About possible variants of the development of the atmosphere unstable states

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In the dynamics of the atmosphere of our planet there occur unpredictable situations, when synoptic processes can develop in different ways with equal probability. In this work the variants of the development of such unstable situations are studied using the numerical model by Zlenko (1987). Ensembles of vortices of finite dimensions are considered, characterized by identical velocity fields and different directions of rotation – cyclones (C) and anticyclones (AC), the distance between them being comparable with their dimensions. The calculations by Pokhil et al. (1991 – 2000) provide information about the interaction of the vortices: about their moving apart, drawing together, fragmentation, changes in their dimensions and form, and about specific cases of sharp change in their behaviour.

The interaction of distributed vortices is examined in the perfect liquid. Note that the interaction of vortices in the perfect liquid (Re = ∞) practically does not differ from their interaction in the viscous liquid at
R > 100.

The wind velocity tangential component profile in the experiments is as follows:

$$V(r)=V\,(r/R)\exp[1/b\cdot(1-(r/R)^b)]$$

where r is the distance from the vortex centre; V is the maximum of the tangential component of the wind velocity; R is the distance at which V is reached; b is the parameter characterizing the change of the wind velocity tangential component in the radial direction (b = 2). Numerical experiments were performed with vortices located in the apexes of polygons, where the nearest neighbours were vortices of different signs. The integer angular momentum was equal to zero.

The dynamics of four vortices located in the apexes of a square. At the initial relative distance between the centres of the neighbouring vortices (C and AC) d/R > 6 these vortices don't interact in the numerical experiment (T = 17). Nevertheless, even in the case of vortices quite distant from one another the interaction can start after a while, because in the rear of the vortex an area of vorticity of opposite sign forms, which, getting larger, reaches the neighbouring vortex and starts interacting with it (Fig. 1); another reason can be the instability of the velocity sharp decrease at r > R and gradual "spreading out" of the vortex peripheral part.

At shorter distances (d/R ~ 3-6) the group splits into two pairs moving in the opposite directions (Fig. 1). In the rear of the pairs a cloud of small vortices forms, which is typical of distributed vortices. At d/R_o <1 a so-called "two-headed" vortex forms whose centre of gravity is precessing. Such vortices are observed in nature and have been obtained using a numerical model (Pokhil, 1996).

The dynamics of four vortices located in the apexes of a rhomb (Fig. 2). In the performed experiments at an insignificant change of d one could observe different kinds of interaction, with the vortices following different tracks. In Fig. 2, after the central vortices merge into a big vortex, secondary vortices start interacting with quite distant peripheral ones. This is the cause of spiral-shaped trajectories of the peripheral vortices (Fig. 2 g).

The dynamics of the ensembles of six vortices located in the apexes of a regular hexagon. In the case of certain specific relationships between the parameters of vortices and the distances between them a group of vortices splits into three pairs, which move away from the centre, in the ideal case, at an angle of 120º.
If at the beginning of the experiment the vortices are located close to each other in one of the pairs (or if they are located far from other vortices), the dynamics of the vortices is such as is shown in Fig.4.

Conclusions.

1. The evolution of a group of vortices rotating in dissimilar ways can follow different scenarios: with insignificant change of the system parameters one can make the vortices rotate with respect to one another in a cyclonic and in an anticyclonic way and make them move in different directions.
2. Under certain conditions the interaction of vortex systems is accompanied by the formation of a cloud of secondary small vortices, which, while interacting with the initial vortices, can substantially change their behaviour.

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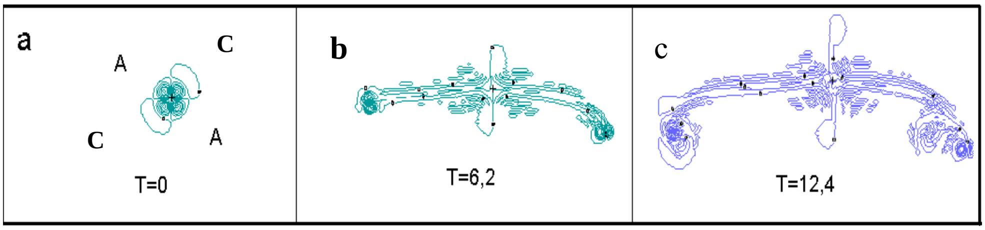

Fig. 1, a,b,c. The evolution of the vorticity fields of 4 interacting vortices of different signs (2 cyclones and 2 anticyclones). The initial relative distance between the vortices d/R=4
f) the tracks of the vortices (the initial positions of the vortices are marked by squares).

