PROCEEDINGS OF SCIENCE

Complex set of cosmic rays monitoring

Germanenko Aleksei Valdimirovich
Polar Geophysical Institute
26a, Academgorodok St., Apatity, 184209, Russia
E-mail: germanenko@pgia.ru

Balabin Yuri Vasilevich[1]
Polar Geophysical Institute
26a, Academgorodok St., Apatity, 184209, Russia
E-mail: balabin@pgia.ru

Gvozdevsky Boris Borisovich
Polar Geophysical Institute
26a, Academgorodok St., Apatity, 184209, Russia
E-mail: gvozdevsky@pgia.ru

Maurchev Evgeny Aleksandrovich
Polar Geophysical Institute
26a, Academgorodok St., Apatity, 184209, Russia
E-mail: maurchev@pgia.ru

Mikhalko Evgenia Aleksandrovna
Polar Geophysical Institute
26a, Academgorodok St., Apatity, 184209, Russia
E-mail: mikhalko@pgia.ru

In the Polar Geophysical Institute a complex set was developed for secondary cosmic rays monitoring. The set integrates detectors of neutron, charged (electron-muon) and electromagnetic components of secondary cosmic rays. Thus the set is collected all kind of secondary cosmic rays in the Earth' atmosphere. Due to it the cosmic ray influence is studied in the wide energy range and different types. At the present there are two complex sets in Apatity and Barentsburg.

35th International Cosmic Ray Conference - ICRC2017
10-20 July, 2017
Bexco, Busan, Korea

[1]Speaker

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1. Instrumentation

The complex set, developed in Polar Geophysical Institute (PGI), includes two detectors of the neutron component, two detectors of gamma-rays, charged particle detector.

The neutron component is measured by two instruments: a conventional neutron monitor 18-NM-64 (NM) and a leadless section (bare NM, bNM). The conventional NM is sensitive to neutrons with energy exceeding ~50 MeV [1], while bNM is sensitive to neutrons with energy from thermal up to hundreds keV only.

Besides, by means of the scintillation detector on a Ø150×110 mm NaI(Tl) crystal, the differential spectrum of background gamma-radiation is measured within the energy range of 0.2-5 MeV. The period of one spectrum gathering is set to 30 minutes. An integral spectrum is recorded by the scintillation detector on a Ø60×20 mm NaI(Tl) crystal within the range of 20-400 keV with two output channels: >20 and >100 keV. The scintillation detectors have lead shell opened from top so the gamma-detectors accept radiation only in upper hemisphere from the atmosphere.

The detector of a charged component consists of two layers of the Geiger-Muller counters. The output of the upper layer and the coincidence of the two layers are used. The upper layer is sensitive to the charged particles and gamma-quanta both, the scheme of coincidence between the upper and lower layers selects the signal corresponding to a charged particle. The energy threshold for charged particles is estimated ~7 MeV.

It would be noted there are two data gathering method. Firstly it is conventional one. Data are recorded with the resolution of 1 minute, i.e. there are count rates of the detectors. Secondly data, which is named pulse information method (PIM), are recorded. PIM means that time of the pulse appearance is recorded with accuracy 1 ms and a tube number (and detector code) too [2]. PIM allows to study fast phenomena in the cosmic rays like multiplicity in NM, coincidence between different components and so on [2].

Some auxiliary devices are integrated to the set too. There are atmospheric pressure and temperature sensors, precipitation gauge, GPS-receiver for time correcting. The functional diagram of the set is shown on Fig.1.

2. Experimental results and discussion

The conventional NM 18-NM-64, which is in operation since 1969, is the core of the set. Later Apatity cosmic ray station was equipped with the additional devices. After 2009 the complex set was completed totally and now it accumulates information about all components. There are two ways of data gathering: conventional and pulse interval method (PIM). Due to PIM-method neutron multiplicity in NM was studied with high accuracy. Fine structure of the multiplicity was carried out [2, 3]. With little differences the same complex set was mounted in Barentsburg station (arch. Spitsbergen) and is in operation since 2009 too.

