Investigation of daily variations of cosmic ray fluxes measured by ASEC monitors

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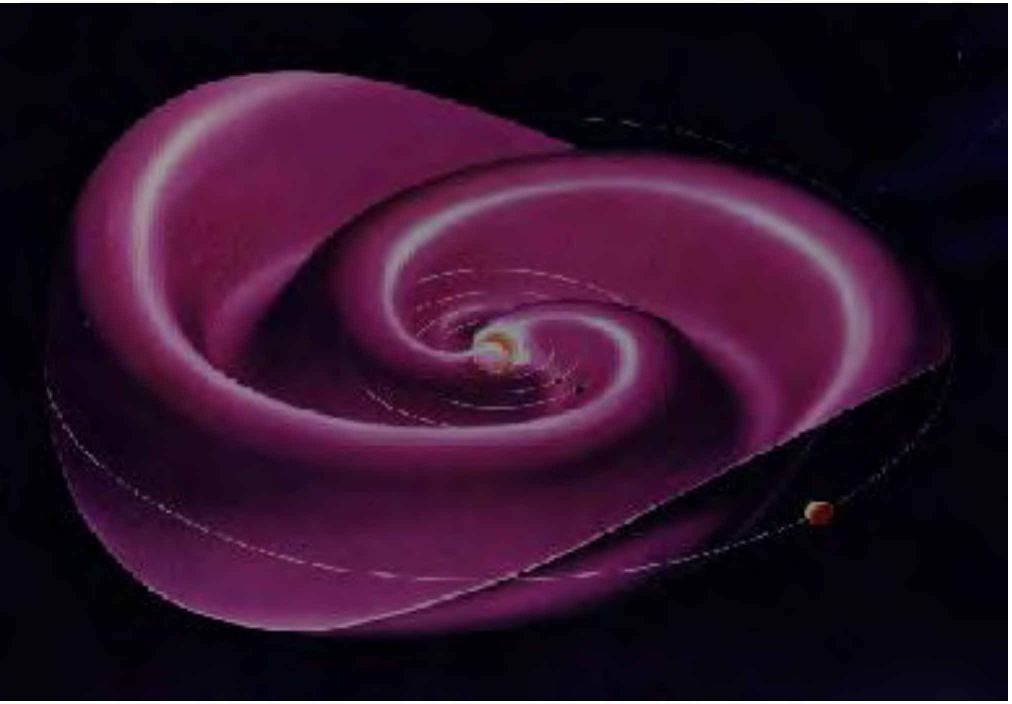
Why does daily variation of cosmic rays exist ?

- Because of rotation of the Sun, Interplanetary Magnetic Field has a form of Parker Spiral.

A three-dimensional form of the Parker spiral that results from the influence of the Sun's rotating magnetic field on the plasma in the interplanetary medium



Intensity of cosmic rays in Solar system results from two processes

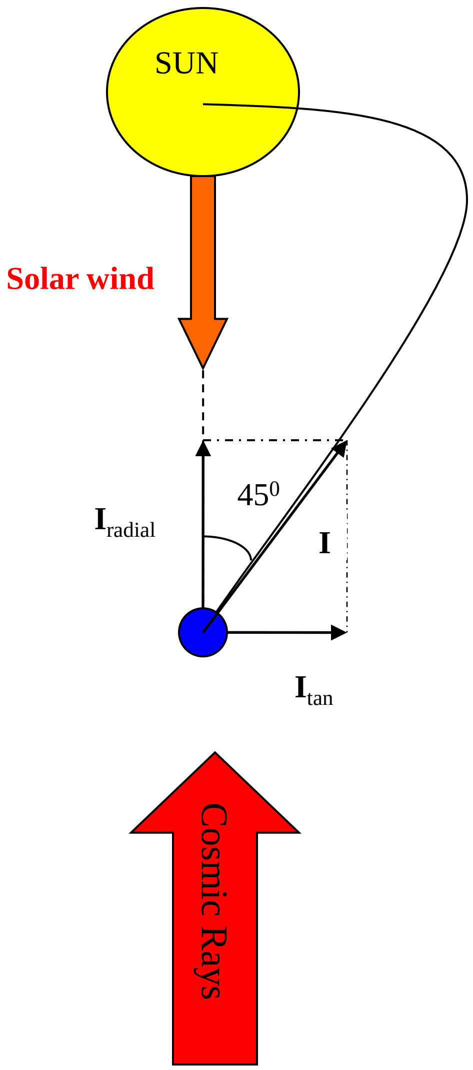
1. Convective outflow of galactic cosmic rays due to scattering on solar wind discontinuities
2. Diffusion of cosmic rays into Solar system

Why does daily variation of cosmic rays exist ?

