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A MODELING PROTOCOL FOR APPLYING MESOPUFF II TO LONG RANGE TRANSPORT PROBLEMS

Office of Air Quality Planning and Standards
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U. S. ENVIRONMENTAL PROTECTION AGENCY
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Technical Support Division
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PREFACE

This report summarizes procedures for applying MESOPUFF II to regulatory problems dealing with the long range transport of relatively inert pollutants. These procedures were developed using a main frame version of the model dated 85360. While newer versions of the model have been constructed, the procedures and recommendations discussed within this document should still generally be applicable.

1.0 INTRODUCTION

Several environmental problems may occur as a result of the transport of air pollutants over long distances. For example, air emissions from a source located in one political jurisdiction may be impeding progress towards attaining the National Ambient Air Quality Standards (NAAQS) in a different political jurisdiction. Similarly, a proposed new source may cause deterioration in air quality at a remote, pristine area far removed from the source. From a regulatory perspective, these types of problems must be addressed by first quantifying the air quality impacts of existing or proposed sources and then determining the appropriate level of emission control that is needed to mitigate those impacts. One approach for performing these types of assessments entails applying an air quality dispersion model to determine the source-receptor relationships associated with long range transport. This document presents a protocol for applying one such model, the MESOPUFF II dispersion model, to long range transport problems within a regulatory framework.[1,2]

Straight-line Gaussian air quality dispersion models have traditionally been used to identify specific source-receptor relationships for transport distances up to about 50km. These models are not appropriate for assessing air quality impacts over longer distances however. They do not adequately simulate long range plume transport and dispersion primarily because they do not account for temporal variations in plume transport direction nor vertical separation of pollutant plumes caused by diurnal changes in the depth of the mixed layer. MESOPUFF II, for which this protocol has been developed, has been designed to address these phenomena. It was selected because it meets several criteria for refined modeling techniques that are outlined in the "Guideline on Air Quality Models".* Specifically,

1) the model is computerized and documented in a user's guide that identifies the mathematical algorithms used in the model, the data requirements of the model, and the program operating characteristics;
2) the model is accompanied with a complete data set for testing; and
3) model performance evaluations have been conducted with the model that compare model predictions with observations.[4]

The protocol presented in this document describes recommended procedures for applying MESOPUFF II to regulatory problems dealing with the long range transport of relatively inert pollutants such as sulfur dioxide (SO_2) and particulate matter. Procedures are proposed for developing the data bases necessary to apply the models, formulating the required model inputs, selecting appropriate model options for the application, and applying the model and processing the output produced by the model. These recommended procedures have evolved principally through experience gained in applying the model, and from results obtained by conducting performance evaluations and sensitivity tests. In addition, the protocol follows general modeling recommendations that are contained in the "Guideline on Air Quality Models"[3] wherever applicable.

As noted above, the protocol is applicable to relatively inert pollutants, and as such, is not applicable to environmental problems associated with more reactive pollutants such

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*"Guideline on Air Quality Models (Revised)" (1986) and its Supplements; see reference 3.

as nitrogen oxides (NO_x) or ozone. Further, the protocol is oriented towards quantifying impacts on a source-by-source basis as opposed to assessing the impacts of wide-scale regional emissions. It has been structured such that both short-term (i.e., averaging times of 24 hours or less) and long-term (i.e., annual averages) impacts can be determined for distances in the range of 50 to 300-400km from a source or group of sources. As such, the procedures outlined here are most likely applicable to regulatory problems dealing with the prevention of significant deterioration (PSD) or other air quality analyses related to the development or revision of a State Implementation Plan (SIP) concerning an individual source or a small group of sources. This document is limited to discussions of modeling issues, however, and does not address administrative aspects of those regulatory programs.

The remainder of this document is divided into three chapters. Chapter 2.0 contains background information on the role of long range transport models in regulatory applications, and includes a brief discussion of some of the technical aspects of MESOPUFF II. Those familiar with MESOPUFF II may wish to proceed directly to Chapter 3.0, which contains the recommended procedures for applying MESOPUFF II within a regulatory framework. Finally, Chapter 4.0 describes an example problem illustrating the application of the model to a regulatory situation.

2.0 BACKGROUND

This portion of the protocol contains background information on the role of long range transport models in regulatory programs and a description of various technical aspects of MESOPUFF II. As noted in the introductory section, the modeling procedures described in this document are applicable only to relatively inert pollutants, and are most applicable to regulatory problems involving PSD and other SIP related analyses. Each of these are discussed below. That discussion is followed by a brief review of the theoretical basis of MESOPUFF II, and an overview of the processing steps required to apply the model.

2.1 ROLE OF LONG RANGE TRANSPORT MODELS

At present, a clear need exists for applying long range transport (LRT) models to assess the impact of distant SO_2 and particulate matter sources on air quality for purposes of the PSD program, the preparation of SIPs for nonattainment areas, and the resolution of interstate transport issues for these pollutants. Typically, assessments of this type arise through the need to evaluate air quality impacts of existing sources as well as proposed new sources or modifications to existing sources. With respect to the PSD program, a number of pristine areas such as National Parks are particularly sensitive to pollutant levels. Acceptable increases in ambient pollutant concentrations (increments) have been established for these areas. In some instances, increases in emissions in upwind areas have already or are soon expected to reduce the available increment for SO_2 and/or particulate matter. Because the acceptable increments are relatively small and because pollutants such as SO_2 and particulate matter can be transported over great distances, the impacts of sources desiring to locate several hundred kilometers upwind may be significant. In some cases, States are concerned that a major portion of the available PSD increment may be consumed by sources outside their regulatory jurisdiction.

Many of the same concerns regarding long range transport of pollutants are raised by States which must address nonattainment problems for both SO_2 and particulate matter. To the extent that these pollutants are transported long distances, they have in the past been considered to be part of an "irreducible" background. As more stringent control programs are implemented, affected States are questioning the effect of transported pollutants. Section 126 of the Clean Air Act provides States with a mechanism to require sources affecting nonattainment to be controlled if the impact can be demonstrated. Thus, modeling techniques are presently needed by States to assess the contribution of distant sources to SO_2 and/or particulate matter nonattainment areas.

In order to address the types of regulatory issues discussed above, LRT models that have the capability to quantify air quality impacts of sources at distant locations are required. These types of models must account for plume meander due to variations in the wind field as well as dispersion of the plume induced by the turbulent actions of the atmosphere. The modeling requirements for PSD and nonattainment issues may be further complicated by the need to address transport, dispersion, and coupling of individual plumes from multiple surface and elevated emission sources. Thus, candidate LRT models should, at a minimum, have the capability to determine the impacts of more than one source in a single model evaluation. Nevertheless, this protocol is oriented towards quantifying impacts on a source-by-source basis as opposed to those more suited to evaluating wide-scale regional emission impacts (e.g., grid models). Models such as MESOPUFF II which are point source specific are considered more appropriate for these types of regulatory applications.

Although a number of mesoscale models have been developed to address the types of regulatory issues discussed above, they have not been routinely applied to such problems. Two major impediments to their use are the data requirements and the costs incurred in applying the models. Another major complicating factor is the need to consider the impact of source emissions for two distinct averaging periods: short-term (i.e., 24 hours or less) and long-term (annual). For both averaging periods, NAAQS and PSD increments are specified such so as to limit the highest ambient concentrations occurring at a specific location. For example, the SO_2 annual average NAAQS concentration is never to be exceeded at any site, and the short-term 24-hour average NAAQS concentration may be exceeded only once per year at each location. LRT models capable of estimating short-term ambient concentrations are relatively expensive to apply for long time periods, whereas long-term models are more computationally efficient for long-term simulations but are incapable of estimating short-term concentrations. Further, techniques have not been developed to select important short-term periods (i.e., episodes) to model, there-by severely limiting the usefulness of conducting episodic type analyses to address regulatory problems. The protocol described in Chapter 3 has been designed to address these problems directly.

2.2 DESCRIPTION OF MESOPUFF II

Presented below is a brief overview of the basic theoretical formulation of MESOPUFF II. MESOPUFF II is a short-term, plume transport model that mathematically simulates the transport and dispersion of pollutant emissions from individual sources. Several preprocessing steps are required to generate the input data to perform these simulations, and they are described as well. The model also contains several technical options to account for plume dispersion, dry deposition, chemical transformation, wet removal, etc. These technical options are discussed in Section 3.4 dealing with the application MESOPUFF II. More detailed discussions of MESOPUFF II and its preprocessors can be found in reference 1 and 2.

MESOPUFF II is a Lagrangian, variable-trajectory, superposition puff model suitable for simulating the transport and dispersion of air pollutants over distances greater than about 50km. A continuous plume from a single source is modeled as a series of discrete puffs (see Figure 2-1). Each puff is transported and dispersed independently, and ground-level ambient concentrations of a pollutant are calculated at discrete receptors according to the proximity of the puff to a receptor and the concentration of the pollutant within the puff. Puffs are emitted at constant, short-term intervals from each source (e.g., every 15 minutes), and tracked until they leave the user defined modeling domain. Tracking takes place in two layers, one below the mixing height and the other above. Transport distance and direction are determined from hourly, gridded wind fields derived from available meteorological measurements of wind speed and direction. Pollutant concentrations within a puff vary temporally and spatially as a result of the growth in puff size due to dispersion. The latter is determined by two sets of time dependent puff

