

# Orographic effect in cosmic rays observing

Yury Balabin\*

Polar Geophysical Institute, 184209 Apatity, 26A Academgorodok, Russia.

**Abstract.** The Baksan neutron monitor (NM) is installed at the Baksan neutrino observatory, the Northern Caucasus, which is located at the bottom of the Baksan gorge, at height of 1700 m above sea level. The cosmic rays flux recorded at the ground level depends on the amount of the substance (air), through which the particles are passing, from the uppermost layers of the atmosphere to a cosmic ray detector. So, besides the cosmic rays flux data, the station records pressure; the pressure meter recordings interval is 1 minute, like that of the cosmic rays. The perennial barometric data have been analysed to show that at the Baksan station one can often observe a daily pressure variation that is related to the topography features. In general, the local conditions (wind, local orographic effect) result in pressure variations, which do not occur in the cosmic rays, because they do not change the thickness of the atmosphere but result from the effect of the ground level. The barometric variation discovered is not so big (about 1 mb), but is also synchronously observed in the cosmic rays. It means that the pressure variation is not a local phenomenon. In this case, the NM detects the amount of the substance in the atmosphere, showing that pressure changes are not due to dynamic reasons (the Bernoulli effect) and it is the atmosphere strata that changes in reality. Hence, the orographic effect covers a significant part of the troposphere, resulting in the change of the atmosphere strata located over the NM. No similar pressure variation is observed in other NMs.

## 1 Introduction

The ground level cosmic rays detectors record secondary cosmic rays. Arriving into the Earth's atmosphere, the primary cosmic rays particles interact with atomic nuclei of the air. There are produced secondary particles that get the energy from the primary particles. If the amount of energy is sufficient, the secondary particles, propagating through the atmosphere, interact with the atomic nuclei to produce the next generation of particles [1]. The cascade process like this is possible till the particles newly produced get the energy sufficient to interact with the air atomic nuclei. All these particles are referred to as secondary cosmic rays (SCR). In so doing, a particle shower is being developed in the atmosphere. As soon as the process of new particles generation stops, the particles of the shower are still propagating into the atmosphere, gradually losing the energy and being absorbed. So, under other things being equal, the ground level SCR flux depends on the amount of the substance (air), through which these particles are passing [1, 2].

---

\*Corresponding author: [balabin@pgia.ru](mailto:balabin@pgia.ru)

This is in general the reason of the barometric effect occurrence in cosmic rays. There are finer effects related to the atmosphere temperature but these are less noticeable and are of no significance in the study. It should be taken into consideration that the barometric effect is related to the particle's absorption in the substance, and considering the degree of the flux attenuation, one can assess the amount of the substance located over the detector, through which the SCR particles have passed on their way to the detector.

The barometric effect is defined by the barometric coefficient  $\beta$  showing the degree of absorption of the SCR particles by the atmosphere per unit of particle path. The technique applied to determine the barometric coefficient is clearly defined in [3]. The barometric coefficient for the nucleon component recorded by the neutron monitor is on the average equal to  $\beta = 0.0072 \text{ mb}^{-1}$ . It is the necessity to make a correction for pressure variants into the NM data that makes us carry out pressure measurements with such an accuracy like that of the NM data, i.e., to take the data every minute. The accurate and detailed data concerning the change in the atmosphere pressure are taken at the cosmic ray stations while the meteorological data are taken once an hour only. When the barometric corrections are made, the NM data correspond the change in the cosmic ray's flux.

