NOAA TM ERL ARL-53

NOAA Technical Memorandum ERL ARL-53

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

Fiscal Year 1974 Summary Report of NOAA Meteorology Laboratory Support to the Environmental Protection Agency

HERBERT J. VIEBROCK, EDITOR

Air Resources Laboratory
RESEARCH TRIANGLE PARK, N. CAROLINA
November 1975

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FISCAL YEAR 1974 SUMMARY REPORT OF NOAA METEOROLOGY LABORATORY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

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PREFACE

The work reported herein was funded by the Environmental Protection Agency (EPA) under agreement EPA-IAG-D4-0305 between the EPA and the Air Resources Laboratories (ARL), National Oceanic and Atmospheric Administration (NOAA), dated May 13, 1974. 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.

Much of the EPA research, development, and operational effort in the atmospheric sciences is the responsibility of 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 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 Regional Offices, as appropriate.

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

ABSTRACT

During Fiscal Year 1974, the Meteorology Laboratory, Air Resources Laboratories, National Oceanic and Atmospheric Administration, provided research and operational meteorological support to the Environmental Protection Agency (EPA). Operational support provided to the Office of Air and Waste Management, the EPA Regional Offices, and other EPA components included the review of the meteorological aspects of environmental impact statements, requests for variances, implementation plans, and grant and contract proposals; the application of dispersion models; and the preparation of dispersion studies and evaluations.

Research support was in the areas of model development and application, climatic analysis and atmospheric effects of pollutants, and the high surface ozone problem. Dispersion models for inert and reactive pollutants are under development as are regional and boundary layer meteorological models and models of the pollutant removal processes. A fluid modeling facility consisting of a wind tunnel and water channel/towing tank is under construction. The Regional Air Pollution Study (RAPS) activities in the St. Louis, Missouri, area begun two years ago have continued.

Climatic studies undertaken included the determination of the meteorological episodes of slowest dilution in the contiguous United States, the calculation of bi-hourly mixing heights, the analysis of air quality trends, and a brief examination of visibility trends. Maintenance of the turbidity network, the examination of the turbidity trends, and study of the radiation in an urban area continued.

Observations of high surface ozone values prompted the beginning of investigations into their causes.

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FISCAL YEAR 1974 SUMMARY REPORT OF NOAA METEOROLOGY LABORATORY

SUPPORT TO THE

ENVIRONMENTAL PROTECTION AGENCY

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1.0 INTRODUCTION

Much of the Environmental Protection Agency's (EPA) research and development work in air pollution meteorology is performed by the NOAA Meteorology Laboratory (ML) (fig. 1). The Meteorology Laboratory also provides technical assistance in the meteorological aspects of air pollution problems. The ML program can be divided into four major areas of acitvity during fiscal year 1974: model development and application (chapter 2), climatic analysis and atmospheric effects of pollutants (chapter 3), high surface ozone problem (chapter 4), and technical assistance (chapter 5).

The ML provides extensive operational support to EPA and its component units. This support includes meteorological counseling, reviewing, conduct of special field studies, evaluation of impact statements and implementation plans, performance of studies to provide needed meteorological data or evaluation, provision of expert witnesses in judicial procedings or hearings, and the preparation of the meteorological portions of EPA documents and reports.

2.0 MODEL DEVELOPMENT AND APPLICATION

A major ML responsibility is the development and application of air quality simulation models for both inert and reactive pollutants. An air quality simulation model defines the air quality at a given time and place for specified emission, chemical, and meteorological conditions. The three basic approaches to the development of air quality simulation models are numerical modeling based on the governing physical equations, numerical modeling of statistical relationships, and physical modeling based on experimental results. ML has used three approaches for finding the solution to specific air pollution problems.

A key input to the air quality simulation model is the required meteorological data, both initially and during the period of application of the model. Since initial data are normally relatively sparse spatially boundary layer models are needed to provide the required meteorological data. A boundary layer model defines and predicts the wind, temperature, and turbulence fields in the lowest few meters of the atmosphere. Such a model was in the initial stages of development during fiscal year 1974. Relationships between the boundary layer meteorology and the regional and synoptic scale.

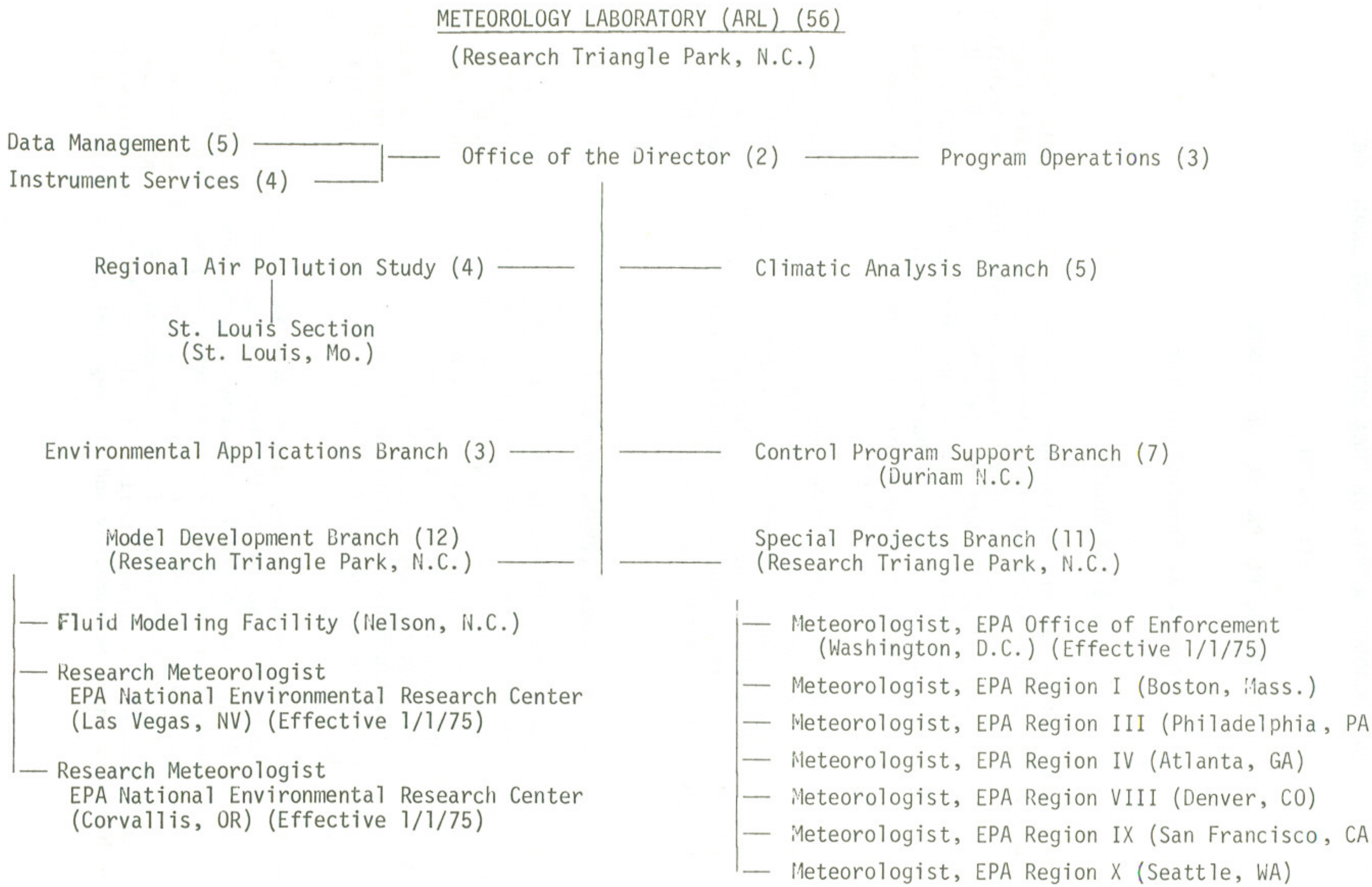


Figure 1. Table of Organization - Meteorology Laboratory, NOAA.

meteorology are also being examined. A regional scale model is under development

Providing comprehensive air quality and meteorological data sets for the development and evaluation of the previously mentioned models is the principal mission of the Regional Air Pollution Study (RAPS). Full operation of the RAPS is scheduled for the summer of 1975.

2.1 Development of Numerical Models for the Dispersion of Inert Pollutants

Numerical modeling based on the equations of motion and the conservation equation, and numerical modeling of statistical relationships were used in the development of dispersion models for inert pollutants. An inert pollutant is a substance that does not significantly change its chemical or physical characteristics during the dispersion period under consideration.

Most of the models mentioned in the succeeding sections are variations, or modifications for special purposes, of the basic "Gaussian plume model." This model assumes that at any point downwind from a continuous source the concentrations within the plume follow a normal, or Gaussian, distribution in the cross-wind and vertical directions.

2.1.1 RAM-Real-time air quality simulation model

This short-term Gaussian steady-state model estimates concentrations of stable pollutants from urban point and area sources. Hourly meteorological data are used. Hourly concentrations and averages over a number of hours can be estimated. Briggs' plume rise formula and the Pasquill-Gifford dispersion equations, with dispersion parameters thought to be valid for urban areas, are used. Concentrations from area sources are determined by Hanna's method. That is, sources directly upwind are considered representative of area source emissions affecting the receptor. Special features of the model include determination of receptor locations downwind of significant sources and determination of locations of uniformly spaced receptors to ensure good area coverage with a minimum number of receptors. The description and users guide for this short term model for urban point and area sources was completed at the end of fiscal year 1974 and will become available during 1975.

2.1.2 Evaluation and documentation of a Gaussian model

The Sampled Chronological Input Model (SCIM) developed under contract by GEOMET was delivered in two versions, the normal version and one compatible with IPP (Implementation Planning Program). This short-term Gaussian steady-state model estimates concentrations of stable pollutants from urban point and area sources for hourly periods. An estimate of the frequency distribution of hourly concentrations over a long period, such as a year, can be obtained by calculating hourly concentrations for a sample of hours over the period not for every hour. In attempting to use the IPP version, the Monitoring and Data Evaluation Division of the Office of Air Quality

Planning and Standards has encountered a number of problems. Both EPA and GEOMET are attempting to resolve these problems.

2.1.3 Tracer study of dispersion from a highway

Within the past few years there has been an increasing number of governmental and private users of highway (line source) air quality models, for environmental impact statement (EIS) preparation and review. The Gaussian dispersion formulation has been widely used because of its ease of use and limited parameter input requirements. Basic to the Gaussian formulation is the vertical standard deviation, σ_z, which indicates the spread of pollution in the vertical, and is a function of atmospheric mixing and downwind travel distance.

Vertical standard deviations have been adequately documented for distances greater than 100 meters. Little is known, however, about the initial spread of pollution due to the turbulent wake of the vehicles and the subsequent dilution within the first hundred meters of travel from the highway. ML sponsored a tracer study of dispersion within the immediate vicinity of a highway, through a contract with ESL, Inc., Sunnyvale, California.

An inert tracer gas (sulphur hexafluoride) was released from a vehicle moving in the traffic stream of a six-lane highway. The gas cloud was sampled at 12 locations out to distances of about 100 meters downwind and 20 meters upwind of the highway. Six of the samplers were placed at 7-meter heights on three towers; one upwind of the highway and the other two downwind. In addition to the sulphur hexafluoride (SF_6) measurements, data were collected on carbon monoxide concentrations at the 12 locations, on mean and standard deviations of the three components of the wind (u,v,w,) at 2- and 15-meter heights on both sides of the highway, and on temperature difference between 2 and 15 meters on one tower. Twenty-six hours of SF_6 tracer data and 55 hours of carbon monoxide and meteorological data were collected over a 4-week period.

ML is analyzing the data. Preliminary results indicate that vertical dispersion in the immediate vicinity of a highway is greater than assumed in the EPA HIWAY Model, and that the turbulent wake of vehicles can be identified by comparing turbulence data upwind and downwind of the highway.

2.1.4 Long-distance transport model

A major problem currently facing the EPA is the delineation of the long-distance transport of pollutants, particularly the oxidants and sulfates. If there is significant transport of pollutants from one air quality control region to another, then present control strategies may be inappropriate. ML's purpose is to develop a trajectory model for long-distance transport for urban air quality, and to identify and model relevant meteorological parameters.

ML is adapting the NOAA Air Resources Laboratories' trajectory program for research applications within the EPA. Scientists at the NOAA Air

Resources Laboratories' are engaged in major research to improve the program and update its data base. The ML effort in long-distance transport modeling is directed to modifications of this program for the EPA use, particularly with respect to the transport of oxidants and sulfates to distances of 50 to 500 km.

2.1.5 Travel of airborne pollen

Transport and dispersion of airborne pollen are being studied at the State University of New York (at Albany) under EPA Grant No. R-800677 which terminates in fiscal year 1975. The major areas of research are: (a) development and evaluation of sampling devices for particles in the pollen size range, (b) development and evaluation of techniques for tagging pollen in living plants with dyes and radioisotopes, (c) dispersion and disposition of pollen from known sources of several configurations, (d) effects of forested areas in removing pollen from the atmosphere, (e) variation in concentrations of pollen from natural sources with distance, height, time, and other variables, (f) feasibility of predicting concentrations of ragweed pollen from unknown sources, (g) occurrence and concentrations of ragweed pollen in a large source-free area, and (h) concentrations of ragweed pollen before and after ragweed eradication efforts.

These studies have resulted in new sampling instruments, a wealth of experimental data, an increased understanding of many phases of pollen dispersion, and the development of useful techniques for predicting pollen concentrations. During fiscal year 1974 the studies centered on particulate dispersion into and within a forest, and mesoscale transport and dispersion of airborne pollens.

Particulate dispersion into and within a 10- to 13- meter tall pine forest was studied using stained ragweed pollen and other tracers ranging from 14 to 54 microns in diameter. The results indicate that a plume approaching a forest is broadened both vertically and horizontally by divergence at the forest edge. Lateral spreading was slow within the forest but vertical spreading was greater than in the open. Particulate material was lost by impacting near the forest edge and in the treetops and by deposition within the forest where plume movement was slow. Most loss took place to the foliage rather than the ground and larger particles were lost faster than smaller ones (Raynor et al., 1975a).

Mesoscale transport and dispersion from generalized area sources were studied to distances of 100 km and heights of 3 km. It was found that large quantities of pollen are transported in orderly fashion, often in large discrete clouds, from their source regions. Pollen is transported to Long Island from the mainland in some quantity. Sea breeze flows greatly decrease low-level concentrations, but pollen is carried aloft at the sea breeze front and recirculated in the return flow aloft (Raynor et al., 1974b).

2.1.6 Mesoscale Pollutant Transport in Southeast Wisconsin

Mesoscale pollutant transport, with emphasis on the lake breeze circulation, is being studied by personnel of the University of

Wisconsin-Milwaukee under Grant No. R-800873. Primary objectives are to document and model coastal air pollution distribution associated with a large lake during those months when the water is cooler than the land surface. With an onshore wind an intense low-level inversion may develop over the land, thus trapping pollutants close to the ground. During lake breezes the problem may be compounded by re-circulation of the pollutants over shoreline regions.

A complete mesoscale observational system has been established in Milwaukee, Wisconsin. An instrumented aircraft is used to obtain data on the spatial distribution of particulates, SO_x, temperature, and humidity. An instrumented automobile records the surface distribution of SO_x and the temperature. Eulerian wind fields are measured at four single theodolite pibal stations positioned on a line normal to the shore. Tetroons, time lapse photography, a low-level wiresonde, and satellite observations are also used in the study.

Field investigations were conducted during the summer of 1973 in Milwaukee, Wisconsin, and in the spring of 1974 at Waukegan, Illinois. The results of the 1973 study in Milwaukee have further documented the lake breeze cell and suggest the re-circulation of ozone within the lake breeze. The data also suggest transport of pollutants from Chicago to Milwaukee by a helix-type lake-breeze circulation (Lyons, 1974). A mesoscale dispersion model has been developed for Milwaukee specifically incorporating plume trapping and continuous fumigation within the lake breeze cell. Initial validation tests of the model for SO_2 and suspended particulate are encouraging (Lyons et al., 1974). The 1974 field study in Waukegan centered on dispersion of an individual power plant plume within the lake breeze circulation. Preliminary data indicate that fumigation concentrations within the lake breeze circulation are one-third to one-half of those predicted by current plume models. Large wind shear within the lake-breeze cell apparently increases lateral dispersion by a factor of two to three. A final series of field experiments is scheduled for the summer of 1974 in Milwaukee.

2.1.7 Processing of New York University air pollution project data

Under a service contract with San Jose State University, Professor Robert D. Borenstein is reducing and collating meteorological and air quality data that were collected during the New York University Air Pollution Project of 1964-1967. The effort is concentrated on a few per ods, each of a few days duration, and on the data collected by helicopter throughout the project. The objective is to provide a set of aerometric data (SO_2 emissions, meteorology, and SO_2 concentrations) that can be readily used to test and develop air quality simulation models. The final product will include project and data descriptions, data listings as printout and on magnetic tape, and microfilm of ground-level air flow.

2.1.8 Application of repro-modeling to air quality modeling

Many current air quality simulation models are highly computational and require a great many input data. As a result it is generally difficult systematically to explore the implications of the models or to use them in a planning context, where many model runs are required. A contract was placed with Technology Service Corporation of Santa Monica, California, to explore the potential of its special technique of "repro-modeling," which is the analysis and replication of the input-output characteristics of complex models through the use of multivariate continuous piecewise-linear regression analysis.

The potential of repro-modeling was demonstrated by application to a very complex numerical model of photochemical smog, developed for the Los Angeles Basin (Horowitz et al., 1973). The repro-model developed was analyzed in a particular application context, namely, a transportation emission control policy evaluation. The repromodel requires several orders of magnitude less computer time than the original model.

It is planned to investigate further the application of the continuous, piecewise-linear regression analysis technique in developing (a) an empirical-statistical, source-oriented, air quality simulation model and (b) a statistical prediction technique for oxidants in the Los Angeles Basin.

2.1.9 Airport modeling

A program of air quality measurement, model development, and model validation at Washington National Airport has been completed by Geomet, Inc. (Thayer et al., 1974). Products of this study include the Geomet Airport Model, the six-months of data collected at Washington National Airport, and a user's manual for retrieving the data. The contract work did not include documentation of the computer code for the model.

2.1.10 Large power plant effluent study (LAPPES)

Comprehensive field studies of the dispersion of effluent from tall stacks began in the fall of 1967 and were concluded by the fall of 1971.

Four volumes of basic data obtained from the LAPPES project were published. Prior analyses of the data were reported by Pooler and Niemeyer (1971) and also in the Fiscal Year 1972 Summary Report (Hosler et al., 1973). More detailed data analysis is being performed, using various objective criteria to select periods of reliable data. These analyses generally support the findings suggested by prior studies, the only exception being that the determination of coefficients to describe the crosswind spread of ground-level concentrations during neutral to unstable conditions is less exact than previously indicated. The best correlations are still obtained by use of time, rather than distance, as the independent variable. Comparisions of ground-level concentrations calculated using σ-values appropriate to stability classes based on the Turner method are being made with concentrations calculated by using the assumption of uniform mixing in the vertical. Results of the analyses will be incorporated in an MS thesis, and a brief report of all significant results prepared.

2.2 Application of Numerical Models for the Dispersion of Inert Pollutants

The applications of air quality simulation models, developed by ML and other, non-EPA, groups to assist in the solution of many problems faced by EPA, are outlined in the following sections. Six of the models most often used have been placed on the User's Network for Applied Modeling of Air Pollution.

2.2.1 Model Preparation and Operation of UNAMAP

The UNAMAP (User's network for Applied Modeling of Air Pollution) started in May 1973, makes available current air quality simulation models to both EPA and non-EPA users in the form of computer programs accessible from remote terminals and connected to a central computer facility by telephone lines.

The six models on the UNAMAP are:

- APRAC - an urban carbon monoxide dispersion model;
- HIWAY - a dispersion model for obtaining hourly concentrations from roadway segments;
- CDM - a climatological dispersion model;
- PTMAX - a model for obtaining the maximum hourly concentration from a point source;
- PTDIS - a model for obtaining the hourly concentrations at various downwind distances from a point source; and
- PTMTP - a model for obtaining the hourly concentrations at various receptor locations from multiple point sources.

Throughout the year there were many inquiries about the network. Several errors in the computer programs were found by users and were corrected.

The "User's Guide for the Climatological Dispersion Model" was published in 1973 (Busse and Zimmerman).

In March, a magnetic tape containing these six models was accessioned by the National Technical Information Service, U.S. Department of Commerce as PB 229711, "User's Network for Applied Modeling of Air Pollution (UNAMAP)". A notice was sent out April 4, 1974, to our mailing list of persons interested in dispersion modeling. The cost of the tape is $175.

2.2.2 Validation, comparison, and adaptation of models

Dr. Werner Klug, Professor of Meteorology at the Technische Hochschule, Darmstadt, West Germany, was at ML from August to October 1973. He worked on a project to validate a short term (especially 24-hour) plume model using data from a Tennessee Valley Authority power plant. The final report is expected shortly.

Numbers 3 and 4 of the "Dispersion Estimate Suggestions" series were prepared as aids for ML and EPA personnel. Number 3 is "Aid in Determining Maximum Concentrations from Line Sources." Number 4 is "Estimation of Concentrations from Area Sources." They are not available for general distribution.

Based upon Gaussian plume principles, a modified model, PAL, to estimate hourly concentrations from combinations of point, area, and line sources, has been assembled from existing computer programs. The modified model is expected to be useful for analysis of indirect sources such as shopping centers and airports. The area source computation is performed by a double integration over the boundaries of the area source. This allows determination of "edge effects", that is, the variation of concentrations near the boundary of a area source. Because this double integration requires considerable computer time, this model should not be considered for application to entire urban areas with many area sources. The computer aspects of this model have been tested quite thoroughly. High priority will be given to documentation of this adaptation during fiscal year 1975.

2.2.3 Highway modeling

Within the past year there has been an ever increasing number of governmental and private users of highway models. These models are used mainly for environmental impact statement (EIS) preparation and review. EPA's highway model, HIWAY, developed within ML has been used extensively (Darling et al., 1974). A user's manual for HIWAY has been prepared for publication.

HIWAY, with other highway models, has been continually criticized for being inadequately validated. The lack of sufficient data has been the cause of this. There are a number of efforts underway to remedy this situation. The Office of Research, Federal Highway Administration, DOT, is obtaining extensive data for different highway configurations and meteorological conditions. ML is analyzing some data obtained through a contract with ESL, Inc.