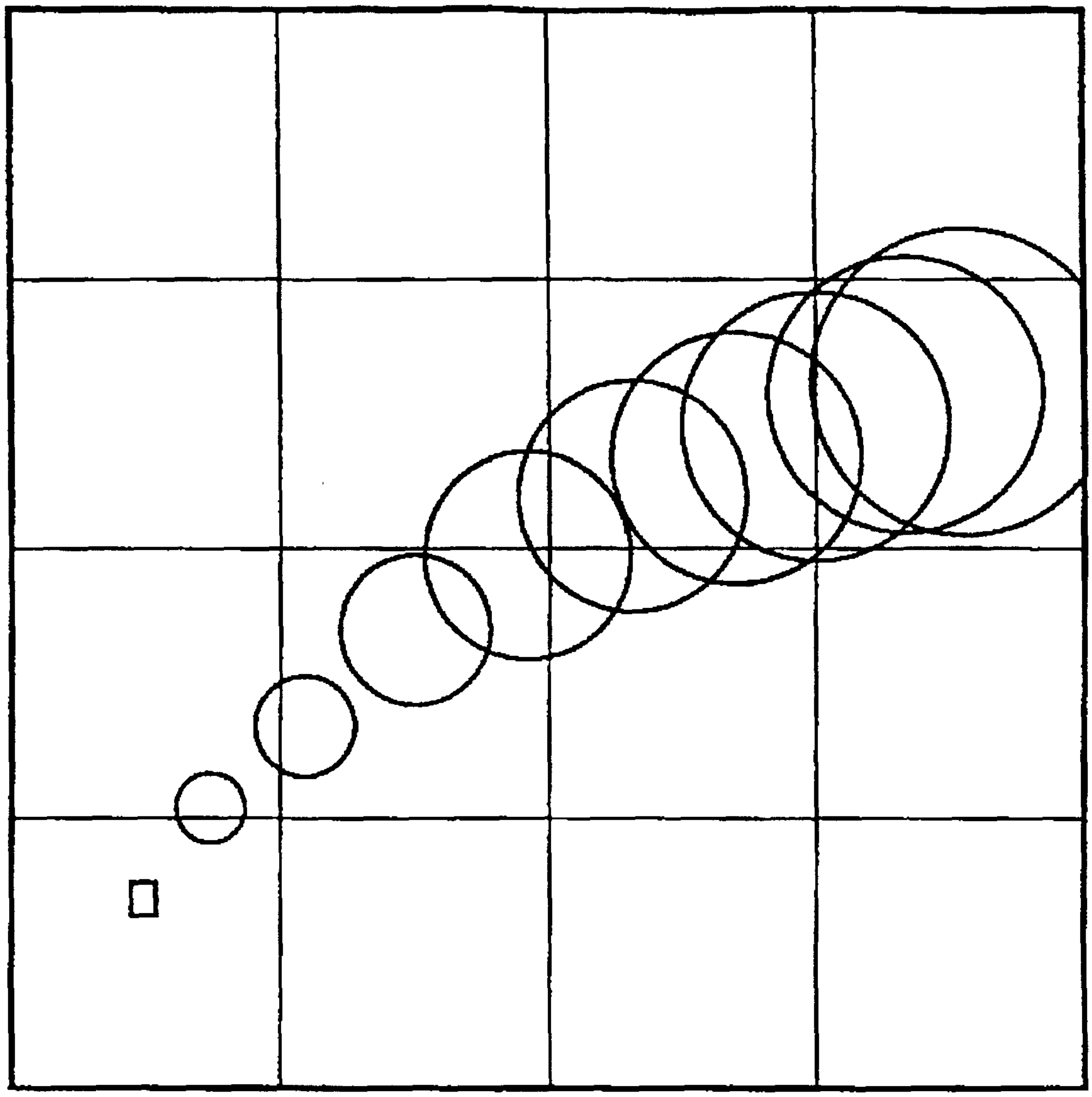


Figure 2-1. Schematic Representation of Puff Superposition Model (adapted from Reference 2)

growth equations relating atmospheric stability to dispersion coefficients, one set for distances of less than 100km and the other for longer distances.

MESOPUFF II has two associated computer programs for preprocessing key meteorological measurements in order to generate the gridded data needed for the transport simulations. The first, READ56, is a preprocessor that edits upper air rawinsonde measurements for missing information, and produces an output file of the data in a special format for use by the second preprocessor, MESOPAC II. MESOPAC II uses these data and hourly surface meteorological data to generate a single output file for use by MESOPUFF II. Both preprocessors are designed to accept meteorological data in standard formats as supplied by the National Weather Service (NWS).

Both MESOPAC II and MESOPUFF II employ a Cartesian coordinate reference frame made up of three nested grid systems: a meteorological grid, a computational grid, and a sampling grid. The meteorological grid is defined through inputs to MESOPAC II, and is the basic reference frame for all spatially varying input data. Thus, coordinates of meteorological stations, sources, and receptors must be specified relative to this grid. The other two grid systems are subsets of the meteorological grid. The computational grid defines that portion of the meteorological grid in which puffs are tracked. The sampling grid can be used to define a group of gridded receptor points at which ambient concentrations are calculated. Discrete nongridded receptors can also be used, however, with their coordinates specified relative to the meteorological grid.

MESOPAC II computes meteorological variables such as wind speed, wind direction, mixing height, stability category, etc., at all nodes of the meteorological grid for each hour of a simulation to be performed by MESOPUFF II. In addition, the wind fields are calculated at two levels: a lower level representing boundary layer flow, and an upper level for flow aloft. The preprocessor uses various spatial and temporal interpolation schemes that operate on the meteorological measurement inputs. Since LRT applications may involve transport over relatively long distances, surface and upper air data from a number of sites near or within the meteorological grid are typically used.

Although MESOPUFF II has the capability to simulate emissions from a limited number of area sources (up to five), it is primarily point source oriented. Up to 20 individual point sources can be modeled in a single evaluation. As noted above, the source coordinates are specified relative to the meteorological grid, and the usual other source data must also be specified (i.e., stack height, stack diameter, effluent exit velocity, exit temperature, and emission rate).

3.0 RECOMMENDED PROCEDURES FOR APPLYING MESOPUFF II

This chapter describes recommended procedures for applying MESOPUFF II and its preprocessors to regulatory problems associated with the long range transport of relatively inert pollutants such as SO_2 or particulate matter. As noted earlier, the procedures recommended in this protocol are most applicable to regulatory problems involving PSD or other SIP related analyses. These recommendations are general in nature, and have been developed to foster consistency in applying MESOPUFF II to problems of these types. They have evolved primarily from results obtained from conducting model performance evaluations and sensitivity analyses, and have been developed to be as consistent as possible with general modeling concepts expressed in "Guideline on Air Quality Models".[3] It is recognized, however, that deviations from these procedures may be warranted in some situations, but in such instances they should be clearly documented and fully supportable.

The discussion that follows is divided into five broad categories: 1) the spatial and temporal scales of an analysis, 2) the compilation of a meteorological data base, 3) application of the MESOPUFF II preprocessors, 4) application of MESOPUFF II, and 5) control strategy evaluation. Each topic is discussed in general terms, with recommended procedures summarized in a single-spaced format. The discussions that follow are limited, however, to describing procedures for developing model inputs and to identifying preferred model options to be used in regulatory applications. Specific operational aspects of the model and its preprocessors and the formats for coding the model inputs are described in reference 2.

3.1 SPATIAL AND TEMPORAL SCALES OF ANALYSIS

This section deals with defining the modeling region (i.e., the geographical area of coverage) and selecting the time period for which the model should be applied. Although the extent of the modeling region must be determined on a case-by-case basis taking into account the locations of the sources, impact areas, and the meteorological stations, some general guidelines are presented below. The time period for which the model is applied determines the length of the model simulations and the period of record of the meteorological data that is needed for the model application. This aspect of the model application is dependent on the intended use of the modeling results. Since this protocol is directed towards PSD and SIP related analyses associated with the NAAQS and PSD increments, more definitive guidance is provided in this area.

3.1.1 Spatial Scale

MESOPUFF II is applicable to estimating impacts at mesoscale distances from a source or group of sources. As such, it is most appropriate for dealing with source impacts in the range of 50 to 400km. Straight-line Gaussian models are preferable for shorter distances, and regional scale models are more applicable for transport distances greater than about 400km. In addition, the model is not applicable to areas with rugged terrain since terrain effects are not directly accounted for in the model.[2]

The modeling region is defined by the meteorological and computational grids that were described in Section 2.2. The meteorological grid is the Cartesian reference frame for all spatially varying input data for both MESOPAC II and MESOPUFF II. Thus, the locations of all sources, meteorological stations, and receptors must be specified relative to this grid. The SW corner of the grid is represented by the point (1.0, 1.0). The size of the grid is determined by specifying the number of grid points in both the west-to-east and south-to-north directions (a maximum of 40 points is allowed in either direction), and by specifying a common, fixed distance between each point (i.e., the grid spacing). The computational grid defines the area in which the model puffs are tracked, and must therefore, encompass both the source locations and the impact areas. It may be defined to be identical to the meteorological grid or as a subset of that grid. Figure 3-1 illustrates two hypothetical configurations.

With respect to a particular model application, both the meteorological and computational grids should be selected to provide broad coverage of the areas of concern. Since the geographical configuration of the sources and receptors is being represented by a Cartesian coordinate system (as opposed to one accounting for the curvature of the earth), the side-widths of the modeling region should probably not greatly exceed 1000km in the west-to-east direction nor 600km in the south-to-north direction. The spacing of the grid points may be on the order of 10 to 50km depending on the overall size of the meteorological grid and the limitation on the number of grid points that may be used. Since meteorological variables are interpolated at grid points from measurements made at the meteorological stations, there is little to be gained from having a much finer resolved spacing of the meteorological grid than the average spacing between the locations of the meteorological stations. Further, computational savings can be realized by limiting the resolution of the grid spacing and by restricting the area of coverage of both the meteorological and computational grids to the immediate area of concern. For example, if impacts are to be assessed at distances of 50 to 150km

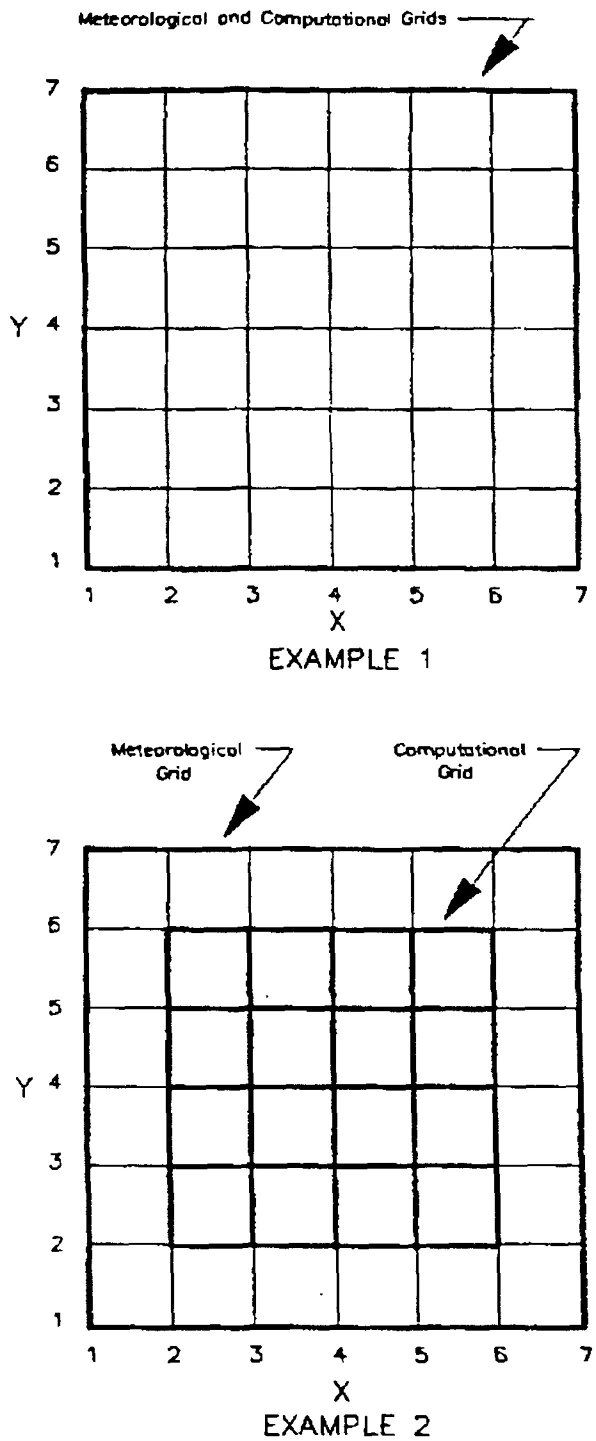


Figure 3-1. Example Grid Configurations

downwind of the source, no need exists to use a grid system that extends up to 400km downwind of the source. Nevertheless, sources and receptors should not be located too near the boundary of the computational grid to avoid possible boundary effects.[2] A cushion of two to three grid points around the edges of the sources and impact areas should be adequate.

