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

Fiscal Year 1973 Summary Report of Meteorology Laboratory Support to the Environmental Protection Agency

CHARLES R. HOSLER
HERBERT J. VIEBROCK, Editors

Air Resources Laboratory
RESEARCH TRIANGLE PARK, N. CAROLINA
September 1974

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA Technical Memorandum ERL ARL-45

FISCAL YEAR 1973 SUMMARY REPORT OF METEOROLOGY LABORATORY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

Charles R. Hosler
Herbert J. Viebrock, Editors

Air Resources Laboratory
Research Triangle Park, North Carolina
September 1974

UNITED STATES DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

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Wilmot N. Hess, Director

DISCLAIMER

PREFACE

Effective communication between individuals or groups is often a difficult process. This is especially true with new problems and new research since many questions must initially be left unanaswered. In this regard, periodic work summaries play an important role, not only as valuable information sources, but also as management assessment aids.

The work reported herein was funded by the Environmental Protection Agency (EPA) under agreement EPA-IAG-113(d) between the EPA and the Air Resources Laboratories (ARL), National Oceanic and Atmospheric Administration (NOAA), dated April 20, 1973. The Meteorology Laboratory (ML) 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 of prime importance 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 with 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. Both EPA and NOAA personnel are assigned to the ML.

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

ABSTRACT

During Fiscal Year 1973, the Meteorology Laboratory, Air Resources Laboratory, provided research and operational meteorological support to the Environmental Protection Agency (EPA). Operational support was provided to the Office of Air and Waste Management, the EPA Regional Offices, and other EPA components. This included the response to emergency requests for assistance in accident emergencies; the review of the meteorological aspects of environmental impact statements, requests for variances, and grant and contract proposals; the application of dispersion models; and the preparation of staff dispersion studies and evaluations.

Research activities were divided into two general areas: model development and application, and climatic analysis and geophysical studies. Within the model development area, models developed or under development include photochemical air quality simulation models, highway dispersion model, climatological dispersion model, maximum 24-hour model, an urban meteorological-pollutant model, real-time air quality simulation model, point source models, street canyon dispersion models, and long-distance transport model. Six models have been placed on the User's Network of Applied Models of Air Pollution (UNAMAP).

Climatic analysis and geophysical studies cover a wide range of problems. These include: the analysis of climatological data pertinent to the preparation of dispersion estimates for large single point sources;

the development of an objective technique for determining hourly mixing heights; the conduct of atmospheric turbidity and urban radiation studies; and the investigation of atmospheric pollutant removal processes.

Meteorology Laboratory activities involve all aspects of air pollution meteorology.

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FISCAL YEAR 1973 SUMMARY REPORT OF METEOROLOGY LABORATORY

SUPPORT TO THE

ENVIRONMENTAL PROTECTION AGENCY

Charles R. Hosler
Herbert J. Viebrock, Editors

The following brief summaries of meteorological research and other activities present the current status of projects the Meteorology Laboratory is conducting for the Environmental Protection Agency.

Uniterms: Abatement, absorption, aerosol, air pollution, air quality modeling, boundary layer, carbon dioxide, carbon monoxide, chemistry, diffusion, meteorology, mixing layer, model, monitoring, oxidants, particulates, photochemical, plume, radiation, radiometer, regional study, stagnation, sulfur dioxide, turbidity, washout, wind tunnel.

1. INTRODUCTION

Much of the Environmental Protection Agency's (EPA) research and development work in the atmospheric sciences focuses on air pollution meteorology and is conducted by the Meteorology Laboratory (ML). The ML is responsible for both research programs and operational support activities. The ML program can be divided into three major areas: model development and application (chapter 2), climatic analysis and geophysical studies (chapter 3), and operational support (chapter 5).

Within the model development and application area, two significant efforts illustrate the scope of the program. The first project is the development of photochemical air quality simulation models. Three separate transport and dispersion models were developed for reactive pollutants; two of these were "trajectory" models and one was a "grid" model. They are all first generation models, usable for single day, daylight use. Emphasis was placed on the modeling of the chemical reactions occurring in the atmosphere; therefore, the meteorological parameters are part of the model input. The models differ in many aspects, including the kinetic reaction module used. For example, the Pacific Environmental Services "trajectory" model has 33 reactions, while the General Research Corporation "trajectory" model has 16 reactions and the Systems Applications, Inc., "grid" model has 15. Work on a second generation model has begun.

The second project is the development and augmentation of a User's Network of Applied Models of Air Pollution (UNAMAP). It currently consists of six programs. They are APRAC which provides the hourly average CO as a function of extraurban diffusion from automotive sources, in upwind cities, intraurban diffusion from roadway sources, and local diffusion within a street canyon; HIWAY which provides an estimate of highway-related air pollution for receptor locations downwind of at-grade and cut highway sections; CDM which provides the long-term average pollutant concentration; PTMAX which estimates the maximum hourly average ground-level concentration from a single stack as a function of stability and windspeed; and PTDIS which estimates the hourly concentration and up to 24-hour average concentration at up to 30 receptors from up to 25 sources.

Within the climatic analysis and geophysical studies area, work included the analysis of U.S. rawinsonde data to obtain the meteorological data pertinent to the preparation of dispersion estimates for large single point sources; the initiation of an investigation to develop an objective technique for determining hourly mixing heights; and the conduct of studies of atmospheric turbidity and urban radiation. A sample study examined the difference in the radiation budgets between rural and urban sites in the St. Louis, Mo., area. Preliminary evaluation of the data indicates that 6 1/2 percent less total solar energy is received at the urban site than at the rural site.

The ML provides extensive operational support to the various sectors of the EPA, including the Office of Air Quality Planning and Standards, the Human Studies Laboratory, the Quality Assurance and Environmental Monitoring Laboratory, the Air Pollution Training Institute, and the EPA Regional Offices. This support includes meteorological counseling, reviewing, conduct of field investigations, conduct of short meteorological studies, impact statement and implementation plan evaluation, and preparation of meteorological portions of EPA documents and reports.

The three major areas of ML activity are discussed more fully in the remainder of the report.

2. MODEL DEVELOPMENT AND APPLICATION

2.1 Select Research Group in Air Pollution Meteorology

A recent concept within the EPA has been the Select Research Group in Air Pollution Meteorology. This group has been involved in the identification and support of an interdisciplinary group at one university that works under the support of the EPA on long-range problems of air pollution meteorology. About a dozen university groups had submitted proposals for a 5-year program; in May 1972, the Pennsylvania State University was awarded a grant to initiate this program. The grant involves both the Department of Meteorology, under the overall direction of Professor A. K. Blackadar, and also the Center for Air Environmental Studies under the direction of Professor W. J. Moroz. A broad interdisciplinary effort has been organized during the past year around several tasks and subtasks.

2.1.1 Development of Regional Scale Prediction Model

This task relates to the development of a three-dimensional regional meteorological-pollutant prediction model that will consider mesoscale flows with horizontal scale of 200 kilometers (km) and time scales of about 24 hours. The horizontal grid spacing will be 20 km and will cover a square domain 600 km on a side. Development of such a regional model is important in its own right, but it also provides an input to in-house efforts of the ML (see discussion in 2.14 of the Wind and Temperature Prediction Code (WATPC)) to model the smaller scale urban flows. The regional model is being developed by appropriate modification of an earlier three-dimensional hurricane model of Anthes (1972).

2.1.2 Modeling of Exchange Processes

This task is to provide an economical parameterization scheme for incorporating the effects of subgrid-scale fluxes into the regional model. The higher order closure schemes discussed for the preceding task do not appear to be applicable on a regional scale, although they will play an important role for the urban-scale model of WATPC. The parameterization scheme which has been investigated so far is equivalent to a turbulent diffusivity function in which the value of K is determined by a self-regulating procedure incorporated into the regional model.

2.1.3 Higher Order Approximations of Turbulent Transports

This task aims to develop a model for subgrid-scale turbulent transport of pollutants and other properties that is superior to K-theory and applicable to microscale modeling of the urban environment. The method is based on closure approximations for the basic governing turbulence equations. During the past year, a general formalism was devised that permits unambiguous generation of successive closure approximations to the third moments, while first and second moments are carried exactly. The work is described in greater detail in a paper by Lumley and Khajeh-Nouri (1973) that was presented at the Second IUGG-IUTAM Symposium on Turbulent Diffusion in Environmental Pollution in April 1973 at Charlottesville, Va.

2.1.4 Interpretation of Remote Sensing Observing Systems

Theoretical studies have been made relating to the interpretation of acdar sounding signals (acoustic radar) and the extent to which changes in the vertical wind and temperature profiles produce identifiable signatures in the received acoustic signals. This research is being undertaken in the belief that acdar has the greatest potential for providing indirect sounding data useful for temperature and wind profiles related to air pollution. Methods will be explored for directly integrating acdar profile data into an operational regional scale prediction model such as the one being developed under work described in 2.1.1.

2.1.5 Meteorological Effects on Air Pollutants

This task is to establish quantitative mechanisms for the changes of the physical characteristics of particles emitted from an urban source as these particles move downstream. Particle releases from the Pittsburgh, Pa., urban complex have been selected for examination and tracking because they contain a natural tracer from the steel industry located in the area. The study will eventually lead to improved modeling of particulate pollutants.

2.1.6 Atmospheric Removal Processes for Air Pollutants

This task is to study natural processes by which pollutants can be removed from the atmosphere. These processes include removal by rain and snow and/or chemical reactions, and also removal resulting from interaction with the earth's surface in its various forms (such as water, mineral, and vegetation). In due course, crude mathematical models will be developed for these removal processes so that they may be incorporated into the overall air pollution model. During the past year, emphasis was placed on an extensive literature survey.

2.1.7 Airborne Air-Chemistry Observing System

This task supplements the Pennsylvania State University aircraft-observing system in the field of air motion (turbulence and Doppler wind) and air pollution sampling; and it is being coordinated with the needs of the EPA Regional Air Pollution Study (RAPS) in the St. Louis area. Field work with the aircraft has included special flights to test and calibrate the motion-sensing system and to determine its capabilities for vertical gust measurements and for other derived quantities such as heat and momentum fluxes that are important in the boundary-layer parameterization studies. In addition, a comprehensive (within the limitations of aircraft weight and power) air-chemistry package that emphasizes aerosol measurements is being assembled.

