

US EPA ARCHIVE DOCUMENT

>>>> This article, FR94, is divided into five files. This is File E: Technical Amendments; Summaries of Alternative Air Quality Models of Appendix B to Appendix X to Part 266 through Appendix C to Appendix X to Part 266, Example Air Quality Analysis Checklist. <<<<

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## Appendix B to appendix X to Part 266-Summaries of Alternative Air Quality Models

### Table of Contents

B.0 Introduction

B.1 Air Quality Display Model (AQDM)

B.2 Air Resources Regional Pollution Assessment (ARRPA) Model

B.3 APRAC-3

B.4 Compter

B.5 ERT Air Quality Model (ERTAQ)

B.6 ERT Visibility Model

B.7 Hiway-2

B.8 Integrated Model for Plumes and Atmospheric Chemistry in Complex Terrain (IMPACT)

B.9 Longz

B.10 Maryland Power Plant Siting Program (PPSP) Model

B.11 Mesoscale Puff Model (MESOPUFF II)

B.12 Mesoscale Transport Diffusion and Deposition Model for Industrial Sources (MTDDIS)

B.13 Models 3141 and 4141

B.14 Multimax

B.15 Multiple Point Source Diffusion Model (MPSDM)

B.16 Multi-Source (SCSTER) Model

B.17 Pacific Gas and Electric Plumes Model

B.18 Plmstar Air Quality Simulation Model

B.19 Plume Visibility Model (PLUVUE II)

B.20 Point, Area, Line Source Algorithm (PAL)

B.21 Random Walk Advection and Dispersion Model (RADM)

B.22 Reactive Plume Model (RPM-II)

B.23 Regional Transport Model (RTM-II)

B.24 Shortz

B.25 Simple Line-Source Model (GMLINE)

B.26 Texas Climatological Model (TCM)

B.27 Texas Episodic Model (TEM)

B.28 Avacta II Model

B.REF References

B.0 Introduction

This appendix summarizes key features of refined air quality models that may be considered on a case-by-case basis for individual regulatory applications. For each model, information is provided on availability, approximate cost in 1986\*, regulatory use, data input, output format and options, simulation of atmospheric physics and accuracy. These summaries are based directly on information supplied by the model developers and have been included without change. The Models are listed by name in alphabetical order.

\*All models on UNAMAP (Version 6) are available from NTIS at a price consistent with the previous version of UNAMAP.

There are three separate conditions under which these models will normally be approved for use: first, if a demonstration can be made that the model produces concentration estimates equivalent to the estimates obtained using a preferred model (e.g. the maximum or high, second-high concentration is within 2% of the estimate using the comparable preferred model); second, if a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the model in appendix B performs better for the application than a comparable model in appendix A; and third, if there is no preferred model for the specific application but a refined model is needed to satisfy regulatory requirements. Any one of these three separate conditions may warrant use of these models. See section 3.2, Use of Alternative Models, for additional details.

Many of these models have been subjected to a performance evaluation by comparison with observed air quality data. A summary of such comparisons for models contained in this appendix is included in "A Survey of Statistical Measures of Model Performance and Accuracy for Several Air Quality Models," EPA-450/4-83-001. Where possible, several of the models contained herein have been subjected to rigorous evaluation exercises, including (1) statistical performance measures recommended by the American Meteorological Society and (2) peer scientific reviews.

B.1 Air Quality Display Model (AQDM)

Reference

TRW Systems Group, 1969. Air Quality Display Model. Prepared for National Air Pollution Control Administration, DHEW, U.S. Public Health Service, Washington, DC. (NTIS No. PB 189194).

Availability

The above User's Guide is available from NTIS at a cost of \$16.95. This model is available at no cost in the form of a punched card deck from: Library Services, MD-35, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, Attn: Ann Ingram.

Abstract

AQDM is a climatological steady state Gaussian plume model that estimates annual arithmetic average sulfur dioxide and particulate concentrations at ground level in urban areas. A statistical model based on Larsen (1971) is used to transform the average concentration data from a limited number of receptors into expected geometric mean and maximum concentration values for several different averaging times.

a. Recommendations for Regulatory Use

AQDM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. AQDM must be executed in the equivalent mode.

AQDM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that AQDM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: Average emissions rates and heights of emissions for point and area sources; stack gas temperature, stack gas exit velocity, and stack inside diameter for plume rise calculations for point sources.

Meteorological data requirements are: Stability wind rose (STAR deck), average afternoon mixing height, average morning mixing height, and average air temperature.

Receptor data requirements are:\* Number and locations of receptors. If the Larsen transform option is to be used to estimate short averaging time concentrations, measured standard geometric deviation of concentrations is required.

c. Output

Printed output includes:

One month to one year average concentrations (arithmetic mean only) at each receptor;

Optional arbitrary averaging time by Larsen (1971) procedure (typically 1-24 hr); and

Optional individual point, area source culpability list for each receptor.

d. Type of Model

AQDM is a Gaussian plume model.

e. Pollutant Types

AQDM may be used to model non-reactive pollutants. Settling and deposition are not treated,

f. Source Receptor Relationship

AQDM applies user-specified locations and stack height for each point source.

AQDM uses any location and size for each area source.

Up to 225 receptors may be located on uniform rectangular grid.

Up to 12 user-specified receptor locations are permitted.

Unique release height is used for each point and area source.

Receptors are assumed to be at ground level.

No terrain differences between source and receptor are treated.

g. Plume Behavior

AQDM uses Briggs (1969) plume rise formulas.

No plume rise is calculated for area sources.

Fumigation and downwash are not treated.

Zero concentration is assumed when plume height is greater than mixing height.

h. Horizontal Winds

Wind data are input as stability wind rose (joint frequency distribution) of 16 wind directions, six wind speed classes, and five stability classes.

No variation in wind speed with height is assumed.

Constant, uniform (steady-state) wind is assumed.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Pollutants are assumed evenly distributed across a 22.5 degree sector.

Frequency of occurrence of a meteorological state is interpolated between sector center lines.

Averaging times from 1 month to 1 year or longer are treated.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used.

Five stability classes are as defined by Turner (1964). Stability classes E and F are combined, and assigned dispersion values equivalent to stability class D.

Neutral stability is split internally into 60% day, 40% night, with the two differing only in the treatment of mixing height.

Mixing height is a function of a single input afternoon mixing height a single input morning mixing height, modified by the stability class.

l. Chemical Transformations

Not treated.

m. Physical Removal

Not treated.

## n. Evaluation Studies

NcNidar, R.R., 1977. Variability Analysis of Long-term Dispersion Models. Joint Conference on Applications of Air Pollution Meteorology, American Meteorology Society, 29 Nov.-2 Dec., 1977, Salt Lake City, UT.

Turner, D.B., J.R. Zimmerman, and A.D. Busse, 1973. An Evaluation of Some Climatological Dispersion Models. In Appendix E, User's Guide to the Climatological Dispersion Model, EPA Publication No. EPA-R4-73-024, Environmental Protection Agency, Research Triangle Park, NC.

Londergan, R.J., D.H. Minott, D.J. Wachter and R.R. Fizz, 1983. Evaluation of Urban Air Quality Simulation Models, EPA Publication No. EPA-450/4-83-020, U.S. Environmental Protection Agency, Research Triangle Park, NC.

## B.2 Air Resources Regional Pollution Assessment (ARRPA) Model

### Reference

Mueller, S.F., R.J. Valente, T.L. Crawford, A.L. Sparks, and L.L. Gautney, Jr., 1983. Description of the Air Resources Regional Pollution Assessment (ARRPA) Model. TVA/ONR/AQB-83/14. Tennessee Valley Authority, Muscle Shoals, AL.

### Availability

The computer code and sample input for this model on magnetic tape and a copy of the User's Guide are available from: Computer Services Development Branch, Office of Natural Resources and Economic Development, Tennessee Valley Authority, OSWHA, Muscle Shoals, Alabama 35660, phone (205) 386-2985. A hard copy of the model output corresponding with the sample input is also available. The cost of copying model information to a buyer-supplied 2400-ft., high density tape is estimated to be about \$100. The User's Guide is free of charge.

### Abstract

The ARRPA model is a medium/long-range segmented-plume model. It is designed to compute air concentrations and surface dry mass deposition of sulfur dioxide and sulfate. A unique feature of the model is its use of prognostic meteorological output from the National Weather Service Boundary Layer Model (BLM). Boundary layer conditions are computed by the BLM on a grid with a spatial resolution of 80 km, and are archived in intervals of 3 hours. BLM output used by this model includes three dimensional wind field components and potential temperature at 10 height levels from the surface through 2000 m above the surface.

### a. Recommendations for Regulatory Use

Use of the model for transport distances of less than 10 km is not recommended. For 10 km to beyond 50 km, there is no specific recommendation at the present time. The model may be used on a case-by-case basis.

### b. Input Requirements

Source data requirements: Location (latitude and longitude), stack height, stack diameter, stack gas exit velocity, stack gas temperature, SO<sub>2</sub> emission rate, SO<sub>4</sub> emission rate, stack base elevation.

Meteorological data requirements: Hourly wind field components (u,v,w), potential temperature ( $\Theta$ ), Pasquill-Gifford stability class and mixing height. These data are obtained as output from the BLM output preprocessing program called MDPP (S.F. Mueller and R.J. Valente, 1983). Required input to MDPP is BLM output (in three-hour intervals) of u, v, w, and  $\Theta$ , surface layer friction velocity ( $u^*$ ) and surface layer values of the inverse Monin-Obukhov length ( $L^{-1}$ ).

Receptor data requirements: Gridded receptor array coordinates (x and y) and receptor heights (z) from a receptor preprocessing program called HEIGHT. HEIGHT produces a user-designed array of points which may be

skewed up to  $\pm 90$  degrees relative to the model x axis. The elevation of each receptor is adjusted to give height above smoothed model terrain. Non-gridded receptors can be specified using latitude/longitude coordinates.

#### c. Output

Printed output includes:

Listings of input parameters (except for meteorological data);

Listing of hours processed and flags for missing data periods.

Disk output: Parameters for controlling analysis and printout options in the postprocessing program called ANALYSIS; hourly  $\text{SO}_2$  and  $\text{SO}_4$  air concentrations and dry deposition amounts at each receptor.

Optional printed output: Two programs are available for displaying model output-DISPLAY and ANALYSIS; DISPLAY prints out hourly gridded concentration and/or deposition fields for user-specified time periods; ANALYSIS prints out (1) the five highest concentrations of  $\text{SO}_2$  and/or  $\text{SO}_4$  at each receptor for 1-hour, 3-hour (optional) and 24-hour (optional) averaging periods, (2) average  $\text{SO}_2$  and/or  $\text{SO}_4$  concentrations at each receptor for the entire analysis period and (3) gridded  $\text{SO}_2$  and/or  $\text{SO}_4$  dry deposition amounts for the day having the greatest dry deposition and for the entire analysis period.

#### d. Type of Model

The ARRPA model is a Gaussian segmented-plume model.

#### e. Pollutant Types

$\text{SO}_2$  and  $\text{SO}_4$  are treated.

#### f. Source-Receptor Relationship

One source is treated per model run, though results from several sources may be superimposed.

Either constant or variable emission rates may be used.

Receptors (up to 100) in gridded network may have different elevations.

Height of receptors above ground is variable.

#### g. Plume Behavior

Plume rise is computed in a piecewise-continuous manner through discrete model layers (Mueller, et al., 1983).

Plume can be isolated from the ground (lofting).

Plume height varies in time and space.

#### h. Horizontal Winds

Hourly horizontal wind components, specified at 80-km intervals across the model grid, are spatially interpolated and vertically averaged through the plume depth to get plume transport vectors. A model option is available that uses the wind vector near the vertical plume center instead of computing a vertically-averaged vector.

#### i. Vertical Wind Speed

The mass-conserving BLM wind field used in this model provides vertical wind components that vary horizontally and vertically, and are used to adjust plume height.

#### j. Horizontal Dispersion

Plume half-width ( $\sigma_y$ ) growth goes through four stages:

- (1) Growth follows Turner curves for  $\sigma_y < 1000$  m;
- (2) A transition in growth behavior from Turner curves to dynamical-statistical (Langevin) theory occurs for  $1000 \text{ m} < \sigma_y < 6000 \text{ m}$ ;
- (3) Growth is based on dynamical-statistical theory for  $\sigma_y > 6000 \text{ m}$ ; eddy diffusivity computed from Pasquill-Gifford stability class;
- (4) Growth approaches that described by Taylor's statistical theory (limit of dynamical-statistical theory for time much larger than the Lagrangian time correlation) for  $\sigma_y > 10000 \text{ m}$ .

#### k. Vertical Dispersion

Plume half-depth ( $\sigma_z$ ) growth is based on combination of Brookhaven curves for elevated plumes and Turner curves for near-ground plumes.

Vertical plume structure is Gaussian, with superimposed reflection terms, until  $\sigma_z$  becomes sufficiently large that a vertically uniform plume assumption is appropriate.

Maximum depth of a plume is 2000 m.

#### l. Chemical Transformation

SO<sub>2</sub> oxidation to SO<sub>4</sub> is treated using a first-order chemical reaction rate constant which is parameterized to vary hourly following diurnal and seasonal cycles.

#### m. Physical Removal

Dry deposition is computed using the source depletion equation. Dry deposition velocities vary according to the stability of the surface layer.

#### n. Evaluation Studies

Muller, S.F. and L.W. Reisinger, 1986. Evaluation of the Air Resources Regional Pollution Assessment (ARRPA) Model. (Report in Progress).

#### B.3 APRAC-3

##### Reference

Simmon, P. B., R. M. Patterson, F. L. Ludwig, and L. B. Jones, 1981. The APRAC-3/Mobile 1 Emissions and Diffusion Modeling Package. EPA Publication No. EPA 909-9-81-002. U.S. Environmental Protection Agency, Region IX, San Francisco, CA. (NTIS No. PB82-103763).

##### Availability



This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

#### Abstract

APRAC-3 is a model which computes hourly average carbon monoxide concentrations for any urban location. The model calculates contributions from dispersion on various scales: Extraurban, mainly from sources upwind of the city of interest; intraurban, from freeway, arterial, and feeder street sources; and local, from dispersion within a street canyon. APRAC-3 requires an extensive traffic inventory for the city of interest. APRAC-3, as it exists on UNAMAP (Version 6), has been updated with Mobile 2 emission factors.

#### a. Recommendations for Regulatory Use

APRAC-3 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. APRAC-3 must be executed in the equivalent mode.

APRAC-3 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated using the criteria in section 3.2, that APRAC-3 is more appropriate for the specific application. In this case the model options/mode which are most appropriate for the application should be used.

Although the user's manual for APRAC-3 contains Mobile 1 emission factors, it is recommended that those emission factors be updated with the latest version of Mobile (Mobile Source Emissions Model) for use in regulatory applications.

#### b. Input Requirements

Source data requirements are: line source (traffic link) end points, road type and daily traffic volume.

Meteorological data requirements are: hourly wind direction (nearest 10 degrees), hourly wind speed, and hourly cloud cover for stability calculations.

Receptor data requirements are: coordinates for up to 10 receptors for any single day and up to 8 receptors for the intersection submodel.

#### c. Output

Printed output includes:

Hourly calculations at each receptor.

#### d. Type of Model

APRAC-3 is a Gaussian plume model.

#### e. Pollutant Types

APRAC-3 may be used to model primary pollutants.

#### f. Source-Receptor Relationship

Traffic links may have arbitrary length and orientation. Off-link traffic is allocated to two-mile square grids. Link traffic emissions are aggregated into a receptor oriented area source array.

The boundaries of the area sources actually treated are (1) arcs at radial distances from the receptor which increase in geometric progression, (2) the sides of a  $22.5^\circ$  sector oriented upwind for distances greater than 1000 m, and (3) the sides of a  $45^\circ$  sector oriented upwind for distances less than 1000 m.

A similar area source array is established for each receptor.

Sources are assumed to be at ground level.

Up to 10 receptors are accepted for any single day.

Up to 625 receptors are accepted for a single-hour.

Up to 8 receptors are accepted for the intersection submodel.

Receptors are at ground level.

Receptor locations are arbitrary.

Four internally defined receptor locations on each user-designated street are used in a special street canyon sub-model.

A box model is used to estimate contribution from upwind sources beyond 32 km based on wind speed, mixing height, annual fuel consumption.

