ГАЗОДИНАМІКА

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New theoretical approach to dynamics of heat-mass-transfer, thermal turbulence and air ventilation in atmosphere of an industrial city

We have developed a new theoretical approach to dynamics of heat-mass-transfer, thermal turbulence and air ventilation in atmosphere of an industrial city, including an improved theory of atmospheric circulation in combination with the hydrodynamic model (with correct account of turbulence in atmosphere of the urban area) and theory of a complex geophysical field is applied to the simulation of heat and air transfer in atmosphere of industrial region. To determine a spectrum of thermal turbulence of an industrial city's zone, the modified approximation of "shallow water" is used. In contrast to the standard difference methods of their solution, we use the spectral expansion algorithm. For calculating air circulation in an industrial city's periphery we use theory of a plane complex geophysical field. Equating the speed components determined in the shallow water model and plane complex geophysical field model, one can find spectral matching between the wave numbers that define the functional elements in the Fourier-Bessel series with source element of a plane field theory.

***Key words**: heat-mass-transfer, thermal turbulence, city's atmosphere*

Introduction. One of the most actual and important problems of the modern physics of aerodispersed systems, atmospheric and climate systems is study of an energy-, heat-, mass-transfer in natural continuous environments such as atmosphere or other geospheres. The most of different simplified approaches that allow to estimate the temporal and spatial structure of air ventilation in an atmosphere, significantly use as the simple molecular diffusion models as system of regression equations [1-14]. Disadvantages of these approaches are well known and became very critical if the atmosphere contains elements of convective instability. In our previous papers [7, 15-18] we have developed an advanced approach to the simulation of heat and air ventilation in atmosphere of an industrial region (so called local scale atmospheric circulation complex-field (LACCF) approach). The approach includes an improved theory of atmospheric circulation in combination with the hydrodynamic forecast model (with quantitatively correct account of turbulence in the atmosphere at local scales) and the Arakawa-Schubert model of cloud convection. Here we present a new theoretical approach to dynamics of heat-mass-transfer, thermal turbulence (as in a heat island zone as in a city's periphery) and air ventilation in atmosphere of an industrial city.

Spectrum of thermal turbulence of an industrial city's zone. The modified approximation of "shallow water" is used, but, in contrast to the standard difference

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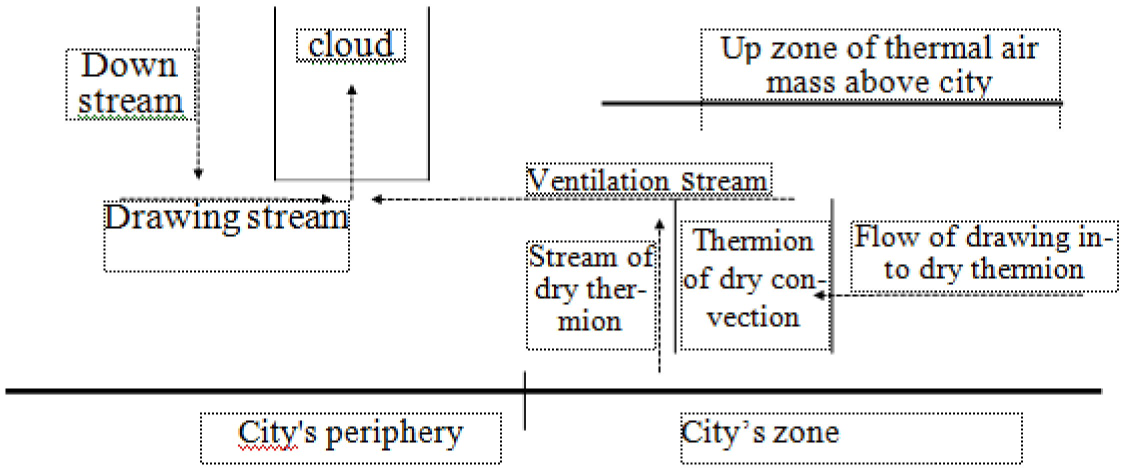

Figure 1. Flowchart of air mass transfer between the city and its periphery

methods of solution, in further we will use the spectral expansion algorithm [7, 15]. The necessary solution, for example, for the v_x-iv_y component for the city's heat island has the form of expansion into series on the Bessel functions. As usually, we attribute the movement to the polar coordinates (r, θ) in the area located within the zone of action of the thermal "cap" (or "heat island") of the city [7]. Flowchart of the ventilation over the urban region territory by air flows in a presence of the cloud's convection is presented in Figure 1 and explains the key physical processes [16].

