Three-dimensional numerical model of powerful convective cloud

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In work the short description of three-dimensional non-stationary model of convective cloud with the detailed description of hydrothermodynamic, microphysical and electrical processes is presented, some results of numerical experiments which specify a structure and physics of thunderstorm are resulted.

The hydrothermodynamic block of model consists of the equations describing of damp convection in approach by Bussinesk in which advective and turbulent airflows, forces of buoyancy, a friction and baric gradients [1,2] is included.

Nucleation, condensation, coagulation of drops with drops, sublimation, accretion, freezing of drops, sedimentation of cloudy particles in the field of a gravity, their carrying over by air streams, and also interaction of cloud particles under the influence of cloud electric field are included in the microphysical block of the model . The system of the equations is composed for weights distribution functions of drops f_1 ($\vec{r}$, m, t), ice particles f_2 ($\vec{r}$, m, t) and splinters of freezing of drops f_3 ($\vec{r}$, m, t) [3].

The model includes electrization of cloud particles at fast freezing of drops and accretion (collision of drops with ice crystals). Large ice particles, graupel and hailstones are charged mainly negatively, freezing splinters (the small ice particles, produced at drop freezing) described by function of distribution f_3 ($\vec{r}$, m, t)), are charged positively.

Drop freezing produces the emission of charged microparticles (splinters) [3]. The same process observed at interaction of crystals with overcooled drops. Experimental dependences of emissions of microparticles on the size of a freezing drop and on values of division factor at drop freezing and interaction of crystals with overcooled drops have been approximated to calculate particle charges and a cloud electric field. Volume charges in a cloud, potential of the electrostatic field created by these charges, and also horizontal and vertical components of intensity of a field of a cloud [3] are calculated in the model on each time step.

Radar-tracking reflectivity of a modelling cloud on lengths of waves 0.03 m off and 0.10 m is calculated for comparison to the data of radar-tracking observation.

The sizes of spatial area at calculations were set 60 km horizontal and 16 km - on a vertical. The grid step on co-ordinates X, Y is 500 m, on Z - 250 m. The cloud was initiated by the thermal impulse at an earth surface with an overheat ΔT=1-3 ^{o}C (value of an overheat varied in a series of experiments). The impulse has a form of a cylindrical disk, its diameter in horizontal plane D=5 km, on vertical H=2.0 km.

On fig. 1 are resulted area of a concentration of drop fraction (1) and area of formation of large ice particles (2) on 60th minute of development of a cloud. Also isolines of ascending and descending streams in the vertical plane crossing a cloud are represented.

By results of calculations the ice phase in a cloud is formed at the expense of drops freezing, the further growth of large ice particles, graupels and hailstones occurs by accretion.

At calculation of electrical parameters of a cloud the condition is accepted that formation and accumulation of electric charges in a cloud results from freezing of drops and process accretion (interactions of drops and crystals). Owing to a difference of speeds of falling in air of the microsplinters charged mainly positively, and larger particles, graupels and the hailstones, charged mainly negatively, there is a spatial division of charges: in a pretop part of a cloud the positive volume charge, more low - negative prevails. The positive charge in volume unit at 40th minute reaches values of $2.7 \cdot 10^{-9}$ C/m^3, negative $-1.4 \cdot 10^{-9}$ C/m^3. By results of modelling have been investigated, besides other parametres, spatial distribution of a total volume charge and intensity of an electrostatic field in a cloud during the various moments of time. The electric field potential made an order $1,8\cdot10^9$ V. Components of intensity of a field have values E_x, $E_y \approx 1600$ V/sm, and $E_z \approx 2300$ V/sm.

Values of an electrostatic field intensity, calculated in knots of a spatial grid on time step, were used to calculate coagulation factors of drops and crystals.