2.2 Modeling of Atmospheric Turbulence and the Dispersal of Atmospheric Pollutants

The method of so-called invariant modeling, developed by Dr. C. duP. Donaldson (Aeronautical Research Associates of Princeton (N.J.), Inc.), was briefly described in the Fiscal Year 1972 Summary Report (NOAA, 1973). From this earlier application of the method to atmospheric dispersion, it appeared that a powerful new technique might be successfully developed for computing the dispersive power of the atmosphere under a wide variety of meteorological conditions. During the past year, these studies were extended to include analysis of diffusion:

(a) in an unstable surface atmospheric layer capped by a temperature inversion;

(b) from a point source in three spatial dimensions; and

(c) in the Ekman spiral of the planetary boundary layer.

In addition, a comprehensive monograph was prepared that provides a connected, detailed account of the derivation of the appropriate mathematical equations for the model of atmospheric turbulence and transport. The material for this monograph was presented by Dr. C. duP. Donaldson as part of a workshop on micrometeorology, sponsored by the American Meteorological Society in August 1972. The method of invariant modeling by way of second-order closure of the turbulence equations was also developed and applied to chemical reactions occurring in a turbulent and inhomogeneously mixed-binary reaction system. Some illustrative computations have been made for a two-dimensional atmospheric dispersion situation where turbulence would have a pronounced effect on the effective rate of chemical reaction. The above work has been reported in the contract reports:

(a) Atmospheric turbulence and the dispersal of atmospheric pollutants: EPA-R4-73-016a, Environmental Monitoring Series, EPA, March 1973.

(b) Derivation of a non-Boussinesq set of equations for an atmospheric shear layer: EPA-R4-73-016b, Environmental Monitoring Series, EPA, March 1973.

(c) A coupled two-dimensional diffusion and chemistry model for turbulent and inhomogeneously mixed reaction systems: EPA-R4-73-016c, Environmental Monitoring Series, EPA, March 1973.

In a new contract that has been placed with Aeronautical Research Associates of Princeton, Inc., the following special tasks are under study:

(1) Inclusion of a predictive equation for length scales in the parameterization. A length-scale prediction equation can be developed from the dynamics of the two-point (spatial) correlation which can be applied to the prediction of arbitrary closure coefficients to improve the reality of the model.

(2) Verification and calibration of the models developed in task (1) by detailed comparisons of the model prediction with such data as have been collected on the turbulence structure of the planetary boundary layer. This verification and calibration will include both conventional terrain types as well as the large-scale roughness of a typical urban area. Both field and wind tunnel data will be used where available.

(3) Verification and calibration of the models developed in task (1) by detailed comparisons of the model prediction with results from comprehensive three-dimensional numerical simulations of the turbulent planetary boundary layer.

(4) The model resulting from tasks (1) to (3) will be applied to predicting the diffusion from an elevated point source for a matrix of the three parameters — surface roughness, surface heat flux, and windspeed — with approximately three values for each. Specific situations simulated thereby will include the source located within and upstream from an urban complex and upstream and downstream from a large body of water.

(5) Development of a simplified version of the invariant models resulting from tasks (1) to (4) for use as a closure scheme

in more complex combined meteorological air quality numerical models currently under development in the ML, EPA. This will consist essentially of finding a best single equation for the turbulent kinetic energy.

2.3 Urban Meteorological-Pollutant Model

Work was continued under contract with The Center for The Environment and Man, Inc. (CEM), Hartford, Conn., to develop further an urban meteorological-pollutant model. The urban boundary-layer model that has previously been described by Pandolfo _et al_. (1971) of the CEM has been modified and used in 40 test runs employing selected data for carbon monoxide concentrations in the Los Angeles Basin. It has been shown that an economical, objective, physically consistent, and precisely specified (though with some arbitrary elements) procedure can be achieved for obtaining and predicting the three-dimensional meteorological fields that are needed. In several of the runs, the input topography, land-water distribution, and other physical characteristics of the underlying surface were varied. The results demonstrate that ready generalization to other regions should be possible. The modeled region was simulated with a relatively coarse (8-mi.) grid spacing. This is in contrast to some other recent air quality simulation models (Sklarew _et al_., 1971; Roth _et al_., 1971) that use a 2-mi. grid spacing, but for which the actual wind velocity field is an input rather than the predicted field. Nonetheless, the temporal and spatial variations of air temperature, humidity, and wind are simulated with an encouraging degree of realism. Temporal and spatial variations of carbon monoxide concentration are also simulated fairly realistically, and it is reasonable to expect improved simulation accuracy if a finer horizontal grid can be used. The above work has been reported in the contract reports:

(a) Tests of an urban meteorological-pollutant using CO validation data in the Los Angeles metropolitan area, vol. I: EPA-R4-73-025a, Environmental Monitoring Series, EPA, May 1973.

(b) Tests of an urban meteorological-pollutant using CO validation data in the Los Angeles metropolitan area, vol. II, Fortran program and input/output specification: EPA-R4-73-025b, Environmental Monitoring Series, EPA, May 1973.

In addition to the above modeling activity, the contract with the CEM was expanded to include development and evaluation of a specific scheme of mesoscale wind-field prediction (Anderson, 1971). The predictive scheme is being evaluated using the available data on wind trajectories for the Los Angeles Basin as estimated both from the surface-wind network and from tetroon trajectory data previously obtained by the Air Resources Laboratory (ARL) of NOAA.

2.4 Validity of the Air Quality Display Model Calibration Procedure

Under a small contract with a meteorological-statistical consultant (Dr. G. W. Brier), a special study was made, based on statistical theory, of the validity of the "calibration procedure" that is frequently used with climatological models of multiple-source urban air pollution. In particular, the validity of the calibration procedure was examined, if the air quality prediction were made for a distribution of pollutant emissions differing from that for which the calibration was actually established. This situation arises in pollution control strategy studies that involve air quality comparisons for various hypothetical emissions distributions and also in long-range planning studies where concern is with the pattern of air quality from future pollution emissions. The analysis is reported in Validity of air quality display model calibration procedure: EPA-R4-73-017, Environmental Monitoring Series, EPA, January 1973.

2.5 Particle-in-Cell Method for Numerical Solution of the Atmospheric Diffusion Equation

During Fiscal Year 1972, under a contract with Systems, Science and Software of La Jolla, Calif., a new particle-in-cell method was developed for the solution of the atmospheric diffusion equation (K-theory). When this method was applied to photochemical air pollution problems that involve chemical reactions in addition to atmospheric transport and diffusion, the chemical kinetics were specified in an Eulerian hydrodynamical framework rather than the more appropriate Lagrangian, thereby introducing errors in the simulation of the chemical reactions. In an extension of the previous contract, work during the past fiscal year was directed toward an appropriate chemical kinetics in a three-dimensional Lagrangian rather than an Eulerian framework.

The two formulations are being illustrated and compared by actual application to selected observations for one day of photochemical pollution in the Los Angeles Basin. Full documentation of the various numerical codes that have been developed, together with a user's manual, will permit immediate utilization of these findings in the photochemical modeling activities of the ML.

2.6 Highway Dispersion Model

The National Environmental Policy Act of 1969 requires that federal highway construction is to be preceded by an impact statement analyzing the effect of the proposed roadway on air quality. In response to this need for methods to provide estimates of highway air pollution, a simple Gaussian plume computer dispersion model for non-reactive pollutants (carbon monoxide) has been developed. This model treats the highway as equivalent to a number of continuous, finite, uniform line sources; it has been given the acronym "HIWAY."

Estimates of highway air pollution can be obtained for receptor locations downwind of at-grade and cut-section highways. To obtain estimates of air pollution concentration for the at-grade highway, each lane of traffic is modeled as though it were a straight, continuous line source of pollution with a uniform emission rate. The process of finding air concentration downwind of a line source entails simple trapezoidal integration of a series of point sources situated along the line source. The distance between these point sources is successively halved until the values of calculated air pollution concentration do not materially change by further reduction of the spacing between these point sources.

To estimate air pollution concentration for each cut-section highway, the top of the cut section is considered to be an area source. This area source is modeled by using a number of line sources at the top of the cut section.

An interactive version of the highway dispersion model has been placed on the EPA User's Network of Applied Models of Air Pollution (UNAMAP) which is in active use by EPA regional offices in evaluating highway impact statements. A user's manual for the model is being drafted.

2.7 Airport Model Validation Project

The Airport Dispersion Model developed for EPA by Northern Research and Engineering Corp. (NREC), Rockville, Md., is now being validated under Contract 68-02-0665 by Geomet, Inc., Rockville, Md. As originally designed, the NREC Airport Dispersion Model simulates line sources, such as the taxiing of an aircraft to the runway, by means of equally spaced point sources located along the line source. In principle, the Aircraft Dispersion Model operates in a manner similar to the model developed by Martin (TRW Systems Group, 1969) once the point sources have been allocated to each line (and also area) source.

For the first phase of the contract period, a network of air quality samplers was established at Washington (D.C.) National Airport. The layout of this network and the instrumentation used is given in table 1. As seen, the primary emphasis was placed on the two non-reactive pollutants, carbon monoxide and particulates. Besides air quality measurements, special meteorological measurements were made including sensing of the temperature structure above the airport by means of a microwave thermosonde. Most data collected were automatically scanned and logged on paper tape for computer processing. At the conclusion of the project, these data will be available on magnetic tape, and a user's manual describing the data will be prepared.

Preliminary efforts of the validation program have been directed toward operating the model with a complete pollution inventory for Washington National Airport and its environs. Modifications to the model being tested are the introduction of more advanced line and area source simulation techniques. In addition, some revision of the aircraft classification system has also been made in the aircraft emissions section of the model. Results of validating the Aircraft Dispersion Model should be available in a final report to be completed early in the next fiscal year.

2.8 Climatological Dispersion Model

In assessing the effect of abatement strategies on the long-term average pollution concentration for nonreactive pollutants, such as sulfur dioxide and particulates, climatological dispersion models have been frequently applied. A Climatological Dispersion Model (CDM) incorporating the concept of the "narrow plume hypothesis" for estimating concentration from area sources, as suggested by Calder (1971), was previously developed and applied to a North Atlantic Treaty Organization (NATO) study of the air pollution conditions of Ankara, Turkey, and St. Louis, Mo. (Zimmerman, 1972).

Table 1. Air Quality Sampling Network at Washington (D.C.) National Airport

Pollutant	Detection principle	Sampling frequency	Monitor site number						
			1	2	3	4	5	6	7
CO	NDIR		x			x	x		x
CO	GC-FID			x	x			x	
NO_2	Colorimetric			x	x			x	
O_3	Chemiluminescence			x	x			x	
HC	Flame ionization			x	x			x	
Particulates	Gravimetric (Hi-Vol)	24 h	x	x	x	x	x	x	x
Particulates	Spot tape	1 h		x	x			x	

This model was applied to 1 year's data for the New York Air Quality Control Region and the results compared with various versions of two other models, the Air Quality Display Model and the Gifford-Hanna Model. A paper, "An evaluation of some climatological dispersion models", was presented and appeared in the Third Meeting of the Expert Panel on Air Pollution Modeling, NATO Committee on the Challenges of Modern Society (Turner et al., 1972).

