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DIURNAL CHANGES OF THE DUST CONTENT OF THE SURFACE LAYER OF THE ATMOSPHERE

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Diurnal Changes of the Dust Content of the Surface Layer of the Atmosphere

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DIURNAL CHANGES OF THE DUST CONTENT OF THE SURFACE LAYER OF THE ATMOSPHERE

K. P. Makhon'ko

At the present time, as a result of atmospheric fallout of the products of nuclear tests onto the earth's surface, there has been accumulation of an appreciable quantity of radioactive matter which is combined with the upper soil layer. As a result of constantly acting wind erosion this radioactive matter, together with soil particles, again enters into the atmosphere, increasing the concentration of radioactive dust in the air.

In order to study certain details of this secondary process we formulated special model experiments for clarification of the diurnal variation of the fallout of virtually weightless dust, continuously forming on the underlying surface. The investigation was carried out by the labeled atoms method and conditions were created making it possible to exclude the distorting influence of global fallout. The fallout at a height of 1 m above the earth's surface was recorded automatically on sticky sheets. In this work we used a simple apparatus with a clock mechanism which wound the sticky sheet at prescribed intervals. The experiments were made in the summer in a meadow with a well-developed grass cover.

The readings from a sheet situated over the dust-forming surface are dependent on the concentration of the weightless radioactive dust in the air, and since this dust is formed on the underlying surface, in the final analysis the readings of such a sheet will characterize the intensity of the dust-forming processes. It is obvious that the intensity of the entrainment of dust from the underlying surface by air currents is dependent for the most part on the state of the soil surface and the value of the vertical air fluctuations, which in turn are associated with the wind velocity and intensity of turbulent exchange in the surface layer of the atmosphere. The aerosol measurements therefore were accompanied by continuous recording of wind velocity and the near-surface temperature gradient.

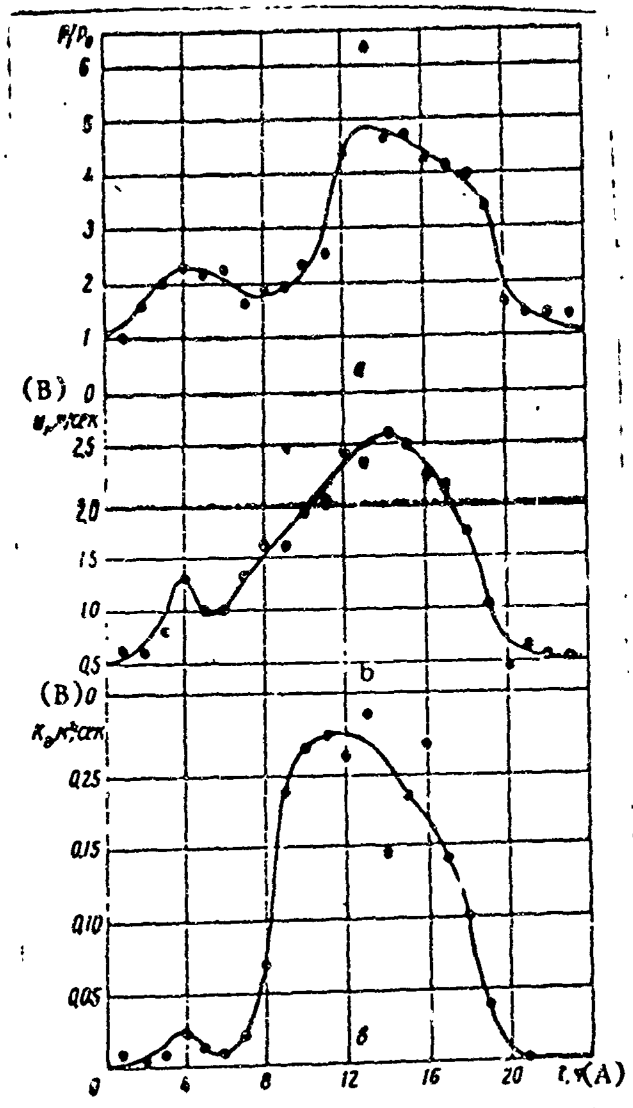

Fig. 1. Diurnal variation of the fallout of radioactive dust (a); wind velocity (b) and the coefficient of vertical turbulent diffusion (c). A -- t, hours; B -- m/sec.

On the basis of these data the Budyko method was used to compute the mean hourly values of the coefficient of vertical turbulent diffusion K_z.

