AA Technical Memorandum ERL ARL-120

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

MEASURED VERSUS EMPIRICAL TECHNIQUES TO DETERMINE THE PLUME SIGMA-Y FOR GROUND SOURCES

Isaac Van der Hoven

Air Resources Laboratory
Rockville, Maryland
May 1983

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Environmental Research Laboratories

NOAA Technical Memorandum ERL ARL-120

MEASURED VERSUS EMPIRICAL TECHNIQUES TO DETERMINE THE PLUME SIGMA-Y FOR GROUND SOURCES

Isaac Van der Hoven

Air Resources Laboratory
Rockville, Maryland
May 1983

UNITED STATES
DEPARTMENT OF COMMERCE
Malcolm Baldrige,
Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
John V. Byrne,
Administrator

Environmental Research
Laboratories
George H. Ludwig
Director

NOTICE

Mention of a commercial company or product does not constitute an endorsement by NOAA Environmental Research Laboratories. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

TABLE OF CONTENTS

MEASURED VERSUS EMPIRICAL TECHNIQUES TO DETERMINE THE PLUME SIGMA-Y FOR GROUND SOURCES

Isaac Van der Hoven

Abstract. Three empirical techniques, namely, the $\Delta T/\Delta Z$, σ_θ, and $\Delta T/\Delta Z$ adjusted by a wind meander factor, were used to predict the crosswind plume concentration standard deviation (σ_y). Ratios of measured to predicted σ_y were formed. The $\Delta T/\Delta Z$ technique adjusted by a meander factor showed the best agreement with measured values.

1. INTRODUCTION

In a previous report Van der Hoven (1981) compared measured crosswind plume concentration standard deviations (σ_y) with those computed by an empirical classification technique based on the temperature gradient in the vertical as suggested by the Nuclear Regulatory Commission (1980) in their Regulatory Guide 1.23. The Guide also suggested a second technique based on the standard deviation of measured wind directions. Further, a modification to the temperature gradient classification is suggested by the Nuclear Regulatory Commission (1979) in Regulatory Guide 1.145 whereby a correction factor is applied to the σ_y value to account for horizontal wind direction meander under low wind speeds and stable to neutral temperature gradients. In all three techniques the numerical value for σ_y is based on the Pasquill (1961) classification as described by Gifford (1961). In addition, as quoted from Regulatory Guide 1.145, "for purposes of estimating σ_y during extremely stable (G) atmospheric conditions, without plume meander or other lateral enhancement, the following approximation is appropriate:

$$\sigma_y(G) = 2/3 \quad \sigma_y(F)",$$

where F is the most stable condition of the Pasquill classification. It is the intent of the present study to compute σ_y by the three techniques using meteorological data from a series of tracer field experiments and compare them with actual measurements of σ_y.

2. DATA BASE

The data base used in this study was the series of tracer field experiments listed in Table 1. Only the ground releases were used. Plume concentration measurements were available at arc distances ranging from 100 to 3,200 meters. Terrain characteristics ranged from the flat, desert terrain in Washington and Idaho to a mountainous, wooded site in Tennessee. A coastal site and actual operating reactor sites were also used. Meteorological measurements were obtained from towers at or near the point of tracer release. Extracted from the reports were the following data:

1) measured σ_y value along each sampling arc

2) temperature profile in the vertical

3) standard deviation of the horizontal wind direction

4) wind speed

Wind speeds were usually measured at a height of 10 meters while temperature gradients were measured between 10 and 40 meters. Tracer gas releases were usually over a one-hour period. In all, there were 369 measurements of σ_y.

3. DATA ANALYSIS

Measured versus predicted ratios of σ_y were computed for each hourly tracer release, sampling arc, and classification scheme. These ratios were then averaged for each site and for each classification scheme and are shown in table 2. Also shown is the standard deviation of the ensemble average. A grand average ratio is also shown combining all the sites.

As a function of arc distance, the ratio values were plotted for each site as shown in figures 1, 2 and 3. The plotted symbols are identified according to site as shown in table 2.

4. DISCUSSION

All other factors being equal, a measured to predicted σ_y ratio greater than 1 indicates a conservative prediction since this would predict a higher concentration than was measured. Ratios less than 1 would predict a lower concentration than was measured and thus would be viewed as nonconservative.

