On the Rational Placing of Land Remote Sensing Network of Urban Air Baku

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***Abstract*— The methodical basis of rational planning of the ground remote sensing network of urban air Baku is considered in this article. The basic criterion is the accuracy of interpolation from points of remote sensing into some other points.**

***Keywords*— remote sensing; optimal interpolation; network; informativity; urban air**

I. INTRODUCTION

At present, in the face of rapid urban growth much attention is paid to remote research methods of ecological state of urban air. Remote sensing methods can correctly solve the problem of rational placement of remote sensing network of the ecological observations. These methods allow to obtain prompt and adequate data on environmental conditions of the air throughout the extended area of the city [1, 2].

In this paper we consider the quantitative approach of choice of the land remote sensing network of urban air. To solve this problem we used multi-year actinometrical data collected in the city of Baku and its suburbs. These data refer to the time of increased urban air pollution during the July - August months.

II. METHODS OF SOLUTION

The rational placing of points of remote optical sensing in the territory of city satisfies the following requirements:

1. Network of optical observations has the lowest density
2. The observation network makes it possible to restore the optical thickness of air layer over the entire urban area, not only in areas where there are points of observation. These requirements are considered by us in a statistical aspect, based on the method developed in meteorology [3].

Let it be required to restore the value of the optical thickness $\tau(t_0)$ of urban air at any point t_0 in terms of its values $\tau(t_i)$, experimentally determined at the points t_i. Let the interpolation is performed according to the formula

$$\tau(t_0) = \sum_{i=1}^{n} a_i \tau(t_i), \qquad (1)$$

where a_i is the coefficients or weighting factors satisfying the following conditions:

$$\sum_{i=1}^{n} a_i = 1. \qquad (2)$$

We consider the region of space where the field values of τ_i can be considered homogeneous and isotropic. Then the interpolation accuracy (1) can be determined by the measure of approximation error ε of values of τ. This error can be defined by specifying the correlation function of values of τ:

$$\mu(t) = \frac{\mu^*(t)}{1+\eta^2}. \qquad (3)$$

Here with the decrease of period of time t correlation function is function tends to the value

$$\mu^*(0) = \frac{1}{1+\eta^2}, \qquad (4)$$

where η is the measure of the measurement errors.

We will distinguish the cases of the linear and optimal approximation of the value of τ [3,4].

Accordingly, the accuracy of the approximation can be written as in the case of:

1) linear interpolation

$$\varepsilon_l = \sum_i \sum_j a_i a_j \mu_{ij} + \sum_i a_i^2 \eta_i^2 - 2\sum_{i=1} l_i \mu_{0i} + 1; \qquad (5)$$

2) optimal interpolation

$$\sum_{j=1} a_j \mu_{ij} + a_i \eta_i^2 = \mu_{0i},$$

$$\varepsilon^2 = 1 - \sum_{i=0}^{n} a_i \mu_{0i} \qquad . \quad (6)$$

In order to meet the requirements of rational placing of remote sensing network the magnitude of interpolation error will be determined from the condition:

$$\varepsilon_m \sim \eta, \qquad (7)$$

where ε_m is the maximum admissible value of interpretation error.

Using the condition (7) allows for the calculated values of the interpolation error to determine the maximum allowable distances l_m between points of observation.

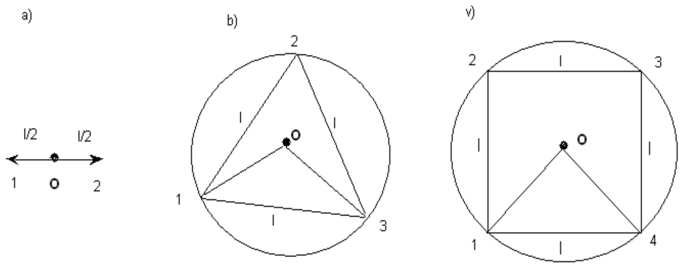


Figure 1.Options of multipoint interpolation: a) - along a straight line, b) - at the center of the the equilateral triangle, v)-at the center of the square.

