Estimation of detectors stability of the neutron monitors network

Asipenka A.*, **Belov A.***, **Gushchina R.***, **Eroshenko E.***, **Kobelev P.***, **Yudachin K.*** **and Yanke V.***

*Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation RAS (IZMIRAN), Moscow, Russia

***Abstract*. Results of continuous monitoring are the experimental basis for great number of works devoted to investigations of cosmic rays variations. In this work independent and complementary methods of detector stability estimation are used. Quantitative estimations of relative efficiencies have been received for the retrospective data with the average daily resolution.**

***Keywords*: neutron monitors network, detector stability**

I. Introduction

Data quality of the neutron monitor network depends on the detector stability itself, on the way of correction and data processing. First of all, it is corrections for the barometric effect. For accurate correction it is necessary to have precision atmospheric pressure (with accuracy of 0.1-0.2 mb for the minute data and more accurate for the hourly data) and the right barometric coefficient which depends on registered particles spectrum modulated by a solar wind [1]. The possible false variations connected with this can reach of 1 %. A special case is the data processing during the arrival of solar cosmic rays [2]. Besides, for some stations the additional processing caused by special environmental conditions in areas of their location is required. It concerns mountain and high-altitude stations. For example, on a number of stations wind speed often reaches 20-40 m per sec. Due to the Bernoulli effect the pressure measured on the ground level is not as much as the weight of air column defining the barometric effect for cosmic rays. The error caused by this effect can reach 1-2 % [3]. For some middle-latitude and low-latitude mountain stations, snow is a very big problem as well. The snow cover over the detector is an additional absorber that decreases the counting rate of a detector. The effect is very great and sometimes it can reach of 8-10 % [4]. The similar situation can last for some months. All the corrections listed above can be considered both in real time and in retrospective.

The control of the ground-level cosmic rays detectors themselves and the quality estimation of their data can be both internal and external. Division of the detector into some (≥ 3) similar modules (sections or channels) and comparison of these modules data among themselves are the basical for the internal control methods. Such methods have doubtless advantages. It keeps data continuity and enables the constant control and it is easy for automation. A principle of the method is: for every n channels and for present time variations relating to some base period are calculated. If detectors work well, then variations of all channels should be the same with the accuracy defined by statistics. All possible channel ratios, (their amount is n^2) up to statistical error should be equal 1 in this case. If this condition is not carried out the channels defining these ratio are damaged, i.e. they have changed their efficiency. In paper [5,6] the method realising the described algorithm and allowing to define the efficiency for every moment and its error is developed. Detector efficiency is a number that is necessary as divider of observable count rate to get rid of variations depending on the detector changes. If the channel efficiency is within corridor limits of 3σ the channel is considered operable. Otherwise this channel is excluded further from the total resulting before clearing up the reasons of such response.

The primary data processing of the ground-level CR observations is usually carried out at the station, directly where the data have been received.At the present stage the primary processing and preparation of full experimental material in real time is very important as now the increasing number of experimental data is integrated in Internet resources in real time and in the same mode is used for the practical problems decision. Below we will consider two methods: a method based on the comparison with variations model (the modell method) and a method based on comparison of variations of stations with similar characteristics (the rations method).

II. The model method.

Comparing the variations expected according to any model, and the observable variations it is possible to judge by the discrepancy not only about model goodness of fit, but about stability of the detector work. However, such approach does not allow to divide these two sources and for their division it is necessary to estimate one of the sources independently. For the model construction we have developed a version of the global shooting method, specially adapted for studying of longtime variations. In this case the analysis was carried out by the daily average database of the neutron monitor network. The observable variations $\delta I^i/I^i$ can be introduced as $\delta I^i/I^i = \int \delta J/J(R) W^i(R, R^i_R, h^i) dR$, where $\delta J/J(R)$ is a spectrum of isotropic variations, and the discrepancy σ^i depicts lack of fit of the used variations

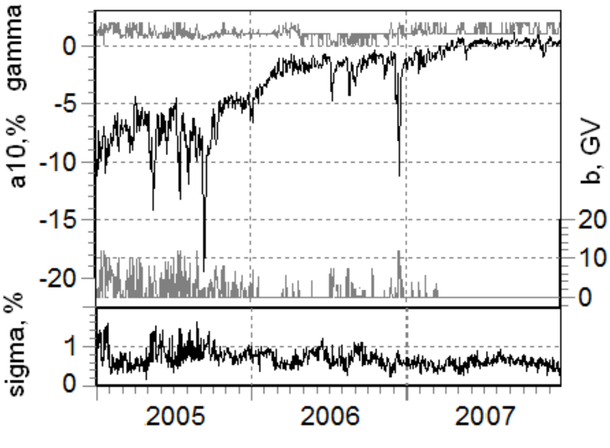

Fig. 1: Parameters of variations spectrum of the galactic CR a, b and γ; on the bottom - the model discrepancy.

