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The Influence of Stability Classification on Atmospheric Diffusion Calculations for Elevated Releases over a Terrain of Major Roughness

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Abstract

A series of atmospheric tracer experiments with 100 m release height have been performed at the Kernforschungszentrum Karlsruhe (KfK) over a terrain of major roughness. The concentration data of the tracers are used to validate the Gaussian plume model if the following methods of stability classification are used:

- Standard deviation of the vertical wind direction observed at 100 m height,
- standard deviation of the horizontal wind direction observed at 40 and 100 m heights as recommended by the USNRC,
- temperature differences between 30 and 100 m heights and 2 and 100 m heights as recommended by the USNRC.

Different sets of dispersion parameters are applied in the Gaussian plume model:

- recommended by IAEA,
- derived from the KfK tracer data used in the validation. In this case the five methods of stability classifaction mentioned above are applied to derive the dispersion parameters.

The validation is based on a linear regression analysis between the calculated and observed logarithms of the normalized diffusion factor and on the ratios of the calculated and observed normalized diffusion factors.

The results demonstrate that the most qualified method of stability classification is that based on the standard deviation of the vertical wind direction. The method based on the standard deviation of the horizontal wind direction is better than those relying on the temperature differences. The dispersion parameters derived from the tracer concentrations used in the validation procedure yield slightly better results than those recommended by IAEA.

Zusammenfassung

Bestimmung der Ausbreitungskategorien bei atmosphärischen Ausbreitungsrechnungen für große Quellhöhen über Gelände mit großer Bodenrauhigkeit

Am Kernforschungszentrum Karlsruhe (KfK) wurden atmosphärische Ausbreitungsexperimente mit Emissionshöhen von 100 m über einem Gelände großer Bodenrauhigkeit durchgeführt. Die dabei gemessenen Daten werden benutzt, um das Gaußmodell bei Anwendung folgender Methoden zur Bestimmung der Ausbreitungskategorien zu überprüfen:

- Standardabweichung der in 100 m Höhe gemessenen vertikalen Windrichtung,
- Standardabweichung der in 40 m und 100 m Höhe gemessenen horizontalen Windrichtung, wie von der USNRC empfohlen,
- zwischen 30 m und 100 m bzw. 2 m und 100 m Höhe gemessene Temperaturdifferenz, wie von der USNRC empfohlen.

Folgende Sätze von Ausbreitungsparametern werden in dem Gaußmodell benutzt:

- wie von der IAEA empfohlen,
- abgeleitet aus den oben erwähnten Tracerdaten des KfK. Bei der Ableitung werden die fünf aufgeführten Methoden zur Bestimmung der Ausbreitungskategorien angewandt.

Die Überprüfung des Gaußmodells stützt sich auf eine lineare Regressionsanalyse zwischen den Logarithmen des berechneten und gemessenen normierten Ausbreitungsfaktors und auf das Verhältnis zwischen berechnetem und gemessenem normierten Ausbreitungsfaktor.

Die Ergebnisse zeigen, daß sich die Standardabweichung der vertikalen Windrichtung am besten eignet zur Bestimmung der Ausbreitungskategorie. Es folgen die Standardabweichung der horizontalen

Windrichtung und schließlich die Temperaturdifferenz. Die aus den Tracerdaten abgeleiteten Ausbreitungsparameter führen bei der Überprüfung des Gaußmodells zu besseren Ergebnissen als die von der IAEA empfohlenen Parameter.

Table of Contents

1. Introduction

A series of atmospheric dispersion experiments with releases at 100 m height over a terain of major roughness have been performed at the Kernforschungszentrum Karlsruhe (KfK, Karlsruhe Nuclear Research Center). These experiments provide a source of data which allow to examine the effect of stability classification on atmosperic diffusion calculations.

Classification methods based on the vertical temperature difference ΔT or the standard deviation σ_Θ of the horizontal wind direction have been recommended by the USNRC /US72/ and have been generally adopted for atmospheric diffusion calculation in many countries including the People's Republic of China. Moreover, at KfK the standard deviation σ_ϕ of the vertical wind direction is used for stability classification, too.

The purpose of this study is to quantify the uncertainty associated with the centerline ground-level normalized exposure estimates for elevated releases and major roughness terrain derived from different methods of classification relying on the KfK data set. Besides a comparison is performed among these different methods of stability classification.

2. The Dispersion Experiments Performed at the KfK Site

2.1. Site Description and Meteorological Measurements

Figures 1 and 2 show a photograph and a map, respectively, of the KfK site and its environment. The test field consists of open spaces and builtup as well as wooded areas. The 10 - 30 m high buildings on the premises of the research center and the forests surrounding it characterize the surface roughness of the site. A roughness length of about 1.5 m has been determined by evaluating the wind profiles measured at the meteorological tower.

The meteorological information system of KfK includes 48 instruments in total which measure the vertical profiles of the wind velocity, wind direction, wind vector, and temperature at the 200 m high meteorological tower. A detailed description of the instrumentation and computerized data acquisition and processing is given in /HO84/.