The system of equations of motion is as follows [7]:

$$\begin{gathered} \frac{\partial u}{\partial t} - 2\omega v + g\frac{\partial \varsigma}{\partial r} = 0, \\ \frac{\partial v}{\partial t} - 2\omega u + \frac{g}{r}\frac{\partial \varsigma}{\partial \theta} = 0, \\ \frac{\partial u}{\partial r} + \frac{1}{r}\frac{\partial v}{\partial \theta} + \frac{u}{r}\frac{\partial w}{\partial z} = 0, \\ w = \frac{\partial \varsigma}{\partial t}. \end{gathered} \tag{1}$$

(where u, v, w – components of wind speed, ω – angular velocity of rotation of the circulation ring around the city heat island; g is acceleration of gravity, ζ is free surface level of the shallow water equations (1)) with boundary conditions:

$$\frac{\partial \zeta}{\partial t}\Big|_{z=0} = u\frac{\partial H}{\partial r} + \frac{v}{r}\frac{\partial H}{\partial \theta} \tag{2a}$$

$$\frac{\partial \zeta}{\partial t}\Big|_{z=\bar{H}} = \frac{1}{gp}\frac{\partial P}{\partial t} - \int_0^{\bar{H}} \left[\frac{\partial u}{\partial r} + \frac{1}{r}\frac{\partial v}{\partial \theta} + \frac{u}{r}\right]dz + u\frac{\partial \zeta}{\partial r} + \frac{v}{r}\frac{\partial \zeta}{\partial \theta}, \tag{2b}$$

where P – is the atmospheric pressure, H – height of the thermal head or free level.

Lateral boundary condition: $\zeta|_{r=1} = 0$ corresponds to the absence of disturbances at the boundary of the circulation ring. In a single-layer fluid approximation:

$$\frac{\partial \omega}{\partial z} \approx \frac{\frac{\partial \zeta}{\partial t}|_{z=\bar{H}} - \frac{\partial \zeta}{\partial t}|_{z=0}}{H}. \quad (3)$$

Equation (2) can be rewritten as follows:

$$\frac{\partial \zeta}{\partial t} = \frac{1}{gp}\frac{\partial P}{\partial t} - \int_0^{\bar{H}} \left[\frac{\partial u}{\partial r} + \frac{1}{r}\frac{\partial v}{\partial \theta} + \frac{u}{r}\right] dz + u\frac{\partial \zeta}{\partial r} + \frac{v}{r}\frac{\partial \zeta}{\partial \theta} - \left[u\frac{\partial H}{\partial r} + \frac{v}{r}\frac{\partial H}{\partial \theta}\right]. \quad (4)$$

Equation (1) are transformed into independent ones with respect to u and v:

$$\left(\frac{\partial^2}{\partial t^2} + 4\omega^2\right) u = -g\frac{\partial^2 \zeta}{\partial r \partial t} - 2\omega g \frac{\partial \zeta}{r \partial \theta}, \quad (5a)$$

$$\left(\frac{\partial^2}{\partial t^2} + 4\omega^2\right) v = 2\omega g\frac{\partial \zeta}{\partial r} - g\frac{\partial^2 \zeta}{r \partial \theta \partial t}. \quad (5b)$$

Applying the operator $\left(\frac{\partial^2}{\partial t^2} + 4\omega^2\right)$ to equation (5), and excluding u and v, taking into account advection, we obtain a nonlinear differential equation with respect to ζ:

$$\left(\frac{\partial^2}{\partial t^2} + 4\omega^2\right)\frac{\partial \zeta}{\partial t} = g\bar{H}\left[\frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2}{\partial \theta}\right]\frac{\partial \zeta}{\partial t} + \left(\frac{\partial^2}{\partial t^2} + 4\omega^2\right) \times$$

$$\times \left\{-\frac{1}{gp}\frac{\partial P}{\partial t} - \int_0^{\bar{H}} \left[\frac{\partial u}{\partial r} + \frac{1}{r}\frac{\partial v}{\partial \theta} + \frac{u}{r}\right] dz + u\frac{\partial \zeta}{\partial r} + \frac{v}{r}\frac{\partial \zeta}{\partial \theta} - \left[u\frac{\partial H}{\partial r} + \frac{v}{r}\frac{\partial H}{\partial \theta}\right]\right\}. \quad (6)$$

