THE ANALYSIS OF INFORMATIVE DATA OF GROUND REMOTE SENSING OF URBAN AEROSOL LAYER ON THE CITY OF BAKU

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The statistical structure of the field of aerosol scattered light on the city of Baku is investigated. The database of the day sky brightness measurements for the years period 2002 ÷ 2006 is used.

Introduction

Due to expansion of the cities and industrial centers the problem of working out more elaborate scientific and practical methods of monitoring the city atmosphere aerosol pollution is becoming acute at present. [1-3]. Aerosol pollution in the form of gas admixtures and aerosol particles cloudy layer is a characteristic feature of the city territory micro-climate. The thickness of the layer reaches 3 ÷ 5 km depending on the city territory size and seasonal varieties of the meteorological regime of city air [1, 2].

Certain significance is attached currently to remote optic methods in solution of the city atmosphere aerosol pollution as they based on measuring the characteristics of the radiation slowed down by atmospheric aerosol field [4, 5]. These methods allow to obtain operative and adequate information about the parameters of the aerosol in natural conditions of its existence depending on many factors: influences of a spreading surface, concentration of gas predecessor admixtures, meteorological regime and solar radiation [1, 2].

In the present work the problem of the analysis of informativeness of remote sensing data of urban aerosol layer is solved. For this purpose the actinophotometric measurements database lead in territory of city Baku and its suburb for the year's period of 2002÷2006 is used. The decision of this problem represents practical interest for revealing local heterogeneity of urban aerosol layer, studying of its spatial structure and as rational accommodation of a network of items of optical sensing of urban aerosol.

The method of calculation of the basic characteristics of the field of brightness

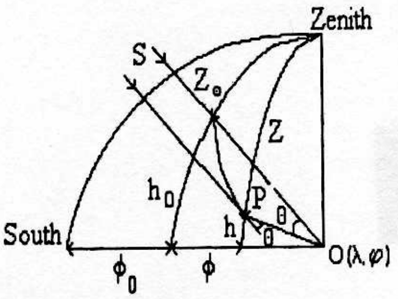

Fig.1. Geometry of scattering light.
O - ground observed point with the geographical coordinates δ and φ, longitude and latitude;
OS - direction to the Sun with the elevation h_0, zenith angle $Z_0 = 90° - h_0$ and azimuth ϕ_0;
OP - directions of the observation with the elevation h, zenith angle Z and azimuth ϕ from solar vertical.

1. Geometry of scattering light. Observable brightness of the sky depends from coordinates of the place and time of observation and also from observation angle. For the description of scattering sunlight in atmosphere we shall use the spherical system of coordinates shown on fig.1. The observation (sighting) angle equal to the scattering angle θ and it is defined from the decision of spherical triangle OPS:

$$\cos\theta = \cos Z_0 \cos Z + \sin Z_0 \sin Z \cos\phi \tag{1}$$

Below as spatial coordinate of observed point on the sky the observation angle θ is used, which is defined by the formula (1).

2. Optical parameters. At the analysis of urban aerosol spatial structure we shall use the following optical parameters: brightness (scattering) function $f_\lambda(\theta)$ with a scattering angle θ and optical thickness $\tau_\lambda = \int f_\lambda(\theta) \sin\vartheta d\theta$ of urban air. The listed characteristics concern to monochromatic radiation in windows of a transparency of the atmosphere at $\lambda =$ 0,55mkm, where scattering of light basically is determined by the aerosol particles. Scattering function $f_\lambda(\theta)$ it is defined from the day sky brightness $B_\lambda(\theta)$ measurements in almucantars of the Sun and from the illumination of direct solar radiation S_λ at optical mass of the atmosphere in a direction of the Sun m_0 [2, 3]:

$$f_\lambda(\theta) = \frac{B_\lambda(\theta)}{S_\lambda m_0}. \tag{2}$$

Optical thickness τ_λ is define from comparison of Bouger curves of atmospheric air on measurements of illumination of direct solar radiation in city S_λ and in its suburb. $S_{b\lambda}$ [2]:

$$\ln S_\lambda - \ln S_{b\lambda} = (\tau_\lambda - \tau_{b\lambda}) m_0. \tag{3}$$