In street canyon sub-model, contribution from other streets is included in background.

#### g. Plume Behavior

Plume rise is not treated.

Fumigation and downwash are not treated except in street canyon sub-model.

In street canyon sub-model, a helical circulation pattern is assumed.

#### h. Horizontal Winds

User input hourly wind speed and direction in tens of degrees are used.

No variation of wind speed or direction with height is assumed.

Constant, uniform (steady-state) wind is assumed within each hour.

The model can interpolate winds at receptors if more than one wind is provided.

#### i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero except in street canyon sub-model.

Helical circulation assumed by street canyon sub-model.

#### j. Horizontal Dispersion

Sector averaging is used with uniform distribution within sectors. Sector size is 22.5 degrees beyond 1 km and 45.0 degrees within 1 km.

#### k. Vertical Dispersion

Six stability classes are used. Stability class is determined internally from user-supplied meteorological data modified from Turner (1964).

Dispersion coefficients are adapted from McElroy and Pooler (1968).

No adjustments are made for variations in surface roughness.

Downwind distance variation of  $\sigma_z$  is assumed to be  $ax^b$  for purposes of doing analytical integration.

In street canyon sub-model, an empirical function of wind speed and street width and direction is used.

Perfect reflection at the surface is assumed.

Mixing height is ignored until concentration equals that calculated using box model. A box model (uniform vertical distribution) is used beyond that distance.

#### l. Chemical Transformation

Not treated.

#### m. Physical Removal

Not treated.

#### n. Evaluation Studies

Ludwig, F. L. and W. F. Dabberdt, 1972. Evaluation of the APRAC-IA Urban Dispersion Model for Carbon Dioxide, SRI Project 8563. Stanford Research Institute, Menlo Park, CA.

### B.4 COMPTER

#### Reference

State of Alabama, 1980. COMPTER Model Users Guide. Alabama Department of Environmental Management, Air Division, Montgomery, AL.

#### Availability

This model is available to users for tape and reproduction charges. If a tape is sent, the reproduction is free. Send tape and desired format and specifications to: Mr. Richard E. Grusnick, Chief, Air Division, Alabama Department of Environmental Management, 1751 Federal Drive, Montgomery, Alabama 36109.

#### Abstract

COMPTER is based on the Gaussian steady-state technique applicable to both urban and rural areas. The model contains the following attributes: (a) Determines maximum 24-hour, 3-hour, 1-hour and variable hour concentrations for both block and running averages; (b) elevated terrain considered with the standard plume-chopping technique or stability dependent plume path trajectory; (c) uses annual hourly meteorological data in the CRSTER preprocessor format; (d) uses Pasquill-Gifford stability curves; (e) allows for stability class substitution in the stable categories. Typical model use is in rural areas with moderate to low terrain features.

#### a. Recommendations for Regulatory Use

COMPTER can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. COMPTER must be executed in the equivalent mode.

COMPTER can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that COMPTER is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: annual or hourly values of emission rate, exit velocity, stack gas temperature, stack height, and stack diameter.

Meteorological data requirements are: Hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is optional.

Receptor data requirements are: individual receptor coordinates; or a location and distance from the center of five rings of receptors; or a combination of individual receptors and either the rectangular grid or the rings of receptors. Elevations of all receptors may be input.

#### c. Output

Printed output includes:

Highest and second highest concentrations for the year at each receptor for averaging times of 1, 3 and 24-hours, a user-selected averaging time which may be 2-12 hours (variable hourly), and a 50 high table for 1, 3, variable hourly, and 24-hours;

Annual arithmetic average at each receptor; and the highest 1-hour and 24-hour concentrations over the receptor field for each day considered.

Computer readable output includes:

Hourly, 3-hourly, variable hourly, and 24-hourly concentrations for each receptor on magnetic storage device.

#### d. Type of Model

COMPTER is a Gaussian plume model.

#### e. Pollutant Types

COMPTER may be use to model primary pollutants. Settling and deposition are not treated.

#### f. Source-Receptor Relationship

A maximum 50 sources and 200 receptors are treated.

COMPTER applies user-specified locations of sources and receptors.

User input stack height and source characteristics for each source are applied.

User input topographic elevation for each receptor is applied.

Receptors are assumed to be at ground level.

g. Plume Behavior

Briggs' (1969, 1971, 1972) plume rise equations with limited mixing are used.

Plume height is adjustable according to stability with use of plume path coefficient.

h. Horizontal Winds

Constant, uniform (steady-state) wind is assumed for an hour.

Straight line plume transport is assumed to all downwind distances.

Power law wind profile exponents used are .10, .15, .20, .25, .30, .30, for stability classes A through F, respectively. Anemometer height is assumed to be 10 meters.

i. Vertical Wind Speed

Vertical wind speeds are assumed equal to zero.

j. Horizontal Dispersion

Dispersion coefficients are from Turner (1969), with no further adjustments made for variations in surface roughness or averaging time.

Optionally, stability class 7 may be treated as Class 6.

Other options for stable class substitution include changing stabilities F and G to E, and reducing E, F, and G to D, E, and F, respectively.

k. Vertical Dispersion

Dispersion coefficients are from Turner (1969), with no further adjustments made for variations in surface roughness.

Optionally, by source, buoyancy induced dispersion ( $\Delta H^2/10$ ) is included.

Optionally, stability class 7 may be treated as class 6.

Other options for stable class substitution include changing stabilities F and G to E; and reducing E, F, and G to D, E, and F, respectively.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wackter, T. Kincaid and D. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models. EPA Publication No. EPA-450/4-83-003. U.S. Environmental Protection Agency, Research Triangle Park, NC.

## B.5 ERT Air Quality Model (ERTAQ)

### Reference

Environmental Research & Technology, Inc., 1980. ERTAQ User's Guide. ERT Document No. M-0186-001E. Environmental Research & Technology, Inc., Concord, MA.

### Availability

The above report and a computer tape are available from: Computer Products, National Technical Information Service, U.S. Department of Commerce, 5825 Port Royal Road, Springfield, Virginia 22161, phone (703) 487-4650.

### Abstract

ERTAQ is a multiple point, line and area source dispersion model which utilizes the univariate Gaussian formula with multiple reflections. With the fugitive dust option, entrainment of particulates from ground-level sources and subsequent deposition are accountable. The model offers an urban/rural option, and calculates long-term or worst-case concentrations due to arbitrarily located sources for arbitrarily located receptors above or at ground level. Background concentrations and calibration factors at each receptor can be user specified. Unique flexibility is afforded by postprocessing storage and manipulation capability.

#### a. Recommendations for Regulatory Use

ERTAQ can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. ERTAQ must be executed in the equivalent mode.

ERTAQ can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that ERTAQ is more appropriate for the specific application in this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: Up to six pollutants may be specified, citing quantity and calibration factor for each (and particle size, if appropriate); heat rate and height of emissions per source for determining plume height.

Meteorological data requirements are: Stability wind rose, plus annual average ambient air temperature and mixing height.

Receptor data requirements are: Cartesian coordinates for each receptor.

#### c. Output

Printed output includes: Mean concentrations at designated receptors for long-term mode. In worst-case mode, concentrations for user-specified meteorological conditions.

#### d. Type of Model

ERTAQ is a climatological Gaussian plume model.

#### e. Pollutant Types

ERTAQ treats primary pollutants with or without significant settling velocities.

#### f. Source-Receptor Relationship

Up to 501 user-specified locations for point, area, and line sources, and up to 128 arbitrarily located receptors are permitted.

User-specified release heights are applied for all sources.

Simple terrain relief is treated.

Receptors may be at or above ground level.

g. Plume Behavior

Briggs (1975) final plume rise only is used.

Briggs calm formula is used when wind speed is less than 1.37 meters per second.

Plume rise may be calculated for point and area sources.

Top or mixed layer is perfect reflector (full or no plume penetration).

Fumigation and downwash are not treated.

Buoyancy-induced dispersion is not treated.

h. Horizontal Winds

Steady state and homogeneous winds are assumed.

Sixteen wind directions and six speed classes are treated.

Exponential vertical profile extrapolates observed wind to release height for plume rise and to plume height for downwind dilution.

The exponents used are .10, .15, .20, .25, and .30 for stability classes A through E, respectively.

i. Vertical Wind Speed

Vertical wind speed is assumed to be zero.

j. Horizontal Dispersion

Uniform distribution in 22.5 degree sector, or triangular distribution in 45-degree sector (user specified).

k. Vertical Dispersion

Gaussian plume with initial mixing specification is assumed.

Five stability categories are treated (converts all stability class F to class E).

Rural dispersion coefficients from Turner (1969) are used with no adjustments made for surface roughness.

Urban case is treated by shifting each stability category (except class A) one class toward unstable.

Top of mixed layer is perfect reflector (full or no plume penetration).

Ground surface is total reflector.

Surface deposition reduces entire plume concentration using a source depletion factor.

#### l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

#### m. Physical Removal

Particle deposition for ground-level sources is treated.

#### n. Evaluation Studies

Londergan, R.J., D.H. Minott, D.J. Wackter and R.R. Fizz, 1983. Evaluation of Urban Air Quality Simulation Models. EPA Publication No. EPA-450/4-83-020. U.S. Environmental Protection Agency, Research Triangle Park, NC.

### B.6 ERT Visibility Model

#### Reference

Drivas, P.J., Savithri M., and D.W. Heinold, 1980. ERT Visibility Model: Version 3; Technical Description and User's Guide. Document M2020-001. Environmental Research & Technology, Inc., Concord, MA.

#### Availability

The above report and a computer tape are available from: Computer Products, National Technical Information Service, U. S. Department of Commerce, 5825 Port Royal Road, Springfield, Virginia 22161, phone (703) 487-4650.

#### Abstract

The ERT Visibility model is a Gaussian dispersion model designed to estimate visibility impairment for arbitrary lines of sight due to isolated point source emissions by simulating gas-to-particle conversion, dry deposition, NO to NO<sub>2</sub> conversion and linear radiative transfer.

#### a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The ERT Visibility model may be used on a case-by-case basis.

#### b. Input Requirements

Source data requirements are: stack height, stack temperature, emissions of SO<sub>2</sub>, NO<sub>x</sub>, TSP, fraction of NO<sub>x</sub> as NO<sub>2</sub>, fraction of TSP which are carbonaceous, exit velocity, and exit radius.

Meteorological data requirements are: Hourly ambient temperature, mixing depth, wind speed at stack height, stability class, potential temperature gradient, and wind direction.

Receptor data requirements are: Observer coordinates with respect to source, latitude, longitude, time zone, date, time of day, elevation, relative humidity, background visual range, line-of-sight azimuth and elevation angle, inclination angle of the observed object, distance from observer to object, object reflectivity, surface reflectivity, number and spacing of integral receptor points along line-of-sight.

Other data requirements are: Ambient concentrations of O<sub>3</sub> and NO<sub>x</sub>, deposition velocity of TSP, sulfate, nitrate, SO<sub>2</sub> and NO<sub>x</sub>, first-order transformation rate for sulfate and nitrate.

#### c. Output



Printed output includes both summary and detailed results as follows: Summary output: Page 1-site, observer and object parameters; page 2-optical pollutants and associated extinction coefficients; page 3-plume model input parameters; page 4-total calculated visual range reduction, and each pollutant's contribution; page 5-calculated plume contrast, object contrast and object contrast degradation at the 550 nm wavelength; page 6-calculated blue/red ratio and  $\Delta E (U^*V^*W)$  value for both sky and object discoloration.

Detailed output: Phase functions for each pollutant in four wavelengths (400, 450, 550, 650 nm), concentrations for each pollutant along sight path, solar geometry, contrast parameters at all wavelengths, intensities, tristimulus values and chromaticity coordinates for views of the object, sun, background sky and plume.

#### d. Type of Model

ERT Visibility model is a Gaussian plume model for estimating visibility impairment.

#### e. Pollutant Types

Optical activity of sulfate, nitrate (derived from  $\text{SO}_2$  and  $\text{NO}_x$  emissions), primary TSP and  $\text{NO}_2$  is simulated.

#### f. Source Receptor Relationship

Single source and hour is simulated. Unlimited number of lines-of-sight (receptors) is permitted per model run.

#### g. Plume Behavior

Briggs (1971) plume rise equations for final rise are used.

#### h. Horizontal Wind Field

A single wind speed and direction is specified for each case study. The wind is assumed to be spatially uniform.

#### i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

#### j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used.

#### k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used. Mixing height is accounted for with multiple reflection handled by summation of series near the source, and Fourier representation farther downwind.

#### l. Chemical Transformation

First order transformations of sulfates and nitrates are used.

#### m. Physical Removal

Dry deposition is treated by the source depletion method.

#### n. Evaluation Studies

Seigneur, C., R.W. Bergstrom, and A.B. Hudischewskyj, 1982. Evaluation of the EPA PLUVUE Model and the ERT Visibility Model Based on the 1979 VISTTA Data Base, EPA Publication No. EPA-450/4-82-008, U. S. Environmental Protection Agency, Research Triangle Park, NC.

White, W.H., C. Seigneur, D.W. Heinold, M.W. Eltgroth, L.W. Richards, P.T. Roberts, P.S. Bhardwaja, W.D. Conner and W.E. Wilson, Jr., 1985. Predicting the Visibility of Chimney Plumes: An Intercomparison of Four Models with Observations at a Well-Controlled Power Plant. *Atmospheric Environment*, 19:515-528.

## B.7 HIWAY-2

### Reference

Petersen, W.B., 1980. User's Guide for HIWAY-2. EPA Publication No. EPA-600/8-80-018. U.S. Environmental Protection Agency, ESRL, Research Triangle Park, NC (NTIS PB 80-227-556).

### Availability

This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

### Abstract

HIWAY-2 can be used to estimate the concentrations of non-reactive pollutants from highway traffic. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of "at-grade" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation, and receptor location. The model was developed for situations where horizontal wind flow dominates. The model cannot consider complex terrain or large obstructions to the flow such as buildings or large trees.

#### a. Recommendations for Regulatory Use

HIWAY-2 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. HIWAY-2 must be executed in the equivalent mode.

HIWAY-2 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that HIWAY-2 is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: A uniform emission rate by lane, roadway end points; height of emission; length, width, and number of lanes; and width of center strip.

Meteorological data requirements are: One set at a time of hourly averages of wind speed, wind direction, and mixing height and the Pasquill-Gifford stability class. Wind speed and direction are preferred to be at 2 meters above ground.

Receptor data requirements are:

Coordinates of each receptor.

#### c. Output

Printed output includes: One hourly average concentration at each specified receptor location.

d. Type of Model

HIWAY-2 is a Gaussian plume model.

e. Pollutant Types

HIWAY-2 may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

HIWAY-2 applies user-specified end points for a single roadway segment, and user-specified receptor locations.

Plume impact on receptor is calculated by finite difference integration of a point source along each lane of the roadway.

g. Plume Behavior

HIWAY-2 does not treat plume rise.

h. Horizontal Winds

Constant, uniform (steady-state) wind is assumed for an hour.

Straight line plume transport is assumed to all downwind distances.

An aerodynamic drag factor is applied when winds are parallel to the roadway and speeds are less than 2 m/sec.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

The total horizontal dispersion is that due to ambient turbulence plus the turbulence generated by the vehicles on the roadway.

Beyond 300 m downwind total turbulence is considered to be dominated by atmospheric turbulence, with plume dispersion as described by Turner (1969).

Three stability classes are considered: Unstable, neutral and stable.

k. Vertical Dispersion

The total horizontal dispersion is that due to ambient turbulence plus the turbulence generated by the vehicles on the roadway.

Beyond 300 m downwind total turbulence is considered to be dominated by atmospheric turbulence, with plume dispersion as described by Turner (1969).

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point.

Three stability classes are considered: Unstable, neutral and stable.

## l. Chemical Transformation

Not treated.

## m. Physical Removal

Not treated.

## n. Evaluation Studies

Rao, S.T., and J.A. Visalli, 1981. On the Comparative Assessment of the Performance of Air Quality Models, *Journal of Air Pollution Control Association*, 31:851-860.

