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ГАЗОДИНАМІКА

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New energy, angle momentum and entropy balance approach to modelling climate and macroturbulent atmospheric dynamics, heat and mass transfer at macroscale. II. Computational algorithm

A new non-stationary balance approach to modelling global mechanisms of climate and macro turbulent atmospheric low-frequency processes, including processes of heat-mass transfer at spatial and temporal macro scales, is based on the balance relationships for entropy, energy and angular momentum, spectral theory of atmospheric macroturbulence, atmospheric moisture flow in further connection with the continuity of atmospheric circulation forms (teleconnection, genesis of fronts). This article gives a detailed description of the computational algorithm (block diagram) of balance approach with emphasis on modeling macroturbulent, circulation low-frequency processes, calculating the balance of the atmosphere angular momentum etc.

***Kew words**: macro turbulent atmospheric processes, heat-mass transfer*

Introduction. The quantitative study of global mechanisms in atmospheric low-frequency processes, teleconnection effects etc attracts a fundamental interest in a modern physics of climate and heat-and mass transfer in complex aerodispersed (atmospheric) systems [1-10]. Nowdays there are popular such methods of description macro- and micro- turbulent processes in atmosphere such as Modèle lagrangien de dispersion de particules d'ordre, Numerical atmospheric-dispersion models, Regional atmospheric transport model, model of the European Center for Meium-Range Weather Forecasts and others [1-15]. Despite the presence of sufficiently correct and consistent approaches to global atmospheric processes, the heat-and mass transfer processes in an atmosphere, macromodelling dispersion of the pollutants in an atmosphere there are remained very actual and hitherto unsolved problems. Earlier we developed a new non-stationary balance approach to modelling global mechanisms of climate and macro turbulent atmospheric low-frequency processes, including processes of heat-mass transfer at spatial and temporal macro scales, teleconnection effects (c.g. [16-19]). It is based on the using balance relationships for the angular momentum of the Earth (atmosphere) as well as an entropy, energy and, spectral theory of atmospheric macroturbulence, atmospheric moisture flow in further connection with the continuity of atmospheric circulation forms. Here we present the detailed description of the computational algorithm or the advanced non-stationary balance approach with accounting for the macro turbulent, circulation low-frequency processes.

1. Advanced angle momentum balance approach and spectral analogue of atmosphere dynamics equations in a low-frequency range. As some elements of

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our theory were in details presented earlier [16-19], we are limited only by the key aspects. An advanced non-stationary angular momentum balance equation of in the planetary dynamic movements of air masses is written as follows:

$$\frac{\partial}{\partial t}\int \rho M dV = \int_{\phi_1}^{\phi_2}\int_0^H\int_0^{2\pi} \rho v M d\phi dz d\lambda + \int_0^H\int_{\phi_1}^{\phi_2}\int_0^{2\pi}\left(p_E^i - p_W^i\right) a\cos\phi dz d\phi d\lambda + - \\ + \int_{\phi_1}^{\phi_2}\int_0^{2\pi}\int_0^H \tau_0 a\cos\phi d\phi d\lambda 2\pi, \tag{1}$$

where $M = \Omega a^2\mathbf{cos}\varphi + ua\mathbf{cos}\varphi$ – angular momentum; Ω – the angular velocity of rotation of the Earth; a – radius of the Earth; φ – Latitude ($\varphi_1 - \varphi_2$ – separated latitudinal belt between the Arctic and polar fronts); λ – longitude; u, v – zonal and meridional components of the wind velocity; ρ – air density; V – the entire volume of the atmosphere in this latitude belt from sea level to the average height of the elevated troposphere waveguide – H (in notations [1] $H = \infty$); $p_E^i - p_W^i$ – the pressure difference between the eastern and western slopes of the i-th mountains; z – height above sea level; τ_0 – the shear stress on the surface.

