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Formation of Bulk Electric Charges and Fields during Development of Thunderstorm Clouds

Aleksey A. Bychkov*[1] and Vitaly A. Shapovalov[2]

[1]Autonomous Nonprofit Organization "Agency of Atmospheric Technologies",
15, Druzhinnikovskaya str., Moscow, 123242, Russia.
[2]Federal state institute "High Mountain Geophysical Institute",
2, Lenin av., Nalchik, 360030, Russia.

Abstract

There was developed a three-dimensional numerical model of convective cloud taking into account the thermodynamic, microphysical and electric processes. The model uses detailed microphysics. We took into concideration: charge accumulation in the cloud, the electric field strength, electric coagulation of cloud particles. The technique of forming a three-dimensional source of thermodynamic parameters of the troposphere during the initialization of the model. Based on the model used to study the formation of macro- and microstructural, and electrical parameters, the dynamics of change of parameters deep clouds on the stage of growth and maximum development. Investigated electrical characteristics of powerful convective clouds in different moments of time and their relationship with microstructure parameters. Defined spatial structure of volumetric electric charges in the cloud, three-dimensional distribution of the electric field.

Keywords: Mathematical modeling, 3D-model, storm cloud, electric parameters, formation of charges.

INTRODUCTION

Along with the progress made in the physics of clouds over the past decades, it should be noted that many issues still remain poorly understood. This applies, above all, to processes in clouds with participation of ice particles, cloud electricity, interaction of processes in clouds, etc.

Models of clouds of varying complexity have been developed in our country [1-6] and abroad [7-16], including models taking into account electrical processes [1, 3, 6, 11, 12, 15, 16].

Further progress in the physics of convective clouds and active influences on them requires solution of qualitatively new problems. It comprises of studying clouds as a whole, taking into account their system properties, i.e., taking into account the interaction of processes in clouds with each other and clouds with the surrounding atmosphere.

At the present stage of development of cloud physics, the role of mathematical modeling is greatly enhanced, which is the main means of studying complex systems which include thunder hailstorm clouds [1-3, 14].

Directions of research in the physics of clouds are as follows:

- Improvement of mathematical models in terms of clarifying and expanding processes they take into account;
- use of more efficient methods of calculation;
- improvement of methods of input data generation;
- study of regularities in formation of macro- and micro structural characteristics of convective clouds under natural development and active action;
- study of interaction of physical processes within clouds and clouds with the surrounding atmosphere.

The objective of the work is the development of a three-dimensional numerical model of a convective cloud with a detailed account of thermodynamic, microphysical and electrical processes and the study of formation of macro- and micro structural characteristics, electrical parameters on its basis and interaction of physical processes within clouds.

The survey of the simulation of convective clouds taking into account electrical processes in our country and abroad showed that the electric processes in the models are not sufficiently taken into account, especially with detailed micro physics. The main problems are formalization of electrification processes and taking into account the influence of electrical characteristics of a cloud on the microstructure of clouds. It is not enough to take into account the interaction of physical processes in clouds, but these issues are beginning to be considered [3, 4, 6, 17-20].

MODEL DESCRIPTION

The developed three-dimensional non-stationary model of convective cloud is represented below, the detailed description of thermodynamic, microphysical and electric processes are given. The model is distinctive by the detailed micro physics usage with several dozens of gradations of liquid and solid particles sizes. There was taken into account: charge accumulation in the cloud, the potential and tension of the electric field strength, electric coagulation of cloud particles.

The hydro thermodynamic block of the model consists of equations of motion describing moist convection in the Boussinesq approximation, in which advective and turbulent transport, buoyancy, friction and pressure gradients are taken into account. The microphysical block of the model describes processes of nucleation, condensation, coagulation of droplets with droplets, sublimation, accretion, freezing of droplets, deposition of cloud particles in the field of gravity, their transfer by air currents, and interaction of cloud particles under the influence of the electric field of a cloud [1, 3, 4].

