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NUMERICAL MODELING OF THE ANTHROPOGENIC DUST TRANSFER BY MEANS OF QUASISTATIC AND NON-QUASISTATIC MODELS

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Summary: *Kinematics of the anthropogenic dust propagation emitted into the atmosphere by big cities and separate sources using numerical integration of the system of three-dimensional non-linear quasistatic and non-static equations of atmosphere hydrothermodinamics and equation of dust transfer-diffusion in the atmosphere are studied. It is obtained through modeling that kinematics of a dust propagation obtained by quazistatic and non-static equations have both common and different features. In case of beta- mesoscale diffusion, which is described by means of quazistatic equations, advective diffusion plays the key role in the dust transfer process of. In case of gamma-mesoscale diffusion, which is described by means of non-static equations, the major role in the process of dust transfer, is played by convective diffusion.*

Key words: *Dust, Tbilisi atmosphere pollution, numerical modelling.*

Introduction

Modeling of atmospheric air anthropogenic polluton in big towns and industrial centers, study of peculiarities of its spatial and time distribution is one of the topical problems related to human health and environment protection. Polluting sources are numerous, and their origination sources (www.eea.europa.eu/themes/air/air-pollution-sources), transformation kinematics and propagation dynamics [1] are diverse. Respectively, the mathematical models describing wide range of the problem from local one to global-scale processes are multifarious. One of the research directions is a propagation of polluting ingredients from separate sources at the territories of local scale and beta-mesoscale areas. Mathematical systems describing local propagation of ingredients use semi-empirical methods, stationary or non-stationary Gaussian models or rest on numerical integration of Navier-Stocks's nonstationary nonlinear non-static equations on the high-definition numerical grid.

Empirical system of atmosphere pollution assessment became widely used in Georgia and post-Soviet countries [2]. It is used for assessment of environment pollution extreme level, maximum permissible exhausts and common pattern of contamination and doesn't reflect the local features of pollutions caused by separate sources.

The goal of the presented work is to investigate a process of dust diffusion by the non-static (on a grid with very high-definition 10-20m ability) and quasi-static (on a grid with high-definition 800m ability) equations of the atmosphere hydrothermodynamics and equation of transfer-diffusion of substances.

Research methods and ways of solution

Experiment 1. Tbilisi dust propagation in the atmosphere is simulated by means of regional model of meteorological fields evolution and polluting substances propagation. Pollution source is presented by dust available in Tbilisi, and major source of its origination is motor transport operation. Maximum value of dust content in the atmosphere sometimes 2 or more times exceeds the corresponding maximum permissible concentration (MPC = 0,5 mg/m^3) (nea.gov.ge/ge/service/garemos-dabindzureba/7/biulete). Modeling is conducted at the territory of 94x72 sq.km area, in the centre of which Tbilisi is located. Taking into account geometrical dimensions of the territory, a complete system of equations of atmosphere thermodynamics in quasistatic approximation is used. Horizontal step is 800, and vertical step is 300 m. Meteorological conditions are in compliance with a light eastern wind, when background wind velocity is changed from 1 (at 2 m height) to 15 m/sec (during tropopause).

In Fig. 1 there are shown dust concentration and wind velocity fields against the background of Tbilisi region terrain at 2 and 100 m height from ground surface, when t = 0 h. Concentration value is given in units of maximum MPC.

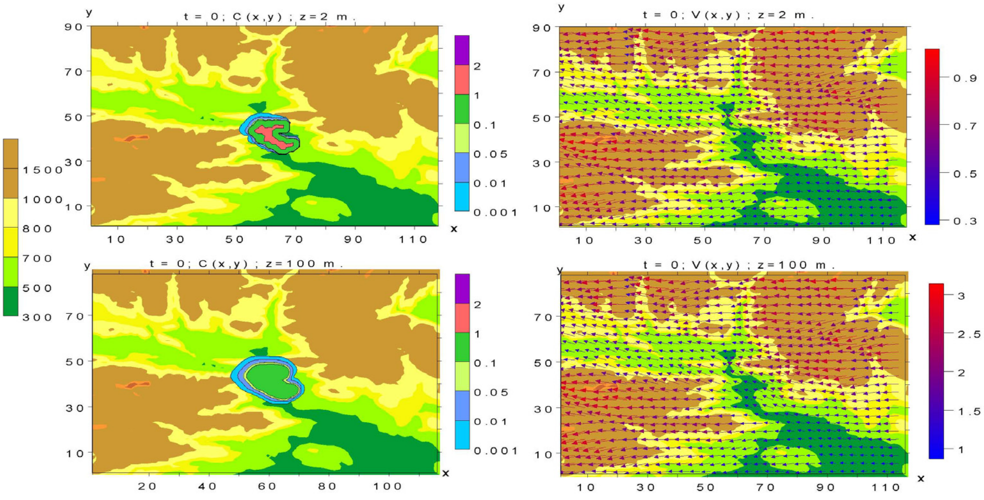

Fig. 1. Distribution of region terrain height, dust concentration isolines and wind velocity vector at 2 and 100 m heights from the Earth surface, when t = 0 h.