Here:

$$\frac{\partial P}{\partial t} = -u\frac{\partial P}{\partial r} - \frac{v}{r}\frac{\partial P}{\partial \theta} + \frac{C_p}{C_v} RT \frac{\partial p}{\partial z}$$

where T and $\frac{\partial P}{\partial t}$ set the temperature and baroclinic modes. The solution of equation (6) is divided into the solution of a homogeneous differential equation:

$$\left(\frac{\partial^2}{\partial t^2} + 4\omega^2\right)\frac{\partial \zeta}{\partial t} - g\bar{H}\left[\frac{\partial^2}{\partial} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2}\right]\frac{\partial \zeta}{\partial t} = 0. \quad (7)$$

and further determination of a total solution in the form as a superposition of particular solutions of the equation (7). The natural definition of particular solution is as follows: $\zeta = \zeta'(r)\cos(m\theta - \sigma t)$. Its substitution to Eq.(7) allows to obtain:

$$\frac{\partial^2 \zeta'}{\partial r^2} + \frac{1}{r}\frac{\partial \zeta'}{\partial r} + \left(x^2 - \frac{m^2}{2}\right)\zeta' = 0 \quad (8)$$

where

$$x^2 = \frac{\sigma^2 - 4\omega^2}{H}. \quad (9)$$

Equation (8) coincides with the Bessel equation and, as it is known, its own solutions will also be the Bessel functions: $\zeta'(r) = J_m(xr)$. The total solution can be presented as follows:

$$\varsigma(r,\theta,t)=\sum_{m=0}^{M}\sum_{n=0}^{M}\left(A_{m,n}\cos m\theta\cos\sigma_{m,n}t+B_{m,n}\sin m\theta\sin\sigma_{m,n}t\right)J_m\left(\lambda_{m,n}r\right), \quad (10)$$

where $\lambda_{m,n}$ is "n" root of the function $J_m(r)$. It is known that it is directly related to frequency $\sigma_{m,n}$ if x in a particular solution is identified with $\lambda_{m,n}$ in a complete solution. The constants $A_{m,n}$, $B_{m,n}$ are then determined either from the initial level for $t = 0$ for the function ζ, which in this case is a solution of the homogeneous equation (7), or according to the method of solving the inhomogeneous equation (6), but without satisfying, in the general case, the initial condition [19]. The series (10) is simultaneously the Fourier-Bessel series for the function $\zeta(r,\theta)$. Further, one can easily get:

$$u=\sum_{m=0}^{R}\sum_{n=0}^{R}\left[\frac{g}{\sigma_{m,n}^2-4\omega^2}\left(\sigma_{m,n}\frac{dJ_n\left(\lambda_{m,n}r\right)}{dr}-\frac{2m\omega J_n\left(\lambda_{m,n}r\right)}{r}\right)\times\right.$$
$$\left.\times\left(A_{m,n}\sin m\theta\cos\sigma_{m,n}t+B_{m,n}\cos m\theta\sin\sigma_{m,n}t\right)\right];$$
$$v=\sum_{m=0}^{R}\sum_{n=0}^{R}\left[\frac{g}{\sigma_{m,n}^2-4\omega^2}\left(-2\omega\frac{dJ_n\left(\lambda_{m,n}r\right)}{dr}+\frac{m\sigma_{m,n}J_n\left(\lambda_{m,n}r\right)}{r}\right)\times\right. \quad (11)$$
$$\left.\times\left(A_{m,n}\cos m\theta\cos\sigma_{m,n}t+B_{m,n}\sin m\theta\sin\sigma_{m,n}t\right)\right].$$

The initial function of the thermal relief of an industrial city and the fields associated with it are determined by the following Fourier-Bessel series:

$$F(r,\theta)=\sum_{m=0}^{M}\sum_{n=0}^{M}\left(C_{m,n}\cos m\theta\cos\sigma_{m,n}t_j+D_{m,n}\sin m\theta\sin\sigma_{m,n}t_j\right)J_{m,n}\left(\lambda_{m,n}r\right), \quad (12)$$

$$C_{m,n}=\frac{2\cos\sigma_{m,n}t_j}{\pi J_m^{'2}(\lambda_{m,n})}\int_0^1\int_0^{2\pi}F(\theta,r)\cos m\theta J_m(\lambda_{m.n}r)rd\theta dr, \quad (13)$$

$$D_{m,n}=\frac{2\cos\sigma_{m,n}t_j}{\pi J_m^{'2}(\lambda_{m,n})}\int_0^1\int_0^{2\pi}F(\theta,r)\sin m\theta J_m(\lambda_{m.n}r)rd\theta dr. \quad (14)$$

It is interesting to note that further, for example, the diffusion of impurities in atmosphere of industrial city inside the city's heat island from some point sources is read by the method of simple advection according to the values of the velocity projection calculated by formulas (11). One could also directly use the equation of molecular (wave) diffusion. The vertical rise of the impurity is calculated by the formula (2b).