## 2 The Baksan neutron monitor

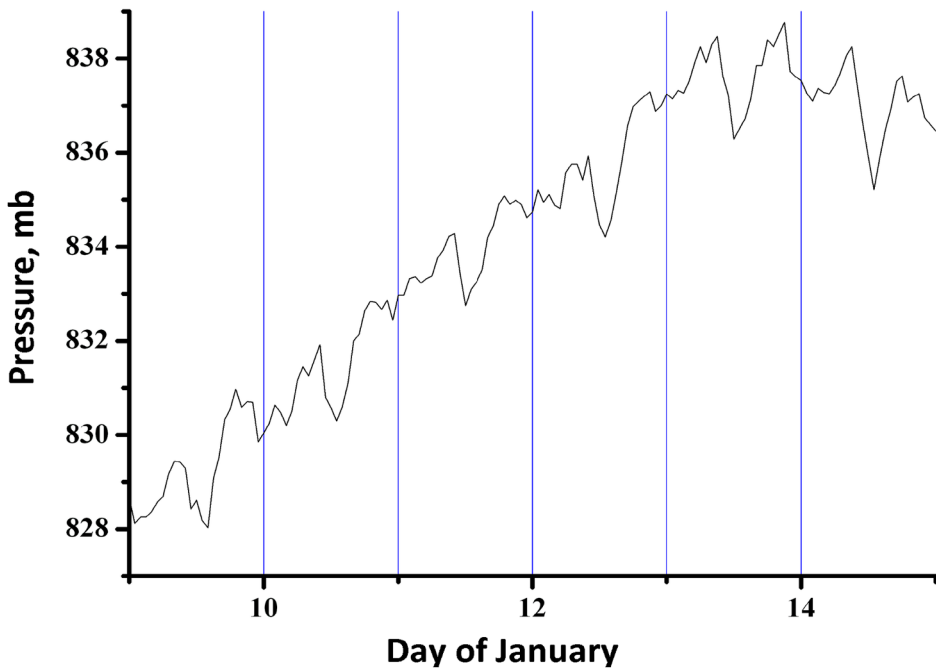
As it was mentioned, the Baksan neutron monitor is at the neutrino observatory in the village of Neutrino in the Northern Caucasus in the Baksan gorge at height of 1700 m above sea level. The coordinates of the NM location are:  $43^\circ 16' 22.81'' \text{ N}$  and  $42^\circ 41' 06.04'' \text{ E}$ . The building, where the NM is installed, is at the foot of the slope of the Mt. Andyrchy, being of more than 3900m high. The southern slope of the gorge is formed by the spurs of the Greater Caucasus Mountain Range of at least 3500 m high. The northern slope of the gorge is a bit lower than the southern slope, with the height of the peaks exceeding 3000 m. In the very vicinity of the settlement of Neutrino there is the peak Moukal of 3800 m high. The gorge's bottom is only of some hundreds of meters wide along its extent, extending from the town of Tyrnyauz to the village of Terskol, being of over 40km long. Thus, the Baksan gorge is very narrow and deep in its upper part. Figure 1 shows the gorge as seen from the slope of the Mt. Andyrchi.



**Fig.1.** The Baksan gorge as seen from the slope of the Mt. Andyrchi. The gorge bottom, flat and narrow, is clearly seen.

### 3 The NM abnormal daily pressure and count variation

In close analyzing the data taken from the Baksan NM, attention has been paid to an obvious daily pressure variation, which sometimes appeared and lasted for some consecutive days (Fig.2). The variation amplitude was about 1 mb. This variation can overlap other variations, preserving its isolation. The close verification of the instrumentation, an additional control over the in-room temperature and the temperature inside the case of pressure sensor have shown that the daily change in temperature is 1-4 °C and cannot be the reason of the significant pressure variations. The primary NM data and the barograph data were compared to show that the NM count variation is observed during the days when the pressure variation was observed, with these variations occurring out of antiphase.

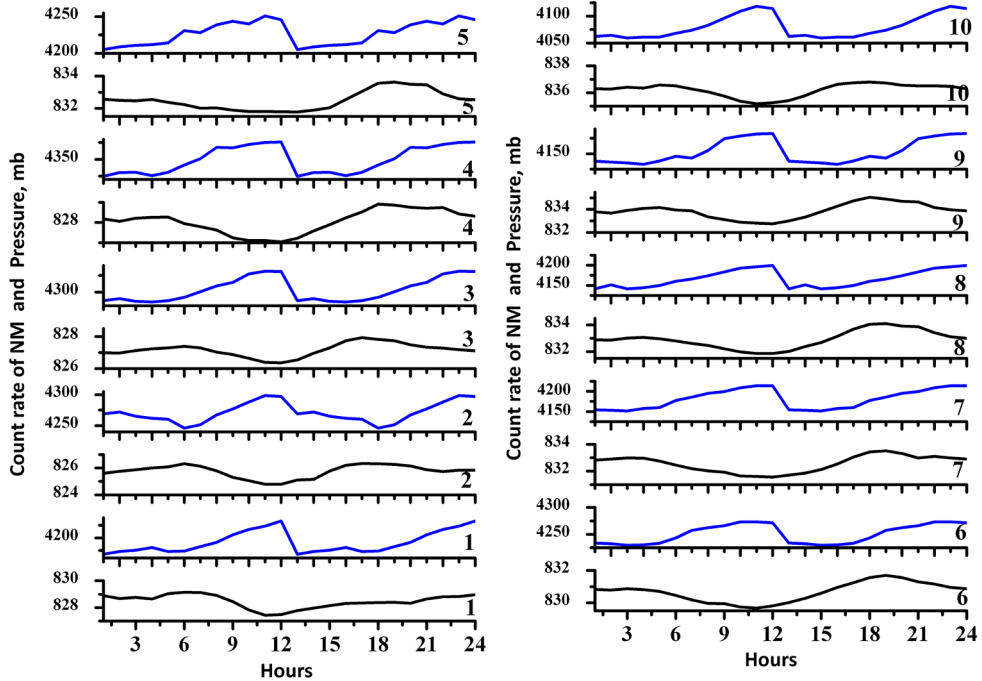


**Fig. 2** The NM pressure measurements during several days. Of interest were daily pressure gaps in the middle of the day.

