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NUMERICAL MODELLING OF SOME ABNORMAL PROCESSES IN A MESOSCALE BOUNDARY LAYER OF AN ATMOSPHERE

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Abstract. Some abnormal meteorological processes are simulated on the basis of the numerical model developed by us , in particular, a simultaneous existence of a cloud and a fog; the incorporated complex "fog-cloud"; daily continuous overcasting. Contributions of certain meteorological parameters, especially, relative humidity and turbulent factors, are revealed to formation of abnormal processes.

Keywords and phrases: A mesoscale boundary layer of an atmosphere, a fog, a cloud, a numerical simulation, a local weather forecast.

AMS subject classification: 60H10, 60H3X.

Statement of the problem. In this article some abnormal meteorological processes are simulated on the basis of the numerical model [1] developed by us. So we have 2-direction the non-stationary problem about mesoscale boundary layer of an atmosphere (MBLA) over a temperature nonhomogeneous underlying surface. The initial system of equations and boundary-initial conditions has such view [1]:

$$
\begin{aligned}
&\frac{du}{dt} = -\frac{\partial \pi}{\partial x} + \Delta' u,\\
&\frac{\partial \pi}{\partial z} = \lambda \theta,\\
&\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} = 0,\\
&\frac{d\theta}{dt} + Sw = \frac{L}{c_p}\Phi + \Delta' \theta,\\
&\frac{dq}{dt} + \gamma_q w = -\Phi + \Delta' q,\\
&\frac{dv}{dt} = \Phi + \Delta' v,\\
&\frac{d}{dt} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + w\frac{\partial}{\partial z},\\
&\Delta' = \mu \frac{\partial^2}{\partial x^2} + \nu \frac{\partial^2}{\partial z^2},
\end{aligned}
$$

where u, w are horisontal and vertical components of an air velocity, respectively, π, θ, q - deviations of a pressure analog, a potential temperature and a water-vapor mixing ratio from their undisturbed fields, respectively, v - a liquid-water mixing ratio, μ, ν -

horisontal and vertical coefficients of turbulence, respectively.

$$
\begin{array}{llllll}
\text{at } z=0 & u=0, & w=0, & \theta=F(x,t), & q=0, & v=0, \\
\text{at } z=Z & u=0, & \pi=0, & \theta=0, & \dfrac{\partial q}{\partial z}=0, & \dfrac{\partial v}{\partial z}=0, \\
\text{at } x=0,X & \dfrac{\partial u}{\partial x}=0, & \dfrac{\partial \theta}{\partial x}=0, & \dfrac{\partial q}{\partial x}=0, & \dfrac{\partial v}{\partial x}=0, & \\
\text{at } t=0 & u=0, & \theta=0, & q=0, & v=0, &
\end{array}
$$

where X, Z horizontal and vertical sizes of MBLA, and temperature of MBLA underlying surface which we take from meteoexperiments [2, 3]:

$$
F(x,t)=\begin{cases} 0 & 0 \le x \le 32\text{km}, \qquad 48\text{km} < x \le 80\text{km}, \\ 5\sin\omega t & 32\text{km} \le x \le 48\text{km}, \end{cases}
$$

here ω is an angular velocity of daily rotation of the Earth.

The sense and value of other constants and parametres are in detail given in [1].

A simultaneous existence of a cloud and a fog. It was simulated such regime of MBLA on a basis of our model when simultaneously exists both a cloud, and a fog. Easing of a cloud and strengthening of a fog take place at this time. Their simultaneous existence is interesting not only from the point of view of local weather forecast, but also with the purpose of research of the ecological party of a considered process. In this case allocation of the latent condensation heat causes formation of multilayered (undercloud, overcloud, overfog and etc.) temperature inversion in which accumulation of polluting substances takes place. Matveev has denominated to this phenomenon "Inversion of a dynamic origin " [2, p. 579].

Certainly, this regime is reached at high relative humidity ($f = 0.95$, $\mu = 10^4 \frac{m^2}{sec}$, $\nu = 10 \frac{m^2}{sec}$). Corresponding Isolines of liquid-water mixing ratio are given on Fig. 1. Apparently from this figure, by 15 o'clock simultaneously exists both the cloud, and a fog, besides maximal a fog liquid-water mixing ratio ($v_{max} = 1.00 \frac{g}{kg}$) is essential more maximal a cloud liquid-water mixing ratio ($v_{max} = 0.70 \frac{g}{kg}$).

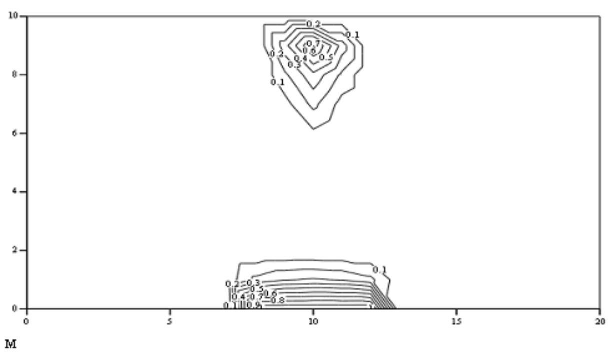

Fig.1.

Besides, a fog transformation in a cloud at both edges of thermal "island" takes place is caused by that at gradual heating of a underlying surface. The fog and the rest, top-circle fog gradually disappears turns to a cloud. Actually, from one fog it is received two clouds.

