Variations of Barometric Coefficients of the Neutron Component in the 22-23 Cycles of Solar Activity

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Abstract: The barometric coefficient of the neutron component of cosmic rays is calculated for several cosmic ray stations over the last two solar cycles. Barometric effect in the whole has studied well enough, but at many stations the changes in barometric coefficient with the time is not always taken into account. Under analysis of the data the primary cosmic ray variations were previously excluded, that allowed to use continuous series of data over the whole investigated period.

Keywords: neutron monitor, meteorological effect, barometric coefficient.

1 Introduction

The barometric coefficient of the different components of secondary cosmic rays, as a whole, is studied well [1]. Its altitude and latitude dependence, first of all, for neutron component, has been found [2]. Barometric coefficients for all operating muon telescopes have been calculated [3]. For some stations researches of time dependence of barometric effect have been performed [4]. However, on the majority of stations reduction of observable count rate to standard level of observation still is carried out with an insufficient precise. In the first time it concerns the time dependence of the barometric coefficient. Error in 0.02% / mb in its definition can lead to a 1% error in the corrected variations.

2 Methods of determining a barometric coefficient

Counting rate of detector N, taking into account primary variations δ, can be represented as

$$N = N_0/(1+\nu)\exp(-\beta(h-h_0)), \qquad (1)$$

where h is the current atmospheric pressure at the moment, N_0 and h_0 is a values of count rate and pressure, averaged over the interval of determining the barometric coefficient. The variation of counting rate is determined with respect to this same interval. Taking logarithm, we turn to a linear of β expression:

$$\ln N - \ln N_0 + \ln(1+\nu) = -\beta(h-h_0) \qquad (2)$$

We can consider several methods.

a) Case when the variations can be ignored during the reporting period ($\nu \approx 0$).

$$\ln N - \ln N_0 = -\beta(h-h_0) \qquad (3)$$

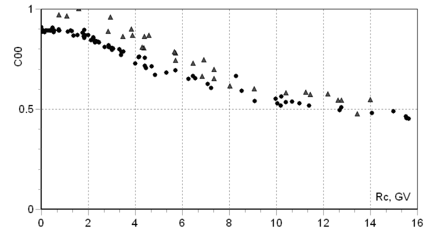

Figure 1. Coupling coefficients of zero harmonic coincidence. For mountain stations they are shown as a triangles.

b) The variations can be included from the data obtained on the reference station S with similar parameters. If the coumpling coefficient of the zero harmonic was C_0^S (Fig. 1), and the time-dependent variations were determined for the reference station, then we can write

$$\ln N - \ln N_0 + \ln\left(1+\frac{C_0}{C_0^S}\nu_S\right) = -\beta(h-h_0) \qquad (4)$$

We have reduced expression for estimating β to the version with one-parameter representation. This approach is acceptable if we can neglect the variations of the first and higher order harmonics, or, or to consider the average daily data

c) If we have a minor variation ($\nu \leq 0.2$), then after the expansion in (2) $\ln(1+\nu)$ can be written

$$\ln N - \ln N_0 = -\beta(h - h_0) - \alpha \nu_S \qquad (5)$$

We have reduced to a variant of a two-parameter representation for the estimation of parameters α and β. The parameter α is $\alpha = C_0 / C_0^S$ essentially, but in this case it is determined experimentally.

3 Input data

We used hourly values of the counting rates and atmospheric pressure. However, in order to control and reduce the influence of anisotropy of the cosmic rays (perhaps the only advantage), we carried out parallel calculations on the basis of daily main values. The disadvantage is a narrower range of pressure changes, and, most importantly, an incomplete match counting rate and pressure, if during the day there were large changes in the rate bill or of atmospheric pressure.

Barometric coefficient was calculated separately for each month. This is a sufficient period to assess the barometric coefficient.

4 Discussion about results

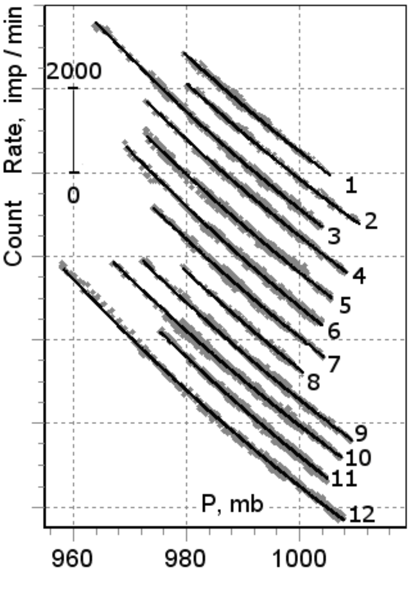

Figure 2. Dependence of counting rate on the atmospheric pressure for a quiet period in 2009 at Moscow station.

