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# Numerical Modelling of Dust Propagation in the Atmosphere of Tbilisi City: The Case of Background Eastern Gentle Breeze

**[1]Vepkhia G. Kukhalashvili, [2]George I. Kordzakhia,[2]Natia G. Gigauri , [1,2]Aleksandre A. Surmava, [2]Liana N. Intskirveli**

*[1]M. Nodia Institute of Geophysics at the Iv. Javakhishvili Tbilisi State University,*
*1, M. Aleksidze Str., 0160, Tbilisi, Georgia, e-mail:aasurmava@yahoo.com*
*[2]Institute of Hydrometeorology at the Georgian Technical University, 150-a D.Agmashenebeli Ave,*
*0112 Tbilisi, Georgia, E-mail:intskirvelebi2@yahoo.com*

***ABSTRACT***

*Dust propagation at the territory of Tbilisi is studied using the 3D regional model of atmospheric processes evolution and integration of the equation of contaminant transfer-diffusion. The dust pollution process that takes place in case of background eastern gentle breeze is numerically modeled. It is obtained that micro-scale dust propagation substantially depends on the terrain of city and its surrounding territories, on the magnitude and direction of background wind velocity. Dust dispersed in Tbilisi is mainly concentrated in the lower 600 m thick atmospheric boundary layer. At 2 m height over a ground maximum concentration 1.0-1.5 maximum allowable concentration (MAC = 0.5 mg/m$^3$) is formed in the time interval from 12 a.m. to 9 p.m. in the central and southern parts of the city as well as at relatively low-lying territories. Peculiarities of dust vertical distribution and time variation are studied.*

***Keywords:*** *Numerical modeling, pollution source, diffusion, dust propagation, wind.*

**Introduction**.

The research goal is to study via numerical modeling Tbilisi atmopsheric air pollution by dust in case of background eastern gentle wind. Dust propagation at Tbilisi city territory is simulated using the 3D regional model of evolution of atmospheric processes in the Caucasus and integration of the equation of admixtures transfer-diffusion [1, 2]. Motor transport is a source of dust pollution. It is assumed that the quantity of dust dispersed in the atmosphere linearly depends on traffic intensity. The magnitude of background eastern gentle breeze at 100 m height from earth surface (upper boundary of surface layer of atmosphere) equals to 5 m/sec and linearly increases up to 23 m/sec at 9 km altitude above sea level. Time and space variation of meteorological fields that are necessary for modeling are calculated by the numerical model described in [1, 2]. Meteorological situation corresponds to dry weather of June, when relative atmospheric humidity is 50%. Calculations are made along parallel and meridian with 300 and 400 m horizontal steps. Vertical step in the free atmosphere varies in time and equals 300 m in average. In 100 m thick surface layer of the atmosphere a vertical step varies from 2 to 15 m. Tbilisi city having complex terrain is disposed in the center of modeling area.

**Modeling results**

Spatial distribution of dust concentration and wind velocity obtained via calculation at 2, 100 and 600 m height over a ground at t = 0, 3 and 6 h of the first day is shown in Fig. 1. Concentration is given in units of maximum allowable concentration (MAC = 0.5 mg/m$^3$). It is seen from Fig. 1 that at 2 m height from underlying surface the maximum value of dust concentration, 0.5-0.7 MAC is obtained in the south-western part of the city, at low-lying territory of Ponichala in the shape of a narrow and long band, and in the Tbilisi Sea surroundings. At the rest territory a concentration value is within a limit of 0.001-0.3 MPC. The area of maximum pollution extends with height increase. At 100 m height concentration of 0.5-0.7 MPC is formed in three parts of the city. Above the surface layer of atmosphere dust concentration is getting smaller. Its value is within 0.1-0.3 MAC at 600 m height over a ground.

Starting with t = 0 h city air pollution gradually decreases and becomes minimal at 6.00 a.m. At this time a concentration value varies within a range of 0.001-0.3 MAC in the city and its surrounding territories.

