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Features of the interaction of space plasma flows with atmospheric aerosols of the Earth

We considered the interaction of solar plasma flows with atmospheric gas containing molecules and particles with a condensed dispersed phase (hereafter CDF). Modeling and calculations of existing electric currents and their structure are carried out. Conclusions are made about the influence on the structure of the current both from the side of the atmosphere and from the side of space flows of different composition. The equation of motion of the plasma with the CDF in the Earth's ionosphere is considered. Conclusions are made about the influence of CDF on the thermal balance of the plasma. Cosmic plasma flows include a component with high-energy particles and form showers of secondary radiation and currents of cosmic radiation that are not involved in the operation of current tubes. It has been proven that in the discharged layers of the ionosphere, plasma flows mixed with CDF are subjected to significant additional heating by CDF particles. Heavy ionization losses lead to the formation of a secondary electronic component in the upper atmosphere. It has been proven that the electrons arising in this case are drawn into the main plasma flow. The work emphasizes that the registration of shown of secondary particles is a diagnostic criterion useful for calibrating the structure of the plasma flow in the lower part of the Earth's atmosphere. It is noted that small absolute values of currents of protons and particles are compensated by their significant kinetic energy. In the lower layers, CDF particles are a heat-dissipating agent. Explosive processes producedby fluctuations in plasma flows, electric current and cause fluctuations in currents inside magnetic tubes. The possibility of their influence on the operation of power supply networks during strong solar flares and their influence on the operation of power lines in the mountains around the polar and equatorial zones is separately noted. The impact parameters depend on the amplitude fluctuations of the physical parameters of the medium that forms the atmospheric currents. It is shown that the significant amplitude character of changes in atmospheric currents and large induction areas of the systems form a significant additional EMF during the indicated disturbances. An analysis of the necessary equipment for monitoring the measurement of the induced voltage during fluctuations in the current structures of the layers of the Earth's atmosphere was carried out.

Keywords: *ionosphere plasma, plasma with CDP in magnetic tubes of the ionosphere, local magnetic fields.*

1. Introduction. The Earth's atmosphere is constantly exposed to directed flows of cosmic plasma. As a result of their interaction with a magnetic field produce currents of electrons, protons, and less often α-particles. During the period of meteor activity several times a year, the presence of the dust component of the interplanetary medium should be added to these fluxes. The well-known distribution function of these particles N(a) by size a is presented as $N(a) = N_0 a^{-3.4}$ where N_0 is the total concentration of dust particles in 1 $см^3$. In interplanetary space, the concentration of particles is on average 3% of the concentration of atoms. The concentration of atoms is 3 particles per 1 $см^3$. When the Earth collides with the meteor showed that N_0 increases to 10 $см^3$ and more. Being in the radiation field of the Sun, such particles

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create a significant positive charge [1]. The maximum speed of the CDF during a head-on collision with the atmosphere does not exceed 60 km/s. According to the distribution N(a) presented above, the CDP particles are maximally provided with small sizes. Observations show that the atmosphere "burns" larger particles while small particles are entrained by the plasma. The distribution function N(a) is characterized shows that the quantitative fraction of small particles is much larger than the particles with large sizes. Moreover, half of the total mass of CDP falls on small particles. When micro- and nano-particles of space plasma dust interact with the Earth's magnetic field, the CDF is involved in a directed current motion towards the poles. Protons and α-particles experience significant ionization losses in the form of a decrease in kinetic energy, which increases the electron concentration and the degree of ionization of the atmospheric plasma. As a result, electric currents in various layers of the atmosphere are amplified. Such currents, induced by the interaction of charged cosmic particles, radioactive cosmic dust, and solar wind currents, cause variations in the local, near-surface magnetic field. Particular attention consists the phenomena of transport and heat-mass-exchange in plasma flows with CDP moving towards the poles. The variations of the magnetic field leads to fluctuation boundaries of the induced magnetic field. During strong magnetic storms, it was found that the regular magnetic field lines are strongly deformed, pressed from the side of the normal component of the flow direction to the earth's surface. In the deformed state, the magnetic field has a large bend towards the equator. This indicates that magnetic flux variations may occur near the equatorial atmosphere. In the "saddle" type configuration is formed additional equatorial current. The presence of the equatorial current and its rather significant fluctuations in the case of strong solar activity leads to the appearance of an induced inductive current along the entire surface of the equator and adjacent regions of the globe. In this case, one should expect the appearance of induced currents in open conductors in high-mountainous regions of middle geographic latitudes. Particularly in power lines.