It should be noted [1] that the cycle of balance of angular momentum in the contact zones with the hydrosphere and lithosphere of the Earth becomes a singularity, which is usually detected through the occurrence of zones of fronts and soliton-type front. Then the kernel of equation (1) can be defined in the density functional ensemble of complex velocity potential [16, 17]:

$$f = \overline{v_\infty} z + \frac{1}{2\pi}\sum_{k=1}^{n} q_k \ln\left(z - a_k\right) + \frac{1}{2\pi}\sum_{k=1}^{p}\frac{M_k e^{\alpha_k i}}{z - c_k} - \frac{i}{2\pi}\sum_{k=1}^{m}\Gamma_k \ln\left(z - b_k\right) \tag{2}$$

and the corresponding complex velocity (c.g. [1, 2]). Here where f complex potential; v_∞ – complex velocity general circulation background (mainly zonal circulation); b_k – coordinates of vortex sources in the area of singularity; c_k – coordinates of the dipoles in the area of singularity; a_k – coordinates of the vortex points in areas of singularity; M_k – values of momenta of these dipoles;α_k – orientation of the axes of the dipoles; Γ_k, q_k – values of circulation in the vortex sources and vortex points, respectively.

The detailed description of different methods of choice the parameters sets for some synoptical situations is presented in Refs. [17-19]. Regarding the physical mechanism of the angular momentum transfer, nn the known balance scheme by Oort [1] the Hadley circulation cell in angular momentum in the north part runs into a zone of the Arctic front, and at the time of the lithosphere it is included in the coverage of the polar front. Convergence of these atmospheric fronts could then close the cycle of atmospheric angular momentum balance in the same frequency range of atmospheric fluctuations without giving effect by an ocean and the lithosphere. The Hadley tropical cell carries teleconnection of the polar front with southern process by means of the link mechanism which is similar to link between the tropical and polar fronts or the Hadley tropical cell with a cell Hadley of temperate latitudes. The balance of angular momentum in conditions of the close convergence of the Arctic and Polar fronts over the ocean is largely respected by centrifugal "pull" moisture along the front section of the polar front to south of a center of the cyclonic-depressive these. The physical features of the atmospheric ventilation predetermine the necessary modification of the Arakawa-Schubert model [15]. The model includes the budget equations for mass, moist static energy, total water content plus the equations of motion. In [15] it is also defined a cloud work function which is an integral measure of the buoyancy force in the clouds. If A is work of a convective cloud then it consists of a convection work and work of down falling streams in the neighbourhood of a cloud [17,18]:

$$dA/dt = dA/dt_{conv} + dA/dt_{downstr}, dA/dt_{downstr} = \int_0^{\lambda_{max}} m_B(\lambda')K(\lambda,\lambda')d\lambda', \qquad (3)$$

Here λ is a velocity of involvement, $m_B(\lambda)$ is an air mass flux, $K(\lambda, \lambda')$ is the Arakawa-Schubert integral equation kernel, which determines the dynamical interaction between the neighbours clouds (c.g., the definition of $K(\lambda, \lambda')$ in Refs. [15, 17]). If

$$\frac{dA}{dt}_{downstr.} = F(\lambda), \int_0^{\lambda_{max}} K(\lambda,\lambda')m_B(\lambda')d\lambda' + F(\lambda) = 0. \qquad (4)$$

is an mass balance equation in the convective element (thermal), then one writes [9]:

$$m_B(\lambda) = F(\lambda) + \beta \int_0^{\lambda_{max}} m_B(\lambda')K(\lambda,\lambda')d\lambda'. \qquad (5)$$

Here β is parameter which determines disbalance of cloud work due to the return of part of the cloud energy to the organization of a wind field in their vicinity, and balance regulating its contribution to synoptic processes. Solution of (5) with accounting for air stream superposition of synoptic processes is given by resolvent method [19]:

$$m_B(\lambda) = F(\lambda) + \beta \int_0^{\lambda_{max}} F(s)\Gamma(\lambda, s;\beta)ds, \qquad (6)$$

where resolvent Γ can be presented as follows:

$$\Gamma(\lambda, s:\beta) = \sum_{m=1}^{\infty} \beta^{m-1} K_m(\lambda, s); \_K_m(x,s) = \\ = \int_0^{\lambda_{max}} \ldots \int_0^{\lambda_{max}} K(x,t_1)K(t_1,t_2)\ldots K(t_{m-1},s)dt_1dt_2\ldots dt_{m-1}; \qquad (7)$$

The key idea [17,19] is to determine a resolvent as an expansion to the Laurent series in complex plane ζ. Representation for resolvent is given by the Fourier expansion:

$$\Gamma = \sum_{n=-\infty}^{\infty} c_n (\zeta - a)^n, \qquad (8)$$

$$c_n = \frac{1}{2\pi i} \oint_{|\varsigma|=1} \frac{f(\varsigma)d\varsigma}{(\varsigma - a)^{n+1}} \qquad (9)$$

where a is centre of convergence ring of the Laurent series.

