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Conical Model of Non-Uniform Rotation and Interaction of Elements of the Atmospheric Rotation Chain in a Linear Approximation

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ABSTRACT

The global atmosphere can be considered as an open thermodynamic system within which various disturbing factors act. For example, even in calm atmospheric conditions, orography can cause a violation of the stationary thermal balance between the Earth and the atmosphere. In general, the formation of vortex structures in any gaseous or liquid medium is stochastically determined. This means that the process of vortex formation is to a certain extent probabilistic. Therefore, in mathematical modeling of the field of atmospheric gyres, it is rational to exclude random factors by identifying specific contributing conditions. For example, a strong division of the earth's relief contributes to turbulence of air flows on a regional and local scale. In particular, the process of formation of low-intensity atmospheric vortices in mountain valleys can always be considered as a violation of local stability, the cause of which is the unevenness of the temperature field created at the boundary of different orography and landscapes. Also, the generation of vortices and the process of their dissipation in the atmosphere can always be considered as a violation of the stability of the environment on certain spatial scales, which is expressed in the violation of its thermodynamic parameters.

Keywords: *atmospheric vortices, thermodynamic parameters, relief, mathematical modeling.*

The class of atmospheric vortices with spatial scales that differ sharply from weak atmospheric vortices includes two phenomena of seemingly similar thermodynamic nature: vortices and tornadoes. A vortex is an atmospheric process caused locally by air currents rising from the extremely hot surface of the Earth, the intensity of whose circulation increases sharply from the periphery of the vortex to its center. The speed of its rotational motion is quite high, in some cases destructive, reaching several tens of meters per second. Traces of dust particles carried away by the vortex from the surface of the Earth show that the movement of the mass inside it is upward and has the character of a large-scale screw rotation. Such a process usually retains a regular form and is more or less amenable to mathematical modeling, unlike another type of atmospheric phenomena called a tornado. The origin of this gigantic atmospheric phenomenon in scale, unlike an ordinary vortex, occurs in the so-called "Mother" in the cloud, from where the tornado body descends to the ground in the form of a long "tornado". Inside a tornado, the air rotates at a particularly high speed, which can be even an order of magnitude higher than the linear rotation speed characteristic of a normal vortex. A tornado has a so-called "Eye", a stagnation zone, i.e. a zone of immobility (rest) of the air mass. Unlike a tornado, the "parent" cloud is the source of a small storm, which has a spiral structure in space, directed from the cloud towards the Earth. From an energy point of view, a vortex can be explained as the result of a local disturbance of the thermodynamic system of the atmosphere. In this sense, a tornado is incomparably more powerful and larger than a vortex. In this case, we are dealing not with a local disturbance of the atmosphere, but with the formation of a large-scale open thermodynamic system. Perhaps this is why there is no systematic theory of a tornado as a catastrophic natural phenomenon. For example, it is possible to explain why a group of vortices of much smaller scales will be observed in the vicinity of the "eye" of a tornado. A qualitative explanation of this phenomenon is probably possible through laboratory modeling if the phase portrait method is also used to interpret the experimental data.

Modeling atmospheric vorticity in a kinematic approximation. It is known that in the atmosphere, which is a dissipative medium, the dynamics of vortices is described by the Navier-Stokes equation, the exact solution of which is usually associated with special difficulties [1]. In cases where the coefficient of air viscosity can be neglected, it is permissible to use the Euler equation, which is simpler than the Navier-Stokes equation, valid for an ideal medium. However, in some cases, due to mathematical complexities, an exact analytical solution to the Euler equation is also impossible. For example, mathematical modeling of the interaction of vortices of different sizes, due to the nonlinear nature of this process, is possible only with the use of certain simplifying assumptions. In particular, in an ideal gas medium, this problem can be reduced to such a simplified scheme of vortex interaction that it gives a qualitative picture of the time development of the dissipation process in the atmosphere in a linear approximation. This goal can be achieved using any kinematic model of a vortex. Such a model, at a minimum, must satisfy the continuity equation of the medium, which is one of the conditions for the dynamic possibility of motion. There are various kinematic models, including a non-uniform rotating flat stationary model, which was used in the problem of the magnetohydrodynamic effect of rotation of the ionospheric medium in the Earth's polar cusp [2]. Using this model, a solenoidal solution was obtained, which, in addition to the continuity equation, also satisfies the Euler equation.