Recommended Procedure. MESOPUFF II can be used to estimate source impacts at distances 50 to 400km downwind. The meteorological and computational grid systems used to define the modeling region should be formulated so as to encompass all sources and impact areas, with neither being located too near the edge of the computational grid. Grid dimensions that greatly exceed 1000km in the west-east direction or 600km in the south-north direction are not recommended. Finally, spacing of the meteorological grid on the order of 10 to 50km will probably be adequate for most applications, depending on the overall grid size and relative spacing between meteorological stations.

3.1.2 Temporal Scale

The second portion of this section deals with the time frames for conducting the modeling analyses. As described in Section 2.1, PSD and SIP regulatory analyses typically involve estimating source impacts for both short-term (e.g., 3-hour and 24-hour) and long-term (e.g., annual) averaging periods. Further, MESOPUFF II is oriented towards evaluating short-term impacts, i.e., it operates on hourly meteorological data and predicts ambient concentrations at hourly intervals from which concentrations for longer averaging periods can be computed. As discussed in Section 2.1, procedures do not currently exist for identifying critical short-term periods *a priori* (i.e., selecting those short-term periods with the highest and second-highest concentrations without running the model for a full year). Thus, it is recommended that the model be applied for a minimum period of record of one full year. From such an annual simulation, both the short and long-term critical concentrations can be determined. The minimum 1-year recommendation is made recognizing that computational expense and data availability may prohibit the routine application of the model to a longer period of record.

In making the recommendation to model a complete year, it is recognized that computer limitations may preclude completing an annual simulation in a single model run. Model simulations can be conducted for shorter time periods, however, and the results concatenated to produce concentration estimates for a complete year. As described in the next chapter, the annual simulation for the example problem was developed by performing 12 individual monthly simulations. When this procedure is used, it will be necessary to set the simulation starting day at least four days prior to the actual period of interest in order to account for initial transport and dispersion. The modeling results for the first four days would then be discarded. For example, a simulation for the month of June would have a starting day of May 28, and the model predictions for May 28 through May 31 would be ignored. In order to avoid having to obtain two years of meteorological data to follow this procedure for the beginning of the year, the starting point of the annual simulation could be January 1 (as opposed to December 28 of the preceding calendar year).

Recommended Procedure. For regulatory applications of MESOPUFF II, it is recommended that a minimum one year period of record be simulated in order to identify the critical short- and long-term impacts. Computational limitations will likely necessitate that full annual simulations be obtained by performing a series of simulations for shorter time periods (e.g., monthly periods) and concatenating the model predictions. In such cases, the starting point for the shorter simulations should be set to four days prior to the start day for the period being modeled, and the model predictions for these first four days be discarded. It is not necessary to follow this procedure for the start of the annual period however.

3.2 COMPILATION OF METEOROLOGICAL DATA BASES

The principal meteorological data required for application of MESOPUFF II include twice-daily upper air soundings and hourly surface meteorological files. The MESOPUFF II preprocessors are designed to accept data in formats previously used by the National Climatic Data Center (NCDC) in Asheville, NC. For the upper air data that format is Standard Tape Deck Format 5600 (TDF5600), and for the surface data it is Card Deck 144 (CD144). While the formats currently used by NCDC for archiving these two data types have changed, NCDC has the capability to convert the new formats to TDF5600 and CD144 upon special request. As indicated in the preceding section, at least one full year of data is required for each meteorological station used in the analysis.

The MESOPAC II preprocessor is designed to handle data from up to 25 surface stations and 10 upper air stations. Since the use of a large number of sites provides greater confidence in accurately simulating prevailing wind fields and resultant plume transport, the inclusion of as many stations as possible in the analysis is desirable. Thus, the use of all NWS sites with available data within or near the edges of the meteorological grid is recommended. Additional stations surrounding the domain (e.g., outside the boundaries) may be included as well if data are available. Should the total number of stations exceed the maximum allowable for either the upper air or surface stations, the stations should be selected for the application on the basis of providing the best spatial coverage throughout the meteorological grid. Since a minimum one year period of record is needed for each station, it is recommended that the year with the most available meteorological data be selected for regulatory applications.

The MESOPAC II preprocessor requires complete data sets for both TDF5600 upper air data and CD144 surface data (i.e., it is not designed to handle missing data). In order to provide as much spatial coverage as possible in model applications, it is recommended that stations not be eliminated on the basis of some missing data. Rather, the data sets for each station should be screened to identify missing or spurious values, and then edited to eliminate gaps or clearly erroneous values. The upper air measurements used by MESOPUFF II include pressure, height, temperature, wind direction, and wind speed. If a mandatory pressure level (850mb or 700mb) is missing, it is recommended that the entire sounding from the station be replaced with one from another station most closely representative of the one with the missing data. Missing temperatures, wind speeds, and wind directions for any pressure level may be replaced by an interpolated value using measurements from adjacent levels. The hourly CD144 data used by the model include cloud cover, ceiling height, precipitation type, wind speed, wind direction, surface pressure, and temperature. Missing or obviously spurious values for short time periods may be replaced by interpolating values from adjacent hours, or assuming an earlier value persists over the period in question. Large data gaps (e.g., several hours or more) may be replaced by data from another representative station as a last resort to obtain a complete data base. As described in the next section, READ56 can be used to identify missing upper air data, but it will be necessary for the user to develop the screening procedure for the surface data.

Finally, the MESOPAC II program is also designed to accept hourly precipitation data in Tape Deck 9657 format. These data are ultimately used by MESOPUFF II in estimating the rate of wet removal of pollutants. As will be discussed in Section 3.4, including wet removal in regulatory applications is not currently recommended. Thus, for the applications discussed here, it is not necessary to obtain or process these data.

Recommended Procedure. Upper air and hourly surface data from as many stations as possible that are located within the modeling domain should be included in the modeling simulations. It is recommended that the year of record be chosen on the basis of maximum meteorological data availability. Both upper air and surface data sets should be screened and edited so as to provide complete data sets for the period of record to be modeled.

3.3 APPLICATION OF MESOPUFF II PREPROCESSORS

The preceding sections described the spatial and temporal scales for applying MESOPUFF II to regulatory problems, and discussed the meteorological data base that is needed to perform such applications. This section contains recommendations for using the meteorological data base with the two MESOPUFF II preprocessors to generate the information used by the model in a simulation. As described in Section 2.2, the READ56 preprocessor is used to screen upper air data and to produce output files for use by the second preprocessor, MESOPAC II. MESOPAC II uses the upper air data and the CD144 hourly surface data along with other information to construct the temporally and spatially varying fields of meteorological data used by MESOPUFF II. The use of each preprocessor is discussed separately below. In these discussions and the ones that follow, reference is made to some of the variable names used in the MESOPUFF II User's Manual, and these are shown in capital letters.

3.3.1 Application of READ56

As described in Section 3.2, the upper air data need to be screened and edited prior to using them with the MESOPAC II preprocessor. The READ56 program can be used to identify missing values and data gaps, but it does not contain built-in procedures for correcting erroneous or missing data (i.e., the user must make any necessary corrections to the data files independently of the execution of the program). Corrections can be made either to the original TDF5600 data, or can be made directly to the output produced by READ56. Of course, if the first option is chosen it will be necessary to run the TDF5600 data back through the READ56 program to produce a corrected output file for use by MESOPAC II. Note that data from only one station can be processed in a single application of the READ56 program, so it will be necessary to apply the program separately to each TDF5600 data set used in the analysis.

The input data for READ56 include six variables to control the time period of the data selected for the run, one variable to define the top pressure level for each sounding for which data are to be extracted, and four variables to determine how missing data are handled. Since it is likely that the MESOPUFF II application will be divided into a number of smaller runs, the first four variables may be used to extract the TDF5600 data that correspond to the time period of the simulation. The variable for the top pressure level has to be equal to one of the mandatory pressure levels (i.e., 850, 700, or 500mb), and it controls the height up to which data are extracted for use in MESOPAC II. As will be discussed in Section 3.3.2, upper air data are only needed up to the 700mb pressure level for most applications, so the variable defining the top pressure level (PSTOP) can be set to 700mb. The remaining four variables control the treatment of missing height, temperature, wind direction, or wind speed found in any one pressure level. To be consistent with the recommended procedures of Section 3.2, the control variable for height should be set so that the pressure level is eliminated if the height is missing (i.e., LHT set to **TRUE**), and the remaining variables set to flag missing data (i.e., LTEMP, LWS, and LWD set to **FALSE**). Any data flagged as missing must be replaced. Also, mandatory pressure levels (e.g., 850mb and 700mb) that are missing or eliminated due to missing data will also be flagged and must be corrected. In both cases the procedures outlined in Section 3.2 may be used.

Recommended Procedure. READ56 may be run for each upper air station to identify missing data. Data up to 700mb need only be extracted, and the variables controlling missing data should be set to eliminate a pressure level if the height is missing and to flag missing temperatures, wind speeds, and wind directions. The flagged data can be replaced using the procedures outlined in Section 3.2. Finally, corrected READ56 output files must be generated for use with MESOPAC II.

3.3.2 Application of MESOPAC II

The MESOPAC II preprocessor uses the output files generated by READ56, the CD144 surface meteorological data, and other inputs to produce a single output file for use in a MESOPUFF II simulation. The output file contains time and space interpolated fields of the following variables: lower and upper level u,v wind components, mixing height, convective velocity scale, friction velocity, Monin-Obukhov length, and PGT (Pasquill-Gifford-Turner) stability class. In addition, it contains other information such as surface roughness length at each grid point, land use category at each grid point, average surface air density, air temperature at each surface station, etc. To generate these outputs, MESOPAC II uses several inputs in addition to the basic surface and upper air data. These inputs have been grouped into 15 different categories in the

User's Manual as shown in Table 3-1. Recommended procedures for formulating the inputs are discussed below by input category. In addition to these recommendations, a modification to the MESOPAC II program is also suggested, and it is described immediately following the discussion of the model inputs.

Groups 1-3. Most of the input variables in these groups are simple run control parameters that will need to be developed on a case-by-case basis (e.g., title, starting time by number of hours to be processed, number of surface stations, etc.). The input variables in Group 3 define the meteorological grid, so they should be developed in accordance with the recommended procedures outlined in Section 3.1.

Group 4. Input variables for this group control the amount and form of the output produced by MESOPAC II. One variable, LSAVE, controls whether the output for MESOPUFF II is to be saved to tape or disk. Thus, whenever a MESOPUFF II simulation is to follow the application of MESOPAC II, this variable must be set to **TRUE**, and the output stored on an appropriate storage medium. The remaining variables control printed output of meteorological data both input to and computed by the program. Since the volume of printed output from MESOPAC II for a run of any length can be quite large, these variables will normally be set to suppress printing of the output results.