2. A total spectral analogue for atmospheric dynamics equation of motion. Earlier we derived and studied the simplified form of equation of motion for atmospheric dynamics in the low frequency limit [17-19]. The method for calculating a turbulence spectra should be based on the standard tensor equations of turbulent tensions. As usually, it is convenient to partition velocity ***u***$(v_x,v_y,w)=(U,V,W)$, pressure p, temperature θ into equilibrium and departures from equilibrium values (for example: $p=p_0+p'$etc). The total system includes equations for the Reynolds tensions, moments of connection of the velocity pulsations with entropy ones and the corresponding closure equations. The technique of using Reynolds tension tensors of the second rank is well known (for example, in the form of an analytical representation). The circuit equations with accounting the Coriolis force can be rewritten as [18]:

$$\frac{\partial \overline{V'^2}}{\partial t}=-\frac{i}{a}\left[\overline{V'^2}L_1\left(\bar{V}\right)+2\bar{V}\overline{V'L_1\left(V'\right)}+\overline{V'^2L_1\left(V'\right)}\right]-\frac{i}{a}[L_2\left(\bar{V}\right)\overline{V'U'}+$$
$$+\bar{V}\overline{U'L_2\left(V'\right)}++\bar{U}\overline{V'L_2\left(V'\right)}+\overline{V'U'L_{\ 2}\left(V'\right)}]+4\omega i\cos\theta\overline{V'^2}+\frac{2i}{a}\overline{V'L_6\left(\Phi'\right)}\,, \tag{10a}$$

$$\frac{\partial \overline{U'^2}}{\partial t}=-\frac{i}{a}\left[\overline{V'U'}L_3\left(\bar{U}\right)+\bar{V}\overline{U'L_3\left(U'\right)}+\bar{U}\overline{V'L_3\left(U'\right)}+\overline{V'U'L_3\left(U'\right)}\right]-$$
$$-\frac{i}{a}[\overline{U'^2}L_4\left(\bar{U}\right)+2\bar{U}\overline{U'L_4\left(U'\right)}+\overline{U'^2L_4\left(U'\right)}]-4\omega i\cos\theta\overline{U'^2}+\frac{2i}{a}\overline{U'L_5\left(\Phi'\right)}\,, \tag{10b}$$

$$\frac{\partial \overline{V'U'}}{\partial t}=-\frac{i}{2a}\left[\overline{V'^2}L_3\left(\bar{U}\right)+2\bar{V}\overline{V'L_3\left(U'\right)}+\overline{V'^2L_3\left(U'\right)}\right]-$$
$$-\frac{i}{2a}\left[\overline{V'U'}L_4\left(\bar{U}\right)+\bar{U}\overline{V'L_4\left(U'\right)}++\bar{V}\overline{U'L_4\left(U'\right)}+\overline{V'U'L_4\left(U'\right)}\right]+ \tag{10c}$$
$$+\frac{i}{a}\overline{V'L_6\left(\Phi'\right)}-\frac{i}{2a}\left[\overline{U'^2}L_2\left(\bar{V}\right)+2\bar{U}\overline{U'L_2\left(U'\right)}\right]-\frac{i}{2a}\begin{bmatrix}\overline{U'V'}L_1\left(\bar{V}\right)+\bar{U}\overline{V'L_1\left(V'\right)}+\\+\bar{V}\overline{U'L_1\left(V'\right)}+\overline{V'U'L_1\left(V'\right)}\end{bmatrix},$$

where $L_j=\frac{\partial(...)}{\partial\theta}-\left(-1\right)^j\frac{i}{\sin\theta}\frac{\partial(...)}{\partial\lambda}+b_j\,\mathrm{ctg}\,\theta(...)$, $b_j=1$, $j=1,4$; $b_j=-1$, j = 2, 3; $b_j=0$, j=5, 6. The velocity's correlates are determined as follows [2]:

$$\overline{u_i'u_j'u_k'}=-b\lambda_1\left(\frac{\partial\overline{u_iu_j}}{\partial x_k}+\frac{\partial\overline{u_iu_k}}{\partial x_j}+\frac{\partial\overline{u_ju_k}}{\partial x_i}\right), \tag{11a}$$

