DOE/OR/00033--T743

MASTER'S TECHNICAL REPORT

**A Field Study Evaluation of Short-Term Refined
Gaussian Dispersion Models**

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A FIELD STUDY EVALUATION OF SHORT-TERM REFINED GAUSSIAN
DISPERSION MODELS

DOE/OR/00033--7743

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A technical report submitted to the Faculty of the University of North
Carolina at Chapel Hill in partial fulfillment of the requirements for the
degree of Master of Science in Public Health in the Department of
Environmental Sciences and Engineering.

Chapel Hill

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ACKNOWLEDGEMENTS

Financial support for this project was provided by the Oak Ridge Institute for Science and Education (ORISE), U.S. Department of Energy, Oak Ridge, Tennessee, under the Industrial Hygiene Graduate Fellowship Program.

I would like to thank Dr. Joseph J. Vervier, Technical Director of the U.S. Army's Edgewood Research, Development and Engineering Center, and Dr. Clyde Franke, Deputy Assistant Secretary of Energy, for their support of my research at the Center for NBC Environmental Technology.

I would like to express my sincere gratitude to Mr. Howard Feldman, Senior Environmental Scientist of the American Petroleum Institute and Mr. Russ Lee of NOAA, U.S. E.P.A. for their indispensable help throughout this project. Without their knowledge, kindness, insight and charity, this project would have been much more difficult.

Additional thanks go to all the professionals who took time to explain and discuss concepts and ideas with me, especially early on in the learning curve! These people include Ms. Judy Zwicker of Remote Sensing Air, Mr. Jim Paumier of Pacific Environmental Services, and of course my advisor, Dr. Lori Todd, who helped me see the big picture.

Special thanks go to Mr. Don Gamiles, DOE. Thanks for calming me down and talking me through it.

Of course, the largest thanks go to my Mom, Pat Piper, for her support and encouragement.

A FIELD STUDY EVALUATION OF SHORT-TERM REFINED GAUSSIAN DISPERSION MODELS

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ABSTRACT

A tracer study was conducted at the Duke Forest Site in Chapel Hill, North Carolina in January, 1995 to evaluate the ability of three short-term refined Gaussian dispersion models to predict the fate of volume source emissions under field study conditions. Study participants included the American Petroleum Institute (API), the United States Environmental Protection Agency (EPA), the United States Department of Energy (DOE), the University of North Carolina at Chapel Hill (UNC), and private consulting firms. The models evaluated were Industrial Source Complex - Short Term versions 2 and 3 (ISC2, ISC3) and the American Meteorological Society (AMS)/Environmental Protection Agency (EPA) Regulatory Model Improvement Committee (AERMIC) model, AERMOD. All three models are based on the steady-state Gaussian plume dispersion equation, which predicts concentrations at downwind receptor locations when integrated over the distance between the source and receptor. Chemicals were released at known rates and measurements were taken at various points in the study field using Tedlar® bag point sampling and open-path Fourier Transform Infrared (OP-FTIR) monitoring.

The OP-FTIR comparisons were conducted by configuring the models to predict point concentrations along the FTIR spectrometer open-paths, then path-integrating the predictions over the sampled time intervals. The Tedlar® bag point sample comparisons were conducted by configuring the models to predict point concentrations at the Tedlar® point sample locations for each five-minute interval during the point sampling one-hour time period. The model predictions were then time-averaged for comparison with the Tedlar® one-hour point samples. The chemical used in this study analysis was sulfur hexafluoride (SF₆).

The study found that ISC and AERMOD underpredicted the measured concentrations for each dataset collected in the field study. ISC and AERMOD each underpredicted the OP-FTIR dataset by a factor of approximately 1.6. ISC underpredicted the Tedlar® dataset by approximately 2.1, while AERMOD underpredicted by a factor of approximately 2.6.

Regardless of source configuration or measurement technique used, under-prediction with respect to the measured concentration was consistently observed. This indicates that safety factors or other corrections may be necessary in predicting contaminant concentrations over the distances examined in this study; i.e., in the near field of less than 200 meters.

INTRODUCTION

Air quality models are designed to simulate the transport and fate of contaminants in the atmosphere. The U.S. Environmental Protection Agency recommends the use of air quality models to predict the short and long-range fate of industrial emissions for regulatory, public policy and industrial planning purposes^{1,2}. Validation of the models' predictive ability is necessary to ensure that the goals of environmental protection and public health are effectively addressed. It is important that the models not only predict high concentrations with reasonable accuracy but that the models have an accurate "model-physics" basis, which increases confidence in their application to modeling scenarios outside the evaluated range³. Previous field and statistical studies have compared observed and predicted concentrations which were paired in time, but not necessarily in space; and not over distances of less than 500 meters, due to the lack of applicable datasets^{3,4,5}.

A review of model validation studies conducted by the American Petroleum Institute⁶ identified deficiencies including the lack of simulation studies of model performance in the very near field or beyond a few hundred meters and the lack of sufficient experimental data for "rigorous testing of the models that are used to represent area/volume source impacts for a variety of regulatory permitting and compliance applications". Some of the insufficiencies included datasets comprised of instantaneous syringe samples, which are not appropriate for evaluating the models used in this study due to the lack of time-integration, and the lack of samplers deployed at various downwind distances in arcs,

which is needed to investigate lateral model dispersion performance. In addition, none of the previous comparisons of AERMOD and ISC (the models used in this study, formally introduced later in this section) evaluated the model predictions with respect to open-path Fourier Transform Infrared (OP-FTIR) spectroscopy measurements. Interest in OP-FTIR spectroscopy is increasing in part due to the possibilities presented by using OP-FTIR for fence-line monitoring to compute emission estimations. The purpose of this study is to compare model predictions in the downwind range of less than 500 meters from the source release with measured concentrations collected using both traditional point samples and OP-FTIR spectroscopy.

Concentrations were measured using open-path FTIR (OP-FTIR) spectroscopy and Tedlar® bag point samples, arranged in arcs downwind of the source release, to create two datasets with which to evaluate the model predictions. This study uses OP-FTIR spectrometer data and Tedlar® point samples to evaluate the air quality models on a spatially-resolved, temporal basis in order to determine the relationship between the contaminant measurement technologies and the model predictions. Figure 1 presents a diagram of the Duke Forest Site.

OP-FTIR offers advantages over traditional point samples due to the data's path-integrated nature, enabling it to "smooth out" the concentrations along each arc radii; whereas point samples can easily miss large or small concentrations which are between sampling points. The two-instrument OP-FTIR spectrometer configuration used in this

study also offers advantages over a single open-path configuration due to the ability to spatially resolve the plume components. With retroreflectors arranged in an arc downwind of the emission source, it can be determined if the plume is entirely captured or represented by the sampling mechanism.

The models selected for use in this study were Industrial Source Complex Short Term - Two (ISC2), Industrial Source Complex Short Term - Three (ISC3), and the American Meteorological Society (AMS)/Environmental Protection Agency (EPA) Regulatory Model Improvement Committee (AERMIC) model, AERMOD. All three models are based on the steady-state Gaussian plume dispersion equation, which predicts a normal contaminant distribution from the source release point(s) toward locations downwind of the release. Integration of the Gaussian dispersion equation over the distance from the source emission to a receptor location downwind produces a concentration prediction for a specific point. Each model estimates the concentration value for each source and receptor combination for each input meteorology time interval. Emission sources can be characterized as point, area, volume or open pit emissions. In this study, SF₆ was released from a simulated volume source emission and the models were evaluated with volume source emission configurations.

The ISC models are the most commonly used models in industry for short-term (defined as less than 50 km transport and 1-24 hours from starting emission time) regulatory applications. They are the Environmental Protection Agency (EPA) approved models for

short-term "complicated source" (including area and volume sources) regulatory purposes in simple terrain for both rural and urban land use classifications⁷. The ISC models are single line segment models, which refers to representing the source area as a single line oriented normal to the wind direction. This technique is a simplification of the multiple line segment technique used in models such as PAL (Point, Area, Line) and FDM (Fugitive Dust Model)⁸.