Formulation of the problem of the mathematical model of a convective cloud includes the following equations of thermodynamics, microphysics and electrostatics:

$$\frac{\partial u}{\partial t} + (\vec{V} \cdot \nabla) u = -\nabla \pi' + \Delta' u + l v \,, \tag{1}$$

$$\frac{\partial v}{\partial t} + (\vec{V} \cdot \nabla) v = -\nabla \pi' + \Delta' v - l u \,, \tag{2}$$

$$\frac{\partial w}{\partial t} + (\vec{V} \cdot \nabla) w = -\nabla \pi' + \Delta' w + g\left(\frac{\theta'}{\theta_0} + 0{,}61 s' - Q_S\right), \tag{3}$$

continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = \sigma w \,, \tag{4}$$

equations of thermodynamics

$$\frac{\partial \theta}{\partial t} + (\vec{V} \cdot \nabla) \theta = \frac{L_{\text{К}}}{c_p} \frac{\theta}{T} \frac{\delta M_{\text{К}}}{\delta t} + \frac{L_C}{c_p} \frac{\theta}{T} \frac{\delta M_C}{\delta t} + \frac{L_{\text{З}}}{c_p} \frac{\theta}{T} \frac{\delta M_{\text{З}}}{\delta t} + \Delta' \theta \,, \tag{5}$$

$$\frac{\partial s}{\partial t} + (\vec{V} \cdot \nabla) s = -\frac{\delta M_{\text{К}}}{\delta t} - \frac{\delta M_C}{\delta t} + \Delta' s \,,$$

Equations for distribution functions of droplets, crystals, and frost-fragmentation by mass:

$$\frac{\partial f_1}{\partial t} + u \frac{\partial f_1}{\partial x} + v \frac{\partial f_1}{\partial y} + (w - V_1) \frac{\partial f_1}{\partial z} = \left(\frac{\partial f_1}{\partial t}\right)_{\text{К}} + \left(\frac{\partial f_1}{\partial t}\right)_{\text{КГ}} + \left(\frac{\partial f_1}{\partial t}\right)_{\text{АК}} + \left(\frac{\partial f_1}{\partial t}\right)_{\text{ДР}} + \left(\frac{\partial f_1}{\partial t}\right)_{\text{З}} + \Delta' f_1 + I_1 \,, \tag{7}$$

$$\frac{\partial f_2}{\partial t} + u \frac{\partial f_2}{\partial x} + v \frac{\partial f_2}{\partial y} + (w - V_2) \frac{\partial f_2}{\partial z} = \left(\frac{\partial f_2}{\partial t}\right)_{C} + \left(\frac{\partial f_2}{\partial t}\right)_{\text{АК}} + \left(\frac{\partial f_2}{\partial t}\right)_{\text{З}} + \Delta' f_2 + I_2 + I_{\text{АВ}} \,, \tag{8}$$

$$\frac{\partial f_3}{\partial t} + u \frac{\partial f_3}{\partial x} + v \frac{\partial f_3}{\partial y} + (w - V_2) \frac{\partial f_3}{\partial z} = \left(\frac{\partial f_3}{\partial t}\right)_{\text{З}} + \left(\frac{\partial f_3}{\partial t}\right)_{\text{АК}} + \Delta' f_3 \,, \tag{9}$$

Poisson equation for potential of an electrostatic field

$$\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2} + \frac{\partial^2 U}{\partial z^2} = -\frac{\rho_{\text{e}}}{\varepsilon_0} \,, \tag{10}$$

Initial conditions for equations (1) - (12) have the following form:

$$u(\vec{r},0) = u_0(\vec{r}),\, v(\vec{r},0) = v_0(\vec{r}),\, w(\vec{r},0) = w_0(\vec{r}),\, \theta(\vec{r},0) = \theta_0(\vec{r}),\, s(\vec{r},0) = s_0(\vec{r}), \tag{11}$$

$$f_1(\vec{r},m,0) = f_2(\vec{r},m,0) = f_3(\vec{r},m,0) = 0,\ \rho_-(\vec{r},0) = \rho_+(\vec{r},0) = 0. \tag{12}$$

