## Long Time Modulation Of The Neutron Monitors Barometric Coefficients

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ABSTRACT

The variational barometric coefficients for the neutron monitors of the world network were computed on the base of the long time cosmic ray modulation data in 1954-1991. A simple way for calculation of the barometric coefficient variations is proposed. Calculated time dependence has been compared with experimentally found for Kiel and Moscow stations over 1981-1991.

### 1. INTRODUCTION.

The barometric coefficient determining a relation between the counting rate of any cosmic ray (CR) detector and the air mass above it hasn't to be considered as the constant value (Dorman,1972). The primary CR variations in the solar activity cycles are the main reason of the barometric coefficient modulation. However modulation of the barometric coefficient is not taken into account on the many neutron monitors of the world network, that causes to the considerable systematic errors in the data corrected for the standard air pressure and tells on the reliability of the scientific results.

The aim of the report is to get a convenient form of the connection between the barometric coefficient of neutron monitors and long time CR variations.

### 2. METHOD AND DATA.

Modulation of the neutron monitor barometric coefficient may be described as follows (Griffits et al.,1965; Belov,Dorman,1980):

$$\beta = \beta_0 + \beta_\delta(t)\,\frac{\delta}{1+\delta} \tag{1}$$

where $\delta=\delta(t,t_0,g,h)$ is variation of the neutron monitor counting rate relative to the base level (in this work relative to 1965 year), when $\beta_0=\beta(t_0,g,h)$; $\beta_\delta(t)=\beta_\delta(t,t_0,g,h)$ is the variational barometric coefficient, which determines the modulation depth for the barometric coefficient. By the definition $d(\ln\delta) = \beta_\delta dh$, or in form where response functions $W=W(t,g,h,R)$ are used:

$$\beta_\delta = \int_g^\infty \frac{\Delta I}{I_0}\frac{\partial W}{\partial h}dR \Bigg/ \int_g^\infty \frac{\Delta I}{I_0} W dR \tag{2}$$

Here $\Delta I/I_0$ is the variation of the primary CR concentration I relative to the moment $t_0$ ($I_0=I(t_0)$). So, if the barometric coefficient and response functions (including their altitudinal dependence) are known for the moment $t_0$, then, by means (1) and (2) the value $\beta$ can be computed for any period when the rigidity spectrum of the primary CR variation is known. In order to calculate $\beta_\delta$ the mean annual data of the rigidity spectrum of the CR primary variations obtained by Belov et al.(1993) over the 38 years period (1954-1991) have been used. The response functions for the solar activity minimum (Dorman,Yanke,1979) were used by the similar way as in (Belov et al.,1990).

From other side the modified method of two stations (Belov et al.,1992) was used for determining of the barometric coefficient $\beta$ by the experimental data (daily mean values of the counting rates and atmospheric pressure). Barometric coefficients have been determined separately for each of 132 months over the 1981-1991 period. Unprecedented large CR variations (>27% on the Moscow station by monthly data) in 22-nd cycle of solar activity make this period especially suitable for study of the barometric coefficients modulation.

## 3. DISCUSSION OF THE RESULTS.

The variational barometric coefficients $\beta_\delta$ have been computed by formula (2) for different neutron monitors of the world network and then were used for calculating by formula (1) the barometric coefficients for a number of sea level stations with different cut-off rigidities (Fig.1).

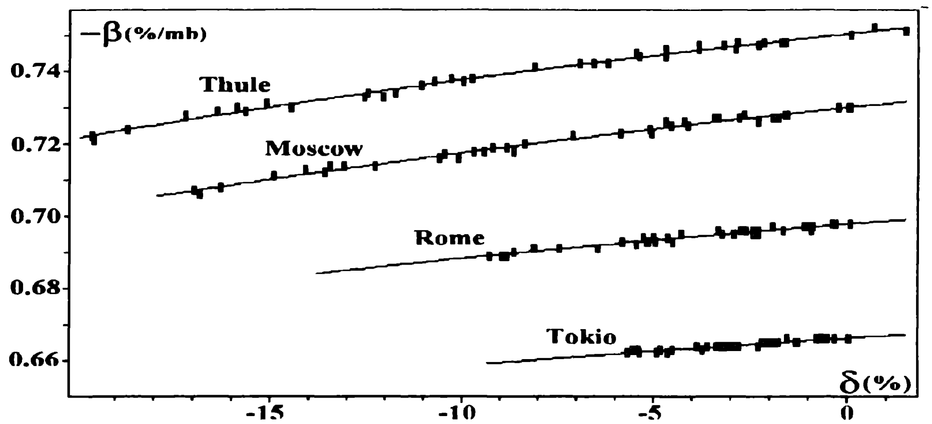


Fig. 1: Mean annual barometric coefficient β for Thule, Moscow, Rome, Tokyo neutron monitors (rectangles) computed over the 1954-1991 period in dependence on calculated counting rate variations, and corresponding regression curves.

