for a source of geomagnetic storms among CMEs and flares, and, strictly speaking, these values are not true estimates of the geoeffectiveness. The latter results are also in contrast with the results of the two-stage tracing of the events: first a storm — an interplanetary disturbance, and then an interplanetary disturbance — a CME/flare.

International Science & Technology Center – Support of High Energy Astrophysics in Armenia: 1996-2007

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High Energy Astrophysics research in Armenia started in 1942 by first expedition on Aragats mountain leading by Artem Alikhanyan and Abram Alikhanov. In1943 Yerevan Physics Institute (YerPhI) was founded, now named after Artem Alikhanyan. The Cosmic Ray Division (CRD) of YerPhI till now continues active research in high energy astrophysics at 2 high altitude stations Nor Amberd and Aragats.

The ultimate goal of CRD activity is to continue experiments on high energy astrophysics in Armenia, to start new scientific topics where CRD have world priority, to provide our research with most advanced technologies in electronics and informatics and to educate students from Armenian Universities.

This ambitious program needs funds not fully available from the Republic of Armenia sources. Since 1997 International Science & Technology Center (ISTC) allocates 1,230 M USD for CRD, funding 4 projects:

- **ISTC A116, "The Development and Implementation of Applied Neural Information Technologies". Project manager A. Chilingarian, period 1997-2000, status – accomplished, funding party – European Union, total funds received – $250,000.**
- **ISTC A216, "Detection of the Neutron Flux from the Solar Flares at the Aragats Cosmic Ray Observatory". Project manager A.Chilingarian, period 2001-2004, status – accomplished, funding parties – Japan, USA, total funds – $280,000.**
- **ISTC A-757, "Nonparametric methods of data analysis in Cosmic Ray Astrophysics. An applied theory of Monte Carlo statistical inference. Monograph". Project manager A. Chilingarian, period 2002-2003, status – accomplished, funding parties USA, and total funds - $30,000.**
- **ISTC A1058 Development of a Prototype Detector System for Space Weather Monitoring and Forecasting World-Wide Network. ". Project manager A. Chilingarian, period 2003-2006, status – implementing, funding parties Europe, USA, total funds - $670,000.**

New scientific directions for the CRD – Solar Physics and Space Weather started in 1996 and were continuously supported by the ISTC grants. During last years CRD organized the Aragats Space Environmental Center ASEC, now the world's largest facility for detecting Cosmic Ray secondary fluxes. ISTC grants help to equip ASEC facilities with modern electronics, computers and networking equipment. ISTC support participation of ASEC experts in numerous International Conferences and specially organized ISTC workshops in USA, Japan and Armenia.

Along with tens of scientific papers and reports, CRD Internet information product – **"Data Visualisation Interactive Network for the Aragats Space-environmental Center"** – *DVIN for ASEC*, was officially announced as the world's best project in the category of e-science at the World Summit on the Information Society (WSIS) 2003 in Geneva, December 9-13. In 2005 the modernized DVIN2 product gets another prise in all-Armenian competition "Mashtoc-1600".

All this successes was achieved only because of the continuity of ISTC support during 10 years.

Correlation Analysis of Transient Solar Events by the Facilities of Aragats Space Environmental Center

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Starting from autumn 2002 Aragats Space Environmental Center (ASEC) detectors perform monitoring of different species of secondary cosmic rays at two altitudes and with different energy thresholds. The ASEC monitors located on the slope of mountain Aragats in Armenia at 40°30'N, 44°10'E, altitude 2000 and 3200 meters, provides on-line data in 15 asymptotic directions, significantly improving the directional coverage of the pre-existing network and the capability of advance warning on the onset of space weather effects at Earth. Detector is equipped with a modern electronics, allowing various software triggers, microcontroller based electronic units (HV power supply and counting modules) together with optional environmental sensors. The wireless Internet and satellite modems ensure the real-time data transmission rates sufficient for the forecasting within several minutes after signal detection.

We present results on sensitivity of secondary cosmic ray flux to geophysical conditions, taking as examples the solar extreme events 2003-2005. We introduce multivariate correlation analysis of the different components of registered time-series as a tool for the classification of the geoeffective events, i.e. Ground Level Enhancements, Forbush decreases and effective reductions of the geomagnetic cutoff rigidity. The rigidity cutoff of ASEC monitors is 7.6 Gv, so the variations of the terrestrial magnetic field are pronounced much stronger compared with high-latitude monitors. Applying correlation analysis to the monitors with high energy threshold as well as to detectors with lower threshold it is possible to estimate the energy range of variation of primary cosmic rays.