2.2. Performance of the Experiments

The tracers tritiated water vapor (HTO), difluorodibromomethane (CF_2Br_2), and Frigen-11 ($CFCl_3$) have been released, the first one via the stack of the FR2 research reactor, the others from a platform of the meteorological tower. The position of the meteorological tower and the stack can be seen from Figs. 1 and 2, respectively. As shown in Tab. 1, in some of the experiments two different tracers were released simultaneously.

The tracers were emitted from electrically heated evaporating boilers. The emission rates were determined by measurements of the reduction in weight during the time of steady-state conditions of evaporation. After August 1976 the filling level of the boilers was also controlled.

It had to be ensured that all sampling locations were exposed to the tracer plume generated at a constant rate of emission before sampling started. Therefore, the evaporating boilers were heated up in time before sampling of the tracers begun. This time depends on the heating-up time of the respective evaporator, the prevailing wind velocity, and the maximum distance of the sampling locations from the source.

Air was sampled at 25 up to 61 positions downwind of the source during up to two successive periods of 30 min duration each. The sampling area was different in each experiment, depending on the wind direction and the stability class to be expected. The stability class determined the angular width of the area and the minimum and maximum downwind distances of the sampling positions. These were arranged approximately on five concentric arcs of a circle surrounding the source. Each radius of the arcs was twice the radius of the preceding one.

2.2.1. Tritiated Water

Sampling was carried out by congelation of the airborne water vapor on an aluminum plate located on slabs of dry ice. A layer of hoarfrost was formed on the plate. The hoarfrost was scraped off and filled manually into a test flask.

A liquid scintillation spectrometer was used to determine the specific tritium activity of the air humidity, whose limit of detection was about 1 pCi/g, i.e. a factor of 10^3 below the measured concentration maxima. The tritium activity concentration of the air equals the product of the specific activity of the sampled air humidity and the absolute water vapor content of the ambient air which was measured at various locations in the sampling area. The errors in concentration were about 6 %.

2.2.2. Halogenated Hydrocarbons

During sampling ambient air was sucked via a calibrated capillary tube into an evacuated glass sampler of about 1 l volume. An electronic clock controlled electromagnetic valves which opened and closed the capillary tubes. At the clock a time interval between zero and six hours had been preset in steps of 30 min duration. In each experiment the preset intervals of all clocks were identical and all clocks started simultaneously. During the preset interval the samplers were brought into the selected sampling area.

At the laboratory the air samples were analyzed by gas chromatography using an electron capturing detection with Ni-63, operated at 105 °C. The $CFCl_3$ tracer has a background of about 1.5 µg/m³. As the other tracer, CF_2Br_2, is but rarely used in industrial applications, no background was detectable. The detection limits of $CFCl_3$ and CF_2Br_2 are smaller than 0.1 µg/m³ and 0.8 µg/m³, respectively. For concentrations well above the detection limit the errors are about 5 % for both tracers.

The detailed measured data of each experiment are published in /TH76a, TH81a/.

2.3. Determination of Dispersion Parameters

The double Gaussian function for elevated sources describing the concentration C(x,y) close to the ground level at the field point P(x,y) downwind of the source reads:

$$C(x,y) = \frac{\dot{A}_o}{\pi u \sigma_y(x)\sigma_z(x)} \exp\left(-\frac{y^2}{2\sigma_y^2(x)} - \frac{H^2}{2\sigma_z^2(x)}\right) \qquad (1)$$

This follows from the diffusion equation for steady-state conditions, constant emission rate, and reflection of the tracer at the ground, where

$\dot{A}_o$	emission rate in Ci/s or g/s,
u	mean wind velocity measured at 60 m height in m/s,
x	downwind distance in m,
y	crosswind distance in m,
H	emission height in m,
σ_y, σ_z	horizontal and vertical dispersion parameters, respectively, in m.

The foot of the source coincides with the origin of the Cartesian coordinate system.

The dispersion parameters σ_y and σ_z describing the horizontal and vertical distributions, respectively, of the concentration perpendicular to the transport direction are functions of the downwind distance x. For this dependence on x, the power functions

$$\sigma_y = p_y x^{q_y} \quad , \quad \sigma_z = p_z x^{q_z} \qquad (2)$$

are chosen. The four coefficients p_y, q_y, p_z, q_z must be found to fit Eq. 1 to the measured concentrations in such a way that the sum of the square deviations becomes a minimum. According to the preceding method the dispersion coefficients p_y, q_y, p_z, q_z of the sampling periods indicated in Tab. 1 were calculated. They are compiled in Tab. 1. A more detailed description of this evaluation technique is published in /TH81b/.

3. Validation of the Gaussian Plume Dispersion Model

3.1. Method of Validation

The normalized diffusion factor $\chi(x,y)$ can be derived from Eq. 1:

$$\chi(x,o) = \frac{C(x,o)u}{\dot{A}_o} = \frac{1}{\pi\sigma_y\sigma_z} \exp\left(-\frac{H^2}{2\sigma_z^2}\right) \qquad (3)$$

A possible way for the validation is to compare the observed and predicted normalized diffusion factors χ_{ob} and χ_{pr}. The KfK atmospheric diffusion experiments provide systematically the χ_{ob}-values for different stability classes /TH76a,TH81a/ by using the following equation:

$$\chi_{ob} = \frac{C_{max}\ u}{\dot{A}_o} \qquad (4)$$

Here C_{max} is the maximum concentration in each sampling arc.