To control data quality the dependences of the counting rates of a detector on the atmospheric pressure were plotted for each month and for every station. Figures 2 and 3 show such dependences in the quiet and disturbed periods, and the result of approximation. In the case of a quiet period in 2009 due to large changes in atmospheric pressure, is a clear nonlinear dependence of count rate versus atmospheric pressure. In this case, the uncorrected and corrected for variations in the primary virtually indistinguishable, in contrast to the disturbed period, an example of which is shown in Fig. 3 In July 1991, there was a very large Forbush decrease (~ -20%).

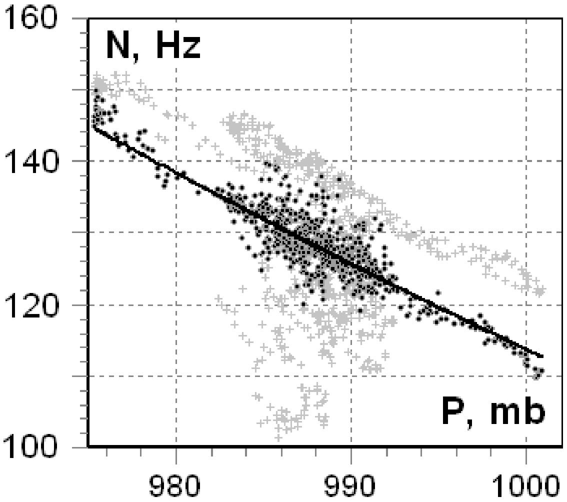

Figure 3 Dependence of counting rate on the atmospheric pressure for a strongly perturbed period in June 1991. Light grey points correspond to uncorrected by variations counting rate.

Figure 4 shows another example of variations due to changing the flux of solar particles during the GLE in January 2005 (20%). These bright examples show that the correction for variations into account only the zero harmonics allows good accuracy the data even during these periods. For a more correct evaluation of the barometric effect in the perturbed periods, they should either be excluded from consideration, or involve variations of the model that takes into account higher order harmonics.

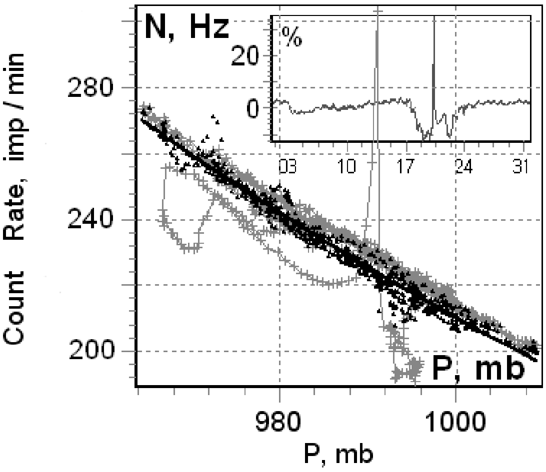

Figure 4 Dependence of counting rate on the atmospheric pressure for a period of sun flare in Janyary 2005..Light grey points correspond to uncorrected by variations counting rate.

In accordance with the described technique we assessed the barometric coefficient of Moscow station, whose data were corrected for variations referring to the station Newark. Conversely, the barometric coefficient was calculated for station Newark, but as a reference station is used station Moscow.

Fig. 5 shows the monthly and annual mean (horizontal lines) values of the barometric coefficient (left scale) for the period 1977 to 2010 at. Moscow station. In the lower panel of Fig. 5 is shown also the correlation coefficient (right scale) for the station. The line bounding the shaded area in the upper panel represents the density of galactic cosmic rays, obtained by a global survey method (GSM) in approach of zero harmonic. As a refer was used the Newark.

Fig. 6 shows the result for the Newark station, but as a reference station in this case is a Moscow station. Fig. 7 shows the calculated barometric coefficients for the station Kiel for the period 1965-2010 years, with the reference station Moscow.