## B.8 Integrated Model for Plumes and Atmospheric Chemistry in Complex Terrain (IMPACT)

### Reference

Fabrick, Allan J. and Peter J. Haas, 1980. User Guide to IMPACT: An Integrated Model for Plumes and Atmospheric Chemistry in Complex Terrain. DCN 80-241-403-01. Radian Corporation, 8501 Mo-Pac Blvd., Austin, TX.

### Availability

A magnetic tape containing the IMPACT model, a set of test data and a copy of the IMPACT User's Guide are available for a cost of \$500 from: Howard Balentine, Senior Meteorologist, Radian Corporation, Post Office Box 9948, Austin, Texas 78766.

### Abstract

IMPACT is an Eulerian, three-dimensional, finite difference grid model designed to calculate the impact of pollutants, either inert or reactive, in simple or complex terrain, emitted from either point or area sources. It automatically treats single or multiple point or area sources, the effects of vertical temperature stratifications on the wind and diffusion fields, shear flows caused by the atmospheric boundary layer or by terrain effects, and chemical transformations.

### a. Recommendations for Regulatory Use

IMPACT can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. IMPACT must be executed in the equivalent mode.

IMPACT can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that IMPACT is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

There is no specific recommendation concerning the use of IMPACT for photochemical applications. IMPACT may be used on a case-by-case basis.

### b. Input Requirements

Source data requirements are: for point sources-location (I, J), stack height, exit temperature, volume flow rate or stack diameter and exit velocity, hourly emission rates for all pollutants; for area sources location of corners, and hourly emission rates for each pollutant.

Meteorological data requirements are: Hourly wind speed and direction, surface and elevated, from meteorological stations within and surrounding the modeling area, temperature, pressure, humidity and insolation (the three last variables are optional).

Receptor data requirements are: None since concentrations are output for cells in the computational grid.

Air quality data (optional): One or more vertical concentration profiles for each pollutant.

Other data: 2-D array of terrain heights, 2-D array of surface roughness values (optional).

#### c. Output

Printed output options include: Surface and elevated horizontal cross sections of pollutant concentrations (instantaneous, or averages over N hours where  $N = 1, 2, 3, \dots$ ); Horizontal cross sections of diffusivities and wind velocities; and Arbitrary vertical and horizontal cross sections of pollutant concentrations and diffusivities, and CALCOMP wind field vector plots are generated by the POST post-processor program.

Computer readable output includes: Concentration, wind field and diffusivity data for each hour.

#### d. Type of Model

IMPACT is an Eulerian finite difference model.

#### e. Pollutant Types

IMPACT may be used to model any inert pollutant.

IMPACT may be used to model  $\text{SO}_2$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_x$ ,  $\text{NO}_2$ ,  $\text{O}_3$ , hydrocarbons (depends upon chemistry mechanism selected).

#### f. Source-Receptor Relationship

Up to 20 point sources and 20 area sources may be treated (greater number of sources may be treated by increasing common block storage allocation).

Concentrations are calculated at the center of each cell in the grid.

#### g. Plume Behavior

Briggs (1975) formulation for plume rise is used.

Elevated inversions are considered.

#### h. Horizontal Winds

A three dimensional stability and terrain dependent nondivergent wind field is interpolated from single or multiple wind data measurements using a Poisson technique.

#### i. Vertical Wind Speed

Vertical wind speed is treated at each wind site, user specified or extrapolated from surface data. Interpolated is accomplished as part of the three dimensional wind field interpolation.

#### j. Horizontal Dispersion

A three dimensional diffusivity field is calculated using either the technique of Myrup/Ranzieri or the DEPICT method (see User Guide, Fabrick and Haas, 1980).

#### k. Vertical Dispersion

A three dimensional diffusivity field is calculated using either the technique of Myrup/Ranzieri or the DEPICT method (see User Guide, Fabrick and Haas, 1980).

#### l. Chemical Transformation

Either 3, 6, 8 or 15-species mechanisms are currently available (see User Guide). Calculations are also performed for inert pollutants.

#### m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

#### n. Evaluation Studies

Fabrick, A.J., R. Sklarew, and J. Wilson, 1977. Point Source Model Evaluation and Development Study. Report prepared for the California Air Resources Board.

Fabrick, A.J., and P.J. Haas, 1980. Analysis of Dispersion Models used for Complex Terrain Simulation. Presented at the Symposium on Intermediate Range Transport Processes and Technology Assessment, Gatlinburg, TN.

Sklarew, R., and V. Mirabella, 1979. Experience in IMPACT Modeling of Complex Terrain Fourth Symposium on Turbulence, Diffusion and Air Pollution, Reno, NV.

Sklarew, R., J. Wilson, A.J. Fabrick and V. Mirabella, 1976. "Rough Terrain Modeling." Presented at Geothermal Environmental Seminar '76, Clear Lake, CA.

Sklarew, R., and K. Tran, 1978. "The NEWEST Wind Field Model with Applications to Thermally Driven Drainage Wind in Mountainous Terrain." Presented at the AMS Meeting, Lake Tahoe, NV.

Wackter, D., and R. Londergan, 1984. Evaluation of Complex Terrain Air Quality Simulation Models. EPA Publication No. EPA-450/4-84-017. U.S. Environmental Protection Agency, Research Triangle Park, NC.

#### B.9 LONGZ

##### Reference

Bjorklund, J.R., and J.F. Bowers, 1982. User's Instructions for the SHORTZ and LONGZ Computer Programs, Volumes I and II, EPA Publication No. EPA 903/9-82-004. U.S. Environmental Protection Agency, Region III, Philadelphia, PA.

##### Availability

The model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

##### Abstract

LONGZ utilizes the steady-state univariate Gaussian plume formulation for both urban and rural areas in flat or complex terrain to calculate long-term (seasonal and/or annual) ground-level ambient air concentrations attributable to

emissions from up to 14,000 arbitrarily placed sources (stacks, buildings and area sources). The output consists of the total concentration at each receptor due to emissions from each user-specified source or group of sources, including all sources. An option which considers losses due to deposition (see the description of SHORTZ) is deemed inappropriate by the authors for complex terrain, and is not discussed here.

#### a. Recommendations for Regulatory Use

LONGZ can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. LONGZ must be executed in the equivalent mode.

LONGZ can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that LONGZ is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: For point, building or area sources, location, elevation, total emission rate (optionally classified by gravitational settling velocity) and decay coefficient; for stack sources, stack height, effluent temperature, effluent exit velocity, stack radius (inner), emission rate, and ground elevation (optional); for building sources, height, length and width, and orientation; for area sources, characteristic vertical dimension, and length, width and orientation.

Meteorological data requirements are: Wind speed and measurement height, wind profile exponents, wind direction standard deviations (turbulent intensities), mixing height, air temperature, vertical potential temperature gradient.

Receptor data requirements are: Coordinates, ground elevation.

#### c. Output

Printed output includes: Total concentration due to emissions from user-specified source groups, including the combined emissions from all sources (with optional allowance for depletion by deposition).

#### d. Type of Model

LONGZ is a climatological Gaussian plume model.

#### e. Pollutant Types

LONGZ may be used to model primary pollutants. Settling and deposition are treated.

#### f. Source-Receptor Relationships

LONGZ applies user specified locations for sources and receptors.

Receptors are assumed to be at ground level.

#### g. Plume Behavior

Plume rise equations of Bjorklund and Bowers (1982) are used.

Stack tip downwash (Bjorklund and Bowers, 1982) is included.

All plumes move horizontally and will fully intercept elevated terrain.

Plumes above mixing height are ignored.

Perfect reflection at mixing height is assumed for plumes below the mixing height.

Plume rise is limited when the mean wind at stack height approaches or exceeds stack exit velocity.

Perfect reflection at ground is assumed for pollutants with no settling velocity.

Zero reflection at ground is assumed for pollutants with finite settling velocity.

LONGZ does not simulate fumigation.

Tilted plume is used for pollutants with settling velocity specified.

Buoyancy-induced dispersion is treated (Briggs, 1972).

#### h. Horizontal Winds

Wind field is homogeneous and steady-state.

Wind speed profile exponents are functions of both stability class and wind speed. Default values are specified in Bjorklund and Bowers (1982).

#### i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

#### j. Horizontal Dispersion

Pollutants are initially uniformly distributed within each wind direction sector. A smoothing function is then used to remove discontinuities at sector boundaries.

#### k. Vertical Dispersion

Vertical dispersion is derived from input vertical turbulent intensities using adjustments to plume height and rate of plume growth with downwind distance specified in Bjorklund and Bowers (1982).

#### l. Chemical Transformation

Chemical transformations are treated using exponential decay. Time constant is input by the user.

#### m. Physical Removal

Gravitational settling and dry deposition of particulates are treated.

#### n. Evaluation Studies

Bjorklund, J.R., and J.F. Bowers, 1982. User's Instructions for the SHORTZ and LONGZ Computer Programs, Volume I and II. EPA Publication No. EPA-903/9-82-004, U.S. Environmental Protection Agency, Region III, Philadelphia, PA.

### B.10 Maryland Power Plant Siting Program (PPSP) Model

#### References



Brower, R., 1982. The Maryland Power Plant Siting Program (PPSP) Air Quality Model User's Guide. Ref. No. PPSP-MP-38. Prepared for Maryland Department of Natural Resources, by Environmental Center, Martin Marietta Corporation, Baltimore, MD. (NTIS No. PB82-238387).

Weil, J.C. and R.P. Brower, 1982. The Maryland PPSP Dispersion Model for Tall Stacks. Ref. No. PPSP-MP-36. Prepared for Maryland Department of Natural Resources, by Environmental Center, Martin Marietta Corporation, Baltimore, MD. (NTIS No. PB82-219155).

#### Availability

Two reports referenced above are available from NTIS. The model code and test data are available on magnetic tape for a cost of \$210 from: Power Plant Siting Program, Department of Natural Resources, Tawes State Office Building, Annapolis, Maryland 21401, attn: Dr. Michael Hirshfield.

#### Abstract

PPSP is a Gaussian dispersion model applicable to tall stacks in either rural areas, but in terrain that is essentially flat (on a scale large compared to the ground roughness elements). The PPSP model follows the same general formulation and computer coding as CRSTER, also a Gaussian model, but it differs in four major ways. The differences are in the scientific formulation of specific ingredients or "sub-models" to the Gaussian model, and are based on recent theoretical improvements as well as supporting experimental data. The differences are: (1) Stability during daytime is based on convective scaling instead of the Turner criteria; (2) Briggs' dispersion curves for elevated sources are used; (3) Briggs plume rise formulas for convective conditions are included; and (4) plume penetration of elevated stable layers is given by Briggs' (1984) model.

#### a. Recommendations for Regulatory Use

PPSP can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. PPSP must be executed in the equivalent mode.

PPSP can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that PPSP is more appropriate for the scientific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: Emission rate (monthly rates optional), physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature.

Meteorological data requirements are: Hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: distance of each of the five receptor rings.

#### c. Output

Printed output includes: Highest and second highest concentrations for the year at each receptor for averaging times of 1, 3, and 24 hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours;

Annual arithmetic average at each receptor; and

For each day, the highest 1-hour and 24-hour concentrations over the receptor field.

d. Type of Model

PPSP is a Gaussian plume model.

e. Pollutant Types

PPSP may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

Up to 19 point sources are treated.

All point sources are assumed at the same location.

Unique stack height and stack exit conditions are applied for each source.

Receptor locations are restricted to 36 azimuths (every 10 degrees) and five user-specified radial distances.

g. Plume Behavior

Briggs (1975) final rise formulas for buoyant plumes are used. Momentum rise is not considered.

Transitional or distance-dependent plume rise is not modeled.

Penetration (complete, partial, or zero) of elevated inversions is treated with Briggs (1984) model; ground-level concentrations are dependent on degree of plume penetration.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law variation, with different exponents for different stability classes and variable reference height (7 meters is default). Wind speed power law exponents are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Constant, uniform (steady-state) wind assumed within each hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion parameters are Briggs (Gifford, 1975), with stability class defined by  $u/w^*$  during daytime, and by the method of Turner (1964) at night.

Urban dispersion is treated by changing all stable cases to stability class D.

Buoyancy-induced dispersion (Pasquill, 1976) is included (using  $\Delta H / 3.5$ ).

k. Vertical Dispersion

Rural dispersion parameters are Briggs (Gifford, 1975), with stability class defined by  $u/w^*$  during daytime, and by the method of Turner (1964).

Urban dispersion is treated by changing all stable cases to stability class D.

Buoyancy-induced dispersion (Pasquill, 1976) is included (using  $\Delta H / 3.5$ ).

I. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Weil, J.C. and R.P. Brower, 1982. The Maryland PPSP dispersion model for tall stacks. Ref. No. PPSP MP-36. Prepared for Maryland Department of Natural Resources. Prepared by Environmental Center, Martin Marietta Corporation, Baltimore, MD (NTIS No. PB 82-2199155).

Londergan, R., D. Minott, D. Wackter, T. Kincaid, and D. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models, Appendix G: Statistical Tables for PPSP. EPA Publication No. EPA 450/4-83-003, Environmental Protection Agency, Research Triangle Park, NC.

B11 MESOSCALE PUFF MODEL (MESOPUFF II)

Reference

Scire, J.S., F.W. Lurmann, A. Bass, S.R. Hanna, 1984. User's Guide to the Mesopuff II Model and Related Processor Programs. EPA Publication No. EPA 600/8-84-013. U.S. Environmental Protection Agency, Research Triangle Park, NC (NTIS PB 84-181775).

Availability

This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, phone (703) 487-4650.

Abstract

MESOPUFF II is a short term, regional scale puff model designed to calculate concentrations of up to 5 pollutant species ( $\text{SO}_2$ ,  $\text{SO}_4$ ,  $\text{NO}_x$ ,  $\text{HNO}_3$ ,  $\text{NO}_3$ ). Transport, puff growth, chemical transformation, and wet and dry deposition are accounted for in the model.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The model may be used on a case-by-case basis.

b. Input Requirements

Required input data include four types: (1) Input control parameters and selected technical options, (2) hourly surface meteorological data and twice daily upper air measurements. hourly precipitation data are optional, (3) surface land use classification information, (4) source and emissions data.

Data from up to 25 surface National Weather Service stations and up to 10 upper air stations may be considered. Spatially variable fields at hour intervals of winds, mixing height, stability class, and relevant turbulence parameters are derived by MESOPAC II, the meteorological preprocessor program described in the User Guide.

Source and emission data for up to 25 point sources and/or up to 5 area sources can be included. Required information are: Location is grid coordinates, stack height, exit velocity and temperature, and emission rates for the pollutant to be modeled.

Receptor data requirements: Up to a 40 x 40 grid may be used and non-gridded receptor locations may be considered.

c. Output

Line printer output includes: All input parameters, optionally selected arrays of ground-level concentrations of pollutant species at specified time intervals.

Liner printer contour plots output from MESOFILE II post-processor program.

Computer readable output of concentration array to disk/tape for each hour.

d. Type of Model

MESOPUFF II is a Gaussian puff superposition model.

e. Pollutant types modeled

Up to five pollutant species may be modeled simultaneously and include: SO<sub>2</sub>, SO<sub>4</sub>, NO<sub>x</sub>, HNO<sub>3</sub>, NO<sub>3</sub>.

f. Source-Receptor Relationship

Up to 25 point sources and/or up to 5 area sources are permitted.

g. Plume behavior

Briggs (1975) plume rise equations are used, including plume penetration with bouyancy flux computed in the model.

Fumigation of puffs is considered and may produce immediate mixing or multiple reflection calculations at user option.

h. Horizontal Winds

Gridded wind fields are computed for 2 layers; boundary layer and above the mixed layer. Upper air rawinsonde data and hourly surface winds are used to obtain spatially variable u,v component fields at hourly intervals. The gridded fields are computed by interpolation between stations in the MESOPAC II preprocessor.

i. Vertical Wind Speed

Vertical winds are assumed to be zero.

j. Horizontal Dispersion

Incremental puff growth is computed over discrete time steps with horizontal growth parameters determined from power law equations fit to sigma y curves of Turner out to 100 km. At distances greater than 100 km, puff growth is determined by the rate given by Heffter (1965).

Puff growth is a function of stability class and changes in stability are treated. Optionally, user input plume growth coefficients may be considered.

#### k. Vertical Dispersion

For puffs emitted at an effective stack height which is less than the mixing height, uniform mixing of the pollutant within the mixed layer is performed. For puffs centered above the mixing height, no effect at the ground occurs.