The computer program for the CDM has been described in a user's guide which details the operation of the model and provides an illustrative sample problem for testing it. The CDM has also been developed in interactive format and has been placed on the UNAMAP.

2.9 Maximum 24-Hour Model

As the result of a pressing need of the Monitoring and Data Evaluation Division to assess the impact upon air quality of a large number of power plants in the Midwest, a computational procedure was devised to aid in estimating the maximum 24-hour concentration that occurs once a year from a single plant emitting from one to six stacks.

Calculations are performed hour-by-hour for each source, using a steady-state Gaussian plume model. The dispersion parameter values are those suggested by Pasquill (1961) and Gifford (1961). Plume rise is determined for each source, using Briggs' plume rise equations (Briggs, 1969). Calculations are made for receptor points at five distances from the source. Based on the individual source, the distances selected generally include the distance of the maximum concentration for critical windspeed for Pasquill stability types A through E. Concentrations are calculated radially about the source for each 10° azimuth. Because the wind direction is reported to the nearest 10°, each hour's wind direction is randomized within the 10° sector by generating a random digit from 0 to 9 and using this digit to add from -4° to +5° to the reported wind direction. Twenty-four-hour average concentrations (from midnight to midnight) are determined for each receptor.

Input to this calculational scheme includes the hourly meteorological data for a representative weather station for a year and the mixing height data (two values per day) for the same period obtained from Holzworth (1964). So far, only data from the year 1964 have been used with this model because this is the only year with wind direction reported to 10° and with all 24 hourly observations readily available.

Output consists of mean annual concentration, maximum 24-hour concentration, and maximum hourly concentration for each receptor. Because this is a steady-state model and because fumigation concentrations are not adequately considered, the hourly maxima may be underestimated. It is assumed that the 24-hour maximum concentration is little affected by fumigation because of the distance and generally short duration of the occurrence of fumigation concentrations.

An interim user's guide for the use of the model was prepared and the program given to the Office of Air Quality Planning and Standards (OAQPS) for its analysis of a number of power plants. It is recognized that year-to-year variations of the 24-hour maximum can be considerable, but lack of hourly data for additional years hampers efforts to investigate this. It is anticipated the model will be documented and made available to users.

2.10 Real-Time Air Quality Simulation Model

In recognition of the need for a versatile short-term (hourly to a day) model for urban areas, primarily for use in episode control, development of a model was initiated. It was recognized that any model useful in episode control would have to be applicable to stagnation situations. Formulation of a stagnation submodule is now underway. This submodule will be incorporated into the overall model structure whenever it becomes available. Development of the stagnation submodule is not only important for the episode uses, but also for estimating the maximum 24-hour concentration once a year in urban areas. It is anticipated that the meteorological conditions which are concurrent with the highest 24-hour concentration annually in urban areas will be light and variable winds with little overall transport, allowing buildup of concentrations in urban air mass.

A steady-state Gaussian plume model is used to estimate concentrations hour-by-hour from point and area sources in urban areas for conditions where a single wind direction, windspeed, and stability class can be chosen to be representative of the urban area.

Emission estimates are made for both area and point emissions. Area sources may be of varying sizes; usually the various side lengths are multiples of the side length of the smallest source area considered. Any arbitrary user coordinate system can be used, provided it is rectangular with major east-west and north-south axes. Emission rates are given for each square. Information for point source locations is given in the same coordinate system as that used for area sources. It must include emission rates as well as stack gas temperature, stack gas velocity, and stack diameter to estimate Briggs' plume rise.

Meteorological input consists of wind direction, windspeed, stability class, and mixing height selected to be representative of the entire urban area for each hour of the period of interest.

Calculations are performed in the usual manner for point sources, with consideration given to upwind and crosswind distances of the point source from the receptor. The Hanna technique is used to determine concentrations from area sources. This technique considers area emission rates found directly upwind of the receptor as representative of emissions affecting the receptor. Concentrations are determined by integration in the upwind direction for the given stability, considering both the variation of area emission rate with distance and the effective area source height.

A unique feature of this plume model includes determination of receptor locations (where concentrations would be expected to be highest) downwind of major point and area sources as part of the computational procedure. Options include the use of other receptors, such as air quality measurement stations, with coordinates specified. Also, to insure adequate area coverage, additional receptors are added in a hexagonal or honeycomb pattern in areas where initially no other receptors are present. For the most significant point and area sources, partial concentrations (that is, the concentration resulting from a particular source at a receptor) are stored hour-by-hour so that estimates for the same time periods may be made, assuming varying control tactics. The partial concentrations resulting from a particular source are proportionately reduced according to emission reductions for the appropriate hours. This allows testing of several control tactics without having to reapply the model for each one.

The computer routines to perform the calculations were completed and tested for mathematical correctness. A user's guide describing the technical aspects of the model and documenting the computer routines will be prepared. The stagnation submodule will be added whenever it becomes available. The model will be tested against measured concentrations.

2.11 Point Source Models

Three different point source models of the steady-state Gaussian type were programmed in the interactive mode and placed on the UNAMAP (User's Network of Applied Models of Air Pollution) system. All three perform calculations suggested in the Workbook of Atmospheric Dispersion Estimates (Turner, 1970) and use dispersion parameter values for σ_y and σ_z as suggested by Pasquill (1961) and Gifford (1961). Each program estimates concentrations that are representative of hourly averaging times. Each program estimates plume rise, using procedures of Briggs (1969); level terrain is assumed.

The program PTMAX performs an analysis of maximum ground-level concentration from a point source (a single stack) as a function of stability and windspeed. By an examination of the concentrations for the various windspeeds at a given stability, the critical wind velocity (associated with the maximum concentration) can be determined for that stability. Outputs for each stability and windspeed pair include the effective height of emission, the maximum concentration, and the distance from the source to the point of maximum. A limit to vertical mixing (mixing height) is not considered in this analysis.

The program PTDIS determines ground-level concentrations from a point source (a single stack) for specified distances downwind from the source for a specific windspeed, stability, and mixing height. An option allows the user to specify a concentration for which the half width (distance) of the concentration isopleth is determined at each of the specified distances. This information is useful to determine the area in concentrations that is above a given magnitude.

The program PTMTP determines hourly concentrations and average concentrations for up to 24 hours at a number of receptor points (up to 30) from multiple point sources (up to 25). Coordinates of both sources and receptors must be specified in a rectangular 1-km coordinate system. Receptor heights may be above ground level. Meteorological data for each hour consist of wind direction, windspeed, stability class, and mixing height. Concentrations at each receptor are determined and printed for each hour. An average for the period is also printed. Partial concentrations, that is, the concentration resulting from each source upon each receptor, is available optionally for each hour and for the time period.

The batch versions of these programs will be documented and made available as part of a collection of FORTRAN programs for estimating dispersion.

2.12 Screening Procedure

At the request of the Strategy and Implementation and the Stationary Source Enforcement Divisions, a procedure was devised that can be easily applied to evaluate in a gross fashion the impact, relative to the air quality standard, of a point source releasing a nonreactive pollutant. It is anticipated that the procedure would be used by state and regional air pollution personnel to aid them in analyzing sources releasing sulfur dioxide or particulate matter and in reviewing applications for new sources or modifications of existing ones. The procedure is based on the pessimistic view that maximum short-term (hourly) concentrations from point sources occur with unstable conditions whenever a lid on vertical mixing occurs near plume height. The procedure leads to one of three conclusions: (1) The source is likely to cause ground-level concentrations above the standard; (2) the source is unlikely to cause ground-level concentrations above the standard; or (3) a more detailed analysis of the impact of this source upon air quality is required. A draft, "A simple screening technique for estimating the impact of a point-source of air pollution relative to the air quality standards," by D. B. Turner and E. L. Martinez, will be revised and published as an EPA Research and Monitoring publication.

2.13 Evaluation and Documentation of a Gaussian Model

Geomet, Inc., Rockville, Md., under contract, has evaluated a Gaussian plume urban diffusion model developed under a previous contract (CPA70-94). This Sampled Chronological Input Model (SCIM) was used to make estimates for a 3-month period in St. Louis, for 1 month in Chicago, and for 1 year in New York City. Comparisons were made with measurements and also with estimates from a simplified model (Gifford and Hanna, 1973).

Comparing the results of the SCIM and the Gifford-Hanna (1973) model with concentrations from point sources, as determined by the SCIM, added to the concentrations determined from area sources. The SCIM produced the least annual mean error at six of 10 receptors and the least error in estimating the maximum measured concentration at six of 10 receptors; the Gifford-Hanna model produced the least root-mean-square errors at all 10 receptors.

It is concluded that there is a need to improve the input data used with the multiple-source Gaussian plume model, particularly atmospheric stability information, because the model is very sensitive to the rather gross stability changes that are routinely introduced.

Results have demonstrated no conclusive improvement in model validity by the use of mean emission rates over the use of variable emission rates for the SCIM and Gifford-Hanna models.

The evaluation is contained in the Phase I report. The preparation of a user's manual for the SCIM and a training session for EPA personnel on the use of the model will complete the contract work.

2.14 Wind and Temperature Prediction Code

The Wind and Temperature Prediction Code (WATPC) is a three-dimensional numerical model of the wind and temperature field as a function of space and time in a region extending horizontally about 30 by 30 km and vertically 2 km. The model consists of a solution of the Boussinesq equations for the three velocity components (u, v, w) and the potential temperature, and of an inversion of the Poisson equation resulting from the imposition of incompressibility ($\nabla \cdot \underset{\sim}{V} = 0$) on the system to determine the nonhydrostatic pressure field. This portion of the code has been inputted into the 370/165 computer at the Triangle University's Computer Center. Current activity centers on: (a) specification of proper boundary conditions to allow nesting the WATPC within a few grid points of a larger scale mesoscale prediction model, such as that under development in a current research grant with Pennsylvania State University (see discussion in 2.1); (b) incorporation of a meaningful surface energy balance; and (c) inclusion of additional model equations for the generation of turbulent dissipation and turbulent energy required to parameterize the subgrid scale dynamics.

