NOAA Technical Memorandum ERL ARL-

FISCAL YEAR 1977 SUMMARY REPORT

OF NOAA METEOROLOGY LABORATORY SUPPORT

TO THE ENVIRONMENTAL PROTECTION AGENCY

Herbert J. Viebrock, Editor

Meteorology Laboratory
Research Triangle Park, North Carolina

Air Resources Laboratories
Silver Spring, Maryland
July 1978

NOTICE

The Environmental Research Laboratories do not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to the Environmental Research Laboratories or to this publication furnished by the Environmental Research Laboratories in any advertising or sales promotion which would indicate or imply that the Environmental Research Laboratories approve, recommend, or endorse any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of the Environmental Research Laboratories publication.

PREFACE

The work reported herein was funded by the Environmental Protection Agency (EPA) under agreement EPA-IAG-D6-0305 between the EPA and the Air Resources Laboratories (ARL), National Oceanic and Atmospheric Administration (NOAA). The Meteorology Laboratory (ML) staffed with both NOAA and EPA personnel serves as the vehicle for implementing the agreement. This relationship was established in 1955 and has continued since that time.

The EPA research, development, and operational effort in air pollution meteorology is primarily performed and managed by the ML. Research activities define, describe, and study the meteorological factors important to air pollution control activities; operational support activities apply meteorological principles to assist the EPA in the evaluation and implementation of air pollution abatement and compliance programs. Research activities, which are sponsored by the Environmental Sciences Research Laboratory, EPA, and other EPA groups, are conducted within the ML and through contract and grant activities. The ML provides technical information, observational and forecasting support, and consultation on all meteorological aspects of the EPA air pollution control program to all the EPA offices, including the EPA Office of Air Quality Planning and Standards and the Regional Offices, as appropriate.

Any inquiry on the research or support activities outlined in this report should be directed to the Director, Meteorology Laboratory, Environmental Protection Agency, Research Triangle Park, NC 27711.

CONTENTS

FIGURES

TABLES

FISCAL YEAR 1977 SUMMARY REPORT OF NOAA METEOROLOGY LABORATORY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

Herbert J. Viebrock, Editor

During Fiscal Year 1977, the Meteorology Laboratory continued to provide research and operational support to the Environmental Protection Agency. Operational support provided to the Office of Air and Waste Management, the Environmental Protection Agency Regional Offices, and other Environmental Protection Agency components included review of environmental impact statements, implementation plans, and grant and contract proposals; the application of dispersion models; and conduct of dispersion studies and evaluations. Research support was in the areas of model development and application, and climatic analysis. Dispersion models for inert and reactive pollutants on all temporal and spatial scales continued under development and evaluation. Work on the description and modeling of the planetary boundary model continued following the conclusion of boundary layer meteorological field experiments in the St. Louis area. The field experiment portion of the Regional Air Pollution Study ended and the evaluation and validation of regional air quality simulation models was begun. The Fluid Modeling Facility conducted experiments on the flow over hills and ridges and on plume rise in calm stably-stratifed atmospheres. A field program was begun to study the dispersion of pollutants in complex terrain surrounding the Clinch River Power Plant near Carbo, VA. Climatic studies included an analysis of the relationships between pollutant concentrations, such as sulfates and ozone, and meteorological parameters; an examination of the relationship air quality and the optical properties of the atmosphere; and continuation of the preparation of a climatology of effective chimney heights.

1.0 INTRODUCTION

The Environmental Protection Agency's (EPA) research and development effort in air pollution meteorology is performed and managed primarily by the NOAA Meteorology Laboratory (ML). The ML also provides operational meteorological support and technical assistance to various EPA organizational components. The ML effort during 1977 fiscal year was approximately evenly divided between research and operational support, even though the research effort will receive greater coverage in this report. During the fiscal year, the ML research program, which was sponsored by the Environmental Sciences Research Laboratory, EPA, was divided into two major areas: model development and evaluation, and air quality and meteorology.

2.0 RESEARCH ACTIVITIES

2.1 Meteorology Laboratory Research Projects

2.1.1 Empirical urban mixed layer growth model

An empirical mathematical model has been developed to predict the growth of the urban mixed layer during the morning transitional period in summer. The data base consisted of mixing heights, defined as the base of the nocturnal inversion, which were determined from temperature profiles obtained during the Regional Air Pollution Study boundary layer field studies in St. Louis, MO. Details and objectives of the boundary layer field program can be found in the Fiscal Year 1976 Report (Viebrock, 1977). Data selected for this study was obtained at an urban location about 2 km. west of downtown St. Louis and a rural site located near Bi-State Parks Airport, an 'undeveloped' area approximately 6 km. southeast of the city. Mixing heights were limited to sunny morning experiments. Figure 1 shows the variation in the depth of the morning base near sunrise. Figure 2, however, reveals the more typical surface-based inversions common to non-urban areas near dawn. A second order least squares polynomial expression was fitted to each data set to model the mean mixed layer growth. The results are

$$h_u(t) = 163.5 - 16.8t + 25.6t^2 \tag{1}$$

$$h_r(t) = 25.8t + 23.7t^2. \tag{2}$$

Figures 1 and 2 show the quadratic curves model the mixed layer growth quite well with correlation coefficients of 0.89 and 0.92 at the urban and rural sites, respectively. Figure 3 reveals the mixing height grows more rapidly in the rural location and attains the same height as at the urban site near the time of nocturnal inversion break-up. The difference between the urban and rural mixing heights, Δh_{U-R}, is also shown in Figure 3 as the dashed line and is given by

$$\Delta h_{U-R}(t) = 164.9 - 20.7t - 1.7t^2 \tag{3}$$

Further analysis of the urban data indicated the urban mixed layer growth to depend on the inital mixed layer depth, h_o, at sunrise. A mixed layer growth model for the urban site which only requires a knowledge of h_o is given by

$$h_u(t) = h_R(t) + \frac{h_o}{A}\left(\Delta h_{U-R}(t)\right) \tag{4}$$

where A = 160 meters is the mean summer mixed layer depth in St. Louis at sunrise and $h_R(t)$ and $\Delta h_{U-R}(t)$ are given by (2) and (3), respectively. The model was evaluated against the observed urban mixing height data and had a standard error of estimate of 56 meters with a mean error of less than 20% in predicting the urban mixing height for each hour after sunrise. A more

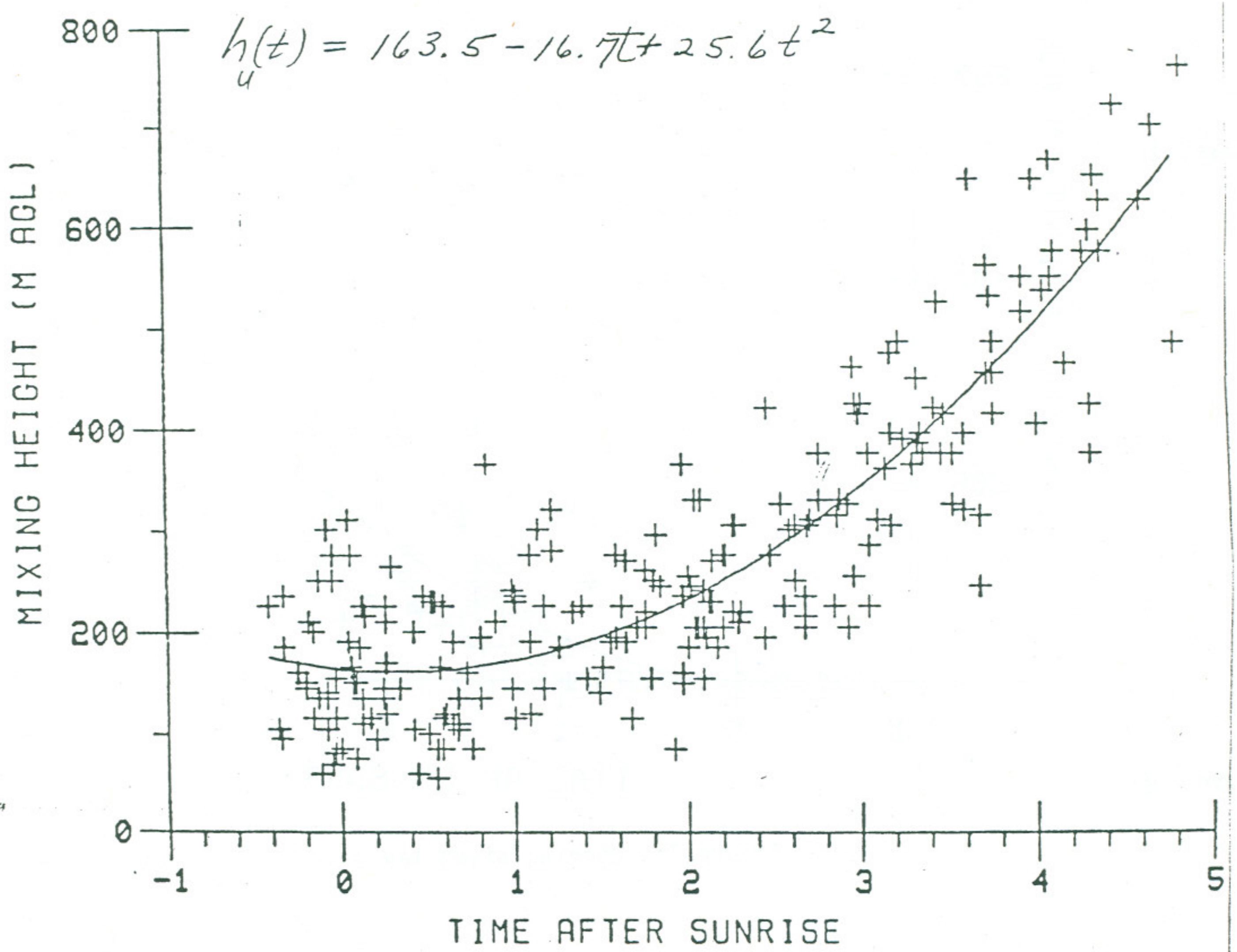

Figure 1: Morning mixed layer at an urban site

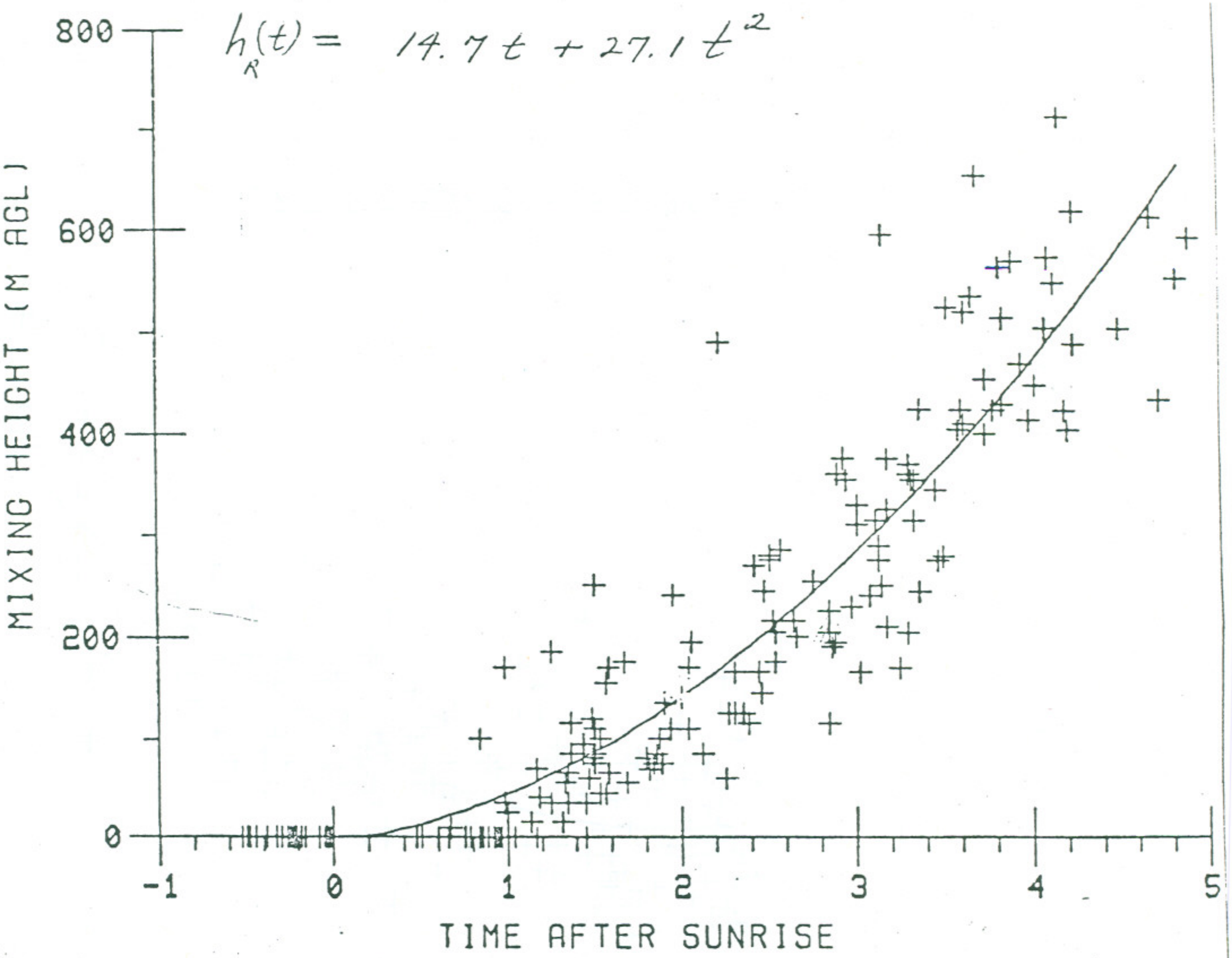

Figure 2: Morning mixed layer at a rural site

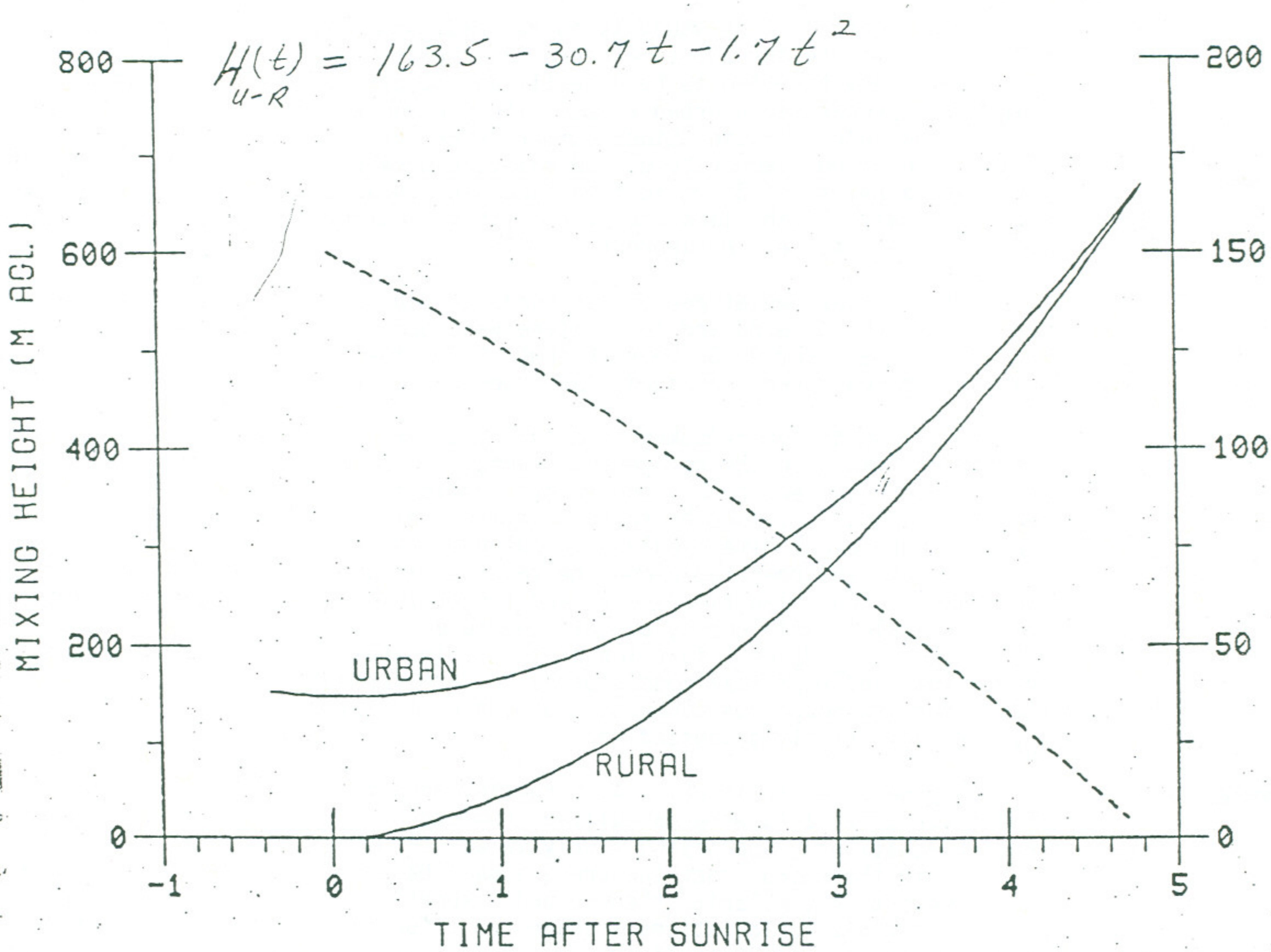

Figure 3: Comparison of urban and rural mixing layer heights prior to nocturnal inversion break-up. The dashed line is the difference between the urban and rural mixing layer heights.

general model is envisioned when data from other sites of different land uses and for different seasons are incorporated into this study.

2.1.2 Turbulent structure of the urban surface boundary layer

The purpose of this study is to describe and parameterize through data representation the turbulent boundary layer over a city: St. Louis, Missouri. The results are expected to be directly applicable to modeling air flow and dispersion processes in urban areas. The program was initiated in 1976 within the Regional Air Pollution Study summer intensive field study. Measurements of turbulent wind, temperature, and moisture were obtained over a five week period at a height of 30 mm in five land use areas: a rural site and four urban sites. Details of the land use at the sites, instrumentation, and field procedures are contained in Viebrock, (1977).

A fall experimental period was conducted in St. Louis. Similar measurements of turbulent wind and temperature were obtained at the rural site and two urban sites from 26 October through 20 November 1977. Data for both summer and fall seasons were processed. Analyses of the processed data was begun.

According to Monin-Obukhev similarity theory the statistics of equilibrum atmospheric flows in the homogeneous surface layer are completely determined by the roughness length, z_o, the friction velocity, U_*, and the Monin-Obukhev length, L. Hourly values of these quantities along with turbulent moments, fluxes and relevant dimensionless turbulence parameters were computed from the data base and compared among the various sites on a diurnal basis for the two seasons. Eulerian time/scales and spectral characteristics are being determined along with energy budgets and relationships between various parameters (e.g., σ_w/U_* as a function of z/L). The results will be tested against theoretical and empirical models based on data for homogeneous, fully developed flows over low roughness elements. Some preliminary results for z_o and $\sigma_u,v,w/\overline{U}$ are briefly discussed here.

Roughness length is physical parameter dependent only on characteristics of the surface. z_o's were calculated from the Nickerson-Smiley (1975) wind profile equation by specifying hourly values of $\overline{U}$, U_*, and z/L. Thus it is implicit in the method that the present data base can be parameterized within the framework of similarity theory, and assumption yet to be demonstrated. Results of the z_o calculations averaged as a function of wind direction are presented in Fig. 4. Site 109 is in a rural area while 105, 107, and 111 are urban sites.

Roughness lengths, as might be expected in a complex urban environment, appear to vary markedly with wind direction. Values averaged over all the data for a given site have the same, although somewhat lower, relative values as obtained using Kutzbach's (1961) technique based on a visual site survey. A similar analysis for the fall data demonstrated the same trend of z_o among the the three sites, however, values were lower at those sites where deciduous vegetation was believed to be an important factor in the roughness during the summer period (sites 107 and 109).

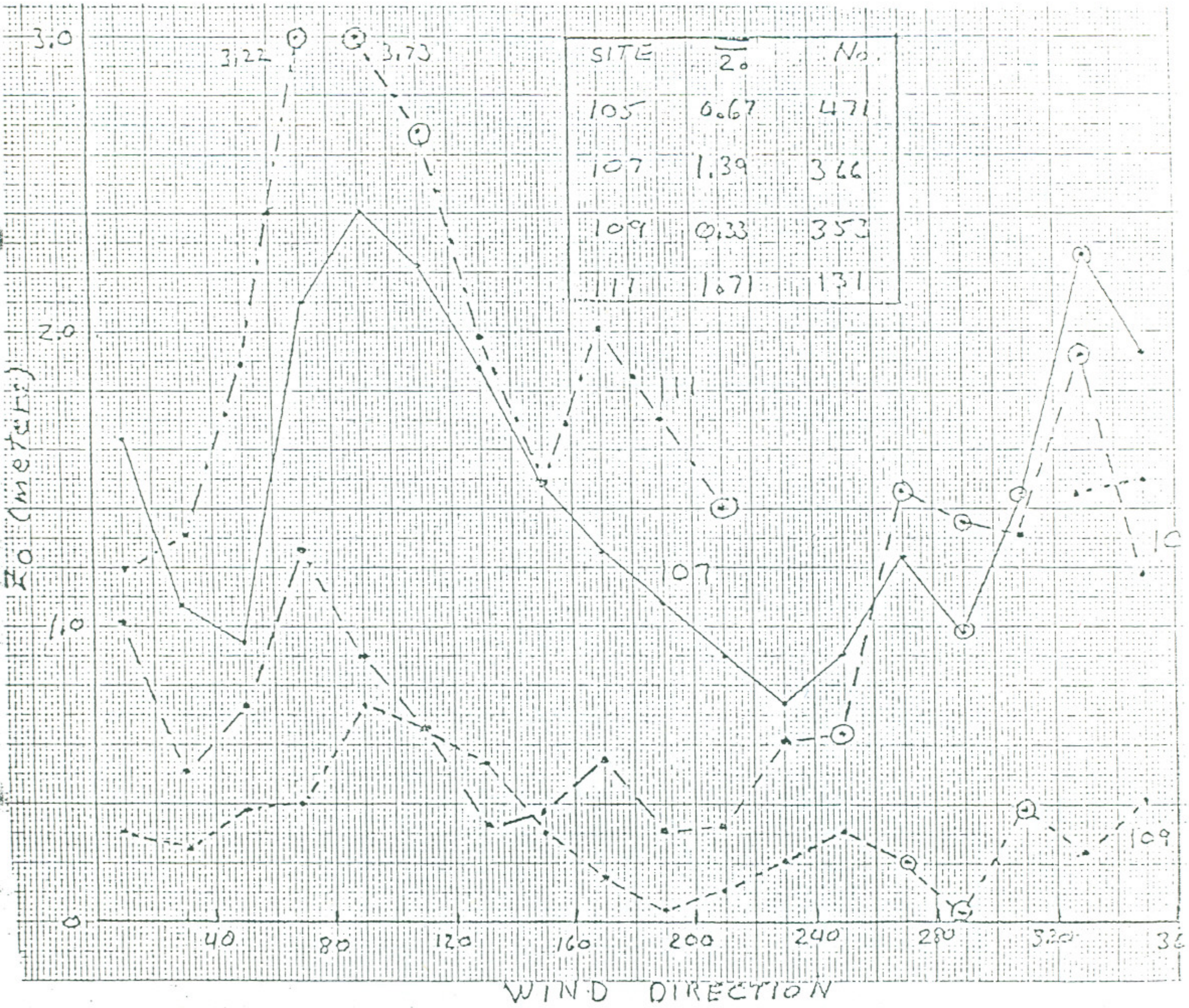

Figure 4: z_0 as a function of wind direction for four land use areas. Circles points indicate four or less values in the average. Number of cases and average z_0 for each site are given in the inset.

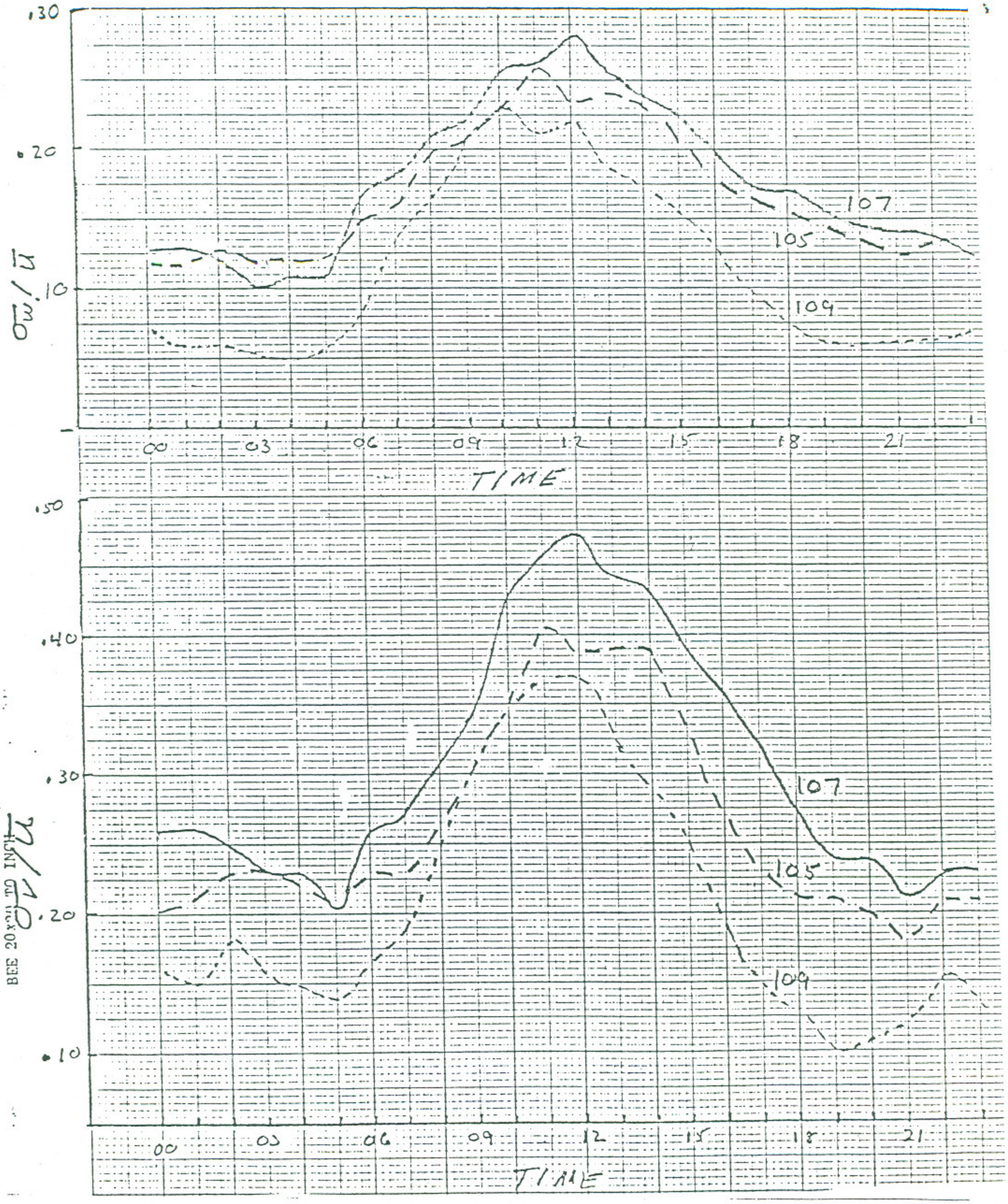

Figure 5: Average value of $\sigma_W/\overline{U}$ (top) and σ_V/U by hour of the day for three land use areas.

The vertical and crosswind components of turbulence intensity ($\sigma_w, v/\overline{U}$) can be related to atmospheric diffusion coefficients through the Taylor diffusion theory. Hourly average values of $\sigma_w/\overline{U}$ and $\sigma_v/\overline{U}$ over the diurnal cycle for the summer period are presented in Fig. 5 for a rural site (109, $\overline{z}_o$ = 0.33m) and two urban sites (105, z_o = 0.67m and 107, z_o = 1.39m). Clearly, turbulence intensity, and consequently diffusion, is a function of surface roughness. Other analyses of both the summer and fall data sets indicates intensity to be nearly a linear function of surface roughness for neutral atmospheric stability. $\sigma_w/\overline{U}$ and to a lessor extent $\sigma_w, v/\overline{U}$ appears to a well defined function of z/L in the range of +:5 to -1.

2.1.3 Inversion rise and sensible heat flux in St. Louis

The strength and vertical displacement of the base of the nocturnal inversion is strongly dependent on the magnitude and variation of the surface sensible heat flux. The objective of this study is the analyses of these changes for the period immediately after sunrise which is characterized by changes in both the depth of the mixed layer and the heat flux. This period was analyzed from data collected during the 1976 Regional Air Pollution Study intensive boundary layer field program. Details of that program can be found in Viebrock (1977).

The analyses difficulties are compounded by the fact that large spatial variation exists due to contrasting land use variations in St. Louis. In order to study these temporal and spatial variations, the enthalpy budget technique was used to estimate the the sensible heat fluxes:

$$H_o - H_h = \int_0^h \frac{\partial \theta}{\partial t}\, dz + \int_0^h \vec{V} \cdot \nabla_h \theta \, dz + \int_0^h w \frac{\partial \theta}{\partial z}\, dz$$

where H_o and H_h are the heat flux at the surface and at h, the top of the mixed layer, respectively, and θ is the potential temperature. Radiative flux divergence was neglected. Vertical and horizontal temperature data required in the budget calculations were obtained from vertical soundings from an instrumented helicopter which spiraled over the various sites for a 4 to 5 hour period after sunrise. The surface temperature and winds were obtained from the 30m tower data while the mixed layer winds were derived from pibal data at a site near downtown St. Louis. H_h was assumed proportional to H_o. h, the height of the base of the elevated nocturnal inversion was found to vary both as a function of time after sunrise and also with distance from downtown St. Louis. These variations were factored into the calculation scheme. It was noticed that the rate of change of h with time was greater away from the center of the city where h initially was greatest.

The spatial variation of the sensible heat flux as well as its local and advective components were examined for one case study. Both components contribute positively to the heat flux near the center of the city while the area west of the city indicates a negative contribution. This reversal of the sign of the advective heating accentuates the spatial variation of the heat flux due to the local heating rate term. The cold air advection within 10 km of the urban center is replaced by warm air advection from about 15 km west of the city.

The vertical variation of the heat flux, and its local and advective heating components were examined for an urban site located within 5 km of the city center and for a site in a semi-industrial urban area about 15 km west of the urban site. The vertical variation at the urban site appears linear suggesting that the temperature changes uniformily with height during this period. There is curvature near the top of the mixed layer at the non-urban site primarily due to the non-linear vertical variations of the advection term in this case. Also, the boundary layer at the urban site is dryer at this time reflecting the difference in the mixed layer noted earlier. Also the advectin term is negative throughout most of its boundary layer at the non-urban site in contrast to the urban site. Finally the flux divergence, or equivalently, the net heating rate $\frac{d\theta}{dt}$ is seen to be about twice as large at the urban site (0.9 $\frac{watts}{m3}$) vs. 0.4 at the non-urban site. Further studies are in progress with other data sets to test the generality of this case study.

2.1.4 Boundary layer radiative transfer model

The 12 interval model of Binkowski (1976a) has been improved in several ways. First, the number of spectral intervals has been reduced to 5 by combining intervals, but, however retaining the original intervals for the 8 to 13 micron window and for the water vapor carbon dioxide overlap. Second the specification for the absorption in the window has been changed by using the parameters recommended by Roberts et al. (1976). Third, the upper boundary condition has been changed from a crude emissivity. An isothermal layer is assumed to exist above the top boundary of the computational domain which may be any where between 12 and 16 km. The amount of ozone and water vapor and carbon dioxide in the isothermal layer are obtained by specifying which of 5 standard atmospheres (McClatchey, et al., 1972) is to be used. Fourth, aerosols and clouds are included in the model only in the 8 to 12 micron window. Extensive testing and validation are under way.

2.1.5 Photochemical box model

The development and verification of a Photochemical Box Model (PBM), begun in 1976, was continued through 1977. The earlier work on the PBM concentrated on setting up a model framework, implementing the various components of the model, and some preliminary testing using the St. Louis RAPS data base. The emphasis during this year has been on the refinement of particular model components, particularly chemistry, emissions, and mixed layer growth, and on the systematic verification of the PBM with the RAPS data base. In conjunction with the latter task, algorithms have been developed for the efficient processing of the Regional Air Pollution Study data base to aid in forming inputs of boundary and initial species concentrations.

The PBM may be considered as a single-cell reactor volume centered over an urban area with appropriate pollutant species fluxes at each boundary.

The structure of the model is schematically illustrated in Figure 6. Figure 6 shows all fluxes in the horizontal aligned along the prevailing wind direction through the cell into the box, the advection inflow and outflow parameters, the dilution effect of the expanding volume of the box as the mixed layer rises as well as the entrainment of any pollutant species aloft, and the production and/or destruction of species due to chemical reactions within the volume. Assumptions implicit in the use of the box model include horizontal homogeneity and one-hour stationarity of emissions sources, existence of a prevailing wind throughout the box, instantaneous mixing in the vertical, and negligible horizontal diffusion.

The generalized chemical kinetic mechanism within the PBM describes the HC (5 lumped classes: 4 reactive) -NO_x - O_3 photo-oxidation cycle with 24 species in 38 reactions. Each species being simulated is accounted for in the model by an ordinary differential equation composed of advective, volume expansion, chemical, and emissions terms. The set is solved numerically in time using a version of the Gear routine (1971).

Diurnally-varying photolytic rate constants for NO_2, HONO, and aldehydes are required by the chemical kinetic mechanism. They are calculated by one of the PBM's preprocessors wherein the rate constant for NO_2, k_1, is determined by an empirical method based on the functional relationship between k_1 and total solar radiation from Saegar (1977). The other photolytic rate constants are computed by scaling their theoretical values from Schere and Demerjian (1977) by the ratio of k_1 (empirical)/k_1(theoretical).

A second preprocessor sets up hour-averaged winds within the modeling domain and also computes initial and boundary pollutant concentrations. The diurnal growth of the mixed layer in the model is controlled by a piecewise-linear function where the morning minimum mixed layer depth and the afternoon maximum are reference inputs for the function. The minimum depth may be obtained from the 12Z NWS sounding and the afternoon maximum may be estimated from Holzworth's method (1972).

The major (local) forcing function in the model is the emissions term. Source emissions originate from area, line, and point sources. The HC-NO_x-O_3 reaction system in the PBM is most sensitive to the mobile source emissions. These represent a major portion of the total emissions eminating from an urban area. The source emissions inventory used by the model has been adapted from the National Emissions Data Systems (NEDS). The yearly NEDS emissions rates were subdivided equally into daily rates, and a diurnal traffic curve was then superimposed upon these rates. A newly formulated source emissions inventory for the model test area of St. Louis will be available shortly. This inventory will be incorporated into the PBM.

Initial model application has centered on the St. Louis area and the Regional Air Pollution Study data base including 25 Regional Air Monitoring Study (RAMS) stations providing surface-based meteorological and air quality data. The modeling domain is described by a 20km x 20km x H volume centered on the downtown area, where H is the temporally varying depth of the mixed layer. The domain includes most of the emissions sources for the St. Louis area as well as twelve of the RAMS stations. Nine of the remaining stations are available for determining the background inflow conditions.

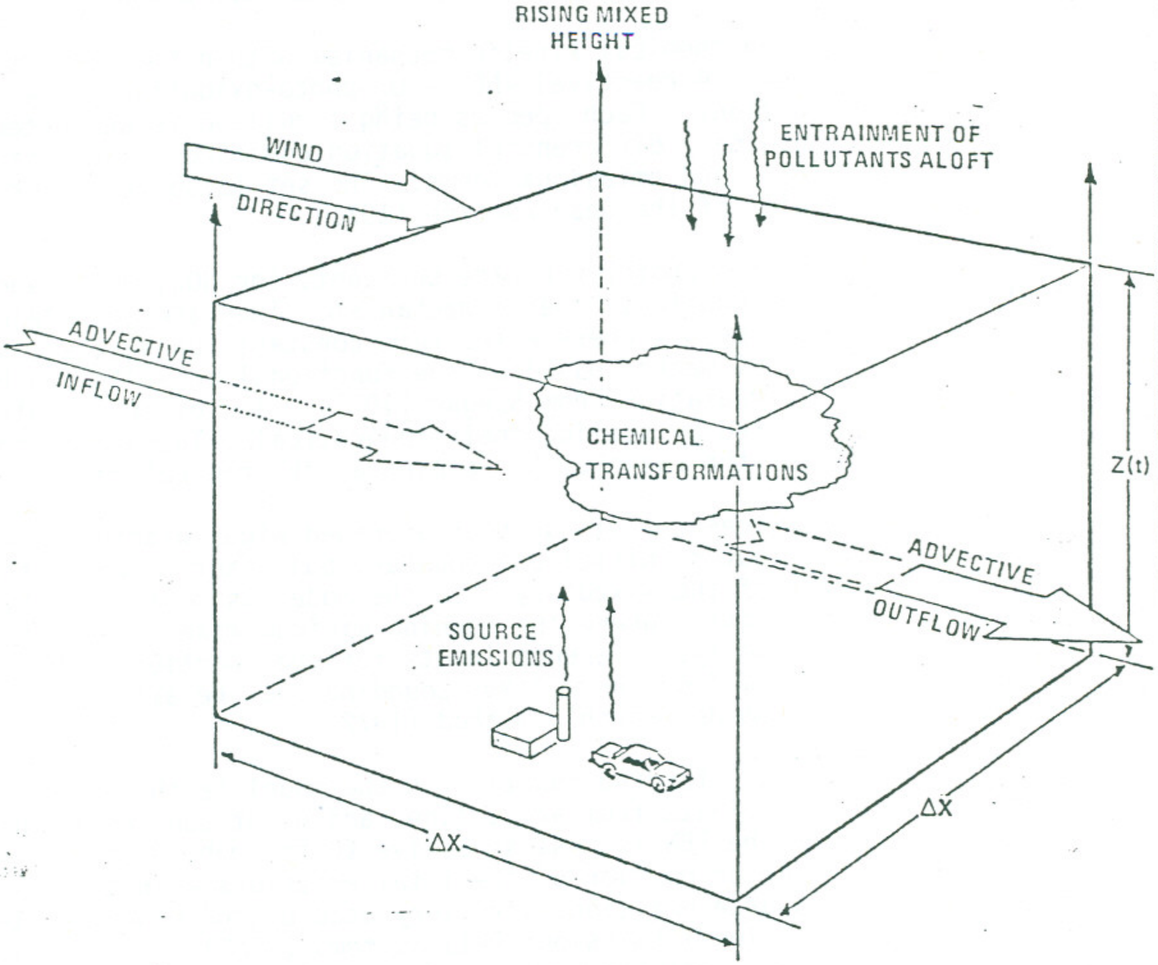

Figure 6: Schematic diagram of modeling domain for the Photochemical Box Model.

Model simulation periods for the PBM should occur on mostly sunny weekdays with a prevailing wind direction. Ten test cases were chosen from the period of June through August 1976 when all required input data were available. Simulation results for the non-reactive species have been quite good and those of the reactive species have been more variable. As an example, consider the model simulation results for July 23, 1976 for O_3 in Figure 7. The concentration envelope represents the total range of concentrations observed at any given hour over the RAMS stations within the modeling domain. Simulation results seem rather poor here. It was later learned however that substantial amounts of O_3 were entraining into the mixed layer from aloft on this day. The model was rerun with an O_3 entrainment term proportional to the observed concentrations aloft. The improved simulation results for this run are displayed in Figure 8. This illustrates another factor (entrainment) which may have a demonstrative effect on an air quality simulation model, and the ability of the PBM to adapt to it.

Further model testing on the RAMS data base is planned with the inclusion of the new emissions inventory. Updates of selected chemical kinetic mechanism parameters will be performed as new information becomes available.