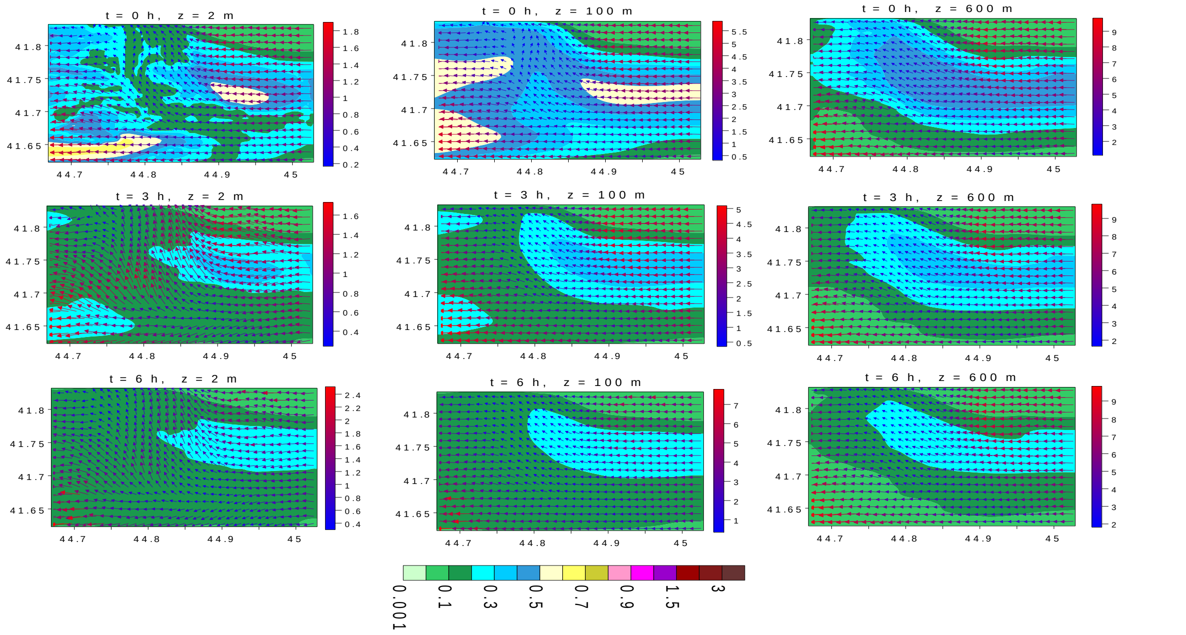


Fig. 1. Wind velocity (m/sec) and dust concentration (MAC) distribution, when t = 0, 3 and 6 h at 2, 100 and 600 m height over a ground

After t = 6.00 h, along with vehicular traffic intensity growth the dust pollution of city atmosphere starts to increase in the vicinity of pollution sources – along the city mains and nearby (Fig. 2). When t = 9 h dust concentration at z = 2 m height is especially high in the mains crossing areas and low-lying territories. Vake, Saburtalo, Gldani, TEMKA and Ortachala are among these districts. Concentration values reach 1 MAC in these areas.