Border conditions:

$$u(\vec{r},t) = u_0(\vec{r}),\, v(\vec{r},t) = v_0(\vec{r}),\, w(\vec{r},t) = w_0(\vec{r}),\, \theta(\vec{r},t) = \theta_0(\vec{r}),\, s(\vec{r},t) = s_0(\vec{r})\Big|_{x=0,L_x;\,y=0,L_y;\,z=L_z}$$

$$u(\vec{r},t) = v(\vec{r},t) = w(\vec{r},t) = 0,\, \theta(\vec{r},t) = \theta_0(\vec{r}),\, s(\vec{r},t) = s_0(\vec{r})\Big|_{z=0} \tag{13}$$

$$f_1(\vec{r},m,t)=f_2(\vec{r},m,t)=f_3(\vec{r},m,t)=0\Big|_{x=0,L_x;y=0,L_y;z=L_z}$$

$$\frac{\partial f_1(\vec{r},m,t)}{\partial z}=\frac{\partial f_2(\vec{r},m,t)}{\partial z}=\frac{\partial f_3(\vec{r},m,t)}{\partial z}=0\Bigg|_{z=0} \tag{14}$$

$$\frac{\partial U(\vec{r},t)}{\partial x}=0\Bigg|_{x=0,L_x},\ \frac{\partial U(\vec{r},t)}{\partial y}=0\Bigg|_{y=0,L_y},\frac{\partial U(\vec{r},t)}{\partial z}=0\Bigg|_{z=L_z},U(\vec{r},t)=0\Big|_{z=0} \tag{15}$$

The system of equations is applied to the space-time domain

$$0\le x\le L_x,\ 0\le y\le L_y,\ 0\le z\le L_z,\quad 0\le m<\infty,\ t>0. \tag{16}$$

The following notation is used:

$$\left(\vec{V}\cdot\nabla\right)\equiv u\frac{\partial}{\partial x}+v\frac{\partial}{\partial y}+w\frac{\partial}{\partial z},$$

$$\Delta'=\frac{\partial}{\partial x}K\frac{\partial}{\partial x}+\frac{\partial}{\partial y}K\frac{\partial}{\partial y}+\frac{\partial}{\partial z}K\frac{\partial}{\partial z},$$

$\vec{r}=\{x,y,z\}$- coordinate vector, $\vec{V}=\{u,v,w\}$ – speed vector, $u(\vec{r})$, $v(\vec{r})$, $w(\vec{r})$ - velocity vector components; *l* – inertial force considering parameter; $\theta(\vec{r})$ – potential temperature; $\pi(\vec{r})=c_p\bar{\theta}(P(z)/1000)^{R/C_p}$ – dimensionless pressure; $\bar{\theta}$ – mean potential temperature; *R* – gas constant; $s(\vec{r})$ - specific air humidity; $Q_S(\vec{r})$ – the total ratio of the mixture of liquid and solid phases in the cloud; $\sigma(z)$ – a parameter which takes into account the change in air density with altitude; $P(z)$ and $T(\vec{r})$ – respectively, pressure and temperature; c_p - air heat capacity at constant pressure; $L_K, L_C, L_З$ – respectively, the specific heat of condensation, sublimation and freezing; $\pi'(\vec{r}),\theta'(\vec{r}),s'(\vec{r})$- deviations of dimensionless pressure, potential temperature and specific humidity from their background values in the ambient atmosphere $\pi_0(\vec{r}),\theta_0(\vec{r}),s_0(\vec{r})$; $\frac{\delta M_K}{\delta t}$, $\frac{\delta M_C}{\delta t}$ - changes in specific humidity due to diffusion of steam into droplets and crystals; $\frac{\delta M_З}{\delta t}$ – the mass of dropping water that freezes per time unit in a volume unit of air; $K(\vec{r})$ – turbulent diffusion rate. $V_1(m),V_2(m)$ – steady-state velocities of incidence of liquid and solid particles; $\left(\frac{\partial f_1}{\partial t}\right)_K$, $\left(\frac{\partial f_1}{\partial t}\right)_{КГ}$, $\left(\frac{\partial f_1}{\partial t}\right)_{АК}$, $\left(\frac{\partial f_1}{\partial t}\right)_{ДР}$, $\left(\frac{\partial f_1}{\partial t}\right)_З$ – changes in distribution function of droplets due to microphysical condensation processes, coagulation of droplets, accretion of droplets and crystals, crushing and freezing respectively; $\left(\frac{\partial f_2}{\partial t}\right)_C$, $\left(\frac{\partial f_2}{\partial t}\right)_{АК}$, $\left(\frac{\partial f_2}{\partial t}\right)_З$ – changes in distribution function of crystals due to sublimation, accretion and freezing of droplets; $\left(\frac{\partial f_3}{\partial t}\right)_З$, $\left(\frac{\partial f_3}{\partial t}\right)_{АК}$ – changes in the distribution function $f_3(\vec{r},m,t)$ due to formation of fragments during spontaneous freezing of supercooled cloud droplets and their accretion with crystals; I_1 и I_2 – sources of droplets and crystals; I_{AB} – source of artificial crystals under active influence; ε_0 – dielectric constant of vacuum.