Group 5. Land use categories at each grid point of the meteorological grid must be supplied to MESOPAC II. Table 3-2 shows the 12 different categories that have been defined for use in MESOPAC II. Appropriate classifications for each grid

Table 3-1

Summary of MESOPAC II Run Control Inputs

Group Number	Description
1	Run title
2	General information (starting time, number of hours in the run number of meteorological stations, etc.)
3	Grid data (number of west-east grid points, number of south-north grid points, grid spacing)
4	Output options (e.g., print control keys)
5	Land use categories for each grid point
6	Default override options
7	Wind speed measurement height (optional)
8	von Kármán constant (optional)
9	Friction velocity constants (optional)
10	Mixing height constants (optional)
11	Wind field variables (optional)
12	Surface roughness lengths (optional)
13	Radiation reduction factors (optional)
14	Surface station information
15	Upper air station information

Table 3-2

Land Use Categories Used in MESOPAC II*

Category	Land Use Type
1	Cropland and Pasture
2	Cropland, woodland and grazing land
3	Irrigated crops
4	Grazed forest and woodland
5	Ungrazed forest and woodland
6	Subhumid grassland and semiarid grazing land
7	Open woodland grazed
8	Desert shrubland
9	Swamp
10	Marshland
11	Metropolitan city
12	Lake or ocean

*adapted from reference 1

point must be determined on a case-by-case basis using information obtained from land use maps or digitized land use inventories.[2]

Groups 6-13. Group 6 of this set of inputs provides nine options for overriding default procedures used in calculating various output meteorological variables. For regulatory applications of MESOPAC II, however, the default procedures are recommended in all cases. The defaults, which are summarized in Table 3-3, are consistent with the procedures used in the model performance evaluations conducted with MESOPUFF II. With the use of all default procedures, no inputs need be supplied for groups 7 through 13. A tenth option is contained in group 6, however, to indicate whether the starting point of the MESOPAC II simulation coincides with the starting point of the meteorological data bases. This option should be set appropriately.

Group 14-15. These two groups of inputs provide information to the program on the surface and upper air stations such as station identification number, x,y coordinates, latitude, longitude, and time zone. These data must be determined on a case-by-case basis. Recall from the discussion in the previous section that hourly precipitation data are not required for regulatory applications, so corresponding input data are not needed.

Program Modification. A program modification is recommended for MESOPAC II to correct a potential problem that could occur infrequently. Under some meteorological conditions, the mixing height due to mechanical turbulence exceeds the height corresponding to the 700mb pressure level. When this happens, the program is

Table 3-3

Summary of Default Procedures Recommended for Regulatory Applications of MESOPAC II

1) Wind speed measurement height is equal to 10m.

2) von Kármán constant is set to 0.4.

3) Constants used in calculation of friction velocity are set to 4.7 for gamma and 1100 for A.

4) Constants used in calculation of mixing heights are set to 1.41 for B, 0.15 for E, 200m for the layer depth used in estimating the previous hours lapse rate, 0.001° K/meter for the minimum potential lapse rate, and 2400 for the constant N in the stable (mechanical) mixing height equation.

5) Wind field control variables are set to 99 grid units for RADIUS, 2 for IIWF (i.e., use vertically averaged winds from the earth's surface to the mixing height for the level wind field), and 4 for IUWF (i.e., use vertically averaged winds from the mixing height up to the height that corresponds to the 700mb pressure level for the upper level wind field).

6) Default surface roughness lengths are determined according to specified land use categories.

7) Default solar radiation reduction factors are based on tenths of cloud cover as follows:

Cloud Cover (tenths):	0	1	2	3	4	5	6	7	8	9	10
Reduction Factor:	1.0	0.91	0.84	0.79	0.75	0.72	0.68	0.62	0.53	0.41	0.23

8) Heat flux constant at each grid point is set to 0.3.

stopped since the average wind flow for the upper layer cannot be computed. The recommended program modification to correct this problem entails limiting the height of the mixed layer to 4000m (or to the height of the 700mb level if lower than 4000m) in the calculations of the average winds aloft. It can be implemented in the program by modifying subroutine VERTAV as follows:

```
        •
        •
HTMIX=ZI(IG,JG)
HTMIX=AMIN1(HTMIX,4000.)
ISTAB=IPGT(IG,JG)
        •
        •
```

where the middle line of code shown above has been added to the subroutine. Alternatively, another option may be chosen to define the upper level for flow aloft, e.g., 500mb instead of 700mb (see Section 2.2.1 of the User's Guide[2]).

Recommended Procedure. All inputs related to run control, meteorological station identification, meteorological grid definition, and input/output control must be formulated on a case-by-case basis. Land use categories for each grid point must be defined using available information according to the classification scheme shown in Table 3.2. Default values are recommended for all technical options contained in input Group 6 (i.e., IOPTS(1), IOPTS(2) ... IOPTS(9) should be set to zero). Finally, it is recommended that the program be modified as described above in order to limit the height of the mixed layer to 4000m in the calculation of the vertically averaged winds aloft.

3.4 APPLICATION OF MESOPUFF II

This section contains recommended procedures for developing the model inputs required to use MESOPUFF II in regulatory applications involving the transport and dispersion of relatively inert pollutants. As described in Section 2.2, pollutant emissions from individual sources are modeled as a series of discrete puffs emitted at regularly spaced time intervals. Ambient concentrations of pollutants are calculated at individual receptor points that can be specified in one of two ways: as part of a gridded sampling network, or as discrete nongridded points. With the procedure that is recommended under this protocol, MESOPUFF II is used to compute one-hour average pollutant concentrations at each receptor for each hour of the simulation. The results are saved on a computer output file, and later used to calculate concentrations for longer averaging periods (e.g., 3 hours, 24 hours and annual). This last procedure is discussed further in Section 3.5.

As noted above, two types of receptor networks can be specified for MESOPUFF II applications, and both types may be used in the same run. The particular network(s) that is chosen for any one application will necessarily have to be determined on a case-by-case basis depending on the purpose of the application. For example, if the application is intended to assess impacts at a remote Class I PSD area alone, receptor locations would normally be restricted to the proximity of the area of concern. If the intent of the application is to identify maximum impacts of a source at distances greater than 50km downwind regardless of where they occur, then the receptor network would have to cover a much broader area. Because it is not possible to identify critical short-term periods without first running the model, it will not be possible to perform screening tests to identify areas with potentially high concentrations. Although exceptions may occur, higher concentrations tend to be found nearer the source in long range transport problems. Thus, a polar coordinate network may be more suited for evaluating source impacts over large areas since the receptors are more closely spaced along rings nearer the source. Conversely, a rectangular gridded network may be more appropriate for assessing impacts in well defined, limited areas. Examples of both are illustrated in the example problem described in the next chapter. Although the use of a large number of receptors may be desirable to obtain good spatial coverage, it should be emphasized that computational requirements increase with the number of receptors used.

MESOPUFF II was originally designed to simulate the transport, dispersion, transformation/formation, and removal of up to five specific individual species: SO_2, $SO_4^=$, NO_x, HNO_3, and NO_3^-. For the regulatory applications covered by this protocol, however, it is recommended that the pollutant transformation and removal mechanisms currently incorporated in MESOPUFF II **not** be used. Considerable research is underway to develop techniques for quantifying the effects of these phenomena, but no single set of approaches has yet gained universal acceptance. As a consequence, it is recommended that emissions of relatively nonreactive pollutants such as SO_2 and particulate matter be modeled as if they do not react nor are removed from the atmosphere over the transport distances for which MESOPUFF II is applicable. Sensitivity tests conducted with MESOPUFF II indicate that including chemical transformation and dry removal in simulations of SO_2 lowers the highest and second highest concentration by about 20 to 30 percent over distances of 50 to 300km downwind from an elevated source. Nevertheless, these reductions might be offset by considering a longer period of record in an analysis (i.e., conducting multi-year simulations). Until such time as transformation and removal processes become better understood and approaches for quantifying their effects are agreed upon, the most viable approach for dealing with relatively inert pollutants in a regulatory framework is to assume that plume mass is conserved.

Besides the input file that is generated by the MESOPAC II preprocessor, MESOPUFF II requires a number of other input variables to control the run, set computational parameters, select various technical options, and define the array of receptor points used in the simulation. The MESOPUFF II User's Manual categorizes these inputs according to the 16 groups shown in Table 3-4. Recommended procedures for developing the inputs are described below.

Groups 1-2. Most of the input variables in these two groups are of the run control variety, and must be specified on a case-by-case basis (e.g., title, starting day, starting hour, number of hours in a simulation, etc.). One variable controls the number of pollutants and their designation. When the transformation and removal mechanisms are not included in a simulation (as is recommended), however, the pollutant naming scheme is not relevant since all pollutants are treated identically. Thus, to model only one pollutant (e.g., SO_2 or particulate matter), the number of pollutants (NSPEC) would be set to 1 and all concentration output produced by MESOPUFF II would be labeled as if it were SO_2. If two pollutants were to be modeled in a single run (e.g., SO_2 and particulate matter), the number of pollutants would be set to 2, and the concentration outputs for the first and second pollutants would be labeled SO_2 and $SO_4^{=}$, respectively.

Group 3. This group consists of seven variables that affect various computational aspects used in a model simulation. The first controls the averaging time for the computed concentrations. As discussed above, a one hour period is recommended (i.e., IAVG=1). Four variables (NPUF, NSAMAD, LVSAMP, and WSAMP) control the number of puffs released from each source during each hour of a simulation and the

Table 3-4

Summary of MESOPUFF II Run Control Inputs

Group Number	Description
1	Run title
2	General information (starting time, number of hours in the run, number of point sources, number of non-gridded receptors etc.)
3	Computational variables (averaging time, puff release rate, minimum sampling rate, etc.)
4	Grid information (definition of computational and sampling grids)
5	Technical options (vertical concentration distribution, chemical transformation, dry deposition, etc.)
6	Output options
7	Default override options
8	Dispersion parameters (optional)
9	Vertical diffusivity constants (optional)
10	SO_2 canopy resistances (optional)
11	Other dry deposition constants (optional)
12	Wet removal parameters (optional)
13	Chemical parameters (optional)
14	Point source data
15	Area source data
16	Non-gridded receptor coordinates

rate at which puffs are sampled in the concentration calculations. In general, accurate representation of a continuous plume is enhanced by increasing puff release rate and sampling frequency, albeit at the expense of increasing computational burden. The recommendations made here were determined from several sensitivity tests designed to assess the effect of these variables on design concentrations (i.e., high and second high) at distances varying from 50 to 300km downwind of an elevated source. The results suggest that a puff release rate of four (NPUF=4) and a minimum sampling rate of two (NSAMAD=2) represent a reasonable compromise between computational accuracy and computer resource requirements. In addition, it is recommended that the variable sampling rate be used (LVSAMP=TRUE), and that the reference wind speed used with the variable sampling option be 2 m/s (WSAMP=2). The remaining two variables control the use of a sampling grid and the minimum age for puffs to be sampled. While the selection of sampling grid must be determined on a case-by-case basis, it is recommended that the minimum puff sampling age be set to 900s. Since it is recommended that MESOPUFF II only be used to estimate concentrations at downwind distances of 50km and beyond, the choice of the latter input is probably not too critical since its primary purpose is to minimize the possibility of abnormally high concentration spikes close to the sources (i.e., distances within one hour's travel time).