The next step was to calculate an average variation profile. The superimpose method was used. Not to lose the possible seasonal differences in variations, the days with variations were distributed through months. Use was made of more than the 2-year continuous NM data with synchronous recording the atmosphere pressure, as well as the primary NM data which was not under barometric correction. During some months, the number of days with variations was small, in other months, the variation was lasting for about a month. It was supposed that the variation was absent during the days when the weather was bad. However, the meteorological data showed that variations are present in days of dense low cloudiness and are absent in clear days. The reason of pressure variation is not clear.

Figure 3 shows the result. The plots are presented in pairs: the NM daily profile of the counting rate and the pressure. The month is shown in number on the right. The NM counting changes through months, it is related to the cosmic ray variations and the Sun's activity. The pressure also changes, which is due to the different number of cyclones and

anticyclones having passed through the point of observation during a month. The daily pressure profiles differ through a year; however, the position of the minimum is unchanged, being close to that at noon. At the author's opinion the poorly pronounced variations in January and May were due to a small amount of suitable days, as well as due to that during those months, a lot of pressure drops was observed, which distorted the daily variation. Due to that, the data obtained in the days like those, were not taken into consideration in deriving of the average profile.



**Fig.3.** The daily pressure variation profiles (black line) and the NM count rate (blue line). At the NM station the atmosphere pressure is about 830 mb, the NM count rate is more than 4000. The numbers at the right edge of the plot are the numbers of the months. Use was made of the hour average data; no pressure corrections have been made.

In general, the daily NM variation is similar to the pressure variation in antiphase; however, there are some significant peculiarities. The daily variation of the NM count rate starts simultaneously with the pressure variation, and smoothly increases reaching its maximum, but, having reached maximum, the counting suddenly stops, decreasing in fact to the level before the beginning of the increase. At the same time, the pressure dropped as smoothly as it increased. The duration of the pressure decrease (and the NM counting increase duration) also changes through the year: in February it lasts from 8 to 16 hours, increasing in March and April, and in June-July it lasts from 5 to 18 hours.

## 4 Discussion

Firstly, there is an important question: has the similar variation been observed at other mountain stations of cosmic rays? The analysis of the database available from other NMs has shown that there are no variations at these stations. However, this fact does not make the Baksan NM data doubtful. Attention should be paid to the fact that other NM stations (Irkutsk-2 and Irkutsk-3 in the Sayans, the peak Lomnitsky in Tatry, Jungfrau in the Alps

are located close to a peak or a plateau. The Baksan NM is the only station located at 1700 m above sea level, though being in a deep and narrow gorge. The unique location of this station is obvious.

That this pressure variation is not due to the Bernoulli effect (the dynamic barometric effect) is confirmed by the synchronous variation in the NM count rate. The air flow (wind) can made interference to the barometer data but it cannot influence the rate of NM count rate, because NM is sensitive to the total amount of substance above it. In case of the dynamic effect, one would observe the daily variation in pressure, but the NM count rate would not experience the synchronous and antiphase changes.

Meteorology is not the author's specialty, that's why there is no comprehensive explanation of the effect observed that could be presented in this study. One can only suppose that a significant orographic effect takes place. Its significance is in that it affects the state of the atmosphere not only just at the surface level but extends its influence at least 2-3 km from the earth's surface into the atmosphere. The objective of the study is of the other nature: the objective is to demonstrate the possibilities of the neutron monitor as an instrument to probe the strata of the atmosphere. The NM network in Russia consists of a dozen and a half monitors, which enable making exact and detailed measurements of the atmosphere pressure. The comparison between the pressure and the NM count rate variations allows making an unambiguous conclusion about the nature of the pressure variations.

## 5 Conclusion

An interesting daily variation has been discovered in the Baskan NM data, which is observed simultaneously in both the NM data and the pressure meter data. The variations are synchronous and are antiphase, which indicates that the pressure variation is not due to the Bernoulli effect. It may be supposed that the reason is the significant orographic effect observed over a significant part of the atmosphere. The study demonstrates a possibility to employ the NM as an instrument to probe the strata of the atmosphere and to distinguish the variations related to the changes in the strata of the atmosphere.

## References

1. S. Hayakawa, *Cosmic Ray Physics. Nuclear and Astrophysical aspects* (Wiley-Interscience, New York, 1969)
2. Dorman L.I. *Experimental and theoretical fundamental astrophysics of cosmic rays* (NAUKA, Moscow, 1975) (in Russian)
3. Dorman L.I. *Meteorological effects of cosmic rays* (NAUKA, Moscow, 1972) (in Russian)