Boundaries of the spatial domain are denoted by $0, L_x, 0, L_y$ и $0, L_z$.

To describe coagulation processes in the cloud, an integral-differential equation is used in the form:

$$\left(\frac{\partial f}{\partial t}\right)_{КГ}=-f_1(\vec{r},m,t)\int_0^\infty\beta_1(m,m')\cdot f_1(\vec{r},m',t)dm'+ \\ +\int_0^{m/2}f_1(\vec{r},m-m',t)\beta_1(m,m-m')f_1(\vec{r},m',t)dm', \tag{17}$$

where

$\beta_1(m,m')=\pi(r(m)+r(m'))^2\cdot|V_1(m)-V_1(m')|\cdot e_1(m,m')$; $r(m)$ и $r(m')$ is radii of colliding particles; $V_1(m)$ и $V_1(m')$ is their speed of fall; $e_1(m,m')$ is efficiency of gravitational capture for droplets.

Interaction of droplets and crystals is calculated on the basis of the following relationships:

$$\left(\frac{\partial f_1}{\partial t}\right)_{АК}=-f_1(\vec{r},m,t)\int_0^\infty\beta_2(m,m')\cdot f_2(\vec{r},m',t)dm', \tag{18}$$

$$\left(\frac{\partial f_2}{\partial t}\right)_{AK} = -f_2(\vec{r},m,t)\int_0^{\infty}\beta_2(m,m')\cdot f_1(\vec{r},m',t)dm' +$$

$$+\int_0^{m}\beta_2(m,m-m')\,f_2(\vec{r},m-m',t)\,f_1(\vec{r},m',t)dm', \qquad (19)$$

where
$\beta_2(m,m') = \pi(r(m)+r(m'))^2\cdot|V_1(m)-V_2(m')|\cdot e_2(m,m')$,
$e_2(m,m')$ is the capture rate for droplets and crystals. The assumption is made that the collision of crystals with droplets results in freezing of the latter.

The model takes into account the detailed processes of electrization of cloud particles based on the obtained patterns of thunderstorm activity in clouds and the values of charge separation rates associated with freezing of water droplets, growth of graupel and hailstones, and interaction of hailstones with ice crystals and supercooled droplets [3].

Due to microphysical processes of freezing droplets and accretion in the cloud, a negative charge accumulates on ice particles. At the same time, a positive charge is formed consisting of charges of individual particles – fragments of freezing of droplets.

For freezing droplets with a diameter greater than 200 μm, the electrification process is described with sufficient accuracy by the expression

$$q(m) = a\cdot m, \qquad (20)$$

where m is a mass of a frozen drop, a is rate of proportionality, the value of which varies depending on the content of impurities in a drop and the temperature of its freezing ($a \approx 3{,}5\cdot 10^{-10}$ Kl/g while T = -8...-16 °C).