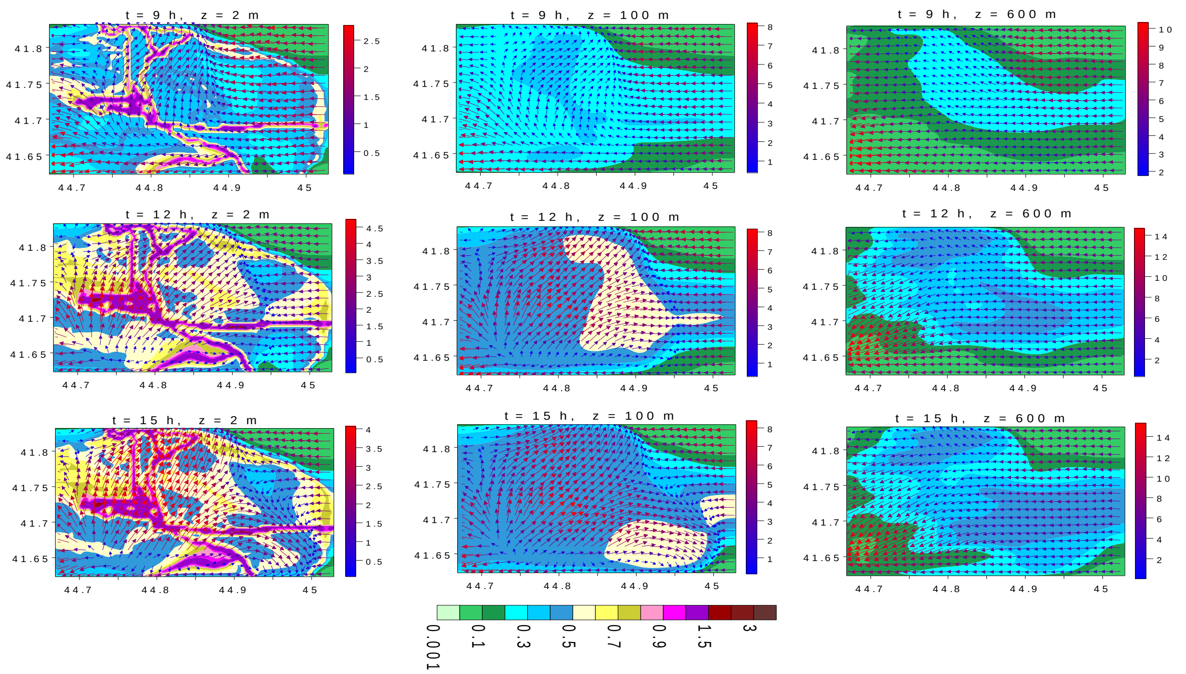


Fig. 2. Wind velocity (m/sec) and dust concentration (MAC) distribution, when t = 9, 12 and 15 h at 2, 100 and 600 m height over a ground

Maximum dust pollution level is obtained in the time period from t =12.00 H to 21.00 h. Heavy pollution zones include the center of city, Vake, Saburtalo and Ortachala. Concentration varies within a limit of 1.0-1.5MAC at these territories. In the urban parts distanced from city mains, dust concentration varies within a range of 0.5-0.7 MAC. As for recreational and unsettled territories, where we have no dust pollution sources, pollution occurs according to the mechanism of advective and diffusive transfer. As a result, a ground level concentration varies from 0.3 to 0.5 MAC.

At t = 9.00 h an intense vertical convective transfer of the dust begins, due to which a dust originated near the ground starts to propagate towards upper layers, and when t = 12.00 h, dust concentration reaches 0.7 MAC at 100 m height.

From t=18.00 to 21.00h there takes place a slight increase of dust concentration and change of size and location of heavily polluted areas at 2 m height. This change is caused by wind velocity daily evolution in the surface layer of atmosphere (Fig. 3). The area of high concentration zone is increased in the center of southern part of the city, at the territories adjacent to Ponichala, and in the vicinity of Rustavi and Marneuli highways. Concentration is decreased in the central and northern parts close to Georgian Military Road and Gldani main.

In the time period from t=15.00 to 21.00h a vertical turbulent and convective diffusion of the dust becomes especially high. As a result, concentration magnitude reaches 0.9-1.2 MAC at 100 m height above the major part of the city. At 600 m height a concentration reaches 0.6 MAC. After t = 21.00 h a sharp decrease of concentration takes place. When t = 24.00 h, a spatial distribution of concentration is similar to distribution obtained early in the day.