Inhomogeneous rotation, in addition to the curvilinear movement of liquid or gaseous medium, also implies the possibility of developing certain types of hydrodynamic instability. This factor is a particularly important point in terms of the problem of the generation of atmospheric whirlwinds and their dissipation. Therefore, we believe that the flat model mentioned above will be useful, especially since there is a possibility of its correct transformation into a spatial model, taking into account the effect of the compressibility of the environment. However, in order to satisfy the dynamic criterion of the possibility of movement, it is necessary to introduce additional simplifying restrictions, which, in our opinion, cannot have a qualitative impact on the content of the transformed model. According to the first constraint, the density of the atmospheric medium is only a function of time. The second limitation concerns the vertical component of the spatial atmospheric vorticity velocity, which, according to the assumption, depends only on the coordinate of the corresponding direction. Taking into account these additional conditions, the equation of continuity in cylindrical coordinates will have the form

$$\frac{\partial\rho}{\partial t}+\rho\left(\frac{1}{r}\frac{\partial(rV_r)}{\partial r}+\frac{1}{r}\frac{\partial V_\varphi}{\partial\varphi}+\frac{\partial V_z}{\partial z}\right)=0\ , \qquad (1)$$

where ρ- the density, V_r , V_φ , V_z - velocity components.

Thus, the spatial transformation of a plane kinematic model of inhomogeneous rotation has the form

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

$$V_z=u_0\left(\frac{z}{h_0}\right),\ \ \rho=\rho_0e^{-\frac{u_0}{\mathrm{h}0}t}\quad , \qquad (2)$$

where u_0 - is the characteristic linear velocity of the vortex, R_0 - is the characteristic radius of the vortex, h_0 - is the characteristic height of the vortex. z- momentary direction of rotation axis.

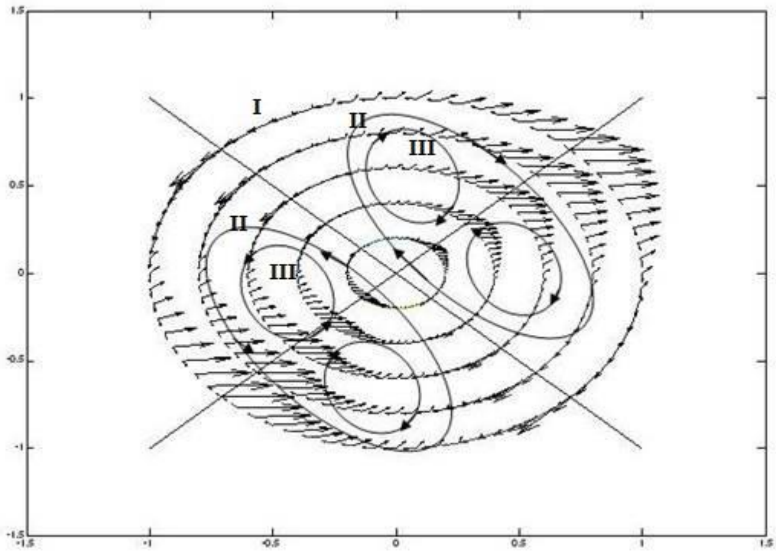

Fig. 1. Scheme of flat vortex decomposition normalized to u_0

The first two members of the model (2) : $V_r = \frac{1}{2}u_0\left(\frac{r}{R_0}\right)(cos\varphi + sin\varphi)$ and $V_\varphi = u_0\left(\frac{r}{R_0}\right)(cos\varphi - sin\varphi)$, Determine the non-uniform nature of rotation. A flat vortex is unstable, which means that its decay gives rise to a chain of vortices [3]. Based on the principle of hydrodynamic similarity, the chain links obtained through the decomposition of the initial vortex are schematically easy to imagine. In the static approach, the gyral chain forms an abstract cone in space, the axis of which can be directed anywhere (Fig. 2). In dynamics, as a result of the interaction of secondary eddies with different linear scales, generated due to the inevitable bifurcation of multiple eddies constituting the turbulent field, a permanent change of the turbulent field should take place in the atmosphere. Therefore, the physical task requires that the model (2) is only linearly approximated and qualitatively corresponds to the hydrodynamic picture of the transformation of the gyre field in time. Nevertheless, such a scheme of atmospheric vortex breakdown, which is visualized in Fig. 2, is quite useful. Such a process corresponds to a sequence of unstable and short-lived but equilibrium states. At the same time, it qualitatively quite convincingly presents the mechanism causing local disturbance of the temperature field and other thermodynamic parameters of the atmosphere as a result of the dissipation of eddies.