The AERMIC model, AERMOD, is an air quality model developed by a joint effort between the American Meteorological Society (AMS) and the EPA. AERMOD differs from the ISC models in that it uses current planetary boundary layer (PBL) theory to determine the dispersion parameters σ_y and σ_z (the standard deviation of the dispersion in the y and z directions) instead of depending on Pasquill-Gifford-Turner (PGT) stability curves (which are based exclusively on short-range dispersion from ground level surface releases and are a measure of dispersion rather than turbulence levels). AERMOD is therefore applicable to elevated releases, while ISC is not^{9,10}.

BACKGROUND AND THEORY

Evaluation of Model Predictions with FTIR

The relationship between OP-FTIR spectrometer measurements and source emission rates has been explored by Piccot *et al* and Carter *et al* through the estimation of source emission strength based on OP-FTIR measured concentrations down-wind from a contaminant release ^{11,12}. Both of these studies used mathematical algorithms based on Gaussian dispersion assumptions, which are employed in the models selected for evaluation in this study. Piccot *et al* found their system to be within +/- 25 to 30 percent accurate in estimating the emissions from a ground level source. Carter *et al* concluded that the smaller the meteorological interval averaging time, the greater the accuracy of model predictions of source emission strength. The Gaussian dispersion equation was found to perform better at distances greater than 50 meters than at those less than 50 meters ¹².

Outdoor field studies have been conducted to evaluate the accuracy and precision of OP-FTIR in comparison to multiple point samplers set up along the path ^{13,14}. In these studies, qualitative and quantitative results varied both by the OP-FTIR system used and by the contaminant measured. A field study conducted by Carter *et al* ¹⁵ investigated the relationship between OP-FTIR measurements and point sampling canisters and concluded that the OP-FTIR data displayed a lower precision than that obtained by the canisters but was comparable to canisters in accuracy for all three OP-FTIR systems tested ¹⁵.

Model Evaluation Studies

A developmental evaluation of AERMOD with comparisons to ISC2 was conducted using point sample datasets collected from two SF₆ tracer studies (1984, 1988) and one SO₂ study (1958). The study releases (both passive and buoyant) were conducted from surface-level and elevated sources, flat and complex terrain and in rural and urban areas¹⁶. For surface releases, AERMOD exhibited a tendency to underpredict the maximum concentrations as measured by point sampling by a factor of 1.35 in convective and 1.2 in stable conditions, while ISC2 showed a tendency to overpredict by a factor of 2 in convective and a factor of 1.4 in stable conditions. However, for rural elevated releases, both models tended toward underprediction at locations nearest to the source, with AERMOD underpredicting by approximately 1.1 and ISC2 underpredicting by nearly a factor of three.

The API evaluated the "reasonableness" of the various dispersion algorithms of six short-term refined dispersion models, including ISC2, using mathematical simulations (not tracer studies) and concluded that the ISC2 area models were ill-suited for predicting concentrations on or close to a source's boundaries or at other near-field receptors (less than 500 meters)⁶. The API then evaluated the same models using SF₆ tracer datasets (created by various chemical and petroleum companies for purposes other than model evaluation)⁴. The ISC2 volume source models were found to perform reasonably well on a qualitative basis, except at the closest receptors⁴. However, the API identified

deficiencies in the data sets available for model evaluation, including a lack of concentration data in the very near field or beyond a few hundred meters, lack of data covering various meteorological conditions, and lack of sampler coverage to provide a full crosswind plume mass distribution⁴.

Model Algorithms

The models evaluated in this study are based on the Gaussian plume dispersion model, which predicts a normal contaminant distribution downwind of the source release.

Assumptions of the Gaussian model include the following parameters: a three-dimensional axis system of downwind, crosswind and vertical coordinates with the origin at the ground; that the concentrations are from a continuously emitting plume and are proportional to the emission rate; and the concentrations are diluted by the wind at the point of the emission at a rate inversely proportional to the wind speed. The model assumes that the time-averaged pollutant concentrations crosswind and vertically near the source are well described by Gaussian or normal (bell-shaped) distributions and that the standard deviations of the plume concentration in these two directions (σ_y in the crosswind, σ_z in the vertical) are empirically related to the levels of turbulence in the atmosphere and increase with distance from the source.

In its simplest form, the Gaussian model assumes that the pollutant does not undergo chemical reactions or other removal processes in traveling away from the source and that pollutant material reaching the ground or the top of the mixing height as the plume grows

is reflected back toward the plume centerline¹⁷. The basic Gaussian plume model for stable conditions is given by the equation:

$$C(x,y,z) = \frac{Q}{\mu} \left\{ \frac{g_1}{[(2\pi)^{0.5} \sigma_y]} \right\} \left\{ \frac{g_2}{[(2\pi)^{0.5} \sigma_z]} \right\} \quad \text{Equation 1}$$

In this equation, $C(x,y,z)$ is the concentration at the receptor located at the coordinates x, y , and z ; Q is the source emission rate in grams per second; μ is the mean wind speed in meters per second; σ_y and σ_z are the standard deviations of the horizontal and vertical dispersion; and g_1 and g_2 are exponential functions which vary depending on whether the meteorological conditions are stable, convective or neutral.

The ISC2 and ISC3 models differ from one another in their area source algorithms, not in their volume source algorithms. Therefore, the ISC2 and ISC3 volume source model outputs are identical and are referred to simply as "ISC volume", without indicating ISC2 or ISC3.

The ISC volume source model is "virtual point source" model. This means that an imaginary or virtual point source is located at a certain distance upwind of the volume source to account for the initial size of the volume source plume. The equation used in the ISC volume source model is :

$$C(x,y) = \frac{(QKVD)}{(2 \pi u \sigma_y \sigma_z)} \exp \left[-\frac{1}{2} \left(\frac{y^2}{\sigma_y^2} \right) \right] \quad \text{Equation 2}$$

In this equation, $C(x,y)$ represents the receptor location coordinates (the receptor is limited to ground level, with $z=0$); z represents the plume dispersion height; K is a scaling coefficient used to convert the calculated concentration to the desired units (a default of

1×10^6 for Q in g/s and conc. in $\mu\text{g}/\text{m}^3$); V is a vertical term which includes the effects of source elevation, plume rise, limited vertical mixing, and gravitational settling and dry deposition of particles; and D is a decay term which accounts for pollutant removal by physical or chemical processes (function of downwind distance, x). The σ_y and σ_z values are calculated using the following PGT stability curve equations: $\sigma_y = 465.11628 (x) \tan(\text{TH})$ where $(\text{TH}) = 0.017453293[c * d \ln(x)]$; (where c and d are constants which depend on PGT stability class); and $\sigma_z = ax^b$; where a and b are constants which depend on PGT stability class. The mean wind speed at release height, u_s , is determined through the equation: $u_s = u_{\text{ref}} [h_s/z_{\text{ref}}]^p$; (where p is dependent on PGT stability and wind speed class, u_{ref} = wind speed at the reference height, h_s = effective stack height, z_{ref} = height of the wind speed measurement).

The ISC2 short term area source model is based on the equation for a finite crosswind line source, in which the ground level concentration (C) at downwind distance x and crosswind distance y is given by:

$$C(x,y) = [(Q_A V K E x_0)/(4\sqrt{2}u_s\sigma_z)] \quad \text{Equation 3}$$

In this equation, the Q of Equation 1 is replaced by Q_A , the area source emission rate in $\text{g}/\text{s}/\text{m}^2$. E is an error function term given by the equation: $E = \text{erf} \{ [r_0' + y]/[\sqrt{2}\sigma_y] \} + \text{erf} \{ [r_0' - y]/[\sqrt{2}\sigma_y] \}$; (where r_0' = effective radius of area source = $x_0/(\sqrt{2}\pi)$ m; and x_0 = length of the side of the area source (m))⁸.