Daily variations are understood to result from a combination of inward diffusion along the spiral interplanetary magnetic field and outward convection by the solar wind.

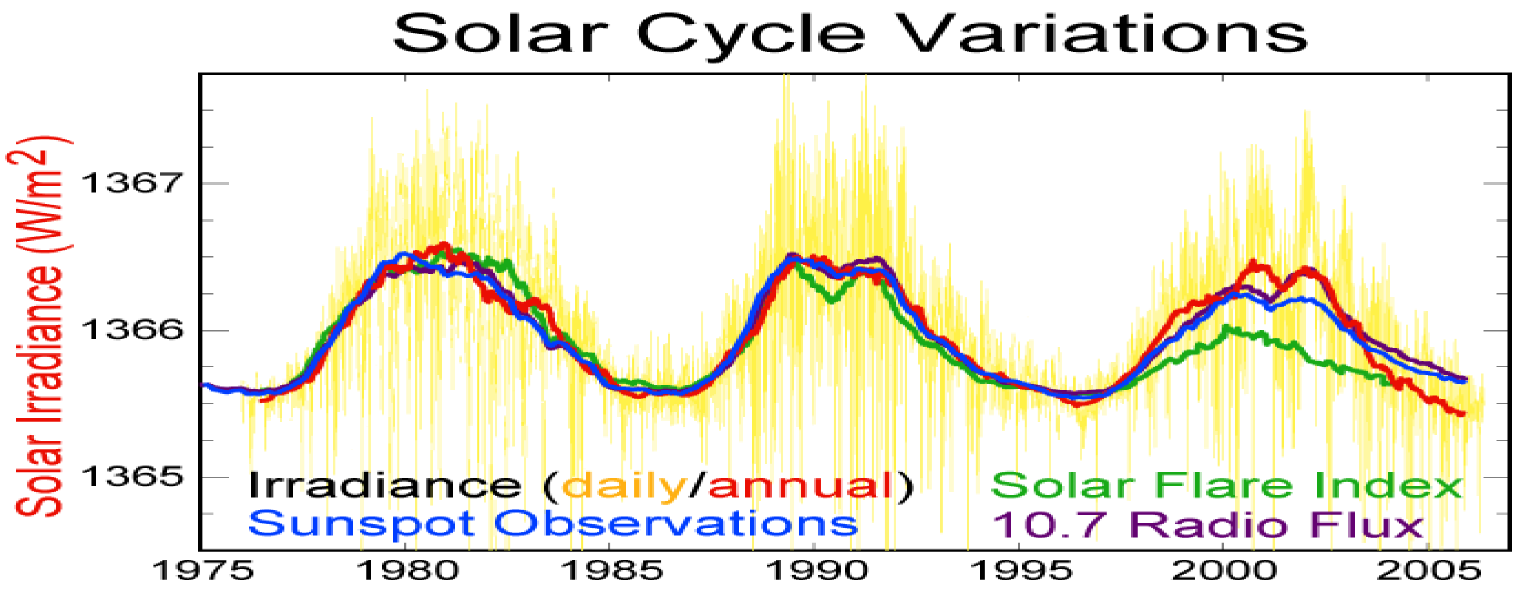
If we decompose cosmic ray flux into radial and tangential components, radial flux of galactic cosmic rays will be compensated by solar wind convective outflow.

Tangential component, due to Earth's rotation, causes variation with maximum at 18:00 local time.

