PRELIMINARY ANALYSIS OF RESULTS OF A MOUNTAIN AREA ATMOSPHERIC DIFFUSION TEST(U) FOREIGN TECHNOLOGY DIV
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FOREIGN TECHNOLOGY DIVISION

PRELIMINARY ANALYSIS OF RESULTS OF A MOUNTAIN AREA ATMOSPHERIC DIFFUSION TEST

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Preliminary Analysis of Results of a Mountain Area Atmospheric Diffusion Test

Atmospheric Testing Technical Group*

I. Preface

Following the continuous advances in industry, there has been an increasing amount of harmful gases discharged into the atmosphere each day. In order to guarantee that the atmospheric environment of human life satisfies air quality standards, it is necessary on the one hand to rationally lay out newly constructed enterprises and add controls to the discharge of substances by already constructed enterprises; on the other hand, it is necessary to announce in advance the future harm levels of pollutants. All of these items urgently demand an understanding of the diluting capabilities of the atmosphere towards pollutants under different meteorological conditions.

In recent years, because there have been an increasing number of factories built in varied mountain areas and along the coasts, research on low level atmospheric structures under non-uniform topographical conditions and atmospheric diffusion laws has been getting an increasing amount of serious attention. When comparing mountain areas and plains, the atmosphere near stratum structures and diffusion diluting capability are very different. The problems of how to fully use the beneficial factors of mountain areas, avoid non-advantageous conditions and reduce the industrial pollution of factories constructed in mountain areas so that the natural environment, the atmosphere, is the responsibility of engineering design and rational

*Composed of members of Qinghua University, Central Meteorological Department, Atmospheric Physics Institute of Chinese Academy of Sciences and Lanzhou Plateau Atmospheric Physics Institute. Beijing University, worker-peasant-soldier students of Qinghua University and the Geological Institute of the Chinese Academy of Sciences also participated in the work.
industrial layout is a major task of atmospheric physics workers.

This paper used the results of diffusion tests of artificial smoke clouds and neutron activated smoke in a certain mountain area during the spring and autumn of 1975 as well as related meteorological observation data. It also used different methods to calculate the atmospheric diffusion parameters of this mountain area especially focusing on the differences of the diffusion diluting capabilities of the pollutants in the mountain area and on the plain and compared them with related foreign results whereupon useful results were obtained.

II. General Situation of the Test and Sources of Data

1. Topography. The test site was a mountain area and its topography is as shown in Fig. 1. In the figure, point A is an iron tower with a height of 98.2 meters, the base of the tower is located on a platform 372 meters above sea level. To its west, north and east are high mountains and to the south it faces a level area. The tower is located on one end of a north-south running valley.

![Fig. 1 Topography of the atmospheric test. The solid lines are contour lines (meters), A is the iron tower, \( \mathbb{A} \) is the photographing point, \( \mathbb{ab} \) is the three-dimensional photographic datum line, \( \mathbb{C} \) is the architectural complex, H is the chimney. Key: (1) North; (2) Kilometers.](image-url)
2. Meteorological Observations on the Tower

The meteorological observation instruments were installed on the movable cantilever arm extending from the tower. The arm length is twice the length of the side of the tower. We used the electrical registering anemograph, thermister thermometer and hot line anemometer (separately at the eight heights of 2, 13.4, 22.4, 31.4, 44.9, 62.9, 80.9 and 97.4 meters) to measure the average wind and temperature gradients. Observations were done once an hour and the average time was 20 minutes. The horizontal wind direction pulsating data was obtained by an improved EL-2 instantaneous wind direction anemograph (installed at a height of 49.4 meters).

3. Artificial Smoke Cloud Diffusion Tests

48 kilogram smoke containers were erected at different heights on the iron tower and acted as release sources of the artificial smoke clouds. The amount of smoke produced by this method was uniform and the smoke issuing time of each container was 8-12 minutes. In the downwind direction of the flue we used the two methods of the common camera and the ground three-dimensional camera [1] to continuously photograph the smoke cloud. Each cloud could be continuously photographed 10 to 20 times and the sampling time was about 10 minutes.

4. Diffusion Tests of Tracer Elements

Twenty tests were carried out at heights of 80 meters on the iron tower. The emission of indium nitrate in each test was 200-500 grams and the emission mode was burning an alcohol solution of indium nitrate in a high pressure blowlamp to form indium oxide particles with diameters smaller than 0.1mm so as to simulate the diffusion movements of the discharged gases in the atmosphere. When released, they separately arranged fan-shaped specimen points on the seven arcs downwind 0.4, 0.8,
1.5, 3.0, 5.0, 10.0 and 45.0 kilometers (the relative elimination point tensor angle was 60°).

After completing the mountain tests, we also carried out 5 tests on level fields about 2 kilometers south of the tower. Seven specimen points were distributed equidistantly on four arcs (in a 60° fan-shape) downstream 50, 150, 250 and 450 meters. Each release was 100 grams of indium nitrate.

III. Use of the Photographic Method to Determine the Diffusion Parameters of the Smoke Cloud

1. Method for Calculating Diffusion Parameters

On the downwind side of the release point, we calculated the basic relationship of vertical diffusion parameter $\sigma_x$ from the smoke cloud's average contour for the smoke cloud's locus photograph as [2]

$$\sigma'_z = z_c \left\{ \ln \frac{z_m}{z_e} \right\}^{-1} \tag{1}$$

In the formula, $z_c$ is the distance from the average flue axis to the visible boundary (also called the vertical half width), $z_m$ is the maximum vertical half width and $e$ is the bottom of the natural logarithm.

By using the graphic method to find transcendental equation (1), we can obtain vertical diffusion parameter $\sigma_z$ based on the $z_e$ measured on a certain downward distance. By using the completely analogous method, we can obtain diffusion parameter $\sigma_y$ of the beam wind direction.

2. Major Results

Based on the various different conditions, we will now separately discuss the results obtained through observations as
follows:

(1) Diffusion of Leeward Slope of Airflow Passed the Mountain

When there is a northwest wind passing the northern ridge, the smoke source's discharge point on the tower is located in the cavity area of the leeward slope and its diffusion characteristic point is the flue's inclined lower pressure and strong perturbation motion. See line 1 in Fig. 2a for the results of the average of the four data measured in the tests. (Afterwards, aside from special explanations, the stability is given based on Pasquill's [3] method of categorization.)

(2) Diffusion Under Local Circulation Control

a. Diffusion When the Wind is to the North

When there is no systematic airflow passed the mountain, there is a clear night and the main body of the cold air accumulated in the mountain area flows out from the eastern gorge. The wind direction of the smoke cloud's discharge point on the tower is predominantly northeastern and the flue is relatively stable. See solid line 2 in Fig. 2a for the mean results of the five data measured from tests.

b. Diffusion When the Wind is to the South

During 9 tests when there was wind towards the south the flue was even more stable than when there was a north wind because the airflow flowed from the level area to the mountain area and perturbation motion was relatively small. See lines 3 and 4 in Fig. 2a for the mean results.

(3) Diffusion of Opposite Level Area
In order to compare and discuss the differences of the diffusion of different positioned leeward slopes, we also photographed and measured the flue discharge from the chimney H (see Fig. 1) of the opposite level area. Its northern section was an architectural complex with a 500 square meter range and the average height was 20 meters. Its southern section was relatively level farmland and the chimney height was 37 meters.