Formation of fragments during freezing of droplets is taken into account as follows:

$$\left(\frac{\partial f_3}{\partial t}\right)_3 = \int_m^{\infty} n(m,m')R(\vec{r},m',t)\,f_1(\vec{r},m',t)dm', \qquad (21)$$

where $n(m,m')$ is the number of ice mass shards m, formed during freezing of mass droplets m', $R(\vec{r},m',t)$ is probability of freezing of droplets by mass m' per time unit.

The number of ice shards $n(m,m')$ is determined according to experimental dependences of micro-particle emissions on the size of a freezing drop. The data obtained at the High-Geophysical Institute and from literature sources were used.

Microscopic frost shards are carried out by streams to the upper part of the cloud, where a predominantly positive space charge is formed $\rho_+(\bar{r},t)$. The region of concentration of negatively charged ice particles forms a zone of predominantly negative space charge $\rho_-(\bar{r},t)$.

Simulation at each time step calculates volume charges in the cloud, the potential of electrostatic field generated by these charges, as well as horizontal and vertical components of the electric field tension of the cloud.

The value of total (positive and negative) space charges $\rho_e(\vec{r})$ is used to determine the potential $U(\vec{r})$ of the created electrostatic field. For this, the three-dimensional Poisson equation (10) is solved at each time step.

The electric field strength $\vec{E}(x,y,z)$ at the point (x,y,z) is determined by the formula:

$$\vec{E}(x,y,z) = -\left(\vec{n}_x\frac{\partial U}{\partial x} + \vec{n}_y\frac{\partial U}{\partial y} + \vec{n}_z\frac{\partial U}{\partial z}\right). \qquad (22)$$

Values of electric field tension were taken into account in the work for calculation of rates of electric coagulation of cloud particles. For this, approximating formulas constructed from the existing theoretical and experimental data for this parameter were used [1].

For comparison with observational data, the radar reflectivity of the cloud Z (in dBZ) at wavelengths of 3 cm, 5 cm and 10 cm was calculated in the model.

The system of equations of the model (1) - (16) was solved by methods of splitting by physical processes and componentwise.

The results of testing of the model demonstrated the high accuracy of the implemented numerical methods and calculation algorithms used in the model.

To analyze calculation results, author software for three-dimensional data visualization has been developed. The program provides a detailed analysis of simulation data and an objective physical interpretation.

THE RESULTS OF STUDY OF ELECTRICAL PARAMETERS OF POWERFUL THUNDERSTORM CLOUDS

Let us turn our attention to the results of studies of formation of thermodynamic, microstructural and electrical parameters of convective clouds under different atmospheric conditions.

Dimensions of the spatial domain in calculations were set from 40 to 80 km horizontally and 16 km vertically. The grid spacing along the X, Y coordinates was 500-1000 m, along the Z – 250-500 m. The X axis is directed to the east, Y – to the north, Z is vertical. The cloud was initiated by setting the pulse at the earth surface with overheat δT 1-4 °C. The shape and size of the pulse varied in numerical experiments.

The developed numerical model of a convective cloud with detailed microphysics makes it possible to study formation of microstructural characteristics of clouds, formation of precipitation particles, accumulation of electric charges, and electric coagulation of cloud particles.

For description of microphysical processes, detailed equations for mass distribution functions of particles are used. The results obtained with this model reflect nonlinear effects of cloud physics that can not be studied and evaluated using simpler models, for example, with parametrized microphysics.

When performing numerical experiments, aerological sounding data were used at the Mineralnye Vody Airport, and in a number of experiments three-dimensional data on components of horizontal wind were used. Days when there were showers, thunderstorms, hailstorms in fact, were chosen.

Figure 1 shows in vector form flows in a vertical plane passing through a cloud.