Calculations of the values l_m correspond to the estimation of requirements for the density of the network of observations. We start from the multipoint interpolation accuracy for the cases shown in Figure 1.The corresponding formulas for interpolation errors are defined in table 1.

TABLE 1. THE FORMULAS OF THE INTERPOLATION ERRORS.

№	Correlation functions	$\mu(0)$	α
1. Western direction	$\mu(t) = \mu(0)\cdot(1-\alpha t)\cdot\exp(-\alpha t)$	0,75	0,25
2. Southern direction	$\mu(t) = \mu(0)\cdot(1-\alpha t)$	0,75	0,17
3. Northern and eastern directions	$\mu(t) = \mu(0)\cdot\exp(-\alpha t)$	0,75	0,18

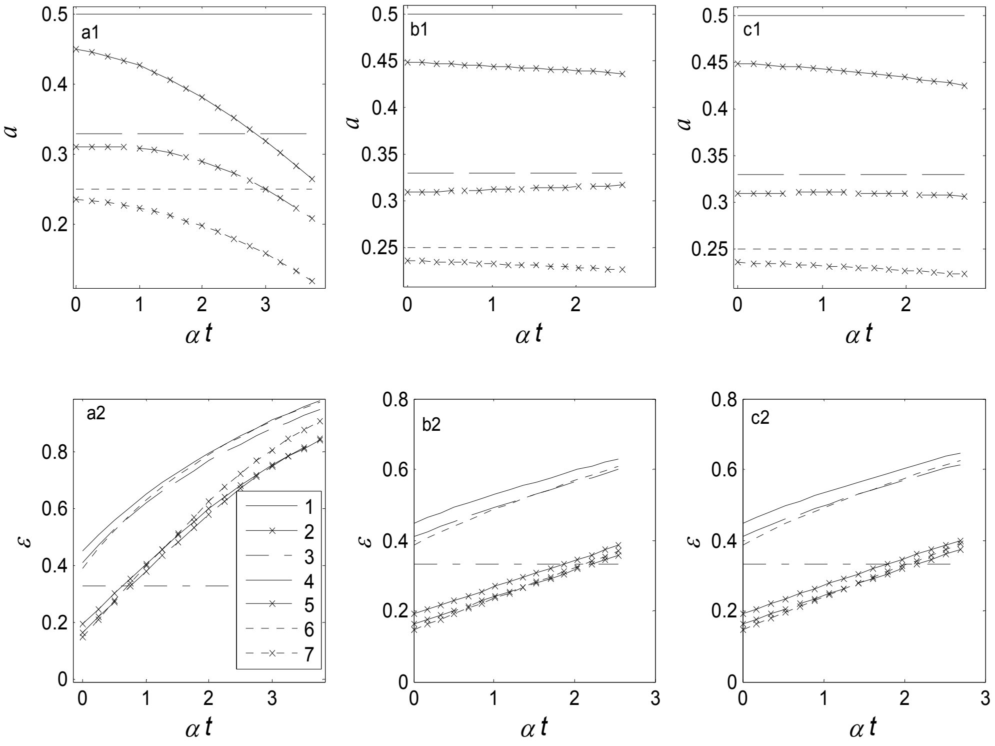
In accordance with the results of our work [2, 5] to calculate correlation functions we use a variety of approximation formulas (table 2). This is due to the difference in scale temporal correlation of the optical thickness of the urban air in different directions (sectors) in the city of Baku.

TABLE 2. CORRELATION FUNCTION OF VARIATIONS IN TIME OF THE OPTICAL THICKNESS OF THE URBAN AIR OF BAKU IN DIFFERENT DIRECTIONS.