As is seen from Fig. 1, at 2 m height maximum dust concentration 1-2 MPC is obtained in urbanistic part of the city. Dust concentration around this part rapidly decreases and in the eastern, western and southern parts within 2-3 km band drops down to 0,001 MPC. In the north-west part of the city under the influence of weak south-east air flow formed along the Mtkvari River valley dust pollution propagation takes place approximately in 1-2 km band. In this part concentration is getting smaller from 0,1 MPC to 0,001 MPC. The similar distribution of concentration is obtained at 100 m height from earth surface. This difference is quantitative. Dust concentration above the urbanistic part of the city varies within 0,1-1 MPC.

It is obtained by modeling, that local wind velocity and at the same time dust advective transfer increases by t = 12 h both in surface layer of atmosphere and in the boundary layer of atmosphere. Dust is preferentially distributed in north-west direction throughout Kartli plain located along Mtkvari River. Dust pollution cloud is of ellipsoid-shaped form. At 2 m height Tbilisi dust is distributed approximately over 10 km distance, at 100 m height – 12-14 km and more than 30 km distance – at 600 m height. Obtained dust concentration distribution shows that in the surface layer of the atmosphere the vertical turbulent dust diffusion prevails, while above 100 m height horizontal advective dust transfer increases along with increase of altitude.

Local circulation in the boundary layer caused by daily thermal regime predetermines change in wind velocity vertical distribution. Convective ascension of warm air masses originated in the vicinity of Tbilisi takes place in evening and night hours. It is substituted by the air cooled in night hours at surrounding mountain slopes. Formed mountain-plain circulation, along with the terrain form existing in the vicinity of Tbilisi, originates north-west wind in the lower 200 m atmospheric layer. As a result of described thermodynamic process the dust propagation direction is changed and in the 200 m thick surface area it is transferred in south-east direction throughout plain territory located along Mtkvari River valley (Fig. 3). At higher altitudes the terrain impact on local circulation gradually reduces and in 600-150 m high layer a dust is transferred westward in the form of narrow 16 km width band.

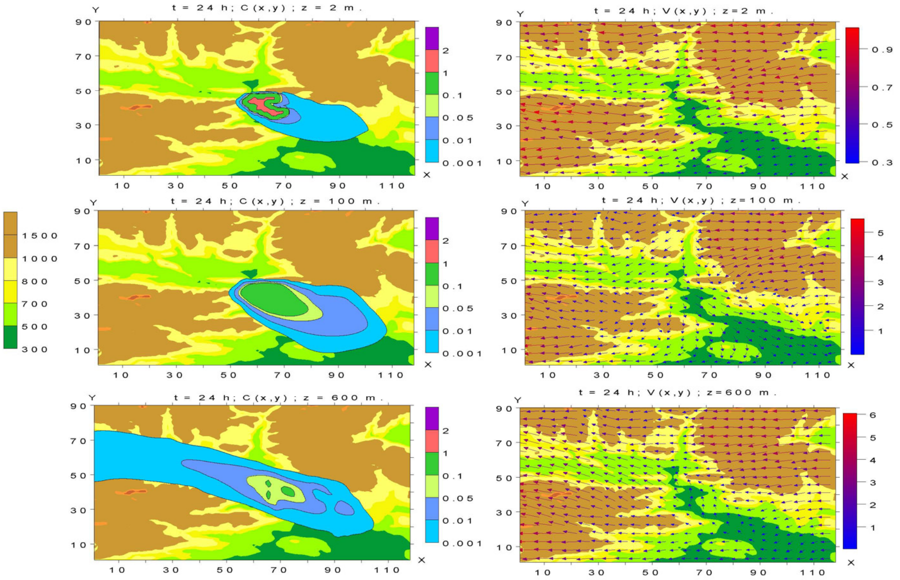

Fig. 2. Distribution of region terrain height, dust concentration isolines and wind velocity vector at 2, 100 and 600 m height from the Earth surface, when t = 24 h

For the next 24 hours dust diffusion process is repeated on a quasiperiodic basic, during which dust transfer direction in the surface layers of the atmosphere is changed from south-east to north-west one. Dust transfer in the upper part of the surface layer occurs in the direction of background wind – i.e. westward.

Experiment 2. The process of local diffusion (gamma-mesoscale diffusion process) of dust emitted into the atmosphere from two basic sources located at 22 and 42m heights is investigated. For numerical modeling the system of non-static full equations of atmospheric hydrothermodinamics is used [3]. The domain of modeling is 800m x 800m. In the center of domain two sources of pollution are located at 22 and 402m heights.

Spatial distribution of dust concentration obtained through calculations during background calm air, when thermal convection is the main mechanism of dust propagationis is shown in Fig. 3 and 4. It is seen from this figure that after emission from gas-cleaning systems a dust is propagated in the atmosphere in the form of two vertical cylindrical streams independent from each other.