The works formula for determine of brightness of the aerosol layer looks like

$$B_\lambda(\theta) = \frac{n_{di}}{n_{sc}} \frac{A_\lambda}{\pi} \pi S_{0\lambda} p_\lambda^{m_0} \frac{r_0^2}{r^2}, \tag{4}$$

where $B_\lambda\left(\frac{Wt}{sm^2 \cdot sr \cdot mkm}\right)$ is the spectral brightness of the sky (in the further the index λ we shall lower);

n_{di}, n_{sc} is the reports of the device from an observable point of the sky and from the screen accordingly;

A_λ is the spectral albedo the plaster screen;

$\pi S_{0\lambda}$ is the spectral solar constant taken according to work [6];

p_λ is the spectral transparency of an atmosphere;

m_0 is the atmospheric mass in a direction to the Sun;

$\frac{r_0^2}{r^2}$ is the amendment considering seasonal changes of distance of the Earth from the Sun.

3. Statistical characteristics. We consider selective statistical sets of the calculated values of optical parameters τ and $f(\theta)$ depending on the sighting angle θ. We shall designate through $\xi_i^j = \xi_i(\theta j)$ the j-th realization ($j = 1, 2, ..., n$) these parameters in points with sighting angle θ_j ($j = 1, 2, ..., k$). With the purpose of the analysis of spatial statistical structure of sets ξ_i^j we shall define dependence of their two-point moments: covariation $k_f(\theta_i, \theta_j)$. and correlation $r_f(\theta_i, \theta_j)$ functions from directions of observation θ_j.

The primary database, in view of their significant volume, we shall preliminary subject to primary processing [6]. It provides: 1) ordering of database by their division on coordinates of round observed points, coordinates Z and ϕ of observation points on sky sphere and arrangements its in chronological sequence (in our case for separate day and months);

2) rejection of erroneous data which consists in the following; at everyone fixed θ_j are calculated the average arithmetic $\overline{\xi^j}$ and average quadratic deviation σ all data of the random variable ξ. For the control of the defective data the rule 4σ is used:

$$| \xi_i^j - \overline{\xi^j} | \geq 4\sigma^j \tag{5}$$

The statistical number made of realizations ξ has the indicator ω_i^j equal 1 for not defective data and equal 0 when these data are defective. Then the number of observation will be equal

$$n^j = \sum_{i=1}^{n} \omega_i^j . \tag{6}$$

For the characteristic of communication of values ξ their two point statistical moments are calculated:
matrix of covariation with elements

$$k_\xi(\theta^j, \theta^k) = \frac{1}{n_{jk}} \sum_{i=1}^{n} (\xi_i^j - \overline{\xi^{jk}})(\xi_i^k - \overline{\xi^{jk}})\omega_i^{jk}, \tag{7}$$

coefficients of correlations

$$r_\xi\left(\theta^j, \theta^k\right) = \frac{k_\xi\left(\theta^j, \theta^k\right)}{\sigma_j^{jk} \sigma_k^{jk}}, \tag{8}$$

where $\omega_i^{jk} = \omega_i^j \omega_i^k$, and $n_{jk} = \sum_{i-1}^{n} \omega_i^{jk}$ is the represents number of realizations, for which in both points θ_j and θ_k there are data of observations. Thus of value of averages and average quadratic deviations in any two points θ_j and θ_k pay off anew.

Results of calculations

In the beginning we shall consider dependence covariation $k_f(\theta_i, \theta_j)$. and coefficients of correlations $r_f(\theta_i, \theta_j)$ of aerosol scattering function from directions of observation θ_j. On the fig.2 the schedules illustrating this dependence in southern and northern directions from solar vertical are resulted. At construction of the specified schedules data received in suburb of Baku are used.