When there was a systematic northwest wind and the chimney was still located in the wake flow area of the mountain area's rough air, adding on the influence of the architectural complex, the swinging of the flue was relatively large. See line 1 in Fig. 2b for the mean results of 4 measurements.

When the airflow blows from the south section's level area, the flue is relatively level and straight. See line 2 in Fig. 2b for the mean values of three measurements.

![Graph](image-url)

Fig. 2 Curve of $\sigma$, measured by photographic method changes with the distance.
(See next page for key)
IV. Use of Wind Direction Pulsation Data to Calculate Diffusion Parameters

1. Calculation of Wind Direction Pulsation Standard Difference $\sigma_\theta$

From statistical analysis of smoke cloud crosswise diffusion and release point wind direction pulsation data [4], we can obtain a method which uses the wind direction pulsation data to calculate the density distribution of the pollutants. Its wind direction pulsation standard difference is indicated as $(\sigma_\theta)_{\tau s}$. In this, $\tau$ is the sampling time, $s = \frac{x}{T}$ is the mean time, $\beta = \frac{T}{s}$ is the ratio of the Lagrangian time scale and the Eulerian time scale, $T = \frac{x}{U}$ is the particle movement time, $x$ is the distance of the tailwind direction particle movement and $U$ is the mean wind speed of the tailwind direction. Thus, $(\sigma_\theta)_{\tau s}$ is the wind direction pulsation standard difference on the release point with the sampling time being $\tau$ and the mean time being $s = \frac{x}{\beta U}$. During tests, we used the improved EL-2 spontaneous anemorumbometer. Its inertial time is less than 5 seconds, the paper moving speed of the wind direction recorder is 0.5mm/second and in sampling time $\tau$, it reads one wind direction pulsation $\theta_i$ every 5 seconds. We obtained a new sequence of different $\theta_i$ for the different mean times recorded.
As \( \Theta_{s,i} \), its variance is expressed as

\[
\overline{\Theta_{s,i}}^2 = (\overline{\Theta_{s,i}} - \Theta_{s,i})^2 = \frac{1}{N} \sum_{i=1}^{N} \left[ \Theta_{s,i} - \frac{1}{N} \sum_{i=1}^{N} \Theta_{s,i} \right]^2
\]

(2)

In the formula, \( \Theta_{s,i} \) is the horizontal wind direction pulsation value and \( N \) is the number of samples. From formula (2) we can derive the curve of \( \sigma_{\theta}^2 \) which changes with the mean time. We can also calculate the various \( \sigma_{\theta} \) values with different degrees of stability.

2. Results of Calculation of \( \beta \) Values

By using the wind direction pulsation data on the tower (49.4 meters) and the diffusion test (smoke cloud and tracer element indium) data, we can establish the following relationship

\[
\frac{\sigma_y^2}{x^2} = \frac{\sigma_{\theta}^2}{\tau \cdot s_0}
\]

(3)

When we determine the \( \sigma_y^3 \) of a certain distance \( x \) from the diffusion tests as well as the curve of observed \( \sigma_{\theta}^2 \) which changes with \( s \), we find and satisfy the \( s_0 \) value of \( \sigma_{\theta}^2 = \sigma_y^2 \) on the curve. Then, from

\[
\beta = \frac{s}{\bar{u} \cdot \tau}
\]

(4)

we can find the \( \beta \) value. During the entire calculation, sampling time \( \tau = 10 \) minutes and \( \bar{u} \) is the mean wind velocity within 10 minutes. For mountain area conditions, \( \sigma_y \) is obtained with \( x = 1000 \) meters using the photographic method; for the level area, \( \sigma_y \) is obtained from the concentration distribution data of indium when \( x \) is within 450 meters. The calculation results of related \( \beta \) values are listed in Tables 1 and 2.
Table 1 \( \beta \) values of mountain areas.

Key: (1) Stability type; (2) Mean.

<table>
<thead>
<tr>
<th></th>
<th>D-E</th>
<th>C-D</th>
<th>F</th>
<th>E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>2.4</td>
<td>2.9</td>
<td>2.1</td>
<td>1.7</td>
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</tbody>
</table>

Table 2 \( \beta \) values of level area.

Key: (1) Stability type; (2) Mean.

<table>
<thead>
<tr>
<th></th>
<th>D</th>
<th>B-C</th>
<th>F</th>
<th>E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>4.5</td>
<td>8.9</td>
<td>2.1</td>
<td>3.7</td>
</tr>
</tbody>
</table>

We can see from the tables that in the opposite level area, \( \beta \) changes in the 2.1 to 8.9 range, the mean is 5.2 which is larger than the \( \beta \) value of 4 calculated by Hay and Pasquill [4] (distance source is 100 meters) and it is basically the same as the (distance source 400-800 meters) mean value of 5.4 (its changing range is 2.4-10.5) which we obtained in diffusion tests carried out at an open coastal mountain area. However, the value of \( \overline{\beta} = 2.0 \) for diverse mountain areas is lower than the above mentioned results. This shows that the strength of the mountain area's turbulent flow is larger than that of the level area and thus \( \beta \) tends to be small; on the other hand, the \( \beta \) determined by \( \sigma_y \) calculated from the photographed data still has a certain error and whether or not these results reflect the actual situation still awaits more accurate test data confirmation.

3. Relationship of \( \sigma_y \) and the Sampling Time

The relationship of \( \sigma_y \) and the sampling time can be empirically expressed as
From the 6 two hour data observed on the tower in the mountain area, we separately calculated the 6 sets of \( \sigma_\theta (\tau_i) \) of \( \tau = 10, 20, 30, 60, 90 \) and 120 minutes and afterwards using the linear regression analysis method very easily derived the \( p \) values. The mean of the \( p \) values of 6 data was 0.21 and its changing range is 0.14-0.31. The foreign plain areas [5] usually take \( p = 0.2 \) which is the same as the results in this paper.

4. Results of Calculations of \( \sigma_y \)

Based on the obtained \( \sigma_\theta \), \( \tau \), and \( \beta \) values mentioned previously, we can very conveniently derive the \( \sigma_y \) values on different downwind distances. See Fig. 3 for the results of different wind directions and different stability types on mountain and level area topography.

Fig. 3 Calculation of \( \sigma_y \) from wind direction pulsation data. (see next page for key)
Fig. 3 (continued)

Key: (1) Line 1, mountain area, wind to the south; C-D type, average of 18 times; (2) Line 2, mountain area, wind to the north, D-E type, average of 18 times; (3) Line 3, mountain area, wind to the north, E type, average of 4 times; (4) Line 4, level area, wind to the north, D type average of 3 times; (5) Line 5, level area, wind to the south, C type, average of 3 times; (6) Average time 10 minutes, measured height 49.4 meters; (7) Measured height 3 meters, mean time 10 minutes; (8) Meters; (9) Meters.

V. Use of Profile Data to Calculate Diffusion Parameters

1. Mean Wind Velocity Profile Characteristics

Based on the temperature vertical gradient, we divided the measured mean wind gradient data (145 times) into the three different stability types of temperature inversion, neutral and decreasing by degrees. See Fig. 4 for the mean wind velocity profile flow.

Fig. 4 Profiles of mountain area wind velocity.

