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ON THE MODELING OF THERMAL MECHANISM OF VORTEX GENERATION IN THE LOWER ATMOSPHERE

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Summary: *Energy dissipation in the atmosphere layer near the Earth surface is associated with diffusive and convective processes, which are determined by differential equations of the second order. Self-consistency in hydrodynamic equations systems is a particularly difficult mathematical problem. Therefore, there is a method of using simplifying assumptions in order to receive an image of atmospheric mass motion. Namely, during any laminar motion in the sea or atmosphere there may generate a vortex that will cause a local perturbance.*

Key words*: vortex, model, inversion, valley.*

Introduction.

The painful experience of 13.06.2015 makes it obvious that the flood problem in the Vere Gorge are actual in the future as well. This problem can be solved only by means of relevant forecasting model regarding emergency situations. For its construction we used the classical hydrodynamic theory of liquid flow in pipes, theory of ideal liquid jets and bifurcation theory.

However, there is also the problem of narrow mountain canyons bordering fairly high slopes which is identical to the problem of the Vere Valley problem in terms of microclimate. In particular, such valleys are on the southern slope of the Caucasus, as well as on the Gombori ridge.

In these valleys there is a systematic disturbance of the lower layers of the atmosphere under the influence of the sun, which spreads in the form of hurricanes of different sizes in the environment.

Formally, we may consider the existence of vortex as stability violation in the environment, i.e., generation of a turbulent supplement in a laminar flow. To fully describe such a process may appear quite difficult. Therefore, the problem is often reduced to approximate modeling of the image of perturbance distribution in the medium, which adequately describes the real motion. In some cases such goal is quite effectively reached by means of some kinematic model of hydrodynamic velocity, which must satisfy certain criteria, i.e., the conditions of dynamic potential of motion [1,2], for example, below, the cylindrical coordinate system shows a plane analytical model of velocities, which fulfills Euler equation of noncompressible ideal liquid motion and gives so called solenoid solution

$$V_r = \frac{1}{2} u_0 \left(\frac{r}{R_0}\right) (\cos\varphi + \sin\varphi), \qquad V_\varphi = u_0 \left(\frac{r}{R_0}\right) (\cos\varphi - \sin\varphi), \qquad (1)$$

where R_0 radius is a linear scale of the problem, u_0 is velocity characteristic of the vortex perturbance distribution.

In case if we consider the medium viscosity as a substantial factor, the motion of which must lead us to the formation of a boundary layer, we can construct a model

$$V_\varphi = u_0 \frac{R_0 - r}{R_0} (\cos\varphi - \sin\varphi), \; V_r = \frac{u_0}{2} \frac{R_0 - r}{R_0} (\cos\varphi + \sin\varphi), \qquad (2)$$

which unlike Model (1), does not fulfill the plane equation of medium infiniteness. It means there must be a motion towards Z axis. Such limitation decreases the value of the kinematic model, which more or less corresponds to the vortex motion, though only in certain conditions. Despite that, the kinematic model (2) appeared quite useful in regard to quantitative assessment of viscosity effect.

Inversion of wind direction in canyons and generation of small-scale atmospheric vortex. Generally, narrow valleys with similar morphologic parameters are characterized with almost the same local climatic-meteorological regimes. Naturally, there are many such canyons in Georgia, among which are, for example: The Vere, the upper height of which is 1672 m above sea level and the lower height is 390 m above sea level, i.e., the difference between heights is 1282 m, whereas the length of the river is 42.5 km. The river generates at the south-eastern ending of the Trialeti Ridge (the highest peak of the ridge is Shaviklde with height of 2850 m, the heights of other summits vary between 2300-2800 m). It reaches its characteristic width of 400-450 m at the lower section of the valley (about 7 kilometers before joining the river Mtkvari). (fig.1.)

