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USER'S GUIDE FOR THE ADVANCED STATISTICAL TRAJECTORY REGIONAL AIR POLLUTION (ASTRAP) MODEL

ATMOSPHERIC SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

USER'S GUIDE FOR THE ADVANCED STATISTICAL TRAJECTORY REGIONAL AIR POLLUTION (ASTRAP) MODEL

by

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ABSTRACT

The Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model simulates long-range, long-term transport and deposition of air pollutants, primarily oxides of sulfur and nitrogen. The ASTRAP model is designed to combine ease of exercise with an appropriate detail of physical processes for assessment applications related to acid deposition.

The theoretical basis and the computational structure of the ASTRAP model are described. The model is evaluated with observed data, and an illustrative exercise is provided. Computer codes of the model subprograms are provided in appendices.

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SYMBOLS AND ABBREVIATIONS

μ_x, μ_y	:	mean position of a puff on the horizontal grid
σ_x, σ_y	:	one standard deviation spread of puff in x and y
ρ_{xy}	:	correlation between x and y in the puff
H (x,y)	:	two-dimensional density function of horizontal dry puff
H_w (x,y)	:	two-dimensional density function of wet-deposited puff
R	:	fractional bulk removal by precipitation
P	:	precipitation rate in cm/6 hr
N	:	number of source cells
M	:	fraction of unit emission still aloft
b	:	M in the case of no previous wet deposition
L	:	number of emission layers
E	:	emission rate in tonnes per six hours
c	:	one-dimensional surface concentration ($\mu g\ m^{-1}$)
C	:	three-dimensional surface concentration ($\mu g\ m^{-3}$)
n	:	number of trajectories contributing to a dry deposition statistic
m	:	number of trajectories contributing to a wet deposition statistic
d	:	dry deposition increment per time step
D	:	cumulative dry deposition ($g\ m^{-2}$)
W	:	cumulative wet deposition ($g\ m^{-2}$)
S.D.	:	standard deviation
Ob	:	observed value
Mod	:	modeled value
Res	:	residual (Ob-Mod)
ρ_{om}	:	correlation between observations and modeled values
K_z	:	vertical eddy diffusivity in meters squared per second

ACRONYMS

ASTRAP :	Advanced Statistical Trajectory Regional Air Pollution model
VERT :	VERTical dispersion subprogram
HORZ :	HORZontal dispersion subprogram
CONCDEP:	CONCentration and DEPosition subprogram
NMC :	National Meteorological Center
AES :	Atmospheric Environment Service of Canada
SURE :	SUlfur Regional Experiment
MOI :	Memorandum of Intent between the U. S. and Canada on transboundary air pollution
UTM :	Universal Transverse Mercator map projection
LRT :	Long-Range Transport and deposition
NAPAP :	National Acid Precipitation Assessment Program

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EXECUTIVE SUMMARY

The Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model calculates atmospheric concentrations and deposition of oxides of sulfur or nitrogen over spatial scales of 100 km to continental, and over temporal scales of one to three months.

The model assumes linearity between emissions and deposition, although the linear rate itself varies diurnally and seasonally and can be changed as a user's option. ASTRAP is not an appropriate model for short-term or episodic conditions, nor for near-source air quality. Yearly simulations can be made by averaging atmospheric concentrations and adding deposition from seasonal simulations.

ASTRAP is structured here to treat as many as 730 source cells with up to six emission layers and to make calculations for a 51 x 45 grid across the United States and Canada, with grid spacing 100-130 km, depending upon latitude. Preprocessed emission fields and time series of continental wind and precipitation analyses are required in order to exercise the model. If the user desires to change the size of the emission grid or the concentration/deposition grid, simple coding changes would be necessary.

The deposition fields are integrated across each state and province in turn, but in this version of the code all sources are in a single inventory. If the concentration and deposition from individual sources or source areas are to be produced separately as in a source-receptor transfer matrix, some coding changes would be required.

The subprograms in ASTRAP do not contain simple options to select the modeling alternatives discussed above, but guidance as to particular changes that might be necessary is given in the section on applications.

Among the features of ASTRAP are the following:

- efficient long-term simulations of continental scale.
- diurnal and seasonal variations of dry deposition velocities, chemical transformation rate, and vertical stability profile.
- layers in the vertical to allow for the effect of different effective emission heights.
- use of analyzed synoptic meteorology, to allow examination of meteorologically induced variability.
- integrated deposition fields.
- leakage to the free troposphere.

The ASTRAP model consists of three major subprograms, VERT, HORZ, and CONCDEP, which calculate one-dimensional vertical profiles, two-dimensional horizontal dispersion, and concentrations and deposition, respectively. On an IBM 3033, VERT requires 210K (bytes) storage and 5-10 minutes of computation time, plus one output file, for a seasonal simulation. HORZ requires 500K

storage and 10 minutes computation time, two input tape drives, and an output file for a seasonal simulation. CONCDEP requires 500K storage and 10 minutes computation time, an emission file, the output files from the other two programs, a file used to identify each receptor cell as to state or province, and an output file for a seasonal simulation. If only the emission inventory or the receptor grid is changed, only CONCDEP need be rerun. If the year of meteorology is changed, both CONCDEP and HORZ must be rerun. If the season of meteorology is changed, all subprograms must be rerun.

1. INTRODUCTION

Acid rain, as the atmospheric deposition of acidifying substances is commonly termed, is only one of many potential environmental and health problems involving long-range transport and deposition of airborne pollutants. Investigations of the transport and deposition of many different substances over a wide range of spatial and temporal scales eventually may be necessary, in order to develop and improve assessments of potential actions and regulations. A common approach in such investigations is numerical simulation of the atmospheric pathways. The Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model described here has been developed to simulate the long-term (monthly to yearly), regional-scale (resolution about 100 km) deposition of oxides of sulfur and nitrogen, the major contributors to acid deposition. Many of the modeling techniques in ASTRAP are based upon previous work by Taylor (1921), Durst et al. (1959), Bolin and Persson (1975), and Sheih (1977). The ASTRAP techniques can be extended to other pollutants, provided that linear parameterizations of chemical transformation and removal processes are suitable, and can be extended to other spatial scales, if appropriate meteorological data can be obtained. Unmodified extension of the modeling techniques used in ASTRAP to shorter, episodic temporal scales is not recommended, because of certain statistical features of the model, which are discussed in following sections.

The ASTRAP model consists of three submodels and various preprocessors and postprocessors. Use of particular preprocessors and postprocessors depends upon application and data availability. The submodels are the vertical diffusion program (VERT), the horizontal dispersion program (HORZ) and the concentration and deposition program (CONCDEP). The processes of vertical diffusion, chemical transformation, and dry deposition are simulated in VERT through parameterizations that are independent of horizontal location or particular meteorological conditions. In HORZ, the processes of horizontal advection, horizontal diffusion, and wet deposition are simulated with the use of time series of wind and precipitation analyses. CONCDEP combines the statistics produced by the first two programs with emission inventories to produce fields of average atmospheric concentration and cumulative deposition.

Data requirements for ASTRAP simulations are presented in Section 2, while the features and limitations of ASTRAP are sketched in Section 3. The theoretical basis of the ASTRAP model is outlined in Section 4. The primary subprograms are described, preprocessors and postprocessors are discussed, and model verification statistics are presented. Specific computer aspects are discussed in Section 5 and a test simulation is presented in Section 6. The computer codes of the subprograms, included in appendices, are written to be exercised with meteorological data from 1980, as described in Section 4.

2. DATA REQUIREMENTS

The data requirements for ASTRAP simulations are monthly to seasonal time series of transport wind and precipitation analyses, and a source inventory. Ideally, wind and precipitation analyses should be at intervals of six hours, should have a spatial resolution of about 300 and 100 km, respectively, and should extend well beyond the region of interest in order to allow accurate calculations of recurving trajectories. Unfortunately, these desirable features are not always available. Rawinsonde upper-air wind measurements are made routinely at intervals of 12 hours rather than six hours, and the spatial coverage of rawinsonde stations, while adequate over the United States and southern Canada, is sparse over northern Canada and essentially missing over oceanic areas. This can cause serious difficulties in obtaining wind fields suitable for deposition simulations for Florida or the Canadian Maritime Provinces, for instance. A similar difficulty can arise from inadequate spatial coverage of precipitation fields. The temporal resolution of precipitation data is usually better than for upper air winds, since many stations report hourly precipitation.

Analysis of a one-layer transport wind field requires definition of the depth of the field. There is no universally accepted transport layer, since over a single location fresh pollutants might be transported in a growing planetary boundary layer while aged pollutants might be transported in a deeper layer defined by the previous day's maximum mixing depth upstream. Definition of a mixed layer depth is adversely affected also by the practice of making routine soundings only twice a day, as there is a typical diurnal cycle of planetary boundary growth and decay.

The objective analysis of observed winds to produce a gridded analysis does filter small-scale wind variations from the field, but that does not appear to be a major cause of uncertainty for long-term simulations. In gridding precipitation observations, however, frequency of precipitation occurrence is increased as the grid increment increases, since a cell average is non-zero if any one of perhaps several observation stations within the cell is non-zero. Without adjustment by a threshold value, this could lead to overprediction of wet deposition by ASTRAP, since the wet removal parameterization was developed from observations at a point, not across a grid, and is a function of both precipitation frequency and amount.

Initial preparation of wind and precipitation fields for ASTRAP simulations has been performed at the University of Michigan by Professor Perry Samson. His wind fields, produced every 12 hours, are for 500 m layers to 3000 m MSL for a 17 x 19 horizontal grid of National Meteorological Center (NMC) spacing. (The NMC polar stereographic projection, aligned along 80° W and true at 60° N with 381 km spacing there, reduces to about 306 km spacing at 30° N.) The wind grid is the coarser grid shown in Figure 1, with values of west-east and south-north components at the cell centroids (i.e., components not aligned along grid system). The corners of the grid, too far from rawinsonde stations for the analysis method, are coded as missing values, as are layers that were in effect below the elevation of the terrain. Speed is given in meters per second. Further processing has been necessary at Argonne before the analyses could be used in ASTRAP simulations. For spring and summer, the bottom 3 non-missing values have been averaged at each gridpoint; for fall and winter the bottom 2 non-missing values have been

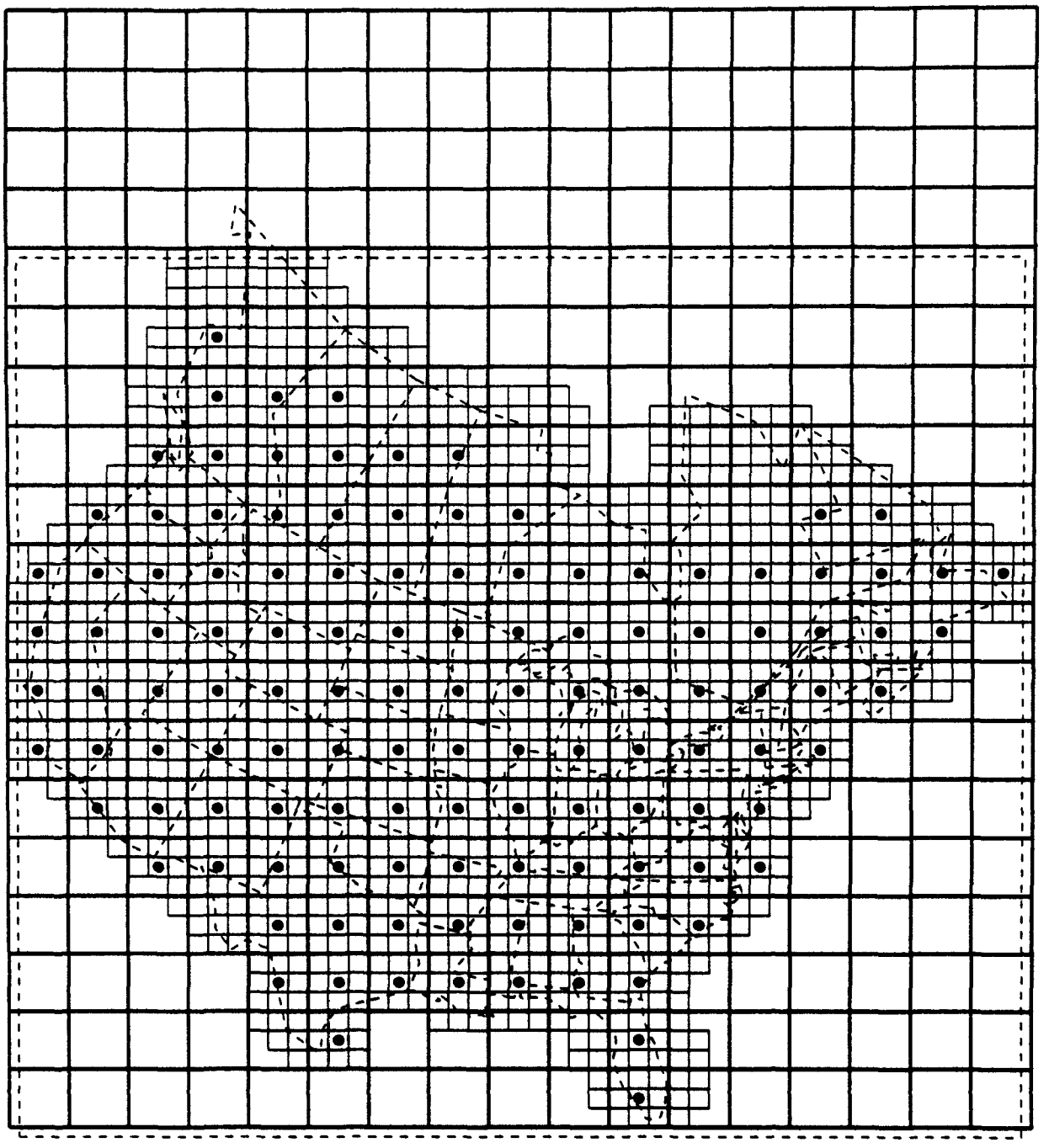

Figure 1. Grid system for ASTRAP input and output: wind field analyses (centers of large cells); precipitation analyses (centered about intersections of small cells with complete coverage within dashed rectangle); trajectory virtual sources (•); emission field and concentration/deposition fields (centers of small cells; not all cells contain emissions). North Pole (large dot) is the (0,0) point of the grid system, with X increasing to right and Y increasing downward.

averaged. For grid points still with missing value indicators, extrapolation has been used to produce wind values. Finally, linear temporal interpolation has created fields at 6-hr intervals, and the wind analyses have been combined into files three months long (Dec - Feb, Mar - May, Jun - Aug, and Sep - Nov). The wind components are converted to components along the NMC axes internally in the HORZ subprogram.

The precipitation analyses produced at the University of Michigan are on a 50 x 45 grid with 1/3 NMC spacing, as outlined in Figure 1. The original analyses are hourly, with a special code for missing values. Precipitation amount is in millimeters. At Argonne the hourly fields have been added to produce 6-hrly fields, with missing values filled in by interpolation and extrapolation. The precipitation data are organized in monthly files. Any missing fields of either wind or precipitation have been replaced by temporal interpolations in the processing at Argonne, so there are no date-time indicators written with the fields.

For the version of ASTRAP in this user's guide, an SO_2 inventory has been created in which the seasonal emissions in kilotonnes are given by effective emission layer (0-100 m, 100-200 m, 200-300 m, 300-400 m, 400-600 m, and 600-800 m) and NMC position of the lower left corner of the grid cell (the NMC coordinate system is 0,0 at the north pole). No separate SO_4 emission inventory is used, so primary sulfate emissions factors are applied in CONCDEP. The primary sulfate emission factor for sources in the bottom layer is assumed to be 0.05 (i.e., one unit of SO_2 equivalent emission is treated as 0.95 units of SO_2 and 1.5(0.05) = 0.075 units of primary sulfate, where the 1.5 factor arises because the ratio of the molecular weight of sulfate to that of SO_2 is 96/64); the primary sulfate emission factor for elevated sources is assumed to be 0.03 in Florida and in the Northeast, and 0.015 elsewhere. The emission grid is the same spacing as the precipitation grid, but is irregular because the inventory is organized by state and province. The emission information has been derived from a preliminary version of the National Acid Precipitation Assessment Program (NAPAP) inventory for 1980 produced for the 1985 Assessment. Wind, precipitation, and emission data are all written in binary format for efficiency.

A different emission inventory for ASTRAP would need to be preprocessed to the form described above, or some of the model code would require changes. If an NO_x inventory were to be used, this version of ASTRAP would expect the inventory to be expressed as equivalent kilotonnes of NO_2, and it would require a different output from program VERT (described in the Vertical Dispersion subsection of the Technical Description section).

3. FEATURES AND LIMITATIONS

The ASTRAP model can be applied in emission policy assessments, for which the model can be exercised to predict how deposition fields would change in response to changes in the pollutant emission field (Streets et al., 1983). This assumes linearity between emissions and deposition. In assessment of future actions, the specific meteorological conditions and short-term emission variations that will occur are not known, and thus an expected or long-term average deposition field, such as provided by ASTRAP, is generally appropriate. The model can be used to estimate concentration and deposition at specific receptor locations, and can estimate the individual contribution from different sources or source regions.

The following major simplifications and assumptions have been incorporated into the ASTRAP model:

1. Long-term horizontal dispersion and long-term vertical dispersion can be simulated independently.

2. Long-term horizontal diffusion can be approximated by the spread of plume centerlines, with small-scale diffusion about individual plumes ignored.

3. Chemical transformation can be parameterized as a linear first-order process.

4. Wet removal is a function of the half-power of the precipitation amount over 6 or 12 hours.

5. Transport is two-dimensional.

6. The dry deposition parameterization is horizontally uniform (not intrinsic to the ASTRAP approach but a part of the ASTRAP version described here).

The separation of calculations of horizontal and vertical dispersion in ASTRAP into two-dimensional horizontal processes and one-dimensional vertical processes is much lower in computational requirements than three-dimensional Eulerian numerical modeling, while the assumption of independence of horizontal and vertical dispersion processes over periods of a month or longer appears to give acceptable results. Because of the separation of the calculations of horizontal and vertical dispersion, however, any parameterization occurring solely in VERT has no horizontal variation, and any parameterization occurring entirely in HORT is independent of the height of release.

The "statistical trajectory" in ASTRAP refers to the treatment of horizontal dispersion. Rather than diffusion of individual plumes, the distribution of the plume centerlines resulting from synoptic scale variations in transport wind fields is calculated. For monthly and longer-term dispersion over the regional scale, the latter process is dominant. For episodic and shorter time scales, however, ASTRAP should not be used without modification to account for plume spreading.

4. TECHNICAL DESCRIPTION

HORIZONTAL DISPERSION

In order that HORZ need be exercised only once for a particular meteorological period, regardless of the number of emission scenarios examined, horizontal dispersion statistics are calculated in HORZ for a virtual source grid covering all of the contiguous states and the Canadian provinces, and subsequently interpolated when concentrations and deposition are calculated. The grid is of National Meteorological Center (NMC) spacing, i.e., 381 km at 60° N, with 123 virtual sources as indicated in Fig. 1.

The meteorological data are time series of horizontal transport wind and precipitation fields, as described in the data requirements section. The wind fields are organized in quarterly files, while the precipitation data are organized in monthly files.

Since similar calculations are made for each virtual source, this discussion focuses on a single virtual source. For a one- to three-month sequence of meteorological analyses, simulated tracers of unit mass are released from the source at intervals of six hours. Calculations in HORZ are independent of the height of release. The tracers are tracked for 28 time steps (seven days), unless they leave the wind grid. At each successive tracer position, the precipitation field is checked to see whether there should be wet removal.

Positions are determined for the midpoints of the six-hour segments, and thus the first trajectory segment is three hours long, while all subsequent segments are six hours long. The statistics calculated in HORZ are ensemble statistics, where each ensemble represents all trajectory positions (endpoints) of a particular plume age (time since release) for each source for the length of the meteorological analysis.

The statistics generated for a puff describing the density of the ensemble of equal age trajectory endpoints are the coordinates μ_x and μ_y of the mean position, the standard deviations σ_x and σ_y, the correlation term ρ_{xy}, and n, the number of equivalent tracer masses contributing to the ensemble statistics. The statistics are collected for a puff associated with airborne or dry tracers and for another puff associated with wet deposited tracers.

A problem inherent in fitting a bivariant normal distribution to the tracer ensembles is that tracers of a common age may not represent identical masses because of differential wet removal. Calculation of the first moment is routine, since it in effect becomes a weighted average. Weighting of tracers in the usual sum-of-squares method can also be accomplished for variance and covariance calculations; however, the degrees of freedom are ill-defined. There might be, for instance, eight trajectories in which wet deposition deposits 2.8 normalized mass units for a particular time step. The approach chosen here is to assume that the initial degrees of freedom are equal to the number of trajectories involved in computing the statistic.

Since the density function fit to the trajectory endpoint ensembles is of infinite domain, each puff has a non-zero effect on every point at which

concentration and deposition are calculated. For efficiency, however, extremely low contributions outside approximately 2.0 - 2.5 standard deviations of plume spread are skipped. The contributions at the other points are scaled upward by 1.046 to compensate for the mass lying outside the threshold puff density.

The wet deposition parameterization is based upon the work of Hicks and Shannon (1979), but the coefficients have been modified to take into account a different analysis method for the precipitation fields. The parameterization is

$$R_{ij} = \begin{cases} \min \begin{cases} 0.5\ P_{ij}^{1/2}\ M_{ij} \\ 0.5\ M_{ij} \end{cases} & P_{ij} > 0.1 \\ 0 & P_{ij} \leq 0.1 \end{cases} \qquad (1)$$

where R_{ij} is the fractional pollutant deposition at time step (plume age) j of the tracer mass from virtual source i, P_{ij} is the six-hour precipitation in centimeters encountered by the tracer during time step j, and M_{ij} is the initial normalized mass less the accumulated wet removal before time step j. A mass equal to the wet deposition (or 1/2 of the removal from the mixed layer) is shifted to the free troposphere, where it is subject to subsequent wet deposition processes but no longer contributes to dry deposition nor to atmospheric surface concentrations. Because of the "min" function, precipitation amounts greater than 1 cm have the same effect as a 1-cm amount, while because of the threshold, amounts less than or equal to 1 mm have no removal effect.

As previously mentioned, there are separate sets of statistics for wet and dry tracer ensembles. The same trajectory endpoints are used in calculation for each corresponding pair of wet and dry ensembles, but the weights are different (most of the wet ensemble have zero weight), and thus the wet and dry ensemble puffs differ. The ensemble puffs for dry deposition and surface concentration tend to be more regular in the trend of their overlapping positions than do the wet deposition puffs. This is because wet removal is a highly irregular process and thus exhibits more statistical variation for a single season. The mathematical description representing each puff j from source i is a bivariant normal density function (Mood and Graybill, 1963):

$$H(x,y) = \frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-\rho_{xy}^2}}\ e^{\left(\frac{-1}{2(1-\rho_{xy}^2)}\left[\left(\frac{x-\mu_x}{\sigma_x}\right)^2 - 2\rho_{xy}\left(\frac{x-\mu_x}{\sigma_x}\right)\left(\frac{y-\mu_y}{\sigma_y}\right) + \left(\frac{y-\mu_y}{\sigma_y}\right)^2\right]\right)} \qquad (2)$$

where x and y are any receptor coordinates and the terms μ_x, μ_y, σ_x, σ_y, and ρ_{xy} are functions of source and plume age. Examples of sequences of 28 puffs are shown in Figs. 2 and 3 for dry and wet processes, respectively, from a hypothetical Oklahoma source during summer of 1980. Weighting of the mass associated with each puff is not shown here; older puffs have less mass because of wet and dry removal enroute. Sometimes an apparent curl in the sequence of mean dry puff centroids during the last time steps is produced as a result of tracers beginning to exit the boundaries of the wind fields. The endpoint ensembles thus become "slow" subsets of preceeding ensembles. It is clear that the dry puffs describe the mean dry plume better than the wet puffs

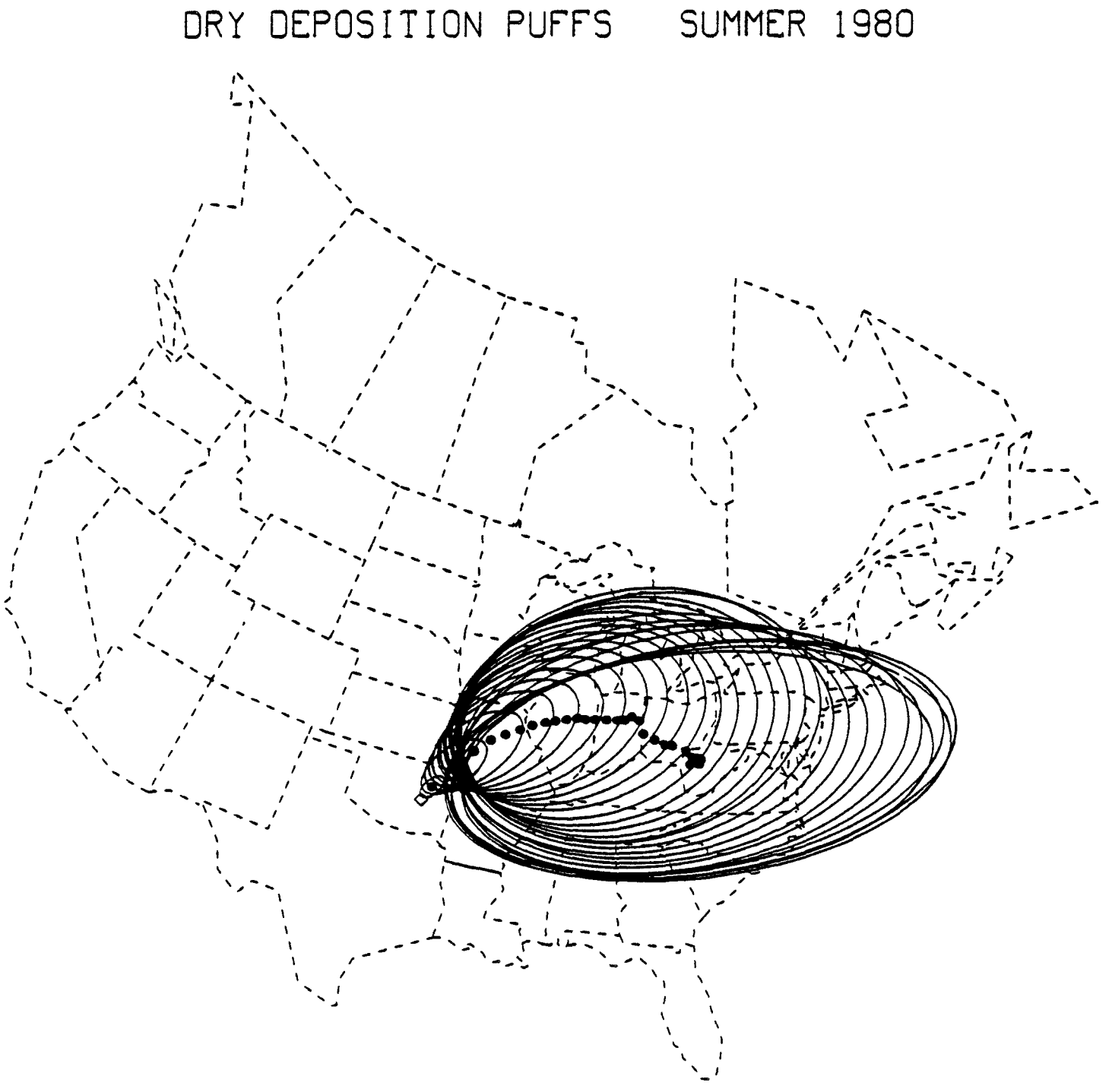

Figure 2. Time series of horizontal dry puff densities from a hypothetical source in Oklahoma, contoured at one standard deviation. Puff centroids are indicated by (•).