$$\overline{u_k'u_j'\theta'}=-b\lambda_2\left(\frac{\partial\overline{u_k'\theta'}}{\partial x_j}+\frac{\partial\overline{u_j\theta'}}{\partial x_k}\right);\overline{u_i\theta'^2}=-b\lambda_3\left(\frac{\partial\overline{\theta'^2}}{\partial x_i}\right), \tag{11b}$$

$$\overline{p'\frac{\partial\theta'}{\partial x_i}}=-\frac{b}{3l_1}\overline{u_i\theta'}-\frac{1}{3}\sigma_{i3}\frac{g}{\theta_0}\overline{\theta'^2}, \tag{11c}$$

$$\overline{p'\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)}=-\frac{b}{3l_1}\left(\overline{u_iu_j}-\frac{1}{3}\sigma_{ij}b^2\right)+cb^2\left(\frac{\partial\overline{u_i}}{\partial x_j}+\frac{\partial\overline{u_j}}{\partial x_i}\right). \tag{11d}$$

Here c, l_1, λ_i are constants which define the scales of turbulent vortexes and measure of their influence on an averaged motion and atmosphere turbulence anisotropy [17]. Components of tensor of the turbulent tensions are (spectral modes of velocity field):

$$\hat{V}^2 = \sum_{k=1}^{\infty}\sum_{s=-k}^{k} V_{k,s}T_{1,s}^{k}\left(\sum_{q=1}^{\infty}\sum_{j=-q}^{q} V_{q,j}T_{1,j}^{q}\right) =$$
$$= \sum_{k=1}^{\infty}\sum_{s=-k}^{k}\sum_{q=1}^{\infty}\sum_{j=-q}^{q} V_{k,s}V_{q,j} \times \sum_{\nu=|k-q|}^{k+q} \sigma_{1,1,2}^{k,q,\nu}\sigma_{s,j,s+j}^{k,q,\nu}T_{2,s+j}^{\nu} = \overline{v_1' v_1'} = b^2 \quad (12)$$

where $T_{1,j}^{q}$ are the vector-tensor spherical functions (c.g. [19,20]). An effective approach to determination of the atmospheric flow velocity is given by plane complex field method in a full analogy with the known Karman vortices chain model [17]:

$$v_x - iv_y = \frac{df}{d\xi} = \frac{\Gamma}{2\pi i}\left[\frac{1}{\zeta-\zeta_0} + \sum_{k=1}^{\infty}\left(\frac{1}{\zeta-\zeta_0-kl} + \frac{1}{\zeta-\zeta_0+kl}\right)\right] + \frac{d}{d\zeta}\left[\sum_{k=1}^{n}\Gamma_k \ln(\zeta-b_k)\right]. \quad (13)$$

Here Γ_k – circulation on the vortex elements, created by clouds, b_k – co-ordinates of these elements, Γ – circulation on the standard Karman chain vortices of, l – distance between standard vortices of the Karman chain, ζ – co-ordinate of the convective perturbations line (or front divider) centre, $\zeta_0 - kl$ – co-ordinate of beginning of the convective perturbation line, ζ_0+kl – co-ordinate of end of this line. It is very important to note that equating the velocity components determined in the global circulation model and plane complex field theory, one could find the spectral matching between the wave numbers that define the functional elements in the Fourier-Bessel series with the source element of a plane field theory. As usually, it is worth to remind that any vector field u can be separated into rotational and divergent parts, i.e., $u = \nabla\psi + u_f$ (the Helmholtz's theorem). If the vector field is a horizontal wind, one can define a current function ψ, to express the rotational part, and a velocity potential f, to express the divergent part. Usually these parameters are of a practical interest in applied analysis of the global atmospheric ventilation [1, 2, 5, 6, 18].

Flowchart of the computational algorithm of the balance approach. In Table 1 we list a flowchart (block-scheme) of the computational algorithm of the developed balance approach to modelling the global mechanisms of climate and macroturbulent atmospheric low-frequency processes, including processes of heat-mass transfer at spatial and temporal macro scales, teleconnection and front-genesis effects.

The approach is based on the energy, angular momentum balance relationships for the global atmospheric macroturbulent low-frequency processes, link of tropospheric waveguides with atmospheric moisture circulation and, accordingly, with the shape of atmospheric circulation over the position of the front sections of (atmospheric fronts as the main drives moisture). The results of calculating the balance of angular momentum, atmospheric circulation in link with continuity of atmospheric circulation forms will be presented in the next paper for a whole region of Pacific ocean.