ML is working with the Quality Assurance and Environmental Monitoring Laboratory (QAEML) in the Los Angeles catalyst study (LACS) to sample sulfate levels near a roadway both before and after the use of catalytic converters on production motor vehicles. The Transportation Systems Center, DOT, in Boston has developed a system for storing and retrieving highway data once they are collected; it is called the Transportation Air Pollution Studies (TAPS) System (Prepau and Downey, 1974).

2.2.4 Averaging-time model application

A single air quality data analysis system is needed for relating air pollutant effects, air quality standards, air quality monitoring, diffusion calculations, source-reduction calculations, and emission standards. A mathematical model based on averaging time, developed to meet the need for such a single system (Larsen, 1971) was published and distributed by the Meteorology Laboratory. The averaging-time model has three basic characteristics:

1. Concentrations are lognormally distributed for all averaging times.
2. The median concentration is proportional to averaging time raised to an exponent (and thus plots as a straight line on logarithmic paper (fig. 2)).

3. Maximum concentration is approximately inversely proportional to averaging time raised to an exponent.

In response to various requests, the model has been applied to many additional types of air pollution problems and has also been improved. The improvements and additional applications of the model have been described in Larsen (1973, 1974).

During the past year the averaging-time model has been applied to a variety of air pollution problems. Some applications have related sulfur dioxide effects to potential criteria and standards, relating oxidant concentrations to needed automobile emission controls in California, have related carbon monoxide concentrations due to cars to potential particulate sulfate concentrations that might come from catalyst-equipped cars, and have related air quality standards for various states to the Federal standards.

The averaging-time model was used to assist the Polish government by applying it to the regional air pollution problem in southern Poland during a 3-week mission in that area.

2.2.5 Fuel distribution studies

Studies of the aggregate impact of the implementation plans on low sulfur coal requirements indicated a probable deficit supply in 1975. Localized shortages of low-sulfur oil were also identified. It was proposed that this low-sulfur coal deficit could be alleviated by selective granting of variances to power plants. These variances would be subject to the condition that short-time and long-term National Ambient Air Quality Standards were not violated.

To estimate savings in low-sulfur coal resulting from the granting of variances, a dispersion model was applied to the plumes from selected power plants in 20 states with high coal consumption by power plants. Hourly emissions and meteorological data were used for each plant to estimate peak 1-hour, 24-hour, and annual concentrations. The analysis (EPA, 1973a) of data for 181 power plants indicated that attainment of primary SO_2 air quality standards near the coal-fired plants would not be jeopardized by application of full variances to 62 plants and of limited variances to an additional 39 plants. No variance would be appropriate for 80 plants. The projected shift in average sulfur content of fuel burned by these 181 plants is from 1.2 percent under implementation plan requirements to 2.1 percent under the applicable variance status (table 1). This shift should result in an annual saving of 137 million tons of low (less than 1.0 percent sulfur) sulfur coal.

The air quality impact of switching approximately 40 east coast power plants from oil to coal was evaluated at the request of the Federal Energy Administration. FEA's mandate was to require power plant conversions to coal on a plant-by-plant basis, while insuring that National Ambient Air Quality Standards would not be violated. It was necessary to consider a large number of plants in a short period of time; thus, the analysis was elementary but thorough.

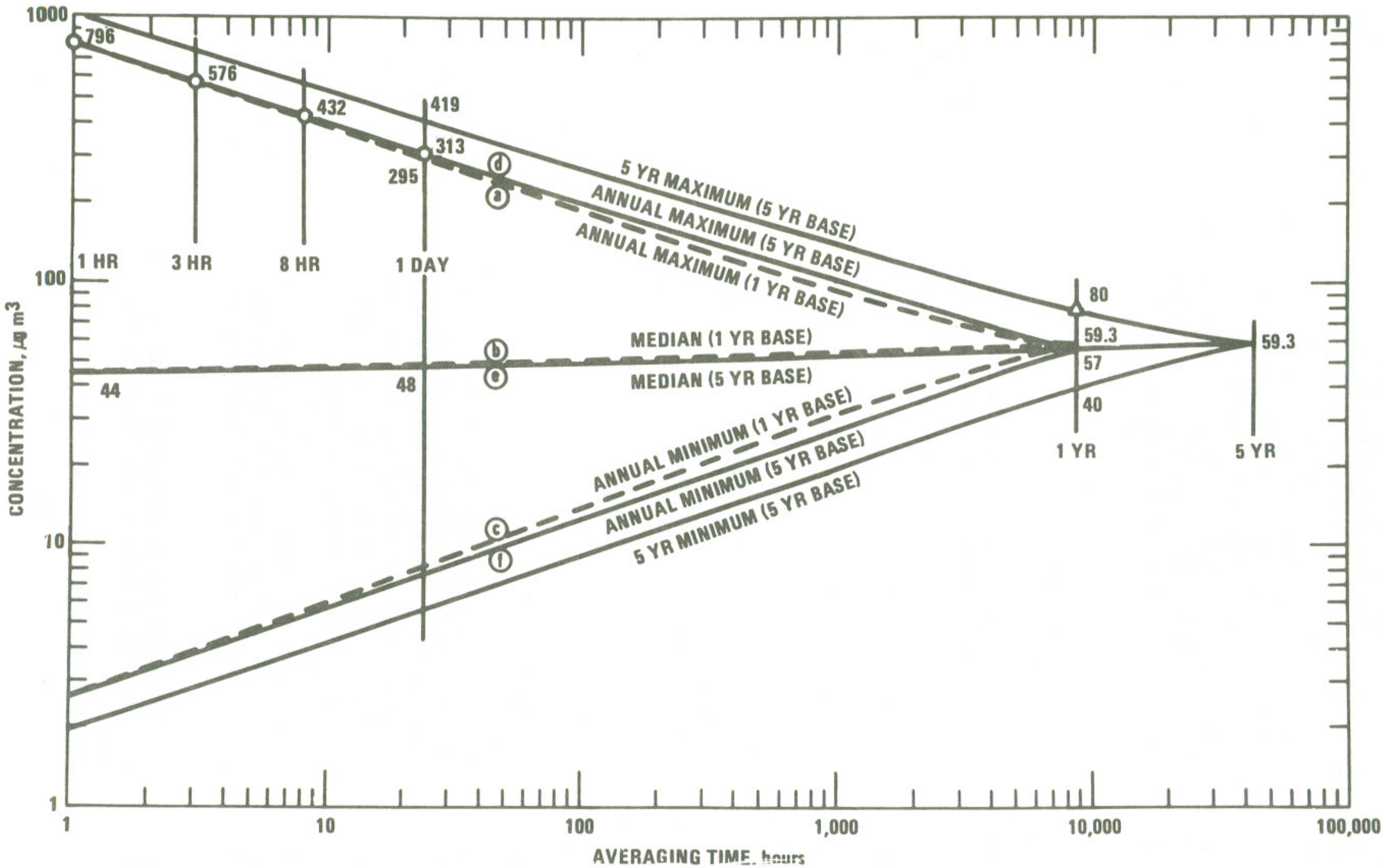


Figure 2. Comparison of averaging time model with a 5 yr base (solid lines) with a 1 yr base (dotted lines) when standard geometric deviation for 1 hr averages is 2.13 (CAMP SO_2 median) and annual maximum hour is 796 g m^3 (Larsen, 1971).

The latest source data available for each plant were used with the limited mixing and high wind fumigation dispersion models to estimate maximum 24-hour average concentrations of SO_2 and particulate matter. These dispersion models have been shown to be the critical models for sources with tall stacks. With these calculations, it was possible to estimate the impact of the proposed fuel switches on air quality. Available upper air meteorological data were used to estimate the frequency of adverse meteorological situations. Comments on the impact of surrounding terrain on estimate concentrations were also included. This analysis (EPA, 1974a) provided FEA with a rational basis for preliminary selection of plants to undergo the oil-to-coal conversion.

Table 1. Summary of Power Plant Coal Usage

Situation	1975 Coal Use 1.000 Tons/Yr	Coal Percent Sulfur At SIP	At Variance
Plants Where Full Variance Is Possible = 62 Plants	106,532	1.1	2.6
Plants Where Limited Variance Is Possible = 39 Plants	81,442	0.7	1.9
Plants Where No Variance Is Appropriate = 80 Plants	102,057	1.6	1.6
Totals = 181 Plants	290,031	1.2	2.1

2.2.6 Other applications

Since the inception of EIS reviews for Federal projects by EPA, meteorologists have provided the necessary review of meteorological aspects and dispersion modeling applications. During FY 1974, meteorologists reviewed a total of 54 EIS's of which the majority, 36, involved proposed nuclear plant facilities. Assistance was also provided in the preparation of guidelines for review of highway and airport impact statements.

Several dispersion analyses were conducted to estimate the impact of industrial emissions on ambient ground-level concentrations. Dispersion estimates were made for emissions from the following industrial sources and pollutants:

1. Primary aluminum industrial facilities (fluorides).
2. Sulfur recovery plants at petroleum refineries (H_2S, SO_2, COS, CS_2, CO).
3. Phosphate fertilizer complex (fluorides).

4. Submerged-arc ferroalloy furnaces (particulates).
5. Electric arc furnaces (CO and particulates).

Dispersion analyses were also conducted to estimate allowable mercury and beryllium emissions from sewage sludge incinerators. Interest has increased considerably over the past several years regarding the impact of elevated plumes on orographic features.

A computer model was developed in-house using very simple concepts, and has been applied to many types of sources in complex terrain. Several models have been developed by consultant firms (e.g., Intercomp Resources Development and Engineering, Inc.; H. E. Cramer Co., Inc.), using more sophisticated numerical techniques for defining pollutant trajectories. Unfortunately, appropriate field data do not exist for validation of these models, for the stable atmospheric condition, at ground level at or near the centerline elevation of the plume. It is anticipated that funding for such field studies will be available in fiscal year 1975.

During July and August 1973 two reports: "Exercise on Urban Dispersion Modeling of Sulfur Dioxide" and "Estimated Sulfur Dioxide Concentrations from Two Power Plants and the Effects of Using Low Sulfur Fuel" were prepared and, with a report prepared by George C. Holzworth, "Climatological Aspects of the Optimum Use of Low Sulfur Fuel," were submitted to the White House Office of Energy Programs.

Short term (1-hour to 24-hour) concentrations of air pollutants from motor vehicles were estimated by use of dispersion models, for receptor locations near busy expressways. Estimates were made for platinum, sulfate, and manganese.

Dispersion estimates were made of sulfur dioxide concentrations from power plants in the New York area, that would result from modifications of pollution abatement implementation plans.

Estimates were made of the increases in short term (1-hour and 24-hour) sulfur dioxide and sulfate concentrations caused by switching some existing power plants to coal. These estimates were used for a briefing on sulfates to the EPA Administrator and his staff.

2.3 Numerical Modeling of the Dispersion of Reactive Pollutants

ML is developing dispersion models for reactive pollutants, i.e., pollutants that change their chemical or physical characteristics or that are formed as secondary pollutants. While the main thrust of the effort has been toward the development of a regional photochemical air quality simulation model, the problem of modeling reactive plumes has also been examined, though only in a preliminary fashion. One large field program was conducted in the Los Angeles area to provide a data base for the evaluation and development of photochemical air quality simulation models.

2.3.1 Photochemical air quality simulation modeling

The continuation of photochemical air quality simulation model development in fiscal year 1974 consisted of one large contract effort. Following evaluation of the results and techniques employed in the models of Eschenroeder et al. (1972) Wayne et al. (1973) and Reynolds et al. (1973), developed under ML sponsorship during the past several years, it was decided that a major commitment during 1974 should be made to one contractor for evaluation studies, as well as for further research and development of the photochemical air quality simulation models in hand.

The contract includes the following primary activities:

(1) The programing of an improved photochemical mechanism developed under an EPA Chemistry and Physics Laboratory program.
(2) The development and testing of a subgrid scale model for important point and line sources and their inclusion where appropriate in the urban scale model.
(3) The improvement of techniques in the treatment of vertical diffusivity, the upper windfield, and the inversion base.

The contract also calls for the following:

(1) Determine quantitatively the ranges of validity and conditions of validity of both grid point and trajectory models.
(2) Analyze existing validation results for the three photochemical models developed by ML in the past two years.
(3) Undertake sensitivity studies for various meteorological, emission, and chemical mechanistic input parameters for the models.
(4) Modify existing models for use in multi-day simulation.
(5) Adapt the models for use in St. Louis (RAPS).

A late start due to difficulties regarding computer link-up with RTP facilities has necessitated an extension of the completion date to April 1975. A discussion of progress to date follows.

Regarding the validity of urban airshed models employing trajectory or grid point approaches it has been concluded that:

(1) Neglect of horizontal diffusion in the trajectory approach introduces only minor errors.
(2) Neglect of the vertical wind component in the trajectory approach can lead to significant errors. These errors are proportional to the magnitude of the vertical wind component, which depends on terrain and/or heat island effects.
(3) Neglect of wind shear in the vertical direction in the trajectory approach leads to the most serious error. Based on numerical experiments the absolute error can be as large as one order of magnitude.
(4) The error due to the finite differencing (numerical diffusion) that is used in solving the grid point model, is wave-like in nature, grows with simulation time, depends on parameters such as spatial variability of the concentration field, the wind speed, and spatial (or temporal) step sizes. The error is also dependent on the type of differencing scheme used. Under worst-case conditions

the absolute error introduced by numerical diffusion for a 9-hour simulation was approximately 50 percent.

Using various statistical techniques, results of past model verification studies have been analyzed. The analyses show that none of the models adequately represents the observed data for NO, NO_2 and O_3, but in the case of CO two of the models (SAI and GRC) were acceptable. These results indicate definite inadequacies in the chemical kinetic mechanism used in simulating photochemical smog formation. It is important to note, also, that a high degree of uncertainty in both the accuracy and representativeness of the measured observed data could contribute significantly to the presently observed shortcomings of the models.

The first phase of the airshed model modification for multi-day simulation has been completed. Modifications in the SAI program have made possible multi-day simulations of CO.

Sensitivity studies performed on the grid point model show major effects due to variations in wind speed and radiation intensity, moderate effects due to variations in mixing depth and emission rate, and slight effects due to variations in vertical diffusivity.

2.3.2 Local emissions of reactive pollutants

A major problem in regional photochemical air quality simulation models is the treatment of large sub-grid emission sources. JRB Associates, Inc., under contract to EPA, developed a numerical model to calculate the trajectories and concentrations of reactive pollutants emitted from localized sources. The basic methodology uses the concept of Lagrangian mass points, i.e. point particles to represent pollutant mass.

The numerical model is a modification of a model developed by Hirt and Cook (1972). Essentially, the model solves the full three-dimensional Navier-Stokes equations, and solves the species density equation by summing over the Lagrangian mass points. The mass points are transported by the mean wind field and moved with a random walk technique that simulates turbulent diffusion.

Several evaluations were made of the model. First, the model calculation of a point source in a uniform wind field was compared with the analytic solution of an inert Gaussian plume. The mean values of the model calculation agreed with the analytic results. Then the method for adjusting particle masses due to changes from chemical reactions was tested by using the simple rate equation $dc/dt = -\lambda C$ for comparison with an analytic solution. The match was excellent.

Finally, a simple three-reaction kinetic model was incorporated into the model. It consisted of the inorganic photochemical reactions

$h\nu + NO_2 \rightarrow NO + O$,
$O + O_2 + M \rightarrow O_3 + M$, and
$O_3 + NO \rightarrow NO_2 + O_2$

A simple program was written to solve the finite difference form of the diffusion equation. Figure 3 compares mean model values with solutions of the diffusion equation for NO_2 emitted into clean air. The closed and open dots represent the model computation; the bars represent the variance; and the lines represent the solution of the diffusion equation. The agreement between the mean model values and the solution of the diffusion equation is good. More information on the model and a user's guide are available in Fabrick et al. (1974).

2.3.3 Atmospheric photochemical smog measurements over San Francisco Bay

Scientists at Stanford Research Institute (SRI), under a program funded jointly by the EPA and Coordinating Research Council (CRC), studied a San Francisco Bay smog in an attempt to relate meteorological factors, on a mass balance basis, to the changes in concentration and composition of gaseous pollutants in an aging air mass. An air parcel, marked by a free-floating constant-level balloon, was followed and sampled using an instrumented houseboat and helicopter. Measurements on the houseboat consisted of ozone, nitric oxide, nitrogen dioxide, total hydrocarbon, carbon monoxide, turbidity, temperature, relative humidity, and solar intensity; on the helicopter, only total oxidant, nitric oxide, nitrogen dioxide, carbon monoxide, and temperature were measured.

The field portion of the program was conducted during the autumn of 1972 over San Francisco Bay; but, unfortunately, the photochemical activity was low throughout the period. This limits the usefulness of the data for model verification.

Analyses of the data showed a good correlation (0.87) between the $|NO| |O_3| / |NO_2|$ ratio and NO, and a poor correlation (-0.14) between the ratio and solar intensity. The correlation was 0.77 when all values for NO>15 pphm were omitted.

The observed concentrations of NO over the Bay were inhomogeneously distributed. The concentrations varied from 6 to 40 pphm over distances of 5 kilometers or less. These inhomogeneities did not appear to be accompanied by increases of NO_2, CO, or Aitken nuclei. The ozone concentration did not show any significant decrease in areas of high NO concentration. The cause or origin of these NO inhomogeneities cannot be identified on the basis of the available data.

Further information, including a data compilation, may be found in Cavanaugh and Smith (1973 a and b).

2.3.4 Simulation of the photochemical reaction processes within a power plant plume

In light of recent chemical kinetic studies of SO_2 reactions with HO_2 and HO free radicals, it seems an appropriate time to consider the incorporation of SO_2 reactions into the various photochemical smog simulation mechanisms presently available.

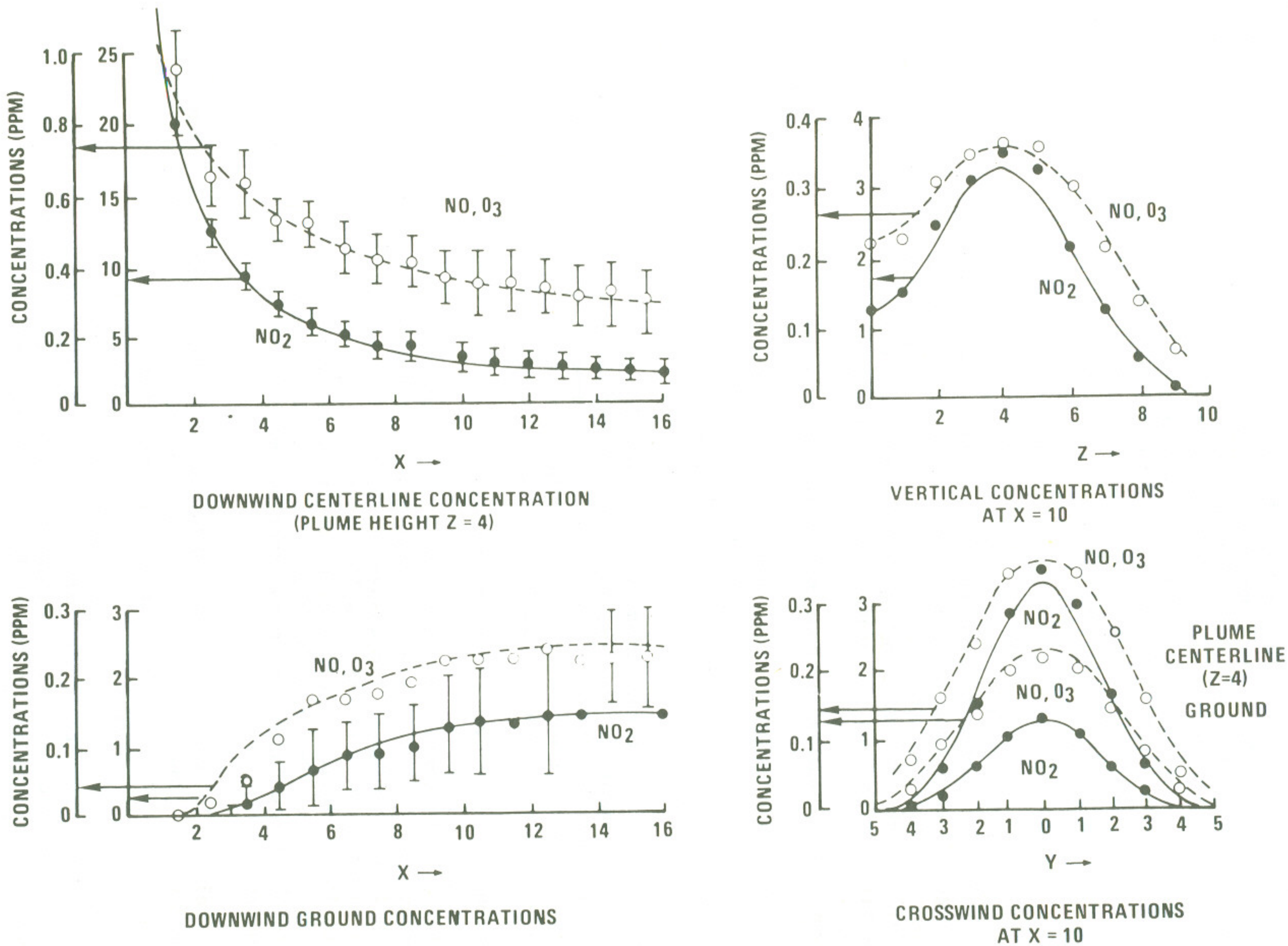


Figure 3. Distribution of NO, O_3 and NO_2 downwind of an NO_2 source.

A chemical-kinetic mechanism developed by Demerjian et al. (1974) for the simulation of C-NO_x-H_2O- air smog chamber systems was extended to include the known homogeneous gas phase reactions of SO_2. A preliminary (first approximation approach) model has been developed using a Gaussian plume model and the above chemical mechanism to investigate $SO_2 \rightarrow SO_4^=$ transformation in power plant plumes. Preliminary results indicate low rates of $SO_2 \rightarrow SO_4^=$ transformation within the plume (2 to 3%/hr). These results do not agree with earlier experimental field studies of Gartrell et al. (1963), who observed conversion of the order of 20%/hr, but do agree with some recent studies of Manowitz et al. (1972), who report conversions of the order of the modeled results. The large observed differences between the two experimental studies may be due to radically different analytical techniques, or may be real because of variation in plume composition of the power plants studied. That is to say, in the Gartrell work the plume studies were known to have large concentrations of particulate which might lead to SO_2 conversion by means of heterogeneous catalytic reactions, whereas the Manowitz et al. (1972), work studies plumes with low particulate concentrations and therefore only homogeneous gas phase conversion processes were of importance.