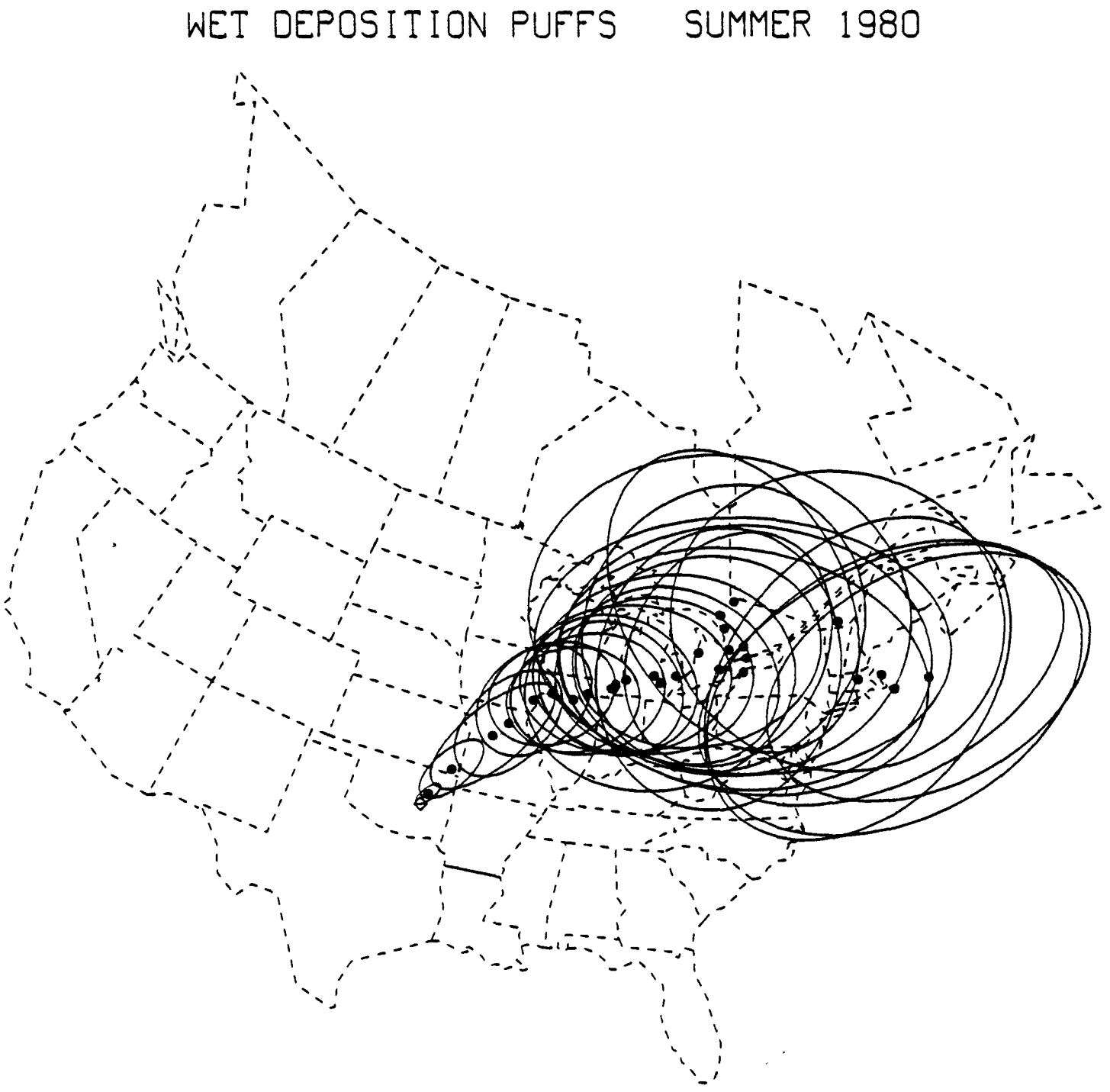

Figure 3. Time series of horizontal wet puff densities from a hypothetical source in Oklahoma, contoured at one standard deviation. Puff centroids are indicated by (●).

describe the wet deposition "plume". This is a statistical feature arising because dry conditions are much more frequent. The average of a number of summers would produce a smoother wet plume.

As in many atmospheric dispersion problems, plume resolution (here formed by overlapping puffs) is most critical near the source. The basic model calculations extend seven days in six-hour time increments, which means that one of the major computational loops in the concentration and deposition program would normally be exercised 28 times. Postprocessing statistical trajectory and vertical integration results within CONCDEP before making concentration and deposition calculations combines the 28 six-hour steps into 4 six-hour steps, 4 12-hour steps, and 4 24-hour steps, extending through the same seven days of dispersion but reducing computation time by more than a factor of two.

VERTICAL DISPERSION

The processes of turbulent vertical diffusion in the mixed layer, leakage to the free troposphere, chemical transformation, and dry deposition are calculated in program VERT of ASTRAP with a one-dimensional version of the Gaussian Moment Conservation (GMC) technique (Shannon, 1979). The GMC version here has nine layers plus a storage layer representing the free troposphere.

The diurnal variation or "breathing" of the planetary boundary layer, i.e., the periodic decoupling and coupling of the surface and elevated portions of the mixing layer by the cycle of nocturnal inversion formation, intensification, lifting, and destruction by convective mixing from below, has been characterized in field investigations (Hicks et al., 1981) and is parameterized in VERT through a seasonally and diurnally varying stability profile (vertical eddy diffusivity K_z specified for each layer). The vertical resolution is that of the layer thicknesses (0-100, 100-200, 200-300, 300-400, 400-600, 600-800, 800-1000, 1000-1400, and 1400-1800 m). An example of input K_z profiles (here two-hourly rather than hourly as in VERT) is provided in Figure 4. The K_z values are roughly similar to the eddy viscosity calculations of Yamada (1977), given the discrete layered structure of ASTRAP, which acts as a filter for some turbulent eddies, and given that the ASTRAP parameterizations represent the mix of sunny, well-mixed conditions with cloudy, more stable conditions.

The variations in dry deposition associated with typical diurnal and seasonal patterns of both atmospheric stability and surface resistances are parameterized through average diurnal values of dry deposition velocities for each season (Wesely and Hicks, 1977; Wesely and Shannon, 1984; Wesely et al., 1984). The primary uncertainty arises in extending the measurements taken at a few high quality, well characterized research sites to the continent as a whole. The seasonal patterns currently used in ASTRAP for SO_x and NO_x species are plotted in Figs. 5 through 8.

A diurnal variation in the linear first-order transformation rate of the primary pollutant (SO_2 or NO/NO_2) to a secondary pollutant (SO_4^{2-} or NO_3^-), directly or indirectly due to photochemical activity patterns, is also included (Gillani et al., 1981). The seasonal patterns, illustrated in Figs. 9 and 10 for the SO_x and NO_x pollutant systems as parameterized in ASTRAP, are intended to include all chemical transformation pathways except those

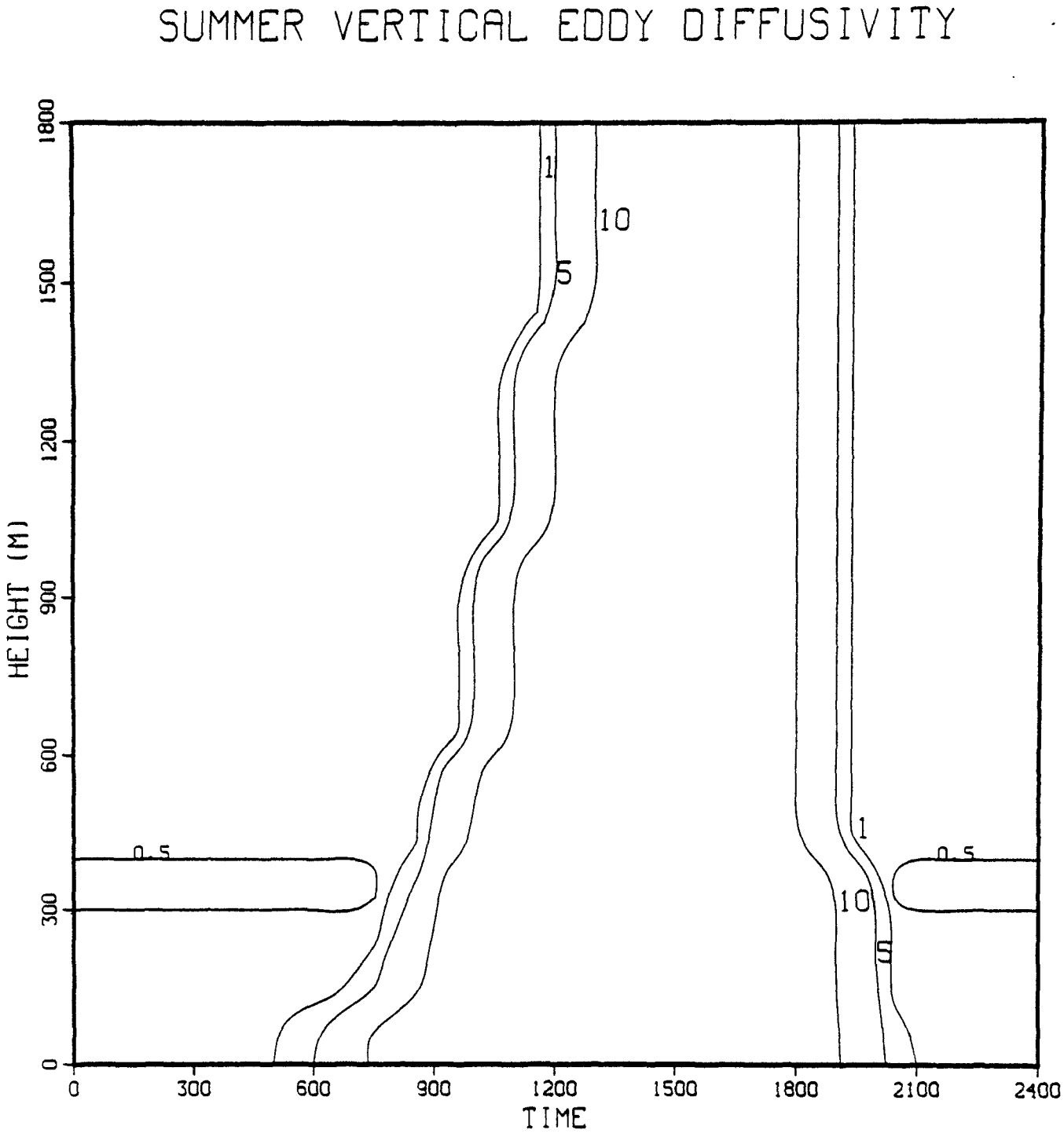

Figure 4. Time-height cross section of vertical eddy diffusivity in m^2s^{-1} for summer conditions in ASTRAP.

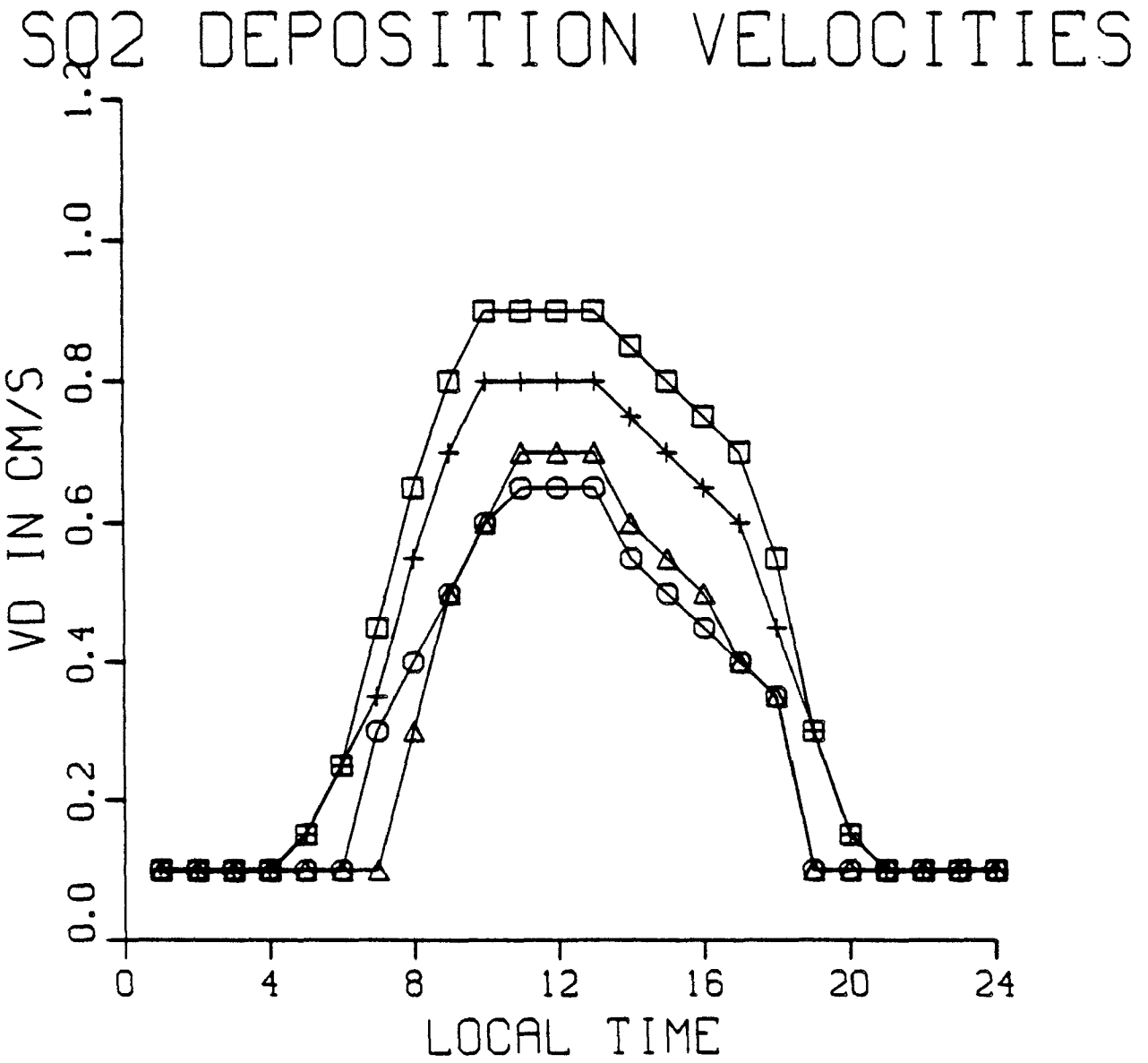

Figure 5. Diurnal patterns of SO_2 dry deposition velocities of ASTRAP for winter (Δ), spring (+), summer (□), and autumn (o).

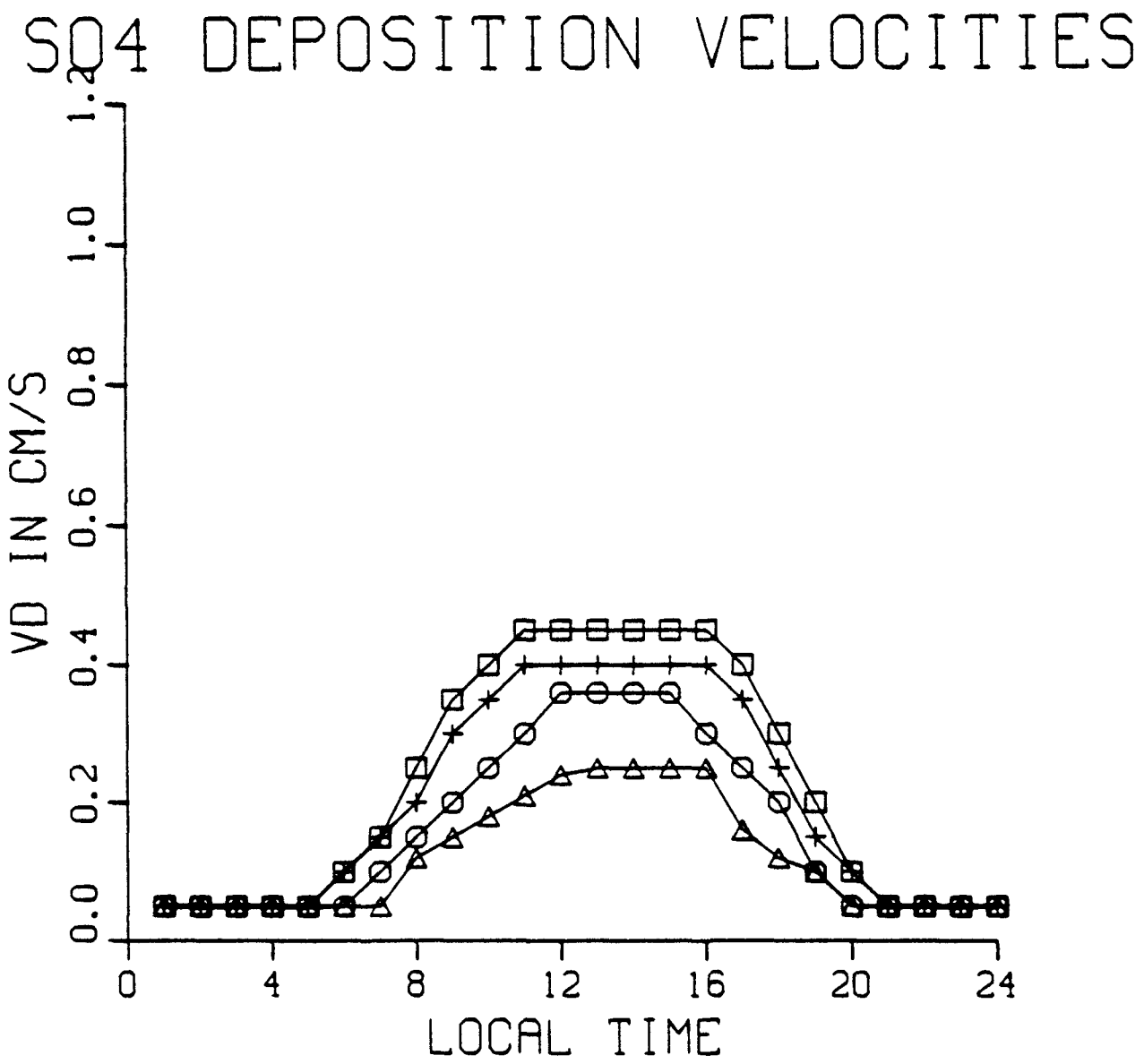

Figure 6. Diurnal patterns of SO_4 dry deposition velocities in ASTRAP for winter (Δ), spring (+), summer (□), and autumn (o).

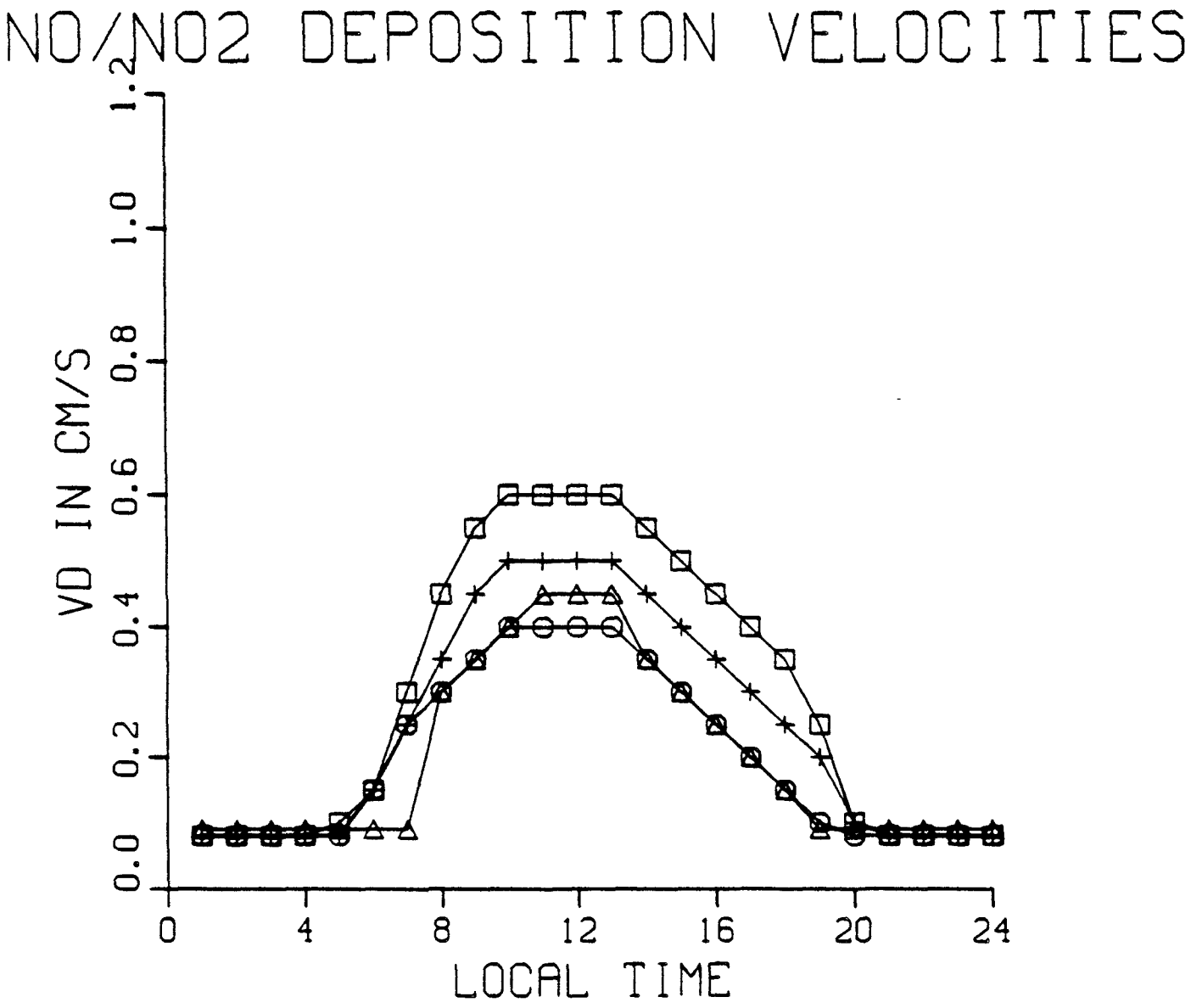

Figure 7. Diurnal patterns of NO/NO_2 dry deposition velocities in ASTRAP for winter (Δ), spring (+), summer (□), and autumn (o).

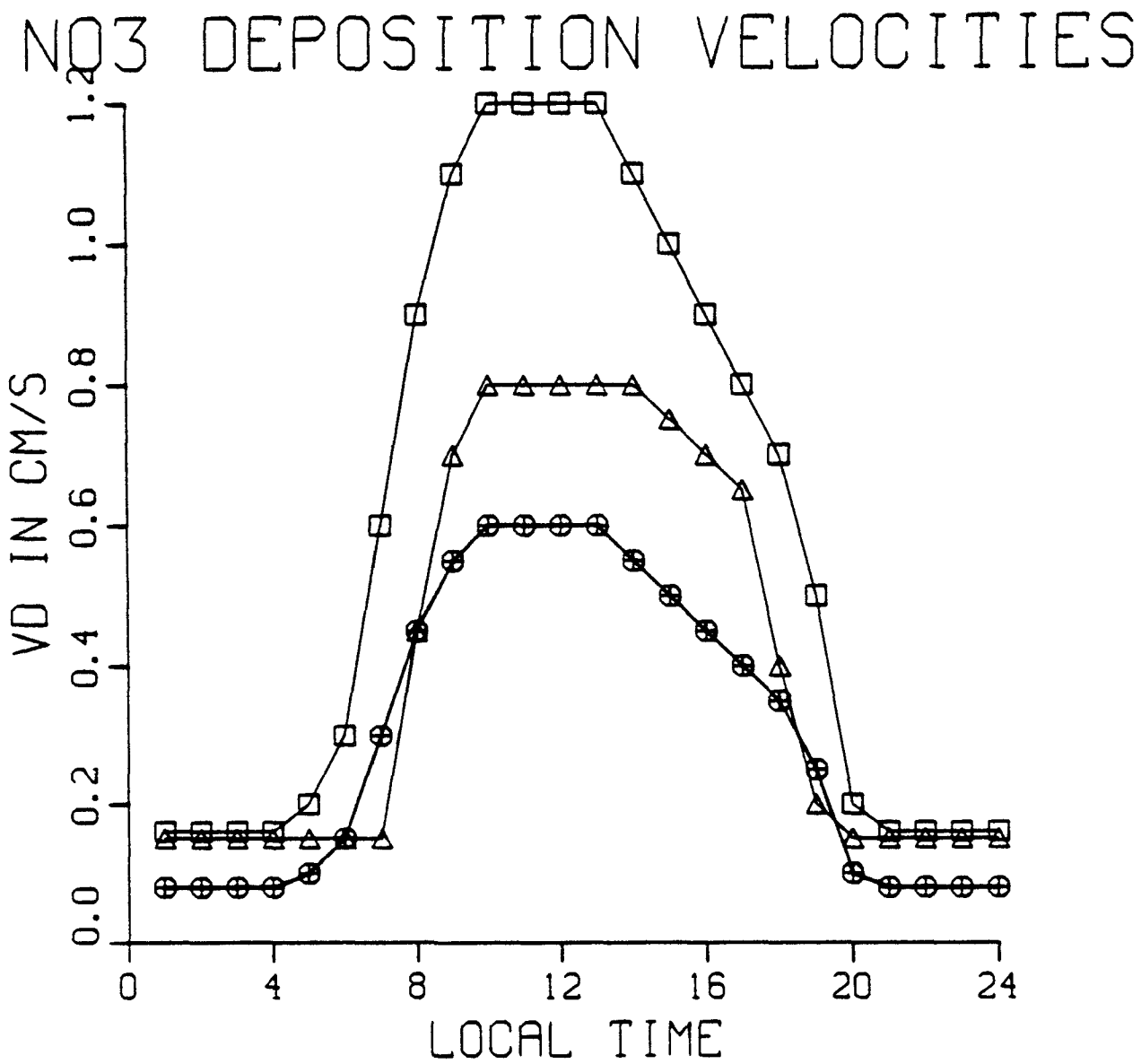

Figure 8. Diurnal patterns of NO_3 dry deposition velocities in ASTRAP for winter (Δ) spring and autumn (⊕) and summer (□).

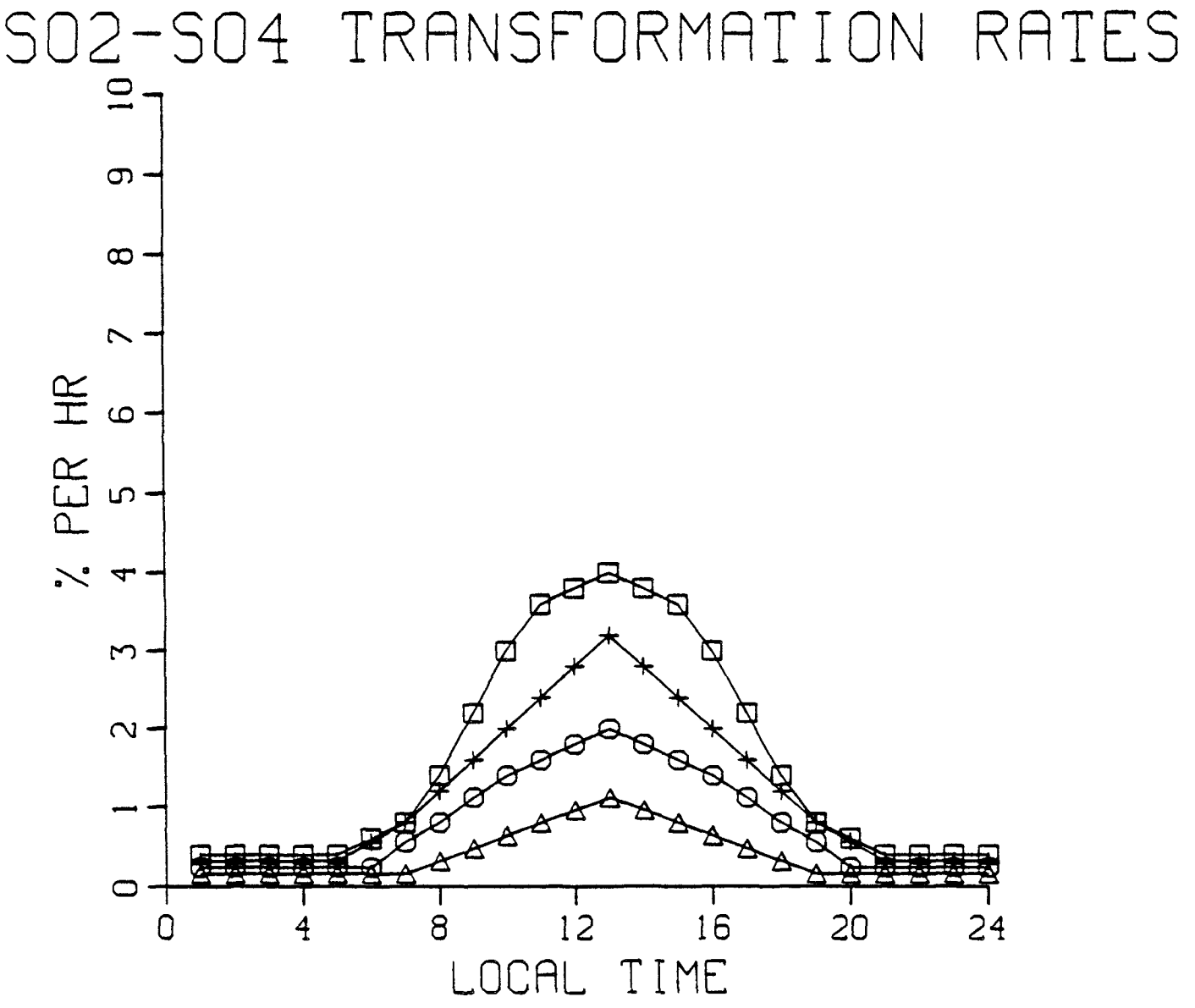

Figure 9. Diurnal patterns of the rate of transformation of SO_2 to SO_4 in ASTRAP for winter (Δ), spring (+), summer (□), and autumn (o).