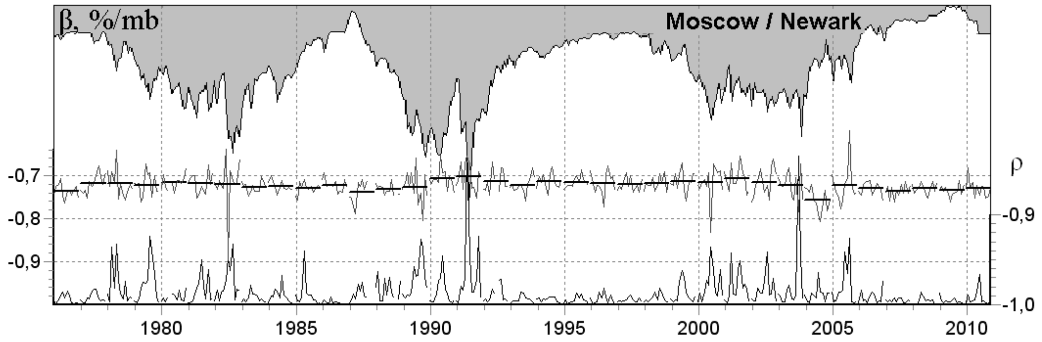

Figure 5 The result of analysis of barometric effect at the Moscow station , corrected by variations respond to the Newark station

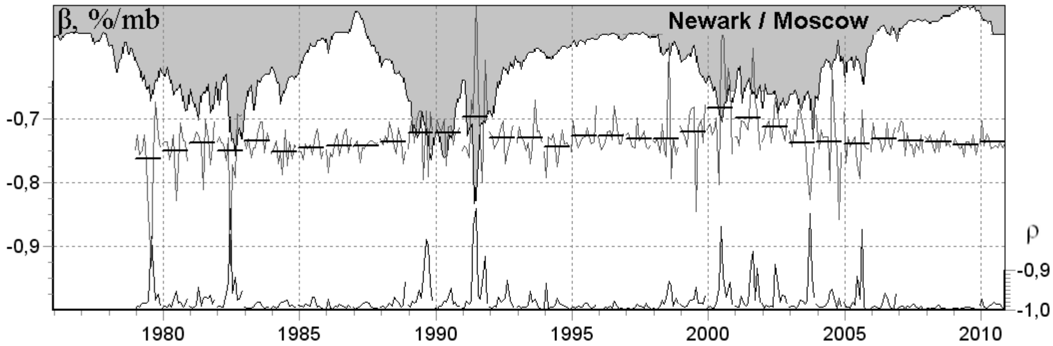

Figure 6 The result of analysis of barometric effect at the Newark station , corrected by variations respond to the Moscow station

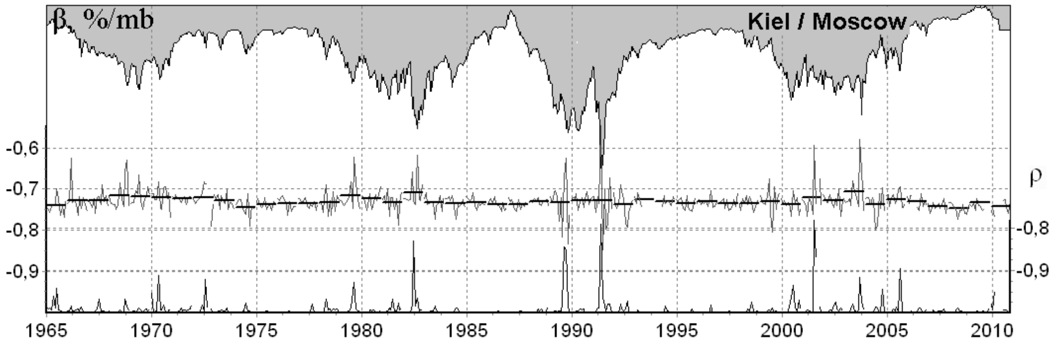

Figure 7 The result of analysis of barometric effect at Kiel station, corrected for variations according to the Moscow station

Let investigate in more detail the dependence of the barometric coefficient of variation of primary cosmic rays. In [4,5] is shown that the modulation of the barometric coefficients of neutron monitors is well described by a two-parameter expression,

$\beta = \beta_0 + \alpha \dfrac{\nu_S}{1+\nu_S}$, where ν_S - is the experimentally determined variation of the counting rate of the neutron monitor at the base station, and α determines a sensitivity to changes in barometric coefficient of variation of the spectrum. As the baseline period in [4] and in this work the year 1976 is taken and during this period $\beta = \beta_0$. However, as an indicator of variations is more convenient to take, for example, the amplitude of the zero harmonic cosmic rays [6], which is determined by analyzing the data world network of stations and is therefore statistically more secure. The amplitude of the zero harmonic describes the variation outside the magnetosphere. Observed variations in the approximation of the zero-harmonic amplitude are

determined and adopted by zero harmonic coefficients.