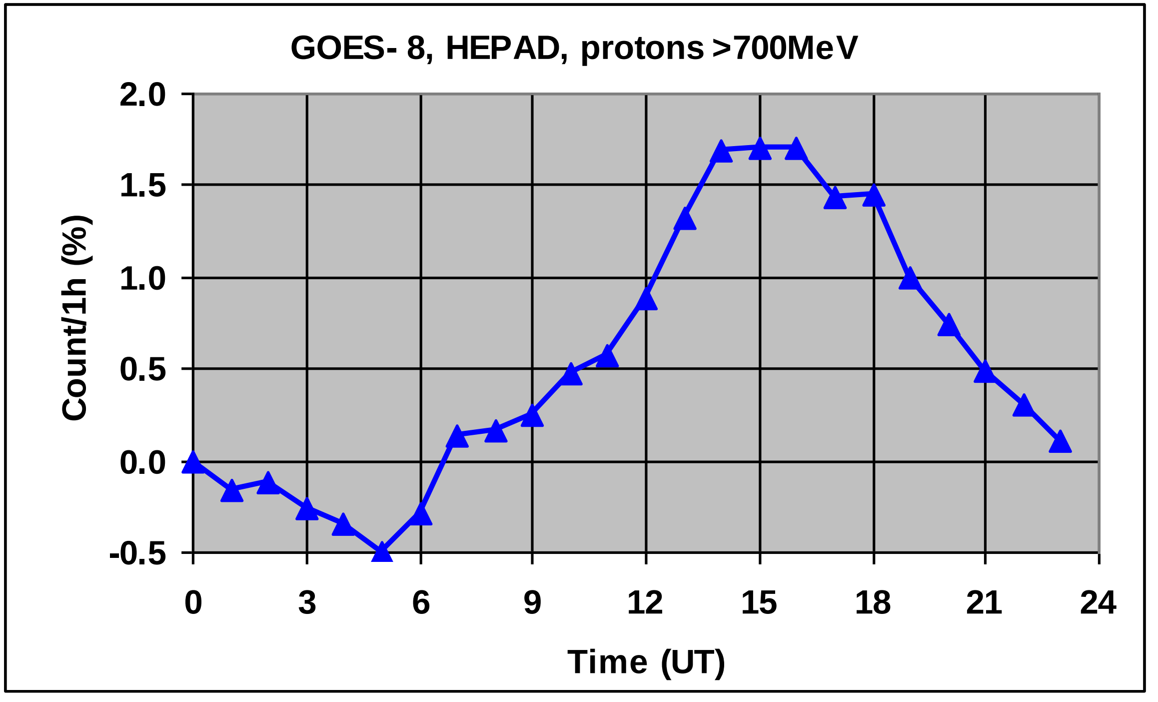


Why it is important to investigate the daily variations in the minimum of solar activity cycle?

- In the minimum of solar activity cycle interplanetary magnetic field is not disturbed and all of variations are caused not by solar activity. Investigation of daily changes during minimum of solar activity will enable us to study their dependence on solar activity.



Daily variation of protons > 700MeV registered by GOES-8



What we expect?

- Earlier studies have found that the maximum of daily changes should be at 18:00 local time, but due to bending from Earth's magnetic field, maximum is 1-4 hours earlier.
- Lower energy particles are more influenced by IMF. So changes will be bigger for lower energy cosmic rays. It's also expected that daily changes of different populations of secondary particles will be different. Besides, changes can depend on the location height of detector.

Data and methodology

For daily variation studies, we use one-month time series taken from May 2008 until January, 2009.
Data from the SEVAN Aragats (located at 3200m)
is available from October 2008.We took data of SEVAN Yerevan from January and February 2009.
Data from SEVAN Bulgaria and SEVAN Croatia - from December 2008.