2.15 St. Louis Air Quality Submodel

To incorporate the first data available from the EPA Regional Air Pollution Study (RAPS), an air quality submodel is being developed for incorporation into the general RAPS model under development. In particular, an Eulerian representation solving the inert pollutant concentration equations over a 30- by 30- by 10-km grid in St. Louis is under study. The first pollutant to be considered is SO_2. The best available inventory has been accumulated and translated into a useful initial (boundary) condition for the St. Louis Air Quality Submodel. Modern numerical techniques allow the effects of numerical diffusion to be minimized. The specification of eddy coefficients will be a prime activity next year, based upon the so-called super-equilibrium theory developed by Donaldson (1973).

2.16 Street Canyon Diffusion

Researchers at the Los Alamos Scientific Laboratory (LASL), Los Alamos, N.Mex., have completed an analytical/numerical study of air pollution transport in street canyons. This work was conducted under an interagency agreement with the Atomic Energy Commission (AEC).

Numerical studies were made of a two-dimensional street canyon problem. Comparison with the results of water channel studies showed excellent qualitative agreement of the overall flow structures, but, because of free-slip boundary conditions, secondary vortexes that appeared in experimental results did not appear in the numerical results. When comparing concentration patterns with fluid model results, it became evident that constant eddy diffusivity assumptions were inappropriate and that a full set of turbulence equations was needed.

An analytical expression was also developed to predict the pollutant concentrations in a simple notch, this expression being an idealization of a street canyon with automobile exhaust emitted at the bottom and a crosswind passing over the top. The form of the equation is quite similar to previous semi-empirical formulas, but the derivation is useful in that it shows how previous semi-empirical formulas can be improved.

Finally, a three-dimensional numerical model of a specific street canyon in St. Louis was constructed to compare results with those obtained from field measurements that had been made there previously. Although concentration values have to be scaled to match the measured values at some point in the canyon, the shapes of the isopleths and the values predicted in other parts of the canyon (after matching at one point) showed fair agreement with the measured values.

2.17 Diffusion in the Turbulent Surface Layer

Scientists at the University of Notre Dame, Notre Dame, Ind., are conducting an analytical and experimental study of diffusion in the turbulent surface layer of the atmosphere under a research grant with the ML.

On the analytical side, a simple phenomenological theory of turbulent shear flow has been applied to turbulent diffusion problems for ground-level point and line sources under neutral and stratified conditions. A technical report has been received that shows quite favorable comparisons with the results of previous wind tunnel and atmospheric studies. Additional analytical work is being done on elevated point and line sources under different stratification and ground roughness conditions.

On the experimental side, a new type of atmospheric wind tunnel, which uses active devices for controlling wind profiles and turbulence jets, has been constructed. The wind tunnel has been shown to be capable of generating thick (40-in.) boundary layers with variable turbulence intensities (up to 30 percent) using an 18-ft long test section. Measurements and comparisons of Reynolds stresses, power spectra, and correlation functions are presently being made.

2.18 Composition and Distribution of Forest Fire Smoke

Laboratory and field investigations of the composition and distribution of forest fire smoke have been conducted at Washington State University under a research grant with the ML. During the field phase in the summers of 1968-70, several 10- to 50-acre plots of cutover slash were burned in a national forest in Montana. The smoke plumes were sampled by equipment located at specified ground-level sites and on a fixed-wing aircraft. The data were compared with those obtained with similar instrumentation for fires ignited on experimental burning tables at the university and at other institutions. The primary objectives of the study are the determination of the composition and distribution of combustion products and the definition of environmental conditions (such as meteorological and soil) and fuel variables which will minimize air pollution from such slash burning. The study is an integral part of a larger program concerning the environmental (ecological) effects of different forest management strategies.

2.19 A Numerical Model of the Urban Atmosphere

The dynamics of urban microclimate, land use patterns, pollution emission, transport and diffusion, and human comfort have been synthesized into a highly interrelated system by L. O. Myrup and D. L. Morgan of the University of California-Davis, working under a research grant with the ML. In the first part of a three-volume final report, Myrup and Morgan (1972) present a detailed analysis of the physical structure of an urban surface in terms of land use categories. This research organizes a city into significant study parcels, delineates the textural cells making up the city, and quantifies the local and general fabric and the aerodynamic roughness of an urban area. A dual approach to the problem has been formulated in which data are available either in terms of land use or as an average over areas determined by a regular spatial grid.

The micrometeorology group at Davis has developed a series of numerical models, based on the energy transfer processes at the surface of the earth, which simulate the microclimate as a function of substrata properties and meteorological input. Model results demonstrate a close correspondence between the geophysical processes and land use categories.

The microclimate calculations serve as input information to several analyses and model calculations. For instance, the phenomena of human comfort are highly related to the microclimate. From an analysis of the relation between city texture, microclimate, and human physiologic comfort and an extensive review of the literature of thermal comfort, a model of the budget of human physiologic heat energy is developed. From microclimate parameters and specified activity level and clothing, the model predicts skin temperature from which conventional indices of human comfort are derived. One result of this phase of the work is an analysis of human comfort in relation to land use categories.

Volume II of the final report will be devoted to a description of a mesoscale meteorological and air quality measurement program which was primarily executed during the summer of 1971. Volume III will present the analyses and calculations made in regard to air quality.

2.20 Geophysical Characteristics and Energy Budget of the Urban Surface

Stanford Research Institute scientists are conducting, under a research contract, an experimental and analytical investigation of the geophysical parameters of significance in urban energy budget studies.

Representative surface areas encompassing different land use or surface types were chosen in metropolitan St. Louis. Techniques for determining representative values of geophysical surface characteristics (albedo, emissivity, aerodynamic roughness, and thermal admittance) were determined for the selected areas. During special periods in August 1972 and April 1973, measurements were made of these geophysical parameters over the areas and for two or three complete diurnal cycles of reflected solar radiation and infrared window-channel irradiance. The data are being analyzed by a climatological model to determine the feasibility of ascertaining the diurnal thermal response at the surface in terms of the incident radiation and geophysical characteristics and of evaluating the manner in which such characteristics induce local climate variations at the surface.

Results of this investigation will, in part, determine the feasibility and the techniques and procedures for conducting the more detailed energy budget studies planned under the RAPS program. In addition, it was also a direct supplement to an in-house urban-rural radiation study that was carried out in St. Louis during the summer of 1972.

2.21 Inadvertant Weather Modification by Urban Pollution

Under a research grant, personnel from the University of Wyoming are conducting an experimental investigation of inadvertant weather modification by an urban area during the summertime in conjunction with the larger Metropolitan Meteorological Experiment (METROMEX). Emphasis during the 1971 and 1972 field studies was primarily on urban-related alterations in the nature of the airflow during convective cloud genesis and development and during precipitation processes. Emphasis during 1973 will be on boundary layer structure and exchange processes associated with the urban modification of the airflow and on urban budgets of energy, moisture, and aerosols (Aitken nuclei) associated with the objective of the emerging RAPS program. The studies will be coordinated with an in-house ML investigation on boundary layer structure. During experiments, measurements of meteorological variables (e.g., temperature, dew point, and pressure), cloud physics parameters, and hydrometeors are made with an instrumented fixed-wing aircraft and two mobile vans. In addition, special rawinsonde and pibal runs are made when needed.

A comprehensive discussion of the results of the previous field investigations and the plans for the continuing study are found in Auer and Dirks (1973). A significant finding regarding airflow modification is an apparent doming of the mixing layer over the metropolitan area on occasion during summer days with light windspeed and nearly clear skies. The urban plume downwind of St. Louis during the daytime experiments often was up to 1°C warmer than and contained 0.5 g/k_g more water vapor than its surroundings. Convective clouds forming over or downwind of the urban area contained more and much smaller cloud droplets than upwind clouds of the same category. Also, cloud condensation nuclei and Aitken nuclei were enhanced over and downwind of the city, while freezing nuclei were observed in smaller number than in the natural atmosphere over the Great Plains.

2.22 Urban Boundary Layer Study

An experimental, theoretical program is underway on the structure and turbulent processes within the urban planetary boundary layer. The basic tenet underlying the program is that the structure of the urban boundary layer is determined by the structure of the undisturbed flow upwind of an urban area and of modifications induced primarily by the varying heat, moisture, and momentum fluxes occurring at the earth-air interface over the urban area. An improved knowledge of this structure and of its principal physical-causative mechanisms will allow the development of improved urban-scale meteorological and urban diffusion models and of integrated meteorological and diffusion models.

Initially, the program concentrated on the nocturnal period during which urban-rural differences in boundary layer structure normally are the greatest and the "heat-island" phenomenon is usually developed to its maximum extent. The first experimental studies were conducted over metropolitan Cincinnati, Ohio, located in somewhat varying terrain. Detailed accounts of the experimental studies and their principal results were published by Clarke (1969) and by Clarke and McElroy (1970).

The experimental program was subsequently shifted to metropolitan Columbus, Ohio, situated on relatively flat terrain, to verify, quantify, and generalize the findings of the Cincinnati study in other locales. A total of 12 comprehensive field investigations were made. On each occasion, measurements normally started near sunset and continued until sunrise, except for a 2- to 3-hour break beginning around midnight. The primary data consist of vertical profiles of dry- and wet-bulb temperature obtained during helicopter ascents, winds aloft obtained by theodolite observations of slowly rising balloons, air temperature near the surface obtained during automobile traverses, surface (skin) temperature obtained with an infrared thermometer flown in a fixed-wing aircraft, and an emission inventory of anthropogenic heat production. On three occasions, grab samples of air were collected at several elevations and locations during helicopter ascents and later analyzed quantitatively for carbon monoxide content. On one occasion, a meteorological tracer (sulfur hexafluoride) was disseminated, and air was sampled at several locations near the surface and aloft. In addition, turbulent wind fluctuations were measured at two elevations in the downtown area, and "constant-level" balloons (tetroons) were flown across the metropolitan area on several occasions.

The primary data reduction, processing, and analysis have been completed. A detailed account of the Columbus experimental program and some of its principal results was presented by McElroy (1971). A summary of results and of tentative conclusions was recently reported in a paper by McElroy and Clarke (1972) at the Annual Fall Meeting of the American Geophysical Union. A report is planned that will include the basic information given in the above papers as well as a presentation of the primary data. Finally, a comprehensive summary of the results of the tetroon flights was reported by Angell *et al*. (1971).

A numerical model of the nocturnal urban boundary layer was developed from an existing one-dimensional, time-dependent model (Estoque, 1963). A comprehensive presentation of the model and its application to the

Columbus experimental data is contained in McElroy (1972). A digest of portions of the former was published by McElroy (1973) in the journal <u>Boundary-Layer Meteorology</u>.