2.1.6 Gridded emissions for long-range transport

The gridded point source emission rates of the five criteria pollutants were apportioned to grid squares on the 35 by 30 grid network (for use with a long-distance transport model) using only estimated emission rates from NEDS. Emission maps for the long-range transport model were constructed using either estimated or calculated point source emission rates. Calculated emission rates were regarded to be more accurate than estimated emission rates if the latter were determined either by a guess of the emission factors for AP-42. The gridded area source emission maps were based upon calculated emission rates.

A listing was compiled of those point sources in NEDS (nearly 200 within the grid domain) emitting more than 50,000 tons of any of the five criteria pollutants in the period of one year. Many of these sources were listed as emitting more than 100,000 tons per year of one or more of the pollutants. The NEDS contacts at the respective EPA Regional Offices were notified about those sources with extremely high emission rates and asked to verify the figures. They were also informed of the significant number of errors in source locations in NEDS.

In addition point and area source emission rates (tons per year) for the five criteria pollutants have been gridded onto 20 by 20 grid maps with a spacing of approximately 40 km encompassing much of the northeast United States and southeast Ontario (Figure 9). The grid domain includes the area from Fredericksburg, Virginia to Ottawa, Ontario and from Cleveland, Ohio to Portsmouth, New Hampshire. The emission rates and location of the sources were extracted from the NEDS data base.

These gridded emissions data will be used in future air pollution studies. One study will examine the effects on urban air quality from the emissions from downwind urban centers.

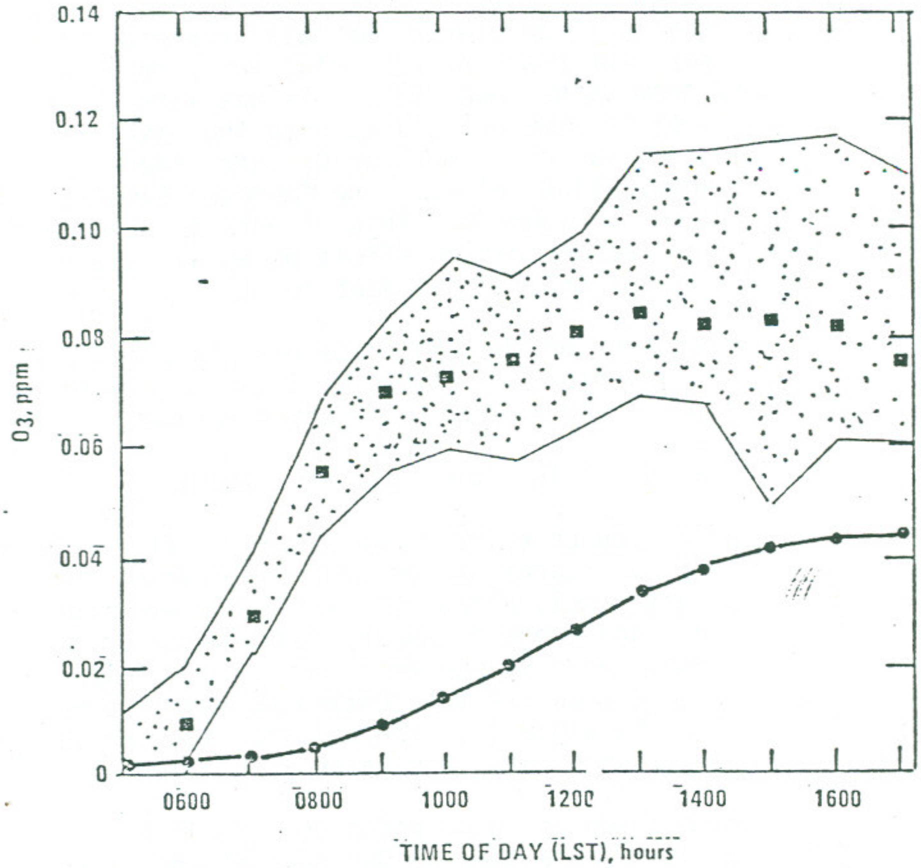

Figure 7: Hour averaged model predictions (circles) and observed concentrations (squares) for O_3 for July 23, 1976 at St. Louis. Concentration envelope is indicated by shaded area.

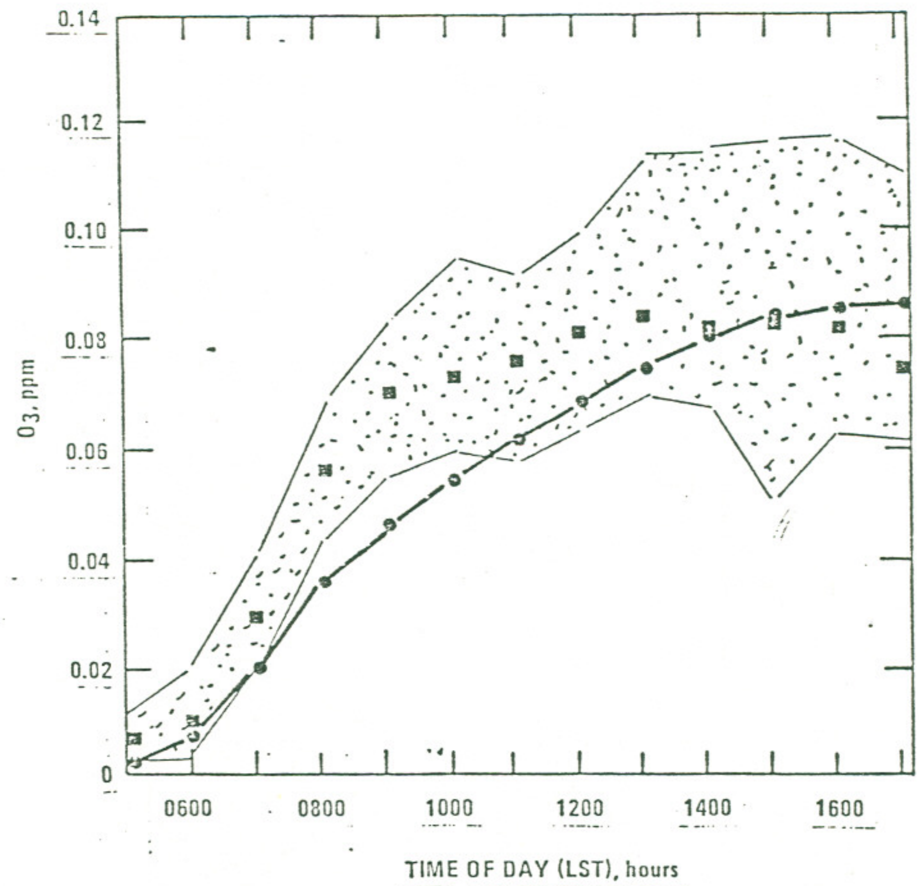

Figure 8: Hour averaged model predictions (circles) and observed concentrations (squares) for O_3 for July 23, 1976 at St. Louis with vertical entrainment of O_3 included. Concentration envelope is indicated by shaded area.

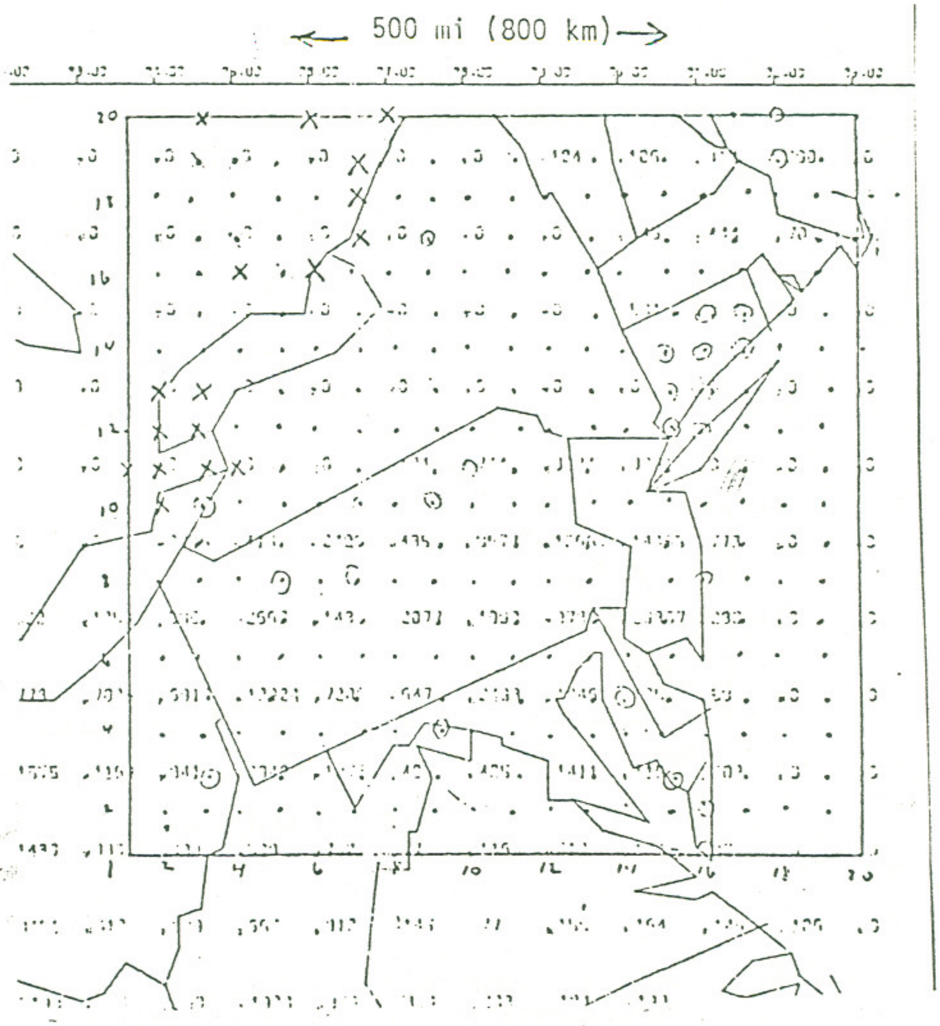

Figure 9: Grid for Northeast emission rates.

2.1.7 Source-transport-receptor analysis model (STRAM)

The Source-Transport Receptor Analysis Model (STRAM) (Hales, et al., 1977), developed under EPA support, was executed on the UNIVAC computer and tested using uniform wind fields.

The model is composed of two programs: 1) a supportive program that generates layer-averaged wind fields from upper-level wind reports obtained at regular intervals and 2) a variable trajectory, reactive plume-segment model for ground level air pollution assessments resulting from multi-source emissions on a multi-state scale.

The wind field and the advective process are determined on a grid network with a resolution not greater than the grid used to calculate the diffusion, dry and wet depletion, and the reactive chemistry. The former grid is limited to a 17 by 13 grid configuration while the latter grid is limited to a 13 by 13 configuration.

Sulfur transport and transformation to SO_4 will be modeled by a 13 by 13 grid network with approximately a 20 km grid spacing encompassing much of northern Tennessee, western Kentucky and southern portions of both Illinois and Indiana (Figure 10). The emission rates of SO_2 and stack heights of the Shawnee and Paradise steam plants in Kentucky and the Johnsonville, Cumberland, and Gallatin steam plants in Tennessee have been obtained from NEDS. Uniform hourly changes in mixing heights and stability will be considered.

Wind fields have been constructed for the first five days of August 1974. The model was run for 72-hours (August 1-4) and the results are being examined. Morning mixing heights were estimated each day from Nashville, Tennessee radiosonde data. Hourly changes in the mixing heights and atmospheric stability were subjectively estimated from hourly meteorological conditions at Nashville.

The output of the model consists of a print-out of surface concentrations of both SO_2 and SO_4 at 12-hour intervals at each of the 169 grid points and a maximum of ten user-located receptors. In addition, fields of maximum concentrations and average concentrations for the two pollutants over the entire period are printed.

In the future more model executions will be made. It is hoped that a better understanding of the relationship between SO_2 and SO_4 concentrations in regions where large SO_2 sources are located can be achieved.

2.1.8 Urban-rural differences in wind speed and direction

The difference between urban and surrounding rural areas may, at a minimum, be defined in terms of the surface roughness and the heating rates. The existence of the heat island and roughness contrast may conceivably influence the relation between mean winds recorded simultaneously in the city and the adjacent countryside. Because the understanding of the systematic variation of winds around St. Louis is important when formulating mean transport winds in numerical air quality models, a study was undertaken to determine the rural-urban differences in the wind speed and direction from the RAMS data.

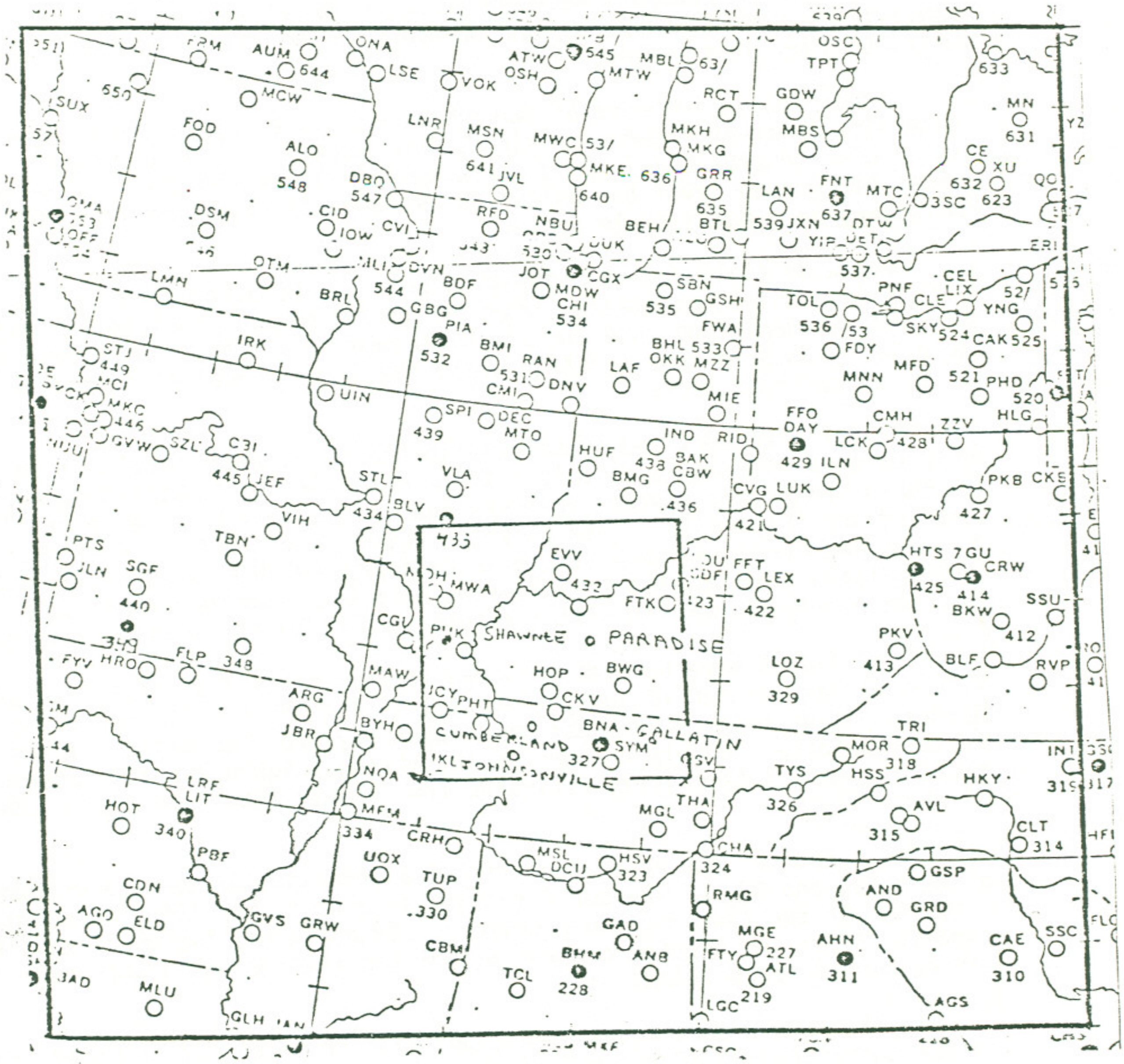

Figure 10: Grid domain for the wind field and advection calculations (larger) and SO_2 and SO_4 concentrations calculations (smaller) for STRAM.

Previous studies with tower data (Chandler, 1965; Lee, 1977; Borstein and Johnson, 1977) have tended to support the following view. With strong winds, speeds are lower in the city than in rural areas. The deceleration is caused by the urban roughness and is accompanied by a cyclonic turning. With light winds, and particularly with a well-developed heat island, speeds are higher in the city than in the countryside. The speed increase may be due to the overturning of the stable rural flow or an acceleration caused by heat island-induced pressure gradients.

It should be realized, however, that in previous studies great reliance has been placed on single stations for giving representative urban and rural winds. In examining the RAMS data, it became apparent that significant differences exist between measurements from stations of similar locale. These differences change with wind direction and stability, but not in a way consistent with simple concepts associated with heat island circulation. In fact, virtually any proposition about the urban influence on winds may be supported by selectively choosing single urban and rural stations. For this reason winds from Stations 122-125 were averaged to compute the rural wind, while the urban wind was similarly derived from measurements at Stations 101, 105-107 and 112. RAMS data also supply direct measurements of vertical temperature gradients and heat island intensity. Hour averaged data were analyzed for all of 1976, with data classified into 30 degree wind direction sectors and according to heat island intensity and wind speed.

The results are shown here for the south direction sector only. Figure 11 shows the RAMS network and the average heat island for 199 hours when wind speed was 1.5-3.5 m/s and the heat island was well-developed. It can be seen that the flow undergoes a rather abrupt encounter with the city when the wind is from the south. Figure 12 and 13 show the mean speed and direction differences (urban minus rural) as function of rural wind speed. Both high and low heat island (HHI and LHI) cases are plotted.

For strong winds, the results agree well with those of previous studies and theoretical expectations in showing a deceleration with cyclonic turning. Of all directions considered, differences were found greatest for winds from the south. Under light wind conditions, results are not in agreement with previous findings. Under LHI, RAMS data indicate higher speeds in the city; under HHI conditions, the urban speeds remain significantly below rural speeds. This result is firmly established for other wind directions as well. It does not appear possible to determine significant changes in wind direction when dealing with light winds.

In view of the results of earlier investigations, the present findings for low speed winds are somewhat surprising. However, the RAMS data set is likely superior in quantity, quality, and detail to those employed in previous studies. St. Louis also does not have great problems induced by sea breeze or considerable topography. A theoretical explanation of the new findings is being sought.

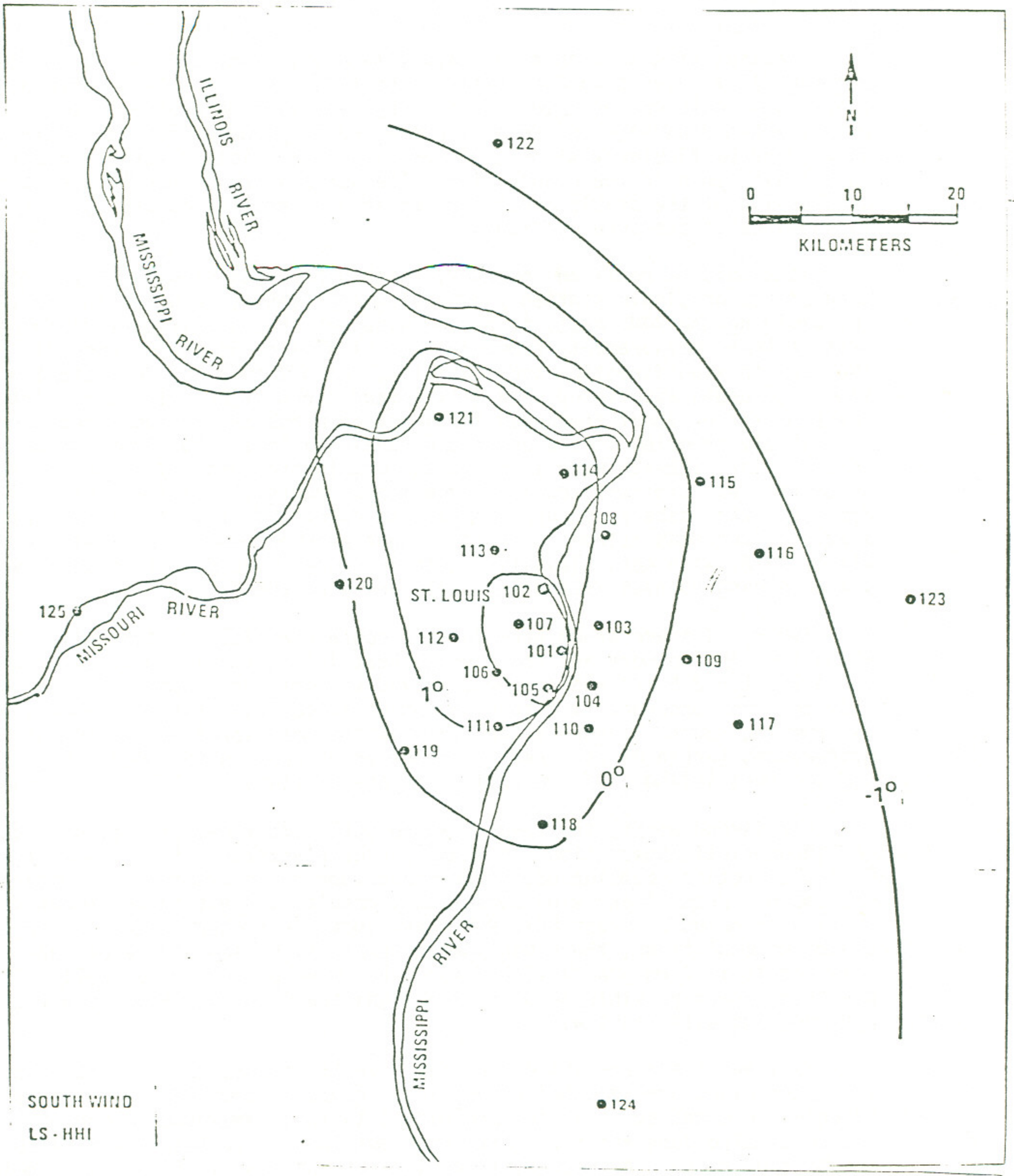

Figure 11: Mean, relative isotherms derived from 199 hours of data taken in 1976 when wind was from the south at 1.5-3.5 m/s and the urban heat island was well developed.

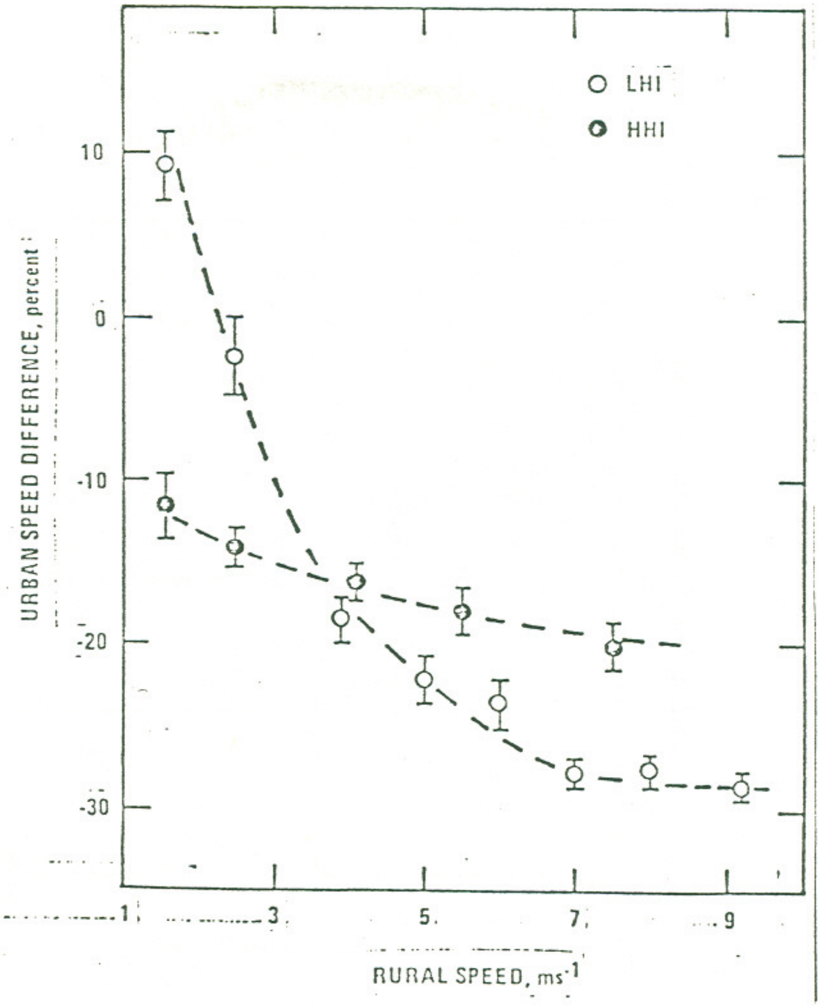

Figure 12: The urban-rural speed difference for south winds during 1976. A negative difference indicates speeds are lower in the city. Results are presented separately for low and high heat island intensities (LHI and HHI).

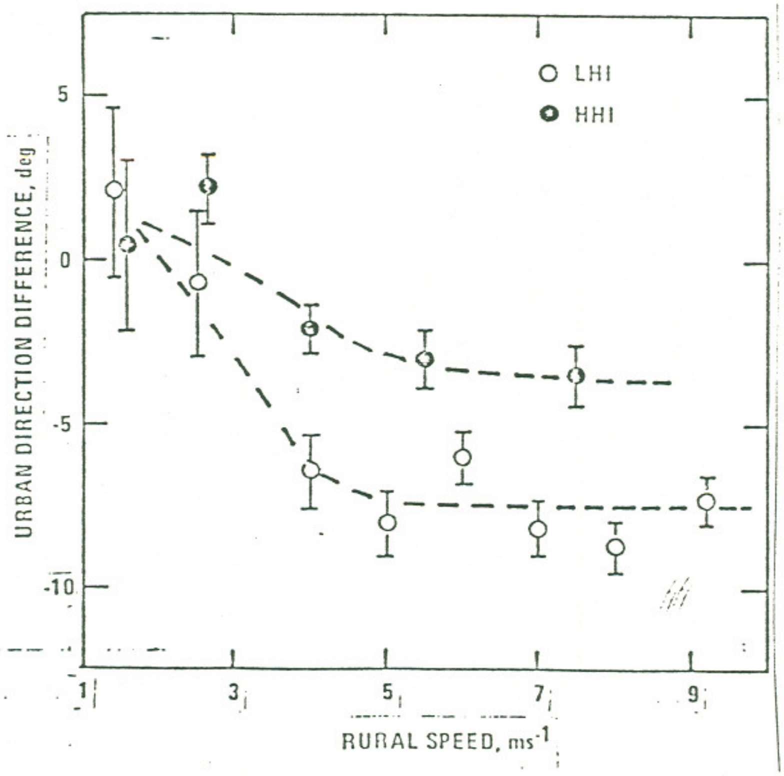

Figure 13: The urban-rural direction difference for south winds during 1976. A negative difference indicates a cyclonic turning of the wind as it moves into the city.

2.1.9 Non-divergent wind analysis algorithm

The documentation for the algorithm to create non-divergent wind fields for St. Louis, Missouri has been published as an EPA technical report (Clark and Eskridge, 1977). A complete listing of computer program, as well as illustrative examples of the model output are included.

Non-divergent wind fields are required in most Eulerian air pollution models. These models treat the atmosphere as several vertically-stacked two-dimensional layers, implying that the vertical velocity everywhere is zero. Divergence ($\nabla \cdot \overline{V}$) across a grid square could cause an erroneous loss of pollutant since

$$\frac{\partial c_i}{\partial t} = \overline{V} \cdot \nabla c_i - c_i \nabla \cdot \overline{V} ,$$

where c_i is the concentration and $\overline{V}$ the velocity.

The algorithm first constructs u and v wind component fields via a scan radius technique developed by Hovland et al. (1977). A 46 by 46 grid network with spacing of 1 km is used and encompasses 21 of the 25 RAPS data sites (see Figure 14). Non-divergent u and v wind fields are created next by slightly altering the wind components at grid point (i, j) where the divergence ($D_{i,j}$) exceeds 1.0×10^{-5} sec^{-1} (Liu and Goodin, 1976).

The technique is an iterative procedure which first calculates the divergence across each grid square by Eq. 1 and the u and v corrective terms by Eqs. 2 and 3, respectively.

$$D_{i,j} = \frac{u_{i+1,j} - u_{i-1,j}}{2 \Delta x} + \frac{v_{i,j+1} - v_{i,j-1}}{2 \Delta y} \tag{1}$$

$$\tilde{u}_{i,j} = -2D_{i,j} \Delta x \quad (f_{i,j+1} + f_{i,j-1} + f_{i+1,j} + f_{i-1,j}) \tag{2}$$

$$\tilde{v}_{i,j} = -2D_{i,j} \Delta y \quad (f_{i,j+1} + f_{i,j-1} + f_{i+1,j} + f_{i-1,j}) \tag{3}$$

where Δx and Δy are the grid spacing in the x and y directions; and f is a weighting function whose value is 0.25 at the closest grid points to the data sites, 0.50 at the grid points Δx and Δy away, and 1.00 elsewhere. New values of $u_{i,j}$ and $v_{i,j}$ are determined by Eqs. 4-7.

$$u_{i+1,j} = u_{i+1,j} + f_{i+1,j} \tilde{u}_{i,j} \tag{4}$$

$$u_{i-1,j} = u_{i-1,j} - f_{i-1,j} \tilde{u}_{i,j} \tag{5}$$

$$v_{i,j+1} = v_{i,j+1} + f_{i,j+1} \tilde{v}_{i,j} \tag{6}$$

$$v_{i,j-1} = v_{i,j-1} - f_{i,j-1} \tilde{v}_{i,j} \tag{7}$$

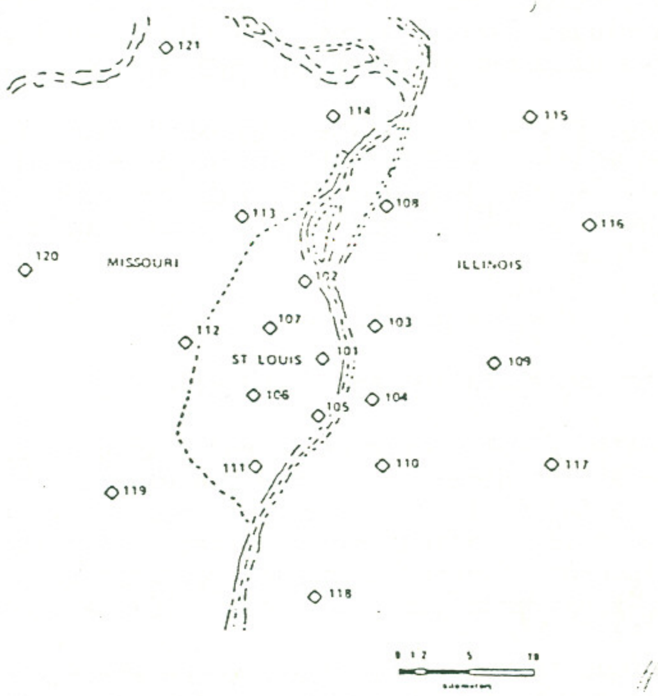

Figure 14: The 46 by 46 grid domain encompassing 21 RAPS sites used in the algorithm.

The process terminates when the divergences across each grid square are minimized.

2.1.10 Fluid Modeling Facility (FMF)

The FMF has a total of three wind tunnels and two water channel/towing tanks. Some of the major features of the FMF are described in Thompson and Snyder (1976).

The Meteorological Wind Tunnel (MWT) is used for the study of dispersion under neutral atmospheric conditions. Boundary layers are generated by artificially roughening the floor of the test section (3.7 m wide, 2.1m high, and 18.3m long). The wind speed is variable from 0.5 to 10.0 m/s. Model scales of 1:100 to 1:2000 are commonly used.

The Air Pollution Training Institute Wind Tunnel has a 1m wide, 1m high, 3m long test section. It is quite useful for instrument calibration, testing of techniques for use in the MWT, and for studies that can be carried out in the smaller test section.

An additional, low-cost wind tunnel was built for a special project. This tunnel is of the simplest design and is quite limited in its application.

By blocking off the ends of the 2.4m wide, 1.2m deep, 2.5m long test section of the water channel/towing tank and filling with layers of salt water of various densities, a stably-stratified environment can be created for the study of dispersion under stably-stratified conditions. Models are suspended into the water from a platform and towed through the stationary fluid to simulate the wind. Operating as a recirculating water channel, speeds up to 1 m/s can be obtained in the test section. A smaller water channel/tow tank (1/12th the size of the large one) is used to calibrate hot-film anemometers, to develop techniques for use in the large channel and to perform some visualization studies.

2.1.10.1 Dispersion around three-dimensional hills

This study is providing a broad data base on the flow and dispersion around isolated, three-dimensional hills. The experimental measurements are being made primarily in the stratified towing tank, but the meteorological wind tunnel is also being used for comparison and for more detailed measurement for the neutral cases. The small tow tank is also used for flow visualization.

Three hill shapes are being studied: conical, hemispherical, and polynomial (bell-shaped). For baseline comparisons, measurements will be made with no hill. Linear stable stratification of selected gradients combined with the tow velocity makes a range of internal Froude numbers possible.

A point source located upstream of the hill provides the tracer for qualitative and quantitative study of the flow and dispersion. Use of a visible tracer allows for photographing the flow field (see Figure 15).

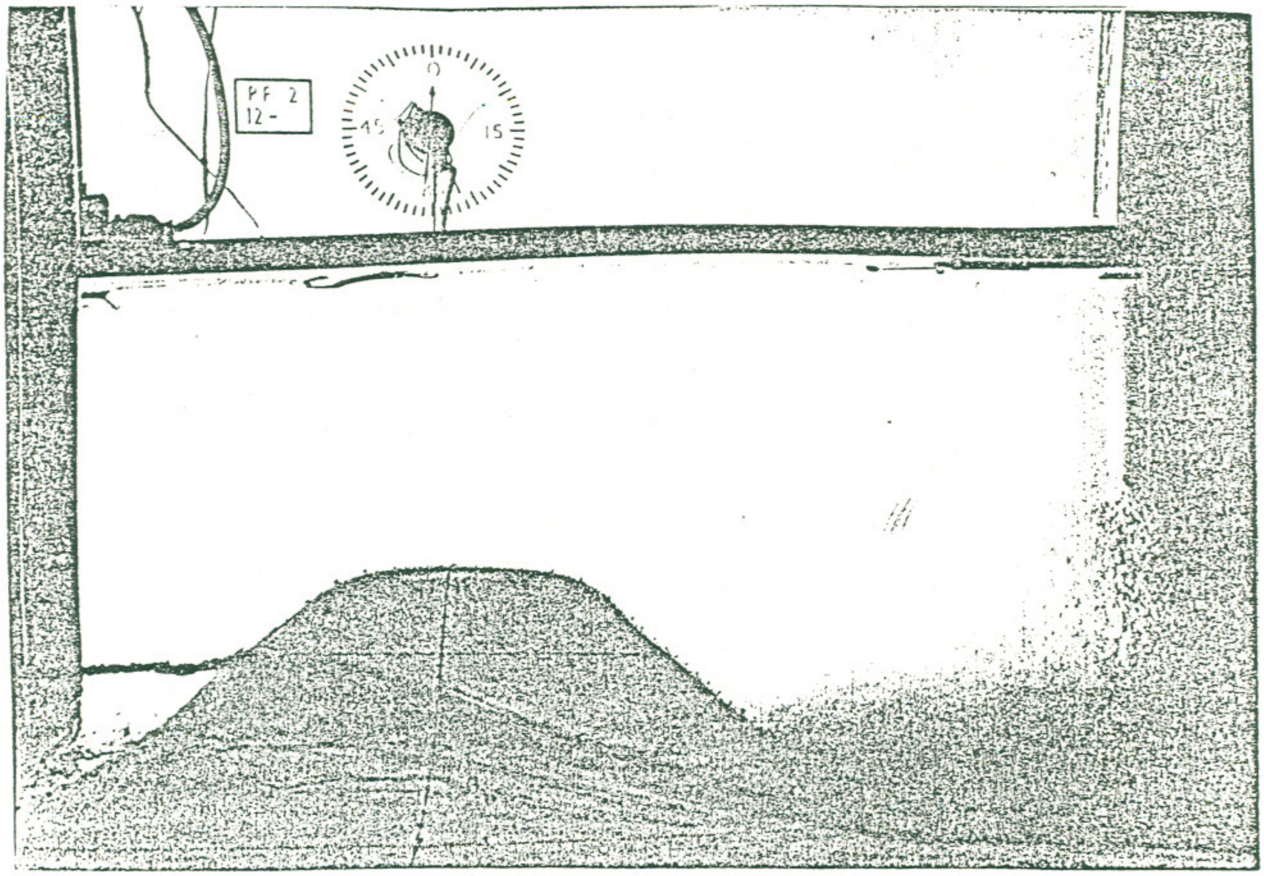

Figure 15: Plume dispersion past polynomial hill model in FMF water channel/towing tank.

Ports on the surface of the hill and on a movable rake collect samples of the tracer for quantitative concentration measurements. The position of the source is varied to find the critical conditions that determine whether the plume impacts on the hill or goes around the sides or over the top.

The baseline measurements were completed as well as most of the measurements on the polynomial hill under stratified conditions. The neutral case to be conducted in the wind tunnel should be completed early next year.

Two techniques of flow visualization are being used in the small tow tank. A pulsing hydrogen-bubble generating wire is placed upstream of the hill and used to generate sheets of bubbles. The trajectories of the bubble sheets are photographed to record the resulting pattern over the hill. The surface of the model is also coated with a thin film of a dark gelatin. Towing the length of the test section erodes the gelatin from regions of high velocity and turbulence. Photographs are taken of these patterns also.

2.1.10.2 Dispersion in grid-generated turbulence

A basic study to determine the diffusion and plume growth in a turbulent, stably-stratified layer was begun in the large tow tank. A point source of dye was positioned downstream of a grid that was towed through the large tow tank. The vertical and horizontal plume concentration profiles were determined at five downstream distances for various combinations of stratification gradient and tow speed. Side and bottom view photographs were taken when the turbulence in the variable density fluid did not cause very severe distortions (Figure 16). Gaussian distributions were fitted to the plume profiles according to the computed standard deviations of plume spread.

2.1.10.3 Plume rise in calm stably-stratified atmosphere

The rise and spread of plumes eminating from sources in calm, stably-stratified atmospheres were measured in the large water channel/towing tank. This work was performed in cooperation with Dr. Gary A. Briggs during his assignment to the FMF from the Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, Tennessee.

The plumes were generated by injecting dyes into the stratified tow tank from a stationary platform. A mixture of salt water (to control the buoyancy of the effluent) and food dye (to make the plume visible) was injected from a round tube into the tank. The effluent Reynolds number and momentum were controlled by using tubes of different diameter and using different flow rates.