Simulation of the incorporated complex "fog-cloud". On the basis of our numerical model also it has been simulated not only simultaneous existence of a fog and a cloud, but also their incorporated complex. It is reached in the certain regime, in particular, at $f = 0.95$, $\mu = 10^4 \frac{m^2}{sec}$, $\nu = 10 \frac{m^2}{sec}$.

Realization of a complex "fog-cloud" has occured only by narrow, one-dot "neck", Corresponding Isolines of liquid-water mixing ratio are given on Fig. 2. Therefore we have been compelled to take a plenty isolines. They aren't designated their numerical values on isolines to not complicate the figure. For clearness all we shall note, that maximal cloud and fog liquid-water mixing ratio are equaled $1.72 \frac{g}{kg}$, and $1.01 \frac{g}{kg}$, respectively. If we had more a high-resolution of a countable grid, complex "neck", likely, would turn out more widely. The complex "fog-cloud" existed within 4 hours, from 13 till 17 o'clock.

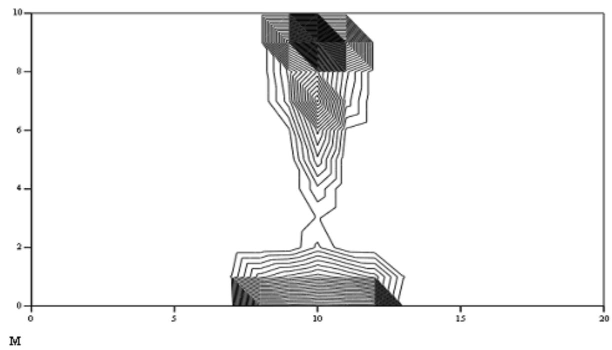

Fig.2.

Generally speaking, stratus, convective clouds, tropical cyclones and tornadoes are described by the different equations and initial-boundary conditions. The main distinction consists that in stratus is accepted quasistatical approach, and in convective clouds, tropical cyclones and tornadoes are considered the full third equation for vertical components of an air velocity. In the equations describing tropical cyclones and a tornado, except this distinction there is also Coriolis force [4]. Certainly, these problems differ by corresponding regional conditions. But despite it our MBLA model which the stratus and a fog are simulated in, could catch some characteristic features of a tornado, its "trunk" - differently we cannot name an incorporated complex of a fog and a cloud.

We can conclude from the analysis of some numerical experiments, that for formation of meteoprocesses very important mutual relation between horizontal and vertical coefficients of turbulence. It is possible even to enter certain factor $\kappa = \frac{\mu}{\nu}$. Have found out, that a meteoprocess "extension" process is inversely proportional to κ in a vertical direction, and directly proportional to κ in a horizontal direction. The Same it is possible to tell and under the relation an meteoprocess "extension" in a horizontal direction, but upside-down. It is possible to assume, that the basic distinction between a tropical cyclone and a tornado is caused by that fact, that tropical cyclone κ is more tornado κ. We hope, that further it will be possible to define certain critical κ at which the tropical cyclone and a tornado will be mutually transformed. Once again we will notice, that these results are received by means of MBLA models (it only stratus and fogs are formed in) which the general has no anything with convective clouds, tropical cyclones and tornados.

Simulation of daily continuous overcasting. In the certain conditions ($f = 0.95$, $\mu = 10^4 \frac{m^2}{sec}$, $\nu = 10 \frac{m^2}{sec}$) our model describes also such meteosituations when it is had a dayly continuous overcasting. A dependence of cloud and fog maximal liquid-water mixing ratio from time for this case is given on Fig. 3. Here a cloud maximal liquid-water mixing ratio, v_{max} reached $2.94 \frac{g}{kg}$ at t=9 hour., and a fog v_{max} - $1.44 \frac{g}{kg}$, at t=18 hour. Minimal liquid-water mixing ratio, $v_{min} = 0.40 \frac{g}{kg}$, naturally, we have in a saddle point at t = 25 hour.

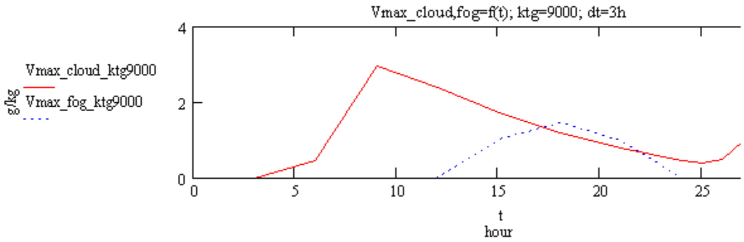

Fig.3.

It is possible to assume, that dayly continuous overcasting, naturally, it is caused by high relative humidity and decreasing of a horizontal turbulence. The role of this last factor, in our opinion, consists that its decreasing causes spatial localization of a cloud-form process, its smaller horizontal prevalence.

The above-stated abnormal processes are often observed in the nature; they are described in different experimental works [2, 3] . As a first approximation we can assume, that our numerical model. qualitatively well describes processes considered by us.

R E F E R E N C E S

1. Geladze G. Sh. A distribution of a periodic thermal wave to a mesoscale boundary layer of an atmosphere. *Rep. Enl. Sess. Semin. I. Vekua Inst. Appl. Math.* vol. 24, N (2010).

2. Matveev L. T. Rate of the General Meteorology. Physics of an Atmosphere. *L.: Gidrometeoizdat*, 1976.

3. Vorontsov P. A. Aerological Researches of a Boundary Layer of an Atmosphere. *L.: Gidrometeoizdat*, 1960.

4. Rill G. Tropical Meteorology. M.: 1963.

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