Application of the theory of a plane complex field for calculating air circulation in an industrial city's periphery. Within the new geophysical approach [16-18], an air flux speed over a city's periphery in a case of convective instability can be found by method of plane complex field theory (in analogy with the Karman vortices chain model) [6,19]:

$$v_x - iv_y = \frac{df}{d\varsigma} = \frac{\Gamma}{2\pi i}\left\{\frac{1}{\varsigma-\varsigma_0} + \sum_{k=1}^{\infty}\left(\frac{1}{\varsigma-\varsigma_0-kl} + \frac{1}{\varsigma-\varsigma_0+kl}\right)\right\} + \frac{d}{d\varsigma}\left[\sum_{k=1}^{n}\Gamma_k \ln(\varsigma - b_k)\right]. \quad (15)$$

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, ζ_0 - kl – co-ordinate of beginning of the convective perturbation line, ζ_0+kl – co-ordinate of end of this line. The indicated parameters are the input model ones and explained in details in Ref. [7].

Naturally, we further assume that possible convective disturbances on the periphery of an industrial city approach it in the form of convective ridges. The required ridges of cloudiness can be set in the problem in the field of the velocity of vertical currents and associated currents of involvement by formula (15). The model stability of a front segment or a convective line in the general dynamics of the atmosphere can be formulated by combining solution (11) with the formula of the theory of a plane complex field (15):

$$\sum_{m=0}^{R}\sum_{n=0}^{R}\left[\frac{g}{\sigma_{m,n}^2 - 4\omega^2}\left(\sigma_{m,n}\frac{dJ_n(\lambda_{m,n}r^/)}{dr} - \frac{2m\omega J_n(\lambda_{m,n}r^/)}{r}\right)(A_{m,n}\sin m\theta^/ \cos\sigma_{m,n}t + B_{m,n}\cos m\theta^/ \sin\sigma_{m,n}t)\right] -$$
$$i\sum_{m=0}^{R}\sum_{n=0}^{R}\left[\frac{g}{\sigma_{m,n}^2 - 4\omega^2}(-2\omega\frac{dJ_n(\lambda_{m,n}r^/)}{dr} + \frac{m\sigma_{m,n}J_n(\lambda_{m,n}r^/)}{r})(A_{m,n}\cos m\theta^/ \cos\sigma_{m,n}t + B_{m,n}\sin m\theta^/ \sin\sigma_{m,n}t)\right] =$$
$$= \frac{\Gamma}{2\pi i}\left\{\frac{1}{\varsigma-\varsigma_0} + \sum_{k=1}^{\infty}\left(\frac{1}{\varsigma-\varsigma_0-kl} + \frac{1}{\varsigma-\varsigma_0+kl}\right)\right\} + \frac{d}{d\varsigma}\left[\sum_{k=1}^{n}\Gamma_k \ln(\varsigma - b_k)\right] + \quad (16)$$
$$+\frac{C_m}{(z-a_m)^m} + \frac{C_{m-1}}{(z-a_{m-1})^{m-1}} + \ldots + \frac{C_1}{z-a_1}.$$

Here the coordinates $r^/, \theta^/$ are located in the zone of action of the functional ensemble of the front or the line of convective instability; the coordinates $a_m, a_{m-1}, \ldots, a_1$ $a_m, a_{m-1}, \ldots, a_1$, "contouring" the said section of the frontal section include the coordinates $r^/, \theta^/$ in the immediate vicinity. The consistency of the coefficients $A_{m,n}, B_{m,n}$ with the similarity coefficients $\sigma_m, \sigma_{m-1}, \ldots, \sigma_1$ of the Laurent series in a certain neighborhood with nearby coordinate points $a_m, a_{m-1}, \ldots, a_1$ determines the stability at the time point of the physical process specified by the complex velocity potential in the process of thermal circulation at the boundary of the city's thermal ring with the general solution of the thermal circulation model given by series (2). The area of solution of the problem (1) – (2) in this case belongs to the line of maximum speeds in the zone of the thermal circulation ring of the city. The multipole coefficients $\sigma_m, \sigma_{m-1}, \ldots, \sigma_1$ specify the total contribution of focal convection beyond the lines of convective perturbations. Next, one could find the spectral agreement between the wave numbers that define the functional element in the Fourier-Bessel series with the element source of the theory of a plane field:

$$\frac{g}{\sigma_{M,N}^2 - 4\omega^2}\left(\sigma_{M,N}\frac{dJ_N(\lambda_{M,N}r^/)}{dr} - \frac{2M\omega J_N(\lambda_{M,N}r^/)}{r}\right)\exp[i(M\theta^/ - \sigma_{M,N}t)](A_{N,M} + iB_{N,M}) -$$

$$-i\frac{g}{\sigma_{M,N}^2-4\omega^2}(-2\omega\frac{dJ_N(\lambda_{M,N}r^/)}{dr}+\frac{M\sigma_{M,N}J_N(\lambda_{M,N}r^/)}{r})\exp[i(M\theta^/+\sigma_{N,M}t)]\times$$
$$\times(A_{N,M}+iB_{N,M})=\frac{\Gamma}{2\pi i}\left\{\frac{1}{\varsigma-\varsigma_0}+\left(\frac{1}{\varsigma-\varsigma_0-kl}+\frac{1}{\varsigma-\varsigma_0+kl}\right)\right\}+\frac{d}{d\varsigma}[\Gamma_k\ln(\varsigma-b_k)]+\frac{C_1}{z-a_1}; \quad (17)$$

In this case, the linearity of the circulation model is actually used. Further one can write:

$$C_1=\frac{1}{2\pi i}\oint_0\frac{1}{(z-a_1)^2}\left\{\frac{g}{\sigma_{M,N}^2-4\omega^2}(\sigma_{M,N}\frac{dJ_N(\lambda_{M,N}r^/)}{dr}-\frac{2M\omega J_N(\lambda_{M,N}r^/)}{r})\times\right.$$
$$\times\exp[i(M\theta^/-\sigma_{M,N}t)](A_{N,M}+iB_{N,M})-$$
$$-i\frac{g}{\sigma_{M,N}^2-4\omega^2}(-2\omega\frac{dJ_N(\lambda_{M,N}r^/)}{dr}+\frac{M\sigma_{M,N}J_N(\lambda_{M,N}r^/)}{r})\exp[i(M\theta^/+\sigma_{M,N}t)]\times \quad (18)$$
$$\times(A_{N,M}+iB_{N,M})-\frac{\Gamma}{2\pi i}\{\frac{1}{\varsigma-\varsigma_0}+(\frac{1}{\varsigma-\varsigma_0-kl}+\frac{1}{\varsigma-\varsigma_0+kl})\}+\frac{d}{d\varsigma}[\Gamma_k\ln(\varsigma-b_k)]\}d\varsigma;$$

Here M,N are the wave numbers of the two-dimensional harmonic: $e^{i(m\phi+\sigma_{n,m}t)}J_n(\lambda_{m,n}r^/)$, which best approximates the functional field of the dipole in the circle of convergence of the Taylor series. As a result, the spectrum in the Fourier-Bessel series is consistent with the source with weight C_1. Of course, here we are talking about coordinate wise matching of the spectral mode with a source in a small subdomain of the total solution. In other subareas, the desired solution may be inconsistent. Nevertheless, it is possible to achieve fairly good agreement across the formula (17) with the coefficients $\sigma_m,\sigma_{m-1},...,\sigma_1$ and spectral modes: $A_{m,n},B_{m,n}$. Thus, in fact, the problem is not solved at a specific point, but on average along the convergence ring of the Laurent series. Coordinates $r^/,\theta^/$ are recalculated when calculating into a coordinate ς on a complex plane. An additional way to clarify the stability of the front section or the line of convective disturbance in the field of action of the thermal circulation of the city is based on the formula (theory of complex variable functions):

$$f(z)=-\frac{1}{2\pi i}\oint_0\frac{f(\varsigma)d\varsigma}{\varsigma-z}=\frac{C_{-1}}{z-a}+\frac{C_{-2}}{(z-a)^2}+...+\frac{C_{-n}}{(z-a)^n}+... \quad (19)$$

Here, obviously, the Laurent series with convergence in the ring in the neighborhood of the point (a) is already applied. Further, we can represent the vortex chain formula in the form of successive vortex sources in the field of the complex velocity potential ω in the complex plane with the coordinate z:

$$\frac{d\omega}{dz}=\frac{\Gamma}{2\pi i}\{\ln[\frac{(z-z_0)}{l}]+\sum_{k=1}^{\infty}[\ln(\frac{z-z_k}{-lk})+\ln(\frac{z-z_{-k}}{lk})]\}+const. \quad (20)$$