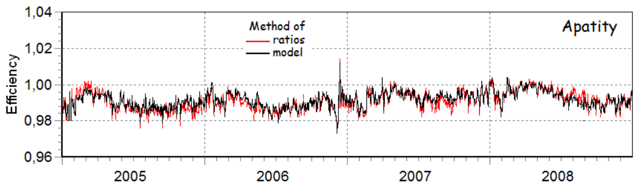

Fig. 2: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Apatity station.

model and possible instrument variations. The coupling functions $W^i(R, R^i_{R_c}, h^i)$ is from [10]. In the model the variations spectrum is set in three-parameter form and defined as $\delta J/J(R) = a/(b+R)^\gamma$. The parameters field of uses $b = 0 \div 12$ and $\gamma = 0 \div 2$ R is measured in GV. It was shown before [11] that three-parameter approximation of the variations spectrum of galactic CR is good for the discription of the longtime variations spectrum in the range of 5-50 GV. While calculating the noted above equation system for ~ 40 stations the parameters a, b and γ that are shown in Fig. 1. were defined.

On the bottom panel root-mean-square deviations of the variations received directly from the experimental data and variations defined from the model are resulted. The dimension of deviations gives the chance to estimate goodness of fit of applied variations model as a whole. It is important to choose the base period as it allows to calculate variations. In our case the base period is April, 2008. At the model construction the daily average data from 38 operating stations were used. More then a half of them are being updated in real time [12].

The discrepancy between observed and expected according to model variations, characterises both stability of the given detector and the model goodness of fit. But to divide these two characteristics it is necessary to involve another independent method of the detector stability.

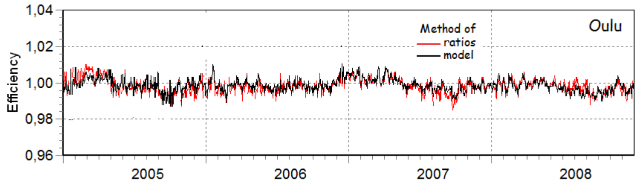

Fig. 3: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Oulu station.

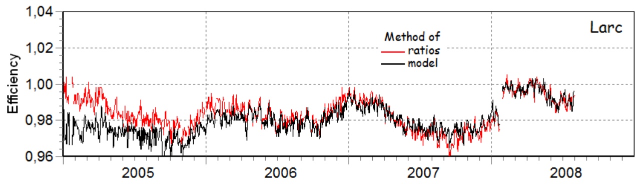

Fig. 4: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Mc-Murdo station.

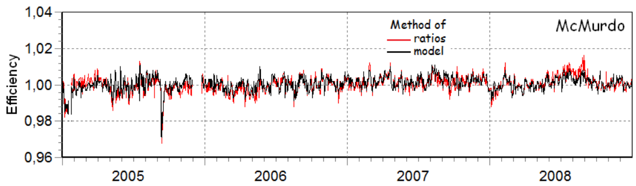

Fig. 5: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Larc station.

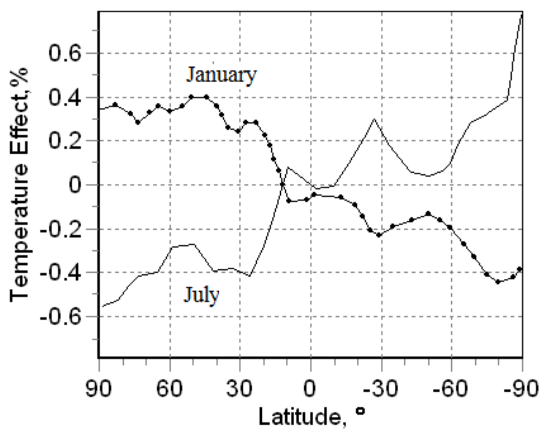

Fig. 6: Latitudinal dependence of expected temperature variations for winter and summer month for $20E$.