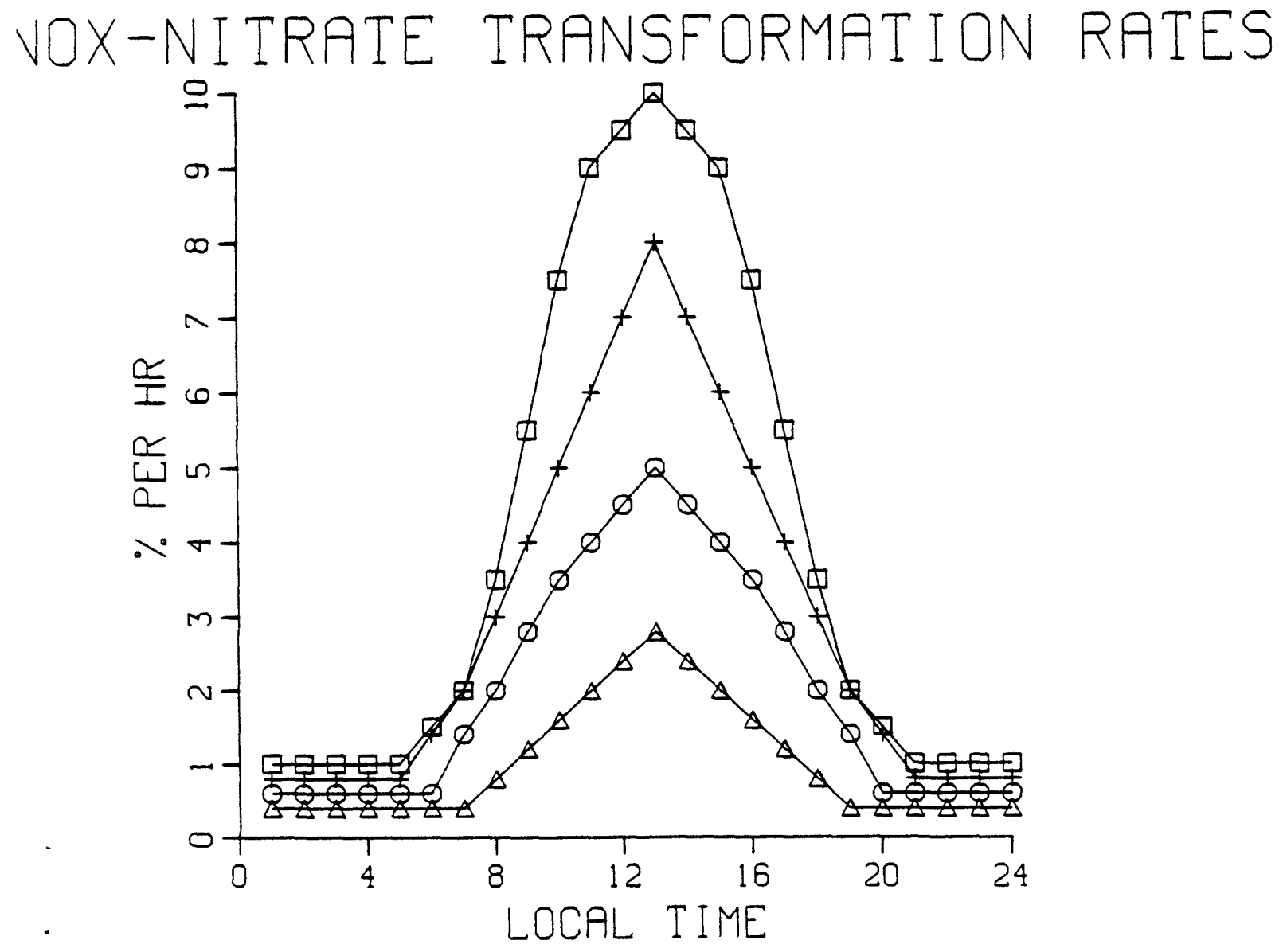

Figure 10. Diurnal patterns of the rate of transformation of NO/NO_2 to NO_3 in ASTRAP for winter (Δ), spring (+), summer (□), and autumn (o).

associated with precipitating clouds. The rates of SO_2 transformation, for example, are greater than normally found in clear-air experiments (Meagher and Bailey, 1983) because the rates include the effects of chemical processing in non-precipitating clouds (Hegg et al., 1984.)

Since most emissions from minor low-level sources are concentrated in urban areas, where polluted air masses typically are more reactive chemically (Alkezweeny and Powell, 1977) than in the less urbanized surroundings of many tall-stack major sources, the chemical transformation rate in VERT is increased during initial time steps for near-surface sources,

$$\Delta Txr = 0.5\ B(3 - \ell)(4 - t)/(2 - 0.5A); \quad \ell<3,\ t<4 \qquad (3)$$
$$0, \text{ otherwise}$$

where ΔTxr is the increase in transformation rate in % hr^{-1}, B is a constant defined by the pollutant system (1.0 for SO_2, 0.5 for NO_2), ℓ is the model layer, t is the plume age in hours, and A is a seasonal constant (2 for summer, 1 for spring and fall, 0 for winter).

The dry deposition velocities and low-level eddy diffusivities during the first 2.5 hours of dispersion are not allowed to decline below arbitrarily specified seasonal thresholds (Table 1), as urban areas are less prone to strong nocturnal inversions than rural areas because of the local heat island and aerodynamic roughness effects in the urban areas. Likewise, the dry deposition velocity for SO_2 during the first 2.5 hours of dispersion is not allowed to rise above a specified seasonal maximum, since urban surfaces are generally drier than rural surfaces. Elevated releases are less affected by these changes than are low-level releases, because the diurnal stability cycles in layers aloft are not modified, and the pollutant must diffuse downward before dry deposition can take place. The dry deposition of primary particles is set to 1.0 cm s^{-1} during the first 2.5 hours to simulate some gravitational settling of larger particles from small sources, presumed to be inefficiently controlled.

Most modelers and field experimentalists agree that there must be "leakage" from the mixed layer to the free troposphere through exchange mechanisms such as fair-weather cumuli, but no definitive field experiments quantifying such vertical transport mechanisms for pollutants on a regional basis have been completed and analyzed. A parameterization for such a loss is now included in ASTRAP, but the rates have been set at relatively low values until such time as more is learned about the long-term regional significance of the mechanism. (Loss to the free troposphere from the mixed layer via precipitation-related processes is accomplished in subprogram HORZ by "depositing" in the free troposphere 1/2 of the bulk wet removal from the mixed layer, where it is subject to subsequent wet removal but not dry removal.)

Since time evolution of incremental dry deposition and of the vertical profiles of concentrations varies with the time of release, simulated releases are made and diffused for seven days from each hour of the day in turn and then averaged separately for emissions in each of the first six layers, and stored in that form. Calculations could be made also for the top three model layers, but normally no emissions start that high (800 m). In an earlier version of ASTRAP (Shannon, 1981), a diurnal emission variation function was

Table 1. EARLY DISPERSION PARAMETERIZATION LIMITS

Season	V_{d2} (max)	V_{d2} (min)	V_{d4} (min)	K_z (min)
Summer	0.50	0.30	0.20	3.0
Autumn	0.40	0.15	0.20	3.0
Winter	0.40	0.15	0.20	3.0
Spring	0.40	0.20	0.20	3.0

V_{d2} and V_{d4} are the dry deposition velocities of SO_2 and SO_4, respectively, in $cm\ s^{-1}$. K_z is the vertical eddy diffusity within the bottom 200 m in $m^2\ s^{-1}$.

used to weight the average, but experience indicated that such detailed emission information was almost never available with desired accuracy in emission inventories or scenarios, and so that variation was removed from the model. The coding here includes the parameterization, but there is no variation in the rate.

The calculated and stored normalized statistics from the vertical dispersion program for a seasonal simulation include the one-dimensional surface concentration, the pollutant mass remaining aloft, and the pollutant mass deposited by dry processes during the time increment (six hours except the initial three-hour step). Separate sets of statistics are maintained for SO_2, primary SO_4^{2-} and secondary SO_4^{2-} or for NO/NO_2, primary NO_3^-, and secondary NO_3^-.

The eddy diffusivity, chemical conversion, and dry deposition parameterizations for a particular season are applied everywhere, regardless of latitude or surface vegetation. This is an obvious limitation of the ASTRAP algorithms, which include some oversimplifications in order to achieve computational simplicity. A possible improvement would be to calculate the vertical dispersion program with different input parameterization values for distinct source regions, such as the Deep South or New England, with different typical surface and meteorological conditions. This still would be imprecise, however, since the trajectories eventually pass out of the source region.

CONCENTRATION AND DEPOSITION

The program CONCDEP combines the statistics produced by programs HORZ and VERT with an emission inventory to calculate primary and secondary pollutant surface atmospheric concentrations and dry and wet deposition. The version described here produces those calculations for a regularly spaced grid.

Each emission source or cell is nested within the coarser trajectory virtual source grid. The emission cells overlie the smaller cells in Fig. 1, although there are no man-made emissions in the oceanic cells nor in some of the continental cells. The bias between the emission location and the

appropriate trajectory starting point is added to all ensemble puff mean positions as calculated from that trajectory virtual source. The standard deviations of each ensemble puff are increased by a term accounting for the emission and deposition grid resolution and, for wet deposition puffs, the precipitation analysis grid resolution. In the version of ASTRAP provided here, all of the grid increments are 1/3 NMC, and the assumed rectangular distribution across a cell has a standard deviation of 1/3 NMC unit/$\sqrt{12}$.

A portion of the coding in CONCDEP is designed to decrease computation requirements by ignoring the effect of puffs outside their 2.5 σ range. The mass associated with the puff is adjusted such that there is no loss of mass.

The concentration and deposition fields are calculated by overlaying puffs (N source cells x 12 telescoped time steps) and adding their densities over the receptor grid (illustrated by the smaller cells in Fig. 1). Puff superposition avoids computational difficulties often encountered with continuous plume models in complex flows (Johnson, 1983). For this the puffs must be weighted by both the emission rate per 6 hours for the source and the number of normalized tracer masses contributing to the puff:

$$C(x,y) = \sum_{i=1}^{N} \sum_{\ell=1}^{L} E_{i\ell} \sum_{j=1}^{12} \frac{n_{ij}}{n_o - j + 1} H(x,y)_{ij}\, c_{\ell j} , \qquad (4a)$$

$$D(x,y) = \sum_{i=1}^{N} \sum_{\ell=1}^{L} E_{i\ell} \sum_{j=1}^{12} n_{ij}\, H(x,y)\, d_{\ell j} , \text{ and} \qquad (4b)$$

$$W(x,y) = \sum_{i=1}^{N} \sum_{\ell=1}^{L} E_{i\ell} \sum_{j=1}^{12} m_{ij}\, H_w(x,y)\, b_{\ell j} . \qquad (4c)$$

where C is the long-term average concentration of either gaseous or particulate pollutant, $c_{\ell j}$ is the corresponding one-dimensional surface concentration of the pollutant as a function of emission layer and time step, L is the number of layers, $E_{i\ell}$ is the emission rate to layer ℓ from source i, n_{ij} is the number of normalized emission units of age j from source i contributing to the statistic, n_o is the number of simulated tracers released, D is the cumulative dry deposition of pollutant, $d_{\ell j}$ is the deposition increment of the corresponding pollutant during time step j from layer ℓ, W is the cumulative wet deposition of pollutant, m_{ij} is the number of normalized emission units from source i deposited during time step j, H_w is the wet analogue to H, and $b_{\ell j}$ is the fraction of the original pollutant mass from layer ℓ still airborne at time step j if there had been no previous wet deposition.

The NMC polar stereographic map projection defining the various ASTRAP input and output fields is not an equal area projection. In order to integrate the deposition field, therefore, the area represented by a grid cell must be computed. This requires a transformation of the NMC cell centroid coordinates to latitude and then calculation of the map scale factor at that latitude. The map scale factor is then multiplied by the grid increment at 60° N, where the map projection is true.

Provided that deposition gradients are not too steep over the region of interest relative to the deposition grid resolution, the simplest way to define an irregular area of deposition integration is with an integer indicator array, which classifies each cell. The integrated deposition can then be scaled by the ratio of the actual area of the region of interest to the sum of the areas of the cells designated as being within the region of interest.

PREPROCESSORS AND POSTPROCESSORS

For ASTRAP use, horizontal locations of emission sources must be defined in NMC coordinates, or in units convertible to NMC coordinates, such as latitude and longitude or UTM coordinates. Effective plume height, or stack parameters (height, diameter, exhaust speed, and exhaust temperature) sufficient to calculate the effective plume height according to a plume rise formula such as that of Briggs (1971) must be provided; ambient wind speed and temperature can be estimated from climatology. Since information on fuel type is often lost by the time an emission inventory is compiled, the primary SO_4^{2-} emission factor is estimated here through a parameterization that varies with location (fuel oil combustion, most common in the Northeast, emits a higher fraction of sulfur oxides as primary sulfate than does coal combustion) and layer (surface sources, as in residential heating, are more likely to be oil-fired). If many sources are included in the scenario, it is usually more convenient to apportion emissions to a three-dimensional grid, expressed in polar stereographic coordinates horizontally and expanding coordinates vertically.

When output is in the form of gridded concentration and deposition fields, the normal mode of graphic production is to draw isopleths over a background map of the region of interest. Since the available graphics packages vary considerably from one computer system to another, these program codes are not included here. The output grid is defined in NMC coordinates which are (0,0) at the pole, X increasing to the right, Y increasing downward, and oriented along 80° W longitude; conversions of NMC coordinates to latitude and longitude, and latitude/longitude to NMC coordinates are given below:

$$
\begin{aligned}
A &= 6397/381 \\
B &= 3.1416/2 \\
D &= 57.29 \\
C &= A(1 + \sin(60./D)) \\
LAT &= D(B - 2\tan^{-1}[(X^2 + Y^2)^{1/2}/C]) \\
LONG &= 80.0 - D[\tan^{-1}(X/Y)]
\end{aligned}
\qquad (5)
$$

or

$$
\begin{aligned}
E &= (80.0 - LONG)/D \\
F &= LAT/D \\
G &= (1.0 + \sin(60.0/D)/(1.0 + \sin(F)) \\
X &= A\ G\ \cos(F)\ \sin(E) \\
Y &= A\ G\ \cos(F)\ \cos(E)
\end{aligned}
\qquad (6)
$$

EVALUATION

At this time, no model of long-range transport and deposition can be completely verified. This is because proven capabilities for monitoring dry deposition have not yet been developed and because regionally representative

air quality networks are not routinely operated, although the past Sulfur Regional Experiment (SURE) (Environmental Research & Technology, 1982) provided a valuable network for much of 1977 and 1978. Unfortunately, wet deposition networks were very limited then. Current observations of wet deposition measure the combined effect of all emissions, including natural emissions, and do not directly evaluate the individual source-receptor relationships actually calculated by ASTRAP. Observations also contain "noise", in terms of both regional unrepresentativeness produced by local source effects and errors associated with precipitation undercatch or windblown dust contamination. A model of transport and deposition represents a relationship between emissions and deposition. Model performance statistics can be adversely affected by errors in emission inventories, as well as by errors or unrepresentativeness of observations. Thus, even a "perfect" model of source-receptor relationships could never explain all observed variance.

There are at least two approaches to "correcting" observation data sets that contain apparent local effects before comparison with model output. Detailed analysis of local sources near each observation site may allow one to eliminate sites from the set subjectively, or the raw observations may be used to produce an objectively analyzed field on the same scale as model output, with local effects and error presumably filtered to some extent.

Verification statistics recommended by the American Meteorological Society (Fox, 1981, 1984) apply best to plume models, i.e., near the source and with negligible travel time for removal or transformation processes to become significant. The techniques offered are most useful for individual locations where a sensor is affected by only one or a few sources. Also, a measurement is considered both accurate and representative of an ensemble of possible measurements for the particular conditions. For long-range transport (LRT) modeling the verification techniques available are not so direct. Dry deposition is clearly important in the sulfur budget and is likely important in pollutant loading to ecological systems, but it is not monitored. Horizontal net mass fluxes could provide an important check for model consistency, but are not measured. Interpretation of monitored wet deposition is hampered by the fact that various monitoring networks have different sampling and analysis protocols. Hence, proper LRT model validation is a contentious and complicated matter.

A qualitative evaluation of three models, including ASTRAP, developed as part of the Multistate Atmospheric Power Production Pollution Study (MAP3S) program (Shannon et al., 1982) gave a subjective comparison of observed and modeled isopleth patterns of atmospheric concentrations, and presented concurrent simulations of wet deposition without comparison with observations. ASTRAP and seven other models were evaluated in studies related to the Memorandum of Intent (MOI) on Transboundary Air Pollution between the United States and Canada (Schiermeier and Misra, 1982; Ferguson and Machta, 1982). However, verification statistics were inconclusive because large discrepancies in different emission inventories for 1978 were never resolved and because the period of comparison was rather limited--two months in the case of ASTRAP. A comparison of ASTRAP simulations with selected high-quality Canadian wet sulfate deposition observations was given by Voldner and Shannon (1983).

More complete ASTRAP wet deposition verification is given here. Several precipitation chemistry networks in the United States and Canada provide data on annual wet deposition of sulfate and nitrate at about 100 sites in 1980 (Niemann, 1982). In this comparison, the contribution from natural sources (not included in the emission inventory) is estimated in terms of the observed rainfall at the sites by subtracting assumed concentrations resulting from natural sources from the observations. Thus, the comparison is between simulations of wet deposition of anthropogenic sulfate and nitrate and adjusted observations of the same species. Comparisons of ASTRAP simulations with observations are shown in Fig. 11 for wet sulfate deposition and in Fig. 12 for wet nitrate deposition. Statistics associated with these comparisons are listed in Table 2. About 69% to 73% of the observed variance of sulfate or nitrate wet deposition over the continent is explained by the model. An emission inventory for 1980, a preliminary version of the NAPAP inventory, has been used.

In a further evaluation of ASTRAP, the 1980 SO_x emission inventory has also been used with meteorological data from 1978 in recalculation of SO_2 and SO_4^{2-} average atmospheric concentrations and wet sulfate deposition for January and July 1978 and for the entire year as examined in the MOI studies. The SURE January air quality observations were for 10-31 January. The appropriate 22 days of meteorological data were used, but that is probably shorter than desirable for ASTRAP simulations. Comparisons are plotted in Figs. 13 through 15 and are summarized in Table 3. The arbitrary adjustment for the effects of natural sources at wet deposition receptors (all in the east) is larger than that for the 1980 data; the 1978 observations were mostly from monthly collection, whereas almost all of the 1980 were collected daily or weekly in higher quality networks. Model performance is generally better than that presented for ASTRAP in the MOI model comparisons, even though emissions are for a different year. The ASTRAP simulations in the MOI work for annual concentrations and deposition were actually an average or sum of January and July results, since those were the only months of meteorological data analysed in model-usuable form for ASTRAP at the time. Here the 12 months of meteorological data are December 1977 through November of 1978, so there still is not a complete temporal overlap.

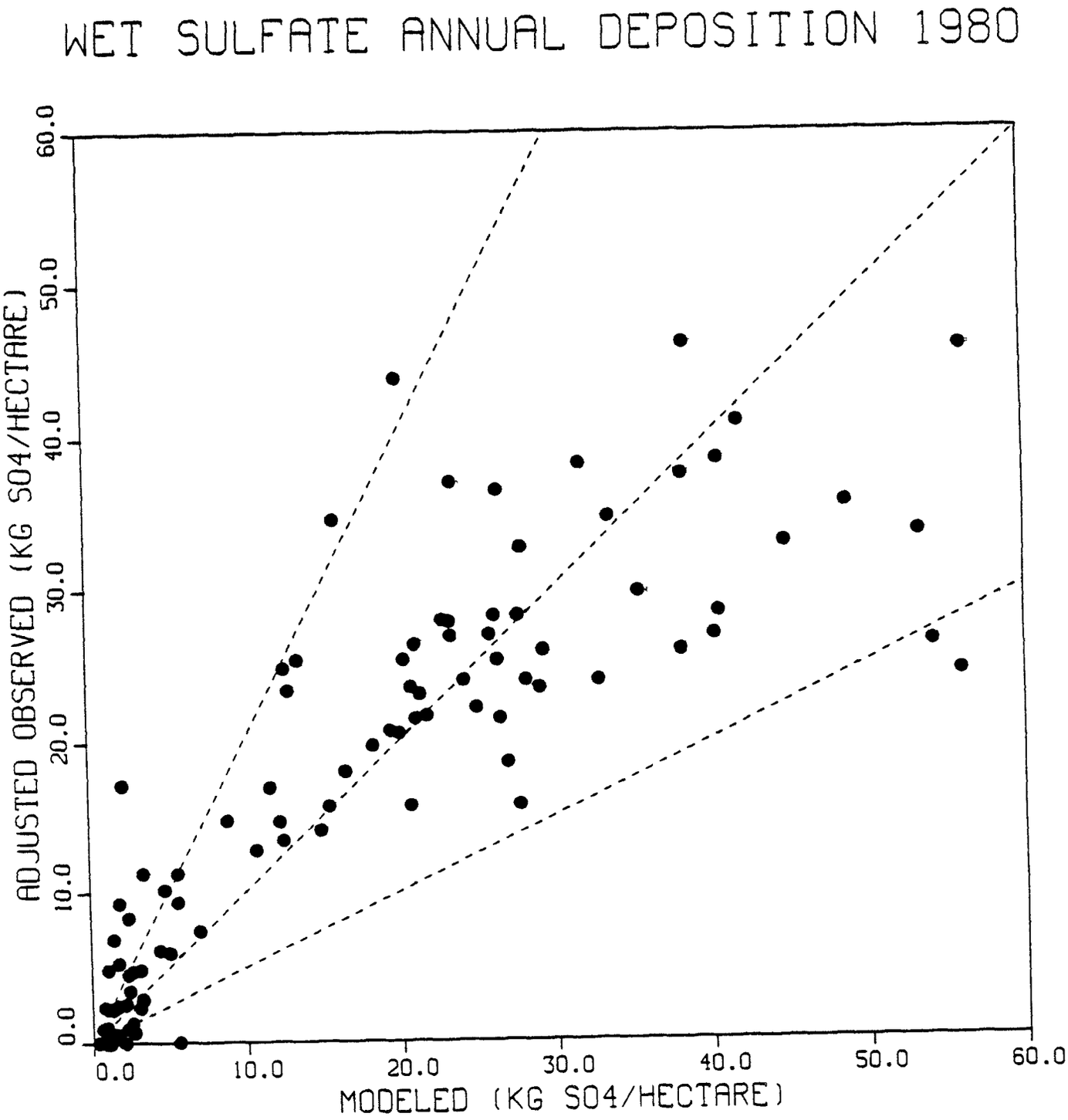

Figure 11. Comparison of ASTRAP simulations with observed annual wet sulfate deposition during 1980. (Dashed lines are for a perfect fit and for factor of two range about a perfect fit.)

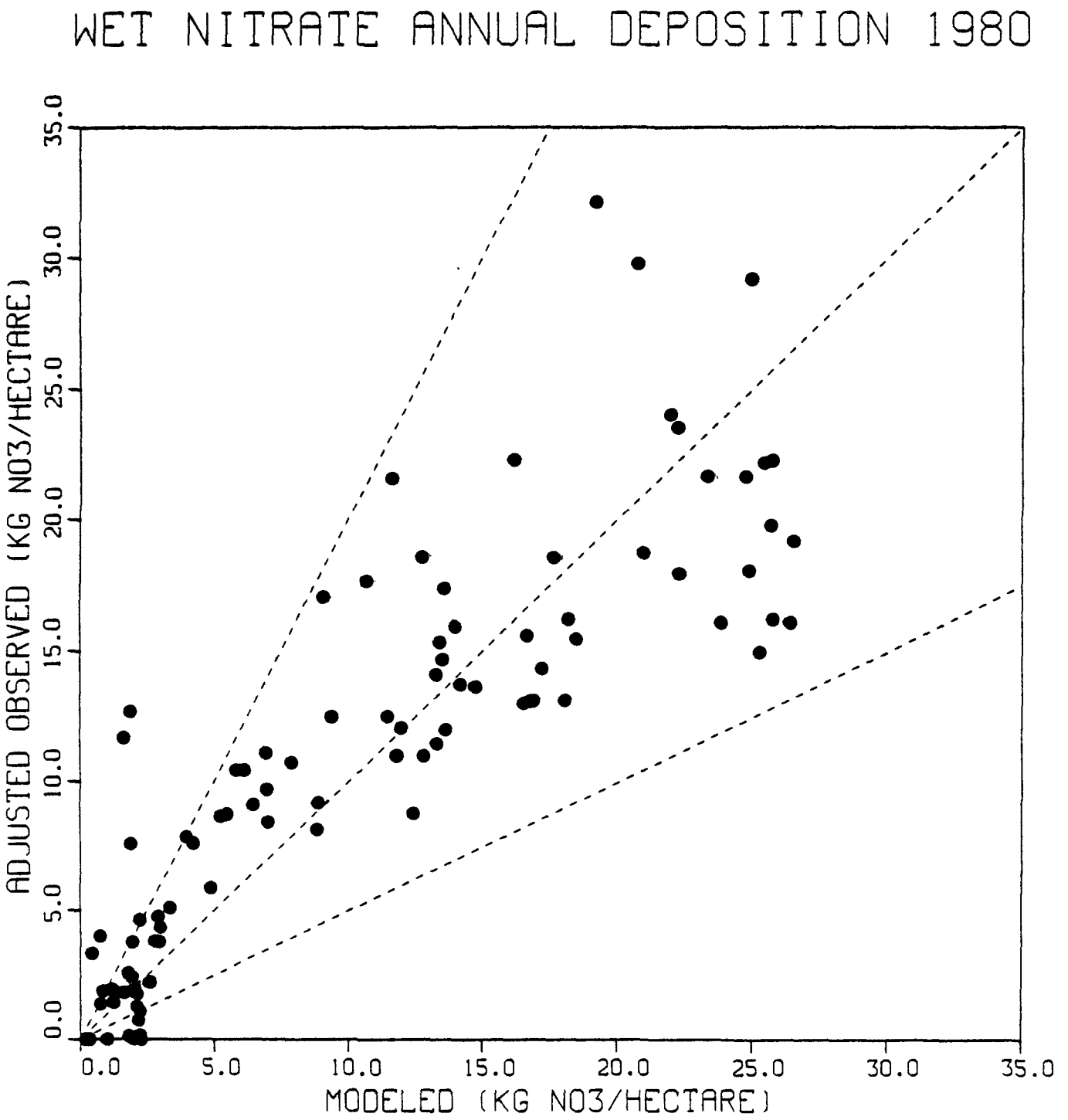

Figure 12. Comparison of ASTRAP simulations with observed annual wet nitrate deposition during 1980. (Dashed lines are for a perfect fit and for factor of two range about a perfect fit.)

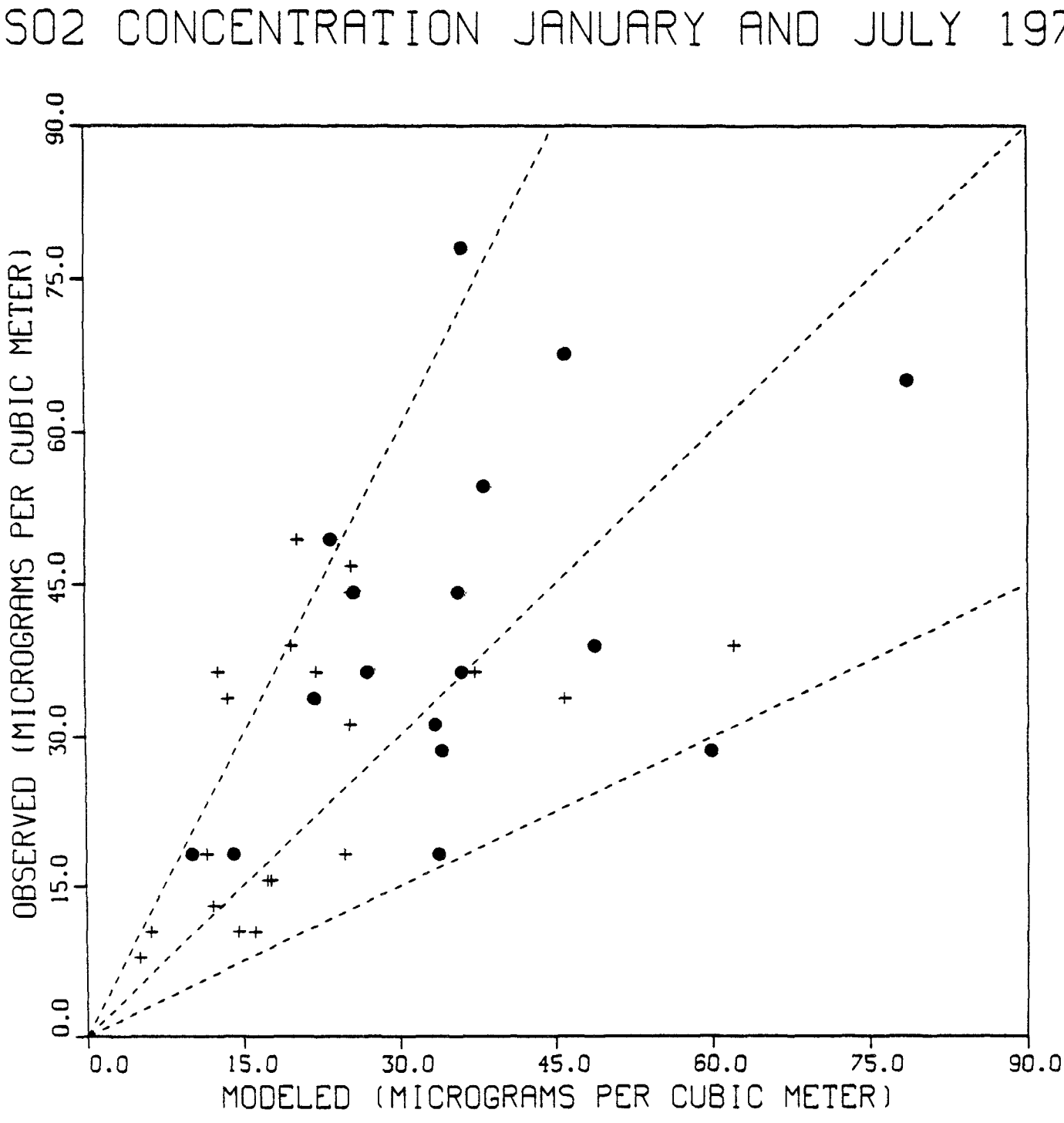

Figure 13. Comparison of ASTRAP simulations with observed average SO_2 concentrations for January (•) and July (+) 1978. (Dashed lines are for a perfect fit and for factor of two range about a perfect fit.)