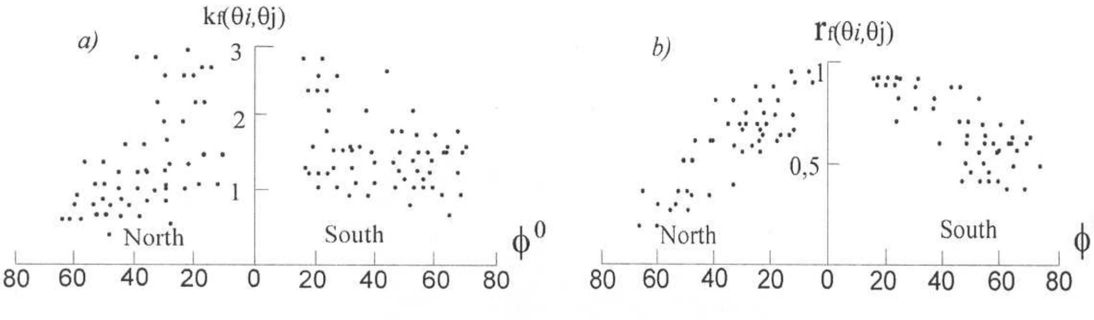

Fig. 2. Azimuthally dependence of the moments of aerosol scattering function from solar vertical: *a*- covariation $k_f(\theta_i, \theta_j)$; *b*-coefficients of correlations $r_f(\theta_i, \theta_j)$ (λ =0,55mkm, July÷August, 2006, forenoon, Mushvigabad is the suburb of Baku).

The range of scattering angle on fig. 2 corresponds to area of the heavenly sphere completely covering area of the arrangement of the aerosol layer.

From comparison of figures 2*a* and 2*b* follows, that the disorder of points of values is most strongly shown for covariation Practically dependence $k_f(\theta_i, \theta_j)$ from distance it is not shown. At the same time, on fig. 2*b* such dependence for $r_f(\theta_i, \theta_j)$ it is clearly visible.

On fig. 3 the average vertical correlation relations of optical parameters: optical thickness and scattering function of urban atmosphere on measurements of brightness of the cloudless sky during the 2006÷2006 years period in territory of city Baku and its suburb are presented. On fig. 3*a* autocorrelation relations of optical thickness depending on height h_o of the Sun above horizon are given. Such consideration speaks that background conditions of aerosol turbidity of a city atmosphere raises from horizon to zenith [2]. Apparently from fig. 3*a* the range of values of height h_0 where are observed close between levels correlation relations of optical thickness of a city atmosphere is allocated. To define stability of this law on height on fig. 3б the azimuthally cut of between levels correlations of scattering function $r_f(h_{oi}, h_{oj})$ is given.

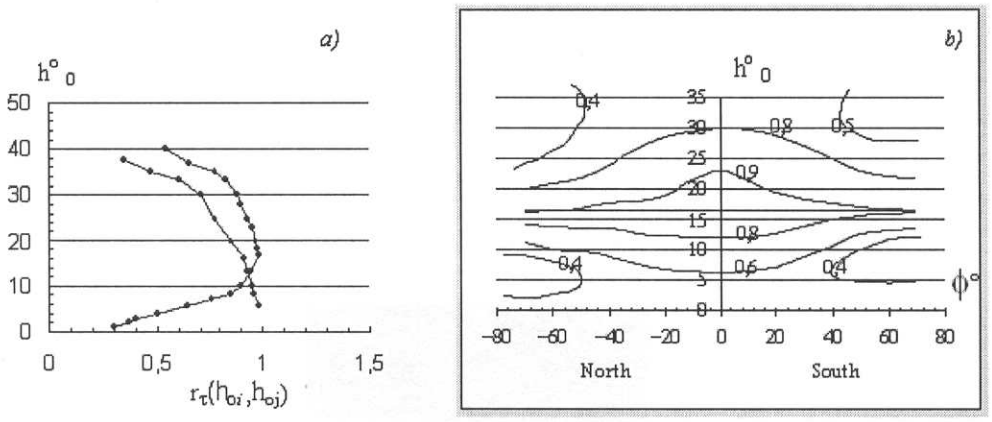

Fig. 3. Between levels correlation relations of urban aerosol: *a* - optical thickness $r_\tau(h_{oi,}h_{oj})$, (b) -scattering functions $r_f(h_{oi,}\ h_{oj})$ (λ=0,55mkm,August-July 2002 ÷ 2006, Baku).

From the analysis of this cut it is visible, that vertical correlation relations $r_f(h_{oi,}\ h_{o\ j})$ fade slowly enough in a powerful layer of air (with coefficients of correlation $r_f(h_{oi,}\ h_{oj})\geq 0,5$).