Key: (1) Line 1 represents temperature inversion, average of 8 times, wind to the north; (2) Line 2 represents the neutral condition, average of 55 times; (3) Line 3 represents condition of decreasing by degrees, wind to the south. The solid line is the calculated value; (4) 0 is the measured value (mean time is 20 minutes); (5) Meters; (6) Meters/second.
Fig. 5 Mean wind velocity profile under different wind direction conditions.

Key: (1) Line 1 represents the wind to the south in a neutral condition, average of 25 times; (2) Line 2 represents the wind to the north in a neutral condition, average of 30 times; (3) 0 is the measured value (mean time is 20 minutes); (4) Meters; (5) Meters/second.

We can see from profile 1 (average of 8 times) that up to a height of 100 meters, the mean wind velocity which follows the height distribution basically satisfies the logarithmic linear law's measured value and calculated value and the two are very similar. The wind direction is mainly to the north.

Profile 2 (average of 55 times) represents the mean wind velocity profile of the neutral layer junction. We can see that up to a height of 100 meters, the wind basically satisfies the logarithmic law and the calculated and measured values are the same. At the same time, it is easy to obtain the mean roughness length as 0.62 meters from the point of crossing of the straight line and longitudinal axis.

We can see from profile 3 (average of 77 times) that when
below 60 meters, it can basically satisfy the logarithmic law and then the upwind velocity decreases very slowly with the height. However, the entire layer uses the logarithmic linear law for approximation and the calculated and measured values are quite similar. The wind direction is mainly to the south.

In order to explain the effects of surface roughness changes on the mean wind velocity profiles, we categorized the neutral layer junction data according to the wind direction. Curves 1 and 2 in Fig. 5 separately represent the mean wind velocity profiles of the wind to the south and to the north. We can see from this that the wind velocity profiles are all formed from two logarithmic profiles with different slopes. These two different slopes reflect the effects of the different roughness topographies on it. The low section shows the effect of the topography near the tower on the airflow and the high section shows noticeably different effects of more distant topography as compared with the roughness near the tower. Thus, the roughness lengths of the two sections are also different. There are also foreign results regarding the effects of topographical changes on the wind velocity profile. It is unanimously considered that there is an interface between the low layer effected by the topography near the tower and the high layer effected by more distant topography and that the profile on this interface shows points of inflection. The data analysis in this paper shows that the mean height of the points of inflection of the profiles is about 60 meters. The height of the single profile point of inflection varies with the difference of the wind direction.

2. Calculation of Logarithmic Linear Profile Parameters and Results

We can clearly see from the discussion in the above section that under non-neutral conditions, the mean wind velocity profiles can be approximated by the logarithmic linear relationship.
The meteorological observations carried out on the coast of Japan by Sensku [6] show that the height suitable for the logarithmic linear law can exceed 100 meters and can sometimes reach 200 meters. Aside from a small number of profiles which do not coincide with this law (for example, among 90 non-neutral profiles, there were 5 parabolic alphabets of lines under radiation temperature inversion conditions), this paper calculates the logarithmic linear profile parameters with various stability types.

The near ground layer similarity theory can only be applied when the stability and uniformity conditions are satisfied, but strictly speaking, the mountain areas in these tests were not satisfied. Here, we will use some relational formulas derived by the similarity theory as a type of empirical approximation but we will not carry out theoretical discussions. From the similarity theory of the near ground layer, we can express the average wind and temperature which follow the distribution of the height as [7]

\[ u(s) = \frac{u_*}{K} \left( \ln \frac{s}{z_o} + \frac{s}{L} \right) \]  

\[ T(s) - T(z_o) = T_* \left( \ln \frac{s}{z_o} + \frac{s}{L} \right) \]  

In the formula, \( u_* \) is the friction speed, \( T_* \) is the temperature scale, \( K \) is the Karman constant (usually 0.4), \( z_o \) is the roughness length, \( L \) is the Obukhov length scale and \( \sigma \) is a universal constant.

In the same way, we assume that the average wind and temperature profiles of each observation can be written as the following experimental expressions

\[ u(s) = A_u \sigma s + B u_* + C_* \]  

\[ T(s) = A_T \sigma s + B_T s + C_T \]
In the formulas, \( A_u, B_u, A_T, B_T, C_u \) and \( C_T \) are the measured values of each wind and temperature profile derived by the binary linear regression method. Further through a contrastive analysis of formulas (6)-(9), we can derive the following relationships

\[
\begin{align*}
\bar{u} &= 0.174 A_u \text{ (米/秒)} \\
L &= 13.3 A_T / A_T \text{ (米)} \\
\alpha &= 15.2 \left( \frac{B_u}{A_u} + \frac{B_T}{A_T} \right) \frac{A_T^2}{A_T} \\
\lg z &= - \frac{C_T}{A_u}
\end{align*}
\]

Key: (1) Meters/second; (2) Meters.

Based on the above method, we calculated a total of 42 profile examples in order to coordinate with the smoke cloud diffusion test data. There have already been many conclusions abroad related to the \( \alpha \) values and for comparison the values of \( \alpha \) are listed in Table 3.

<table>
<thead>
<tr>
<th>Author</th>
<th>Monin-Obukhov</th>
<th>Priestley</th>
<th>Yamamoto</th>
<th>Taylor</th>
<th>Passhy</th>
<th>Kondo</th>
<th>Sensku</th>
<th>本文</th>
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<td>( a )</td>
<td>2.25</td>
<td>0.6</td>
<td>2-12</td>
<td>2.5-12</td>
<td>4.5</td>
<td>3.3</td>
<td>1.07</td>
<td>1.8±1.15</td>
</tr>
</tbody>
</table>

Table 3 Table of comparison of \( a \) values [6].

Key: (1) Author; (2) This paper.

We can see from the table that aside from the values given by Monin-Obukhov and Sensku, the \( a=1.8±1.15(0.5-4.6) \) value of this paper is the smallest. This is possibly related to the mountain area topography's perturbation motion being large which causes the wind velocity changes to become small.

3. Use of Profile Data to Calculate Diffusion Parameters

The vertical standard difference \( \sigma_x \) can be given by the following empirical relationship [8]:

15
In the formula, \( \sigma_w \) is the vertical wind velocity pulsation standard difference and \( g(x) \) is the distance function. From the results given by Monin [9], \( \sigma_w \) can be expressed as

\[
\sigma_w = n_o \left[ 1 - \frac{1}{F(\zeta)} \right]^{\frac{1}{2}}
\]  

(12)

In the formula, \( F(\zeta) \) is a universal constant and when calculating the bottom, all are approached using the logarithm linear relationship, \( \zeta = \frac{z}{L} \). This equation is also derived under stable and uniform conditions. Here, we will only use this relational formula as a type of empirical approximation. Based on this processing, if there is a very large difference with the test results, this explains that this type of approximation is not rational; on the contrary, this type of approximation can be accepted in actual work and thus formula (12) can be written as

\[
L > 0 \quad \sigma_w = n_o \left[ 1 - \frac{\zeta}{1 + \sigma_o} \right]^{\frac{1}{2}}
\]

\[
L < 0 \quad \sigma_w = n_o \left[ 1 + \frac{\zeta}{1 - \sigma_o} \right]^{\frac{1}{2}}
\]

(13)

In actual calculations, the \( g(x) \) in formula (11) is empirically given as \( x^r \) and \( r \) is given as \( (r = \frac{2-n}{2}) \) from the mean wind velocity based on the following formula of exponent \( n \) changing according to the exponential law

\[
\bar{u} - \bar{u} \left( \frac{1}{\bar{u}} \right)^{\frac{1}{2-n}}
\]

(14)
Then

\[ L > 0 \quad \sigma_c = \frac{\bar{u}}{a} \left[ 1 - \frac{\xi}{1 + a^2} \right]^\frac{1}{2} \cdot \frac{1}{z^2} \]

\[ L < 0 \quad \sigma_c = \frac{\bar{u}}{a} \left[ 1 + \frac{\xi}{1 - a^2} \right]^\frac{1}{2} \cdot \frac{1}{z^2} \]

(15)

In the formulas, \( \bar{u} \) takes the mean of the entire layer's wind velocity, \( u_a \), \( a \), \( L \) and \( r = \frac{2-n}{2} \) are already calculated and given. \( z \) takes the geometric mean height of the observed layer (in the actual calculations, \( z = \sqrt{97.4 \times 2} \approx 14 \) meters). Then, we can derive the relationship of \( \sigma^2_z \) which follows downwind distance \( x \) from the formula (15).