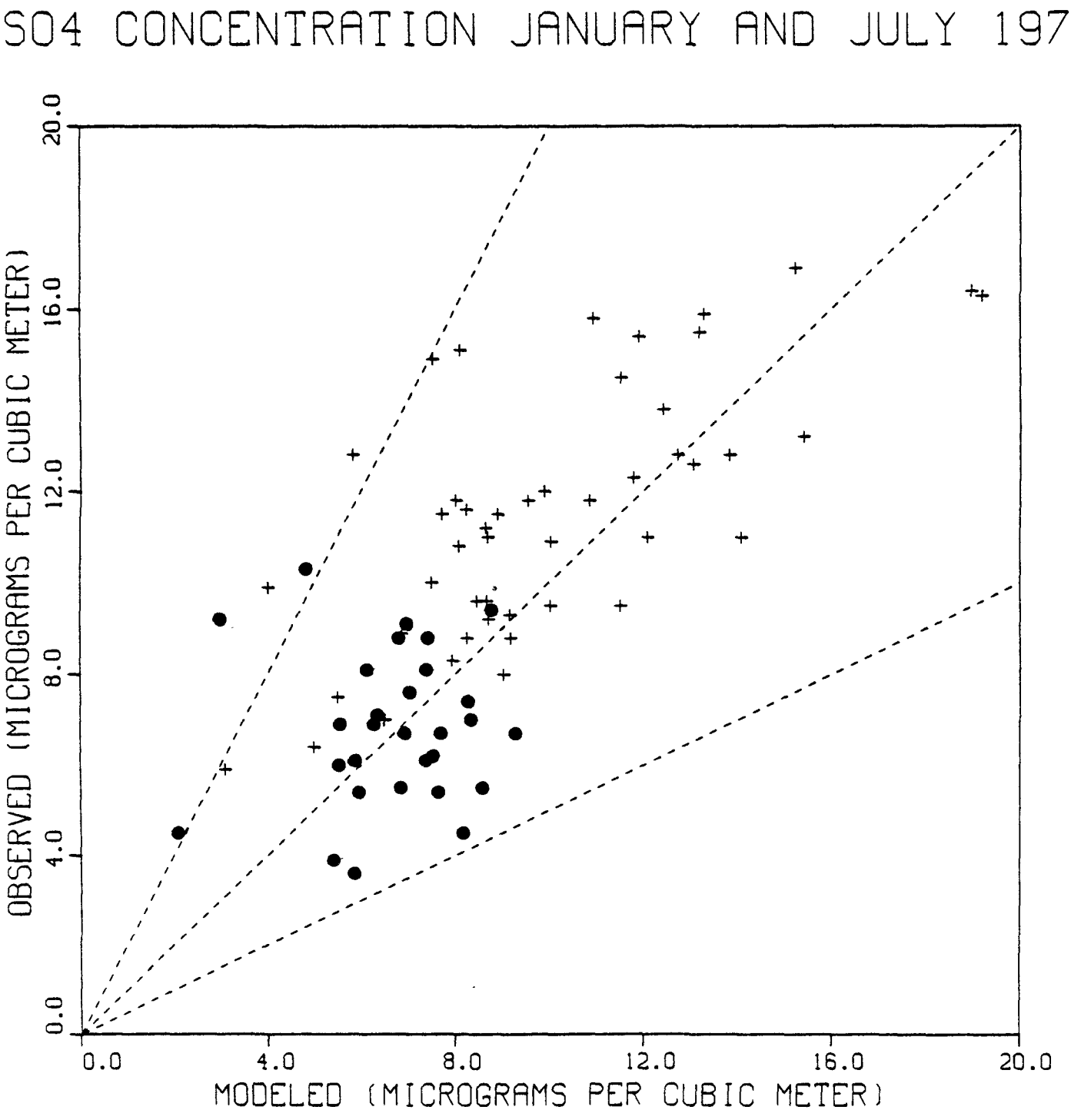

Figure 14. Comparison of ASTRAP simulations with observed average SO_4 concentrations for January (•) and July (+) 1978. (Dashed lines are for a perfect fit and for factor of two range about a perfect fit.)

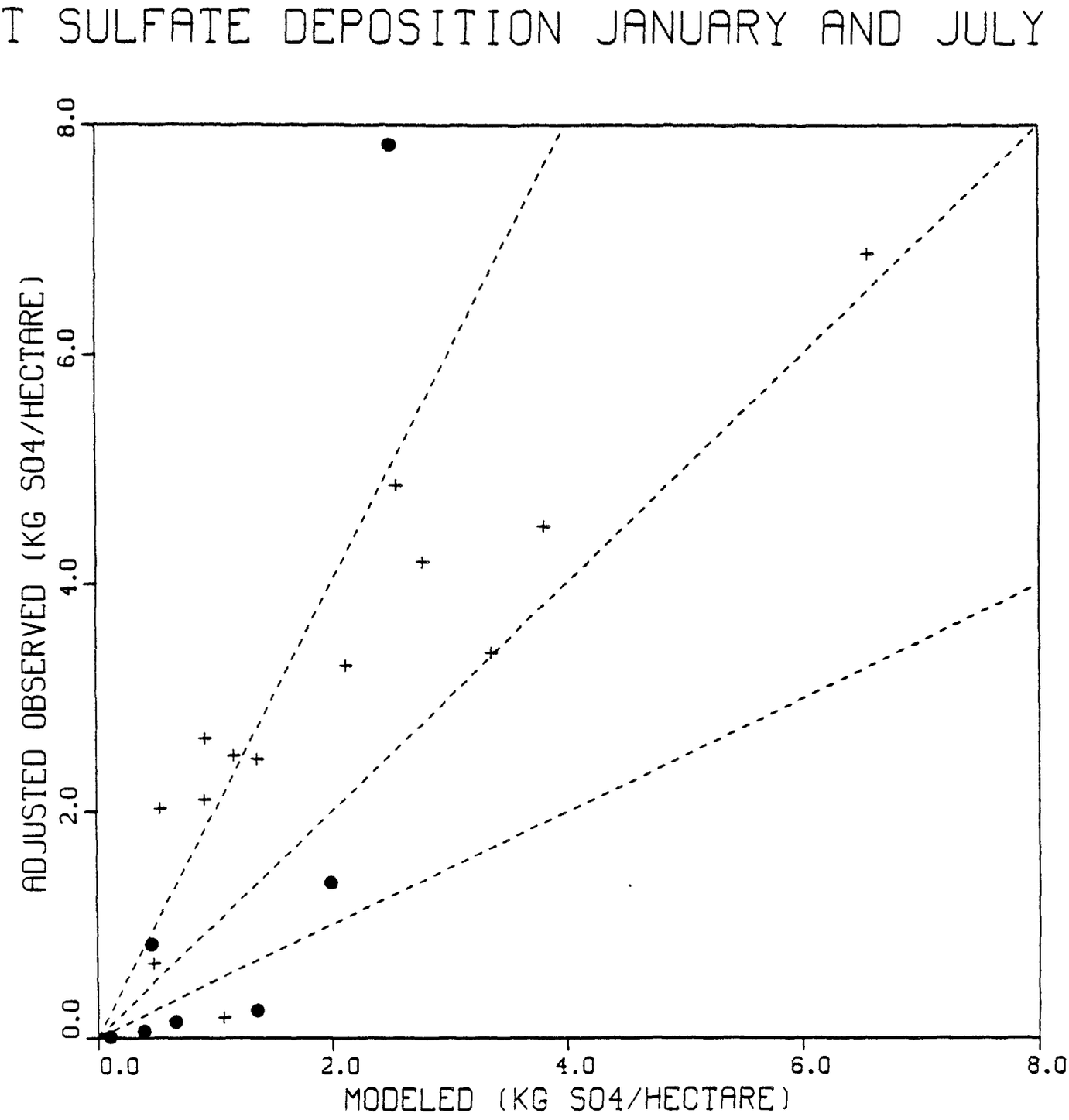

Figure 15. Comparison of ASTRAP simulations with observed wet sulfate deposition for January (●) and July (+) 1978. (Dashed lines are for a perfect fit and for factor of two range about a perfect fit.)

TABLE 2. ASTRAP ANNUAL WET DEPOSITION VERIFICATION STATISTICS.[a]

Case[b]	#Obs.	$\overline{Ob}$	$\overline{Mod}$	$\overline{Res}$	$S.D._o$	$S.D._m$	$S.D._r$	ρ_{om}
1980 sulfate	95	20.2	17.6	2.5	12.4	15.3	8.3	0.83
1980 sulfate*	95	17.7	17.6	0.1	12.9	15.3	8.0	0.84
1980 nitrate	95	11.8	10.5	1.2	7.5	8.4	4.3	0.85
1980 nitrate*	95	11.0	10.5	0.4	7.7	8.4	4.2	0.86

[a]Wet deposition units are kilograms/hectare.

[b]An asterisk (*) indicates that observations have been reduced by estimated natural source contribution (SO_4: 2 micromoles/liter east of the Mississippi or Manitoba and 7 micromoles/liter west; NO_3: 1 micromole/liter east and 3.5 micromoles/liter west).

TABLE 3. ASTRAP VERIFICATION STATISTICS FOR 1978.[a]

Case[b]	#Obs	$\overline{Ob}$	$\overline{Mod}$	$\overline{Res}$	$S.D._o$	$S.D._m$	$S.D._r$	ρ_{om}
Jan SO_2	17	40.7	35.5	5.2	17.7	16.5	17.6	0.44
Jul SO_2	20	27.3	21.8	5.5	13.9	13.5	13.5	0.49
Annual SO_2	3	30.3	32.8	-2.4	15.9	13.2	5.0	0.64
Jan SO_4	29	6.8	6.7	0.1	1.7	1.6	2.3	0.06
July SO_4	47	11.5	10.0	1.5	2.8	3.4	2.5	0.69
Annual SO_4	9	9.1	9.2	-0.1	1.9	1.5	1.9	0.35
Jan wet sulfate*	7	1.5	1.1	0.4	2.8	0.9	2.2	0.67
Jul wet sulfate*	13	3.1	2.1	0.9	1.8	1.7	0.8	0.82
Annual wet sulfate*	8	28.0	14.7	13.2	15.6	13.1	6.8	0.79

[a]Units are micrograms/cubic meter for air concentrations and kilograms/hectare for wet deposition.

[b]An asterisk (*) indicates that observations have been reduced by estimated natural source contribution (5 micromoles/liter).

5. COMPUTER ASPECTS

As currently structured, ASTRAP consists of three programs, HORZ, VERT, and CONCDEP, the first two of which must be run to create data files required by CONCDEP. There is no prescribed order in running HORZ and VERT, and they could be run simultaneously. The job control language is appropriate for the IBM 3033 mainframe at Argonne National Laboratory, and would require some modifications for use on other systems. While programming is in standard FORTRAN, input and output algorithms may require coding modification for other computer systems. A simplied flow chart for the overall model is shown in Fig. 16. Obviously there is preprocessing of raw wind and precipitation observations in order to produce the gridded fields, but as the fields were initially processed elsewhere as discussed in the Data Requirements section no discussion of their preprocessing is provided here.

On an IBM 3033, VERT requires 210K (bytes) storage and 5-10 minutes of CPU time, plus one output file, for a seasonal simulation. HORZ requires 500K storage and 10 minutes CPU time, two input tape drives, and an output file for a seasonal simulation. CONCDEP requires 500K storage, 10-15 minutes CPU time, an emission input file, the output files from the other two subprograms, a file used to identify each receptor cell as to state or province, and an output file for a seasonal simulation. The meteorological fields on tape input to HORZ are written in binary, as are the output files from HORZ and VERT, the emission file, and the output file from CONCDEP.

Quarterly sets of wind analyses and monthly sets of precipitation analyses are written on two separate tapes. The internal file number of the nonlabeled wind file (file 10 in HORZ), and the names and internal file numbers of three corresponding precipitation data sets (files 20-22 in HORZ), as well as the tape number for different years must be changed whenever a different season is simulated. The names of data sets created by the three programs should be changed every time a different period is simulated.

In normal application ASTRAP is structured so as to read an emission file from disk storage. Since the emission inventory is likely to be the first data set that a user would change, however, the appropriate code is "commented out" for the test example and an algorithm defining a single hypothetical source is added. The write file is unit 9 for each program; the input files in CONCDEP must be renamed when different meteorological periods have been used in HORZ or VERT.

The output file from CONCDEP is normally stored on disk, and postprocessors are later used to display the results graphically. Since available graphics libraries will vary greatly from one computer system to another and are often partly proprietary, the postprocessor is not included here. Input parameters for the ASTRAP programs are listed in Table 4, while input/output files are summarized in Table 5. Some changes which a prospective user of ASTRAP might wish to make are discussed in the following section on the test application of ASTRAP.

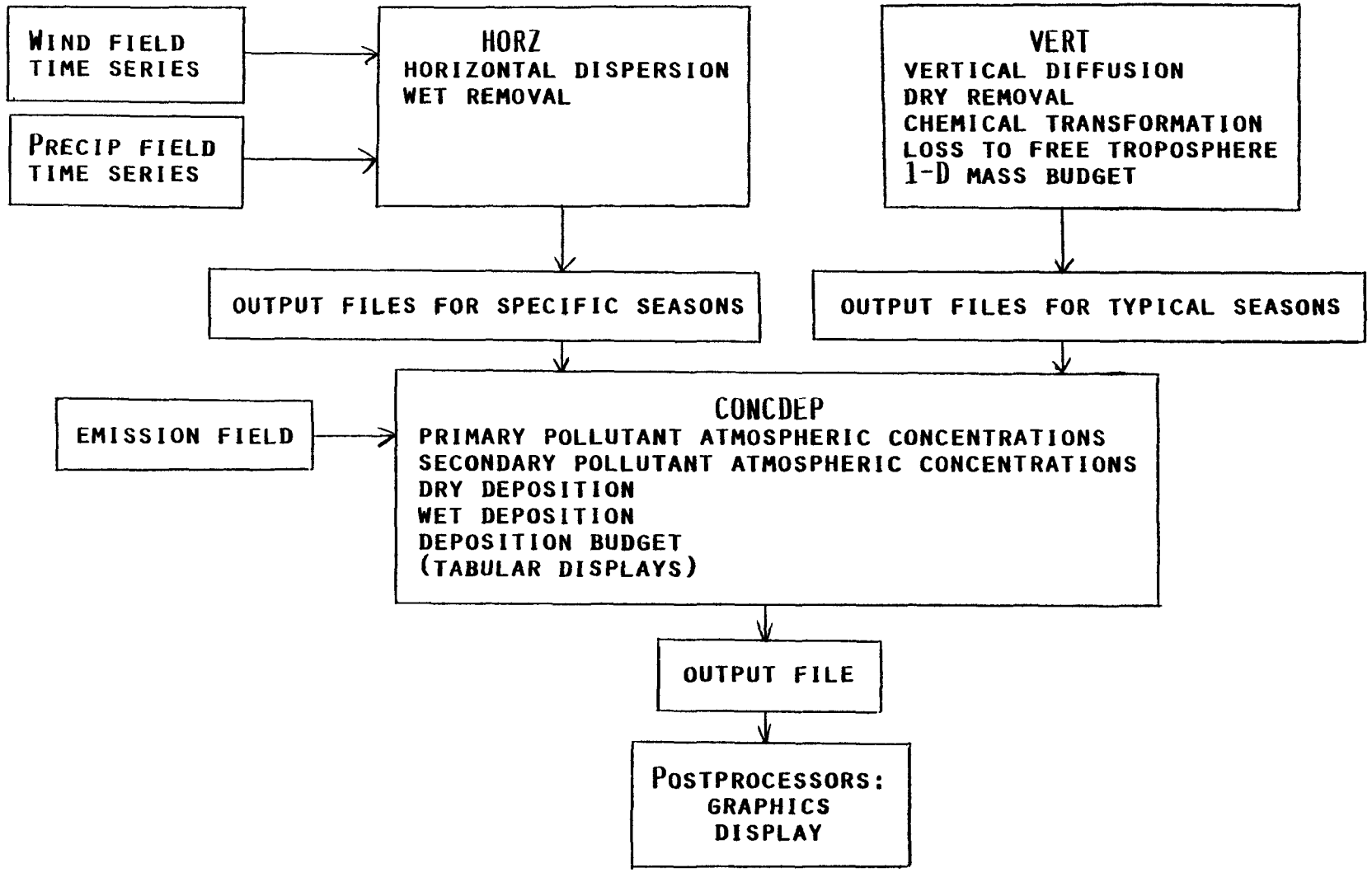

FIGURE 16. ASTRAP PROGRAM STRUCTURE

TABLE 4. ASTRAP INPUT PARAMETERS

NAME	DESCRIPTION	UNITS	PROGRAM	I/O UNIT	FORMAT	ARRAY SIZE
AREA	Area of each state and province	10 sq mi	CONCDEP	CARDS	10F6.0	(60)
CO	Dry horizontal puff ensemble statistics	-	CONCDEP	Unit 10	Unformatted	(6,28,123)
DCOR	Density of each layers as a fraction of lowest layer density	-	VERT	CARDS	14F5.0	(10)
DEPT	Dry deposition S or N mass increment for each time step, pollutant (gas, primary and secondary particle) and emission layer	Normalized	CONCDEP	Unit 20	Unformatted	(28,3,6)
DX	Horizontal increment of emission cells along X	NMC	CONCDEP	Unit 30	Unformatted	
DY	Horizontal increment of emission cells along Y	NMC	CONCDEP	Unit 30	Unformatted	
DZ	Thickness of each layer	m	VERT	CARDS	14F5.0	(10)
EM	Emissions by source cell and layer	kT per season	CONCDEP	Unit 30	Unformatted	(720,6)
EW	Puff weighting in the telescoped time step	-	CONCDEP	CARDS	12F2.0	(12)

(continued)

TABLE 4 (continued)

NAME	DESCRIPTION	UNITS	PROGRAM	I/O UNIT	FORMAT	ARRAY SIZE
IDD	Initial day of model simulation	-	HORZ	CARDS	4(2x,I2)	(4)
IND	Defines grid elements necessary for isopleth drawing	-	CONCDEP	CARDS	33I2	(51,45)
INDD	State and province identifier	-	CONCDEP	CARDS	17I3	(51,45)
IPOL	Pollutant (SO_x = 1, NO_x = 2)	-	VERT	CARDS	I3	
IS	Season (Winter = 1, Spring = 2, Summer = 3, Fall = 4)	-	CONCDEP	CARDS	I3	
ISTPR	Abbreviation of each state and province	-	CONCDEP	CARDS	18A4	(60)
KZ	Vertical eddy diffusivity by layer and by hour	m^2/s	VERT	CARDS	12F5.1	(2,9,24)
LANDE	Trajectory virtual source grid identification proceeding row by row from lower left	-	HORZ	CARDS	19I3	(19,16)
MAXN	Maximum potential trajectories contributing to telescoped time step	-	CONCDEP	CARDS	12F2.0	(12)

(continued)

TABLE 4 (continued)

NAME	DESCRIPTION	UNITS	PROGRAM	I/O UNIT	FORMAT	ARRAY SIZE
NDAY	Number of days model is to be be run	-	HORZ	CARDS	I4	
NF	Number of puff releases for period of simulation	-	CONCDEP	Unit 10	Unformatted	
NS	Number of emission source cells	-	CONCDEP	Unit 30	Unformatted	
NSEASON	Season (Summer = 1, Fall = 2, Winter = 3, Spring = 4	-	VERT	CARDS	I3	
NTS	Number of 6-hour time steps	-	HORZ	CARDS	I2	
NZ	Number of emission layers	-	CONCDEP	Unit 30	Unformatted	
PRECIP	6-hour precipitation totals	mm	HORZ	Unit ITP (20-22)	Unformatted	(17,19)
SBUD	Remaining airborne S or N mass for each time step, pollutant, and emission layer	normalized	CONCDEP	Unit 20	Unformatted	(28,3,6)
SOX	Vertical 1-D concentration profiles for each time step, pollutant, and emission layer	normalized	CONCDEP	Unit 20	Unformatted	(28,3,6)

(continued)

TABLE 4 (continued)

NAME	DESCRIPTION	UNITS	PROGRAM	I/O UNIT	FORMAT	ARRAY SIZE
TR	Hourly transformation rate of SO_2 SO_4, NO_x, NO_3	%	VERT	CARDS	12F4.4	(24)
U,V	X,Y components of the transport wind (along 80°W, X is west-east, Y is north-south)	m/s	HORZ	Unit 10	Unformatted	(17,19)
UTROP	Fractional wet removal to free troposphere by convection	-	HORZ	CARDS	F5.0	
VD	Deposition velocity; functional of plume age, pollutant, time of day	m/s	VERT	CARDS	12F4.4	(2,24,2)
WD	Wet deposition puff ensemble statistics	-	CONCDEP	Unit 10	Unformatted	(6,28,123)
XS	X coordinates of emission cells	NMC	CONCDEP	Unit 30	Unformatted	(720)
YS	Y coordinates of emission cells	NMC	CONCDEP	Unit 30	Unformatted	(720)

TABLE 5. ASTRAP INPUT/OUTPUT FILES

UNIT #	INPUT / OUTPUT	PROGRAM	PARAMETER NAMES	COMMENTS
9	OUTPUT	HORZ	CONC(6,28,123), WD(6,28,123), LANDE(19,16), NF, NXEM, NYEM, XEMLL, YEMLL, DXEM, DYEM, NTS	Output from HORZ read into CONCDEP containing seasonal simulation of horizontal statistics
9	OUTPUT	CONCDEP	SO_2(51,45), SO_4(51,45), DDEP(51,45), WDEP(51,45), SUMM, ADRY(60), AWET(60)	Final output file from CONCDEP containing all concentration and deposition data, usually stored on disk to be used later by postprocessors
10	INPUT	HORZ	U(17,19), V(17,19)	Nonlabeled seasonal 6-hour wind file, requires input tape drive.
10	INPUT	CONCDEP	CO(6,28,123), WD(6,28,123), LANDE(19,16), NF	Results of HORZ, containing seasonal simulation of horizontal trajectory statistics
11	OUTPUT	VERT	AVSFC(28,3) AVDD(28,3) AVBGT(28,3)	Output file from VERT read into CONCDEP containing 1-D surface concentration data, dry deposition increment and total airborne mass for each emission layer
20	INPUT	CONCDEP	SOX(28,3,6), DEPT(28,3,6), SBUD(28,3,6)	Results of VERT for all emission layers
ITP (20,21,22)	INPUT	HORZ	PRECIP(50,45)	Three monthly 6-hour precipitation files, require input tape drive
30	INPUT	CONCDEP	EM(720,6), XS(720) YS(720), NS, NZ, DX, DY	Emissions in kT SO_x as SO_2 by source cell and layer for each season
50	INPUT	CONCDEP	INDD(51,45)	Input file which contains state and province geographical information

6. TEST APPLICATION

The computer codes attached as appendices to this report simulate the ASTRAP exercise described here. In order to make the test example simple, a section of code defining a single source is inserted. In more typical simulations a preprocessed emission inventory, gridded on a 1/3 NMC scale, provides seasonal SO_2 emissions for layered virtual sources. This more relevant code remains in the program, but is skipped by a GO TO 4444 statement. In normal ASTRAP simulations certain randomizations are done to avoid biases associated with discrete source and deposition grids. These are temporarily commented out for this test example (see statements containing RANF in CONCDEP). An emission of 1000 kT SO_x as SO_2 per year from a hypothetical source in Oklahoma (same location as source of ensemble puffs in Figs. 2 and 3) is combined with summer vertical dispersion statistics and with trajectory statistics for summer (June through August) of 1980 in CONCDEP to produce the concentration and deposition fields printed in Tables 6 through 9. The printed fields begin in the 11th small cell column of Fig. 1. The integrated deposition amounts for each state and province are shown in Table 10. (Deposition to the Great Lakes is totaled without regard to state or province.)

Obviously, a user of ASTRAP would wish to make changes from this test case of model coding. The most likely changes would be in either the emission field, the concentration and deposition field, or both, in CONCDEP. The key to defining successfully a different emission field is to describe the field horizontally in terms of NMC coordinates and NMC spacing, if gridded, and vertically according to the layers in VERT. A change in the concentration/deposition grid can be easily accomplished by changing the variables describing the dimension, spacing, and lower left corner. To change to an irregular set of n receptors, however, the two-dimensional receptor grids would need to be changed to (n x 1) fields, and the X and Y arrays would need to be described in NMC coordinates and dimensioned to (n). The integration of the deposition field should then be skipped.

For the more sophisticated user who might wish to change a parameterization, the default values included in the code as input data and illustrated in Figs. 4 through 10 could be replaced, as well as some default values (such as minimum deposition velocities during initial dispersion) which are part of the program code. A change in the input meteorological fields to different spatial scales can be fairly straightforward, as long as the dimension, spacing, and corner of the various arrays are changed in a consistent fashion. A change in the temporal scale would involve more complicated changes.

This user's guide is incomplete without the accompanying program codes, which have been augmented by numerous comment statements. It is suggested that any potential user read the code in detail.

TABLE 6: AVERAGE CONCENTRATION OF SO2 IN MICROGRAMS PER CUBIC METER

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	2.	3.	2.	2.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	4.	5.	3.	2.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	6.	4.	2.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	2.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 7: AVERAGE CONCENTRATION OF SO4 IN MICROGRAMS PER CUBIC METER

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	2.	2.	2.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	2.	2.	2.	2.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	2.	2.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 8: CUMULATIVE DRY DEPOSITION OF TOTAL SULFUR IN GRAMS PER SQUARE METER SIMULATION

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
45	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
44	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
43	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
42	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
41	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
39	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
38	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
37	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
36	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
35	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
34	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
33	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
31	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
30	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
29	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
26	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0
25	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0
24	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0
23	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0
22	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.02	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.02	.03	.03	.03	.02	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.04	.06	.05	.04	.03	.02	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
16	.00	.00	.00	.00	.00	.00	.00	.00	.01	.03	.09	.10	.07	.04	.03	.02	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.09	.14	.08	.05	.02	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.06	.02	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

TABLE 9: CUMULATIVE WET DEPOSITION OF TOTAL SULFUR IN GRAMS PER SQUARE METER SIMULATION

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
45	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
44	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
43	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
42	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
41	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
39	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
38	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
37	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
36	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
35	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0
34	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
33	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0
32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0
31	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
30	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
29	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
28	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
27	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
26	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0
25	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0
24	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0
23	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.02	.02	.02	.01	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0
22	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.02	.02	.03	.03	.02	.02	.02	.02	.02	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.01	.01	.02	.03	.03	.04	.04	.03	.03	.03	.02	.02	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
20	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.01	.02	.03	.04	.04	.05	.04	.04	.04	.03	.02	.02	.02	.01	.01	.01	.01	.01	.01	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
19	.0	.0	.0	.0	.00	.00	.00	.00	.00	.01	.01	.03	.04	.05	.05	.05	.05	.05	.04	.03	.03	.02	.02	.01	.01	.01	.01	.01	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0
18	.0	.0	.0	.0	.00	.00	.00	.00	.00	.01	.02	.03	.05	.06	.06	.05	.05	.04	.04	.03	.02	.02	.02	.01	.01	.01	.01	.01	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0
17	.0	.0	.0	.0	.00	.00	.00	.00	.00	.01	.03	.04	.05	.06	.06	.05	.04	.03	.03	.02	.02	.02	.01	.01	.01	.01	.01	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
16	.0	.0	.0	.0	.00	.00	.00	.00	.00	.01	.05	.05	.04	.04	.04	.03	.03	.02	.02	.02	.02	.01	.01	.01	.01	.01	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
15	.0	.0	.0	.0	.0	.00	.00	.00	.00	.04	.04	.03	.02	.02	.02	.02	.02	.02	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
14	.0	.0	.0	.0	.0	.00	.00	.00	.00	.04	.02	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
13	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
12	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
11	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

CONTINENTAL DRY AND WET DEPOSITION OF TOTAL S IN KILOTONNES

23.70 57.17

TABLE 10: STATE/PROVINCE SEASONAL DRY AND WET DEPOSITION OF TOTAL SULFUR IN KILOTONNES

AL	0.102	0.111
AZ	0.001	0.0
AR	0.794	0.399
CA	0.0	0.0
CO	0.045	0.011
CT	0.006	0.065
DE	0.004	0.026
DC	0.000	0.001
FL	0.013	0.019
GA	0.103	0.191
ID	0.0	0.0
IL	1.844	6.327
IN	0.676	2.921
IA	1.251	4.998
KS	3.625	2.382
KY	0.375	1.254
LA	0.030	0.012
ME	0.014	0.300
MD	0.021	0.139
MA	0.007	0.101
MI	0.326	3.609
MN	0.223	1.722
MS	0.110	0.070
MO	7.643	7.294
MT	0.002	0.014
NB	0.270	0.563
NV	0.0	0.0
NH	0.008	0.120
NJ	0.013	0.105
NM	0.023	0.001
NY	0.095	1.041
NC	0.101	0.398
ND	0.022	0.110
OH	0.326	2.044
OK	4.185	1.657
OR	0.0	0.0
PA	0.136	1.012
RI	0.001	0.013
SC	0.043	0.121
SD	0.084	0.346
TN	0.271	0.562
TX	0.090	0.012
UT	0.000	0.0
VT	0.008	0.130
VA	0.107	0.567
WA	0.0	0.0
WV	0.103	0.593
WI	0.374	3.747
WY	0.010	0.009
G LK	0.331	3.862
ALTA	0.0	0.0
BC	0.0	0.0
MAN	0.010	0.225
NB	0.005	0.161
NFLD	0.0	0.159
NS	0.002	0.086
ONT	0.284	4.447
PEI	0.000	0.007
QUE	0.093	3.009
SASK	0.000	0.031