The model was also used to demonstrate the necessity of incorporating meteorological information in the decision-making process in urban land use zoning and planning and the utility at least of using meteorological models as submodels in comprehensive environmental (ecological) models. Specifically, simulations were made for a hypothetical symmetrical city with a land use similar to, and initial data for, Columbus under strong heat-island conditions. The simulations were compared with those for other hypothetical cities with the same major land use areas but with these land use areas (e.g., greenbelts, high rise apartments, and shopping centers) placed within or between the major land use areas. In addition, simulations were made over several megalopolitan areas each consisting of several of the hypothetical symmetrical cities linked together. Results of this investigation were reported in a paper by McElroy (1972) at the <u>Conference on the Urban Environment and Second Conference on Biometeorology</u>, published by the American Meteorological Society.

The urban boundary layer program has been expanded to allow detailed consideration of atmospheric structure during other diurnal periods. These studies will be made primarily in conjunction with RAPS in St. Louis. The initial experimental studies to be conducted during the summer of 1973 will concentrate on the temporal and spatial variability in the structure of the boundary layer across metropolitan St. Louis, especially during the rapid transitional (fumigation) periods that occur around sunrise and sunset. Experimental investigations will also be performed over typical urban and rural surfaces at a site near Butner, N.C. (north of Durham), to provide quantitative information on the subsurface, sensible, and latent heat fluxes at the earth-air interface for such surfaces and on their parameterization in meteorological models.

2.23 Travels of Airborne Pollen

Transport and dispersion of airborne pollen are being studied by researchers at the State University of New York (at Albany) under a grant with the ML. The basic objective of the grant is to gain a better understanding of pollen dispersion, transport, and removal in the atmosphere.

During the past year, field studies and analyses of data centered on: (1) studies on pollen dispersion over distances of 150 km and to altitudes of 3 km; (2) efficiencies of forest and hedges for removing pollen (and other particles) from the atmosphere; (3) study of the variation in time and space of pollen concentrations in rural and urban locations; and (4) study of emission patterns from local sources of potentially allergenic pollens and of variations in concentrations with height, time, terrain, and weather.

Results of the studies suggest that source configurations and meteorological conditions are more important variables than particle characteristics in determining both dispersion and deposition rate. Consequently, results of low-level dispersion experiments using pollen can be applied to problems involving nonbiological particulates. Conversely, methods, such as using Gaussian diffusion models which have proven successful for calculating pollution concentrations, can be applied to problems involving pollen dispersion. The grant is scheduled for completion on September 30, 1973. Activity to that date will center on analysis of data and preparation of material for publication.

2.24 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. The LAPPES project sought to determine the pattern of ground-level concentrations of pollutants released to the atmosphere from large coal-burning mine-mouth power plants. From these investigations, improved dispersion models are being developed.

Four volumes of basic data obtained from the LAPPES project have been published. The final documentation, containing data from the 1971 field experiments, was published in Fiscal Year 1973 (Schiermeier, 1972). Analysis of the data has been reported by Pooler and Niemeyer (1970) and is found also in the Fiscal Year 1972 Summary Report (NOAA, 1973).

2.25 Mesoscale Pollution Transport in Southeast Wisconsin

Mesoscale pollution transport with emphasis on the lake breeze circulation is being studied by personnel of the University of Wisconsin-Milwaukee under a grant with the ML. Primary objectives are: (1) detailed study of the recirculation of pollutants within the lake breeze cell, including the estimation of percentage of mass and size distribution of aerosols which fall out of the system into the lake; (2) field measurements and development of a computer model of the continuous fumigation of plumes from elevated shoreline sources, for example, a power plant during lake-breeze flow regimes; and (3) further development and testing of a mesoscale pollutant transport model (including sea breeze circulation) for southeast Wisconsin, and the refinement of short-range mesoscale prediction methods necessary for fuel-switching air pollution control strategies.

The grant period began in March 1972, and the first year was essentially devoted to acquisition and testing of field instrumentation and to pilot studies of proposed field investigation techniques. A complete mesoscale observational system has been established.

Extensive field investigations will be conducted during the summer of 1973. In addition to standard data, instrumentation on a twin-engine aircraft measures SO_2, total suspended particulates, and particle concentration in two size ranges. A chain of six pibal stations, normal to shore, measures the wind field, while optically tracked tetroons determine wind trajectories. Personnel in an instrumented van measure ground-level SO_2 concentrations and temperatures.

The observational data are to be compared with results from computer models. A computer program, using all point and area sources in southeastern Wisconsin, makes detailed calculations of pollution concentrations (SO_2 and particulates). The program, an advanced version of the "Turner model" u't' tet Gaussian plume assumption, is designed to account for such phenomena as plume trapping and continuous fumigation. In other models, observed Eulerian wind fields will be used to determine trajectories of the aerosols.

2.26 Long-Distance Transport Model

This in-house study will evaluate the relative importance of interurban and interregional transport of air pollutants and will identify meteorological conditions associated with "significant" long distance transport of pollutants.

Long distance transport involves downwind travel distances greater than 100 km. Visibility restrictions resulting from long distance transport of pollutants appear to be common in the Eastern United States, particularly over northern New England. The basic meteorological pattern associated with this phenomenon is a quasi-stationary high pressure system over the Ohio Valley or Middle Atlantic Coastal States. Because of extensive sources and poor dispersion conditions, visibility restrictions become widespread over the area. The stagnation pattern is eventually broken down with the approach of a frontal system from the west or northwest that causes accumulated fine particulate (and resulting visibility restriction) to be transported to relatively clean areas of the country. The local air pollution episode that occurred in May 1972 in Miami, Fla., has been attributed primarily to long-distance transport of particulates from the Ohio Valley, a transport distance of over 1,500 km.

A quantitative evaluation of long-distance pollutant transport is in progress. Metal fractions of National Air Sampling Network particulate data at non-urban stations are being used as tracers. The probable origin of the particulate for each sample will be determined by constructing reverse trajectories from the sampling site. The data will be statistically analyzed relative to meteorological conditions, source-receptor distance, and source strength. A long-distance transport model will be developed to evaluate the regional pollution burden from specific large sources, such as a city or power plant complex. The trajectory program has been completed and tested. Presently, climatological and air quality data are being prepared for analyses.

2.27 Surface Energy Budget Parameterization for Urban-Scale Models

An important aspect of the urban-scale modeling problem is the translation of physical boundary conditions into computational boundary conditions. The vertical transport of heat, momentum, and pollutants within the surface portion of the planetary boundary layer must be described in a physically consistent manner to permit reasonably long (6 to 8 hour) simulations of the urban environment. However, a proper balance ought to be maintained between the levels of sophistication for the treatment of each boundary layer process.

A simple boundary layer model has been developed to meet the needs of first-generation urban-scale models. The model uses a transcendental equation for the Monin-Obukhov length L derived from: (a) the Businger-Dyer-Deardorff surface layer formulations; (b) parameterizations of the moisture flux, ground storage, and counter radiation terms in the surface energy budget; and (c) the (predicted) wind and temperature at a height H above a surface characterized by a roughness length z_o. The solution procedure easily handles the transition period from a stable to an unstable regime, or vice versa. The surface temperature, the friction velocity, and the vertical heat flux are then obtained from the computed value of L.

A one-dimensional, time-dependent model has been formulated to test the parameterization procedure, and the predicted fluxes and profiles compare favorably with the O'Neill data. Current research efforts are directed toward a sensitivity analysis to illustrate the effects of the parameterizations on the evolving boundary layer structure.

2.28 Atmospheric Photochemical Smog Measurements Over San Francisco Bay

Researchers at Stanford Research Institute (SRI) are in the analysis and final report preparation stage of a San Francisco Bay smog study, funded jointly by the EPA and the Coordinating Research Council (CRC). The object of the research is to relate meteorological factors on a mass balance basis to the changes in concentration and composition of gaseous pollutants in an airmass as it ages. The data collection method entails the following and sampling of an airmass over San Francisco Bay, using an instrumented mobile (waterborne) laboratory and an instrumented helicopter. Free-floating constant-level balloons (tetroons) are used to mark the air parcel.

Photochemical smog results from photochemically initiated reactions in the atmosphere between hydrocarbons and nitrogen oxides. To date (1973), knowledge of the photochemical smog reaction process is based largely on controlled experiments in laboratory test chambers and on statistical correlation analyses using atmospheric data. In the latter instance, most of the data have come from observations in the Los Angeles Basin. The interpretation of aerometric measurements from Los Angeles, however, presents major problems. Each sample contains a wide mixture of emissions, having various histories, times of reactions, and exposures to atmospheric influences. The San Francisco Bay study, however, avoids some of the ambiguities inherent in the Los Angeles data because the photochemical process will have proceeded without significant addition of fresh materials from nearby sources.

The SRI houseboat data consist of hydrocarbon distribution, O_3, NO, NO_2, total hydrocarbon, CO, turbidity, temperature, relative humidity, and solar intensity. Data collection by the helicopter provides total oxidant, NO, NO_2, CO, and temperature. A preliminary analysis indicates the existence of significant short-term fluctuations in the concentrations of NO, NO_2, and CO. The helicopter data, on the other hand, indicate rather small gradients in NO, NO_2, CO, and temperature. The calculation of (a) a concentration ratio $[NO] \times [O_3]/[NO_2]$ versus light intensity, and (b) ratios for pollutants versus CO concentration should lead to an increased understanding of photochemical smog processes.

2.29 Negatively Buoyant Plume Study

Under a research grant, the Colorado State University researchers have completed a study of negatively buoyant gas plumes. Such plumes may result from wet-washing of the gases (to remove SO_2) or from cooling towers. Flow visualization of smoke and quantitative measurements using radioactive gas in a wind tunnel were used to study the effects of gas density variations on the plume behavior both from isolated stacks and from stacks associated with nearby simple geometrical structures. Measurements in a water plume were also conducted to extend the range of parameters. Initial data showed unusually high lateral-spreading rates for dense plumes once they had reached ground level. This phenomenon is evidently associated with the pooling of the dense gas and its increased settling speed.

2.30 Fluid Modeling Facility

A wind tunnel is being constructed to study the flow and diffusion of pollutants over and around buildings, highway configurations, and complex terrain. The initial wind tunnel will be an open-return, nonstratified tunnel, with a test section 12 ft wide, 7 ft high (adjustable ceiling), and 60 ft long and a maximum speed of 25 ft/s. An instrument carriage will permit the remote positioning and readout of a probe anywhere within the test section. The construction contract was awarded to Aerolab Supply Co., Laurel, Md. The tunnel is to be installed by January 1974. Plans have been made to modify the EPA/Trailer Storage Facility in Bethesda, N.C., to house the wind tunnel and associated shops, laboratories, and offices. Further progress awaits the return of a bid from the building owner. Supplies, materials, shop equipment, and electronic instrumentation are presently being acquired for the operation of the fluid modeling program.