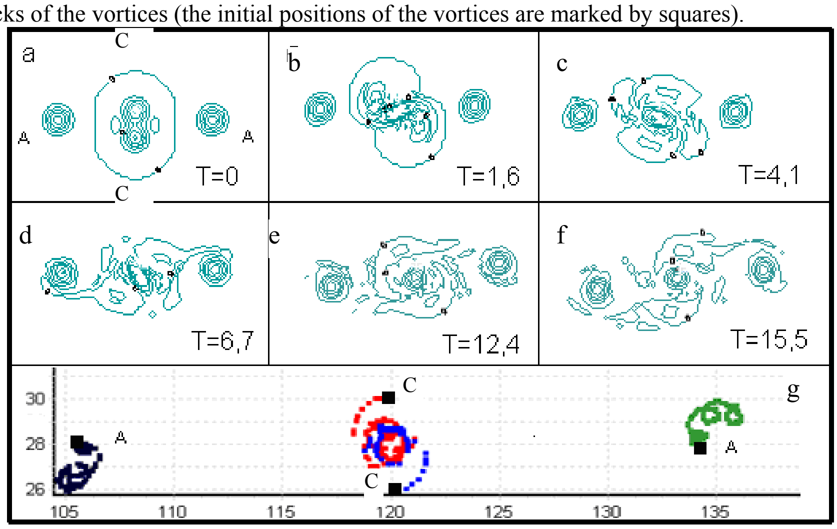

Fig. 2 a,b,c,d,e,f. The evolution of the vorticity fields of 4 interacting vortices of different signs (2 cyclones and 2 anticyclones). The initial relative distance between the central vortices d/R_C=2.2, between the central and the peripheral vortices d/R_{CP}=6.8; g) the tracks of the vortices (the initial positions of the vortices are marked by squares).

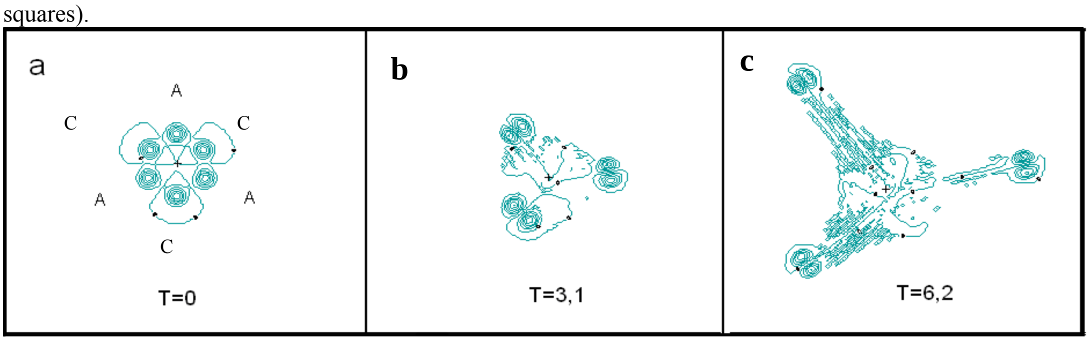

Fig.3 a,b,c. The evolution of the vorticity fields of 6 interacting vortices of different signs (3 cyclones and 3 anticyclones). The initial relative distance between the central vortices d/R~3.35.

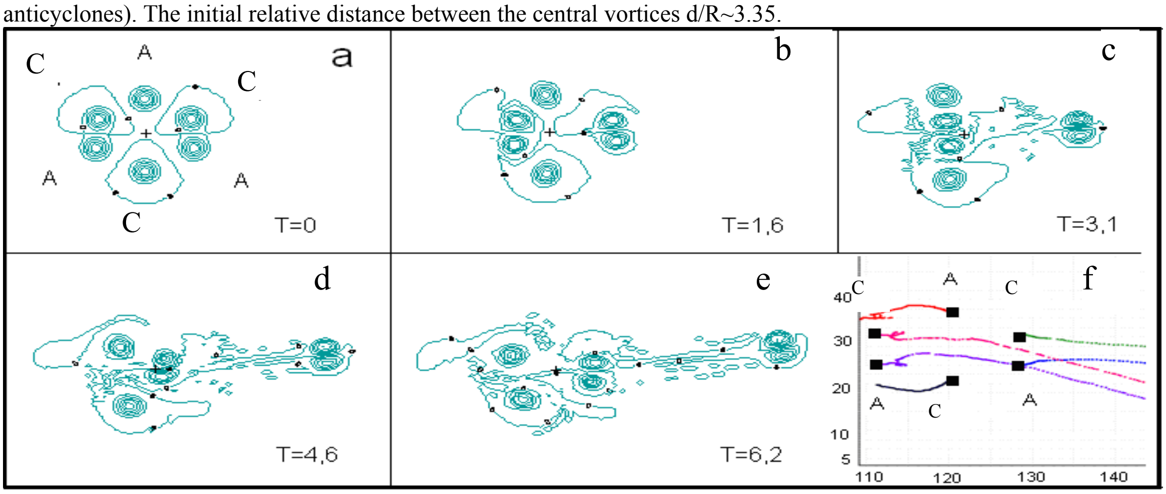

Fig. 4 a,b,c,d,e,f. The evolution of the vorticity fields of 6 interacting vortices of different signs (3 cyclones and 3 anticyclones). The initial relative distance between the vortices of the right-hand pair d/R~3.25 is less than that between the others. g) the tracks of the vortices (the initial positions of the vortices are marked by squares).