Monitoring of Asymptotic Distribution of the CR variations

This part is very important for searching for the precursors of Forbush effects (and geomagnetic storms) by the data of world wide NM network (NMN), using the method of "station ring".

***Input data*:** hourly counting rates from the neutron monitors of world wide network – 30-40 stations homogeneously distributed by longitude. For pitch-angle distribution hourly data of IMF vector are also needed.
***Output data*:** graphic presentation of longitudinal distribution of CR variations for one hour (or, pitch-angle distribution), with hourly updating. There is no digital data output.

Neutron monitors record secondary cosmic rays which associated with primaries in the energy range from hundreds MeV (depending on geomagnetic cut-off rigidity at the point of observation) to hundreds GeV. The variation in the intensity provides valuable information on the heliospheric disturbances with characteristic scales of 10^{11} - 10^{15} cm, (0.01 to 100 AU), and reflects processes in the heliosphere with characteristic time scales of 10^{2}-10^{8} s.

The galactic cosmic rays (GCR) interact with transients moving in the space toward the Earth. Due to their high speed they might provide the information about coming disturbed region well in advance it arrives to Earth, creating so-called 'precursor' effect. Precursor effect consists of combination of two kinds of galactic CR variations: pre-decrease and pre-increase before the shock arrival. Precursory decreases apparently result from a "loss-cone" effect, in which a neutron monitor station is magnetically connected to the cosmic ray-depleted region downstream the shock (Fig.1).

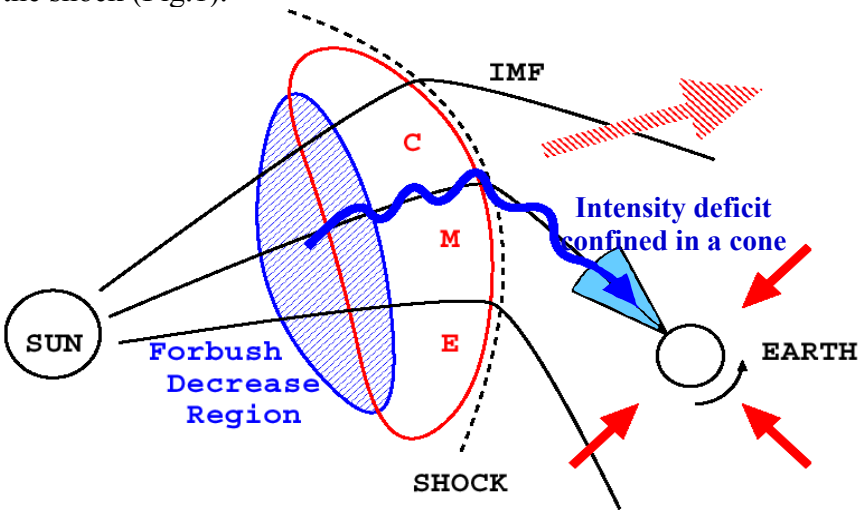

Figure 1. Illustration of a "loss cone" effect in cosmic ray variations observable at Earth.

Pre-increase is usually caused by particles reflecting from the approaching shock. The many of predictors have a peculiar longitude (or, pitch-angle) dependence of CR intensity with the abrupt transfer from minimum to maximum of CR variations which cannot be fitted by the sum of only the first two harmonics. These sharp transfers occur most probably within the 140-180° and 270-310° longitude regions, near usual direction of the intertplanetary magnetic field line (sunwards and anti-sunward). The shock effect is most prominent over the distance corresponding to one circular orbit of the cosmic ray particle in the magnetic field (the Larmor radius) in front of the shock. For protons of 10 GV rigidity on the quiet background of the mean interplanetary magnetic field intensity before the shock arrival (about 5 nT) the Larmor radius is bout 0.04 AU (1 astronomical unit = average Sun-Earth distance). A shock at 500 km/s needs

about 4 hours to travel this distance before arriving at Earth. So, these anomalies are most often observed in the last hours before shock arrival. However, they sometimes span a longer period, and persist downstream of the shock. The neutron monitor network can identify these signatures and therefore emit a warning of the imminent onset of a geomagnetic storm.

The NMN is a good tool for detecting such anomalies in the pitch-angle or longitudinal distribution. At present, when data of many stations are accessible in real time, it would be desirable to search such anomalies in real time mode and use this information in the short time forecasting of geomagnetic activity. Precursory effect is very anisotropic, thus the sky coverage in the asymptotic directions of the stations used, should be as full as possible, otherwise we can miss any precursor.

In the Bartol Research Institute the system of real time monitoring of the precursors is created on the base of pitch angle distribution http://neutronm.bartol.udel.edu//spaceweather/. They use a limited number of stations (only 9) but distributed homogeneously by longitudes (Spaceship Earth). The system is working well but it depends on the reliability of all station operating (break at one station create a gap in the scanning of ~50^0 of celestial sphere) and on a persistence of interplanetary magnetic field (IMF) data which are used for pitch angle calculations.

IZMIRAN offers another approach based on the distribution of CR variation by asymptotic longitudes. It is defined from the 'ring station method', and this procedure is more easy and reliable, and not less informative. Creation of NMDB in the frame of EC FP7 project "Real time neutron monitor database with short time resolution" allows the use hourly data from many stations (about 23 at present) for constructing and plotting asymptotic longitudinal distribution of the CR variations at any time. It is preferable to use stations with cutoff rigidity Rc<4 GV and homogeneously distributed by the ring around the globe (Station Ring method), but we elaborated the simplified version specially for real time data allowing the use also of stations with higher rigidities (Rome, Athens, Almaty, Jungfraujoch) from NMDB.