Using the dispersion parameters recommended in /IA82/ for 100 m release height compiled in Tab. 2, χ_{pr} can be calculated from Eq. 3. The dispersion parameters recommended in /IA82/ are derived from tracer experiments performed at KFA Jülich and KfK /GE81/.

The statistical tools commonly employed in data analysis are based on the assumption that the data are distributed normally. It has been shown, however, that the frequency distribution of air concentration is not always a normal one /MI79/. An analysis of both the observed and predicted normalized diffusion factors indicates that both approximate a lognormal rather than a normal distribution. Consequently, the logarithms of the data were used in all statistical calculations.

3.2. Stability Classification

Five types of meteorological measurements were used to determine the atmospheric stability classes:

1. The standard deviation σ_ϕ of the vertical wind direction measured by a vector vane at 100 m AGL (above ground level).

2. The standard deviation σ_θ of the horizontal wind direction measured by a vector vane at 40 m AGL.

3. The standard deviation σ_θ of the horizontal wind direction measured by a vector vane at 100 m AGL.

4. The vertical temperature difference between 2 m and 100 m AGL.

5. The vertical temperature difference between 30 m and 100 m AGL.

Tab. 3 shows the criteria used to determine the stability classes. The stability classes that prevailed during the diffusion experiments had been determined at KfK using the σ_ϕ (100 m)-method. The corresponding classes are listed in Tabs. 1 and 4. The ΔT- and σ_θ-methods have been widely adopted in the U.S., in the People's Republic of China, and in other countries. The diffusion experiments listed in Tab. 1 and used in this paper are those from /TH76a, TH81a/ for which all meteorological data are available that are necessary for stability classifications as mentioned above.

Comparisons are made between χ_{ob} and χ_{pr} for each column in Tab. 4.

3.3. Results

The results of the linear regression analysis are compiled in Tab. 5. It reveals that the correlation coefficient decreases from 0.512 to 0.315, if stability classes are determined using the σ_ϕ (100 m)-, σ_Θ (40 m)-, ΔT(30 m/100 m)- and σ_Θ (100 m)-method, respectively. The correlation coefficient is statistically significant (confidence level 99 %) for these four methods. No correlation was found for the ΔT(2 m/100 m)-method.

This correlation results because the dispersion parameters recommended in /IA82/ are based on diffusion experiments some of them performed at KfK. For the evaluation of these experiments the atmospheric stability was determined using the σ_ϕ (100 m)-method. As mentioned in Ch. 2.1 buildings up to 30 m height and forests are characteristic of the surface roughness of the KfK site. The methods using σ_ϕ (100 m), σ_Θ (40 m), ΔT (30 m/100 m) and σ_Θ (100 m) mainly reflect the character of the higher air layer but the ΔT (2 m/100 m)-method is more influenced by the character of the lower layer near the ground.

Table 6 shows the frequency distributions of the ratios of the predicted and observed values of the normalized diffusion factor for each method of stability classification. It can be seen from Tab. 6 that an over- or underestimation of the normalized diffusion factor within only a factor of 2 occurs with a frequency of

- 40.7 % for the σ_ϕ (100 m)-method,
- 41.8 % for the σ_Θ (40 m)-method,
- 40.7 % for the σ_Θ (100 m)-method,
- 36.3 % for the ΔT (30 m/100 m)-method, and
- 20.9 % for the ΔT (2 m/100 m)-method.

4. Comparison of Different Methods of Stability Classification

4.1. Frequency of Occurrence of Differences in Stability Classes

It can be seen from Tab. 4 that the five methods do not yield the same stability class during one sampling period. Table 7 shows the frequency of occurrence of differences in classes that had been determined by σ_ϕ (100 m) and the other meteorological data, respectively. The respective information is compiled in Tab. 7, when the σ_Θ- and ΔT-method is applied for different heights AGL. To prepare Tab. 7, the numbers 1 through 6 have been assigned each to the classes A through F.

4.2. Dispersion Coefficients Obtained by the Application of Different Methods of Stability Classification

The mean dispersion parameters $\bar{\sigma}_y$ and $\bar{\sigma}_z$ belonging to the same stability class are calculated via the geometric mean value. Considering Eq. 2 this corresponds to

$$\bar{p} = \left[\prod_{i=1}^{N} p_i \right]^{1/N} \tag{5}$$

and

$$\bar{q} = \frac{1}{N} \sum_{i=1}^{N} q_i , \tag{6}$$

where p and q represent p_y, p_z and q_y, q_z, respectively. N is the number of periods belonging to the same stability class. Based on the information given in Tabs. 1 and 4 five sets of mean dispersion coefficients corresponding to five different methods of stability classification are calculated. The results are listed in Tab. 8.