2.3.5 Simple photochemical oxidant models for urban areas

This study, now in its initial stages, will attempt to develop a photochemical oxidant model based on a sophisticated chemical kinetic mechanism and a simplified meteorological model (possibly something similar to the Gifford and Hanna approach).

Two chemical kinetic mechanisms will be considered. The first will be the generalized lumped kinetic mechanism being developed under EPA Chemistry and Physics Laboratory contract, for use in the grid-point model being developed at ML. The second will be a specific kinetic mechanism that will look at the reaction of key hydrocarbons in the particular urban area of interest.

2.3.6 Los Angeles reactive pollutant program

Beginning in September 1973 and running until mid-November, field work was conducted for the Los Angeles Reactive Pollutant Program (LARPP). The LARPP is an investigation of the changes in air quality experienced by an air parcel as it passes over the Los Angeles basin. The basic objective of the program is to provide an air quality and meteorological data base for studying and modeling the chemical reactions occurring in the atmosphere and the dispersion of the various chemical species emitted into or formed within the atmosphere.

Full-scale field operations were conducted on 35 days covering a range of smog conditions. The air parcel to be studied was defined on the basis of the centroid of a three-tetroon array, all three tetroons being launched simultaneously from the same site. Five release sites were used during the 35 operational days, but two sites were used more frequently--downtown Los Angeles and Downey. FP tracer was released by helicopter. Observations were made in a rectangular pattern around the centroid at several levels by instrumented helicopters and on the surface under the centroid.

Airborne and surface measurements were made of O_3, NO, NO_x, CH_4, non-methane hydrocarbon, CO, FP tracer, and air temperature. Bag samples for later analysis were taken aloft and on the surface. The helicopters also measured dewpoint and aerosol light scattering. Lidar measurements were made along the track. Continuous daily records of UV radiation were taken throughout the operational period at five stations on an east-west line from the coast to San Bernardino. The tetroons and helicopters were continuously tracked and guided by radar.

Many groups participated in the field portion of the program: ML, EPA; National Environmental Research Laboratories - Las Vegas, EPA; ARL Field Research Office - Idaho Falls, NOAA; California Air Resources Board; General Research Corporation, Santa Barbara, California; Systems Innovation and Development Corporation, Los Angeles, California; and Metronics Associates, Inc., Los Angeles, Cafifornia.

The General Research Corporation is responsible for the reduction, processing, and archiving of the data, Upon completion of the data processing, the full data set with appropriate operational comment will be made available to the scientific community.

2.3.7 Mobile LIDAR study of the Los Angeles Basin

Under contract, Systems Innovation and Development (SID) participated in the Los Angeles Reactive Pollutant Program (LARPP). Personnel from SID operated a vertically-firing LIDAR across the Los Angeles Basin in special experiments during September-November 1973. Normally, during experiments the LIDAR was fixed at several locations along the path of a moving block of air represented by a triad of tetroons. The LIDAR data were recorded on magnetic tape and later analyzed to yield estimates of mixing layer depth.

The results generally demonstrate a marked spatial variability in mixing layer depth across the basin. Agreement between mixing layer depths estimated by LIDAR and those determined from local rawinsonde observations was usually quite good. Thick for and/or stratus clouds sometimes obscured the LIDAR data, particularly near the coastal portions of the basin. Formation of secondary pollutants and local variations in pollutant concentrations due to mesoscale weather patterns induced by the complex topography and meteorology in the area also complicated interpretation of the LIDAR data.

A magnetic tape containing the LIDAR mixing layer data is scheduled for completion in July 1974. This tape will be placed in the LARPP data bank and later released for distribution through the National Technical Information Service. A final report outlining SID participation in the LARPP, in addition to analysis of the LIDAR data and comparisons between LIDAR data and supplementary meteorological and air quality data, is scheduled for submission in draft form in August 1974.

2.3.8 LARPP radiation measurements

As part of a comprehensive photochemical pollution field experiment, the Los Angeles Reactive Pollutant Program (LARPP), a team from ML conducted a program of solar radiation measurements. The measurements were designed to provide input to photochemical diffusion models and to be cataloged as part of the LARPP data bank. In addition, the measurement program was designed to document urban-rural and intra-urban spatial and temporal differences of incident solar energy. Because of the photochemical basis for this experiment emphasis was placed on measurements of the ultraviolet (UV) portion of the solar spectrum.

In Los Angeles data were collected continuously from August 30 through November 7, 1973. Incident global all-wave and UV (300 to 380 nm wavelength) solar radiation were measured at each of six sites in the greater Los Angeles area. Five of the sites were in the urban area approximately on an east-west line from Los Angeles International Airport on the west to San Bernardino some 70 miles to the east. The sixth (rural) site was at a usually pollution-free location on Mt. Disappointment (about 2 miles west-northwest of Mt. Wilson). This clean mountain site is at 6000 feet elevation about 15 miles northeast of downtown Los Angeles. At two sites, Mt. Disappointment and El Monte (11 miles east of downtown), the following additional observations were made: (1) normal incidence solar radiation with occasional use of cut-off filters, (2) atmospheric turbidity at 380 and 500 nm, (3) global UV radiation in 10-nm wavelength intervals and (4) atmospheric aerosol concentrations as indicated by a nephelometer. Although the data reduction and analysis are not complete at this time, there are some interesting preliminary aspects of the broad-band UV observations at El Monte (urban) and Mt. Disappointment (rural).

The Los Angeles experiment was characterized by significant urban-rural variation of atmospheric aerosol concentrations and incident solar radiation. However, based on the comprehensive measurements by Stair (1955) in the 1950's and Nader (1967) on several days during October 1965, significant depletion of UV energy was expected on days with high pollution concentrations. When the visibility at El Monte was approximately 3 to 5 miles (a common occurrence during the pollution season) the incident UV energy was typically about 30 to 40 percent less than that received at Mt. Disappointment, depending on solar elevation. The lower values of UV depletion generally corresponded to higher sun angles. In a Rayleigh atmosphere, the height difference between the two stations (5700 feet) would cause a difference in global UV radiation of about 5 percent at mid-day solar angles. Thus, the effect of the atmospheric pollution over El Monte was to reduce the incident UV energy by some 25 to 35 percent during these poor visibility situations.

One area of potential application of this result is in the field of photochemical pollution modeling. Because of the attenuation of UV energy by the pollution itself, the top of a pollution layer receives considerably more (25 to 35 percent on occasion) UV irradiance than the bottom of the layer. However, most photochemical models today treat UV energy in a simplistic way and do not account for its vertical variation through the pollution layer. These models might be improved by allowing for such vertical variation of the UV radiation.

Another characteristic of the pollution concentrations throughout the Los Angeles Basin as shown by our observations was their nonuniformity in space and time. Both the atmospheric turbidity and incident radiation data showed marked diurnal variations corresponding to the photochemical pollution cycle. At El Monte the highest pollution concentrations usually occurred around mid-day when the westerly or southwesterly winds transported polluted air from the region of dense automobile traffic around Los Angeles. The observed UV depletion at El Monte varied during the day, from day-to-day, and from weekday-to-weekend in response to changes of atmospheric pollution.

An example of the day-to-day variability of the incident UV energy -- and by inference the variability of the vertically integrated pollution concentrations -- at El Monte is presented in figure 4. The relative UV irradiances from September 25, 26, and 27, 1973 are plotted as a function of PST. On the 26th the greatest UV depletion occurred about 1030. In contrast, UV energy on the 27th shows high morning and low afternoon readings with the largest depletion about 1300. On the 25th two "dips" occurred, about 1100 and 1230. Thus, these data indicate that "clouds" of pollution of at least 30 minutes duration moved over the site each day, either preceded or followed by significantly cleaner air. Moreover, the time of arrival of the pollution cloud varied by more than 2 hours during these three days. These conclusions are also in agreement with the visual impressions of the amount of atmospheric haze at El Monte.

The relative UV irradiance measured at El Monte on September 9 and 11, 1973 is shown in figure 5. The wide daily variability is again evident. Following the dissipation of the morning stratus overcast up to 25 percent (at 1230) less energy was received on the 11th than on the 9th. The general meteorological situation was similar on both days but the mixing height was lower on the 11th. An 1130 PST radiosonde from Los Angeles International Airport indicated the subsidence inversion base was at 2990 and 2530 feet on the 9th and 11th, respectively. The most important reason, however, for the differences in UV radiation may have been that the 9th was a Sunday, a day of reduced automobile emissions (Schuck et al., 1966). Thus, the curves on figure 5 apparently reflect weekday-weekend differences in pollutant emissions and vividly contrast the UV irradiance on relatively clean and polluted days.

2.3.9 Atmospheric effects on particulate pollutants

Pennsylvania State University under an EPA grant is attempting to establish quantitative mechanisms for the changes of the physical characteristics of particles emitted from an urban area as these particles move downwind. The site selected for field investigation was the area downwind from Pittsburgh. This site was chosen primarily because it is a steel production center which would provide a strong, identifiable particle source. Further, the particles at this source would contain a high concentration of iron and other specific metals that would serve as chemical tracers for following and identifying the plume from a diffuse urban source. During fiscal year 1974 effort has focused heavily on the development of a sampling and analysis system capable of identifying the chemical species of the particles collected in microgram qualities.

2.4 Meteorological Models

A basic input into dispersion models is the meteorological data.

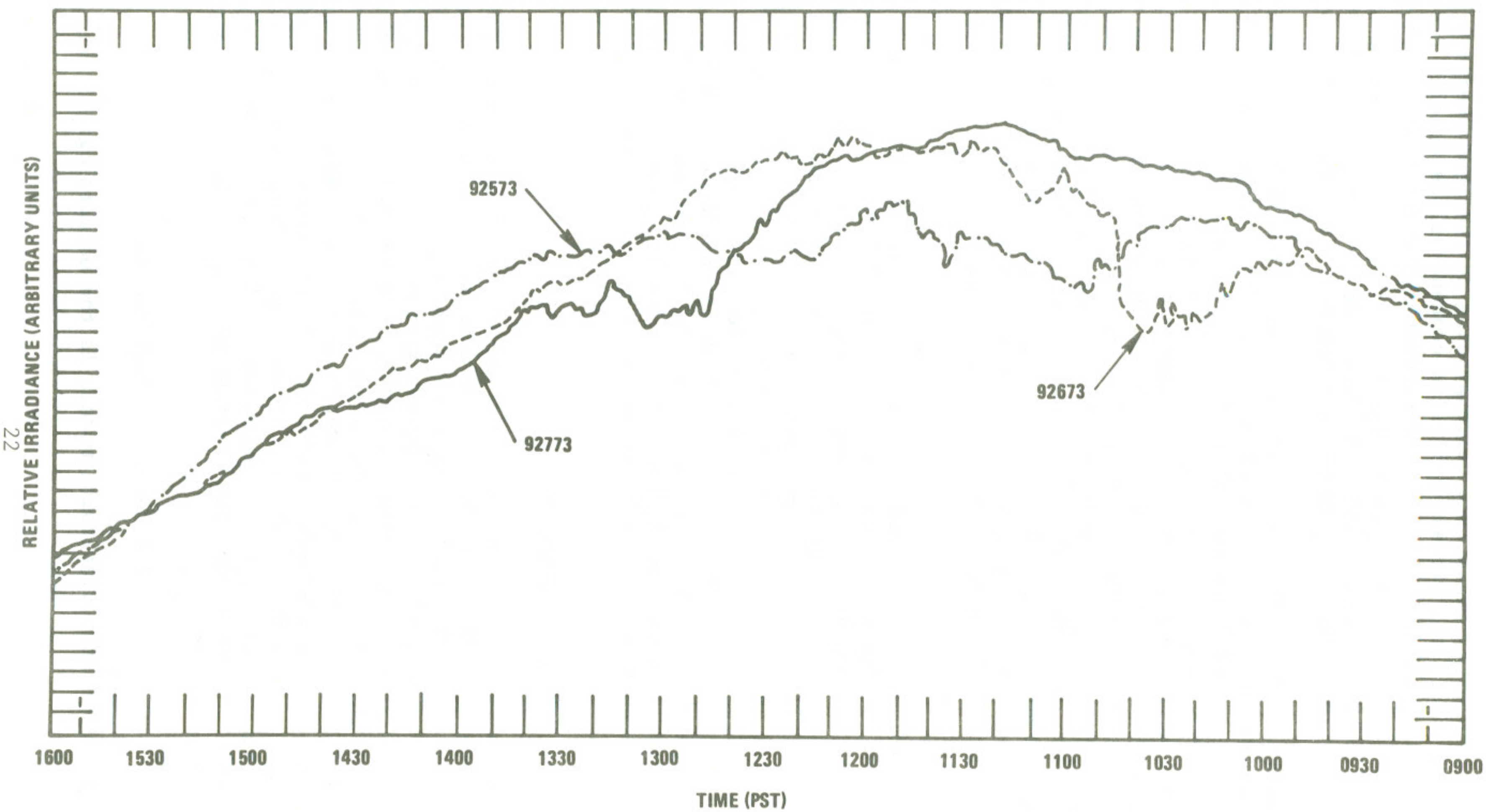


Figure 4. Relative irradiances measured at El Monte on Sept. 25 (92573), 26 (92673), and 27 (92773), 1973.

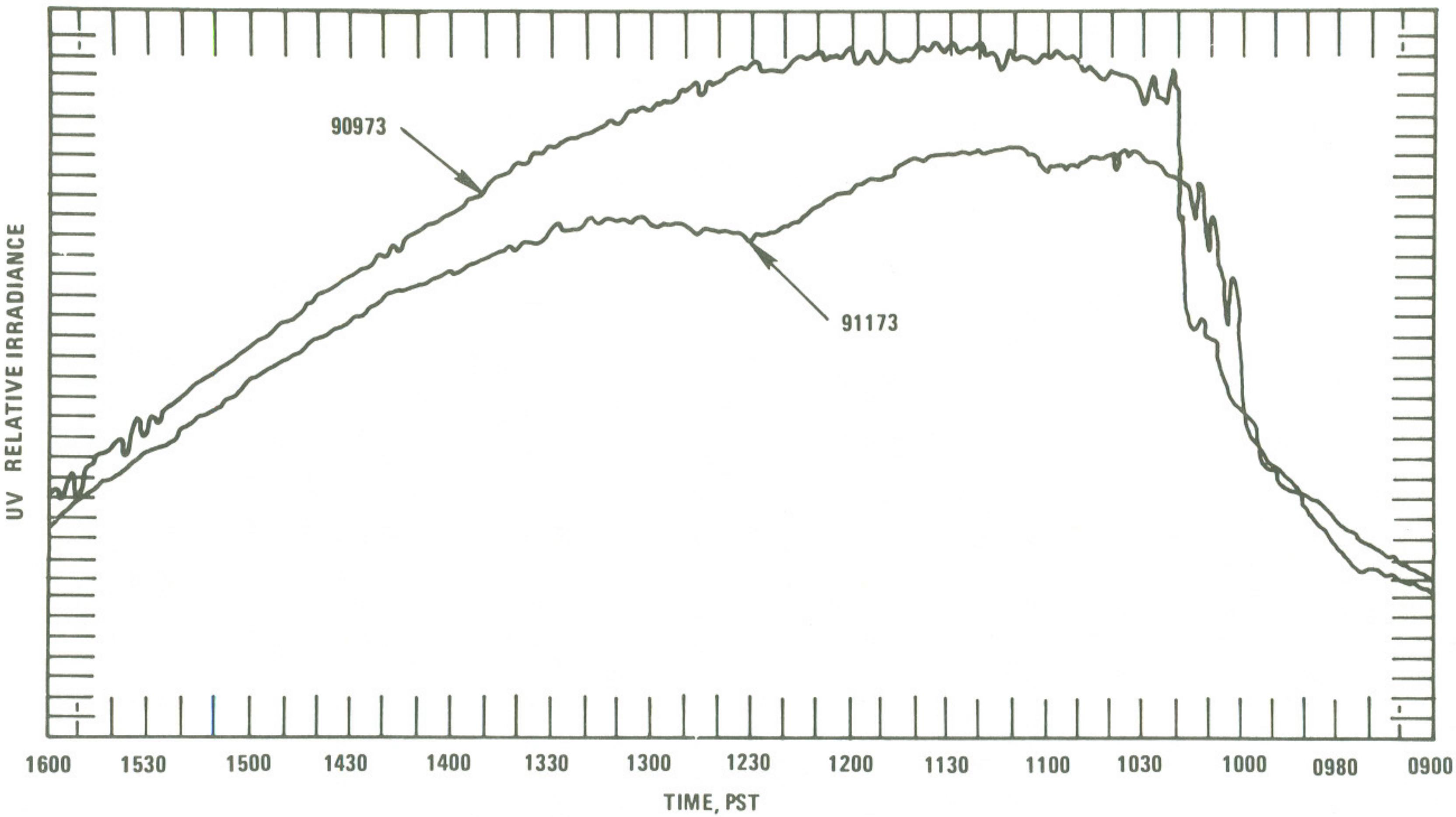


Figure 5. Relative irradiance at El Monte on Sept. 9 (90973) and 11 (91173), 1973.

Currently this requires either the use of climatological data assumed to be representative for the entire dispersion period, the use of actual or modified observed data assumed representative for the dispersion period, or the use of observed data entered into the dispersion model at periodic intervals. Very few dispersion models compute or predict the meteorological parameters over the dispersion period. The development of boundary layer and regional meteorological models will help remedy this situation which is of critical importance in areas with limited observational data available.

2.4.1 Wind and temperature prediction model

Development work was done on a comprehensive prognostic model for the air flow in an urban area. It is a numerical model of the wind and temperature field as a function of space and time. The model predicts the flow field over a 1 km by 1 km horizontal grid with a total area of approximately 40 km by 40 km and a vertical extent of 2 km. It consists of a solution of the three-dimensional equations of motion along with the temperature equation for an urban area (Fox, 1974).

Several aspects of the model were considered during FY 1974: development of a surface energy budget model (see Section 2.3.2) capable of calculating the heat flux boundary condition at the lowest grid level; determination of the lateral boundary conditions to allow the correct propagation of large scale flow features into the smaller scale model; examination of proper closure mechanisms, particularly a closer study of the theory of second order turbulence closure; and the use of a variable eddy viscosity instead of the current assumption of a constant eddy viscosity. Work in all these areas is incomplete.

2.4.2 Surface energy budget parameterizations for urban scale models

A critical problem in urban-scale models, such as the wind and temperature prediction model (discussed in Section 2.4.1), is the determination of the computational boundary conditions. This requires the conversion of actual physical boundary conditions into computational boundary conditions.

A procedure has been developed to describe the surface energy budget using the Monin-Obukhov length L (Nickerson and Smiley 1974). A transcendental equation was derived for L from (a) the Businger-Dyer surface layer formulations, (b) parameterizations of the moisture flux, ground storage, and counter radiation terms, and (c) the wind and temperature at 10 meters above a surface characterized by a roughness length z_0. The surface temperature, friction velocity, and sensible heat flux may then be determined from the computed value of L.

The parameterized surface energy budget equation was tested on the data from O'Neil, Nebraska. It demonstrated that the parameterization procedure can provide a reasonable description of the surface energy balance. More data on the energy budget components over various surfaces and land use categories, for all seasons of the year, are required before the procedure can be used operationally.

2.4.3 Urban boundary layer study

An experimental and theoritical program is underway on the structure and turbulent processes within the urban planetary boundary layer. These studies are being carried out in metropolitan St. Louis in conjunction with the Regional Air Pollution Study (RAPS). Experiments were conducted during special intensive periods in Summer 1973 and Winter 1974 and concentrated on the rapid transitional (fumigation) periods around sunrise and sunset and on the so-called "urban heat plume."

During experiments, measurements of air temperature, moisture, and pollutant concentrations were made aloft from a helicopter and near the surface from road vehicles. Those of aerosol backscatter (and hence mixing depth) were made from LIDARS housed in a van and in a fixedwing aircraft. Supplementary radiosondes at 6-hourly intervals and pibals at hourly intervals were also obtained at an urban site and a rural site.

Future studies will also be concerned with microscale circulations induced over heteorogeneous land-use areas and over such features as large parks and bodies of water, and with the release of meteorological tracers for simulation of atmospheric dispersion processes.

2.4.4 Geophysical characteristics and energy budget of the urban surface

Stanford Research Institute conducted an experimental and analytical investigation of the geophysical characteristics of significance in the urban surface energy budget. Analysis of data taken in August 1972 and April 1973, over metropolitan St. Louis, showed significant variability in values of the surface geophysical properties over the land-use types. Albedos showed a maximum near 16 percent over the rural sites comprising farms, fields, and woods with a minimum near 13 percent over the older urban residential and commercial/industrial sites. Urban surface temperatures were higher than their rural counterparts with the maximum difference (10-15^{o}C) occurring in the early afternoon. The thermal admittance ranged from a minimum near 20 millilangley sec $^{-1.2}$ C^{-1} for urban and suburban sites to about 85 for the wooded sections. The inverse Bowen ratio varied from 0.22 for the urban area to 2.9 for farmland.

A comprehensive report on the project was published by the EPA in April 1974 (Dabberdt and Davis, 1974).

2.4.5 Modeling of turbulence and diffusion in the planetary boundary layer

The method of so-called invariant modeling developed by Dr. C. du P. Donaldson (Aeronautical Research Associates of Princeton (N.J.), Inc.) has been further developed during FY 74, towards the goal of a viable computer model, based on second-order closure of the turbulent correlation equations, for predicting the dispersion of non-chemically reacting pollutants released in the atmospheric boundary layer. The invariant model has been modified both by extending its capabilities and by developing approximations to the full system of equations, which may be used in complicated flow geometries where economy of computing time justifies some compromise in accuracy.

Calculations have been made for the diurnal variations in the turbulence distributions in the planetary boundary layer that are induced by the unsteady surface heat flux; for the spatial variation of turbulence occurring when the wind blows over an abrupt change in surface roughness; and for the dispersal of a plume released at different heights, under different stability conditions, and over different terrain. This work is reported in Lewellen et al. (1974).

Future work under the ARAP contract will include

(1) Coupling the pollutant model directly to an upgraded form of the turbulence generation model.