As shown in table 2 and in figures 1,2 and 3, none of the σ_y ratios were less than 1, so one would conclude that on average, all of the three σ_y predictive techniques were conservative. On average, using the temperature gradient (ΔT) technique as shown in figure 1, the River Bend, Clinch River and Rancho Seco sites indicated considerably larger ratios than the Idaho, Hanford and San Onofre sites. However, when modifying the ΔT technique by the meander factor as shown in figure 2, the ratios of all the sites show considerably better agreement on average, ranging from 1.01 to 2.35 as a function of arc distance. Similarly, using the horizontal wind standard deviation (σ_θ) the average measured to predicted average ratio ranged from 1.47 to 2.66. The similarity between figures 2 and 3 should not be surprising since the standard deviation of the wind direction would also include the lower frequency meander when averaged over an hour.

As a measure of the scatter of the individual ratios around the average, the standard deviation was computed and are shown in table 2. The greatest amount of scatter occurred when using the ΔT diffusion classification scheme, which, as an average of all the sites, was 4.03 ± 3.32. In a statistical sense the interpretation would be that 68% of the individual ratios were between 0.71 and 7.35. The least amount of scatter (1.65 ± 1.01) occurred using the ΔT scheme modified by a meander factor followed closely by the σ_θ scheme with a value of 1.95 ± 1.14.

An inspection of figures 1, 2 and 3 does not show any clear trend of the ratios as a function of downwind distance. The obviously large ratios of measured to computed σ_y values shown in figure 1, as noted in the beginning of this section, was probably due to the large number of thermally stable cases during the tracer releases at Rancho Seco, Clinch River and River Bend. For these three sites, 46 cases were stable, 10 were neutral and 5 were unstable as defined by the vertical temperature profile.

5. CONCLUSION

For the real-time assessment of an accidental release of radioactive effluents from a nuclear power plant, the use of a σ_y value as determined from the temperature change with height ($\Delta T/\Delta Z$), which has been adjusted for wind direction meander, appears to agree more closely with measured σ_y values as determined from a series of tracer field experiments. The σ_θ approach to determine σ_y also does well as shown by measured to predicted ratios. However, this technique has the problem in that at wind speeds below the starting speed of the anemometer, the vane is not moving and σ_θ cannot be determined. This problem can be seen in table 2 where measured σ_θ values were not available at the River Bend and Clinch River sites because of the very low wind speeds during stable conditions. Except for the San Onofre site, the highest measured to predicted (and therefore the most conservative) ratio occurred using the $\Delta T/\Delta Z$ approach. This was also true for the standard deviation of the ratios.

6. ACKNOWLEDGMENT

This work was supported by the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission.

7. REFERENCES

Gifford, F.A. (1961), Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion. <u>Nuclear Safety</u>, 2(4), 47-51.

Gulf States Utilities Co. (1974), Dispersion of Tracer Gas at the Proposed River Bend Nuclear Power Station. Preliminary Safety Analysis Report, Amend. 24, Dockets 50-458 and 50-459.

Islitzer, N.F., and R.K. Dumbauld (1963), Atmospheric Diffusion-Deposition Studies Over Flat Terrain. <u>Int. J. Air-Water Poll.</u>, 7, 999-1022.

Metropolitan Edison Co. (1972), Atmospheric Diffusion Experiments with SF_6 Tracer Gas at Three Mile Island Nuclear Station Under Low Wind Speed Inversion Conditions. Final Safety Analysis Report, Amend. 4, Docket 50-289.

Nickola, P.W. (1977), The Hanford 67-Series: A Volume of Atmospheric Field Diffusion Studies. PNL-2433, Battelle Pacific Northwest Laboratories, 448 pp.

Nuclear Regulatory Commission (1972), Onsite Meteorological Programs. Regulatory Guide 1.23, Office of Standards Development, 6 pp.

Nuclear Regulatory Commission (1979), Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants. Regulatory Guide 1.145, Office of Standards Development, 14 pp.

Nuclear Regulatory Commission (1980), Meteorological Programs in Support of Nuclear Power Plants. Regulatory Guide 1.23, Rev. 1, Office of Standards Development, 34 pp.

Pasquill, F. (1961), The Estimation of Dispersion of Wind Borne Material. Meteorol. Mag. (UK), 90, 33-49.

Sagendorf, J.F., and C.R. Dickson (1974), Diffusion Under Low Wind Speed, Inversion Conditions. NOAA Tech. Memo. ERL ARL-52, 89 pp.