Photographs, both side and bottom views, of the plume as it developed were taken at prescribed times (Figure 17). Enlarged prints of these photographs formed the basis for the analyses of the geometry of the developing plume. The geometry of neutrally buoyant plumes was found to be independent of Reynolds number provided it was above about 2000. For buoyant plumes, this critical Reynolds number was considerably smaller, about 200. The outer boundary of the plume profiles were digitized and recorded on magnetic tape for later analysis. The diameter of the plume was found to increase

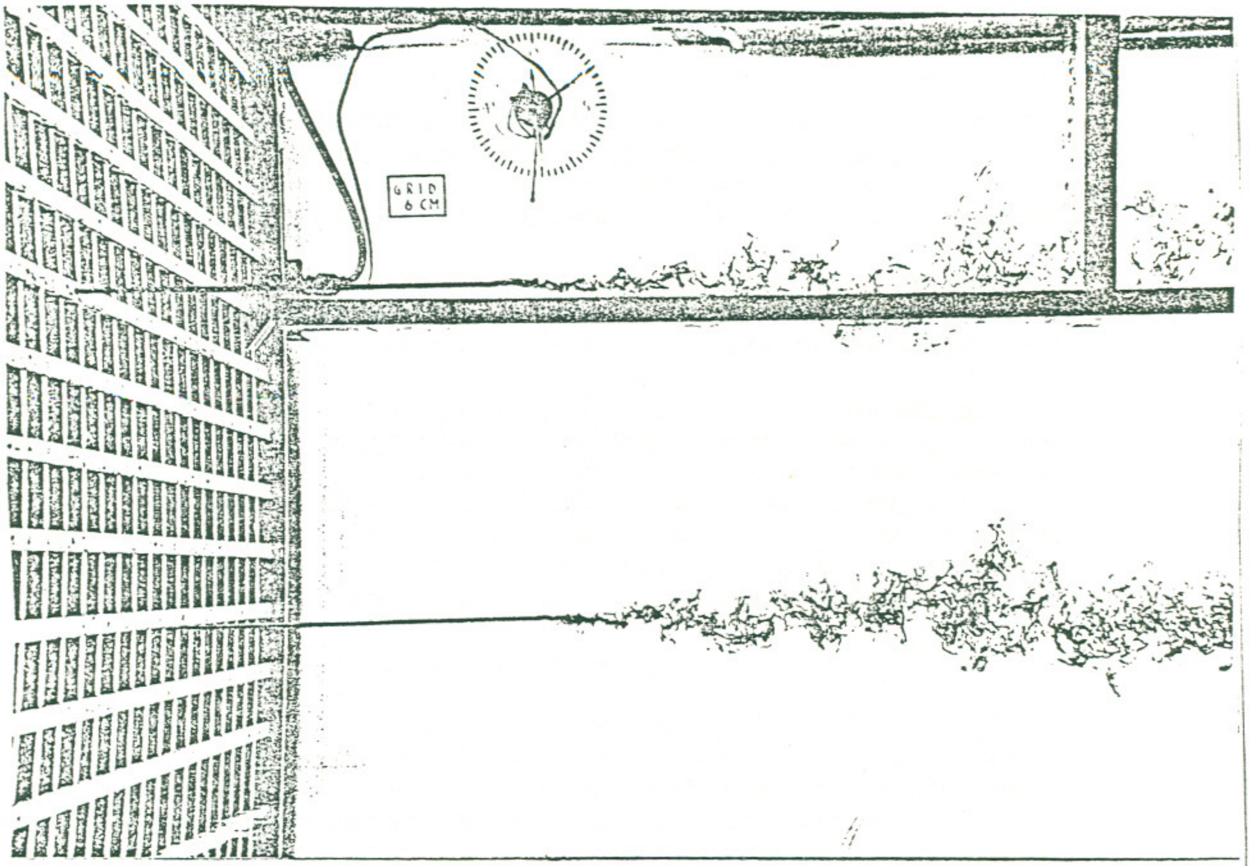

Figure 16: Dispersion from point source in Grid Generated Turbulence.

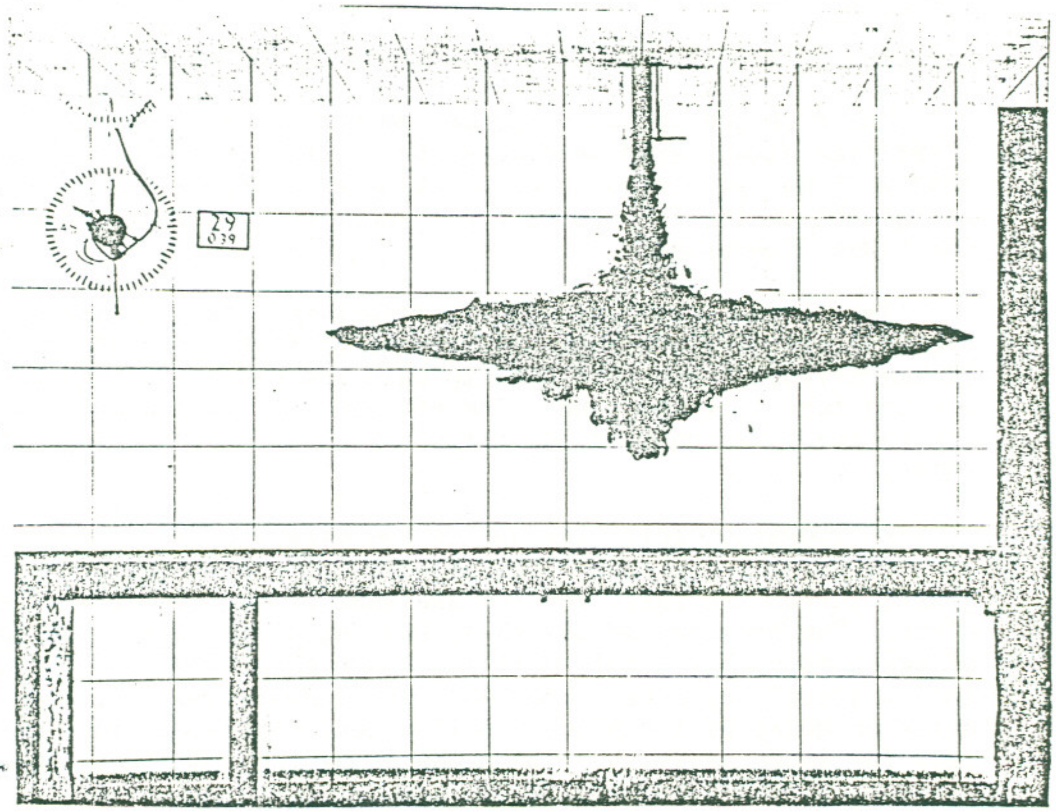

Figure 17: Side view of developing plume in calm, stably-stratified atmosphere.

with the square root of elapsed time (Figure 18). A report on this work is currently under preparation.

2.1.10.4 Dispersion of roof-top emissions

The final report on the wind tunnel study of the dispersion of roof-top emissions from isolated buildings has been released (Thompson and Lombardi, 1977). A non-buoyant, low-momentum effluent was released at the center of the roof of rectangular shaped buildings. Downwind concentrations were measured for each of four building shapes. A neutral boundary layer was used throughout the study.

A cubical building oriented perpendicular to the wind was used as the reference case. Rotating the cubical building to an angle of 45° to the wind increase the maximum ground-level concentration by a factor of six. Doubling or tripling the height of the building while keeping the other dimensions the same significantly decreased the maximum ground-level concentrations.

2.1.10.5 Clinch River Power Plant Model

A wind tunnel study has been planned in conjunction with the Geomet, Inc. field study of the Clinch River Power Plant on dispersion in complex terrain. Features of the area surrounding the Clinch River Power Plant that made it suitable for a field study site also make it an interesting area to model in the wind tunnel. The power plant is the only major pollution source in the area. The mountains in the Clinch River valley are typically 150-180m high. At a scale of 1:1920, the model will be of a section of the Clinch River Valley that lies between two ridges of mountains that are about three times as high as those in the valley. The primary wind direction to be studied will be southwest or up the river valley. The field study data will be scanned to determine periods of neutral atmospheric conditions with this wind direction for the wind tunnel simulation. The preliminary data reports for the field study provide hourly values of pertinent variables to compute the necessary wind tunnel model values of meteorological and emission parameters.

A contract has been let for the construction of the terrain model that will nearly fill the test section of the Meteorological Wind Tunnel. The completed model will be delivered in December 1977 and installed in the wind tunnel early in 1978.

2.1.10.6 Pine bark beetle flight speed

Under an informal arrangement with the Forest Insecticides Research Division of the U. S. Forest Service Forest Research Laboratory in the Research Triangle Park, NC, the Fluid Modeling Facility is assisting in a wind tunnel study of the flying capabilities of pine bark beetles. The pine bark beetle is responsible for much damage to pine forests in the U.S. There is much to be learned about how the beetles are carried by prevailing winds. By allowing the beetles to emerge naturally from an infested bolt of a pine tree placed in the middle of the test section of a small wind

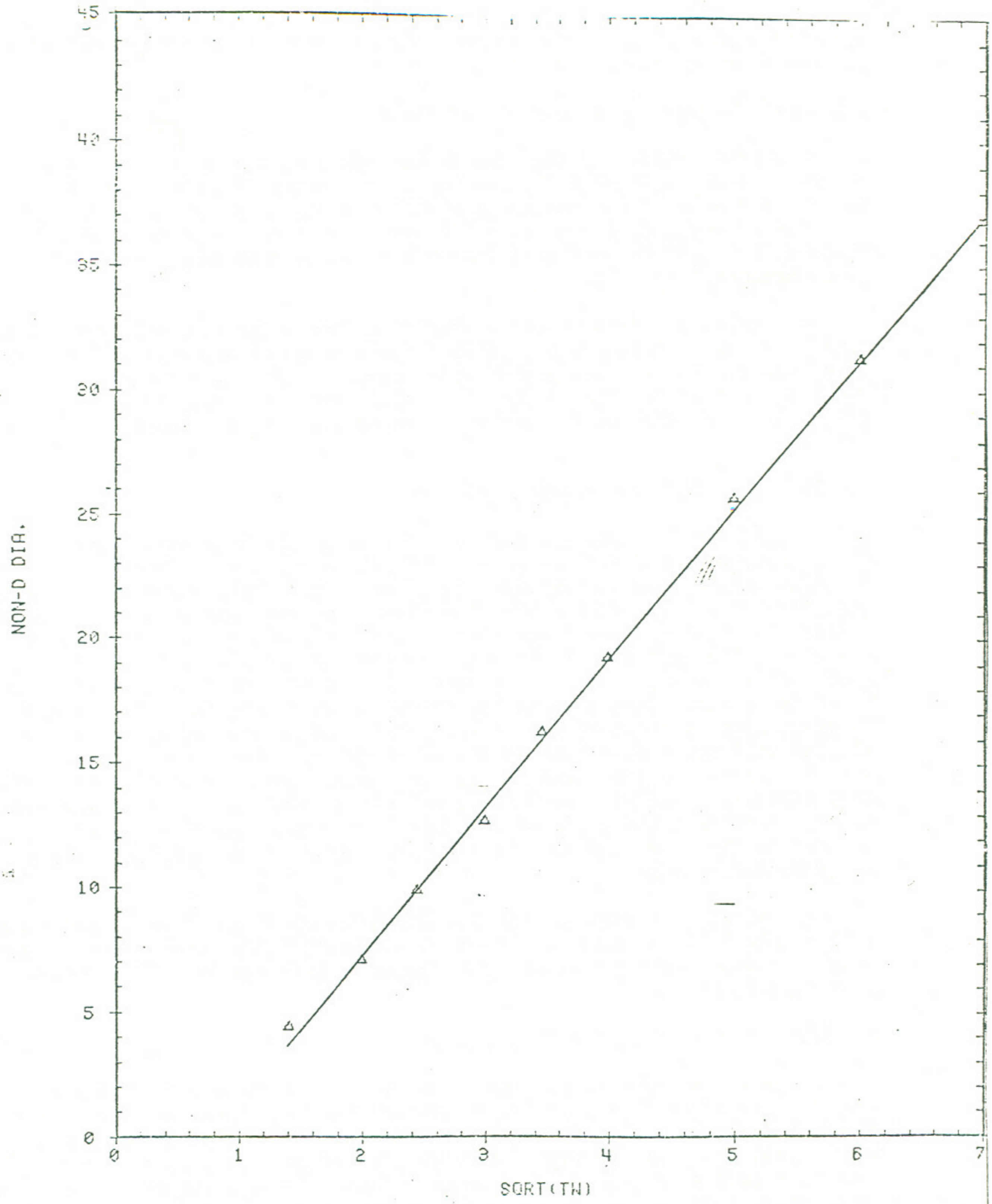

Figure 18: Diameter of plume in calm stably-stratified atmosphere as function of elapsed time.

tunnel, their flight speed can be determined. The tunnel is set to operate at a steady speed and allowed to run for a period of about two weeks while the beetles emerge. Metal screens coated with a sticky substance are placed both upstream and downstream of the bolt; the proportion of beetles trapped on each is a measure of their success at flying against the wind. Tests have been conducted at speeds of 0.5, 1.0, and 2.0 miles per hour with and without an attractant upwind. The beetles were found to be capable of flying into a 0.5 mph wind but not a 1 or 2 pmh wind even when enticed with the attractant.

2.1.11 Climate of the Eastern United States

A brief climatology of the United States east of the Mississippi River was prepared for a newly planned study of Sulfate Transport and Transformation in the Environment (STATE). This EPA-sponsored project was formulated at the Workshop on Regional Air Pollution Studies at Asheville, North Carolina in June 1976. The report used only readily available data and gave particular attention along a line from St. Louis, Missouri, to Wheeling, West Virginia where STATE experiments are expected to be conducted.

The report provided a description of six general climatic regimes in the eastern United States and then gave summaries of some of the meteorological parameters. The data included maps with mean values of temperatures, mixing heights, relative humidities, and precipitation. There were also maps of frequencies of fronts, inversions, and various wind speeds. Other data included wind direction presistence, daily solar radiation, frequently seen trajectories and streamlines, as well as the general movements of air masses.

2.1.12 Summary of NWS rawinsonde data

Routine rawinsonde data summarized last year to describe various features of inversions were plotted and analyzed on maps. The data are from 75 stations in the United States and Puerto Rico. Preliminary results were presented in a paper at the AMS/APCA Joint Conference on Meteorology in November 1977 and published in accompanying Proceedings (Fisher, 1977). This work was first described by Holzworth (1974a and 1974b).

The final report is nearing completion and will include the frequencies of surface-based and elevated temperature inversions, the height of the tops of surface inversions, the depth of elevated inversions and the intensity of inversions. Also provided will be wind speed and relative humidity data at and above the surface when inversions are and are not present. The data are for 1115 GMT and 2315 GMT and by season.

As an example of some of the data, Figure 19 shows isopleths of percent frequencies of surface-based inversions (solid lines) and all inversions (dashed lines) during the winter at 1115 GMT. The straight lines indicate the angle of the sun with the horizon at 1115 GMT on January 15. Notice that all inversions occur more than 90% of the time over most of the United States, except the Pacific Northwest. Surface inversions are most frequent in the western mountains while elevated inversions occur most frequently around the Great Lakes Region.

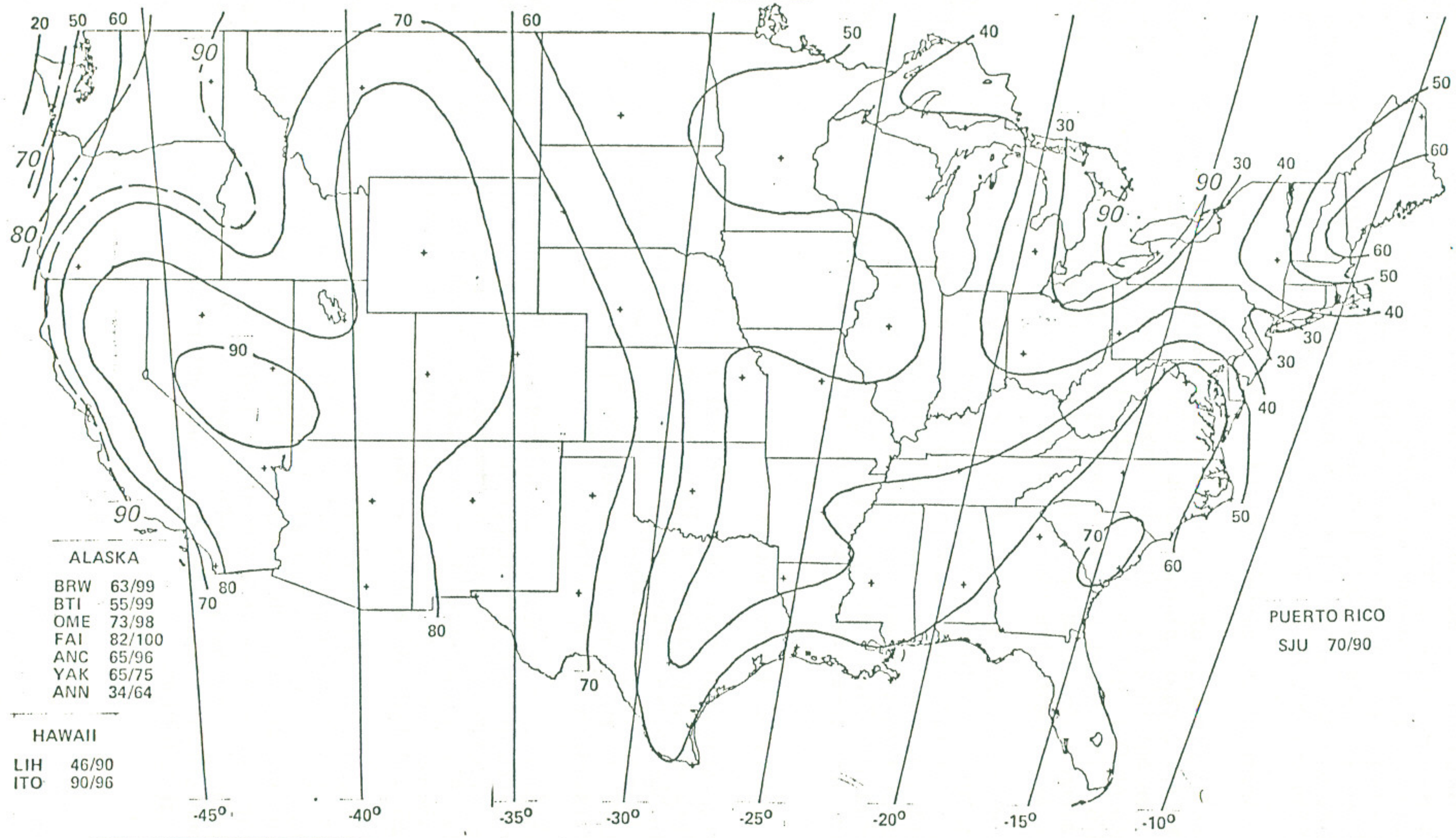

Figure 19: Percentage of winter 1115 GMT sounding with surface-based inversions (solid) and all inversions (dashed). Data for non-continental and Alaskan stations are plotted for the margins (Surface/All). Straight lines are angles of solar elevation at 1115 GMT on January 15.

Figure 20 shows isopleths of percent frequencies of surface-based inversions in the winter at 1115 GMT with wind speeds greater than 5 m/s at the surface (dashed) and at 300m (solid). The highest wind speeds at all levels occur in the south Central Great Plains and in northern Montana.

Publication of about 120 data maps and accompanying description is planned.

2.1.13 Ozone transport

Relying heavily on RAPS data, both large-scale and local transport of ozone were shown to occur frequently in the St. Louis, MO, area (Karl, 1978a). Ozone concentrations above the NAAQS occured at rural stations 121 through 125 (Figure 21) on 15 days between July 1 through September 15, 1975 and May 1 through June 19, 1976 when it was clear the urban industrial complex of St. Louis had very little influence on these high concentrations. On these days the air arriving in St. Louis had been confined for a least three days to the eastern half of the United States where there are numerous urban-industrial centers. During these three days the movement of air was contained within anticyclones.

The results suggest that the National Ambient Air Quality Standard will be exceeded in St. Louis due to large-scale ozone transport regardless of precursor emissions from the urban-industrial areas of St. Louis. The results also imply that the precursors and ozone emitted from St. Louis can, under certain meteorological conditions, combine with significantly high precursor emissions from other areas to contaminate areas outside of the St. Louis region.

The local transport of ozone generated within St. Louis must also be considered in order to explain the ozone concentrations measured in the Regional Air Monitoring System (RAMS). When rural areas were situated downwind of the urban-industrial area of St. Louis, ozone concentrations were often observed to be higher than at other times. In fact the concentrations were frequently higher than urban concentrations which were located in areas of high precursor emissions. This was exemplified on one particular day by following the movement of a surface-based cloud of ozone, which originated in the urban-industrial complex of St. Louis (Figure 22). The concentrations within the ozone cloud increased as the cloud moved north and west of the city, resulting in extremely high concentrations at outer sites.

In light of these results which are reported and discussed by Karl (1978a), it would be most appropriate to develop control strategies for ozone which considers both the consequences of large-scale ($\geq$ 200 km) and local transport of ozone.

2.1.14 Day of the week variations of photochemical pollutants

Various photochemical pollutants (O_3, NO, NO_2, and total hydrocarbons) and some selected meteorological variables (wind speed, temperature, and solar radiation) were analyzed with respect to the day of the week using 11 months of data collected during warm months of the year--periods during which high ozone concentrations were common in St. Louis. The difference

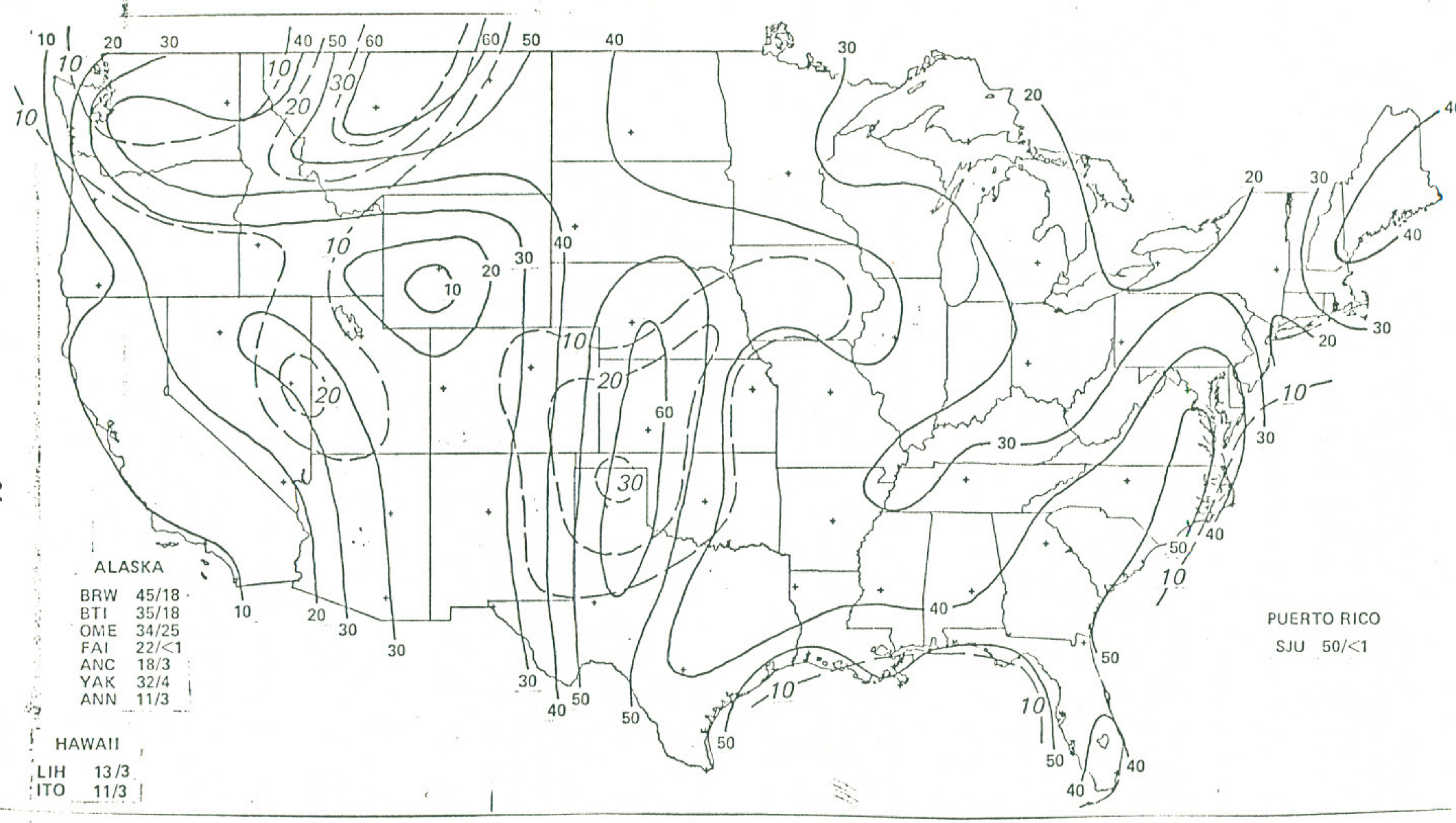

Figure 20: Percentage of winter 1115 GMT sounding with a surface-based inversion and wind speeds greater than 5 m/s at 300m AGL (solid) and at 6 m AGL (dashed). Data for non-continental and Alaskan stations are plotted in the margins (U_{300}/U_{sfc}).

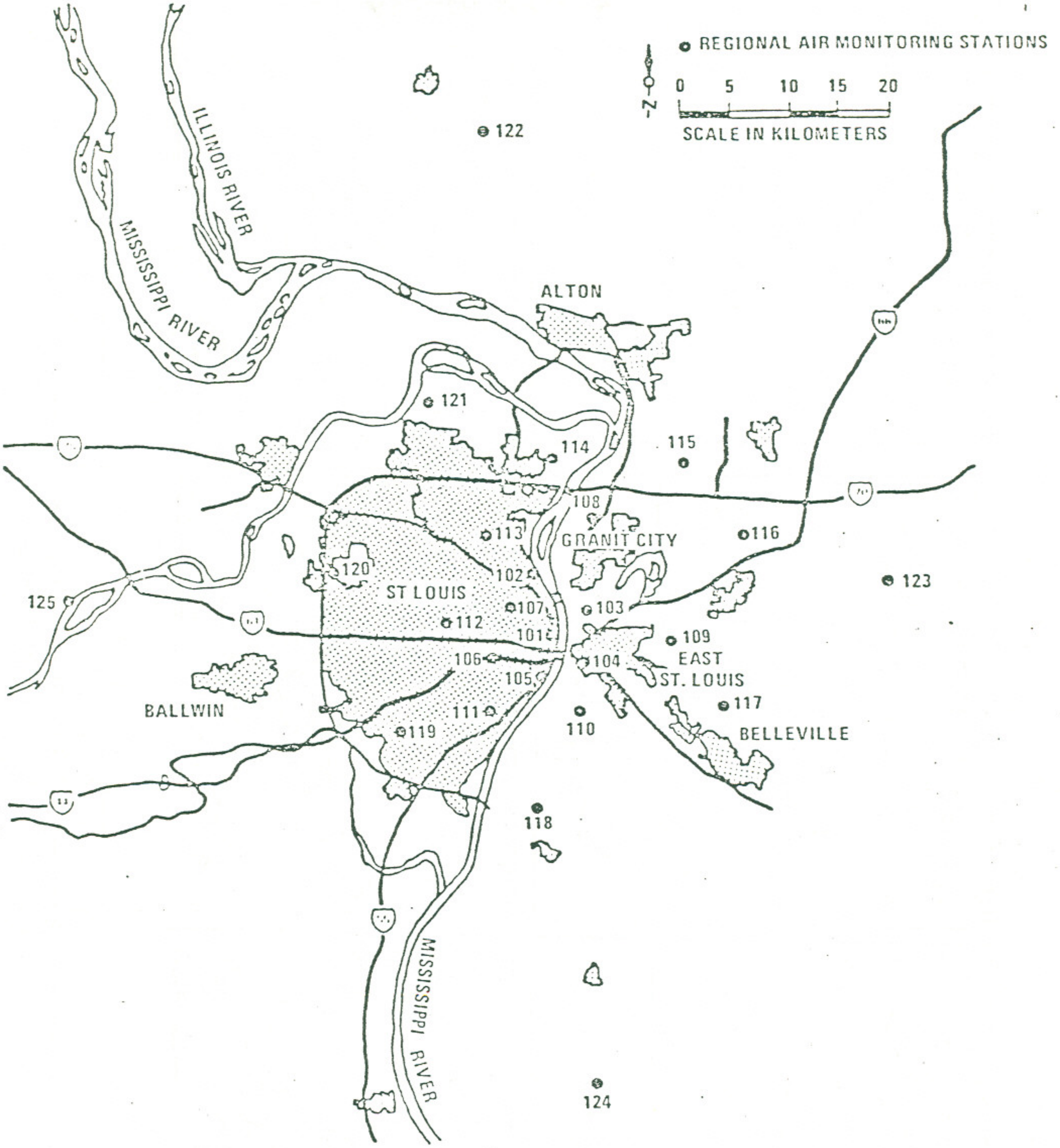

Figure 21: The Regional Air Monitoring Stations in St. Louis.

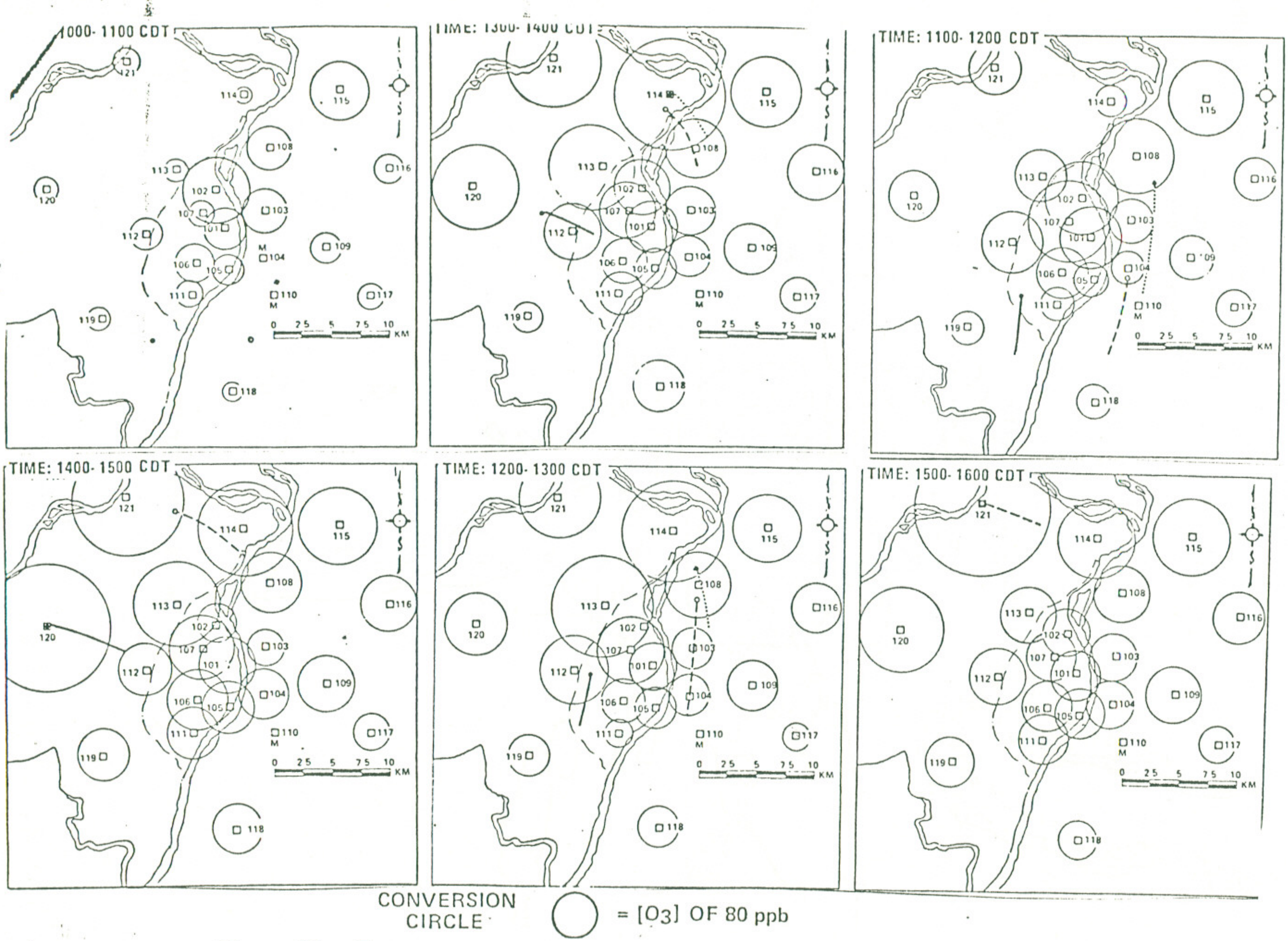

Figure 22: Time sequence of ozone concentrations in the RAMS for August 19, 1975. Ozone concentrations at each site can be estimated by the use of the conversion circles. Trajectory segments are shown which represent the one-hour movement of the air which arrived at stations 114, 120, and 121 during the hour of maximum ozone

in the daily average concentrations of the photochemical pollutants NO, NO_2, NMHC, and O_3 from Sundays to workdays depended to a large extent on the distance of the measurement from the urban area of St. Louis. Concentrations of O_3 were observed to decrease from Sundays to workdays inside the city of St. Louis, opposite to what was observed at stations located tens of kilometers outside the city (Figure 23). Karl (1978b), shows that meteorological conditions were not responsible for the regional differences of ozone concentrations; he argues that the data support the contention that decreases of O_3 concentrations observed on workdays inside the city are due to the impact of NO on the ambient O_3 concentrations.

2.1.15 Forecasting ozone concentrations

Using input from the National Meteorological Center's (NMC) Limited-area Fine Mesh (LFM) model, a technique called Model Output Statistics (MOS) was utilized to forecast maximum ozone concentrations out to 48 hours. The LFM model is routinely run twice daily by NMC. For this reason, with the cooperation of NMC, operational ozone forecasts could be made on a daily basis if the MOS approach provides useful ozone forecasts. To test the hypothesis that MOS could provide useful ozone forecasts the technique was applied to ozone data collected in St. Louis. Essentially, a statistical relationship was developed between the daily 1-hr maximum ozone concentration for various regions in St. Louis and the output from the numerical model as well as other available information regarding air quality and current weather. Several statistical models were developed and tested on independent data from St. Louis. Preliminary results look encouraging and a paper describing the technique in detail as well as its performance will be forthcoming.

2.1.16 Air quality and meteorology

In order to better cope with violations of air quality standards it is necessary to understand the influences of weather on such phenomena. A number of studies were undertaken to document the general meteorological conditions associated with periods during which air quality standards were exceeded. DeMarrais (1978a) examined ozone concentrations in the Norfolk, Virginia region during July-August, 1974, and found that the one-hour standard of 80 ppb was exceeded on 40 percent of the days. Although these high concentrations occurred with a wide range of meteorological conditions, they were often associated with trajectories that passed over metropolitan areas to the northwest and north before arriving in the area. The analysis for one day, August 20, 1974, which is shown in Figure 24, demonstrated that long range transport and only a negligible local emission could have been associated with the observed high concentrations. The hourly surface winds averaged 15 knots and the air came from over the ocean; the trajectories indicated the air had not been in contact with land for 36 hours, yet showed a high concentration after an overland travel time of less than a half-hour.

During July 6-11, an ozone episode occurred over much of the region encompassed by Virginia-Ohio-Massachusetts-Virginia. The episode was particularly pronounced in the Richmond-to-Baltimore corridor and a meteorological investigation (DeMarrais, 1978b) focused on that region. The episode occurred during a stagnation period associated with a slow-moving high

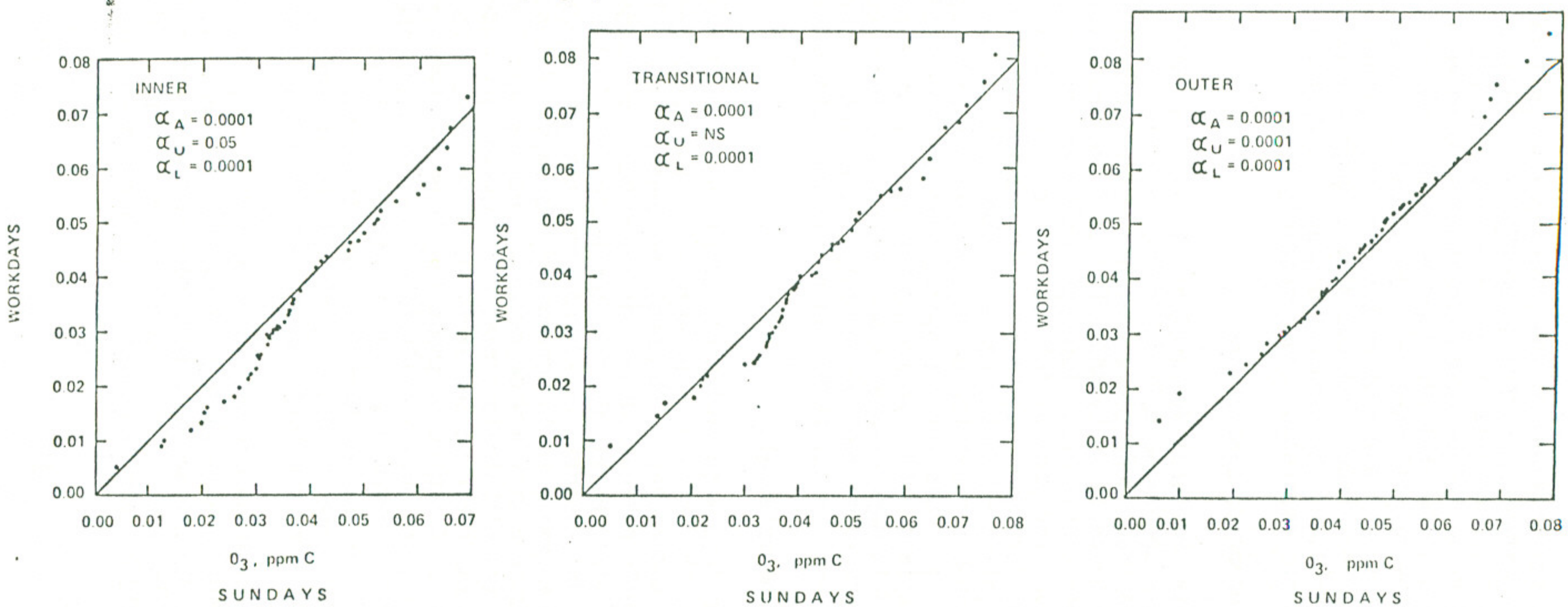

Figure 23: Quantile-quantile plots of ozone for Sundays versus workdays. α gives the significance level for rejection of the null hypothesis that there is no difference between paired values. Subscript A denotes all quantiles plotted; U denotes quantiles at or above the 50th percentile; L denotes quantiles at or below the 50th percentile. NS implies no significance, the null hypothesis must be accepted.

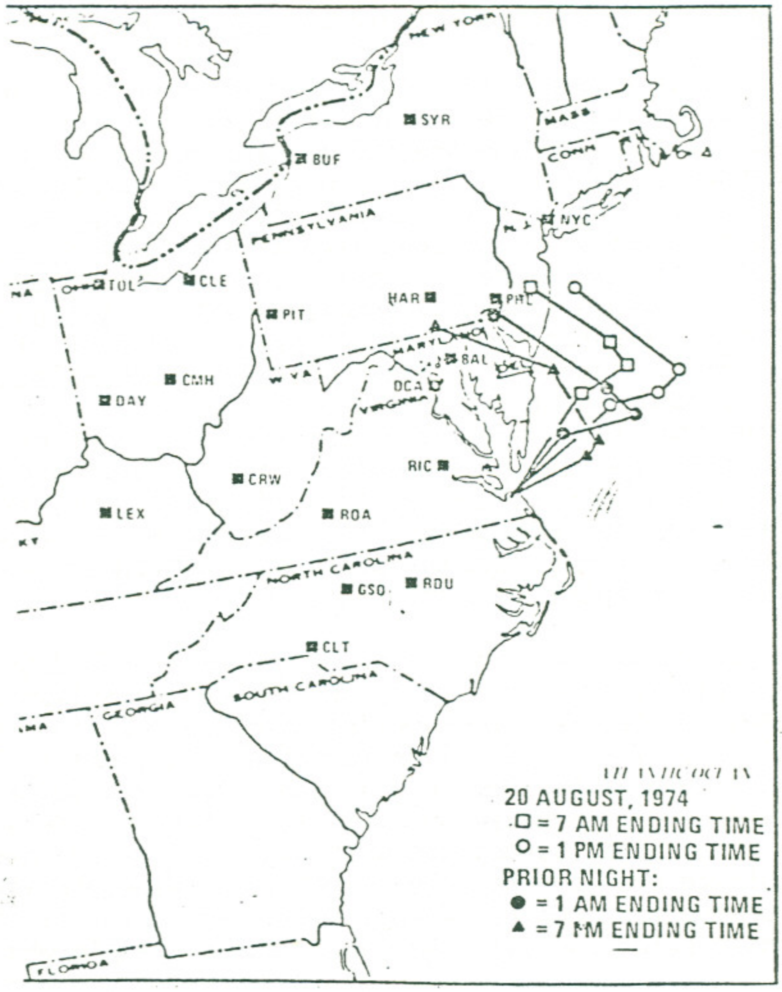

Figure 24: 48-hour backward trajectories, surface to 700 meter layer, 20 August 1974, 12-hour intervals.

pressure area. In spite of the overall stagnation, 48-hour trajectories of the layer between the surface and 1000 m showed some movements as great as 1000 km; long range transport readily occurred during the stagnation period. The trajectories for the three cities of Richmond, Washington and Baltimore on July 9, 1974 are shown in Figure 25. It can be seen that the air brought into each city had rapid movement in the most recent 12 hours, but earlier moved very slowly over distant areas; stagnation combined with long range transport was involved in the episode on this day.