2. Physical conditions in the Earth's atmosphere in the zone of collision of plasma flows. In the upper layers of the Earth's atmosphere, the number of ions are $n_i \approx 10^8 cm^{-3}$, Z_d is the dust grain charge $Z_d \approx (3-8) \cdot 10^3$ electric charge units. T_e, particle temperature in eV (1-2 eV), the size a is about 3-10 microns. Let us introduce the dimensionless charge $\bar{Z}$ instead of the charge number of the CDP particle Z_d.

$$\bar{Z} = \frac{Z_d e^2}{a T_e} \tag{1}$$

Where $T_e$in eV, α is the particle radius in cm. In the intervals of the considered parameters, $\bar{Z}_d \approx 10^{-4}$. Under these conditions, the dusty plasma is considered ideal. The presence of fluxes of positively charged ions and electrons through the particle surface noticeably changes the actual size of the screening region around the charged particle. In our case, the size of such a region is determined by the ionic Debye radius λ_{Di}

$$\lambda_{Di} = \sqrt{T_i / 4\pi n_i e^2} \approx (1-2)\ km \tag{2}$$

The fluxes of the gas component of the Low Temperature Plasma (therefore) through individual dust particles are given by the mean free paths of the ions. For free paths by dust particles of radius for λ_{fp} we have the formula: $\lambda_{fp} = (\lambda_{Di})^2/aP$, where $P = n_d\overline{Z_d}/n_{i,0}$. Substitution of all data leads to the inequality $\lambda_{fp} \gg \lambda_{Di}$.

When a supersonic shock front passes through a dusty plasma at rest, the average distance between particles ahead of the front decreases. At this moment, the self-potential energy of the KDF particles in the plasma is U ($U = Z_d^2 e^2/2a$) changes so that the "effective" charge is shifted downward.

At the same time, observations record that the heating of the gas reaches 40,000 K in the upper ionosphere. Within the framework of the above physical conditions, a sharp rise in temperature can be caused only when the impact interaction in the boundary layer is maintained for a long time. The capture of radioactive charged particles CDP and the solar wind by the Earth's magnetic field is carried out in a rarefied part of the atmosphere. Their further directed motion towards higher densities and the fluctuations of the concentrations of moving particles in magnetic tubes, which were originally laid down by solar flares, are the subject of our work.

The variability of the charges of the dust particles themselves leads to the fact that in the potential electric field **E** = - **∇**φ (φ is the potential of the electric field), the force acting on the dust particle is no longer regularly potential. In this way, systems of charged dust particles of finite size differ from the usual physical ensemble of point charged particles. As a result, an excitation of a vortex electric field appears during the movement of the CDP, expressed by the relations: $[\nabla x Z_d \boldsymbol{E}] = [\nabla Z_d x \boldsymbol{E}] \neq 0$. One of the reasons for the excitation of eddy electric fields is the presence of a charge gradient in CDP particles is (∇Z_d). We believe that the self-radiation of dust will be recorded by ground-based instruments simultaneously with the recording of infrasonic frequencies [2, 3].

In a plasma flow, the interaction of the gas component with highly charged dust generates a high shear viscosity. That is, the dust is more strongly carried away by the gas when the direction of its flow changes. The latter circumstance leads to the fact that cosmic dust and dust from meteor showers, having small dimensions and a large charge, become part of the meridian and equatorial flows - electric currents.

3. The equations of hydrodynamics. Let us consider the deceleration of one counter gas jet by an infinite plane-parallel NTP flow with a CDP. Let us attribute the particle size distribution to the CDP as $N(a) = N_0 a^{-3.5}$As noted in [1,6], the interstellar medium placed in powerful high-energy radiation fields has a bell-shaped (monodisperse) size distribution. Thus, for considered flow, we have two continuity equations for gas and CDP separately, and one equation for a counter flow of gas (generally at rest). The average mass fraction of particles is 1% of the total mass of the interstellar medium. Mass and volume fractions of CDP are denoted by the index p. Index i denotes the corresponding coordinates: I = 1,2,3 → x,y,z. With a sufficiently strong rarefaction of the medium, we consider the collision of counter-moving particles with a gas - equation (3a) and gas with gas (3b).

$$\frac{\partial}{\partial t}\left(\rho+\rho_p\right)+\frac{\partial}{\partial x_i}\left(\rho u_i-\rho_p u_{pi}\right)=0, \tag{3a}$$

$$\frac{\partial}{\partial t}\left(\rho+\rho_w\right)+\frac{\partial}{\partial x_i}\left(\rho u_i-\rho_w u_{wi}\right)=0. \tag{3b}$$

