APPLICATION OF THE AERIAL REMOTE SENSING IN THE STUDY ON LAND ROUNGHNESS AND DIFFUSION MODEL IN SHANGHAI

Wang Zhi Sheng

(Shanghai Normal University, Shanghai, Chnia)

Abstract

Land roughness is the main factor causing the diffusion of mechanical turbulence near the ground surface, the main conclusions of which are obtained via the interpretation of the Shanghai colour infrared aerial maps with 1:5000 and by the numerical calculation method: first, the land roughness from 0 to 1 metre under different wind directions occupies an absolute dominant position in Shanghai, while the average land roughness greater than 5 metres is less than 9%; secondly, the regional distribution of vertical turbulent diffusion in Shanghai can be divided into five scales from A to E. Notwithstanding the directions of the wind, diffusion conditions in the city proper are all less than or equal to level B. The diffusion model in the form of discontinuous polygonal frame under the north or south wind directions can match the distribution of the pollutant concentration very well.

Key words: Remote Sensing Application, Image Interpretation, Roughness length.

Foreword

Deducing and predicting the concentration distribution of urban atmospheric pollution may design many kinds of diffusion models; in each diffusion model, the diffusion parameter value σ is a parameter which is more sensitive to concentration distribution.Because of the close relation of the atmospheric pollution diffusion rate with the index of wind speed profile, the latter is strongly influenced by atmospheric stability and the properties of underlying surface (i.e. land roughnees). Therefore, the value σ should be the comprehensive index of various kinds of differences for atmospheric stability and underlying surface. Pasquill's P-G curve method is always used as its traditional method of ditermination. But, this method is obtained by test under the conditions that underlying surface of the land surface in the plains is more single. The condition errors used for the urban complicated underlying surface are obviously great. After taking the geometric parameters reflecting the land roughnees from the image source and forming a data base via the interpretation of the aerial maps for the color infrared images in Shanghai and according to the geographic coded mesh points, and in terms of numerical calculation method, the value Z of roughness under the different prevailing wind directions is quantitatively derived. After correcting by augmentation coefficient method, and finally, the value σ -- the diffusion parameter -- for determining atmospheric diffusion capacity is obtained, while the structure of special distribution of vertical diffusion parameter σ_z in Shanghai can be simulated by "land surface source" and "overhead source".

I. Method & Principle

1. Z--land surface roughness: one physical quantity of air turbulence of underlying surface, caused by being rough surface, can be measured to some extents by land roughness.H. H. Lettau applied the following experimental formula [1] during his solving the urban roughness in 1970:

$$Z=\frac{1}{2}\cdot\frac{H\cdot a}{A} \qquad (1)$$

where,H: the height (metre) of obstacle met by the air stream;
a: lateral area (m^2) of the obstacle met by the air stream;
A: the covered area (m^2) of the obstacle.

For one city, the obstacles met by the air stream,i.e. different types of buildings, and building complex with different shapes, while the different size of building density and the location azimuth of the buildings can affect directly the diffusion rate of the pollutants under a certain prevailing wind direction in general, thus, according to Lettau's caculating formula, the following three kinds of caculating formula under the different conditions have been deduced and derived.

a.When the prevailing wind direction is vertical with the azimuth of building:

$$Z=\frac{1}{2}\cdot\frac{H^2\cdot L}{S} \qquad (2)$$

b.When the prevailing wind direction is paralleled with the azimuth of building:

$$Z=\frac{1}{2}\cdot\frac{H^2}{L} \qquad (3)$$

c.When the prevailing wind direction is oblique with the azimuth of building:

$$Z=\frac{1}{2}\cdot\frac{H^2\cdot L'}{S} \qquad (4)$$

In the formula mentioned above,
H: the covered height of the building;
S: area of the building covered;
L: length of building:

$$L'=\sqrt{L^2+(S/L)^2}$$

2. Augmentation coefficient η : Due to the complexity of environmental conditions,the atmospheric diffusion model, established and obtained by stable and uniform turbulent field in the region of plains, has no universal significance. Especially, for

the urban region, under the conditions of its underlying surface being complex and multi-changed, there will be more difference in diffusion parameter and that in the region of plains with more single underlying surface. While the difference between the two cases can be reflected in time,i.e. the correction coefficients of atmospheric diffusion parameters---augmentation coefficient η[2]:

$$\eta = \frac{\sigma_2}{\sigma_1} \qquad (5)$$

where,

σ_1 : representing the diffusion parameter in the region of plains;