Septoff, M., A.E. Mitchell, and L.H. Tuescher (1977), Final Report of the Onshore Tracer Tests Conducted December 1976 through March 1977 at the San Onofre Nuclear Generating Station, NUS-1927, Vol. 1 and 2.

Start, G.E., and J.H. Cate, C.R. Dickson, N.R. Ricks, G.R. Ackermann, and J.F. Sagendorf (1977), Rancho Seco Building Wake Effects on Atmospheric Diffusion. NOAA Tech. Memo. ERL ARL-69, 185 pp.

Start, G.E., N.F. Hukari, J.F. Sagendorf, J.H. Cate, C.R. Dickson, and N.R. Ricks (1980), EOCR Building Wake Effects on Atmospheric Diffusion. NOAA Tech. Memo. ERL ARL-91, 220 pp.

Van der Hoven, I. (1981), A Comparison of Measured Versus Model-Predicted Effluent Diffusion for Ground Releases. NOAA Tech. Memo. ERL ARL-105, 33 pp.

Wilson, R.G., G.E. Start, C.R. Dickson, and N.R. Ricks (1976), Diffusion Under Low Windspeed Conditions Near Oak Ridge, Tennessee. NOAA Tech. Memo. ERL ARL-61, 83 pp.

Table 1. Tracer Field Experiments

Location	Reference
Idaho National Engineering Lab., ID	Izlitzer et al. (1963)
" " " " "	Sagendorf et al. (1974)
" " " " "	Start et al. (1980)
Pacific Northwest Labs., WA	Nickola (1977)
Three Mile Island Reactor Site, PA	Metropolitan Ed. Co. (1972)
River Bend Reactor Site, LA	Gulf State Utilities (1974)
Clinch River Reactor Site, TN	Wilson et al. (1976)
San Onofre Reactor Site, CA	Septoff et al. (1977)
Rancho Seco Reactor Site, CA	Start et al. (1977)

Table 2. Ratio of Measured versus Predicted σ_y.

		$\frac{\sigma_y(m)}{\sigma_y(\theta)}$		$\frac{\sigma_y(m)}{\sigma_y(\Delta T)}$		$\frac{\sigma_y(m)}{\sigma_y(\Delta T) x MF}$	
TEST SERIES	PLOTTED SYMBOL	AVERAGE RATIO	STANDARD DEVIATION	AVERAGE RATIO	STANDARD DEVIATION	AVERAGE RATIO	STANDARD DEVIATION
IDAHO	X	2.13	± 0.61	3.01	± 3.16	1.81	± 1.59
HANFORD	●	1.65	± 0.55	2.49	± 1.36	1.36	± 0.70
RIVER BEND	O	--	--	5.70	± 2.63	1.70	± 0.76
CLINCH RIVER	+	--	--	5.86	± 1.89	2.06	± 0.51
RANCHO SECO	*	1.81	± 1.45	6.54	± 4.29	2.07	± 1.20
SAN ONOFRE	_	2.64	± 1.57	1.58	± 1.19	1.18	± 0.62
GRAND AVERAGE		1.95	± 1.14	4.03	± 3.32	1.65	± 1.01

$\sigma_y(m)$ - measured

$\sigma_y(\theta)$ - as determined by standard deviation of wind direction

$\sigma_y(\Delta T)$ - as determined by vertical temperature gradient

$\sigma_y(\Delta T)$ x MF - as determined by vertical temperature gradient and multiplied by Meander Factor