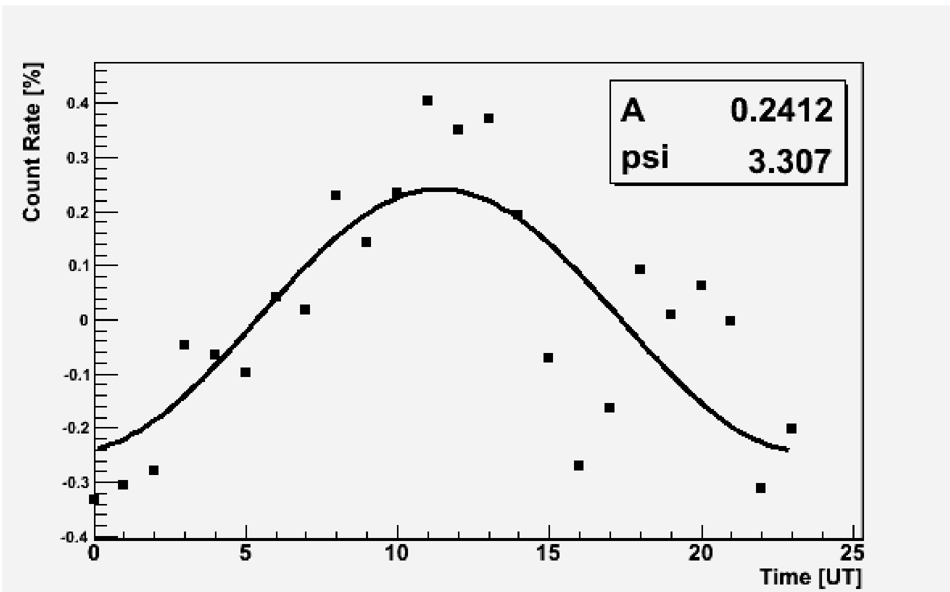
Daily data were fitted by the harmonic approximation function for each day of selected period and then obtained amplitudes and phases were averaged

$$f(t_i) = A + B.\cos(\omega t_i + \psi)$$

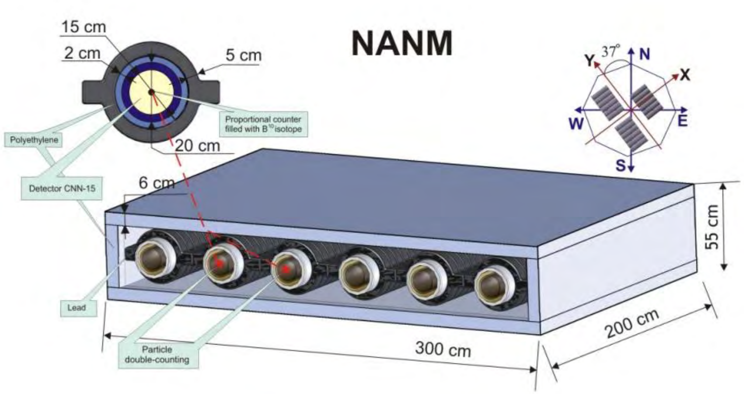
The accuracy of the fit, the difference between experimental data and the fit is calculated

$$d^2 = \sum_{i=1}^{n} d_i^2 = \sum_{i=1}^{n} [Y_i - f(t_i)]^2$$

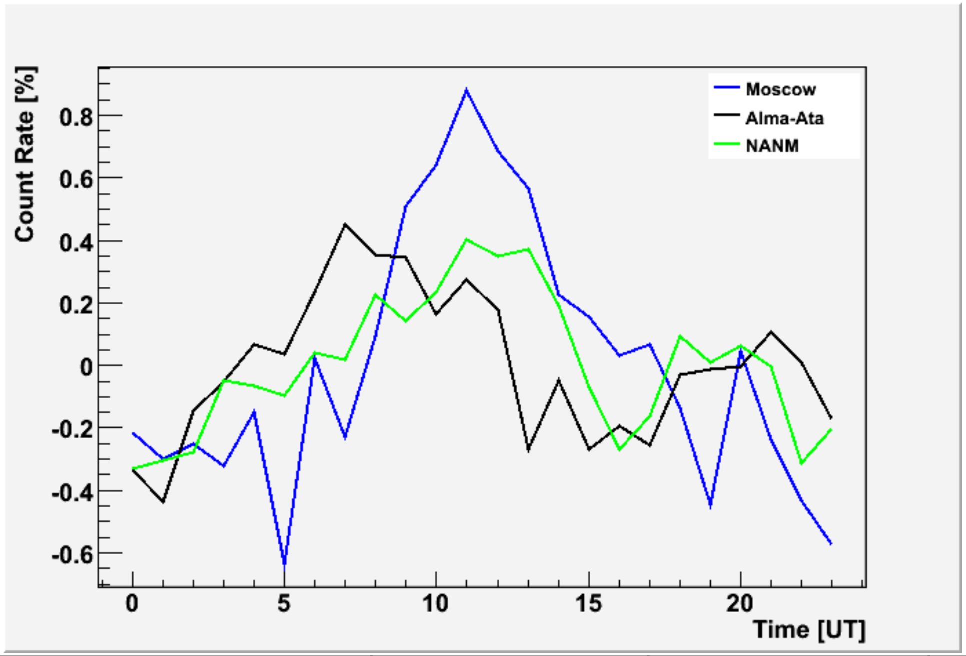
Daily variations according to Nor Amberd neutron monitors



As we can see the amplitude of variation is about 0.24% and phase is 3.307 in radians, which corresponds to 11:22 in UT or 15:21 in local time.