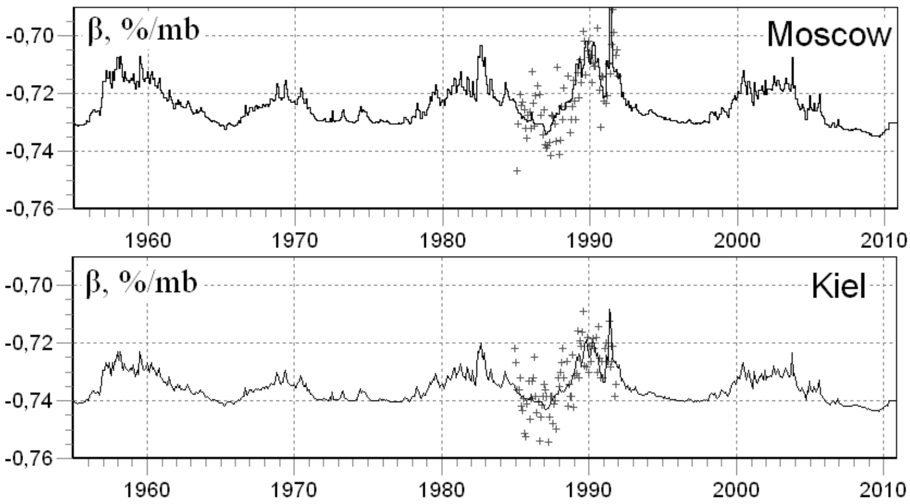

Figure 8 Monthly mean values of approximated barometric coefficient for the whole observation period (solid line) and experimentally founded values for 1985-1991 years (crosses) for the station Moscow and Kiel.

Given this dependence of the barometric coefficient on variation of primary cosmic rays can be written as

$$\beta = \beta_0 - \alpha \frac{C_0 a_{10}}{1 + C_0 a_{10}} \qquad (6)$$

Fig. 8 shows the monthly values of the barometric coefficient of neutron monitor stations and the Moscow station of Kiel for the entire period of observation, calculated by formula (6). Also shown are experimentally determined in [7,8] barometric coefficients for these stations for 22 cycles CA.

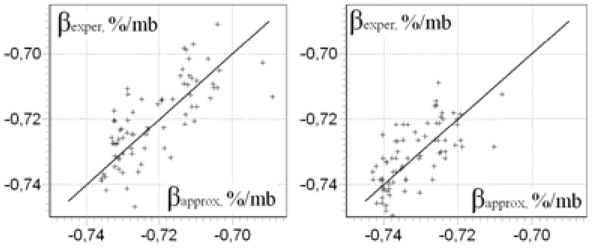

Figure 9. Comparison of the approximate and experimental values for the stations Moscow (left) and Kiel (right).

Approximate expressions for the barometric coefficient can be written for Moscow and Kiel as:

$$\beta = -0.732 - 0.11 \frac{C_0 a_{10}}{1 + C_0 a_{10}} \qquad \beta = -0.740 - 0.08 \frac{C_0 a_{10}}{1 + C_0 a_{10}}$$

The numerical values of the mean monthly barometric coefficients obtained for neutron monitors for the entire period of observation can be found in [9]. On the Fig. 9 we compare the approximate and experimental values for the stations Moscow (left) and Kiel (right).

5 Conclusion

Methodology used can satisfactorily estimate the long-term changes in barometric coefficient for the neutron detectors of global cosmic rays stations network. However, it would be extremely useful to increase the accuracy of barometric coefficient calculation up to a few thousandths of a%/mb, especially during periods of high solar activity. This can be achieved by attracting to exclude variations of a more complete model variations, taking into account the higher harmonics.

Acknowledgements

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