The ISC3 short term area source model differs from the ISC2 area source model in the addition of the decay term and the deletion of the error function term. Downwind concentrations are determined using the following equation with variables defined as in Equation 3¹⁸:

$$C(x,y) = Q_A K \sqrt{2 \Pi u} \int [VD/\sigma_y \sigma_z] \{ \exp [1/2 (y^2/\sigma_y^2)] dy \} dx \quad \text{Equation 4}$$

AERMOD has different algorithms based on the dominant meteorology characteristics of the area over which the predictions are to be made; there is one algorithm for point, area and volume emission sources in stable conditions, and another for use in convective conditions. The downwind concentration of a pollutant in stable conditions is given by:

$$C(x,y,z) = [(Q/U) p_z(x,z,H_p) \bullet p_y(x)] \quad \text{Equation 5}$$

In this equation, Q is the source emission rate, U is the mean wind speed, p_y , and p_z are probability density functions of particle position in the y and z directions (length)⁻¹ given by the equations: $p_z = [1/\sqrt{2\Pi} \sigma_z] \Sigma \{ \exp [-(z - H_p + 2nh_s)^2/2\sigma_z^2] + \exp [-(z + H_p + 2nh_s)^2/2\sigma_z^2] \}$ and $p_y = [1/\sqrt{2\Pi} \sigma_y] \exp [-y^2/2\sigma_y^2]$. σ_y and σ_{ze} , used in the previous equations, are given by: $\sigma_y = \text{plume horizontal spread} = (\sigma_\theta)x$ (σ_θ = standard deviation of wind direction fluctuations - measured at the site) and $\sigma_z = [(\sigma_w x/u)/(1+t/2T_{lw})^{1/2}]$ where T_{lw} = the Lagrangian time scale for vertical velocity fluctuations⁹.

In convective conditions, the downwind concentration is determined by the equation:

$$C(x,y,z) = [(Q/U) p_y(y;x) \bullet p_z(z;x)] \quad \text{Equation 6}$$

with the primary difference being the derivation of the p_y and p_z parameters: $p_z = [1/\sqrt{2\Pi} \sigma_z)] \exp [-z^2/2\sigma_z^2]$ and $p_y = [1/\sqrt{2\Pi} \sigma_y)] \exp [-y^2/2\sigma_y^2]$.⁹

The differences between ISC and AERMOD in terms of meteorological requirements is presented in Table 2: Meteorological Variables.

METHODS

The API/EPA field study was conducted at the Duke Forest Site in Chapel Hill, North Carolina, in January, 1995. The OP-FTIR spectrometer data used in this evaluation was collected by a team from The University of North Carolina at Chapel Hill (UNC) and the U.S. Department of Energy (DOE) headed by Dr. Lori Todd and Don Gamiles, respectively. The point sample data used in this evaluation was collected by Ogden Environmental and Energy Services Co., Inc., for the API. Figure 2 shows the actual source release tower. Figure 3 presents the release points on the source release tower.

The onsite meteorological data used in this study was collected at two locations, using a fixed-location 10-meter meteorological station and a portable two-meter meteorological station. Data collected by the 10-meter meteorological station included orthogonal wind components, (u,v,w), temperature at two vertical levels (1.8 m and 8.4 meters) and solar radiation at two meters. The data was collected and saved as one minute averages. Data collected by the portable two-meter station included wind speed and direction, temperature, barometric pressure and relative humidity. The meteorological parameters used in the models were averaged over five-minute intervals. Surface weather data was provided by the National Weather Service (NWS) at Raleigh-Durham International Airport (RDU). Upperair soundings for AERMOD were provided from NWS data by Jim Paumier of Pacific Environmental Services, Research Triangle Park, NC. Meteorological data can be found in Appendix C: Meteorological Data.

SF₆ was released from a simulated volume source in the field study for approximately 2.5 hours. SF₆ was monitored using an open-path FTIR spectrometer, manufactured by ETG, and integrated samples collected in Tedlar® bags. Carbon tetrafluoride, ethane and methane were also released from the source emission tower on January 18, 1995. Carbon tetrafluoride was not used in this study analysis because it was not measured using point samples. Methane and ethane were not used in this study analysis because background samples showed varying quantities of both gases already present at the study site. Table 1 shows the tracer release data for January 18, 1995.

The OP-FTIR spectrometer data was quantified by the classical least squares (CLS) method for SF₆ using software provided by ETG Services. The data was collected as four scan data, indicating that four scans between the instrument and the retroreflector were taken in succession and coadded to produce one path average. The data was collected using one wavenumber resolution. Specific spectral analysis parameters are presented in Appendix B: "Sampling Data / Model Input Parameters". Concentrations along each open-path were determined for each OP-TIR scan and then averaged over the short-path network in five-minute intervals. Five-minute averaging was selected in order to facilitate comparison of the OP-FTIR data with the model predictions; each OP-FTIR scan was completed in approximately 30 seconds, while the meteorological data used in this study was collected in one-minute averages. Additionally, a five-minute averaging time allowed for scanning of the entire sampling network during each meteorological sampling interval. These averages produced area concentrations which can be compared with five minute

area averages of the model predictions. The OP-FTIR concentrations for SF₆ can be found in Appendix B, "Sampling Data / Model Input Parameters".

The Tedlar® bag samples were analyzed with a gas chromatograph/electron capture detector (GC/ECD) model 215BGC tracer analyzer manufactured by Lugas Applied Technology, Inc. Of San Diego, CA¹⁹. Each Tedlar® bag sample was collected over a one-hour interval to obtain a one-hour average concentration in micrograms per cubic meter of air. The Tedlar® bag sample concentrations can be found in Appendix B, "Sampling Data / Model Input Parameters".

Additional field study design and data collection techniques are described in the API document "Initial Assessment of Data Generated by the EPA/API Cooperative Remote Sensing/Dispersion Study"¹⁹.

In order to evaluate the importance of configuring the source emission tower as a volume source, as opposed to an area source, each model was also run as an area source emission. Model input files can be found in Appendix B, "Sampling Data / Model Run Inputs".

RESULTS

Figures 4 and 5 present the linear regressions of the measured concentrations vs. the volume source model predicted concentrations for the OP-FTIR and Tedlar® point sample datasets, respectively. Table 3 presents the slope (with 95% confidence intervals), y-intercept values (with 95% confidence intervals) and agreement factors for the linear regressions of the measured concentrations vs. the model predictions for the ISC and AERMOD volume source models. The linear regressions were forced through zero. The agreement factors can be interpreted as indicating a factor with which the models agree with the measured concentrations.

Figure 6 presents the linear regressions of the comparisons between the ISC2 and ISC3 area and volume source models against the OP-FTIR dataset. Figure 7 presents the linear regressions of the comparisons between the AERMOD area and volume source models against the OP-FTIR dataset. Table 4 presents the slopes and intercepts of the area and volume source models, with 95% confidence intervals, for the OP-FTIR dataset. Figure 8 presents the linear regressions of the comparisons between the ISC2 and ISC3 area and volume source models against the Tedlar® dataset. Figure 9 presents the linear regressions of the comparisons between the AERMOD area and volume source models against the Tedlar® dataset. Table 5 presents the slopes and intercepts of the area source models, with 95% confidence intervals, for the Tedlar® dataset.

ISC and AERMOD underpredicted the measured concentrations for each dataset. The slope of the regression line of the ISC predicted concentrations against the OP-FTIR concentrations, in ppm-m, was significantly different from unity at the 95% confidence level, indicating underprediction. The slope of the regression line of the AERMOD predicted concentrations against the OP-FTIR concentrations, in ppm-m, was also significantly different from unity at the 95% confidence level, indicating under-prediction. Similar results were seen in the Tedlar® dataset, with both the ISC and AERMOD regression line slopes indicating significant differences from unity at the 95% confidence level in the negative direction (indicating underprediction).

By forcing the regression models through the origin, a factor relationship between the model predictions and the measured concentrations can be derived. Using this method, the AERMOD and ISC models were found to underpredict the OP-FTIR dataset by a factor of approximately 1.6 each. The ISC model was found to underpredict the Tedlar® dataset by a factor of approximately 2.6, while the AERMOD model underpredicted by a factor of approximately 2.1.

The ISC2, ISC3 and AERMOD area models underpredicted the measured concentrations in a manner similar to that of the volume source models for both the OP-FTIR and Tedlar® datasets. For the OP-FTIR dataset, the three area models had slopes which were significantly different from unity at the 95% confidence level, indicating underprediction. For the Tedlar® dataset, the ISC2, ISC3 and AERMOD area models also had slopes

which indicated significant difference from unity at the 95% confidence level in the direction of underprediction.

The ISC2, ISC3 and AERMOD area models underpredicted the measured concentrations by a slightly lower factor than the volume source models for each dataset; however, the difference was not significant at the 95% confidence level.