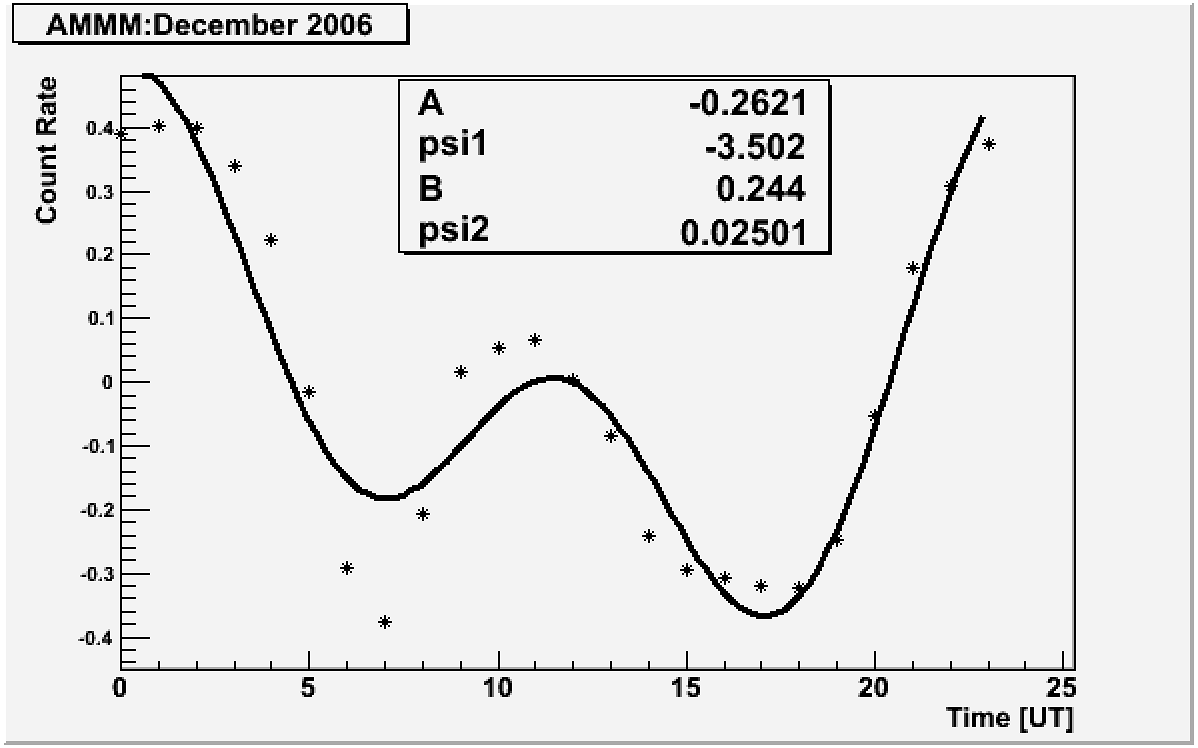
Comparison of Oulu, Moscow, Alma-Ata and Nor Amberd neutron monitors' daily data