Table 8 indicates that an atmospheric diffusion experiment program can lead to significantly different sets of dispersion coefficients if methods of stability classification are adopted the criteria of which are taken from the literature. Now it will be investigated which method is best suited for elevated sources and a terrain of major roughness.

4.3. Method of Comparison

Again the logarithms of the observed and predicted normalized diffusion factors χ_{ob} and χ_{pr} are compared in a regression analysis as described in Chap. 3. But now

- χ_{pr} is calculated from the dispersion coefficients compiled in Tab. 8, and
- χ_{ob} is chosen by reference to Tab. 4,

using for each analysis the same method of stability classification.

4.4. Results

The results of the linear regression analysis are compiled in Tab. 9. The correlation is highest with a coefficient of 0.680 again for the σ_{ϕ}-method and decreases monotonously as indicated in Tab. 9. The correlation coefficients corresponding to all methods are statistically significant with a confidence level higher than 99 %. There is a moderate correlation with coefficients between 0.680 and 0.557 for all methods except for the ΔT(30 m/100 m)-method with a coefficient of only 0.268.

Comparison of Tabs. 5 and 9 reveals the following phenomena, and the following explanations can be given:

- With the exception of the ΔT(30 m/100 m)-method, the correlation coefficients in Tab. 9 are higher than those of Tab. 5. The explanations are:

- In Tab. 9 exactly the same experimental data have been used to evaluate the dispersion coefficients for χ_{pr} and to take the χ_{ob} to validate the Gaussian plume model.
- In Tab. 9 the same method of classification is used to establish dispersion coefficients from tracer experiments and to select the dispersion coefficients for χ_{pr} and to select χ_{ob} for the validation.

- In Tab. 9 the ΔT(2 m/100 m)-method is almost as good as the σ_{ϕ}(100 m)-method. This method may well be used for the selection of dispersion coefficients if this method is also used to establish these coefficients from the tracer experiments. Due to the fact that in Tab. 9 the correlation coefficients of the ΔT(2 m / 100 m)-method is higher than that of the ΔT(30 m/ 100 m)-method and is also higher than that of the ΔT(30 m/ 100 m)-method in Tab. 5, the following can be stated:
  - The temperature difference between 2 m and 100 m height reflects better the turbulence intensity at a site like that of KfK than the temperature difference between 30 m and 100 m.
  - It might be expected that a σ_{Θ}-method corresponding to 10 m above the height of disturbance and applied as outlined in Chap. 4.2 will show as good results as the ΔT(2 m/100 m)-method.

Table 10 shows the frequency distribution of the ratios of the predicted and observed normalized diffusion factors. It can be seen from the table that the normalized diffusion factor is over- or underestimated by only a factor of 2 with a frequency of

- 50.6 % for the σ_{ϕ}(100 m)-method,
- 39.6 % for the σ_{Θ}(40 m)-method,
- 38.5 % for the σ_{Θ}(100 m)-method,
- 30.8 % for the ΔT(30 m/100 m)-method, and
- 30.8 % for the ΔT(2 m/100 m)-method.

As compared to the figures of Tab. 6 and described in Chap. 3.3, the σ_ϕ(100 m)- and the ΔT(2 m/100 m)-methods furnish better results. The σ_ϕ(100 m)-method with a frequency of 50.6 % is the best as compared to the other methods.

5. Conclusions

The Gaussian plume model for releases from 100 m height over a terrain of major roughness has been validated by dispersion data of tracers, depending on different methods of stability classification. The tracer experiments were performed in the environment of KfK. The dispersion parameters used in the Gaussian model are those recommended by the IAEA and those derived directly from the tracer experiments, respectively. In the latter case, the method of stability classification is the same in the evaluation of the tracer experiments and in the application of the Gaussian plume model. From the results the following conclusions can be drawn:

- The normalized diffusion factor is more frequently under- than overestimated. This is demonstrated by the slope being smaller than one in Tabs. 5 and 9 and more directly in Tabs. 6 and 10.
- Comparison of the different methods of stability classification yields that the most qualified one is that of σ_ϕ(100 m).
- Concerning the frequency of over- or underestimation of the normalized diffusion factor by only a factor of 2 or less, the σ_Θ-methods are better than the ΔT-methods. For the σ_Θ-methods there is no significant difference between the measurements made at 40 m- and 100 m-heights, and the results are the same independent of whether dispersion parameters are applied as recommended by IAEA, or derived directly from the tracer experiments used in the validation.
- A comparison of the sets of dispersion parameters as recommended by the IAEA or derived from the tracer experiments used in the validation shows that the latter are better qualified. This statement holds especially for the ΔT(2 m/100 m)-method, but not for the ΔT(30 m/100 m)-method.

More generally, the following statements can be made:

- The same series of atmospheric tracer experiments will result in different sets of dispersion parameters if different methods of classification are applied.
- The method of stability classification should be the same for the derivation of the dispersion parameters from tracer experiments and for the application of these dispersion parameters to predict pollutant concentrations.
- Recommended sets of dispersion parameters generally refer to a distinct release height and roughness length and to a well defined method of stability classification. If these dispersion parameters are applied at a new site all these factors should be carefully considered.