(2) Programming the coupled set of equations to run on EPA's UNIVAC 1110 computer.

(3) Using the model results to generate dispersion coefficients for use with Gaussian plume models for a number of typical atmospheric conditions where the model would indicate that such Gaussian formulations are approximately valid.

(4) Reviewing critically the validation tests and present limitations of ARAP invariant modeling.

2.4.6 Atmospheric turbulence statistics: Lowest 300 meters

Turbulence data collected in May 1973 at the Savannah River Laboratory's (SRL) instrumented tower under an EPA grant to North Carolina State University have been analyzed. Data were time averaged over 40-minute periods. Each of six levels had information on wind speed and direction as well as temperature. A Gill U-V-W anemometer and a thermistor mounted at 18 meters were used in calculation L, the Monin-Obukhov length scale. Altogether, about 240 40-minute blocks of data were analyzed.

In order to compare the field measurements with results from similarity theory, the data were edited to remove periods of "laminar" flow, upward transports of momentum (characterized by negative U_* values), transition such as sunrise, or during which the thermistor output went off scale. About 120 forty-minute periods were rejected for these reasons.

The values of standard deviation of azimuth and elevation (σ_V and σ_E) are of special interest in diffusion calculations in the Ekman layer. During analysis it was found that σ_A and σ_E are functions of zf/u_* in neutral conditions. During stable and unstable conditions σ_E and σ_A are functions of z/L and a/a_o. The convenient approximation, $\sigma_V/\sigma_A = \bar{V}$, was found to be statistically "correct" (linear regression) with a correlation coefficient of 0.90.

The nondimensional wind shear was found to be a function of z/L. Scatter increased with height but basically the results were in good agreement with similarity theory. When centered finite difference approximations are used the value appears to be 0.4 or larger depending on whether or not the cup anemometers are corrected for over speeding It is concluded that the data are not closely enough spaced in the vertical to determine k accurately.

Roughness lengths were determined from wind profiles in unstable conditions. The roughness length appropriate to a southerly fetch was determined to be about 8 cm.

The turbulence statistic, σ_w/u_*, was found to have an average value of 1.27. Wavelength of the maxima of the vertical velocity spectra were found to agree well with Pasquill's results for neutral and unstable data. For stable data there seemed to be a nearly linear increase of λ_m with height.

2.4.7 Development of boundary layer and regional models

Under the direction of Professors J. Lumley and H. Tennekes of Pennsylvania State University, model equations are being developed for the description of the turbulent processes in the atmospheric boundary layer. Under an EPA grant development of a complete system of second order equations for turbulent flow is continuing. It is now anticipated that these will in due course provide the basis for a sophisticated urban-scale (20 km x 20 km) air pollution model. Simplified equations are being used to study the development of convective boundary layers and the daily cycle of the mixing height.

Further need exists for a simple method of taking into account the rates of exchange of momentum, heat, water-vapor, and other properties that result from the action of sub-grid scale motions in regional scale models. Previously the method under investigation was equivalent to a K-type closure with the turbulent energy constituting the most important parameter for the determination of the eddy diffusivity function K. During fiscal year 1974 emphasis has been placed on the use of simplified second-order closure schemes to derive the turbulent fluxes for the regional model.

Also during fiscal year 1974 emphasis was placed on the numerical aspects of the three-dimensional regional model and its two-dimensional analog. This includes the solution of the technical problems associated with the lateral boundary conditions (e.g., the use of nested grids), the effects of errors in initial data (e.g., use of stochastic methods) and the efficiency of computation (e.g., use of semi-implicit rather than explicit methods). These studies have involved a large number of numerical experiments.

All this work was performed under the EPA Select Research Group in Air pollution Meteorology grant.

2.5 Physical Modeling

Another approach to the solution of dispersion problems is to model the situation physically in a wind tunnel or water channel. During fiscal year 1974 the first component of the Fluid Modeling Facility, a wind tunnel, was installed. The system will be expanded to include a water channel/towing tank.

2.5.1 Fluid Modeling Facility

A fluid modeling facility is being established to study the flow and diffusion of pollutants around buildings, highway configurations, and complex terrain. Major progress has been made in the past year. The wind tunnel, minicomputer, and necessary electronic equipment have been received; a building has been leased to house the facilities; support services have been contracted, and a contract has been awarded for the construction of a water channel/towing tank.

The Meteorological Wind Tunnel, described in Hosler and Viebrock (1974), was turned over to EPA in June 1974 (see fig.6). Preliminary testing showed the flow in the empty test section to be highly uniform and steady at speeds from 1 to 10 m/sec. Further testing is planned in the immediate future to determine turbulence levels in the empty tunnel and to characterize the thick boundary layers developed by elliptic-wedge vortex generators.

The Meteorological Wind Tunnel and the instrument calibration wind tunnel of the EPA/Manpower Development Staff (MDS) were installed in the Grand Slam Building (formerly indoor tennis courts) at the intersection of Page Road and Interstate 40 near Research Triangle Park. The building was modified to house the two wind tunnels, model shop, electronics shop, instrument laboratory (MDS), photographic darkroom, computer room, storage room, and three offices. A chemistry laboratory is to be added soon.

A Digital Equipment Corporation PDP 11/40 minicomputer was acquired in late June for direct on-line acquisition and analysis of data from the wind tunnel. Peripherals included with the system are disc and magnetic tape drives, electrostatic printer/plotter, and CRT display.

A contract was awarded in March 1974 to Northrop Services, Inc. to provide support services to the Fluid Modeling Program. Now included in the contract are a model technician, an electronics technician, a laboratory technician, and a programmer.

Another contract was awarded in June 1974 to Aerolab Supply Company of Laurel, Maryland, for the construction of a recirculating water channel/stratified towing tank. The test section of this facility is to be 2.4 m wide, 1.1 m deep, and 24 m long and is to be constructed with glass sidewalls and bottom (open top). In the recirculating mode of operation, the maximum speed will be 1 m/sec. A smoothly operating towing carriage with speeds up to 2 m/sec will be provided for towing models (inverted on the surface) and instrumentation. Layered mixtures of salt-water (NaCl) will be used in the test section (towing tank mode of operation) to produce density stratification. A contract to install a mixing and filling system is anticipated in the near future.

2.5.2 Stratified towing tank simulation of plume dispersion over complex terrain

Flow Research, Inc., Kent, Washington, under contract to EPA, conducted a towing tank study of the dispersion of a plume from an elevated source upwind of an idealized mountain (Gaussian-shaped saddle) under neutral and stably stratified flow conditions (Lin et al., 1974). The model was inverted and towed through the tank, with a concentrated salt solution as the effluent. In the inverted configuration, the dense saltwater solution simulates a

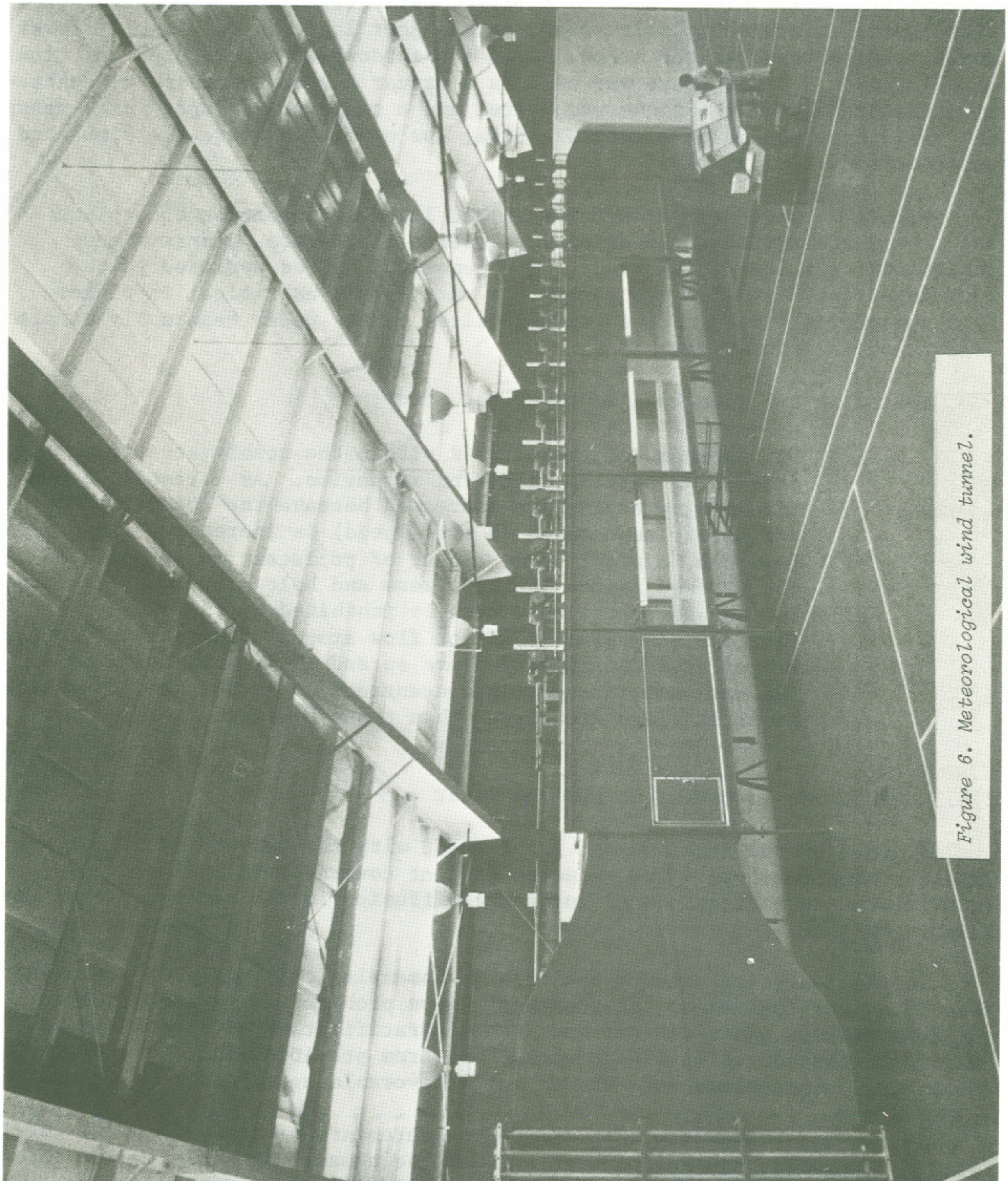


Figure 6. Meteorological wind tunnel.

buoyant effluent. Linear density profiles were created by filling the tank with layered mixtures of salt water, each higher layer being slightly lower concentration than the one below. Dyes and shadowgraphs were used for flow visualization. Temperature was used as a tracer for quantitative concentration measurements. The plume was heated and a temperature gage, which measures the resistance change of a metallic film, was used to measure the simulated concentration.

Figure 7, which compares vertical and lateral boundaries of a plume over the terrain with those of a plume over a flat plate, displays many qualitative results of the study. The numerical values assigned to the most important dimensionless parameters were chosen as typical in plumes from industrial plants in the western United States under reasonably stable meteorological conditions.

Following are some highlights of the study;

(1) The presence of the terrain within the stably stratified flow creates an upstream blocking situation. As a result, plume rise and spreading are increased because the local velocity ratio (effluent speed to wind speed) is increased. In one instance, a significant amount of pollutant was trapped in the blocked region just upstream and below the mountain ridge.

(2) Because the vertical motion is inhibited by the stable stratification, the plume tends to flow around rather than over the ridge; thus the lateral plume spread is greatly enhanced.

(3) The mean and fluctuating concentrations at stations on the mountain ridge are larger than those measured on the upwind slope.

2.5.3 Diffusion in turbulent surface layer

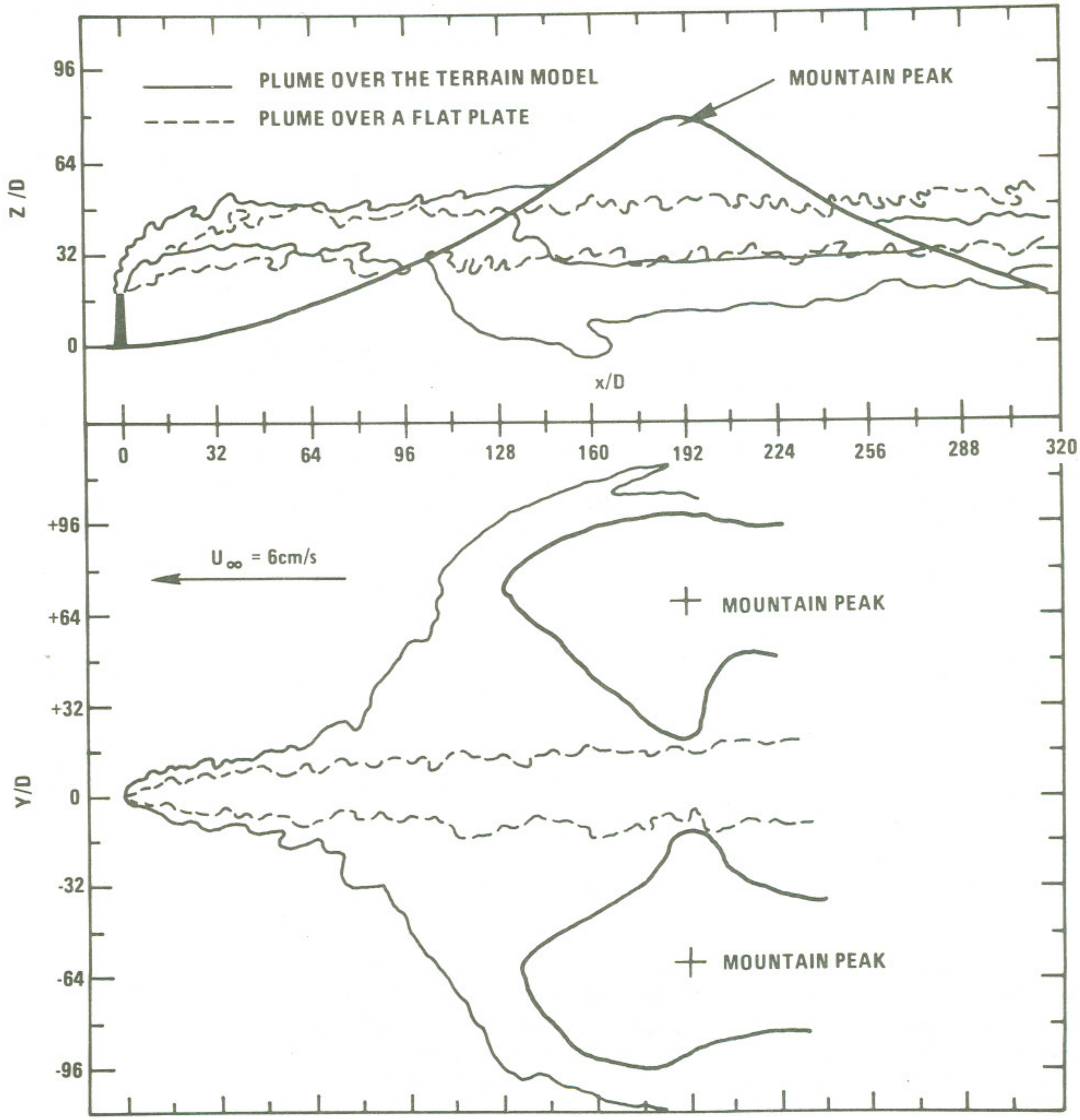
A draft of the final report for a grant with the University of Notre Dame has been received. The research project covered both analytical and experimental investigations of turbulent diffusion in the atmospheric surface layer.

In the analytical study, a simple phenomenological theory of turbulent shear flow was applied to turbulent diffusion problems for groundlevel point and line sources under neutral and stable stratification. Comparisons of calculated concentration fields with those from previous wind tunnel data and limited atmospheric data showed quite favorable agreement.

In the experimental study, limited measurements of mean velocity, turbulence intensity, and Reynolds stress have been made with only two or three out of many possible jet arrangements. No diffusion experiments as was originally proposed were conducted in the wind tunnel.

2.6 Modeling of Pollutant Removal Processes

Generally pollutants emitted into the atmosphere must eventually, in one form or another, leave the atmosphere. The form and magnitude of the



EFFLUENT FROUDE NO. = 3.16
AMBIENT FROUDE NO. (BASED ON RIDGE HEIGHT) = 2.64
AMBIENT FROUDE NO. (BASED ON STACK HEIGHT) = 6.22

EFFLUENT SPEED/WIND SPEED = 3.4
EFFLUENT REYNOLDS NO. = 530

Figure 7. Vertical and lateral spreads of plumes in stratified flows over a flat plate and over mountainous terrain, z/D and y/D are dimensionless numbers, where z is the vertical distance, y the lateral distance, and D the stack diameter.

removal processes are important for inclusion in dispersion models and for determining the effect of the various pollutants on the biosphere, hydrosphere, and material surfaces.

A major removal process is the scavenging of pollutant material by precipitation. Study of this process was emphasized by ML during fiscal year 1974. Plans include the consideration of the dry deposition of pollutants.

2.6.1 Precipitation washout of sulfur compounds

Battelle-Pacific Northwest Laboratories have developed a model for the washout of sulfur dioxide from power-plant plumes. This model is based upon reversible gas absorption phenomena. It can be used for predicting washout of pollutant gases other than sulfur dioxide upon the substitution of the appropriate physical properties.

The model is based on the concepts of reversible behavior and negligible plume distortion by the washout. The theoretical basis and development of the model are outlined in Hales (1972). Field experiments during the study showed that sulfur dioxide concentrations in rain can be calculated within a factor of two of observed values, although the predictive capability is reduced in the immediate vicinity of the source and complicated by the occurrence of chemical reactions.

Conclusions from the model, verified by observation, include the following:

(1) Washout of sulfur dioxide from a concentrated, high-elevation plume can be obscured by the presence of low-elevation, low-concentration background levels.
(2) The acidity of rain strongly influences its sulfur dioxide scavenging potential.
(3) Negative washout occurs as the result of desorption of sulfur dioxide plume.

Field experiments were conducted at three sites: Keystone Power Plant in western Pennsylvania, Quillayutte Airfield in Washington state, and Centralia Steam Plant in Washington state. Sulfur dioxide and sulfate washout were also measured. An approximate reaction-washout analysis indicates that a rapid initial oxidation occurs, which slows with increasing distance downwind. The results indicate that the rate of sulfur removal by sulfate washout is up to five times more rapid than that by sulfur dioxide washout. The sulfate washout coefficient, using the approximate analysis procedure, appears to be about 0.05 hr^{-1} for background $pH \geq 5.2$, but could be much smaller for more acid drops. The effects of dry deposition upon the experimental results appear to be unimportant for rainfall rates over one mm hr^{-1}.

The results of the field experiments are presented in the final report on the study (Dana et al., 1973).

2.6.2 Precipitation scavenging of aerosols

Under an EPA grant, researchers at the Universtiy of California, Los Angeles, are conducting a laboratory study of the water droplet scavenging of atmospheric aerosols. The study involves charged and uncharged water droplets and aerosol particles of various sizes and shapes. Three special facilities are being used: a large vertical wind tunnel, a walk-in cloud chamber, and a 35-m high rain shaft. The experimental results are being compared with theoretical calculations.

Theoretical and experimental collision efficiencies have been determined for micron and submicron aerosol particles scavenged by small raindrops. Numerical calculations were carried out to determine collision efficiencies for small raindrops with micron sized particles (Beard and Grover, 1974). The results for drop radii $40<\Lambda<600\mu m$ and particle radii $a\leq 1\mu m$ are intermediate to previously calculated collision efficiencies, but do not follow the Langmuir interpolation formula. Comparison with experimental results shows good agreement when electric forces are unimportant. A new interpolation scheme was outlined for a range of atmospheric conditions of 800-1100 mb and 0-30°C.

Similar work has been done for the scavenging of submicron particles by small raindrops (Beard, 1974). Experimental scavenging efficiencies were measured for freely falling drops of 0.40 to 0.85 μm diameter and charge of 10^{-5} to 10^{-3}esu. The particles present had a radius of 0.4μm and a density of 1.5 g cm^{-3}. Numerically evaluated collision efficiencies were found to increase for the smaller particles because of wake capture. The numerical model used was an expanded version of that presented in Beard and Grover (1974). Work in this area is continuing.

2.6.3 Precipitation scavenging of inorganic pollutants from metropolitan sources

In the summers of 1972 and 1973 field experiments by Battelle-Pacific Northwest Laboratories measured the precipitation scavenging of inorganic pollutants from the St. Louis metropolitan area. Primary field measurements were made of concentrations of trace inorganic pollutants in rainwater collected along arcs of collectors at specified distances from the St. Louis Arch. Precipitation samples were analyzed for H^+, SO_3^{--}, SO_4^{--}, NH_4^+, NO_2^-, and NO_3^-. All the measurements were made during convective storms.

The concentration measurements have shown that precipitation scavenging by convective storms can be an effective mechanism for the removal of urban pollutants from the atmosphere. Measurements indicate that spatial concentration distributions of common inorganic pollutants in their higher oxidation states -- sulfate and nitrate -- show little variability over the scale of a kilometer or more. Substances in lower oxidation states, with the exception of ammonia, tend to exhibit more variability. Concentration and scavenging rate measurements made at two distances downstorm of the urban area indicate that scavenging removal rates can equal urban emission rate estimates.

The above conclusions are preliminary and tentative. Results of the field experiments are presented in Dana et al. (1974).

2.6.4 Atmospheric removal processes for air pollutants

During fiscal year 1974 an extensive survey of the literature on sources and sinks of gaseous pollutants was conducted. This information outlines the nature and size of anthropogenic and natural emissions of H_2S, SO_2, N_2O, NO, NO_2, NH_3, CO, O_3, and Hydrocarbons their ambient background concentrations, and lists the major sinks indentified to date. This work, reported in Rasmussen, et al. (1974), was performed under an EPA grant to Pennsylvania State University.

2.7 Regional Air Pollution Study (RAPS)

During fiscal year 1974, Rockwell International Corporation procured and equipped office and laboratory space for the central facility in St. Louis which houses the central computer and the laboratories for analyzing gaseous and particulate pollutant samples. National Weather Service facsimile and teletype drops were installed to provide means for operational weather briefings during expeditionary study periods.

Installation of the aerometric stations was delayed by difficulties in obtaining necessary zoning variances for the station shelters and the towers for supporting meteorological equipment. At year's end, however, permits had been obtained for all but two sites, and four stations were completely checked out and capable of transmitting data to the central computer.