The averaged results of measurements, made on days without precipitation and with a dry soil surface, have been shown in Fig. 1. The value of the fallout of radioactive dust has been plotted on the graph in relative units P/P_0, where P_0 is the minimum value of the fallout, observed at 0100-0000 hours. The notation u_1 is used for the wind velocity at a height of 1 m above the soil surface and K_z is the coefficient of vertical turbulent diffusion, also measured at a height of 1 m. It should be noted first that the general variation of all three curves coincides well. This confirms the profound influence which wind velocity and the degree of atmospheric turbulence exert on the process of dust formation. However, this influence is not identical. The diurnal variation of P/P_0 correlates far better with the diurnal changes of wind velocity u_1 than the coefficient K_z. If the ratios of the maximum diurnal values u_1 and P/P_0 to the minimum values are approximately identical, K_z changes in considerably broader limits. This is evidence that in processes of dust formation the principal role is played by the wind. The influence of turbulence is expressed primarily in the daytime hours when K_z assumes maximum values. In actuality, the principal maxima of the curves are displaced from one another by approximately 1 hour in such a way that the maximum value K_z is attained at 1200 hours, P/P_0 at 1300 hours, and u_1 at 1400 hours, that is, the maximum dust formation occurs in the period between the K_z and u_1 maxima. Consequently, in the daytime both these factors play an appreciable role in the dust formation process.

A more detailed study of the variation of the curves made it possible to establish specific phenomena of lag of the dust content of the surface air layer with a change in wind velocity and the coefficient of turbulent exchange in a closed cycle. We now will determine the dependence of the value of fallout of radioactive dust on wind velocity, noting the sequence of changes of measured values. Connecting in sequence the experimental points, we obtain the figure shown in Fig. 2. The derived double closed loop reflects the processes of lag in the state of dust content of the atmosphere over a dusty underlying surface and therefore also in the processes of dust formation on this surface. It has been proposed /1/ that this process be called "hysteresis of the dust content". A still clearer hysteresis is observed if the same method is used to determine the dependence of the fallout value on the coefficient of vertical turbulent diffusion. The desired dependence is represented in Fig. 3. The variation of both curves is extremely similar. At 0100-0000 hours there is a dust content minimum. An increase of u_1 and K_z sets in soon thereafter, which causes an increase of capture of dust from the ground surface, first very rapid, but gradually dropping to zero toward 0400. At this time there is the first maximum

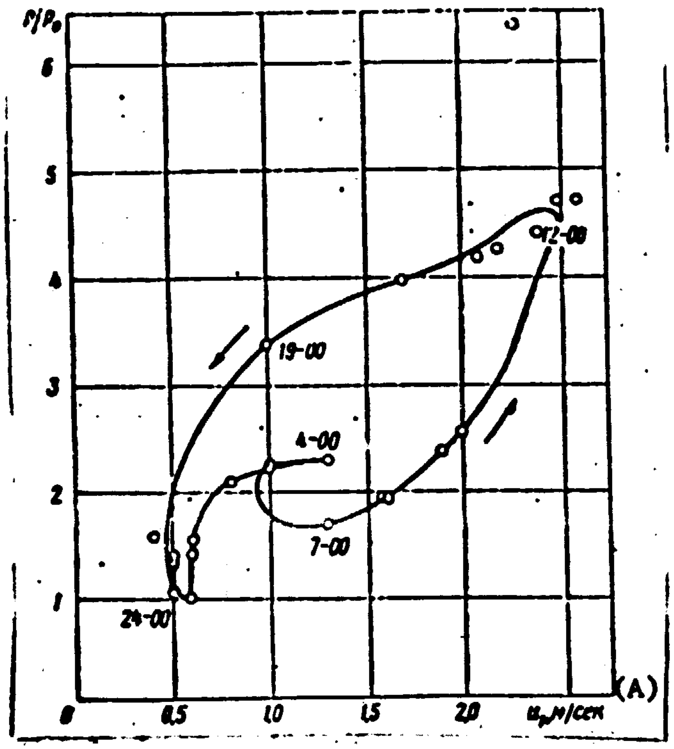

Fig. 2. Hysteresis of dust content with a change of wind velocity. A) m/sec.