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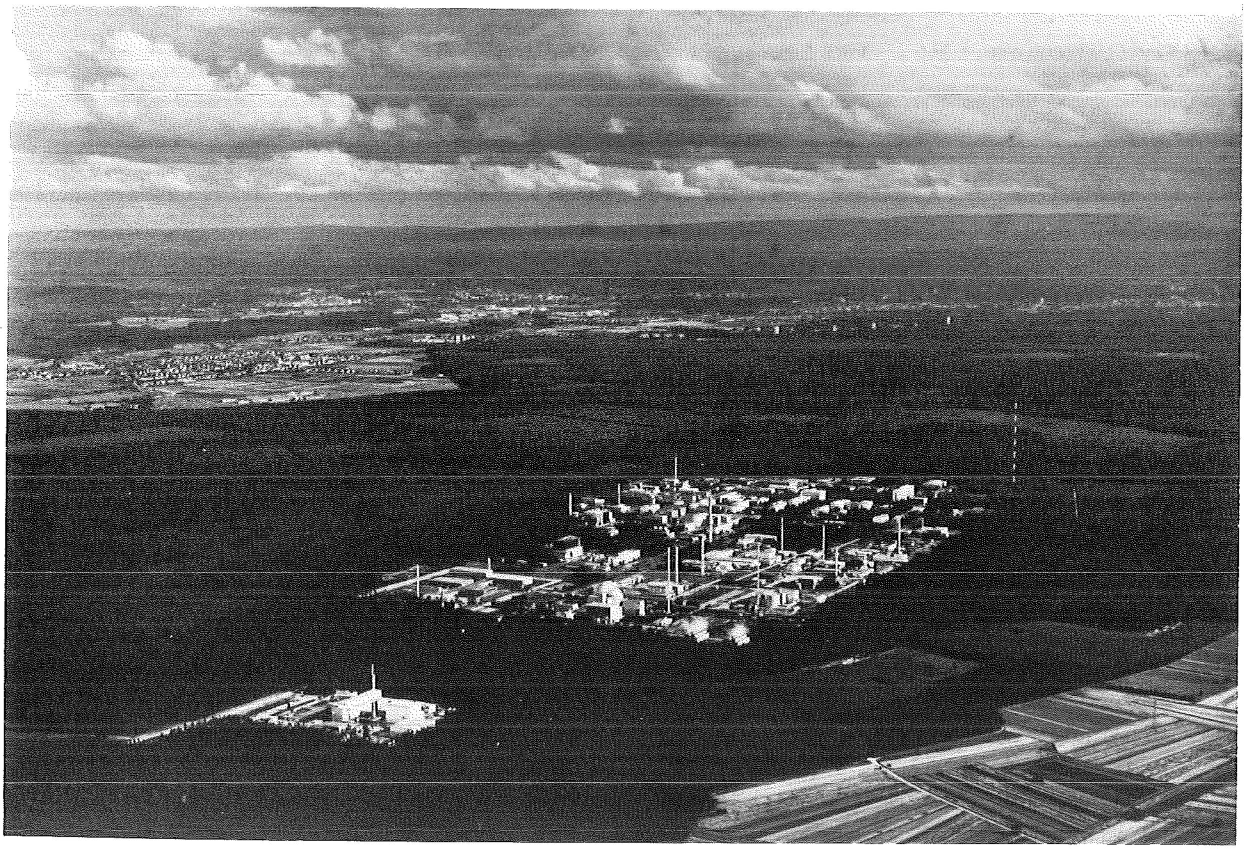

Fig. 1: Aerial photo of the Karlsruhe Nuclear Research Center and its environment, taken from the northwest