Contracts were let to develop the RAPS emission inventory These included contracts for survey and specification of line vs. area sources for vehicular emissions, for surveys of stationary point sources to identify those for which source sampling and/or monitoring should be performed, and for development of methodologies for treating emission data from various kinds of sources. All emission inventory work is performed under the auspices of EPA's National Air Data Branch.

Data formats were set up and software developed for the RAPS data bank. This bank will include the emission data and emission models, all data from the aerometric network, meteorological sounding data from radiosonde and pibal observations, and most data from special studies to be performed in conjunction with RAPS. Some data will be readily accessible; other data, for which a low demand is expected, will be stored on auxiliary tapes and discs.

Expeditionary or special studies during August and September 1973, and during February 1974 were performed to describe the urban boundary layer structure with emphasis on the morning and evening transition periods. In addition a number of investigators made extensive measurements of aerosols in and around the St. Louis area under the auspices of EPA's Chemistry and Physics Laboratory.

An expeditionary study period was planned for the summer of 1974. Two large helicopters from EPA's Environmental Research Center at Las Vegas were outfitted with sampling equipment for most parameters measured at the fixed surface stations. The helicopters will be used both for obtaining vertical soundings at or near the surface stations, and in support of studies of emissions from particular sources and of transformation processes, including aerosol formation. Most of the special studies will be carried out in conjunction with the METROMEX project, with exchange of data between all METROMEX and RAPS participants anticipated.

2.7.1 Objective procedures for optimum location of air pollution observation stations

A contract was placed in fiscal year 1973 with Kaman Sciences Corp., Colorado Springs, Colorado, to develop a mathematical theory for optimization, by an objective method, of the location of the sampling stations in an air quality network. An "optimum network" ideally refers to one that is free of redundant observations; a statistical technique that minimizes such redundancy has been developed by Dr. C. Eugene Buell of Kaman Sciences Corp. The technique is based on the modern statistical theory of random scalar fields and involves consideration of the covariance function for air pollution concentrations and the statistical technique of factor analysis. The structure of the covariance function is determined by an appropriate analysis of synthetic values generated by available methematical models of urban air pollution and also from existing observational data. Based on these specifications of the statistical properties of the two-dimensional field of air quality, a theory has been developed to describe the efficiency of various multiple-point interpolation formulae for obtaining estimates of air quality at locations between actual sampling stations. The optimal spacing of the sampling locations, in order to achieve a specified accuracy for the interpolated field is determined by an objective procedure that includes consideration of the case where some of the sampling locations are prescribed by practical considerations.

It was anticipated that this study would be completed during fiscal year 1974. Although the mathematical formulations were all completed, unforeseen problems in the computerized formulation delayed submission of the final report by the contractor. This report is now expected early in fiscal year 1975.

2.7.2 Interpretation of ACDAR sounding observations

A propagating pulse of acoustic energy emitted by an ACDAR transmitter is refracted by the average spatial gradients of temperature and wind, and also scattered by local turbulent velocity and temperature fluctuations. The research project is based on the thesis that if the ACDAR "system" function can be precisely defined for any specified operational sounder, and can adequately model the refraction and scattering of ACDAR signals in the atmosphere, then many experiments that are critical to improved understanding of ACDAR measurements can be performed by use of numerical simulation, in which the system parameters and the atmospheric conditions (the independent variables) can be precisely controlled. A major aspect of the theoretical work in the project therefore consists of the analysis of the ACDAR and Doppler equations. The magnitude of the received power and the characteristics of the signal Doppler shift (due to a scatterer in motion) as a function of the range, depend on both the properties of the sounding system and the complex physical state of the atmosphere. These effects are being separated and modeled.

Schemes for automatically and objectively processing the return ACDAR signals are being studied, as a basis for eventual continuous input of data into a running regional- or urban-scale predictive model.

A second area of theoretical study, performed as part of the EPA grant to Pennsylvania State University, has concerned the analysis of refractive propagation of sound in surface-based and elevated temperature inversions. When such inversions exist it is, at least theoretically, possible to infer the temperature gradient up to the top of the inversion by using sound refractively propagated over a 3-20 km path.

3.0 CLIMATIC ANALYSIS AND ATMOSPHERIC EFFECTS OF POLLUTANTS

The preparation and analysis of climatological information to provide input to the various air quality simulation models and to provide guidance for the assessment and solution of air pollution and land-use problems, the determination and assessment of the effects of pollutants on meteorology and climate, and the understanding of the relationship between meteorology and air quality are of prime concern to ML.

3.1 Climatic Analysis

3.1.1 Analyses of rawinsonde observations

Analyses, begun in fiscal year 1973, of the rawinsonde observations from 62 stations, to establish the climatology of mixing height and wind speed, continued. The summaries are for the same 62 stations and same period of record as used to establish climatological values of mixing height and wind speed. Preliminary mapping of several variables has been completed. Figure 8 shows isopleths of the percent frequency of winter afternoon/evening observations (balloons released at 2315 GMT) with an inversion based at the surface, and isopleths of solar elevation. These data suggest that solar elevation is not the only important factor influencing the occurrence of surface-based inversions. For example, the nature of the surface and climatological factors are thought to be important, also. Figure 9 shows the percent frequency of winter afternoon/evening observations with an inversion at some level between the surface (i.e., excluding surface-based inversions) and 3000 m above, i.e., subsidence inversions for the most part. It should be pointed out that the rawinsonde summaries only consider the lowest inversion. Observations with a surface-based inversion and a distinctly separate inversion aloft only consider the surface-based inversion. Thus, the frequency of subsidence inversions <u>may</u> be underestimated by an amount not greater than the frequency of surface-based inversions. Figure 10 shows the percent frequency of summer afternoon/evening observations with no inversion in the lowest 3000 m and with a very superadiabatic structure ($\Delta T/\Delta Z \leq -1.21°C/100m$) in the lowest 100-m layer. The area of higher frequencies in the western United States agrees roughly with the area of higher afternoon mixing heights.

Tables prepared from the rawinsonde data obtained from the National Climatic Center relating temperature variation with height to concurrent Pasquill stability categories for selected stations. Table 2 shows that there is general agreement in the variation of stability as defined by the

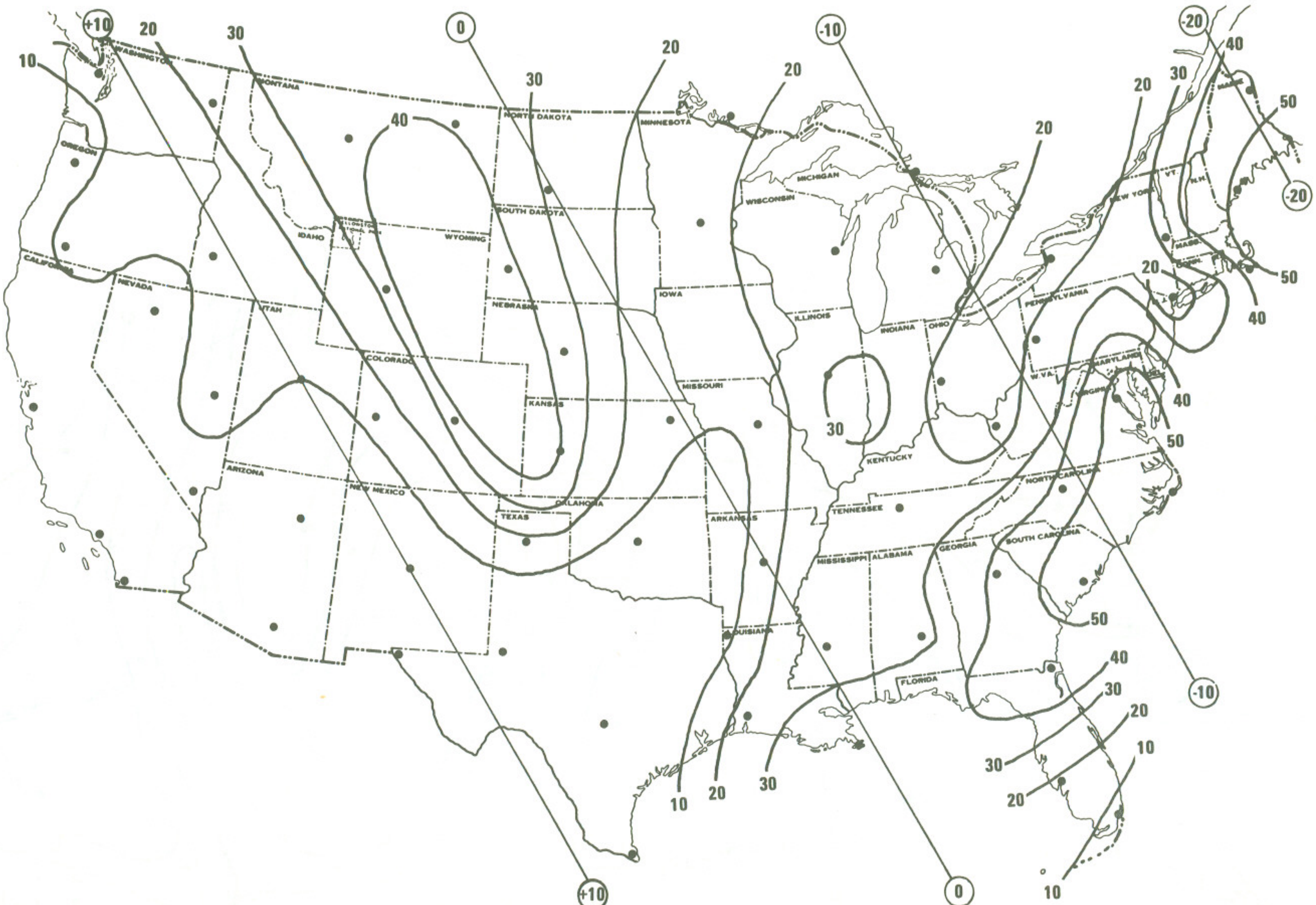


Figure 8. Isopleths of percent frequency of winter afternoon/evening rawinsonde observations (balloons released at 2315 GMT) with a surface-based inversion, based on data for 1960-1964 at observation locations shown by dots. Straight lines with circuled labels indicate solar elevation at 2315 GMT, January 15.

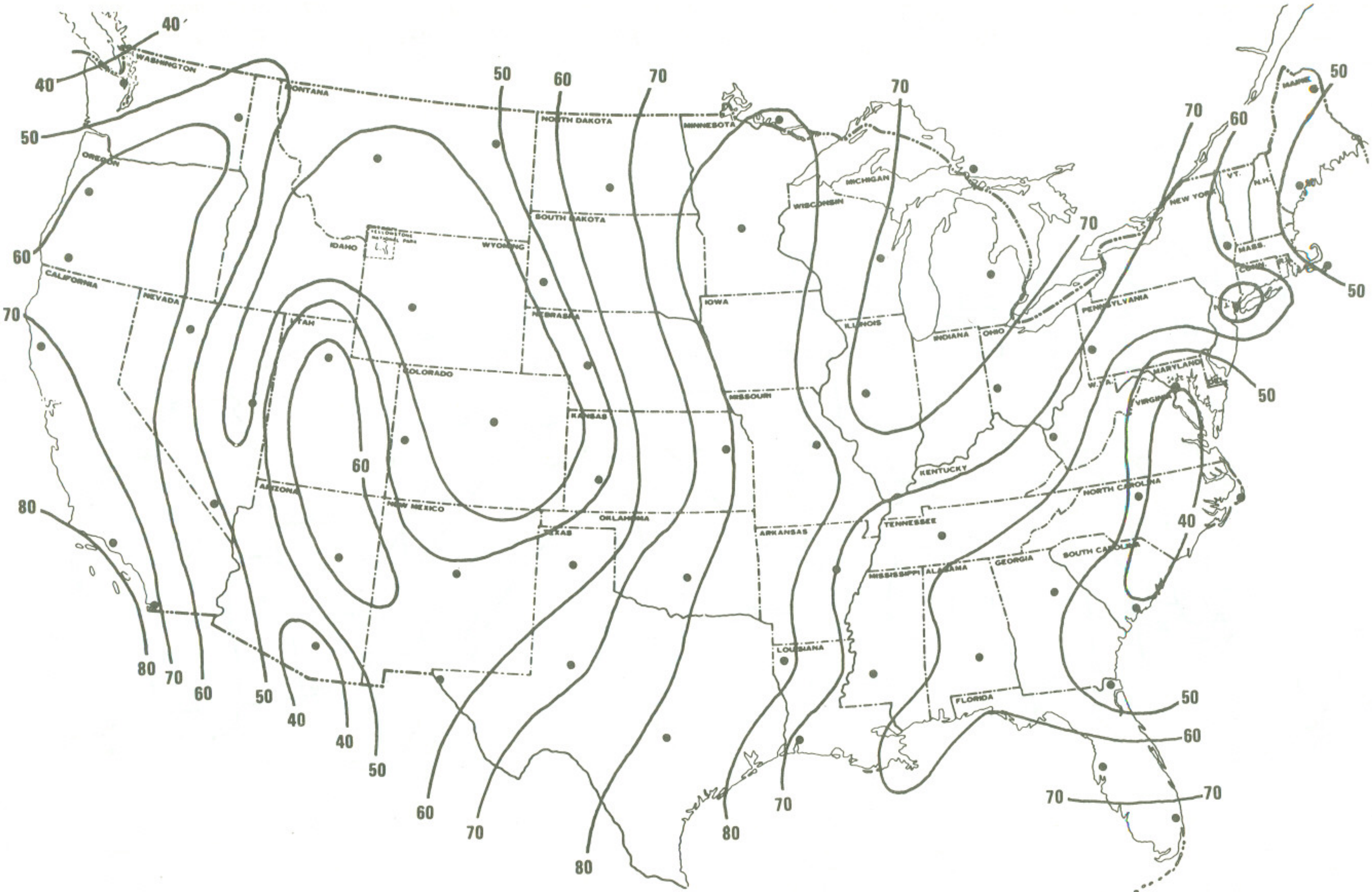


Figure 9. Same as figure 8, except the isopleths are of observation with an inversion base aloft in the lower 3000m and without a surface-based inversion.

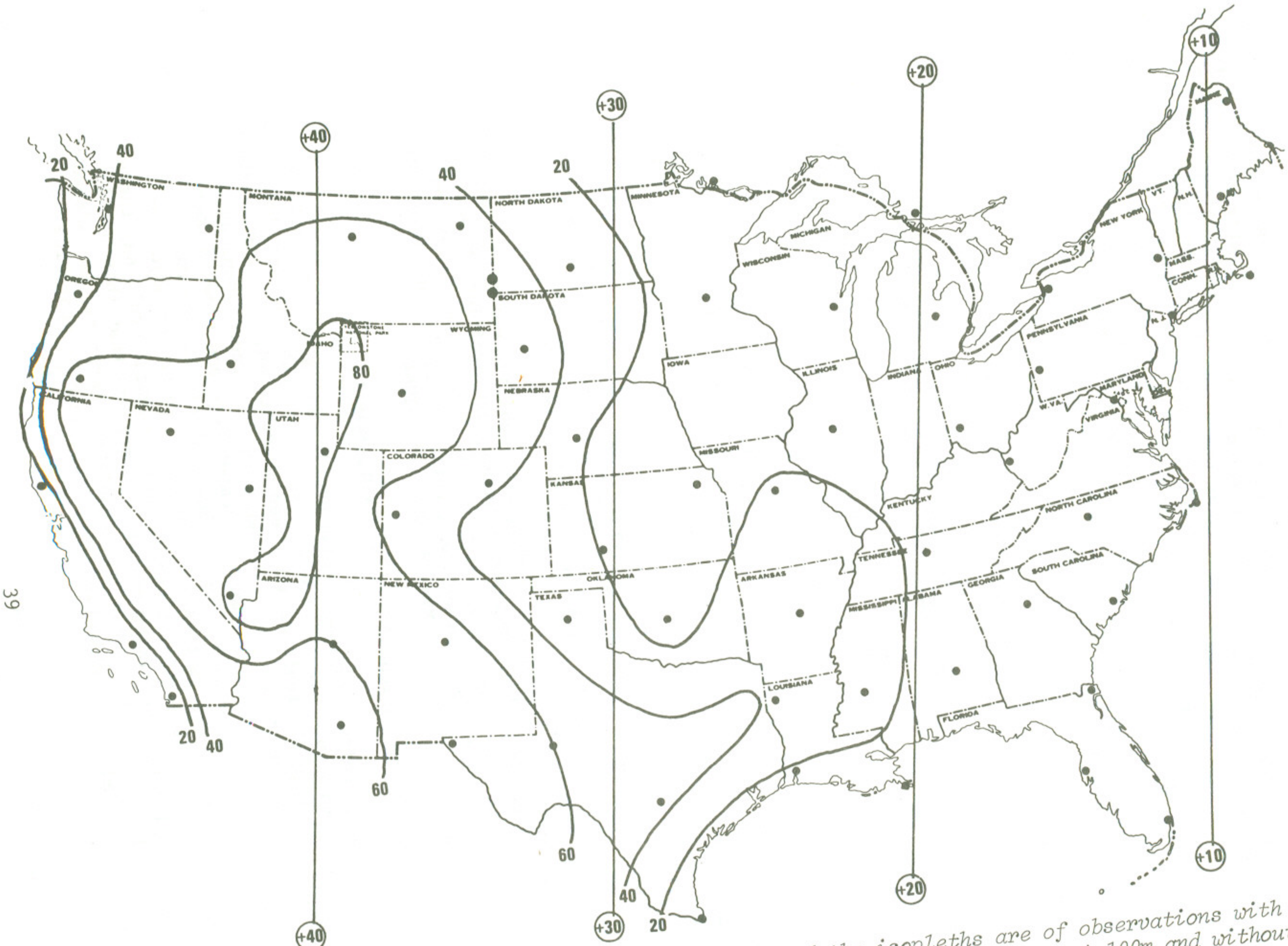


Figure 10. Same as figure 8, except the season is summer and the isopleths are of observations with a very superadiabatic temperature difference ($\Delta T/\Delta Z<1.21°C/100m$) through the lowest 100m and without any inversion in the lowest 3000m. Solar elevations (circled labels) are at 2315 GMT, July 15.

two methods. For example, the average value of ΔT/ΔZ increases from -1.6°C/100 m for Pasquill category B to +2.6°C/100 m for category G, and there is a similar variation in the average value of the Pasquill categories with specified values of ΔT/ΔZ. Notice that the range of average Pasquill categories is from 3.2 to 6.5 (i.e., C.2 to F.5) and the largest frequencies by far are for near-neutral conditions as specified by both Pasquill and ΔT/ΔZ categories. It should be pointed out, however, that while the methods generally agree in their variation of stability, the average values of Pasquill categories and ΔT/ΔZ vary by season and by time of day. These data are being analyzed further.

*Table 2. Percent Frequencies of Pasquill Stability Categories.***

	Pasquill Category								
ΔT/ΔZ (°C/100m)	A=1	B=2	C=3	D=4	E=5	F=6	G=7	TOT	AVG
Less than -1.60		2	6	4				12	3.2
-1.21 to -1.60		1	4	6		*		11	3.6
-0.81 to -1.20		1	8	16	1	*		26	3.6
-0.41 to -0.80			*	7	2	2	1	12	4.7
-0.01 to -0.40				1	1	1	*	3	5.2
+0.00 to +0.47			*	1	1	2	2	6	5.5
+0.48 to +1.14				1	1	2	2	6	6.0
+1.15 to +2.82				1	2	4	5	12	6.0
+2.83 to +6.00					2	3	5	10	6.3
More than +6.00					*	1	2	3	6.5
TOT		4	18	37	10	15	17	101	
AVG ΔT/ΔZ		-1.6	-1.5	-0.9	+1.2	+2.0	+2.6		

* indicates <0.5 and >0.0

** The table shows the frequencies of Pasquill stability categories at 0400 and 1600 LST and corresponding rawinsonde temperature profiles at 0415 and 1615 LST for all of the following layers: lowest 100 m if no inversion, entire inversion layer if based at surface, entire layer beneath inversion if based aloft. Data for El Paso, Texas, Autumn, 1960-1964.

3.1.2. Objective determination of hourly mixing heights

An objective technique for calculating hourly mixing heights is being developed. This technique uses twice daily radiosonde observations and allows for advection. However difficulties have been encountered. The most serious one occurs on a clear to partly cloudy day when the afternoon sounding balloon is released at the time of the maximum temperature and shows a deep (>1000 m) surface-based layer with a less-than-adiabatic lapse rate (on occasions the indicated lapse rate is 0.6°C/100 m). Under the objective system the mixing height is zero, yet professional judgment would say there must be a finite value for the mixing height. It appears that this problem cannot be resolved with a simple objective technique; therefore, an independent method not included in the objective technique, such as searching out wind shear and dew point discontinuities, will have to be used to determine mixing heights in these cases.

A second difficulty with the objective technique is the number of contingencies that have to be considered. Initial efforts to computer-analyze data in accord with the technique have failed.

In order to obtain a workable method, attempts are being made to simplify the procedure. Initially the major problem with the less-than-adiabatic lapse rate at the time of the maximum temperature will be left unresolved. In the computer program such cases will be flagged and the user will be instructed to find the mixing heights on these days by manual analysis. It may be necessary to use additional flagging to reduce the coverage given possible contingencies. This additional flagging would make the design of the computer program an easier task and the operation of the program would require less time. A workable computer program that produces useful results should be operational before the end of fiscal year 1975.

3.1.3 Calculated bihourly mixing heights

Special, pertinent mixing height summaries, prepared by the National Climatic Center (NCC), will be available from the NCC before the computerized program using the objective technique for determining mixing height is available. For 15 stations, for each day, for the period 1960 through 1964, the observed morning radiosonde observation has been used to determine mixing heights for the hours 0800, 1000, 1200, 1400, and 1600 LST. The intersection of dry adiabats from the observed surface temperatures for the respective hours and the temperature profile of the morning sounding determined the mixing heights. In addition, mixing heights have been determined for temperature increases above the morning minumum of 1.0°, 2.5°, 5.0°, 7.5°, 10.0°, 12.5° and 15.0°C for each day. Each day has been categorized with regard to average wind speed (three classes) and average cloud cover (three classes). Summaries showing the 10th, 50th, and 90th percentile have been prepared for each of the nine categories (3 classes x 3 classes) for each of the four seasons. The calculated bihourly mixing heights show the temporal variation of mixing height with wind speed-cloud cover class. The temperature increment data are useful as forecast tools for early morning mixing heights over an urban area (using a forecast of average wind speed and cloud cover and urban-rural temperature difference) and afternoon maximum mixing heights (using a forecast of average winds and cloud cover and increases of temperature from morning minimum to afternoon maximum).

