THERMODYNAMIC AND ENERGY CHARACTERISTICS OF CONVECTIVE CLOUDS ON DIFFERENT STAGE OF THEIR DEVELOPMENT

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I. INTRODUCTION

Convective clouds are very difficult object for experimental investigation and modelling. The problem of their formation and further evolution had been studied by many authors. It is known, that atmosphere instability is a necessary condition of existence of cumulus clouds. Moreover, updrafts take energy at the expense of this instability. It is possible to divide into two main groups the theories of convection and formation of convective clouds: the theory of termics and theory of convective streams. The first of them is applicable for description of the initial stage of the cloud formation and the second is applicable for already developed and long existing convective cloud.

In spite of considerable progress in investigation of convective clouds many problems of their formation and further existence have been remaining opened. Interrelation thermal, dynamic and energy characteristics are present among at its number. Similar problem had been considered by a few authors (Brown, 1967; Lucas, Zipser and LeMone, 1994; Michaud, 1996).

II. METHODOLOGY OF RESEARCH

Investigation of convective clouds and their features are realized using a complex approach. It is contain analyse of surface charts (and satellite image), radiosounding data and numerical modelling. Research is carried out in some stages. The first assumes studying and the analysis of synoptic conditions. Spatial fields of the basic meteorological characteristics (temperature, pressure, etc.) are restored at the second stage on the basis of the data of a network of radiosounding with the help of 3-D nowcasting model that has been developed in Ukrainian Hydrometeorological Institute for study of frontal systems of warm and cold season (see Pirnach, 1998; Palamarchuk and Pirnach, 1992; Pirnach and Belokobylski, 2000). Horisontal steps were 10km for streched grids and 2-5km for nested grids, vertical step was 50m in all calculations.

The stage of development of cloud was determined based upon (Palamarchuk and Krakovskaia, 1996; Palamarchuk, Pirnach and Shpyg, 2004; Palamarchuk et al., 2007), where it was shown, that:

- Vertical component of vortex velocity (Ω_Z, see eq.1) can be indirect criterion of identification of stage of Cb development.
- Stable zones of updrafts give rise to formation of Cb cells (multiple of tens of kilometers) with intensive vortex of cyclonic circulation. It is typical for initial stage of their development.
- Decay of cyclonic centers on separate pair vortexes with cyclonic and anticyclonic circulation occurred at the end of stage of maximal development of Cb. It is show on tendency to destruction of cloud.
- Last stage is stage of decay. It was accompanied by decrease absolute values of updrafts, decrease of vertical highness of layers with updrafts and domination of anticyclonic circulation.

Thus, area with positive values of integral thermodynamical rate of condensation, with updrafts > 1m/s, with cyclonic kind of vortex (any values) was identified as Cb on initial stage of their development. When pair vortexes with cyclonic and anticyclonic circulation occurred, it was considered on stage of maximal development. It was admitted that on this stage vertical motions can have different sign in one cloud margins. Cb was on stage of decay, when zone with anticyclonic rotation was lagger by area and value Ω_Z than zone with cyclonic rotation (it has subjective estimation).

$$\Omega_Z = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}, \qquad (1)$$

where *u*, *v* – horisontal component of wind velosity by OX and OY axeses accordingly.

The component part of general equation of vorticity was analysed too. It has main role in tornado formation (see Romov, 1955; Matveev, 1956; Romov et al., 1987):

$$\frac{\partial \Omega_{zs}}{\partial t} = w_y u_z - w_x v_z = N_{zs} \qquad (2)$$

In eq.2 *w* is vertical component of wind velosity. The danger of rise of tornado in cloud occurs at that time, when its value equal to $1 \cdot 10^{-4}$ s^{-2} and more. At the same time the value of Ω_Z approaches to $1 \cdot 10^{-2}$ – $1 \cdot 10^{-1}$ c^{-1} (Romov et al., 1987). Vertical motions, pseudo-potential temperature and energy of instability E_{inst} were considered in all cases.

III. RESULTS AND CONCLUSIONS

The series of vertical cross-sections of different convective clouds were maded with the help 3-D nowcasting model.