Oxidant concentrations exceeding 8 ppb were observed at many locations in a seven-county area in southern California from February 25 to March 4, 1975. Figure 26, showing the maximum hourly concentrations at almost 50 stations on February 28, indicates the extensive area that was adversely affected. Because this was a violation of the air quality standard at a time when relatively low concentrations were normally anticipated the meteorological conditions associated with this large scale episode were evaluated (DeMarrais, 1978c). The episode was associated with very slow air movement, slightly elevated temperatures, abundant solar radiation, limited vertical mixing at the coast, and vertical mixing varying from negligible at night to relatively deep in the daytime at inland sites. The maximum temperatures were 3° to 6° cooler than those normally associated with high oxidant concentrations, but the solar radiation, as deduced from sky cover and sunshine records, was about equivalent to that at the end of the usual oxidant season. The differences in vertical mixing, combined with the overall stagnation and weak sea breeze at the surface in the afternoon, appeared to cause the oxidant concentrations to be higher inland.

There is a need for a greater knowledge and understanding of the meteorology associated with high concentrations of sulfates. This need is acute because of the 24-hour sampling time and the time required for laboratory analysis. Whereas sampling techniques for most pollutants indicate the existence of a problem in real time, that for sulfates does not show the existence of a problem until it is history. With a greater knowledge of the meteorology associated with high sulfate concentrations, one could expect a sulfate problem when the appropriate meteorological conditions occur. Accordingly, a control agency could reduce the sampling time, use a more sophisticated analysis and could caution people who are susceptible to sulfate.

A study of a sulfate episode in Southern California was undertaken. The episode occurred from February 26 to March 5, 1975. Figure 27 shows the extent and magnitude of high concentrations of sulfates. Preliminary indications are that this was an off-season episode that practically coincided with an oxidant episode; there was a one-day lag in the beginning and ending of the sulfate episode. The meteorological conditions associated with the episode were: a) slow moving air; b) abundant sunshine; c) elevated temperatures; d)limited vertical mixing at the coast and inland vertical mixing varying from negligible at night to relatively deep in the daytime; e) relatively very poor visibilities due to smoke, haze, and fog; and f) high relative humidities at all times at the coast and at night at inland locations, but very low relative humidities in the daytime over inland locations.
The ozone episode ended with the onset of strong winds and rain, while the sulfate episode persisted into the windy and wet period. Differences in the

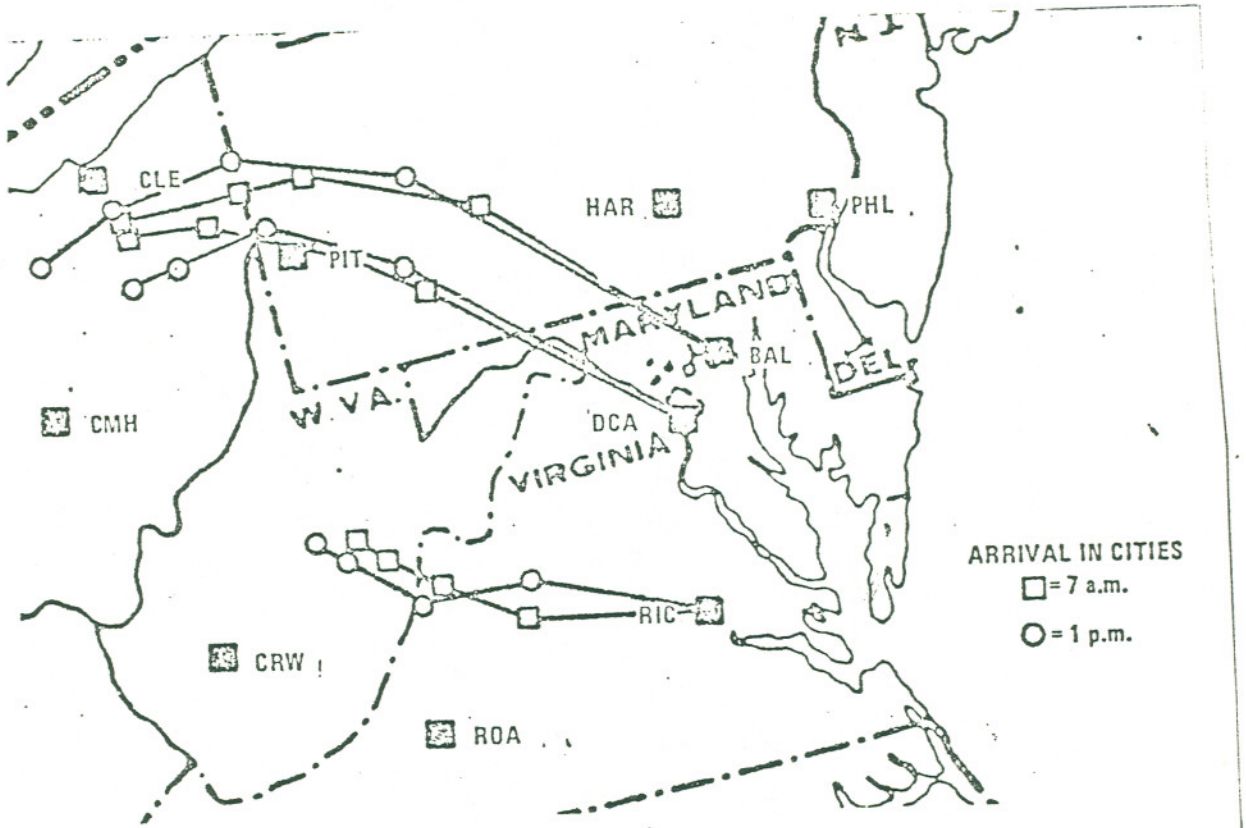

Figure 25: Forty-eight-hour trajectories (12-hour increments) surface to 1000 meter, July 9, 1974.

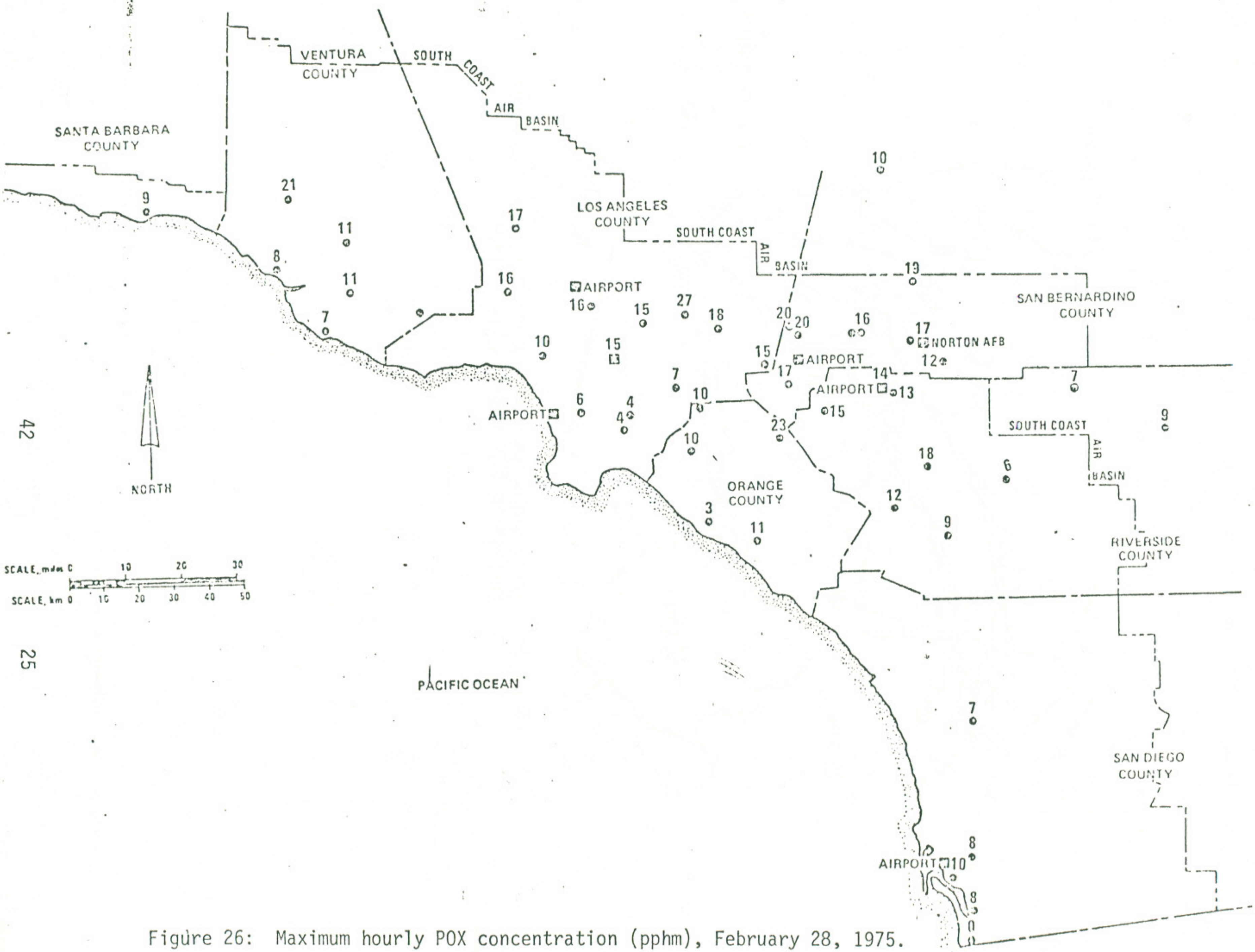

Figure 26: Maximum hourly POX concentration (pphm), February 28, 1975.

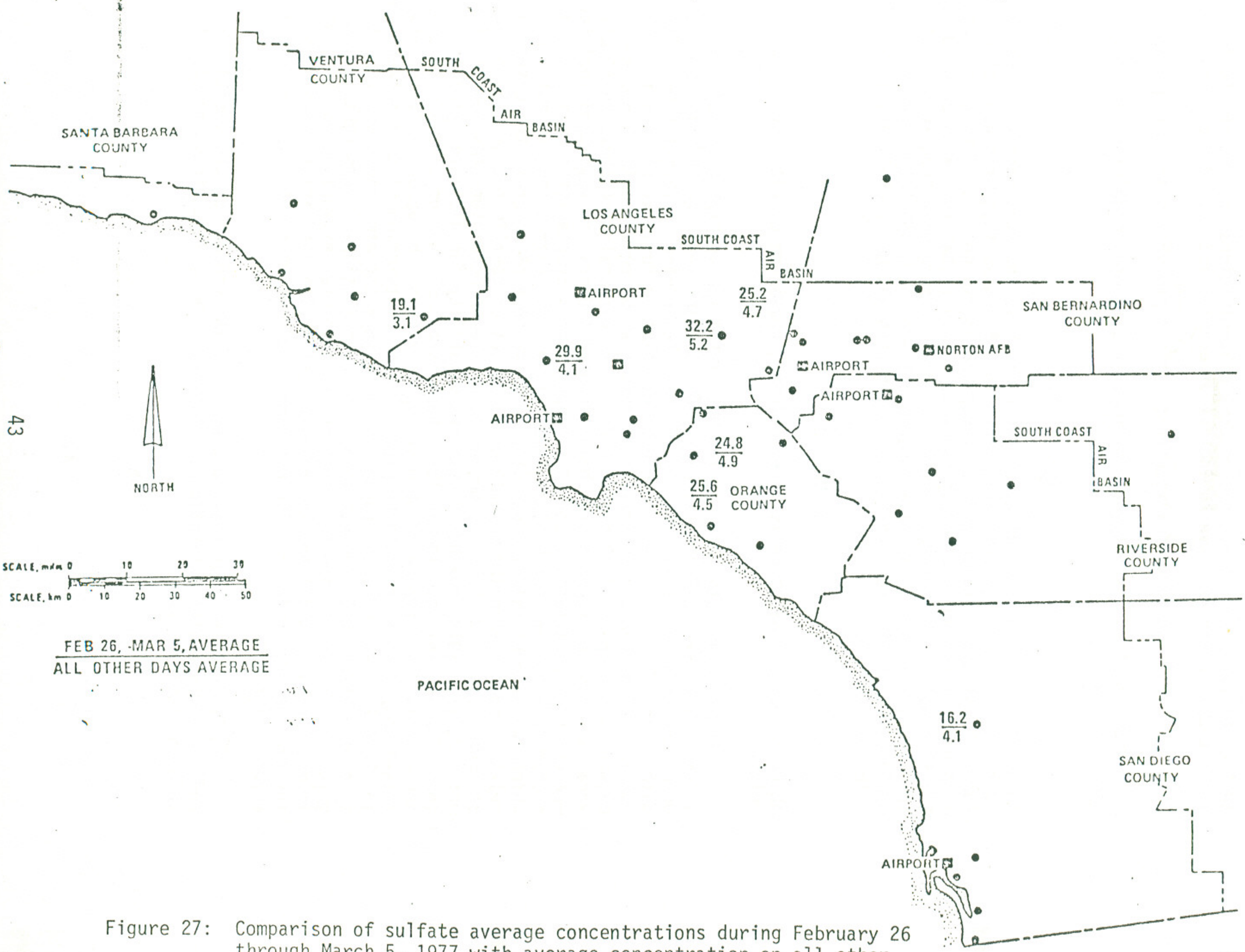

Figure 27: Comparison of sulfate average concentrations during February 26 through March 5, 1977 with average concentration on all other days in the same months.

spatial patterns in sulfate and oxidant concentrations are attributed to differences in the relative humidities at coastal and inland locations.

2.1.17 Relation between atmospheric optical properties and air quality

Under certain assumptions, Koschmieder's theory (Middleton, 1952) gives the relation

$$V_2\sigma = 3.912 \tag{1}$$

in which V_2 is the meteorological range and σ is the atmospheric extinction coefficient. The meteorological range is defined as that distance for which the contrast transmission of the atmosphere is two percent. The subscript 2 is used on the meteorological range to indicate that the value assumed for the threshold of brightness contrast is 0.02. There have been investigations to determine if a similar relationship between the visibility V and the nephelometer extinction coefficient b (Horvath and Noll, 1969) existed. The relation found was

$$Vb = 3.5 \tag{2}$$

which suggests that there is an excellent correspondence with the Koschmieder relation.

Nephelometer data taken at the Research Triangle Park and visibility data taken at the Raleigh-Durham Airport (RDU) for the years of 1972 through 1976 were used to test the validity of (2) for the Research Triangle Park. The data used were restricted to an ambient relative humidity of less than or equal to 65 percent, a visibility of less than or equal to 10 miles, and between the times of 1000 and 1500 EST. The rationale for these restrictions were: 1) With the nephelometer being located indoors, it was found that the measurements were being taken at a temperature characteristic of the inside rather than the ambient outdoor temperature. By restricting the data for which the ambient relative humidity was less than 65 percent, the effect of relative humidity on the nephelometer extinction coefficient should not be a serious factor. 2) From the beginning of the nephelometer measurements (1972) until July of 1975, the RDU prevailing visibility for distances greater than 12 miles was reported as 12+. Such data could not be used and to be conservative, a distance of 10 miles was chosen as the upper limit for which prevailing visibility would be used. 3) The restriction of data between 1000 and 1500 EST was chosen as being the times when the atmosphere would be the most homogeneous with respect to aerosol distributions. This restriction gives recognition to the fact that the nephelometer extinction coefficient is measured at a point and the relevant extinction coefficient needed is the average extinction coefficient along the line of sight. The results are given in Table 1.

In Table 1, $\overline{Vb}$ signifies an average of the product of the visibility and the nephelometer extinction coefficient. Thus, in contrast to (2), the relation obtained was

$$Vb = 1.9 \tag{3}$$

Table 1. Average Values of Prevailing Visibility V and Nephelometer-Measured Extinction Coefficient

Year	$\overline{Vb}$	Standard Deviation	Observations
1972	1.78	0.86	368
1973	2.01	0.69	304
1974	2.05	0.95	328
1975	1.90	0.76	565
1976	1.75	0.55	483
1972-1976	1.88	0.77	2048

The validity of (2) has also been examined for Los Angeles (Tri-City Study, 1973). A constant of 2.86 instead of 3.5 was obtained. Thus, these results suggest that the average of the product of the prevailing visibility and the nephelometer extinction coefficient varies with location.

The data were also treated in a different manner. The nephelometer extinction coefficient was sorted according to the prevailing visibility and the reciprocal of the extinction coefficient was averaged. The results are shown in Figure 28 in which the prevailing visibility is plotted against the reciprocal of the extinction coefficient. The rectangles are formed by using the average of the reciprocal extinction coefficient with its standard deviation for the horizontal length and the differences of the visibility values for the vertical length. The numbers in the rectangles are the number of observations during the five-year period. The solid line on Figure 28 is a plot of

$$V = 1.9\ b^{-1} \tag{4}$$

and the dashed line is for

$$V = 3.9\ b^{-1} \tag{5}$$

Clearly (4) is an excellent fit of the data while (5) fits none of the data.

The data were also sorted according to month and the product of the prevailing visibility and the nephelometer extinction coefficient averaged. A cyclic trend was found, with $\overline{Vb}$ being largest during the summer and smallest during the winter. The results are shown in Figure 29.

A relationship was developed between the turbidity coefficient B_λ of a dual wavelength (380 and 500 nm) sun photometer and the nephelometer extinction coefficient b.

By definition

$$B_\lambda = \int_0^{S_\lambda} b_\lambda\ (s)ds \tag{6}$$

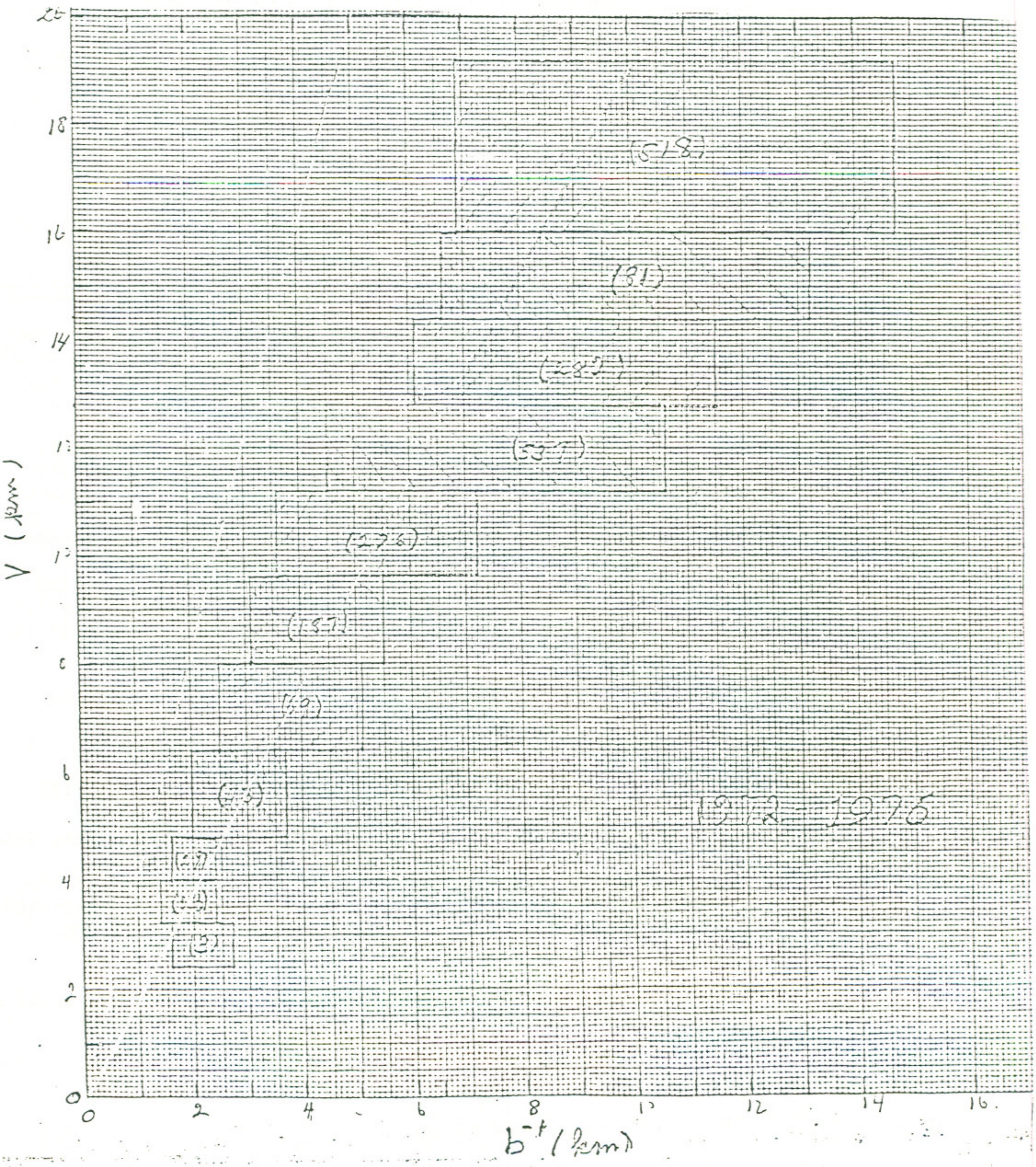

Figure 28: Prevailing visibility versus the average of b^{-1} for 1972-1976.

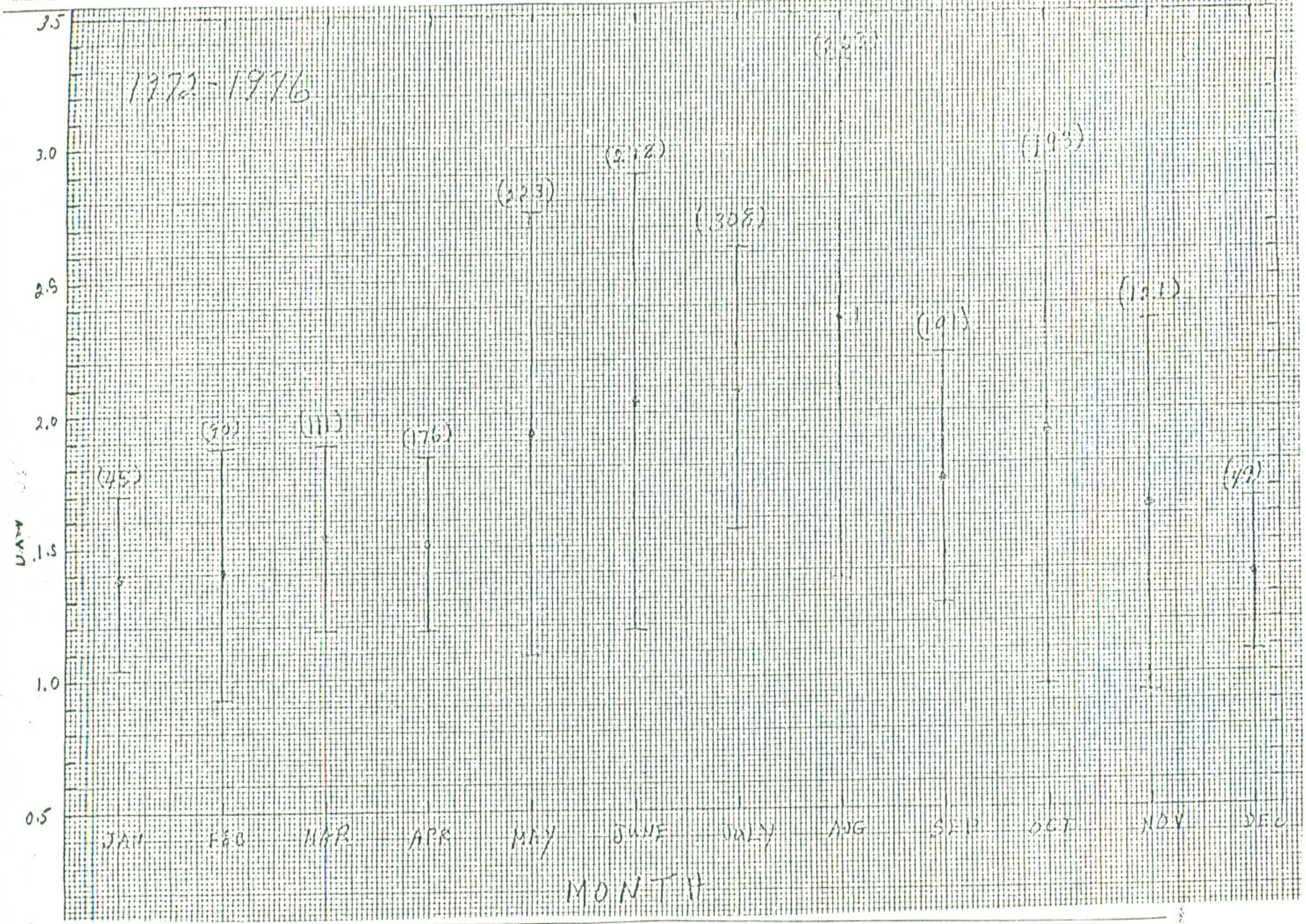

Figure 29: Monthly average of bV. Standard deviation is given as well as the number of observations.

where the turbidity measurements are for a 10-nm bandwidth centered on wavelength λ and $b_\lambda(s)$ is the corresponding extinction coefficient at position s along the line of sight from the sun photometer toward the sun. S_λ is the distance at which the extinction coefficient $b_\lambda(s)$ for a wavelength λ and position s no longer gives a significant contribution to the integral. On the other hand, the average extinction coefficient $\overline{b}_\lambda$ is defined by

$$\overline{b}_\lambda = S_\lambda^{-1} \int_0^{S_\lambda} b_\lambda(s) ds \qquad (7)$$

Thus

$$B_\lambda = \overline{b}_\lambda S_\lambda \qquad (8)$$

We will now define a constant α_λ such that

$$\alpha_\lambda = \overline{b}_\lambda / b \qquad (9)$$

and (8) can be written as

$$B_\lambda b^{-1} = \alpha_\lambda S_\lambda \qquad (10)$$

Thus, an average of $B_\lambda b^{-1}$ is of interest because it is related to the average path length along which the contributions to the turbidity originate. Restricting measurements of B_λ and b to between 1100 and 1500 EST and a relative humidity of less than or equal 65 percent, annual averages are shown in Table 2.

Table 2. Average Values of Ratio of Sun Photometer-Measured Turbidity B at 380 and 500 nm to Nephelometer-Measured Extinction Coefficient b

Year	$\overline{b^{-1}B_{380}}$ (km)	Standard Deviation (km)	$\overline{b^{-1}B_{500}}$ (km)	Standard Deviation (km)	Observations
1972	1.62	0.80	1.18	0.57	258
1973	1.63	0.56	1.25	0.44	285
1974	1.73	0.70	1.24	0.56	197
1975	1.58	0.83	1.19	0.65	278
1976	1.99	0.98	1.45	0.72	113
1972-1976	1.67	0.77	1.24	0.58	1131

Assuming that $b_\lambda(s)$ decreases monotonically or remains constant between 0 and S_λ, then by the use of (9)

$$\alpha_\lambda \leq 1 \qquad (11)$$

which implies that the extinction coefficients B_{380} and B_{500} were determined over a minimum average path length of 1.7 km and 1.2 km respectively for the period of 1972 through 1976.

The data for $b^{-1}B_{\lambda}$ were also sorted according to month. A seasonal cyclic variation was found for both $b^{-1}B_{380}$ and $b^{-1}B_{500}$, with a maximum occurring during the summer and a minimum during the winter. The trends are analogous to the trend shown in Figure 29. A plausible explanation for this trend is that the aerosols are mixed through greater depths in the summer than in the winter.

2.1.18 Influence of relative Humidity on the nephelometer extinction coefficient

Some experimental work was undertaken to examine the dependence of the extinction coefficient on relative humidity. It is observed that, for a given relative humidity which is large enough, the extinction coefficient is different if the given relative humidity is reached by increasing the relative humidity than by decreasing the relative humidity. The phenomena is known as the hysteresis effect (Hanel, 1971). While the hysteresis effect has been observed, the measurements of the temperature and dew point are not accurate enough for quantitative results as yet.

2.1.19 Meteorological influences on the temporal variability of the nephelometer extinction coefficient

A detailed study on the temporal variability of the nephelometer extinction coefficient due to the influence of meteorology for data collected during February, 1977 at the Research Triangle Park was completed. Meteorology affects the extinction coefficient by its influence on the physical and chemical properties characterizing the aerosols. These properties include the size distribution, the number and mass density, shape, and chemical composition of the aerosols. The temporal variability of the extinction coefficient was studied for (1) stable atmospheric conditions; (2) unstable atmospheric conditions; (3) fumigation; (4) ground-based inversion breakup; (5) frontal passages; (6) precipitation including rain and snow; and (7) a dust episode. Only one case is described here.

Under fair-weather, clear-sky conditions, the observed diurnal variation of the extinction coefficient was observed to be divided into three phases.

They are:

(1) In the evening after radiation cooling began, the extinction coefficient increased monotonically with time. Often, it would stop increasing by 0200 EST and remain relatively constant until about sunrise.

(2) After sunrise, the extinction coefficient increased relatively rapidly and eventually reached a maximum before noon. It would then decrease, with the most rapid decrease occurring at the time of the estimated breakup of the ground-based temperature inversion.

(3) After the breakup of the inversion, the extinction coefficient continued to decrease monotonically. Usually, it would stop decreasing by 1500 EST and remain relatively constant until the beginning of radiation cooling.

Before presenting the diurnal variation of a particular case, it will be helpful to mention that continuous measurements of the aerosol number density have been made in the size ranges of 0.25 to 0.35 μm, 0.25 to 0.7 μm, 0.7 to 1.5 μm, 1.5 to 2.5 μm, and 2.5 to 5 μm (Jennings, 1976). For all of these size ranges, the diurnal variation of the number density was observed to be similar to the diurnal variation of the extinction coefficient mentioned above. Further, the variation of the Aitken nuclei number density were observed to decrease during the night and increase during the day. It should be emphasized that this diurnal variation of the Aitken nuclei number density is opposite to the diurnal variation of the extinction coefficient given in Phases (1) and (3) above. A particular case will now be discussed.

On February 9 and 10, 1977, the Research Triangle Park was under the influence of a cold continental high. The variation of the extinction coefficient between 1800 EST on February 9 to 1200 EST on February 10 is shown in Figure 30. For convenience of presentation, the extinction coefficient variation is not shown between midnight and 0500 EST. The sky was clear throughout this period. The wind was very light until 1000 EST and started gusting to 5 ms^{-1} thereafter. The trend of the extinction coefficient after 1200 EST is not shown, but the strip chart indicated a decrease to about 6×10^{-5} m^{-1} by 1500 EST.

Turbulent processes associated with solar heating are largely responsible for the decrease of the extinction coefficient during the day. In the afternoon, the turbulent mixing intensity decreases and it would be expected that the vertical aerosol distribution would tend toward another distribution. It might be thought that gravitational settling of aerosols would be an important process to account for the increase of the extinction coefficient during the night. However, since most of the aerosols sensed by the nephelometer lie in the size range between 0.1 μm and 1 μm (Charlson et al., 1974), no appreciable settling is expected for aerosols with radii less than 1 μm (Junge, 1963). Thus, in general, it does not appear likely that gravitational settling would be an important process to account for the increase of the extinction coefficient during the night. The observation, mentioned earlier, that the Aitken nuclei concentration decreases during the night suggests that coagulation may be an important process to account for the increase of the extinction coefficient during the night. Since the relative humidity usually increases during the night, it is also possible that the relative humidity plays a role in an explanation for the increasing trend of the extinction coefficient during the night.

Let us now confine our attention to the maximum of the extinction coefficient of Figure 30. As the mixing processes associated with solar radiation commence, the extinction coefficient starts to increase, eventually reaching a maximum, and subsequently decreasing. If there is a decrease in the aerosol concentration with height, the appearance of the maximum is easily understood. As the intensity of the mixing increases the larger aerosol

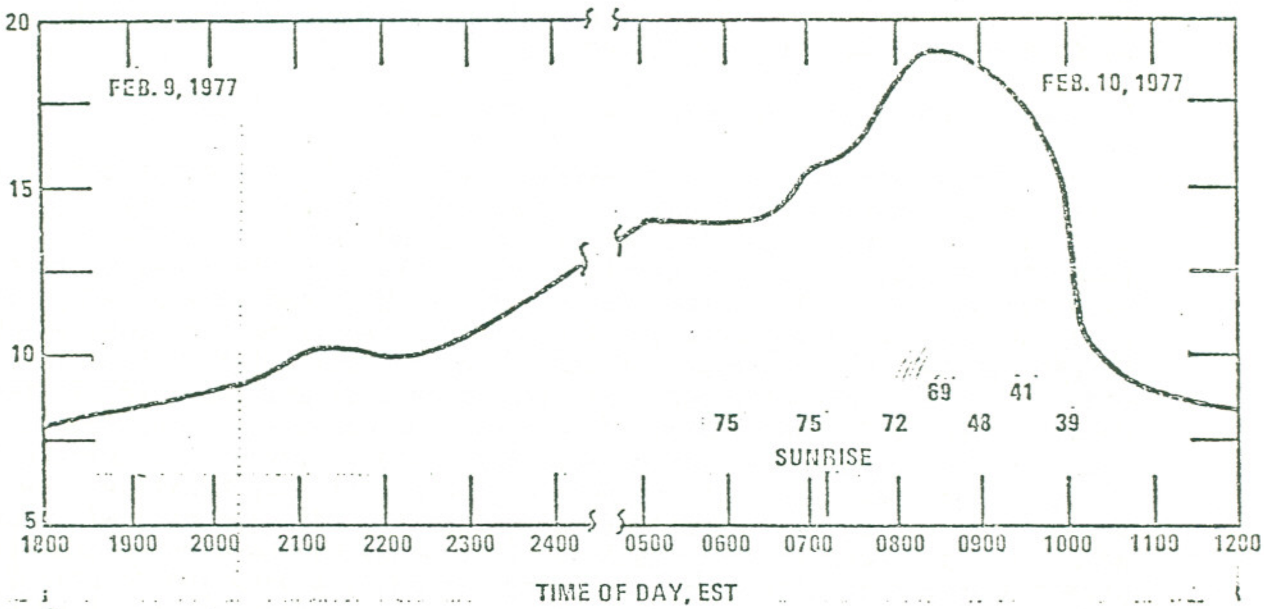

Figure 30: Temporal variation of the extinction coefficient during a clear, still night. The ambient relative humidity is given at selected times.

concentration below the nephelometer orifice is mixed upward, thereby accounting for the increase of the extinction coefficient. Eventually a maximum will be reached and there will be a decrease of the extinction coefficient due to the mixing of the less dense aerosol concentration downward. The relatively rapid decrease of the extinction coefficient at 1000 EST appears to be associated with the breakup of the ground-based temperature inversion. By making use of the 0700 EST Greensboro radiosonde data, an estimate of 1000 EST for the breakup of the ground-based temperature inversion was obtained. It is also of interest to remark that this is also the time at which the wind ceased to be calm. It will also be noted that the relative humidity decreased from 69 percent to 48 percent between 0830 and 0900 EST. Using the temperature and dew point strip charts, it was estimated that 16 percent was due to solar heating and 5 percent was due to the mixing downward of dry air aloft to account for the decrease of 21 percent.

2.1.20 Averaging-time model development and application

A single air quality data analysis system is needed for interrelating air pollutant effects, air quality standards, air quality monitoring, diffusion calculation, source-reduction calculations, and emission standards. A two-parameter averaging-time mathematical model has been developed to meet the need for such a single system (Larsen, 1971, 1973, and 1974). Urban air pollutant concentration data usually fit this two-parameter model quite well. Concentrations measured near isolated point sources often do not fit the model. A three-parameter model has therefore been developed to fit these data (Larsen, 1977a and 1977b). The first two parameters (the geometric mean and the standard geometric deviation for any averaging time) are the same. The third parameter is an increment (either positive or negative) that can be added to each measured concentration so that the adjusted data will more nearly fit a lognormal distribution. This model can be used to characterize either measured or diffusion-calculated air quality data and to calculate the degree of emission reduction needed to achieve air quality standards.

As noted above, techniques are needed for relating air pollutant concentrations to air pollutant effects so that air quality standards can be set at the levels necessary to prevent various unwanted effects (Finklea, et al., 1977). An animal mortality mathematical model has been developed as part of this effort (Larsen, Gardner, and Coffin, 1977). The model is based on an analysis of mortality data from several years of experiments in which mice have been exposed to various nitrogen dioxide concentrations for various durations and have then been exposed to an aerosol of a lung pathogen. Excess mortality was found to be proportional to nitrogen dioxide concentration multiplied by exposure duration raised bo the 0.33 power. The concentration (c) expected to cause a certain mortality level (z), as a function of the hours of exposure (t), can be expressed as

$$c = 9.55(2.42)^{z}t^{-0.33}$$

As an example, the model can be used to calculate expected excess mortality if mice are first exposed to the ambient nitrogen dioxide concentrations measured at sites in Chicago, Los Angeles, or Chattanooga, and then are challenged with an aerosol of a lung pathogen (Figure 31).

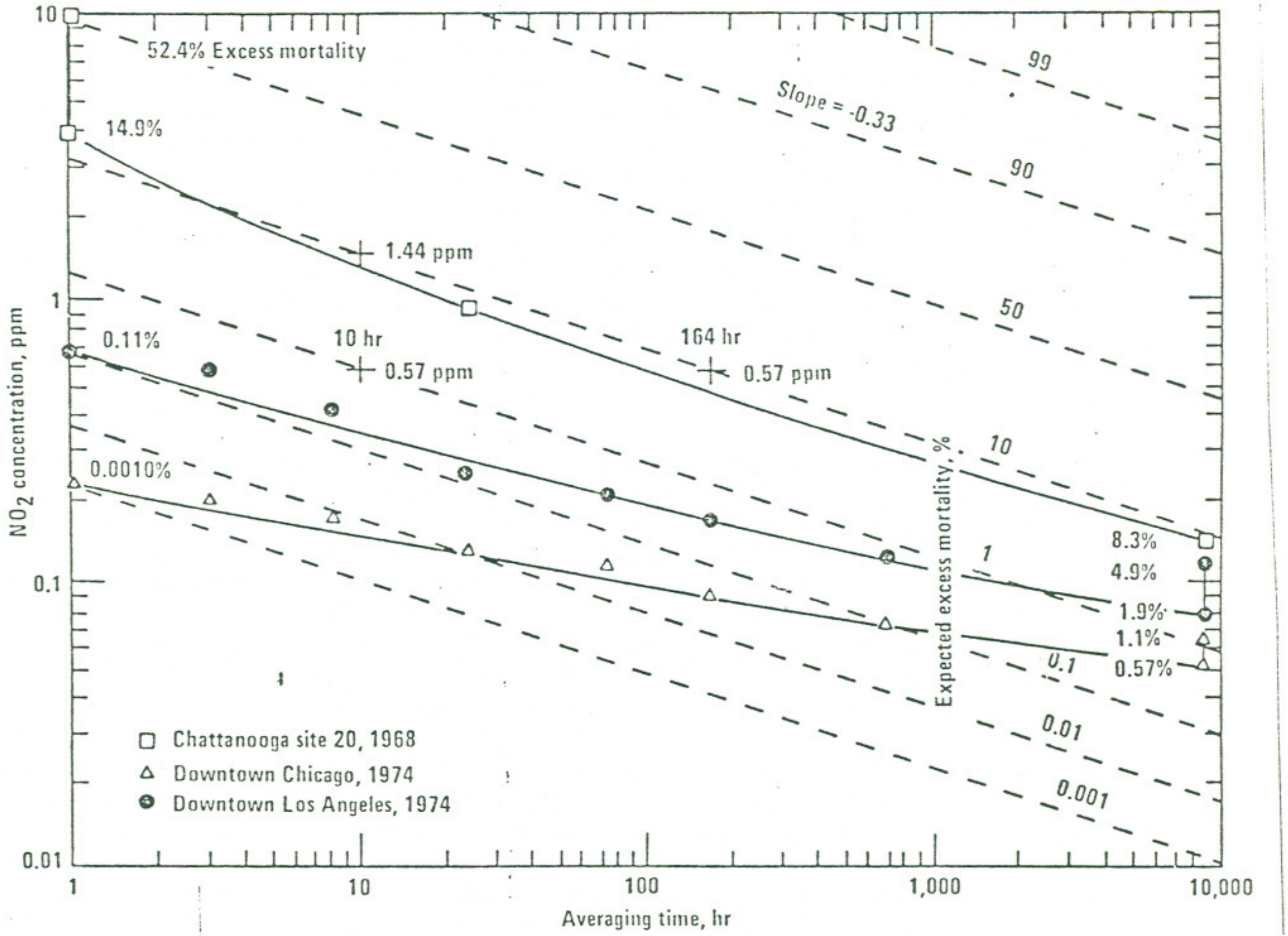

Figure 31: Excess mortality expected if mice are first exposed to the maximum NO_2 concentrations measured at sites in Chicago, Los Angeles, or Chattanooga, and then are challenged with an aerosol of a lung pathogen.