SW31

Nor-Amberd Multidirectional Muon Monitor: New Detector for the World-Wide Network

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For early forecasting of possible dangerous impacts of the interplanetary shocks headed toward Earth, the network of the surface cosmic ray detectors, measuring the modulation effects of the approaching solar plasma cloud, are used. To measure precisely the directional anisotropy of the cosmic ray intensity enhanced by the modulation effects, the muon detector network should have a wide directional coverage. Nor Amberd multidirectional muon monitor (NAMMM), located on the slope of mountain Aragats in Armenia at 40°30'N, 44°10'E, altitude 2000 m, provides on-line data in 15 asymptotic directions, significantly improving the directional coverage of the pre-existing network and the capability of advance warning on the onset of space weather effects at Earth. Detector is equipped with a modern electronics, allowing various software triggers; microcontroller based electronic units (HV power supply and counting modules) together with optional environmental sensors. The wireless Internet and satellite modems ensure the real-time data transmission rates sufficient for the forecasting within 3 minutes after signal detection.

SW32

Aragats Multidirectional Muon Monitor

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Aragats Multidirectional Muon Monitor (AMMM) has been used to measure the flux of cosmic-ray muons with threshold energy 5 GeV, arriving from different directions. The detector setup allows registration of the muon flux in zenith angels $\vartheta = 5^o \div 60^o$ and azimuth angels $\varphi = 45^o \div 360^o$. The angular accuracy depends on the direction and changed from 3^o to 5^o for ϑ and from 10^o to 15^o for φ. In this work we present detailed calculation of the expected muon flux from the different directions taking into account the detector response and make comparisons with the measured muon flux.

SW33

The Response of Aragats Space Environmental Center Detectors to Ground Level Enhancement of 20 January 2005

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At January 20, 2005 all detectors of Aragats Space Environmental Center (ASEC, cutoff rigidity ~7.6GeV) registered ground level enhancement. Aragats Neutron Monitor (ANM) and Nor-Amberd Neutron Monitor (NANM) registered the enhancements of 5.2σ at 7:12 and 2.9σ at 7:00 correspondingly, Solar Neutron Telescope (5cm scintillator) – 2.2σ at 7:01, and Aragats Multidirectional Muon Monitor (AMMM, registering muons with energy >5GeV) – 2σ at 7:03. According to our calculations the median of energy distribution of primary protons giving rise to 5 GeV muons is about 50 GeV. Convincing measurements, proving that in solar flares the particles can be accelerated up to ~50GeV energies is still missing. Detailed statistical analysis of all ASEC monitor's measuring channels in the same time interval validates possible detection of 5 GeV muons by AMMM at 7:03. We discuss the significance of obtained enhancement and possible maximal energy of solar protons.

Channel-to-channel Analysis of Aragats Muon Monitor's Data Improves the Reliability of detecting 5GeV Muons in Solar Flare of 20 January 2005

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Output data of Aragats Multidirectional Muon Monitor (AMMM) is composed by the summing the counts of its all 42 channels, each comprising from 1 m^2 scintillator. During solar flare of 20 January 2005 this output data got the maximal excess of ~ 2σ at 7:03. The probability that the value >=2σ is caused by random fluctuation (false alarm) is ~ 0.023. We apply more detailed statistical analysis of the detector channel's data trying to reduce the probability of false alarm and to increase detection reliability. Using 1min data, we find the number of channels in excess of 1σ or greater, and calculate the chance probability of appearing of such event by using binomial distribution. In time interval 6:45 – 7:15 20 January 2005, this probability gets values fluctuated near 0.5, except of time 7:03, when the excess >=1σ was observed in 15 channels from 42. The probability of the false alarm for such combination of channel counts is ~ 10^{-3}. Thus applied approach, exploiting all measuring channels of detector, allows significantly decrease the probability of false alarm, making detection of >5GeV muons more reliable.
We apply new methodology also to other extreme events.