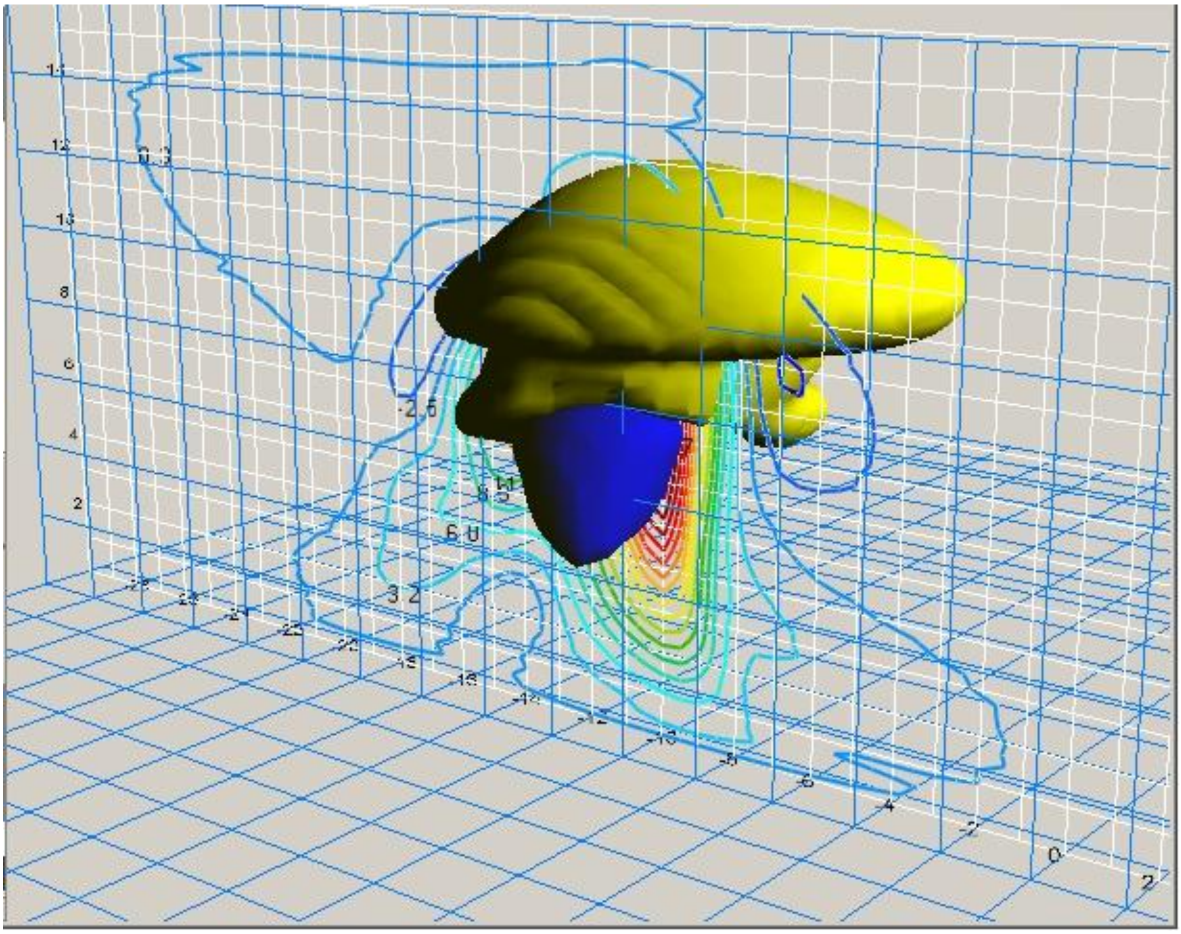

Figure 1 - Area of a concentration of liquid fraction (1) and area of formation of large ice particles (2) on 60th minute of development of a cloud. The cloud height makes 14 km, the maximum reflectivity 65 dBZ. In a vertical plane the isolines of ascending and descending streams expressed in metres per second are resulted. The auxiliary grid 2x2 km is resulted.

Approximately by 60th minute the cloud reaches stages of the maximum development and already gives liquid and firm precipitations. Eventually a charge in a cloud, and, accordingly field potential, increase ($U=2\cdot10^9$ V, E_z=2700 V/sm). The potential maximum is observed in the field of "anvil".

The structure of a modelling cloud radioecho matchs the data of observed thunderstorms in a stage of the maximum development.

Numerical experiments with electric coagulation of cloud particles and without it are made. Comparison of time of precipitation formation in these two cases has shown that time of growth of precipitation particles in a powerful convective cloud is essentially reduced (approximately to 20 30 %) due to electric coagulation.

Results of modelling on the basis of three-dimensional model with the detailed account of hydrothermodynamic, microphysical and electric processes show that interaction of various physical processes takes place. In particular, dynamic processes make considerable impact on formation of thermodynamic fields in a cloud which, in turn, define a course of microphysical processes and character of precipitation growth.

It is necessary to underline that mathematical modelling is the unique tool of studying of mutual influence of physical processes in clouds. It is not obviously possible to study these processes with other methods.

The basic results of work:

- Values of thermohydrodynamic and microstructural parametres in a convective cloud at different stages of development are specified.
- Formation of positive and negative volume electric charges is investigated, characteristics of an electrostatic field in the course of cloud evolution are calculated.
- Influence of electric coagulation of cloud particles on speed of formation of precipitation in a powerful convective clouds is investigated.

The literature

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