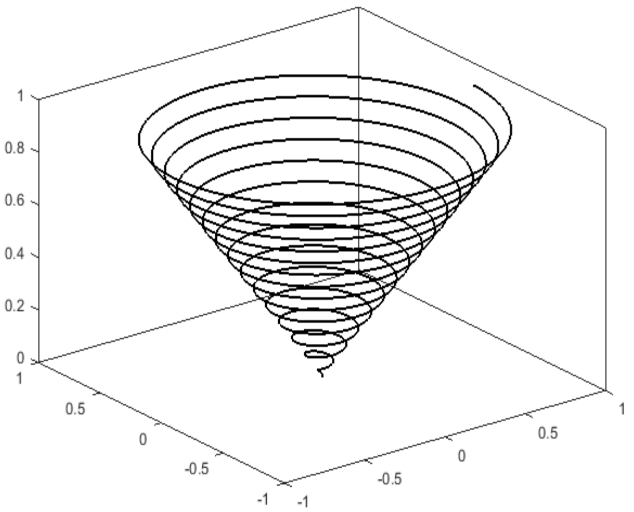

Fig. 2. Visualization of the spatial model of non-uniform rotation.

Atmospheric eddies transport mass and energy. Therefore, in the process of their disintegration and mixing, the level of heterogeneity of the environment changes, which becomes the reason for the creation of new eddies. We do not touch on the details of this process, we consider it necessary to note that the stability of the air mass, that is, the threshold of the turbulization process is considered to be the criterion: - $\frac{\partial P}{\partial z} < \frac{g}{c_p}$, where P is atmospheric pressure, c_p is the specific heat capacity of air. According to this criterion, in the case of a 100 m high mountain, a temperature drop < 1^0 is enough to maintain the stability of the atmosphere. Otherwise, convection begins, which usually occurs during strong heating of the earth's surface by the sun. It is natural that the final result of the convective movement should be such mixing of the air mass as to eliminate the temperature gradient.

The presence of free atmospheric vortices in a turbulent medium is excluded. Naturally, in most cases their interaction takes place, which, generally speaking, will be a nonlinear process that cannot be characterized by simple merging. The interaction between vortices, relatively nonlinear, is easier to imagine in a linear approximation, when the combination of vortices in space creates such structures, the shape of which is similar to a ring. For example, such an idea was formulated by V. Artsukovsky, a well-known adherent of the theory of physical ether, according to whose hypothesis vortex rings can be considered as moving formations in a viscous compressible gas, which is given an impulse by an air stream. Although the concept of ether is considered erroneous, since it essentially contradicts quantum mechanics, we believe that within the framework of Artsukovsky's idea it is possible to consider the interaction of simple vortex rings, when there is only toroidal rotation, when a vortex ring in the form of a tube rotates around its axis of symmetry. Under the conditions of such an assumption, the interaction between vortex rings is possible only in the following cases [4]:

1. Rings rotating in the opposite direction are close to each other and have a common imaginary axis;

2. One ring pulls the other, i.e. the speed of the first exceeds the speed of the second;

3. The rings move in opposite directions along the imaginary axis;

4. Rings move parallel, or their trajectories of movement cross close.

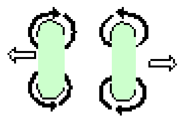

Fig. 3. Vortex rings moving in the forward direction.

In the first case, if the rings rotating in the opposite direction are very close, the loading forces will act between them (Fig. 3). At fairly large distances, the same displacement effect occurs, but in this case the reason is the rings' own rotation. In the second case, when one ring touches another, or rings with a common imaginary axis moving in the same direction come into contact, mutual penetration is possible between them, when the rear ring passes the front. . Then this process is repeated, that is, it is possible to change the sequence of rings multiple times (Fig. 4).

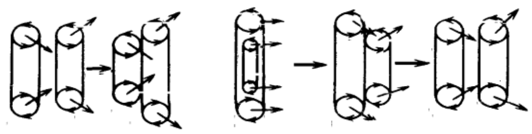

Fig. 4. Alternation of gyral rings.