3.1.4 Heat island intensity investigation

An investigation into heat island intensities compared local climatological data for 1964 for pairs of urban and rural stations in 31 United States cities. The results indicate that early morning urban-rural temperature differences varied over a large range. The results further indicate that the technique of assuming a constant urban-rural temperature difference in forecasting morning mixing heights is questionable. It is recommended that the Clarke-Peterson (1972) technique, or a similar method, for calculating heat island intensity be considered a replacement for the constant value temperature difference technique used in forecasting mixing heights.

3.1.5 Air quality trend analysis

In August 1974, the Monitoring and Data Analysis Division of EPA published its first annual report (EPA, 1973c) on air quality and emissions trends. The trend analysis focused on data collected over the past several years. In general, the data showed a downward trend for most major pollutants in urban areas as a result of recent air pollution control efforts, but no discernible trend in rural areas. Typical of such trends is that for total suspended particulates (TSP) over a 12-year period through 1971 (fig. 11).

The importance of meteorology in the interpretation of trends was recognized in the annual report. A vivid example of meteorological influence discussed in the report is that of an atypical pattern of significant upward trends in TSP over the western U.S. for 1968-71. This trend is apparently related to a decrease in rainfall over the same period. Figure 12 shows the distribution of significant up and down trends in TSP over the U.S. between the first two years, 1968-69, and the second two years, 1970-71, of the 4 year period. Superimposed in the distribution of downward patterns of total precipitation between the two pairs of years. The relationship between the upward trends in TSP and decreasing rainfall was found to be statistically significant. The physical explanation of the apparent relationship is that TSP monitors are affected by contribution of particulate matter from all sources including natural dustiness; there appears to be an increase in fugitive dust emissions (e.g., agricultural, unpaved roads, construction) during drier periods.

3.1.6 Effects of maximum and minimum temperatures on human mortality

The Epidemiology Branch of the EPA Human Studies Laboratory is continuing the study of human mortality as influenced by maximum and minimum temperatures. An analysis of mortality patterns for 10 days through the New York City 1966 heat wave (107°F maximum), 30 June to 9 July 1966, and for 10 days through the St. Louis 1966 heat wave (105°F maximum), 8 July to 17 July 1966, revealed diagnosed deaths were mainly attributed to cardiovascular causes such as atherosclerotic heart, arteriosclerosis, and stroke. Heat syndrome was not recognized as a cause in New York City; at St. Louis 41 of 146 deaths occurring on the hottest day, 13 July 1966, were attributed to heat syndrome and 74 to cardiovascular cause. The same pattern of increased cardiovascular deaths during extreme heat was observed in urban, suburban, and rural areas, with the heat island effect exacerbating the impact in urban areas. A Study of a cold wave (-4°F minimum) at Birmingham, Alabama, on 30 January 1966 revealed 26 deaths, 2.29 times the expected for that day, cardiovascular cause accounting for 18 of the 26. Additional statistical analyses of human mortality and temperature and other meteorological parameters are planned for fiscal year 1975.

3.1.7 CHESS visibility study

Support of the Community Health Environmental Surveillance Study involved the estimation of air pollution trends in the urban areas using

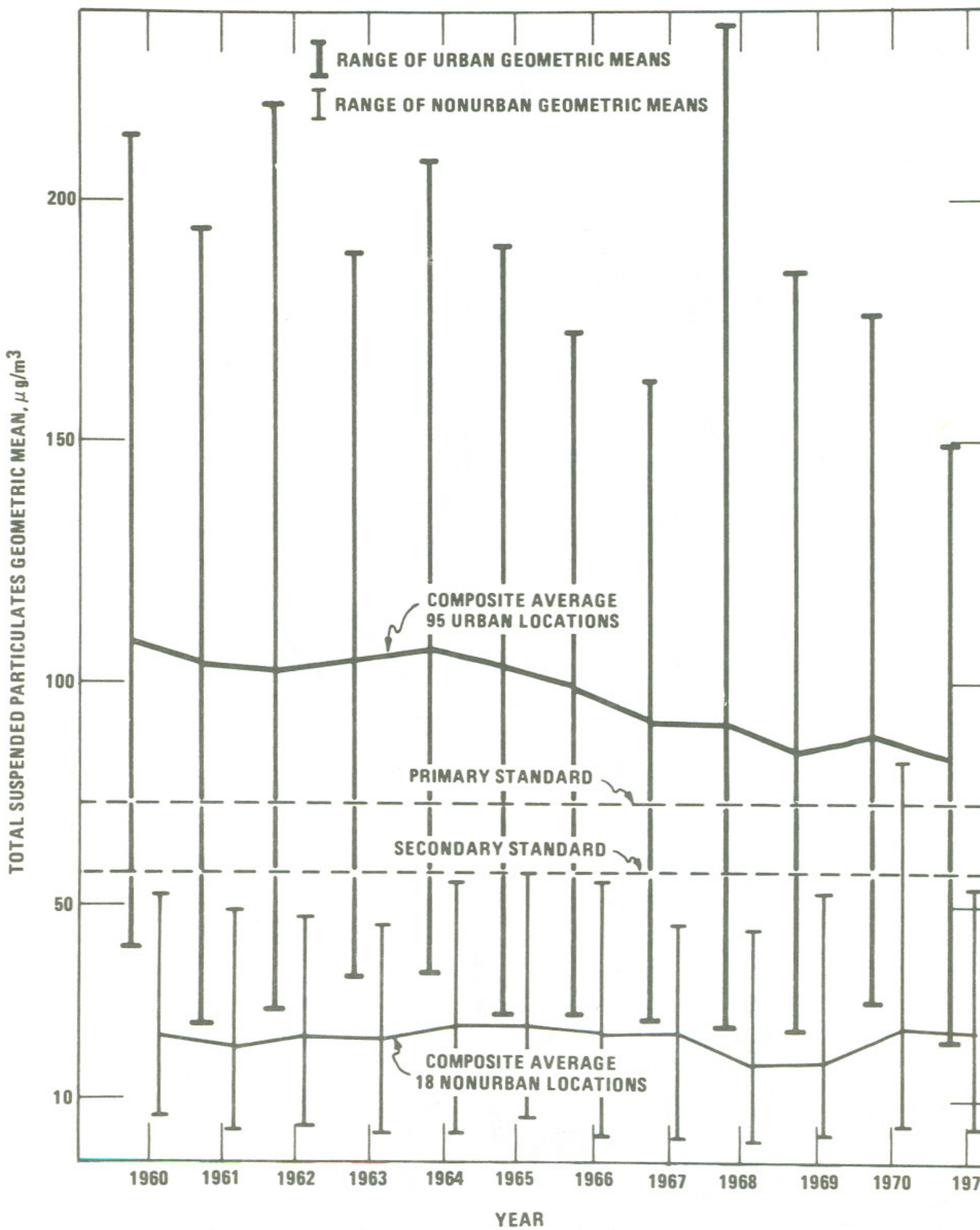


Figure 11. Composite annual means of total suspended particulate at urban and non-urban National Air Sampling Network (NASN) stations.

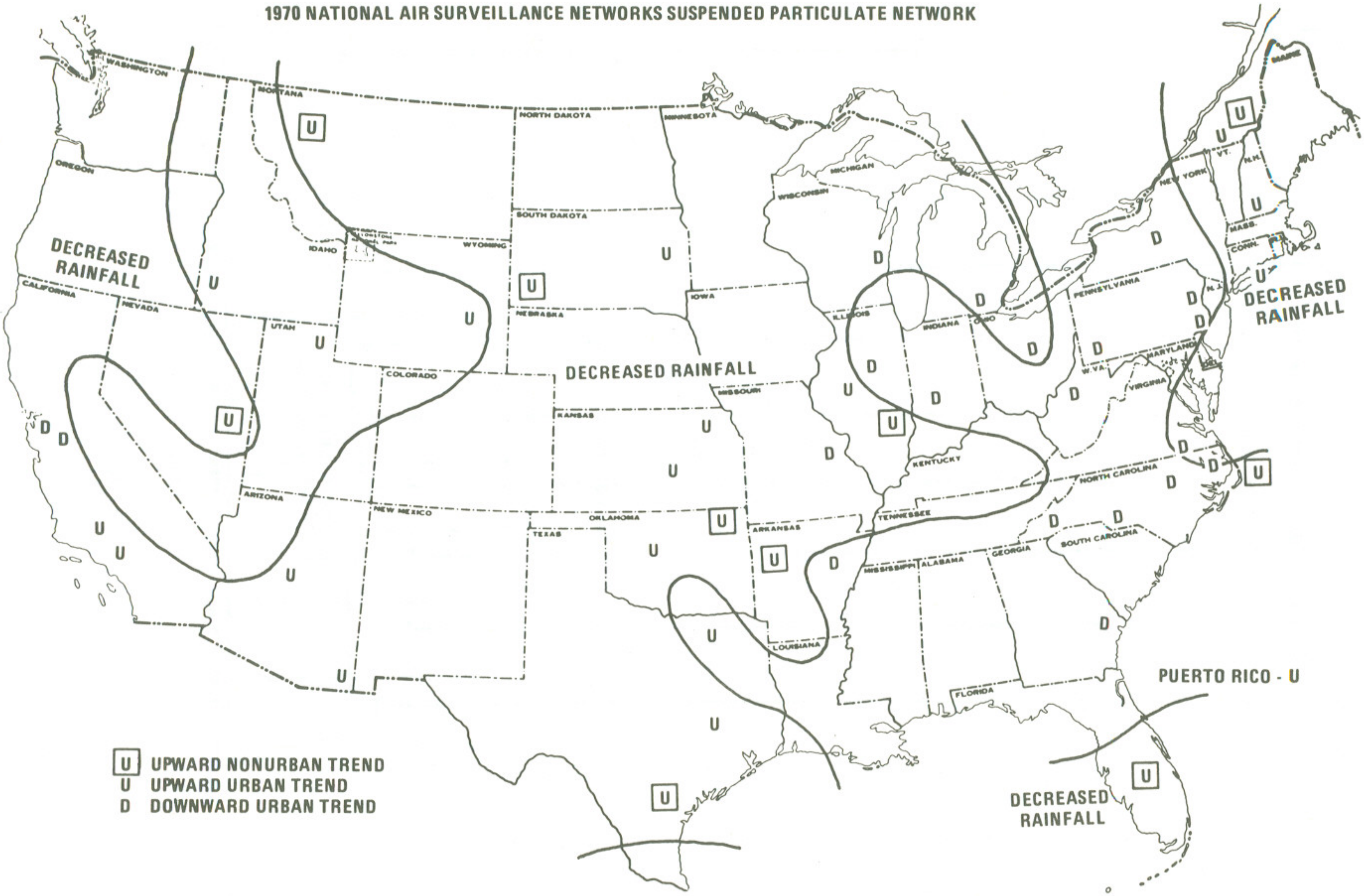


Figure 12. Comparison of increased and decreased rainfall with upward and downward trends in suspended particulate matter concentrations for 1968-1971.

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climatological records of visibility recorded at local NWS airport stations. Visibility observations for 12 airports for the period 1948 to 1971 were analyzed to determine any trends that might be related to air pollution. Observations were restricted to conditions of daylight, no precipitation, and less than 70% relative humidity. Percent frequencies of visibilities were grouped in ranges, 0-2.5 miles, 3-6 miles, 7-14 miles, 15-30 miles or 15 plus, and 30 plus, by years through the period and were fitted with a least squares linear trend line for each range. Trends toward improving visibility were noted at the three airports in the Los Angeles Basin (Los Angeles International, Long Beach, and Burbank) and at Birmingham, Alabama (fig.13). Deteriorating trends appeared at Salt Lake City (fig. 14), San Diego, and Charlotte, N.C.; little or no change was revealed at St. Louis, Chattanooga, and the three airports of New York City: LaGuardia, J.F.K., and Newark, N.J.

3.2 Atmospheric Effects of Pollutants

The most direct and obvious effect of pollutants on the atmosphere is the effect on the radiation budget, particularly in urbanized areas. Consequently, during fiscal year 1974 ML has focused on this effect.

3.2.1 Atmospheric turbidity

No major changes have been made in the number and location of turbidity stations supported by the ML during fiscal year 1974. As detailed in the previous annual report (Hosler and Viebrock, 1974), the number of stations is about 80, with 50 of these in the continental United States and 30 around the world. Sixty of the stations use the dual-wavelength (0.38 and 0.50μ) sunphotometer while the remainder use the Volz type G (0.50μ) instrument.

The lack of precision of the sunphotometer remains a problem. Six to eight instruments maintained as reference sunphotometers, are regularly and frequently compared with good results. However, field instruments returned for recalibration occasionally show relatively large shifts in calibration for no obvious reason.

In response to a suggestion from Dr. Frohlich of the World Radiation Center in Davos, Switzerland, two sunphotometers have been modified to provide a 1°30' limiting angle of view (opening angle 0°50'). This should eliminate most of the errors in the spectral turbidity values caused by variations in the circumsolar radiance from different haze types. The two narrow-view instruments are being compared with regular sunphotometers and it is expected that all of the EPA sunphotometers will be modified to the 1 1/2° limiting angle.

Summaries of turbidity measurements at a number of stations having long records have recently been prepared. The stations examined were Huron, South Dakota, St. Cloud, Minnesota, Youngstown, Ohio, Greensboro, North Carolina, Oak Ridge, Tennessee, Meridian, Mississippi, and New York City.

In the search for trends in turbidity, average values, both monthly and annual, and frequency distributions of daily average values were studied.

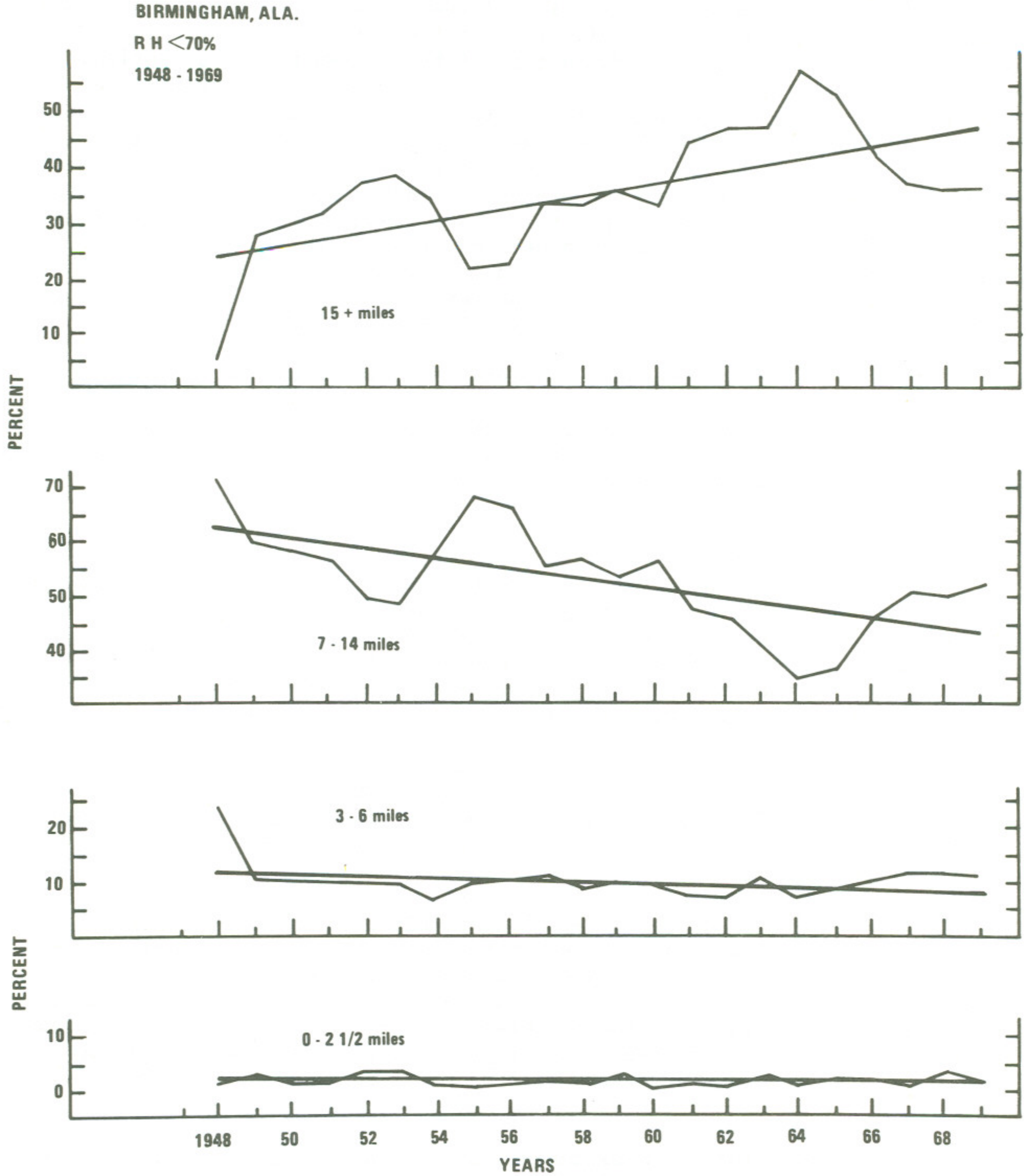


Figure 13. Percent frequencies of visibilities in given ranges for Birmingham, Ala., with a relative humidity of less then 70 percent during 1948-1969.

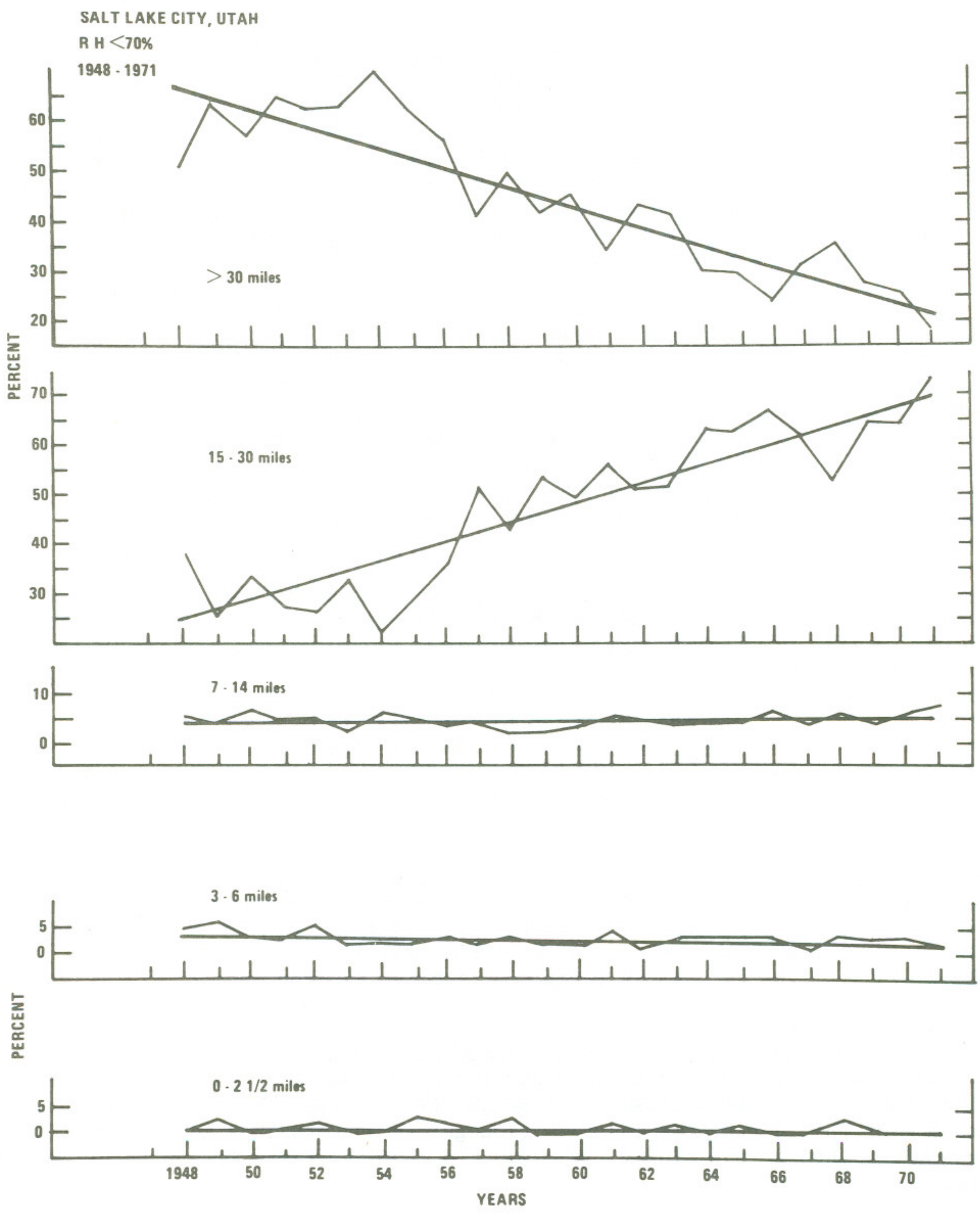


Figure 14. Percent frequencies of visibilities in given ranges for Salt Lake City, Utah, with a relative humidity of less than 70 percent during 1948-1971.

Figure 15 presents the monthly average turbidity for four of the stations in the form of 12-month running averages. The data are plotted so that the July value is the annual average for that year. Youngstown and Meridian appear to show trends, Youngstown downward and Meridian upward. Both of the records are considered good. Both the Huron and St. Cloud records show an interesting feature in the early years. The validity of the high values in 1961 followed by lower values in 1962-63 would be questionable if only one of the records were availavle but with the feature appearing in both records it probably is genuine. Both records appear to show no marked changes during the last half of the 1960's. The anomaly in the Huron record for 1971 is probably caused by a bad instrument in use during that year.

Because turbidity observations are made only when the line of sight to the sun is free of cloud, the number of observations made during any time period varies from year to year and station to station, making average values less reliable. Also, frequency distributions of turbidity values are all positively skewed because of the natural lower limit of turbidity. Consequently monthly average values sometimes may be inordinately affected by a few days of very high turbidity. This effect occurs most frequently in urban areas and in the summer period in southeastern United States, the area of the Appalachian (blue) haze. Thus average values are not the best feature to use to look for trends.