There is also an interaction of particles with the flow's own gas. However, compared with the interaction with the incident flow, this interaction can be neglected. The interaction of particles with gas is taken into account at the stage of constructing the momentum conservation equation in the form of a hydrodynamic analogy of Newton's second law. Assuming that the volume occupied by the CDP is insignificant, a new term appears in the equations of motion for two different phases in the form of an external forceF_{pi} acting from particles per unit volume of gas. Then for the accompanying gas we have:

$$\frac{\partial}{\partial t}\left(\rho u_i\right)+\frac{\partial}{\partial x_j}\left(\rho u_i u_j\right)=\frac{\partial}{\partial x_j}\left(-p\delta_{ij}+\tau_{ij}\right)+F_{pi} \tag{4}$$

For a counter flow of gas, relation (4) will be rewritten in the form:

$$\frac{\partial}{\partial t}\left(\rho u_{w,i}\right)+\frac{\partial}{\partial x_j}\left(\rho u_{w,i} u_j\right)=\frac{\partial}{\partial x_j}\left(-p\delta_{ij}+\tau_{ij}\right)+F_{p;w,i} \tag{5}$$

The interaction between particles corresponds to the equations of motion in the form:

$$\frac{\partial}{\partial t}\left(\rho_p u_{p,i}\right)+\frac{\partial}{\partial x_j}\left(\rho_p u_{p,i} u_{p,j}\right)=-F_{p,i} \tag{6}$$

Where τ_{ij} is the viscous stress tensor for the gas in which the particles keep it undisturbed. For given parameters of the problem, in layers with a large regular component, a random (including Brownian) component and other types of pressure are excluded.

Of the numerous forms of the energy balance equation, it is more convenient to use the Marble expression [5]:

$$\frac{\partial}{\partial t}\left[\rho\left(e+\frac{1}{2}u_i^2\right)\right]+\frac{\partial}{\partial x_j}\left[\rho u_j\left(e+\frac{1}{2}u_i^2\right)\right]=$$

$$=\frac{\partial}{\partial x_j}\left[u_j\left(-p\delta_{ij}+\tau_{ij}\right)-q_j\right]+Q_p+u_{pi}F_{pi}. \tag{7}$$

and for a cloud of particles, the energy balance equation will

$$\frac{\partial}{\partial t}\left[\rho_p\left(e_p+\frac{1}{2}u_{pi}^2\right)\right]+\frac{\partial}{\partial x_j}\left[\rho_p u_{pj}\left(e_p+\frac{1}{2}u_{pi}^2\right)\right]=-Q_p-u_{pi}F_{pi} \tag{8}$$

It is necessary to dwell in more detail on the notation used and the interpretation of the quantities in formulas (5) and (6). Q_p; $u_{pi}F_{pi}$. We represented that the power expended on the transfer of heat from the cloud of particles to the gas phase. Together with this the work performed by the particles passing through the gas. Of particular note the assumption about the "smoothing" of the continuum variables for the gas. The speed and temperature of the gas change strongly in the vicinity of a particle that moves and exchanges heat with the gas. But the values of u_i, T and p, which appear in continuum relations, are, in a sense, values averaged over a volume of gas containing a certain number of particles. The use of the same average values in the continuity, momentum, and energy relations requires that all traces of particles in the area of their direct influence quickly, during the time between one or two subsequent collisions, dissipate (become Brownian). In an ideal dusty plasma, this condition is not always satisfied. Especially if plasma particles and dust experience ionization losses as a result of moving in a directed plasma flow with a high intrinsic velocity. We have found that effective deceleration in the form of ionization losses occurs in the outer part of the Earth's atmosphere. At low altitudes from observation has been seen regular electric currents in magnetic tubes are already described in the thermodynamic approximation.

The simplified forms of the energy conservation equations adopted above for each phase, when using the appropriate equation of motion, lead to the following "thermodynamic" form:

$$\rho\left(\frac{\partial e}{\partial t}+u_i\frac{\partial e}{\partial x_i}\right)+p\frac{\partial u_i}{\partial x_i}=\left(Q_p-\frac{\partial q_i}{\partial x_i}\right)+\tau_{ij}\frac{\partial u_i}{\partial x_j}+\left(u_{pi}-u_i\right)F_{pi}, \quad (9)$$

$$\rho_p\left(\frac{\partial e_P}{\partial t}+u_{pi}\frac{\partial e}{\partial x_i}\right)=-Q_p \quad (10)$$