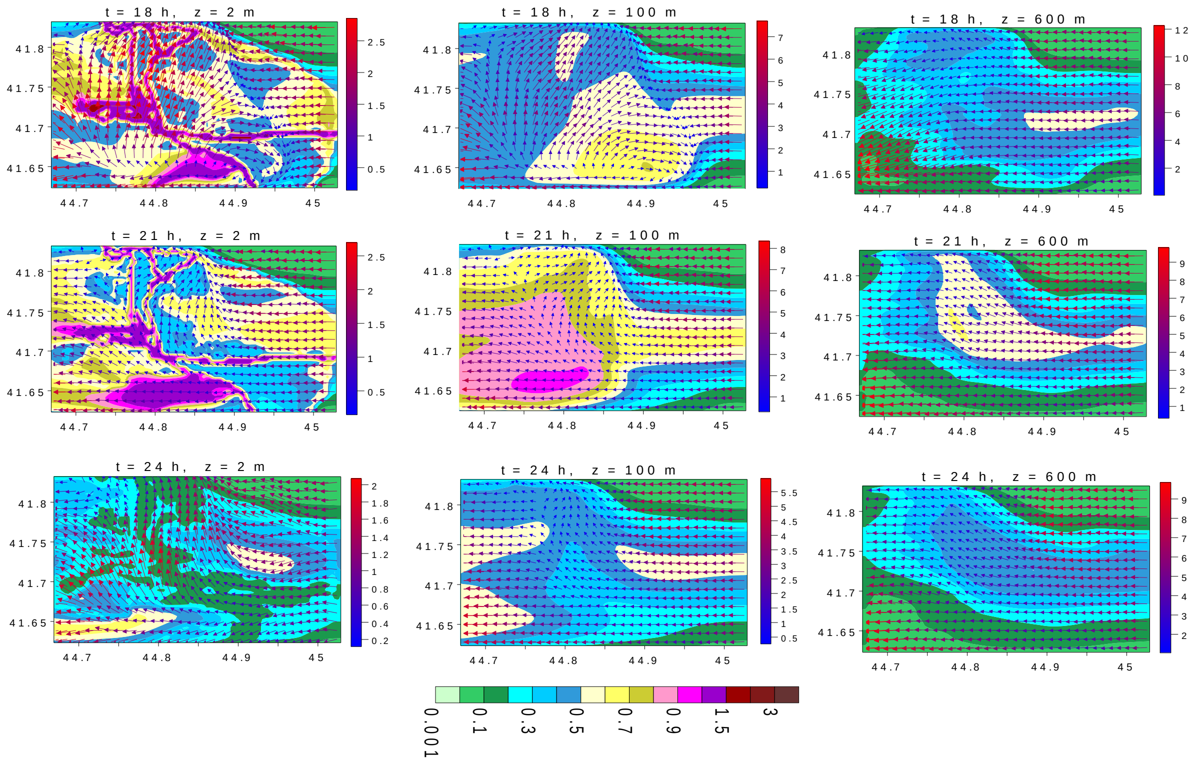


Fig. 3. Wind velocity (m/sec) and dust concentration (MAC) distribution, when t = 18, 21 and 24 h at 2, 100 and 600 m height over a ground

In Fig. 4 there is shown a vertical distribution of dust concentration in three vertical sections drawn along the parallel in the surface layer of atmosphere, latitudes of which are 41.69$^{O}$ N, 41.72$^{O}$ N, 41.77$^{O}$ N. It is seen from the Figure that the vertical distribution of concentration varies during a day in all three sections. From t = 0.00 to 6.00 h a dust concentration reduction takes place in the ground-level layer. This decrease is caused by termination of dust pollution process and dust transfer from modeling area to the outside.

The process of dust vertical diffusion that is caused by diurnal convective motion of heated air existing near a ground, becomes intense. Air flow catches dust particles. Transfer occurs by means of separate convective cells having different sizes and shape due to orography. As a consequence we have a situation, during which the dust concentration transferred to the upper 50 m area of surface layer of atmosphere exceeds the dust concentration remained in the lower 50 m area.

From t=6.00 to 12.00 h, the quantity of dispersed dust increases along with vehicular traffic intensification and, respectively, atmosphere pollution in the lower part of the surface layer nearby traffic arteries is getting higher.

