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Estimate of long-term detector stability of the worldwide neutron monitor network

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Results of continuous monitoring of cosmic rays (CR) by the neutron monitor (NM) network are the experimental basement for a large number of papers studying CR variations. The problem of long-term stability of NM detectors is extremely important. In this work two independent methods for estimate of the long-term stability of NM are used. Quantitative estimates are obtained for detectors operating more than one solar cycle.

1. Introduction

More than 50 years researchers have such a powerful instrument as a worldwide NM network. The purpose of this work is to determine a data quality of each station. This problem was considered already [1]. In order to estimate quantitatively a data quality one need some standard. Arbitrary unjustified approach is used, when some "reliable" station is adopted as such a standard. A number of stations have a reputation of "reliably" working, but it is difficult to use them as the standard, because each station is sensitive to a particular part of the CR spectrum. Here we use the model of CR variations as the standard. A discrepancy with the model for a particular station we describe by the data quality of this station. Surely this approach has its own disadvantages since a construction of adequate model is a complex problem itself. But this problem is resolved by the method of successive approximations, if the model for corresponding changes is rather succeeded describing CR variations in the heliosphere for fifty years of the observations. We have elaborated the second independent method estimating a stability of the station operation, which is called the method of ratios. In this method a given set of stations (with nearly equal effective rigidities of registered particles R_{eff}) is divided into groups of "reliably" and "non-reliably" working by the elaborated algorithm. In this case a group of stations having similar variations and defined as "reliably" working determines the standard, moreover they should be in majority. This method allows determining an efficiency of each station and an accuracy of this estimate. Each method has its own advantages and limitations, but basing on both of them it is possible to get reliable quantitative estimates of long-term detector stability for the worldwide NM network. The analysis has been performed basing of monthly average values obtained by averaging of hourly data published in [2].

2. Model method

In [3] a variant of the global survey was elaborated for studying of long-term variations. The analysis was performed by using monthly average data of NM's (45 stations), stratospheric (3 stations) and ionization chamber (2 stations) observations. The observed variation $\delta I^i / I^i$ can be expressed as $\frac{\delta I^i}{I^i} = \int \frac{\delta J}{J}(R) \cdot W^i(R, R^i_{R_c}, h^i) \cdot dR + \sigma^i$, where $\delta J / J(R)$ - a spectrum of isotropic variations, and a discrepancy reflects some problems of the model and possible instrumental variations. The coupling coefficients $W^i(R, R_{R_c}, h^i)$ are adopted from [4]. The model which is given by

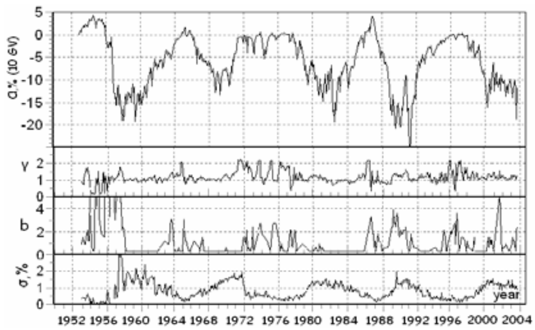

Figure. 1. Parameters of galactic CR spectra variations a_0, γ and b; below – a discrepancy of the model.

$\delta J / J(R) = a_0 / (b + R^{\gamma})$; parameter changes are within $b = 0 \div 10$ and $\gamma = 0 \div 2$, if R is given in GV. The approximation of three parameters for galactic CR spectra variations is suitable for description of long-term spectra variations in the range of 5-50 GV as shown in [3]. Only a few stations continuously operate during 5 cycles of SA. Some stations were closed, another open. In order to account a varied number of stations and make an influence of possible detector drift for so long time the spectra were calculated for several base periods. As a result all variations have been determined relatively the base period of 1976. Fig. 1 shows the obtained parameters of galactic CR spectra variations a_0, b и γ. The bottom panel presents average square deviations of experimental data and the model, which allows estimating an appropriateness of the model proposed.