DISCUSSION

This study demonstrates the ability of the models to predict concentrations in the near-field with some degree of accuracy when compared against both the path-integrated OP-FTIR measurements and the point samples. While the models underpredicted the measured concentrations in each case comparison, the largest underprediction of the OP-FTIR measurements was only a factor of 2.1, indicating relatively high correlation, considering the measurements were on the order of less than 10 parts per million-meter (ppm-m). The strengths of this field study include high temporal resolution (short averaging time, five-minute meteorological and concentration data averages), and two different reference concentration measurement techniques (OP-FTIR spectrometry and GC-ECD samples). The factors also limit the comparability of this study to previous evaluations of ISC2 and AERMOD^{16,20}, which were conducted using only one-hour averages of meteorological and concentration data and point sample data collection. Despite these differences, however, the models behaved similarly to the previous EPA evaluations, with underprediction at the near-field receptors.

The EPA program for evaluation of air quality simulation model performance relies on a standard set of statistical and graphical procedures for assessing the model performance. According to this program, refined models should reach a factor-of-two performance target^{7,21,22}. Both ISC and AERMOD produced agreement within a factor of two against the OP-FTIR dataset, and just exceeded this criteria for the Tedlar® dataset. In each case this factor of agreement was in the direction of underprediction.

For each dataset, the area models underpredicted the measured concentrations by factors comparable to those of the volume source models, indicating that any error introduced by characterizing the source as a volume instead of an area is minimal.

The comparisons may have been inherently biased toward underprediction due to their inability to correct for the density of the tracer gas. The weather during the field study was overcast with very little vertical mixing and winds of less than 6 miles per hour; therefore, a heavy gas (SF_6 has a high density, nearly five times heavier than air) may have exhibited less dispersion than under other conditions. This explanation becomes even more plausible in a closer evaluation of the data, which reveals that at many of the closest receptors, the models predicted zero but the OP-FTIR detected measurable amounts of SF_6 .

CONCLUSIONS

All models evaluated in this study underpredicted the measured concentrations.

Regardless of source configuration or measurement technique used, under-prediction with respect to the measured concentration was observed in each instance. This consistent underprediction indicates that safety factors or other corrections may be necessary in predicting contaminant concentrations over the distances examined in this study; i.e., in the near field of less than 200 meters.

Although a general trend was observed between the area source model predictions and the volume source model predictions (the area source models tended to underpredict the measured concentrations by a slightly smaller margin than the volume source models, for each dataset); this difference was not significant at the 95% confidence level and does not indicate that the source was incorrectly configured for receptor locations in the near-field.

RECOMMENDATIONS

1. Future model evaluation studies should include a variety of non-endogenous chemicals and varying emission rates;
2. The inability to compare the Tedlar® point samples directly to the OP-FTIR added a degree of uncertainty to this evaluation. This could be eliminated in future studies by taking Tedlar® point samples along the FTIR open-paths which are of similar time duration, and comparing these numbers against model predictions of the same time averages.

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Appendix A:

FIGURES AND TABLES

FIGURE 1:
Duke Forest Site

FIGURE 2

Source Release
Tower

FIGURE 3: Source Release Tower

A. Front View

B. Top View

- 1 TRACER FLOW CONTROLS
- RELEASE POINTS

SRI Volume Source Tracer Release Configuration

FIGURE 4:
SF6 FTIR Data vs. Model Predictions

- ◆ ISC
- AERMOD
- ▲ Line of Equivalence
- Linear (Line of Equivalence)
- Linear (AERMOD)
- Linear (ISC)

isc
 $y = 0.6026x$
 $R^2 = 0.3794$

aermod
 $y = 0.6396x$
 $R^2 = 0.3683$

FIGURE 5:
Tedlar SF6 Data vs. Model Predictions

FIGURE 6:
Area vs. Volume Configurations,
ISC2 and ISC3 with FTIR SF6 Dataset

ISC3 area
 $y = 0.5954x$
 $R^2 = 0.3517$

ISC volume
 $y = 0.6026x$
 $R^2 = 0.3794$

ISC2 area
 $y = 0.6083x$
 $R^2 = 0.3069$

FIGURE 7:
Area vs. Volume Configurations,
AERMOD with FTIR SF6 Dataset

FIGURE 8:
Volume vs. Area Configurations,
ISC2 and ISC3 with Tedlar SF6 Dataset

ISC volume
 $y = 0.3714x$
 $R^2 = 0.668$

ISC3 area
 $y = 0.5312x$
 $R^2 = 0.6333$

ISC2 area
 $y = 0.5087x$
 $R^2 = 0.5981$

FIGURE 9:
Volume vs. Area Configuration;
AERMOD with Tedlar SF6 Dataset

TABLE 1

Tracer Release Data for the EPA/API Cooperative Field Study

DATE:	JAN 17	JAN 18	JAN 18	JAN 18	JAN 18	JAN 23	JAN 24	JAN 24	JAN 25	JAN 25	JAN 26	JAN 26	JAN 26	JAN 26
DAY OF WEEK:	TUES	WEDNES	WEDNES	THURS	THURS	MON	TUES	TUES	WEDNES	WEDNES	THURS	THURS	THURS	THURS
START TIME:	1557 HRS	1148 HRS	1533 HRS	1020 HRS	1440 HRS	1427 HRS	1030 HRS	1328 HRS	1055 HRS	1358 HRS	1157 HRS	1300 HRS	1415 HRS	1445 HRS
STOP TIME:	1800 HRS	1413 HRS	1840 HRS	1235 HRS	1850 HRS	SCRIP 181	1235 HRS	1535 HRS	1302 HRS	1600 HRS	1300 HRS	1410 HRS	1440 HRS	1500 HRS
DURATION OF RUN MINUTES:	83	147	87	135	130	103	125	129	127	122	63	70	25	15
TRACER LOG SEQUENCE NO.:	10	11	12	13	14	15	16	17	18	19	20	20A	20B	20C
TEST NOTATIONS:	SF6-PNT	LMT-STGR	LMT-STGR	LMT-STGR	LMT-STGR	SF6 ONLY	LMT-STGR	LMT-STGR	LMT-STGR	LMT-STGR	SF6 ONLY	ADD C1&C	CONT'D	SF6 ONLY
	CALMWND	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE	RELEASE
ALL CORRECTED TO 25°C & 760 mmHg														
LOWER MANIFOLD														
CH4 FLOW IN LITERS/MINUTE		182.8275	188.8331	189.2357	187.015		175.8194	171.3029	175.7516	174.5958		211.1488	210.1957	
C2H6 FLOW IN LITERS/MINUTE												69.27793	68.98522	
C3H8 FLOW IN LITERS/MINUTE									8.789902	8.206159				
SF6 FLOW IN LITERS/MINUTE	1.3887	1.138932	1.132885	1.14328	1.134128	1.413457	1.183643	1.142469	1.181834	1.182302	1.393509	1.383049	1.378806	1.38946
GRAND TOTAL FLOW LITERS/MINUTE	1.3887	184.0685	189.788	170.379	188.1492	1.413457	178.983	172.4454	185.7234	183.9842	1.393509	281.8098	280.5377	1.38946
SRI DGM VERIFICATION LITERS/MINUTE		158.558		163.1971					174.8433	178.7802				
CENTER POINT SOURCE														
CB/F3 FLOW IN LITERS/MINUTE				3.107327	3.09288		2.309983	2.280848	2.272435	2.051514				
CF4 FLOW IN LITERS/MINUTE		2.985495	2.945302											
GRAND TOTAL FLOW LITERS/MINUTE	0	2.985495	2.945302	3.107327	3.09288	0	2.309983	2.280848	2.272435	2.051514	0	0	0	0
UPPER MANIFOLD														
CH4 FLOW IN LITERS/MINUTE												211.6457	212.738	
C2H6 FLOW IN LITERS/MINUTE		45.75869	45.80421	48.08348	45.81399		48.75333	48.41548	47.11093	48.81763		68.19475	68.54871	
C3H8 FLOW IN LITERS/MINUTE									7.688081	7.190417				
SF6 FLOW IN LITERS/MINUTE	1.347837	0.980723	0.968348	0.972	0.96432	1.402415	0.987727	0.978148	0.993272	0.993091	1.375907	1.416422	1.423733	1.370496
GRAND TOTAL FLOW LITERS/MINUTE	1.347837	46.71741	46.87058	47.05548	46.77831	1.402415	47.74108	47.39163	55.79229	55.00113	1.375907	281.2569	282.7084	1.370496
SRI DGM VERIFICATION LITERS/MINUTE			47.70132		49.45825							294.1028	281.2828	