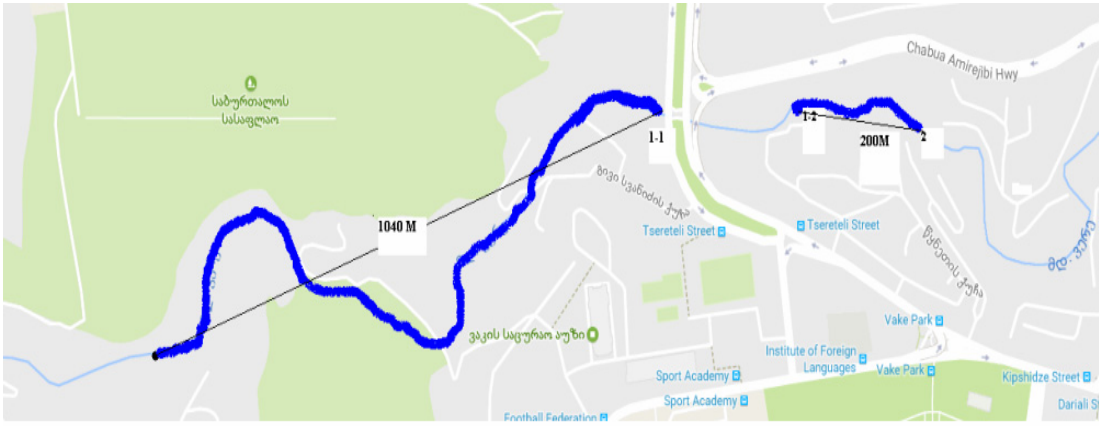

Fig.1. Topology of the river Vere

In the region of Kakheti: the Kisiskhevi has the upper height of 1755m and the lower height is 64 m above sea level, i.e., the difference between the heights is 1691 m. The length of the river is 37km.

Batsara river, Batsara gorge, length about 15 km, borderon the right by Tsinagora rodge, on the left by Kekhuriskhevi ridge, its headwaters are located at 2000 m above sea level. Attached to the river Alazani (Sea level 700m).

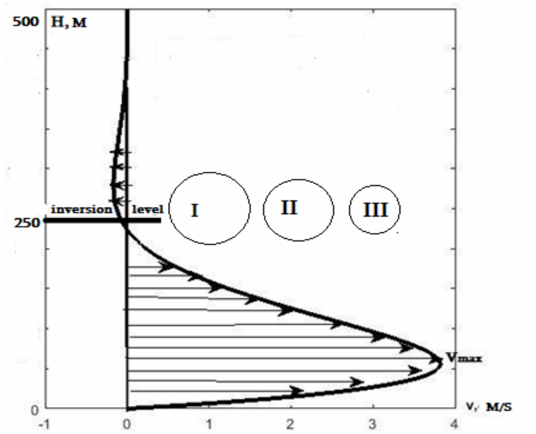

Fig.2. Profile velocity from Kanion level;V_{max}=3.8m/s

We can consider these valleys as an analogy of the channel of liquid motion curve, where the moving liquid is bounded by rather high walls. In the canyon, together with the height, the parameters of the surface atmosphere layer parameters also change. Motion of air masses generated due to pressure gradient in the narrow valley permanently undergoes perturbance due to interaction with the valley slopes. Namely, it is known that at certain heights (200-250 m) of canyons, on so called "inversion" surface the wind velocity direction changes oppositely. This effect is caused by the inhomogeneity of the temperature field of the lower atmosphere that is associated with the main orographic property of the canyon, the ridges bordering the valley. The daily variation of the mountain slopes surface temperature in natural conditions takes place in a quite large diapason, whereas the hydrodynamic model of the process of the air mass motion associated with it, belongs to L. Prandtl, author of the boundary layer theory. The effect, which is qualitatively observed identically practically in all valleys, quantitatively may be expressed variously. Generally, it is known that the "inversion" height during the increase in atmospheric instability grows as well as the wind velocity. In normal (calm), less cloudy natural conditions, wind flow on the mountain slope, approximately half an hour after the sun set, moves downwards the valley. In warm conditions, after the sun rise, the wind blows in the same direction approximately during an hour. Further, the direction of the wind changes from downwards to upwards. In calm conditions the characteristic velocity of the wind is (1-3) m/s [3] (Fig.2).