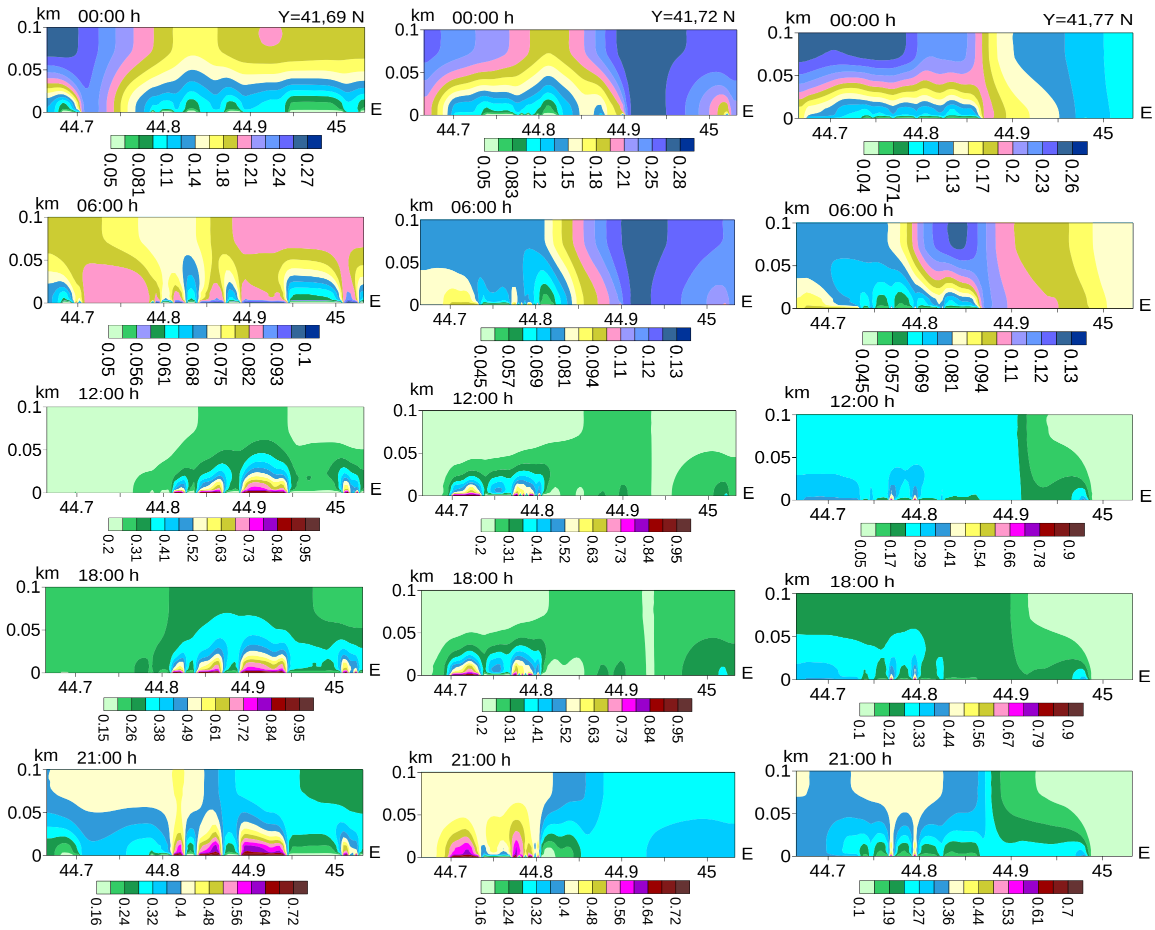


Fig. 4. Dust concentration vertical distribution (MPC) in three vertical sections (41.69$^{O}$ N, 41.72$^{O}$ N, 41.77$^{O}$ N) drawn along the parallel in the surface layer of atmosphere

By t = 12 h a dust cloud similar to a ground-level wide thermal is formed in the lower part of atmospheric boundary layer, in some areas of the city. This cloud gradually increases in size and creates high concentration areas. From this period the concentration in 50 m thick lower layer of the atmosphere exceeds the concentration existing in upper 50 m layer. The areas maximally polluted according both geometrical dimension and concentration, create in t =18.00-21.00 h time interval. After t = 21.00 h, due to vertical advective and diffusive transfer, dust concentration starts to decrease nearby earth surface and to increase in its upper part.