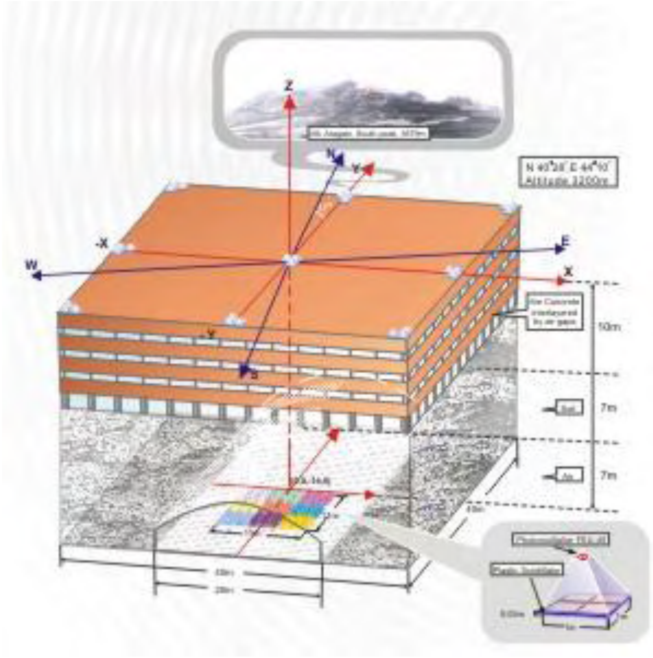


After fitting the 11 May, 2008 data of Moscow, Alma-Ata and
Nor Amberd monitors the following values of amplitudes were obtained – 0.47%, 0.20% and 0.24% respectively.
Phases in local time for these monitors are 14:53, 15:25 and 15:21 respectively.

May 1-31, 2008	Median amplitude [%]	Median phase [Local time]	Median quality of the fit (2)	Most probable primary energies
NANM	0.24	14:34	0.67	7.1 GeV
ARNM	0.24	14:07	0.62	7.1 GeV
Alma-Ata NM	0.24	14:38	0.61	6.7 GeV
Moscow NM	0.38	14:49	0.91	2.46 GeV
Oulu NM	0.29	15:13	1.03	0.81 GeV

