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NUMERICAL MODELING OF KUTAISI CITY ATMOSPHERIC AIR POLLUTION WITH PM2.5 PARTICLES IN WINTER DURING CALM

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Abstract. *Propagation of PM2,5 particles discharged by the motor transport in Kutaisi city air in winter under background calm meteorological conditions has been numerically simulated through combined integration of 3D model of meso-scale atmospheric processes in Caucasus and equation of atmospheric propagation of passive polluting admixtures. It has been shown that ground-level concentrations reach high figures twice a day – at 7-9 h in the morning (7-9AM) and 20-21 h in the evening (8-9PM). It has been obtained that the process of aerosol propagation depends on orography of dynamic fields, territory and thermal regime of underlying surface.*

Key words. *PM2.5, atmospheric pollution, numerical modeling, concentration, calm.*

Introduction

Numerical modeling of atmospheric propagation of PM2.5 particles is of great relevance nowadays for industrial centers, megapolices and separate small cities, where their air concentration frequently exceeds maximum permissible levels [1-3]. According to observation point data [air.nea.gov.ge] Kutaisi is not ranked among heavily polluted cities of the world [4], however, in separate cases air concentration of PM2.5 particles surpasses maximum permissible values [5]. Patterns of propagation and time change of PM2.5 particles discharged in the atmosphere of Kutaisi and its adjacent territories due to motor transport traffic have been simulated and analyzed in the presented article by means of computer modeling of atmospheric propagation of admixtures.

Research method

Propagation of PM2,5 particles discharged by the motor transport in the atmosphere of Kutaisi city has been numerically simulated through combined integration of 3D model of meso-scale atmospheric processes development in Caucasus and equation of atmospheric propagation of passive polluting admixtures [6, 7].

Numerical modeling results

PM2.5 aerosol propagation has been modeled in the spatial domain with an area of $13.4 \times 13.4 \times 9$ km^3, with Kutaisi in its center. Orography height in the modeling area varies from 80 to 400 m. Numerical integration of equations of mathematical model [8, 9] has been made using respective initial and boundary conditions. Numerical grid steps in horizontal direction are 200 m, and in vertical direction of free atmosphere – 300 m. Vertical steps in the 100 m thick surface layer of the atmosphere vary from 0.3 to 15 m. The time step is 1 sec. Calculations have been made for a 3-day period. A case of Kutaisi atmospheric pollution with PM2.5 has been modeled in December. At 100 m height of the atmosphere surface layer a situation of calm – background wind with velocity 0 m/sec takes place. There is a western wind above the surface layer, its velocity linearly increases with height and reaches 20 m/sec at 9 km height. Relative humidity of the atmosphere is 50%.

It has been assumed that the atmosphere is polluted with PM2.5 as a result of motor transport traffic in Kutaisi and its adjacent territory. Aerosol is discharged from the earth ground to 0.3 m height in areas of 5 types: at highways, central streets of the city, residential, industrial zones and unpopulated territories of adjacent villages. Emission rate is different depending on the area, is periodical with 24-hour period and proportional to motor transport traffic intensity. It is minimal within the 0-4 h time interval, then linearly increases from 4 to 10h, and is constant within the time interval from 10 to 18 h. From 18 to 24 h, emission rate linearly decreases and becomes equal to that existing at 0h.

Fig. 1 shows fields of wind velocity and PM2.5 during concentration increase at 2, 100 and 600 m heights from the Earth surface obtained via modeling. It is seen from this Figure that during background calm the effect of Kutaisi terrain forms local cyclonic vortex of wind velocity. This vortex is quasi-stationary. Its center is located in the north-east part of Kutaisi at the territories of administrative units of City-Museum, Ukimerioni and Dzelkviani having complex terrain.