At the comparision of the spatial distributions of pseudo-potential temperature with spatial distributions of updrafts it was resulted that intensive updrafts coincide with zones of large vertical gradientes of pseudo-potential temperature.

In this work it is shown that the negative values of N_{ZS} can be complied with positive values of Ω_Z (see fig.1). At the same time such change of their signs hasn't effect on vertical distribution of energy of instability. But the magnitude of vertical gradient of energy of instability depends from coincidence of signs Ω_Z and N_{ZS} on the background of general tendency of cloud's development. At the general increase (decrease) of E_{inst} with height, when

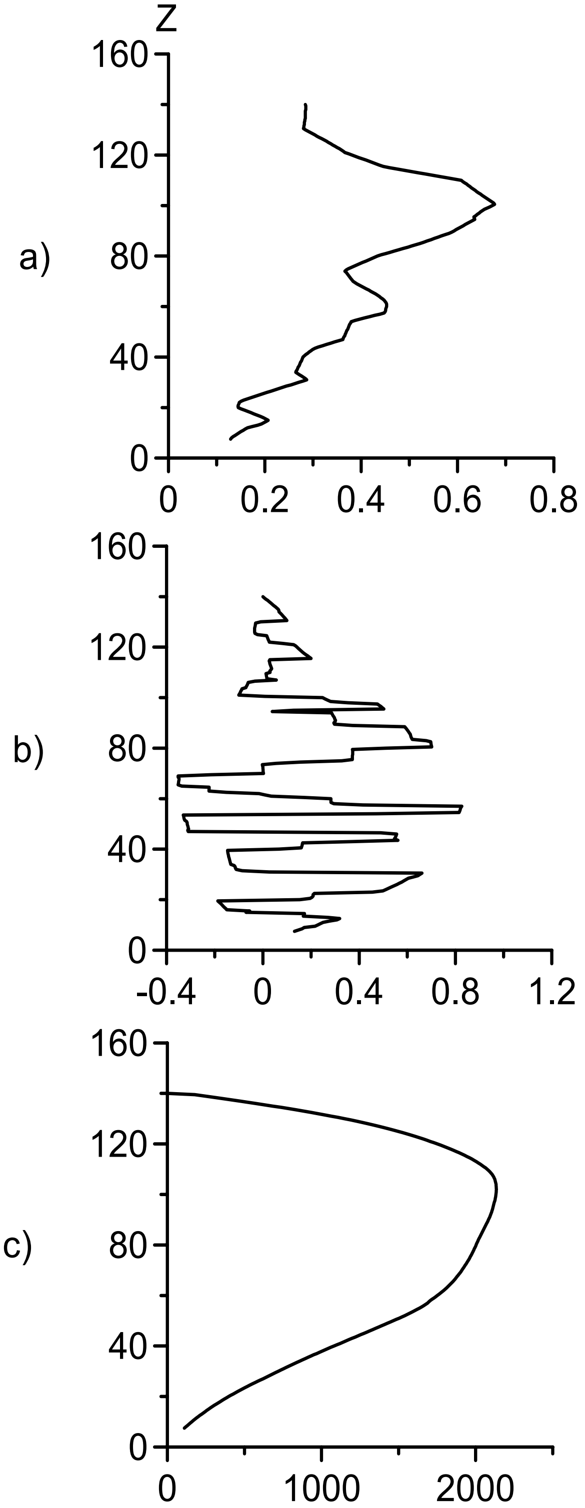

FIG. 1: Vertical distributions [Ω_z, 10^{-3} s^{-1} – (a), N_{zs}, 10^{-6} s^{-2} – (b), E_{inst}, J – (c)] in powerful convective cloud, Z is height, hm

positive values of Ω_z and N_{zs} are present on two neighbour levels, its vertical gradientes are larger by absolute value. When Ω_z and N_{zs} have different signs, increase (decrease) of E_{inst} has value smaller than other cases. When Ω_z and N_{zs} have negative sign, the value of increase (decrease) of E_{inst} will be smaller (larger).

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