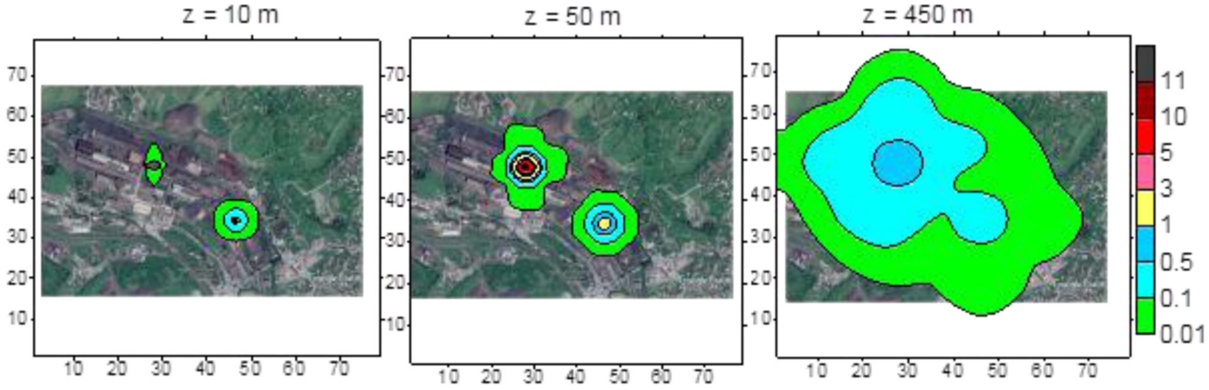

Fig. 3. Dust concentration isolines in the atmosphere during calm air at 10, 50 and 450 m altitudes

The basic dust mass (with concentration >0.1MPC) is distributed in the narrow area, which is getting wider and unites (gets together) approx. at 200-350 m height. Cylindrical column spread angle varies within the limits of 5-45°. At the higher levels a dust pollution cloud is of “mushroom”-like shape that is caused by origination of vertical vortex in the process of convection.

Concentration > 3 MPC is obtained directly above the emission site in a 100-meter column. Concentration value 0.01-0.1 MPC is obtained at the significant territory of modeling area, at 10, 50m heights from the Earth surface and higher. We got low dust concentration 0.5-0.01 MPC close to the Earth surface, within 10 meters, around the waste treatment facilities of the source. 1. In the vicinity of relatively higher waste treatment facilities of the source No. 2 dust concentration 0.1-0.01 MPC is obtained at substantially smaller area.

Spatial pattern of concentrations obtained through calculations is formed by velocity distribution peculiar for thermal convection (Fig.4).

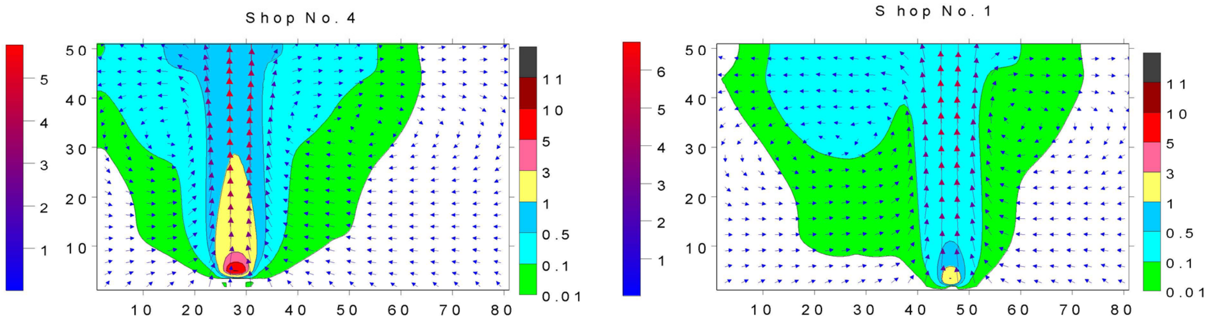

Fig. 4. Dust concentration isolines and wind velocity vector projections in XOZ planes passing through treatment facilities

It is seen from the figures that the emitted warm gas and dust mass cause development of thermal convection. Formation of a powerful vertical stream is peculiar for them. Clearly defined convergent zone is formed in the 350m thick stream layer, and intensification of vertical motion and dust transfer to the upper layer take place. Above 350m air convergent stream gradually turns into divergent one, vertical velocity is getting smaller, wind is increased in horizontal direction and dust horizontal diffusion process is getting more intense. In the middle part of the modeling horizontal and vertical vortexes of wind velocity are formed, the unity of which creates a complex pattern of spatial annular stream. The maximum value of wind velocity 6 m/s is obtained in the convectional vertical stream.

Motion kinematics shows that dust propagation in the central part of the modeling area occurs resulting from convective, advective, vortex processes and turbulent diffusion. The contribution of convective transfer and vertical turbulent diffusion in the vertical plane is roughly the same. In the horizontal plane a vortex turbulent diffusion prevails compared to an advective transfer.

Gas emitted from waste treatment facilities changes atmosphere temperature in the vertical cylindrical area located near to the source (Fig. 4). Temperature change is minimal close to the earth and maximal in the vicinity of aeration lanterns. Warm air column penetrates through the space up to its upper limit. At the 450m height the maximum value of ambient temperature perturbation reaches 5°C.

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