Table 2: Meteorological Variables

ISC	AERMOD
year, month, day, Julian day, hour	year, month, day, Julian day, hour
friction velocity**	sensible heat flux (W/m^2) = energy flux driven by temp dif. between ground and atmosphere surface friction velocity = shear stress of ground slowing air flow div. by air density
vertical potential temperature gradient	vertical potential temperature gradient in the 500 m layer above the PBL
rural mixing height	height of the PBL
urban mixing height	
Monin-Obukhov length**	Monin-Obukhov length = height at which shear production of turbulence is approx. equal to prod. of turbulence by buoyancy
surface roughness length**	surface roughness length Bowen ratio = ratio of latent heat flux* to sensible heat flux albedo = reflectivity of the ground
wind speed (m/s)	wind speed
flow vector (degrees)	wind direction (from) height ws and wd measured at
ambient temperature	temperature height temperature measured σ_θ = s.d. of wind direction (degrees) σ_w = s.d. of wind speed (m/s)
stability class	
precipitation code/ rate	
*latent heat flux = energy used to evaporate moisture from the ground	
**dry or wet deposition only	

TABLE 3: Linear Regression Results for ISC Volume and AERMOD Volume Predictions; OP-FTIR and Tedlar® Datasets

Model	² Slope	CI (lower)	CI (upper)	Factor (of under-prediction)	R-squared
ISC (OP-FTIR)	0.6026	0.4130	0.7922	1.66	0.3794
Aermod (OP-FTIR)	0.6396	0.4385	0.8408	1.56	0.3683
ISC (Tedlar®)	0.3754	0.3078	0.4430	2.66	0.7163
Aermod (Tedlar®)	0.4613	0.3848	0.5378	2.17	0.754967

Table 4: Linear Regression Results for Area Predictions; OP-FTIR Dataset

Model	² Slope	CI (lower)	CI (upper)	Factor (of under-prediction)	R ²
ISC2 area	0.6083	0.3247	0.8918	1.64	0.3069
ISC3 area	0.5954	0.3738	0.8170	1.68	0.3517
Aermod area	0.6814	0.4113	0.9516	1.47	0.3173

Table 5: Linear Regression Results for Area Predictions; Tedlar® Dataset

Model	² Slope	CI (lower)	CI (upper)	Factor (of under-prediction)	R ²
ISC2 area	0.5230	0.4285	0.6174	1.91	0.7318
ISC3 area	0.5435	0.4442	0.6427	1.84	0.7196
Aermod area	0.5486	0.4639	0.6332	1.82	0.7881

Appendix B:

SAMPLING DATA /
MODEL INPUT PARAMETERS

**UNC/DOE Five Minute Averages
of Open-Path FTIR Data:**

Time	Concentration SF6, ppm-m
1223	2.147498
1228	2.156538
1233	1.587224
1238	0.401929
1243	1.564114
1248	1.388699
1253	1.837388
1258	1.730313
1303	1.907801
1308	1.153931
1313	1.213326
1318	2.388645
1323	1.733626

Sample FTIR Analysis Output with Spectral Regions Used

Z mda Remote FTIR Sensor Concentration Analysis Module

SCRIPT FILE : C:\DATA\SCRIPTS\ALLCOMP.SPT

ABSORBANCE FILE: C:\DATA\F2SP001.SPC

ABSORBANCE MEMO: ETG SPECTRAL FILE

ABSORBANCE DATE: Wed Jan 18 12:20:00 1995

ONE-WAY PATHLENGTH: 1.00 meters

TEMPERATURE : 283.0 Kelvin

PRESSURE : 760.0 Torr

REJECTION RATIO : ****

MEASUREMENT UNITS : PPM-M

DATE OF ANALYSIS : Tue Sep 12 11:54:11 1995

REGION	COMPOUND NAME	CONCENTRATION
--------	---------------	---------------

1: 2882.50 - 2994.30	METHANE	302.0854 (6.9077)
2: 2849.40 - 3077.30	Ethane	25.5584 (9.0931)
3: 829.24 - 1069.80	Propylene	< MDL = 17.855
4: 934.23 - 954.96	Sulfur Hexafluoride	4.23206 (0.45872)
5: 1175.80 - 1223.03	Bromotrifluoromethane	< MDL = 0.78224
6: 1271.80 - 1291.50	Carbon Tetrafluoride	6.05680 (0.56907)

SUMMARY:

-Compound Name-----Reject--Hits/Regions--Conc--(3 sigma)----

METHANE	2.00	1/1	302.0854 (6.9077)
Ethane	2.00	1/1	25.5584 (9.0931)
Propylene	2.00	0/1	< MDL = 17.855
Sulfur Hexafluoride	2.00	1/1	4.23206 (0.45872)
Bromotrifluoromethane	2.00	0/1	< MDL = 0.78224
Carbon Tetrafluoride	3.00	1/1	6.05680 (0.56907)

POINT SAMPLE SUMMARY

PROJECT: EPA/API Dispersion Study

TEST: Test F - SF6

DATE: 01/18/95

Anal. #	Sample ID	Sample Time	Tracer (ppb)	Concen. ugm/m3	GC Units	Calib. ID
F-1	1812A150	1200 EST	3.2	20.8	43	F-SF1
F-2	1812A160	1200 EST	8.4	54.7	103	F-SF1
	1812A170	1200 EST				F-SF1
F-3	1812A180	1200 EST	24.3	158.3	250	F-SF1
	1812A190	1200 EST				F-SF1
F-4	1812A200	1200 EST	23.7	154.4	245	F-SF1
F-5	1812A210	1200 EST	29.3	190.9	289	F-SF1
✓ F-6	1812B140	1200 EST	0.1	0.7	1	F-SF1
F-7	1812B150	1200 EST	0.2	1.3	3	F-SF1
F-8	1812B160	1200 EST	2.6	16.9	96	F-SF2A
F-9	1812B170	1200 EST	20.8	135.5	222	F-SF2B
F-10	1812B180	1200 EST	5.1	33.2	65	F-SF1
F-11	1812B190	1200 EST	6.6	43.0	83	F-SF1
F-12	1812B200	1200 EST	7.6	49.5	94	F-SF1
F-13	1812B210	1200 EST	6.3	41.0	79	F-SF1
F-14	1812B220	1200 EST	3.5	22.8	46	F-SF1
F-15	1812B320	1200 EST	0.0	0.0	0	F-SF1
F-16	1812B000	1200 EST	0.0	0.0	0	F-SF1
F-17	1812C150	1200 EST	0.2	1.3	9	F-SF4
F-18	1812C160	1200 EST	1.3	8.5	75	F-SF4
F-19	1812C170	1200 EST	0.9	5.9	51	F-SF4
F-20	1812C180	1200 EST	2.0	13.0	121	F-SF4
F-21	1812C190	1200 EST	2.2	14.3	131	F-SF4
F-22	1812C200	1200 EST	3.3	21.5	197	F-SF4
F-23	1813A170	1200 EST	5.7	37.1	36	F-SF6
F-24	1813A180	1200 EST	5.9	38.4	37	F-SF6
F-25	1813A190	1200 EST	3.8	24.8	24	F-SF6
F-26	1813A200	1315 EST	8.0	52.1	92	F-SF8
F-27	1813A210	1315 EST	10.3	67.1	116	F-SF8
F-28	1813A220	1315 EST	9.5	61.9	108	F-SF8
F-30	1813A230	1315 EST	14.5	94.5	156	F-SF8
F-29	1813A250	1315 EST	22.0	143.3	221	F-SF8
	1813B170	1315 EST				F-SF9
F-33	1813B180	1315 EST	1.7	11.1	25	F-SF9
F-34	1813B190	1315 EST	1.2	7.8	18	F-SF9
F-35	1813B200	1315 EST	2.0	13.0	29	F-SF9
F-36	1813B210	1315 EST	2.7	17.6	38	F-SF9
F-37	1813B220	1315 EST	0.6	3.9	9	F-SF9
F-38	1813B230	1315 EST	2.8	18.2	40	F-SF9
F-39	1813B240	1315 EST	3.5	22.8	48	F-SF9
F-31	1813B000	1315 EST	0.0	0.0	0	F-SF8
F-32	1813B030	1315 EST	0.0	0.0	0	F-SF8
F-40	1813C180	1315 EST	0.3	2.0	5	F-SF9
F-44	1813C190	1315 EST	0.3	2.0	16	F-SF11
F-45	1813C200	1315 EST	1.0	6.5	64	F-SF11