On the abscissa the variations of the cosmic ray counting rate, which had to be expected for chosen response functions and primary variations, calculated from the formula (2) denominator, are plotted. As for $\beta_0$ in formula (1) for Thule, Rome, Tokyo stations its were taken as the values β used on these stations in 1976.

The analysis of the obtained variational barometric coefficients $\beta_\delta$ reveals the following features: 1) On the atmospheric depths, where all neutron monitors are replaced, $\beta_\delta<0$, otherwise, along the deepening into the atmosphere the absolute value of the observed cosmic ray variations decreases together with the cosmic ray intensity. 2) $\beta_\delta$ value is large enough to provide a significant (~0.03%/mb on the high latitudes) difference of the mean annual barometric coefficients on the various phases of the 11-years solar activity cycle. 3) Under cut-off rigidity increasing $\beta_\delta$ decreases more rapidly than $\beta_0$ does (1.8-2.2 times from high latitude to equator). The consideration of the barometric coefficient modulation for high latitudinal stations is more important than for the low latitudinal ones. 4) For the typical rigidity spectrum and middle latitude at the 500 mb altitude $\beta_\delta$ is less on ~40% than at the 1000mb. 5) The softer spectrum of the variations, the larger $\beta_\delta$. For the rather hard variations spectrum near the solar activity minimum $\beta_\delta$ is in 1.5-2.0 times less than the same values in the maximum.

The values β obtained for each station by means of the $\beta_\delta$ are well regulated near the straight line that is illustrated on the Fig.1. This peculiarity has a great practical sense. It makes possible to change function $\beta_\delta(t)$ in formula (1) on the effective time independent value $\beta_\delta^*$, and to use the simple two-parameter formula for β calculations on any station:

$$\beta = \beta_0 + \beta_\delta^* \frac{\delta}{1+\delta} \qquad (3)$$

Parameters $\beta_0$ and $\beta^*_\delta$ were determined for a number of neutron monitors using least square method and computed mean annual values of the CR variations and barometric coefficients. Regression curves corresponding to (3) with these parameters are presented on the Fig.1. Tight correlation (with coefficients up to 0.996) is evident between the calculated CR variations and barometric coefficients.

To make easier obtaining of the barometric coefficient for any neutron monitor the calculations of the $\beta^*_\delta$ were made within the wide range of the atmospheric depths and cut-off rigidities. These results are presented in Table. It makes possible to get $\beta^*_\delta$ for the chosen monitor by means a simple interpolation and then to find $\beta$ for any period. Since the time dependence $\beta^*_\delta(t_0)$ is weak it will not be mistaken to take CR variations $\delta$ relative to those level where $\beta_0$ is known well.

TABLE. The calculated values of the variational barometric coefficients $\beta_\delta$(%/mb)·(-1000) for the neutron monitors with the different cut-off rigidities g and air pressures h.

| g(GV) | h (mb) 500 | 550 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 75 | 77 | 80 | 83 | 87 | 91 | 95 | 100 | 105 | 111 | 116 | 122 |
| 1.0 | 75 | 77 | 80 | 83 | 87 | 91 | 95 | 100 | 105 | 111 | 116 | 122 |
| 2.0 | 70 | 73 | 76 | 79 | 83 | 87 | 92 | 97 | 102 | 107 | 113 | 120 |
| 3.0 | 63 | 66 | 69 | 72 | 76 | 80 | 85 | 89 | 95 | 100 | 106 | 112 |
| 4.0 | 57 | 60 | 62 | 66 | 69 | 73 | 78 | 82 | 87 | 93 | 99 | 105 |
| 5.0 | 53 | 55 | 58 | 61 | 64 | 68 | 72 | 77 | 82 | 87 | 92 | 99 |
| 6.0 | 49 | 51 | 54 | 57 | 60 | 64 | 68 | 72 | 77 | 82 | 87 | 93 |
| 7.0 | 47 | 49 | 51 | 54 | 57 | 61 | 64 | 68 | 73 | 78 | 83 | 89 |
| 8.0 | 45 | 47 | 49 | 52 | 54 | 58 | 61 | 65 | 70 | 74 | 79 | 85 |
| 9.0 | 43 | 45 | 47 | 49 | 52 | 55 | 59 | 63 | 67 | 71 | 76 | 81 |
| 10.0 | 41 | 43 | 45 | 48 | 51 | 54 | 57 | 60 | 64 | 69 | 73 | 79 |
| 12.0 | 39 | 41 | 43 | 45 | 48 | 50 | 54 | 57 | 61 | 65 | 69 | 74 |
| 16.0 | 37 | 38 | 40 | 42 | 44 | 46 | 49 | 52 | 55 | 59 | 63 | 67 |

To compare the real and calculated barometric coefficients the mean monthly values of the $\beta$ were computed for Kiel and Moscow stations over the 1981-1991 years period (Belov et al.,1992).