3. Method of ratios

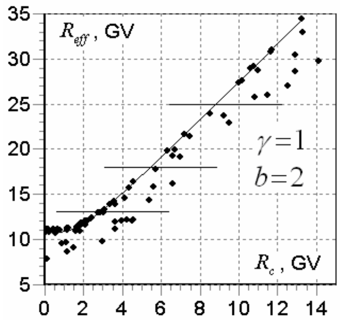

Figure. 2. Effective particle rigidity for different stations; sea level stations are at the curve; high altitudes stations are below it.

This method was elaborated for internal control of data quality of CR ground based detectors. During the earlier stage of network creation a transfer from the 2-section IGY monitor (where it was possible ascertaining instrument variations only) to the 3-section NM64 neutron monitor, when a variation comparison between different, but one type sections, allows to select a defective section. Modern methods of internal control are based on dividing of a detector into maximal possible number of identical and independent elementary detectors (this is a number of counters in a case of NM). This approach allows determining a relative efficiency of each elementary detector, i.e. this method provides a tool for permanent control of data quality [5]. The detector efficiency can be defined as a number, by which should be divided the observed count rate to remove variations associated with changes of the detector itself. The method of ratios was adopted for the analysis of long-term detector stability of the NM network. A condition of applicability of the method for analysis of long-term detector stability is forming groups of stations with very close characteristics, for instance, similar effective rigidities of registered particles. We considered 4 groups of stations with effective rigidities of registered particles <13, 13-18, 18-25, >25 GV (Fig. 2). It is an advantage of this approach that it is not model dependent. Its disadvantage is a necessity to consider group of stations with close effective rigidities of registered particles.

4. Discussion and conclusions

A detailed coincidence of efficiencies found by the two methods supports both of them. The analysis of

