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Cosmic rays intensity and atmosphere humidity at near earth surface

V V Oskomov, A N Sedov, N O Saduyev, O A Kalikulov, A Zh Naurzbayeva,
N Sh Alimgazina, I E Kenzhina

Institute of Experimental and Theoretical Physics of Al-Farabi Kazakh National
University, 71 al-Farabi Ave., Almaty, Kazakhstan

E-mail: kenzhina_inesh@mail.ru

Abstract. Experimental studies of estimation the mutual influence of humidity and flux of cosmic rays in first approximation were carried out. Normalized cross-correlation function of time series of neutron monitors count rate and level of relative atmosphere humidity near cosmic rays registration point is studied. Corrected and uncorrected on pressure minute and hour data of 6NM64 neutron monitor count rate were used for the study. Neutron monitor is located in Al-Farabi Kazakh National University, at an altitude of 850 m above sea level. Also, data from NM64 neutron monitor of Tien Shan mountain research station of Institute of Ionosphere, located at an altitude of 3340 m above sea level were used. Uncorrected on pressure cosmic rays intensity better reflects the changes in relative atmosphere humidity. Average and sometimes strong relationship is often observed by time changes of atmosphere humidity near the point of cosmic rays detection and their intensity: the value of normalized cross-correlation function of respective signals, even in case of their long duration and a large number of data (eg, for minute changes at intervals of up to several months) covers 0.5 - 0.75 range, sometimes falling to ~ 0.4 .

1. Introduction

Determination of atmosphere humidity at near Earth's surface is one of the most important tasks of hydro-meteorological and glaciological observations carrying out in agriculture, hydropower and water supply. Existing contact measurement methods are inefficient, time-consuming, and their accuracy is relatively low [1].

It is necessary to estimate the degree of mutual influence of humidity and flux of cosmic rays for experimental studies. In the first approximation it can be made by examining the normalized cross-correlation function of time series of neutron monitor count rate and the level of relative atmosphere humidity near the registration point of CR (cosmic rays) [2-3].

II. Method and calculations

Corrected and uncorrected on pressure minute and hour data of 6NM64 neutron monitor count rate were used for the study. Neutron monitor is located at al-Farabi Kazakh National University, at an altitude of 850 m above sea level. Also, data from NM64 neutron monitor of Tien Shan mountain research station of Institute of Ionosphere, located at an altitude of 3340 m above sea level were used. As well, data on changes in relative humidity were used, obtained from meteorological Tien Shan mountain station near Almaty, located at $43^{\circ} 15'N$, $76^{\circ} 57'E$. and at a height of 848 m above sea level [5].



The majority of neutrons (over 90%) are produced in nuclear reactions such as "evaporative stars." In these reactions, the high-energy cosmic-ray hadrons collide with atmosphere nuclei, creating new unstable nuclei that emit secondary particles. The task is to calculate the average number of neutrons at different heights in the air to estimate their interaction with nuclei of material (elastic and inelastic scattering, absorption) and also to calculate the number of neutrons crossing the horizontal plane at different heights, that is neutron fluxes [6].

The flow of primary particles N depends on the height exponentially:

$$N = N_0 \cdot \exp\left(-\frac{x}{L}\right) \quad (1)$$

Here, x – thickness of layer (g/cm^2), passing by cosmic radiation is measured from top of atmosphere;

L – thickness of material layer, weakening the flow of e ($L \cong 140 \text{ g}/\text{cm}^2$);

N_0 - nominal flow of particles at the border of atmosphere.

The average number of neutrons, "evaporated" by unstable nucleus is denoted as N_k (for air $k=1$). The distribution of evaporation neutrons at energies is well described by expression:

$$\frac{\Delta N_k(E)}{\Delta E} = \frac{E}{\tau_k^2} \cdot \exp\left(-\frac{E}{\tau_k}\right) \quad (2)$$

Where τ_k is the average temperature (energy per nucleon) of unstable nuclei in the k substance.

These neutrons have energies of a few MeV order. The angular distribution of born neutrons is isotropic. The energy spectrum of neutrons is described satisfactorily by "evaporation" model. The generation of low-energy neutrons can be described by the following expression:

$$Q(x, E) = \int_{(E^*)}^{(E)} N_{ucn}^k(E^*) \frac{dn_{ucn}^k(E^*, E)}{dE} \cdot \mu_n^k \cdot \Phi_n(x, E^*) dE^* \quad (3)$$

Hadron component of cosmic rays at sea level consists mainly of high-energy neutrons, and its distribution can be written as:

$$\Phi_n(x, E^*) = \varphi(E^*) \cdot \exp(-\mu_1 \cdot x) \quad (4)$$

where:

$\varphi(E^*)$ - energy spectrum of neutrons at sea level at high energies ($E > 10\text{-}100 \text{ MeV}$)

$\mu_1 = 140 \text{ g}/\text{cm}^2$ – path of high energy neutron absorption in atmosphere.

"Evaporative" neutrons with energies of 1 MeV due to elastic and inelastic scattering on atoms nuclei are slowed down to thermal energies. Thermal neutrons are eliminated from the flow due to radiation absorption forming gamma rays, proton or other particles.

For the calculation of neutrons passing through the substance are given the interaction cross-section σ_{jm}^{tot} , σ_{jm}^{el} , σ_{jm}^a (full, elastic and absorption, respectively) with the atoms of the j element in the m neutron energy gradation (the average energy of gradation is E_m).

The calculations take into account the interaction of neutrons with the nuclei of atmosphere atoms.

III. Results and discussions

It was found that the uncorrected intensity of CR on pressure better reflects the changes in relative humidity of atmosphere: the value of normalized cross correlation function between the humidity and uncorrected counting rate of NM (neutron monitor) for all examined periods of time is considerably higher than in the case of corrected values of count rate. This is understandable when you consider that the air pressure depends on level of atmosphere humidity.