Shift of the effective position of station from its geographic longitude because of the Earth magnetic field was taken into account by using the coupling coefficients for the flat rigidity spectrum of the first harmonic up to 100 GV. Thus, at each hour we can plot a distribution of CR variations by the asymptotic longitudes. This method provides obtaining of different than harmonic longitudinal distribution of CR intensity and it is less depended on an uncertainty of the model of isotropic and anisotropic variations.

This fact makes it incumbent to use data from the stations distributed by the globe with overlapping of the celestial sphere by the asymptotic directions. We included for use hourly data from NMDB for the stations: Almaty, Apatity, Athens, Baksan, NorAmberd, Aragats, ESOI, Irkutsk, Irkutsk2, Jungfraujoch (IGY and 3NM64), Kerguelen, Kiel, Lomnitsky Stit, Magadan, Moscow, Mirny, Novosibirsk, Oulu, Rome, Terre Adelie, Tixie Bay, Yakutsk. Some of them still are not ready for continues quality data presenting (NorAmberd, Aragats, Esoi, Kiel, Novosibirsk), but we hope, this is a question of the nearest future.

Special scripts were elaborated to get real time hourly data from NMDB. The procedure of data downloading from the NMDB is present by the address: http://nest.nmdb.eu. But we should remember that real time data at some stations have not been subjected to rigorous quality control; it may contain "glitches" that produce false alarms or fail to detect true space weather disturbances.

Neutron monitor hourly data from the western stations (Forth Smith, Pewanyuk, Newark, McMurdo, Thule) are also used (from USA, Bartol group: http://neutronm.bartol.udel.edu/) to complete scanning of celestial sphere. All data are retrieved into the local DB (http://cr0.izmiran.rssi.ru/common/All_CR_stations_H.htm) which is implicated in different Applications.

There are also relevant data on the solar wind and geomagnetic activity (http://cr20.izmiran.ru/sw/main.htm) which are necessary for a complex analysis.

Description of the site of internet project

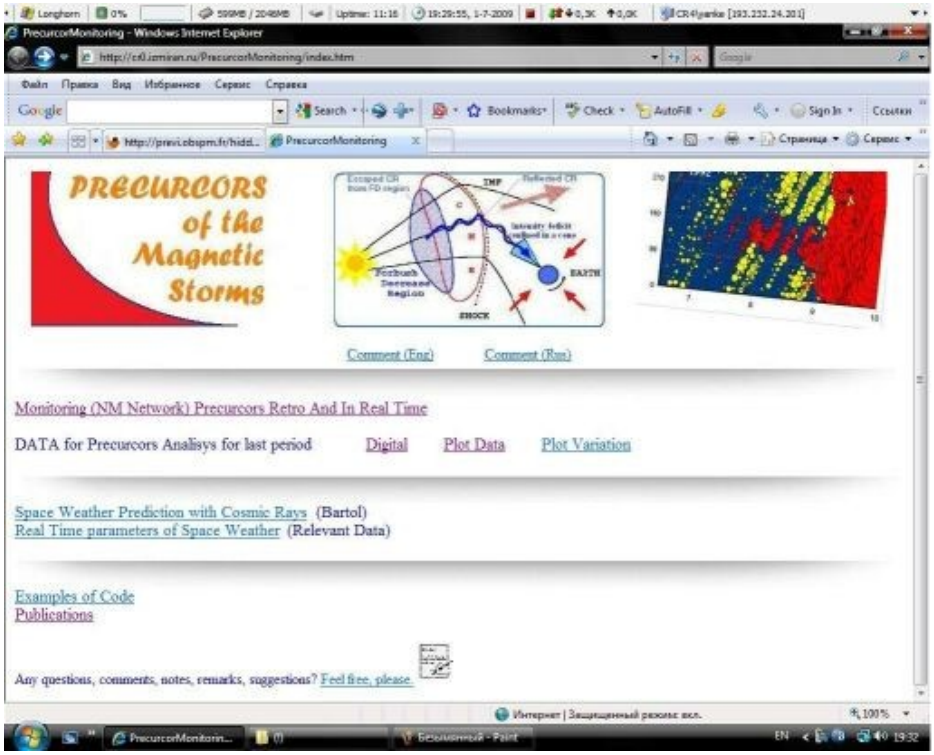

Fig.2. Presentation of the software for plotting hourly CR variations by the asymptotic longitudes and demonstration of the magnetic storm precursors.

Some explanations to this site:
"Monitoring (NM Network) Precursors Retro and Real Time"
This line opens a picture "Monitoring of CR anisotropy", where one can see asymptotic longitudinal distribution of CR variations for the current hour. Elaborated software can provide also graphic presentation of longitudinal distribution of the CR variations as function of time by the retrospective data which also can be taken from NMDB. Yellow circles in the picture mark increase and red circles – decrease in CR variations. Size of circles is proportional to the magnitude of variation.
"Data for precursor analysis for last period" Digital Plot Data Plot Variations
Clicking this line you can look data from all stations (separately and altogether) used at a current moment in digital and graphic forms that gives a chance for brief control of data quality at different stations.
There are also the lines of access to Bartol Space Weather site (for comparing) and to the relevant data on the solar and geomagnetic activity (for analysis in the case).