Through a cooperative arrangement with the EPA/Manpower Development Staff, an instrument calibration wind tunnel was set up and made operational in the EPA Trailer Storage Facility just outside Research Triangle Park. The test section size of this tunnel is 1 by 1 by 3 m long. It is powered by a 25-hp dc motor. Solid-state rectifiers provide motor speed control so that the flow speed in the test section may be varied continuously from 0 to 50 mph. Tests of flow uniformity in the test section at top speed and at one-half speed showed the flow in the core (outside the wall boundary layers) to be well within ±3 percent. Tests at lower flow speeds await the arrival of appropriate instrumentation.

Some tests were conducted on the effect of the yaw angle on the response of a temperature sensor to be mounted on a helicopter skid. Yaw angles up to 45° at windspeeds up to 50 mph were found to have negligible effects on the temperature readings.

Data are being collected for a study on the effect of plume buoyancy on the "1.5 times" rule. This "rule of thumb" states that the stack effluent speed must exceed 1.5 times the windspeed to avoid downwash in the wake of a stack. This rule is presumably valid for neutrally buoyant effluents. The purpose of this study is to determine the effects of plume buoyancy (positive or negative) on this rule. Helium (one-seventh as dense as air), smoke, and Freon 12 (4.5 times as dense as air) are being used to vary stack froude numbers over several orders of magnitude.

2.31 Tower Turbulence Data

An experiment to determine atmospheric turbulence data over nonsmooth terrain at heights up to 300 m has been undertaken jointly by personnel at North Carolina State University and the AEC Savannah River Laboratory (SRL). Data from a sonic anemometer, several bivanes, and cup anemometers located on the SRL Meteorological Tower (radio station WJBM) near Beach Island, S.C., will be recorded on magnetic tape. Computer programs have been written to analyze the data which are currently being collected. The data will be analyzed to determine the variation of standard deviations of azimuth (σ_A) and elevation (σ_E) of wind direction fluctuations with height, Richardson number, and roughness length. The ratio σ_E/σ_A will be studied for variation with height and Richardson number. The standard deviation of the vertical component of wind velocity will be studied for variation with height, wind direction, stability, and roughness length. The approximate transformation $\sigma_W = \nabla\sigma_E$ and $\sigma_V = \nabla\sigma_A$ will be investigated for accuracy. The transfer function of the bivanes and cup anemometers will be determined with the help of data from the sonic anemometer. The variation of ratio of the standard deviation of vertical wind velocity fluctuations to friction velocity will be determined. Rate of energy dissipation will be determined from spectra indicating an inertial subrange. Cross and coherance spectra between velocity components at different levels will be examined.

2.32 Ecological Activities

ML personnel were asked by the EPA/Office of Research and Development to consider the modeling capability that exists in the EPA and to comment on areas of needed development. In this regard, Dr. D. G. Fox travelled to NERC/Corvallis, Oreg., to discuss water quality modeling with the National Thermal Pollution Research Program (NTPRP) and the

National Coastal Pollution Research Program. Based on the results of this trip, an internal report was prepared concluding that the state of water quality modeling was well advanced within the EPA and that cooperation between personnel would be useful. This cooperation has begun in the area of cooling tower plume models developed by NTPRP and reviewed by ML. In 1974, it is anticipated that some enhanced interaction will be obtained through a joint research program aimed at gathering data on the deposition of salt around a saltwater cooling tower.

The study of the EPA modeling capability was continuing in the National Ecological Research Program (NERP). While the NERP is attempting to build a modeling capability, it is clear that this program will need to rely upon the expertise in meteorological diffusion modeling developed in the ML. The conclusion from this study is overwhelming that enhanced cooperation and interaction between the ML and the NERP should be fostered.

Dr. Fox participated in a 2-week expert panel sponsored by the National Science Foundation to determine the extent to which meteorological and ecological models could and should be merged. The air quality picture cannot be modeled without including removal processes, such as surface scavenging which is very biota dependent. Similarly, any understanding of and hence modeling of natural terrestial ecosystems must be largely dependent upon the meteorological component.

2.33 Symposium on Statistical Aspects of Air Quality Data

A Symposium on Statistical Aspects of Air Quality Data, supported by the ML and cosponsored with the Triangle Universities Consortium on Air Pollution, was attended by 120 participants on November 9-10, 1972, in Chapel Hill, N.C. Fifteen papers were presented by foreign and domestic statisticians, meteorologists, chemists, and engineers. Several workshops were also held. The Consortium is editing the proceedings for publication, after which copies of the proceedings will be available from the ML.

2.34 User's Network of Applied Models of Air Pollution (UNAMAP)

The purpose of the UNAMAP is to make current air quality simulation models available to both EPA and non-EPA users by way of a teleprocessing network. The models involved are all in the form of computer programs accessible from remote terminals connected to a central computer facility by telephone lines. The basic potential advantages of this network are that:

(1) EPA could efficiently carry out its responsibility for maintaining and periodically updating the models in a timely fashion when improvements are appropriate;

(2) The users would always have access to a set of models reflecting the latest state of the art;

(3) The users would not have to program any models;

(4) The users would need only minimum modeling expertise; and

(5) There would be a manageable number of consistent models in use, facilitating review and comparison of control plans.

The ML, with the support of the EPA Research Triangle Computer Center, has made the UNAMAP available to the EPA Regional Offices by way of a teleprocessing network connected to an IBM 360/50 mainframe at Research

Triangle Park, N.C. The success of this network has prompted the ML to extend the UNAMAP to non-EPA users by way of a commercial teleprocessing network. The Computer Sciences Corporation (CSC) information network (INFONET) has been selected as the non-EPA outlet for the UNAMAP. The CSC has a General Service Administration contract for teleprocessing services. The cost for this service is based upon the resources used (i.e., computer time, storage, and connect time). Users will pay for their service usage through a direct agreement with the CSC. The EPA will assume the responsibility for storing the models in a readily accessible mode, for updating the models and model inventory, and for providing a message service to the users concerning any UNAMAP changes.

Several models can be executed "on-line" by a user who interactively enters the control parameters specific to his problem (i.e., windspeed and wind direction, source strength, and stack height). Other models require more extensive input data which involve developing a data set separate from the program.

Currently, the UNAMAP consists of the following models:

(1) APRAC — The Stanford Research Institute APRAC-1A model computes the hourly averages of carbon monoxide as a function of extraurban diffusion from automotive sources in upwind cities, intraurban diffusion from roadway sources, and local diffusion within a street canyon. The model requires an extensive emission or traffic inventory for the city of interest. Requirements and technical details are documented in User's Manual for the APRAC-1A Urban Diffusion Model Computer Program, accession number PB-213-091, available from NTIS (National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22151).

(2) HIWAY — This is an interactive program which computes the short-term (hourly) concentration of nonreactive pollutants downwind of roadways. It is applicable when uniform wind conditions and level terrain exist. It is best suited for at-grade highways, but also can be applied to depressed highways (cut-sections).

(3) CDM — The Climatological Dispersion Model (CDM) determines long-term (seasonal or annual) quasi-stable pollutant concentrations at any ground-level receptor, using average emission rates from point and area sources and a joint frequency distribution of wind direction, windspeed, and stability for the same period. This model differs from the Air Quality Display Model (AQDM) primarily in the way in which concentrations are determined from area sources, use of Briggs' plume rise, and use of a power law increase in windspeed with height dependent upon stability. The CDM uses a separate data set for the area of interest.

(4) PTMAX — This is an interactive program which performs an analysis of the maximum short-term concentration from a point source as a function of stability and windspeed.

(5) PTDIS — This is an interactive program which computes short-term concentrations downwind from a point source at distances specified by the user.

(6) PTMTP — This is an interactive program which computes, at multiple receptors, short-term concentrations resulting from multiple-point sources. All interactive models are documented as the programs are executed. The CDM model requires a source listing for a user to understand the data set formats. Manuals for the above models are in preparation and should be available by August 1973. However, APRAC is not available as previously mentioned.

The UNAMAP models listed above are installed on the INFONET and are ready for access. Other models will be added as they are validated. This inventory will eventually include models involving photochemistry for estimating concentrations in areas of complex terrain and for estimating concentrations under stagnation conditions.

2.35 Photochemical Air Quality Simulation Modeling

During the past several years, the ML sponsored the development of three photochemical air quality simulation models. This contract effort culminated in Fiscal Year 1973 with the evaluation of the three first-generation models by the three contractors.

The three models encompass two different approaches; two of which, the models by Pacific Environmental Services (PES) and General Research Corporation (GRC), are "trajectory" models that follow an air parcel within which the chemical processes occur as the air parcel moves over various emission sources. The third model, by Systems Applications, Inc. (SAI), is a regional "grid" or Eulerian model. It is basically a three-dimensional regional multibox model.

All three models predict the CO, NO, NO_2, O_3, and hydrocarbon (HC) concentrations. The model input consists of the initial air quality; emission rates; and boundary values for the air quality, solar radiation, and meteorological data (windspeed, direction, and mixing height). All the models are single-day, daylight models. A major difference between the three models is the system of chemical reactions included in the model. PES uses a 33-reaction kinetic module, while GRC uses 16 reactions and

SAI uses 15 reactions similar to the GRC set. More detailed information on the three models is available in the reports listed at the end of this section.

The three models were evaluated for 6 preselected days in Los Angeles, using data supplied by the EPA. In all cases, the carbon monoxide was used as an inert pollutant to test the nonreactive portion of the model. In all three models, the CO predictions were reasonably good; PES, for example, reporting a correlation coefficient of 0.70 between predicted and observed values.

For nitric oxide, all three models tended to underestimate the concentrations; whereas for nitrogen dioxide, all three models tended to overestimate the concentrations. The ozone is relatively well predicted by all three models, with PES reporting a correlation coefficient of 0.82 between predicted and observed values. SAI reports that two-thirds of the predicted times of the ozone peak were within 1 hour of the observed time and only one-third of the predicted magnitudes of the ozone peak were within 20 percent of the measured values. A thorough discussion of these evaluations is presented in the reports listed below:

I. General Research Corporation Model

(A) A. Q. Eschenroeder, J. R. Martinez, and R. A. Nordsieck (1972): Evaluation of a diffusion model for photochemical smog simulation — Final Report, Report EPA-R4-73-012a, Environmental Protection Agency.