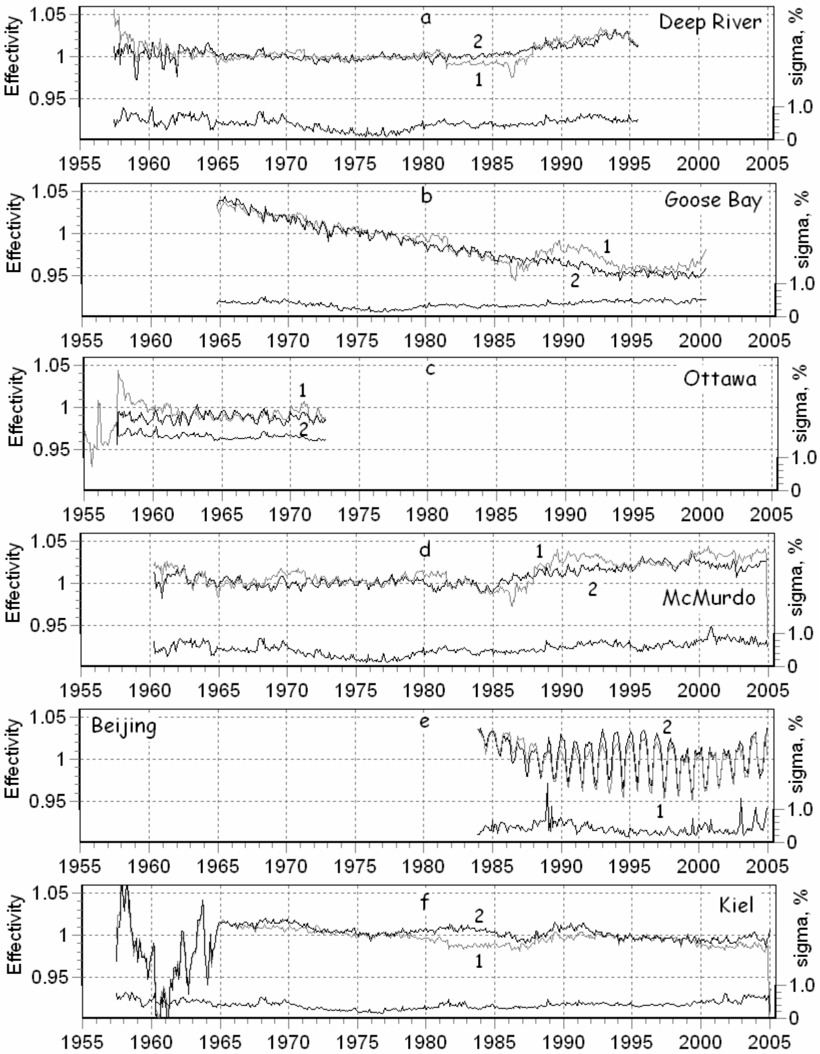

Figure. 3 Efficiencies obtained by different methods (the model method – gray curve 1; the ratio method – black curve 2. The level of 1976 year is unit.

Efficiencies shows that a constant drift by about ± 0.1 %/year is observed for many stations during the whole or, at least, rather long period of observations (Fig. 3a). The largest drift, of about -0.4 %/year, is for data of the Goose Bay station (Fig. 3b). Yearly wave is clearly observed for high latitude stations with amplitude about 1 %, opposite in phase in the North and South hemispheres (Fig. 3c, 3d; Ottawa и McMurdo). It is caused by the temperature effect of neutron component and is negligibly small for equatorial stations [7]. For some stations (see Fig. 3e, for Beijing and Tibet; less for Fort Smith) anomalously large temperature effect (2-4%) is observed. Partly this effect, about 1 %, is caused by the temperature effect of the neutron component, the last part is due to local temperature changes effecting on elements of electron tract, although the Beijing station has a reasonably good long-term stability. Characteristic change of the efficiency is presented in Fig 3f, where a moment of the detector change from IGY to NM64 is well seen. In general changes of the efficiencies have a sporadic character and, apparently, are caused by a human factor. Instrument variations (or drifts) can be classified as 1) daily and season, associated with temperature changes; 2) long-term, associated with properties of probes; 3) sporadic instrument variations. If periodic variations are rather easy separated and corrected than in a case of long-term instrument drift it is very difficult. The largest error in data (up to 0.1 %/year) appears due to the pressure drift. A usage of constant barometric coefficient leads to a false 11-year wave with amplitude up to 0.1 %. Large sporadic changes of efficiencies can be caused, at least, by two reasons. The first is a charge leakage (micro breakdown) along high voltage circuit. The second is low stability of high voltage supply (or malfunction of stabilization scheme). Besides, for some high altitudes stations the snow effect is very important. This effect may lead to a total distortion of variations.

The above discussion allows us to conclude:

1. The model method, when a discrepancy between the modeled and observed variations for each is attributed to data quality, provides a possibility qualitatively and quantitatively verifying long-term stability of each station from the network. A suitability of the model used for CR variations as well as a quality of data sewing between different epochs determines an accuracy of the method.

2. The method of ratios is model independent. In this case for a group of stations with similar effective energy a long-term drift is determined for each station. However not for all energy intervals it is possible to find more than 6 identical stations working simultaneously; this is a disadvantage of such approach.

3. The coincidence in details between efficiencies found by two methods shows a possibility to use both methods. Besides our model of variations describes rather well CR modulation for all 50 years of observations, excluding the region of small rigidities. The South Pole station is an example.

4. For the best stations (about 10) the drift is about 0.04 %/year and comparable with amplitude variation obtained using all data and presented in Fig. 1; this value is comparable with error and equal ~ -0.01 %/year for the period of 1976 - 1997.

5. A stability of about 30 stations working several tens of years is better that 2 % for the whole period of observations. However sporadic changes of the efficiency is characteristic for many of them. The characteristic drift is about $\pm$ 0.1 %/year.

6. For many stations (about 40) the data drift is on the second plan, the data quality is determined by numerous sporadic changes.

7. The whole analyses of the network of CR stations is presented in [6].

4. Acknowledgements

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