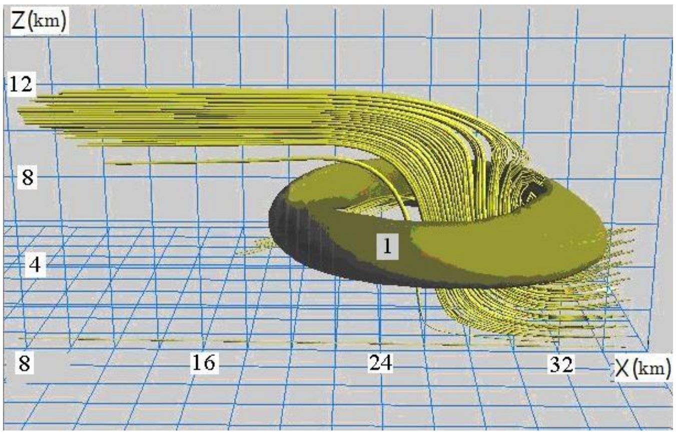


Figure 1: Velocity of air streams in a vertical plane passing through a cloud. Current lines and isosurface Vz = -3 m/s are presented (downward flows around the ascending one). A grid with cells 2x2 km is shown.

Around the cloud, downward currents are noted, on the windward side they are amplified by an external wind, behind a cloud can be weaker, because a hydrodynamic shadow appears behind the cloud.

For comparison with real clouds, the data of radar observations from Doppler weather radars of Russian production were used [5].

Figure 2 shows the results of modeling the change in the background wind in the horizontal plane in presence of a convective cloud. The horizontal wind field interacts with the cloud: the flow spreads out before the cloud, and in the rear part it partially wraps up getting into the cloud.

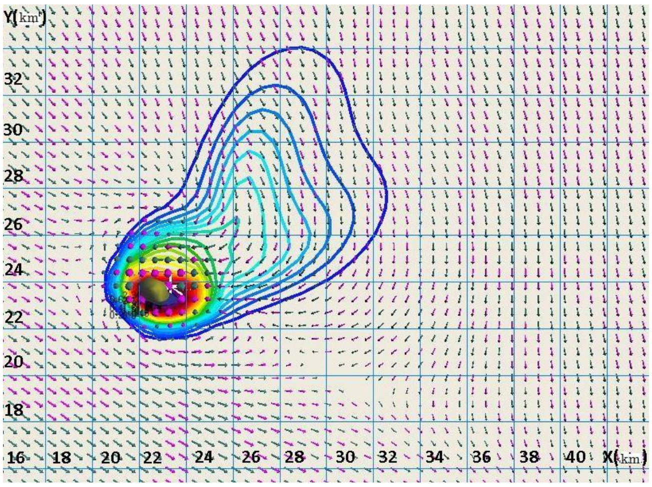


Figure 2: Flow around a convective cloud with a horizontal wind and a twist of flows at a level Z = 4 km.

Numerical experiments performed on various sounding data have shown that characteristics of the cloud resulting from the three-dimensional model are sensitive to vertical distributions of temperature and humidity in the atmosphere and to the three-dimensional structure of the horizontal wind.

A comparison of the characteristics of the model cloud with observational data was performed, qualitative and quantitative agreement of the calculated data with parameters observed in field experiments was noted.

With the help of the 3D visualization program, a picture of development of a cloud is constructed (Fig. 3).