Equation (9) is suitable for gas and shows that the usual relationship for the energy balance is given by:

1. The rate of obtaining heat Q_p from the dispersed phase;

2. Energy dissipation rate $(u_{pi}-u_i)F_{pi}$of particles moving relative to the gas.

This leads to the fact that for a cloud of particles, under the assumptions made above regarding the processes of heat-mass transfer, the thermal energy of a particle can only be changed by the heat flux transferred to it from the outside. Taking this into account, from equation (9), the relation immediately follows:

$$\rho_p\left[\frac{\partial}{\partial t}\left(u_{pi}^2/2\right)+u_j\frac{\partial}{\partial x_j}\left(u_{pi}^2/2\right)\right]=-u_{pi}F_{pi}. \quad (11)$$

Here, the work that occurs when the particles are slowed down by the gas affects only the kinetic energy of the cloud of particles. The processes of deceleration and heat transfer of the CDF, which connect the cloud of particles with the gas, can occur in any mode, with the corresponding Reynolds (Re) and Mach (M) numbers.

It often happens that the flows of the falling gas and dust mixture interact with the atmosphere in the Stokes regime (quadratic or hypersonic). In this case, an analytical description of the modes of motion of the current sheets is allowed. Therefore, the analytical solution of the problem presented above allows us to draw important conclusions and conduct a qualitative analysis based on the analysis of the characteristic times of transport processes in gas and dust plasma; the effects of current fluctuations in the atmosphere are tangible for sensitive ground-based magnetometers at low altitudes.

3.1 Characteristic times of hydrodynamic phenomena. Let us assume that the resistance of particles and heat transfer are described in a flow, where the law of resistance to the movement of particles of Stokes and the Nusselt number $\overline{P}_k$, ($\bar{P}_k \approx$ *1*are valid. Then for particles of radius r and mass m moving in a gas with viscosity μ, the characteristic time is τ_ν:

$$\tau_\nu = \frac{m}{6\pi r \mu}. \tag{12}$$

τ_ν is the time required for the CDF particle to decrease its speed relative to the surrounding gas, e^{-1} times from its initial value in the un accelerated state. This time required to reach a steady velocity gives some idea of the process of interaction of gas with particles in comparison with the time T characterizing the flow. Particles in the flow of interplanetary gas begin to experience acceleration due to movement along a curvilinear trajectory with the simultaneous action of the Earth's magnetic field and friction against the gas at rest.

At $\tau_\nu \gg \tau$ the particle enters the flow region and then leaves it before the elapsed time τ is sufficient to noticeably change its motion in the form of deceleration and deviation from a rectilinear trajectory.

When $\tau_\nu \ll \tau$, the particle "adapts" to the local motion of the gas before it passes through a significant part of the area. If the motion of the gas is uniform, the cloud of particles assumes the same velocity very quickly. When the gas moves with acceleration along the magnetic tube, the flow of particles acquires a certain speed relative to the gas due to inertia and friction, and conditions are provided for the entrainment and acceleration of the particles. As a result, the particle velocities reach values close to the local gas velocity. Then the steady motion of the particle largely depends on the local motion of the gas.

The situation can be considered in a clearer physical context. Considering a gas accelerated to a characteristic velocity U_0over a characteristic length L (for example, the characteristic distances along which the flow moves). Then an acceleration U_0^2/L is applied to the particle, which leads to the sliding velocity of the particle $U_s \equiv U - U_p$ When the particle obeys the Stokes law, the following estimates can be obtained

$$\frac{U_s}{\tau_\nu} \sim \frac{U_0^2}{L} \rightarrow \frac{U_s}{U_0} \sim \frac{U_s \tau_\nu}{L} \equiv \frac{\lambda_\nu}{L}. \tag{13}$$

Here, λ_ν is defined - the characteristic length at which the velocity is balanced, and then $\lambda_\nu \equiv U_0\tau_\nu$is interpreted as the distance that the particle travels during its motion with the gas during the time τ_ν. During the time τ_ν the sliding speed of the particle on the gas decreases to e^{-1} from the initial value. Then we can conclude that the sliding velocity of the particle is always less than the value of the gas velocity. This is true on such scales when τ_ν is smaller compared to the characteristic length of the system L. Dynamically, this condition means that while moving in a gas cloud, the particles “adapt” to the slip values corresponding to the local gas acceleration, overcoming a small distance compared to the characteristic dimension’s systems.