The choice of informative points of observation

As is known, the informativeness network of points of observation is characterized by the accuracy of interpolation from points of observation into some other points [6]. For an estimation of this accuracy we use a measure of the error ε of optimum interpolation in the center of the piece ρ according to on its ends, assuming that uniformity and isotropy in relation to correlation function takes place. As this condition in the atmosphere is carried out only across as angular distance between points of observation we use a difference of their azimuths both $\rho = \theta_k - \theta_j$ at various levels from a terrestrial surface in horizontal directions. In this case the measure of the error of interpolation is defined by the formula (8)

$$\varepsilon = 1 - \frac{2r^2_\xi(\frac{\rho}{2})}{1+\eta^2+r_\xi(\rho)}, \qquad (9)$$

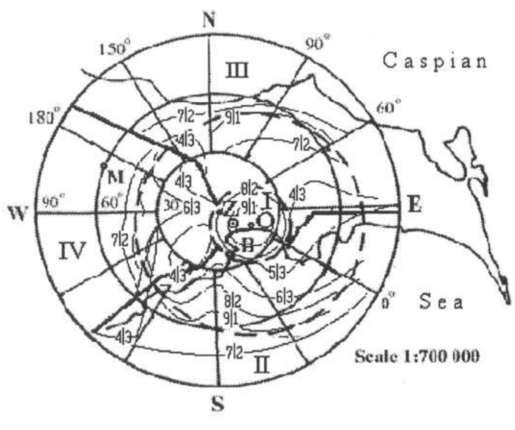

Fig. 4. Distribution $r_f(\theta_{i,}\theta_j)\cdot 10$ (the first figure), $\varepsilon\cdot 10$ (the second figure), ρ_m (the continuous allocated line) for aerosol scattering function (the years period, of Baku). Dotted line is shown area of an arrangement of the aerosol layer of pollution [2].

Let's define the maximal admissible distance ρ_m between informative points of observation on heavenly sphere proceeding from a condition $\varepsilon \geq \eta$ i.e. on the basis of the requirement that accuracy of interpolation was not worse than accuracy of measurements. On fig.4 the graphic decision of the equation (8) rather ρ_m is shown. On this figure are shown izoline measures accuracy to interpolation and identical correlations scattering function the cloudless sky on territory of Baku. For this purpose selective data calculated on distribution isophots (lines of identical brightness) in various almucantars and verticals of the Sun by a method developed in [2,3] are used.

Analysis fig. 4 shows, that four areas of local uniformity and spatial correlation functions of the field of urban aerosol are allocated. These areas on fig.4 are allocated by a continuous line. The central area I, as it has been shown in [2], is at a level of height h=2 km and do not find out influence of a terrestrial surface. This area differs the highest close correlation dependence and practically is statistically homogeneous and isotropic environment. From three extreme areas of an aerosol layer the area II, reaching to the south above coastal waters of Caspian sea, has closer correlation relations of variations, the area IV, being to the west least statistically is homogeneous, and the area III, located to the north, borrows on statistical uniformity intermediate position. Presence of above mention areas is defined by climatic conditions of Absheron.

The basic results

1. The method of calculation of correlation relations of optical parameters of urban aerosol is resulted. Data of measurements of brightness of the cloudless sky in almucantars the Sun in territory and suburb of Baku are used.
2. It is analyzed informative points of observation of the aerosol layer on the basis of comparison of a measure of error of optimum interpolation and accuracy of observation. Four areas of local uniformity of city air are allocated for territories of Baku, defined climatic conditions of Absheron. The first central area differs high local uniformity. Three others test the strong variations connected with influence of the spreading surface: the coastal water surface of Caspian Sea and land. Influence dry in the western direction the strongest.

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BAKI ŞƏHƏRİ ÜZƏRİNDƏ HAVANIN AEROZOL ÇİRKLƏNMƏ QATININ MƏSAFƏDƏN TƏDQİQİ MƏLUMATLARININ ANALİZİ

Bakı şəhəri üzərində işığın aerozol səpilmə sahəsinin statistik quruluşu tədqiq edilir. 2002-2006 illərdə yay dövründə gündüz işığının parlaqlığının ölçülməsinə dair məlumatlar massivi istifadə edilir.

Ф.И. Исмаилов

АНАЛИЗ ИНФОРМАТИВНОСТИ ДАННЫХ НАЗЕМНОГО ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ АЭРОЗОЛЬНОГО СЛОЯ ЗАГРЯЗНЕНИЯ ВОЗДУХА НАД ГОРОДОМ БАКУ

Исследуется статистическая структура поля аэрозольного рассеяния света над городом Баку. Используется массив данных измерений яркости дневного света за летние периоды 2002÷2006гг.

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