#### l. Chemical Transformation

Hourly chemical rate constants are computed from empirical expressions derived from photochemical model simulations.

#### m. Physical Removal

Dry deposition is treated with a resistance method.

Wet removal may be considered if hourly precipitation data are input.

#### n. Evaluation Studies

Results of tests for some model parameters are discussed in: Scire, J.S., F.W. Lurmann, A. Bass, S.R. Hanna, 1984. Development of the MESOPUFF II Dispersion Model. EPA Publication No. EPA 00/3-84-057, U.S. Environmental Protection Agency, Research Triangle Park, NC.

### B.12 MESOSCALE TRANSPORT DIFFUSION AND DEPOSITION MODEL FOR INDUSTRIAL SOURCES (MTDDIS)

#### Reference

Wang, I.T. and T.L. Waldron, 1980. User's Guide for MTDDIS Mesoscale Transport, Diffusion, and Deposition Model for Industrial Sources. EMSC6062.1UR(R2). Combustion Engineering, Newbury Park, CA.

#### Availability

A magnetic tape copy of the FORTRAN coding and the user's guide are available for a cost of \$100 from: Dr. I.T. Wang, Combustion Engineering, Environmental Monitoring and Services, Inc., 2421 West Hillcrest Drive, Newbury Park, California 9320.

#### Abstract

MTDDIS is a variable-trajectory Gaussian puff model applicable to long-range transport of point source emissions over level or rolling terrain. It can be used to determine 3-hour maximum and 24-hour average concentrations of relatively nonreactive pollutants from up to 10 separate stacks.

#### a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The MTDDIS Model may be used on a case-by-case basis.

#### b. Input Requirements

Source data requirements are: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature, and location.

Meteorological data requirements are: Hourly surface weather data, from up to 10 stations, including cloud ceiling, wind direction, wind speed, temperature, opaque cloud cover and precipitation. For long-range applications, user-analyzed daily mixing heights are recommended. If these are not available, the NWS daily mixing heights will be

used by the program. A single upper air sounding station for the region is assumed. For each model run, air trajectories are generated for a 48-hour period, and therefore, the afternoon mixing height of the day before and the mixing heights of the day after are also required by the model as input, in order to generate hourly mixing heights for the modeled period.

Receptor data requirements are: Up to three user-specified rectangular grids.

#### c. Output

Printed output includes:

Tabulations of hourly meteorological parameters include both input surface observations and calculated hourly stability classes and mixing heights for each station;

Printed air trajectories for the two consecutive 24-hour periods for air parcels generated 4 hours apart starting at 0000 LST; and

3-hour maximum and 24-hour average grid concentrations over user-specified rectangular grids are output for the second 24-hour period.

#### d. Type of Model

MTDDIS is a Gaussian puff model.

#### e. Pollutant Types

MTDDIS can be used to model primary pollutants. Dry deposition is treated.

Exponential decay can account for some reactions.

#### f. Source-Receptor Relationship

MTDDIS treats up to 10 point sources.

Up to three rectangular receptor grids may be specified by the user.

#### g. Plume Behavior

Briggs (19 , 1972) plume rise formulas are used.

If plume height exceeds mixing height, ground level concentration is assumed zero.

Fumigation and downwash are not treated.

#### h. Horizontal Winds

Wind speeds and wind directions at each station are first corrected for release height. Speed conversions are based on power law variation and direction conversions are based on linear height dependence as recommended by Irwin (1979).

Converted wind speeds and wind directions are then weighted according to the algorithms of Heffter (1980) to calculate the effective transport wind speed and direction.

#### i. Vertical Wind Field

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Transport-time-dependent dispersion coefficients from Heffter (1980) are used.

k. Vertical Dispersion

Transport-time-dependent dispersion coefficients from Heffter (1980) are used.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Dry deposition is treated. User input deposition velocity is required.

Wet deposition is treated. User input hourly precipitation rate and precipitation layer depth or cloud ceiling height are required.

n. Evaluation Studies

None cited.

B.13 Models 3141 and 4141

Reference

Enviroplan, Inc, 1981. User's Manual for Enviroplan's Model 3141 and Model 4141. Enviroplan, Inc., West Orange, NJ.

Availability

A magnetic tape copy of the FORTRAN coding and the user's guide are available for a cost of \$1,900 from: Environplan, Inc., 59 Main Street, West Orange, New Jersey 07052.

Abstract

Models 3141 and 4141 are modifications of CRSTER (UNAMAP VERSION 3) and are applicable to complex terrain particularly where receptor elevation approximately equals or exceeds the stack top elevation. The model utilizes intermediate ground displacement procedures and dispersion enhancements developed from an aerial tracer study and ground level concentrations measured for a power plant located in complex terrain.

a. Recommendations for Regulatory Use

3141 or 4141 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. 3141 or 4141 must be executed in the equivalent mode.

3141 or 4141 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that 3141 or 4141 is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas exit temperature.

Meteorological data requirements are: Hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: Distance of each of five receptor rings, and receptor elevation.

#### c. Output

Printed output includes: Highest and second highest concentrations for the year at each receptor for averaging times of 1, 3, and 24-hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours.

Annual arithmetic average at each receptor.

For each day, the highest 1-hour and 24-hour concentrations over the receptor field.

#### d. Type of Model

3141 and 4141 are Gaussian plume models.

#### e. Pollutant Types

3141 and 4141 may be used to model non-reactive pollutants. Settling and deposition are not treated.

#### f. Source-Receptor Relationship

Up to 19 point sources are treated.

No area sources are treated.

All point sources are assumed to be collocated.

Unique stack height is used for each source.

Receptor locations are restricted to 36 azimuths (every 10 degrees) and 5 user-specified radial distances.

Unique topographic elevation is used for each receptor.

#### g. Plume Behavior

Briggs (1969, 1971, 1972) final plume rise formulas are used.

If plume height exceeds mixing height at a receptor location after terrain adjustment, concentration is assumed equal to zero.

#### h. Horizontal Winds

Wind speeds are corrected for release height based on power law variation exponents from DeMarrais (1959), different exponents for different stability classes, reference height = 7 meters. Exponents used are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Constant, uniform (steady-state) wind is assumed within each hour.



i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Dispersion coefficients are Pasquill-Gifford coefficients from Turner (1969).

Dispersion is adjusted to 60 minutes averaging time by one-fifth power rule (Gifford, 1975).

Buoyancy-induced dispersion (Briggs, 1975) is included.

k. Vertical Dispersion

Dispersion coefficients are Pasquill-Gifford coefficients from Turner (1969).

Buoyancy-induced dispersion (Briggs, 1975) is included.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Ellis, H.M., P.C. Liu, and C. Runyon, 1979. "Comparison of Predicted and Measured Concentrations for 54 Alternate Models of Plume Transport in Complex Terrain," Presented in APCA Annual Conference, Cincinnati, OH.

Ellis, H.M., P.C. Liu and C. Runyon, 1980. Comparison of Predicted and Measured Concentrations for 58 Alternative Models of Plume Transport in Complex Terrain, Journal of the Air Pollution Control Association, 30(6).

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. Evaluation of Rural Air Quality Simulation Models. EPA Publication No. EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, NC.

Wackter, D., and R. Longergan, 1984. Evaluation of Complex Terrain Air Quality Simulation Models. EPA Publication No. EPA-450/4-84-017. U.S. Environmental Protection Agency, Research Triangle Park, NC.

B.14 Multimax

Reference

Moser, J.H., 1979. MULTIMAX: An Air Dispersion Modeling Program for Multiple Sources, Receptors, and Concentration Averages. Shell Development Company, Westhollow Research Center, P.O. Box 1380, Houston, TX. (NTIS PB 80-170178).

Availability

The above report is available from NTIS (\$16.95 for paper copy; \$5.95 on microfiche). The accession number for the computer tape for MULTIMAX is PB 80-170160, and the cost is \$370.00. Requests should be sent to: Computer Products, National Technical Information Service, U.S. Department of Commerce, 5825 Port Royal Road, Springfield, Virginia 22161, phone (703) 487-4650.

## Abstract

MULTIMAX is a Gaussian plume model applicable to both urban and rural areas. It can be used to calculate highest and second-highest concentrations, for each of several averaging times due to up to 100 sources arbitrarily located.

### a. Recommendations for Regulatory Use

MULTIMAX can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. MULTIMAX must be executed in the equivalent mode.

MULTIMAX can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that MULTIMAX is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

### b. Input Requirements

Source data requirements are: Emission rate, physical stack height, stack gas exit velocity, stack inside diameter, and stack gas temperature.

Meteorological data requirements are: Hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor requirements are: Individual receptor points, arcs and circles of receptors, or lines of receptors may be input, with receptor point locations, receptor line end points, and receptor circle center and radius defined in either cartesian or polar coordinates.

### c. Output

Printed output includes: Highest and second-highest concentrations for the year at each receptor for averaging time of 1, 3, and 24 hours. Annual arithmetic average at each receptor.

Computer readable output includes: Input data and results.

### d. Type of Model

MULTIMAX is a Gaussian plume model.

### e. Pollutant Types

MULTIMAX may be used to model primary pollutants. Settling and deposition are not treated.

### f. Source-Receptor Relationship

Up to 100 point sources at any location may be input.

Area sources are not treated.

Point sources may be at any location.

Unique stack height is used for each source.

Unique topographic elevation is used for each receptor; must be below top of stack.

Receptors can be defined individually, or along lines or arcs.

g. Plume Behavior

MULTIMAX uses Briggs (1969, 1971, 1972) final plume rise formulas.

If plume height exceeds mixing height, concentrations downwind are assumed equal to zero.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law variation exponents from DeMarrais (1959), different exponents for different stability classes, reference height = 10 meters. The exponents are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Constant, uniform (steady-state) wind is assumed within each hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used in MULTIMAX with no adjustments made for variations in surface roughness.

Six stability classes are used, with Turner class 7 treated as Class 6.

Averaging time adjustment is optional.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used in MULTIMAX with no adjustments made for variations in surface roughness.

Six stability classes are used, with Turner class 7 treated as Class 6.

Perfect reflection at the ground is assumed.

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform mixing is assumed beyond that point.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wackter, T. Kincaid, and D. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models. EPA Publication No. EPA-450/4-83-003, U.S. Environmental Protection Agency, Research Triangle Park, NC.

## B.15 Multiple Point Source Diffusion Model (MPSDM)

### Reference

Environmental Research & Technology, Inc., 1984. User's Guide to MPSDM. ERT Document No. PB-881585. Environmental Research & Technology, Inc., Concord, MA.

### Availability

The above report and a computer tape are available from: Computer Products, National Technical Information Service, U.S. Department of Commerce, 5825 Port Royal Road, Springfield, Virginia 22161, phone (703) 487-4650.

### Abstract

MPSDM is a steady-state Gaussian dispersion model designed to calculate, in sequential mode or in "case-by-case" mode, concentrations of nonreactive pollutants resulting from single or multiple source emissions. The MPSDM model may be used for sources located in flat or complex terrain, in a univariate ( $\sigma_z$ ) or bivariate ( $\sigma_y, \sigma_z$ ) mode. Sufficient flexibility is allowed in the specification of model parameters to enable the MPSDM user to duplicate results that would be obtained from many other Gaussian point-source models. A number of features are incorporated to facilitate site-specific model validation studies.

#### a. Recommendations for Regulatory Use

MPSDM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. MPSDM must be executed in the equivalent mode.

MPSDM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that MPSDM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: Hourly or constant emission rate, stack gas temperature, exit velocity, and stack inside diameter.

Meteorological data requirements are: Hourly wind speed, wind direction, air temperature and mixing height; and vertical temperature difference or stability class. Optional meteorological parameters include solar intensity and wind speed standard deviation.

Receptor data requirements are: Northing, easting, and ground level elevation of each receptor.

Air quality data requirements are: Observed concentrations at any monitor for any or all hours ("case-by-case" mode only) will be compared with estimates, or (sequential mode only) will be used to determine background levels. Background is calculated as the average of those monitors more than  $\pm i$  radians from the plume centerline defined in the model. Default for  $i$  is the equivalent of  $60^\circ$ . User input for  $i$  is optional.

#### c. Output

Printed output includes:

"Case-by-case" mode: Printed output includes hourly centerline, off centerline, sector averaged and observed concentrations at all monitors; downwind profiles of centerline concentrations; and a statistical summary of all cases addressed.

Sequential mode: Printed output limited to ratio of predicted maximum concentration to maximum concentration measured at each monitor. Primary output is a file output containing hourly averaged concentrations.

A post-processing program, ANALYSIS, is used to produce averages for longer periods. For a user-specified average period a ranked order of peak concentrations, the cumulative frequency of occurrence of user-specified concentration levels or a summary of hourly meteorological characteristics and concentrations contributing to levels above a user-specified value can also be obtained with the ANALYSIS post-processor.

d. Type of Model

MPSDM is a Gaussian plume model.

e. Pollutant Types

MPSDM may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

Arbitrary locations for sources and receptors are used.

Actual terrain elevations may be specified and accounted for by plume-height adjustments.

Actual separation between each source receptor pair is used.

Receptors are assumed to be at ground level.

Unique stack height is used for each source.

g. Plume Behavior

Briggs (1969, 1974, 1975) plume rise equations are used.

Partial (or total) penetration of plume into elevated inversions (Briggs, 1975) is included.

Stack tip downwash (Briggs, 1975) is treated.

Fumigation (Turner, 1969) is treated.

Convective dispersion using a probability density function model is optional (Venkatram, 1980).

h. Horizontal Winds

User-supplied hourly wind speed and direction are assumed to specify horizontally homogeneous, steady-state conditions.

Wind speeds vary with height according to user-designated profiles for each stability.

Wind direction is specifiable in whole degrees from 1° to 360°.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

ASME (Brookhaven) diffusion coefficients (ASME, 1968) are used.

Options are Pasquill-Gifford coefficients or user input horizontal plume with coefficients of the form  $ax^b$ , or sector average with user-input sector width.

Hourly stability (six classes-very unstable through moderately stable) is determined internally from input vertical temperature gradient and mean wind speed or stability classes.

A buoyancy-induced dispersion algorithm (Pasquill, 1976) is optional.

#### k. Vertical Dispersion

ASME (Brookhaven) diffusion coefficients (ASME, 1968) are used. Options are Pasquill-Gifford coefficients or user input horizontal plume with coefficients of the form  $ax^b$ . One model option employs a convective dispersion algorithm developed by Venkatram (1980).

Hourly stability (six classes-very unstable through moderately stable) are determined internally from input vertical temperature gradient and mean wind speed or stability classes.

A buoyancy-induced dispersion algorithm (Pasquill, 1976) is optional.

Perfect reflection at ground is assumed.

Perfect reflection is assumed at the mixing height of pollutant above or below top of mixing layer (except for partial plume penetration).

#### l. Chemical Transformation

Not treated.

#### m. Physical

Not treated.

#### n. Evaluation Studies

Lavery, T.F., and L.L. Schulman, 1977. The Validity of a Gaussian Plume Point Source Diffusion Model for Predicting Short-Term  $SO_2$  Levels in the Vicinity of Electric Generating Plants in New York State. Joint conference on Applications of Air Pollution Meteorology, AMS/APCA, Salt Lake City, UT.

Londergan R., D. Minott, D. Wackter, T. Kincaid and D. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models. EPA Publication No. EPA-45014-83-003, U.S. Environmental Protection Agency, Research Triangle Park, NC.

#### B.16 Multi-Source (SCSTER) Model

##### Reference

Malik, M.H. and B. Baldwin, 1980. Program Documentation for Multi-Source (SCSTER) Model. Program Documentation EN7408SS. Southern Company Services, Inc., Technical Engineering Systems, 64 Perimeter Center East, Atlanta, GA.

##### Availability

The SCSTER model and user's manual are available at no charge to a limited number of persons through Southern Company Services. A magnetic tape must be provided by those desiring the model. Requests should be directed to: Mr. Bryan Baldwin, Research Program Supervisor, Air Quality Program, Southern Company Services, Post Office Box 2625, Birmingham, Alabama 35202.

#### Abstract

SCSTER is a modified version of the EPA CRSTER model. The primary distinctions of SCSTER are its capability to consider multiple sources that are not necessarily collocated, its enhanced receptor specifications, its variable plume height terrain adjustment procedures and plume distortion from directional wind shear.