The great database has been accumulated and analyzed. Every year 50-70 increase events of 5 to 60 % in amplitude were registered in the gamma-ray flux. The increase events are connected with precipitation. It was proved by special measurements and additional experiments including radionuclide analysis of the precipitation [4]. Such events are observed in electromagnetic component (gamma-rays) and absent in charged particle flux. Hence this phenomenon distinguish to muon acceleration into thunderstorm cloud with strong electric fields. At length thunderstorm is absent in Spitsbergen properly. Also our increase events are observed at summer and winter under rain or snow precipitation. Continuous measurements of differential energetic spectra of gamma-rays have revealed that any increase event has upper limit of the energy about 2.5-3 MeV. Also a fine weather gamma-rays spectrum has a power low form. Under increase event there is an additional flux of gamma-rays with exponential form and upper limit ~ 2.5 MeV [5].

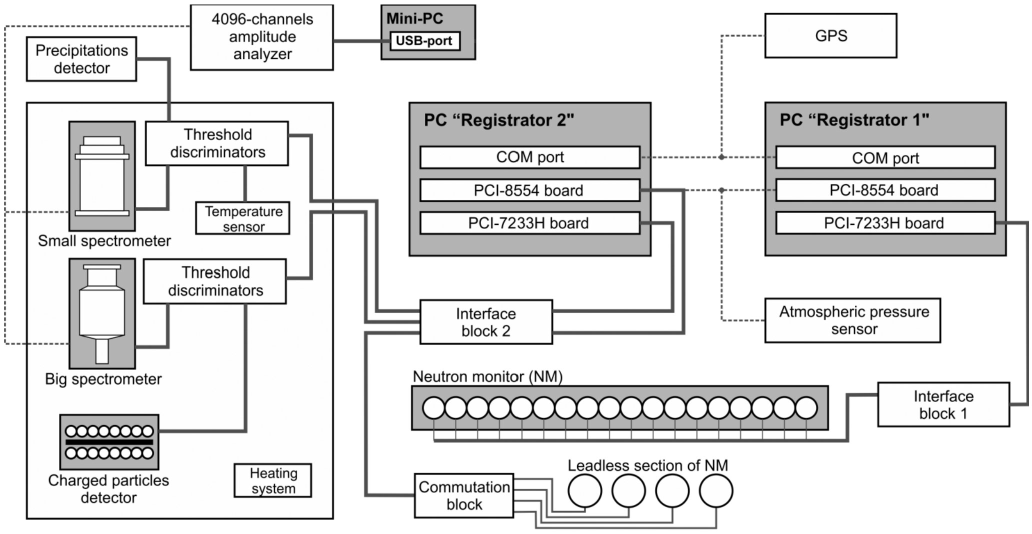

Figure 1: The functional diagram of the complex set for cosmic rays monitoring in Apatity. The small spectrometer has Ø60×20 mm NaI(Tl) crystal, the big one has Ø150×110 mm. Due to the amplitude analyzer the big crystal is used for measuring of the differential energetic spectrum of gamma-rays.