In order to test this method of calculating \( \sigma^2_z \), we compared the calculated values and simultaneously test measured \( \sigma^2_z \) of the smoke cloud diffusion. From the test data on half thickness \( h \) of the smoke cloud's mean contour, by using the following approximation relationship

\[ \sigma_z = \frac{h}{2.15} \]

(16)

we can very conveniently derive \( \sigma^2_z \). Table 4 lists the data of 9 profile observations and as well as completely corresponding photography observations of the smoke cloud, (7 of which were the B-C type and 2 were the E type, including 4 day test data), and the results of 4 representative observations (including identical best and poorest examples).
Table 4 Comparison of calculation of $\sigma_z$ and measurement of smoke cloud.

Key: (1) Time; (2) Meters; (3) Distance X (meters); (4) Stability type; (5) Measurement of smoke; (6) Calculated; (7) Measurement of smoke; (8) Calculated; (9) Measurement of smoke; (10) Calculated; (11) Measurement of smoke; (12) Calculated.

We can see from Table 4 that by using the similarity theory method, from the mean wind and temperature profile data, the derived vertical diffusion parameters and actual situation have relatively good uniformity. The uniformity is even better under unstable conditions. In order to further explain the level of uniformity of the calculated and measured values, we did statistics on the ratio of the calculated and measured values of $\sigma_z$ of the 9 examples (40-300 meters). Results showed that 76.1% had the ratio smaller than 1.5, 87.2% had the ratio smaller than 2 and those with ratios larger than 2 were examples of the E type. This explains that even though the uniform conditions of the mountain area are difficult to satisfy, when the similarity theory method is used empirically, it cannot cause relatively large errors. We applied this method and calculated
a total of 42 examples and divided them into 5 stability types based on length, dimension and size. Each mean parameter is listed in Table 5. See Fig. 6 for results of calculations of $\sigma_z$.

<table>
<thead>
<tr>
<th>Stability Type</th>
<th>Parameter</th>
<th>Frequency</th>
<th>$\sigma_z$ (m/s)</th>
<th>$\alpha$</th>
<th>$b$ (m/s)</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>B-C</td>
<td>14</td>
<td>0.290</td>
<td>1.8</td>
<td>2.70</td>
<td>0.98</td>
</tr>
<tr>
<td>II</td>
<td>C-D</td>
<td>9</td>
<td>0.442</td>
<td>1.8</td>
<td>3.94</td>
<td>0.96</td>
</tr>
<tr>
<td>III</td>
<td>D-E</td>
<td>6</td>
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<td>1.8</td>
<td>2.80</td>
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<td>V</td>
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<td>1.90</td>
<td>0.91</td>
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<td>VI</td>
<td>F</td>
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<td>0.086</td>
<td>1.8</td>
<td>1.30</td>
<td>0.87</td>
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</tbody>
</table>

Table 5 Table of calculations of parameters of $\sigma_z$.
Key: (1) Stability type; (2) Meters; (3) Stability type; (4) Number of times; (5) Meters/second; (6) Meters/second.

Fig. 6 Diffusion parameter $\sigma_z$ calculated by profile data.
Key: (1) Meters; (2) Meters; (3) I and II, wind to south; (4) V and VI, wind to the north; (5) O represents calculated point value.
VI. Use of Concentration Distribution of Indium to Calculate Diffusion Parameters

We used the measured indium ground concentration data to separately calculate the horizontal and vertical diffusion parameters. The $\sigma_z$ is given by

$$\sigma_z = \frac{\sum C_i x_i^2 - (\sum C_i x_i)^2}{\sum C_i}$$  \hspace{1cm} (17)

In the formula, $C_i$ is the sampling point's measured concentration. $\sigma_z$ is derived by the crosswire integral concentration method. Its expression is

$$C_i = \int C_i \Delta y = \sum C_i \Delta y = \sqrt{\frac{2}{\pi}} \frac{Q}{\sigma_z} e^{-\frac{x^2}{2\sigma_z^2}}$$  \hspace{1cm} (18)

In the formula, when crosswire integral concentration $C_i$, source strength $Q$, mean wind velocity $\bar{u}$ and effective source height $H$ are all known quantities, we can then derive $\sigma_z$.

By using the above processing method, we calculated the test data of 3 level topographical conditions with the wind to the south. See Fig. 7 for results of $\sigma_z$ and $\sigma_y$.

![Fig. 7 Diffusion parameters calculated from concentration distribution of indium.](see next page for key)
Fig. 7 (continued)

Key: (1) Meters; (2) Meters; (3) Line 1, level topography $\sigma_z$, C type, average of 3 times, wind to the south; (4) Line 2, level topography $\sigma_z$, C type, average of 3 times, wind to the south; (5) Area is mountain area $\sigma_y$, E type, average of 6 times, average time of one hour, wind to the north; (6) 0 represents measured value of level topography; (7) Average time of 30 minutes.

For the 20 tests on the mountain areas, because the topographical fluctuations within 800 meters were very large, the concentration did not satisfy the normal distribution. Beginning from 800 meters, the topographical fluctuations were relatively small and their concentrations approached satisfying the normal distribution. We only calculated 9 E type (wind to the north) weather examples of $\sigma_y$ on 800 and 1500 meter arcs. See Fig. 7 for mean results.

VII. Discussion of Results

1. Comparison of Mountain Area and Plain Diffusion Parameters

The diffusion parameters of mountain area parameters are usually larger than those of the plain because of topographical fluctuations. For comparison, we compared Pasquill-Gifford's [5] representative values of $\sigma_y$ and $\sigma_z$ as the plain conditions interpolated from the curve of the diffusion parameters which change with the distance and the results of the same stabilities given by the four methods of this paper. The ratios of the 800 meter area diffusion parameters are listed in Table 6.
Table 6 Ratio of mountain area and plain diffusion parameters*.

<table>
<thead>
<tr>
<th>Method</th>
<th>(2)</th>
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Key: (1) Type of weather; (2) Ratio; (3) Method; (4) Indium; (5) Profile method; (6) Photographic method; (7) Pulsation method; (8) South wind; (9) North wind; (10)* The ordinary notation of P indicates the value of the Pasquill plain condition, the lower notation of "level" indicates the observation result of level topography and the lower notation of "mountain" indicates the observation results of mountain areas; (11) Level; (12) Mountain; (13) Mountain; (14) Level; (15) Level; (16) Mountain; (17) Mountain; (18) Mountain; (19) Mountain; (20) Mountain.