Average and sometimes strong relationship is often observed by time changes of atmosphere humidity near the point of cosmic rays detection and their intensity: the value of normalized cross-

correlation function of respective signals, even in case of their long duration and a large number of data (eg, for minute changes at intervals of up to several months) covers 0.5 - 0.75 range, sometimes falling to ~ 0.4 . The phase shift between these signals is typically about 10 hours.

Figures 1 - 3 shows correlation functions of time series of NM count rate and relative humidity for a period of time, confirming the above findings.

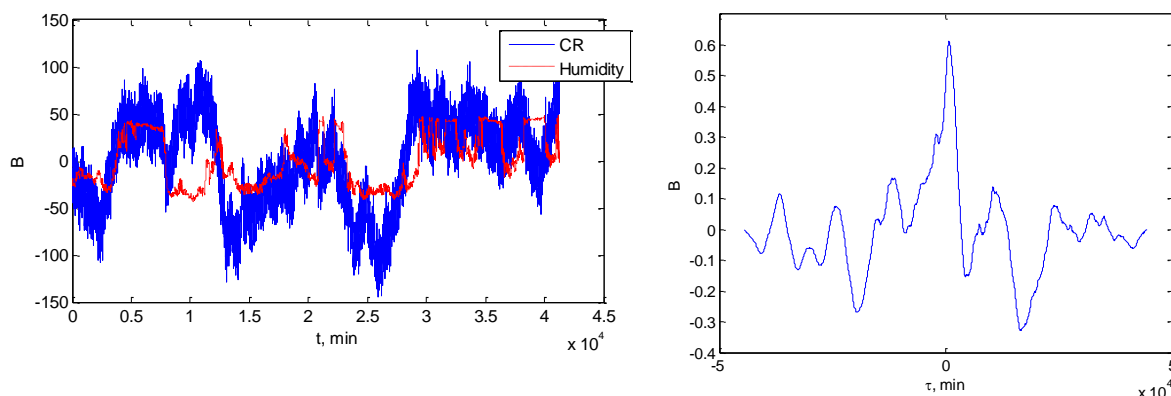


Figure 1. Time series of deviations from the average minute values of NM count rate and relative humidity at Tien Shan mountain station and normalized cross correlation function of the series for January 2014

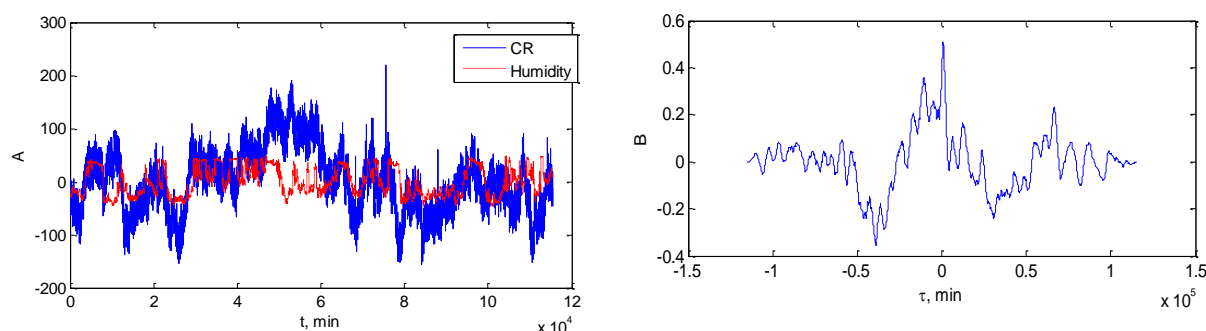


Figure 2. Time series of deviations from the average minute values of NM count rate and relative humidity at Tien Shan mountain station and normalized cross correlation function of the series for March 2014

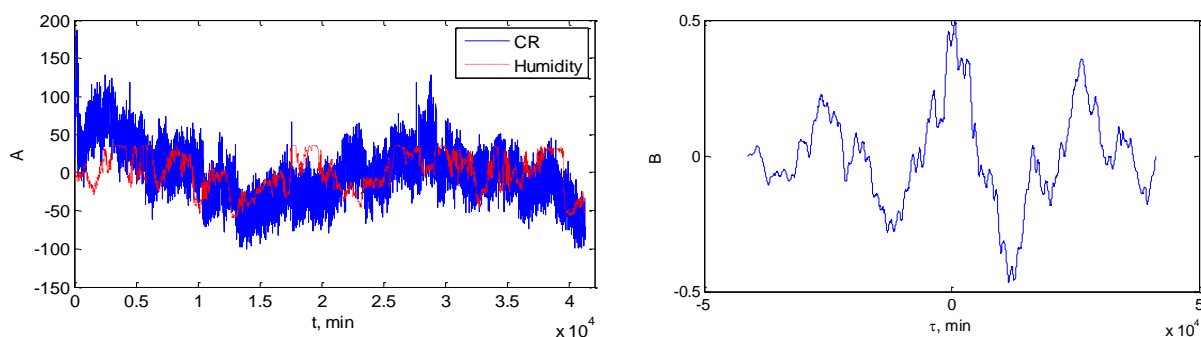


Figure 3. Time series of deviations from the average minute values of NM count rate and relative humidity at Tien Shan mountain station and normalized cross correlation function of the series for September 2014

III. Conclusion

Thus, the correlation between the intensity of cosmic rays and atmosphere humidity near the Earth was investigated.

It is planned to conduct further numerical study of mutual influence of humidity and the intensity of CR using the techniques such as wavelet analysis, analysis of phase synchronization, and others.

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