2.1.21 Analysis of GM test data

High frequency wind data, gathered during the General Motors (GM) Sulfate Dispersion Experiment, were used to estimate the dispersion near roadways. A small sample of the GM data was used to develop the methodology to estimate dispersion from the fluctuation statistics of the wind. For this pilot study the EPA HIWAY Model was modified to use these fluctuation statistics directly to estimate dispersion. The results from the pilot study show that the atmosphere near the roadway was more dispersive than the Pasquill-Gifford stability class indicated. Also, the performance of the HIWAY Model was improved using the dispersion parameters determined from the wind fluctuations. While the results from the pilot study are interesting, the major function of the study was to set forth the techniques that will be used to analyze the whole data set.

2.1.22 NATO/CCMS study

At a NATO/CCMS meeting in 1975 it was decided to conduct a "practical demonstration" of multiple-source Gaussian plume models for SO_2 against a common data base for Frankfurt, Federal Republic of Germany. The Meteorology Laboratory executed two Gaussian-plume urban air pollution models using annual frequency distributions of the meteorology and forwarded these results to the NATO/CCMS Modeling Panel during FY 1976. As part of the Meteorology Laboratory's continued participation in this study, the Climatological Dispersion Model (CDM) was reapplied in order to estimate summer and winter season concentrations at six selected receptor sites. A joint-frequency distribution of wind direction, wind speed, and stability class was generated using the reported synoptic observations for two 183 day periods denoted as summer and winter seasons. The CDM was then applied to each season using an appropriate emission inventory for each season. The resulting average winter season SO_2 concentration estimates were generally ten times higher than the corresponding average summer season SO_2 concentration estimates. The higher winter concentrations resulted mostly from the increased SO_2 emissions due to space heating which was not present during the summer season. Since the summer and winter seasons were of equal length, 183 days each, it was possible to combine the seasonal estimates of concentration and compute annual concentration estimates at the six receptor sites. These computed annual estimates were essentially the same as the estimates previously obtained in the studies conducted during FY 1976. These results were summarized (Turner and Irwin, 1977) and forwarded to the NATO/CCMS modeling panel as documentation for the practical demonstration of Gaussian plume urban air quality simulation models.

2.2 Research Projects Monitored by Meteorology Laboratory Personnel

2.2.1 Mixed layer depths from lidar measurements

Lidar measurements were made at a downtown site in St. Louis, Missouri during the period July 23 to August 13, 1976 as part of the Regional Air

Pollution Study (RAPS) using the Mark IX ruby Lidar System. Vertical shots at one-half minute intervals were made throughout the diurnal cycle and the resulting return signals were recorded digitally on magnetic tape to document the time history of the mixed layer. In this manner, the structure of the aerosol pattern in the air passing by could be studied. These data were then processed at SRI International. Various analyses techniques were explored to develop and test objective analyses methods for determining the thickness of the mixed layer(h). The backscatter returns are shown in Figures 32a and 33a and the vertical gradients of these return signals are shown in Figures 32b and 33b. It was tentatively concluded that the level where the negative gradients were largest gives the best indication of h. The time series of this level is shown in Figures 32c and 33c. Further tests on more data and against other data sets including temperature profiles determined from radiosonde and helicopter soundings of temperature and aerosols and acoustic sounder data are currently in progress.

2.2.2 Urban meteorological measurements

The University of Wyoming, under the auspices of the Regional Air Pollution Study, has made comparative observations of urban and non-urban environments to determine processes responsible for differences in boundary layer characteristics and wind fields. These observations were made in St. Louis, Missouri, during annual four-week field expeditions between mid-July to mid-August in 1972-1976. The 1976 field program emphasized the measurement of the turbulent structure of the urban and the rural boundary layers using the NCAR Clean Air fixed wind aircraft equipped with an inertial navigation system essential for aircraft measurement of turbulence.

Preliminary analyses of turbulent flux data throughout the convective period of the day for various land uses reveal that there are differences in the terms of the turbulent kinetic energy budget between rural and urban atmospheres. Energy dissipation was found to be greater over the city than over the rural sites within the mixing layer, indicating a greater production of turbulence also over the city and over the rural area. Above the elevated inversion level, all turbulent fluxes were found to be very small compared to fluxes within the mixing layer. Buoyancy plays a stronger role in production of turbulence that shear for both the urban and rural surfaces at 150 m above the ground.

The major conclusions derived from the earlier studies have been discussed (Viebrock, 1977).

2.2.3 Field measurements of three-dimensional diffusion coefficients using METRAC™

The objective of this research program was to obtain three-dimensional diffusion coefficients for use in numerical diffusion models. Data were collected in a field program utilizing the METRAC positioning system deployed near St. Cloud, Minnesota. Quasi-horizontally floating super-pressure tetroons are accurately tracked over ranges of several tens of kilometers to obtain three-dimensional Lagrangian turbulence statistics.

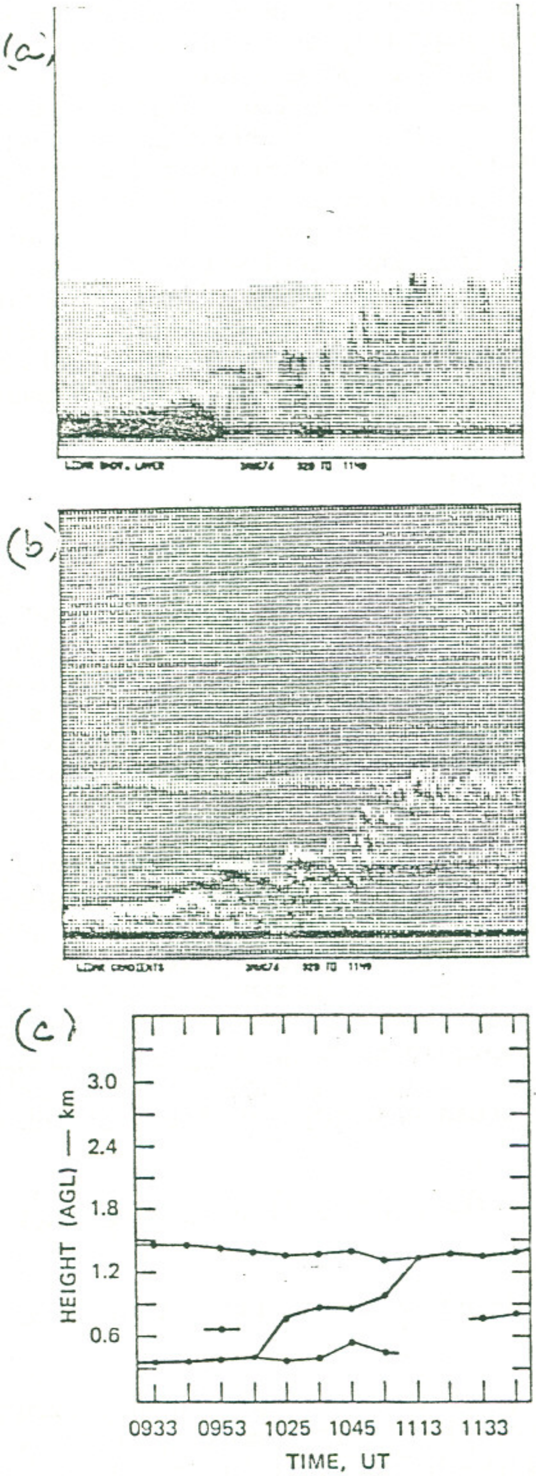

Figure 32: Gray scale display of corrected lidar data from 0929 to 1145 showing the changes produced by thermal mixing. (a) backscatter data. (b) vertical gradients. (c) objectively identified negative gradients.

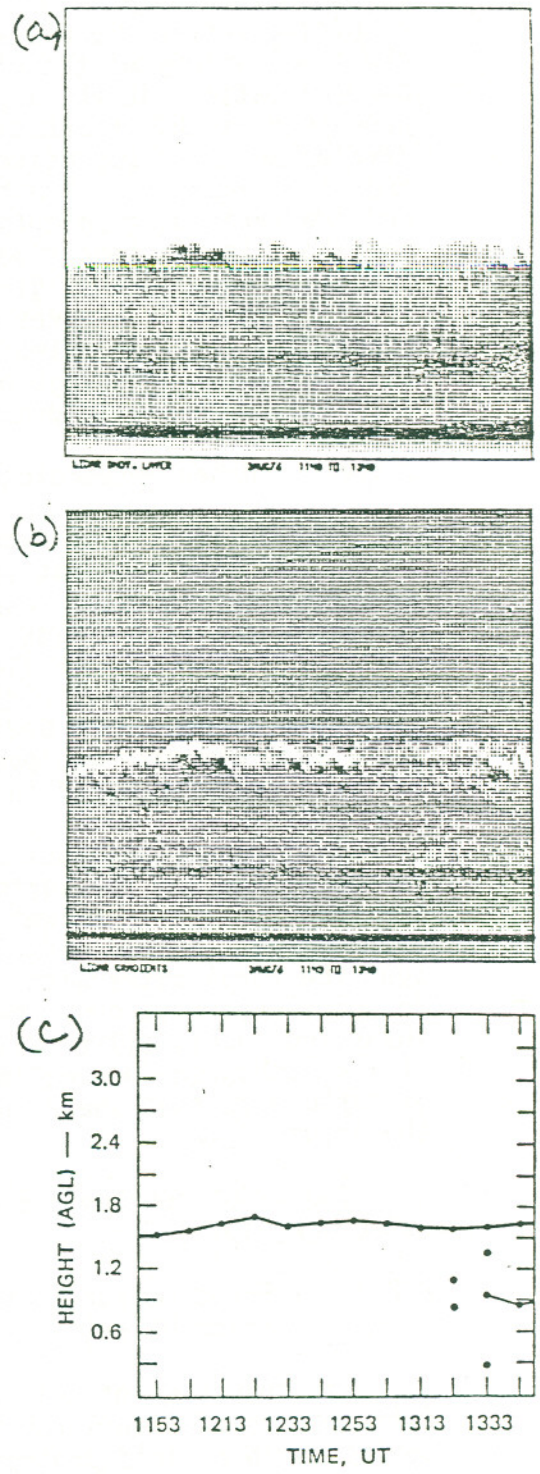

Figure 33: Gray scale display or corrected lidar data from 1149 to 1348 showing typical midday condition (a) backscatter data. (b) Vertic gradients. (c) objectively ident fied negative gradients.

The program consists of two phases. Twelve tetroon flights were made in Phase One of this contract; ten of which were fully processed with results presented. (Jasperson, 1977) all flights were made during the winter months in which the lower atmosphere tends to be nearly isothermal and very stable. These conditions enable extending the curve of vertical velocity variance as a function of stability presented by Hass, et al., (1967). Three dimensional velocity variance statistics and diffusion coefficients were computed and shown to vary over one to two orders of magnitude.

Phase One was dominated by strong low level winds, typical of winter, which resulted in both long averaging times (20 seconds) and short data segments (45-60 minutes) in order to reduce the system induced variance to a negligible part of the measured velocity variances. An effort has been made during Phase Two to increase the data record length. The 33 additional tetroon flights in phase two have been completed and are currently in analysis.

2.2.4 Analysis of tower turbulence measurements

Turbulence measurements of wind using bivanes located at 6 different levels (18, 91, 137, 183, 244, and 305 m) on the 1000 ft. SRL-WJBF instrumented TV tower at the Savannah River Laboratory (SC) were used to calculate roughness length (Z_o) and other boundary layer similarity parameters. Preliminary results show large differences in Z_o at different levels on the tower which suggests the presence of internal boundary layers arising from the inhomogenous terrain upwind of the site. These results are being further analysed by comparison with results of Z_o from wind profile consideration.

In addition, the vertical, lateral and longitudinal Eulerian integral time and length scales and the power spectra for these components were calculated from data at each of the three levels under neutral conditions ($-005 \leq Z/L \leq +0.05$). There appears to be a good relationship between the wavelength of the peak of the spectrum and the integral length/time scale. From these results, one can determine the eddy diffusivity and the other dispersion parameters from spectrum analyses alone if one knows the value of the ratio between the Lagrangian and Eulerian time or length scales.

2.2.5 Second order closure modeling of turbulence

The Meteorology Laboratory has a continuing interest in modeling turbulent flows by the most realistic yet practical methods. A large part of this has been the work done by Aeronautical Research Associates of Princeton (ARAP) under an EPA contract. The most recent endeavor extended the previous dispersion model of Lewellen and Teske (1976) to include bouyant plumes. Neither convectively unstable nor neutrally stratified atmospheres presented any major difficulties but stably stratified atmospheres required major changes to the model. The possibility of exciting wave motions caused by the rising plume demanded a special computational domain which followed the plume motion. Although only about one percent or less of the turbulent energy of the plume is coverted to wave energy, the mere presence of the waves required the special treatment. The model is still in a developmental state.

2.2.6 Select group in air pollution meteorology

The major grant to Pennsylvania State University entered its fifth and final year in October 1976. The effort was in several areas.

Anthes' mesoscale numerical model work is reported in Keyser (1977), Keyser and Anthes (1977), Seaman (1977), Sobel (1977), and Anthes and Warner (1977). The boundary layer measurement studies of Thomson are summarized in Redford (1977), and Scheib (1977). A study of the energetics of the urban surface is given in Boland (1977), while Kabel et al. (1977) describes the effort to characterize the deposition of pollutants upon vegetation. The annual and final grant reports to EPA will document this extensive research effort of Pennsylvania State University more fully.

2.2.7 Investigating nocturnal turbulence formulation and preparing wind and temperature forecasts

The Techniques Development Laboratory (TDL) of the National Weather Service is developing a large-scale boundary layer model for predicting wind, temperature, and humidity within the lowest 2 km of the atmosphere. Developments in the TDL model include: (1) A computer program to compute and plot trajectories from a selected geographical location and heights for a 24-hour period. The program is being generalized so that release times and locations can be chosen arbitrarily; (2) New methods of initializing the model for predicting nocturnal winds. Tests show that the evolution of the nocturnal boundary layer wind is strongly dependent upon the initial wind and pressure fields and may override the importance of the precise formulation of the eddy diffusion coefficients; (3) Development of a numerical technique for calculating eddy diffusion coefficients from temperature measurements within the boundary layer. A variational method has been devised and programmed but not yet tested for computing diffusion coefficients directly from a sequence of temperature profiles; (4) A new, highly stable numerical scheme for integrating the prediction equations for temperature and wind when the diffusion coefficients depend upon local stability. Tests show that conventional schemes work well with large time steps when eddy coefficients are smooth, prescribed functions of height but fail when the equations are non-linearly unstable; (5) New error-checking procedures have been established for use in initializing the wind and pressure fields; (6) An implicit filter has been devised and tested for continuously smoothing most of the model's predicted quantities, particularly wind fields. The filter has a variable weight that causes the two-grid interval noise to be completely removed while damping progressively longer waves if required, and (7) Generation of test cases which will be used as data sets in EPA's atmospheric pollution models.

2.2.8 Model verification and the Regional Air Pollution Study (RAPS)

Model verification studies have been very limited in nature due to the lack of adequate air monitoring data bases against which to test models. The unverified status of Air Quality Simulation Models (AQSM) has proved a considerable deterent in their application, both in terms of the rather extensive data resources required in operating the models and the unknown accuracy of their performance. Uncertainity limits on model prediction inaccuracies resulting from all sources of error can be obtained through extensive comparison of model concentration predictions and ambient measurements. Comparisons should be made for a variety of meteorological and, where possible, emission conditions. Exercising models with sufficient data to establish model prediction accuracy and uncertainty limits will provide insight into establishing the degree to which models can be extrapolated to conditions beyond those in the domain of evaluation.

The St. Louis Regional Air Pollution Study (RAPS), a five-year field program sponsored by the Environmental Protection Agency and initiated in 1972, provides highly resolved spatial and temporal emissions and ground monitoring data for use in model verification studies.

The Fiscal year 1976 report (Viebrock, 1977) covered many facets of the model adoptation and verification program. Major delays in delivery of the St. Louis emission inventories have set back the initiation of the model verification studies to early 1978. Work did continue in model adoptation and data preparation for the verification studies.

The adaptation and optimization for computational efficiency of the second generation photochemical airshed model developed under contract by Systems Applications, Inc. neared completion. Major improvements in the operational and cost characteristics of the model have been realized through extensive streamlining and restructuring of the computer code. Computer code improvements include:

(1) System Restructure: Redesign the handling of the input data to avoid redundant information transfer, reduce program size, and allow easier modifications.

(2) Core Storage Reallocation: Modify the program and data structures to allow overlays and sharing of core memory.

(3) Execution Speed Increase: Rewrite inefficient portions of the program to conform to the known techniques for optimum program execution.

(4) Program Restructure: Redesign the main program to conform to the concepts of modularization and structural programming in order to make revisions easier.

(5) System Documentation: Write a systems programming manual to be used for modifications by non-SAI personnel.

Under an Interagency Agreement with Lawrence Livermore Laboratory (LLL), the air quality models LIRAQ-1 (inert species) and LIRAQ-2 (photochemical) have been adapted for use with the RAPS data base and set up on the Lawrence Berkley Laboratory (LBL) computer system. EPA will have direct access to the models on the LBL system. The modified LIRAQ was tested by LLL and appears to have been successfully adapted, but some further testing will be necessary since EPA was unable to deliver a final emissions inventory as required.

Two additional agreements related to LIRAQ were initiated late in the year. The first agreement is with LLL and calls for final testing of LIRAQ when the emissions inventory becomes final. The second is with LBL and is designed to provide computer time for LIRAQ validation studies after the final testing.

Selection of possible days for model verification runs was completed. Two sets of about 60 days each were chosen, one suitable for use with photochemical models and the other suitable for inert species models. Selection of candidate days was based on data availability and measurements of relatively high concentrations of the pollutants of interest. Specifically, the criteria for selection are as follows:

Inert Species:

(1) sufficient radiosonde data to determine maximum and minimum mixing heights

(2) less than or equal to a trace of rain at the St. Louis airport

(3) maximum network hour average SO_2 greater than 0.03 ppm

(4) greater than 70% SO_2 data available

Photochemical:

(1) and (2) as above

(3) maximum network hour average O_3 greater than 0.06 ppm

(4) greater than 70% O_3, NO, NO_2, THC and CH_4 data available

An hour average must contain 15 minutes or more of data to be considered valid data. The network averaging is carried out over stations 101-121. The requirement for radiosonde data means that few, if any, weekend days will be selected since releases were restricted to weekdays, except during some intensive periods. Days with more than a trace of rain were excluded since none of the models make provisions for washout.

2.2.9 Fluid Modeling Facility Grant

Several studies were started under a one-year grant "Basic Studies of Boundary Layer Flow and Diffusion Over Small Scale Topography" that was awarded to the Department of Geosciences, North Carolina State University. Dr. S. P. S. Arya, of that department, is the principal investigator and directs the work of graduate students who use the FMF equipment. Under this grant agreement, Dr. Julian Hunt of the University of Cambridge, England, spent six months as a visiting scientist at the FMF and NCSU. He was involved in most of the experiments performed under the grant.

The basic studies include modeling in the wind tunnels and towing tanks. Two and three dimensional objects are introduced into neutral and stably-stratified atmospheres to measure the flow and dispersion in the vicinity of such objects as isolated hills, mountain ridges and buildings. Some object shapes were chosen to make direct comparison with theoretical formulations possible.

The work will be continued under a new grant.

2.2.10 Complex terrain field study

Under a contract signed with Geomet, Inc., work on this project has continued. Phase I, an appraisal of current research, was completed and the results were published (Koch et al., 1977). This report is devoted about equally to nonconservative chemical transformation and depletion, and to conservative transport and diffusion. Studies of SO_2 oxidation rates in power plant plumes are described and the primary mechanisms for conversion to sulfate are detailed. Early depletion of background O_3 by stack plumes is documented as well as the reappearance of concentrations above background at great distances from the stack. Precipitation scavenging of SO_2 from plumes appears to increase with distance from the source and has been modeled. Surface contact of plumes and dry deposition appear to be important depletion processes, but quantitative models have not been validated.

Sixteen comprehensive measurement programs of the physical behavior of plumes in complex terrain are reviewed and described, including model-to-measurement comparisons of concentrations. Numerical models that are available to simulate plume behavior are discussed as well as some independent analyses of σ_y and σ_z relationships over complex terrain. The reviews indicate that turbulence is enhanced over complex terrain and that horizontal plume spreading is amplified more than vertical spreading. Models tend to overpredict plume concentrations by factors of five or more within a few kilometers of the source, but predictions improve at greater distances. In general, the models underestimate initial lateral spread and overestimate later vertical spread.

Phase II, the aerometric survey focused on the Clinch River Power Plant in southwestern Virginia, was extended through September 30, 1977, thereby providing 15 months of measurement data. Modifications to the contract called for additional wind and temperature soundings. Sampling from one of the two vans was discontinued because of instrument and logistics problems, and one of the eight fixed monitoring stations, Castlewood, was washed away and completely destroyed in a flood. During a 12-day period in July, 1977, airborne monitoring of the plume was highly successful; 355 horizontal cross-sections of SO_2, NO, and O_3 were obtained. These will be analyzed to determine plume heights, dimensions, and trajectories. Although there were some difficulties with the data collection performance when the stations were first set in operation, the overall data recovery is considered excellent in view of the normal problems expected in such an extensive measurement project. For instance, during the last quarter, pollutant measurements at the fixed stations were around 90 percent or more of all possible hours, 247 wind soundings and 206 temperature soundings were taken, and mobile runs were performed on 53 days. Phase II of the contract will be completed upon submission of an edited magnetic tape of all valid measurements, and a manuscript describing the measurements. The manuscript and a preliminary tape are expected in February, 1978. Ultimately these data will be made generally available for study by others.

Phase III of the contract, which should be completed about July, 1978, calls for various analyses of the data, especially in terms of the impact of complex terrain on transport and diffusion, and on pollutant concentrations.

2.2.11 Analyses of ozone measurements on Mt. Sutro, San Francisco tower

San Jose State University has been supported by a grant to measure and analyze O_3 concentrations on a very tall tower near downtown San Francisco, California. The TV tower, which was instrumented to 219 m above its base, sits atop Mt. Sutro, which itself extends to 254 m above sea level. Consequently, the tower reaches well into the subsidence temperature inversion that is an important factor and is especially prominent during summer in west coast air pollution problems. The Mt. Sutro TV Tower offered an interesting opportunity to study "background" concentrations of O_3. Although the data sensors and acquisition system experienced numerous failures during the study periods, June-October of 1974-1976, sufficient valid data were collected for analysis (MacKay, 1977).

During late summer months, hourly average O_3 concentrations within the subsidence inversion exceeded the National Ambient Air Quality Standard (NAAQS) of 8 pphm during about 9 percent of the hours. Below the inversion and within the marine layer the NAAQS was exceeded 3 percent of the time. Figure 34 shows the diurnal variation (during a month with good data recovery) of mean O_3 concentrations at four levels on the tower. During the first 6 hours of the day O_3 concentrations at levels 1, 3, and 6 fluctuate near 3.5 pphm, while concentrations at level 5 decrease from 6 to 5 pphm. Near sunrise the concentrations at level 6 begin increasing; at level 5 the increase lags by several hours; at levels 1 and 3 within the marine layer the concentrations decrease slightly for a few hours, perhaps due to morning traffic emissions of O_3-destroying NO_x. At all levels the concentrations reach a maximum near 1500 PST, although at level 1 the concentrations are relatively constant. The secondary maxima near 2100 PST at levels 3, 5, and 6 are interesting, but unexplained.

In an attempt to determine the likely source(s) of the O_3 measured on the tower, wind measurements at corresponding levels on the tower were analyzed. Figure 35 is a wind rose of the ratio $(D_i \geq 8/\Sigma D_i \geq 8):(D_i < 8/\Sigma D_i < 8)$ where D_i is a particular wind direction, ≥ 8 and < 8 denote O_3 concentrations equal to or greater than and less than 8 pphm, respectively, and the summation is over all directions. The figure indicates that at level 6, high O_3 concentrations occur most frequently with winds from directions of 360 degrees through 90 degrees. At level 5 the preference is for directions of 30 degrees through 150 degrees. It should be noted that these directions are opposed to the general monsoon flow from the west that predominates during summer. The pollution wind rose for level 3 also shows some preference for directions other than westerly, but it is not statistically significant. In general, Figure 35 suggests that the ultimate sources of the O_3 measured on the tower are within the highly populated San Francisco Bay Region. This hypothesis is comfirmed by detailed analyses of several O_3 episodes, each of several days' duration. These analyses indicate that small perturbations on the

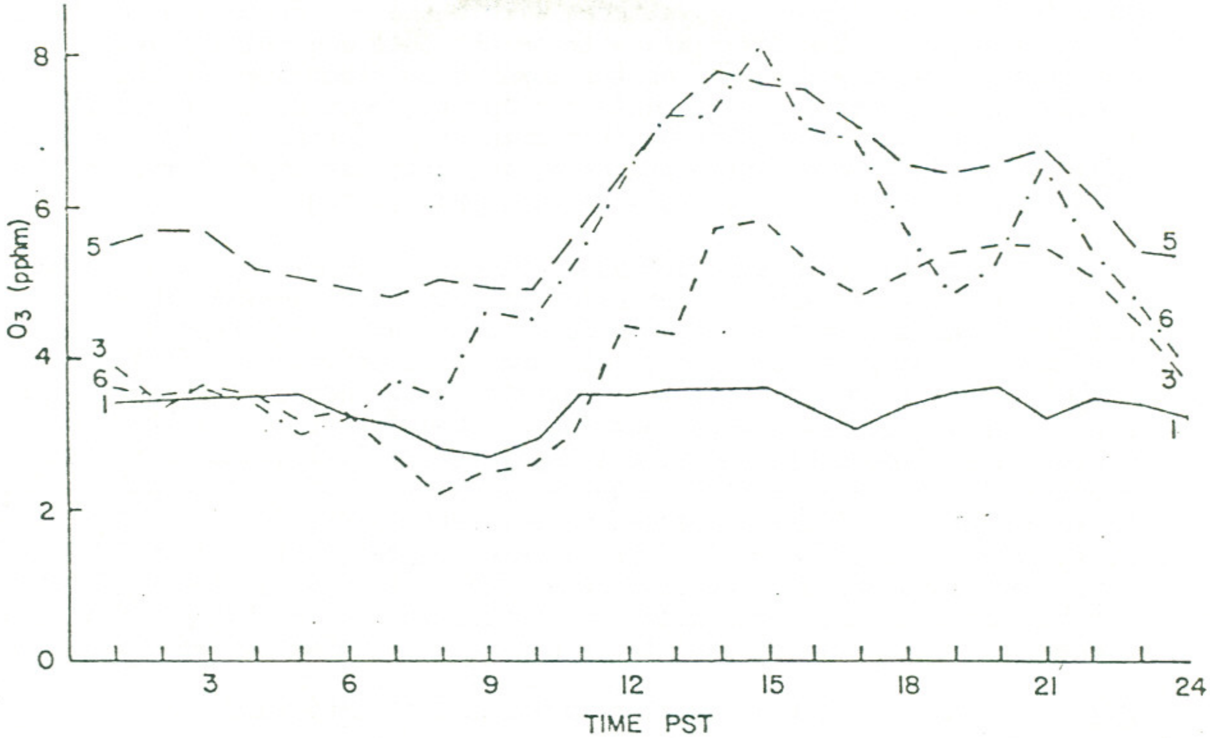

Figure 34: Mean diurnal variation of ozone, Sutro Tower, September, 1974. Numbers key levels (1 = 6 m, 3 = 88 m, 5 = 179 m, 6 = 219 m) above tower base, which is 254 m above sea level.

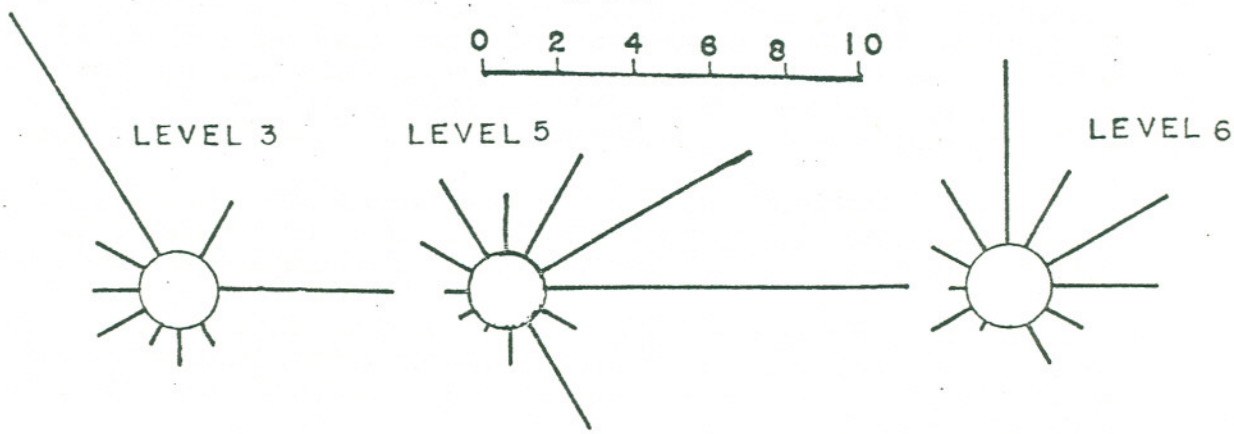

Figure 35: Distribution of the ratio of wind direction for hours with $O_3 \geq 8$ pphm to those with $O_3 < 8$ pphm. Sutro Tower, Summer, 1974. Calms are not included. Numbers key levels (3 = 88 m, 5 = 179 m, 6 = 219 m) above tower base, which is 254 m above sea level.

general large-scale meteorological conditions are sufficient to induce very complicated meso-scale flow patterns within the San Francisco Bay Region. For example, air flow reversals with height that are readily detected in the continuous wind measurements on the tower are seldom seen in the 12-hourly rawinsonde observations from Oakland Airport, about 25 km across the bay. It is also hypothesized that O_3 is transported vertically into the inversion layer by means of convective processes and dissipation/reformation of the inversion in response to surface heating and cooling.

Although the completed analyses indicate that high O_3 concentrations on the Mt. Sutro tower were essentially the result of man-made emissions within the San Francisco Region, the San Jose State University report nevertheless mentions the possibility of a stratospheric contribution. This idea is based largely on some simultaneous measurements of O_3 and radionuclides of stratospheric origin at Quillayute, Washington (Ludwick et al., 1976). On two occasions O_3 concentrations at extremely remote Quillayute in northwestern Washington reached relatively high concentrations of up to 6 pphm. Both of these occasions slightly preceded O_3 episodes in the San Francisco Region during which the large-scale flow pattern suggest that stratospheric air could have been brought into San Francisco. It is suggested that such stratospheric O_3 may contribute to anthropogenic O_3 either additively or as a chemical trigger to enhance the photochemical formation of O_3.

2.2.12 The New York Air Pollution Project of 1964-1969

From 1964 to 1969, New York University conducted the New York City Air Pollution Project under direction of Professor Ben Davidson and under sponsorship of the U.S. Public Health Service. The main goal of the project was to develop an urban air pollution model for predicting the distribution of SO_2 over New York City. Although the model was developed (Shieh, 1969) and the observational data were used extensively by the University, the data were never formally archived and were in danger of being lost forever when the University phased out its Department of Meteorology and Oceanography. In order to make the data available for additional research the EPA contracted with San Jose State University to organize, collate, and describe the very extensive observational data. This has been accomplished in several documents which are available from the National Technical Information Service.

Volume I (Bornstein et al., 1977a) documents the meteorological and SO_2 data collected during three several-day test periods and includes a detailed description of all pertinent data collected during the project.

Volume II (Bornstein et al., 1977b) contains emission rates of SO_2, heat, and moisture; SO_2 concentrations measured from fixed sites and from automotive platforms; and vertical profiles of SO_2 and temperature made from helicopters.

Microfilm includes hourly synoptic analyses of "surface" streamlines and isotachs based on wind speed and direction observations at 97 sites, and bihourly maps of hourly average SO_2 concentration isopleths for the 11 days of the three "primary" test periods.

A magnetic tape lists pilot balloon measurements of winds aloft for 578 balloon launches.

2.2.13 Residence time of atmospheric pollutants and long-range transport

A two-year grant with Colorado State University on the above subject has been completed and a report had been published (Henmi et al., 1978). The report deals with three main topics, a long-range transport model, regional residence times of SO_2 over the eastern United States, and the scavenging of aerosol pollutants in cumulus clouds.

The long-range transport model is a modification of that by Heffter and Taylor (1975). It calculates trajectories based on the 12-hour rawinsonde measurements of the National Weather Service. The model assumes that pollutants are mixed uniformly in the vertical through the mixing layer depth. Transport is by means of a mean wind for the mixing layer and horizontal diffusion is essentially due to vertical wind shear in the mixing layer. The model is capable of dealing with pollutant losses through penetrative convection through the top of the mixing layer, dry deposition, and precipitation scavenging, but chemical transformation are not yet included.

The regional residence times of SO_2 have been calculated for the eastern United States under assumptions that SO_2 is distributed uniformly throughout the mixing layer, there is no leakage through the top of the layer, imported SO_2 amounts across the regional boundary are balanced by exports, and removal is by dry deposition, precipitation scavenging, and transformation into other species by first order reactions. The residence time is

$$T = \frac{1}{\lambda_d + k_p + \lambda_c} \tag{1}$$

It is the e-folding residence time, the time required to reduce the atmospheric SO_2 burden by a factor of $^1/_e$, i.e., by a factor of 0.37. λ_d the decay rate for dry deposition, is given by

$$\lambda_d = V_g/\overline{H} \tag{2}$$

where V_g is the deposition velocity, taken as 1 cm sec^{-1}, and $\overline{H}$ is the seasonal mean mixing layer height. k_p, the decay rate due to precipitation scavenging, is given by

$$k_p = P_p k_1 \overline{P}/\overline{H} \tag{3}$$

where k_1 is the ratio of SO_2 concentration in precipitation to that in water on a volume bases, taken as 5×10^4, $\overline{p}$ is the total seasonal amount of precipitation divided by the total hours of precipitation, and P_p is the probability of a precipitation period, determined from hourly precipitation records. Finally, in eq (1) λ_c is the decay rate due to chemical transformation, taken as 10^{-6} sec^{-1} for SO_2. The results were applied for the United States east of the 105th meridian for the cold (November-April) and warm (May-October) seasons. Figure 36 shows the residence times for the cold and warm seasons. Values are around 20-35 hours in the cold season and 30-60 hours in the warm season. It is interesting that residence times

(a)

(b)

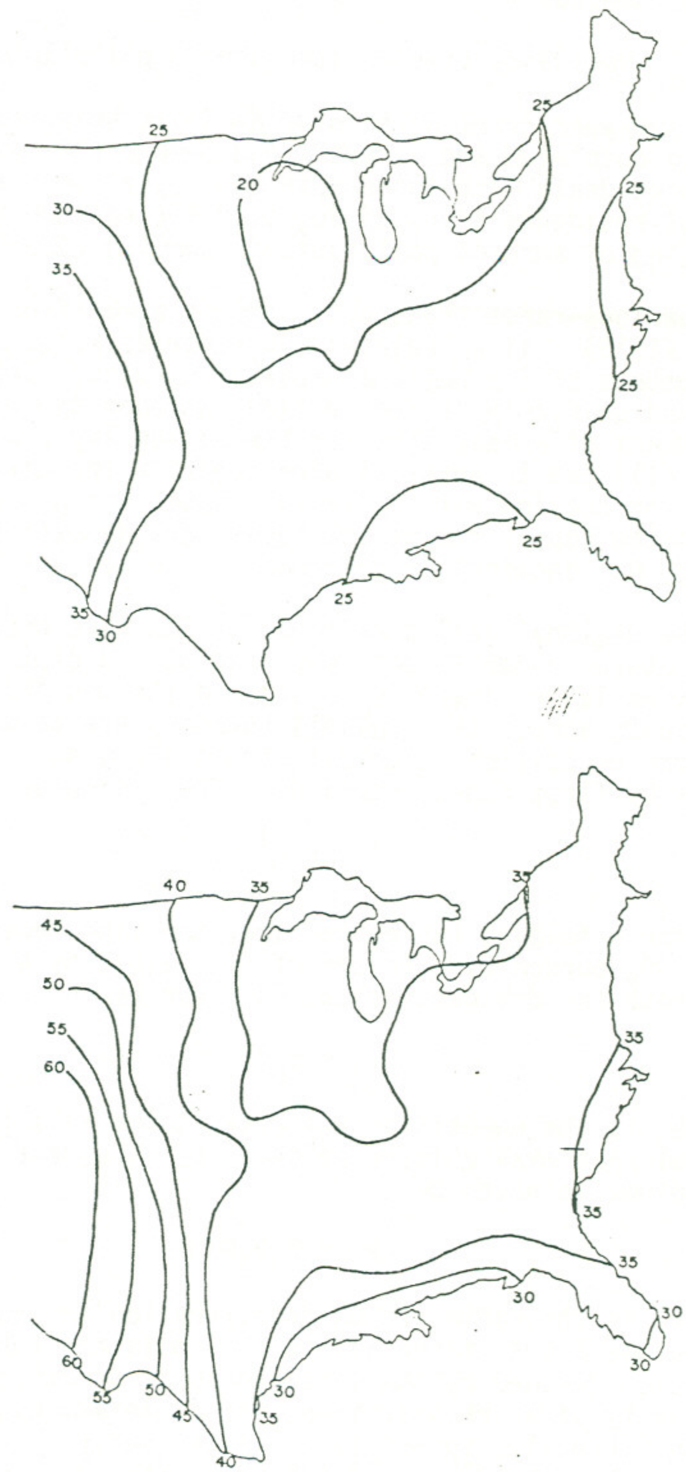

Figure 36: The regional residence time, T (in hours), for SO_2, (a) for the cold season, and (b) for the warm season.

for dry deposition are much like those for total residence times, suggesting that dry deposition is the dominant removal mechanism. These results should be regarded as approximate because of the constant values assumed for some of the variables, especially V_g, k_1 and λ_c.