In the third case, which refers to the gyro rings moving in the opposite direction, the following options are possible: 1. The rings are not calibrated (arbitrary size), general case; 2. Rings are not calibrated, private case; 3. The rings are calibrated.

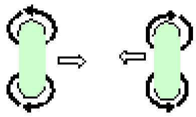

Fig. 5. Interaction of converging gyral rings.

In general, if the rings are not calibrated, a smaller ring passes into a larger one, or one ring expands, as in the case of one ring passing into another. In this case, the ring whose rotation speed is less expands once. After passing through each other, the rings move in different directions. In the special case, when the rings are not calibrated, then in the case of a certain balance of forces, it is possible to establish an equilibrium state in the vortex field, at this time, the small ring remains stationary inside the large one, and the air jet formed in the free space between the rings may act like a jet engine, which drives the pair of vortex rings about the axis of symmetry. along. The result of the collision of rings with the same size depends on the speed of their convergence. If the rings have gathered enough speed, it is possible to deform them (flatten or expand in the plane of contact), or multiple disintegration into small-sized whirling rings. If the counter-rotating calibrated rings with a single axis accidentally come into contact slowly, a thrust force associated with the toroidal rotation of the vortex elements can be induced. This effect will cause the rings to move apart. Such a situation is unstable, because any external influence will disturb the equilibrium picture between the initial gyral rings. Naturally, if the rings move in parallel or cross each other in any way, it is possible to rotate them so that one of the above cases is realized. Also, it should be noted that it is permissible to have gyratory rings which, in addition to being toroidal, can also rotate with respect to the diameter of the ring. In such a case, their interaction with other rings will be non-linear and will no longer be subject to simple determinism.

Thus, the linear approximation provides a sufficient representation of the dynamic process taking place in the turbulent field, the main element of which is the breakup of eddies and the interaction between them. In particular, such a process should take place in the atmosphere of a narrow mountain valley during its spontaneous disturbance, which is likely to accompany the inversion of the direction of the horizontal velocity in the atmosphere in the valley or above it. The question is: How realistic is the formation of gyral rings, for example, during an inversion event in a narrow mountain valley? It is impossible to give an unequivocal answer to this question, however, formally, model (2) allows such a possibility. Imagine a turbulent field in which a vortex rotating in any direction and oriented in any direction moves. It should be noted that the kinetic model of non-uniform rotation does not rule out that in the process of disintegration of the main vortex, such vortices will be formed, which will not have hydrodynamic similarity with the initial vortex. This means that such vortices can have a constant direction of rotation, which will facilitate their unification in a closed ring. The characteristic radius of these vortices will be smaller than the radius of the original vortex. In the process of forming a vortex ring, it is completely permissible to connect the vortexes rotating in the same direction in such a way that each of them maintains the orientation of its axis of rotation. In this way, a gyratory chain with a truly curvilinear axis of symmetry can be formed, which can be locked and take the form of a ring. Presumably, such rings, in contrast to whirligigs with non-uniform rotation, will be quite stable. Therefore, eddies with a constant direction of rotation can be considered as the final stage of the transformation of the turbulent field, followed by the complete dissipation of stochastic disturbance energy. The existence of such an effect can be assumed at the qualitative level, which can become the reason for a sharp change in the local meteorological regime as a result of the development of an inversion event in the atmosphere.