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Appendix A: Program HORZ Listing

```
//HORZ JOB TIME=10,REGION=500K,CLASS=X
//*MAIN ORG=RM080
// EXEC FGICLG
//SYSIN DD *
C ... USING WIND AND PRECIP ANALYSES FROM U MICH, THIS PROGRAM WILL
C     PRODUCE THE TRAJECTORY STATISTICS REQUIRED BY ASTRAP.
C
C                    VARIABLES USED IN MORE THAN ONE SUBROUTINE
C
C      CONC :  STATISTICS DESCRIBING THE AIRBORNE PORTION OF THE
C          TRACERS.
C       CONC(1,*,*)  AND  CONC(2,*,*) :  USED TO CALCULATE THE MEAN
C           LOCATION IN THE X AND Y DIRECTIONS, RESPECTIVELY,
C           OF THE AIRBORNE TRACER FOR EACH TIME STEP/SOURCE
C           COMBINATION.
C       CONC(3,*,*)  AND  CONC(4,*,*) :  USED TO CALCULATE THE STANDARD
C           DEVIATION IN THE X AND Y DIRECTIONS OF THE AIRBORNE
C           TRACER FOR EACH TIME STEP/SOURCE COMBINATION.
C       CONC(5,*,*) :  THE SUM OF THE AMOUNTS OF AIRBORNE TRACER FOR
C           THE TIME STEP/SOURCE COMBINATIONS.
C       CONC(6,*,*) : USED TO DETERMINE THE CORRELATION BETWEEN THE X
C        AND Y POSITIONS IN THE ENSEMBLE PUFFS.
C      DC :  THE NUMBER OF MEASUREMENTS CONTRIBUTING TO THE
C          RESULTS FOR EACH TIME STEP/SOURCE COMBINATION.
C      DELT :  THE NUMBER OF SECONDS IN A TIME STEP.
C      DELX  AND  DELY :  LENGTH OF AN NMC GRID INCREMENT IN METERS
C          AT 60 DEGREES NORTH LATITUDE.
C      DXP  AND  DYP :  THE LENGTHS IN NMC UNITS OF A PRECIPITATION GRID
C          CELL IN THE X AND Y DIRECTIONS.
C      DXWI  AND  DYWI :  THE LENGTH IN NMC UNITS OF A WIND GRID CELL
C          IN THE X AND Y DIRECTIONS, RESPECTIVELY.
C      FAC3 :  A SEASONAL FACTOR USED TO DETERMINE THE SPEED OF THE
C          NOCTURNAL JET.
C      INCPR :  THE TIME INCREMENT FOR WIND/PRECIP DATA.
C      IPER :  A NUMBER FROM 1 TO 4 REPRESENTING THE SIX-HOUR PERIOD
C          OF THE DAY (GMT) TO WHICH THE WIND DATA APPLY.
C      LANDE:  REPRESENTS THE TRAJECTORY CALCULATION GRID.  CELLS WHICH
C          HAVE NONZERO VALUES WILL BE USED AS VIRTUAL SOURCES.
C          THESE CELLS WILL BE ASSIGNED SEQUENTIAL IDENTIFICATION
C          NUMBERS PROCEEDING ROW-BY-ROW FROM THE LOWER LEFT CORNER.
C      MEAS :  THE NUMBER OF MEASUREMENTS READ.
C      NDAY :  THE NUMBER OF DAYS THE PROGRAM SHOULD MODEL.
C      NF :  THE NUMBER OF DATA SETS FOR THE DESIRED PERIOD.
C      NS :  THE NUMBER OF SOURCE (LAND-CONTAINING) CELLS.
C      NTS :  THE NUMBER OF TIME STEPS TO BE CALCULATED.
C      NXP  AND  NYP :  THE NUMBER OF CELLS IN THE X AND Y DIRECTIONS IN
C          THE PRECIPITATION GRID.
C      NXWI  AND  NYWI :  THE NUMBER OF CELLS IN THE X AND Y DIRECTIONS
C          IN THE WIND GRID.
C      PRECIP :  24-HOUR PRECIPITATION TOTALS.
C      P2 :  SET TO PI DIVIDED BY 2.
C      RO :  A CONSTANT USED TO CONVERT LATITUDE AND LONGITUDE TO NMC
C          UNITS.
C      TR :  THE FRACTION OF THE TRACER LEFT FOR EACH TIME STEP/SOURCE
C           COMBINATION.
C      U  AND  V :  X AND Y COMPONENTS OF THE TRANSPORT WIND.
C        ALONG 80 DEGREES WEST LONGITUDE X IS WEST-EAST AND Y IS
C          NORTH-SOUTH.
C      UTROP :  THE FRACTION OF A TRACER LOST TO THE UPPER TROPOSPHERE
C          BY CONVECTION.
C      WC :  THE NUMBER OF WET DEPOSITION EVENTS FOR EACH TIME STEP/
C          SOURCE COMBINATION.
C      WD :  WET DEPOSITION DATA
```

```
C       WD(1,*,*)  AND WD(2,*,*) :  USED TO COMPUTE THE MEAN
C           LOCATION IN THE X AND Y DIRECTIONS, RESPECTIVELY,
C           OF WET DEPOSITION FOR EACH TIME STEP/SOURCE COMBINATION.
C       WD(3,*,*)  AND  WD(4,*,*) :  USED TO COMPUTE THE STANDARD
C           DEVIATION IN THE X AND Y DIRECTIONS OF WET DEPOSITION FOR
C           EACH TIME STEP/SOURCE COMBINATION.
C       WD(5,*,*) :  THE AMOUNT OF MASS REMOVED BY WET DEPOSITION FOR
C           EACH TIME STEP/SOURCE COMBINATION.
C       WD(6,*,*) : USED TO DETERMINE THE CORRELATION BETWEEN THE X AND
C           Y POSITIONS IN THE ENSEMBLE PUFFS.
C
C ... READ PARAMETERS AND INITIALIZE VARIABLES
      CALL INIT
C
C ... READ DATA AND COMPUTE TRAJECTORIES
      CALL MODEL
C
C ... COMPUTE STATISTICS AND PRINT RESULTS.
      CALL RESULT
      STOP
      END

      SUBROUTINE INIT
C
C ... READ USER-SPECIFIED PARAMETERS AND INITIALIZE VARIABLES.
C
C                           VARIABLES USED ONLY IN INIT
C
C       DXEM  AND  DYEM :  NMC LENGTH OF AN TRAJECTORY GRID CELL IN NMC
C           UNITS IN THE X AND Y DIRECTIONS, RESPECTIVELY.
C       NXEM  AND  NYEM :  NUMBER OF CELLS IN THE X AND Y DIRECTIONS,
C           RESPECTIVELY, ON THE TRAJECTORY GRID.
C
      COMMON/WIND/U(17,19),V(17,19),DXWI,DYWI,XWILL,YWILL,DELT,X(17),
     %  Y(19),DELX,DELY,NXWI,NYWI,MEAS
      COMMON/PREC/PRECIP(50,45),WD(6,28,123),DXP,DYP,XPLL,
     %  YPLL,UTROP,WC(28,123),NXP,NYP
      COMMON/STAT/ XC(29,123),YC(29,123),TR(29,123),CONC(6,28,123),
     %  FAC3,DC(28,123),P2,RO,XEMLL,TRL(29,123),
     %  YEMLL,DXEM,DYEM,NS,NTS,IPER,LANDE(19,16),NXEM,NYEM
      COMMON /CONTRL/ NDAY,NF,ITP,IOUTST,IOUTEN,IDD(4)
C
C ... DEFINE MISCELLANEOUS CONSTANTS
      P2=3.14159/2.
      RO=6397./381
C
C ... READ DATA FOR  LANDE .  CALCULATE NMC COORDINATES FOR SOURCE
C     CELLS.
      NXEM=19
      NYEM=16
      XEMLL=-11.5
      YEMLL=20.5
      DXEM=1.
      DYEM=1.
      READ 202,((LANDE(I,(NYEM+1-J)),I=1,NXEM),J=1,NYEM)
  202 FORMAT(19I3)
      NS=0
      DO 103 J=1,NYEM
        DO 103 I=1,NXEM
          IF (LANDE(I,J).EQ.0) GO TO 103
          NS=NS + 1
          IF (NS.GT.123) GO TO 40
          LANDE(I,J)=NS
          XC(1,NS)=XEMLL + DXEM*(I-1)
```

```
              YC(1,NS)=YEMLL - DYEM*(J-1)-16.Ø
 1Ø3Ø         CONTINUE
          GO TO 6Ø
   4Ø     PRINT 2Ø5Ø
 2Ø5Ø     FORMAT(/'##WARNING:  TOO MANY SOURCE CELLS.  ONLY 123 USED ##'/)
          NS=123
   6Ø     PRINT 2Ø7Ø,NS
 2Ø7Ø     FORMAT(I5,' SOURCE CELLS WERE READ')
          PRINT 2Ø8Ø,((LANDE(I,(17-J)),I=1,19),J=1,16)
 2Ø8Ø     FORMAT(/' TRAJECTORY CALCULATION GRID:',16(/T2,19I3))
          PRINT 2Ø9Ø,NXEM,NYEM
 2Ø9Ø     FORMAT(///' TRAJECTORY CALCULATION GRID IS (',I2,' BY ',I2,')')
          PRINT 21ØØ,XEMLL,YEMLL
 21ØØ     FORMAT(' LOWER LEFT CORNER IS X = ',F7.3,'  Y = ',F7.3)
          PRINT 211Ø,DXEM,DYEM
 211Ø     FORMAT(' SPACING ALONG X AND Y IN NMC UNITS IS DX = '
         # ,F7.3,'   DY = ',F7.3)
C
C ... 16.Ø IS SUBTRACTED TEMPORARILY FROM Y VALUES SO THE CALCULATION
C     OF THE MEAN AND VARIANCE DOES NOT SUFFER TRUNCATION PROBLEMS.
C
C ... SET AND PRINT WIND DATA PARAMETERS
          NXWI=17
          NYWI=19
          XWILL=-1Ø.5
          YWILL=19.5
          DXWI=1
          DYWI=1
          PRINT 212Ø,NXWI,NYWI
 212Ø     FORMAT(//' WIND GRID IS (',I2,' BY ',I2,')')
          PRINT 21ØØ,XWILL,YWILL
          PRINT 211Ø,DXWI,DYWI
          YWILL=YWILL-16.Ø
          DELX=3.81EØ5
          DELY=3.81EØ5
C
C ... SET AND PRINT PRECIPITATION DATA PARAMETERS.
          NXP=5Ø
          NYP=45
          XPLL=-32./3.
          YPLL=2Ø.
          DXP=1./3.
          DYP=1./3.
          PRINT 213Ø,NXP,NYP
 213Ø     FORMAT(//' PRECIP GRID IS (',I2,' BY ',I2,')')
          PRINT 21ØØ,XPLL,YPLL
          PRINT 211Ø,DXP,DYP
          XPLL=XPLL-DXP/2.Ø
          YPLL=YPLL+DYP/2.Ø
          YPLL=YPLL-16.Ø
C
C ... INPUT MISCELLANEOUS PARAMETERS.
          READ 214Ø,UTROP
 214Ø     FORMAT(F5.Ø)
          PRINT 215Ø,UTROP
 215Ø     FORMAT(/' FRACTION OF SULFUR LOST TO THE UPPER TROPOSPHERE BY CONV
         %ECTIVE PRECIPITATION = ',F6.3)
          DELT=6.*36ØØ
C
C ... READ DAY/TIME INFORMATION.
          READ 222Ø,IDD,NDAY,NTS
 222Ø     FORMAT(4(1X,I2),I4,1X,I2)
          INCPR=6
  24Ø     NF=4*NDAY
```

```
      ITP=2Ø
 225Ø FORMAT(4(1X,I2))
      PRINT 226Ø,ITP
 226Ø FORMAT(/,' PRECIP DATA:  START WITH FILE',I3)
      PRINT 227Ø,NDAY,(IDD(MM),MM=1,4),NTS,INCPR
 227Ø FORMAT(/,' RUN MODEL FOR',I5,' DAYS STARTING WITH',I3,'/',
     %  I2,'/',I2,I3,'ØØZ USING',I3,' TIME STEPS,',
     %  ' WIND/PRECIP DATA READ EVERY',I3,' HOURS.')
C
      IOUTST=4Ø
      IOUTEN=44
C ... INITIALIZE STATISTICAL ARRAYS
      DO 133Ø J=1,NS
        TR(1,J)=1.
       TRL(1,J)=1.
        DO 133Ø I=1,NTS
          XC(I+1,J)=9999.
          YC(I+1,J)=9999.
          WC(I,J)=Ø.Ø
          DC(I,J)=Ø.Ø
          TRL(I+1,J)=Ø.
          TR(I+1,J)=Ø.
          DO 133Ø K=1,6
            CONC(K,I,J)=Ø
 133Ø       WD(K,I,J)=Ø.
C ... DEFINE THE X AND Y VALUES ALONG THE AXES OF THE WIND FIELD.
      X(1)=XWILL
      Y(1)=YWILL
      DO 135Ø J=2,NYWI
 135Ø   Y(J)=Y(J-1)-DYWI
      DO 136Ø I=2,NXWI
 136Ø   X(I)=X(I-1) + DXWI
      RETURN
      END

      SUBROUTINE MODEL
C
C ... READ DATA AND COMPUTE TRAJECTORIES
C
C                          VARIABLES USED ONLY IN MODEL
C
C       IDP :  CONTAINS THE MONTH, DATE, YEAR (LAST TWO DIGITS),
C           AND LAST HOUR OF THE LAST PRECIP FIELD READ.
C       ITI :  COUNTS THE DAYS.
C       NEWMON :  SET TO 1 WHEN A NEW MONTH WILL BE STARTED.
C       NFEB :  NUMBER OF DAYS IN FEBRUARY FOR THE YEAR BEING MODELLED.
C
      COMMON/WIND/U(17,19),V(17,19),DXWI,DYWI,XWILL,YWILL,DELT,X(17),
     %  Y(19),DELX,DELY,NXWI,NYWI,MEAS
      COMMON/PREC/PRECIP(5Ø,45),WD(6,28,123),DXP,DYP,XPLL,
     %  YPLL,UTROP,WC(28,123),NXP,NYP
      COMMON/STAT/ XC(29,123),YC(29,123),TR(29,123),CONC(6,28,123),
     %  FAC3,DC(28,123),P2,RO,XEMLL,TRL(29,123),
     %  YEMLL,DXEM,DYEM,NS,NTS,IPER,LANDE(19,16),NXEM,NYEM
      COMMON /CONTRL/ NDAY,NF,ITP,IOUTST,IOUTEN,IDD(4)
      DIMENSION IDP(4)
C
      NEWMON=1
      MEAS=Ø
      NF=Ø
C
C ... COMPUTE TRAJECTORIES
      DO 1222 ITI=1,NDAY
        DO 1222 IPER=1,4
```

```
256.      C
257.      C ...      SET SEASONAL VARIABLES IF A NEW MONTH WILL BE STARTED.
258.                 IF (NEWMON.NE.1) GO TO 5Ø
259.                 NEWMON=Ø
26Ø.                 ITEMP=IDD(1)/3+1
261.                 GO TO(4Ø,1Ø,2Ø,3Ø,4Ø),ITEMP
262.      C ...      SPRING (MARCH-MAY)
263.         1Ø      FAC3=1.15
264.                 GO TO 5Ø
265.      C ...      SUMMER (JUNE-AUGUST)
266.         2Ø      FAC3=1.25
267.                 GO TO 5Ø
268.      C ...      FALL (SEPTEMBER-NOVEMBER)
269.         3Ø      FAC3=1.15
27Ø.                 GO TO 5Ø
271.      C ...      WINTER (DECEMBER-FEBRUARY)
272.         4Ø      FAC3=1.Ø5
273.         5Ø      MEAS=MEAS+1
274.      C
275.      C ...      READ WIND DATA.
276.             READ (1Ø,END=996) U,V
277.      C
278.      C ...       READ PRECIPITATION DATA.
279.        998  READ (ITP,END=999) PRECIP
28Ø.      C
281.             GO TO 122Ø
282.        999  REWIND ITP
283.             ITP=ITP+1
284.             IF (ITP.GT.22) GO TO 996
285.             GO TO 998
286.       122Ø      CALL TRAJ
287.       1222  NF=NF+1
288.        996  CONTINUE
289.             RETURN
29Ø.             END
291.
292.
293.             SUBROUTINE TRAJ
294.      C
295.      C ... TRAJ TRANSPORTS TRACERS FOR A TIME STEP AND COLLECTS
296.      C      STATISTICS.
297.      C
298.      C                          VARIABLES USED ONLY IN TRAJ
299.      C
3ØØ.      C       DA ,  DB ,  DD ,  AND  DE :  RECIPROCALS OF THE DISTANCES FROM
3Ø1.      C           THE TRACER'S LOCATION TO THE FOUR CLOSEST WIND MEASUREMENTS.
3Ø2.      C       D1 ,  D2 ,  D3 ,  AND  D4 :  PERPENDICULAR DISTANCES FROM THE
3Ø3.      C           TRACER'S LOCATION TO THE FOUR CLOSEST WIND CELLS.
3Ø4.      C       DT :  NUMBER OF SECONDS IN A CENTER-DIFFERENCED TIME STEP.
3Ø5.      C       FRMOV :  THE FRACTION OF A TRACER REMOVED--BY WET DEPOSITION
3Ø6.      C           AND CLOUD CONVECTIVE EXCHANGE.
3Ø7.      C       FRMAI1 :  THE FRACTION OF THE TRACER REMAINING AFTER WET
3Ø8.      C           DEPOSITION.
3Ø9.      C       FRMOV1 :  THE FRACTION OF THE TRACER DEPOSITED BY WET DEPOSITION.
31Ø.      C       IM :  THE TIME STEP BEING PROCESSED.
311.      C       I :  THE NEXT TIME STEP.
312.      C       IQ  AND  JQ :  THE COLUMN AND ROW, RESPECTIVELY, OF THE TRACER'S
313.      C           LOCATION ON THE TRAJECTORY CALCULATION GRID.
314.      C       IX :  COLUMN OF THE WIND GRID TO THE LEFT OF THE POINT OF
315.      C           INTEREST.
316.      C       IY :  ROW OF THE WIND GRID BELOW THE POINT OF INTEREST.
317.      C       IXX :  COLUMN OF THE WIND GRID TO THE RIGHT OF THE POINT OF
318.      C           INTEREST.
319.      C       IYY :  ROW OF THE WIND GRID ABOVE THE POINT OF INTEREST.
```

```
C       JX  AND  JY :  COLUMN AND ROW ON THE PRECIPITATION GRID FOR THE
C           TRACER'S NEW LOCATION.
C       MM :  INITIAL VALUE OF THE INNER LOOP INDEX SO ONLY TIME
C           STEPS THAT HAVE VALUES WILL BE PROCESSED.
C       PP :  PRECIPITATION IN THE TRACER'S CELL.
C       UU  AND  VV :  THE ESTIMATIONS OF THE U AND V COMPONENTS OF
C           THE WIND IN THE TRANSPORT LAYER.
C
      COMMON/WIND/U(17,19),V(17,19),DXWI,DYWI,XWILL,YWILL,DELT,X(17),
     %  Y(19),DELX,DELY,NXWI,NYWI,MEAS
      COMMON/PREC/PRECIP(50,45),WD(6,28,123),DXP,DYP,XPLL,
     %  YPLL,UTROP,WC(28,123),NXP,NYP
      COMMON/STAT/ XC(29,123),YC(29,123),TR(29,123),CONC(5,28,123),
     %  FAC3,DC(28,123),P2,RO,XEMLL,TRL(29,123),
     %  YEMLL,DXEM,DYEM,NS,NTS,IPER,LANDE(19,16),NXEM,NYEM
C
C ... COMPUTE TRAJECTORIES FOR THE TIME STEP/SOURCE COMBINATIONS.
C
C ... UNTIL THERE ARE DATA FOR EACH TIME STEP, ONLY LOOK AT
C     THE TRAJECTORIES FOR WHICH THERE ARE DATA.
      MM=MAX0(1,(NTS+1-MEAS))
      DO 1040 ITS=MM,NTS
        DO 1040 J=1,NS
          IM=NTS + 1 -ITS
          I=IM+1
C
          DT=DELT
C         IF THIS IS THE FIRST TIME STEP, FORWARD DIFFERENCING IS DONE
C         SO  DT  IS DIVIDED BY 2.
          IF (IM.EQ.1) DT=DELT*.5
C ...     CHECK TO SEE IF THE TRACER IS OUTSIDE THE WIND GRID ( XC  AND
C          YC  ARE SET TO 9999 WHEN A TRACER IS OUTSIDE THE WIND GRID).
          IF (XC(IM,J).GE.1000.) GO TO 30
C
C ...     USE BILINEAR INTERPOLATION TO ESTIMATE THE WIND AT THE CURRENT
C         TRACER LOCATION.
C
C         FIRST OBTAIN THE FOUR CLOSEST GRIDDED WIND VALUES.
          IX=(XC(IM,J)-XWILL)/DXWI + 1.
          IY=(YWILL - YC(IM,J))/DYWI + 1.
      IXX=IX+1
      IYY=IY+1
      IF (IXX.LT.1) IXX=1
      IF (IYY.LT.1) IYY=1
      IF (IXX.GT.NXWI) IXX=NXWI
      IF (IYY.GT.NYWI) IYY=NYWI
          IF (IX.LT.1) IX=1
          IF (IY.LT.1) IY=1
          IF (IX.GT.NXWI) IX=NXWI
          IF (IY.GT.NYWI) IY=NYWI
C
C         OBTAIN SEPARATION DISTANCES.
          D1=XC(IM,J)-X(IX)
          D2=YC(IM,J)-Y(IY)
          D3=XC(IM,J)-X(IXX)
          D4=YC(IM,J)-Y(IYY)
C
C ...     OBTAIN WEIGHTINGS.
          DA=1./(SQRT(D1*D1+D2*D2)+1.E-10)
          DB=1./(SQRT(D1*D1+D4*D4)+1.E-10)
          DE=1./(SQRT(D3*D3+D2*D2)+1.E-10)
          DD=1./(SQRT(D3*D3+D4*D4)+1.E-10)
          DENOM=1./(DA+DB+DE+DD)
C
```

```
C ...      COMPUTE SPEEDS.
           UU=(DA*U(IX,IY)+DB*U(IX,IYY)+DE*U(IXX,IY)
      %     +DD*U(IXX,IYY))*DENOM
           VV=(DA*V(IX,IY)+DB*V(IX,IYY)+DE*V(IXX,IY)
      %     +DD*V(IXX,IYY))*DENOM
           YY=YC(IM,J)+16.Ø
           XLAM=ATAN(XC(IM,J)/YY)
           UMAP=UU*COS(XLAM)-VV*SIN(XLAM)
           VMAP=-UU*SIN(XLAM)-VV*COS(XLAM)
           IF (IPER.GE.3 .OR. IM.GE.4) GO TO 1Ø
C
C ...      DURING A TRACER'S FIRST DAY, IT WILL BE TRANSPORTED FASTER
C          BY NOCTURNAL JETS.  WHEN APPROPRIATE, INCREASE THE WIND SPEED
C          TO SIMULATE A JET.
           UMAP=FAC3*UMAP
           VMAP=FAC3*VMAP
C
C ...     TRANSFORM METERS PER SECOND TO NMC UNITS PER SECOND.
   1Ø      PHI=P2-2.*ATAN(SQRT(XC(IM,J)*XC(IM,J)+YY*YY)
      %     /(1.866*RO))
           SIG=1.866/(1.+SIN(PHI))
           UMAP=UMAP*SIG/DELX
           VMAP=VMAP*SIG/DELY
C
C ...      TRANSPORT THE TRACER FOR A TIME STEP.
           XC(I,J)=XC(IM,J)+UMAP*DT
           YC(I,J)=YC(IM,J)+VMAP*DT
           TR(I,J)=TR(IM,J)
           TRL(I,J)=TRL(IM,J)
C ...      HAVE TRAJECTORIES DEPARTED THE WIND GRID?
           IF (XC(I,J).GT.(X(NXWI)+2.)) GO TO 3Ø
           IF (XC(I,J).LT.(X(1)-2.)) GO TO 3Ø
           IF (YC(I,J).GT.(Y(1)+2.)) GO TO 3Ø
           IF (YC(I,J).LT.(Y(NYWI)-2.)) GO TO 3Ø
C
           FRMAI1=1.Ø
C
C ... IF THE TRACER IS NOT WITHIN THE PRECIPITATION ANALYSIS,
C     EXTEND THE LAST CELL ON THE ROW OUTWARD.
           JX=(XC(I,J)-XPLL)/DXP + 1.
           JY=(YPLL - YC(I,J))/DYP + 1.
           IF (JY.LT.1) JY=1
           IF (JY.GT.NYP) JY=NYP
      IF (JX.GT.NXP) JX=NXP
      IF (JX.LT.1) JX=1
C
C ...      CALCULATE WET DEPOSITION IF THERE IS PRECIPITATION.
           PP=PRECIP(JX,JY)
           IF (PP.LE.1.Ø) GO TO 2Ø
           FRMOV=SQRT(.1*PP)
C ...      DURING THE WINTER ( FAC3 =1.Ø5 IN THE WINTER) IN NORTHERN
C          AREAS, WET DEPOSITION IS REDUCED BECAUSE THERE IS SNOW
C          INSTEAD OF RAIN.
           IF (FAC3.EQ.1.Ø5 .AND. YC(I,J).LT.Ø) FRMOV=FRMOV*.5
           IF (FRMOV.GT.1.Ø) FRMOV=1.Ø
           FRMOV1=(1.Ø-UTROP)*FRMOV
           FRMAI1=1.Ø-FRMOV1
           TRL(I,J)=TRL(IM,J)*(1.-FRMOV)
           TR(I,J)=TR(IM,J)*FRMAI1
C
C ...      GATHER STATISTICS IF ENOUGH STEPS HAVE ELAPSED.
           WTFRAC=TR(IM,J)*FRMOV1
           WD(5,IM,J)=WD(5,IM,J)+WTFRAC
           WD(1,IM,J)=WD(1,IM,J)+XC(I,J)*WTFRAC
```

```
448.                WD(2,IM,J)=WD(2,IM,J)+YC(I,J)*WTFRAC
449.                WD(3,IM,J)=WD(3,IM,J)+XC(I,J)*XC(I,J)*WTFRAC
450.                WD(4,IM,J)=WD(4,IM,J)+YC(I,J)*YC(I,J)*WTFRAC
451.                WD(6,IM,J)=WD(6,IM,J)+XC(I,J)*YC(I,J)*WTFRAC
452.                WC(IM,J)=WC(IM,J)+1.0
453.         20     CONTINUE
454.                DRFRAC=TRL(I,J)
455.                CONC(1,IM,J)=CONC(1,IM,J) + XC(I,J)*DRFRAC
456.                CONC(2,IM,J)=CONC(2,IM,J) + YC(I,J)*DRFRAC
457.                CONC(3,IM,J)=CONC(3,IM,J)+XC(I,J)*XC(I,J)*DRFRAC
458.                CONC(4,IM,J)=CONC(4,IM,J)+YC(I,J)*YC(I,J)*DRFRAC
459.                CONC(5,IM,J)=CONC(5,IM,J)+DRFRAC
460.                CONC(6,IM,J)=CONC(6,IM,J)+YC(I,J)*XC(I,J)*DRFRAC
461.                DC(IM,J)=DC(IM,J)+1.0
462.                GO TO 1040
463.      C
464.      C ...     TAG TRACERS OUTSIDE GRID
465.         30     XC(I,J)=9999.
466.                YC(I,J)=9999.
467.                TR(I,J)=0.0
468.                TRL(I,J)=0.0
469.      C
470.       1040     CONTINUE
471.            RETURN
472.            END
473.
474.            SUBROUTINE RESULT
475.      C
476.      C ... FINISH CALCULATION OF STATISTICS AND OUTPUT RESULTS.
477.      C
478.      C                          VARIABLES USED ONLY IN RESULT
479.      C
480.      C       TITLE ,  WDLBL ,  AND  REMLBL :  LABELS FOR OUTPUT.
481.      C
482.            COMMON/PREC/PRECIP(50,45),WD(6,28,123),DXP,DYP,XPLL,
483.           %  YPLL,UTROP,WC(28,123),NXP,NYP
484.            COMMON/STAT/ XC(29,123),YC(29,123),TR(29,123),CONC(6,28,123),
485.           %  FAC3,DC(28,123),P2,RO,XEMLL,TRL(29,123),
486.           %  YEMLL,DXEM,DYEM,NS,NTS,IPER,LANDE(19,16),NXEM,NYEM
487.            COMMON /CONTRL/ NDAY,NF,ITP,IOUTST,IOUTEN,IDD(4)
488.            DOUBLE PRECISION TITLE(7,6),WDLBL(5),REMLBL(5),NULBL(7)
489.            DATA
490.           %  TITLE/3*'          ',' MEAN LO','CATION I','N X DIRE','CTION OF',
491.           %        3*'          ',' MEAN LO','CATION I','N Y DIRE','CTION OF',
492.           %        4*'          ','  S.D. I','N X DIRE','CTION OF',
493.           %        4*'          ','  S.D. I','N Y DIRE','CTION OF',
494.           %        4*'          ','   SUM O','F THE MA','SSES FOR',
495.           %         4*'         ',' X-Y COR','RELATION','          '/,
496.           %  WDLBL/' WET DEP','OSITION ','EXTRACTI','ON       ','          '/,
497.           %  REMLBL/' REMAINI','NG TRACE','R FRACTI','ONS EXTR','ACTION  '/,
498.           %  NULBL/'  NUMBER',' OF MEAS','UREMENTS',' CONTRIB','UTING TO',
499.           %     ' THE RES','ULTS FOR'/
500.      C
501.      C ... COMPLETE THE CALCULATIONS FOR  CONC .
502.            DO 1030 I=1,NTS
503.              DO 1030 J=1,NS
504.                IF (CONC(5,I,J).LE.0.) GO TO 10
505.                CONC(1,I,J)=CONC(1,I,J)/CONC(5,I,J)
506.                CONC(2,I,J)=CONC(2,I,J)/CONC(5,I,J)
507.                IF (DC(I,J).LT.3.) GO TO 21
508.                DD=DC(I,J)/(DC(I,J)-1.0)
509.                DQ=DC(I,J)/(DC(I,J)-2.)
510.                CONC(3,I,J)=DD*((CONC(3,I,J)/CONC(5,I,J))-CONC(1,I,J)*
511.           %      CONC(1,I,J))
```

```
              CONC(4,I,J)=DD*((CONC(4,I,J)/CONC(5,I,J))-CONC(2,I,J)*
     %          CONC(2,I,J))
              CONC(6,I,J)=DQ*((CONC(6,I,J)/CONC(5,I,J))-CONC(1,I,J)*
     %         CONC(2,I,J))
              IF (CONC(3,I,J).LE.(DXP*DXP/12.)) GO TO 2Ø
              IF (CONC(4,I,J).LE.(DYP*DYP/12.)) GO TO 2Ø
              CONC(2,I,J)=CONC(2,I,J)+16.Ø
              CONC(3,I,J)=SQRT(CONC(3,I,J))
              CONC(4,I,J)=SQRT(CONC(4,I,J))
              GO TO 1Ø3Ø
     1Ø       CONC(1,I,J)=Ø.
              CONC(2,I,J)=Ø.
     21       CONC(6,I,J)=Ø.Ø
     2Ø       CONC(3,I,J)=DXP/SQRT(12.)
              CONC(4,I,J)=DYP/SQRT(12.)
              CONC(2,I,J)=CONC(2,I,J)+16.Ø
  1Ø3Ø        CONTINUE
C
C ... COMPLETE THE CALCULATIONS FOR  WD .
      DO 1Ø6Ø I=1,NTS
        DO 1Ø6Ø J=1,NS
              IF (WD(5,I,J).LE.Ø.) GO TO 4Ø
              WD(1,I,J)=WD(1,I,J)/WD(5,I,J)
              WD(2,I,J)=WD(2,I,J)/WD(5,I,J)
              IF (WC(I,J).LT.3.) GO TO 51
              WW=WC(I,J)/(WC(I,J)-1.Ø)
              WQ=WC(I,J)/(WC(I,J)-2.)
              WD(3,I,J)=WW*((WD(3,I,J)/WD(5,I,J))-WD(1,I,J)*WD(1,I,J))
              WD(4,I,J)=WW*((WD(4,I,J)/WD(5,I,J))-WD(2,I,J)*WD(2,I,J))
              WD(6,I,J)=WQ*((WD(6,I,J)/WD(5,I,J))-WD(1,I,J)*WD(2,I,J))
              IF (WD(3,I,J).LE.(DXP*DXP/12.)) GO TO 5Ø
              IF (WD(4,I,J).LE.(DYP*DYP/12.)) GO TO 5Ø
              WD(3,I,J)=SQRT(WD(3,I,J))
              WD(4,I,J)=SQRT(WD(4,I,J))
              WD(2,I,J)=WD(2,I,J)+16.Ø
              GO TO 1Ø6Ø
     4Ø       WD(1,I,J)=Ø.
              WD(2,I,J)=Ø.
     51       WD(6,I,J)=Ø.Ø
     5Ø       WD(3,I,J)=DXP/SQRT(12.)
              WD(4,I,J)=DYP/SQRT(12.)
              WD(2,I,J)=WD(2,I,J)+16.Ø
  1Ø6Ø        CONTINUE
C
C ... OUTPUT RESULTS.
      WRITE (9) CONC,WD,LANDE,NF,NXEM,NYEM,XEMLL,YEMLL,DXEM,DYEM,NTS
C ... DO REQUESTED PRINTING.
      DO 1Ø8Ø K=6,6
  1Ø8Ø   PRINT 2Ø9Ø,(TITLE(L,K),L=1,7),REMLBL,(J,(CONC(K,I,J),I=1,2Ø),
     %     J=IOUTST,IOUTEN)
  2Ø9Ø FORMAT('-',T15,12A8/(T6Ø,'TIME STEP'/T2,'SOURCE     1      2      '
     % ,'3      4      5      6      7      8      9     1Ø     11     12     ',
     %  '13     14     15     16     17     18     19     2Ø',
     %  55(/T2,I6,2ØF6.1),/T1,'-'))
      PRINT 2Ø9Ø,NULBL,REMLBL,(J,(DC(I,J),I=1,2Ø),
     %     J=IOUTST,IOUTEN)
      DO 11ØØ K=6,6
  11ØØ PRINT 2Ø9Ø,(TITLE(L,K),L=1,7),WDLBL,(J,(WD(K,I,J),I=1,2Ø),
     %  J=IOUTST,IOUTEN)
      PRINT 2Ø9Ø,NULBL,WDLBL,(J,(WC(I,J),I=1,2Ø),
     %  J=IOUTST,IOUTEN)
C
   11Ø REWIND 9
      RETURN
```

```
          END
//GO.FTØ9FØØ1 DD DSN=B25468.TSUM8ØHC,UNIT=ALLPERM,
// DISP=(NEW,CATLG),DCB=(LRECL=X,BLKSIZE=6144,RECFM=VBS),
// SPACE=(TRK,(1Ø,5),RLSE)
//GO.FT1ØFØØ1 DD LABEL=(19,NL,,IN),UNIT=READ625Ø,DISP=(OLD,KEEP),
// DCB=(LRECL=X,BLKSIZE=6144,RECFM=VBS),VOL=SER=2Ø1261
//GO.FT2ØFØØ1 DD DSN=JUN8Ø.PF6HR,LABEL=(7,SL,,IN),UNIT=READ625Ø,
// DISP=(OLD,KEEP),DCB=(LRECL=X,BLKSIZE=6136,RECFM=VBS),
// VOL=SER=2Ø1436
//GO.FT21FØØ1 DD DSN=JUL8Ø.PF6HR,LABEL=(8,SL,,IN),UNIT=READ625Ø,
// DISP=(OLD,KEEP),DCB=(LRECL=X,BLKSIZE=6136,RECFM=VBS),
// VOL=SER=2Ø1436
//GO.FT22FØØ1 DD DSN=AUG8Ø.PF6HR,LABEL=(9,SL,,IN),UNIT=READ625Ø,
// DISP=(OLD,KEEP),DCB=(LRECL=X,BLKSIZE=6136,RECFM=VBS),
// VOL=SER=2Ø1436
//GO.SYSIN DD *
  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø INDICATOR
  Ø  Ø  Ø  Ø123  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø ARRAY FOR
  Ø  Ø  Ø  Ø12Ø121122  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø VIRTUAL
  Ø  Ø  Ø114115116117118119  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø SOURCES OF
  Ø  Ø1Ø41Ø51Ø61Ø71Ø81Ø911Ø111  Ø  Ø  Ø  Ø  Ø112113  Ø  Ø TRAJECTORY
  Ø 87 88 89 9Ø 91 92 93 94 95 96 97 98 991ØØ1Ø11Ø21Ø3  Ø STATISTICS
  Ø 71 72 73 74 75 76 77 78 79 8Ø 81 82 83 84 85 86  Ø  Ø
  Ø 56 57 58 59 6Ø 61 62 63 64 65 66 67 68 69 7Ø  Ø  Ø  Ø
  Ø 42 43 44 45 46 47 48 49 5Ø 51 52 53 54 55  Ø  Ø  Ø  Ø
  Ø  Ø 3Ø 31 32 33 34 35 36 37 38 39 4Ø 41  Ø  Ø  Ø  Ø  Ø
  Ø  Ø  Ø 19 2Ø 21 22 23 24 25 26 27 28 29  Ø  Ø  Ø  Ø  Ø
  Ø  Ø  Ø  Ø  Ø 11 12 13 14 15 16 17 18  Ø  Ø  Ø  Ø  Ø  Ø
  Ø  Ø  Ø  Ø  Ø  4  5  6  7  8  9 1Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø
  Ø  Ø  Ø  Ø  Ø  Ø  2  Ø  Ø  Ø  Ø  3  Ø  Ø  Ø  Ø  Ø  Ø  Ø
  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  1  Ø  Ø  Ø  Ø  Ø  Ø  Ø
  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø  Ø
Ø.5ØØ                          UTROP
  6  1 8Ø  Ø  92 28            MO,DA,YR,HR OF START,# DAYS,# TIMESTEPS
 MO DA YR TI NDY NT
/*
```