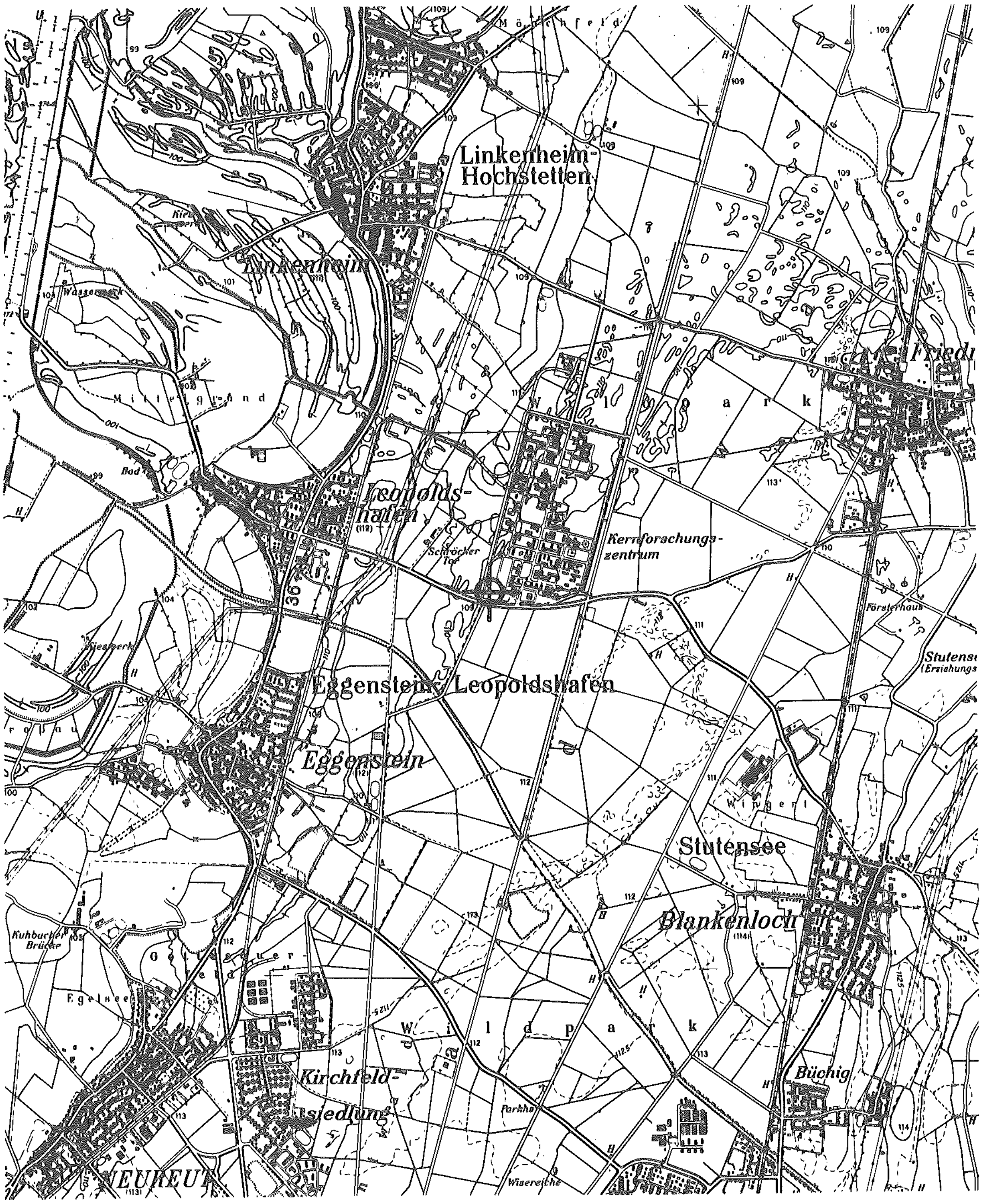

Fig. 2 : Map of the Karlsruhe Nuclear Research Center and its environment, scale 1:60 000; ϕ: position of the meteorological tower.

Table 1: Dispersion Experiments Performed at 100 m Release Height and Dispersion Coefficients Determined /TH76b, TH81b/

No.	Date	Time of Sampling (CET)	Tracer	Stability Class	Dispersion Coefficients, $\sigma = px^q$			
					p_y	q_y	p_z	q_z
1	06.11.1973	20.30 to 21.00	HTO	F	0.782	0.909	0.673	0.586
2	06.11.1973	20.30 to 21.00	$CFCl_3$	F	6.88	0.559	0.776	0.630
3	14.05.1974	14.30 to 15.00	HTO	D	0.330	0.820	0.110	0.980
4	14.05.1974	14.30 to 15.00	CF_2Br_2	D	2.61	0.520	0.0560	1.11
5	14.05.1974	15.00 to 15.30	HTO	D	0.820	0.770	0.110	0.990
6	14.05.1974	15.00 to 15.30	CF_2Br_2	D	0.0420	1.16	0.0360	1.18
7	09.07.1974	15.30 to 16.00	HTO	D	0.0605	1.11	0.189	0.880
8	09.07.1974	15.30 to 16.00	CF_2Br_2	D	0.110	1.09	0.146	0.892
9	07.11.1974	14.00 to 14.30	CF_2Br_2	D	0.00289	1.78	0.805	0.621
10	06.11.1975	14.00 to 14.30	CF_2Br_2	C	0.0760	1.03	0.00154	1.67
11	06.11.1975	14.30 to 15.00	CF_2Br_2	D	4.83	0.470	0.00424	1.51
12	09.11.1976	19.30 to 20.00	CF_2Br_2	E	2.35	o.525	1.44	0.520
13	09.11.1976	20.00 to 20.30	CF_2Br_2	E	3.66	0.573	0.719	0.634
14	25.02.1977	14.10 to 14.40	$CFCl_3$	D	0.0846	1.05	0.00183	1.57
15	25.02.1977	14.40 to 15.10	$CFCl_3$	D	3.42	0.519	0.145	0.911
16	20.04.1977	14.00 to 14.30	$CFCl_3$	A	2.54	0.993	6.91	0.418
17	20.04.1977	14.30 to 15.00	$CFCl_3$	A	0.0194	1.97	7.83	0.458
18	24.05.1977	21.00 to 21.30	$CFCl_3$	D	1.32	0.771	2.70	0.402
19	24.05.1977	21.30 to 22.00	$CFCl_3$	D	0.0229	1.23	2.59	0.404
20	02.08.1977	21.00 to 21.30	$CFCl_3$	E	0.0203	1.37	0.742	0.504
21	02.08.1977	21.30 to 22.00	$CFCl_3$	E	0.000885	1.82	0.722	0.529
22	16.08.1977	20.30 to 21.00	$CFCl_3$	E	0.00137	1.83	1.95	0.424