We can see that the indium made from the level area and the $\sigma_z$ and $\sigma_y$ calculated from the wind direction pulsation data are basically the same as the Pasquill results with the same stability type. When comparing the same type of weather of the mountain area and Pasquill, the mountain area $\sigma_z$ is 1.9-2.5 times that of the plain and the mountain area $\sigma_y$ is 2.0-2.5 times that of the plain. Therefore, we can generally consider that the diffusion parameters of the mountain area are 2.0-2.5 times those of the plain's diffusion parameters. When the wind is especially strong, the topographical perturbation is even stronger. If we use the photographic method, when there is a strong northwest wind of the D type, mountain area $\sigma_z$ is 8 times that of the plain. Therefore, from these test results which are average conditions, we can approximately consider that if we use the diffusion parameters of plain conditions to estimate the concentrations of mountain areas, then it is 4-6 times the actual height. Houind [10] carried out
plateau diffusion tests in certain mountain lands of a mountain area and the results of D type weather \( \frac{C_{\text{calculated}}}{C_{\text{measured}}} = 6.0 \) are identical to those of this paper. In the same way, Start \([11]\) carried out separate diffusion tests on the tops of mountains and in mountain valleys and the neutral condition (equivalent to the C-D type) \( \frac{C_{\text{calculated}}}{C_{\text{measured}}} = 5 \) also is basically the same as the results in this paper.

2. Relationship of Mountain Area's Diffusion Parameters and Wind Direction

Because of the non-uniformity of the mountain area topography's roughness space distribution, great differences are created in the diffusion parameters which follow the direction of the airflow. If the wind is to the south, the topography is relatively level and when the wind is to the north, the upstream is the topography of the high mountain fluctuations. These two conditions have very large differences towards the perturbation of the airflow. By comparing lines 1 and 2 and 3 and 4 of Fig. 2a, we can see that the C-D type of the northeast wind is close to twice as large as the C type \( \sigma_z \) of the south wind and when there is a strong northwest wind, it is even larger. If there is a strong northwest wind, the \( \sigma_z \) of the D type is also much larger than the B type when there is a south wind. Given the same stability type, it can reach 4-5 times larger. Therefore, the wind direction is a very important factor in selecting the mountain area's diffusion parameter.

3. The Mean Wind Velocity Profile Characteristics of the Mountain Area's Near Ground Layer

The mountain area's mean wind gradient data of the near ground layer less than 100 meters shows that when there are non-neutral conditions, the mean wind velocity profile can be approximated by the logarithmic linear law. Its \( \alpha \) value is much
smaller than that of the plateau and the mean results of this paper is $1.8\pm 1.15$. The vertical direction perturbation of this topography is large which creates mixed uniformity. Neutral conditions basically satisfy the logarithmic distribution and the roughness length is 0.62 meters.

References

[9] A.S. Monin, the same as [4], PP331-341.
[10] E. Houind, the same as [6], PP214-217.
一次山区大气扩散试验结果的初步分析

大气试验技术小组

一、前言

随着工业的不断发展，每天排放到大气中的有害气体越来越多，要保证人们生活的大气环境满足空气质量标准，一方面对新建企业要作合理布局，对已建企业的排放物质要加以控制；另一方面对污染物质排放的控制程度要作预告，所有这些，都迫切需要了解不同气象条件下大气对污染物质的稀释能力。

近年来，由于在复杂山区和海岸沿岸的建厂越来越多，因而不均匀地形条件下低层大气结构和大气扩散规律的研究也日益受到重视。山区与平原相比，大气近地层结构和扩散稀释能力都极不相同。如何充分利用山区的有利因素，避开不利条件减少山区建厂的工业污染，使大气这个自然环境为工程设计和工业合理布局服务是大气物理工作者的一项重要任务。

本文利用1975年春秋季，在某山区作的人工烟云和中子活化烟的扩散试验结果及有关的气象观测资料，用不同方法计算了该地区的气扩散参数，特别强调了污染在山区和平原扩散稀释能力的差别，并和国外有关结果比较，得出一些有益的结论。

二、试验概况及资料来源

1. 地形
   试验地点为一山区，其地形如图1所示。图中A点为高98.2米的铁塔，塔基位于海拔372米的台地上，它的西、北和东面为高山地区，南面为相对平坦区，塔处在南北走向山沟出口处的一侧。

2. 塔上的气象观测
   气象观测仪器安装在从塔架伸出来的活动悬臂上，臂长为塔身边长的2倍。应用电接风向风速计、热敏电阻温度计和热线风速仪（分别在2.13.4.22.4.31.4.44.9.62.9.80.9和97.4米八度上）作风向风速测，每小时观测一次。平均时间为20分钟。水平风向脉动资料，采用改进后的EL-2型瞬时风向风速计（安装在49.4米高度上）获得。

*由清华大学、中央气象局、北京大学、中国科学院大气物理研究所和北京高弹体物理研究所共同组织，并参加工作的是有北京大学、清华大学工农系统和中国科学院地理研究所。
3. 人工烟云扩散试验
在铁塔不同高度上架设 48 公斤重的烟筒，作为人工烟云的
释放源，这种方法产生的烟云均匀。每次发烟时间为 8—12 分钟。在铁塔的下风方，用普通
相机和地面立体摄影机两种方法对烟云进行连续拍照。每次发烟可连续拍摄十至二十
张照片，取样时间约 10 分钟。

4. 示踪元素银的扩散试验
在铁塔 80 米高度上进行了 20 次试验，每次发烟量的
放射性为 200—500 克，其发射方式是将放射性同位素装
在加大喷口里燃烧，形成直径
小于 0.1 毫米的氧化银微粒，以模拟排放气体在大气中的扩散运行情况。放量时分别在下
风方向 0.4、0.8、1.5、3.0、5.0、10.0 及 45.0 公里的七道弧上（相对排放点张角为 60°）的扇
形布置采样点。

在完成山地试验后，还在塔的南边约 2 公里的平坦田野进行了五次试验。分别在下
风方 50、150、250 和 450 米的四道弧上（60° 扇形内）等距地布七个采样点。每次释放放射
素的放射性为 100 克。

三、用照相方法测定烟云的扩散参数

1. 扩散参数的计算方法
在释放点的下风侧，对烟云轨迹拍照，由烟云平均轮廓计
算垂直扩散参数 $\sigma_z$ 的基本关系式

$$\sigma_z^2 = x \left( \ln \frac{z}{z_m} \right)^{-1}$$

式中 $x$ 为平均烟道轴线到可见边缘的距离（或称垂直半宽度）$z_m$ 为最大垂直半宽度，$e$
为自然对数的底。

应用解此方程求解超方程（1），就可根据在下风方某一距离上测得的 $z$ 和 $z_m$ 值得到
垂直扩散参数 $\sigma_z$。用完全类似的方法，可以得到该风方向的扩散参数 $\sigma_v$。

2. 主要结果

（1）过山气流背风坡的扩散
当有背风时，因不熟空气主体的山壁气流中送出，烟塔上顶
点的风向以东北风为主，烟道相对平缓，试验测得的五次资料平均结果见图 2a 直线 1。（以后除特殊说明外，稳定风均按 PasquillIII 分类方法给出。）