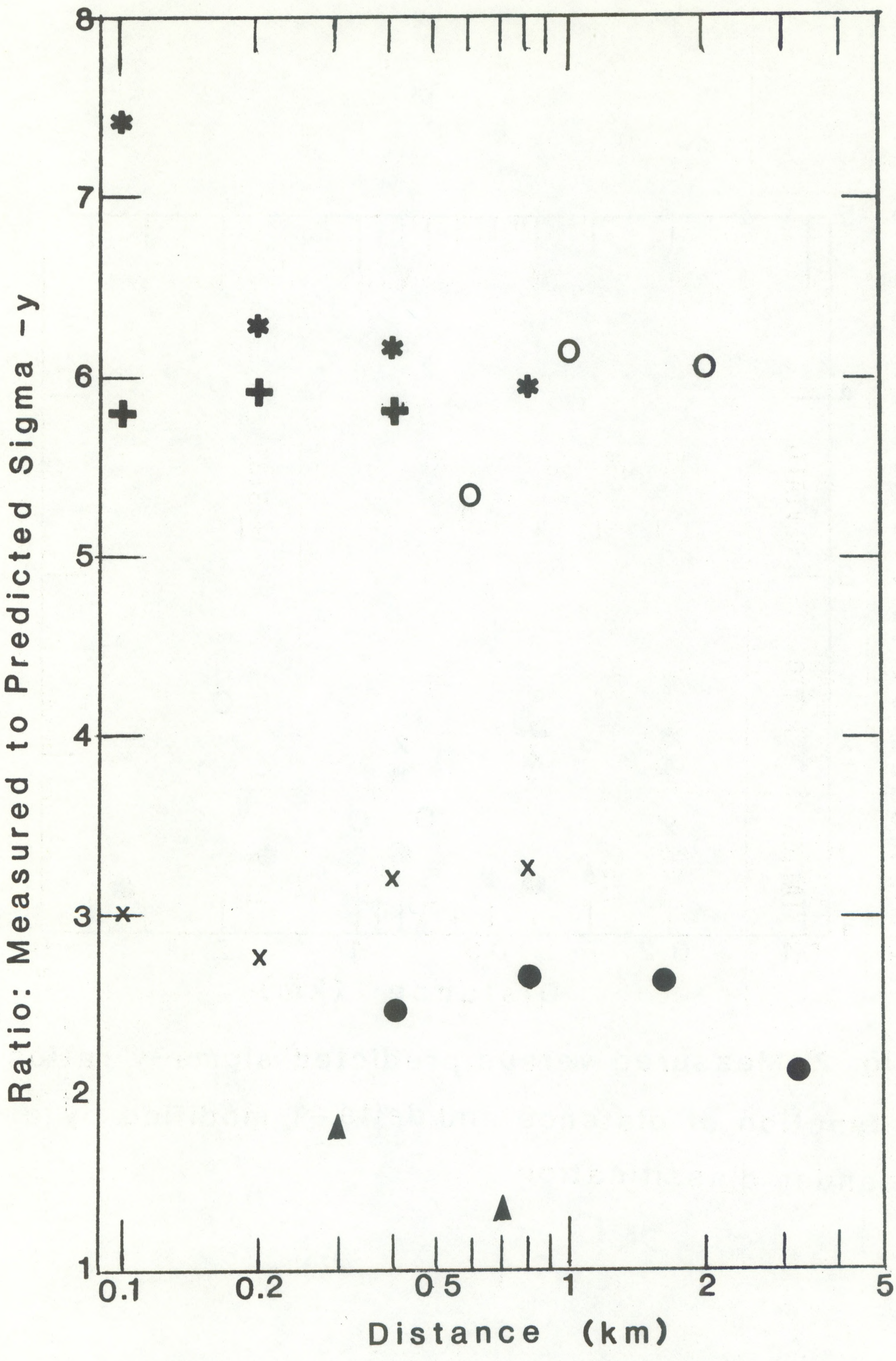

Fig. 1. Measured versus predicted sigma-y ratios as a function of distance and delta-T classification.

