The Effect of Lunar-Tidal Oscillation of the Atmosphere on the Intensity of the Hard Component of Cosmic Rays

A. I. KUZ'MIN AND G. V. SKRIPIN
Yakutsk Branch of the Academy of Sciences of the USSR

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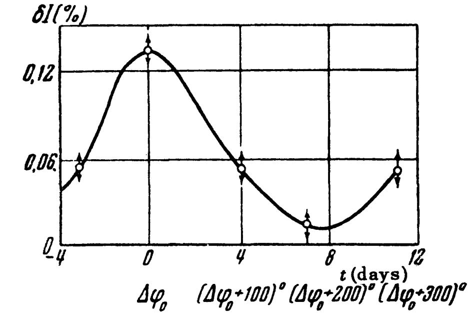
1. The investigation of the effect of the lunar-tidal oscillation of the atmosphere on the intensity of the hard component of cosmic rays is of interest for the study of the nature of the twelve hour variation of cosmic ray intensity[1] and of the diurnal variation of the temperature of the upper layers of the atmosphere[2]. Since the principal period of the lunar-tidal oscillation is equal to one-half a lunar day[3], one would expect it to give rise to a regular variation of the same period in the cosmic ray intensity. However, since regular variations might be masked by statistical fluctuations of the cosmic ray particle flux, the study of the lunar-tidal effect must utilize statistical methods.

Consider the observed twelve hour variation in cosmic ray intensity, δI, as the sum of two waves: one, S, with a period T_S = 12h; and the other M, with period T_M= 12h 25m 14s, half the lunar period. Also, let the phase difference of the two be $\Delta\phi_0$ degrees at time $t_0 = 0$. In a length of time T_S, the phase difference will increase by $360(T_M-T_S)/T_S$ degrees, and in $n = T_S/(T_M-T_S) = 28.6$ periods of T_S, or 14.3 solar days, the phase difference will have changed by 360°. Therefore, S and M will have the same phase differences, $\Delta\phi_i (i = 0,1,2...)$, at the times $t_i, t_i + n, t_i + 2n, \ldots, t_i + kn$. Now, one can average the values of δI at these intervals of time, determining an average value corresponding to a particular phase difference, $\Delta\phi_i$. Repeating this procedure for different starting times, $t_0, t_1, t_2, \ldots$, a curve can be constructed giving the dependence of δI on the phase difference $\Delta\phi_i$. This curve would then show the effect of the lunar-tidal component, M, on the twelve hour variation, δI.

2. Experimental values of δI, obtained with an accuracy of several tenths of one percent per hour of observation, were analyzed according to this scheme. Seventy days of data were used to determine the average amplitudes for the phase differences $\Delta\phi_0$, $\Delta\phi_0 + 100°$, $\Delta\phi_0 + 175°$, and $\Delta\phi_0 + 275°$. The results are shown in the Figure.



It is seen there that δI exhibits a strong dependence on the phase difference, i.e., on the choice of the time t_i, and that its variation is sinusoidal with a period of 14.3 days. This can occur only when δI contains a component of period 12h 25m 14s.

The reality of the wave, M, is substantiated by the Table, in which are listed the amplitudes of δI for two-month intervals of hourly observations. It

Amplitude		Time of Maximum
1951		
March-April	0.069 ± 0.008	1 hr 40 min
May-June	0.078 ± 0.008	2 hr 40 min
July-August	0.036 ± 0.008	1 hr 30 min
September-October .	0.070 ± 0.008	2 hr 40 min
November-December .	0.063 ± 0.008	1 hr 16 min

is seen there that uncertainties in amplitude are on the average 0.008%, while it was seen that the variation of the averages obtained by summing at 14.3 day intervals reached 0.04%. Assuming that the maximum and minimum of the curve in the Figure correspond to the waves S and M being in phase and out of phase by π, and using the data in the Table, one obtains an average amplitude for M of 0.05%. Knowing the amplitudes of S and M, one can determine the phase of the resultant wave for each t_i. Calculations show that the phase of the resultant curve should fluctuate within the limits of three hours (90°). The points shown in the Figure fall within this limit, and the behavior of the curve corresponds to the premises of this calculation.

The amplitude and phase of M exhibited the same characteristics when calculated from 1951-1952 data for δI by summation at intervals corresponding to the principal lunar wave of period 24h 50m 14s.

3. The lunar-tidal wave in the atmosphere[4,5] has an amplitude of surface pressure variation of about 0.08 mb. A pressure variation of this amount can cause 20% of the observed amplitude of the waves M in the intensity of cosmic rays. In order to explain the remaining 0.04% amplitude of M, it is necessary to assume that the main effect of the tidal oscillations is through the vertical redistribution of the mass of the air. Such a redistribution would necessarily be associated with a twelve hour variation in the temperature of the upper layers of the atmosphere, which variation was indeed observed by Selesneva[2] in 1945. The analysis[2] of a large amount of statistical data showed that, starting at an altitude of 3 km, the diurnal fluctuations had several maxima. The basic maximum is of 24-hour period, while the others are 12-hour, and the amplitude of the latter increases with altitude. It would seem that tidal oscillations, as well as the other factors indicated by Selezneva[2] hold an important place in the explanation of the maxima in the diurnal temperature variations of the troposphere.

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Variation of the Global Intensity of the Hard Component of Cosmic Rays During the Passage of Air Mass Fronts

D. D. KRASIL'NIKOV
Yakutsk Branch of the Academy of Sciences, USSR

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1 The investigation of the variation of cosmic ray intensity with typical states of the atmosphere (as regards the vertical density distribution) is of interest in the study of the variation of cosmic ray intensity outside the atmosphere in cases where adequate temperature soundings of the atmosphere are unavailable. In the latter cases (when it is impossible to determine the appropriate integral [1,2]) such study is complicated by the impossibility of determining the magnitude and sign of the meteorological effect. It is hoped that the investigations comprised in this paper may help in estimating this latter quantity, and, in addition, that they may help evaluate the possibilities of bringing about the observation of cosmic ray intensity in meteorological investigations[3] . One can consider making such observations during various meteorologically well-defined different types of fronts[4,5], a type of work of which only one example has been reported to date [6] .

In that paper the average variation of the intensity of the hard component during the passage of four types of fronts, and during periods of no frontal development, was reported. In contrast to the procedures in that study, here: 1) the measurement of cosmic ray intensity was made near sea level in a stationary apparatus, 2) all observations were made during periods of no magnetic activity, 3) the observed intensity variations were corrected for the diurnal effect, 4) the variations in the velocity of the fronts were taken into account, 5) the periods with no fronts were classified according to type of surface pressure change.

2. The average hourly global intensity of the hard component was measured to an accuracy of several tenths of one percent. In addition, surface pressure and the earth's magnetic field were measured every hour, the synoptic situation was recorded every three hours, and the cloud state was observed visually every hour.

Fronts were selected for study if the following conditions were satisfied: 1) magnetic storms did not occur and the horizontal component of the earth's field did not change by more than 100 γ-units during the period of observation; 2) the fronts could be identified by type; 3) they appeared tropospheric and dynamically significant (in the case of warm and cold fronts) and they passed through the point of observation in a direction closely perpendicular to the surface line of the front; 4) secondary passages did not occur during the period of observation; 5) the fronts remained clearly defined during the period of observation (from 1500 km prior to reaching the point of observation, to a distance of 400-500 km past it), and appeared on all synoptic charts during the intervening period.

In all, 107 cases were selected, comprising four