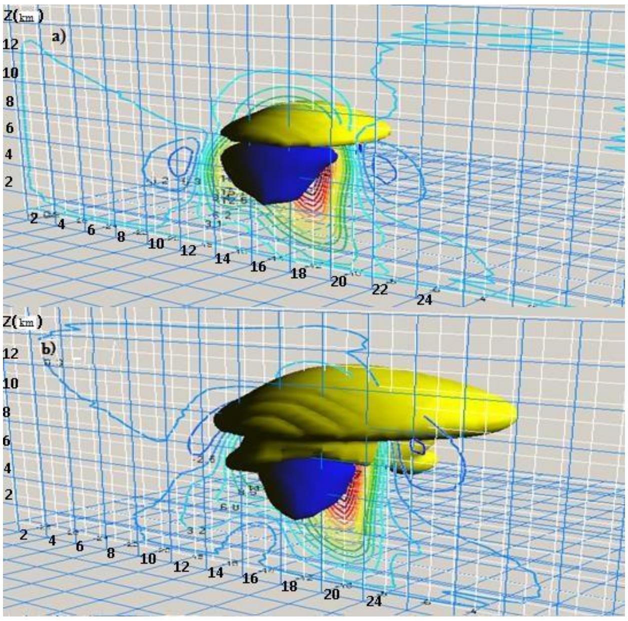


Figure 3: Water content isosurfaces (blue) large droplets and ice (yellow), ice particles at successive instants of time: (a) – 20 minutes, (b) – 30 minutes. The auxiliary grid is 2x2 km.

The analysis of water content, ice content and other parameters in the considered spatial domain at different moments of cloud development is carried out.

Around the 40th minute, the cloud reaches the stage of maximum development, particles of liquid and solid precipitation appear. The maximum upstream velocity Wm = 29 m/s is observed at a level of z = 6 km, the downstream velocity is -3.2 m/s. The column of the ascending stream has a slight slope in the direction of the horizontal air flow.

Formation of precipitation at 40 minutes is shown in Fig. 4. Figure 4a shows isolines of water content, in Fig. 4b isolines of ice are shown.

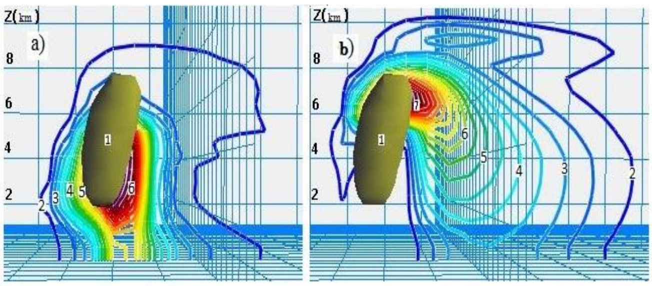
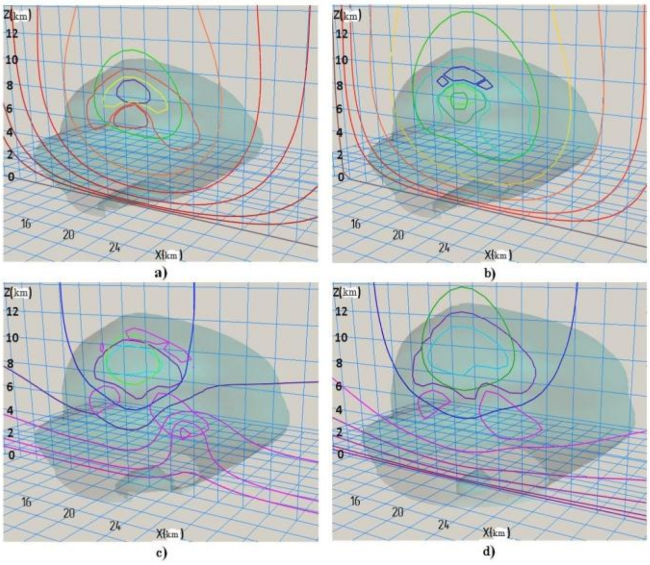


Figure 4: Water isolines (a) and ice cover (b) at the 40th minute of cloud development and isosurface w = 10 m/s (1): 2: q_{lwc}=1.6 g/m^3; 3: q_{lwc}=3.4 g/m^3; 4: q_{lwc}=4.2 g/m^3; 5: q_{lwc}=6.1 g/m^3; 6: q_{lwc}=9.95 g/m^3 – liquid-water content maximum; 2: q_{lwc}=0.2 g/m^3; 3: q_{lwc}=0.8 g/m^3; 4: q_{lwc}=1.2 g/m^3; 5: q_{lwc}=1.5 g/m^3; 6: q_{lwc}=1.8 g/m^3; 7: q_{lwc}=3.80 g/m^3 – ice content maximum.