#### a. Recommendations for Regulatory Use

SCSTER can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. SCSTER must be executed in the equivalent mode.

SCSTER can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that SCSTER is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: Emission rate, stack gas exit velocity, stack gas temperature, stack exit diameter, physical stack height, elevation of stack base, and coordinates of stack location. The variable emission data can be monthly or annual averages.

Meteorological data requirements are: Hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is optional. Wind speed profile exponents (one for each stability class) are optional.

Receptor data requirements are: Cartesian coordinates and elevations of individual receptors; distances of receptor rings, with elevation of each receptor; receptor grid networks, with elevation of each receptor. Any combination of the three receptor input types may be used to consider up to 600 receptor locations.

#### c. Output

Printed output includes:

Highest and second highest concentrations for the year at each receptor for averaging times of 1-, 3-, and 24-hours, a user-selected averaging time which may be 2-12 hours, and a 50 high table for 1-, 3-, and 24-hours;

Annual arithmetic average at each receptor; and the highest 1-hour and 24-hour concentrations over the receptor field for each day considered.

Optional tables of source contributions of individual point sources at up to 20 receptor locations for each averaging period;

Optional magnetic tape output in either binary or fixed block format includes:

All 1-hour concentrations.

Optional card/disk output includes for each receptor:

Receptor coordinates; receptor elevation; highest and highest, second-highest, 1-, 3-, and 24-hour concentrations; and annual average concentration.

d. Type of Model

SCSTER is a Gaussian plume model.

e. Pollutant Types

SCSTER may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

SCSTER can handle up to 60 separate stacks at varying locations and up to 600 receptors, including up to 15 receptor rings.

User input topographic elevation for each receptor is used.

g. Plume Behavior

SCSTER uses Briggs (1969, 1971, 1972) final plume rise formulas.

Transitional plume rise is optional.

SCSTER contains options to incorporate wind directional shear with a plume distortion method described in appendix A of the User's Guide.

SCSTER provides four terrain adjustments including the CRSTER full terrain height adjustment and a user-input, stability-dependent plume path coefficient adjustment for receptors above stack height.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law exponents from DeMarrais (1959), different exponents for different stability classes; default reference height of 7 m. Default exponents are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Steady-state wind is assumed within a given hour.

Optional consideration of plume distortion due to user-input, stability-dependent wind-direction shear gradients.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used.

Six stability classes are used.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used.



Six stability classes are used.

An optional test for plume height above mixing height before terrain adjustment is included.

#### l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

#### m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

#### n. Evaluation Studies

Londergan, R., D. Minott, D. Wackter, T. Kincaid and D. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models. EPA Publication No. EPA 450/4-83-003, U.S. Environmental Protection Agency, Research Triangle Park, NC.

#### B.17 Pacific Gas and Electric Plume5 Model

##### Reference

User's Manual for Pacific Gas and Electric Plume5 Model, 1981. Pacific Gas and Electric, San Francisco, CA.

##### Availability

The User's Manual will be supplied for cost of reproduction. An IBM version of the model can be obtained on a user supplied tape free of charge from: Mr. Robert N. Swanson, Pacific Gas and Electric Company, 245 Market Street, RM 451, San Francisco, California 94106.

##### Abstract

PLUME5 is a steady-state Gaussian plume model applicable to both rural and urban areas in uneven terrain. Pollutant concentrations at 500 receptors from up to 10 sources with up to 15 stacks each can be calculated using up to 5 meteorological inputs. The model in its "basic" mode is similar to CRSTER and MPTEP. Several options are available that allow better simulation of atmospheric conditions and improved model outputs. These options allow plume rise into or through a stable layer and crosswind spread of the plume by wind directional shear with height, initial plume expansion, mean (advective) wind speed, terrain considerations, and chemical transformation of pollutants.

Differences that exist between PLUME5 and CRSTER are in the following areas: Stability class determination, hourly mixing height schemes, hourly stable layer data, randomization of wind direction, extent of data set required for preprocessing meteorological data inputs.

#### a. Recommendations for Regulatory Use

PLUME5 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. PLUME5 must be executed in the equivalent mode.

PLUME5 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that PLUME5 is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: Cartesian or polar coordinates of each source with stack height, diameter, gas temperature, and exit velocity for each stack.

Meteorological data requirements are: Surface data-hourly meteorological data including wind direction, wind speed, temperature, and either ceiling height and total sky cover or sigma A or Delta T depending on how stability is computed; stable layer data-either NCC data or site specific user supplied data.

Receptor data requirements are: cartesian or polar coordinates of each receptor.

c. Output.

Printed output includes:

Highest and second highest concentrations for the year printed out at each receptor for averaging times of 1, 3, and 24-hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours.

Annual arithmetic average at each receptor.

For each day, the highest 1-hour and 24-hour concentrations over the receptor field is printed.

Hourly effective stack height and effective stack height distributions.

Vertical profiles of maximum pollutant concentrations above a designated height ( $Z_o$ ) for the data period processed.

Cumulative number of exceedances of 1 hour and 24-hour specified values for all receptors during the entire meteorological data period. These specified values will normally be National and State Ambient Air Quality Standards.

Computer readable output includes:

Hourly concentrations for each receptor on magnetic tape.

Computer file for input to plotting routine. The file stores the highest 1-hour (or other specified time period) concentration at each receptor for the entire meteorological data period for input into a user supplied plotting routine.

d. Type of Model

PLUME5 is a Gaussian plume model.

e. Pollutant Types

PLUME5 may be used to model primary pollutants. Chemical transformations of pollutants are treated by exponential decay and/or ozone limiting procedures.

f. Source-Receptor Relationship

Can input up to 10 separate sources with up to 15 stacks per source.

Unique stack height for each source. Rectangular or circular receptor locations (up to 500) can be either model generated or user input.

Terrain considerations:

When plume rise,  $H$ , is above the stable layer top concentration estimates will only be calculated for receptors at or above the stable layer top. If the receptor is below the stable layer top, then the concentration is zero.

When plume rise falls within the stable layer, concentration estimates will be only calculated for receptors located within this region. If the receptor height is above or below the stable top, then the concentration is zero.

When plume rise falls below the stable layer and the receptor height is above the stable layer base, then the concentration is zero. If the receptor is below the stable layer base, the receptor height is redefined.

#### g. Plume Behavior

PLUME5 uses Briggs (1975) final plume rise formulas.

Expansion of plumes within and above a stable layer is treated.

#### h. Horizontal Winds

User-supplied hourly wind directions are read to nearest 1, 5, 10, and 22.5 degrees. (The 5, 10 and 22.5 degree values are randomly modified to nearest whole degree within the intervals).

PLUME5 employs the extrapolated mean wind speed at stack height when the effective stack height is equal to or less than the height of the inversion base above ground. If the plume rises into a stable layer, a separate algorithm is used.

Constant, uniform (steady state) wind assumed within each hour.

#### i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

#### j. Horizontal Dispersion

Six stability classes are defined by either radiation index and wind speed (STAR), wind direction fluctuation, or temperature lapse rate. Nighttime stability class is based on wind direction fluctuations or temperature lapse rate and may be modified according to the method of Mitchell and Timbre (1979).

Dispersion curves are from Turner (1969).

#### k. Vertical Dispersion

Six stability classes are defined by either radiation index and wind speed (STAR), wind direction fluctuations, or temperature lapse rate.

Nighttime stability class is based on wind direction fluctuations or temperature lapse rate and modified according to the method of Mitchell-Timbre (1979).

Dispersion curves are from Turner (1969).

#### l. Chemical Transformation

Chemical transformations are treated using exponential decay and/or ozone limiting procedures.

#### m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by user.

#### n. Evaluation Studies

Londergan, R., D. Minott, D. Wackter, T. Kincaid and B. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models. EPA Publication No. EPA-450/4-83-003, U. S. Environmental Protection Agency, Research Triangle Park, NC.

Wackter, D., and R. Londergan, 1984. Evaluation of Complex Terrain Air Quality Simulation Models. EPA Publication No. EPA 450/4-84-017. U. S. Environmental Protection Agency, Research Triangle Park, NC.

#### B.18 PLMSTAR Air Quality Simulation Model

##### Reference

Lurmann, F.W., D.A. Godden, and H. Collins, 1985. User's Guide to the PLMSTAR Air Quality Simulation Model. ERT Document No. M-2206-100, Environmental Research & Technology, Inc., Newbury Park, CA.

##### Availability

The above report and a computer tape are available from: Computer Products, National Technical Information Service, U.S. Department of Commerce, 5825 Port Royal Road, Springfield, Virginia 22161, phone (703) 487-4650.

##### Abstract

PLMSTAR is a mesoscale Lagrangian photochemical model designed to predict atmospheric concentrations of  $O_3$ ,  $NO_2$ ,  $HNO_3$ , PAN,  $SO_2$ , and  $SO_4^{=}$  from reactive hydrocarbons,  $NO_x$  and  $SO_x$  emissions. PLMSTAR is intended to simulate the behavior of pollutants in chemically reactive plumes resulting from major point source emissions. The model's Lagrangian air parcel is subdivided into a 5 layer/9 column domain of computational cells. The approach allows for realistic simulation of the combined effects of atmospheric chemical reactions and pollutant dispersion in the horizontal and vertical directions. Other key features of the model include: the capability for generation of trajectories at any level of a three-dimensional, divergence-free wind field; the capability for calculating and utilizing the time and space varying surface deposition of pollutants; an up-to-date  $O_3$ /RHC/ $NO_x$ / $SO_x$  chemical mechanism that utilizes eight classes of reactive hydrocarbons; the capability for simultaneously handling both point and area source emissions; and the capability to simulate overwater conditions and land/water transitions.

##### a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The PLMSTAR Model may be used on a case-by-case.

##### b. Input Requirements

Source data requirements are: Emission rates, stack parameters, diurnal emission profiles, and RHC,  $NO_x$ , and  $SO_x$  partitioning profiles.

Meteorological data requirements are: Station location, grid geometry, surface winds, surface roughness, surface temperature, temperature profiles, mixing heights (optional), cloud cover, solar radiation, and winds aloft.

Receptor data requirements are: Receptor locations and topography.

##### c. Output

Printed output includes:

Computed concentrations at specified times and receptors along the trajectory.

##### d. Type of Model

PLMSTAR is a Lagrangian photochemical model.

#### e. Pollutant Types

The key chemical species included in the model are  $O_3$ , NO,  $NO_2$ ,  $HNO_3$ , PAN,  $SO_2$ ,  $SO_4^{=}$ , CO, and eight classes of reactive hydrocarbons. Twenty additional intermediate species are included in the chemical mechanism.

#### f. Source-Receptor Relationships

Source-receptor relationships for individual sources are calculated using a differencing technique. That is, simulations are made with and without an individual source (or group of collocated sources) in addition to the  $RHC/NO_x/SO_x$  emissions from all other sources in the region. The emission processors allow for up to 250 point sources and an unlimited number of area sources (allocated to a grid of 36 X 36 squares) to be included in the simulation.

#### g. Plume Behavior

Plume rise calculations are based on Briggs (1975).

#### h. Horizontal Winds

Gridded hourly multi-level horizontal wind fields are generated using techniques similar to those reported by Goodin et al. (1979). These involve wind data interpolation, divergence minimization, and terrain adjustment. Trajectory path segments are then generated by interpolation from the gridded horizontal wind fields in 15 minute steps at the user selected vertical level. Either source or receptor oriented trajectory may be generated.

#### j. Vertical Wind Speed

Vertical speed is produced by WINDMOD, but is not utilized in the trajectory calculation or the pollutant advection algorithm.

#### j. Vertical Dispersion

Vertical eddy diffusivities ( $K_z$ ) over land are calculated as a function of wind speed, stability, surface roughness, and boundary layer height. Over water, wind speed, air-to-sea temperature difference, humidity, and boundary layer height are the key parameters.

The effects of vertical dispersion on pollutant concentrations are calculated by numerically integrating finite difference approximations to the diffusion equation.

Mixing heights can be internally calculated or externally specified.

#### k. Horizontal Dispersion

Horizontal eddy diffusivities ( $K_y$ ) are calculated either as a function of  $K_z$  and stability class or as a function of  $\sigma_y$ . The effects of horizontal dispersion on pollutant concentrations are calculated by numerically integrating finite difference approximations to the diffusion equation.

#### 1. Chemical Transformation

PLMSTAR incorporates a slightly condensed version of the Atkinson et al. (1982) photochemical mechanism for  $O_3/RHC/NO_x/SO_x$ /air mixtures. The mechanism contains 62 reactions involving 38 species, including 8 classes of organic precursors. The effects of chemical transformations on pollutant concentrations are computed by numerically integrating the nonlinear kinetic rate equations.

#### m. Physical Removal

Dry deposition of  $O_3$ ,  $NO_2$ ,  $HNO_3$ , PAN,  $SO_2$ , and  $SO_4^{2-}$  is based on the model of Wesely and Hicks (1977).

#### n. Evaluation Studies

Lurmann, F.W., D.A. Godden and A.C. Lloyd, 1982. The Development and Selected Sensitivity, Tests of the PLMSTAR Reactive Plume Model, Presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX.

Godden, D. and F. Lurmann, 1983. Development of the PLMSTAR Model and its Application to Ozone Episode Conditions in the South Coast Air Basin, ERT Document No. P-A702-200, Environmental Research & Technology, Inc., Newbury Park, CA.

Blumenthal, D.L., T.B. Smith, D.E. Lehrman, N.L. Alexander, F. Lurman, and D. Godden, 1985. Analysis of Aerometric and Meteorological Data for the Ventura County Region, Ref. #90094-511-FR. Sonoma Technology, Inc., and Environmental Research and Technology, Inc., for the Western Oil and Gas Association, Los Angeles, CA.

#### B.19 Plume Visibility Model (PLUVUE II)

##### Reference

Seigneur, C., C. D. Johnson, D. A. Latimer, R. W. Bergstrom and H. Hogo, 1984. User's Manual for the Plume Visibility Model (PLUVUE II). EPA Publication No. EPA 600/8-84-005. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 84-158302).

##### Availability

This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

##### Abstract

The Plume Visibility Model (PLUVUE II) is a computerized model used for estimating visual range reduction and atmospheric discoloration caused by plumes resulting from the emissions of particles, nitrogen oxides and sulfur oxides from a single emission source. PLUVUE II predicts the transport, dispersion, chemical reactions, optical effects and surface deposition of point or area source emissions. Addenda to the User's Manual were prepared in February 1985 to allow execution of PLUVUE II and the test cases on the UNIVAC computer, the addenda are included in the UNAMAP (Version 6) documentation.

#### a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The Plume Visibility Model (PLUVUE II) may be used on a case-by case basis.

#### b. Input Requirements

Source data requirements are: Location and elevation; emission rates of  $SO_2$ ,  $NO_x$  and particulates; flue gas flow rate, exit velocity, and exit temperature; flue gas oxygen content; properties (including density, mass median and standard geometric deviation of radius) of the emitted aerosols in the accumulation (0.1-1.0  $\mu m$ ) and coarse (1.0-10.0  $\mu m$ ) size modes; and deposition velocities for  $SO_2$ ,  $NO_x$ , coarse mode aerosol, and accumulations mode aerosol.

Meteorological data requirements are: Stability class, wind direction (for an observer-based run), wind speed, lapse rate, air temperature, relative humidity, and mixing height.

Other data requirements are: Ambient background concentrations of  $\text{NO}_x$ ,  $\text{O}_3$ , and  $\text{SO}_2$ , background visual range or sulfate and nitrate concentrations.

Receptor (observer) data requirements are: Location, elevation, terrain which will be observed through the plume (for observer based run with white, gray, and black viewing backgrounds).

c. Output

Printed output includes: plume concentrations and visual effects at specified downwind distances for calculated or specified lines of sight.

d. Type of Model

PLUVUE is a Gaussian plume model.

e. Pollutant Types

PLUVUE II treats  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{HNO}_3$ ,  $\text{O}_3$ , primary and secondary particles to calculate effects on visibility.

f. Source Receptor Relationship

PLUVUE treats a single point or area source.