Group 4. The input variables in this group control the definition of the computational grid and the sampling grid (if used). As discussed in Section 3.1, the computational grid can be defined identically to the meteorological grid or as a subset of that grid. Either approach can be followed, provided that the computational grid encompasses both the sources and the impact areas, with neither located too near the boundary of the grid. The sampling grid can be used to define an array of rectangular gridded receptors, and must be determined on a case-by-case basis. It too is determined relative to the meteorological grid, although a finer spatial resolution for the sampling grid can be used. The upper limit on the sampling grid is 40x40 points in either direction.

Group 5. The variables in this group control the use of various technical options incorporated in the model. As discussed at the beginning of this section, the recommended approach for applying MESOPUFF II to the types of regulatory situations considered in this protocol consists of ignoring the potential effects of chemical transformation, dry deposition, and wet removal. Thus, the three variables controlling these options (LCHEM, LDRY, and LWET) would be set to omit these processes. One of the other variables (LGAUSS) in this group controls whether a puff introduced into the mixed layer is instantaneously dispersed or assumes a Gaussian concentration distribution in the vertical. Although the significance of this assumption is probably not too great for travel times greater than a few hours due to plume growth in the vertical direction, the use of the Gaussian distribution is recommended, primarily to be consistent with the procedures used in the model performance evaluations. The final variable in this input group (L3VL) can be used to select three vertical layers when considering dry deposition. Since the inclusion of dry removal is not recommended, it is recommended that this option not be used as well.

Group 6. These variables control the output produced by MESOPUFF II. It will almost always be necessary to save the hourly concentration estimates produced by MESOPUFF II on a tape or disk file by setting the value of LSAVE to **TRUE**. Because of the potentially large volume of printed output that can be generated in a fairly lengthy run of MESOPUFF II, it will usually be desirable to suppress printed output results using the other print control variables.

Groups 7-13. Group 7 of this set of inputs controls six options for overriding MESOPUFF II default technical procedures. The first of these can be used to override the default dispersion parameters. This option is not recommended since the default technique was used in the model performance evaluation (i.e., IOPTS(1)=0). The remaining five variables, IOPTS(2) through IOPTS(6), control various technical options associated with the use of chemical transformation, dry deposition, and wet removal. Thus, these options would not be invoked under the procedures recommended here (i.e., all would be set to zero). The remaining groups (i.e., groups 8 through 13) are used to input information required to override defaults when so indicated by the override options selected with the group 7 inputs. Thus, under the procedures recommended here, inputs would not be required for these six groups.

Groups 14-16. Data inputs for groups 14 and 15 describe the source characteristics for point and area sources, respectively. Since the protocol is directed towards point source problems, area source would not typically be included. The point source data include location, stack height, stack diameter, exit velocity, temperature, and emission rate. Source data should be developed on a case-by-case basis using annual average values. If two or more sources are located in close proximity, computational savings can be realized by combining the sources into one representative source.

Reference 5 contains recommended procedures for deriving appropriate stack parameters for the representative source. Finally, the x and y coordinates (relative to the meteorological grid) for the nongridded receptors, if any, are input with the last group of variables. Again, these inputs will typically be determined on a case-by-case basis.

Recommended Procedure. Many of the inputs for MESOPUFF II applications must be determined on a case-by-case basis (e.g., receptor network specification, number of species, number of sources, etc.). Specific recommended procedures include: 1) computing one hour averages; 2) setting the puff release rate to four; 3) setting the minimum sampling rate to two and using the variable sampling option with a reference wind speed of 2 m/s; 4) setting the minimum age for puff sampling to 900s; 5) using an initial Gaussian distribution of puffs in the vertical; 6) not including chemical transformation, dry deposition, or wet removal in simulations; 7) not using the three vertical layer option; and 8) using all other default options. Specific inputs corresponding to these selections are listed below, and key assumptions associated with all recommendations are summarized in Table 3-5.

IAVG=1
NPUF=4
NSAMAD=2
LVSAMP=TRUE
WSAMP=2.
AGEMIN=900
LGAUSS=TRUE
LCHEM=FALSE
LDRY=FALSE
LWET=FALSE
L3VL=FALSE
IOPTS(1)=0
IOPTS(2)=0
•
•
•
IOPTS(6)=0

Table 3-5

Summary of Default Procedures Recommended for Regulatory Applications of MESOPUFF II

1) One hour average concentrations are computed.

2) Gaussian vertical concentration distribution is assumed for each puff introduced into the mixed layer.

3) For distances up to 100km, the dispersion parameters are from functions fitted to the curves of Turner.[6] For longer travel distances, time dependent growth functions from Heffter are used.[7]

4) Growth rates for puffs above the mixed layer are those corresponding to E stability.

5) Chemical transformation, dry deposition, and wet removal processes are not included in the simulations.

6) The three vertical layer option is not used.

7) Four puffs are released from a source each hour, variable sampling rates are used depending on wind speed, and no puff is sampled within the first 900 seconds of its release.

3.5 CONTROL STRATEGY EVALUATION

This section contains a brief generalized discussion of how the MESOPUFF II modeling results may be processed to assess air quality impacts, and if necessary, determine appropriate emission limitations for a source or group of sources. This protocol is directed towards SIP and PSD analyses associated with SO_2 and particulate matter, so the air quality measures of most concern are the NAAQS and the PSD increments established for these pollutants. Since these measures all involve averaging times longer than one-hour, the discussion below begins with a description of how the one hour average concentrations generated by MESOPUFF II can be used to compute concentration estimates for longer averaging periods.

When the recommended procedure for applying MESOPUFF II to regulatory problems is followed, MESOPUFF II produces an output file which contains estimated one-hour average concentrations at each receptor. As described earlier, it will most likely be necessary to divide a full annual simulation into a series of shorter simulations due to computer limitations. To facilitate further processing of that data, it will probably be advantageous to combine the results obtained from all simulations into a single file containing the concentration estimates for the full year. From this file it is possible to compute concentrations for longer averaging periods and determine the highest and second-highest values predicted to occur during a year that are needed for comparison with the relevant NAAQS or PSD increment. When calculating 3- and 24-hour averages, it is recommended that nonoverlapping periods be used in the calculations (i.e., block averages as opposed to running averages). Annual averages should be computed by summing the hourly concentrations and dividing by the number of hours for which concentrations are available. These calculations can be performed by using the MESOPUFF II postprocessor (MESOFILE) or software developed by the user.

The concentration estimates output by MESOPUFF II represent the total impacts of all sources in a simulation, and the program is not designed to produce a source contribution file. Thus, some special considerations may be required for evaluating the effects of lowering (or raising) emissions from an established base case (e.g., evaluating a control strategy). When only one source has been included in a simulation, the estimated air quality concentrations are directly proportional to the source emission rate. Thus, the effects of changes in emissions can be evaluated directly without rerunning the model. Further, if two pollutants are being modeled in this situation, some computer time could be saved by modeling only one pollutant and deriving the results for the other by scaling according to the ratio of the emission rates.

Control strategy evaluation is more complicated when multiple sources are included in a simulation. If an estimated concentration exceeds some acceptable limit, a control strategy could always be evaluated by changing source emission rates and rerunning the model for the entire year. This can be relatively expensive, however, especially if a large number of strategies are to be evaluated. Some savings may be realized if only a few, short-term episodes are identified as needing additional evaluation (assuming the emission rate at any source is not increased). In this case, only the critical short-term periods would need to be remodeled, but it would be necessary to begin the simulation at least four days prior to the episode of interest. If a large number of episodes are found in which a concentration estimate exceeds an acceptable value, however, it may be easier to rerun the full year with new emission rates. Of course, the full year would need to be rerun if a predicted annual average concentration exceeded an acceptable limit.

Recommended Procedure. Concentration estimates for averaging periods longer than one hour (e.g., 3 hours and 24 hours) should be computed as nonoverlapping (i.e., block) averages. Annual averages concentrations should be computed using all hourly estimates. If only one source is included in a simulation, predicted concentrations are directly proportional to emission rates, and control strategies can be evaluated directly without rerunning a full annual simulation. If multiple sources are included in a simulation, control strategy evaluations must be carried out using MESOPUFF II to evaluate all critical short-term periods, either by simulating a full year or by modeling episodes only if unacceptably high concentrations are found for short-term periods alone.

4.0 EXAMPLE MESOPUFF II APPLICATION

This chapter illustrates the application of MESOPUFF II and its preprocessors to an example regulatory problem using the procedures recommended in the preceding chapter. The example application consists of quantifying air quality impacts of a hypothetical proposed new source at distances of 50 to 300km from the source. This example has been developed for illustrative purposes only, and is not intended to represent an existing or pending regulatory issue involving any specific source. Although the example is presented as one involving emissions of SO_2, the procedures described below could just as easily have been applied to a similar problem dealing with particulate matter.

The discussion below is divided into four sections. The first contains a general description of the example problem. The next section describes the meteorological data base used in the analysis, and the application of the MESOPUFF II preprocessors. The final two sections discuss the MESOPUFF II application and summarize the results of the impact assessment.

4.1 DESCRIPTION OF EXAMPLE PROBLEM

The example problem involves modeling SO_2 emissions from a single power plant stack located near the Ohio River in southeastern Ohio. The modeling region, as defined by the meteorological grid, was chosen to encompass the source and the impact areas, and to make use of meteorological data that are available for this region of the country. Figure 4-1 shows the area encompassed by the boundaries of the meteorological

Figure 4-1. Modeling Region and Source Location

grid and the location of the source relative to the modeling region, and Table 4-1 lists the relevant source data used for the example problem.

As noted above, the modeling problem entails assessing the air quality impacts of SO_2 emissions at distances of 50 to 300km downwind from the source. Two distinct types of assessments are considered. In the first, regionwide air quality impacts in the 50 to 300km range are included in the analysis, regardless of location. Of primary interest are the model predictions of the highest and second-highest ambient concentrations for several different averaging times. This information might be used, for example, to assess the impact of a proposed new source on attainment of the NAAQS. The second type of assessment involves determining impacts in a limited, predefined area located approximately 200km from the source. This type of application illustrates how MESOPUFF II might be used in a PSD problem involving the consumption of available increments in a Class I or II area. As with the first type of assessment, impacts for multiple averaging times are considered. Both assessments were performed in the same MESOPUFF II application in which one full year was simulated, the minimum period of record that is recommended for regulatory applications.