（2）地方性局地环流控制下的扩散
a. 偏北风情况下的扩散
当有系统过山气流时，晴天夜间，山区堆积的冷空气主
体由东部山谷中送出，稻塔上烟道顶点的风向以东北风为主，烟道相对平缓，试验测得的
五次资料平均结果见图 2a 直线 2。

b. 偏南风情况下的扩散
当有近地气流时，因不熟空气主体的山壁气流中送出，烟
塔上顶点的风向以东北风为主，烟道相对平缓，试验测得的五次资料平均结果见图 2b 直线 3 和 4。

（3）相对平坦区的扩散
为了比较说明背风坡不同位置扩散状态的差别，对相对
平坦区的坡地（见图 1）排放出来的烟道，也进行了拍照和量测。它的北向为 500 平方
米范围的建筑物，平均高度为 20 米，它的南是比平坦的农田，烟道高度为 37 米。

当有系统北风时，烟道仍处于高差稍小的陡峻区，加上建筑物的影响，烟道宽度
仍较大，4 次测定的平均结果见图 2b 直线 1。

当气流从南向平坦区吹来时，烟道比较平直，三次测定的平均值见图 2b 直线 2。
图 2 用相法测得的 \( d_e \) 随距离变化曲线

四、用风向脉动资料计算扩散参数

1. 风向脉动标准差 \( \sigma_e \) 的计算 由烟云横向扩散和释放点风向脉动资料的统计分析，可得出风向脉动资料推算污染物浓度分布的方法。其风向脉动标准差表达式为

\[
\sigma_e = \frac{1}{N} \sum_{i=1}^{N} \left( \theta_{i} - \bar{\theta}_i \right)
\]

其中 \( \theta_i \) 为脉冲时间，\( \bar{\theta}_i \) 为脉冲平均，\( \theta_{i} - \bar{\theta}_i \) 为风向脉动标准差。在实验中，采用改进后的 DL-2 型脉冲风向脉动计，其频率大于 5 秒，风向记录器的走纸速度为 0.3 毫米/秒，在脉冲时间 \( t \) 内，每 5 秒读一个风向脉动值 \( \theta_i \) 对不同的平均时间，得到不同的 \( \sigma_e \) 的平均序列，为 \( \sigma_e \)，其方差表达式

\[
\sigma_e = \frac{1}{N} \sum_{i=1}^{N} \left( \theta_{i} - \bar{\theta}_i \right)^2
\]

其中 \( \bar{\theta} \) 为脉冲平均，\( N \) 为平均时间。由 (2) 可以导出 \( \sigma_e \) 随平均时间 \( t \) 的变化曲线，也可计算出各种不同平均时间的 \( \sigma_e \) 值。

2. 位置的计算结果 利用塔上 (49.4 米) 风向脉动资料及扩散试验 (烟云和示踪元素) 资料，可以建立以下关系

\[
\frac{\sigma^2}{\bar{\theta}^2} = \frac{1}{\sigma_{\theta}^2}
\]
由扩散实验测定某一距离x处的σ,，与同时观测的σ/μ随x变化的曲线，在曲线上找出

\[ \beta = \frac{\sigma}{\bar{u}} \]  

(4)

可以求出β值。在整个计算中，取样时间τ=10分钟，\bar{u}为10分钟内的平均风速，对山区
情况，σ,是用照相法在x=1000米以内得到的；对平原区，σ,是由根据微度分布资料，
x在450米以内得到的。有关β值的计算结果列于表1和表2。

表1 山 区 β 值

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<th>C-D</th>
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<td>1.7</td>
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表2 平 坦 区 β 值

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<th>D</th>
<th>B-C</th>
<th>平均</th>
</tr>
</thead>
<tbody>
<tr>
<td>β</td>
<td>4.5</td>
<td>4.3</td>
<td>5.3</td>
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从表中看出，在相对平坦地形区，β在2.1到8.9范围内变化，平均为5.2，比Hay和
Paquist\cite{1}计算的（距离100米处）β值2.1倍，与我们在某海岸和陆地进行的扩散试验得
到的（距100—1800米）平均为2.4（其变化范围为2.4—10.5）基本一致。而复杂山区
β=2.0。这个值比上述结果偏低，这一方面反映了山区疏散程度比平坦区大，因而β偏
小；另一方面，由照相资料测得的σ,所决定的β还存在一定的误差，本结果是否反映实际情
况，还有待更多的实测的实测资料证实。

3. σ,与取样时间的关系 \( \sigma_t \) 与取样时间τ的关系可以经验性地表示为

\[ \sigma_t = \sigma_0 \left( \frac{\tau}{\tau_0} \right)^n \]  

\[ n = 0.5 \]

1 山区，偏南风，C-D类，18次平均。
2 山区，偏北风，D-E类，18次平均。
3 山区，偏北风，E类，4次平均。
4 平坦区，偏北风，D类，3次平均。
5 平坦区，偏南风，C类，3次平均。

图3 由风向脉动资料计算σ,。
\[
\frac{\sigma(x)}{\sigma(y)} = \left( \frac{x}{y} \right)^{\alpha}
\]  (5)

从6次山区塔上观测的2小时资料中，分别计测了r = 10，20，30，60，90和120分钟的6组数据，然后应用线性回归分析方法，很容易求出P值来。6次资料P值平均为0.21，其变化范围为0.14—0.31，国外平原地区通常取P = 0.2，与本文结果较为一致。

4. \( \sigma_x \)的计算结果。根据前面已经得到的 \( \langle \sigma_x \rangle \) 和P值，可以很方便地求出不同下风方距离上的 \( \sigma_x \)值，对山区和平原地形不同风向和不同稳定性类的结果见图3。

五、用滑线资料计算扩散参数

1. 平均风速分布特征。我们将所观测的平均风梯度资料（145次），按照风速垂直梯度分成逆、中性和递减三种不同稳定性类型，每一类的平均风速分布见图4。

从图1（8次平均）看出，直到100米高度，平均风速随高度分布基本上满足大于对数线性规律，观察值和计算值两者相差不大。其风向主要为偏北风。

图2（55次平均）代表中性层的平均风速分布，可以看出，直到100米高度，风基本是均匀分布的，计算值与观测值一致。同时，很容易由直线与纵轴交叉点得到平均粗度高度为0.62米。

从图3（77次平均）看出，60米以上基本上满足对数规律，再往上风速随高度缓慢地减小，不过，整层用对数线性规律去逼近，计算值与观测值比较一致。其风向主要为偏南风。

为了说明地形粗度高度变化对平均风速分布的影响，我们将中性层数据又按风向进行了分类。图5的曲线1和2就是分别代表偏南风和偏北风的平均风速分布。从中看出，风速分布是由两根不同斜率的对数线组成，这两种不同斜率反映了两种不同粗度地形的特征。
形对它的影响，低的部位表示塔附近地形对气流的影响，高的部位反映了与塔附近地面层高度不同的更远地形影响，因而两部分的粗糙度度数也不一样。关于地形变化对风速影响的影响国内已有一些结果，比较一致地认为受塔附近地形影响的低层与受远处的地形影响的高层气流之间有明显界面，在这个界面上风速出现拐点。本文资料分析表明，风速拐点高度平均在60米左右，对单个风线拐点高度随风向不同而异。

2. 对阵线性风线参数计算及结果

从上一节讨论可以看出，在非中性情况下，平均风速拐线均可用对阵线性关系去逼近。Senshu[1]在配同试验的气象观测表明，阵风线性规律在时速超过100米，有时可达500米，除了少数不符合此规律的风线（如90次非中性风线中有5次阵风波浪条件下的抛物线状）外。本文作了各种稳定度类的对阵线性风线参数的计算。