Conclusion. Thus, the variation of the wind direction in the canyon is a precondition for the generation of the local instability that most probably ends with the generation of atmospheric vortex having certain linear scale. Obviously, such votex will undergo bifurcation in a short time, i.e., it will be broken down into smaller size vortices. Consequently, the mechanical energy of the turbulent vortex formation will be dissipated, which may be used for the change of the local thermosdynamical characteristics. The vortex breakdown effect can be imagined as development of balance states that are unsteady but short-term in time. Models (1) and (2) are convenient exactly for description of such a chain of events. The models are given in Figures (3) and (4).

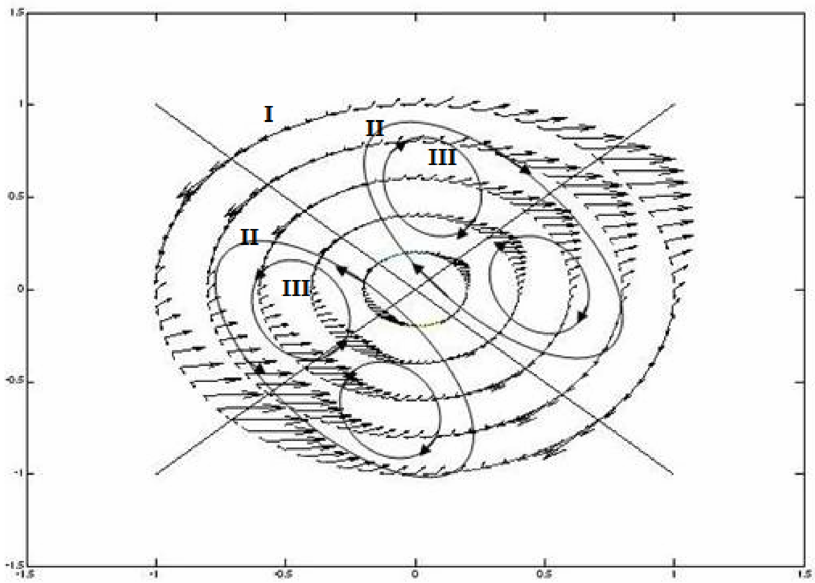

Fig. 3. Breakdown of the vortex. Model (1) is normalized on U_0

These figures, which have symmetric sectoral structures, are quite useful in regard to their development in time. Mainly, it is obvious that the evolution of the vortex chain must occur in the direction of the couple formation. Thus, we may consider the atmospheric vortex chain as the result of hydrodynamical instability development.

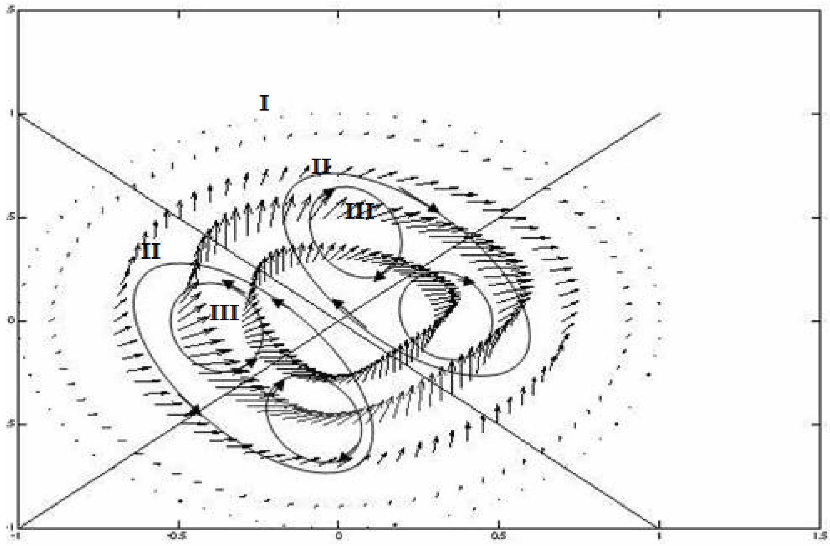

Fig. 4. Breakdown of the vortex. Model (2), I,II,III- vortices

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