A similar discussion can be made for the temperature history of particles. The time of establishment of thermal equilibrium is defined as:

$$\tau_T = \frac{mc_p}{4\pi\sigma k}. \quad (14)$$

This is the time required for the temperature difference between the particle and the gas to decrease to e^{-1} from its initial value. When $\tau_T/\tau \gg 1$, the particle temperature is relatively independent of the local gas temperature, but is strongly related to its initial value. When $\tau_T/\tau \ll 1$, the particle temperature is determined mainly by local conditions; the difference between the particle and gas temperatures is of the order of:

$$\frac{T - T_p}{\Delta T} \sim \frac{U_0 \tau_T}{L} \equiv \frac{\lambda_T}{L}, \quad (15)$$

where ΔT is a characteristic change in the gas temperature in the problem. We also define the thermal balancing length λ_T, which has the physical meaning of the distance that the particles are transported by the gas while they go through this balancing process. It is clear that the cloud of particles and gas are close to thermal equilibrium when $\lambda_T \ll L$. Comparison of equations (12) and (14) confirms that the rate and thermal relaxation processes are similar $\tau_\nu \approx \tau_T$ when the Prandtl number is equal to 2/3. The relaxation time or relaxation length is used in the explicit formulation of the particle strength Fp and the heat transfer rate Qp between the phases. The force acting on a particle moving through a gas is equal to $6\pi\sigma\mu(U_p - U)$so that for n non-interacting particles in a unit volume of space, the effective body force Fp is equal to:

$$F_p = n6\pi\sigma\mu\left(U_p - U\right) = nm\left(\frac{6\pi\sigma\mu}{m}\right)\left(U_p - U\right) = \rho_p \frac{U_p - U}{\tau_\nu}. \quad (17)$$

Similarly, the heat transferred from one particle to a gas is $4\pi\sigma k(T_p - T)$ and the rate of heat transfer per unit volume is

$$:Q_p = n4\pi\sigma k\left(T_p - T\right) = \left(nm\right)\left(\frac{4\pi\sigma k}{mc_p}\right)c_p\left(T_p - T\right) = \rho_p c_p\left(\frac{T_p - T}{\tau_T}\right) \quad (18)$$

The use of these relations in equations (3) - (6) together with the equations of state for gas closes the main system of equations, except for the relations

$$\delta e = c_\nu \delta T, \quad (19)$$

$$\delta e_p = c\delta T_p. \quad (20)$$

In both cases necessary to reconsider the assumption of smoothed continuous variables and the constraint they impose. For example, the same T_p value has been used to indicate the surface temperature of a particle in the transport law and to determine the particle's internal energy in the energy equation. When considering a problem involving very rapid changes in gas temperature, the bulk temperature of a particle can lag significantly behind the surface temperature. For this reason, there is a thermal explosion of large particles flying into the atmosphere.

One limiting form of the coupled equations of gas-particle systems is instructive both physically and analytically. We want to continue observing until me small enough τ_ν and τ_T that the local sliding velocity of the particles and the temperature difference of the gas particles also become small. When $\tau_\nu \to 0$, for example, the value ofU_p obeys the following limit transition $U_p \to U \to 0$. The volumetric force of the particle remains finite. Similarly, as $\tau_T \to 0,\ T_p \to T \to 0$. The main limitation of the physical models under consideration is that the particle radius is small. While the number n of such particles per unit volume increases, so that $\rho_p = nm$ usually remains constant. Then the immediate result of this restriction is that the number of dependent variables is reduced by two, i.e. $T_p \equiv T, u_{pi} \equiv u$. From the equations $\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0;\ \frac{\partial \rho_p}{\partial t} + \frac{\partial}{\partial x_i}(\rho_p u_{pi}) = 0$ it follows that as $u_{pi} \to u$ it turns out that $\frac{D(\rho_p/\rho)}{Dt} = const$ and this, in turn, indicates that the particles are "attached" to the mass element of the gas they are in. If the initial distribution of particles is stationary, then $\rho_p/\rho \equiv k = const$ is constant for the entire medium. Under this condition, the equations of motion for the two phases can be combined to eliminate the interaction force, so that for an ideal gas we have the equation:

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = \frac{-1}{(1+k)\rho} \frac{\partial q_i}{\partial x_i} + \frac{1}{(1+k)\rho} \frac{\partial \tau_{ij}}{\partial x_j}. \tag{21}$$

Combining the energy conservation equations (7) and (8) we get:

$$\frac{c_v + kc}{1+k}\left(\frac{\partial T}{\partial t} + u_j \frac{\partial T}{\partial x_j}\right) = \frac{-1}{(1+k)\rho} \frac{\partial q_i}{\partial x_i} + \frac{1}{(1+k)\rho} \tau_{ij} \frac{\partial u_i}{\partial x_j}. \tag{22}$$

