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.

In conclusion, we would like to thank Prof. E. L. Feinberg for several valuable comments.

Translated by V. A. Nedzel
103

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

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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 $100\,\gamma$-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 types of fronts: 32 warm, 48 cold, 14 warm type occluded, 13 cold type occluded. Corresponding to each case of frontal passage the beginning and end of three intervals of time were recorded: the first and third in the zone of "pure" air mass (corresponding to the cold and warm in the case of warm fronts, and vice versa for cold fronts); and the second in the zone of the projection of the frontal surface (Fig. 1). For the case of occluded fronts two periods were used: 600 km before and 400 km after the passage of the front on the ground. The most reliable of these observations were the observed times of passage of the fronts on the ground, while those of the upper boundaries were determined with the help of data from the literature[4,5,7] and from cloud observations. It was assumed that on the average the upper boundary of a warm front is overhead when the surface boundary is still 800 km away, while that of a cold front is behind the surface boundary by 400 km.

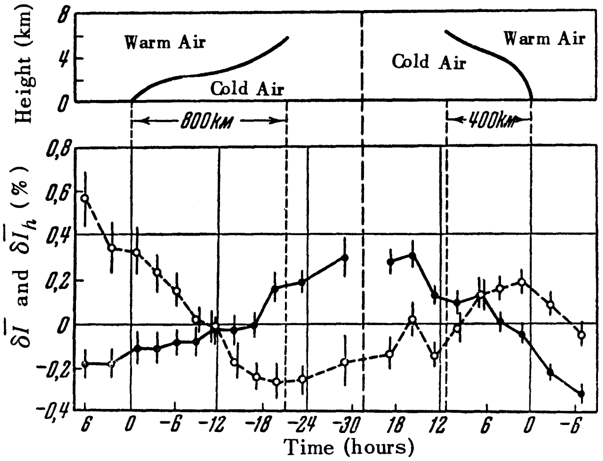

FIG. 1. At the top are shown profiles of a warm front (left) and a cold front (right). Below is shown the average observed variation in the intensity of cosmic rays, $\delta\overline{I}$ (shown by circles), and the same quantity corrected for the barometric effect, $\delta\overline{I}_h$ (shown by dots), during the passage of warm fronts (left; 32 cases) and cold fronts (right; 48 cases).

Periods of observation with no frontal development were used when: 1) the synoptic charts showed no primary or secondary fronts within 1000 km: 2) magnetic storms did not occur nor did the horizontal component of the earth's field change by more than 100 γ-units during the period.

By far the largest number of cases of this type were those in the neighborhood of anticyclones. These periods could be subdivided into two groups on the basis of the type of change of the surface pressure: those in which the pressure rose (54 cases), and those in which it decreased (42 cases). The average change of pressure in the groups cited (5-6 mb) was larger than that occuring in the frontal cases. Corresponding to each of the different cases cited, average curves of the variation of the observed intensity of the hard component $\delta\overline{I}$ were determined, and also the same quantity corrected for the barometric effect, δI_h. In this connection the following points should be noted: 1) For the determination of δI_h the same barometric coefficient was used as that in the previous work[6], namely, $k_\delta = -0.14\%$ of I_0 per 1 mb change in the atmospheric pressure at the point of observation (where I_0 is the mean value of the intensity). 2) The diurnal variation, which is equal to 0.3% of I_0, was excluded from the given values of δI and $\delta\overline{I}_h$; from the observed variation and from supplemental calculations there is an indication that the observed diurnal effect of the hard component near sea level does not depend on the synoptic situation. 3) The curves of $\delta\overline{I}$ and δI_h plotted against time for the individual cases were combined for each type of case by averaging the values of cosmic ray intensity at moments of time corresponding to similar positions of the fronts relative to the point of observation (for the cases with fronts), or corresponding to similar variations of pressure (for the cases without fronts).

The results are shown in Figs. 1-3, in which the scale of time indicated corresponds to the average intervals of observation in the individual cases. The standard deviations shown in Figs. 1 and 2 do not have quite the usual meaning, as they include the effect of the real differences between the fronts averaged. Also, in one case of the passage of a sharply defined cold front, it was possible to calculate the theoretically predicted meteorological effect[1,2] of the variation of the intensity δW (Fig. 4). The calculation was performed using a temperature distribution extending to a height of 300 mb.

3. The following can be seen from the results obtained:

1) The intensity of the hard component of cosmic rays exhibits a characteristic variation during the passage of a front. These variations differ by type corresponding to the type of front. In general, the intensity $\delta\overline{I}_h$ drops during the passage from cold to warm air mass. The minimum is observed in the zone of "pure" warm air and the maximum in cold. This effect in $\delta\overline{I}_h$ varies, on the average, between 0.4% and 0.6% of $\overline{I}_0$.