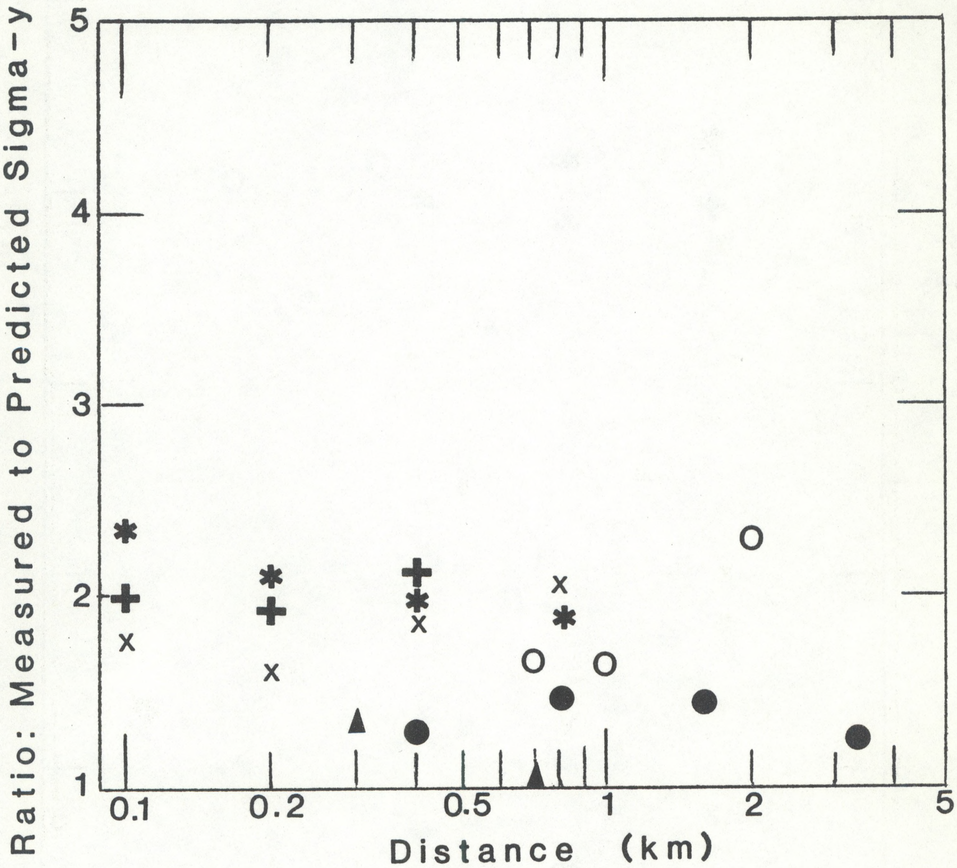

Fig. 2. Measured versus predicted sigma-y ratios as a function of distance and delta-T modified by a meander classification.

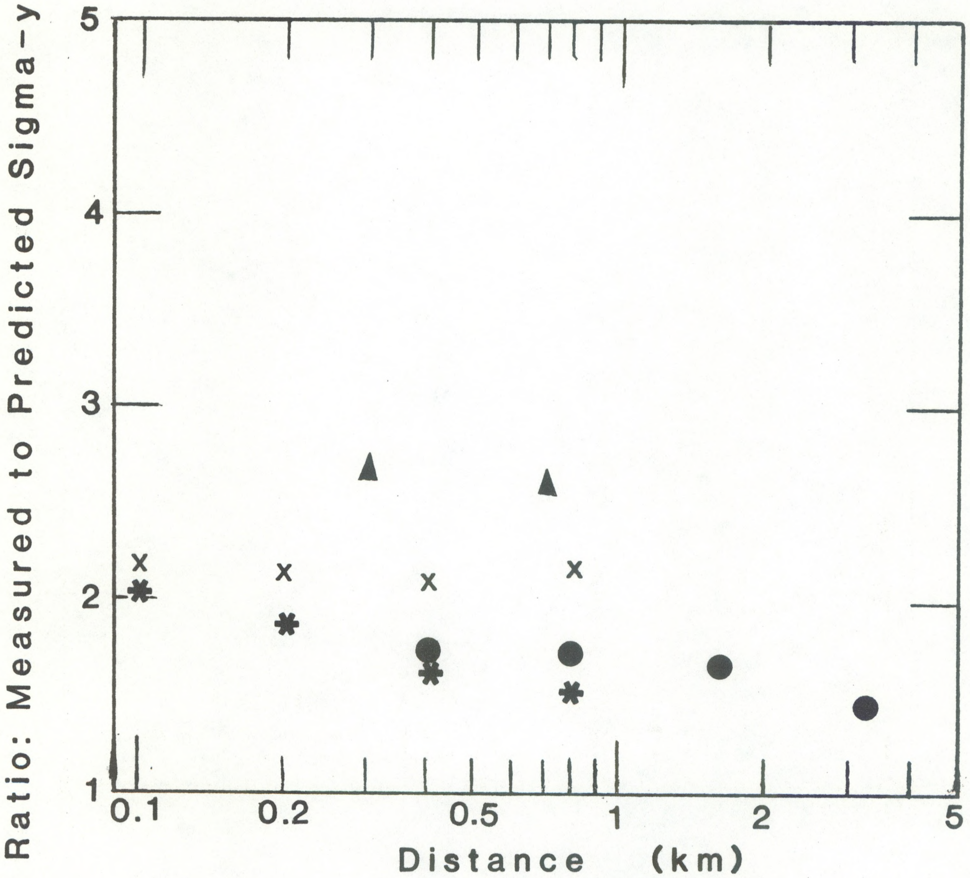

Fig. 3. Measured versus predicted sigma-y ratios as a function of distance and sigma-theta classification.