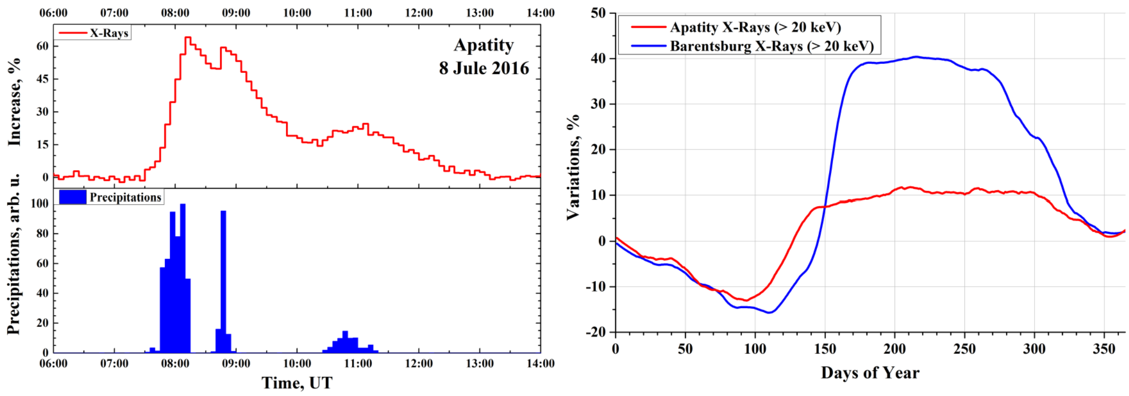

Figure 2: At the left panel. Typical increase event in gamma-rays accompanied precipitation (Apatity) is shown. There was used >100 keV channel and 5-min interval. There are three local maxima in the X-rays profile and three rain strengths accompanied them. At the right panel. Average annual variation of gamma-rays on Apatity and Barentsburg stations are shown. There were used data of 2010-16 years. All data are corrected on atmospheric pressure variation according to its barometric coefficients.

The annual variation of the gamma-ray background with amplitude ~30 % was found too. The same increase events and annual variation are present in Barentsburg data. The annual variation is ~50 %. It would be mentioned radon emanation influence is excluded due to Barentsburg location in permafrost zone. An example of increase event and annual variations are shown in Fig.2.

A seasonal variation on the leadless (bare) NM section was carried out (see Fig.3). Such influence on thermal and moderate neutrons is clear and well known [1]: a thick snow cover is like polyethylene shield on NM. The snow cover reduces albedo neutrons from the soil. At a winter under a thick snow cover scattered neutrons are moderated into snow and don't return to the atmosphere. In this case the count rate of the bNM becomes below. And there was found strong correlation between the bNM count rate and snow thickness. NM and charged particle detector are free of seasonal variations. An interesting phenomenon was found due to monitoring. Seasonal (annual) variations of gamma-rays on the stations (Apatity and Barentsburg) follow to the snow thickness too (see Fig.4)! The flux of gamma-ray follows strongly to snow depth. At the present a production way of this gamma-ray variation of a huge magnitude is not distinct. Detectors are in 5 cm lead shell and don’t accept radiation from the soil and buildings. Many years measurements of differential energetic spectrum of gamma-radiation at winter and summer show that seasonal variation is up to 0.8-1 MeV. At the same time gamma-rays increases have energetic range up to 2.5-3 MeV. So the increase event and the seasonal variation have different origin.

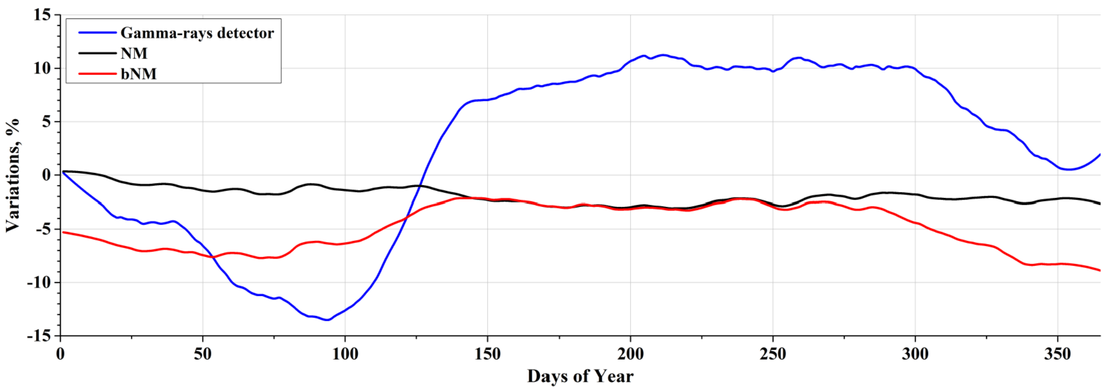

Figure 3: Average annual profiles at NM, bNM and gamma-rays detector in Apatity. There were used 2010-15 years data and superimpose method. Annual variation is absent on the NM because it was especially developed to be non-sensitive to an environment. There is only slow decrease due to the solar activity growth from minimum in 2009 to maximum in 2015. There is small but clear annual variation on bNM about 5 %. At a warm and snow-free period bNM profile is near to NM one. At a winter period bNM count rate is depressed in comparison to warn one. Annual profile of bNM gets a gap at this period.