Atmospheric pollutants are removed in precipitation through "rainout", which comprises scavenging processes within clouds, and "washout" which constitutes precipitation removal processes below clouds. Rainout is generally believed to dominate the overall phenomenon of precipitation scavenging. By studying the physical characteristics of clouds as they interact with pollutants, it will be possible to quantitatively estimate the impact of precipitation on cleansing the atmosphere. The study in this section is concerned with the scavenging of aerosols within two characteristic types of cumulus clouds, continental and maritime. The rainout process in other types of clouds, such as those associated with fronts, should be studied in the future.

Studies by Howell (1949), Mordy (1959), and Neiburger and Chien (1960) show that the influence of cloud nuclei in determining the number and size of cloud-water droplets are restricted to the lowest few meters above cloud base, which is where cloud nuclei are activated and where the concentration of cloud-water droplets is determined. Subsequent condensation only serves to increase droplet size. In this study a continental cumulus is defined as having 300 droplets cm^{-3} with a radius dispersion (ratio of droplet size standard deviation to mean radius) of 0.25 and a maritime cumulus as having 100 droplets cm^{-3} with the same radius dispersion. The model follows the attachment of aerosols to cloud-water droplets to rain-water droplets as well as the conversion of cloud-water droplets to rain-water droplets. By definition, cloud-water droplets have a diameter less than 100 m and rain-water droplets are larger. All droplets are treated as unfrozen, even at temperatures below freezing. The model used in this study is essentially that of Cotton (1972a,b). It involves upward integration with height following the rise of the convective bubble. Although this cumulus model deals only with the actively growing phase, it provides insight into the gross aspects of in-cloud scavenging for clouds with differing characteristics. Aerosols in the boundary layer are transported up into the cumulus cloud by convection where they intermingle and are collected by cloud-water and rain-water droplets. Those droplets that grow large enough to attain a terminal velocity that exceeds the updraft velocity are dropped out of the cloud. Aerosols in the cloud air and in droplets are injected into the environmental air by detrainment. Different aerosol size distributions are used for continental and maritime air (Junge and McLaren, 1971), but the temperature and humidity profiles of the environment air are the same. Initially, it is also necessary to specify an entrainment constant, cloud radius, surface temperature perturbation, updraft velocity, and droplet concentration. The vertical numerical first-order integrations that simulate the physical processes and generate aerosol concentrations in cloud air, cloud water, and rain water proceed by height increments until the updraft velocity vanishes. With reasonable values of the input parameters the cloud tops for both maritime and continental cumulus are at 8300 m; bases are at 1500 m. The scavenging rate of aerosols by cloud-water droplets is one order of magnitude larger in the continental cloud than in the maritime cloud. Since this cloud water ultimately becomes rain water, the mass concentration of aerosols in rain water is greater in continental than in maritime clouds. The application of results from the cloud model to the transport model described earlier here can be made through the relationship for the scanvenging velocity

$$V_p = (K/\chi_o)_v xP$$

where K is the aerosol concentration in rain water, χ_o is the aerosol concentration in near-surface air (both on a volumetric basis), and P is the precipitation rate. If P is known for the area through which the plume passes, the removal of aerosols by precipitation can be calculated.

2.2.14 Fairbanks Heat Island Study

Under an EPA grant the University of Alaska has studied and numerically simulated the heat island generated by the City of Fairbanks (Bowling, 1978). The high-latitude location of Fairbanks means that in mid-winter the effects of incoming solar radiation and evaporation are nil (diurnal temperature variations are difficult to detect) so that the main factors influencing the heat island are man-made heat and effects of pollutants, including water vapor, on infrared radiative transfer. Field measurements have demonstrated that the Fairbanks area, with an estimated population of 65,000, frequently has a winter heat island of 10°C and values up to 14°C have been observed. Figure 37 shows an example of a clear-night, early-spring heat island based on automotive traverses and fixed-station measurements of temperature. An interesting feature of the clear-sky heat islands is the extreme variability of background temperatures. Some features, such as the low temperatures with marked gradients along the east-west road north of the town and the relatively high temperatures near the airport, are fairly common among traverses. On the other hand, the higher temperatures southeast and south of the city are examples of random warm spots, which appear only occasionally. These warm spots represent a weakening, but not an actual breaking of the thermal inversion. Temperatures measured 100 m above the surface with a helicopter during the time covered by Figure 37 ranged from -3°C north of town to -5°C over the Tanana River south of town. The warm spots are believed to be due to partial vertical mixing by small-scale winds or to a combination of local anthropogenic heat emissions and winds. The magnitude of the summer nighttime heat island is only slightly less than in the winter. The daytime heat island disappears from March to September except for a short period in late spring when snowmelt is complete in the city, but not in the surrounding area. The effect of ice fog is to decrease the heat island intensity. This effect is probably due to the fact that ice fog affects the background areas as well as the city.

The Fairbanks heat island appears to extend to roughly 60 m above the city. Temperatures at 90 m are warmer than those at street level under clear and slightly foggy conditions, but greater mixing depths may exist in dense fog. The heat island intensity correlates well with the intensity of the inversion in the lowest 60 m of the atmosphere as shown in Figure 38. Notice that all but three of the cases are within 1.5°C of the predicted value. Considering the complexity and variability of the background inversion, the fit of the points is excellent.

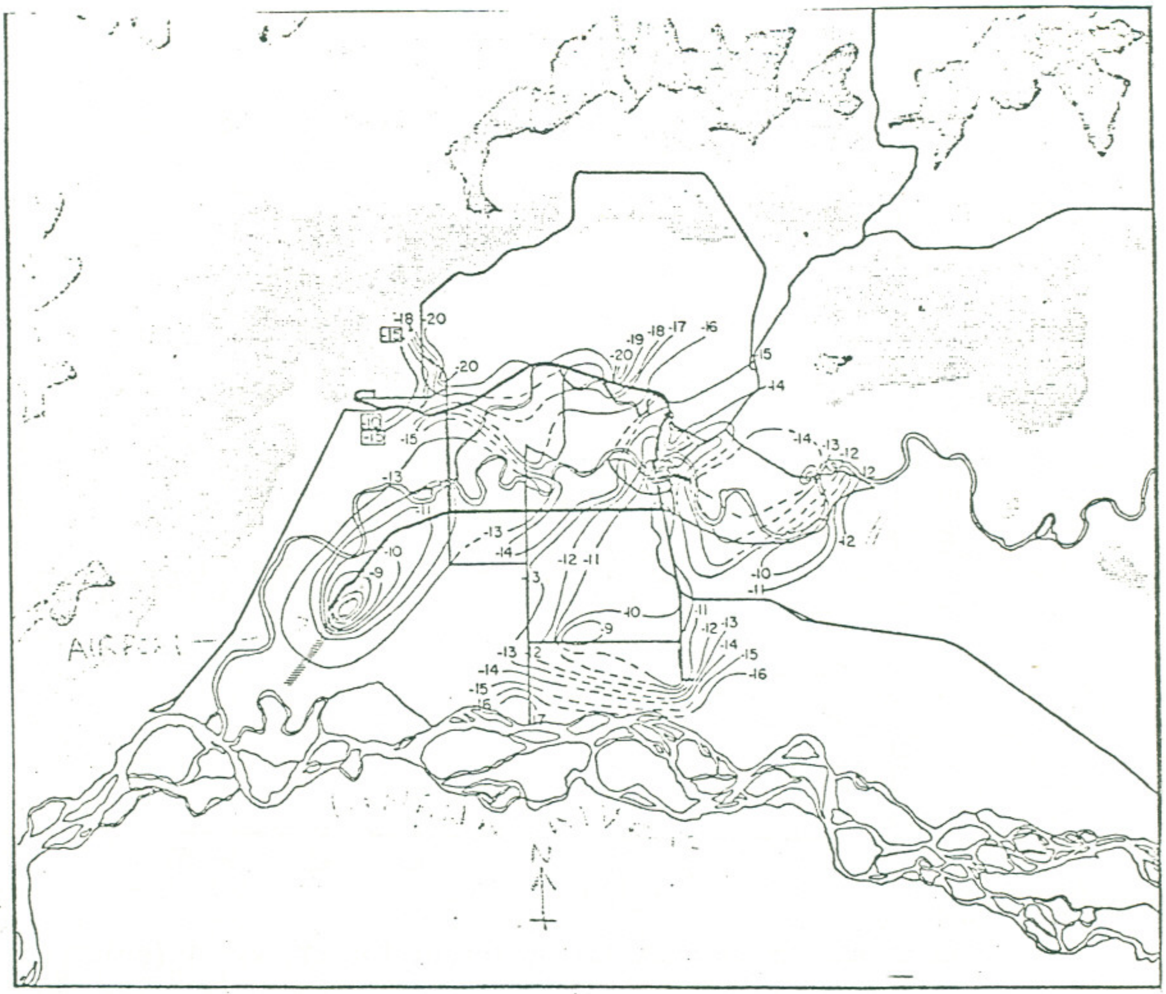

Figure 37: Temperature contours (°C) at 2 m elevation for automobile traverses across Fairbanks region during 2320-0120 AST, March 13-14, 1975, with clear skies. Height contours for 152 and 305 m above MSL.

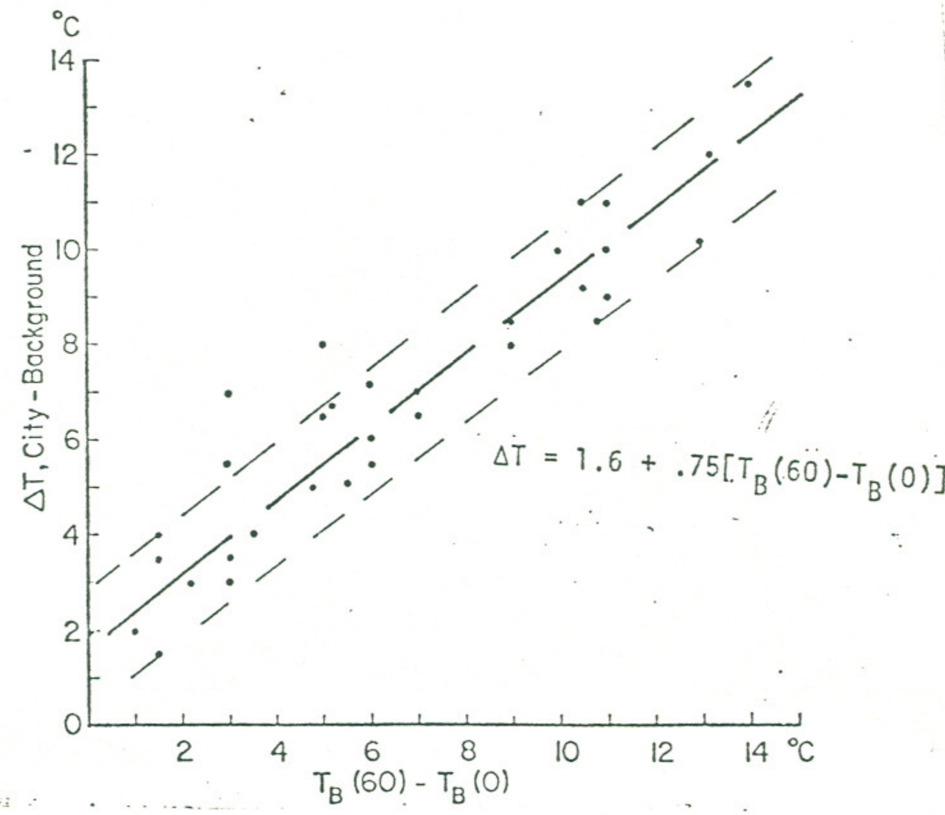

Figure 38: Urban heat island intensity, ΔT, vs. $T_B(60)-T_B(0)$. $T_B(60)$ is the temperature at the University (60 m above the downtown Fairbanks elevation) and $T_B(0)$ is the background temperature used to compute the heat island.

The wind field was found to be extremely complex, with 180° shears being common over distances of 200 m in the horizontal and 25 m in the vertical. Fluctuations with time are also substantial. It was not possible to determine unequivocally the effect of the heat island on the wind field, mainly because of inadequate wind measurements.

Fairbanks is hardly an industrialized area, but the fuel use inventory gave per capita winter energy consumptions of the order to 10 KW/person. This is comparable to Los Angeles or the east coast urbanized strip from Boston to Washington, D.C. Summer energy use is about 5 KW/person. A simple theoretical analysis, including both radiative and convective losses from the surface, gives fairly good agreement with the observed winter heat island, but only if regional wind speeds are kept well below 1 m/sec. This figure is compatible with observations of the wind field.

In summary, the University of Alaska investigations have demonstrated that a strong heat island can exist even when the only contributing factors are self-heating and some disturbance of radiative transfer due to the presence of sizeable buildings. The heat island thus produced is not, however, strong enough to break the Fairbanks inversion even up to 100 m, at least under clear-night conditions.

2.2.15 NY State Field Study

The New York State-Long Island Expressway Dispersion Experiment (ROADS) was completed this year. During this investigation, particulate, gaseous pollutant, micrometeorological and traffic data were collected adjacent to a major highway in a non-urban setting. The data collected from the study are useful for: (a) documenting the distribution of sulfate, lead, total particulate and carbon monoxide at an array of sampling points near the highway, (b) re-evaluating highway air pollutant emission factors, (c) determining the dispersion from wind fluctuation data as well as investigating the general micrometeorological structure adjacent to the highway, and (d) validating highway dispersion models. The Long Island expressway experiment was carried out by the New York State Department of Environmental Conservation through a grant with EPA.

During the study sulfur hexafluoride (SF_6) was released as a tracer gas from specially equipped vehicles. Preliminary evaluation of the EPA HIWAY model, presented by the grantee, using the SF_6 data are summarized in Table 3. Regression analysis were performed on model estimates versus measured SF_6 concentrations using measured concentrations as the independent variable. Thus, slopes greater than one indicate an overestimate by the model. The data were separated according to wind orientation to the road. The entire data set was analyzed using two sets of dispersion parameter values.

It is evident from Table 3 that whatever the wind orientation with respect to the roadway, sigma values representing unstable cases are more appropriate for predicting dispersion of pollutants adjacent to the line source. These preliminary results are consistant with the recent results from a pilot study on the General Motors data.

Table 3. Model Estimates Versus Measured SF_6

Wind Angle	Dispersion Used In The Model	Correlation (r^2)	Slope	Intercept
Perpendicular	Neutral	0.77	1.58	-0.49
	Unstable	0.88	1.20	-0.33
Oblique	Neutral	0.61	1.31	0.03
	Unstable	0.69	0.94	-0.06
Parallel	Neutral	0.52	3.16	-1.93
	Unstable	0.67	1.63	-0.57

3.0 TECHNICAL ASSISTANCE

3.1 Regional Assistance

3.1.1 Region I - Boston, MA

Support was provided to EPA Region I in many areas. These are outlined below.

A. Support to Air & Hazardous Materials Division: Support to this division involved several lengthy and complex projects as well as a variety of special studies. These are noted below:

1. Berkshire APCD: Region I evaluated the impact of increasing the sulfur content of fuel oil from 1% to 2.2% in several Massachusetts APCD's, some located in complex terrain. The latter locations required much research to locate the appropriate meteorology and even air quality models. Finally the Valley model was adopted for use. In this connection, several paper mills in the Berkshire APCD challenged the Valley model results. To resolve the issue, Region I suggested a year long monitoring program to determine maximum impact of the mills. This program is now underway.

2. Refinery: Evaluating a PSD permit for the first oil refinery in New England consumed a significant number of manhours. Disagreements between the refinery consultant and the region over modeling results lead to a variety of meteorological tasks to resolve these differences, e.g., to prove the credibility of postulated worst case conditions. Frequency statistics were developed to prove that the conditions were reasonable. As a result of regional efforts, the refinery has agreed to design changes, notably an increased stack exit velocity, to overcome certain problems.

3. Special Studies:

a) High TSP Day, 11 June 1976: On this day 223 TSP sampling stations in Region I and NY state experienced either a yearly maximum or the next highest concentration. Air quality and meteorological data on this day were documented preparatory to investigating this anomalous situation. The cause of the high TSP concentrations is postulated as arising from an unusually high contribution of sulfates to total TSP weight. The source of the sulfates is long range transport, with local production of SO_4 increased by elevated ozone levels.

b) Remote Sensing: Several remote sensing techniques were investigated for application to regional problems. These included the use of aerial photography for locating monitoring sites; the use of color IR to confirm maximum impact points in chronically polluted valleys; the use of satellite imagery to identify areas with elevated ozone and TSP levels. The results have not been as successful as hoped.

c) Pollens: On certain spring and early summer days, pollens form a significant fraction of total TSP weight. This phenomenon and the possibility of having these days identified were investigated. Several universities, arboretums, and other sources were checked, but no one routinely monitors pollens on a current basis.

d) Acid Rain: Region I records the highest acidity levels in the US, and as a consequence acid rain is a subject of much interest in New England. Developments in this area are continuously monitored.

e) PCB's: A landfull is emitting significant amounts of gaseous PCB's. Experimental procedures were investigated for determining gaseous flux by measurement of vertical gradients of PCB concentrations and wind speed. Ultimately an integrated source term for the landfill is desired; this will enable modeling of PCB concentrations in areas adjacent to the landfill. Flux measurements will also determine the dimension of the problem and the urgency of remedial measures.

B. Support to Enforcement Division: Support to the Division falls into three areas: active participation in enforcement projects, in technical discussions with enforcement engineers, and in review of technical studies prepared for enforcement use.

1. Winslow, Maine: In this project, meteorological guidance was provided for the implementation of a variance extension for a paper mill. The extension sought to prevent air quality violations by strict guidance of mill operations and the threat of a $10,000 per day fine for violations. Advice was provided on the siting of air monitors to detect maximum SO_2 concentrations and on meteorological conditions likely to cause violations. With notice of the latter, the mill had to reduce operations. Despite the mill operator's

efforts, violations occurred on three days causing assessment of penalties against the mill.

2. Berlin, NH: This project has continued for about 20 months and has centered around the study of the air quality and meteorology of a large paper pulp mill located at the confluence of two valleys. It consumed a considerable number of manhours. Tasks included: evaluating the optimum anemometer network for the locality; studying network data for evidence of a wind regime in the surrounding valleys; confirming this against air quality data. The project is to become a state responsibility, with the Region advising as requested.

C. Support to Surveillance and Analysis Division: This usually involved recommending monitoring sites. It has also included several lengthy investigations. In one case, the problem meant attempting to explain a lack of correlation between the composition of local surface soil and the catch in TSP filter by means of meteorological data.

D. Emergency Operations Control Center (EOCC): The Regional Meteorologist as chief of this unit has responsibility for operation of the center when it is activated. Mainly, this means monitoring ozone episodes during the May-September season. The only other duty deriving from this responsibility involved researching the products of Styrene combustion and calculating their concentrations downwind of the incineration point. The press of additional duties prevented routine exercises of unit personnel, and efficiency has further eroded by the withdrawal of assigned personnel to other duties.

3.1.2 Region III - Philadelphia, PA

Support to the EPA Regional Office in Phildelphia continued as in years past with review of various modeling studies submitted to the office, participation in in-house modeling studies for planning and enforcement purposes, review of monitoring programs, preparation of expert testimony for enforcement conferences and hearings, and direction of various research projects.

Review of reports submitted by States included the one for the Westvaco Paper Corporation, Luke, Maryland prepared by Environmental Research and Technology, review of the modeling studies prepared by TERA corporation for the Potomac Electric Power Company, modeling studies done for the State of Pennsylvania by Geomet, Inc., and in-house modeling studies done by the State of Virginia.

One research project completed was a modeling study of four power plants in Virginia and Maryland. This contract was carried out by Walden Research, Inc. Another project nearing completion within the next month or two is the particulate modeling study of Southwestern Pennsylvania. This report should prove interesting to those involved in particulate control since it casts new light on the sources of particulates and their size distribution in heavily industrialized areas. The report may have a significant effect in redirecting the thrust of particulate control in order to meet ambient air quality standards. This contract has been awarded to the H.E. Cramer Company, Salt Lake City, Utah and is under the direction of the Regional Meteorologist.

As for the future, we anticipate that there will be a significant amount of activity in two new areas. One of these will be court activities supporting enforcement cases. One case already on the docket involves the West Penn Power Company's Mitchell Plant. The second new area of involvement will be that of physical modeling. Section 123 of the Clean Air Act specifies that plants may increase their stack height if needed "to overcome terrain downwash." Proof that terrain downwash does exists must come from on-site programs or wind-tunnel studies.

3.1.3 Region IV - Atlanta, GA

Support to EPA Region IV consisted of air quality modeling activities and special studies. Modeling activities included the examination of revisions in state implementation plans and the evaluation of plans to comply with prevention of significant deterioration requirements.

Special studies included validation of the Valley Model using the Ashland Oil Facility in Kentucky from September 1977 to September 1978; validation of CRSTER/PTMTP using the Tampa Electric Company's Big Bend Facility from January 1977 to May 1978; study of ozone in the Tampa Bay area from December 1976 to May 1977; and study of sulfur oxides in Florida from July 1976 to December 1977.

3.1.4 Region VI - Dallas, TX

The NOAA Meteorologist assigned to EPA Region VI provided support for the following activities:

A. Consulting services to the individuals performing diffusion modeling for the Air and Hazardous Materials Division, Region VI. This activity has been conducted on a completely informal basis and has not consumed a large portion of the Meteorologist's time.

B. Supervising the ambient air monitoring program for Region VI. This included review and comment on the recommendations of the Standing Air Monitoring Work Group. In July, a permanent section chief was appointed and the Regional Meteorologist's involvement in the ambient monitoring program reverted to consulting on siting and data evaluation based on meteorological influences.

C. In July, a project was started to estimate precipitation events by date and amount over a three year period at a location where the nearest rain gauge is seven miles away. To complicate the problem, the location is just inside the ground clutter pattern of the nearest NWS weather radar. A large amount of money has been spent with the National Climatic Center to obtain needed data for the study. The study is just over fifty percent complete.

D. The Regional Meteorologist has continued to serve as Project Officer on a sampling project to evaluate brominated compounds in the environment near the bromine industry plants in the El Dorado/Magnolia area of Southern Arkansas. The project was initially pointed specifically at ethylene dibromide, a gasoline additive and fumigant, which has been identified by the National Cancer Institute as a possible carcinogen. Early in the project, it was decided to analyze samples for all brominated compounds, as this could be accomplished at a very small cost increment. Since the project started, two additional products of these plants have received national attention: Tris (2,3 dibromopropyl) phosphate and dibromo chloropropane (DBCP). Tris was manufactured as a flame retardant and its use in the USA was stopped by federal order because of possible hazards and DBCP is the fumigant which produced sterility problems in workers in California and Arkansas. The draft final report is due in mid-January on this project. An extension of this project is being considered.

E. An analysis effort on the ozone data collected in Southern Louisiana in the summer of 1976 is being completed. The Regional Meteorologist has served as Project Officer on the project. The draft final report is undergoing EPA review at the end of the year.

3.1.5 Region VIII - Denver, CO

The following projects were performed in support of EPA Region VIII:

A. A contract was awarded to Systems Application, Inc., San Rafael, California, to develop a regional air pollution model and apply it to the Northern Great Plains area. A preliminary final report has been completed. The study considers sources in 1976 and projected emissions from sources in 1986. Three meteorological scenarios were selected for model simulations. In summary, the preliminary results indicate that neither the 1976 nor the 1986 emissions as estimated in this study are likely to cause significant increases in SO_2 concentrations at locations far from the emissions sources. However, the 1986 emissions from some of the very large sources may cause the Class I increments to be exceeded on certain mandatory Class I areas a few tens of kilometers from certain sources. The report is referenced as "The Development of a Regional Air Pollution Model and Its Application to the Northern Great Plains," EPA-908/1-77-001, June, 1977, U. S. Environmental Protection Agency, Region VIII, Denver, Colorado 80295.

B. At the request of EPA Region VIII, the EPA Office of Research and Development, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada, conducted airborne measurements of the Anaconda Copper Smelter plume near Anaconda, Montana. This study was carried out from October 1, 1976 to December 9, 1976. A draft report has been reviewed and the final report is expected to be available in a few months. Although the intent of the study was to investigate plume dispersion in thermally stable atmospheric conditions over complex terrain, most of the measurements were made with the plume over the broad, relatively flat valley.

The results have not been thoroughly analyzed; however, a preliminary analysis of the results indicates initial dilution is significant near the source. Measured values of the lateral and vertical plume concentration standard deviations, σ_y and σ_z, are larger than Pasquill-Gifford in close and approach the Pasquill-Gifford values with increasing distance out to approximately ten kilometers.

The report is referenced as "Airborne Measurements of a Copper Smelter Plume in Montana," U. S, Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada.

C. EPA Region VIII contracted to Martin Marietta Corporation, Denver, Colorado, to determine baseline atmospheric visibility near Stanton, North Dakota, where considerable energy development activities are planned. Horizontal visibility and optical air quality baseline data were obtained for the months of April, July and October, 1976, and January, 1977. The baseline measurements consisted of horizontal visibility along three views, solar reduction, and vertical atmospheric spectral attenuation coefficient. Basic meteorological data were also taken.

3.1.6 Region IX - San Francisco, CA

Support activities for EPA Region IX are outlined below.

A. Regulations for the prevention of significant harm levels of several pollutants within the South Coast Air Quality Management District were prepared and proposed in the Federal Register in December. A contract for the preparation of a Technical Support Document to support these regulations was monitored. This document summarized the occurrence of various episode levels of pollutants in the Basin and also proposed and evaluated the effectiveness of several control strategies that might be used to insure a reduction of the emissions necessary to prevent further increases in the concentrations. During the next 18 months episode plans will be promulgated for all APCD's in California. Similar technical documents are required and the preparation will be contracted through DSSE.

B. The EPA Environmental Monitoring and Support Laboratory - Las Vegas is preparing a technical document for Region IX, to support SO_2 regulations in Hawaii. As part of this, a field study will continue through early 1978 and began in the spring of 1977 to evaluate the SO_2 concentrations near an oil-field power plant on Maui and one on Oahu. In addition to the field study, various control strategies will be evaluated using a dispersion model selected by the contractor.

C. Regional modeling to satisfy the requirements for Air Quality Maintenance Plans is a major problem in this region. The AQMP guideline documents do not necessarily reflect "state-of-the-art" with respect to modeling and predictions of region-wide oxidant levels resulting from various land use patterns, transportation controls and stationary source control programs must be evaluated. The Regional Meteorologist is a member of the modeling sub-committee for the Bay Area Environmental Management Task Force. The committee has provided advice on data analysis and modeling using the LIRAQ photochemical dispersion model to the Task Force. Other AQMP groups have received advice and assistance concerning less sophisticated modeling requirements. Funds were provided to the State of California to develop a model suitable for regional analysis in San Diego. A contract was let to SAI, La Jolla for this, and the Regional Meteorologist acted as co-project officer. The model developed was MADCAP, it has not yet been successfully run for San Diego.

D. A contract to revise APRAC-1A was completed. The contract was completed under the supervision of the Arizona Planning Section. The revision was undertaken by SRI and incorporated a provision for including meteorological information for more than one location and included a revised emission factor calculator. The code was modularized so that emission factors could be updated more easily. It is hoped that this revised version will become part of the UNAMAP package. A version of this was used in the Phoenix AQMP submission.

E. Approximately 150 EISs were reviewed and comments provided to the Regional EIS Coordinator. To facilitate review, meteorological data for as many locations in the Region as possible were made available on the computer through the assistance of OAQPS, and the VALLEY, CRSTER and UNAMAP models were used to duplicate the air analyses when possible. Considerable consultation with Federal agencies and their contractors generally takes place on all significant EIS's during the pre-draft stage. Meetings are also held upon request to discuss draft comments.

3.1.7 Region X - Seattle, WA

The meteorologist assigned to Region X:

A. Assisted in the design of a study to determine the air quality impact of forestry burning in Oregon and Washington. This study, which continues, will attempt to define the effects of large scale burning of forest residue on ambient concentrations and visibility. The first phase of the study is scheduled to be completed in May 1978.

B. Was responsible for ensuring that an adequate air quality impact analysis was performed for a number of new or modified sources that were subject to EPA's Prevention of Significant Deterioration program. This activity involved working directly with the sources, or their consultants, to ensure that the modeling employed was competent and appropriate for each given situation. Where EPA models were not employed, the Regional Meteorologist performed independent model estimations to check the comparability of the estimates done by the source with the EPA estimates.

3.2 General Assistance

3.2.1 Dispersion estimates suggestions

Two brief notes describing technical aspects of air pollution modeling were released this year. Dispersion Estimate Suggestion 5 described the results of a numerical simulation of the influence of changes in operating loads in the production of electricity at a moderate size steam-electric generating plant on the ground-level maximum concentrations under various meteorological conditions. The results suggest that since the emission characterizations are related to the power-load production rate, that a reduction in power-load production (and hence a corresponding reduction in pollutant emission) does not necessarily result in lower maximum surface concentrations. Dispersion Estimate Suggestion 6 provided guidance on characterizing the variation of the horizontal wind with height as a function of atmospheric stability and surface roughness. The purpose of both technical notes was to promote better practices.

3.2.2 Model Modification

A. PAL - The development of an air pollution dispersion algorithm to estimate concentrations of non-reactive pollutants from point, line, and area sources was completed. This algorithm is referred to as PAL for point, area and line sources. Concentration estimates are based on hourly meteorology, and average concentrations can be computed for averaging times from 1 to 24 hours. Six source types are included in PAL: point, area, two types of line sources, and two types of curved path sources. As many as 30 sources may be included under each source type. PAL is not intended for urban-wide use but is most effective in estimating the contribution of part of an urban area to the concentrations. Portions of urban areas assessed by PAL for impact on air quality are:

- Industrial complexes
- Sports stadiums
- Shopping areas
- Airports

The user's guide for PAL was written and will be available in early 1978.

B. RAM - The provisional use of four versions of RAM by personnel in Regional Offices resulted in detection of deficiencies in the area source algorithm. The deficiencies occurred only with area source inputs having non-integer coordinate boundaries. The algorithm was reprogrammed and extensively tested for numerous configurations. Also because of some desirable possibilities of combinations of averaging times, several modifications were made and tested for acceptability of input combinations. Because of these modifications, RAM was not made available as part of UNAMAP during the fiscal year.

C. CDMQC - The Climatological Dispersion Model (CDM), an urban air-quality model useful for estimating annual concentrations, was modified such that the estimated pollutant concentrations at any receptor location can be partitioned with regards to the point and area emission sources. This allows an estimation of how much pollutant each source is contributing to each receptor location. Such point and area source contribution listings can be used in devising effective control strategies for moderate to large size cities.

3.2.3 UNAMAP and user liaison

Although five additional algorithms were being completed for addition to UNAMAP, the contents of UNAMAP did not change during the fiscal year.

A summary paper entitled, "Experience with UNAMAP" was written and presented September 20, 1977 at the 8th International Technical Meeting on Air Pollution Modeling and its Application sponsored by the NATO Committee on the Challenges to Modern Society. This paper includes experience to July 1, 1977 including statistical summaries by user type and geographical region of the 156 known users of UNAMAP outside EPA.

Many dispersion model users contacted the branch for information and advice. There were 1539 telephone inquiries during the 15 month fiscal year. A most frequent request was for the use of complex terrain models. There is also increased interest in models that will consider gravitational and other removal mechanisms for use with suspended dusts.

Fifty-one U.S. visitors requested appointments and were briefed on model availability. Twenty-four visitors from 17 foreign countries also visited the branch and discussed modeling.

3.2.4 Support to the Health Effects Research Laboratory

NOAA personnel assigned to the EPA Health Effects Research Laboratory provided meteorological and climatological support for various studies of the effect of air pollution on human health.

A. Climatological data were acquired to determine an optimum or "downwind" site location for two HERL mobile laboratories to insure maximum exposure of the tradescantia plant to pollutant sources in the cities under study. Investigations at Brookhaven National Laboratory revealed that a particular plant, tradescantia, can serve as a mutagenic indicator since any chromosomal aberrations cause a definite color change in flower stamen cells in a short period of time. One mobile laboratory was equipped as greenhouse to maintain the plants, and the other fully equipped to continuously monitor all pollutants, air temperature, dew point, wind and barometric pressure. Climatological data were summarized as special wind roses illustrating probable wind patterns during the 14 days of exposure in each city. Locations of pollutant sources and emissions were acquired from the National Emission Data System (NEDS). At the conclusion of each exposure period, special meteorological summaries were produced listing hourly data collected by the mobile laboratory and the nearest NOAA National Weather Service Office. Support was furnished for mutagenic exposure sites at Charleston, WV., Birmingham, AL., Baton Rouge, LA., Houston, TX., Upland, CA., Salt Lake City, UT., and Grand Canyon, AZ., a "clean" or control exposure site.

B. Preparation for a study of the effect of particulate sulfate on acute and chronic respiratory disease required the production of climatological wind roses descriptive of the proposed period of study and the location, northern Ohio, the time when air sampling and health data collection would occur. Locations of pollutant sources and emissions were acquired from NEDS, and wind roses were computed for Cleveland and Akron, Ohio. Tests of a new Hi-Volume air sampler conducted along the Gulf Coast required special climatological wind roses to estimate probable wind flow patterns around the test sites. Wind roses were prepared for Galveston, Houston, and Port Arthur, Texas and Lake Charles, Baton Rouge, Louisiana.

C. An investigation to verify the validity of sulfur dioxide air quality data recorded on instruments susceptible to temperature bias required acquisition of climatological data in the form of hourly temperature records during the years 1968 to 1972 at New York City.

D. Climatological data from the Los Angeles Basin were assembled and analyzed prior to selection of four communities to participate in a study designed to measure acute response of respiratory disease to peak hourly and daily average NO_2 alone and in combination with other pollutants. Since previous studies by HERL had indicated air temperature was a significant factor in respiratory symptom frequency, patterns of temperature variation within the Los Angeles Basin had to be identified along with wind patterns that transport pollutants.

E. In support of a study of human chromosome damage from ozone pollution, climatological data were assembled and analyzed from two locations in California, Angwin College in Napa Valley, and Loma Linda College near Los Angeles. Volunteers in the student populations were to be studied for chromosome abberations by observation of changes in large white-blood cells. Since neither site was located near a major NOAA National Weather Service Office, annual patterns of temperature, humidity. precipitation and wind were determined from observations at second and third order stations.

F. Annual wind rose diagrams were computed for seven locations representing primary metal smelters in support of a study to determine the impact of proximal living to lead, copper and zinc smelter on trace burdens in blood as a function of age.

3.2.5 Support to the Environmental Monitoring and Support Laboratory - Research Triangle Park

Support was provided in a number of activities, including:

A. Participation in a special study in El Dorado, Arkansas, to assist in the disposal of electronic capacitors containing PCB.

B. Participation in the National Forest Ozone Study in Alexandria, LA in the summer of 1976 and Middleburg, VT in the fall of 1976.

C. Participation in determining corrective action to prevent contamination of a fresh air intake by stack exhaust at the EPA Laboratory building in Duluth, MN.

D. Participation in the installation of CHAMP stations in the Akron-Cleveland area.

3.3 Assistance to the Office of Air Quality Planning and Standards

The function of the Air and Waste Management Support Branch (AWMSB) is to support activities of the EPA Office of Air Quality Planning and Standards.

General areas of responsibility include: (1) the development of air pollution control tactics through the application of mathematical-meteorological diffusion models, (2) technical support and assistance in simulation model techniques to other EPA elements, (3) preparation of guidelines concerning various air pollution control and monitoring systems, and (4) organizing and directing aerometric field studies for improving the technical basis of the air quality management approach to air pollution control.

3.3.1 WMO meeting on education and training

The World Meteorological Organization convened a Symposium on Education and Training in the Meteorological Aspects of Atmospheric Pollution and Related Environmental Problems during the last week of January 1977 at EPA facilities in the Research Triangle Park. The United States served as host for the 35 experts from 17 foreign nations, the U.S. and WMO Secretariat in Geneva who presented 23 papers. The subject matter papers covered such topics as air pollution weather forecasting, environmental impact assessments, meteorological instruments, turbulence and diffusion, siting of of monitoring stations and stratospheric pollution. Of the seven papers by U.S. authors, two were presented by AWMSB staff (Dicke, 1977a,b). Since one purpose of the Symposium was to develop syllabi for the training of meteorologists who plan to specialize in air pollution meteorology, each author concluded his work with a training syllabus for the four levels of meteorological personnel as defined by the WMO (WMO, 1969).

Six experts from the original group, including the AWMSB meteorologists, were invited by the WMO Director of Education and Training to remain after the Symposium for a second week to review, revise, and prepare an overall draft of the air pollution training syllabi. Proposed additions to the WMO Guidelines on Curricula for Class I (university-trained) meteorological personnel include as major topics: atmospheric diffusion and transport, air chemistry, monitoring and instrumentation, effects of air pollution modeling and prediction and air resources managements. Corresponding proposals were also prepared for Class II, III and IV curricula as well recommended atmospheric pollution topics to be taught in the general education and training programs for all meteorological personnel. These syllabi have recently been submitted to the WMO Executive Committee Panel of Experts on Education and Training for their approval.

3.3.2 Sulfate prediction modeling using STRAM

AWMSB meteorologists working with EPA engineers continued investigation into using the "Source-Transport-Receptor Analysis Model" (STRAM). STRAM is basically a Gaussian plume model modified to account for temporal variations in point source emission rates and both spatial and temporal variations in wind speed, wind direction, and plume dispersion parameters. The model formulation also allows for dry deposition, washout, and chemical transformation.

STRAM consists of three major routines. First, a trajectory is calculated for each plume increment from each source over a regional scale using wind data that is gridded from historical records. Second, the dispersion and concentration in the plume is calculated after each advection step through dispersion parameters, wet and dry removal, and chemical transformation of the pollutant mass. No interaction between source plumes is considered. Finally, a sampling routine interpolates plume cross-wind concentrations to gridded and nongridded specified receptor locations.

Present efforts involve extensive testing of all program subroutines and comparisons with hand calculations for selected scenarios. Future plans include validation of STRAM and demonstration at selected locations.

3.3.3 Indirect source and hot spot guidelines

Two screening guides have been developed under contract to aid in identifying locations where significant carbon monoxide (CO) concentrations can be attributed to mobile source emissions. Both guides use state-of-the-art traffic engineering practices, emission factors, and dispersion techniques to provide a comprehensive, yet manageable analysis of CO concentration impacts. One guideline is oriented to indirect sources, e.g., shopping malls, sports stadiums, ets., and provides a comprehensive manual methodology for assessing both one and eight-hour average CO concentration impacts corresonding to the National Ambient Air Quality Standards (NAAQS) time averages (EPA, 1977a). Figure 39 is a typical example of those presented in the indirect source guidelines for calculating concentration estimates at, in this case, an intersection. The roadway receptor distance is X and Y_u (Y_d) is the distance to the upwind (downwind) edge of the queue of vehicles from the receptor.