III. The rations method.

The method originally developed for internal quality control of CR detectors data, is adapted for analysis of longtime stability of the stations network detectors. Application conditions of the rations method for a problem of the analysis of detectors longtime stability is the presence of similar stations group with very close characteristics, for example, with close effective rigidities of registered particles. The fact that the given

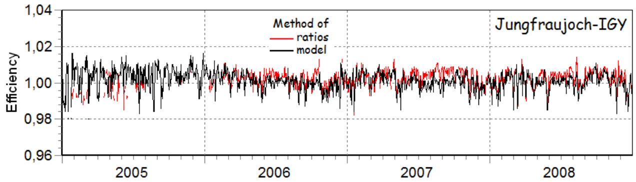

Fig. 7: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Jungfraujoch station. Base period - April 2008.

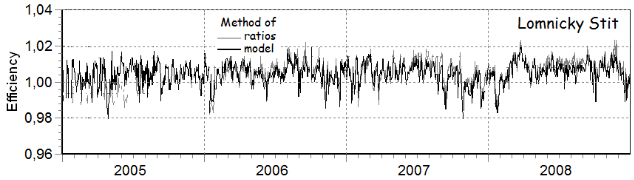

Fig. 8: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Lomnicky Stit station.

approach does not rest on any model is its advantage. The lack of the considered method is necessity of allocation of stations group with close characteristics. Thus even in one enough narrow group the real (not connected with quality of the data) variations of various detectors will not be completely identical. We considerd 4 stations groups: high-latitude (more then 25 detectors), group ($R_c = 3 \div 6$ GV) - Baksan, Hermanus, Irkutsk, Jungfraijoch, Lomnitsky Stit, group ($R_c = 6 \div 10$ GV) - -, Athens, Rome, Tbilisi, Potchefstroom, Tzumeb and the last group ($R_c => 10$ GV) - Beijing, ESOI, Santiago, Thailand.

IV. Results and discussion

In Fig. 2-5 results of the efficiency estimation found by two methods for some high-latitude stations are compared. Base period is April. The detail coincidence of efficiencies found by two methods testifies in favour of the both methods. Besides, such coincidence points to the insignificant contribution of the model lack of fit as the efficiency change defined by the rations method is caused only by instability of the detector work.
For stations of the northern hemisphere at the expense of temperature effect it should be observed negative wave, and for southern hemisphere stations - a positive seasonal wave as it follows from Fig. 6 (see also [12]). For Apatity station the annual temperature wave is clear expressed, unlike the weaker annual temperature wave at Oulu station though they are located in one region. We have only several high-latitude stations data in the southern hemisphere. At McMurdo and Sanae stations the positive annual wave practically is absent. Larc station behaves not clearly: the annual wave approximately twice is more in amplitude and is not conformed in phase with annual wave typical for southern hemisphere stations. It seems that it related with the local temperature effect of some equipment elements.
In Fig. 7-8 time efficiency changes for two stations of $Rc = 3 \div 6$ GV group are shown. The third roup with $Rc = 6 \div 10$ GV (Fig. 9-10) as well as the second one is not numerous group, but the number of stations is enough to receive confidently the efficiency values by ratio method for the whole observable period.

For the fourth group with $R_c > 10$ GV (Fig. 11-14) the rations method practically does not give any results

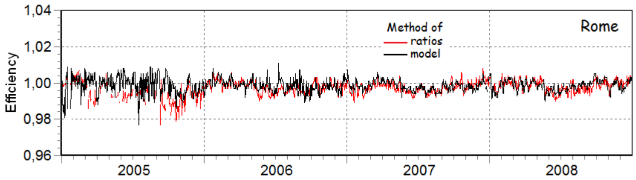

Fig. 9: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Rome station. Base period - April 2008.

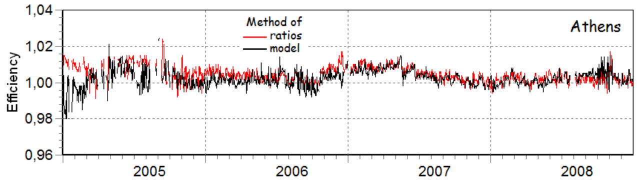

Fig. 10: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Athens station. Base period - April 2008.