We consider increase event in gamma-rays to be caused by electric fields into rain nimbostratus clouds. Electric field strength into rain cloud is up to 10-16 kV/m [6]. Light charged particles into electric field gather additional energy and scatter it along its passes into the atmosphere. In particularly some energy transfers to gamma-radiation via Bremsstrahlung. We called it douskoreny (additional acceleration) effect. The additional acceleration of muons is well known effect [7]. The energy balance is next. Integral additional flux of gamma-rays corresponding to increase event is about 300 keV per a one charged particle coming from the atmosphere. Under a typical cloud thickness (500 m, [8]) and electric field strength 10 kV/m additional gathered energy is 5 MeV totally. Only ~15 % of total gathered energy is spent to gamma-radiation. Hence, the energy balance allows to be present increase event in rain clouds. But the fine phenomenon mechanism is not clear till now. Mainly synchronous measurements of electric fields into clouds and gamma-ray flux are absent.

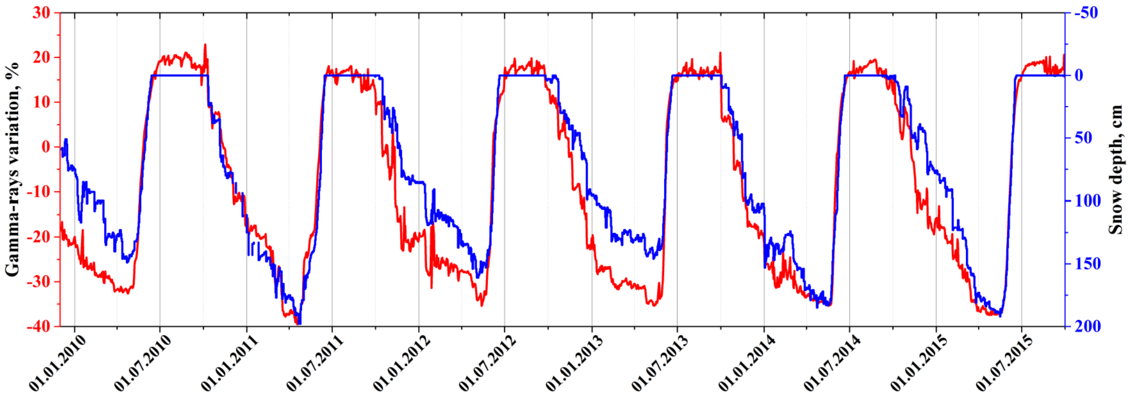

Figure 4: Gamma-rays profile along 2010-15 years in comparison to snow thickness in Barentsburg station. Scale of snow depth is on right and inversed to be more distinctively. The flux of gamma-ray follows strongly snow depth. For example, the gap in 2011 was to -40 % and snow depth was about 200 cm, the gap in 2012 was to -35 % and snow depth was about 150 cm.

Annual variations of bNM and gamma-ray flux are quite similar. This is the key factor pointing to common reason of them. The common reason is albedo neutrons which density is depressed over snow cover. But the way of gamma-rays depression is not clear. It would be noted a direct communication between moderate neutron density in the atmosphere and gamma-rays flux. It is known a free neutron is usually accepted by nuclei of environment and doesn't decay. Perhaps nucleus reactions between moderate neutrons and environment nuclei are generated background gamma-rays in the atmosphere.

3. Conclusions

The complex sets of cosmic ray monitoring are on operation in Apatity and Barentsburg since 2009. The set integrates detectors of different kind (neutrons, charged particles and gamma-rays) of the secondary cosmic rays and auxiliary sensors. Due to the set new phenomena were carried out which revealed new way of interaction between cosmic rays and meteorological processes in the low atmosphere.

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