Appendix B: Program VERT Listing

```
//VERT JOB REGION=210K,TIME=10,CLASS=X
//*MAIN ORG=RM080
// EXEC FGICLG
//SYSIN DD *
C       THIS PROGRAM CALCULATES THE HORIZONTALLY INTEGRATED VERTICAL
C      PROFILES OF GAS, PRIMARY AND SECONDARY PARTICLES
C      AS A FUNCTION OF TIME AFTER RELEASE (PLUME AGE).
C
C       DIURNAL AND VERTICAL VARIATIONS OF PARAMETERS ARE SIMULATED,
C      BUT NOT HORIZONTAL VARIATIONS.  TYPICAL PATTERNS OF VERTICAL EDDY
C      DIFFUSIVITY ARE SPECIFIED BY LAYER AND TIME OF DAY.  THE RATE OF
C      TRANSFORMATION FROM GAS TO PARTICLE IS A FUNCTION OF TIME OF DAY.
C      DEPOSITION VELOCITIES FOR SO2 OR NO/NO2 AND SO4 OR NO3
C      ARE SPECIFIED BY TIME OF DAY.
C
C       THE TYPICAL STABILITY CYCLE IMPLIED BY THE EDDY DIFFUSIVITIES IS
C      A NOCTURNAL INVERSION, FORMING AROUND SUNSET, DEEPENING DURING
C      THE NIGHT, AND RISING AND ERODING FROM BELOW DURING THE MORNING.
C      DURING THE AFTERNOON THE ATMOSPHERE IS UNSTABLE UP TO THE
C      SYNOPTIC-SCALE MIXING HEIGHT.
C
C       THE MODEL CAN HAVE A MAXIMUM OF 9 LAYERS WITHOUT REDIMENSIONING,
C      WITH THE NUMBER OF LAYERS AND THE LAYER THICKNESSES BEING INPUT.
C      CONCENTRATIONS ARE ALSO CALCULATED AT THE SURFACE.
C
C      THROUGHOUT THE PROGRAM, SO2/NO2 IS POLLUTANT 1, PRIMARY SO4/NO3
C      IS POLLUTANT 2, AND SECONDARY SO4/NO3 IS POLLUTANT 3.
C
C
C                              VARIABLES IN LABELLED COMMON
C
C       ABVML :  AVERAGE MASS OF S OR N ABOVE THE MIXING LAYER
C           FOR EACH TIME STEP AND POLLUTANT.
C       A123 ,. A7 , AND  A8 :  PARTIAL CALCULATIONS FOR EACH LAYER.
C       CONV :  FRACTION OF A MOLECULE COMPOSED OF S OR N (BY MASS) FOR
C           EACH POLLUTANT.
C       DCOR :  AIR DENSITY AT EACH LEVEL AS A FRACTION OF SURFACE
C           DENSITY.
C       DEPT :  DRY DEPOSITION MASS INCREMENT FOR EACH TIME STEP AND
C           POLLUTANT, FOR A UNIT EMISSION.
C       DZ :  THICKNESS OF EACH LAYER IN METERS.
C       DZD ,  DZU , AND DZZ :  PARTIAL CALCULATIONS FOR EACH LAYER.
C       EMR :  RELATIVE DIURNAL EMISSION RATE.
C       FAC :  SEASONAL FACTOR AFFECTING THE TRANSFORMATION RATE.
C       KZ :  VERTICAL EDDY DIFFUSIVITY BY LAYER AND HOUR.
C       NTS :  NUMBER OF TIME STEPS.
C       NZ :  NUMBER OF LAYERS.
C       NZ1 :  ONE LESS THAN THE NUMBER OF LAYERS.
C       SBUD :  REMAINING AIRBORNE MASS FROM A UNIT EMISSION OF
C           ATMOSPHERIC S OR N, BY TIME STEP AND POLLUTANT.
C       SOXS :  AVERAGE ONE-DIMENSIONAL SURFACE CONCENTRATION OF
C           S OR N FOR A UNIT EMISSION.
C       SRCLVL :  SOURCE LEVEL POINTER.
C       TR :  HOURLY SO2-SO4 OR NO2-NO3 TRANSFORMATION RATE.
C       USTAR :  FRICTION VELOCITY IN M/SEC.
C       VD :  DEPOSITION VELOCITIES BY AGE OF THE PLUME, HOUR OF
C           THE DAY, AND POLLUTANT.
C       VK :  VON KARMAN CONSTANT.
C       Z1 :  HEIGHT FOR SURFACE CALCULATIONS.
C       Z2 :  HEIGHT OF THE CONSTANT FLUX LAYER.
C       IPOL : POLLUTANT SYSTEM INDICATOR (1=SOX, 2=NOX)
C
C
```

```
C                                VARIABLES ONLY IN MAIN
C
C       AVADML :  AVERAGE MASS OF SOX OR NOX ABOVE THE MIXING LAYER
C           CORRESPONDING TO TRAJECTORY TIME STEPS.
C       AVBGT :  AVERAGE MASS OF AIRBORNE SOX OR NOX CORRESPONDING TO
C           TRAJECTORY TIME STEPS.
C       AVDD :  AVERAGE DRY DEPOSITION CORRESPONDING TO TRAJECTORY
C           TIME STEPS.
C       AVSFC :  AVERAGE SURFACE CONCENTRATIONS CORRESPONDING TO
C           TRAJECTORY TIME STEPS.
C       NSEASN :  CODE FOR THE SEASON (1=SUMMER, 2=AUTUMN, 3=WINTER,
C           4=SPRING).
C       NVI :  NUMBER OF VIRTUAL SOURCE LEVELS.
C
C
      COMMON /DP/ DZ(10),A123(9),A7(9),A8(9),DZD(9),DZU(9),DZZ(9)
      COMMON /R/ DEPT(168,3),SOXS(168,3),SBUD(168,3),ABVML(168,3),Z1,Z2,
     % VK,USTAR,KZ(2,9,24),VD(2,24,2),TR(24),DCOR(10),CONV(4),EMR(9,24)
      COMMON /INT/ NTS,NZ,NZ1,SRCLVL,FAC,IPOL
      DOUBLE PRECISION DZ,A123,A7,A8,DZD,DZU,DZZ
      DOUBLE PRECISION A1,A2,A3
      DOUBLE PRECISION SEASON(4),IPO(2)
      REAL AVSFC(28,3),AVDD(28,3),AVBGT(28,3),AVABML(28,3),KZ
      INTEGER SRCLVL
      DATA SEASON/' SUMMER ',' AUTUMN ',' WINTER ',' SPRING '/
      DATA IPO/' SULFUR ','NITROGEN'/
C
C ... INPUT DATA
      READ 2010,NSEASN,IPOL
 2010 FORMAT(2I3)
      NZ=9
      NTS=168
      NVI=6
      Z1=2.0
      Z2=50.0
      PRINT 2021,IPO(IPOL)
 2021 FORMAT(' CALCULATIONS FOR OXIDES OF ',A8)
      PRINT 2020,NZ,NVI,SEASON(NSEASN),NTS,Z1,Z2
 2020 FORMAT(I2,' LAYERS WITH THE BOTTOM',I2,' BEING SOURCE LEVELS.'/
     % ' MODEL',A3,'WITH',I4,' TIME STEPS.'/' SURFACE CONCENTRATIONS',
     % ' CALCULATED AT',F6.1,'M AND CONSTANT FLUX LAYER AT',
     % F6.1,'M.')
C
C
C ... SET CONSTANTS.
      VK=0.4
      USTAR=0.4
      CONV(1)=32./64.
      CONV(2)=32./96.
      CONV(3)=32./96.
      CONV(4)=96./64.
      IF (IPOL.EQ.1) GO TO 10
      CONV(1)=14./46.
      CONV(2)=14./62.
      CONV(3)=14./62.
      CONV(4)=62./46.
   10 CONTINUE
C ... CHECK PARAMETERS.
      IF (NZ.LE.9 .AND. NVI.LE.9 .AND. NSEASN.LE.4) GO TO 60
      PRINT 2050
 2050 FORMAT(' A USER-SUPPLIED PARAMETER IS TOO LARGE AND MAKES'/
     % ' EXECUTION IMPOSSIBLE.  EXECUTION HALTED.')
      STOP
   60 IF (NZ.GT.1 .AND. NVI.GT.0 .AND. NSEASN.GT.0 .AND. Z1.GT.0)
```

```
     %  GO TO 80
      PRINT 2070
 2070 FORMAT(' A USER-SUPPLIED PARAMETER IS TOO SMALL AND MAKES'/
     %  ' EXECUTION IMPOSSIBLE.  EXECUTION HALTED.')
      STOP
C
   80 NZ1=NZ-1
C
C ... READ THICKNESSES AND DENSITY CORRECTIONS.
      READ 2090,(DZ(I),I=1,NZ)
 2090 FORMAT(14F5.0)
      PRINT 2100,(DZ(I),I=1,NZ)
 2100 FORMAT(//' LAYER THICKNESSES IN M',/,20F6.0)
      READ 2090,(DCOR(I),I=1,NZ)
      PRINT 2110,(DCOR(I),I=1,NZ)
 2110 FORMAT(/' DENSITY CORRECTION',/,11F8.3/)
C
C ... INPUT DATA UNTIL PROPER FIELDS ARE READ.
      DO 1140 KKK=1,NSEASN
       DO 2121 KQ=1,IPOL
 2121  READ 2120,((VD(1,I,J),I=1,24),J=1,2)
 2120   FORMAT(12F4.4)
        IF (IPOL.EQ.1) GO TO 2122
        GO TO 2123
 2122   READ 2120,WASTE
        READ 2120,WASTE
        READ 2120,WASTE
        READ 2120,WASTE
 2123   READ 2130,((KZ(1,I,J),J=1,24),I=1,NZ)
 2130   FORMAT(12F5.1)
       DO 2124 KQ=1,IPOL
 2124  READ 2120,TR
        IF (IPOL.EQ.1) GO TO 2125
        GO TO 1140
 2125   READ 2120,WASTE
        READ 2120,WASTE
 1140 CONTINUE
C
C ... INPUT DUMMY VALUES FOR DIURNAL EMISSION VARIATION.
      DO 9934 I=1,9
       DO 9934 J=1,24
 9934 EMR(I,J)=1.0
C
C ... SET DEPOSITION VELOCITIES FOR THE FIRST 2.5 HOURS EQUAL TO
C     THOSE FOR AFTER 2.5 HOURS, UNLESS THEY ARE LESS THAN A
C     SEASONAL MINIMUM.
C ... IN SUBROUTINE INTGRT THE PRIMARY SULFATE DEPOSITION VELOCITY
C     IS SET TO 1.0 CM PER SECOND DURING THE FIRST 2.5 HOURS TO
C     ALLOW FOR GRAVITATIONAL SETTLING OF LARGE PARTICLES.
C
      GO TO (150,160,170,180),NSEASN
C ... SUMMER
  150 SO2MIN=.0030
      SO2MAX=.0050
      SO4MIN=.0020
      GO TO 190
C ... FALL
  160 SO2MIN=.0015
      SO2MAX=.0040
      SO4MIN=.0020
      GO TO 190
C ... WINTER
  170 SO2MIN=.0015
      SO2MAX=.0040
```

```
      SO4MIN=.002Ø
      GO TO 19Ø
C ... SPRING
  18Ø SO2MIN=.002Ø
      SO2MAX=.004Ø
      SO4MIN=.002Ø
  19Ø DO 12ØØ I=1,24
        VD(2,I,1)=VD(1,I,1)
        IF (VD(2,I,1).LT.SO2MIN) VD(2,I,1)=SO2MIN
        IF (VD(2,I,1).GT.SO2MAX) VD(2,I,1)=SO2MAX
        VD(2,I,2)=VD(1,I,2)
 12ØØ   IF (VD(2,I,2).LT.SO4MIN) VD(2,I,2)=SO4MIN
C
C ... PRINT DEPOSITION VELOCITIES.
      PRINT 221Ø
 221Ø FORMAT(' FIRST 2.5 HOURS OF DISPERSION')
      PRINT 222Ø,(VD(2,I,1),I=1,24)
 222Ø FORMAT(' GASEOUS DEPOSITION VELOCITY IN M/S',/,2(5X,12F7.4,/))
      PRINT 222Ø,(VD(1,I,1),I=1,24)
      PRINT 221Ø
      PRINT 223Ø,(VD(2,I,2),I=1,24)
 223Ø FORMAT(' PARTICLE DEPOSITION VELOCITY IN M/S',/,2(5X,12F7.4,/))
      PRINT 223Ø,(VD(1,I,2),I=1,24)
C
C ... SET EDDY DIFFUSIVITIES FOR THE FIRST 2.5 HOURS EQUAL TO THOSE
C     FOR AFTER THE FIRST 2.5 HOURS, EXCEPT FOR THE FIRST
C     AND SECOND LAYERS.
      DO 124Ø I=1,NZ
        DO 124Ø J=1,24
 124Ø     KZ(2,I,J)=KZ(1,I,J)
      DO 125Ø J=1,24
 125Ø   IF (KZ(2,1,J).LT.3.Ø) KZ(2,1,J)=3.Ø
C
C ... PRINT EDDY DIFFUSIVITIES AND TRANSFORMATION RATES.
      PRINT 221Ø
      PRINT 226Ø,((KZ(2,I,J),J=1,24),I=1,NZ)
 226Ø FORMAT(' EDDY DIFFUSIVITY IN METERS SQUARED PER SEC ',
     % 'BY HOUR AND LAYER',/,9(24F5.1,/))
      PRINT 226Ø,((KZ(1,I,J),J=1,24),I=1,NZ)
      PRINT 227Ø,TR
 227Ø FORMAT(' HOURLY TRANSFORMATION RATE',/,2(5X,12F7.4,/))
C
C ... CALCULATE, FOR LATER USE, FACTORS RELATED TO THE THICKNESSES
C     OF THE LAYERS.
      DO 228Ø K=1,NZ
        KU=K+1
        KD=K-1
        IF (KU.GT.NZ) KU=NZ
        IF (KD.LT.1) KD=1
        DZD(K)=(DZ(K)+DZ(KD))/2.
        DZU(K)=(DZ(K)+DZ(KU))/2.
        DZZ(K)=DZ(K)/2.
        A1=DZU(K)*(DZD(K)*DZD(K)+DZ(KD)*DZ(KD)/4.)/DZD(K)
        A2=(DZD(K)+DZU(K))*DZ(K)*DZ(K)/(4.*DZD(K))
        A3=(DZU(K)*DZU(K)+DZ(KU)*DZ(KU)/4.)
        A123(K)=A1-A2+A3
        A7(K)=(DZD(K)*DZD(K)+DZ(KD)*DZ(KD)/4.)/DZD(K)
 228Ø   A8(K)=DZ(K)*DZ(K)/(4.*DZD(K))
      FAC=2-.5*IABS(NSEASN-3)
C
C ... SET DUMMY VALUES FOR USE IN COMPUTING DIFFUSION UP ACROSS THE
C     TOP OF THE MIXING LAYER.
      DZ(NZ+1)=DZ(NZ)
      DCOR(NZ+1)=DCOR(NZ)
```

```
256.      C
257.      C ... DO FOR EACH SOURCE LEVEL.
258.            DO 139Ø SRCLVL=1,NVI
259.      C
260.              DO 129Ø I=1,168
261.                DO 129Ø J=1,3
262.                  ABVML(I,J)=Ø.
263.                  SBUD(I,J)=Ø.
264.                  SOXS(I,J)=Ø.
265.       129Ø       DEPT(I,J)=Ø.
266.      C
267.      C ...   COMPUTE THE INTEGRATED TOTALS FOR EMISSIONS FROM THE SOURCE
268.      C       LEVEL.
269.              CALL INTGRT
270.      C
271.      C ...   COMPUTE REPRESENTATIVE VALUES CORRESPONDING TO 6-HOUR
272.      C       TRAJECTORY TIME STEPS, AND OUTPUT THOSE VALUES.
273.              DO 132Ø J=1,3
274.                DO 132Ø II=1,28
275.                  I2=6*II
276.                  I1=I2-5
277.                  AVSFC(II,J)=Ø.Ø
278.                  AVDD(II,J)=Ø.Ø
279.                  AVBGT(II,J)=Ø.Ø
280.                  AVABML(II,J)=Ø.Ø
281.                  I22=I2+1
282.                  IF (I22.GT.NTS) I22=NTS
283.      C
284.                  DO 13ØØ I=I1,I2
285.                   AVDD(II,J)=AVDD(II,J)+DEPT(I,J)
286.                   AVABML(II,J)=AVABML(II,J)+ABVML(I,J)/6.Ø
287.       13ØØ       AVSFC(II,J)=AVSFC(II,J)+SOXS(I,J)/6.Ø
288.                  AVDD(II,J)=AVDD(II,J)+DEPT(I22,J)/2.Ø
289.                  IF (II.NE.1) AVDD(II,J)=AVDD(II,J)-DEPT(I1,J)/2.Ø
290.                  AVBGT(II,J)=(SBUD(I2,J)+SBUD(I22,J))/2.Ø
291.       132Ø   CONTINUE
292.      C
293.              PRINT 233Ø,SRCLVL
294.       233Ø   FORMAT(//' SOURCE LAYER',I2)
295.              PRINT 234Ø
296.       234Ø   FORMAT(' SURFACE CONCENTRATION:')
297.              PRINT 235Ø,AVSFC
298.       235Ø   FORMAT(' GAS',2(T21,14(1X,F6.5)/),' PRIMARY PARTICLE',2(T21,14(1
299.           %X,F6.5)/),' SECONDARY PARTICLE',2(T21,14(1X,F6.5)/))
300.              PRINT 236Ø
301.       236Ø   FORMAT(' MASS OF DRY DEPOSITION:')
302.              PRINT 235Ø,AVDD
303.              PRINT 237Ø
304.       237Ø   FORMAT(' MASS OF S OR N ABOVE THE MIXING LAYER:')
305.              PRINT 235Ø,AVABML
306.              PRINT 238Ø
307.       238Ø   FORMAT(' MASS OF AIRBORNE S OR N:')
308.              PRINT 235Ø,AVBGT
309.              WRITE (11) AVSFC,AVDD,AVBGT
310.       139Ø CONTINUE
311.            STOP
312.            END
313.
314.
315.
316.
317.            SUBROUTINE INTGRT
318.      C
319.      C ... DIFFUSE UNIT EMISSIONS OF SOX OR NOX ORIGINATING IN A GIVEN
```

```
C     SOURCE LAYER.
C
C
C                                VARIABLES ONLY IN INTGRT
C
C      AML :  AMOUNT ABOVE THE MIXING LAYER FOR A 1-HOUR
C          TIME STEP.
C      CP :  THE DISPLACEMENT IN METERS OF THE CENTER OF MASS OF A
C          PUFF AFTER DIFFUSION.
C      DEP :  AMOUNT OF DEPOSITION IN A 1-HOUR TIME STEP.
C      DTT :  LENGTH OF A SUBSTEP IN SECONDS.
C      FL2  AND  FL4 :  FLUXES OF GAS AND PARTICLE.
C      ID :  EQUALS 1 AFTER THE FIRST 2.5 HOURS.  EQUALS 2
C          DURING THE FIRST 2.5 HOURS.
C      L :  HOUR OF DAY BEING MODELLED.
C      M1 ,  M2 , AND  M3 :  THE FRACTION OF THE MASS ORIGINALLY IN
C          THE CURRENT LAYER WHICH HAS DIFFUSED TO THE LOWER
C          ADJACENT, THE CURRENT, AND THE UPPER ADJACENT LAYERS,
C          RESPECTIVELY.
C      NTI :  NUMBER OF SUBSTEPS IN AN HOUR.
C      ORIGHR :  HOUR OF THE DAY THE PLUME ORIGINATED.
C      P :  FRACTIONAL ALLOTMENT OF POLLUTANT PUFFS FROM EACH LAYER
C          TO THE LOWER, CURRENT, AND UPPER LAYERS FOR EACH POLLUTANT.
C      RATIO :  RATIO BETWEEN THE CONCENTRATIONS AT THE TOP OF THE
C          CONSTANT FLUX LAYER AND THE SURFACE.
C      SOX :  VERTICAL PROFILES OF SOX OR NOX.
C      TRR :  FRACTION OF GAS NOT TRANSFORMED TO PARTICLE.
C      SX :  HOLDS NEW PROFILE OF SOX OR NOX.
C      TX :  LENGTH OF A TIME STEP IN SECONDS.
C      VAR :  THE SPATIAL VARIANCE OF THE POLLUTANTS' CONCENTRATIONS.
C
C
      COMMON /DP/ DZ(10),A123(9),A7(9),A8(9),DZD(9),DZU(9),DZZ(9)
      COMMON /R/ DEPT(168,3),SOXS(168,3),SBUD(168,3),ABVML(168,3),Z1,Z2,
     % VK,USTAR,KZ(2,9,24),VD(2,24,2),TR(24),DCOR(10),CONV(4),EMR(9,24)
      COMMON /INT/ NTS,NZ,NZ1,SRCLVL,FAC,IPOL
      DOUBLE PRECISION DZ,A123,A7,A8,DZD,DZU,DZZ
      DOUBLE PRECISION SOX(10,3),F1(9),F3(9),AA,AAA,TRR
      DOUBLE PRECISION A12,A21,P(9,3,3),A1,A2,A3,AB,D,DD
      DOUBLE PRECISION RATIO(6),SX(9,3),VDD,VDU,CP,VAR
      DOUBLE PRECISION M1,M2,M3,DEP(3),AML(3)
      REAL KZ
      INTEGER SRCLVL,ORIGHR
C
C ... SET DUMMY VALUES FOR USE IN CALCULATING DIFFUSION ACROSS
C     THE TOP OF THE MIXING LAYER ASSOCIATED WITH CLOUD PENETRATION.
      SOX(NZ+1,1)=0.
      SOX(NZ+1,2)=0.
      SOX(NZ+1,3)=0.
C
      DO 1190 ORIGHR=1,24
        AML(1)=0.
        AML(2)=0.
        AML(3)=0.
C
C ...   INPUT UNIT EMISSIONS OF GAS AND PRIMARY PARTICLE INTO
C       THE SOURCE LAYERS.  PUT A VERY SMALL AMOUNT OF SOX OR NOX INTO
C       THE OTHER LAYERS TO ELIMINATE DIVISION BY ZERO.
        SOX(SRCLVL,1)=1.*EMR(SRCLVL,ORIGHR)
        SOX(SRCLVL,2)=1.*EMR(SRCLVL,ORIGHR)
        DO 1010 J=1,3
          DO 1010 I=1,NZ
            IF (I.EQ.SRCLVL .AND. J.LT.3) GO TO 1010
            SOX(I,J)=DZ(I)*1.E-10
```

```
 1010        CONTINUE
C
C ...    PRODUCE INTEGRATION TO CORRESPOND TO THE TRAJECTORY
C        CALCULATIONS.
         DO 1190 ITT=1,NTS
           ID=1
           IF (ITT.LT.4) ID=2
C
           DEP(1)=0.
           DEP(2)=0.
           DEP(3)=0.
           L=MOD((ITT+ORIGHR-2),24)+1
C
C ...      COMPUTE RATIOS BETWEEN CONCENTRATIONS AT THE TOP OF THE
C          CONSTANT FLUX LAYER AND AT THE SURFACE HEIGHT.
           DO 1020 J=1,2
             RR=VK*USTAR/VD(ID,L,J)
 1020        RATIO(J)=RR/(RR+ALOG(Z2/Z1))
           RATIO(3)=RATIO(2)
C
C ...      COMPUTE RATIOS BETWEEN CONCENTRATIONS AT THE TOP OF THE
C          CONSTANT FLUX LAYER AND AT THE SUITABLE HEIGHT FOR VD.
           DO 1021 J=1,2
             RR=VK*USTAR/VD(ID,L,J)
 1021        RATIO(J+3)=RR/(RR+ALOG(Z2/10.))
           RATIO(6)=RATIO(5)
C
C ...      COMPUTE THE LARGEST ALLOWABLE TIME INCREMENT OF INTEGRATION
C          FOR A SUBSTEP.
           TX=3600.
           DTT=TX
           RS=10000.
           DO 1030 I=1,NZ
             RR=DZ(I)/KZ(ID,I,L)
 1030        IF (RR.LT.RS) RS=RR
C
           AAA=0.
           DO 1040 J=1,3
             DO 1040 I=1,NZ1
               SS=SOX(I,J)+SOX(I+1,J)
               IF (SS.LE.1.E-06) GO TO 1040
               A1=SOX(I,J)/DZ(I)
               A2=SOX(I+1,J)/DZ(I+1)
               A12=DABS(A1-A2)*2
               A21=A1*DZ(I+1)+A2*DZ(I)
               AA=A12/A21
               IF (AA.GT.AAA) AAA=AA
 1040          CONTINUE
C
           DTT=0.1250*RS/AAA
           IF (DTT.GT.TX) DTT=TX
           NTI=TX/DTT + 0.9999
           DTT=TX/NTI
C
C ...      CHECK FLUXES.  IF EITHER IS TOO LARGE, REDUCE THE TIME STEP.
   50      FL2=VD(ID,L,1)*DTT/DZ(1)
           FL4=VD(ID,L,2)*DTT/DZ(1)
           FL4P=0.01D0*DTT/DZ(1)
           IF (ITT.LT.4) FL4=FL4P
           IF(FL2.LE.0.03 .AND. FL4.LE.0.03) GO TO 60
           NTI=NTI+NTI
           DTT=TX/NTI
           GO TO 50
C
```

```
C ...      IF FIRST HOUR, REDUCE THE TIME STEP SINCE DOING FORWARD
C          INSTEAD OF CENTERED FINITE DIFFERENCING.
   60      IF (ITT.EQ.1) DTT=DTT/2.
C
C ...      MODIFY TRANSFORMATION RATE FOR SOURCES IN BOTTOM TWO LAYERS
C          DURING THE FIRST 2.5 HOURS.
           AFAC=0.
           IF (ITT.GT.3 .OR. SRCLVL.GT.2) GO TO 70
           AFAC=0.25*(3.-SRCLVL)*(4.-FLOAT(ITT))/(FAC*FLOAT(IPOL))
   70      TRR=1.0-(TR(L)+AFAC*.01)
C
C ...      MAKE A PORTION OF THE DIFFUSIVITY CALCULATIONS.
           DO 1080 K=2,NZ
             F1(K)=2D0*KZ(ID,K-1,L)*DTT
 1080        F3(K)=2D0*KZ(ID,K,L)*DTT
           F1(1)=0.0
           F3(1)=F1(2)
           F3(NZ)=F3(NZ)*(EXP(-ABS(14.5-L)*.75)*.75+.01)
C
           DO 1150 IA=1,NTI
C
C ...        CALCULATE DIFFUSION FOR EACH LAYER AND POLLUTANT.
             DO 1110 K=1,NZ
               DO 1110 I=1,3
                 IF (SOX(K,I).LE.1.E-04) GO TO 100
C
C ...            CALCULATE THE SHIFT OF THE TOP AND BOTTOM OF THE 'PUFF'
C                WITHIN EACH LAYER.
                 KU=K+1
                 KD=K-1
C ...            USE DUMMY VALUES (STORED AS A "LAYER" ABOVE THE TOP
C                LAYER) TO CALCULATE DIFFUSION UP FROM THE TOP LAYER,
C                AND ALLOW NO DIFFUSION DOWN FROM THE SURFACE LAYER.
                 IF (KD.LT.1) KD=2
                 A1=SOX(K,I)/(DZ(K)*DCOR(K))
                 A2=SOX(KU,I)/(DZ(KU)*DCOR(KU))
                 A3=SOX(KD,I)/(DZ(KD)*DCOR(KD))
C
                 VDU=F3(K)*(A1-A2)/(A1*DZ(KU)+A2*DZ(K))
                 VDD=F1(K)*(A1-A3)/(A1*DZ(KD)+A3*DZ(K))
                 CP=(VDU-VDD)*.5
                 VAR=(DZZ(K) + 5D-1*(VDU+VDD))**2
C
C ...            CALCULATE THE FRACTIONAL ALLOTMENT AFTER DIFFUSION.
                 M3=(CP*(A7(K)-A8(K)+CP)+VAR-DZZ(K)*DZZ(K))/A123(K)
                 M1=(M3*DZU(K)-CP)/DZD(K)
C ...            FOR TOP LAYER
                 IF (K.EQ.NZ .AND. M3.LT.0.) M3=0.
C ...            FOR BOTTOM LAYER
                 IF (K.EQ.1) M1=0.
                 M2=1.-M1-M3
                 P(K,1,I)=M1
                 P(K,2,I)=M2
                 P(K,3,I)=M3
C
                 GO TO 1110
  100            P(K,2,I)=1.
                 P(K,1,I)=0.
                 P(K,3,I)=0.
 1110            CONTINUE
C
C ...        REALLOCATE DISPERSED PUFFS.
             DO 1120 J=1,3
               SX(NZ,J)=P(NZ1,3,J)*SOX(NZ1,J)+P(NZ,2,J)*SOX(NZ,J)
```

```
                  SX(1,J)=P(1,2,J)*SOX(1,J)+P(2,1,J)*SOX(2,J)
                  AML(J)=AML(J)+P(NZ,3,J)*SOX(NZ,J)
                  DO 1120 I=2,NZ1
                    I1=I-1
                    I2=I+1
 1120               SX(I,J)=P(I1,3,J)*SOX(I1,J)+P(I,2,J)*SOX(I,J)
     %                + P(I2,1,J)*SOX(I2,J)
C
C ...           REMOVE MASS LOST THROUGH SURFACE DRY DEPOSITION.
                DO 1130 J=1,3
                  JJ=J
                  IF (JJ.GT.2) JJ=2
                  IF (SX(1,J).LE.(DZ(1)*1.E-10)) GO TO 1130
                  D=10D0*VD(ID,L,JJ)*DTT*RATIO(J+3)*SX(1,J)/DZ(1)
                  IF (J.EQ.2 .AND. ITT.LT.4) D=0.01D0*DTT*RATIO(J+3)*SX(1,J)
     %             /DZ(1)
C             ALLOW NO MORE THAN 3% OF THE S OR N TO BE DEPOSITED IN
C                 ONE SUBSTEP.
                  IF (D.GT.(SX(1,J)*.03)) D=SX(1,J)*0.03D0
                  DEP(J)=DEP(J)+D
                  SX(1,J)=SX(1,J)-D
 1130             CONTINUE
C
C ...           TRANSFER NEW VALUES TO ARRAY  SOX .
                DO 1140 I=1,NZ
                  DO 1140 J=1,3
 1140               SOX(I,J)=SX(I,J)
 1150           CONTINUE
C
C ...         CALCULATE CHEMICAL TRANSFORMATION FROM GAS TO PARTICLE.
              DO 1160 I=1,NZ
                SOX(I,3)=CONV(4)*(1.-TRR)*SOX(I,1)+SOX(I,3)
 1160           SOX(I,1)=TRR*SOX(I,1)
              AML(3)=AML(3)+CONV(4)*(1.0-TRR)*AML(1)
              ABVML(ITT,3)=ABVML(ITT,3)+AML(3)
              ABVML(ITT,2)=AML(2)+ABVML(ITT,2)
              AML(1)=TRR*AML(1)
              ABVML(ITT,1)=ABVML(ITT,1)+AML(1)
C
C ...         SUM FIELDS.
              DO 1180 J=1,3
                SOXS(ITT,J)=SOXS(ITT,J)+SOX(1,J)*RATIO(J)
                DEPT(ITT,J)=DEPT(ITT,J)+DEP(J)
                AB=0.
                DO 1170 I=1,NZ
 1170             AB=AB+SOX(I,J)
 1180           SBUD(ITT,J)=SBUD(ITT,J)+AB
 1190         CONTINUE
C
C ... MULTIPLY BY CONVERSION FACTORS AND CONSTANT VALUES AND
C     COMPUTE AVERAGES.
      DO 1210 J=1,3
        DO 1210 I=1,168
          ABVML(I,J)=ABVML(I,J)*CONV(J)/24.
          SOXS(I,J)=(SOXS(I,J)/24.)/DZ(1)
          DEPT(I,J)=DEPT(I,J)*CONV(J)/24.
 1210     SBUD(I,J)=SBUD(I,J)*CONV(J)/24.+ABVML(I,J)
      RETURN
      END
//GO.FT11F001 DD DSN=B25468.VSUMMER,DISP=(NEW,CATLG),
// UNIT=LONGSHRD,DCB=(LRECL=X,BLKSIZE=6144,RECFM=VBS),
// SPACE=(TRK,(5,1),RLSE)
//GO.SYSIN DD *
  1  1  NSEASN(1=SUM,2=FAL,3=WIN,4=SPR)  IPOL(1=SOX,2=NOX)
```

```
576.      100  100  100  100  200  200  200  400  400  LAYER THICKNESS (M)
577.       1. .988 .975 .965 .950 .930 .910 .880 .840  DENSITY CORRECTION
578.      10   10   10   10   15   25   45   65   80   90   90   90  SO2 DRY DEP     SUMMER
579.      90   85   80   75   70   55   30   15   10   10   10   10  (CM/S)*100
580.       5    5    5    5    5   10   15   25   35   40   45   45  SO4 DRY DEP
581.      45   45   45   45   40   30   20   10    5    5    5    5
582.       8    8    8    8   10   15   30   45   55   60   60   60  NO/NO2 DRY DEP
583.      60   55   50   45   40   35   25   10    8    8    8    8
584.      16   16   16   16   20   30   60   90  110  120  120  120  NITRATE/HNO3 DRY DEP
585.     120  110  100   90   80   70   50   20   16   16   16   16
586.       1.   1.   1.   1.   2.   4.   8.  10.  10.  10.  10.  10.  DIURNAL
587.      10.  10.  10.  10.  10.  10.   6.   2.   1.   1.   1.   1.  PATTERN OF
588.       1.   1.   1.   1.   1.   1.   3.   7.  10.  10.  10.  10.  VERTICAL
589.      10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.  EDDY
590.       1.   1.   1.   1.   1.   1.   1.   5.  10.  10.  10.  10.  DIFFUSIV.
591.      10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.  IN METERS
592.      0.5  0.5  0.5  0.5  0.5  0.5  0.5   3.  10.  10.  10.  10.  SQUARED
593.      10.  10.  10.  10.  10.  10.   5.  0.5  0.5  0.5  0.5  0.5  PER S
594.       1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.  10.  BY HR AND
595.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.  LAYER
596.       1.   1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.
597.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
598.       1.   1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.
599.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
600.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   5.  10.
601.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
602.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   5.
603.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
604.      40   40   40   40   40   60   80  140  220  300  360  380 SO2 OXID. RATE IN %/HR
605.     400  380  360  300  220  140   80   60   40   40   40   40    TIMES 100
606.     100  100  100  100  100  150  200  350  550  750  900  950 NOX OXIDATION RATE
607.    1000  950  900  750  550  350  200  150  100  100  100  100
608.      10   10   10   10   10   20   30   40   50   60   65   65                    FALL
609.      65   55   50   45   40   35   20   10   10   10   10   10
610.       5    5    5    5    5    8   12   16   20   25   30   36
611.      36   36   36   30   25   20   10    5    5    5    5    5
612.       8    8    8    8    8   15   25   30   35   40   40   40
613.      40   35   30   25   20   15   10    8    8    8    8    8
614.       8    8    8    8    8   15   30   45   55   60   60   60
615.      60   55   50   45   40   35   20    8    8    8    8    8
616.       1.   1.   1.   1.   1.   2.   5.   8.  10.  10.  10.  10.
617.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
618.       1.   1.   1.   1.   1.   1.   2.   5.   8.  10.  10.  10.
619.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
620.       1.   1.   1.   1.   1.   1.   1.   3.   7.  10.  10.  10.
621.      10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
622.     .75  .75  .75  .75  .75  .75  .75  .75   3.  10.  10.  10.
623.      10.  10.  10.  10.  10.   5.  .75  .75  .75  .75  .75  .75
624.       1.   1.   1.   1.   1.   1.   1.   1.   1.   3.  10.  10.
625.      10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
626.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.  10.
627.      10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
628.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.  10.
629.      10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
630.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
631.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
632.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
633.       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
634.      24   24   24   24   24   24   56   80  112  140  160  180
635.     200  180  160  140  112   80   56   24   24   24   24   24
636.      60   60   60   60   60   60  140  200  280  350  400  450
637.     480  450  400  350  280  200  140   60   60   60   60   60
638.      10   10   10   10   10   10   10   30   50   60   70   70
639.      70   60   55   50   40   35   10   10   10   10   10   10
```