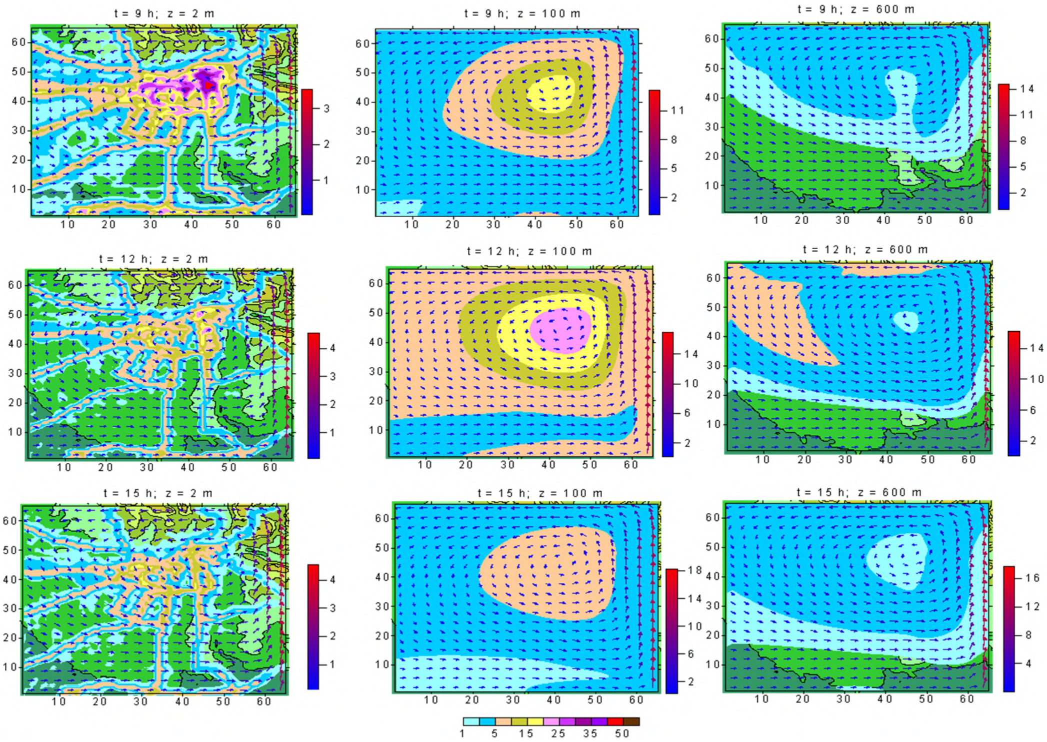

Fig. 1. Distribution of PM2.5 concentration ($\mu g/m^3$) and wind velocity (m/s) fields at 2, 100 and 600 m height from the earth surface, when t = 9, 12 and 15 h

Fig. 2 shows vertical distribution of PM2.5 concentration in the surface layer of the atmosphere obtained via modeling, in the zonal section passing the central part of the city. It is seen from Fig. 2, that atmospheric propagation of PM2,5 particles occurs at the expense of turbulent diffusion and advective and convective processes. The role of these processes is of different importance at different points of time. By 9 h in the morning (9AM) the effect of a convective process on aerosol propagation in the central part of vertical section is more substantial, while at 12 and 18 h (6PM) turbulent and advective processes play active role in aerosol propagation in the lower 40-50 m thick band of surface layer of the atmosphere.

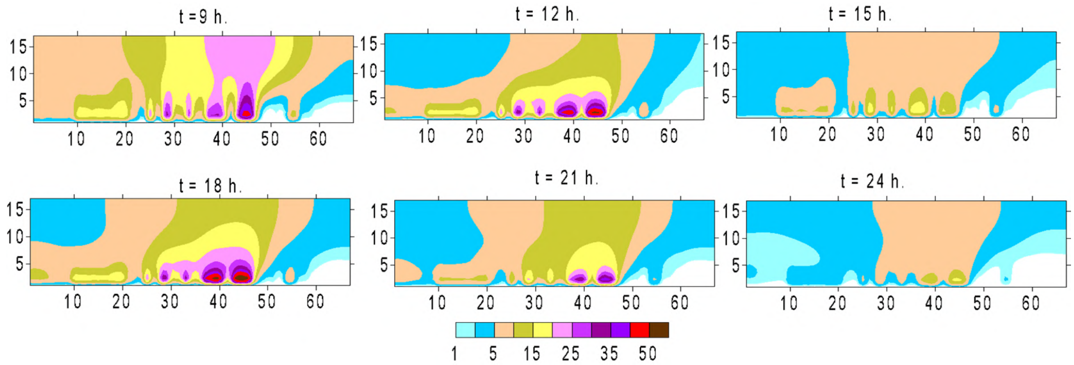

Fig. 2. Distribution of PM2.5 concentrations ($\mu g/m^3$) in surface layer of the atmosphere in the vertical section along a parallel passing the city center

Conclusions

Peculiarities of spatial distribution and time change of PM2,5 particles generated by the motor transport at the territory of Kutaisi has been investigated via numerical modeling in winter season during ground-level calm and background western wind in the free atmosphere. It has been obtained via calculations that in the winter season, interaction of meso-scale regional terrain with background western wind forms a cyclonic vortex of wind velocity. Formed dynamic and thermobaric fields have an effect on spatial distribution of aerosols discharged into the atmosphere due to motor transport traffic. Resulting from modeling, patterns of spatial distribution of PM2.5 concentration have been obtained, time behavior of concentration has been established both in surface and boundary layers of the atmosphere. It has been shown that vertical distribution and time change of concentration depend on both aerosol emission rate and motor transport traffic intensity, and on kinematics of surface layer of the atmosphere and local circulation systems formed due to diurnal variation of thermal regime at underlying surface. High and average pollution levels at the territory of the city and its surrounding and change in their location during a day have been determined.

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