2) The observed variations $\delta\overline{I}_h$ cannot be explained by the use of too high a value of the barometric coefficient. This can be seen by a comparison of the curves of $\delta\overline{I}_h$ in Figs. 1-3. The cause of the variation $\delta\overline{I}_h$, it seems, lies in the

corresponding changes in the temperature profiles of the atmosphere (Fig. 4) as it follows from the theory of the meteorological effect in cosmic rays[1,2] . The latter states that the meteorological effect is related to changes in the atmosphere at altitudes below the generating layers, and not merely within them, as was assumed previously[6].

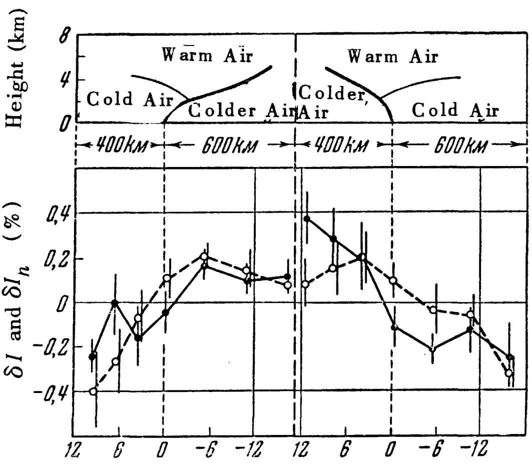

FIG. 2. Above are shown the profiles of warm- and col-type occluded fronts (left and right, respectively). Below are plotted the average variations in the observed intensity, $\delta\bar{I}$ (shown by circles), and the same quantity corrected for barometric effect, $\delta\bar{I}_h$ (shown by dots), during the passage of warm-type occluded fronts (left; 14 cases), and cold-type occluded fronts (right; 13 cases).

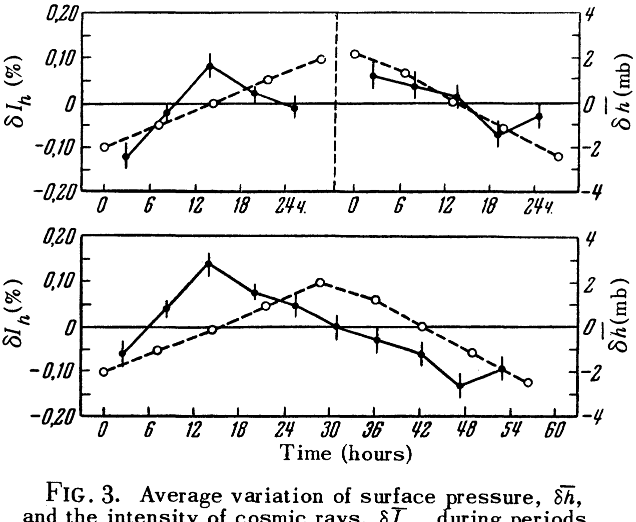

FIG. 3. Average variation of surface pressure, $\delta\bar{h}$, and the intensity of cosmic rays, $\delta\bar{I}_h$, during periods without fronts. Above: $\delta\bar{I}_h$ during increase (left; 54 cases), and during decrease (right; 42 cases), of the surface pressure $\delta\bar{h}$. Below: the variation of $\delta\bar{I}_h$ for the foregoing cases averaged together.

3) The magnitude and the variation of the cosmic ray intensity are not the same in each instance of a particular type of front, but show considerable variation (Fig. 4) which is in accordance with the differences in the strengths and profiles of the individual fronts of a given type[4,7]. The difference in trends of $\delta\bar{W}$ and $\delta\bar{I}_h$ apparently is due to the upper layers of the atmosphere (above $h = 300$ mb).

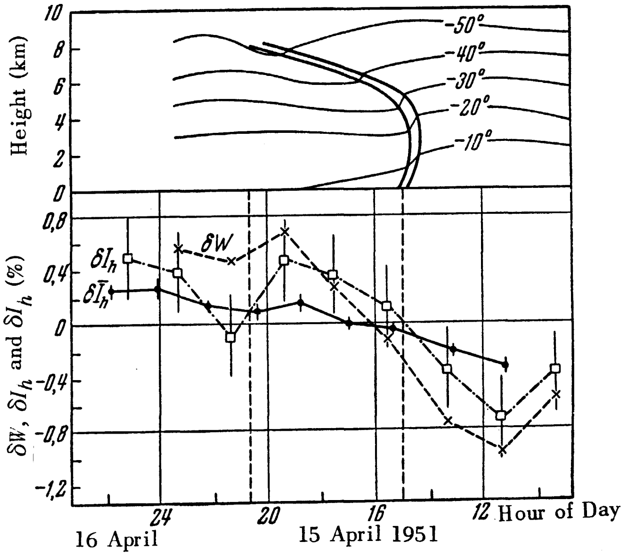

FIG. 4. Variation of the intensity of cosmic rays during the passage of the strong cold front of April 15, 1951. Below: δI_h – the observed variation of the intensity of cosmic rays, corrected for barometric effect; δW – expected variation of cosmic rays[1,2], the integral having been taken in the interval from 300 to 1000 mb; $\delta\bar{I}_h$ – average variation of the cosmic rays during the passage of the cold front (presented for comparison). Above: Temperature profile of the front (° C).