Formation and accumulation of electric charges in the cloud occurs as a result of freezing of droplets, accretion (the interaction of droplets and crystals), and collisions of crystals. Due to different speeds of falling microscopic fragments through the air (which are charged predominantly positively) and larger particles, grains and hail (which are mainly charged negatively), spatial separation of charges takes place: In the pre-peak part of the cloud, a positive volumetric charge prevails, and below it – negative ones. The density of positive charge in the 20th minute reached $2.8*10^{-9}$ Cl/m^3, negative $-1.5*10^{-9}$ Cl/m^3, the electrical potential was $1.4*10^9$ V. Components E_x, E_y of the field strength were about 1300 V/cm, $E_z \approx 2000$ V/cm. Based on simulation results, the spatial distribution of total space charge of the cloud at different times (Fig. 5) was studied. The strength of electrostatic field calculated at each instant in the nodes of spatial grid was taken into account when calculating values of coagulation coefficients of droplets and crystals.



a) b) c) d)

Figure 5: Isolations of space charge and potential in vertical plane passing through the cloud, against the background of the isosurface of the radar reflectivity Z = 10 dBZ, at times a) t = 30 min; b) t = 33.5 min; c) t = 37 min; d) t = 40.5 min. The space charge isolines (closed circuits) have following values: $-5.0 \cdot 10^{-9}$, $-1.0 \cdot 10^{-9}$, $-1.0 \cdot 10^{-10}$, $1.0 \cdot 10^{-10}$, $1.0 \cdot 10^{-9}$, $5.0 \cdot 10^{-9}$ Cl/m^3 and potential of levels created by this charge (in order from the outer contour to the center) $-5.0 \cdot 10^8$, $-2.5 \cdot 10^8$, $-1.0 \cdot 10^8$, $-5 \cdot 10^7$, $-2.5 \cdot 10^7$, $-1.0 \cdot 10^7$, $-5.0 \cdot 10^6$, $5.0 \cdot 10^6$, $1.0 \cdot 10^7$, $2.5 \cdot 10^7$, $5.0 \cdot 10^7$, $1.0 \cdot 10^8$, $2.5 \cdot 10^8$, $5.0 \cdot 10^8$ V.

Over time, the charge in the cloud and, accordingly, the electrostatic potential, increase. The maximum electric potential obtained in calculations was more than 2 · 109 V, the potential maximum region is in the upper frontal part of the cloud in the region of the "anvil". The intensity of electrostatic field at the 40th minute makes 1600 ÷ 2000 V/cm.

Precipitation is formed in the upper part of the ascending stream, then their further growth and fallout (ahead and to the left) from the ascending current take place.

The interaction coefficient of small particles is relatively small. According to various data, it makes from 0.001 to 0.01. As noted above, in the presence of an electric field and charges on particles, this coefficient increases significantly and, under appropriate conditions, can exceed 1.

Numerical experiments were carried out taking into account electrical coagulation of cloud particles and without taking it into account. Comparison of formation time of precipitation in these two cases showed that due to electrical coagulation the growth time of precipitation particles in a powerful convective cloud is substantially reduced (approximately by 10-12 min).

In numerical experiments, it was found that a positive feedback is observed in the cloud between growth of mass of ice particles and the volumetric electric charge. The need to study interaction of processes in convective clouds is associated with their important role in cloud and sedimentation.

CONCLUSION

Formation of positive and negative volumetric electric charges in the cloud is studied, characteristics of electrostatic field at successive instants of time are calculated.

Interaction of microstructural and electrical parameters in high-power convective clouds is analyzed. In numerical experiments, it was found that a positive feedback is observed between growth of mass of ice particles and volumetric electric charge.

The calculated values of electrostatic field strength are applied in the model to correct coagulation factor of cloud particles.

It is determined that due to electric coagulation, growth time of precipitation particles in a powerful convective cloud decreases by 10-12 minutes.

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