Predicted concentrations and visual effects are obtained at user specified downwind distances.

g. Plume Behavior

PLUVUE uses Briggs (1969, 1971, 1972) final plume rise equations.

h. Horizontal Winds

User-specified wind speed (and direction for an observer-based run) are assumed constant for the calculation.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

User specified plume widths, or widths computed from either Pasquill-Gifford-Turner curves (Turner, 1969) or TVA curves (Carpenter, et al., 1971) are used in PLUVUE.

k. Vertical Dispersion

User specified plume depths, or computer from Pasquill-Gifford-Turner curves (Turner, 1969) or TVA curves (Carpenter, et al., 1971) are used in PLUVUE.

l. Chemical Transformation

PLUVUE II treats the chemistry of  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{O}_3$ ,  $\text{OH}$ ,  $\text{O}(^1\text{D})$ ,  $\text{SO}_2$ ,  $\text{HNO}_3$ , and  $\text{H}_2\text{SO}_4$ , by means of nine reactions. Steady state approximations are used for radicals and for the  $\text{NO}/\text{NO}_2/\text{O}_3$  reactions.

m. Physical Removal

Dry deposition of gaseous and particulate pollutants is treated using deposition velocities.

#### n. Evaluation Studies

Bergstrom, R.W., C. Seigneur, B. L. Babson, H. Y. Holman and M. A. Wojcik, 1981. Comparison of the Observed and Predicted Visual Effects Caused by Power Plant Plumes. *Atmospheric Environment*, 15:2135-2150.

Bergstrom, R.W., C. Seigneur, C. D. Johnson, and L. W. Richards, Measurements and Simulations of the Visual Effects of Particulate Plumes. Systems Applications, Inc., San Rafael, CA.

Seigneur, C., R. W. Bergstrom, and A. B. Hudischewskyj, 1982. Evaluation of the EPA PLUVUE Model and the ERT Visibility Model Based on the 1979 VISTTA Data Base. EPA Publication No. EPA-450/4-82-008, U.S. Environmental Protection Agency, Research Triangle Park, NC.

White, W.H., C. Seigneur, D.W. Heinold, M.W. Eltgroth, L.W. Richards, P.T. Roberts, P. S. Bhardwaja, W. D. Conner and W. E. Wilson, Jr, 1985. Predicting the Visibility of Chimney Plumes: An Intercomparison of Four Models with Observations at a Well-Controlled Power Plant, *Atmospheric Environment*, 19:515-528.

#### B.20 Point, Area, Line Source Algorithm (PAL-DS)

##### Reference

Petersen, W.B., 1978. User's Guide for PAL-A Gaussian-Plume Algorithm for Point, Area, and Line Sources. EPA Publication No. EPA-600/4-78-013. Office of Research and Development, Research Triangle Park, NC. (NTIS PB 281306).

Rao, K.S. and H.F. Snodgrass, 1982. PAL-DS Model: The PAL Model Including Deposition and Sedimentation. EPA Publication No. EPA 600/8-82-023. Office of Research and Development, Research Triangle Park, NC. (NTIS PB 83-117739).

##### Availability

This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

##### Abstract

PAL-DS is an acronym for this point, area, and line source algorithm and is a method of estimating short-term dispersion using Gaussian-plume steady-state assumptions. The algorithm can be used for estimating concentrations of non-reactive pollutants at 99 receptors for averaging times of 1 to 24 hours, and for a limited number of point, area, and line sources (99 of each type). This algorithm is not intended for application to entire urban areas but is intended, rather, to assess the impact on air quality, on scales of tens to hundreds of meters, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed. The Gaussian point source equation estimates concentrations from point sources after determining the effective height of emission and the upwind and crosswind distance of the source from the receptor. Numerical integration of the Gaussian point source equation is used to determine concentrations from the four types of line sources. Subroutines are included that estimate concentrations for multiple lane line and curved path sources, special line sources (line sources with endpoints at different heights above ground), and special curved path sources. Integration over the area source, which includes edge effects from the source region, is done by considering finite line sources perpendicular to the wind at intervals upwind from the receptor. The crosswind integration is done analytically; integration upwinds is done numerically by successive approximations.

The PAL-DS model utilizes Gaussian plume-type diffusion-deposition algorithms based on analytical solutions of a gradient-transfer model. The PAL-DS model can treat deposition of both gaseous and suspended particulate



pollutants in the plume since gravitational settling and dry deposition of the particles are explicitly accounted for. The analytical diffusion-reposition expressions listed in this report in the limit when pollutant settling and deposition velocities are zero, they reduce to the usual Gaussian plume diffusion algorithms in the PAL model.

#### a. Recommendations for Regulatory Use

PAL-DS can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. PAL-DS must be executed in the equivalent mode.

PAL-DS can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that PAL-DS is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data: point-sources-emission rate, physical stack height, stack gas temperature, stack gas velocity, stack diameter, stack gas volume flow, coordinates of stack, initial  $\sigma_y$  and  $\sigma_z$ ; area sources-source strength, size of area source, coordinates of S.W. corner, and height of area source; and line sources-source strength, number of lanes, height of source, coordinates of end points, initial  $\sigma_y$  and  $\sigma_z$ , width of line source, and width of median. Diurnal variations in emissions are permitted. When applicable, the settling velocity and deposition velocity are also permitted.

Meteorological data: wind profile exponents, anemometer height, wind direction and speed, stability class, mixing height, air temperature, and hourly variations in emission rate.

Receptor data: receptor coordinates.

#### c. Output

Printed output includes:

Hourly concentration and deposition flux for each source type at each receptor; and

Average concentration for up to 24 hrs for each source type at each receptor.

#### d. Type of Model

PAL-DS is a Gaussian plume model.

#### e. Pollutant Types

PAL-DS may be used to model non-reactive pollutants.

#### f. Source-Receptor Relationships

Up to 99 sources of each of 6 source types: point, area, and 4 types of line sources.

Source and receptor coordinates are uniquely defined.

Unique stack height for each source.

Coordinates of receptor locations are user defined.

#### g. Plume Behavior

Briggs final plume rise equations are used.

Fumigation and downwash are not treated.

If plume height exceeds mixing height, concentrations are assumed equal to zero.

Surface concentrations are set to zero when the plume centerline exceeds mixing height.

#### h. Horizontal Winds

User-supplied hourly wind data are used.

Constant, uniform (steady-state) wind is assumed within each hour.

Wind is assumed to increase with height.

#### i. Vertical Wind Speeds

Assumed equal to zero.

#### j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used with no adjustments made for surface roughness.

Six stability classes are used.

Dispersion coefficients (Pasquill-Gifford) are assumed based on a 3 cm roughness height.

#### k. Vertical Dispersion

Six stability classes are used.

Rural dispersion coefficients from Turner (1969) are used; no further adjustments are made for variation in surface roughness, transport or averaging time.

Multiple reflection is handled by summation of series until the vertical standard deviation equals 1.6 times mixing height. Uniform vertical mixing is assumed thereafter.

#### l. Chemical Transformation

Not treated.

#### m. Physical Removal

PAL-DS can treat deposition of both gaseous and suspended particulates in the plume since gravitational settling and dry deposition of the particles are explicitly accounted for.

#### n. Evaluation Studies

None.

### B.21 Random-Walk Advection and Dispersion Model (RADM)

#### References

Austin, D.I., A.W. Bealer, and W.R. Goodin, 1981. Random-Walk Advection and Dispersion Model (RADM), User's Manual. Dames & Moore, Los Angeles, CA.

Runchal, A.K., W.R. Goodin, A.W. Bealer, D.I. Austin, 1981. Technical Description of the Random-Walk Advection and Dispersion Model (RADM). Dames & Moore, Los Angeles, CA.

Availability:

A magnetic tape of the compute code and the user's manual are available for a cost of \$440.00 from: Mr. C. James Olsten, Dames & Moore, 445 South Figueroa Street, Suite 3500, Los Angeles, California 90071-1665.

Abstract:

RADM is a Lagrangian dispersion model which uses the random-walk method to simulate atmospheric dispersion. The technical procedure involves tracing tracer particles having a given mass through advection by the mean wind and diffusion by the random motions of atmospheric turbulence. Turbulent movement is calculated by determining the probability distribution of particle movement for a user-defined time step. A random number between 0 and 1 is then computed to determine the distance of particle movement according to the probability distribution. A large number of particles is used to statistically represent the distribution of pollutant mass. Concentrations are calculated by summing the mass in a volume around the receptor of interest and dividing the total mass by the volume. Concentrations can be calculated for any averaging time. RADM is applicable to point and area sources.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The RADM model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: Emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature. Hourly rates may be specified.

Meteorological data requirements are: Gridded wind field including wind speed, wind direction, stability class, temperature and mixing height.

Receptor data requirements are: Coordinates, ground elevation, and receptor cell dimensions.

c. Output

Printed output includes:

Average concentration by receptor for user-specified averaging time (concentrations are printed for each block of n hours).

Average concentrations for the entire period of the run.

d. Type of Model

RADM is a random-walk Lagrangian dispersion model.

e. Pollutant Types

RADM may be used to model inert gases and particles, and pollutants with exponential decay or formation rates.

f. Source-Receptor Relationship

Multiple point and area sources may be specified at independent locations.

Unique stack characteristics are used for each source.

No restriction is placed on receptor locations.

Perfect reflection at the surface is assumed for the portion not removed by dry deposition.

Particles leaving the gridded area are removed from simulation.

g. Plume Behavior

Briggs (1975) final plume rise equations are used.

Inversion penetration by the plume is allowed.

Fumigation may occur as mixing height rises above a plume which has penetrated an inversion.

h. Horizontal Winds

Wind speed, wind direction, stability class, temperature and mixing height are supplied on a gridded array.

Any wind field may be used as long as output is in correct format for RADM input.

Wind field is updated at user-specified intervals, which may be less than one hour if data are available.

Vertical wind speed profile is used based on surface roughness and stability using Monin-Obukhov length.

i. Vertical Wind Speed

Assumed equal to zero.

j. Horizontal Dispersion

Dispersion is based on diffusivity values calculated from surface roughness, stability class and Monin-Obukhov length.

Diffusivity is a function of height.

k. Vertical Dispersion

Dispersion is based on diffusivity values calculated from surface roughness, stability class and Monin-Obukhov length.

Diffusivity is a function of height.

l. Chemical Transformations

Simple exponential decay or formation is used.

m. Physical Removal

Dry deposition is treated.

n. Evaluation Studies

Runchal, A.K., A.W. Bealer, and G.S. Segal, 1978. A Completely Lagrangian Random-Walk Model for Atmospheric Dispersion. Proceedings of the Thirteenth International colloquim on Atmospheric Pollution, National Institute for Applications of Chemical Research, Paris, pp. 137-142.

Goodin, W.R., A.K. Runchal, and G.Y. Lou, 1980. Evaluation and Application of the Random-Walk Advection and Dispersion Model (RADM). Symposium on Intermediate Range Atmospheric Transport Processes and Technology Assessment, DOE/NOAA/ORNL, Gatlinburg, TN.

Goodin, W.R., D.I. Austin and A.K. Runchal, 1980. A Model Verification and Prediction study of  $\text{SO}_2/\text{SO}_4$  Concentrations in the San Francisco Bay Area. Second Joint Conference on Applications of Air Pollution Meteorology, AMS/APCA, New Orleans, LA.

## B.22 Reactive Plume Model (RPM-II)

### Reference

D. Stewart, M. Yocke, and M-K Liu, 1981. Reactive Plume Model-RPM-II, User's Guide, EPA Publication No. EPA 600/8-81-021 U.S. Environmental Protection Agency, ESRL, Research Triangle Park, NC. (NTIS PB82-230723)

### Availability

The above report is available from NTIS (\$16.95 for paper copy; \$5.95 on microfiche). The accession number for the computer tape for RPM-II is PB83-154898, and the cost is \$460.00. Requests should be sent to: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

### Abstract

The Reactive Plume Model, RPM-II, is a computerized model used for estimating short-term concentrations of primary and secondary pollutants resulting from point or area source emissions. The model is capable of simulating the complex interaction of plume dispersion and non-linear photochemistry. Two main features of the model are: (1) The horizontal resolution within the plume, which offers a more realistic treatment of the entrainment process, and (2) its flexibility with regard to choices of chemical kinetic mechanisms.

#### a. Recommendations for Regulatory Use

There is no specific recommendations at the present time. The RPM-II Model may be used on a case-by-case basis.

#### b. Input Requirements

Source data requirements are: Emission rates, name, and molecular weight of each species of pollutant emitted; ambient pressure, ambient temperature, stack height, stack diameter, stack exit velocity, stack gas temperature, and location.

Meteorological data requirements are: Wind speeds, plume widths or stability classes, photolytic rate constants, and plume depths or stability classes.

Receptor data requirements are: Downwind distances or travel times at which calculations are to be made.

Initial concentration of all species is required, and the specification of downwind ambient concentrations to be entrained by the plume is optional.

#### c. Output

Short-term concentrations of primary and secondary pollutants at either user specified time increments, or user specified downwind distances.

d. Type of Model

Reactive plume model.

e. Pollutant Types

Currently, using the Carbon Bond Mechanism (CBM-II), 35 species are simulated (68 reactions), including NO, NO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>, SO<sub>4</sub>, five categories of reactive hydrocarbons, secondary nitrogen compounds, organic aerosols, and radical species.

f. Source-Receptor Relationships

Single point source.

Single area or volume source.

Multiple sources can be simulated if they are lined up along the wind trajectory.

Predicted concentrations are obtained at a user specified time increment, or at user specified downwind distances.

g. Plume Behavior

Briggs (1971) plume rise equations are used.

h. Horizontal Winds

User specifies wind speeds as a function of time.

i. Vertical Wind Speed

Not treated.

j. Horizontal Dispersion

User specified plume widths, or user may specify stability and widths will be computed using Turner (1969).

k. Vertical Dispersion

User specified plume depths, or user may specify stability in which case depths will be calculated using Turner (1969). Note that vertical uniformity in plume concentration is assumed.

l. Chemical Transformation

The RPM-II has the flexibility of using any user input chemical kinetic mechanism. Currently it is run using the chemistry of the Carbon Bond Mechanism, CBM-II (Whitten, Killus, and Hogo, 1980). The CBM-II, as incorporated in the RPM-II, contains 35 species and 68 reactions focusing primarily on hydrocarbon-nitrogen oxides-ozone photochemistry.

m. Physical Removal

Not treated.

## n. Evaluation Studies

Stewart, D.A. and M-K Liu, 1981. Development and Application of a Reactive Plume Model, *Atmospheric Environment*, 15:2377-2393.

### B.23 Regional Transport Model (RTM-II)

#### Reference

Morris, R.E., D.A. Stewart, and M-K Liu, 1982. Revised User's Guide to the Regional Transport Model-Version II. Publication No. SYSAPP-83/022, Systems Applications Inc., San Rafael, CA.

#### Availability

The computer code is available on magnetic tape for a cost of \$100 (which includes the User's Manual) from: Systems Applications, Inc., 101 Lucas Valley Road, San Raphael, California 94903.

#### Abstract

The Regional Transport Model (RTM-II) is a computer based air quality grid model whose primary use is estimating the distribution of air pollution from multiple point sources and area sources at large distances (on the scale of several hundred to a thousand kilometers). RTM-II offers significant advantages over other long-range transport models because it is a quasi-three dimensional hybrid (grid plus Lagrangian puff) approach to the solution of the advection-diffusion equation. Furthermore, its formulation allows the treatment of spatially and temporarily varying wind, mixing depths, diffusivity, and transformation rate fields. It is also capable of treating spatially varying surface depletion processes. While the modeling concept is capable of predicting concentration distributions of many pollutant species (e.g.,  $\text{NO}_x$ , CO, TSP, etc.), the most notable applications of the model to date focus on the long-range transport and transformation of  $\text{SO}_2$  and sulfates.

#### a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The RTM Model may be used on a case-by-case basis.

#### b. Input Requirements

Source data requirements are: Major point source  $\text{SO}_2$  and primary sulfate emissions, including stack height, diameter, exit velocity, exit temperature, and hourly emission factors; area source  $\text{SO}_2$  and primary  $\text{SO}_4$  emissions in gridded format.

Meteorological data requirements are: Gridded u, v wind fields at user specified update interval (model configured for separate wind fields in each of two layers), derived from twice daily radiosonde data, time variation linear between a maximum convectively driven boundary layer and a minimum mechanically driven boundary layer, spatial interpolation by an inverse distance weighted objective scheme; gridded hourly precipitation fields determined either by averaging precipitation rate of all stations in grid (if high density), or by inverse distance weighted interpolation (if low density).