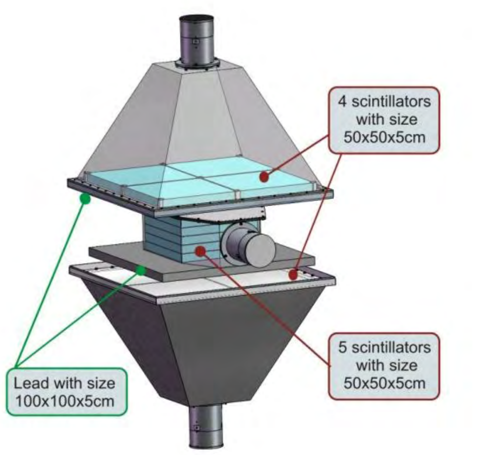
Daily variations of AMMM data

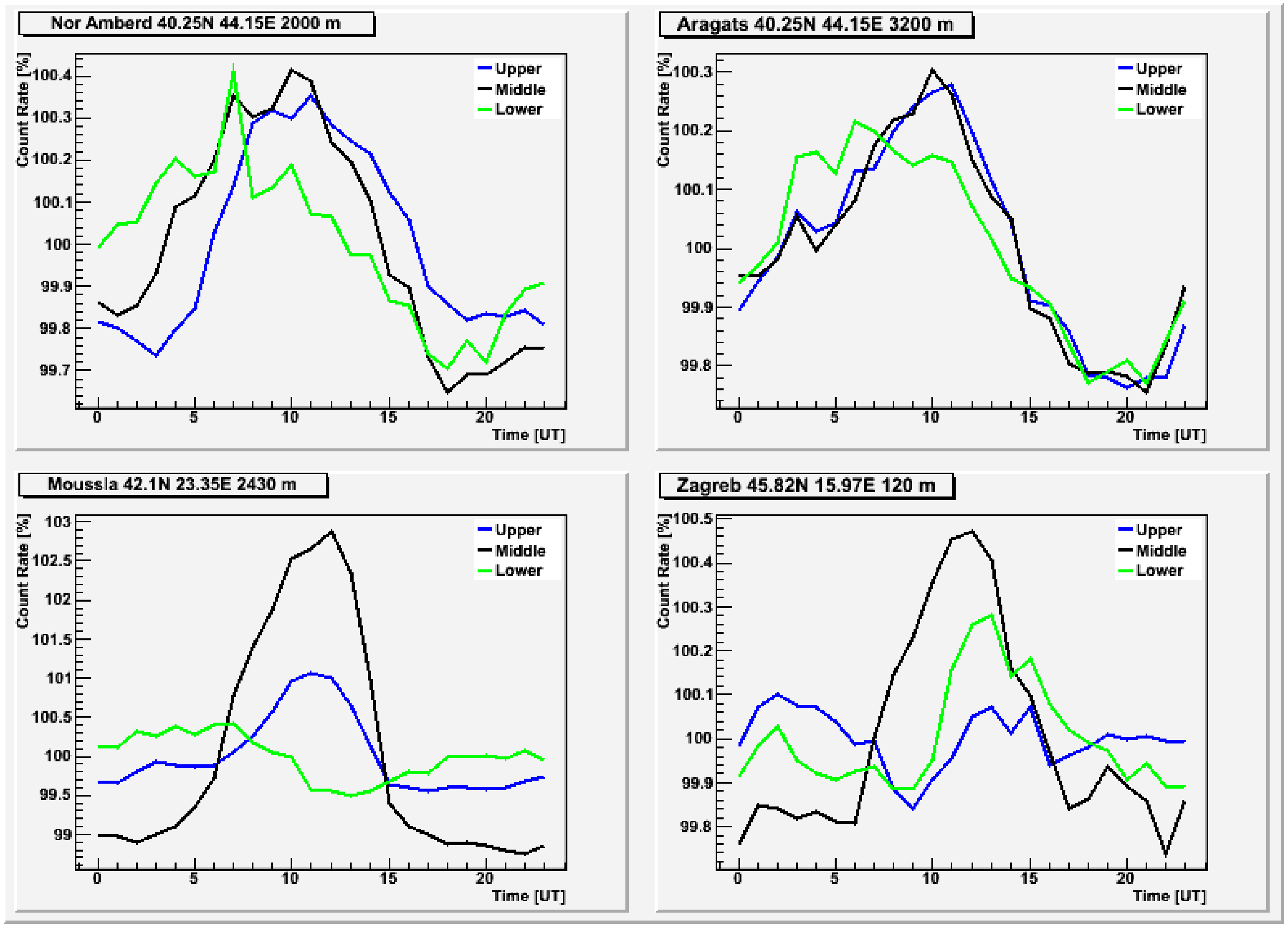




To describe daily variations of muons with energies > 5 GeV, data were fitted by sum of cosines with 24 and 12 hour periods.

Daily variations of high, low energy charged fluxes and neutral fluxes according to SEVAN Nor Amberd, Aragats, Moussala and Zagreb





Different coincidences of SEVAN detector correspond to different species of secondary cosmic rays

Daily variations of data of SEVAN monitors

	Median amplitude [%]	Median phase [Local time]	Quality of the fit	Most probable primary energies
SEVAN NA upper detector	0.28	15:13	1.33	14.6 GV
SEVAN NA middle detector	0.34	12:55	1.15	7.1 GV
SEVAN NA lower detector	0.24	10:36	0.18	18.4 GV
SEVAN Aragats upper detector	0.23	12:42	0.71	14.6 GV
SEVAN Aragats middle detector	0.21	12:27	0.62	7.1 GV
SEVAN Aragats lower detector	0.20	11:17	0.33	18.4 GV
SEVAN Mousalla upper detector	0.55	11:58	2.31	
SEVAN Mousalla middle detector	1.80	12:33	8.16	
SEVAN Mousalla lower detector	No peaks			
SEVAN Zagreb upper detector	Two peaks			
SEVAN Zagreb middle detector	0.28	12:39	1.35	
SEVAN Zagreb lower detector	0.12	14:43	0.51	

Conclusions

- ASEC neutron monitors can register daily variations in large diapason of primary rigidities. It opens possibilities to follow the changes of parameters of daily wave (amplitude, phase, maximal limiting rigidity) during starting 24th solar activity cycle.
- Magnitude of daily variations of neutrons correspondent to the lowest energy primary protons is comparable to the magnitude of variations of charged secondary CR.
- Daily variations of neutron flux are higher for the high latitudes comparing with middle latitudes and for low energy muons comparing with higher energy muons. Time of maximum for high latitude neutron monitors is comparable with those for middle latitude monitors. Amplitude of variation is 0.24% and phase is about 14:00 and 14:30 local time, for Aragats and Nor Amberd neutron monitors, respectively.
- Amplitudes of muon data are bigger or comparable with neutron data, except AMMM data (energy of primary protons higher than 20 GeV), which have more complicated shape of variations and lower amplitude.
- Several SEVAN monitors, which show very high values of magnitude of daily variations, probably have problems connected with light-tightness.

Thank you!