№	linear interpolation	optimal interpolation
1. on two points	$a_1 = \frac{1}{2}$; $\varepsilon_1 = \sqrt{\frac{3}{2} - 2\mu(\frac{t}{2}) + \frac{1}{2}\mu(t) + \frac{1}{2}\eta^2}$	$a_1 = \frac{\mu(\frac{t}{2})}{1+\eta^2+\mu(t)}$; $\varepsilon_1 = 1 - \frac{2\mu^2(\frac{t}{2})}{1+\eta^2+\mu(t)}$
2. on three points	$a_2 = \frac{1}{3}$; $\varepsilon_2 = \sqrt{\frac{3}{4} - 2\mu(\frac{t}{\sqrt{3}}) + \frac{2}{3}\mu(t) + \frac{1}{3}\eta^2}$	$a_2 = \frac{\mu(\frac{t}{\sqrt{3}})}{1+\eta^2+2\mu(t)}$; $\varepsilon_2 = 1 - \frac{3\mu^2(\frac{t}{\sqrt{3}})}{1+\eta^2+2\mu(t)}$
3. on four points	$a_3 = \frac{1}{4}$; $\varepsilon_3 = \sqrt{\frac{5}{4} - 2\mu(\frac{t}{\sqrt{2}}) + \frac{1}{2}\mu(t) + \frac{1}{4}\mu(t\sqrt{2}) + \frac{1}{4}\eta^2}$	$a_3 = \frac{\mu(\frac{t}{\sqrt{2}})}{1+\eta^2+2\mu(t)+\mu(t\sqrt{2})}$; $\varepsilon_3 = 1 - \frac{4\mu^2(\frac{t}{\sqrt{2}})}{1+\eta^2+2\mu(t)+\mu(t\sqrt{2})}$

III. THE RESULTS OF CALCULATIONS

Figures 2 shows the results of calculations of daily changes of the measure errors of linear and optimal interpolation with the measurement error equal to η = 0.33. These calculations were carried out according to the formulas in table 2. From figures 2 it follows that accuracy of linear interpolation is always smaller than the accuracy of optimal interpolation.From a comparison of optimal interpolation in Figures 2 it follows that if the assessment requirements for the density of the network come from the accuracy of the optimal interpolation on the plane and not along the straight line, the allowable distance between the observation points are obtained much larger. In this case the difference between three-and four-point interpolation is not essential. Therefore, when assessing the density of the network in case of an optimal interpolation can recommend the three-point interpolation.



Figures 2. The dependence of the errors of interpolation and the interpolation weights of the dimensionless parameter αt for the correlation functions in table 2: a1 and a2 - western direction, b1 and b2 - northern and eastern directions, c1 and c2 - southern direction; curves correspond: 1,4, and 6-linear interpolation, 2, 5 and 7 - the optimal interpolation; curves of interpolation: 1 and 2 - by two points, 4 and 5 - by three points, 6 and 7 - by four points; 3 - the maximum allowable value of interpretation error on condition (7).

Table 3 gives the values of the maximum period of time variations of the optical thickness of the urban air, for which is satisfied condition (7) (curve 3 in figure 2)

As can be seen from this table, this time increases with the number of initial control points of interpolation. In this case no significant difference between the three-point and four-point the three-point and four-point.

TABLE 3. Periods of forecast variation of urban air Baku interpolations are not observed

curves in figure 2	number of control points	dimensionless parameter, αt	the maximum period of time, t_m
a2	2	0,63	2,52
	3	0,76	3,04
	4	0,72	2,88
b2	2	1,84	10,82
	3	2,20	12,94
	4	2,10	12,35
c2	2	1,77	9,83
	3	2,14	11,89
	4	2,03	11,28

IV. CONCLUSION

1. Compared with linear interpolation optimal interpolation provides a more comprehensible results of the projection optical thickness variations in urban air;

2. The maximum permissible period of time possible variations of the optical thickness of the forecast urban air of Baku are very different for 4 directions: west, north and east and south.

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