The second or hot spot guidelines, on the other hand, are designed to assess urbanwide problems by employing a more general approach for estimating CO concentrations at individual roadways and intersections (EPA, 1977b). The term "hot spot" indicates locations where CO concentrations are estimated to be above the NAAQS. Instead of detailed quantitative CO concentration estimates the hot spot guidelines (1) screen for potential hot spots, and (2) give a worst-case quantitative CO concentration estimate. Figure 40 demonstrates the screening method. The user inputs the average daily traffic at an intersection, chooses the proper curve for the crossroad, and decides

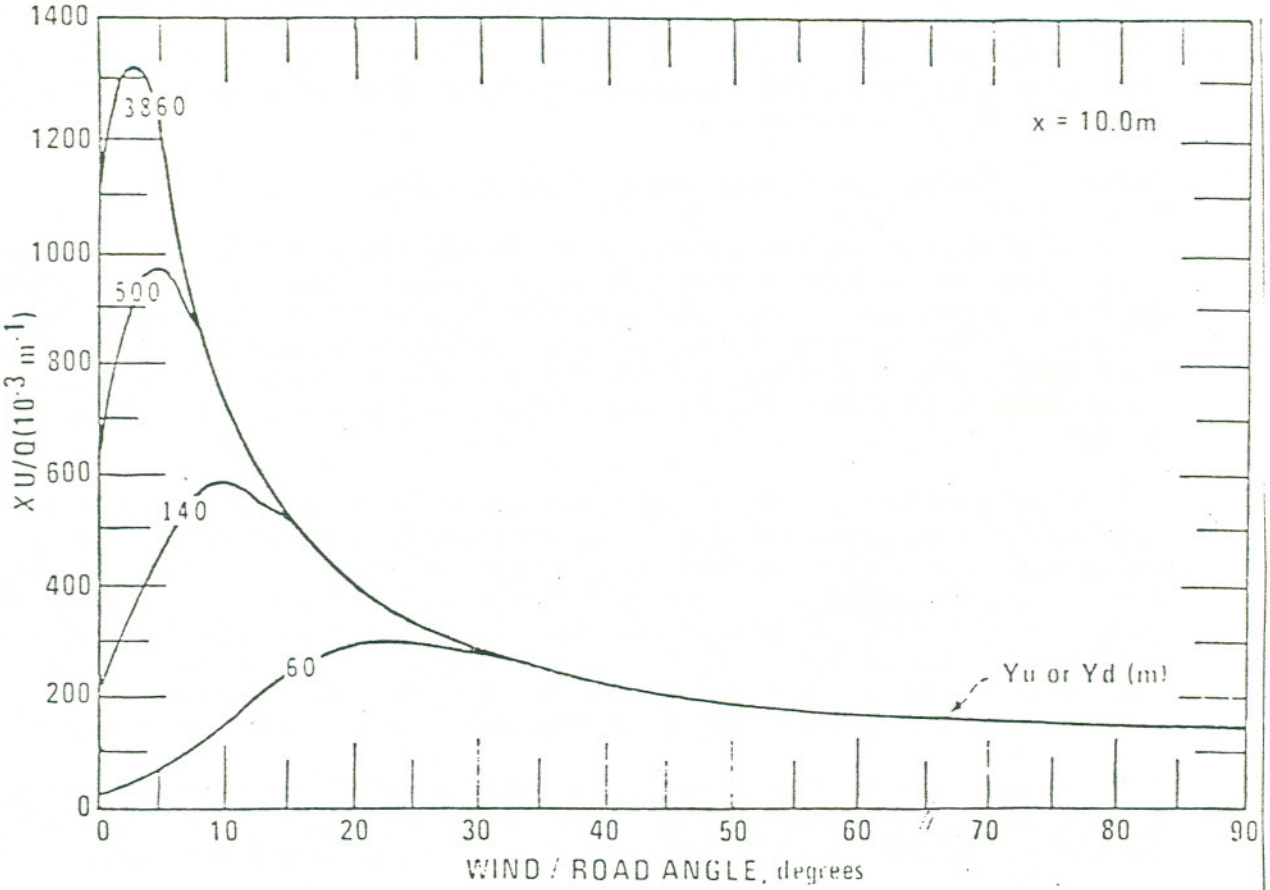

Figure 39: Variation of the normalized CO concentration with roadway length, road/receptor separation (x), and wind/road angle, for stability = D and σ_{z_0} = 5.0 meters.

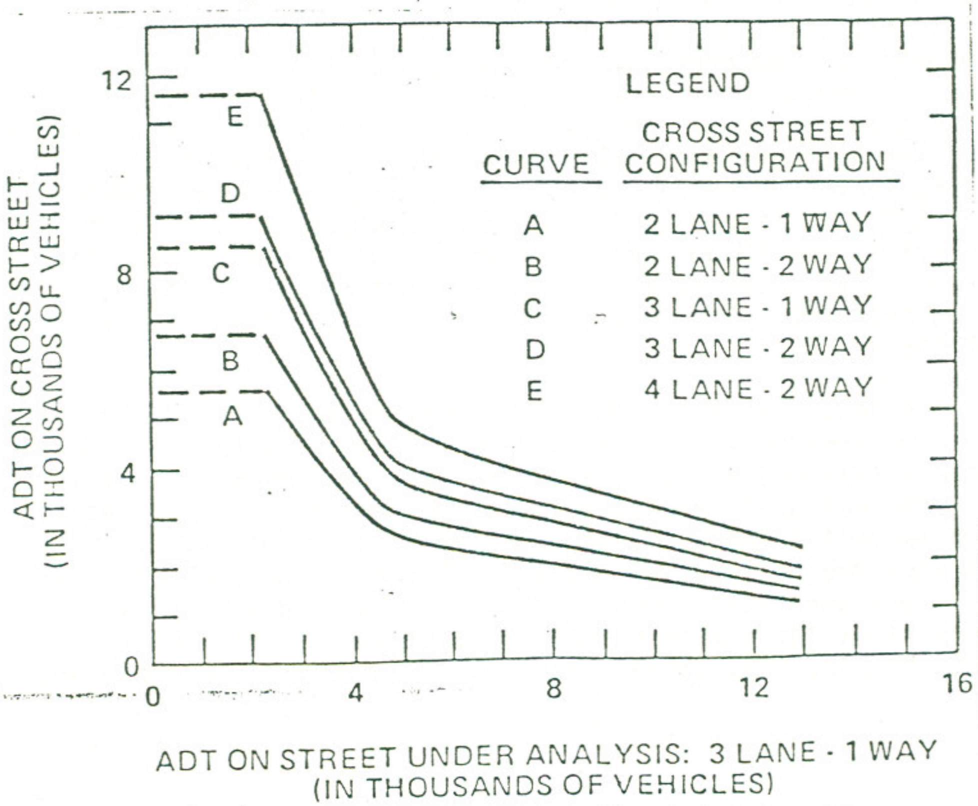

Figure 40: Critical volumes signalized intersections. Above or on the line--a potential hot spot.

whether he is above (potential hot spot) or below (not a hot spot) the critical curve.

Both guidelines use a series of annotated worksheets, graphs, and tables supplemented by background information on technique development and applications. Results of limited validation studies are included in each guide. These guidelines are particularly useful in indirect source evaluation, transportation control planning, assessment of new roadway projects, evaluation and selection of air quality monitoring sites, and other ongoing mobile source-air pollution related projects. They are not intended, however, to replace detailed computer studies.

The two guides presently are only in draft form because AP-42 emission factors for mobile sources are being updated. Final publication and dissemination to users should be possible early in 1978.

3.3.4 CO task force

A task force under the direction of EPA Assistant Administrator Mr. David Hawkins was formed late this fiscal year to address the skepticism that pervades EPA and local agencies about the possible extent of a carbon monoxide (CO) problem. Because of AWMSB expertise and involvement in roadway and mobile source modeling, participation on the task force was requested. Involvement includes a hypothetical roadway configuration analysis, an analysis of intersections in several cities, and a sensitivity analysis of meteorological and modeling parameters.

Close coordination with EPA participants in mobile source emissions, monitor siting and field observations traffic characteristics is essential for this portion of the task force to be effective. The task force will summarize analyses and interpretations in a recommendation in 1978.

3.3.5 Monitoring guidance

Three major monitoring guidance documents were completed, or are nearing completion, relating to pollutants for which air quality standards are applicable. The first of these, "Optimum Site Criteria for SO_2 Monitoring" (Ball and Anderson, 1977) was prepared under contract by the Center for Environment and Man, Inc. The other two were prepared by SRI, International, also under contract. These latter two are entitled: "Selecting Sites for Monitoring Total Suspended Particulates" (Ludwig et al., 1977) and "Selecting Sites for Monitoring Photochemical Pollutants" (Ludwig et al. - In Draft). The photochemical oxidant report is scheduled to be published in early 1978. These are all resource documents which contain comprehensive information on siting monitors for the specific pollutants. They are the basis for developing official EPA monitoring regulations and guidelines. Revisions to monitoring regulations applicable to State and local air pollution control agencies in the Code of Federal Regulations (40CFR51) are currently being revised for establishment of a select number of National Air Quality Trend Stations (NAQTS) nationwide. These NAQTS stations will have to meet stringent siting criteria, quality control and reporting schedules and will be the basis for future EPA reporting of nationwide air quality status and trends.

3.3.6 Tulsa Oxidant Field Study

As part of the OAQPS effort to investigate the generation and impact of photochemical oxidants in urban atmospheres, a field monitoring study was conducted in Tulsa, Oklahoma during July through September, 1977. Past EPA sponsored studies have concentrated in investigating rural ozone levels (EPA, 1974-1975), long-range transport (EPA, 1976), or ozone formation within large urban-industrial areas (EPA 1976, 1977). The Tulsa Study was designed to provide a data base to adequately assess the levels of ozone produced in a typical medium-sized city. An eight station monitoring network was established to continuously record measurements of ozone, oxides of nitrogen, hydrocarbons, wind speed and direction, and solar radiation as shown schematically in Figure 41. The ground level sampling was supplemented on selected days by aircraft measurements aloft of ozone, ozone precursors, light scattering and condensation nuclei within the boundary layer. A typical daily flight pattern included a morning flight at about 900 m MSL between Tulsa and 35 m upwind of the city; and an afternoon flight at approximately the same height out to 60 km downwind of the city. Vertical sampling spirals between 200 m and 3000 m were conducted during morning and afternoon flights. The data generated during the monitoring program will be analyzed in 1978. The results will be published in two volumes to include reporting of data summaries and data analysis, respectively. The various tasks are being performed by Research Triangle Institute under contract to EPA.

The focal point of the data analysis will be to examine the spatial gradients and temporal patterns of ozone and precursor concentrations upwind and downwind of Tulsa to estimate the level of ozone likely to have been produced by emissions within the Tulsa urban core. Another important aspect of the analyses will involve interpretation of discrete hydrocarbon species data with respect to the photochemical mechanisms leading to high ozone concentrations. The Tulsa data base will also be used as input for EPA photochemical model verification studies.

3.3.7 Air quality trends considering meteorological influences

A guidance document on adjusting air quality trends for meteorological variability was prepared by Technology Services Corporation, under contract to EPA (Technology Service Corporation, 1977). The report discusses the basic concepts behind an important topic in air quality trends anslyses: isolating the trend in air quality resulting from pollutant emission changes. The discussion on adjusting air quality data is preceded by a qualitative overview of the state-of-the-art knowledge on the relationships between various meteorological parameters such as surface temperature, surface winds, mixing depth and vertical temperature profile, and the pollutants: CO, oxidant, TSP and SO_2. The representativeness of meteorological measurements with respect to recorded air quality data is also discussed. A tabular summary of the findings of prior work correlating air quality and meteorological parameters for various study cities is included in the report. This background information serves to aid the reader in understanding the basic concepts dealing with meteorological adjustment of air quality data.

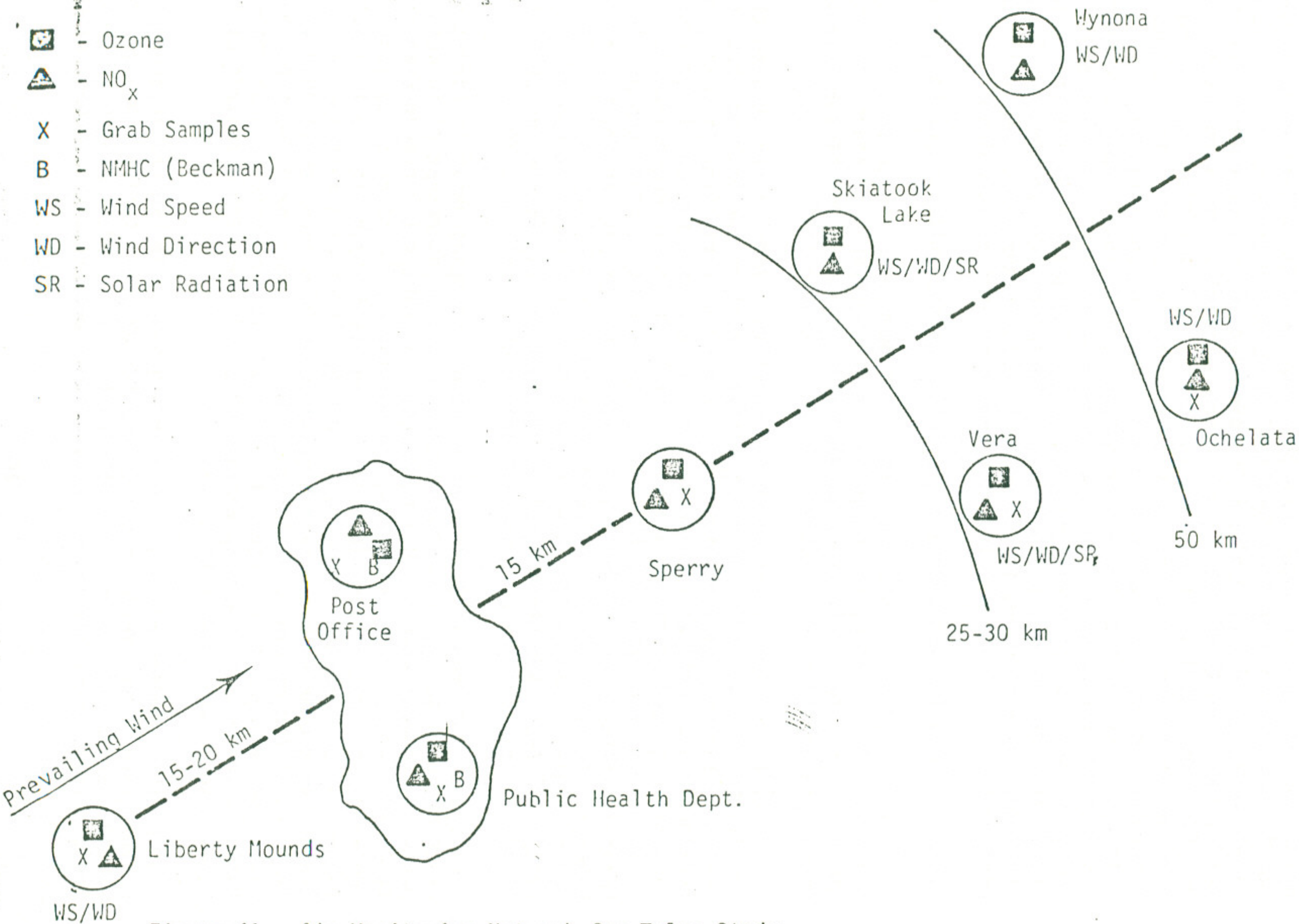

Figure 41: Air Monitoring Network for Tulsa Study

The report describes several approaches for adjusting air quality data, including the use of meteorological indices, classification of meteorological regimes, and linear regression techniques. For example, indices combining mixing height and wind speed have been developed to reflect atmospheric conditions conducive to high levels of oxidants in Los Angeles (Davidson 1975). Other indices have been employed to normalize SO_2 concentrations for mixing depth, the strength of the inversion and daytime surface wind speed (van Dop and Kruizinga, 1976). Meteorological classes of inversion-base height and surface temperature have been used to categorize maximum 1-hour oxidant concentrations in San Francisco (Bay Area Air Control District, 1973). This procedure provides for a "normalized" comparison of maximum oxidant levels from year to year. The linear regression technique was useful in adjusting SO_2 and TSP concentrations in Los Angeles for variations in wind speed, temperature and rainfall (Environmental Protection Agency, 1976). The empirical procedures for using each approach are discussed in the document along with an example analysis combining several techniques.

3.3.8 Analytic procedures for relating photochemical ozone to precursors

Several efforts are being directed at improving the technical basis for quantitatively relating photochemical oxidants (ozone) to their precursors. These efforts are related to evaluating the effectiveness of possible strategies for achieving the oxidant (ozone) air quality standards.

A major project was to convert a conceptual model based on smog chamber simulations (Dodge, 1976) into a practical modeling approach by incorporating several empirical relationships, such as diurnal variations in mixing height, horizontal and vertical transport, etc. This hybrid method of atmospheric simulation is termed the Empirical Kinetic Modeling Approach (EKMA). EKMA is described in a late 1977 EPA publication, "Uses, Limitations and Technical Basis for Procedures for Quantifying Relationships Between Photochemical Oxidants and Precursors" (Environmental Protection Agency, 1977). The document also discusses the use of photochemical dispersion models, linear rollback, and statistical models that may be used to relate oxidants to precursors, but places primary emphasis on describing EKMA.

The use of EKMA is based upon a set of isopleths shown in Figure 42 which are used to relate maximum afternoon ozone concentration to morning precursor concentrations. Mixing height and transport considerations are taken into account for estimating the portion of the observed maximum ozone concentration that is locally generated and that which results from long-range transport and/or from natural sources. Control strategies can be tested using EKMA by evaluating hypothetical reductions in nitrogen oxides (NO_x and/or non-methane hydrocarbon (NMHC) emissions and estimating the impact on maximum ozone concentrations attributed to local source contribution. The relation between ambient NO_x, and NMHC, and emissions of these constituents, are assumed to be 1:1.

Further documentation of the assertions made in EKMA is included in a supporting report which is being prepared by EPA. During the year several studies were performed by AWMSB meteorologists for this document. These include analyses of natural background ozone and precursor concentrations;

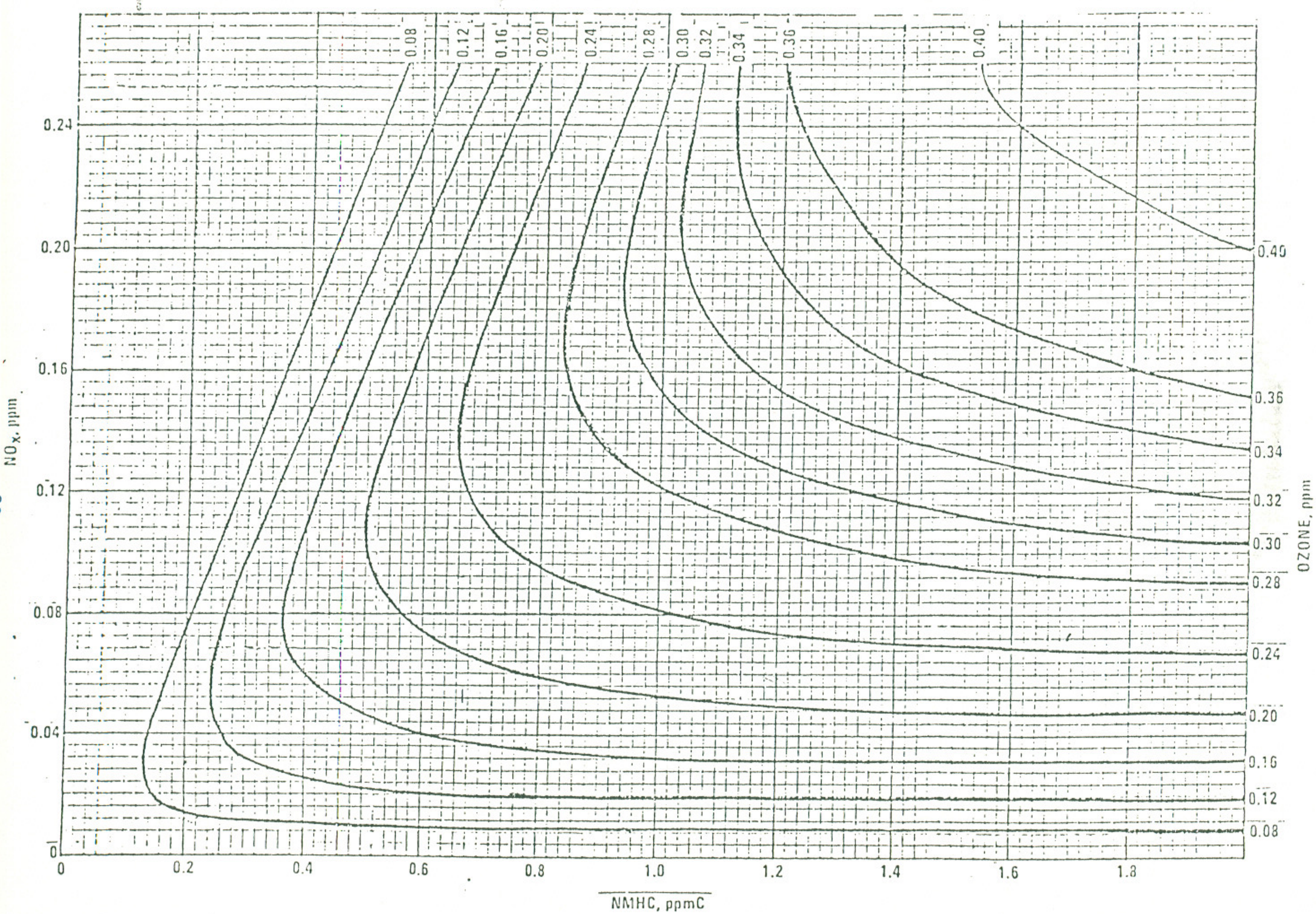

Figure 42: Maximum Afternoon Ozone Concentrations to Morning Precursor Levels

the impact of inaccuracies in non-methane hydrocarbon (NMHC) measurements on the use of EKMA; and, an evaluation of EKMA as a predictive technique.

Considering the possible sources of natural background ozone concentrations, a literature review indicates that the stratosphere is the principal source of natural ozone sensed in the ambient air. Such contributions of ozone in the planetary boundary layer during the smog season (June-September) average about 0.04 ppm. These levels are reduced at night, due to greater efficiency of scavenging under more stable atmospheric conditions. Simulations using the kinetic model underlying EKMA indicated that if 0.04 ppm background of ozone enters an urban area in the early morning, subsequent mixing and interactions with the urban plume will reduce its contributions to the maximum observed ozone concentration to about 0.02 ppm.

A fundamental piece of data inherent in the use of EKMA is the ratio of NMHC concentrations to NO_x concentrations. Unfortunately, significant errors have been noted in ambient NMHC measurements and are associated with instrument and operational problems in most existing continuous hydrocarbon field analyzers. Since ambient NMHC data were used in the development of EKMA, and are required to compute NMHC/NO_x ratios, an analysis were performed to quantify the error in ambient NMHC data. By examining the work or prior laboratory comparisons and field surveys (Environmental Protection Agency, 1974, 1975, 1977), it was estimated that inaccuracy in individual hourly NMHC values may be as high as plus or minus several hundred percent in the range of concentrations below 0.5 ppm C. At higher levels, the error is not quite as large, but may still be ±25% at up to 2.0 ppm C. Through a statistical analysis of the St. Louis RAPS NMHC and NO_x data, it was determined that the error in NMHC values can have a significant impact on the accuracy of individual NMHC/NO_x ratios. However, it was demonstrated that using mean and median ratio values substantially reduces this effect. Further analysis of ambient NMHC concentrations and ratios indicates that, on days of high oxidant levels, NMHC levels are also relatively high and NMHC/NO_x ratios are comparatively similar to magnitude. This suggests that the error in NMHC measurements can be minimized by using ratio values recorded on high oxidant days. Combining both pieces of information led to development of the recommended procedures for computing NMHC/NO_x in EKMA. The median NMHC/NO_x ratios observed on the five days of highest ozone levels (with available NMHC and NO_x data) should be used; however, if data are available from more than one monitoring site within the urban core of the city, the ratio from each site should be averaged for the five highest ozone days and the median of these values used in applying EKMA.

To evaluate the performance of EKMA, a preliminary analysis was conducted to compare predictions generated by the model with ambient oxidant and precursor trend data. The hypothesis tested is that trends in estimated precursor levels, determined from applying historical changes in ambient oxidant levels to the model, should reflect actual trends in observed precursor concentrations. The Los Angeles Basin was selected for study because dispersion conditions (mixing heights and wind speed) in the Basin on days of high oxidant levels most closely approximate conditions assumed in the standard EKMA model (Dodge, 1977). Also, monitoring sites in the Basin have among the most complete oxidant-precursor data base available for long-term analysis.

For this study, eight years (1968-1975) of oxidant, NO_x and hydrocarbon data were examined for the 11 monitoring sites. The data base was divided into two groups, 1968-1971 and 1972-1975, and the median design value oxidant concentration (second maximum value), and $NMHC/NO_x$ ratios were determined for each period. This procedure of aggregating the data was designed to reduce the influence on oxidant and precursor levels of short-term meteorological cycles and rare-event meteorological situations since such conditions are not accounted for in the standard model.

Two scenarios were used to test model predictions. First, the change between 1968-1971 and 1972-1975 in the design value oxidant level was used to predict the percent change in ambient precursor concentrations. Second, actual NO_x and reactive hydrocarbon emission trends (within Los Angeles Co.) were used to predict the change in ambient oxidant concentration. This latter approach assumed a linear relationship between precursor emissions and ambient precursor concentrations. In the first comparison, the model overpredicted the reduction in NMHC and NO_x ambient concentrations by approximately 5% to 10%. The results of the second comparison indicated that the model understimated the decline in ambient oxidant levels by about 5%. Although these results suggest fairly reasonable correspondence between the model's prediction and observed trend data, the analysis is still somewhat preliminary. A more definitive evaluation of EKMA is forthcoming from work conducted by Technology Services Corporation under contract with EPA.

3.3.9 Model improvement studies

Meteorologists in AWMSB are routinely involved in applying dispersion models to a wide variety of point sources. Results of these applications are frequently used in making decisions on the amount of air pollution control required for individual plants and on the adequacy of proposed air pollution control regulations. One of the most frequently used models is the Single Source (CRSTER) Model, derived from the MX24SP model (Turner and Novak, 1976).

The Annual Reports for Fiscal Years 1975 and 1976 described source validation studies which were performed on this model. Beginning last year GCA/Technology Division, under contract to EPA, continued the study of the time-concentration relationships begun as part of the validation study and tested certain potential improvements to this model. This study, which is now completed, consists of three parts:

1. Further analysis of time-concentration relationships (Mills, 1976),
2. Testing and evaluation of improvements to the Single Source (CRSTER) Model (Mills and Stern, 1977),
3. Further analysis of modeling results for possible model improvements (Mills, 1977).

Part 1 is an extension of earlier analysis of ratios of one-hour peak to three-hour mean concentrations, and of ratios of one-hour peak to 24-hour mean concentrations. Part 2 is a study of the effect on model accuracy of the use of four different sets of dispersion coefficients (σ_y and σ_z). The Gifford-Briggs dispersion curves, the F.B. Smith curves, and the Smith-Singer curves are compared with the present use of the Pasquill-Gifford curves (Turner, 1970). The results of parts 1 and 2 were reported in last year's Annual Report (Viebrock, 1977). Part 3 consists of an evaluation of the model performance stratified by six stability classes, three wind speed classes and three mixing height classes.

The accuracy of the model is found to be dependent on stability class. For stabilities A and B, the model shows some tendency to overestimate concentrations, especially near the plant. This implies that vertical dispersion is overestimated in the model, i.e., σ_z values are too large.

For stabilities D, E, and F, the model greatly underestimates concentrations at all but the most distant sampler. This implies that vertical dispersion in the model is underestimated for these stabilities, i.e., σ_z values are too small. For stability C, the model tends to agree with the measurements.

Higher wind speeds result in a tendency toward overestimates at the Muskingum plant, and a tendency toward underestimates at the Canal plant.

For the Canal plant, there does not appear to be a definite pattern between the accuracy of the model estimates and mixing height. However, at the Muskingum plant, large underestimates occur for the lowest mixing height class. This implies that the model is treating the plume as penetrating the top of the mixed layer (with resulting concentration estimates of zero) more frequently than actually happens. Thus, either the mixing heights are underestimated, or the concept of complete plume penetration is unrepresentative.

3.3.10 Screening procedures for new source review

In response to the need for a guidance document on screening procedures for new source review, Volume 10 of the Air Quality Maintenance Planning and Analysis Series was originally prepared under EPA Contract 68-02-1094 (Environmental Protection Agency, 1974). Subsequent comments from the EPA Regional Offices and other users began to point out major deficiencies in that document. It was then decided to re-draft the document in an attempt to accommodate the various comments being received. After further solicitation of comments and extensive review, the document was redrafted by AWMSB meteorologists and published as Volume 10 (Revised): "Procedures for Evaluating Air Quality Impact of New Stationary Sources". The revised Volume 10 provides basic modeling techniques for estimating the air quality impact of new (proposed stationary sources. The revision is in a more readily useable format and incorporated changes and additions to the technical approach. Also, a simple screening procedure has been added. The techniques are applicable to chemically stable, gaseous or fine particulate pollutants. An important advantage of the technique is that a sophisticated computer is not required. A pocket or desk calculator will generally suffice.

3.3.11 Reliability of Supplementary Control Systems

Environmental Research and Technology, Inc. (ERT) has developed a reliability analysis technique for supplementary control systems (SCS) under contract to EPA (EPA, 1976). Reliability is defined as the ability of an SCS to prevent ambient pollutant concentrations from exceeding ambient standards. The draft final report entitled "Case Study Demonstration of Supplementary Control System Reliability" was received from ERT at the end of the fiscal year. A user manual for the computer program PROBL, an integral part of the reliability analysis technique, is appended to the report. After review, by AWMSB staff, publication of the final report is anticipated in early 1978.

The reliability analysis technique requires input source, meteorological and air quality data collected concurrently during several months of SCS operation. Application of the technique can yield information on (1) the overall reliability of an SCS and (2) the degree to which reliability can be improved by adjusting key system parameters.

3.3.12 Co impact of general aviation aircraft

Two AWMSB meteorologists carried out an analysis of general aviation aircraft impact on ambient carbon monoxide (CO) concentrations using the PAL (Point-Area-Line Source) dispersion model (Petersen, 1977). The model handles emissions from a limited number of sources, disperses these emissions (with input hourly meteorological conditions) downwind in a Gaussian manner, and calculates estimates for any averaging time from 1 to 24 hours.

The analysis focused on Van Nuys California Airport which is the busiest general aviation airport in the U.S. The scope of the analysis was confined to single and twin piston-engine aircraft, accounting for 93 percent of aircraft operations at the airport. Emissions were estimated from AP-42 and were affected by such factors as aircraft engine emission factors, modes of operation and aircraft traffic density. The input meteorological conditions were chosen to coincide with realistic worst case (high CO impact) conditions occurring at the airport. Sources modeled include taxiways, taxiway queues, runways, approach and climbout paths (below 900 m above surface), aircraft parking areas, and run-up areas. The source layout is shown in Figure 43 and is a simplification of the actual airport layout.

PAL is able to model these sources simultaneously and estimate the combined CO impact at any specified receptor location. Individual source contributions to each receptor location may also be modeled. The results of the analysis indicate a violation of the 1- and 8-hour NAAQS for CO at receptor locations very near the emission sources. These hot spots are confined to the airport. At short distances ($\sim$ 200-300 meters) downwind of the hot spots, maximum impacts are well below the standards. Figure 43 shows the maximum estimated 8-hour CO concentration ($\mu g/m^3$) at receptor locations.

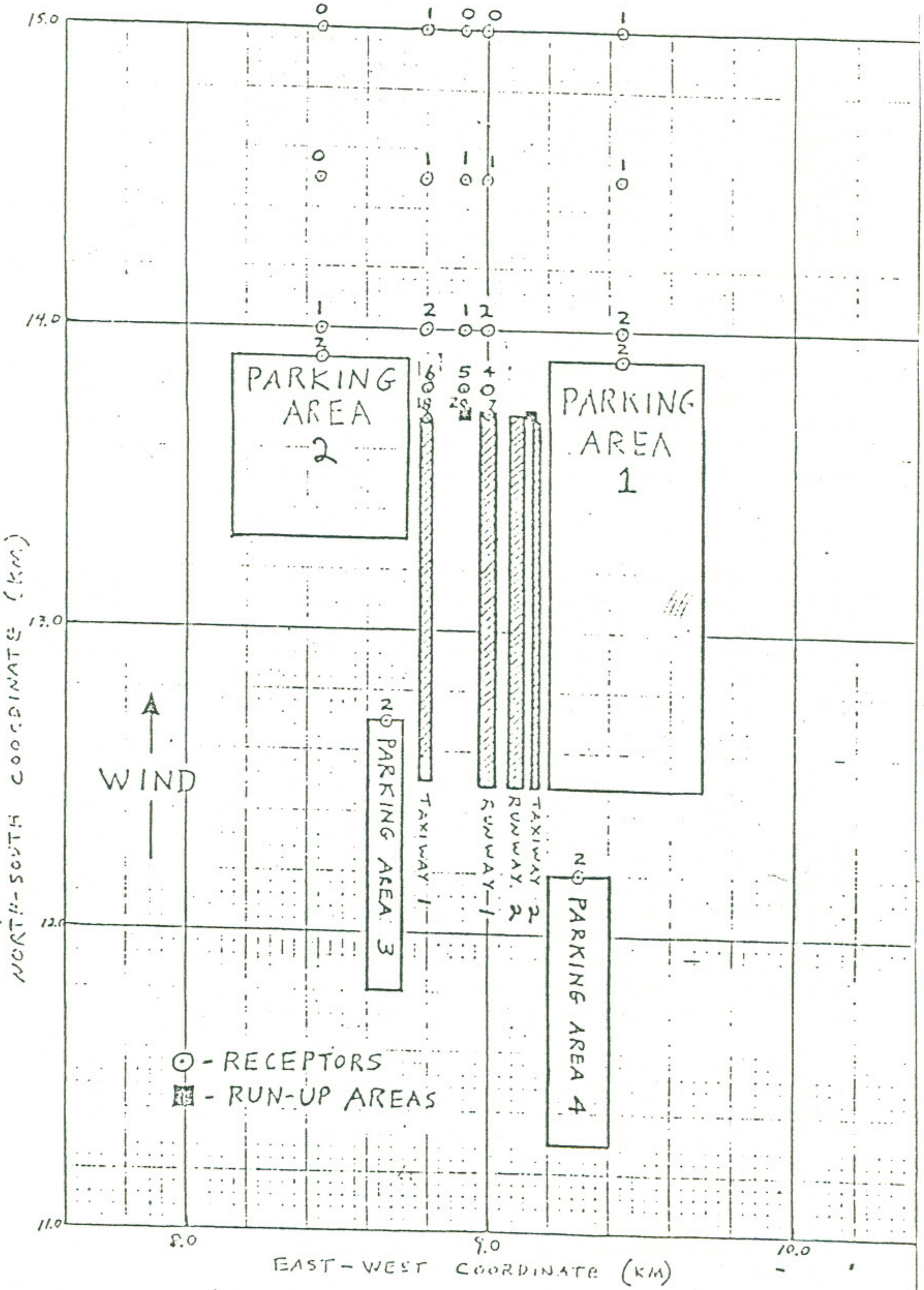

Figure 43: Maximum 8-hour CO concentrations (mg/m^3 when all aircraft use the runway (#1).

3.3.13 Industrial Process Fugitive Particulate Emissions

AWMSB personnel assisted OAQPS in developing a Guideline for Industrial Process Fugitive Particulate Emissions (IPFPE) (Environmental Protection Agency, 1977a). This guideline was widely distributed to State and local air pollution control agencies.

Because they are emitted at or near ground level, industrial process fugitive particulate emissions exert a proportionally higher air quality impact than do traditional stack emissions. Thus there is a strong reason to suspect that IPFPE sources may contribute significantly to the nonattainment of air quality standards for total suspended particulates in many urban areas. The impact of IPFPE's generally is most critical on a short-term basis in the immediate vicinity of the source. Therefore, a control strategy designed to attain annual average air quality standards at sites in an existing area-wide monitoring network may not be sufficiently stringent to assure attainment of 24-hour standards in the immediate vicinity of IPFPE sources where such monitoring sites may not exist. It is therefore essential to address the short-term, localized, impact, as well as the long-term, area-wide impact, in order to develop an adequate control strategy for IPFPE's.

AWMSB personnel wrote and/or provided input to those sections of the IPFPE Guideline that deal with air quality considerations. The application of dispersion modeling IPFPE sources was extensively discussed and a sample problem was presented in detail. Meteorological input was provided to a section in which an example upwind/downwind monitoring program was presented.

3.3.14 Urban/rural oxidant report

A contractual effort directed by AWMSB personnel culminated in a three-volume report to EPA (Ludwig et al., 1977; Singh et al., 1977; Ludwig et al., 1977) by SRI International on the relation of oxidant levels to precursor emissions and meteorological features. The study addressed the formation and transport of photochemical oxidant (expressed as ozone) in the lower troposphere and assessed the stratospheric condition to ozone concentrations at ground level. The study involved isentropic trajectory analysis, lower-tropospheric trajectory analysis, and map comparisons of synoptic weather features with patterns of ground-level ozone concentration.

While not establishing definitive, quantitative relationships for formulating control strategies, the report is qualitiatively convincing and essentially corroborates emerging EPA policy and guidance.

3.3.15 User's Manual for Single Source (CRSTER) Model

Under the direction of AWMSB personnel, a user's manual was developed for the Single Source (CRSTER) Model (Environmental Protection Agency, 1977). The Single Source (CRSTER) Model is a computer program designed to simulate atmospheric dispersion processes for the purpose of calculating ambient concentration levels of atmospheric contaminants. The basic version of the model, originally known as MX24SP, was developed by the Meteorology Laboratory in 1972. The Single Source (CRSTER) Model is a steady-state Gaussian plume dispersion model designed for point-source applications. It calculates pollutant concentrations for each hour of a year, at 180 selected receptor sites, by mathematically simulating the interaction between the pollutant source characteristics and hourly meteorological conditions. The hourly concentrations are averaged to obtain concentration estimates for time increments of specified length, such as 3-hour, 8-hour, and annual.

The Single Source (CRSTER) Model is widely applied in both the private and public sectors to a variety of air pollution problems. It is utilized primarily in simulating the behavior of stack effluents from combustion sources. Although designated as the *Single* Source (CRSTER) Model, the computer program offers the capability of considering up to 19 stacks simultaneously which are located at a common site.

The types of application for which the model is well-suited include:

- Stack design studies
- Combustion source permit applications
- Regulatory variance evaluation
- Monitoring network design
- Control strategy evaluation for SIPs
- Fuel (e.g., coal) conversion studies
- Control technology evaluation
- Design of supplementary control systems
- New source review
- Prevention of significant deterioration

The user's manual is available from NTIS as PB 271-360 and a magnetic tape copy of the source statements (in FORTRAN) may also be purchased by referring to PB 275-701.

3.3.16 The Valley Model

The terrain impaction calculation technique (Valley Model) developed by AWMSB meteorologists and reported on in previous years has been published in the form of a user's guide (Burt, 1977). A magnetic tape copy of the source statements (in FORTRAN) is available from NTIS as PB 275-700. The guide contains an overview of the model's development, a technical discussion of the dispersion equations utilized and complete definitions of input data required as well as program output. Instructions for the computer user and a test run are also included.

During the past year Burt and Slater (1977) used the available appropriate data for evaluating the Valley Model in its primary intended manner-estimating the second highest 24-hour concentration of pollutants on terrain about stable plume height. At four of the six monitoring sites near four major polluters in the Rocky Mountain region, the 24-hour model estimates were within a factor of 2 of the observed second highest values. At the two other sites the model estimates ranged from 3.9 to 6.4 times the observed second highest 24-hour concentrations.

3.3.17 Industrial Source Complex (ISC) Dispersion Model

AWMSB personnel are directing the contractual efforts of H. E. Cramer Co. to develop an Industrial Source Complex (ISC) Model. The ISC Model will be a Gaussian-plume dispersion model intended for wide application by State/local pollution control agencies and industrial interests on problems that are too complex to be adequately handled by existing, generally-available models. EPA recognizes the increasing complexity of the dispersion modeling problems that State/local control agencies and industrial groups are being required to address. These complex problems often require consideration of such factors as building-wake effects, gravitational settling, deposition, and the presence of ill-defined, fugitive-type emissions. The ISC Model is intended to handle such complicating factors. The types of applications for which the model is intended are the same as for the widely used Single Source (CRSTER) Model, which is discussed elsewhere in this report. It is not intended as a replacement for the Single Source (CRSTER) Model, but as an additional model that can be used on pollution sources for which the Single Source (CRSTER) Model is not adequate. The ISC Model is perhaps best described as an enhancement of the Single Source (CRSTER) Model to allow consideration of the following key features:

- Spatial separation of multiple sources
- Area sources and line sources (in addition to point sources)
- Building-wake effects
- Gravitational effects
- Deposition

3.3.18 Support to EPA study of air quality impact to coal substitution

AWMSB played a major role in an EPA study of the air quality effects of the President's Energy Proposals. The results of the study were provided to Congress for their use during deliberations on energy legislation. In the study, OAQPS performed a county-by-county analysis of the administration's coal substitution program, projecting its effects on air quality in 1985. OAQPS employed proportional (i.e., "roll-forward") modeling for arriving at their rough projections. The role of AWMSB was to provide a county-by-county assessment of the limitations imposed by this rough technique and to use alternative, more sophisticated techniques as required. The limitations that were noted were principally two: (1) numerous instances of unrepresentative ratios of pollutant levels to emissions rates in the baseline (1975) year, and (2) numerous instances in which the assumption of proportionality between ground-level pollutant concentrations and emission rates is grossly invalid because of the failure to consider the effective height of release of the emission. Counties earmarked under limitation 1 were recommended for elimination from the study. Limitation 2 primarily involved counties for which the projected growth was in the utilities sector (i.e., large commercial power plants). AWMSB recommended in these cases that the power plant emissions be split out from the proportionality equation and considered separately. The recommendation was taken and AWMSB assessed the air quality impact of the power plant emission using the Single Source (CRSTER) Model.