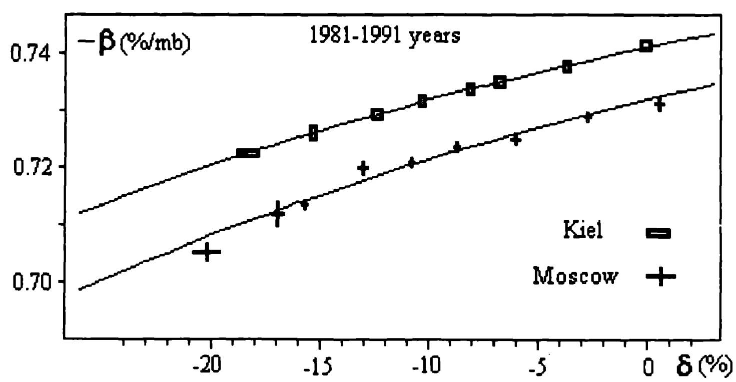


Fig.2: The experimentally found values $\beta$ for Kiel and Moscow stations in dependence on observed variations $\delta$. Height and width of the figures correspond to double rms deflections. Curves are computed by (4) and (5) dependencies $\beta(\delta)$.

Averaged by the groups of close CR variations (in order to reduce the causal effects and reveal the long time variations more reliable) values $\beta$ and $\delta$ are presented on the Fig.2: by rectangles for Kiel and crosses for Moscow. The curves correspond to dependencies computed by means of the experimentally found $\beta$ and $\delta$ for Kiel and Moscow stations:

$$\beta_k = 0.7410^{+0.0002}_{-0.0003} + (0.083^{+0.002}_{-0.008})\frac{\delta_k}{1+\delta_k} \quad (4)$$

$$\beta_m = 0.7319^{+0.0002}_{-0.0005} + (0.095^{+0.005}_{-0.007})\frac{\delta_m}{1+\delta_m} \quad (5)$$

As it has seen from Fig.2, the modulation of the barometric coefficient can be revealed with a good accuracy and experimentally defined values $\beta$ as a whole have a good agreement with the simple two-parameter model (3).

Monthly values $\beta$ calculated for Kiel and Moscow station over the 1958-1991 years by means (4) and (5) are shown on the Fig.3

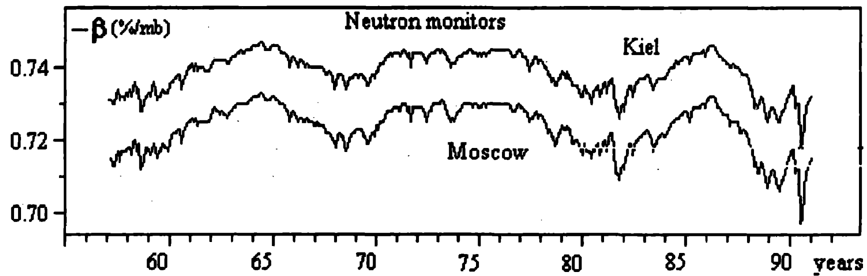


Fig.3: The time dependence of monthly mean barometric coefficients of Kiel and Moscow neutron monitors obtained by means (4) and (5) expressions.

It can be seen that monthly mean values of the barometric coefficient change within the large range. But the experimentally determined modulation of the barometric coefficient for Kiel and Moscow is somewhat weaker than calculated. Perhaps, it indicate of too strong altitudinal dependence of the used response functions. From other side, this modulation is considerable larger than found by Nagashima et al. (1989). The differences of $\beta_0$ and $\beta_\delta$ values for two very similar stations Moscow and Kiel tell about response functions distinction. Perhaps it is caused by a different dead time of these detectors.

## 4. CONCLUSION

Long time modulation of the barometric coefficient forms an appreciable value (>0.03 %/mb for some neutron monitors) and it has to be taken into account. In order to calculate this effect a simple two-parameter approximation may be surely used with the regression coefficients computed in present report. These coefficients really are the variational barometric coefficients for the mean rigidity spectrum of the long time primary cosmic ray variations. As for the annual barometric coefficient the results of the simplified and exact calculations practically are very closely. Good accordance have been observed also for monthly experimentally found coefficients of Kiel and Moscow monitors and calculated by two-parameter expressions. Proposed method gives the basic possibility to account the barometric coefficient modulation by the data observed in real time.

## REFERENCES


Belov A.V.,Dorman L.I.:1986, Geomagnetizm and Aeronomia, 26,4,209
Belov A.V.,Dalgatova Ch.I.,Eroshenko E.A.,Roehrs K.:1992. Geom. and Aeron.32,6
Belov A.V.,Guschina R.T.,Dorman L.I.,Sirotina I.V.:1990.Geom. and Aeron.,30,4,558.
Belov A.V.,Guschina R.T.,Sirotina I.V.: 1993, present conference
Dorman L.I.: 1972,Meteorological effects of Cosmic Rays., Moscow:"Nauka"
Dorman L.I.,Yanke V.G.: 1979, Izvestia ANSSSR,ser.phys.,43,12,2628.
Griffits W.K.,Harman C.V.,Hatton C.G.,Ryder P.:1965, Proc.Int.Cosmic Rays Conf.,1,475
Nagashima K.,Sakakibara S.,Murakami K.,Morishita I.: 1991, Nuovo Cimento,IL,12C.,2,173