Table 2: Dispersion Coefficients Recommended in /IA82/ for 100 m Release Height

Dispersion Coefficients	Stability Classes					
	A	B	C	D	E	F
p_y	0.170	0.324	0.466	0.504	0.411	0.253
q_y	1.296	1.025	0.866	0.818	0.882	1.057
p_z	0.051	0.070	0.137	0.265	0.487	0.717
q_z	1.317	1.151	0.985	0.818	0.652	0.486

Table 3: Criteria Used for the Classification of Atmospheric Stabilities

Stability Classes	σ_θ, Degrees	Temperature Change with Height, K/100m	σ_ϕ, Degrees
A	>22.5	$-1.9>$	>14.5
B	$22.5 \geq \sigma_\theta > 17.5$	-1.9 to -1.7	$14.5 \geq \sigma_\phi > 10.5$
C	$17.5 \geq \sigma_\theta > 12.5$	-1.7 to -1.5	$10.5 \geq \sigma_\phi > 7.0$
D	$12.5 \geq \sigma_\theta > 7.5$	-1.5 to -0.5	$7.0 \geq \sigma_\phi > 3.3$
E	$7.5 \geq \sigma_\theta > 3.75$	-0.5 to +1.5	$3.3 \geq \sigma_\phi > 1.8$
F	$3.75 \geq \sigma_\theta > 2.0$	$>+1.5$	$1.8 \geq \sigma_\phi$
Reference	/US72/	/US72/	/NE80/

Table 4: The Atmospheric Stability Classes Determined by Five Methods for the KfK Diffusion Experiments Listed in Table 1

No.	Method of Determining Stability				
	σ_{ϕ}(100 m)	σ_{Θ}(40 m)	σ_{Θ}(100 m)	ΔT(2/100 m)	ΔT(30/100 m)
1	F	D	F	F	E
2	F	D	F	F	E
3	D	D	D	A	C
4	D	D	D	A	C
5	D	C	D	B	C
6	D	C	D	B	C
7	D	C	D	C	D
8	D	C	D	C	D
9	D	C	D	A	D
10	C	C	D	D	D
11	D	D	E	D	D
12	E	E	F	E	E
13	E	E	F	E	E
14	D	D	E	D	F
15	D	D	E	D	E
16	A	A	A	B	D
17	A	B	B	C	D
18	D	D	E	E	E
19	D	D	E	E	E
20	E	E	F	F	E
21	E	F	G*)	F	F
22	E	D	E	E	D

*) not used in regression analysis

Table 5: Regression Parameters for a Plot of log-predicted versus log-observed Normalized Diffusion Factors Using Five Methods of Stability Classification to Select the Dispersion Parameters from /IA82/

Method	Correlation Coefficient	Slope	Intercept	Number of Samples
σ_ϕ(100 m)	0.512	0.573	0.00589	79
σ_Θ(40 m)	0.471	0.685	0.0219	83
σ_Θ(100 m)	0.315	0.365	0.000215	66
ΔT(30/100m)	0.364	0.467	0.00170	80
ΔT(2/100 m)	0.0911	0.0892	0.0000178	77

Table 6: Frequency Distribution of Ratios of Predicted and Observed Values of the Normalized Diffusion Factor Using σ_y, σ_z of /IA82/ for the Prediction and Tab. 1 Together with Data from /TH76a/ and /TH81a/ for the Observed Values; Percentages in Brackets.

Method of Stability Classification	$\leq$0.05	0.05–0.1	0.1–0.2	0.2–0.5	0.5–1	1 – 2	2 – 5	5 – 10	10 – 20	>20	total
σ_ϕ(100 m)	7 (7.7)	3 (3.3)	4 (4.4)	18 (19.8)	26 (28.6)	11 (12.1)	11 (12.1)	6 (6.6)	4 (4.4)	1 (1.1)	91 (100)
σ_ϕ(40 m)	9 (9.9)	4 (4.4)	5 (5.5)	18 (19.8)	19 (20.9)	19 (20.9)	12 (13.2)	3 (3.3)	2 (2.2)		91 (100)
σ_θ(100 m)	28 (32.6)	3 (3.5)	2 (2.3)	11 (12.8)	18 (20.9)	17 (19.8)	4 (4.7)	1 (1.2)	2 (2.3)		86 (100)
ΔT(30 m/100 m)	13 (14.3)	2 (2.2)	9 (9.9)	18 (19.8)	19 (20.9)	14 (15.4)	5 (5.5)	5 (5.5)	3 (3.3)	3 (3.3)	91 (100)
ΔT(2 m/100 m)	20 (22)	7 (7.7)	11 (12.1)	19 (20.9)	11 (12.1)	8 (8.8)	8 (8.8)		4 (4.4)	3 (3.3)	91 (100)