3.3.19 Support to control strategy development for iron and steel

AWMSB personnel continued to give dispersion modeling support to the joint EPA/industry Task Force on Particulate Emissions for the Iron and Steel Industry. The Task Force is attempting to develop reasonable control strategies for minimizing the impact of the steel industry on concentrations of particulate matter in the ambient air. AWMSB personnel have used dispersion modeling to demonstrate the cost/benefit features of differing control strategies. The work of the Task Force is expected to be completed during 1978.

3.3.20 Assessing the air quality impact of emission standards

Considerable modeling support is provided bo the Emission Standards and Engineering Division (ESED) for the purpose of assessing the air quality impact of New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP). This modeling is done for widely varying types of industrial operations. Since the emission standards are set on an industry-wide basis, the dispersion modeling is done on prototype examples of each industry. Within each industry, various plant sizes, plant configurations, and control strategies are modeled. The modeling results are incorporated into the Standard Support and Environmental Impact Statement (SSEIS) which accompanies the promulgation of each emission standard in the Federal Register.

The dispersion modeling support is summarized on an industry-by-industry basis as follows:

A. Phosphate rock processing--proposed NSPS were found to significantly reduce the air quality impact (particulate matter) from that resulting from typical state emission limits.

B. Coal gasification--the effect of proposed NSPS on ambient levels of SO_2, NO_x, and CO, particulate matter, anc non-methane hydrocarbons was assessed. It was noted that controls significantly reduce the ambient concentrations. It was also noted that the use of tail-gas scrubbing to control SO_2 emissions results in increased ground-level concentrations of the other pollutants. This is because the scrubber cools the exhaust and therefore results in a lower plume rise.

C. Asphalt roofing manufacturing--proposed NSPS for particulate matter were seen to dramatically reduce the ground-level concentrations resulting from the largely low-level emissions from various sources in typical asphalt roofing plants.

D. Non-metallic minerals processing--emission reduction was reflected in dramatic decreases in estimated ambient concentrations of particulate matter. It was also noted that heating the exhaust gas from the low-level stacks significantly lowers the ground level concentrations by causing a relatively large increase in the plume rise.

E. Fossil-fuel-fired power plants--proposed amendments to NSPS for SO_2 and particulate matter were assessed. Specific emission rates were not assumed; rather, normalized air quality estimates were derived. The revised NSPS call for the use of flue-gas scrubbing. This procedure cools the exhaust gas, thus lowering the plume rise and thereby causing higher ground-level concentrations for a given rate of emission. The most notable result of the AWMSB analysis is that a relatively modest reheat of the exhaust gas was shown to significantly reduce the resulting pollutant concentrations at ground level.

F. Lead-acid battery manufacturing plants--the ambient concentrations of acid mist resulting from emissions from battery plants was estimated. The significance of the estimated concentrations is not yet clear.

G. Copper smelters--estimates were made of ground-level concentrations of arsenic resulting from emissions from the acid plant stack at copper smelters. It was seen that concentrations in terrain-impaction situations may be of about the same order as existing standards for worker exposure.

3.3.21 Development of control strategies for hazardous pollutants

AWMSB personnel provide extensive support to the Strategies and Air Standards Division (SASD) in the development of EPA's control strategies to reduce the levels of carcinogens and other hazardous pollutants in the ambient air. AWMSB personnel perform dispersion modeling and provide consultation on ambient monitoring programs in assessing the public threat in the vicinity of sources of these pollutants. AWMSB's support enables SASD to prioritize the sources individually or generically for the purpose of recommending the establishment of emission standards. Pollutants (and their sources) for which AWMSB has given support to SASD are as follows:

Pollutant	Source
benzene	chemical manufacturing facilities, coking plants, petroleum refineries, service stations, automobiles
benzo-alpha-pyrene	coking plants
acrylonitrile	monomer and polymer production plants
ethylene dichloride (EDC)	EDC production plants
arsenic	copper, lead, and zinc smelters, power plants, cotton gins, pesticide plants

3.3.22 Representativeness of meteorological data for dispersion modeling

The reliability of ambient air concentration estimates for air pollution sources is affected by the representativeness of meteorological data input to a dispersion model. Since there are often limitations on the availability of such data, records from arbitrary time periods are frequently utilized. Under a contract with Walden Division of Abcor, Inc., a study is being conducted to determine the representativeness of meteorological data for a specific time interval for the area east of the Mississippi River. The year 1964 was taken as the reference period since it has been used extensively for modeling applications and it is the last year the National Climatic Center routinely keypunched hourly weather observations.

Comparisons with the 30-year climatological record (1940-1970) and with the individual years 1970-1974 are being made. Statistical analyses have examined those meteorological parameters generally considered to affect atmospheric dispersion and transport such as wind speed and direction, stability classification mixing height, average sky cover, ambient temperature and precipitation.

The study is divided into three levels of analysis. First there has been a climatological and statistical evaluation of the representativeness of 1964 in terms of comparison with the 30-year climatology base. The contractor's draft report (Morgenstern, 1977) contains a series of tables similar to Table 4 for EPA Region I. Second, the analysis is being extended to consider the dispersion climatology at a selected number of meteorological stations in the EPA Regions I-V, making a quantitative comparison of 1964 to the five year period 1970-1974. Thirdly, the Single Source (CRSTER) Model will be used to determine the impact upon estimated pollutant concentrations of using 1964 meteorological data versus data from the 1970-1974 period. Comparisons will be made for short (30 m) stacks, moderate (100 m) stacks and tall (200 m) stacks. The draft final report for Region I is undergoing review and comment by AWMSB meteorologists.

Table 4. Summary of General Climatology Comparisons* Between 1964 and 30-Year Norm for Region I

Parameter	Jan	Apr	July	Oct	Year
Daily max avg temperature	R (+)	A	A	R (-)	A
Daily min avg temperature	R (+)	A	A	R (-)	A
Monthly avg temperature	R (+)	A	A	R (-)	A
Heating degree days	R (-)	A	A	R (+)	A
Average wind speed	A	A	A	A	A
Total precipitation	R (+)	A	A	A	R (-)
Average sky cover	A	A	R (+)	A	R (-)

* R - reject null hypothesis of not significant difference
A - accept null hypothesis of no significant difference.
Plus sign indicates 1964 greater than 30-year norm and vice versa.

4.0 REFERENCES

Air Resources Board, State of California, July 1973. Report of the California tri-city aerosol sampling project, visibility, light scattering and mass concentration of particulate matter.

Anthes, R. A. and T. T. Warner, 1977: Applications of general meteorological models to air-quality problems. Presented at ASTM Conference on Air Quality Meteorology, and Atmospheric Ozone 1 to 6 August 1977, Boulder Colorado. 47 pp.

Ball, R. J. and G. E. Anderson, 1977. Optimum site exposure criteria for SO_2 monitoring, EPA-450/3-77-013, Research Triangle Park, NC.

Bay Area Air Pollution Control District, 1973. A Study of Oxidant Concentration Trends in the BAAPCD (1962-1972) Based on Temperature and Inversion Criteria, San Francisco. California.

Binkowski, F. S., 1976a: Modeling radiative transfer in the Planetary boundary layer: preliminary results. Proceedings of the Conference on Environmental Modeling and Simulation 19 to 22 April 1976, Cincinnati, Ohio. EPA 6009-76-016, pp. 473-477, July 1976.

Binkowski, F. S., 1976b: Preliminary results from a simplified closure technique for obtaining turbulent statistics from climatological wind profiles. Presented at Third Symposium on Atmospheric Turbulence, Diffusion, and Air Quality, 19 to 22 October 1976, Raleigh, North Carolina.

Boland, F. E. 1977: A model for determining surface temperatures and sensible heat fluxes over the urban-rural complex. M.Sc. thesis, Department of Meteorology, The Pennsylvania State University. May 1977, 179 pp.

Bornstein, R. D., and D. S. Johnson, 1977: Urban-rural wind velocity differences. Atmospheric Environment, 11, 597-604.

Bornstein, R. D., T. Morgan, Y. T. Tam, T. Loose, K. Leap, J. Sigafoose, and C. Berkowitz, 1977a: New York air pollution project of 1964-1969, Vol. I, description of data. EPA-600/4-77--35a, Environmental Protection Agency, Research Triangle Park, NC 27711, 134 pp.

Bornstein, R. D., T. Morgan, Y.-T. Tam, T. Loose, K. Leap, J. Sigafoose, and C. Berkowitz, 1977b: New York City air pollution project of 1964-1969, Vol II, data. EPA-600/4-77-035b, Environmental Protection Agency, Research Triangle Park, NC 27711, 213 pp.

Bowling, S. A., and C. S. Benson, 1978: Study of the subartic heat island at Fairbanks, Alaska. To be published as an EPA technical report.

Budney, L. J., 1977. Procedures for evaluating air quality impact of new stationary sources. Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10 (Revised). EPA-450/4-77-001 (OAQPS Number 1.2-029R), Environmental Protection Agency, Research Triangle Park, NC. Available from NTIS as PB 274-087.

Burt, E. W, 1977. Valley Model User's Guide. EPA 450/2-77-018, Environmental Protection Agency, Research Triangle Park, NC. Available from NTIS as PB 274-054.

Burt, E. W. and H. H. Slater, 1977. Evaluation of the Valley Model. Preprint Volume of the Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, Utah, pp 192-195. American Meteorological Society, Boston, MA.

Cadle, S. H., D. P. Chock, J. M. Heuss, P. R. Monson, 1976: "Results of the General Motors Sulfate Dispersion Experiment", GMR-2107, Research Laboratory, General Motors Corporation, Warren, Michigan.

Chandler, T. J., 1965: The Climate of London, Hutchinson of London, 292 pp.

Charlson, R. J., A. H. Vanderpol, D. S. Covert, A. P. Waggoner, and N. C. Ahlquist, 1974: $H_2SO_4/(NH_4)_2SO_4$ background aerosol: Optical detection in St. Louis region, Atmos. Environ., 8, 1257-1267.

Clark, T. L. and R. E. Eskridge, 1977: Non-divergent wind analysis algorithm for the St. Louis RAPS network, EPA-600/4-77-049, Environmental Protection Agency, Research Triangle Park, NC, 62 pp.

Cotton, W. R., 1972a: Numerical simulation of precipitation development in supercooled cumuli - part I. Mon. Wea. Rev., 100, 757-763.

Cotton, W. R., 1972b: Numerical simulation of precipitation development in supercooled cumuli - part II. Mon. Wea Rev., 100, 764-784.

Davidson, A., et al., 1975. Air Quality Trends in Los Angeles County, Southern California PACD, Metropolitan Zone.

DeMarrais, G. A., 1978a: The ozone problem in the Norfolk, Virginia area. Environmental Protection Agency. EPA-600/4-78-006, Research Triangle Park, NC, 23 pp.

DeMarrais, G. A., 1978b: The 1974 ozone episode in the Baltimore-to-Richmond corridor. Environmental Protection Agency. EPA-600/4-78-016, Research Triangle Park, NC, 33 pp.

DeMarrais, G. A., 1978c: A prolonged, large-scale, off-season, photochemical oxidant episode. Environmental Protection Agency. EPA-600/4-78-014, Research Triangle Park, NC, 32 pp.

Dicke, J. L., 1977a. The role of the meteorologist in the air quality management process. Presented at the WMO Meeting on Education and Training in Meteorological Aspects of Atmospheric Pollution and Related Environmental Problems, Research Triangle Park, NC.

_____ 1977b. Meteorological aspects of environmental impact assessments. Presented at the WMO Meeting on Education and Training Meteorological Aspects of Atmospheric Pollution and Related Environmental Problems, Research Triangle Park, NC.

Dodge, M. C., 1977. Combined use of modeling techniques and smog chamber data to derive ozone-precursor relationships. International Conference on Photochemical Oxidant and Its Control, Proceedings: Volume II, EPA-600/3-77-001b, Research Triangle Park, NC.

Environmental Protection Agency, 1974. Guidelines for air quality maintenance planning and analysis, Volume 10. EPA-450/4-74-011, Research Triangle Park, NC.

Environmental Protection Agency, 1974. Investigation of ozone and ozone precursor concentrations at nonurban locations in the eastern United States. EPA-450/3-74-034, Research Triangle Park, NC.

Environmental Protection Agency, 1974. Survey of the EPA reference method for measurement of non-methane hydrocarbons in ambient air. EPA-650/4 -75-008, Research Triangle Park, NC.

Environmental Protection Agency, 1975. Hydrocarbon measurement discrepancies among various analyzers using flame-ionization detectors. EPA-600/4-75-010, Research Triangle Park, NC.

Environmental Protection Agency, 1975. Investigation of rural oxidant levels as related to urban hydrocarbon control strategies. EPA-450/3-75-036, Research Triangle Park, NC.

Environmental Protection Agency, 1976. Formation and transport of oxidants along the Gulf Coast and in northern U. S. EPA-450/3-76-003, Research Triangle Park, NC.

Environmental Protection Agency, 1976. Monitoring and air quality trends report, 1974 EPA-450/1-76-001, Research Triangle Park, NC.

Environmental Protection Agency, 1976. Techniques for supplementary control system reliability analysis and upgrading. EPA-450/2-76-015 Research Triangle Park, NC.

Environmental Protection Agency, 1977. Characterization of the Washington, D. C. oxidant problem. EPA-450/3-77-054, Research Triangle Park, NC.

Environmental Protection Agency, 1977. Evaluation of the EPA reference method for the measurement of non-methane hydrocarbons - Final Report. EPA-600/4-77-033, Research Triangle Park, NC.

Environmental Protection Agency, 1977. Potential siting problems for increased coal use (Staff Study). Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC.

Environmental Protection Agency, 1977. Procedures for quantifying relationships between photochemical oxidants and precursors: Supporting documentation, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

Environmental Protection Agency, 1977. Technical guidance for the control of industrial process fugitive particulate emissions. EPA-450/3-77-010, U. S. Environmental Protection Agency, Research Triangle Park, NC.

Environmental Protection Agency, 1977. User's manual for single-source (CRSTER) model. EPA 450/2-77-013, Environmental Protection Agency, Research Triangle Park, NC. Available from NTIS as PB 271-360.

Environmental Protection Agency, 1977. Uses, limitations and technical basis of procedures for quantifying relationships between photochemical oxidants and precursors. EPA-450/2-77-021a, Research Triangle Park, NC.

Eskridge, R. E., 1977. Comments on "An interative algorithm for objective wind field analysis. Mon. Wea. Rev., 105, 1066.

Eskridge, R. E. and K. L Demerjian, 1977: A highway model for the advection, diffusion and chemical reaction of pollutants released by automobiles: Part I - Advection and diffusion of SF_6 tracer gas. Joint Conference on Application of Air Pollution Meteorology, Salt Lake City, 337-341.

Eskridge, R. E. and K. L. Demerjian, 1977: Evaluation of numerical schemes for solving a conservation of species equation with chemical terms. Atmos. Envir., 11, 1029-1035.

Finklea, J. F., C. M. Shy, J. B. Moran, W. C. Nelson, R. I. Larsen, and G. G. Akland, 1977: The role of environmental health assessment in the control of air pollution. Advances in Environmental Science and Technology, Vol. 7, edited by J. N. Pitts, Jr., and R. L. Metcalf; John Wiley and Sons, New York, 315-389.

Fisher, R. W., 1977: Summaries of the climatological structure of the near surface atmosphere. Proceedings of Joint Conference on Applications Of Air Pollution Meteorology, American Meteorological Society, Boston, MA, 88-95.

Gear, C. W., 1971: Algorith 407, DIFSUB for solution of ordinary differential equations:, Comm. A.C.M., 14, 185-190.

Hales, J. M., D. C. Powell and T. D. Fox, 1977. STRAM--An Air Pollution Model Incorporating Nonlinear Chemistry, Variable Trajectories, and Plume Segment Diffusion. EPA-450/3-77-012, U.S. EPA, Research Triangle Park, NC.

Hanel, G., 1971: New results concerning the dependence of visibility on relative humidity and their significance in a model for visibility forecasts. Beitr. Phys. Atm. 44, pp 137-167.

Hass, W. A., W. H. Hoecker, D. H. Pack and J. D. Angell, 1967: Analysis of low-level, constant volume balloon (tetroon) flights over New York City, Quart. J. Roy, Met. Soc., 93, 483-493.

Heffter, J. L. and A. D. Taylor, 1975: A regional-continental scale transport, diffusion, and deposition model. NOAA Technical Memorandum ERL ARL-50, Washington, DC, 27 pp.

Henmi, T., E. R. Reiter, and R. Edson, 1978: Residence time of atmospheric pollutants and long-range transport. EPA-600/4-78-003, Environmental Protection Agency, Research Triangle Park, NC 27711, 89 pp.

Holzworth, G. C., 1972: "Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous United States:, EPA Publication #AP-10, Research Triangle Park, NC 27711.

Holzworth, G. C., 1974a: Climatological data on atmospheric stability in the United States. Presented at the AMS Symposium on Atmospheric Diffusion and Air Pollution, September 1974, Santa Barbara, CA 20 pp.

Holzworth, G. C., 1974b: Summaries of the lower few kilometers of rawinsonde and radiosonde observations in the United States. Presented at the Climatology Conference and Workshop of the AMS, Asheville, NC, 23 pp.

Horvath, H. and K. E. Noll, 1969: The relationship between atmospheric light scattering coefficient and visibility. Atmos. Env. 3, 543-552.

Hovland, D., D. Dartt, and D. Gage, 1977: An Objective Analysis Technique for the Regional Air Pollution Study Part I. EPA-600/4-77-002a, Environmental Protection Agency, Research Triangle Park, NC.

Howell, W. E., 1949: The growth of cloud drops in uniformly cooled air. J. Meteor., 6, 134-149.

Huber, A. H. and W. H. Snyder, 1976: Building effects on short stack effluents. Third Symposium on Atmospheric Turbulence, Diffusion, and Air Quality, American Meteorological Society, Boston, MA.

Irwin, J. S., 1977: The variation of the wind profile power law exponent with changes in surface roughness and atmospheric stability. Dispersion Estimate Suggestion No. 6. Environmental Applications Branch, Meteorology and Assessment Division, Environmental Protection Agency, Research Triangle Park, NC.

Irwin, J. S. and A. M. Cope, 1977: Some of the factors to be considered in estimating the maximum concentrations from elevated buoyant point sources. Dispersion Estimate Suggestion No. 5. Environmental Applications Branch, Meteorology and Assessment Division, Environmental Protection Agency, Research Triangle Park, NC.

Jasperson, W. H., 1977: Diffusion coefficients from metric system turbulence measurements; Phase One report. EPA Contract 68-02-2444. Report, Environmental Protection Agency, Research Triangle Park, NC.

Jennings, S. G., 1976: Physical characteristics of the natural atmospheric aerosol. Final Technical Report, Contract Number DA JA 37-75-C-1913, European Research Office, United States Army, Washington, DC, 51 pp.

Junge, C. E., 1963: Air Chemistry and radioactivity. Academic Press, New York, 382 pp.

Junge, C. and E. McLaren, 1971: Relationship of cloud nuclei spectra to aerosol size distribution and composition. J. Atmos. Sci., 28, 382-390.

Kabel, R. L., R. A. O'Dell, M. Taheri, and D. D. Davis, 1976. A preliminary model of gaseous pollutant uptake by vegetation. CAES Publication No. 455-76, Center for Air Environment Studies, the Pennsylvania State University, State College, PA, 96 pp.

Karl, T. R., 1978a: Ozone transport in the St. Louis area. Atmos. Environ. In Press.

Karl, T. R., 1978b: Day of the week variations of photochemical pollutants in the St. Louis area. Atmos. Environ. In Press.

Keyser, D. and R. A. Anthes, 1977: The applicability of a mixed-layer model of the planetary boundary layer to real-data applications, Monthly Weather Review, 105 1351-1371.

Kock, R. C., W. G. Biggs, P. H. Hwang, I. Lechter, K. E. Pickering. E. R. Sawdey, and J. L. Swift, 1977. Power plant stack plumes in complex terrain, an appraisal of current research. EPA-600/7-77/020, Environmental Protection Agency, Research Triangle Park, NC 27711, 221 pp.

Kutzbach, J., 1961: Investigations of the modification of wind profiles by artifically contructed surface roughness. Annual Rept. 1961, Dept. of Meteorology, University of Wisconsin, Madison, Wisconsin 27-35.

Larsen, R. I., 1971: A mathematical model for relating air quality measurements to air quality standards. EPA Publication AP-89, Environmental Protection Agency, Research Triangle Park, NC 56 pp.

Larsen, R. I., 1973: An air quality data analysis system for interrelating effects, standards, and needed source reductions. Journal of the Air Pollution Control Association, 23, 933-940.

Larsen, R. I., 1974: An air quality data analysis system for interrelating effects, standards, and needed source reductions - Part 2. Journal of the Air Pollution Control Association, 24, 551-558.

Larsen, R. I., 1977a: An air quality data analysis system for interrelating effects, standards, and needed source reductions - Part 4. A three-parameter averaging-time model. Journal of the Air Pollution Control Association, 27, 454-459.

Larsen, R. I., 1977b: An air quality data analysis system for interrelating effects, standards, and needed source reductions - A summary. Proceedings of the Fourth International Clean Air Congress, edited by S. Kasuga et al, The Japanese Union of Air Pollution Prevention Associations, Tokyo, 323-325.

Larsen, R. I., D. E. Gardner, and D. L. Coffin, 1977: An air quality data analysis system for interrelating effects, standards, and needed source reductions - Part 5. Nitrogen dioxide mortality in mice. Presented at the Annual Meeting of the Air Pollution Control Association, Toronto, Ontario, Canada, 14 pp.

Lee, D. O., 1977: Urban influence on wind directions over London. Weather, 32, 162-170.

Liu, C. Y. and W. R. Goodin, 1976: An intersitive algorithm for objective wind field analysis. Mon. Wea. Rev., 104, 784-792.

Ludwick, J. D., T. D. Fox, and L. L. Wendell, 1976: Ozone and radionuclide correlations in air of marine trajectory at Quillayute, WA. J. Air Poll. Cont. Assoc., 26, 565-569.

Ludwig, F. L. and E. Shelar, 1977. Selecting sites for monitoring photochemical pollutants. SRI International, Being Prepared for EPA, Research Triangle Park, NC.

Ludwig, F. L., J. H. S. Kealoha, and E. Schelar, 1977. Selecting sites for monitoring total suspended particulates. EPA-450/3-77-018, Research Triangle Park, NC.

Ludwig, F. L., E. Reiter, E. Shelar and W. B. Johnson, 1977. Relation of oxidant levels to precursor emissions and meteorological features. Volume I: analysis and findings. EPA-450/3-77-022a, Environmental Protection Agency, Research Triangle Park, NC.

Ludwig, F. L., P. B. Simmon, R. L. Mancuso, J. H. S. Kealoha and E. Reiter, 1977. ----. Volume III: Appendices (analytical methods and supplementary data). EPA 450/3-77-022a, Environmental Protection Agency, Research Triangle Park, NC.

MacKay, K. P., 1977: Ozone over San Francisco, means and patterns during pollution episodes. EPA-600/4-77-046, Environmental Protection Agency, Research Triangle Park, NC 27711, 109 pp.

McClatchy, R. A., R. W. Fenn, J. E. A. Selby, F. E. Valz, and J. S. Garing, 1972: Optical properties of the atmosphere (third edition) AFCRL-72-0497 Air Force Cambridge Research Laboratories, L. G. Hancom Field, Bedford, Massachusetts, 108 pp.

Middleton, W. E. K., 1952: Vision through the atmosphere. University of Toronto Press, Toronto, 250 pp.

Mills, M. T., 1977. Improvements to single-source model. Volume III - Further analysis of modeling results. EPA-450/3-77-003c, Environmental Protection Agency, Research Triangle Park, NC.

Mill, M. T., and R. W. Stern, 1976. Improvements to the single source model. Volume I - Time concentration relationships. EPA-450/3-77-003a, Environmental Protection Agency, Research Triangle Park, NC.

Mills, M. T., R. W. Stern, and C. M. Vincent, 1977. Improvements to single-source model. Volume II - Testing and evaluation of model improvements EPA-450/3-77-003b, Environmental Protection Agency, Research Triangle Park, NC.

Mordy, W. A., 1959: Computations of the growth by condensation of a population of cloud droplets. Tellus, 11, 16-44.

Morgenstern, P., 1977. Evaluation of the relation between model predictions and meteorological data bases: Report on Region I analysis. (Draft). Prepared by Walden Division of Abcor, Inc., under Contract No. 68-02-2506, Environmental Protection Agency, Research Triangle Park, NC.

Nickerson, E. C. and V. E. Smiley, 1975: Surface layer and energy budget parameterizations for mesoscale models. J. Appl. Meteor., 14 276-300.

Neiburger, M. and C. W. Chien, 1960: Computations of the growth of cloud drops by condensation using an electronic digital computer. Physics of Precipitation, Geophysical Monograph Series, 5, 191-208, American Geophysical Union, Washington, D.C.

Petersen, W. B., 1977. User's Guide for PAL - A Gaussian plume algorithm for point, area and line sources. (Draft). Environmental Protection Agency, Research Triangle Park, NC.

Redfor, T. G., 1977: Airborne measurements of boundary layer turbulence over St. Louis, Missouri and adjacent rural terrain. M. Sc. thesis, Department of Meteorology, The Pennsylvania State University, State College, PA, 66 pp.

Roberts, R. E., J. E. A. Selby, and L. M. Biberman, 1976: Infrared continum absorption by atmospheric water vapor in the 8-12 micrometer window. Applied Optics, 15, 2085-2090.

Saeger, M., 1977: An experimental determination of the specific photolysis rate of nitrogen dioxide. M.S. Thesis, Depart, of Environ, Sci. and Engr., Univ. of North Carolina, Chapel Hill, NC.

Scheib, N. L., 1977: Application and interpretation of digital display techniques to solar returns. M. Sc. thesis, Department of Meteorology, The Pennsylvania State University. State College, PA, 312 pp.

Seaman, N. L., 1977: The development of a mesoscale semi-implicit numerical model. Ph. D. thesis, Department of Meteorology, The Pennsylvania State University, State College, PA, 213 pp.

Schere, K. L. and K. L. Demerjian, 1977: Calculation of selected photolytic rate constants over a diurnal range: A computer algorithm. #EPA-600/3-77-001b, Research Triangle Park, NC 27711.

Singh, H. B., W. B. Johnson and E. Reiter, 1977. (see Ludwig). Volume II: Review of available research results and monitoring data (as of November 1975). EPA-450/3-77-022b, Environmental Protection Agency, Research Triangle Park, NC.

Snyder, W. H., 1977: The EPA Fluid Modeling Facility. Presented at the US-Japan Bilateral Agreement on Air Pollution, Tokyo, Japan,

Sobel, P. S., 1976: Nested grids in numerical weather prediction and an application to a mesoscale jet streak. Ph. D. thesis, Department of Meteorology, The Pennsylvania State University, State College, PA, 135 pp.

Technology Services Corporation, 1977. Guideline document on use of meteorological data in air quality trend analyses. Final Report, Contract No. 68-02-2317, Environmental Protection Agency, Research Triangle Park, NC.

Thompson, R. S., and D. J. Lombardi, 1977: Dispersion of roof-top emission efrom isolated buildings - A wind tunnel study. Environmental Protection Agency, Research Triangle Park, NC.

Thompson, R. S. and W. H. Snyder, 1976: EPA Fluid Modeling Facility. Proceedings of the Conference on Environmental Modeling and Simulation, EPA, Washington, D.C. EPA 600/9-76/016, 488-492.

Turner, D. B. and J. S. Irwin, 1977: The application of the CDM (Climatological Dispersion Model) to the NATO common data base for Frankfurt, Part II. Winter and Summer. Documentation for Practical Demonstration of Urban Air Quality Simulation Models. Submitted to NATO/CCMS Panel on Modeling.

Turner, D. B., and J. H. Novak, 1976. Revised interim User's Guide for a computational technique to estimate maximum 24-hour concentrations from single sources. NOAA Manuscript. Meteorology Laboratory, Environmental Protection Agency, Research Triangle Park, NC.

van Dop, H. and S. Kruizinga, 1976. The decrease of sulfur dioxide concentrations near Rotterdam and their relation to some meteorological parameters during thirteen consecutive winters (1971-1974), Atmospheric Environment, 10, 1.

Viebrock, H., 1977: Fiscal year 1976 summary report of NOAA meteorology laboratory support to the Environmental Protection Agency, NOAA Technical Memorandum ERLARL-67, Air Resources Laboratories, National Oceanic and Atmospheric Administration, Silver Spring, MD 20910, 158 pp.

World Meteorological Organization, 1969. Guidelines for the education and training of meteorological personnel, WMO-No. 258. TP. 141, Geneva Switzerland.

5.0 PUBLICATIONS AND PRESENTATIONS

Binkowski, F., 1976: Preliminary results from a simplified closure technique for obtaining turbulent statistics from climatological wind profiles. 3rd Symposium on Atmos. Turbulence, Diffusion and Air Quality, American Meteorological Society, Boston MA.

Budney, L. J., 1977: Guidelines for air quality maintenance planning and analysis, Volume 10 (Revised - Procedures for evaluating air quality impact of new stationary sources. EPA-450/4-77-001 Environmental Protection Agency, Research Triangle Park, NC.

Burt, E. W., 1977: Valley model User's Guide. EPA-450/2-78-018, Environmental Protection Agency, Research Triangle Park, NC.

Burt, E. W., and H.H. Slater, 1977: Evaluation of the Valley model. Preprint Volume of the Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, UT, American Meteorological Society, Boston, MA.

DeMarrais, G. A., 1977: Diurnal variations in carbon monoxide concentrations. traffic counts and meteorology. EPA-600/4-77-009, Environmental Protection Agency, Research Triangle Park, NC, 29 pp.

DeMarrais, G. A., 1977: Diurnal variations in traffic flow and carbon monoxide concentrations. EPA-600/4-77-016, Environmental Protection Agency, Research Triangle Park, NC, 50 pp.

DeMarrais, G. A., 1978: The ozone problem in the Norfolk, Virginia area EPA-600/4-78-006, Environmental Protection Agency, Research Triangle Park, NC, 23 pp.

DeMarrais, G. A., 1978: The 1974 ozone episode in the Baltimore-to-Richmond corridor. EPA-600/4-78-016, Environmental Protection Agency, Research Triangle Park, NC, 33 pp.

DeMarrais, G. A., 1978: A prolonged, large-scale, off-season, photochemical oxidant episode. EPA-600/4-78-014. Environmental Protection Agency, Research Traingle Park, NC, 32 pp.

DeMarrais, G. A., 1978: Atmospheric stability class determinations on a 481-meter tower in Oklahoma. To be published in Atmospheric Environment.

Demerjian, K. L., 1977: Modeling the Polluted Troposhere. Gordon Research Conference on Environmental Sciences, New Hampton, NH.

Dicke, J. L., 1977: Meteorological Aspects of environmental impact assessments. Presented at the WMO Meeting on Education and Training in Meteorological Aspects of Atmospheric Pollution and Related Environmental Problems, Research Triangle Park, NC.

Dicke, J. L., 1977: The role of the meteorologist in the air quality management process. Presented at the WMO Meeting on Education and Training in Meteorological Aspects of Atmospheric Pollution and Related Environmental Problems, Research Triangle Park, NC.

Dimitriades, B., M. Dodge, J. Bufalini, K. Demerjian, A. Altshuller, 1976. Correspondence on the Chmeides and Stedman paper "Ozone Formation from NO_x in Clean Air." Environmental Science and Technology, 10, 934-936.

Fine, D. H., D. P. Rounbehler, A. Rounbehler, A. Silvergleid, E. Sawicki, K. Krost and G. A. DeMarrais, 1977: Determination of dimethylnitrosamine in air, water and soil by thermal energy analysis- Measurements in Baltimore, MD. Environmental Science and Technology, 11, 581-584.

Fine, D. H., D. P. Rounbehler, E. D. Pellizzari, J. E. Bunch, R. W. Berkley, J. McCrae, J. T. Bursey, E. Sawicki, K. Krost and G. A. DeMarrais, 1976: N-nitrosodimethylamine in air. Bulletin of Environmental Contamination and Toxicology, 15, 739-746.

Fine, D. H., D. P. Rounbehler, E. Sawicki, K. Krost and G. A. DeMarrais, 1976: N-nitroso compounds in the ambient community air of Baltimore, Maryland. Analytical Letters, 9, 595-604.

Fisher, R. W., 1977: Summaries of the climatological structure of the near-surface atmosphere. Proceedings of Joint Conference on Applications of Air Pollution Meteorology, American Meteorological Society, Boston, MA, 88-95.

Holzworth, G. C., 1977: Climatic data on estimate effective chimney heights in the United States. Proceedings of Joint Conference on Applications of Air Pollution Meteorology, American Meteorological Society, Boston, MA, 80-87.

Holzworth, G. C., 1978: Estimated effective chimney heights based on rawinsonde observations at selected sites in the United States, Journal of Applied Meteorology, 17, 1, 64-69.

Karl, T., 1976: Summertime Surface Wind Fields in St. Louis. Third Symposium on Atmospheric Turbulence, Diffusion and Air Qualtiy, American Meteorological Society, Boston, MA.

Karl, T. R., 1978: Ozone transport in the St. Louis area, Atmos. Environ. In press.

Karl, T. R., 1978: Day of the week variation of photochemical pollutants in the St. Louis area. Atmos. Environ. In press.

Larsen R., 1977: An air quality data analysis system for interrelating effects, standards, and needed source reductions: Part 4. A three-parameter averaging-time model. J. Air Pollution Control Assoc. 17, 254-459.

Larsen, R., 1977: An air quality data analysis system for interrelating effects standards, and needed source reductions: Part 5-nitrogen dioxide mortality in mice. Annual Air Pollution Control Association Meeting, Toronto, Canada.

Larsen, R., 1977: An air quality data analysis system for interrelated effects, standards, and needed source reductions--A summary. Proceedings of the Fourth International Clean Air Congress, S. Kasuga et al, editors, The Japanese Union of Air Pollution Prevention Association, Tokyo, 323-325.

Larsen, R., 1977: The role of environmental health assessment in the control of air pollution. Advances in Environmental Science and Technology, 7, 315-389.

Martinez, E. L., and W. D. Bach, Jr., 1977: Photochemical oxidant transport in the Texas-Louisiana Gulf Coast area. Presented at the National Meeting of the American Institute of Chemical Engineers, Houston, TX.

Petersen, W., 1977: EPA Modeling (PAL). Informal Meeting on Airport Modeling and Monitoring, Washington, D. C.

Peterson, J., 1976: Application of air quality simulation models to land use planning. Proceedings of the WMO Symposium on Meteorology as Related to Urban and Regional Land Use Planning, World Meteorological Organization Report #444, Geneva, Switerland, 203-217.

Pooler, F., 1976: Current thoughts of local vs. regional air pollution sources and effects. Meeting of the Governor's Science Advisory Committee, Harrisburg, PA.

Possiel, N. C., 1977: Oxidant trends and the effect of meteorology and emissions. Presented at the 70th Meeting of the Air Pollution Control Association, Toronto, Canada.

Reagan, J., 1977: Data acquisition system for air quality computer modeling. meeting of the St. Louis chapter, Inst. of Environmental Sciences. St. Louis, MO.

Schere, K., K. Demerjian, 1977: Calculation of selected photolytic rate constants over a diurnal range. A Computer Algorithm. EPA-600-4-77-015, Environmental Protection Agency, Research Triangle Park, NC.

Schiermeier, F., 1977: A regional study of the atmospheric pollution of St. Louis. International Congress of the Environment, Paris, France.

Thompson, R., and D. Lombardi, 1977: Dispersion of roof-top emissions from isolated buildings - A wind tunnel study. EPA-600/4-77-006. Environmental Protection Agency, Research Triangle Park, NC.

6.0 METEOROLOGY LABORATORY STAFF
FISCAL YEAR 1977

(All personnel are assigned to the Environmental Protection Agency from the National Oceanic and Atmospheric Administration, except those designated (EPA)=Environmental Protection Agency employees or (PHS)= Public Health Service Commissioned Corps personnel).

Office of the Director

Lawrence E. Niemeyer, Meteorologist, Director
Kenneth L. Calder, Meteorologist, Chief Scientist
Paul A. Humphrey, Meteorologist
Herbert J. Viebrock, Meteorologist, Assistant to the Director
Juanita P. Jones, Technical Information Assistant, Librarian (EPA)
Vickie P. Sanders, Secretary (EPA)

Regional Studies

Dr. Francis Pooler, Jr., Meteorologist, Research Coordinator
Gene D. Prantner, Meteorologist, Field Director
Francis A. Schiermeier, Meteorologist, Field Operations Coordinator
Ernest Daniel, Administrative Officer

Atmospheric Assessment and Modeling Branch

Dr. Kenneth L. Demerjian, Physical Scientist, Chief
Dr. Jason K. Ching, Meteorologist
John F. Clarke, Meteorologist
Dr. Robert E. Eskridge, Meteorologist
Dr. Ernest W. Peterson, Meteorologist (Corvallis, OR)
Karl F. Zeller, Meteorologist (Las Vegas, NV)
Dr. Jack H. Shreffler, Physical Scientist
Dr. Francis, S. Binkowski, Meteorologist
Terry L. Clark, Meteorologist
Bess M. Flowers, Secretary (EPA)

Data Management Section

Robert H. Browning, Computer Systems Analyst, Chief (EPA)
Adrian D. Busse, Computer Specialist
Dale H. Coventry, Meteorologist
Robert D. Jurgens, Physicist
Theresa Burton, Clerk-Typist (EPA)

Fluid Modeling Section

Dr. William H. Snyder, Physical Scientist, Chief
Roger S. Thompson, Environmental Engineer (PHS)
Lewis A. Knight, Electronic Technician
Joseph C. Smith, Meteorological Technician

Geophysical Research Branch

George C. Holzworth, Meteorologist, Chief
Dr. George W. Griffing, Physical Scientist
Gerard A. DeMarrais, Meteorologist
Dr. James T. Peterson, Meteorologist
Thomas Karl, Meteorologist
John Rudisill, Meteorological Technician
Ralph Soller, Meteorological Technician
Robert Chalfant, Electronic Technician
Hazel D. Hevenor, Secretary (EPA)

Environmental Applications Branch

D. Bruce Turner, Meteorologist, Chief
Dr. Ralph I. Larsen, Physical Scientist (EPA)
John S. Irwin, Meteorologist
L. Lea Prince, Secretary (EPA)
Lawrence E. Truppi, Meteorologist (Health Effects Research Laboratory)
Everett Quesnell, Meteorological Technician (Health Effects Research Laboratory)
Valentine Descamps, Meteorologist (Boston)
Peter Finkelstein, Meteorologist (Philadelphia)
Lewis Nagler, Meteorologist (Atlanta)
Franklin Hall, Meteorologist (Dallas)
Donald Henderson, Meteorologist (Denver)
Charlotte Hopper, Meteorologist (San Francisco)
Dean Wilson, Meteorologist (Seattle)

Air and Waste Management Support Branch

James L. Dicke, Meteorologist, Chief
Emerico L. Martinez, Meteorologist
Edward W. Burt, Meteorologist
Russell F. Lee, Meteorologist
Laurence J. Budney, Meteorologist
Philip L. Youngblood, Meteorologist
Norman C. Possiel, Jr., Meteorologist
George Schewe, Meteorologist