In this case, the equation of state is reduced to the following form:

$$p = (1+k)\rho\left(\frac{R}{1+k}\right)T. \tag{23}$$

With the resulting form of equations, the analogy with ideal gases is complete. The physical system behaves exactly like an ideal gas with modified thermodynamic parameters: where the density is corrected by increasing to (1+ K)ρ, and the molecular weight increases by (1+ K) times the true value for a pure gas (no dust), $c_p,\ c_v$ is specific heat capacities at constant pressure and volume. Having determined the state of the system by the characteristic quantities τ_ν and τ_T, we proceed to solving the problem. The use of the Stokes approximation allows us to reduce the solution of previous equations in the scope of the similarity method. Spatially this is Sedov dimension method with the Zel'dovich-Raiser correction. To do this, we pass to the group of dimensionless heat capacities and the associated coefficient γ (meaning the adiabatic exponent), which are a combination of the dimensional $c_p,\ c_v$ and the dimensionless quantity γ are redefined as follows:

$$\tilde{c}_v = \frac{c_v + kc}{1+k}, \qquad \tilde{c}_p = \frac{c_p + kc}{1+k}, \qquad \overline{\gamma} = \frac{c_p + kc}{c_v + kc} \tag{24}$$

Dimensionless groups of parameters, namely effective kinematic viscosity ν^*, Reynolds number – $\bar{R}_N$, Mach number – $\bar{M}$ and parameter – $\bar{P}$ are also redefined as:

$$\nu^* = \mu/(1+\kappa)\rho \tag{25}$$

$$\begin{cases} \bar{R}_N = \dfrac{U_0 L}{\nu^*} = (1+k)U_0 L / \nu \\ \bar{M} = \dfrac{U_0}{\bar{a}} = \dfrac{U_0}{a}\left\{\dfrac{(1+k)(1+kc/c_v)}{(1+kc/c_v)}\right\} \\ \bar{P}_k = \tilde{c}_p \mu / \kappa \end{cases} \tag{26}$$

So that, in addition to the changed gas parameters, the effective flow becomes uniform for large Reynolds and Mach numbers. With a large mass fraction of particles, that is, K » 1, the Mach and Reynolds numbers increase markedly, then the ratio of heat capacities is close to unity. In this case, the flow of CDP particles behaves as a free molecular one. The convenience of the presented approach also lies in the fact that the resulting "equilibrium" limit is a solution around which one can build a series expansion under small perturbations. In this case, the expansion parameters are τ_ν/τ or λ_ν/λ. Let us indicate the initial and boundary conditions for the velocity and temperature of the particle. When $\tau_\nu \to 0$ или $\lambda_\nu \to 0$ the region in which the particle state relaxes from the initial state to stable slip experiences compression into a small boundary layer. Main conclusion is that the detailed nature of heat transfer and the laws of gas-dynamic resistance do not affect the nature of equilibrium in the above limit for $\tau_\nu, \lambda_\nu \to 0$..

4. The flows around a sphere. Despite the irregular shape of dust falling into the Earth's atmosphere, the approximation of a flow around a sphere of radius R is one of the most frequently considered examples and illustrates the problems that arise in such applications. Meteor showers rarely collide head-on with the Earth's atmosphere. We often deal with intersecting courses of the Earth's movement of CDF streams, giving an average collision velocity of 5-20 km/s. The main part of large particles under the noted conditions is instantly destroyed, evaporates and burns in the upper layers of the atmosphere, forming a plasma column. At even lower velocities, the gas-plasma flows around a charged CDP particle according to the Rutherford law. In the limit of the lowest, subsonic velocities, we have an approximation of the motion of a CDP particle through an inviscid and incompressible fluid with a velocity potential in a steady equilibrium flow, defined as:

$$\varphi_o = u_0 r cos\vartheta\left(1+\frac{1}{2}\left(\frac{R}{r}\right)^3\right), \tag{27}$$

where r and ϑ are spherical polar coordinates in an axially symmetric flow and $u_0$is the initial velocity uniform in orientation.

If the perturbed non rotational, equilibrium flows are small, the sliding velocity vector $u_{s,1}$ is non-rotational. In this case particle sliding velocities follow from the potential $\varphi_{s,i}$ i.e.,$u_{s,1} = \frac{\partial \varphi_{s,1}}{\partial x_i}$. Than equation of particle motion is reduced to a simple form of the integral of motion:

$$-\frac{u_0}{\lambda_\nu}\varphi_{s,1}+\frac{1}{2}\left(u_0^2+v_0^2\right)=const \qquad (28)$$

where u_0 и v_0 are components of the non-rotational equilibrium velocity can be written in terms of the slip velocity vector and the value $\varphi_{s,1}$.