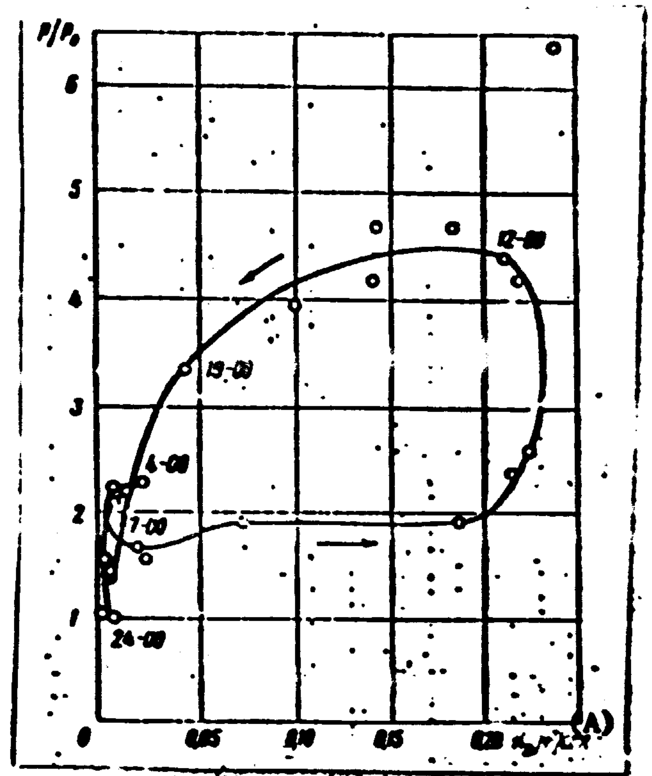

Fig. 3. Hysteresis of dust content with a change of the coefficient of vertical turbulent diffusion. A) m/sec.

of u_1, K_z and P/P_0. After 0400 the wind begins to die down and the coefficient of turbulent diffusion decreases, but the dust still is suspended in the air. The decrease of P/P_0 therefore occurs at higher values than in the corresponding increasing part of the curve. The first weakly expressed hysteresis loop is formed at this time. Beginning at 0600 the wind again begins to intensify and K_z increases, which it would seem should intensify the capture of dust from the underlying surface. But at exactly this time, from 0600 to 0700, there occurs an intensive formation of dew on the underlying surface. For this reason the value of dust capture during all this time decreases continuously. After 0700 and to midday there is an intensification of atmospheric turbulent exchange and wind velocity increases. This is accompanied by a rapid increase of the quantity of dust carried up from the underlying surface and an increase of the atmospheric dust content. Then u_1 and K_z again begin to decrease, which causes a decrease of receipts of dust from the ground surface and a decrease of its concentration in the air. However, despite the same intensity of turbulent exchange and wind force the dust concentration in the afternoon hours is considerably greater than in the forenoon period.

Two possible reasons for the development of this effect can be noted.

Since the recording instrument was situated low over the dust-forming surface the dust captured from the ground very quickly reached its level. Therefore, with an increase of the values u_1 and K_z the increase of the near-surface dust concentration occurs without a lag. During the course of this process, as a result of turbulent diffusion, the dust penetrates into the higher layers of the near-surface atmosphere. Then, with a decrease of u_1 and K_z, the entry of dust from the underlying surface decreases, but on the other hand the dust begins to diffuse to the level of the recording instrument from the above-lying layers of the atmosphere. The presence of this influx of dust from above also retards the decrease of the dust concentration at the ground surface.

In addition, the character of the interaction between dust particles and the underlying surface can play a role in the lag phenomenon. This process still has not been studied under natural conditions, but it is known that part of the dust settling on the underlying surface seemingly is reflected from it and returns to the atmosphere [2].

Thus, with an increase of u_1 and K_z there is an intensification of the emanation of the dust of the underlying surface and an increase of the dust content of the atmosphere. With a decrease of u_1 and K_z, when these values pass through their former numerical values in reverse order, the dust content of the atmosphere decreases more slowly because a part of the dust does not return to the underlying surface, but is reflected from it. From the energy point of view, the detachment of a mass of dust from the underlying surface and its suspension in the air requires the exertion of a definite quantity of energy of air movements, and the condition for return of this mass to the underlying surface is a lesser intensity of atmospheric disturbance, since otherwise the dust apparently will be reflected more intensively from the underlying surface and will remain in the atmosphere.

All these processes apparently create the phenomenon of hysteresis of the dust content in the reverse course of variation of wind velocity and turbulent exchange. However, for the time being it is not possible to evaluate the role of each of these processes in the formation of the hysteresis. The size of the hysteresis loop, after detailed study of the mechanism of the process, possibly will make it possible to estimate the value of the coefficient of reflection of radioactive dust from the underlying surface. In addition, on the basis of the area occupied by the loop it will be possible to judge the quantity of energy expended on the detachment of the radioactive particles from the underlying surface.

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