Multidetector Correlation Study of Solar Transient Events

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Aragats Space Environmental Center (ASEC) has the advantage to monitor cosmic rays simultaneously by several detectors. To benefit from this possibility, we developed an approach, which combines the data of 3 monitors to reveal solar transient events more reliably. As it was demonstrated earlier, the correlation coefficients (CC) between different monitor's time series are good indicators of the space storms strength and other solar induced events. For the magnifying of this effect we consider not one CC, but product of 3 CCs between Aragats Neutron Monitor, Nor-Amberd Neutron Monitor and Solar Neutron Telescope. CCs are calculated by 120 points in 120 min interval, which moves gradually with the step 1min. The product usually fluctuates randomly around zero with the dispersion ~ 0.001. However, sometimes it gets large values with amplitude > 0.015 during solar events such as ground level enhancement (GLE), Forbush decrease (Fd) or geomagnetic storm. We performed Monte-Carlo simulation for the 120 min averaged product (which was defined as the A-value), to derive the probability of appearance of large random fluctuations. This random event is defined as "false alarm". In the result we obtained the probability distribution of false alarm versus the A-value. Using this distribution we estimated the probability of appearance of fluctuations with different A-values. It is obtained that the probability of false alarm during the GLE, Fd and geomagnetic storms are extremely small (< E-8), i.e. large A-values reliably indicates on the solar event. We established the level 0.015 for A-value, for estimating the efficiency of the approach. If A-value of observed fluctuation is greater than 0.015 then such fluctuation is defined as an event and this event is revealed. The efficiency of the approach was studied by analyzing 2 GLEs, 3 Fds and several geomagnetic storms during 2003, 2005. In all cases the A-value considerably surpassed the level 0.015, so the events were revealed.

SW36

Correlations of the Estimated Arrival Times of the Relativistic Solar Ions at 1 AU and Starts of Ground Level Enhancements (GLEs).

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We investigated possible correlations between the calculated arrival times of the first relativistic ions at Earth and GLE start times registered by surface monitors. The analysis is based on the arrival times and energies of the first solar ions, registered by the Solar Isotope Spectrometer (SIS) on board of the ACE satellite, and protons, registered by GOES satellites. We consider two cases: when the interplanetary propagation of the first high energy ions is essentially scatter-free and the diffusive propagation of high energy ions in the interplanetary magnetic field.
We extrapolate the time-velocity and time-rigidity relationships to calculate the expected arrival times of the relativistic ions that are energetic enough to enter the atmosphere at the Aragats geographical location and produce secondary fluxes that reach the monitors.

SW37

Temporary Change of Solar Proton Spectrum Parameters and GLE model for the January 20, 2005 event

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The temporary behavior of proton energetic spectrum at January 20, 2005 in the near-earth space environment measured by GOES satellites was investigated. During the first hour the spectrum parameters (power spectral index and spectral “knee” energy) changed with definite regularity. In 6:50UT the spectral index and knee energy have the values ~5 and 390MeV respectively. These values are preserved until 8:00UT. Approximately at 8:00UT these parameters acquire the values of ~3,7 and ~170MeV which are preserved until 18:00UT. After 18:00UT their values are 2,9 and 50MeV which are preserved almost until the arrival of shock wave unleashed by the flare. We assume, that these changes are not caused by passing of the particles through the interplanetary space; they are connected with acceleration processes. The comparative analysis of these results and the 20 January GLE data obtained with the help of neutron monitors demonstrates that the acceleration of the main part of relativistic protons happened during the flare itself. Obtained results can serve as a basis for the construction of the GLE model for the January 20, 2005 event.

A new type of solar neutron telescope

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We discuss the problem of solar neutrons energy measurement by existing neutron telescopes and their sensitivity. In order to increase the sensitivity and to reduce existing uncertainty in energy measurement of solar neutrons, a new type of solar neutron telescope installed deep underwater is proposed for the next solar cycle 24^{th}. It is shown that due to installation of the telescope under thick absorber, the sensitivity can be increased up to 10 times by decreasing background rate – from mainly neutral particles. The concept and construction of new telescope and estimations of its performances are presented. We propose to install such telescopes in some high altitude lakes such as Titicaca (Bolivia), Cucunor (China). The testing measurements of prototype telescope at Kar-Lich and Sevan (Armenia) lakes are supposed. Finally some considerations of technical design of proposed telescope are discussed.