An alternative method is to look at frequency distributions of the daily average turbidity values, and the changes with time of the frequency of the values in the lowest turbidity class interval. Figures 16a and 16b present this type of data for five of the stations. Because of the different ranges of B values at the different stations, the size of the class intervals is twice as large for the stations in a as for those in b. The data plotted are for the 2nd lowest class interval of turbidity. These data tend to verify the increasing turbidity trend at Meridian with the frequency of daily average turbidities less than B=0.081 decreasing from 20-25% in 1965-66 to 4% and less in 1970-72. The Youngstown record is less clear but there is a suggestion of an increase in the frequency of low trubidity values with time. The New York City record also suggests an increase of low values. Data for Oak Ridge (not plotted) tend to show a decrease with time whereas the data from Greensboro (not plotted) show no change with time. The Huron and St. Cloud data show only small changes after 1964 but rather large changes before then. The 1961-63 period is clearly anomalous from the limited record of turbidity data available.

Although the longest of the turbidity records is only from 1961, some interesting changes appear to be occurring which may be significant when a much longer record is available. From the limited amount of data examined, it appears that certain urban areas (Youngstown and New York City) may be less turbid now than in the mid-60's whereas the opposite trend may be occurring in some rural areas.

3.2.2 Urban model of radiative effects of pollutants

During FY 1974 Purdue University continued its work on a numerical model of the urban wind, temperature and pollutant structure under a research grant

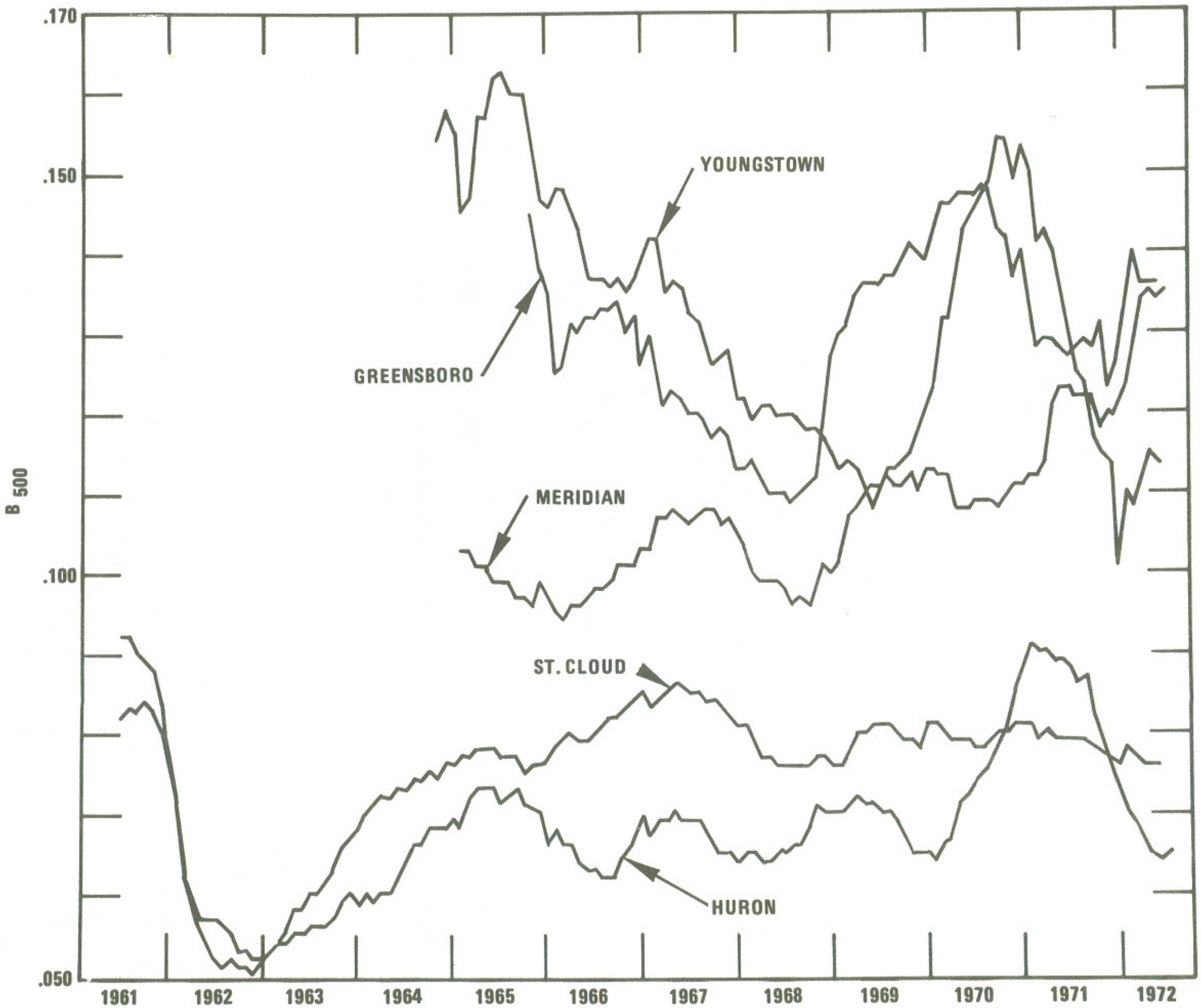


Figure 15. Twelve-month running average of monthly average B_{500}.

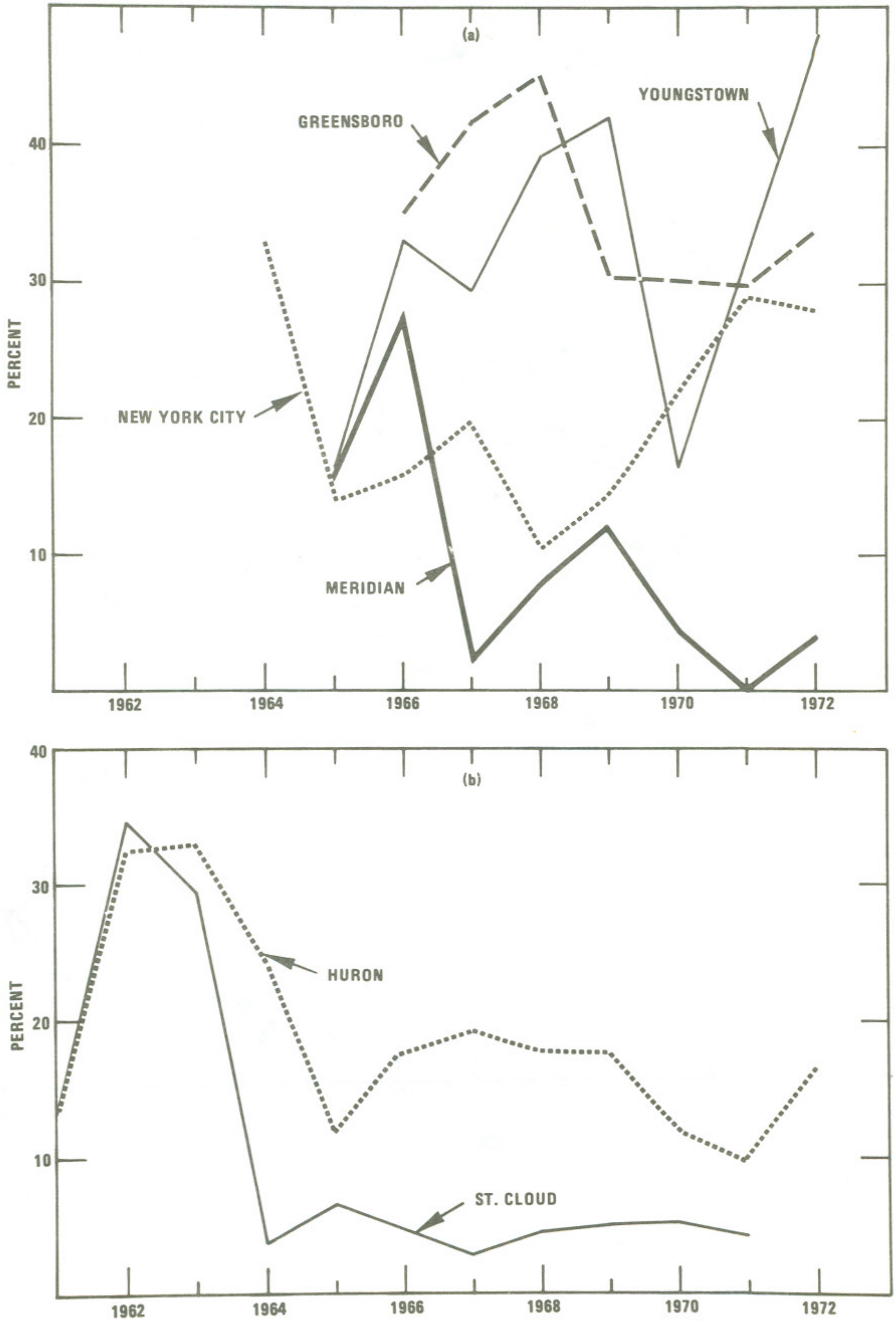


Figure 16. Frequency distribution of monthly average B_{500} for (a) $B_{500} < .081$ and (b) $B_{500} < .041$.

from ML. The focus of the project, under the direction of Professor Raymond Viskanta, is to include accurately the radiative effects of atmospheric pollutants in a time dependent model of an urban atmosphere.

A one-dimensional numerical model was completed during FY 1973 and detailed reports have been published (Bergstrom and Viskanta 1973a, 1973b, 1973c, 1973d, 1973e). In general, the model showed that pollutant aerosols attenuate solar radiation and thereby reduce the daytime surface temperature. At night, absorption and emission of thermal (infrared) radiation by gaseous and aerosol pollutants raise the surface temperature. The nocturnal warmer surface temperature decreased the stability of the atmosphere causing lower maximum pollutant concentrations from low-level sources. The cooler daytime surface temperatures only slightly reduced the instability of the atmosphere and only slightly affected pollutant concentrations in the planetary boundary layer.

Recently, the emphasis of this project has been toward extending the model to two dimensions. The model predicts the time dependent wind velocity, temperature, humidity, and pollutant concentration profiles. Advection, turbulent diffusion, radiative transfer, and radiative participation of pollutants are being accounted for. Surface and elevated pollutant sources are considered but chemical reactions of the pollutants are neglected. The model is now being tested and run on the NCAR CDC 660 computer. It is anticipated that a report on the results of the two dimensional model will be available next fiscal year.

3.2.3 Atmospheric aerosol characteristics from radiation observations

Dr. Glenn Shaw of the University of Alaska has been working on the problem "On the Relation Between Circumsolar Sky Brightness and Atmospheric Aerosols," under EPA Grant No. 80113.

The objective of the study is to use measurements of the intensity of scattered radiation in the sun's aureole to deduce the aerosol particle size distribution and other characteristics of the atmospheric aerosol. Measurements have been made in Alaska with two instruments: (1) a photoelectric coronameter to measure the intensity of the solar aureole at angles of 1.2° and 6.2° from the sun; and (2) a direct sun photometer to measure the sun's irradiance in several narrow wavelength regions. The photometer is also used to measure sky brightness in the sun's vertical and horizontal planes. A final report is expected in FY 1975.

3.2.4 Urban radiation

Plans were completed for the solar radiation measurement program in the St. Louis RAPS monitoring network. Four stations will be instrumented with three pyranometers (to measure direct and diffuse radiation) and a pyrheliometer (to measure direct beam only). One pyranometer will have a clear filter, one will have a 3950 Angstrom cutoff filter. The pyrheliometers, which are positioned on equatorial mounts to track the sun, will have a filter wheel which automatically sequences through a series of cutoff filters (clear, 3950, 4750, 5300, 5700, 6300, 6950, and 7800 Angstroms) at one minute intervals.

Two additional stations will have only two pyranometers, one with a clear filter and one with a 3950 Angstrom cutoff filter. It is anticipated that the RAPS monitoring network will become operational during fiscal year 1975.

4.0 HIGH SURFACE OZONE PROBLEM

During fiscal year 1974 high surface ozone concentrations began to be observed in non-urban areas and in some urban areas, and explanations were sought for the observed values. The sudden recognition of a high ozone problem was the result of an increased sampling network. High ozone values were reported from many parts of the United States, including Florida, New England, and the Chicago area. ML initiated a number of efforts to assist in attempting to find reasonable explanations for the observed values.

4.1 High Ozone Concentrations in Florida

The EPA Office of Air Quality Standards and Planning, and the EPA Regional Office, Atlanta, are being assisted with an attempt to trace air movements in order to determine the source of occasional high ozone concentrations in Florida. It is necessary to know whether or not local traffic control will alleviate the problem. So far it seems that some ozone is locally produced from automobile exhaust precursors, some has been traced from other Florida cities, and some seems to come from sources outside of Florida. The Air Resources Laboratory, NOAA, is assisting with this effort by making available a new computer program and data bank for computing trajectories over long distances.

4.2 Comments on High Surface Ozone Concentrations

Recently high surface ozone concentrations have been observed in rural areas remote from urban centers. These values have at times exceeded the national ambient air quality standard. As part of an examination of this problem, and internal review was prepared of the possible natural sources of high ozone concentrations. The review encompassed possible mechanisms for bringing ozone down from the stratosphere, formation during lightning discharges, and near-surface chemical processes.

As a consequence of the dearth of data and specific studies, only highly tentative conclusions could be drawn:

(1) The stratospheric contribution appears to consist of three parts:
   (a) Direct transport of ozone downward through the jet stream region behind strong cold fronts resulting in very high surface values.
   (b) Slow downward diffusion and transport of ozone injected into tropospheric anticyclones resulting in slightly raised surface ozone values.
   (c) Downward transport of ozone, previously injected into the

upper troposphere, by convective activity resulting in moderately high surface ozone concentrations.

(2) Lightning contributes only brief small rises in the ozone concentration.

(3) Chemical reactions may make significant contributions over a period of time. This needs more exploration.

Any single high surface ozone event can be the result of any one or combination of the above mechanisms.

4.3 1971 Summer Study of Ozone at 33 Cities

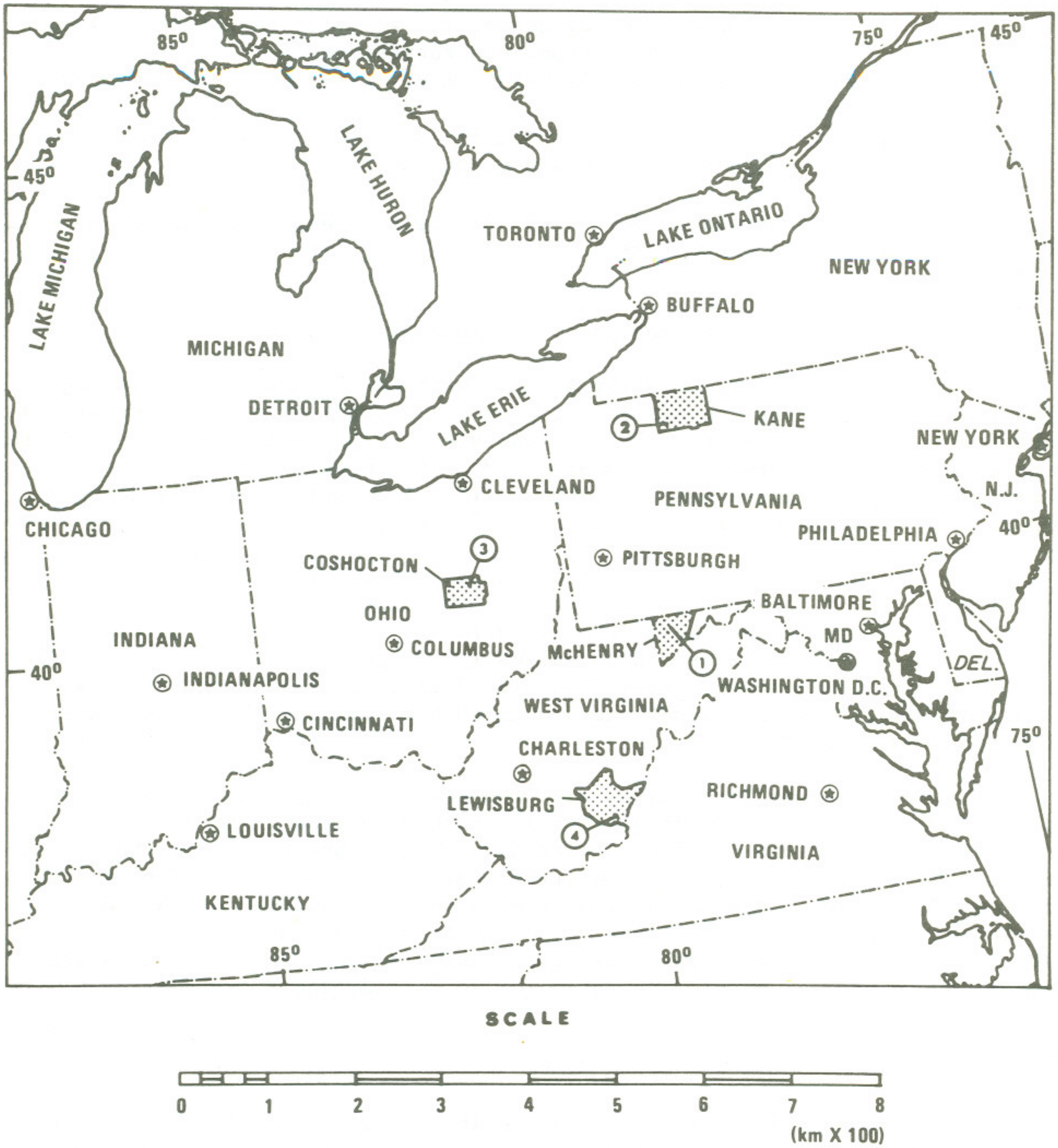
At the request of the Quality Assurance and Environmental Monitoring Laboratory, an internal report was prepared on a study of ozone observations obtained during the summer of 1971 in the vicinity of 33 cities in the middle and eastern parts of the United States. Hourly concentrations of ozone were measured by the chemiluminescent method. The sites were located generally about 8 km from the estimated area of heaviest traffic.

The frequency distributions of the hourly concentrations were obtained. An examination of the 50th percentile concentrations shows a band of high values ($\geq$0.02 ppm) extending diagonally across the country from Rochester, New York, to El Paso, Texas. High values ($\geq$0.10 ppm) in the 99th percentile are found in the northern states from Wisconsin through Illinois, Michigan, Indiana, Ohio, Kentucky, and Pennsylvania to New York and along the Texas-Louisiana Gulf Coast.

The ozone values were paired with the corresponding hourly wind direction and speed for the individual cities. Generally, the study showed the highest concentrations of ozone occurred when the winds blew from the direction of the center of the city. Nevertheless, there were still cases where this was not true. These situations remain to be adequately explained. A closer examination of four cities--Omaha, Nebraska; Milwaukee, Wisconsin; New Orleans, Louisiana; Rochester, New York--suggests the observed high values may be due either to local circulation or to long-distance transport.

4.4 Non-Urban Ozone Investigations

With meteorological support, EPA continued and intensified investigations designed to determine the cause and extent of non-urban concentrations of ozone (O_3) which have exceeded the one-hour National Ambient Air Quality Standard (NAAQS) of 160 $\mu g/m^3$ (0.08 ppm). In the summer of 1973, sampling was conducted at four widely separated sites (fig. 17) in the eastern U. S. to determine how widespread were the levels of high non-urban O_3 (Johnston 1974). The frequencies with which the O_3 NAAQS were exceeded varied from 15 to 37 percent of the hours during this study. The diurnal variation of the average hourly O_3 concentrations at the four sites is shown in figure 18. A meteorological analysis is in progress to correlate these O_3 levels with National Weather Service upper air and surface observation data. The objective of this analysis is to determine the significance of upwind trajectories,



STATION NO.	TOWN	COUNTY
1	McHenry	GARRETT
2	KANE	McKean
3	COSHOCTON	COSHOCTON
4	LEWISBURG	GREENBRIER

Figure 17. Ozone and ozone precursor monitoring stations.

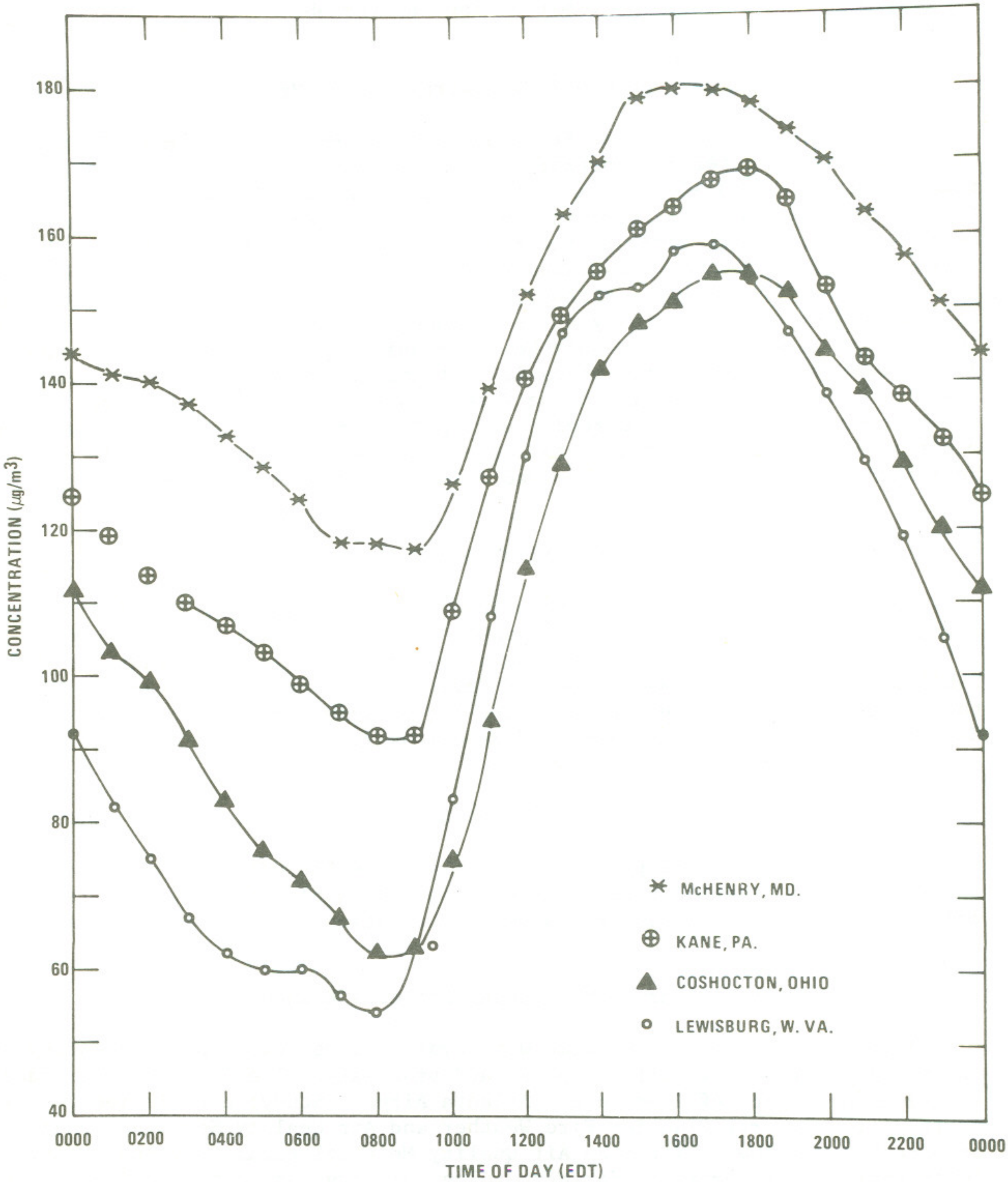


Figure 18. Mean diurnal ozone concentrations at selected non-urban sites from June 26 to September 30, 1973.

spatial variations of relevant meteorological variables, and frontal passages.