近地面层相似理论只有在平垫均匀条件满足时才能应用，而本实验地点山区，严格讲是不满足的。我们这里借用一些由相似理论导出的关系式，作为一种经验性的近似，不作理论讨论，由近地面层的相似理论，平均风速与高度随高度分布可以表达成

\[ u(z) = \frac{u_0}{K} \left( \ln \frac{z}{z_0} + a \frac{z}{L} \right) \]  

\[ T(z) - T(z_0) = T_a \left( \ln \frac{z}{z_0} + a \frac{z}{L} \right) \]  

式中 \( u_0 \) 是摩擦速度，\( T_0 \) 是温度尺度，\( K \) 为卡门常数（通常为0.4），\( z_0 \) 为粗糙度长，\( L \) 为Obukhov长度尺度，\( \alpha \) 为一恒定常数。

同样，我们假设每次观测的平均风和温度梯度，可以写成以下实验表达式

\[ u(z) = A_1 \log z + B_1 z + C_1 \]  

\[ T(z) = A_T \log z + B_T z + C_T \]  

式中 \( A_1, B_1, A_T, B_T, C_1 \) 和 \( C_T \) 为每次风和气温的基线值，应用二元线性回归方法求出，又由（6）（9）对比分析，可以导出以下关系

\[ u_0 = 0.174 A_1 \text{（米/秒）} \]  

\[ L = 13.3 A_1 / A_T \text{（米）} \]  

\[ \alpha = 15.2 \left( \frac{B_1}{A_1} + \frac{B_T}{A_T} \right) A_1 A_T \]  

\[ \log z_0 = - \frac{C_1}{A_1} \]  

按照上述方法，为配合烟云扩散实验资料，一共计算了42次风线例子。有关\( \alpha \) 值国外还有许多结果，为了比较本文的\( \alpha \) 值列于表 3。

<table>
<thead>
<tr>
<th>作者</th>
<th>Monin-Obukhov</th>
<th>Primley</th>
<th>Yamamoto</th>
<th>Taylor</th>
<th>Panolsky</th>
<th>Kondo</th>
<th>Senshu</th>
<th>本文</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>2.25</td>
<td>2.6</td>
<td>4</td>
<td>2–12</td>
<td>2.5–12</td>
<td>4.5</td>
<td>3.3</td>
<td>1.07</td>
</tr>
</tbody>
</table>

从表中可以看出，除了 Monin-Obukhov 和 Senshu 给出的值外，本文的 \( \alpha = 1.8 ± 1.15 \text{（0.5–6.0）} \) 值最小，这可能与山区地形扰动大，使风速变化减小有关。

3. 用风线资料计算扩散参数

垂直方向标准差 \( \sigma_z \) 可用以下经验关系

\[ \sigma_z = \frac{C_z}{u} g(x) \]  

式中 \( C_z \) 为垂直方向风速脉动标准差，\( g(x) \) 为距离函数，由 Monin[5] 给出的结果。

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σν可表达为

$$\sigma_n = \sigma_0 \left[1 - \frac{1}{(\xi)} \right]^{\frac{1}{4}}$$  (12)

式中(ξ)为一常数函数，下面计算时，均用对数线性关系图近似。ξ = $\frac{x}{L}$，此方程也是在平
稳均匀条件下导出来的，我们这里借用这个关系式，只作为一种试验性的近似。按此处
理，如果与实验结果相差很大，说明这种近似并不合理；反之，这样的近似实际上工作中是
可以接受的。则(12)式可写为

$$L > 0 \quad \sigma_n = \sigma_0 \left[1 - \frac{\xi}{1 + a\xi} \right]^{\frac{1}{4}}$$  (13)

$$L < 0 \quad \sigma_n = \sigma_0 \left[1 + \frac{|\xi|}{1 - a|\xi|} \right]^{\frac{1}{4}}$$

(11)式中的$g(x)$，在实际计算中，经验地给成$s^r$，$r$由平均风速按下式指数规律变化的
指数$\nu$给出($r = \frac{2 - n}{n}$)。

$$\bar{u} = u_0 \left(\frac{x}{n}\right)^{\frac{1}{n}}$$

则

$$L > 0 \quad \sigma_n = \frac{\nu}{\nu_0} \left[1 - \frac{\xi}{1 + a\xi} \right]^{\frac{1}{4}} \cdot \left(\frac{r}{x}\right)^{\frac{1}{n}}$$  (14)

$$L < 0 \quad \sigma_n = \frac{\nu}{\nu_0} \left[1 + \frac{|\xi|}{1 - a|\xi|} \right]^{\frac{1}{4}} \cdot \left(\frac{r}{x}\right)^{\frac{1}{n}}$$

式中$\bar{u}$取整层风速的平均，$\nu_0$，σ，$\nu$ 及 $r = \frac{2 - n}{n}$ 已经计算给出。$\bar{u}$ 取观测层的几何平
均高度，(在实际计算中，$n = \sqrt{97.4 \times 2 \approx 14}$ 米)。则由(15)式可导出$\sigma_n$ 与下风位
离$x$ 的关系来。

为了对这种计算$\sigma_n$ 的方法作检验，我们将计算值和同时作的烟云扩展试验实测的$\sigma_n$
进行比较。由烟云平均轮廓的半厚度$s$ 的实验资料，应用以下的近似关系

表 4 计算$\sigma_n$ 与烟云实测比较

<table>
<thead>
<tr>
<th>时间</th>
<th>距离X (米)</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>300</th>
<th>400</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:30</td>
<td>实测</td>
<td>3.4</td>
<td>4.5</td>
<td>5.4</td>
<td>6.4</td>
<td>8.5</td>
<td>10.3</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>计算</td>
<td>1.4</td>
<td>2.03</td>
<td>2.65</td>
<td>3.26</td>
<td>4.7</td>
<td>6.2</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>8:30</td>
<td>实测</td>
<td>3.4</td>
<td>5.1</td>
<td>7.0</td>
<td>8.8</td>
<td>13.5</td>
<td>18.0</td>
<td>28.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>计算</td>
<td>3.9</td>
<td>5.45</td>
<td>7.4</td>
<td>9.15</td>
<td>13.4</td>
<td>17.4</td>
<td>23.7</td>
<td></td>
</tr>
<tr>
<td>9:20</td>
<td>实测</td>
<td>3.6</td>
<td>5.0</td>
<td>6.4</td>
<td>7.8</td>
<td>11.0</td>
<td>14.0</td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>计算</td>
<td>3.04</td>
<td>4.4</td>
<td>5.75</td>
<td>7.05</td>
<td>10.2</td>
<td>13.4</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>实测</td>
<td>3.6</td>
<td>5.1</td>
<td>6.6</td>
<td>8.1</td>
<td>11.5</td>
<td>15.0</td>
<td>21.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>计算</td>
<td>2.8</td>
<td>3.94</td>
<td>5.1</td>
<td>6.2</td>
<td>8.9</td>
<td>11.5</td>
<td>16.4</td>
<td></td>
</tr>
</tbody>
</table>

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\[ \sigma_0 = \frac{b}{2.15} \]  

