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III-4-12. Atmospheric Effects of Extensive Air Showers of Various Mean Sizes

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The barometric and temperature effects of extensive air showers (EAS) in mean sizes interval of 10^4 to 10^6 particles at 100 m above sea level have been determined.

1. EAS frequencies data have been obtained with *G-M* counters by the coincidences and anticoincidences methods. The counter trays areas are 0.17, 0.5 and 1.0 m² and distances between them 3.8, 40, 57 and 80 m. The arrangement consists of 36 counter trays, total area of which is equal to 12 m². The observations for various mean sizes of EAS are simultaneous and have been carried out since 1958 in Yakutsk, at 100 m above sea level.

The atmospheric effects of EAS frequencies arise because of both shower number spectrum (that results mainly in the barometric effect) and scale deformation of lateral distribution function of shower particles (that results in the geometrical effects) when atmospheric pressure and temperature change.

The atmospheric effects of both types are considered.

2. The geometrical effects for all types of shower registration in distinction from the method applied usually[(1), 2) and other)] have been estimated differentiating the function W (W is shower registration probabilities integrated over the whole plane of the arrangement) along the parameter R (which is defined below) of particles lateral distribution function.

The last was approximated irrespectively of EAS sizes in form

$$\varphi(r, R) \propto \begin{cases} r^{-1} \times \exp(-r/R) & \text{for} \quad r < 100\,\text{m} \\ r^{-2.6} & \text{for} \quad r > 100\,\text{m} \end{cases}$$

where

$R = R_0 \times (H/H_0)$, $R_0 = 55$ m, H—geometrical height of atmosphere layer near the ground where barometer decreases by 100 millibars $H_0 = 930$ m—mean value of H in Yakutsk.

* This paper was combined with III-4-13 and presented by D. D. Krasilnikov.

The differential number spectrum of EAS in these calculation has been taken in form:

$$K(N) \propto \begin{cases} N^{-2.4} & \text{for} \quad N \lesssim 10^5 \\ N^{-2.7} & \text{for} \quad N \gtrsim 10^5 \end{cases}$$

The geometrical effects in reference to 1m of H change for frequencies of shower detected by method of n-fold coincidences with counters area σ and distances D are given by the formula:

$$\alpha_H(n, \sigma, D)\% m^{-1} = \frac{100}{C(n, \sigma, D)} \times \int_0^\infty K(N)\, dN \times \frac{\partial W}{\partial R} \frac{\partial R}{\partial H}$$

The calculated values of geometrical effects for some types of $C(n, \sigma, D)$ are presented in table I. In lines 5 and 6 there are given for comparisons the barometric and temperature coefficients of geometrical effect, which correspond to the change of H due only to the temperature change when the barometer remains constant (β_T) and vice versa (β_h).

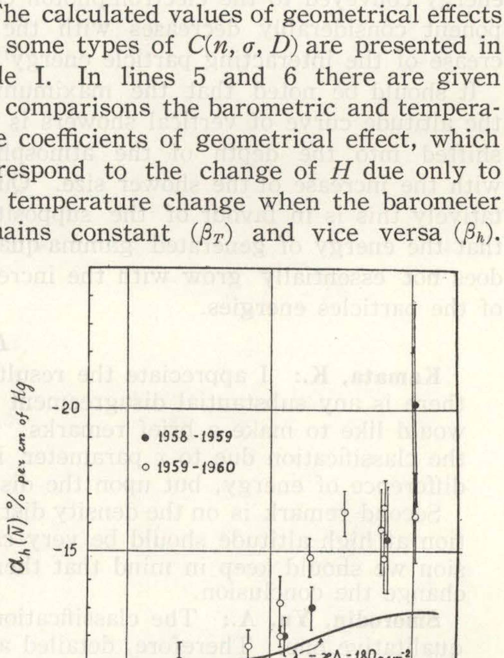

Fig. 1. The observed barometric coefficients for EAS of various mean sizes after correction for geometrical effects. Solid line-expected barometric coefficients in case $\lambda = 180$ g/cm² for EAS of any size.

Table I

separation distance D	3.8 m			57 m		
$C(n;\sigma;D)$	C(3;1.0;3.8)	C(3;0.5;3.8)	C(3;0.17;3.8)	C(6;1.0;57)	C(6;0.5;57)	C(6;0.17;57)
$\bar{N}$	1.5×10^4	2.5×10^4	7×10^4	1.2×10^5	2.1×10^5	6×10^5
$\alpha_H(n;\sigma;D)$, %m^{-1}	−0.06	−0.07	−0.09	0.013	0.010	0.008
β_T, % (°C)$^{-1}$	−0.21	−0.26	−0.33	0.050	0.035	0.028
β_h, % (mb)$^{-1}$	0.053	0.066	0.084	−0.012	−0.009	−0.007
$\beta_T(d)$, (°C)$^{-1}$	-0.26 ± 0.02			0.035 ± 0.015		

The estimations of α_H, α_T and β_h have been made with accuracy~10%. In the last line there are given the temperature effects estimated according to the usual formula[1),2)] using the exponent d of D-dependence curve measured by us[3)] (in the regions of small deviations of D it may be described as $C(D) \propto D^{-d}$).

$\bar{N}$ is mean (median) size of EAS.

A comparison of this method with the usual formula of estimation of EAS geometrical effects shows a satisfactory agreement. But our method is more convenient in practical application allowing one not to go into details of complicated relations between pressure h and temperature T.

3. The barometric coefficients. The daily frequencies data for observed EAS after a corresponding correction for geometrical effect (according to table I and proceeding from every day aerological data on changes of height H at the station of shower observation) have been plotted in $\log C(n,\sigma,D)_H - h$ scales. The results of determinations of barometer coefficients are presented in Fig. 1. The solid line represents the expected barometric coefficients estimated using relationship $\lambda=\gamma\Lambda$ and assuming shower particles absorption length $\lambda=180\ \text{g/cm}^2$ irrespectively of shower size and exponent of EAS integral number spectrum $\gamma=1.4$ for $N<2\times10^5$ and $\gamma=1.7$ for $N>2\times10^5$.

It is seen that the measured barometric coefficients do not agree with the assumption of constancy of shower particles absorption length. The shower attenuation length corresponding to the measured barometric coefficients decreases from $\Lambda=130\pm4\ \text{g/cm}^2$ for EAS of $\bar{N}\lesssim5\times10^4$ to $\Lambda=82\pm3\ \text{g/cm}^2$ at $\bar{N}\simeq10^6$.

The observed decreases of Λ and λ with the increase of $\bar{N}$ are impossible to explain either by incorrect estimation of the geometrical effects or by the increase of exponent γ. This is testified by our results of consideration of EAS number spectrum and of seasonal variations of shower frequencies.

The conclusion on the independence of shower particles absorption length λ on the shower size was obtained in work (4). Their conclusion is in our opinion erroneous and is due partially to the over-estimation of γ by these authors and partially to their simplified estimation of geometrical effects.

We think that these results indicate about the change of the character of EAS development at shower size $N\simeq10^5$. This change may be associated with the corresponding increase of heavy nuclei fraction in primaries or with a change of multiplicity and composition of secondaries at energy region $E\gtrsim10^{14}-10^{15}$ eV. It is also possible that the increase of the exponent γ in sea level number spectrum of EAS is connected partially with this change of EAS development.

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