(B) J. R. Martinez, R. A. Nordsieck, and M. A. Hirschberg (1973): User's guide to diffusion/kinetics (DIFKIN) code, Report EPA-R4-73-012b, Environmental Protection Agency.

(C) A. Q. Eschenroeder, G. W. Deley, and R. J. Wahl (1973): Field program designs for verifying photochemical diffusion models, Report EPA-R4-73-012c, Environmental Protection Agency.

(D) J. R. Martinez, R. A. Nordsieck, and A. Q. Eschenroeder (1973): Impacts of transportation control strategies on Los Angeles air quality, Report EPA-R4-73-012d, Environmental Protection Agency.

II. Pacific Environmental Services Model

(A) L. G. Wayne, A. Kokin, and M. I. Weisburd (1973): Controlled evaluation of the Reactive Environmental Simulation Model (REM)—volume I: Final Report, Report EPA-R4-73-013a, Environmental Protection Agency.

(B) A. Kokin, L. G. Wayne, and M. Weisburd (1973): Controlled evaluation of the Reactive Environmental Simulation Model (REM)—volume II: User's guide, Report EPA-R4-73-013b, Environmental Protection Agency.

III. Systems Applications, Inc., Model

(A) S. D. Reynolds, Mei-Kao Liu, T. A. Hecht, P. M. Roth, and J. H. Seinfeld (1973): Urban airshed photochemical simulation model study—volume I: Development and evaluation, Report EPA-R4-73-030a, Environmental Protection Agency.

(B) P. J. Roberts, Mei-Kao Liu, S. D. Reynolds, and P. M. Roth (1973): Urban airshed photochemical simulation model study—volume I, appendix A:

Contaminant emissions model and inventory for Los Angeles, Report EPA-R4-73-030b, Environmental Protection Agency.

(C) T. A. Hecht (1973): Urban airshed photochemical simulation model study — volume I, appendix B: Generalized mechanism for describing atmospheric photochemical reactions, Report EPA-R4-73-030c, Environmental Protection Agency.

(D) Mei-Kao Liu, and P. M. Roth (1973): Urban airshed photochemical simulation model study — volume I, appendix C: Microscale model of local vehicular service contributions to measured pollutant concentrations, Report EPA-R4-73-030d, Environmental Protection Agency.

(E) S. D. Reynolds (1973): Urban airshed photochemical simulation model study — volume I, appendix D: Numerical integration of continuity equations, Report EPA-R4-73-030e, Environmental Protection Agency.

(F) S. D. Reynolds (1973): Urban airshed photochemical simulation model study — volume II: User's guide and description of computer programs, Report EPA-R4-73-030f, Environmental Protection Agency.

(G) D. Whitney (1973): Urban airshed photochemical simulation model — volume II appendix: Data preparation programs, Report EPA-R4-73-030g, Environmental Protection Agency.

(H) Mei-Kao Liu, D. Whitney, S. D. Reynolds, and P. M. Roth (1973): Urban airshed photochemical simulation model study — volume III: Automation of meteorological and air quality data, Report EPA-R4-73-030h, Environmental Protection Agency.

3. AIR POLLUTION POTENTIAL, CLIMATIC ANALYSIS, AND GEOPHYSICAL STUDIES

3.1 Analyses of Rawinsonde Data

Routine rawinsonde observations, made by the National Weather Service (NWS) at 0000 and 1200 GMT, are being computer-processed at the National Climatic Center (NCC), Asheville, N.C., to obtain meteorological data pertinent to dispersion estimates. Such information will serve as a basis for assessing the meteorological potential of large point sources such as power plants. The data are being stored on tape and include the following:

(1) Wind direction and windspeed at the surface and at 150, 300, 600, 900, and 1,200 m above the surface.

(2) Inversion base and top, temperatures, and heights. If no inversion below 3,000 m, then lapse rate in the layers: 1-100, 100-250, 250-500, 500-750, 750-1,000, and 1,000-1,500 m above the surface.

(3) Average relative humidity within and below inversion. If no inversion below 3,000 m, average relative humidity in the layers specified in (2) above.

The analyzed soundings are also being summarized in tabular form of which table 2 is an example of the temperature profile summary (final version of this computer output is being changed slightly). In table 2, station 23160 is Tucson, Ariz.; scheduled radiosonde observation time is 1200 GMT (0500 MST); and season 03-05 is defined as March, April, and May.

Table 2. Percent Frequency of Temperature Lapse Rate Classes (DELTA T/H) by Inversion Base Height and Inversion Thickness (DELTA HEIGHT) and by Indicated Height Increments (DELTA HEIGHT) for Soundings With No Inversion Below 3,000 m (NONE)

Station 23160 Time 12 Season 03-05

Base of Inversion	1 - 100				101 - 250				251 - 500				501 - 750				751 - 1000				1001 - 1500				TOTAL	NONE	GRAND TOTAL
	DELTA T/H				DELTA T/H				DELTA T/H				DELTA T/H				DELTA T/H				DELTA T/H						
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D			
Surface			4	24	37	52	141	370	7	24	159	37	4	20	26		4	2							911		
1 - 100																											
101 - 250	7																								7		
251 - 500																											
501 - 750																											
751 - 1000						2																			2		
1001 - 1500	2				7																				9		
1501 - 2000							2			2				2			2								9		
2001 - 2500														2											2		
2501 - 3000			2	2	2																				7		
TOTAL	9		7	26	46	54	143	370	7	26	159	37	4	24	26		7	2							946		
NONE	17	26	9	2	15	53	7		4	46	4		4	48	2		2	48	4			46	9			54	
GRAND TOTAL																											1000
MISSING																											

DELTA T/H INVERSION LAYER

A	0.0000 - 0.0047 C/M
B	0.0048 - 0.0114 C/M
C	0.0115 - 0.0282 C/M
D	> 0.0282 C/M

DELTA T/H NO INVERSION

A	<0.0000 TO -0.0040
B	-0.0041 TO -0.0080
C	-0.0081 TO -0.0120
D	< -0.0120

The table indicates that 91.1 percent of the 0500 MST observations detected a surface-based inversion. Surface-based inversions with a thickness (DELTA HEIGHT) of 251 m or more occurred in 28.3 percent (i.e., 0.7 + 2.4 + 15.9 + 3.7 + 0.4 + 2.0 + 2.6 + 0.4 + 0.2) of the observations. Thus, for an effective emission height of 251 m, it could be assumed that the plume would not penetrate through the inversion on about 28 percent of spring mornings and would likely be followed after sunrise by the fumigation process. Alternatively, using the taped data, the effective emission height could be calculated for each sounding. For each thickness, data are also given on the rate of temperature increase through the inversion (DELTA T/H). For example, in table 2 for surface-based inversions with a thickness of 251 to 500 m, the inversion temperature increase exceeded 0.0282°C/m (DELTA T/H INVERSION LAYER = D) in 3.7 percent of the observations. No inversion (NONE) below 3,000 m occurred in 5.4 percent of the observations; most had temperature profiles in specified layers that were subadiabatic (i.e., DELTA T/H NO INVERSION = A or B). For example, with no inversion (NONE), the temperature change with height in the layer (DELTA HEIGHT) from 501 to 750 m was in the range < 0.0000 to -0.0040°C/m (i.e., DELTA T/H NO INVERSION = A) in 0.4 percent of the observations.

The summary for 0000 GMT (1700 MST) observations corresponding to table 2 indicates that surface-based inversions only occurred in 0.2 percent, inversions below 3,000 m occurred in 20.4 percent, and no inversion below 3,000 m occurred in 79.6 percent of the observations. For these afternoon no-inversion cases, the percent frequency distribution of temperature change with height (DELTA T/H) by layers is shown in table 3.

Table 3. Percent Frequency Distribution of Temperature Change With Height (DELTA T/H) by Layers for Afternoon No-Inversion Cases

Layer (m)	A Weak lapse	B Near standard	C Near adiabatic	D Super-adiabatic	Total
1,000 - 1,500	0.2	5.7	73.7	0.0	79.6
750 - 1,000	0.0	3.0	76.6	0.0	79.6
500 - 750	0.2	3.3	75.4	0.7	79.6
250 - 500	0.2	2.2	73.1	4.1	79.6
100 - 250	0.2	2.4	42.4	34.6	79.6
Sfc - 100	0.0	2.4	26.3	50.9	79.6

Superadiabatic conditions predominate (50.9 percent) in the lowest layer, surface to 100 m, but decrease rapidly with height to only 4.1 percent in the layer from 250 to 500 m. For layers above 250 m, the lapse rate is overwhelmingly nearly adiabatic, as may be generally expected for afternoons in the southwestern desert.

3.2 Worst Stagnation Episodes

The data that formed the basis for the OAP Publication AP-101 (Holzworth, 1972) have been analyzed to determine the worst stagnation (i.e., slowest dispersion) episodes lasting 1, 2, 3, 4, and 5 days for each of 62 rawinsonde stations. Basically, the analyzed data consist of 5 years (at most stations) of daily morning (Mrng) and afternoon (Aftn) values of mixing height (H) and mixing layer average windspeed (U). Mrng and Aftn data are assumed to be separated by 12 hours. Thus, a 1-day episode lasts through three consecutive data sets, a 2-day episode lasts through five, and so forth. A worst stagnation episode is defined as a continuous period during which:

(1) Significant precipitation did not occur;

(2) The greatest value of any H or any U did not exceed the combination of limiting values (limits): $H_L \leq 250$, 500, 750, 1,000, 1,500, 2,000 m and $U_L \leq 2.0$, 4.0, 6.0, 8.0 meters/second (m/s), which had the smallest product ($H_L \times U_L$); and

(3) The episode-average value of individual values of H x U (i.e., $\overline{H \times U}$) was the smallest.

As an example, data for the worst 1-day stagnation episode at Rapid City, S.Dak., are as follows:

	Date	H	U	H x U	Limits		
Time	Mo/Da/Yr	(m)	(m/s)	(m^2/s)	H_L	U_L	No.
Mrng	12/11/60	40	0.8	32.0	250	2.0	2
Aftn	12/11/60	103	0.9	92.7			
Mrng	12/12/60	42	0.9	37.8			

Average (i.e., $\overline{H \times U}$): 54.2

The number (No.) of Limits indicates that there were two episodes lasting at least 1 day with the limits $H_L \leq 250$ m and $U_L \leq 2.0$ m/s, but the dates indicated are for the 1-day episode with the smallest value of $\overline{H \times U}$.