Table 1

Flowchart of calculating height variation of an elevated tropospheric waveguide, the balance of the angular momentum, the macroturbulence factor, field of current function of the wind flows conjugated to this process

The parameterization block of the geopotential field by vortex and mass sources; input of geographical coordinates

↓ ↓ ↓

input of complex coordinates of the vortex sources	input of complex coordinates of the mass sources	input of the function of parameterizing the fronts

↓ ↓ ↓

Input of magnitudes of abundances of vortex sources	Input of magnitudes of dipole moments and their orientation angles	Fractional-linear conformal transformation of the parametrization function of the front to the real configuration

↓ ↓ ↓

Calculation of the parametrizing function

$$V_x - iV_y = \frac{\Gamma}{2\pi i}\left[\frac{1}{\xi-\xi_0} + \sum_{k=1}^{\infty}\left(\frac{1}{\xi-\xi_0-kl} + \frac{1}{\xi-\xi_0+kl}\right)\right] + \frac{d}{d\xi}\sum_{k=1}^{n}\Gamma_k \ln\left(\xi-b_k\right) + \frac{1}{2\pi}\times \left[\sum_{k=1}^{n}\frac{q_k}{z-a_k} + \sum_{k=1}^{p} M_k \exp\frac{\alpha_k i}{\left(z-c_k\right)^2}\right] \quad (1)$$

⇄

Calculation of potential maps and current functions, construction of isolines, comparative analysis, correction of function parameters $V_x - iV_y$, repeated calculation after correction if necessary, etc.

↓ ↓

Isolation of the pulsation component in the field $V_x - iV_y$ by the method of expansion into Laurent series in the ring of convergence and Fourier on the boundary of the ring (the field is closed by rings of convergence)

↓ ↓

Substituting pulsation component into Eqs (10)

$$\frac{\partial \overline{V'U'}}{\partial t} = -\frac{i}{2a}[\overline{V'^2}L_3(\overline{U}) + 2\overline{V}\,\overline{V'L_3(U')} + \overline{V'^2 L_3(U')}] - ...$$

Averaging by the operation of a re-expansion into Fourier-Laurent series. A significant deviation from geostrophicity due to turbulence sets the temperature background of the thermal wind.

→

Computing hydrodynamic pressure and torque of hydro-dynamic pressure forces for planar projection:

$$R = X - iY = i\rho\Gamma v_\infty;$$

$$L = \mathrm{Re}\left(-\rho v_\infty \sum_{k=1}^{m}\Gamma_k b_k - i\rho M v_\infty\right)$$

↓ ↓

Visual correction on the monitor by mapping the connection of the macro turbulence factor with the moment of hydrodynamic pressures. Iterative multiple reconciliation of both factors by correcting the vortex and mass sources

↓ ↓

The solution of the integral equation (1)

Is reducible to $a(t)\phi(t)+\frac{b(t)}{2\pi}\oint\phi(\xi)\frac{d\xi}{\xi-t}+$

$+\oint K(t,\xi)\phi(\xi)d\xi=f(t)$ (3) by operator:

$a(t)\omega(t)+\frac{b(t)}{2\pi}\oint\omega(\xi)\frac{d\xi}{\xi-t}$ (4) and Resolvent

$\Gamma(x,s,\beta)=\sum^{\infty}\beta^{m-1}K_m(\lambda,\lambda,s)$ (7)

The Arakawa-Schubert model: compilation of parameters

$M(z)=\iint m_B\eta(z,\lambda)d\lambda$,

$\int_0^{\lambda_{max}} Km_B(\lambda')d\lambda'+F=0$.

Solution of the SLAE, SDE:

$\eta(\lambda)\to\eta_{max}\to H,\ \Delta H$

R-waveguide height

Subblock of the census of equation (1) to special form by the residues theory method

Action of the operator (4) according to Eq.(3) with the aim of reducing Eq. (3) to the Fredholm equation

Calculation of resolvent (7). The translation of resolvent to the form of a record of type (1)

Analysis through mapping a resolvent (7) to detect areas of balance imbalance, Eq (1); these zones are analyzed for excess of mass, reeduced to rotation in a different latitude belt

Elimination of the imbalance by introduction to a field of the resolvent of vortex structures, vortex & mass sources: $(\sim)\frac{\Gamma}{2\pi}\left[\frac{1}{\xi-\xi_0}+...\right];\sim\frac{d}{d\xi}\left[\Gamma_k\ln(\xi-b_k)\right];(\sim)\frac{q_k}{z-a_k}+(\sim)M_k\exp\frac{\alpha_k i}{(z-c_k)^2}$.