可以很方便地求出 \( \sigma_0 \) 来。由 9 次解线观测和烟云照相时间完全对应的资料（其中七次属 B-C 类两次属 E 类，包括四天实验资料），两种方法计算的 4 次有代表性（包括均速度较好和较差的例子）的结果列于表 4。

从表 4 可以看出，应用相似理论方法，由平均风和温度解线资料，导出的垂直扩散参数与实际情况有较好的一致性，尤其在不稳定条件下均速度更好。为了进一步说明计算值与实际值一致的程度，我们将这九次例子（40—300 米之间）所有 \( \sigma_0 \) 的计算值与实际值的比较作了统计，结果表明：比值小于 1.5 的占 76.1%，小于 2 的占 87.2%，大于 2 的基本上是 E 类的例子出现的。这说明尽管山区均速度条件很难满足，相似理论方法作为经验性的使用，不会引起较大的误差。我们应用此方法一共计算了 42 次例子，并按长度尺度大小分成五种稳定度类，每类平均参数列于表 5，\( \sigma_0 \) 的计算结果见图 6。

<table>
<thead>
<tr>
<th>稳定度</th>
<th>( L (\text{米}) )</th>
<th>速度范围</th>
<th>次数</th>
<th>( \sigma_0 ) (米/秒)</th>
<th>( \sigma ) (米/秒)</th>
<th>( r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-27</td>
<td>B-C</td>
<td>14</td>
<td>0.290</td>
<td>1.8</td>
<td>2.70</td>
</tr>
<tr>
<td>II</td>
<td>-100</td>
<td>C-D</td>
<td>9</td>
<td>0.442</td>
<td>1.8</td>
<td>3.94</td>
</tr>
<tr>
<td>III</td>
<td>-300</td>
<td>D-E</td>
<td>6</td>
<td>0.280</td>
<td>1.8</td>
<td>2.80</td>
</tr>
<tr>
<td>V</td>
<td>100</td>
<td>E-F</td>
<td>8</td>
<td>0.133</td>
<td>1.8</td>
<td>1.90</td>
</tr>
<tr>
<td>VI</td>
<td>25</td>
<td>F</td>
<td>5</td>
<td>0.086</td>
<td>1.0</td>
<td>1.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1, II 静风.</th>
<th>V, VI 静风.</th>
</tr>
</thead>
<tbody>
<tr>
<td>○ 代表计算点值.</td>
<td></td>
</tr>
</tbody>
</table>

图 6 轮线观测资料的扩散参数 \( \sigma_0 \)。

六、用铅的浓密分布计算扩散参数

应用实测地面铅浓度资料，分别计算了水平和垂直扩散参数，其 \( \sigma_0 \) 由

\[ \sigma_0 = \frac{\mathcal{C} \rho y^2}{\mathcal{C}_v} \left( \frac{\mathcal{C} \rho y}{\mathcal{C}_v} \right)^{1/5} \]  

给出，式中 \( \mathcal{C}_v \) 为采样点实测浓度。\( \sigma_0 \) 用横向积分浓密方法求出，其表达式为

\[ C_v = \int \frac{\mathcal{C}_v \rho dy - \sum C_i \Delta y}{\mathcal{C}_v} - \frac{2 \rho}{\sigma^2} \]  

式中横向积分浓度 \( C_v \)，铅锌 \( \rho \)，平均核风速 \( u \) 和有效高 \( h \) 均为已知量，则 \( \sigma \) 可以求出。

利用上述处理方法，计算了三次平原地形偏南风条件的实验资料，其 \( \sigma_0 \) 和 \( \sigma_0 \) 的结果见图 7。

对山区的 20 次试验，由于 800 米以内地形起伏太大，浓度不满足正态分布，从 800 米
开始地形起伏较小，其浓度近似满足正态分布。我们只作了 800 和 1500 米两道溪上天气类型属于 E 类（偏北风情况）的 9 次例子的 $\sigma_z$ 计算，其平均结果也见图 7。

![图 7 由稀的浓度分布计算扩散参数](image)

1. 平坦地形 $\sigma_z$，C 类，3 次平均，偏南风。
2. 平坦地形 $\sigma_z$，C 类，3 次平均，偏南风。
3. 山区 $\sigma_z$，E 类，6 次平均，平均时间一小时，偏北风。
4. 代表平坦地形实测值。

图 7 由稀的浓度分布计算扩散参数

七、结果讨论

1. 山区和平原扩散参数比较。由于山区地形起伏，扩散参数往往比平原要高，为比较起见，我们将从 Pasquill-GiffordI 的扩散参数随距离变化曲线中取得的 $\sigma_x$ 和 $\sigma_z$ 为平原情况的代表值，与本文四种方法给出的同一类稳定性结果进行比较，其 800 米处扩散参数的比值列于表 6。

可以看出，在平坦地区作的图和风向脉动资料计算的 $\sigma_x$ 和 $\sigma_z$ 与同一稳定性类的 Pasquill 结果基本上一致。山区与 Pasquill 同类天气比较，山区 $\sigma_z$ 为平原的 1.9—2.5 倍，山区 $\sigma_x$ 为平原的 2.0—2.5 倍。因此可以平均地认为，山区的扩散参数为平原扩散参数的

<table>
<thead>
<tr>
<th>天气类型</th>
<th>C（西风）</th>
<th>E（北风）</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_x/\sigma_2$</td>
<td>$\sigma_z/\sigma_2$</td>
</tr>
<tr>
<td>平原</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>山区</td>
<td>—</td>
<td>1.3</td>
</tr>
<tr>
<td>平原</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>山区</td>
<td>—</td>
<td>2.5</td>
</tr>
<tr>
<td>平原</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>山区</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

注：凡标有 P 的表示 Pasquill、平原情况的值，下标有 “山” 的表示山区地形实测结果，标有 “偏” 的表示偏北风情况计算结果。
2.0—2.5倍，当风特别大时，地形扰地更强，两者差别大。如用照相法，在西头大风时，山区σ为平原的8倍。因此，从本实验结果，就平均情况，可以近似认为，如果采用平原情况的扩散系数来估计山区的浓度，则比较实际高4—6倍。Hound在山区的某一开阔处做过高架桥扩散试验，对D类天气C_{eq}/C_{ref}=6.0，与本文的结果比较一致。同样，Star在山顶和山谷中分别作扩散试验，中性情况（相当C—D 类）C_{eq}/C_{ref}=5，也和本文结果基本一致。

2.山区扩散参数与风向关系　由于山区地形粗糙度空间分布的不均匀性，造成扩散系数随气流来向有很大差别。如偏南风时，地形较平坦，偏北风时，上游为高山起伏的地形，这两种地面状况对气流的扰动差别很大。把图2a中1、2和3、4作比较可以看出，东北风的C—D类比南风的D类σ大将近两倍。在西北风大风时大得更多。如西北大风时D类的σ比南风时的A类还要大得多，同一稳定度类，可大4—5倍。因此，在山区扩散参数的选取中，风向是一个非常重要的因素。

3.山区近地面层平均风速廓线特征　100米以下近地面层山区平均风速廓线分析表明，非中性条件下平均风速廓线可以用对数线性规律描述。其σ值比平原小得多，本文平均结果为1.8±1.15，这地形垂直方向扰动大，造成混合均匀有关。中性条件下数据满足对数分布，其粗糙度长为0.62米。

参考数据
[1] 中国科学院冰川冻土研究所等，地面蒸发散影响的霜及其应用，1973。