Appendix C: Program CONCDEP Listing

```
640.      5   5   5   5   5   5   5  12  15  18  21  24                    WINTER
641.     25  25  25  25  16  12  10   5   5   5   5   5
642.      9   9   9   9   9   9   9  30  35  40  45  45
643.     45  35  30  25  20  15   9   9   9   9   9   9
644.     15  15  15  15  15  15  15  45  70  80  80  80
645.     80  80  75  70  65  40  20  15  15  15  15  15
646.      1.   1.   1.   1.   1.   1.   1.   5.  10.  10.  10.  10.
647.     10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
648.      1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.  10.
649.     10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
650.      1.   1.   1.   1.   1.   1.   1.   1.   3.  10.  10.  10.
651.     10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
652.     .75  .75  .75  .75  .75  .75  .75  .75  .75  10.  10.  10.
653.     10.  10.  10.  10.   5.  .75  .75  .75  .75  .75  .75  .75
654.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.  10.  10.
655.     10.  10.  10.  10.   1.   1.   1.   1.   1.   1.   1.   1.
656.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.  10.
657.     10.  10.  10.  10.   1.   1.   1.   1.   1.   1.   1.   1.
658.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
659.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
660.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
661.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
662.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
663.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
664.     16  16  16  16  16  16  16  32  48  64  80  96
665.    112  96  80  64  48  32  16  16  16  16  16  16
666.     40  40  40  40  40  40  40  80 120 160 200 240
667.    280 240 200 160 120  80  40  40  40  40  40  40
668.     10  10  10  10  15  25  35  55  70  80  80  80                    SPRING
669.     80  75  70  65  60  45  30  15  10  10  10  10
670.      5   5   5   5   5  10  15  20  30  35  40  40
671.     40  40  40  40  35  25  15  10   5   5   5   5
672.      8   8   8   8   8  15  25  35  45  50  50  50
673.     50  45  40  35  30  25  20  10   8   8   8   8
674.      8   8   8   8  10  15  30  45  55  60  60  60
675.     60  55  50  45  40  35  25  10   8   8   8   8
676.      1.   1.   1.   1.  1.5   3.   7.  10.  10.  10.  10.  10.
677.     10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.
678.      1.   1.   1.   1.   1.  1.5   4.   8.  10.  10.  10.  10.
679.     10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.
680.      1.   1.   1.   1.   1.   1.   3.   6.  10.  10.  10.  10.
681.     10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.
682.     .75  .75  .75  .75  .75  .75  .75   5.  10.  10.  10.  10.
683.     10.  10.  10.  10.  10.  10.   5.  .75  .75  .75  .75  .75
684.      1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.  10.
685.     10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.
686.      1.   1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.
687.     10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.
688.      1.   1.   1.   1.   1.   1.   1.   1.   1.   5.  10.  10.
689.     10.  10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.
690.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   5.  10.
691.     10.  10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.
692.      1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   5.
693.     10.  10.  10.  10.   5.   1.   1.   1.   1.   1.   1.   1.
694.     32  32  32  32  32  56  80 120 160 200 240 280
695.    320 280 240 200 160 120  80  56  32  32  32  32
696.     80  80  80  80  80 140 200 300 400 500 600 700
697.    800 700 600 500 400 300 200 140  80  80  80  80
698.    /*
```

```
//CONCDEP JOB TIME=1,REGION=500K,CLASS=W
//*MAIN ORG=RM080
// EXEC FGICLG
//SYSIN DD *
      DIMENSION CO(6,28,123),WD(6,28,123),LANDE(19,16)
      DIMENSION SO2(51,45),SO4(51,45),DDEP(51,45),WDEP(51,45)
      DIMENSION X(51),Y(45),INDD(51,45)
      DIMENSION SOX(28,3,6),DEPT(28,3,6),SBUD(28,3,6),MAXN(12)
      DIMENSION EM(720,6),XS(720),YS(720),WF(6),EW(12)
      DIMENSION ISTPR(60),IND(51,45)
      DIMENSION AREA(60),AREAA(60),ADRY(60),AWET(60)
      REAL MAXN
      RO=6397./381.
      RO18=1.866*RO
      P2=3.14159/2.
C
C ... NSP IS THE NUMBER OF TELESCOPED TIME STEPS.
      NSP=12
C
C ... SBXX AND SBYY ARE THE VARIANCES OF A UNIFORM DISTRIBUTION ACROSS
C      A 1/3 NMC CELL, AND ARE USED IN RESOLUTION LIMITATIONS.
      SBXX=(1./3.)*(1./3.)/12.
      SBYY=(1./3.)*(1./3.)/12.
C
C ... CK1 AND OUTSID ARE USED IN REDISTRIBUTING PUFF MASS BEYOND .
C      2.5 STANDARD DEVIATIONS.
      OUTSID=1.046
      CK1=0.0175*0.3989*2.0*3.14159
      CK1=ALOG(CK1)
C
C ... FAC1 AND FAC2 ARE USED IN CALCULATING CONCENTRATION AND DEPOSITION
C      FIELDS.
      FAC1=1.E06*OUTSID
      FAC2=365.*OUTSID
C
C ... UTROP IS THE FRACTION OF SULFUR MASS REMOVED FROM
C      THE PBL BY PRECIPITATION TRANSFERRED TO THE FREE
C       TROPOSPHERE.
      UTROP=1./2.
      UT=UTROP/(1.-UTROP)
C
C ... INPUT PARAMETERS DESCRIBING CONCENTRATION/DEPOSITION GRIDS.
      NXC=51
      NYC=45
      X(1)=-10.83
      DXC=1./3.
      X0=X(1)-DXC/2.0
      Y(1)=19.833
      DYC=1./3.
      Y0=Y(1)+DYC/2.0
      DO 3333 I=2,NXC
 3333 X(I)=X(I-1)+DXC
      DO 3332 J=2,NYC
 3332 Y(J)=Y(J-1)-DYC
C
      FACX=381.*381.*2.*3.1416/(1.866*1.866)
      FACXX=381.*381.*DXC*DYC/(1.866*1.866)
C
C ... DEFINE PARAMETERS DESCRIBING TRAJECTORY PROGRAM FIELDS.
      NG=19
      MG=16
      XL=-11.5
      YL=20.5
```

```
      GX=1.Ø
      GY=1.Ø
      NTS=28
C
      DO 9Ø1 I=1,NXC
      DO 9Ø1 J=1,NYC
      SO2(I,J)=Ø.Ø
      SO4(I,J)=Ø.Ø
      DDEP(I,J)=Ø.Ø
  9Ø1 WDEP(I,J)=Ø.Ø
C
C ... NVI IS THE NUMBER OF LAYERS OF EMISSIONS.
      NVI=6
C ... IS DENOTES SEASON (1=WINTER,2=SPRING,3=SUMMER,4=AUTUMN).
      READ 7ØØ5,IS
C
C ... IND IDENTIFIES THE CONTINENT AND SUFFICIENT ADJACENT WATERS
C      FOR ISOPLETH CONTOURING.
      READ 7ØØ2,((IND(I,J),I=19,NXC),J=1,NYC)
      READ 7ØØ3,((IND(I,J),I=1,18),J=1,NYC)
 7ØØ3 FORMAT(18I2)
 7ØØ2 FORMAT(33I2)
C
C ... INDD IDENTIFIES EACH STATE AND PROVINCE.
      DO 94J JJ=1,45
      J=46-JJ
  94Ø READ (5Ø,7ØØ5) (INDD(I,J),I=1,51)
 7ØØ5 FORMAT(17I3)
C
C ... AREA CONTAINS THE ACTUAL AREA OF EACH STATE AND PROVINCE.
      READ 7ØØ6,AREA
 7ØØ6 FORMAT(1ØF6.Ø)
C
C ... ISTPR IDENTIFIES EACH STATE AND PROVINCE BY ABBREVIATION.
      READ 7ØØ7,ISTPR
 7ØØ7 FORMAT(18A4)
C
      DO 93Ø I=1,6Ø
      AREAA(I)=Ø.Ø
      ADRY(I)=Ø.Ø
      AWET(I)=Ø.Ø
  93Ø AREA(I)=AREA(I)*1.61*1.61*1Ø.Ø
C
C ... MAXN IS USED IN CALCULATING THE MAXIMUM POTENTIAL TRAJECTORIES
C      CONTRIBUTING TO A STATISTIC IN THE TELESCOPED TIME STEPS.
      READ 8Ø2Ø,MAXN
 8Ø2Ø FORMAT(12F6.1)
C
C ... EW IS USED TO WEIGHT PUFFS IN THE TELESCOPED TIME STEPS.
      READ 8Ø21,EW
 8Ø21 FORMAT(12F2.Ø)
C
C
C ... READ RESULTS OF TRAJECTORY PROGRAM.
C      IN THE TRAJECTORY PROGRAM ARRAY CO IS CALLED CONC.
      READ (1Ø) CO,WD,LANDE,NF
      XNF=NF
      DO 7ØØ J=1,123
      DO 7Ø1 I=1,23
      CO(6,I,J)=CO(6,I,J)/(CO(3,I,J)*CO(4,I,J))
  7Ø1 WD(6,I,J)=WD(6,I,J)/(WD(3,I,J)*WD(4,I,J))
C
C
C
```

```
C
C ... POST-PROCESSING OF TRAJECTORY STATISTICS TO COMPRESS TIMESTEPS.
      DO 5ØØ K=3,4
      DO 5Ø2 I=1,4
      IA=2*I+4
      IB=IA-1
      IC=I+4
      W1=CO(5,IA,J)
      W2=CO(5,IB,J)
      WA=W1+W2
      IF (WA.LE.Ø.) WA=1.
      X1=WD(5,IA,J)
      X2=WD(5,IB,J)
      XA=X1+X2
      IF (XA.LE.Ø.) XA=1.
      Y1=CO(K-2,IA,J)
      Y2=CO(K-2,IB,J)
      Z1=WD(K-2,IA,J)
      Z2=WD(K-2,IB,J)
      YY=(W1*Y1+W2*Y2)/WA
      ZZ=(X1*Z1+X2*Z2)/XA
      CC=(W1*CO(K,IA,J)*CO(K,IA,J)+W2*CO(K,IB,J)*CO(K,IB,J)+
     1 W1*(Y1-YY)*(Y1-YY)+W2*(Y2-YY)*(Y2-YY))/WA
      DD=(X1*WD(K,IA,J)*WD(K,IA,J)+X2*WD(K,IB,J)*WD(K,IB,J)+
     2 X1*(Z1-ZZ)*(Z1-ZZ)+X2*(Z2-ZZ)*(Z2-ZZ))/XA
      CO(K,IC,J)=SQRT(CC)
      WD(K,IC,J)=SQRT(DD)
  5Ø2 CONTINUE
      DO 5Ø3 I=1,4
      IA=4*I+12
      IB=IA-1
      IC=IA-2
      ID=IA-3
      IE=I+8
      W1=CO(5,IA,J)
      W2=CO(5,IB,J)
      W3=CO(5,IC,J)
      W4=CO(5,ID,J)
      WA=W1+W2+W3+W4
      IF (WA.LE.Ø.) WA=1.
      X1=WD(5,IA,J)
      X2=WD(5,IB,J)
      X3=WD(5,IC,J)
      X4=WD(5,ID,J)
      XA=X1+X2+X3+X4
      IF (XA.LE.Ø.) XA=1.
      Y1=CO(K-2,IA,J)
      Y2=CO(K-2,IB,J)
      Y3=CO(K-2,IC,J)
      Y4=CO(K-2,ID,J)
      Z1=WD(K-2,IA,J)
      Z2=WD(K-2,IB,J)
      Z3=WD(K-2,IC,J)
      Z4=WD(K-2,ID,J)
      YY=(W1*Y1+W2*Y2+W3*Y3+W4*Y4)/WA
      ZZ=(X1*Z1+X2*Z2+X3*Z3+X4*Z4)/XA
      CC=(W1*(CO(K,IA,J)*CO(K,IA,J)+(Y1-YY)*(Y1-YY))+
     1 W2*(CO(K,IB,J)*CO(K,IB,J)+(Y2-YY)*(Y2-YY))+
     2 W3*(CO(K,IC,J)*CO(K,IC,J)+(Y3-YY)*(Y3-YY))+
     3 W4*(CO(K,ID,J)*CO(K,ID,J)+(Y4-YY)*(Y4-YY)))/WA
      DD=(X1*(WD(K,IA,J)*WD(K,IA,J)+(Z1-ZZ)*(Z1-ZZ))+
     1 X2*(WD(K,IB,J)*WD(K,IB,J)+(Z2-ZZ)*(Z2-ZZ))+
     2 X3*(WD(K,IC,J)*WD(K,IC,J)+(Z3-ZZ)*(Z3-ZZ))+
     3 X4*(WD(K,ID,J)*WD(K,ID,J)+(Z4-ZZ)*(Z4-ZZ)))/XA
```

```
192.            CO(K,IE,J)=SQRT(CC)
193.            WD(K,IE,J)=SQRT(DD)
194.        5Ø3 CONTINUE
195.        5ØØ CONTINUE
196.            DO 71Ø K=1,6
197.            IF (K.EQ.3) GO TO 71Ø
198.            IF (K.EQ.4) GO TO 71Ø
199.            DO 7Ø2 I=1,4
2ØØ.            IA=2*I+4
2Ø1.            IB=IA-1
2Ø2.            IC=I+4
2Ø3.            W1=CO(5,IA,J)
2Ø4.            W2=CO(5,IB,J)
2Ø5.            WA=W1+W2
2Ø6.            X1=WD(5,IA,J)
2Ø7.            X2=WD(5,IB,J)
2Ø8.            XA=X1+X2
2Ø9.            IF (WA.LE.Ø.) WA=1.
21Ø.            IF (XA.LE.Ø.) XA=1.
211.            CO(K,IC,J)=(W1*CO(K,IA,J)+W2*CO(K,IB,J))/WA
212.        7Ø2 WD(K,IC,J)=(X1*WD(K,IA,J)+X2*WD(K,IB,J))/XA
213.            DO 7Ø3 I=1,4
214.            IA=4*I+12
215.            IB=IA-1
216.            IC=IA-2
217.            ID=IA-3
218.            IE=I+8
219.            W1=CO(5,IA,J)
22Ø.            W2=CO(5,IB,J)
221.            W3=CO(5,IC,J)
222.            W4=CO(5,ID,J)
223.            WA=W1+W2+W3+W4
224.            X1=WD(5,IA,J)
225.            X2=WD(5,IB,J)
226.            X3=WD(5,IC,J)
227.            X4=WD(5,ID,J)
228.            XA=X1+X2+X3+X4
229.            IF (XA.LE.Ø.) XA=1.
23Ø.            IF (WA.LE.Ø.) WA=1.
231.            CO(K,IE,J)=(W1*CO(K,IA,J)+W2*CO(K,IB,J)+W3*CO(K,IC,J)+
232.           1 W4*CO(K,ID,J))/WA
233.        7Ø3 WD(K,IE,J)=(X1*WD(K,IA,J)+X2*WD(K,IB,J)+X3*WD(K,IC,J)+
234.           2 X4*WD(K,ID,J))/XA
235.        71Ø CONTINUE
236.        7ØØ CONTINUE
237.            DO 7Ø I=1,12
238.            DO 7Ø J=1,123
239.            IF (WD(6,I,J).GT.Ø.99) WD(6,I,J)=Ø.99
24Ø.            IF (WD(6,I,J).LT.-Ø.99) WD(6,I,J)=-Ø.99
241.            IF (CO(6,I,J).GT.Ø.99) CO(6,I,J)=Ø.99
242.            IF (CO(6,I,J).LT.-Ø.99) CO(6,I,J)=-Ø.99
243.            CO(3,I,J)=SQRT(CO(3,I,J)*CO(3,I,J)+2.*SBXX)
244.            CO(4,I,J)=SQRT(CO(4,I,J)*CO(4,I,J)+2.*SBYY)
245.            WD(3,I,J)=SQRT(WD(3,I,J)*WD(3,I,J)+3.*SBXX)
246.            WD(4,I,J)=SQRT(WD(4,I,J)*WD(4,I,J)+3.*SBYY)
247.         7Ø CONTINUE
248.      C
249.      C
25Ø.      C
251.      C
252.      C ... READ RESULTS OF VERTICAL DISPERSION PROGRAM.
253.      C        NVI IS THE NUMBER OF EFFECTIVE EMISSION LEVELS FOR WHICH
254.      C        VERTICAL INTEGRATIONS ARE MADE.
255.            DO 1Ø J=1,6
```

```
      READ (20) ((SOX(I,K,J),I=1,NTS),K=1,3),((DEPT(I,K,J),I=1,NTS),
     # K=1,3),((SBUD(I,K,J),I=1,NTS),K=1,3)
   10 CONTINUE
      REWIND 20
C
C
C
C
C ... POST-PROCESSING OF VERTICAL INTEGRATION STATISTICS TO COMPRESS
C      TIMESTEPS.
      DO 706 K=1,NVI
      DO 706 J=1,3
      DO 707 I=1,4
      IA=2*I+4
      IB=IA-1
      IC=I+4
      SOX(IC,J,K)=(SOX(IA,J,K)+SOX(IB,J,K))/2.
      DEPT(IC,J,K)=(DEPT(IA,J,K)+DEPT(IB,J,K))/2.
  707 SBUD(IC,J,K)=(SBUD(IA,J,K)+SBUD(IB,J,K))/2.
      DO 708 I=1,4
      IA=4*I+12
      IB=IA-1
      IC=IA-2
      ID=IA-3
      IE=I+8
      SOX(IE,J,K)=(SOX(IA,J,K)+SOX(IB,J,K)+SOX(IC,J,K)+SOX(ID,J,K))/4.
      DEPT(IE,J,K)=(DEPT(IA,J,K)+DEPT(IB,J,K)+DEPT(IC,J,K)+DEPT(ID,J,K))
     $ /4.
  708 SBUD(IE,J,K)=(SBUD(IA,J,K)+SBUD(IB,J,K)+SBUD(IC,J,K)+SBUD(ID,J,K))
     # /4.
  706 CONTINUE
C
C
C
C
      GO TO 4444
C ... IS DEFINES THE APPROPRIATE SEASONAL EMISSION FIELD.
      DO 4460 L=1,IS
      READ (30) NS,NZ,((EM(I,J),I=1,NS),J=1,NZ),(XS(I),
     1 I=1,NS),(YS(I),I=1,NS),DX,DY
 4460 CONTINUE
      DO 4488 I=1,NS
      XS(I)=XS(I)+DX
 4488 YS(I)=YS(I)-DY
C
C
C
C
C ... THE GO TO 4444 STATEMENT AND THE FOLLOWING 11 STATEMENTS
C ... AND COMMENT CARDS SHOULD BE DELETED IN REAL SIMULATIONS.
 4444 NS=1
      XS(1)=-4.5
      YS(1)=15.5
      EM(1,5)=250.0
      EM(1,1)=0.0
      EM(1,2)=0.0
      EM(1,3)=0.0
      EM(1,4)=0.0
      EM(1,6)=0.0
C ... EMISSION SOURCE IS LOCATED IN EASTERN OKLAHOMA.
C ... EMISSION RATE IS 250 KT SO2 PER SEASON.
C
C
C
```

```
C
C
      SUMM=Ø.Ø
      DO 771 I=1,NS
      DO 771 J=1,NVI
      SUMM=SUMM+EM(I,J)/365.
  771 EM(I,J)=1.EØ3*EM(I,J)/365.
C ... PROGRAM BELOW REQUIRES EMISSIONS IN TONNES SO2 PER SIX HOURS.
C
C ... SUMM IS THE TOTAL EMISSION IN KILOTONNES S PER SIMULATION.
      SUMM=365.*SUMM/2.
      PRINT 2Ø47
      PRINT 8ØØØ,SUMM
C
C
C ... MAKE MAGIC CONCENTRATION AND DEPOSITION CALCULATIONS.
      DO 9999 IJ=1,NS
C
C ... DETERMINE THE TRAJECTORY VIRTUAL SOURCE APPROPRIATE FOR THE
C       EMISSION CELL.
      I1=XS(IJ)-(XL-GX/2.Ø)+1.Ø
      J1=YL-YS(IJ)+1.Ø+GY/2.Ø
      IF (I1.LT.1) GO TO 9999
      IF (I1.GT.NG) GO TO 9999
      IF (J1.LT.1) GO TO 9999
      IF (J1.GT.MG) GO TO 9999
      IF (LANDE(I1,J1).EQ.Ø) GO TO 779
      GO TO 778
  779 I3=I1-1
      I4=I1+1
      J3=J1-1
      J4=J1+1
      IF (I3.LT.1) I3=1
      IF (I4.GT.NG) I4=NG
      IF (J3.LT.1) J3=1
      IF (J4.GT.MG) J4=MG
      DO 777 K=I3,I4
      DO 777 L=J3,J4
      IF (LANDE(K,L).GT.Ø) GO TO 77Ø8
  777 CONTINUE
      GO TO 9999
 77Ø8 I1=K
      J1=L
  778 CONTINUE
      XBI=XS(IJ)-(XL+GX*FLOAT(I1-1))
      YBI=YS(IJ)-(YL-GY*FLOAT(J1-1))
      I=LANDE(I1,J1)
 8ØØØ FORMAT(' TOTAL EMISSIONS = ',F8.1,' KT S PER SIMULATION')
C
C ... PMF IS THE FRACTION OF TOTAL SULFUR EMITTED AS
C       PRIMARY SULFATE.  IT IS HIGHER IN THE NORTHEAST, FLORIDA, AND
C       IN THE FIRST EMISSION LAYER, UNDER THE ASSUMPTION
C       THAT MOST EMISSIONS THERE ARE FROM OIL COMBUSTION.
      PMF=Ø.Ø15
      IF (XS(IJ).GT.Ø.5) PMF=Ø.Ø3
      IF (YS(IJ).GT.17.5 .AND. XS(IJ).GT.-3.Ø) PMF=Ø.Ø3
C
      DO 86 M=1,NVI
   86 WF(M)=Ø.Ø
C
C ... DO-LOOP FOR THE TELESCOPED TIME STEPS.
      DO 1ØØ J=1,NSP
      JJ=J-1
      IF (J.EQ.1) JJ=1
```

```
384.      C
385.      C ... CALCULATE MASS WEIGHTING OF DRY AND WET PUFFS.
386.            TW=CO(5,J,I)/(XNF-MAXN(J))
387.            WTW=WD(5,J,I)/(XNF-MAXN(J))
388.      C
389.      C ... COMBINE EFFECTS OF EMISSIONS AT ALL LEVELS IN THE SOURCE CELL.
390.            V2=Ø.Ø
391.            V4=Ø.Ø
392.            WETF=Ø.Ø
393.            DRYF=Ø.Ø
394.            DO 95 M=1,NVI
395.            IF (EM(IJ,M).LE.Ø.) GO TO 95
396.            PMQ=PMF
397.            IF (M.EQ.1) PMQ=Ø.Ø5
398.            EMQ=1.Ø-PMQ
399.            PMQ=1.5*PMQ
4ØØ.            V2=V2+EW(J)*EM(IJ,M)*SOX(J,1,M)*EMQ
4Ø1.            V4=V4+EW(J)*EM(IJ,M)*(SOX(J,2,M)*PMQ+SOX(J,3,M)*EMQ)
4Ø2.            IF (J.EQ.1) GO TO 995
4Ø3.            DO 85 L=1,JJ
4Ø4.         85 WF(M)=WF(M)+(UT*WD(5,L,I)*(EMQ*(DEPT(JJ,1,M)
4Ø5.           1 +DEPT(JJ,3,M))+PMQ*DEPT(JJ,2,M))/(UT*WD(5,L,I)+CO(5,L,I)))
4Ø6.            WETF=WETF+EW(J)*EM(IJ,M)*(WF(M)+(SBUD(JJ,1,M)+SBUD(JJ,3,M))*EMQ
4Ø7.           # + PMQ*SBUD(JJ,2,M))
4Ø8.            WQ=UT*WD(5,JJ,I)+CO(5,JJ,I)
4Ø9.            IF (WQ.LE.Ø.) GO TO 996
41Ø.            WF(M)=WF(M)*(1.Ø-WD(5,J,I)/WQ)
411.            GO TO 996
412.        995 WETF=WETF+Ø.5*EW(J)*EM(IJ,M)
413.        996 CONTINUE
414.            DRYF=DRYF+EW(J)*EM(IJ,M)*((DEPT(J,1,M)+DEPT(J,3,M))*EMQ
415.           % + PMQ*DEPT(J,2,M))
416.         95 CONTINUE
417.      C
418.      C ... ADD BIAS BETWEEN TRAJECTORY VIRTUAL SOURCE AND EMISSION CELL TO
419.      C       PUFF CENTROID, AND DETERMINE RECEPTOR GRID RECTANGLE CONTAINING
42Ø.      C       2.5 STANDARD DEVIATION PUFF FOR CONCENTRATIONS AND DRY DEP.
421.            IF (TW.LE.Ø.) GO TO 6Ø1
422.            XB=XBI+CO(1,J,I)
423.            YA=YBI+CO(2,J,I)
424.            SCALE=CO(3,J,I)*CO(4,J,I)*FACX
425.            RO1=SQRT(1.-CO(6,J,I)*CO(6,J,I))
426.            RO2=-2.*RO1*RO1
427.            ROW=-2.*CO(6,J,I)
428.            RO1=RO1*SCALE
429.            TWR=TW/RO1
43Ø.            I1=(XB-2.5*CO(3,J,I)-XØ)/DXC + 1.
431.            I2=(XB+2.5*CO(3,J,I)-XØ)/DXC + 1.
432.            IF (I1.LT.1) I1=1
433.            IF (I2.GT.NXC) I2=NXC
434.            J1=(YØ-YA-2.5*CO(4,J,I))/DYC + 1.
435.            J2=(YØ-YA+2.5*CO(4,J,I))/DYC + 1.
436.            IF (J1.LT.1) J1=1
437.            IF (J2.GT.NYC) J2=NYC
438.            DO 99 K=I1,I2
439.            DO 98 L=J1,J2
44Ø.            IF (IND(K,L).EQ.Ø) GO TO 98
441.            NI=1
442.            FI=1.Ø
443.            IF (J.GT.1) GO TO 65
444.            NI=1Ø
445.            FI=Ø.1
446.         65 CONTINUE
447.      C ... PHI IS THE LATITUDE OF A RECEPTOR POINT.
```