POINT SAMPLE SUMMARY

PROJECT: EPA/API Dispersion Study

TEST: Test F - SF6

DATE: 01/18/95

Anal. #	Sample ID	Sample Time	Tracer (ppb)	Concen. ugm/m3	GC Units	Calib. ID
F-46	1813C210	1315 EST	0.7	4.6	44	F-SF11
F-47	1813C220	1315 EST	0.8	5.2	54	F-SF11
	1813C230	1315 EST				F-SF11
F-48	1813C240	1315 EST	2.3	15.0	149	F-SF11

2/11/16

CO STARTING
TITLEONE ISC3 1 AREA sf6 UNC 1A3SU.INP
MODELOPT DFAULT RURAL CONC
AVERTIME 1
POLLUTID SF6
UNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION 1LOWER AREA -5.6 2.5 -2.32
SRCPARAM 1LOWER 0.005516 2.44 11.89 3.66
SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0.0 0.0
POL2 DIST 5. 10. 15. 20. 25. 30. 35. 40. 45.
POL2 DIST 50. 55. 59.09 62.82 65.12 67.42 71.11
POL2 DIST 72.11 79.56 87.13
POL2 GDIR 14 140. 5.
POL2 END
RE FINISHED

ME STARTING
INPUTFIL C:\5MIN.PRN
ANEMHGHT 2
SURFDATA 116 1995
UAIRDATA 1 1995
TARTEND 95 01 18 01 95 01 19 04
WDROTATE 180
ME FINISHED

OU STARTING
POSTFILE 1 ALL PLOT C:\1A3SU.XLS
OU FINISHED

1AASU.inp

2/11/96

CO STARTING
TITLEONE AER 1 AREA SF6 UNC
MODELOPT CONC MSGPRO
AVERTIME 1
POLLUTID SF6
RUNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION 1LOWER AREA -5.6 2.5 -2.32
SRCPARAM 1LOWER 0.0055160 2.44 11.89 3.66
SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0.0 0.0
POL2 DIST 5. 10. 15. 20. 25. 30. 35. 40. 45.
POL2 DIST 50. 55. 59.09 62.82 65.12 67.42 71.11
POL2 DIST 72.11 79.56 87.13
POL2 GDIR 14 140. 5.
POL2 END

RE FINISHED

ME STARTING
SURFFILE C:\AERMET1.SFC
PROFFILE C:\AERMET.PFL
UAIRDATA 0 1995
SURFDATA 13722 1995
ITEDATA 13722 1995
M. FINISHED

OU STARTING
POSTFILE 1 ALL PLOT C:\1AASU.XLS
OU FINISHED

2/10/96

vasu.inp

CO STARTING
TITLEONE unc aermod VOL SF6
MODELOPT CONC MSGPRO
VERTIME 1
OLLUTID SF6
RUNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION UPPER VOLUME 0.0 0.0 0.0
** Volume Source VE RHT SY SZ
** Parameters: ----
SRCPARAM UPPER 0.240106 3.81 2.765116 3.544

SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL1 STA
POL1 ORIG 0.0 0.0
POL1 DIST 5.0 10.0 15.0 20.0 25.0 30.0 35.0
POL1 DIST 40.0 45.0 50.0 55.0 59.09 62.82 65.12 67.42
POL1 DIST 71.11 72.11 79.56 87.13
POL1 GDIR 14 140. 5.
POL1 END

RE FINISHED

ME STARTING
SURFFILE C:\aermet1.SFC
PROFFILE C:\AERMET.PFL
UAIRDATA 0 1995
SURFDATA 13722 1995
SITEDATA 13722 1995

ME FINISHED

OU STARTING

POSTFILE 1 ALL PLOT C:\VASU.XLS
OU FINISHED

2/10/96

CO STARTING
TITLEONE isc2 vol sf6 ted v2st.inp
MODELOPT DFAULT RURAL CONC
AVERTIME 1
POLLUTID SF6
RUNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION UPPER VOLUME 0.0 0.0 0.0
** Volume Source VE RHT SY SZ
** Parameters: -----
SRCPARAM UPPER 0.240106 3.81 2.765116 3.544

SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0. 0.
POL2 DIST 50. 100. 150.
POL2 GDIR 9 150. 10.
POL2 END

RE FINISHED

M STARTING
INPUTFIL c:\TEDMET.prn
ANEMHGHT 2
SURFDATA 116 1995
UAIRDATA 1 1995
STARTEND 95 01 18 01 95 01 19 04
WDROTATE 180
ME FINISHED

OU STARTING
POSTFILE 1 ALL PLOT C:\v2st.xls
OU FINISHED

2/10/96

CO STARTING
TITLEONE AER VOL SF6 TED VAST.INP
MODELOPT CONC MSGPRO
VERTIME 1
POLLUTID SF6
RUNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION UPPER VOLUME 0.0 0.0 0.0
** Volume Source VE RHT SY SZ
** Parameters: -----
SRCPARAM UPPER 0.240106 3.81 2.765116 3.544

SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0. 0.
POL2 DIST 50. 100. 150.
POL2 GDIR 9 150. 10.
POL2 END

RE FINISHED

MF STARTING
SURFFILE C:\tedmet1.SFC
PROFFILE C:\tedmet.PFL
UAIRDATA 0 1995
SURFDATA 13722 1995
SITEDATA 13722 1995

ME FINISHED

OU STARTING

POSTFILE 1 ALL PLOT C:\VAST.XLS
OU FINISHED

2/11/96

CO STARTING
TITLEONE ISC3 1 AREA SF6 TED 1A3ST.INP
MODELOPT DFAULT RURAL CONC
AVERTIME 1
OLLUTID SF6
RUNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION 1LOWER AREA -5.6 2.5 -2.32
SRCPARAM 1LOWER 0.005516 2.44 11.89 3.66
SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0.0 0.0
POL2 DIST 50. 100. 150.
POL2 GDIR 9 150. 10.
POL2 END
RE FINISHED

ME STARTING
INPUTFIL C:\TEDMET.PRN
ANEMHGHT 2
SURFDATA 116 1995
UAIRDATA 1 1995
STARTEND 95 01 18 01 95 01 19 04
DROTATE 180
ME FINISHED

OU STARTING
POSTFILE 1 ALL PLOT C:\1A3ST.XLS
OU FINISHED

2/11/96

1a 2st.inp

CO STARTING
TITLEONE isc2 ted 1 area sf6
MODELOPT DFAULT RURAL CONC
VERTIME 1
POLLUTID SF6
RUNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION 1LOWER AREA -5.6 2.5 -2.32
** Area Source VE RHT XINIT YINIT
** Parameters: -----
SRCPARAM 1LOWER 0.005516 2.44 6.5962

SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0.0 0.0
POL2 DIST 50. 100. 150.
POL2 GDIR 9 150. 10.
POL2 END

RE FINISHED

ME STARTING
INPUTFIL c:\TEDMET.prn
ANEMHGHT 2
SURFDATA 116 1995
UAIRDATA 1 1995
STARTEND 95 01 18 01 95 01 19 04
WDROTATE 180
ME FINISHED

OU STARTING

POSTFILE 1 ALL PLOT C:\1A2ST.XLS
OU FINISHED

511176

1AAsst.inp

CO STARTING
TITLEONE AER 1 AREA SF6 TED
MODELOPT CONC MSGPRO
AVERTIME 1
OLLUTID SF6
UNORNOT RUN
ERRORFIL ERRORS.OUT
CO FINISHED

SO STARTING
LOCATION 1LOWER AREA -5.6 2.5 -2.32
SRCPARAM 1LOWER 0.0055160 2.44 11.89 3.66
SRCGROUP ALL
SO FINISHED

RE STARTING
GRIDPOLR POL2 STA
POL2 ORIG 0.0 0.0
POL2 DIST 50. 100. 150.
POL2 GDIR 9 150. 10.
POL2 END
RE FINISHED

ME STARTING
SURFFILE C:\TEDMET1.SFC
PROFILE C:\TEDMET.PFL
UAIRDATA 0 1995
SURFDATA 13722 1995
SITEDATA 13722 1995
ME FINISHED

OU STARTING
POSTFILE 1 ALL PLOT C:\1AAsT.XLS
OU FINISHED

Appendix C:

METEOROLOGICAL DATA

NATIONAL WEATHER SERVICE
RALEIGH, NC

SURFACE WEATHER OBSERVATIONS
PRELIMINARY WFI-108

JANUARY 18, 1995
TO CONVERT LST TO GMT
ADD 05 HRS. SUBTRACT

HRS.