The location of vortex elements and their fractional-linear conformal transformation in a field of resolvent (7) is performed by pointing detected poles in resolvent function. All together shows movement of a frontal section and the change in the form of circulation.

Calculation of angular momentum, ψ, f, u_f, density gradient; estimate of height variation of radiowaveguide from displacement of the zones of frontogenesis;

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Новий балансовий по ентропії, енергії і кутовому моменту підхід до моделювання клімату та макротурбулентної динаміки атмосфери, тепло-масо-переносу в макромасштабі. II. Комп'ютерний алгоритм

АНОТАЦІЯ

Новий балансовий підхід до моделювання глобальних механізмів кліматичних і макротурбулентних атмосферних низькочастотних процесів, у т.ч., процесів тепло-масопереносу , ефектів телеконнекції тощо, базується на використанні балансових співвідношень по ентропії, енергії і кутовому моменту, спектральній теорії атмосферної макротурбулентності і волого-обороту у зв'язку із наступністю форм атмосферної циркуляції (телеконнекція, генезис фронтів). У цій статті дано детальний опис комп'ютерного алгоритму (блок-схеми) підходу з акцентом на моделювання макротурбулентних, циркуляційних процесів, балансу кутового моменту тощо. Метод демонструє основу того нового напряму у фізиці атмосфери і теорії клімату, зокрема, довгострокових і над довгострокових прогнозів, який в даний час стає домінуючим. У практичному плані суть моделювання також націлена на виявлення та апробацію нових предикторів для довгострокових прогнозів динаміки атмосферної (кліматичної) системи. Йдеться про адаптацію модифікованої теорії макротурбулентності стосовно до атмосферних радіохвилеводів з метою їх можливого використання поряд з іншими в якості предикторів у довгостроковому плані. Блок-схема висвічує потенціал запропонованих нами перших кількісних моделей обчислення балансу кутового моменту, атмосферного вологообороту у зв'язку з генезисом тропосферних радіохвильоводів і процесами спадкоємності форм атмосферної циркуляції (телеконнекції, фронтогенезу) для цілей освоєння нових для прогностичної практики предикторів.

***Ключові слова**: макротурбулентні атмосферні процеси, теплоперенос*

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Новый балансовый по энтропии, энергии и угловому моменту подход к моделированию климата и макротурбулентной динамики атмосферы, тепло-массо-переноса в макромасштабе. II. Компьютерный алгоритм

АНОТАЦИЯ

Новый балансовый подход к моделированию глобальных механизмов климатических и макротурбулентных атмосферных низкочастотных процессов, в т.ч.. процессов тепло-массо-переноса, эффектов теле коннекции и др., базируется на использовании балансовых соотношений для энтропии, энергии, углового момента, спектральной теории атмосферной макротурбулентности и влагооборота в связи с преемственностью форм атмосферной циркуляции (телеконнекция, генезис фронтов). В статье дано детальное описание компьютерного алгоритма подхода с акцентом на моделирование макротурбулентных, циркуляционных процессов, баланса углового момента и т.д. Метод демонстрируют основу того нового направления в физике атмосферы и теории климата, в частности, долгосрочных и сверхдолгосрочных прогнозов, которое в настоящее время становится доминирующим. В практическом плане суть моделирования нацелена на обнаружение и апробацию новых предикторов для долгосрочных и сверхдолгосрочных прогнозов динамики атмосферной (климатической) системы. Речь идет также об адаптации модифицированной теории макротурбулентности применительно к атмосферным радиоволноводам с целью их применения наряду с другими в качестве предикторов в долгосрочном плане. Блок-схема высвечивают потенциал предложенных нами первых количественных моделей расчета баланса углового момента, атмосферного влагооборота в связи с генезисом тропосферных радиоволноводов и преемственностью форм атмосферной циркуляции (телеконнекции, фронтогенеза) для целей освоения новых для прогностической практики предикторов.

Ключевые слова: *макротурбулентные атмосферные процессы, теплоперенос.*