SW39

On the possibility to deduce the solar proton energy spectrum of the 20 January 2005 GLE using Aragats and Nor-Amberd neutron monitors data.

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30-year largest solar particle event that occurred on 20 January 2005 was unusual from many points of view. The analysis of the event is already started and will be continued with involving data from neutron monitors and muon detectors, as well as by using the new statistical analysis methods. The analysis presented in this report is based on the low energy proton fluence spectrum obtained from instruments on ACE and SAMPEX spacecraft, the intensity of >100 MeV protons measured by GOES11 spacecraft and Aragats and Nor-Amberd neutron monitors count rates increases during the solar flare event. These two neutron monitors are located at different altitudes (3200m and 2000m above sea level), but at the same geographical coordinates. The effective cutoff rigidity of the location is 7.56GV.

The idea to deduce the spectra of solar flare protons using two neutron monitors located close by at the same vertical cutoff rigidity but at different altitudes above sea level was proposed by J.A.Lockwood et all. Using Mt. Washington and Durham neutron monitors count rates, coupled with the knowledge of the proton specific yield functions, they have derived the rigidity spectra, $AP^{-\gamma}$, for selected solar flare events since 1960.

Our method is based on the modelling of the response of Aragats and Nor-Amberd neutrons monitors. Assuming that there is a knee at proton energy spectrum around E_{kin}~1GeV we have estimated Aragats and Nor-Amberd count rates increases for the different possible spectral indexes. The simulation of the primary protons transport through the Earth atmosphere was performed using CORSIKA package with FLUKA code. Comparing the measured count rate increases, as well as their ratio, to ones calculated for different γ, the spectral index of the power-law proton energy spectrum is found to be ~6.

Calculation of the Aragats Space Environmental Center Monitors Response to Galactic and Solar Cosmic Rays

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Monitors of Aragats Space Environmental Center (ASEC) register secondary fluxes of different energy thresholds generated by high energy particles as they enter the Earth's atmosphere. Using CORSIKA code we have simulated the propagation of primary particles through the Earth's atmosphere. Simulated ground level particle intensities were used to calculate ASEC monitors count rates. The calculated response of ASEC monitors to galactic cosmic rays and to different transient events, such as Ground Level Enhancement (GLEs) and geomagnetic storms, influencing cutoff rigidity threshold values, is compared with corresponding measurements. It is shown that the November 20, 2003 event could be associated with the cutoff rigidity decrease of ~1GV. Transforming Dst variation into R_c variation the intensity-time profile of the event is simulated. The obtained time-profile can be used to correct the rigidity cutoff at each moment of time during November 20, 2003 event.

Calculation of the threshold energies of the Aragats Solar Neutron Telescope

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The Solar Neutron Telescope (SNT) is in operation at the Aragats research station (3200 m. above sea level) and constitutes the part of world-wide network, coordinated by Nagoya University group. In order to realize continuous observation of solar flares and the production of the neutrons, it is necessary to install neutron detectors at every 90 degrees of longitude surrounding the globe. Armenia, located in the mid-longitude between the Swiss Alps and the Tibet highlands, is a suitable place for such neutron detector. The first solar neutron detector has a detection area of $4m^2$ and began its observations in the autumn of 1997. The anticoincidence shielding for this telescope was constructed in 2001.
Detecting volume is formed from standard slabs of size 50x50x5 cm, stacked vertically on the horizontal slab of 100x100x5 cm. (total 164 slabs). Four, the same type scintillator slabs of 5 cm. thickness and 1 m^2 surface, are located 1 m. above the detecting volume, with the goal to veto the near vertical charged flux. Incoming neutrons in nuclear reactions produce protons inside the thick scintillator target. The probability to produce protons in 5 cm. of scintillator is vanishingly small. The energy, have been deposited due to ionization by protons, is measured by the photomultiplier over the scintillators. The output signal's amplitudes of the photomultipliers are discriminated according to 4 threshold values of 50, 100, 150, 200 mV. The dependences of the efficiencies of the particles (the muon and the neutron) registration in 60 centimeter scintillator on initial energy for different energy releases were investigated. The energy thresholds corresponding to four level of the amplitude discrimination were determined by the Monte Carlo simulation. Also, the same energy thresholds were obtained by the calibration experiment with the thick (60 cm) and thin (5cm.) scintillators and the results are compared with the simulation.