4) $\delta\bar{I}_h$ during periods without fronts is not constant, but shows definite trends (Figure 3), in contrast to previous results[6]. It also leads the surface pressure variation, δh, by about 1/4 of a wave length. The reason for this, according to theory[1,2], should be sought in the relationship of changes of pressure at the surface and at altitude, about which there exist certain meteorological views[4,8] (cf. the curves of Shedler[4]).

5) The observed variations of the intensity, $\delta\bar{I}_h$ (which were not observed in a previous study[6]), related to the upper boundaries of fronts (Fig. 1), the points of occlusion (Fig. 2), and the regions of increase and decrease of surface pressure, are of interest from the point of view of meteorology as well as from that of cosmic rays.

4. It follows from the preceding that:

1) The definite exclusion of the meteorological effect in each case when temperature profile data are unavailable requires a more detailed classification of the meteorological processes.

2) The question of the use of cosmic ray measurements in meteorological investigations requires further study. It appears to us that one can calculate $\delta\overline{W}_{\text{tropospheric}}$ given average tropospheric temperature profiles corresponding to typical meteorological situations. Assuming that the observed variations of $\delta\overline{I}_h$ are caused basically by changes in the temperature profile, i.e., $\delta\overline{I}_h \approx \delta\overline{W}$, one can calculate the contribution of the upper layers of the atmosphere, $\delta\overline{W}_{\text{upper}} \approx \delta\overline{I}_h - \delta\overline{W}_{\text{tropospheric}}$, corresponding to each typical meteorological process in the troposphere. The variation $\delta\overline{W}_{\text{upper}}$ can be considered as an indirect, though objective, factor that can be used along with other meteorological data in studying the character of the relationship of tropospheric processes with those in the layers above. As is well known, this relationship is not very well understood (References 4,5, and others).

In conclusion, I would like to express my gratitude to Prof. E. L. Feinberg, Iu. G. Shafer, and G. A. Tolstobrov for their advice and help.

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104

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The Contribution of Meteorological Changes in the Earth's Atmosphere to the Diurnal Effect in Cosmic Rays

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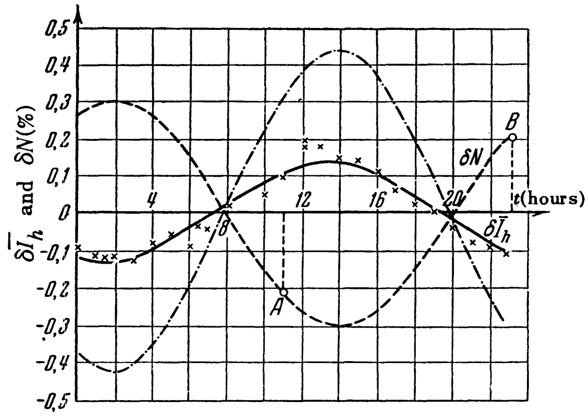
1. IT is important in the investigation of the diurnal effect on the intensity of cosmic rays, as well as in the study of other regular and irregular fluctuations, to isolate those effects related to meteorological changes in the earth's atmosphere. The contribution to the diurnal effect by meteorological factors has been investigated previously (in studies 1-3 and others). In all of these investigations, however, the effect of the redistribution of the atmosphere[4] was not considered. This is as important as the effect of simple absorption of mesons, caused by variation in the mass of air overhead and the change in altitude of the meson-generating layer accompanying a change in the temperature of the atmosphere. Further, in one work[2] the so-called "temperature effect"[5] is incorrectly taken into account.

The present paper reports very accurate determinations (to a precision of several tenths of a percent per hour of observation), at a height of 100 meters, of the global intensity of the hard component of cosmic rays, δI. The analysis was based on a theoretical scheme proposed by Feinberg[4] and generalized by Dorman[5] to include μ-meson production throughout the atmosphere by the disintegration of the π-mesons produced by the primaries.



2. The Figure shows the diurnal variation of the intensity of the hard component, δI_h, corrected for the barometric pressure (barometric coefficient $k = -0.14\%$ per 1 mb), obtained by averaging the data obtained during continuous observation from July 1949 to May 1952. The solid line shows the first harmonic, with the experimental points indicated by x's. The two points A and B are values of δN (the intensity of the hard component theoretically expected from consideration of the meteorological effect) calculated from averaged meteorological data. Data were used only from those days on which radio-sonde flights extended to at least 12 km height during both the day and the night periods. This requirement avoids the danger of bias in the results due to an unequal distribu-