In any place on Earth, during calm weather, the atmosphere regularly circulates under the influence of convection. In mountainous terrain, the dynamics of the atmosphere are particularly affected by changes in the meteorological regime and the vertical convection currents associated with them. However, this picture may change due to a sharp change in the meteorological regime as a result of the generation of vortex structures in the air. However, it is known that in narrow mountain valleys, even in calm atmospheric conditions, such a spontaneous disturbance of the atmospheric circulation may occur, the occurrence of which is associated with impulsive changes in the gradient of atmospheric temperature. The existence of such a factor is determined by the unevenness of solar radiation on the slopes of a narrow valley, which, together with the geographical position of the valley, may be associated with seasonal and orographic factors, as well as with the mobility of the valley slopes. In some cases, the cause of a spontaneous violation of the hydrodynamic pattern of atmospheric mass movement may be instability caused by the inversion of the direction of the horizontal component of the air velocity in the valley, which is associated with the spontaneous generation of atmospheric vortices. The interaction of these vortices in the atmosphere leads to the dissipation of hydrodynamic energy, which causes nonlinear phenomena to develop, the analysis of which is a complex physical problem. However, it is permissible to consider the process of vortex interaction in a linear approximation, which gives a qualitatively correct idea, for example, of the event of spontaneous disruption of the local atmospheric regime of a narrow mountain valley. It is here that an irregular thermal mechanism can be stochastically activated, the action of which will lead to the convective movement of air masses surrounding the ridge that surrounds the valley. This phenomenon has the nature of an atmospheric disturbance, since the convective velocity vector changes its direction at a certain height (inversion phenomenon). Prandtl's theoretical model is known, which analytically determines the vertical profile of the horizontal convection velocity coefficient [5] in the approximation of a hydrodynamic boundary layer, which is unstable, since it has a maximum at a certain height, i.e., it has a critical point. Physically, this means that hydrodynamic instability of Rayleigh-Jones or Kelvin-Helmholtz may develop in this place. Therefore, there is a high probability of the formation of atmospheric vortices in this area. Their decay will lead to the transformation of the energy of hydrodynamic disturbances into disturbance of the atmospheric temperature field, which will entail an impulsive change in the local meteorological regime in the canyon. For example, this phenomenon may be dangerous for those who like to fly in narrow mountain valleys on individual aircraft (hang gliders, paragliders).

By means of ingenious mathematical transformations, in the approximation of a weakly turbulent atmosphere, where the coefficients of temperature transfer and kinematic viscosity can be considered equal to each other, Prandtl connected the boundary layer formed on a valley slope with the perturbation of the temperature field. In particular, he showed that the temperature θ in the free atmosphere increases linearly with the height, and the surface of the ridge slope introduces a small θ perturbation into the temperature field, after which the keystone equation of the Prandtl model was obtained

$$\frac{\partial^4 \theta'(n)}{\partial n^4} + \frac{g\beta B \sin^2\alpha}{\nu^2}\theta'(n) = 0, \qquad (3)$$

where n is the height calculated from the canyon slope, β is the air temperature expansion coefficient, $B = const$ is the vertical temperature gradient, ν is the air kinematic viscosity coefficient.
Based on physical considerations, Prandtl used only one of the four possible solutions of equation (3)

$$\theta' = \theta'_0 \exp\left(-\frac{n}{L}\right)\cos\frac{n}{L}, \qquad (4)$$

which met the following boundary conditions [4. Khrigian]

$$\theta' = \theta'_0 , \quad \text{when } n = 0 ; \qquad \theta' = 0, \quad \text{when } n = \infty, \qquad (5)$$

The image (4) includes a characteristic vertical scale, the height corresponding to the maximum of the convection speed, which depends on the environmental parameters

$$L = \sqrt[4]{\frac{4\nu^2}{g\beta B \sin^2\alpha}} \quad . \qquad (6)$$

Disturbance of the temperature field along the slope of the canyon leads to the convective movement of the air mass, the speed of which is determined by the formula

$$V_1 = \theta'_0 \sqrt{\frac{g\beta}{B}} \exp\left(-\frac{n}{L}\right)\sin\frac{n}{L} \quad . \qquad (7)$$

The image (7) gives a vertical profile of the convective movement speed, which has an inversion point (level) in which the speed changes direction (Fig. 6). This place can be imagined as an abstraction of a tangential discontinuity surface, on which there is such a speed shift, which in a liquid (gas) environment is a prerequisite for the development of Kelvin-Helmholtz or Rayleigh-Taylor hydrodynamic instability. Figure 6 shows the vertical profile of the convection speed for a typical set of atmospheric parameters. In addition to the inversion point, the profile also contains the inflection point (Vmax), in which the development of hydrodynamic instability and the generation of atmospheric vortices are also possible. Thus, in the Prandtl model, the height of the velocity maximum (n_(m)=Lπ/4) and the height of the inversion level corresponding to the first minimum of the trigonometric function (n_(m)= πL) are clearly defined.