σ_2 : representing the diffusion parameter in the urban region;

The analytic equation of augmentation coefficient η is as follows:

$$\eta = \frac{\lg H_i - \lg Z_0}{\lg H_i - \lg Z_i} \cdot \left(\frac{Z_0}{Z_i}\right)^{\beta-1} \qquad (6)$$

where,

H_i: height(m) of the building at the ground of urban region;

Z_i: value (m) of the land roughness in urban region;

Z_0: minimum value(m) of land roughness in urban region;

β : index of atmospheric stability;

i=1,2,...,n: serial no. of computing mesh points. In the process of quantitizing the augmentation coefficient η , several descriptions are given as follows:
(a) The minimum value Z_0 of land surface roughness of urban area is identical with 0.03; (b) During calculating $Z_i < 0.03$m of mesh point, then, 0.03m is taken as the value Z_i at that point; (c) Value β is the function of atmospheric stability. According to the result observed by Deacon[3], the different atmospheric stabilities have different value β correspondingly, while its correspoding relation is shown in Table 1. (d) The values H for the height of buildings are taken respectively from the following conditions: the first one: type of ground surface source height, i.e. average height of the buildings on each mesh point; the second one is that 50m (constant) is taken as H_i, the meaning of which is to consider the land surface overhead source and the height of rising of smoke gas, in general, 50m being Flux layer.

3. Vertical diffusion parameters:
In general, the formula for calculating the distribution of maximum falling ground concentration:

$$\sigma_z = \frac{H_i}{2} \qquad (7)$$

At the maximum falling site, there is an expression formula for Briggs power function in the formula for determining the vertical diffusion parameters σ_z :

$$\sigma_z = a \cdot X^b \qquad (8)$$

where, X: maximum distance of the falling site; while a,b: coefficent values. Under the different atmospheric stabilities , values a and b in the expression formula for power function of diffusion parameters is correspondingly varied. In the calculation of simulation, we consult in the estimating method of Briggs diffusion parameters and via optimization treatment. Finally, all of the conditions shown in Table 2 are chosen. The equations (7) and (8) are simultaneous, while the maximum falling ground concentration distance X under the conditions of a certain source height and the determined stability can be worked out. The reference for calculation is the distribution conditions of maximum falling ground concentration taking the atmospheric stability as the scale D (neutral state). The quantities of simulation under the other different kinds of stability are obtained by reversely deriving the maximum falling land concentration distance of the scale D with equation (8). based on the calculation result mentioned above, finally,correcting the augmentation coefficients can be realized by means of the equation (5), therefore, obtaining the simulation quantity σ_z required by analysis:

$$\sigma_z = \eta \cdot a \cdot X^b = \frac{\lg H_i - \lg Z_0}{\lg H_i - \lg Z_i} \left(\frac{Z_0}{Z_i}\right)^{\beta-1} \cdot a \cdot X^b$$

II. Data Soure & Processing Method

Based on the information of remote sensing image provided by the image picture (1:5000) of Shanghai color infrared aerial maps in 1988, and via interpretation,

Scales of Pasquill's atmospheric stability	β of stability index
unstable B	1.15
more unstable C	1.10
neutralizing D	1.00
stable E	0.90

Table 1: Table for scales of Pasquill's atmospheric stability corresponding to index β

scales of stability	a	b
B	0.127	0.964
D	0.105	0.826
E	0.093	0.788

Table 2. Expression formula of power function of diffusion parameters

Shanghai municipal urban geographic information database was established, the mesh type being adopted as data format, while the decomposition unit being 50 x 50 (m^2). In the process of the whole calculation, the following several information were taken from the data base; building area: (s); building length: (L); the location azimuth building: (M); and the building height: (H). The calculation of roughness Z was directly carried out on the mesh points of 50 x 50 (m^2). For the sake of considering the accuracy requirements of atmospheric diffusion and in simulating the augmentation coefficient and diffusion coefficients, the information required by calculating were taken by taking 250 x 250 (m^2) as the average value of simulation units.The total roughness values on 128000 mesh points, as well as the values of augmentation coefficients & diffusion parameters on more than 5000 simulation units have been simulated. The data processing was completed on PC 286 microcomputer, the software being designed by ourselves to carry out man-machinedialog, real-time processing and has the functions, such as, consulting words, correcting, renewal, replacement, enhancement with a certain image analysis, picture enlargement and reduction,etc.. Fig.1 is the block diagram of the whole process.