4.2 PREPROCESSOR APPLICATIONS

As described in the preceding portions of this document, the modeling region is defined by means of the meteorological grid shown in Figure 4-2. This grid system consists of 24 points in the west-east direction and 21 points in the south-north direction, with a grid spacing of 40km between each point. For most applications of this type, the meteorological grid would normally be defined such that the source is located near the

Table 4-1

Source Data For Example Problem

Stack Height	250m
Stack Diameter	8m
Exit Velocity	26 m/s
Stack Gas Temperature	430° K
Emission Rate	6000 g/s

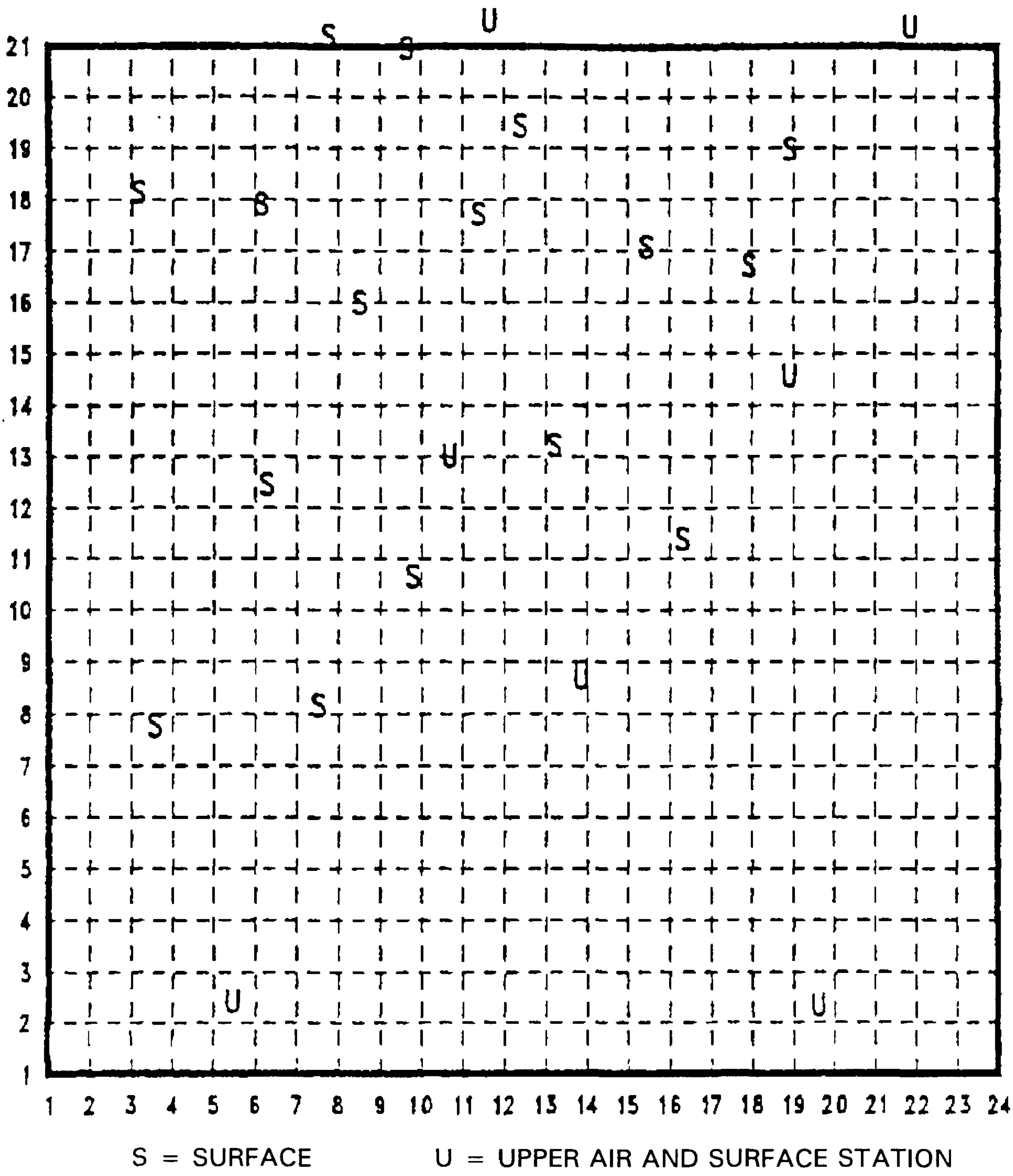


Figure 4-2. Locations of Surface and Upper Air Stations

center of that grid. The particular meteorological grid used in this application is extended somewhat in the westerly direction, however, in order to include more meteorological stations in the preprocessor applications. Meteorological data used in the study are from measurements taken during 1975 at 23 NWS surface stations and 7 NWS upper air stations. The location and identification numbers of each station are listed in Table 4-2, and the location of each station relative to the meteorological grid network is shown schematically in Figure 4-2.

As recommended in section 3.2, all meteorological data were screened and edited to eliminate missing or spurious values. The upper air data consisted of twice-daily upper air soundings taken at 00 GMT (7 PM EST) and 12 GMT (7 AM EST) at each station for the entire year. Missing temperatures, wind speeds, or wind directions within any one pressure level were replaced with values interpolated from adjacent pressure levels. A pressure level was eliminated if the height was missing, and an entire sounding was replaced with one from another station if a mandatory pressure level was missing. Both procedures were carried out using an automated routine that operated on the basic upper air data files (i.e., changes were made to base upper air data files as opposed to the READ56 output files). The replacement of an individual sounding with one from another station was performed using the replacement order shown in Table 4-3. Data for each station were processed for the complete year, and then supplied to the READ56 program for final checking and subsequent creation of the input files used by MESOPAC II.

Table 4-2

List of Surface and Upper Air Stations

Location	Surface Station Number	Upper Air Station Number
Pittsburgh	94823	72520
Erie	14860	
Buffalo	14733	72528
Huntington	03860	72425
Parkersburg	03804	
Greensboro	13723	72317
Louisville	93821	
Nashville	13897	72327
Cleveland	14820	
Dayton	93815	72429
Columbus	14821	
Cincinnati	93814	
Toledo	94830	
Detroit	94847	
Flint	14826	72637
Grand Rapids	94860	
Evansville	93817	
Fort Wayne	14827	
Indianapolis	93819	
South Bend	14848	
Youngstown	14852	
Chicago	14819	
Lansing	14836	

Table 4-3

Primary and Alternate Upper Air Stations*

Greensboro, NC (72317)
- Huntington, WV (72425)
- Cape Hatteras, NC (72304)
- Athens, GA (72311)
- Nashville, TN (72327)

Nashville, TN (72327)
- Salem, IL (72433)
- Athens, GA (72311)
- Huntington, WV (72425)
- Greensboro, NC (72317)

Huntington, WV (72425)
- Dayton, OH (72425)
- Pittsburgh, PA (72520)
- Washington, D.C.-Dulles (72403)
- Greensboro, NC (72317)

Dayton, OH (72429)
- Huntington, WV (72425)
- Pittsburgh, PA (72520)
- Flint, MI (72637)
- Nashville, TN (72327

Pittsburgh, PA (72520)
- Buffalo, NY (72528)
- Washington, D.C.-Dulles (72403)
- Huntington, WV (72425)
- Dayton, OH (72429)

Buffalo, NY (72528)
- Pittsburgh, PA (72520)
- Flint, MI (72637)
- Albany, NY (72518)
- Washington, D.C.-Dulles (72403)

Flint, MI (72637)
- Dayton, OH (72429)
- Green Bay, WI (72645)
- Buffalo, NY (72528)
- Pittsburgh, PA (72520)

*Alternate stations are listed below the primary station in descending order of preference. NWS station numbers are shown in parentheses.

The hourly surface data used for the MESOPAC II applications had been previously screened and edited for use with straight-line Gaussian models applicable to distances up to 50km. As part of that procedure, the wind data for hours with calms had been modified such that the wind speed was set to 1.0 m/s and the wind direction to the value for the preceding hour. Although this procedure would not necessarily have to be performed for a MESOPUFF II application, no attempt was made to convert the data back to its original form. It is unlikely that changing the wind data for calms in this manner would lead to significant differences in model predictions since the wind fields are developed by interpolating the wind direction and speed at each grid point using measurements from several stations.

Besides the meteorological data, the only other set of regional specific inputs required by MESOPAC II is the land use categories that must be assigned to each grid point. these values were obtained from available land use maps using the classification scheme listed in Table 3-2. All other MESOPAC II inputs were chosen in accordance with the recommended procedures described in Section 3-3.

As indicated above, both the surface and upper air data were screened and edited to produce computerized data sets for the entire year. Because of computer limitations, however, it was not practical to generate a single MESOPAC II output file for the full year. Instead, the model simulations for a complete year were divided into 12 monthly simulations, with each month processed by first running READ56, followed by MESOPAC II, and finally MESOPUFF II. Only the MESOPUFF II output data were saved for further processing. For most runs of READ56 and MESOPAC II, the time period for the application was selected such that it overlapped the time period for the subsequent preprocessor or model run. For example, if the MESOPUFF II simulation period was to include May 28 through June 30, the MESOPAC II application would be set to cover May 27 through July 1, and the READ56 period to cover May 26 through July 2. This approach ensured that the output files generated by each preprocessor contained a sufficiently lengthy period of record for the application of the next program in the series. For the beginning and ending periods of the annual simulation, however, the same periods were used for all program applications. An example input data set for both READ56 and MESOPAC II are contained in Appendix A. A description of the computer time necessary to apply these preprocessors is included in the next section.

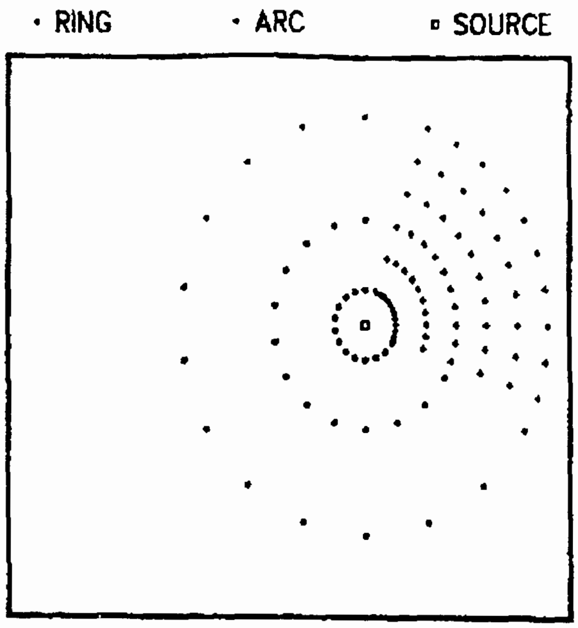
4.3 APPLICATION OF MESOPUFF II

The MESOPUFF II simulations were conducted using inputs that were developed according to the procedures outlined in Section 3.4. As described earlier in this section, two objectives of the example application were to estimate regionwide source impacts at distances of 50 to 300km, and to estimate the impacts at a predefined area that might represent a remote Class I or II PSD area. The application of MESOPUFF II to both types of assessments is described below.

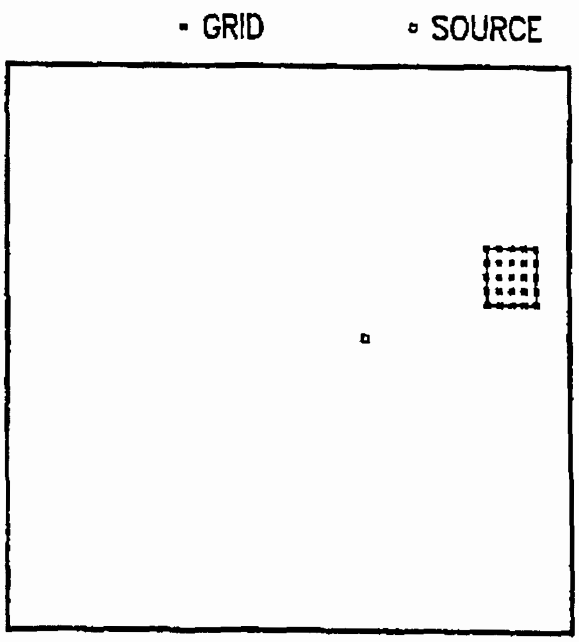
In order to determine regionwide impacts of the source between 50 and 300km downwind, two receptor networks were used. The first network consists of three concentric rings located at downwind distances of 50, 150, and 300km from the source, with receptors spaced at 20° intervals on each ring. This network is designed to detect air quality impacts in all directions from the source. The second network is a group of more densely packed receptors located along arcs extending from 20° to 110° east of the source. Downwind arc distances extend from 50 to 300km at incremental distances of 50km, and receptors are positioned at 10° intervals along each arc. With the second network, more receptors are located in the predominant downwind direction since it is anticipated that higher concentrations would be found in this area. A schematic representation of both receptor networks is shown in Figure 4-3A.