**Conclusion**

The kinematics of dust change created by motor transport at Tbilisi territory and daily pattern of its spatial distribution are studied in case of background eastern gentle breeze. Via analysis of wind velocity and concentration fields it is obtained that spatial distribution of heavily polluted areas depends on city mains disposition, and local circulation systems formed under dynamic impact of terrain and diurnal change of thermal regime on the underlying surface. Maximum concentration 1.0-1.5 MAC is formed in t = 12.00-

21.00 h time interval in the central, southern and relatively low-lying territories of the city. At 600 m height from earth surface a maximum value of concentration reaches 0.7 MAC, when t = 21.00 h.

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**References**

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## ქ.თბილისის ატმოსფეროში მტვრის გავრცელების რიცხვითი მოდელირება: აღმოსავლეთის ფონური საშუალო სიქარის ქარის შემთხვევა

ვ. კუხალაშვილი, გ. კორძახია, ნ. გიგაური, ა. სურმავა, ლ. ინწკირველი

### რეზიუმე

ატმოსფერული პროცესების ევოლუციის 3D რეგიონალური მოდელისა და მინარევების გადატანა-დიფუზიის განტოლების ერთობლივი ინტეგრირებით შესწავლილია მტვრის გავრცელება ქ.თბილისის ტერიტორიაზე. რიცხვობრივად მოდელირდება დამტვერიანების პროცესი, რომელიც მიმდინარეობს ფონური აღმოსავლეთის საშუალო სიჩქარის ქარის დროს. მიღებულია, რომ მტვრის მიკრომასშტაბური გავრცელება მნიშვნელოვნად არის დამოკიდებული ქალაქისა და მიმდებარე ტერიტორიის რელიეფზე, ფონური ქარის სიჩქარის სიდიდეზე და მიმართულებაზე. ქ.თბილისში გაფრქვეული მტვერი ძირითადად კონცენტრირებულია ატმოსფეროს სასაზღვრო ფენის ქვედა 600 მ ფენაში. მიწის ზედაპირიდან 2 მ სიმაღლეზე მაქსიმალური კონცენტრაცია 1.0-1.5 ზდკ ფორმირდება 12.00 – 21.00 საათის ინტერვალში ქალაქის ცენტრალურ და სამხრეთ ნაწილებში და შედარებით ჩაღმავებულ ტერიტორიებზე. გამოკვლეულია მტვრის ვერტიკალური განაწილების და დროში ცვლილების თავისებურებები.

## ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ РАСПРОСТРАНЕНИЯ ПЫЛИ В АТМОСФЕРЕ г.ТБИЛИСИ: СЛУЧАЙ ФОНОВОГО ВОСТОЧНОГО СРЕДНЕГО ВЕТРА

**В.Г. Кухалашвили, Г.И. Кордзахиа, А.А. Сурмава, Н.Г. Гигаури, Л.Н. Инцкирвели**

### Резюме

С помощью региональной модели атмосферных процессов на Кавказе и уравнения переноса-диффузии примесей изучено распространение пыли на территории г.Тбилиси. Численно моделируется процесс запыленности воздуха выбросами автотранспорта протекающий при средней скорости восточного фонового ветра. Было получено, что микро масштабное распределение пыли существенно зависит от рельефа города и его окрестностей, а также направления и величины скорости ветра. Пыль, рассеянная в г. Тбилиси, в основном сконцентрировано в нижней, 600-метровой зоне пограничного слоя атмосферы. На высоте 2 метра с поверхности земли концентрация 1.0-1.5 ПДК формируется во второй половине дня от 12.00 до 21.00 часа в центральной и южной частях города. Изучены особенности изменения во времени вертикального распределения пыли в приземном слое атмосферы г. Тбилиси.