Other data requirements are: Parameter file, containing region definition, starting time, output and averaging time intervals, region top specifications, and various operational flags; horizontal diffusivity fields calculated from wind fields; land use type file; deposition velocities and roughness length determined internally from tabulated values associated with land use types; initial conditions and boundary conditions for both layers (boundary conditions may be time varying).

#### c. Output

Printed output includes:

Diagnostic information.

Instantaneous SO<sub>2</sub> and sulfate concentration fields for lower and upper layers at pre-specified time intervals.

Average SO<sub>2</sub> and sulfate concentration fields for upper and lower layer, over pre-specified time intervals.  
Accumulated dry and wet deposition for each species over pre-selected time intervals.

d. Type of Model

RTM-II is a hybrid Eulerian grid and Lagrangian puff model.

e. Pollutant Types

RTM-II is configured for SO<sub>2</sub> and sulfate only. Primary sulfate emissions may be included.

f. Source Receptor Relationships

Area sources and minor point sources are specified at each grid within the modeling domain.

Up to 500 major point sources (modeled with the Gaussian puff submodel) are allowed.

Grid average concentration and deposition totals are provided at each grid within the modeling domain (dry deposition for lower layer grid only). All lower grid average concentration values are assumed to be representative of ground-level receptors.

g. Plume Behavior

Plume rise (Briggs, 1971) is calculated for all major point sources regardless of whether they are treated in the Gaussian puff submodel.

h. Horizontal Winds

Gridded u, v wind fields are used at a user specified update interval for each layer.

Gaussian puff submodel tracks puff centroids horizontally at user specified time intervals.

i. Vertical Wind Speed

Considered implicitly if convergent or divergent winds are provided.

j. Horizontal Dispersion

Plume dispersion is based on  $\sigma_y$  differentials derived from a power law fit to Turner (1969) dispersion curves. Variable stabilities within adjacent cells are considered.

Horizontal eddy diffusivities are proportional to the wind field deformation and are calculated from the gridded wind fields as ancillary input. Maximum and minimum constraints are imposed on the magnitude of the diffusivities.

k. Vertical Dispersion

Plume dispersion is based on  $\sigma_z$  differentials derived from a power law fit to Turner (1969) dispersion curves. Variable stabilities within adjacent cells are considered.



Vertical dispersion across the mixed layer-surface layer interface is considered when calculating pollutant deposition.

#### l. Chemical Transformation

Linear SO<sub>2</sub> oxidation is treated. Rate constant is diurnally and latitudinally variable. A minimum oxidation rate constant is specified to account for heterogeneous oxidation during the nighttime.

#### m. Physical Removal

Dry deposition of SO<sub>2</sub> and sulfate is treated. Precipitation scavenging of SO<sub>2</sub> (reversible) and sulfate (irreversible) is treated.

#### n. Evaluation Studies

Stewart, D.A., R.E. Morris, M-K Liu, and D. Henderson, 1983. Evaluation of an Episodic Regional Transport Model for a Multiple Day Episode. *Atmospheric Environment*, 17:1225-1252.

### B.24 SHORTZ

#### Reference

Bjorklund, J.R., and J.F. Bowers, 1982, User's Instructions for the SHORTZ and LONGZ Computer Programs, Volumes I and II. EPA Publication No. EPA 903/9-82004a and b, U.S. Environmental Protection Agency, Region III, Philadelphia PA.

#### Availability

This model is available as part of UNAMAP. (Version 6). The computer code is available on magnetic tape from: Computer Products, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, phone (703) 487-4650.

#### Abstract

SHORTZ utilizes the steady state bivariate Gaussian plume formulation for both urban and rural areas in flat or complex terrain to calculate ground-level ambient air concentrations. It can calculate 1-hour, 2-hour, 3-hour etc. average concentrations due to emissions from stacks, buildings and area sources for up to 300 arbitrarily placed sources. The output consists of total concentration at each receptor due to emissions from each user-specified source or group of sources, including all sources. If the option for gravitational settling is invoked, analysis cannot be accomplished in complex terrain without violating mass continuity.

#### a. Recommendations for Regulatory Use

SHORTZ can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. SHORTZ must be executed in the equivalent mode.

SHORTZ can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that SHORTZ is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: For point, building or area sources, location, elevation, total emission rate (optionally classified by gravitational settling velocity) and decay coefficient; for stack sources, stack height, effluent temperature, effluent exit velocity, stack radius (inner), actual volumetric flow rate, and ground elevation (optional) ;

for building sources, height, length and width, and orientation; for area sources, characteristic vertical dimension, and length, width and orientation.

Meteorological data requirements are: Wind speed and measurement height, wind profile exponents, wind direction, standard deviations of vertical and horizontal wind directions, (i.e., vertical and lateral turbulent intensities), mixing height, air temperature, and vertical potential temperature gradient.

Receptor data requirements are: Coordinates, ground elevation.

c. Output

Printed output includes: Total concentration due to emissions from user-specified source groups, including the combined emissions from all sources (with optional allowance for depletion by deposition).

d. Type of Model

SHORTZ is a Gaussian plume model.

e. Pollutant Types

SHORTZ may be used to model primary pollutants. Settling and deposition of particulates are treated.

f. Source-Receptor Relationships

User specified locations for sources and receptors are used.

Receptors are assumed to be at ground level.

g. Plume Behavior

Plume rise equations of Bjorklund and Bowers (1982) are used.

Stack tip downwash (Bjorklund and Bowers, 1982) is included.

All plumes move horizontally and will fully intercept elevated terrain.

Plumes above mixing height are ignored.

Perfect reflection at mixing height is assumed for plumes below the mixing height.

Plume rise is limited when the mean wind at stack height approaches or exceeds stack exit velocity.

Perfect reflection at ground is assumed for pollutants with no settling velocity.

Zero reflection at ground is assumed for pollutants with finite settling velocity.

Tilted plume is used for pollutants with settling velocity specified.

Buoyancy-induced dispersion (Briggs, 1972) is included.

h. Horizontal Winds

Winds are assumed homogeneous and steady-state.

Wind speed profile exponents are functions of both stability class and wind speed. Default values are specified in Bjorklund and Bowers (1982).

i. Vertical Wind Speed

Vertical winds are assumed equal to zero.

j. Horizontal Dispersion

Horizontal plume size is derived from input lateral turbulent intensities using adjustments to plume height, and rate plume growth with downwind distance specified in Bjorklund and Bowers (1982).

k. Vertical Dispersion

Vertical plume size is derived from input vertical turbulent intensities using adjustments to plume height and rate of plume growth with downwind distance specified in Bjorklund and Bowers (1982).

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Time constant is input by the user.

m. Physical Removal

Settling and deposition of particulates are treated.

n. Evaluation Studies

Bjorklund, J.R., and J.F. Bowers, 1982. User's instructions for the SHORTZ and LONGZ Computer Programs. EPA Publication No. EPA-903/9-82-004. EPA Environmental Protection Agency, Region III, Philadelphia, PA.

Wackter, D., and R. Londergan, 1984. Evaluation of Complex Terrain Air Quality Simulation Models. EPA Publication No. EPA 450/4-84-017. U.S. Environmental Protection Agency, Research Triangle Park, NC.

B.25 Simple Line-Source Model (GMLINE)

Reference

Chock, D.P., 1980. User's Guide for the Simple Line-Source Model for Vehicle Exhaust Dispersion Near a Road, Environmental Science Department, General Motors Research Laboratories, Warren, MI.

Availability

Copies of the above reference are available without charge from: Dr. D.P. Chock, Environmental Science Department, General Motors Research Laboratories, General Motors Technical Center, Warren, Michigan 48090. The User's Guide contains the short algorithm of the model.

Abstract

GMLINE is a simple steady-state Gaussian plume model which can be used to determine hourly (or half-hourly) averages of exhaust concentrations within 100m from a roadway on a relatively flat terrain. The model allows for plume rise due to the heated exhaust, which can be important when the crossroad wind is very low. It also utilizes a new set of vertical dispersion parameters which reflects the influence of traffic-induced turbulence.

a. Recommendations for Regulatory Use

GMLINE can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. GMLINE must be executed in the equivalent mode.

GMLINE can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that GMLINE is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: Emission rate per unit length per lane, the number of lanes on each road, distances from lane centers to the receptor, source and receptor heights.

Meteorological data requirements are: Buoyancy flux, ambient stability condition, ambient wind and its direction relative to the road.

Receptor data requirements are: Distance and height above ground.

#### c. Output

Printed output includes: Hourly or (half-hourly) concentrations at the receptor due to exhaust emission from a road (or a system of roads by summing the results from repeated model applications).

#### d. Type of Model

GMLINE is a Gaussian plume model.

#### e. Pollutant Types

GMLINE can be used to model primary pollutants. Settling and deposition are not treated.

#### f. Source-Receptor Relationship

GMLINE treats arbitrary location of line sources and receptors.

#### g. Plume Behavior

Plume-rise formula adequate for a heated line source is used.

#### h. Horizontal Winds

GMLINE uses user-supplied hourly (or half-hourly) ambient wind speed and direction. The wind measurements are from a height of 5 to 10 m.

#### i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

#### j. Dispersion Parameters

Horizontal dispersion parameter is not used.

#### k. Vertical Dispersion

A vertical dispersion parameter is used which is a function of stability and wind-road angle. Three stability classes are used: Unstable, neutral and stable. The parameters take into account the effect of traffic-generated turbulence (Chock, 1980).

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Chock, D.P., 1978. A Simple Line-Source Model for Dispersion Near Roadways, Atmospheric Environment, 12:823-829.

Sistla, G., P. Samson, M. Keenan, and S.T. Ras, 1979. A Study of Pollutant Dispersion Near Highways, Atmospheric Environment 13:669-685.

B.26 TEXAS CLIMATOLOGICAL MODEL (TCM)-2)

Reference

Staff of the Texas Air Control Board, 1980. User's Guide to the TEXAS CLIMATOLOGICAL MODEL (TCM). Texas Air Control Board, Permits Section, 6330 Highway 290 East, Austin, TX.

Availability

The TCM-2 model is available from the Texas Air Control Board at the following cost: User's Manual only-\$20.00. User's Manual and Model (Magnetic Tape)-\$80.00.

Requests should be directed to: Data Processing Division, Texas Air Control Board, 6330 Highway 290 East, Austin, Texas 78723.

Abstract

TCM is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual arithmetic) average pollutant concentrations of non-reactive pollutants.

a. Recommendations for Regulatory Use

TCM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. TCM must be executed in the equivalent mode.

TCM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that TCM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: Point source coordinates emission rates (by pollutant), stack height, stack diameter, stack gas exit velocity, stack gas temperature; area source coordinates (southwest corner), size, emission rate.

Meteorological data requirements are: Stability wind rose and average temperature.

Receptor data requirements are: Size and spacing of the rectangular receptor grid.

c. Output

Printed output includes:

Period average concentrations listed, displayed in map format, or punched on cards at the user's options.

Culpability list option provides the contributions of the five highest contributors at each receptor.

Maximum concentration option provides the maximum concentration for each scenario (run).

d. Type of Model

TCM is a Gaussian plume model.

e. Pollutant Types

TCM may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

Arbitrary location of point sources and area sources are treated.

Arbitrary location and spacing of rectangular grid of receptors are used. (Area source grid is best defined in terms of the receptor grid, so that the receptors fall in the center of the area source).

Receptors located in simple terrain may be modeled.

g. Plume Behavior

Briggs (1975) plume rise equations, including momentum rise, are used for point sources.

Two-thirds power law is used when transitional rise option is selected.

Flares are treated.

h. Horizontal Winds

Characteristic wind speed is calculated for each direction-stability class combination.

This characteristic speed is the inverse of the average inverse speed for the stability-wind direction combination.

Wind speed is adjusted to stack height by a power law using exponents of .10, .15, .20, .25, .30, and .30 for stabilities A through F, respectively.

i. Vertical Wind Speed

Vertical wind speed is assumed to be zero.

j. Horizontal Dispersion

Uniform distribution within each 22.5 degree sector is assumed

#### k. Vertical Dispersion

Dispersion parameters for point sources are fit to Turner (1969); for area sources in the urban mode the fit is to Gifford and Hanna (1970).

Seven stability classes are used.

Pasquill A through F are treated, with daytime "D" and nighttime "D" given separately.

In the urban mode, E and F stability classes are treated as D-night.

Perfect reflection at the ground is assumed.

#### l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

#### m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

#### n. Evaluation Studies

Londergan, R.J., D.H. Minott, D.J. Wachter and R.R. Fizz, 1983. Evaluation of Urban Air Quality Simulation Models. EPA Publication No. EPA-450/4-83-020. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Durrenberger, C.S., B.A. Braberg, and K. Zimmerman, 1983. Development of a Protocol to be Used for Dispersion Model Comparison Studies. Presented at the 76th Annual Meeting of the Air Pollution Control Association, Atlanta, GA.

#### B.27 TEXAS EPISODIC MODEL (TEM-8)

##### Reference

Staff of the Texas Air Control Board, 1979. User's Guide to the TEXAS EPISODIC MODEL. Texas Air Control Board, Permits Section, 6330 Highway 290 East, Austin, TX.

##### Availability

The TEM-8 model is available from the Texas Air Control Board at the following costs: User's Manual only-\$20.00. User's Manual and Model (Magnetic Tape)-\$80.00.

Requests should be directed to: Data Processing Division, Texas Air Control Board, 6330 Highway 290 East, Austin, Texas 78723.

##### Abstract:

TEM is a short-term, steady-state Gaussian plume model for determining short-term concentrations of non-reactive pollutants.

#### a. Recommendations for Regulatory Use

TEM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. TEM must be executed in the equivalent mode.

TEM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that TEM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

#### b. Input Requirements

Source data requirements are: locations, average emission rates and heights of emissions for both point and area sources; stack gas temperature, stack gas exit velocity, and stack inside diameter for point sources for plume rise calculations.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Any combination of hourly meteorological data up to 24 hours may be used, (e.g. 1, 3, 5, 8, 24 hours).

Receptor requirements are: size, spacing and location of rectangular grid of receptors.

#### c. Output

Printed output includes: concentration list;

Spatial array (concentrations displayed as on a map);

Punched cards of the concentration list;

Culpability list (percent contributions) of the five highest contributors to each receptor;

Maximum concentration; and

Point source list.

#### d. Type of Model

TEM is a Gaussian plume model.

#### e. Pollutant Types

TEM can be used to model non-reactive pollutants. Settling and deposition are not treated.

#### f. Source-Receptor Relationship

Arbitrary locations of point sources and area sources are treated.

Arbitrary location and spacing of rectangular grid of receptors is treated. Area source grid is best defined in terms of the receptor grid so that the receptors fall in the centers of the area sources.

Receptors located in simple terrain may be modeled.

#### g. Plume Behavior

Briggs (1975) plume rise equations are used, including momentum rise, for point sources.

Transitional rise is calculated.

Stack-tip downwash may be evaluated.



#### h. Horizontal Winds

Wind speeds are adjusted to release height by power law formula, using exponents of .10, .15, .20, .25, .30 and .30 for stabilities A through F respectively.

Steady-state wind is assumed.

#### i. Vertical Wind Speed

Vertical wind is assumed equal to zero.

#### j. Horizontal Dispersion

Gaussian plume coefficients are fitted to Turner (1969). The Turner curves are treated as 10-minute averages and the coefficients are adjusted to represent 30-minute or hourly as appropriate.

In the urban mode, stable cases are shifted to neutral nighttime (D-night) conditions and urban mixing heights are used.

#### k. Vertical Dispersion

Dispersion parameters for point sources are fit to Turner (1969); for area sources, in the urban mode, the fit is to Gifford and Hanna (1970).

Total reflection of the plume at the ground is assumed.

In the urban mode, E and F stability classes are treated as D-nighttime.

#### l. Chemical Transformation

Chemical transformation is treated using exponential decay. Half-life is input by the user.

#### m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

#### n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata, 1983. Evaluation of Rural Air Quality Simulation Models, EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, NC.

Durrenberger, C.J., B.A. Broberg, and K. Zimmermann, 1983. Development of a Protocol to be Used for Dispersion Model Comparison Studies. Presented at the 76th Annual Meeting of the Air Pollution Control Association at Atlanta, GA.