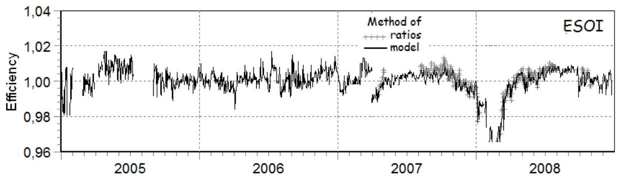

Fig. 11: Efficiencies received by the model method (black curve) and by the ration method (red curve) for ESOI station. The specific efficiency response in 2007-2008 years is related with uncorrected for the snow effect data. Base period - April 2008.

as there are not enough stations. For example, for ESOI station it is possible to receive efficiency only for the end of 2007 and since March 2008. Character of the efficiency response at the turn of the years is caused by that the data not corrected for snow for this period were used. At Beijing station a very big seasonal effect related with local hardware temperature effect is visible. For Thailand station it is a very short period of observations. However, in all cases when it was possible to receive efficiencies for the both independent methods, the agreement always was very good, and the model method always allows to define efficiency of station.

The efficiency analysis shows that for the majority of stations for the considered period efficiency is constant

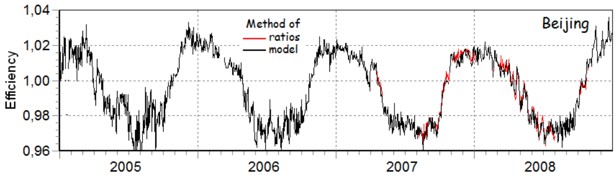

Fig. 12: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Beijing station. Base period - April 2008.

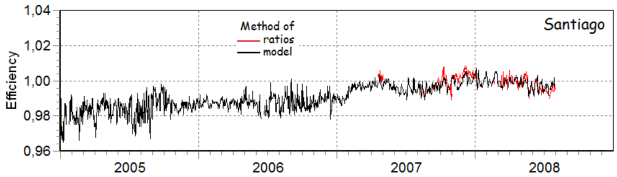

Fig. 13: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Santiago station. Base period - April 2008.

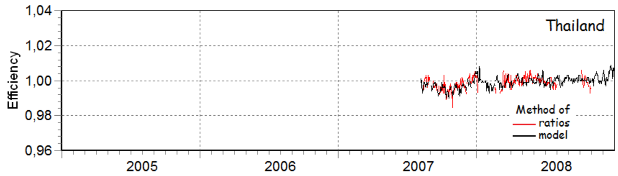

Fig. 14: Efficiencies received by the model method (black curve) and by the ration method (red curve) for Thailand station. Base period - April 2008.

within the several tenth of %, i.e. within the error of efficiency definition. For some stations (for example, Santiago, Fig. 13) constant drift approximately of 0.7 %/year is observed. For others - the anomalously big annual seasonal effect of (2-4%) is observed (Fig. 12). The part of this effect $< 1\%$ is caused by the temperature effect of neutron component. Another part appears apparently because of the local temperature change influencing the elements of electronic route though the stations have quite good longtime stability. Basically efficiency changes have sporadic character that is probably connected with the human factor. Hardware variations can be classified as 1) daily and seasonal connected with temperature changes; 2) longtime connected with change of gauges properties; 3) and sporadic hardware variations.

The big sporadic changes of the efficiency can be caused by several reasons. A part of them are problems with high-voltage power supplies: leak of charge (microbreakdowns) on the high-voltage circuit; deficient stability of high-voltage power supplies; malfunction of the antihunting circuit. Besides, for some stations especially mountain ones the snow effect is very important. This effect can lead to total distortion of variations [4].

V. Conclusions

1. For the observable period 2005-2008 the coincidence of efficiencies definded by two methods indicates applicability of the both methods in details. Besides, it is shown that our variation model works well for the whole range of rigidities interesting us.
2. The model approach gives the chance to estimate the long-term stability of each station work qualitatively and quantitatively. The accuracy is defined by goodness of fit of the used CR variations model.
3. The ratio method doen't depend on the model of variation and for group stations of close cut off rigidity if allow to define the long-term drift of eatch station. It is well working for about 25 polar and subpolar stations. However, for the stations of higher cut off is difficult to form group with sufficient number of stations with close characteristics/ This is a lack of such an approach.
4. Details coincidence of results of both methods indicates sufficient goodness of fit of the model as the efficiency change defining by the ration method is caused only by instability of the detector.
5. All stations approximately can be divided into three equal groups. For the best stations the characteristic drift can reach of 0.03 %/year. For another less stable group drift can be 10 times more. For the last group (with the worst quality) drift is the secondary factor, quality f the data is defined by numerous sporadic changes.

Acknowledgements

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