Here l is the distance between the vortices in the Karman chain; $z_0,z_2,...,z_k$ are the complex coordinates of the centers of the vortices, the coordinates z_{-k} were introduced by Karman, but can be eliminated in relation to atmospheric disturbances if the coordinate z_0 coincides with a certain center of intense convection of the intramass manifestation: $\Gamma = \Omega\sigma$ – circulation along the contour of an individual element of the vortex chain, where Ω is a projection of the vortex element onto the normal to the surface of a certain section separating the zone of intramass convection from the rest of the solution area; σ is the area ofthe normal section of the elementary vortex in the chain. Specific model applications of the presented approach will be considered in subsequent works. It is interesting to remind that the processes in the thermal "cap" or heat island zone can be defined by analogy with the known soliton of fogging as a "locale", which has its own wave and turbulent (or chaotic) structure. These structures are rigidly connected to each other. Namely, the energy spectra of harmonics of the Fourier or Fourier-Bessel transforms can be understood both as a wave spectrum and as a spectrum of turbulent vortices (c.g. [19-21]). This is also clear from theories of energy estimates of the spectrum of turbulent pulsations [7].

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Новий теоретичний підхід до динаміки тепло-масо-переносу, теплової турбулентності і вентиляції повітря в атмосфері промислового міста

АНОТАЦІЯ

Запропоновано новий теоретичний підхід до опису динаміки тепломасопереносу, теплової турбулентності і вентиляції повітря в атмосфері промислового міста, що включає вдосконалену теорію атмосферної циркуляції в поєднанні з моделлю гідродинамічного прогнозу (з кількісно коректним урахуванням турбулентності в атмосфері міської території), теорією плоского комплексного геофізичного поля. Для визначення спектру теплової турбулентності в зоні забудови промислового міста використову-

ється модифіковане наближення «дрібної води». На відміну від стандартних різницевих методів їх вирішення, в роботі пропонується використовувати так званий алгоритм спектрального розкладання. Для розрахунку циркуляції повітря на периферії промислового міста використовується теорія плоского комплексного геофізичного поля. Прирівнюючи компоненти швидкості, певні в моделі дрібної води і моделі плоского комплексного геофізичного поля, можна знайти спектральний відповідність між хвильовими числами, які визначають функціональні елементи в ряду Фур'є-Бесселя, з вихідним елементом теорії плоского поля. Величини спектральних мод, що відповідають хвильовим числам в розкладаннях в ряди Фур'є-Бесселя метеорологічних полів, додатково визначають вагу неізотропності в турбулентному режимі атмосфери міста. Мала неізотропність при великих спектральних модах істотна як покажчик наявності нестаціонарності в турбулентному режимі в ландшафті міста.

Ключові слова: *тепломасоперенiс, теплова турбулентність, атмосфера міста.*

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Новый теоретический подход к динамике тепло-массо-переноса, тепловой турбулентности и вентиляции воздуха в атмосфере промышленного города

АНОТАЦИЯ

Предложен новый теоретический подход к описанию динамики тепломассопереноса, тепловой турбулентности и вентиляции воздуха в атмосфере промышленного города, включающий усовершенствованную теорию атмосферной циркуляции в сочетании с моделью гидродинамического прогноза (с количественно корректным учетом турбулентности в атмосфере городской территории), теорией плоского комплексного геофизического поля. Для определения спектра тепловой турбулентности в зоне застройки промышленного города используется модифицированное приближение «мелкой воды». В отличие от стандартных разностных методов их решения, в работе предлагается использовать так называемый алгоритм спектрального разложения. Для расчета циркуляции воздуха на периферии промышленного города используется теория плоского комплексного геофизического поля. Приравнивая компоненты скорости, определенные в модели мелкой воды и модели плоского комплексного геофизического поля, можно найти спектральное соответствие между волновыми числами, которые определяют функциональные элементы в ряду Фурье-Бесселя, с исходным элементом теории плоского поля. Величины спектральных мод, соответствующих волновым числам в разложениях в ряды Фурье-Бесселя метеорологических полей, дополнительно определяют вес неизотропности в турбулентном режиме атмосферы города. Малая неизотропность при больших спектральных модах существенна как указатель наличия нестационарности в турбулентном режиме в ландшафте города.

Ключевые слова: *тепломассоперенос, тепловая турбулентность, атмосфера города.*