CLOUD AND OBSCURING PHENOMENA																				NET						
TIME	STAT	WY	HFT	REL	SKY	LAYER 1				LAYER 2				LAYER 3				LAYER 4				OPQ	PRE	3HR	SUN	HRLY
LST	(HNS)	(HF)	(HF)	(%)	CLD	AMT	TYPE	HGT	AMT	TYPE	HGT	TOT	AMT	TYPE	HGT	TOT	AMT	TYPE	HGT	SKY	TEN	CHG	MIN	PCPN		
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40		
0050	27695	40.0	33.7	89.1	0															0	1	015		.00		
0150	27695	40.0	33.7	89.1	4	4	CI	250												0				.00		
0252	27733	31.0	37.2	72.5	4	4	CI	250												0				.00		
0353	27715	37.0	36.2	72.5	4	4	CI	250												0	3	020		.00		
0450	27705	37.0	36.2	72.5	3	3	CI	250												0				.00		
0550	27723	37.0	36.2	72.5	3	3	CI	250												0				.00		
0650	27730	36.0	35.2	72.5	6	6	CI	250												1	3	015		.00		
0750	27750	35.0	35.2	72.5	6	6	CI	250												1				.00		
0850	27770	31.0	37.2	72.5	3	3	CI	250												2				.00		
0950	27730	44.0	41.0	76.5	5	5	CI	250												2	2	060		.00		
1053	27715	53.0	45.3	61.7	7	7	CI	250												3				.00		
1150	27710	54.0	47.7	61.7	7	7	CI	E250												6				.00		
1253	27750	56.0	49.1	57.6	10	10	CI	E250												6	8	040		.00		
1350	27730	58.0	50.5	57.6	10	0	SC	25 10	CI	E250 10										6				.00		
1450	27715	57.0	50.9	57.4	10	0	SC	25 10	CI	250 10										5				.00		
1553	27710	58.0	50.9	59.1	10	0	SC	25 10	CI	250 10										4	6	040		.00		
1650	27725	55.0	49.5	56.7	10	1	SC	15 9	CI	E250 10										6				.00		
1751	27730	52.0	41.5	77.2	10	1	SC	15 9	CI	250 10										5				.00		
1850	27730	51.0	43.0	50.1	10	3	SC	15 7	CI	E250 10										8	1	020		.00		
1954	27735	52.0	43.0	30.1	10	10	SC	H 15												10				.00		
2050	27730	50.0	47.5	33.1	10	10	SC	H 13												10				.00		
2150	27730	50.0	47.5	33.1	10	10	SC	H 11												10	4	000		.00		
2250	27715	47.0	47.0	36.2	10	10	ST	H 9												10				.00		
2350	27710	47.0	47.5	37.3	10	10	ST	H 7												10				.00		

SYNOPTIC OBSERVATIONS

TIME (LST)	PRECIP (LST)	SNOW FALL (LST)	SNOW DEPTH (LST)	MAX TEMP (LST)	MIN TEMP (LST)	STATE OF GRND	SOIL TEMP (LST)	STATION TIME (LST)	PRESSURE STATION PRESSURE	COMPUTATIONS BAROMETER CORRECTION
42	44	45	46	47	48	50	56	59	63	65
410 0050	0.00	0.0		42	39			0050	29.690	.0005
0050	0.00	0.0	0	41	39			0650	29.730	.000
0650	0.00	0.0	0	40	35			1253	29.750	.000
1253	0.00	0.0	0	57	35			1850	29.730	.000
1850	0.00	0.0	0	51	51					
410.	0.00	0.0	0	52	49					

Five-Minute Meteorological Data Averages

KEY: Year, Month, Day, 5-minute interval, wind direction, wind speed, temperature, PGT stability class, mixing height

95 118 1	12.166	4.3462	284.88	4	500
95 118 2	5.933	4.0828	285.32	4	500
95 118 3	31.076	4.0338	285.42	3	500
95 118 4	46.5	3.4874	285.15	3	500
95 118 5	34.178	3.7448	285.68	4	500
95 118 6	55.196	4.0994	285.60	3	500
95 118 7	64.204	3.2314	285.47	2	500
95 118 8	351.976	4.6864	286.05	4	500
95 118 9	9.468	5.1238	285.82	4	500
95 118 10	27.462	5.006	285.74	3	500
95 118 11	40.398	4.5776	285.74	4	500
95 118 12	355.62	3.8566	285.78	4	500
95 118 13	5.068	3.0784	285.97	4	500
95 118 14	104.474	3.1554	286.23	2	500
95 118 15	56.53	3.6948	286.40	2	500
95 118 16	61.302	4.8634	286.48	4	500
95 118 17	86.306	5.1232	285.95	4	500
95 118 18	93.66	4.6144	285.84	4	500
95 118 19	75.938	5.1244	286.03	4	500
95 118 20	71.916	4.1484	286.25	4	500

Appendix D:

MODEL OUTPUTS

V2ST.XLS

	ug/m ³	
0.742881	0.742881	A150
0.031267	12.09735	A160
0.004611	45.82281	A180
12.09735	74.39144	A200
2.68648	82.18918	A210
1.001802	0.031267	B150
42.86527	2.68648	B160
19.66757	19.66757	B170
11.49364	17.28136	B180
45.82281	16.29761	B190
17.28136	31.4371	B200
9.105023	28.19607	B210
49.8611	43.76064	B220
16.29761	0.004611	C150
7.966414	1.001802	C160
74.39144	11.49364	C170
31.4371	9.105023	C180
18.01723	7.966414	C190
82.18918	18.01723	C200
28.19607	35.49554	A170
13.93917	13.33056	A180
101.2833	0.884458	A190
43.76064	1.085088	A200
25.17878	8.829451	A210
98.05107	26.03691	A220
34.80065	43.61838	A230
17.89178	3.722017	B180
1.522445	0.037345	B190
0.098933	0.096283	B200
0.016998	2.250884	B210
17.59757	9.985417	B220
5.88885	16.25311	B230
2.777109	1.571346	C180
35.49554	0.004964	C190
18.66593	0.021747	C200
11.59258	0.938138	C210
13.33056	5.373966	C220
3.722017		