Our interest in such a motion lies in the fact that in an appropriate ratio of the characteristic parameters of the system has next properties. The gas incident on the particle flows around it without noticeable energy losses. An important consequence of the latter is that the CDP particle accompanying the plasma current reaches the end point, the North (rarely South) magnetic pole.

If $\left(\frac{u_0}{2\lambda_\nu}\right)^2 - C\frac{u^2{}_0}{R\lambda_\nu} > 0, \nu > 0$. No impact occurs even at the forward stagnation point, and the particle cloud does not reach the body at all. In other words, the condition $\frac{\lambda_\nu}{R}=\frac{1}{4C}$ gives the ratio between the parameters in the critical mode.

The value C is semi-empiric value and has been determined from the model experiment planned by us, which is close to the conditions of the physical problem being solved.

If $\frac{\lambda_\nu}{R}>\frac{1}{4C}$ system going to blow.The case of the reverse inequality $\frac{\lambda_\nu}{R}<\frac{1}{4C}$ does not allow particle collisions.

Thus, we come to the following conclusions:

1. Micro meteoric and interplanetary particles of sufficiently small sizes represent a stream accompanying the solar wind. The currents formed in this case in the magnetic tubes include electrons, protons, and charged CDP particles.

2. The above physical conditions for the functioning of currents in near-Earth magnetic tubes make it possible to conclude that the presence of significant CDP concentrations in the solar wind plasma leads to a significant redistribution of the energy balance. Due to energy loss by the electronic component [6]. The power of the flow decreases, the thermodynamic temperature increases due to the decrease in the energy of the directed motion of the plasma flow (solar wind). In this case, the current strength experiences fluctuations of interest to us.

3. The observed impulsive nature of solar flares leads to the fact that the solar wind flow has an irregular structure. Fluctuations in density, temperature, and pressure during the entry of plasma into the Earth's magnetosphere lead to fluctuations in the concentration of electric ions in magnetic tubes over the entire region.

5. Examples, numerical estimates. Physical aspects: The average resource of a solar flare was fixed with the help of the first satellites. $M_{fl} \approx 10^{13} g,\ N \approx 10^{40}$ protons, electrons), regular solar wind velocity $V_{SW} \approx 4 \cdot 10^7 cm/s$. Observed flare temperatures in Sun is $T \approx 10^8 K$. Proton velocity $V_p \approx 6 \cdot 10^7 cm/s,\ V_e \approx 6{,}7 \cdot 10^9 cm/s$. There are 10^{13}electrons and protons per 1 cm^3 in the region of the Earth after a spherically symmetric explosion in the solar chromosphere. Electrons create a current of 1600 A, protons 1.6 A and particles have μA. After interaction with a magnetic field, the structure and direction of the current changes. The movement of charges along the normal is replaced by their movement along the meridian direction of the magnetic field along the magnetic tubes. The total charge resource is a multiple of $(10^{29} - 10^{30})$ charge units. To obtain the total maximum possible current strength, it is necessary to know the duration of solar flares. Usually it is several days. Therefore, the structure of the current pulse is as follows. The maximum current amplitude is $1{,}6 \cdot 10^{10}\ A$ for the entire flash period, $1.6 \cdot 10^{4}\ A$

Geometric factors. The configuration of the Earth's magnetic field is constantly changing. It has long been known that the magnetic poles change during geological epochs. However, during the processes under consideration, its unperturbed structure is known and can be considered in the next approximation. In the capture zone of LTP with QDF in the form of the solar wind, we assume a uniform rotation of the plasma along a magnetic tube of a cylindrical structure with a simultaneous outflow towards the poles. The role of each plasma component is defined above. Here we note that in order to cause the aurora, it is necessary that, after ionization losses, its energy potential be sufficient for this. Additional energy in the current sheet is achieved due to the cone-shaped narrowing of magnetic tubes near their entrance to the North or, more rarely, to the South Pole of the Earth. The plasma is sharply compressed, heats up and is able to ionize the middle layers of the Earth's atmosphere. Plasma fluctuations embedded at the point of entry into the atmosphere manifest themselves only in the near-surface layers of the atmosphere.