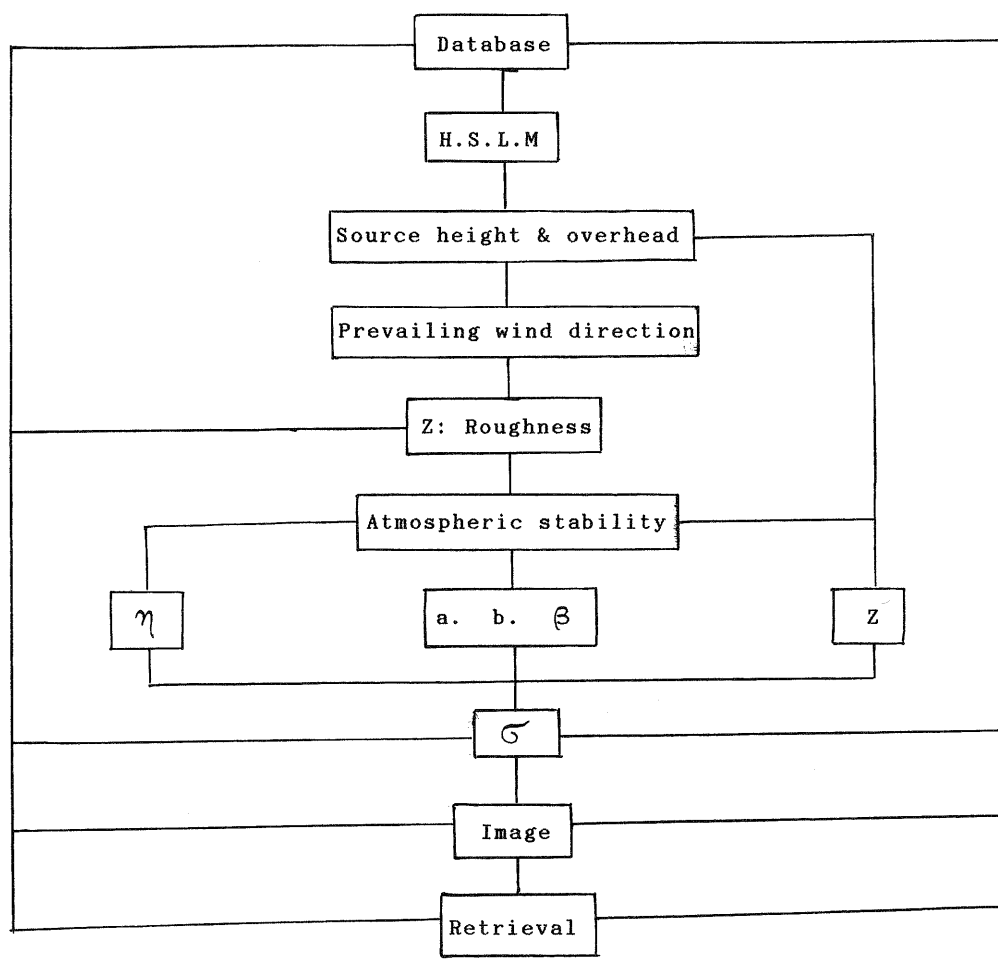

Fig. 1. Block diagram for computing atmospheric diffusion conditions

III. Conclusion

1. The result of computation for Shanghai land surface roughness and the urban roughness reported at home and abroad are same order of magnitude, while the statistical result of its percentage can be shown in Table 3, by which, it is shown that the law of the regional distribution for roughness is clearly affected by the prevailing wind direction.