Analysis and identification of events caused by rigidity cutoff variations

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The geomagnetic storms are driven by the shocks followed by magnetized plasma clouds, reaching the Earth from 15 hours till several days. The strength of the geomagnetic storms depends on the magnitude and space distribution of the cloud's "frozen" magnetic fields. The changing intensity of the Galactic Cosmic Rays (GCR), detected by surface monitors, also reflects the large scale structure of the IMF and the diurnal variability of cosmic rays and has a rather complicated shape. That is the reason why we need multivariate, multidetector measurements of as many components of the changing secondary cosmic rays as possible. A sudden correlated variation in the flux of neutrons, muons, and electrons, detected by the surface monitors could be an indication of an upcoming severe radiation or geomagnetic storms. Changes in the geomagnetic cutoff rigidities (Rc), usually occurring during the recovery phase of the Forbush decreases, are well pronounced at low latitudes. Other transient events caused by the modulation of the GCR by solar transient events, as Forbush decreases (Fd) and Ground Level Enhabcements (GLE) in contrast are much better pronounced at high latitudes. Therefore, monitors of the Aragats Space-Environmental Center (ASEC), located at 40°30'N, 44°10'E, are very well suited for the detection and investigation of the geomagnetic storms causing strong variability of Rc.

In the report an attempt is made to utilize information on changing fluxes of secondary cosmic rays during strong geomagnetic storms, and explore new possibilities opening by ASEC detection of recent extreme events.

Data Visualization Interactive Network

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DVIN2 for ASEC (Data Visualization Interactive Network for Aragats Space Environmental Center) is product for accessing and analyzing Space Weather conditions. The on-line data from Solar Monitors located at high altitude research station on Mt. Aragats in Armenia is used for displaying and warning on severe conditions of the Space Weather. The first version of DVIN was officially announced as the world's best project in the category of e-science at the first World Summit on Information Society (WSIS) 2003 in Geneva, December 9-13.
Second version has several important advantages and provides more services to users:

- DVIN2 is based on MySQL database.
- The speed of simple data analyzing has been increased.
- Such a new features as correlation analyses of time series and other statistical parameters like standard deviation, average etc. have been added.
- The new interface is more user-friendly.

ASEC monitors measure many species of cosmic rays at two high altitude stations. As a result, the ability to analyze many time series simultaneously becomes a powerful tool for processing. Being an online processing tool, DVIN2 can work at any platform.
The DVIN2 modules provide successive steps of data processing: keeping up-to-date the files, preliminary data processing, off-line analysis, web interface to access data and off-line analysis program.

SW44

The Diurnal Variations of EAS Intensity according to MAKET-ANI Array Data

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The reference data on diurnal variations were obtained mainly in the energy region 1 – 100 TeV. We have analyzed the count rate of MAKET-ANI array during the period 1998 – 2004 for significantly larger energies $E_o > 5\cdot10^{14}$ eV.

The barometric and temperature coefficients are determined and the amplitudes and phases of daily waves of intensity in solar and sidereal times were obtained after corrections for pressure and temperature.

The effective declination of MAKET-ANI array is determined. Reducing the measured amplitude of the first harmonic in solar time to zero declination, the daily wave amplitude and phase were determined. We present and discuss the energy dependences of the amplitude and phase of first harmonic of mean diurnal variations of cosmic ray intensity.

SW45

The Study of Geomagnetic Storms with the Use of MAKET-ANI Surface Detector

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The analysis of geomagnetic storms, occurred in the current 23-rd cycle of solar activity was performed by using the data of MAKET-ANI detector. The installation MAKET-ANI is located on the southern slope of Mt. Aragats (N40º30', E44º 10') on the altitude 3200 m above see level and is composed of 92 scintillation detectors with total surface of 75m^2. Along with the maim data acquisition system, the sampling of low energy charged secondary fluxes is carried out for all array detectors with the sampling time 80sec for each of 6 detectors.
The measured fluxes of charged secondary cosmic rays (mainly muons and electrons, with the threshold energies ~ 6 -7 MeV) are monitored every 21 min for all detectors. Obtained data base was used for the study of geomagnetic storms.