Vast.xls

	Order	
	ug/m ³	
5.648328	5.648328	A150
1.193273	20.46079	A160
0.381514	61.35507	A180
20.46079	96.0724	A200
6.699923	98.2403	A210
3.067483	1.193273	B150
40.59972	6.699923	B160
15.38505	15.38505	B170
8.088343	21.85831	B180
61.35507	30.65555	B190
21.85831	34.45224	B200
10.90335	33.9711	B210
84.51016	36.71066	B220
30.65555	0.381514	C150
15.48506	3.067483	C160
96.0724	8.088343	C170
34.45224	10.90335	C180
17.48747	15.48506	C190
98.2403	17.48747	C200
33.9711	0.000275	A170
16.72161	0.049899	A180
101.7249	0.875745	A190
36.71066	4.651882	A200
18.9292	12.60076	A210
97.89763	26.34451	A220
34.43056	57.45091	A230
17.11595	0.002008	B180
0	0.101382	B190
0	1.007133	B200
0	3.779775	B210
0	8.275476	B220
0	18.15777	B230
0	0.000173	C180
0.000275	0.020333	C190
1.67E-06	0.339273	C200
0	1.712501	C210
0.049899	4.052288	C220
0.002008		
0.000173		

updated
2/18/96

1A3ST.XLS

	ug/m^3	
0.41263	0.41263	A150
0.009497	19.73263	A160
0.000749	68.3536	A180
19.73263	119.7053	A200
3.019517	107.0233	A210
0.982042	0.009497	B150
81.72224	3.019517	B160
33.23601	33.23601	B170
17.23365	22.51949	B180
68.3536	18.68465	B190
22.51949	48.56459	B200
10.94144	31.5123	B210
63.5399	68.0654	B220
18.68465	0.000749	C150
8.679618	0.982042	C160
119.7053	17.23365	C170
48.56459	10.94144	C180
25.5187	8.679618	C190
107.0233	25.5187	C200
31.5123	66.70706	A170
14.63776	13.65752	A180
166.9416	0.149287	A190
68.0654	0.166599	A200
4.2099	4.861823	A210
0.1201	31.0289	A220
45.28501	61.01313	A230
21.53771	3.063185	B180
1.404617	0.005913	B190
0.047241	0.018674	B200
0.007825	1.402088	B210
37.06022	11.90878	B220
9.128495	20.81723	B230
3.635988	1.221708	C180
66.70706	0	C190
32.12169	0.007141	C200
17.71184	0.632568	C210
13.65752	6.141016	C220
3.063185		
1.221708		

1A4ST.XLS

	ug/m^3	
12.57975	12.57975	A150
2.113501	31.58903	A160
0.634571	77.67649	A180
31.58903	114.4727	A200
8.403822	116.7253	A210
3.639795	2.113501	B150
53.90695	8.403822	B160
16.7227	16.7227	B170
8.282493	23.6396	B180
77.67649	32.219	B190
23.6396	36.06688	B200
11.26768	35.5061	B210
101.7376	38.01805	B220
32.219	0.634571	C150
15.69295	3.639795	C160
114.4727	8.282493	C170
36.06688	11.26768	C180
17.67246	15.69295	C190
116.7253	17.67246	C200
35.5061	0.003138	A170
16.95324	0.133197	A180
120.8887	1.170221	A190
38.01805	4.812609	A200
18.85841	12.11877	A210
122.6536	25.16094	A220
37.31376	55.65108	A230
17.86289	0.006531	B180
0	0.140663	B190
0	1.049361	B200
0	3.543979	B210
0	7.77804	B220
0	17.54423	B230
0	0	C180
0.003138	0.030248	C190
0	0.371671	C200
0	1.632809	C210
0.133197	3.797653	C220
0.006531		

1A2ST.XLS

	ug/m^3	
0.019318	0.019318	A150
0.001998	4.578171	A160
0.000538	78.50313	A180
4.578171	104.0015	A200
1.164004	108.9146	A210
0.492971	0.001998	B150
67.77527	1.164004	B160
28.5818	28.5818	B170
15.33092	24.8548	B180
78.50313	14.89795	B190
24.8548	45.70764	B200
11.79498	29.8203	B210
45.08676	64.60335	B220
14.89795	0.000538	C150
7.380746	0.492971	C160
104.0015	15.33092	C170
45.70764	11.79498	C180
24.66553	7.380746	C190
108.9146	24.66553	C200
29.8203	80.62038	A170
13.62942	20.86643	A180
140.9802	0.166271	A190
64.60335	0.004099	A200
34.89326	0.907824	A210
171.1112	17.4173	A220
47.8109	56.37548	A230
21.82404	4.206771	B180
0.082249	0.005278	B190
0.007243	0.002752	B200
0.001831	0.596047	B210
15.02519	9.208535	B220
4.758312	20.21959	B230
2.244987	1.588803	C180
80.62038	0.000823	C190
34.48538	0.0015	C200
18.45841	0.35461	C210
20.86643	5.211746	C220
4.206771		

1H35U.XLS

tro *21.27 liters at 50F/mw sf6)		
in ret	ppm-m	5 min are
0.061125	0.00058	1.471985
0.416889	0.004093	1.539894
1.117291	0.011571	0.739596
7.200141	0.083421	0.062201
18.61054	0.236158	0.273145
361.0283	3.791479	0.005342
611.5842	5.59499	0.010994
238.9612	2.05359	1.793159
0.255702	0.002425	1.257646
2.054718	0.020174	0.836431
5.120387	0.05303	0.035624
32.79049	0.37991	1.818641
84.84048	1.076581	2.020694
637.8616	6.698752	0
379.7499	3.474088	0.046451
71.46953	0.614196	0
0.250325	0.002374	2.19E-06
0.789893	0.007755	0
1.260098	0.01305	0
3.042691	0.035253	0
805378	0.060978	
1.4939	0.330746	

V2SU.XLS

tro *21.27 liters at 50F/mw sf6)		
5 min ret	ppm-m	5 min are
0	0	1.396112
9.270264	0.091018	1.519646
14.34146	0.148528	0.726977
34.75082	0.402623	0.24428
55.76361	0.707611	0.64176
324.8656	3.411703	0.08375
470.0742	4.300407	0.073506
245.1771	2.107008	1.612312
7.229701	0.068559	1.205221
18.51517	0.181787	0.706719
28.5678	0.295864	0.276094
72.0334	0.834579	1.778167
122.3188	1.552161	2.015493
464.6054	4.879234	0
348.3748	3.187057	0.123924
1.7396	1.157928	0
0	0	0.027716
0	0	0
0	0	0
3.150414	0.094431	0
12.47643	0.158319	
9.50877	0.624954	

1A25U.XLS

tro *21.27 liters at 50F/mw sf6)		
5 min ret	ppm-m	5 min are
0	0	1.641872
0	0	1.927526
6.67E-07	6.9E-09	0.194957
0.000911	1.06E-05	0.000323
0.025066	0.000318	0.015433
116.7245	1.225828	1.72E-07
796.144	7.28341	2.12E-06
538.2254	4.625414	1.81476
0	0	1.480175
0.000517	5.08E-06	0.341185
0.007617	7.89E-05	0.000101
0.509352	0.005901	1.749389
4.776396	0.06061	2.551732
637.3009	6.692864	0
738.2301	6.753593	0.000272
221.9222	1.90716	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0.054052	0.000568	

1AASU.XLS

tro *21.27 liters at 50F/mw sf6)		
5 min ret	ppm-m	5 min are
0.249285	0.002364	1.440275
3.187875	0.031299	1.764766
8.33365	0.086308	0.710979
41.60973	0.48209	0.212485
81.03653	1.028311	0.560178
336.4737	3.533609	0.020807
420.355	3.845558	0.022378
292.3797	2.512659	1.752499
2.711172	0.02571	1.168576
17.74706	0.174246	0.627358
36.97269	0.382909	0.1677
124.1749	1.43869	2.309685
196.8518	2.497945	2.867782
423.2737	4.445174	0
376.1788	3.441418	0.072764
199.2174	1.712039	0
0.001723	1.63E-05	0.000837
0.066359	0.000652	0
0.256551	0.002657	0
2.31603	0.026834	1.3E-06
5.659996	0.071822	

V4SU.XLS

5 min ret	ppm-m	5 min are
2.714615	0.025743	1.424777
8.304971	0.081541	1.612418
14.09556	0.145981	0.810726
43.54867	0.504555	0.297912
77.64784	0.98531	0.694623
327.2304	3.436537	0.079815
422.0022	3.860627	0.05885
274.3743	2.357924	1.694513
6.351291	0.060229	1.257193
19.64144	0.192845	0.789959
34.13585	0.353529	0.314223
103.7805	1.202401	1.924092
168.3535	2.136318	2.132044
396.2415	4.161285	0
356.2814	3.25939	0.13464
178.4239	1.533343	1.91E-09
3.85E-06	3.65E-08	0.023961
0.034865	0.000342	1.18E-05
0.127769	0.001323	1.95E-0
6.227445	0.072151	0.0034
10.796	0.136996	
74.55385	0.782956	

M97053620

Report Number (14) DOE/OR/00033--T743

Publ. Date (11)

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Sponsor Code (18)

DOE, XF

UC Category (19)

UC-900, DOE/ER

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