The second example assessment consists of determining the source impacts at a remote Class I or Class II PSD area. For this assessment, it was assumed that such an area is located approximately 200km to the east-northeast of the source. This area was covered by a group of uniformly gridded receptors spaced at 20km intervals. Figure 4-3B shows the location of the PSD area relative to the source, and the receptor grid network used to assess impacts in that area.

All of the MESOPAC II and MESOPUFF II simulations were conducted using the Sperry 1100 computing system at EPA's National Computing Center (NCC). As indicated earlier, the year-long simulation was divided into 12 shorter monthly simulations. Except for the first month, all simulations were started four days prior to the beginning of the month and the results for those days discarded. The model predicted concentrations for each month were saved in individual files, and later concatenated into a single output file containing data for the entire year. Table 4-4 summarizes the computer resource usage required to apply MESOPUFF II and its preprocessors. The variations in computer time required to perform the MESOPUFF II simulations reflect



A) Regionwide Assessment



B) PSD Assessment

Figure 4-3. Schematic Representation of Receptor Networks

Table 4-4

Summary of Computer Resources Used for Monthly Simulations

Program	Storage*	CPU Time**,***
READ56	20K	2
MESOPAC II	100K	45
MESOPUFF II	100K	60-120

*Words of core storage required

**Minutes of CPU time on the EPA NCC Sperry 1110 computer

***Total CPU time for complete annual simulation (all three programs) is approximately 25 hours differences in puff residence times and sampling frequency occurring between months. Example inputs for MESOPUFF II are contained in Appendix A.

4.4 SUMMARY OF RESULTS

Although the results obtained from the example application are specific to the situation modeled, they can provide some insight into prediction patterns that might be obtained through a real application. Table 4-5 lists the highest and second-highest concentrations predicted at the receptors used in the regionwide assessment for four different averaging times. For reference, the levels of the NAAQS are also shown where applicable. To provide some indication of where the greatest impacts occur, Table 4-6 was prepared. This table lists the top ten second-high concentrations for the short-term averages and the ten highest annual average concentrations predicted at the receptors used in the regionwide assessment. The location of the receptor relative to the source and the network of which it is a part is also shown for each entry. Recall from previous discussions that receptors located in the arc network are in the expected predominate downwind direction, whereas those in the ring network are outside this region. As is evident from Table 4-6, most of the second-high concentrations for the short-term averaging periods tend to occur nearest the source (i.e., 50km) and in the predominate downwind direction. For the longer averaging time period, however, this tendency is not as great. These results suggest that significant source impacts as predicted by MESOPUFF II could occur at variable distances downwind from the source, and in virtually any direction. For this particular application, the predicted concentrations are well below the level of the SO_2 NAAQS. Thus, unless other sources were to contribute

Table 4-5

Greatest Regionwide Impacts[*]

Averaging Time	High 2nd High	Downwind Distance	Level of NAAQS[**]
1-hr	683	50km	NA
	350	100km	NA
3-hr	338	100km	NA
	194	50km	NA
24-hr	79	50km	NA
	55	50km	365
annual	3	150km	80
	3	50km	NA

[*]All concentrations are in units of $\mu g/m^3$.

[**]NA = not applicable.

Table 4-6

Top Ten High/Second-high Predicted Concentrations*
Regionwide Assessment

Receptor Network	Direction from Source**	Downwind Distance***	Second-high Concentration
	1-hour averaging time		
Arc	110	100	350
Arc	40	50	327
Arc	110	50	324
Arc	100	50	308
Arc	30	50	307
Ring	160	50	268
Arc	70	50	262
Arc	80	50	258
Ring	280	50	258
Arc	20	50	257
	3-hour averaging time		
Arc	110	50	194
Arc	100	50	181
Ring	140	50	181
Ring	240	50	157
Arc	30	50	156
Ring	300	50	154
Ring	260	50	152
Ring	280	50	148
Arc	70	50	142
Arc	80	50	142
	24-hour averaging time		
Arc	110	50	55
Arc	40	50	50
Arc	100	50	41
Arc	30	50	40
Ring	240	50	37
Ring	120	150	37
Arc	90	50	35
Arc	70	50	31
Ring	140	50	30
Ring	320	50	30
	Annual averages		Highest Concentration
Arc	60	150	3
Arc	60	50	3
Arc	80	50	3
Arc	100	50	2
Arc	80	150	2
Arc	100	150	2
Arc	120	50	2
Ring	120	150	2
Arc	40	50	2
Ring	140	50	2

*All concentrations in units of $\mu g/m^3$

**compass degrees, with due North equal to 0°

***kilometers

substantially to ambient concentrations in this area, no further control strategy evaluations would appear warranted for this assessment.

The second portion of the regulatory application involved estimating source impacts at the hypothetical PSD area that is covered by the gridded receptor network located approximately 200km downwind. Table 4-7 shows the extremes of the second-high short-term concentrations and highest long-term concentrations predicted at the receptors located in this grid. The allowable PSD increments for both a Class I area (i.e., pristine area) and a Class II area (i.e., an area currently attaining the NAAQS) are also shown where applicable. The highest and lowest impacts of concern differ by about a factor or two. Less variation in model predictions is found for this limited area than for the more extensive ring and arc networks. The highest second-high concentrations are all significantly lower than the Class II PSD increments, but exceed the allowable increments for a Class I area. Thus, the modeling results suggest that SO_2 emissions would need to be reduced by about 67 percent to meet the allowable 24-hour average increment for a Class I area assuming no other source contribution.

The model application described above illustrates how a model such as MESOPUFF II can be used within a regulatory framework to address two different types of problems. Although the processing time and the computer costs are not insignificant, the model can be applied to simulate a yearly record of short-term concentrations for regulatory assessments (e.g., for comparison with NAAQS or allowable PSD increments). It should be noted that the example problem included only one source, and greater computer costs would be incurred if multiple sources were modeled. The costs for

Table 4-7

Summary of Model Predictions for PSD Assessment*

Averaging Time Increment**	Highest 2nd High	Lowest 2nd High	Class I PSD Increment**	Class II PSD
1 hour	68	30	NA	NA
3 hours	40	20	25	512
24 hours	15	7	5	91
annual	2	1	2	20

*All concentrations are in units of $\mu g/m^3$, rounded to the nearest $\mu g/m^3$; lowest and highest maxima are shown for the annual average.

**NA = not applicable.

MESOPAC II and READ56 would remain the same, however, so the total costs of modeling more than one source would not increase proportionally.

5.0 REFERENCES

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2. Environmental Protection Agency, 1984. User's Guide to the MESOPUFF II Model and Related Preprocessor Programs. EPA Publication No. EPA-600/8-84-013. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 84-181775)

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6. Turner, D. B., 1970. Workbook of Atmospheric Dispersion Estimates, AP-26, U.S. Environmental Protection Agency, Research Triangle Park, NC.

7. Heffter, J. L., 1965. The Variations of Horizontal Diffusion Parameters with Time for Travel Periods of One Hour or Longer. *Journal of Applied Meteorology*, 4: 153-156.

APPENDIX A

EXAMPLE INPUT DATA SETS FOR READ56, MESOPAC II AND MESOPUFF II

Example Inputs for READ56

```
75 146 00 75 183 23 500.
T F F F
```

Example Inputs for MESOPAC II

MESOPAC II SIMULATION FOR JUNE

```
   75   147   864     23     7     5
   24     21 40000.
    T      F    12     F
 2 21212 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 1 11212 2 2 2 2 2 2 2 2 2 2121212121212 2 2 2 2
 1 11212 2 2 2 2 2 2 2 2 2 2121212121212 2 2 2 2
 1 1 1 1   2 2 2 2 2 2 1 11212 2 2 2 2 2 5 5 2 2
 1 1 1 1 2 2 2 2 2 2 1 11212 2 2 2 2 2 2 5 5 2 2
 1 1 1 1 2 2 2 2 2 2 1 11212 2 2 2 2 2 2 5 5 2 2
 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5 5 5 5 2 2
 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5 5 5 5 2 2
 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5 5 2 2 2 2
 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5 5 2 2 2 2
 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5 5 2 2 2 2
 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5 5 2 2 2 2
 2 2 2 2 2 2 2 2 2 2 5 5 5 5 5 5 5 5 2 2 2 2 2 2
 2 2 2 2 2 2 4 4 2 2 5 5 2 2 2 2 2 2 2 2 2 2 2 2
 2 2 2 2 2 2 4 4 2 2 5 5 2 2 2 2 2 2 2 2 2 2 2 2
 2 2 2 2 4 4 5 5 5 5 5 5 2 2 2 2 2 2 2 2 2 2 2 2
 2 2 2 2 4 4 5 5 5 5 5 5 2 2 2 2 2 2 2 2 2 2 2 2
 2 2 2 2 2 2 2 2 5 5 5 5 2 2 2 2 2 2 2 2 2 2 9 9
 2 2 2 2 2 2 2 2 5 5 5 5 2 2 2 2 2 2 2 2 2 2 9 9
         1
94823 18.91     14.58     40.50     80.22     5.0     7           999
14860 18.94     18.98     42.08     80.18     5.0     9           999
14733 21.88     21.39     42.93     78.77     5.0     10          999
03860 13.86     8.69      38.37     82.55     5.0     11          999
03804 16.32     11.39     39.35     81.43     5.0     12          999
13723 19.61     2.34      36.08     79.95     5.0     13          999
93821 7.52      8.17      38.18     85.73     5.0     14          999
13897 5.46      2.42      36.12     86.68     6.0     15          999
14820 15.47     17.08     41.40     81.85     5.0     16          999
93815 10.70     13.01     39.90     84.22     5.0     17          999
14821 13.23     13.23     40.00     82.88     5.0     18          999
93814 9.80      10.66     39.07     84.67     5.0     19          999
94830 11.41     17.72     41.60     83.80     5.0     20          999
94847 12.44     19.45     42.23     83.33     5.0     21          999
14826 11.68     21.51     42.97     83.73     5.0     22          999
94860 7.78      21.22     42.88     82.52     5.0     23          999
93817 3.58      7.78      38.05     87.53     6.0     24          999
14827 8.53      16.00     41.00     85.20     5.0     25          999
93819 6.29      12.46     39.73     86.28     5.0     26          999
14848 6.17      17.91     41.70     86.32     5.0     27          999
14852 17.95     16.71     41.27     80.67     5.0     28          999
14819 3.19      18.14     41.78     87.75     6.0     29          999
14836 9.66      20.98     42.78     84.60     5.0     30          999
72520 18.91     14.58     40.50     80.22     5.0     61
72528 21.88     21.39     42.93     78.77     5.0     62
72425 13.86     8.69      38.37     82.55     5.0     63
72317 19.61     2.34      36.08     79.95     5.0     64
72327 5.46      2.42      36.12     86.68     6.0     02
72429 10.70     13.01     39.90     84.22     5.0     03
72637 11.68     21.51     42.97     83.73     5.0     04
```