#### B.28 AVACTA II

##### Reference

Zannetti, P., G. Carboni and R. Lewis, 1985. AVACTA II User's Guide (Release 3). AeroVironment, Inc., Technical Report AV-OM-85/520.

##### Availability

A magnetic tape copy of the FORTRAN coding and the user's guide are available at a cost of \$2,500 (non-profit organization) or \$3,500 (other organizations) from: AeroVironment, Inc., 825 Myrtle Avenue, Monrovia, CA 91016, phone (818) 357-9983.

## Abstract

The AVACTA II model is a Gaussian model in which atmospheric dispersion phenomena are described by the evolution of plume elements, either segments or puffs. The model can be applied for short time (e.g., one day) simulations in both transport and calm conditions.

The user is given flexibility in defining the computational domain, the three-dimensional meteorological and emission input, the receptor locations, the plume rise formulas, the sigma formulas, etc. Without explicit user's specifications, standard default values are assumed.

AVACTA II provides both concentration fields on the user specified receptor points, and dry/wet deposition patterns throughout the domain. The model is particularly oriented to the simulation of the dynamics and transformation of sulfur species ( $\text{SO}_2$  and  $\text{SO}_4^-$ ), but can handle virtually any pair of primary-secondary pollutants.

### a. Recommendations for Regulatory Use

AVACTA II can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. AVACTA II must be executed in the equivalent mode.

AVACTA II can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in section 3.2, that AVACTA II is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

### b. Input Requirements (all time-varying)

A time-varying input is required at each computational step. Only those data which have changed need to be input by the user.

Source data requirements are: Coordinates, emission rates of primary and secondary pollutants, initial plume sigmas (for non-point sources), exit temperature, exit velocity, stack inside diameter.

Meteorological data requirements are: surface wind measurements, wind profiles (if available), atmospheric stability profiles, mixing heights.

Receptor data requirements are: receptor coordinates.

Other data requirements: coordinates of the computational domain, grid cell specification, terrain elevations, user's computational and printing options.

### c. Output

The model's output is provided according to user's printing flags. Hourly, 3-hour and 24-hour concentration averages are computed, together with highest and highest-second-highest concentration values. Both partial and total concentrations are provided.

### d. Type of Model

AVACTA II is Gaussian plume segment/puff model.

### e. Pollutant Types

AVACTA II can handle any couple of primary-secondary pollutants (e.g.  $\text{SO}_2$  and  $\text{SO}_4^-$ ).

#### f. Source Receptor Relationship

The AVACTA II approach maintains the basic Gaussian formulation, but allows a numerical simulation of both nonstationary and nonhomogeneous meteorological conditions. The emitted pollutant material is divided into a sequence of "elements," either segments or puffs, which are connected together but whose dynamics are a function of the local meteorological conditions. Since the meteorological parameters vary with time and space, each element evolves according to the different meteorological conditions encountered along its trajectory.

AVACTA II calculates the partial contribution of each source in each receptor during each interval. The partial concentration is the sum of the contribution of all existing puffs, plus that of the closest segment.

#### g. Plume Behavior

The user can select the following plume rise formulas:

Briggs (1969, 1971, 1972)

CONCAWE (Briggs, 1975)

Lucas-Moore (Briggs, 1975)

User's functions, i.e., a subroutine supplied by the user

With cold plumes, the program uses a special routine for the computation of the jet plume rise. The user can also select several computational options that control plume behavior in complex terrain and its total/partial reflections.

#### h. Horizontal Winds

A 3D mass-consistent wind field is optionally generated.

#### i. Vertical Wind Speed

A 3D mass-consistent wind field is optionally generated.

#### j. Horizontal Dispersion

During each step, the sigmas of each element are increased. The user can select the following sigma functions:

Pasquill-Gifford-Turner (in the functional form specified by Green et al., 1980)

Brookhaven (Gifford, 1975)

Briggs, open country (Gifford, 1975)

Briggs, urban, i.e., McElroy-Pooler (Gifford, 1975)

Irwin (1979)

LO-LOCAT (MacCready et al., 1974)

User-specified function, by points

User-specified function, with a user's subroutine

The virtual distance/age concept is used for incrementing the sigmas at each time step.

#### k. Vertical Dispersion

During each step, the sigmas of each element are increased. The user can select the following sigma functions:

Pasquill-Gifford-Turner (in the functional form specified by Green et al., 1980)

Brookhaven (Gifford, 1975)

Briggs, open country (Gifford, 1975)

Briggs, urban, i.e., McElroy-Pooler (Gifford, 1975)

LO-LOCAT (MacCready et al., 1974)

User-specified function, with a user's subroutine

The virtual distance/age concept is used for incrementing the sigmas at each time step.

#### l. Chemical Transformation

First order chemical reactions (primary-to-secondary pollutant)

#### m. Physical Removal

First order dry and wet deposition schemes.

#### n. Evaluation Studies

Zannetti, P., G. Carboni and A. Ceriani, 1985. AVACTA II Model Simulations of Worst-Case Air Pollution Scenarios in Northern Italy. 15th International Technical Meeting on Air Pollution Modeling and Its Application, St. Louis, Missouri, April 15-19.

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## APPENDIX C TO APPENDIX X TO PART 266-

### Example Air Quality Analysis Checklist

#### C.O INTRODUCTION

This checklist recommends a standardized set of data and a standard basic level of analysis needed for PSD applications and SIP revisions. The checklist implies a level of detail required to assess both PSD increments and the NAAQS. Individual cases may require more or less information and the Regional Meteorologist should be consulted at an early stage in the development of a data base for a modeling analysis.

At pre-application meetings between source owner and reviewing authority, this checklist should prove useful in developing a consensus on the data base, modeling techniques and overall technical approach prior to the actual analyses. Such agreement will help avoid misunderstandings concerning the final results and may reduce the later need for additional analyses.

#### Example Air Quality Analysis Checklist<sup>1</sup>

<sup>1</sup>The "Guidelines for Air Quality Maintenance Planning and Analysis," Volume 10R, EPA-450/4-77-001, 1977 should be used as a screening tool to determine whether modeling analyses are required. Screening procedures should be refined by the user to be site/problem specific.

##### 1. Source location map(s) showing location with respect to:

- Urban areas<sup>2</sup>

<sup>2</sup>Within 50 km or distance to which source has a significant impact, whichever is less.

- PSD Class I areas
- Nonattainment areas<sup>2</sup>
- Topographic features (terrain, lakes, river valleys, etc.)<sup>2</sup>
- Other major existing sources<sup>2</sup>
- Other major sources subject to PSD requirements
- NWS meteorological observations (surface and upper air)
- On-site/local meteorological observations (surface and upper air)
- State/local/on-site air quality monitoring location<sup>2</sup>
- Plant layout on a topographic map covering a 1-km radius of the source with information sufficient to determine GEP stack heights

##### 2. Information on urban/rural characteristics:

● Land use within 3 km of source classified according to Auer, A.H. (1978): Correlation of land use and cover with meteorological anomalies, J. of Applied Meteorology, 17:636-643.

- Population

-total

-density

- Based on current guidance determination of whether the area should be addressed using urban or rural modeling methodology

3. Emission inventory and operating/design parameters for major sources within region of significant impact of proposed site (same as required for applicant)

- Actual and allowable annual emission rates (g/s) and operating rates<sup>3</sup>

<sup>3</sup>Particulate emissions should be specified as a function of particulate diameter and density ranges.

- Maximum design load short-term emission rate (g/s)<sup>3</sup>

- Associated emissions/stack characteristics as a function of load for maximum, average, and nominal operating conditions if stack height is less than GEP or located in complex terrain. Screening analyses as footnoted on page 1 or detailed analyses, if necessary, must be employed to determine the constraining load condition (e.g., 50%, 75%, or 100% load) to be relied upon in the short-term modeling analysis.

- location (UTM's)

- height of stack (m) and grade level above MSL

- stack exit diameter (m)

- exit velocity (m/s)

- exit temperature (°K)

- Area source emissions (rates, size of area, height of area source)<sup>3</sup>

- Location and dimensions of buildings (plant layout drawing)

- to determine GEP stack height

- to determine potential building downwash considerations for stack heights less than GEP

- Associated parameters

- boiler size (megawatts, pounds/hr. steam, fuel consumption, etc.)

- boiler parameters (% excess air, boiler type, type of firing, etc.)

- operating conditions (pollutant content in fuel, hours of operation, capacity factor, % load for winter, summer, etc.)

- pollutant control equipment parameters (design efficiency, operation record, e.g., can it be bypassed?, etc.)

- Anticipated growth changes

4. Air quality monitoring data:

- Summary of existing observations for latest five years (including any additional quality assured measured data which can be obtained from any state or local agency or company)<sup>4</sup>

<sup>4</sup> See footnote 1.

- Comparison with standards



- Discussion of background due to uninventoried sources and contributions from outside the inventoried area and description of the method used for determination of background (should be consistent with the Guideline on Air Quality Models)

#### 5. Meteorological data:

- Five consecutive years of the most recent representative sequential hourly National Weather Service (NWS) data, or one or more years of hourly sequential on-site data

- Discussion of meteorological conditions observed (as applied or modified for the site-specific area, i.e., identify possible variations due to difference between the monitoring site and the specific site of the source)

- Discussion of topographic/land use influences

#### 6. Air quality modeling analyses:

- Model each individual year for which data are available with a recommended model or model demonstrated to be acceptable on a case-by-case basis

- urban dispersion coefficients for urban areas

- rural dispersion coefficients for rural areas

- Evaluate downwash if stack height is less than GEP

- Define worst case meteorology

- Determine background and document method

- long-term

- short-term

- Provide topographic map(s) of receptor network with respect to location of all sources

- Follow current guidance on selection of receptor sites for refined analyses

- Include receptor terrain heights (if applicable) used in analyses

- Compare model estimates with measurements considering the upper ends of the frequency distribution

- Determine extent of significant impact-provide maps

- Define areas of maximum and highest, second-highest impacts due to applicant source (refer to format suggested in Air Quality Summary Tables)

- long term

- short term

#### 7. Comparison with acceptable air quality levels:

- NAAQS

- PSD increments

- Emission offset impacts if nonattainment

#### 8. Documentation and guidelines for modeling methodology:

- Follow guidance documents
- Guideline on Air Quality Models, Revised, EPA-450/2-78-027R
- Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10R, EPA-450/4-77-001, 1977
- Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations), EPA-450/4-80-023R, 1985
- Ambient Air Monitoring Guidelines for PSD, EPA-450/4-80-012, 1980
- "Requirements for Preparation, Adoption and Submittal of Implementation Plans; Approval and Promulgation of Implementation Plans," CFR title 40 parts 51, 1982 (Prevention of Significant Deterioration)

#### AIR QUALITY SUMMARY

##### For New Source Alone

| Pollutant _____ * |                     |                     |         |        |
|-------------------|---------------------|---------------------|---------|--------|
| _____ **          |                     | _____ **            |         | Annual |
| Highest           | Highest<br>2nd High | Highest<br>2nd High | Highest |        |

##### Concentration Due to Modified Source

( $\mu\text{g}/\text{m}^3$ )  
 Background Concentration ( $\mu\text{g}/\text{m}^3$ )  
 Total Concentration ( $\mu\text{g}/\text{m}^3$ )  
 Receptor Distance (Km) (or UTM Easting)  
 Receptor Direction ( $^\circ$ ) (or UTM Northing)  
 Receptor Elevation (m)  
 Wind Speed (m/s)  
 Wind Direction ( $^\circ$ )  
 Mixing Depth (m)  
 Temperature ( $^\circ\text{K}$ )  
 Stability  
 Day/Month/Year of Occurrence  
 Surface Air Data From  
 Surface Station Elevation (m)  
 Anemometer Height Above Local  
 Ground Level (m)  
 Upper Air Data From  
 Period of Record Analyzed  
 Model Used  
 Recommended Model

\*Use separate sheet for each pollutant ( $\text{SO}_2$ , TSP, CO,  $\text{NO}_x$ , HC, Pb, Hg, Asbestos, etc.)

\*\*List all appropriate averaging periods (1-hr, 3-hr, 8-hr, 24-hr, 30-day, 90-day, etc.) for which an air quality standard exists.

##### For All New Sources

| Pollutant_____ |                     |                     |         | *                 |
|----------------|---------------------|---------------------|---------|-------------------|
| _____          |                     | _____               |         | **                |
| Highest        | Highest<br>2nd High | Highest<br>2nd High | Highest | Annual<br>Highest |

Concentration Due to Modified Source  
 (µg/m³)  
 Background Concentration (µg/m³)  
 Total Concentration (µg/m³)  
 Receptor Distance (Km) (or UTM Easting)  
 Receptor Direction (°) (or UTM Northing)  
 Receptor Elevation (m)  
 Wind Speed (m/s)  
 Wind Direction (°)  
 Mixing Depth (m)  
 Temperature (°K)  
 Stability  
 Day/Month/Year of Occurrence  
 Surface Air Data From  
 Surface Station Elevation (m)  
 Anemometer Height Above Local  
 Ground Level (m)  
 Upper Air Data From  
 Period of Record Analyzed  
 Model Used  
 Recommended Model

\*Use separate sheet for each pollutant (SO<sub>2</sub>, TSP, CO, NO<sub>x</sub>, HC, Pb, Hg, Asbestos, etc.)  
 \*\*List all appropriate averaging periods (1-hr, 3-hr, 8-hr, 24-hr, 30-day, 90-day, etc.) for which an  
 air quality standard exists.

For All Sources

| Pollutant_____ |                     |                     |         | *                 |
|----------------|---------------------|---------------------|---------|-------------------|
| _____          |                     | _____               |         | **                |
| Highest        | Highest<br>2nd High | Highest<br>2nd High | Highest | Annual<br>Highest |

Concentration Due to Modified Source  
 (µg/m³)  
 Background Concentration (µg/m³)  
 Total Concentration (µg/m³)  
 Receptor Distance (Km) (or UTM Easting)  
 Receptor Direction (°) (or UTM Northing)  
 Receptor Elevation (m)  
 Wind Speed (m/s)  
 Wind Direction (°)  
 Mixing Depth (m)  
 Temperature (°K)  
 Stability  
 Day/Month/Year of Occurrence  
 Surface Air Data From  
 Surface Station Elevation (m)  
 Anemometer Height Above Local

Ground Level (m)  
Upper Air Data From  
Period of Record Analyzed  
Model Used  
Recommended Model

\*Use separate sheet for each pollutant (SO<sub>2</sub>, TSP, CO, NO<sub>x</sub>, HC, Pb, Hg, Asbestos, etc.)  
\*\*List all appropriate averaging periods (1-hr, 3-hr, 8-hr, 24-hr, 30-day, 90-day, etc.) for which an air quality standard exists.

#### STACK PARAMETERS FOR ANNUAL MODELING

| Stack No. | Servin g | Emis- sion Rate for each Pollu- tant (g/s) | Stack Exit Diame- ter (m) | Stack Exit Velo- city (m/s) | Stack Exit Tempe- rature (°K) | Phys- ical Stack Height (m) | GEP Stack Height (m) | Stack Base Eleva- tion (m) | Building Dimensions (m) |       |        |
|-----------|----------|--------------------------------------------|---------------------------|-----------------------------|-------------------------------|-----------------------------|----------------------|----------------------------|-------------------------|-------|--------|
|           |          |                                            |                           |                             |                               |                             |                      |                            | Height                  | Width | Length |

#### STACK PARAMETERS FOR SHORT-TERM MODELING\*

| Stack No. | Servin g | Emis- sion Rate for each Pollu- tant (g/s) | Stack Exit Diame- ter (m) | Stack Exit Velo- city (m/s) | Stack Exit Tempe- rature (°K) | Phys- ical Stack Height (m) | GEP Stack Height (m) | Stack Base Eleva- tion (m) | Building Dimensions (m) |       |        |
|-----------|----------|--------------------------------------------|---------------------------|-----------------------------|-------------------------------|-----------------------------|----------------------|----------------------------|-------------------------|-------|--------|
|           |          |                                            |                           |                             |                               |                             |                      |                            | Height                  | Width | Length |

\*Separate tables for 50%, 75%, 100% of full load operating condition (and any other operating conditions as determined by screening or detailed modeling analyses to represent constraining