In the paper [6] it was shown that the use of only one private solution of equation (3) limits the possibility of the Prandtl model. The operation of the principle of synergy is generally characteristic of atmospheric processes. Therefore, it would be fair to consider the time-varying effect of the boundaryconditions in the physical picture of the generation of turbulence-inducing eddies in the valley atmosphere. Often, such an approach is used to solve long-term prognostic meteorological problems. Variation of boundary conditions is expected to be useful for quantitative correction as well. During modeling of short-term local atmospheric processes. Therefore, within the framework of the Prandtl model, it is permissible to use another pair of boundary conditions, different from (4)

$$\theta' = \theta'_0 \ , \quad \text{when } n = 0 \ ; \quad \theta' = \infty, \quad \text{when } n = \infty. \qquad (8)$$

These boundary conditions are satisfied by the particular solution of the equation (3), which also includes the inversion effect and (4) differs from the image only by the sign of the power of the exponential multiplier

$$\theta' = \theta'_0 \exp\left(\frac{n}{L}\right)\cos\frac{n}{L} \ , \qquad (9)$$

which also corresponds to the velocity image, which was obtained by using a different model of the temperature field change, which formally allows for an unlimited increase in temperature with height [5].

$$V_2 = -\theta'_0\sqrt{\frac{g\beta}{B}}\exp\left(\frac{n}{L}\right)\sin\frac{n}{L} \ . \qquad (10)$$

In this case, the velocity inversion event will occur at altitude $n_m = \frac{3L\pi}{4}$.

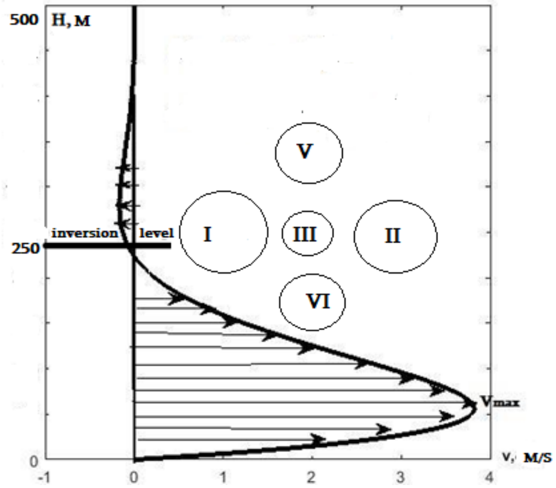

Fig. 6. Convection speed profile and atmospheric eddies

Thus, the vertical profile of the convection velocity in the atmosphere of the valley may have a critical point (points), where the probability of the development of Kelvin-Helmholtz hydrodynamic instability is high. At this time, the generation of atmospheric eddies will take place, which can be broken up and interacted in a linear approximation according to the scheme presented in the first part of this paper. This leads to the transformation of mechanical energy into thermal energy and disturbance of the atmospheric temperature field. This factor may contribute to the disturbance of the locally balanced, but unstable, thermodynamic state and the change of the meteorological regime in the valley. The characteristic time duration of this event will depend on the intensity of the temperature field disturbance. In case of strong turbulence, this process can be strongly non-linear. In particular, it is possible that disturbance of the temperature field in the area of velocity inversion causes the so-called "dynamo-effect", i.e. impulsive strengthening of turbulence. Since the generation of a chain of eddies in a limited space in a certain direction is possible, the structure of the temperature field in the area of velocity inversion should probably be non-uniform and asymmetric. There is a solution to a similar mathematical problem, but for an object of a different spatial scale. In this work, which deals with the asymmetry of the temperature field in the polar cusp region of the Earth, the kinetic model of inhomogeneous rotation was also used [7].

There are many examples in nature of the transition from ordered motion to chaotic motion, the spatial scale of which varies from molecular to gigantic. Abstractly speaking, almost all of them have the same initial scenario, the ideological source of which is the Landau model and its further development, the so-called Ruel-Taken Model. According to these scenarios, the transition from the phase of laminar hydrodynamic motion to the turbulent (chaotic) phase occurs through the so-called infinite cascade of Hofi bifurcations. For example, in the case of an atmospheric vortex (blizzard, tornado), this process means that the intensity of turbulent pulsations generated in the vortex region, i.e. the power of the discrete frequency spectrum generated by the infinite sequence of Hof bifurcations, as a result of cascade doubling, expands, gradually becomes continuous and approaches a certain limit. At the initial stage of this process, the power of the frequency spectrum, growing like an avalanche, gradually decreases, which in some specific case, for example, for an atmospheric vortex, means the end of the process of its scattering. Unlike the Landau model, in the Ruelle-Tanken model the transition from the initial regular (laminar) motion to chaos occurs much faster due to a special factor, the so-called "strange attractor". In the problem of flow around smooth surfaces by a laminarly moving liquid, the presence of this factor is associated with the peculiarity of the analytical solution of the Navier-Stokes equation in the region of the critical point. The phase space provides an adequate representation of the specifics of the flow at the critical point and the mathematical complexities arising from it, with the help of which the behavior of the circles of the laminar flow in the region of the critical point is visualized. It is here that the integral surface is formed, onto which various topological variants of the special behavior (aspirations) of the circles of the laminar flow are projected. The physical reason for such diversity is the formation of reverse flows in the region of the critical point and their mixing with the main flow. Accordingly, in the laminar approximation of flow near the critical point, the topological diversity of the pattern of boundary current circles is due to the mixing of two currents of different causes. The main flow is due to the pressure gradient, and the reverse flow is due to the orography of the surrounding surface in the region of the critical point. Naturally, such an effect occurs only with laminar turbulence, although it is worth noting that this phenomenon can develop both in an ideal and in a viscous liquid (gas) near the critical point of any vortex structure, including tornadoes and whirlwinds [8,9].