2. The value of diffusion parameters derived via augmentation coefficients method is used for simulating the relative difference distribution for the diffusion conditions in the urban spacial region, which, therefore, is more visible and clear.Table 4 is the calculation example. It is confirmed that under the stability of scale D, the value σ obtained in the urban industrial region is basically same as the value σ derived by the method of determining atmospheric diffusion parameters in terms of raising the scale promulgated by Ministry of Urban and Rural

Construction and Environmental Protection.[4]

It can be known from the regional distribution features of vertical turbulent diffusion parameters in Shanghai that no matter what winf direction is, all of the diffusion conditions in the city proper belong to " greater than scale B ", thus, forming a kind of lay-out for discontinuous ring type frame(see Fig. 2).The border line is approximately at the juncture of new and old city regions, indicating that the diffusion conditions in the city proper region are worse, in which , the result of the simulation in the direction of N-S is matched better with the concentration distribution of actual measured pollutants.

Scale (m) / f / Wind direction	0-1	1-2	2-3	3-5	5	total	remarks
NE-SW	48	22	12	10	8	100	In the power series >5, in which, the roughness of >10; amounting to 17% in NE-SW; amounting to 18% in N-S; amounting to 20% in NW-SE.
N - S	43	22	12	12	11	100	
NW-SE	52	21	10	10	7	100	

Table 3. Statistical survey for percentage (f) of various kinds of rounghness in Shanghai

Measuring point	Stability	Source height: 50 m, and distance for maximum falling ground concentration: 1147.23 m					
		wind direction					
		NE-SW		N-S		NW-SE	
		η	σ	η	σ	η	σ
II70a a	B	1.32	149.11	1.37	154.46	1.33	150.54
	D	2.63	92.90	2.79	98.63	2.67	94.44
	E	3.62	86.84	3.89	93.27	3.70	88.57
JH27ad	B	1.26	142.93	1.26	142.27	1.18	133.25
	D	2.44	86.14	2.43	85.90	2.12	75.28
	E	3.31	79.29	3.30	79.02	2.80	66.97
Remark	One & half a scale are raised based on the scale D promulgated by the Minidtry, the stability -- the value σ should be 86.86. The range between values in the table and their errors are (+11.76) -- (-11.78).						

Table 4. Example of the value σ under the different wind directions calculated via augmentation coefficients

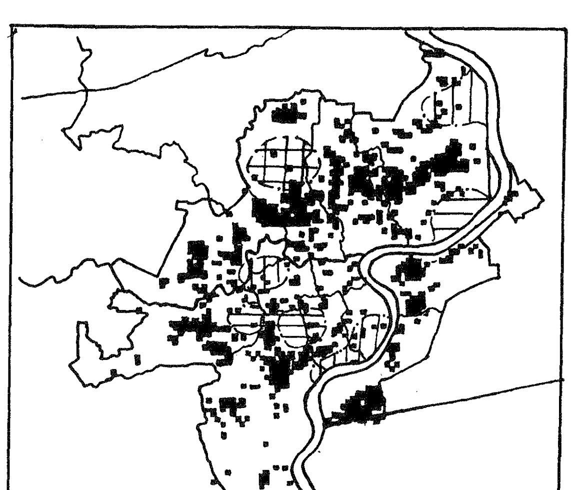

Fig. 2. Drawing for distribution of scale A of simulating overhead source σ_z in N-S wind direction in Shanghai

■: σ_z

⊕: Annual average maximum drifting dust centre in N & S wind direction in 1988;

⊖: Annual average drifting dust concentration centre in S wind direction in 1988;

⦶: Annual average drifting dust concentration centre in N wind direction in 1988;

(N -- North wind, S -- South wind)

References

[1] Principle & application of air pollution meteorology. Compiled & edited by Li Zong Kai, Meteorological Publishing House, 1985.

[2] Study on the influence of roughness Z_0 of urban region upon σ — atmospheric diffusion parameter (Proceedings). Compiled by Tie Xue Xi, Research Institute of meterorology, Tianjing Meteorological Bureau.

[3] Micrometeorology, Compiled by O.G. Sutton, Higher Learning Publishing House,1959.

[4] Handbook for preventing & treating atmospheric pollution, Compiled by Beijing Institute of Environmental Protection Science, Shanghai S&T Publishing House,1987.