Conclusions. Phenomena accompanying the collective movement of LTP with CDP in the Earth's atmosphere have an impact on many types of practical activities. In addition to the destruction of the ozone layer and disruption of radio communications, the collision of the solar wind with the Earth's atmosphere leads to an atmospheric glow similar to auroras. In some cases, there are such amplitude fluctuations of the electric current inside the tubes of the Earth's magnetic field that it causes an overload of open-type power lines. It has always been believed that such a phenomenon can only be attributed to the electronic component of the solar wind. In the present work, the role of CDP of cosmic origin in the course of the noted processes was indicated. In addition to the CDP, the proton component causes active ionization along its track and forms a secondary electronic component. those. protons “pump” a magnetic tube with fast secondary electrons like cosmic showers from cosmic rays of significant energies [4,6]. Being "frozen" into the fiery clumps of the solar wind during flares, all plasma components have the same speed. In such a plasma, the main kinetic energy of directed motion is carried by protons. It is the proton component that is responsible for maintaining the auroras for a much longer time than the solar flare itself.

Results: In this article, we touched upon the role of the CDP in the formation of current structures inside magnetic tubes. The presence of the CDP leads to the following consequences in the plasma flow that forms the currents.

1. Only very small particles are present in the current sheet, which were carried towards the meridian and equatorial flows by the incident plasma flow.

2. The presence of dust in the current sheet actively removes kinetic energy for its own radiation and reduces the kinetic energy of chaotic motion.
3. At sufficiently low velocities and the criteria given in the work, the oncoming plasma flow goes around small particles without collisions with them.
4. Larger particles are destroyed and burned in the atmosphere and do not affect the formation of currents.
5. We hase found that during the formation of current pulses for every second, the amplitude of the current strength changes in the likeness of atmospheric lightning. However, such a process of changing the amplitude during the day forms a constant additional EMF, causing overload and destruction of electrical networks.
6. The presence of the QDF reduces the amplitude of current disturbances.

Authors' contribution: DND formulated the theoretical foundations for the movement of charged meteor dust and plasma from solar flares in magnetic current tubes and makes up 60% of the volume of the article. DMD participated in the joint writing of all sections, personally developed and designed the technical means for further field studies of induced currents from plasma flows in the atmosphere in the highlands of Bulgaria. 40% of the volume of the article.

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Особливості взаємодії потоків космічної плазми із атмосферними аерозолями Землі.

Резюме. *У статті розглядаєтьсявзаємодіяпотоків сонячної плазми з атмосферним газом, якій містить молекули та частинки з конденсованою дисперсною фазою (далі КДФ). Проведено моделювання та розрахунки існуючих електричних струмів та їх структури. Зроблено висновки про вплив на структуру струму як з боку атмосфери, так и з боку космічних потоків різного складу. Розглянуторівняння руху плазми з КДФ в іоносфері Землі. Зроблено висновки відносно впливу КДФ на термобаланс плазми.Потоки космічної плазми включають компонент з частинками високих енергій і формують зливи вторинних випромінювань і струмів космічних випромінювань, не беруть участь у роботі струмових трубок. Доведено, що в розряджених шарах іоносфери змішані з КДФ потоки плазми зазнають значного додаткового нагрівання частинками КДФ.Вагомі іонізаційні втратидоводять до формування вторинної електронної компоненти у верхній атмосфері. Доведено, що електрони, які виникають у цьому випадку, залучаються до основного потоку плазми.У роботі підкреслено, що реєстрація зливів вторинних частинок є діагностичним критерієм, корисним для калібрування структури потоку плазмиу нижній частині атмосфери Землі. Відзначено, що малі абсолютні значення струмів протонів та α-часток компенсуються їх значною кінетичноюенергією. Унижніх шарах ці частинки є тепло відвідним агентом. Вибухові процесиформують флуктуації потоків плазми,електричного струму і доводять до флуктуації струмів усередині магнітних трубок. Окремо відзначено можливістьїхвпливу на роботу мереж електропостачання під час сильних сонячних спалахів таїх влив на роботу лінії електромереж у горах, навколо полярних та екваторіальних зон. Параметри впливу залежать від амплітудних флуктуацій фізичних параметрів середовища, формуючого атмосферні струми.Доведено, що значний амплітудний характер зміни атмосферних струмів і великі площі індукції систем, формують суттєву додаткову електрорухаючу сілу під час зазначених обурень. Проведено аналіз необхідного обладнання для контролю вимірювання індукованої напруги під час флуктуацій у струмових структурах шарів атмосфери Землі.*

Ключові слова*: іоносферна плазма, плазма з КДФ у магнітних трубках іоносфери, локальні магнітні поля.*