Tornado and waterspout as topologically similar catastrophic events. To date, there are no known works that formulate a unified theory of large-scale atmospheric vortices. Existing publications mainly present a morphological interpretation of the results of meteorological observations. For example, it is known that the source of a tornado's energy is an ascending flow of warm air rotating unevenly. Its central, toroidal body-like part, the "trunk", rises sharply above the Earth's surface and extends quite high horizontally. However, in fact, the vortex is reflected in the atmosphere, not on the Earth's surface. Its main cause, unlike a tornado, is a thermodynamic process in a cloud. Over time, the air sucked into the vortex cools down and descends as a result of condensation of the steam mixed with it, but, despite the increase in density, continues to rotate around an imaginary vertical axis. A tornado, like a tornado, is distinguished by a certain stability and retains a funnel-shaped structure when moving significant distances along the earth's surface. At this time, the linear speed of rotation of the absorbed mass from the periphery of the tornado in the direction of its "mouth" (the throat of the funnel) can increase by an order of magnitude or even more than the typical value of 10 m / s. In terms of energy, a stochastic storm of a gigantic nature, a tornado, which is disproportionately stronger than a hurricane, usually occurs in the World Ocean, rarely in the area of large water bodies. A tornado, like a tornado, as a catastrophic natural phenomenon, has been well studied from a morphological point of view, the consequences of its destructive action are analyzed in detail [10-14]. However, a full-fledged theoretical modeling of this atmospheric phenomenon is associated with insurmountable physical and mathematical problems [1, 15]. The reasons for this situation are associated, first of all, with a multitude of factors, the joint action of which forms the environmental conditions that contribute to the emergence of a tornado. In particular, the cornerstone of theoretical modeling of a tornado is associated with solving a system of three-dimensional equations of thermogasdynamic motion with adequate initial and boundary conditions of the dynamic characteristics of the real environment. Therefore, at this stage, the solution to this problem exceeds the capabilities of modern analytical methods and computer technology [15].

Conclusion.

The process of transition from laminar to turbulent atmospheric motion can have different stages. Therefore, this process can be presented as very diverse depending on how much certain deterministic characteristics change, determining it during the formation of vortices in the medium. Their presence at specific spatial scales determines the similarity of the elements of the environment. From this point of view, the transition from ordered motion to chaotic motion is nothing more than a sign that the turbulent medium loses its homogeneous quantitative characteristics at smaller and smaller scales. At this time, the main characteristic of the elements of the environment becomes chaotic rotation, creating a chaotic background. Naturally, the linear approximation gives only a simplified mechanical representation of such a process. In this sense, the kinematic model of non-uniform rotation is generally consistent with the deterministic scheme of chaos generation. In particular, with its help, at the initial stage of chaos development, it is quite easy to construct a qualitative picture of the process of vortex energy dissipation.