Example Inputs for MESOPUFF II

MESOPUFF II SIMULATION FOR JUNE

```
   75   148    01   816     1     0  139     1
    1     4     2     T    2.     T 900.
    1    24     1    21     7    20     6    15     2
    T     F     F     F     F
    T     F    01     F     1    24
000000
15.6 11.4 250. 8.00 26.0 430. 6000.
     15.60      12.65              1     50.0 KM RING          .0 DEG
     16.03      12.57              2     50.0 KM RING        20.0 DEG
     16.40      12.36              3     50.0 KM RING        40.0 DEG
     16.68      12.02              4     50.0 KM RING        60.0 DEG
     16.83      11.62              5     50.0 KM RING        80.0 DEG
     16.83      11.18              6     50.0 KM RING       100.0 DEG
     16.68      10.77              7     50.0 KM RING       120.0 DEG
     16.40      10.44              8     50.0 KM RING       140.0 DEG
     16.03      10.23              9     50.0 KM RING       160.0 DEG
     15.60      10.15             10     50.0 KM RING       180.0 DEG
     15.17      10.23             11     50.0 KM RING       200.0 DEG
     14.80      10.44             12     50.0 KM RING       220.0 DEG
     14.52      10.77             13     50.0 KM RING       240.0 DEG
     14.37      11.18             14     50.0 KM RING       260.0 DEG
     14.37      11.62             15     50.0 KM RING       280.0 DEG
     14.52      12.02             16     50.0 KM RING       300.0 DEG
     14.80      12.36             17     50.0 KM RING       320.0 DEG
     15.17      12.57             18     50.0 KM RING       340.0 DEG
     15.60      15.15             19    150.0 KM RING          .0 DEG
     16.88      14.92             20    150.0 KM RING         0.0 DEG
     18.01      14.27             21    150.0 KM RING        40.0 DEG
     18.85      13.28             22    150.0 KM RING        60.0 DEG
     19.29      12.05             23    150.0 KM RING        80.0 DEG
     19.29      10.75             24    150.0 KM RING       100.0 DEG
     18.85       9.52             25    150.0 KM RING       120.0 DEG
     18.01       8.53             26    150.0 KM RING       140.0 DEG
     16.88       7.88             27    150.0 KM RING       160.0 DEG
     15.60       7.65             28    150.0 KM RING       180.0 DEG
     14.32       7.88             29    150.0 KM RING       200.0 DEG
     13.19       8.53             30    150.0 KM RING       220.0 DEG
     12.35       9.52             31    150.0 KM RING       240.0 DEG
     11.91      10.75             32    150.0 KM RING       260.0 DEG
     11.91      12.05             33    150.0 KM RING       280.0 DEG
     12.35      13.28             34    150.0 KM RING       300.0 DEG
     13.19      14.27             35    150.0 KM RING       320.0 DEG
     14.32      14.92             36    150.0 KM RING       340.0 DEG
     15.60      18.90             37    300.0 KM RING          .0 DEG
     18.17      18.45             38    300.0 KM RING        20.0 DEG
     20.42      17.15             39    300.0 KM RING        40.0 DEG
     22.10      15.15             40    300.0 KM RING        60.0 DEG
     22.99      12.70             41    300.0 KM RING        80.0 DEG
     22.99      10.10             42    300.0 KM RING       100.0 DEG
     22.10       7.65             43    300.0 KM RING       120.0 DEG
     20.42       5.65             44    300.0 KM RING       140.0 DEG
     18.17       4.35             45    300.0 KM RING       160.0 DEG
     15.60       3.90             46    300.0 KM RING       180.0 DEG
     13.03       4.35             47    300.0 KM RING       200.0 DEG
     10.78       5.65             48    300.0 KM RING       220.0 DEG
```

Example Inputs for MESOPUFF II (continued)

9.10	7.65	49	300.0 KM RING	240.0 DEG
8.21	10.10	50	300.0 KM RING	260.0 DEG
8.21	12.70	51	300.0 KM RING	280.0 DEG
9.10	15.15	52	300.0 KM RING	300.0 DEG
10.78	17.15	53	300.0 KM RING	320.0 DEG
13.03	18.45	54	300.0 KM RING	340.0 DEG
16.03	12.57	55	50.0 KM ARC	20.0 DEG
16.22	12.48	56	50.0 KM ARC	30.0 DEG
16.40	12.36	57	50.0 KM ARC	40.0 DEG
16.56	12.20	58	50.0 KM ARC	50.0 DEG
16.68	12.02	59	50.0 KM ARC	60.0 DEG
16.77	11.83	60	50.0 KM ARC	70.0 DEG
16.83	11.62	61	50.0 KM ARC	80.0 DEG
16.85	11.40	62	50.0 KM ARC	90.0 DEG
16.83	11.18	63	50.0 KM ARC	100.0 DEG
16.77	10.97	64	50.0 KM ARC	110.0 DEG
16.46	13.75	65	100.0 KM ARC	20.0 DEG
16.85	13.57	66	100.0 KM ARC	30.0 DEG
17.21	13.32	67	100.0 KM ARC	40.0 DEG
17.52	13.01	68	100.0 KM ARC	50.0 DEG
17.77	12.65	69	100.0 KM ARC	60.0 DEG
17.95	12.26	70	100.0 KM ARC	70.0 DEG
18.06	11.83	71	100.0 KM ARC	80.0 DEG
18.10	11.40	72	100.0 KM ARC	90.0 DEG
18.06	10.97	73	100.0 KM ARC	100.0 DEG
17.95	10.54	74	100.0 KM ARC	110.0 DEG
16.88	14.92	75	150.0 KM ARC	20.0 DEG
17.47	14.65	76	150.0 KM ARC	30.0 DEG
18.01	14.27	77	150.0 KM ARC	40.0 DEG
18.47	13.81	78	150.0 KM ARC	50.0 DEG
18.85	13.28	79	150.0 KM ARC	60.0 DEG
19.12	12.68	80	150.0 KM ARC	70.0 DEG
19.29	12.05	81	150.0 KM ARC	80.0 DEG
19.35	11.40	82	150.0 KM ARC	90.0 DEG
19.29	10.75	83	150.0 KM ARC	100.0 DEG
19.12	10.12	84	150.0 KM ARC	110.0 DEG
17.31	16.10	85	200.0 KM ARC	20.0 DEG
18.10	15.73	86	200.0 KM ARC	30.0 DEG
18.81	15.23	87	200.0 KM ARC	40.0 DEG
19.43	14.61	88	200.0 KM ARC	50.0 DEG
19.93	13.90	89	200.0 KM ARC	60.0 DEG
20.30	13.11	90	200.0 KM ARC	70.0 DEG
20.52	12.27	91	200.0 KM ARC	80.0 DEG
20.60	11.40	92	200.0 KM ARC	90.0 DEG
20.52	10.53	93	200.0 KM ARC	100.0 DEG
20.30	9.69	94	200.0 KM ARC	110.0 DEG
17.74	17.27	95	250.0 KM ARC	20.0 DEG
18.72	16.81	96	250.0 KM ARC	30.0 DEG
19.62	16.19	97	250.0 KM ARC	40.0 DEG
20.39	15.42	98	250.0 KM ARC	50.0 DEG
21.01	14.53	99	250.0 KM ARC	60.0 DEG
21.47	13.54	100	250.0 KM ARC	70.0 DEG
21.76	12.49	101	250.0 KM ARC	80.0 DEG
21.85	11.40	102	250.0 KM ARC	90.0 DEG
21.76	10.31	103	250.0 KM ARC	100.0 DEG
21.47	9.26	104	250.0 KM ARC	110.0 DEG

Example Inputs for MESOPUFF II
(continued)

18.17	18.45	105	300.0 KM ARC	20.0 DEG
19.35	17.90	106	300.0 KM ARC	30.0 DEG
20.42	17.15	107	300.0 KM ARC	40.0 DEG
21.35	16.22	108	300.0 KM ARC	50.0 DEG
22.10	15.15	109	300.0 KM ARC	60.0 DEG
22.65	13.97	110	300.0 KM ARC	70.0 DEG
22.99	12.70	111	300.0 KM ARC	80.0 DEG
23.10	11.40	112	300.0 KM ARC	90.0 DEG
22.99	10.10	113	300.0 KM ARC	100.0 DEG
22.65	8.83	114	300.0 KM ARC	110.0 DEG
20.60	12.65	115	200.0 KM COL	ROW 1
20.60	13.15	116	200.0 KM COL	ROW 2
20.60	13.65	117	200.0 KM COL	ROW 3
20.60	14.15	118	200.0 KM COL	ROW 4
20.60	14.65	119	200.0 KM COL	ROW 5
21.10	12.65	120	220.0 KM COL	ROW 1
21.10	13.15	121	220.0 KM COL	ROW 2
21.10	13.65	122	220.0 KM COL	ROW 3
21.10	14.15	123	220.0 KM COL	ROW 4
21.10	14.65	124	220.0 KM COL	ROW 5
21.60	12.65	125	240.0 KM COL	ROW 1
21.60	13.15	126	240.0 KM COL	ROW 2
21.60	13.65	127	240.0 KM COL	ROW 3
21.60	14.15	128	240.0 KM COL	ROW 4
21.60	14.65	129	240.0 KM COL	ROW 5
22.10	12.65	130	260.0 KM COL	ROW 1
22.10	13.15	131	260.0 KM COL	ROW 2
22.10	13.65	132	260.0 KM COL	ROW 3
22.10	14.15	133	260.0 KM COL	ROW 4
22.10	14.65	134	260.0 KM COL	ROW 5
22.60	12.65	135	280.0 KM COL	ROW 1
22.60	13.15	136	280.0 KM COL	ROW 2
22.60	13.65	137	280.0 KM COL	ROW 3
22.60	14.15	138	280.0 KM COL	ROW 4
22.60	14.65	139	280.0 KM COL	ROW 5

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1. REPORT NO. EPA-454/R-92-021	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE A Modeling Protocol for Applying MESOPUFF II to Long Range Transport Problems		5. REPORT DATE October 1992
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Gerald L. Gipson		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Technical Support Division Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-023733
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		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This guidance document describes recommended procedures for the application of MESOPUFF II to long range transport problems, including a discussion of spatial and temporal scales of analysis, compilation of meteorological data bases, application of MESOPUFF II preprocessors, and control strategy evaluation. An example MESOPUFF II application for a single isolated power plant stack located near the Ohio River in southeastern Ohio is presented. Example input data sets for two meteorological preprocessor programs, READ56 and MESOPAC II, are presented in an appendix.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Atmospheric Dispersion Modeling Long Range Transport Puff Models		

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