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      PHI=P2-2.*ATAN(SQRT(X(K)*X(K)+Y(L)*Y(L))/RO18)
      SIG=1.Ø+SIN(PHI)
      SIG=SIG*SIG
      DO 96 INI=1,NI
C ... ACCOUNT FOR RANDOM LOCATION OF SOURCE WITHIN EMISSION CELL.
C
C
C
C
C
C ... FOLLOWING 2 STATEMENTS SHOULD BE DELETED AND THE 2 STATEMENTS
C ... FOLLOWING THEM SHOULD BE ACTIVATED IN REAL SIMULATIONS.
      X5=X(K)
      Y5=Y(L)
C     X5=X(K)-(RANF(-1)-Ø.5)*DXC
C     Y5=Y(L)-(RANF(-1)-Ø.5)*DYC
      DLX=ABS(X5-XB)/CO(3,J,I)
      DLY=ABS(Y5-YA)/CO(4,J,I)
      AA=(DLX*DLX+ROW*DLX*DLY+DLY*DLY)/RO2
      IF (AA.LT.CK1) GO TO 96
      HCON=FI*TWR*EXP(AA)/SIG
      SO2(K,L)=SO2(K,L)+HCON*V2
      SO4(K,L)=SO4(K,L)+HCON*V4
      DDEP(K,L)=DDEP(K,L)+HCON*DRYF
   96 CONTINUE
   98 CONTINUE
   99 CONTINUE
  6Ø1 CONTINUE
C
C ... ADD BIAS BETWEEN TRAJECTORY VIRTUAL SOURCE AND EMISSION CELL
C      LOCATION TO WET DEPOSITION PUFF CENTROID, AND DETERMINE THE
C      RECEPTOR RECTANGLE CONTAINING THE 2.5 STANDARD DEVIATION PUFF.
      IF (WTW.LE.Ø.) GO TO 6ØØ
      A=XBI+WD(1,J,I)
      B=YBI+WD(2,J,I)
      SCLW=WD(3,J,I)*WD(4,J,I)*FACX
      WR1=SQRT(1.-WD(6,J,I)*WD(6,J,I))
      WR2=-2.*WR1*WR1
      WROW=-2.*WD(6,J,I)
      WR1=WR1*SCLW
      WTWW=WTW/WR1
      I1=(A-2.5*WD(3,J,I)-XØ)/DXC + 1.Ø
      I2=(A+2.5*WD(3,J,I)-XØ)/DXC + 1.Ø
      IF (I1.LT.1) I1=1
      IF (I2.GT.NXC) I2=NXC
      J1=(YØ-B-2.5*WD(4,J,I))/DYC + 1.Ø
      J2=(YØ-B+2.5*WD(4,J,I))/DYC + 1.Ø
      IF (J1.LT.1) J1=1
      IF (J2.GT.NYC) J2=NYC
      DO 92 K=I1,I2
      DO 91 L=J1,J2
      IF (IND(K,L).EQ.Ø) GO TO 91
      NI=1
      FI=1.Ø
      IF (J.GT.1) GO TO 64
      NI=1Ø
      FI=Ø.1
   64 CONTINUE
      PHI=P2-2.*ATAN(SQRT(X(K)*X(K)+Y(L)*Y(L))/RO13)
      SIG=1.Ø+SIN(PHI)
      SIG=SIG*SIG
      DO 93 INI=1,NI
C
C
```

```
C
C
C
C ... FOLLOWING 2 STATEMENTS SHOULD BE DELETED AND THE 2 STATEMENTS
C ... FOLLOWING THEM SHOULD BE ACTIVATED IN REAL SIMULATIONS.
      X5=X(K)
      Y5=Y(L)
C     X5=X(K)-(RANF(-1)-Ø.5)*DXC
C     Y5=Y(L)-(RANF(-1)-Ø.5)*DYC
      WLX=ABS(X5-A)/WD(3,J,I)
      WLY=ABS(Y5-B)/WD(4,J,I)
      BB=(WLX*WLX+WROW*WLX*WLY+WLY*WLY)/WR2
      IF (BB.LT.CK1) GO TO 93
      WCON=FI*WTWW*EXP(BB)/SIG
      WDEP(K,L)=WDEP(K,L)+WCON*WETF
   93 CONTINUE
   91 CONTINUE
   92 CONTINUE
  6ØØ CONTINUE
  1ØØ CONTINUE
 9999 CONTINUE
      DO 92ØØ I=1,NXC
      DO 92ØØ J=1,NYC
      SO2(I,J)=SO2(I,J)*FAC1
      SO4(I,J)=SO4(I,J)*FAC1
      DDEP(I,J)=DDEP(I,J)*FAC2
 92ØØ WDEP(I,J)=WDEP(I,J)*FAC2
      PRINT 2Ø6Ø
      PRINT 2Ø7Ø
 2Ø6Ø FORMAT(1H1,//,' TABLE 6:  AVERAGE CONCENTRATION OF'
     1 ,' SO2 IN MICROGRAMS PER CUBIC METER')
      DO 17Ø JJ=1,NYC
      J=NYC+1-JJ
  17Ø PRINT 2Ø61,J,(SO2(I,J),I=11,5Ø)
 2Ø61 FORMAT(I3,1X,4ØF3.Ø)
 2Ø7Ø FORMAT('     11 12 13 14 15 16 17 18 19 2Ø 21 22 23 24 25 26 27 28
     $29 3Ø 31 32 33 34 35 36 37 38 39 4Ø 41 42 43 44 45 46 47 48 49 5Ø
     %')
      PRINT 2Ø62
      PRINT 2Ø7Ø
 2Ø62 FORMAT(1H1,//,' TABLE 7:  AVERAGE CONCENTRATION OF'
     2 ,' SO4 IN MICROGRAMS PER CUBIC METER')
      DO 171 JJ=1,NYC
      J=NYC+1-JJ
  171 PRINT 2Ø61,J,(SO4(I,J),I=11,5Ø)
      PRINT 2Ø62
      PRINT 2Ø7Ø
 2Ø63 FORMAT(1H1,/,' TABLE 8:  CUMULATIVE DRY DEPOSITION OF'
     3 ,' TOTAL SULFUR IN GRAMS PER SQUARE METER SIMULATION')
      DO 172 JJ=1,NYC
      J=NYC+1-JJ
  172 PRINT 2Ø64,J,(DDEP(I,J),I=11,5Ø)
 2Ø64 FORMAT(I3,1X,4ØF3.2)
      PRINT 2Ø65
      PRINT 2Ø7Ø
 2Ø65 FORMAT(1H1,/,' TABLE 9:  CUMULATIVE WET DEPOSITION OF'
     4 ,' TOTAL SULFUR IN GRAMS PER SQUARE METER SIMULATION')
      DO 173 JJ=1,NYC
      J=NYC+1-JJ
  173 PRINT 2Ø64,J,(WDEP(I,J),I=11,5Ø)
      CONDRY=Ø.Ø
      CONWET=Ø.Ø
      DO 2ØØ I=1,NXC
      DO 2ØØ J=1,NYC
```

```
      IF (INDD(I,J).LE.Ø) GO TO 2ØØ
      PHI=P2-2.*ATAN((X(I)*X(I)+Y(J)*Y(J))**Ø.5/RO18)
      SIG=1.+SIN(PHI)
      SF=SIG*SIG*FACXX
      IQ=INDD(I,J)
      IF (IQ.EQ.Ø) GO TO 2ØØ2
      AREAA(IQ)=AREAA(IQ)+SF
      ADRY(IQ)=ADRY(IQ)+SF*DDEP(I,J)
      AWET(IQ)=AWET(IQ)+SF*WDEP(I,J)
 2ØØ2 CONDRY=CONDRY+SF*DDEP(I,J)
      CONWET=CONWET+SF*WDEP(I,J)
  2ØØ CONTINUE
      DO 921 I=1,6Ø
      IF (AREAA(I).LE.Ø.) GO TO 921
      ADRY(I)=ADRY(I)*1.E-3*AREA(I)/AREAA(I)
      AWET(I)=AWET(I)*1.E-3*AREA(I)/AREAA(I)
  921 CONTINUE
C
      PRINT 9151
 9151 FORMAT(///,' CONTINENTAL DRY AND WET DEPOSITION OF TOTAL S',
     1' IN KILOTONNES')
      CONDRY=CONDRY/1ØØØ.
      CONWET=CONWET/1ØØØ.
      PRINT 915Ø,CONDRY,CONWET
 915Ø FORMAT(2F15.2)
C
C ... OUTPUT RESULTS ON FILE.
      WRITE (9) SO2,SO4,DDEP,WDEP,SUMM,ADRY,AWET
C
C ... PRINT INTEGRATED STATE AND PROVINCE DRY AND WET DEPOSITION.
      PRINT 2Ø45
 2Ø45 FORMAT(1H1)
 2Ø47 FORMAT(' JUN-AUG 198Ø')
      PRINT 2Ø46
 2Ø46 FORMAT(' TABLE 1Ø:  STATE/PROVINCE SEASONAL DRY AND',
     & ' WET DEPOSITION OF TOTAL SULFUR IN KILOTONNES')
      PRINT 2Ø44,(ISTPR(I),ADRY(I),AWET(I),I=1,6Ø)
 2Ø44 FORMAT(1ØX,A4,2F12.3)
C
      STOP
      END
//GO.FT1ØFØØ1 DD DSN=B25468.TSUM8ØHC,DISP=OLD
//GO.FT5ØFØØ1 DD DSN=B25468.ITC.DATA,DISP=OLD
//GO.FT2ØFØØ1 DD DSN=B25468.VSUMMER,DISP=OLD
//GO.FT3ØFØØ1 DD DSN=B25468.EM198ØSU.AU84,DISP=OLD
//GO.FTØ9FØØ1 DD DSN=B25468.CONDTEST,DISP=(NEW,CATLG),
// UNIT=LONGSHRD,DCB=(LRECL=X,BLKSIZE=6144,RECFM=VBS),
// SPACE=(TRK,(1Ø,5),RLSE)
//GO.SYSIN DD *
  3   IS IDENTIFIES EMISSION SEASON (1=W,2=SP,3=SU,4=F)
 Ø                          3 3 3 3
                          3 3 1 1 3 3
                          3 3 1 1 3 3
                        3 3 1 1 1 3 3
                        3 3 1 1 1 3 3
          3 3 3 3 3 3 3 3 3 1 1 3 3
 3 3 3 3 1 1 3 3 3 1 1 1 1 1 3 3
 2 2 1 1 1 1 1 1 1 1 1 1 1 1 3 3
 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3 3
```

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640.    2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
641.    2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
642.    2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
643.    2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3
644.    2 2 2 1 1 1 1 1 1 1 1 1 1 1-1 1 1 1 1 1 1 1 1 3 3
645.    2 2 2 1 1 1 1 1 1 1 1 1 1 1-1-1-1 1 1 1 1 1 1 3 3
646.    2 2 2 1 1 1 1 1 1 1 1 1 1 1-1-1-1-1-1 1 1 1 1 3 3
647.    2 2 2 2 1 1 1 1 1 1 1 1 1 1-1-1-1-1-1-1-1 1 1 1 3-1 3 3
648.    2 2 2 2 1 1 1 1 1 1 1 1 1-1-1-1-1-1-1-1-1-1 1 1-1-1-1-1 3 3
649.    2 2 2 2 1 1 1 1 1 1 1 1 1-1-1-1-1-1-1-1-1-1-1 1-1-1-1-1-1 3 3
650.    2 2 2 2 1 1 1 1 1 1 1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 3 3
651.    2 2 2 2 1 1 1 1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 3 3 3 3 3 3
652.    2 2 2 2 2-2-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 3 3 3 3 3-1 3 3 3 3
653.    2 2-2-2-2-2-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 3 3 3-1-1-1-1 3 3
654.   -2-2-2-2-2-2-1-1-1-1-1-1-1-1-1 3 3-1-1-1-1-1-1-1-1-1-1-1-1-1 3-1-1-1 3 3
655.   -2-2-2-2-2-2-2-1-1-1-1-1-1-1-1 3-1-1-1-1-1-1-1-1-1-1-1-1-1-1 3-1 3 3
656.   -2-2-2-2-2-2-2-2-1-1-1-1-1-1 3 3-1-1-1-1-1-1-1-1-1-1-1-1-1 3 3 3
657.   -2-2-2-2-2-2-2-2-2-1-1-1 3 3 3 3-1-1-1-1-1-1-1-1-1-1-1-1-1 3 3
658.   -2-2-2-2-2-2-2-2-2-2 3 3 3 3 3 3-1-1-1-1-1-1-1-1-1 3 3 3
659.   -2-2-2-2-2-2-2-2-2 3 3        3-1-1-1-1-1-1-1-1 3 3 3
660.   -2-2-2-2-2-2-2-2-2 3 3        3-1-1-1-1 3-1-1 3 3
661.   -2-2-2-2-2-2-2-2-2 3 3        3-1-1-1-1 3-1 3 3
662.   -2-2-2-2-2-2-2-2-2 3 3        3 3 3 3 3 3 3 3
663.   -2-2-2-2 3 3 3 3 3 3
664.   -2-2 3 3 3
665.   -2 3 3
666.    3 3
667.    0
668.    0
669.    0
670.    0
671.    0
672.    0
673.    0
674.    0                                   3 3 3
675.                                      3 3 2 3 3
676.                                    3 3 2 2 3 3
677.                                    3 3 2 2 2 3
678.                                    3 3 2 2 2 2
679.                                    3 3 2 2 2 2
680.                                  3 3 3 2 2 2 2 2
681.                                3 3 2 2 2 2 2 2 2
682.                              3 3 2 2 2 2 2 2 2 2
683.                              3 3 2 2 2 2 2 2 2 2
684.                          3 3 3 2 2 2 2 2 2 2 2 2
685.                        3 3 2 2 2 2 2 2 2 2 2 2 2
686.              3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
687.              3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
688.            3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
689.          3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
690.    3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
691.    3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
692.    3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
693.    3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
694.    3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
695.    3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
696.    3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
697.    3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
698.    3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
699.      3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
700.      3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2-2-2
701.        3 3 2 2 2 2 2 2 2 2 2 2 2-2-2-2-2-2
702.          3 3 2 2 2 2 2 2 2 2 2-2-2-2-2-2-2
703.            3 3 2 2 2 2 2 2-2-2-2-2-2-2-2-2
```

INDICATOR ARRAY FOR CONC/DEP GRID
(-2) INDICATES WESTERN CANADA
(-1) INDICATES EASTERN CANADA
(1) INDICATES EASTERN U.S.A.

```
704.                3 3 2 2 2-2-2-2-2-2-2-2-2  (2) INDICATES WESTERN U.S.A.
705.                  3-2-2-2-2-2-2-2-2-2-2-2  (3) INDICATES NEAR-SHORE REGION
706.                  3-2-2-2-2-2-2-2-2-2-2-2      NECESSARY FOR PLOTTING
707.                  3-2-2-2-2-2-2-2-2-2-2-2
708.                  3-2-2-2-2-2-2-2-2-2-2-2
709.                  3 3-2-2-2-2-2-2-2-2-2-2
710.                    3-2-2-2-2-2-2-2-2-2-2
711.                    3 3-2-2-2-2-2-2-2-2 3
712.                      3 3 2-2-2-2-2-2 3 3
713.                      3 3 2-2-2-2-2 3 3
714.                      3 3 2-2-2-2 3 3
715.                      3 3 2 2-2-2 3 3
716.      5160 11390  5310 15870 10420   501   206    07  5860  7300  STATE/PROV.
717.      8360  5640  3630  5630  8230  4040  4850  3320  1060   825  AREA IN TENS
718.      5820  8410  4770  6970 14710  7720 11050   930   784 12170  OF SQ. MILES
719.      4960  5270  7070  4120  6990  9700  4530   121  3110  7700
720.      4220 26730  8490   961  4080  6820  2420  5610  9790  9470
721.     25530 36630 24650  2800 15540  2110 41260   218 59490 21570
722.      AL  AZ  AR  CA  CO  CT  DE  DC  FL  GA  ID  IL  IN  IA  KS  KY  LA  ME
723.      MD  MA  MI  MN  MS  MO  MT  NB  NV  NH  NJ  NM  NY  NC  ND  OH  OK  OR
724.      PA  RI  SC  SD  TN  TX  UT  VT  VA  WA  WV  WI  WYG LKALTA  BC MAN  NB
725.    NFLD  NS ONT PEI QUESASK
726.        00    10    20    30    45    65    85   105   135   175   215   255
727.     1 1 1 1 2 2 2 2 4 4 4 4
728.    /*
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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

The Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model simulates long-range, long-term transport and deposition of air pollutants, primarily oxides of sulfur and nitrogen. The ASTRAP model is designed to combine ease of exercise with an appropriate detail of physical processes for assessment applications related to acid deposition.

The theoretical basis and the computational structure of the ASTRAP model are described. The model is evaluated with observed data, and an illustrative exercise is provided. Computer codes of the model subprograms are provided in appendices.

17. KEY WORDS AND DOCUMENT ANALYSIS

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