The Prandtl model and its modifications physically allow the possibility of formation of atmospheric vortices. In combination with this, using the kinematic model of non-uniform rotation, it is possible to simulate the interaction of atmospheric vortices in a linear approximation. This approach gives a fairly complete picture of the development of spontaneous crystalline disturbances in the atmosphere of a narrow mountain valley. The interaction of primary vortices formed due to the inversion of the convection velocity into simple vortices and rings formed during their subsequent connection, within the framework of the Artsukovsky hypothesis, determines the scale of turbulence and causes a change in the temperature field of the atmosphere. Accordingly, the level of its disturbance depends on the time scales and intensity of the generation of storm formations, as well as on the thermodynamic regime of the environment. Thus, the kinematic model of non-uniform rotation gives a qualitative idea of the mechanism of the process of generation and decay of atmospheric vortices. In addition, with its help, the disturbance of the temperature field of the atmosphere can be modeled using one of the particular solutions of the temperature conductivity equation.

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არაერთგვაროვანი ბრუნვის კონუსისებური მოდელი და ატმოსფერული გრიგალური ჯაჭვის ელემენტების ურთიერთქმედება წრფივ მიახლოებაში

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რეზიუმე

გლობალური ატმოსფერო შეიძლება განვიხილოთ, როგორც ღია თერმოდინამიკური სისტემა, რომლის შიგნით მოქმედებენ სხვადასხვა შემაშფოთებელი ფაქტორები. მაგალითად, წყნარ ატმოსფერულ პირობებშიც კი ოროგრაფია შეიძლება გახდეს დედამიწასა და ატმოსფეროს შორის სტაციონარული სითბური ბალანსის დარღვევის მიზეზი. საზოგადოდ, გრიგალური სტრუქტურების წარმოქმნა ნებისმიერ გაზობრივ თუ თხევად გარემოში სტოქასტიკურად დეტერმინირებულია. ეს ნიშნავს, რომ გრიგალის წარმოქმნის პროცესი, მნივნელოვან წილად, ალბათურია. ამიტომ, ატმოსფერული გრიგალური ველის მათემატიკური მოდელირების დროს რაციონალურია შემთხვევითი ფაქტორების გამორიცხვა კონკრეტული ხელისშემწყობი პირობების გამოკვეთის გზით. მაგალითად, დედამიწის რელიეფის ძლიერი დანაწევრება ხელს უწყობს რეგიონალურ და ლოკალურ მასშტაბებში ჰაერის დინების ტურბულიზაციას. კერძოთ, სუსტი ინტენსივობის ატმოსფერული გრიგალების წარმოქმნის პროცესი მთიან ხეობებში

ყოველთვის შეიძლება განვიხილოთ, როგორც ლოკალური სტაბილურობის დარღვევა, რომლის მიზეზია განსხვავებული ოროგრაფიისა და ლანდშაფტების საზღვარზე შექმნილი ტემპერატურული ველის არაერთგვაროვნება. ასევე გრიგალების გენერაცია და მათი დისიპაციის პროცესი ატმოსფეროში ყოველთვის შეიძლება განვიხილოთ, როგორც გარკვეულ სივრცულ მასშტაბებში გარემოს სტაბილურობის დარღვევა, რაც გამოიხატება მისი თერმოდინამიკური პარამეტრების შეშფოთებაში.

საკვანძო სიტყვები: ატმოსფერული გრიგალები, თერმოდინამიკური პარამეტრები, რელიეფი, მათემატიკური მოდელირება.

Коническая модель неоднородного вращения и взаимодействие элементов вращательной цепи атмосферы в линейном приближении

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Резюме

Глобальную атмосферу можно рассматривать как открытую термодинамическую систему, внутри которой действуют различные возмущающие факторы. Например, даже в спокойных атмосферных условиях орография может стать причиной нарушения стационарного теплового баланса между Землей и атмосферой. В целом, формирование вихревых структур в любой газообразной или жидкой среде является стохастически детерминированным. Это означает, что процесс образования вихря в определенной степени вероятностный. Поэтому, при математическом моделировании поля атмосферных круговоротов рационально исключить случайные факторы, выявив конкретные способствующие условия. Например, сильное разделение земного рельефа способствует турбулентности воздушных потоков регионального и локального масштаба. В частности, процесс формирования атмосферных вихрей слабой интенсивности в горных долинах всегда можно рассматривать как нарушение локальной устойчивости, причиной которого является неравномерность температурного поля, создаваемого на границе различной орографии и ландшафтов. Также генерацию вихрей и процесс их рассеяния в атмосфере всегда можно рассматривать как нарушение устойчивости среды в определенных пространственных масштабах, что выражается в нарушении ее термодинамических параметров.

Ключевые слова: атмосферные вихри, термодинамические параметры, рельеф, математическое моделирование.