4.5 Background Ozone Concentrations on Mt. Sutro

Under a grant to San Jose State University, Professor Kenneth P. MacKay is attempting to determine "background" O_3 concentrations based on O_3 and CO measurements on a 737-foot broadcast tower, whose base is at 830 feet above MSL, near the top of Mt. Sutro in San Francisco. The study will also use meteorological measurements on the tower that are supported by the National Science Foundation. The measurements will also be used to study the vertical exchange processes and the destruction of O_3. The basic premise for the study is that O_3 may occur naturally or as a consequence of anthropogenic emissions, but the latter will most commonly be accompanied by CO emissions. An extremely interesting aspect of the study is that the upper part of the Mt. Sutro tower will very often be within the intense subsidence inversion layer that occurs persistently over the region during the summer. By June 1974 the ozone monitors had been tested and installed on the tower. The CO monitors will be installed in fiscal year 1975, and data collection/analysis will begin.

5.0 TECHNICAL ASSISTANCE

ML has both a research and technical assistance mission. To fulfill the technical assistance mission ML personnel are assigned to six EPA Regional Offices, the Office of Air Quality Planning and Standards, the Human Studies Laboratory, the Quality Assurance and Environmental Monitoring Laboratory, the Office of Manpower Development, and the National Environmental Research Centers in Las Vegas, Corvallis, and Research Triangle Park.

5.1 General

Technical assistance provided to the various EPA offices covered the entire range of meteorological services from the application of dispersion models to environmental impact statement evaluation to the provision of expert testimony.

5.1.1 Technical Assistance - ML Special Projects Branch

A considerable amount of time was devoted to reviewing and commenting on technical reports, scientific papers, and proposals. The Chief of the Branch served as a project officer on the Atlanta Airport Study; contributed to the draft of the Federal Plan for Fire Weather and Air Quality Services being prepared by the Subcommittee on Air Quality Meteorological Services of the Interdepartmental Committee for Meteorological Services of the Office of the Federal Coordinator; gave meteorological input to scientific summary reports being written by the Office of the Director, NERC/RTP on specific elements or compounds such as chromium and nitrates; and prepared and presented a paper at the 2nd Joint Conference on Sensing of Environmental Pollutants, December 10-12, Washington, D. C.

Some technical assistance was provided on legal or enforcement problems. Six wind systems were loaned to Federal Judge Miles Lord and two were loaned to the EPA Minnesota-Wisconsin District Office for the Lake Superior Asbestos Study. Dispersion estimates were made for the International Paper Co., Ticonderoga, N. Y., and advice was provided to the Office of Technical Analysis Office of Enforcement and General Council, at a meeting in New York City between EPA, New York State, and the paper company representatives. Further assistance has been given to the Enforcement Office, EPA Region VII, Kansas City, Mo., with the review and evaluation of a technical report on the American Refining and Smelting Co. smelter at Glover, Mo.

5.1.2 Support to EPA Regional Offices

NOAA meteorologists are assigned to the EPA Regional Offices in Boston, Philadelphia, Atlanta, Denver, San Francisco and Seattle. There are ten Regional Offices altogether to which ML provides technical assistance as required.

Regional Offices in New York, Chicago and Dallas have EPA personnel with some meteorological capability; however, the Kansas City office is without any local meteorological support.

A Regional Meteorologist provides for all of the meteorological needs of the EPA Regional Office including advice and technical assistance given to state and local control agencies. He assists with plume rise and dispersion estimates from stationary and mobile sources, mathematical modeling, meteorological data, evaluation of air quality data, and air pollution forecasting. He also plays a role in air pollution episode response and in accidental emergencies. Further, he reviews and comments on legal or regulatory material pertaining to meteorology and serves as an expert witness as necessary. Some highlights of the activities of the six NOAA meteorologists follow:

Boston (Region I)

Advised on dispersion modeling for fuel switching at power plants; is a member of Regional Power Plant Siting Committee; and reactivated the low-level sounding program at M.I.T. campus under State sponsorship.

Philadelphia (Region III)

Prepared impact statement for a sludge incinerator in Washington, D. C.; directed ambient air monitoring in the vicinity of beryllium sources; is a member of a Hearing Panel for evaluation of State implementation plans; is the meteorological advisor for three contracts - SO_2 modeling of Allegheny County; wind tunnel modeling of Clariton Coke Works, Clairton, Pa., and particulate monitoring and modeling of southwest Pennsylvania; reviewed EPA transportation control plan for oxidants; and is a member of the tall stack subcommittee of the Governor of Pennsylvania's Committee on energy Resources.

Atlanta (Region IV)

Has modeled TVA power plants; prepared air quality analysis for the vicinity of a new Federal Office Building, Atlanta (internal report); evaluated the Georgia control stategy (report of Air Programs Office, EPA Region IV); gave meteorological support to ozone monitoring studies; assisted the State of Georgia in efforts to establish low-level sounding program in Atlanta; and assisted with refinement of the State capacity for episode response.

Denver (Region VIII)

Is the meteorologist for the Northern Great Plains Resources Program; has modeled all the smelters in the Region; provided special consultation on rough terrain modeling; and is advisor on environmental impact statement for Salt Lake City International Airport.

San Francisco (Region IX)

Has modeled indirect sources (Air Quality Analysis for Yerba Buena Center Project, and Oakland Shopping Center); evaluated oxidant trends in California, evaluated the impact of the Navajo Power Plant; modeled a copper smelter, McGill, Nev., and evaluated transportation plans for San Diego.

Seattle (Region X)

Is a member of the climatological committee of the Pacific Northwest River Basin Commission; was advisor during an air pollution episode at Kellogg, Idaho, associated with smelter operations; is advisor on Fairbanks, Alaska, episodes causing high carbon monoxide levels during winter inversion situations; and is reviewer of traffic control plans for Seattle which include re-establishment of daily low-level soundings in the Seattle area.

5.1.3 Tall stacks

Considerable assistance was given to other EPA elements, Regional Offices, and state agencies in analyzing the impact of pollutant emissions from tall stacks. The Ohio Attorney General's Office was provided with meteorological expertise for State adjudicatory hearings on SO_x. A meteorologist assisted in preparation for the hearings, cross-examination of witnesses and review of testimony. Region IV was assisted in determining allowable emission levels for TVA power plants and for power plants in Georgia. Considerable effort was devoted to determining the need for flue gas desulfurization or low sulfur fuel versus the use of tall stacks and supplementary control systems. The Division of Stationary Source Enforcement and other Regional Offices were assisted with evaluation the impact of major power plants in preparation for legal actions.

Significant efforts have been devoted to evaluation studies of plume behavior and ground level concentrations around several power plants located in the southwestern United states. The plants are striving to avoid compliance with a requirement to achieve 70 percent control of SO_x emission. Aircraft monitoring is being used to show that such stringent control is not required.

5.1.4 Supplementary Control Systems (SCS)

Meteorologists took an active part in the development of EPA proposed regulations on supplementary control systems. Such control systems rely heavily on an ability to understand and forecast the meteorological conditions that might cause an islolated major pollutant source to violate the National Ambient Air Quality Standards, and to reduce pollutant emissions at those times. An acceptable SCS is based on (1) field studies, (2) timely ambient measurements, (3) mathematical models, (4) meteorological forecasts, and (5) technical experience.

The development of these regulations has been supplemented by two contractually supported efforts. One (EPA 1973b) involves the development of a methodology for analyzing the reliability of an SCS and the application of that methodology to hypothetical and case study systems. The second (EPA 1974b) is the development of a guideline for evaluation of a proposed system.

In a related effort a study was undertaken to determine if fuel-switching on a monthly or seasonal basis may be used in addition to or in lieu of an SCS at urban power plants in the northeast. On the basis of seasonal distributions of episode days, area source SO_2 emissions and measured ambient concentrations, it was determined that spring and summer are the best times for such power plants to burn high sulfur fuel; a lower risk of excessive ground-level SO_2 concentrations occurs during those seasons in northeastern cities.

5.1.5 Denver air pollution study

Tne NERC/RTP Chemistry and Physics Laboratory is being assisted with the analysis of air pollution data collected during a special field study of Denver, Colo. Air Pollution sometimes appears north of the city as a "brown cloud" that flows back to overspread most of the river basin occupied by the city. Wind direction and speed data are available from a number of points in and around the city. Local trajectory analyses are being attempted, but the wind stations are too sparse for a definitive analysis.

5.1.6 Atlanta airport study

The Chief, Special Projects Branch, served as a joint project officer with Mr. Roy Evans, EPA NERC/Las Veges, on the FAA/EPA study at the Atlanta International Airport to test the effect of reducing jet aircraft emissions during taxi-in and taxi-out. Air monitoring and meteorological observations were conducted by the Geomet Corporation. Results are reported in MacWaters et al. (1974).

Although a maximum hourly reduction of about 15 percent occurred in the aircraft emissions, it was not possible to detect a statistically significant reduction in air quality levels that could be attributed to the emissions control procedures. A valuable source of detailed data relating to aircraft emissions, meteorological conditions, and air quality levels is available for future model validation studies.

5.1.7 Air quality maintenance

Guidelines for the analysis of Air Quality Maintenance Areas were prepared. Guidelines (EPA 1974c) for the review of the effect of indirect sources, e.g., shopping centers, sports stadiums, on ambient air quality relied heavily on the use of a line source model for estimating the impact of traffic queues. Meteorologists contributed to the correct use of this model and the proper input of data. New sources evaluation guidelines (EPA 1974d) were prepared under contract. These guidelines are used to evaluate the individual impact of new sources once their location and design characteristics are known. Guidelines (EPA 1974e) for the application of atmospheric simulation models describe basic assumptions and limitations, input data, types of estimates, applicability with regard to pollutants and sampling times, and calibration of the simpler models for various pollutants and sampling times. These guidelines are used to determine whether (1) anticipated growth in an area will cause the National Ambient Air Quality Standards to be endangered in 1985 and (2) a given maintenance plan will allow standards to be met. An analysis guideline (EPA 1974f) enumerates key elements in the analysis and projection of future air quality levels. This guideline provides a framework for other guidelines concerned with monitoring, simulation models, and emissions projects.

5.2 Monitoring

A significant portion of the technical assistance provided to EPA is the provision of air quality and meteorological data monitoring advice, instruction, and installation.

5.2.1 Monitoring Requirements

To assure adequate air quality information is available to judge compliance with air quality standards in 1975 and beyond, EPA promulgated regulations specifying minimum monitoring networks that must be in operation by July 1974. Gaps in the required networks have become apparent leading to the preparation of revisions to the regulations. Meteorologists have been active in the preparation of the revisions, particularly those intended to apply to non-urban monitors for ozone and monitors placed around point sources. The former monitors are needed to determine the impact of long-range transport of photochemical pollutants on high ozone levels in non-urban areas. Highest ground-level concentrations resulting from emissions from a point source are sensitive to meteorological and topographical factors, such that the locations of monitors, the number of samplers, and sampling frequencies require complex meteorological judgments. General requirements for minimum network design are to be specified in the revised regulation.

5.2.2 Smelter ambient air monitoring project

Wind direction and speed data have been collected for a study of the sulfur dioxide concentrations in the vicinity of 12 copper smelters in the Rocky Mountain area. Spot checking and correction of these wind data were accomplished in a routine quality control program through November 1973, when the operation of the project was reassigned to the regions and states involved.

5.2.3 Los Angeles catalyst study

Advice has been given on the placement of sampling and wind equipment for 24-hour and 4-hour observations of sulfates and total sulfur near a Los Angeles freeway. Over a 3-year period interest will be focused on the effects of catalysts in automobile exhaust systems on the production of sulfur compounds. Wind data collected will be analyzed as they become available to determine when the sampler is downwind of the freeway.

5.2.4 Asbestos air pollution monitoring

Trips were made to locate, set up, and operate wind equipment for air sampling studies. Two trips were made to Duluth, Minn., where asbestos fibers could become airborne during the processing and handling of iron ore. Two trips were also made to Morrisville, Vt., where asbestos is mined and processed. Another trip was made to Amber, Pa., where asbestos is processed into finished products.

The wind data for each of the three asbestos studies have been analyzed to determine which samples could be considered clean, or background samples, under the changing wind conditions.

5.2.5 Community Health Environmental Surveillance System (CHESS)

Meteorological support was furnished to the Human Studies Laboratory for the installation of temperature-dew point and wind instruments at seven locations around the Los Angeles Basin as part of the Community Health Environmental Surveillance System (CHESS) operating in that urban area. The meteorological data are recorded at 5-minute intervals along with 17 pollutant concentrations required for statistical analysis of the human health effects reported in the seven communities under study. Of particular concern is the relationship of high relative humidity to sulfate particle concentrations and to the frequency of reported respiratory symptoms. Climatological data from all National Weather Service and Federal Aviation Administration stations in the Los Angeles Basin were obtained from the National Climatic Center for the CHESS data period and special wind rose and relative humidity summaries were produced for inclusion in the CHESS statistical analysis.

5.2.6 Refinery study using monitoring aircraft

A meteorological technician was provided to supply surface wind and pilot balloon data to an experimental study sponsored by the Office of Air Quality Planning and Standards for determining the feasibility of using a monitoring airplane to quantify the rate of emissions of hydrocarbons from a whole refinery. The Texaco refinery near Lawrenceville, Ill., was used for the study and the period of observation was June 11-28. The aircraft sampled cross sections of the plume at various distances from the source and the concentrations measured were used to approximate total emissions. Flight operations were conducted by Washington State University, with personnel from The Research Corporation of New England observing, in order to plan for future similar observations at other refineries.

6.0 International Affairs

ML personnel have been active in many international activities. The Laboratory has served as host for numerous visitors from other nations and there has been at least one visiting scientist with the ML at all times.

6.1 North Atlantic Treaty Organization (NATO)/ Committee on the Challenges of Modern Society (CCMS)

Mr. K. L. Calder (Chairman), Mr. L. E. Niemeyer, Dr. D. G. Fox, Dr. K. H. Jones and Mr. H. H. Slater represented the U.S. Environmental Protection Agency at the Fifth Meeting of the Expert Panel on Air Pollution Modeling, held 4-6 June 1974, at the Danish Atomic Energy Commission Research Establishment, Ris, Roskilde, Denmark. In an attempt to improve the communications between the designers of air qualtiy models and the users or decision makers in the air quality management process, a 1 1/2-day "modeler-user workshop" was included at the Fifth Meeting. The remaining period was devoted to the presentation of papers and to discussions on five technical items relating to air quality modeling. These were the development of a common data base for air quality modeling, the validation of air quality simulation models, short-term and real-time modeling, the modeling of complex topographic effects, and recent developments in air quality modeling.

Like several of the earlier meetings of the NATO/CCMS Panel On Modeling, the Fifth Meeting invited wide participation, to encourage a maximum exchange of information on a broad international basis. Sixty-seven individuals attended the meeting, representing fourteen countries as follows: U.K. (4), Spain (1), Norway (2), Sweden (3), Denmark (20), Italy (4), France (2), The Netherlands (5), Belgium (3), Switzerland (2), W. Germany (8), Canada (2), Turkey (1), U.S.A. (10). Invitations to participate had also been sent to the U.S.S.R., Hungary, and Japan. The Proceedings of the Fifth Meeting have been published as NATO/CCMS Air Pollution, No. 35, August 1974. At the May 1974 NATO/CCMS Plenary the delegates from the NATO member countries agreed that the activities of the Panel on Modeling should be continued, and the Federal Republic of Germany, as one of the original copilot countries, agreed to introduce a follow-up initiative on air quality modeling and assessment at the next CCMS Plenary, for continuation of the joint efforts for at least another two years. The 2-year period will be used primarily to improve communications and provide closer contacts between the modelers and the users, through exchange of ideas, more complete discussion of users' needs, and demonstration of various modeling techniques.

6.2 Cooperative U.S.-French Study of the Dispersion of Effluents from the Conemaugh, Pa., Power Plant

A cooperative study between the French Meteorological Service and the ML was begun in 1970 to compare the results of field measurements of plume diffusion in complex topography with the results of measurements made in the water channel. ML made measurements of meteorological conditions, plant output, and concentration fields associated with the Conemaugh power plant in the vicinity of Johnstown, Pa., during the spring and fall of 1970 and 1971 (Schiermeier, 1972a, b). Meteorological and plant output data for selected days with near neutral stability and topographical maps were supplied to the French Meteorological Service. It constructed a topographical model at a scale of 1:18000 and made some exploratory runs in its water channel using its colorimetric technique. This technique involves coating the surface of the model with pH-sensitive paint. Hydrochloric acid is released from model stacks and diffuses to ground level, thereby changing the color of the surface. Each color change, blue to green to yellow to orange to red, indicates a change of an order of magnitude in concentration. This, at the end of a run, ground level concentrations are vividly portrayed.

One of the wind directions studied in the exploratory runs corresponded roughly to field data. Comparisons between model and field results, however, were difficult for several reasons: (1) most of the field samplers had been placed outside the range of the topographical model; (2) helicopter measurements of ground level concentrations were accurate to only 1 pphm (27 $\mu g/m^3$); and (3) the mean wind direction shifted somewhat during the field measurements. The few samplers located within the range of the model gave results quite different from those measured in the water channel. In view of the difficulties, the comparisons must be judged inconclusive.

A later study allowed a more detailed comparison. Meteorological parameters measured on October 28, 1970, over the Conemaugh area showed that the period from 1030 to 1230 hours could be considered as nearly ideal. The temperature profiles were very close to adiabatic and the mean wind profiles were unchanging. All the "bubblers" (SO_2 measuring instruments) were operating under or within the plume, and plant output conditions remained constant. Although the time of operation as well as the averaging time varied slightly from station to station, average values were calculated for the approximate 2-hour period. According to the French Meteorological Service, the corresponding averaging time in the model was 3 hours, 45 minutes. The table below compares the results.

Bubbler Number	Bubbler Concentration ($\mu g/m^3$)	Model Concentration ($\mu g/m^3$)
G26	81	$\chi > 100$
G36	20	$10 < \chi < 100$
G8	101	$10 < \chi < 100$
G25	95	$\chi > 100$
G16	61	$10 < \chi < 100$
G35	14	$1 < \chi < 10$
G6	59	$1 < \chi < 10$
G1	0	$1 < \chi < 10$
G27	40	$< \chi < 100$

Strictly speaking, only three of the nine measurements are within the bounds predicted by the model. Allowing for the inaccuracies in the bubbler readings of $\pm$ 1 pphm ($\pm$ 27 $\mu g/m^3$), eight of the nine measurements are within the bounds. Slight changes in wind direction can also change the concentrations drastically. For example, a 10° rotation of the wind might result in concentration changes at G36 from χ < 100 $\mu g/m^3$ to zero.

In summary, whereas the comparisons shown here neither prove nor disprove the validity of the water channel simulation technique, they do lend plausible support.

The French company Securipol, at Evian, has contructed a large water channel, with provisions for producing stratified flows, to study similar types of problems using the colorimetric technique of the French Meteorological Service. Securipol is eager to continue the Conemaugh study, particularly under stratified conditions. ML is presently preparing the data for transmittal to Securipol.

6.3 Miscellaneous International Activities

Dr. Douglas G. Fox served as a member of the U.S. Delegation to the US-USSR Joint Working Group on Cooperation in the Field of Air Pollution Modeling, Instrumentation, and Measurement Technology. He attended meetings in the Soviet Union in October 1973 and June 1974.

Dr. Ralph I. Larsen, serving as a WHO Consultant, visited Denmark and the Silesian region of Poland in October 1973.

Dr. Everett C. Nickerson, in October 1973, presented a paper by Nickerson and Smiley at the Nordic Symposium on Urban Air Pollution in Valback, Denmark. He also presented a paper by Dr. D. G. Fox, "The Mathematical Simulation of Air Quality," at the Symposium on the Atmospheric Boundary Layer in Mainz, Federal Republic of Germany.

George C. Holzworth submitted a paper to the WMO Working Group on the Applications of Meteorology and Climatology to Environmental Problems.

A number of scientists have spent time with ML as visiting scientists during fiscal year 1974.

Dr. Werner Klug, Federal Republic of Germany spent August-October 1973 with ML where he initiated a study of the dispersion of sulfur dioxide from tall stacks.

Mr. Knut Gronskei, Norway, spent November-December 1973 with ML securing material for presentation at the fifth meeting of the NATO/CCMS Expert Panel on Air Pollution Modeling. He returned in June 1974 to begin a 6-month stay to study current and future needs for air quality simulation models.

Mr. Wojcieck Raczynski, Poland, spent July 1973 studying the applications of climatology to air pollution problems.

Dr. F. Barry Smith, United Kingdom, spent 6 weeks in October-November 1973 with ML for studies of mesoscale meteorological modeling and parameterization schemes being developed for the planetary boundary layer. He prepared a review paper on atmospheric turbulence during his stay.

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9.0 METEOROLOGY LABORATORY STAFF
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