Table 7: Frequency of Occurrence in % of Differences of Stability Classes Determined by two Different Methods During the KfK Atmospheric Diffusion Experiments

Difference in Stability Classes	σ_Θ (40 m) $-\sigma_\phi$(100 m)	σ_Θ(100 m) $-\sigma_\phi$(100 m)	σ_Θ (40 m) $-\sigma_\Theta$(100 m)	ΔT(30/100m) $-\sigma_\phi$(100m)	ΔT(2m/100m) $-\sigma_\phi$(100m)	ΔT (2m/100m) -ΔT(30m/100m)
-5	0	0	0	0	0	0
-4	0	0	0	0	0	0
-3	0	0	0	0	13.6	4.5
-2	9.1	0	9.1	0	9.1	9.1
-1	27.3	0	72.7	31.8	9.1	27.3
0	54.5	50.0	18.2	31.8	36.4	31.8
1	9.1	54.4	0	27.3	27.3	27.3
2	0	4.5	0	0	4.5	0
3	0	0	0	9.1	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

Table 8: Dispersion Coefficients Obtained with Different Methods of Stability Classification

Stability	Method of Stability Classification																			
	σ_θ(40 m)				σ_θ(100 m)				ΔT(2 m/100 m)				ΔT(30 m/100 m)				σ_ϕ(100 m)			
	p_y	q_y	p_z	q_z	p_y	q_y	p_z	q_z	p_y	q_y	p_z	q_z	p_y	q_y	p_z	q_z	p_y	q_y	p_z	q_z
A	2.54	0.993	6.91	0.418	2.54	0.993	6.91	0.418	0.136	1.04	0.171	0.904					0.222	1.48	7.36	0.438
B	0.0194	1.97	7.83	0.458	0.0194	1.97	7.83	0.458	0.444	0.974	0.301	0.863								
C	0.0607	1.16	0.0721	1.04					0.0505	1.39	0.607	0.743	0.415	0.818	0.0703	1.07	0.0760	1.03	0.00154	1.67
D	0.439	0.868	0.186	0.853	0.120	1.04	0.0736	1.04	0.571	0.767	0.00645	1.42	0.0684	1.28	0.251	0.859	0.232	0.941	0.113	0.954
E	0.559	0.823	0.916	0.553	0.197	0.978	0.158	0.870	0.204	0.986	1.70	0.477	0.586	0.834	0.449	0.685	0.0463	1.22	1.02	0.522
F	0.000885	1.82	0.722	0.529	0.987	0.788	0.833	0.576	0.0991	1.17	0.727	0.563	0.000885	1.82	0.722	0.529	2.32	0.735	0.723	0.610
G					0.000885	1.82	0.722	0.529												

Table 9: Regression Parameters for a Plot of log-predicted Versus log-observed Normalized Diffusion Factors Using Five Methods of Stability Classification to Calculate and Select the Dispersion Parameters (Tab. 8)

Method	Correlation Coefficient	Slope	Intercept	Number of Samples
σ_ϕ(100 m)	0.680	0.753	0.0741	86
σ_Θ(40 m)	0.557	0.713	0.0424	81
σ_Θ(100 m)	0.657	0.793	0.117	83
ΔT(30m/100m)	0.268	0.332	0.000331	81
ΔT (2m/100m)	0.645	0.968	1.14	80

Table 10: Frequency Distribution of Ratios of Predicted and Observed Normalized Diffusion Factors Using σ_y and σ_z of Tab. 8 for the Prediction and Tab. 1 and 4 together with /TH76a,TH81a/ for the Observed Values.

Method of Stability Classification	<0.05	0.05–0.1	0.1–0.2	0.2–0.5	0.5–1	1 – 2	2 – 5	5 – 10	10 – 20	>20	Total
σ_ϕ(100 m)	5 (5.5)	4 (4.4)	11 (12.1)	17 (18.7)	23 (25.3)	23 (25.3)	7 (7.7)	1 (1.1)			91 (100)
σ_Θ (40 m)	6 (6.6)		14 (15.4)	23 (25.3)	30 (33.0)	6 (6.6)	7 (7.7)	3 (3.3)	1 (1.1)	1 (1.1)	91 (100)
σ_Θ(100 m)	6 (6.6)	1 (1.1)	13 (14.3)	25 (27.5)	21 (23.1)	14 (15.4)	8 (8.8)	2 (2.2)	1 (1.1)		91 (100)
ΔT(30m/100m)	9 (9.9)	2 (2.2)	15 (16.5)	21 (23.1)	17 (18.7)	11 (12.1)	8 (8.8)	3 (3.3)	4 (4.4)	1 (1.1)	91 (100)
ΔT (2m/100m)	8 (8.8)	1 (1.1)	11 (12.1)	31 (34.1)	16 (17.6)	12 (13.2)	7 (7.7)	4 (4.4)	1 (1.1)		91 (100)