The variation among locations of the degree of worst stagnation can be judged by the variation of $\overline{H \times U}$ values. Such values for some stations for which the worst stagnation was generally severe, moderate, or mild (i.e., smallest values of $\overline{H \times U}$ were relatively small, medium, or large, respectively) are:

	Episode duration				
	1-day	2-day	3-day	4-day	5-day
Severe					
Lander, Wyo.	14	17	34	57	55
Medford, Oreg.	34	46	61	153	142
Moderate					
Buffalo, N.Y.	271	393	402	469	651
Hatteras, N.C.	316	370	503	910	1,540
Mild					
Miami, Fla.	809	1,325	1,312	2,129	2,195
Midland, Tex.	441	1,018	1,375	2,308	1,952

The EPA report includes some summaries of episodes, including a station ranking of worst stagnation by episode duration and an analysis of seasonal variation. In many cases, the worst stagnation episodes are coincident with warm-type anticyclones and occur almost simultaneously at adjacent stations. An outstanding example is the widespread air pollution incident in the Eastern United States in November-December 1962 which included the worst stagnation episodes at several stations (Lynn *et al.*, 1964).

The purpose of the EPA report is to provide information on worst stagnation episodes for those engaged in applications of dispersion models and in appraisals of emission control strategies. Even for those seeking more detailed information, dates of worst stagnation should be very useful.

3.3 Objective Determination of Hourly Mixing Heights

The use of computer models to evaluate short-term variations in air quality has brought attention to the need for hourly mixing height data (Ludwig et al., 1970; Cooke and Roberts, 1971). The technique being developed by the ML takes into account more physical principles and places less reliance on linear interpolation between data points. A draft of a preliminary set of rules using 12-hourly rawinsonde and hourly surface weather observations to determine the hourly variation of mixing heights at rural sites is being reviewed and tested. These rules include rough corrections for horizontal advection and techniques for handling the discontinuity which normally occurs in mixing height when convective mixing is terminated in late afternoon.

It is anticipated that the technique will not only be useful to mathematical modelers, but also to air pollution meteorologists who make daily forecasts relating to air quality.

3.4 Urban Radiation

A field experiment to measure solar radiation and atmospheric aerosols was conducted from mid-July to mid-August 1972 in the St. Louis area. The measurements were made continuously at two sites, one urban and one rural. The city location, about 1 mi. west of the Gateway Arch, was at the western edge of the downtown district; the other was 34 mi. to the west-southwest near Pacific, Mo. The purpose of the experiment was to study the radiation component of the St. Louis energy budget and the reasons for urban-rural differences in that component. In addition, the experiment served as a pilot study for more extensive measurements planned in the forthcoming EPA-sponsored Regional Air Pollution Study (RAPS). (See discussion in 4 of RAPS).

The following radiation measurements were made at both sites: incident global (direct and diffuse) solar radiation in three broad bands (ultraviolet, visible, and infrared); normal incidence solar energy with periodic use of six cutoff filters to give spectral resolution; atmospheric turbidity (aerosol extinction coefficient) at 380 and 500 nanometers (nm); and downward-directed long-wave irradiance. Atmospheric particles were measured by three instruments: nephelometer, high-volume filter, and paper tape sampler.

During clear conditions, the radiation measurements at the two sites can be compared to give information about the atmospheric aerosol and/or water vapor concentrations. We believe the observed differences primarily reflect aerosol variations because the urban-rural variation of solar attenuation is greatest at ultraviolet wavelengths and because dewpoint observations at both sites generally showed slightly lower values in the city.

The overall aerosol effect is evident from the average urban-rural values of incident solar energy. The city site averaged 2 to 3 percent less global solar energy than did the rural site and about 6 to 7 percent less ultraviolet radiation. There were, however, rather large day-to-day variations in these numbers. An example of the urban-rural contrast of incident ultraviolet radiation is shown by figure 1. The observed data, which are multiplied by 10 for this ordinate scale, exhibit typical diurnal variability. On August 10, 1972, only a few

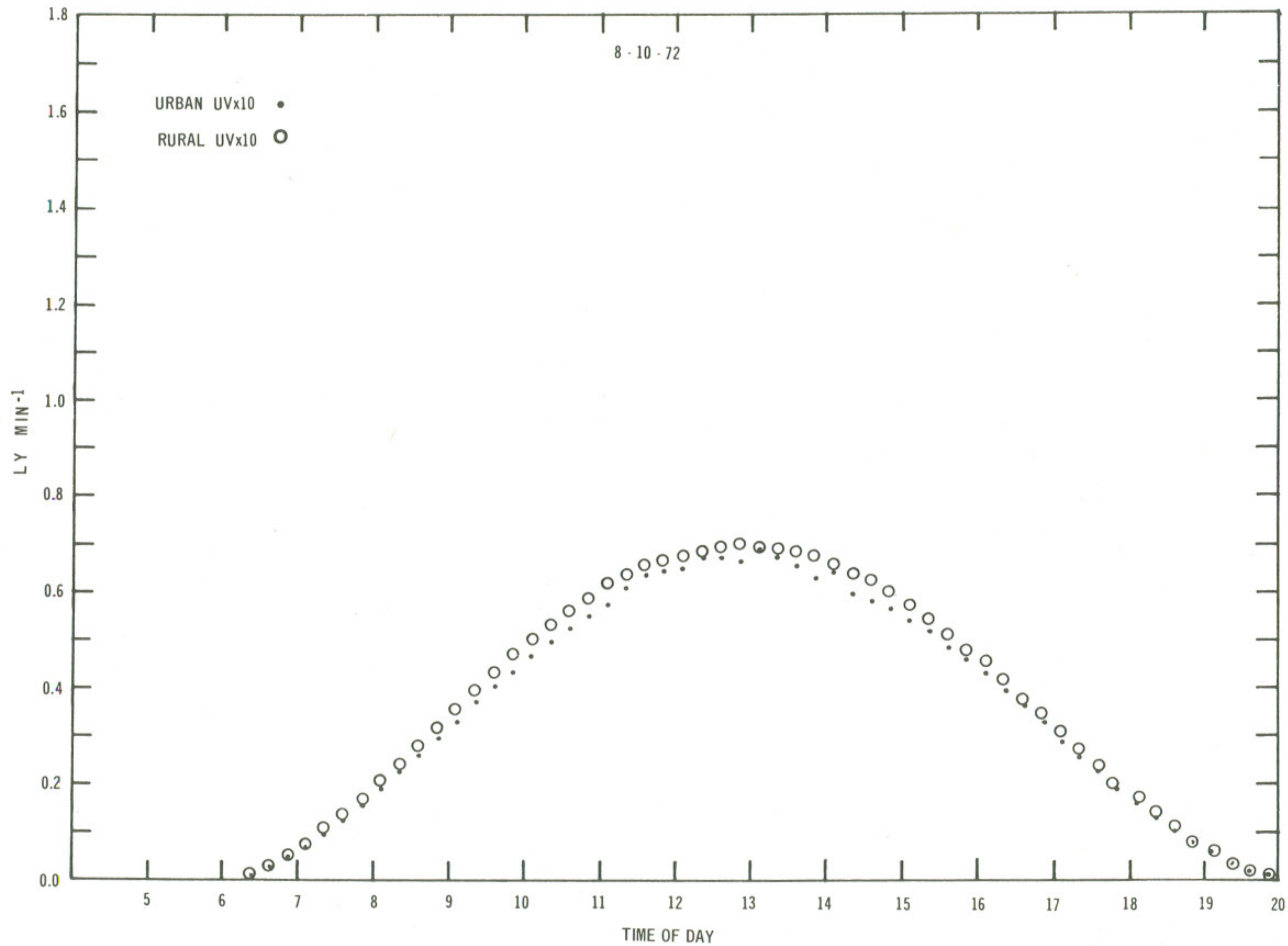

Figure 1. Incident ultraviolet radiation measured at urban and rural sites near St. Louis, Mo., on August 10, 1972.

afternoon cumulus clouds occurred and relatively little atmospheric haze was evident at either site. However, the aerosol concentration was slightly greater over the city. The 24-hour high-volume filter mass values showed 78 and 58 $\mu g/m^3$ at the city and rural sites, respectively. In addition, the nepholometer readings were about 10 percent higher at the urban site.

For the complete 28 days, during all meteorological conditions, the cumulative total solar energy received at the city site was 6 1/2 percent less than that received at the rural site. Naturally, such data are strongly influenced by variations in cloudiness and thus they do indicate more cloudiness — either more frequent or more dense cloudiness — over the city. This information supports some of the findings of the METROMEX program (Changnon et al., 1972). The Illinois State Water Survey, for example, has studied individual rain cells and concluded that "urban-effect" cells have greater total areal extent, duration, and path lengths than do non-urban-effect cells. Several investigators have found that the city is a source of cloud condensation nuclei and that these nuclei can materially affect the microstructure of clouds.

Still, the question remains as to whether the 6 1/2-percent energy reduction is the usual situation or an unusual short-term effect peculiar to the small 28-day sample. If this is a persistent phenomenon, it could have a noticeable effect on the city energy budget and local wind flow patterns.

The RAPS monitoring network will have six radiation sites located throughout the St. Louis area and will be in operation by the summer of 1974. Those continuous measurements for 3 years should serve to clarify the radiative component of the urban energy budget.

3.5 Atmospheric Turbidity

Table 4 gives a breakdown by type of instrument and location of active turbidity stations maintained by the ML on April 1, 1973.

Table 4. Instrument Type and Location of Turbidity Stations

Instrument Type	Total number	Continental U.S.	Outside U.S.
Dual wavelength:			
EPA model	34	16	18
EPPLEY model	25	14	11
Other	1	1	0
Volz type-G	20	19	1
Total	80	50	30

Additional stations on islands in the Pacific and Atlantic Oceans will probably begin observations next year.

About 1 to 1 1/2 years of turbidity data are now available for most of the dual-wavelength stations, but only cursory analyses have been made, basically for the purpose of maintaining quality checks on the data. As more years of data are obtained from the world network, turbidity climatologies will be determined so that future turbidity anomalies may be discerned and analyzed. Figure 2 presents monthly mean values for B_{500} (turbidity at 500-nm wavelength) and α (Angstrom's wavelength exponent) from dual-wavelength measurements made in the Research Triangle Park area of North Carolina from July 1969 through March 1973. Annual patterns in B and α are apparent. These particular curves exhibit strong local characteristics, namely, the high average turbidities during summer and the relatively low values in winter. Other stations in different geographical areas will show variations of these patterns, but the common feature at all stations is the summer maximum and winter minimum in turbidity.

The responsibility for the collection, review, and publication of the world turbidity data has been given to the NCC. The ML has cooperated with the NCC in its quality control of the turbidity data. Feedback from data checking has been helpful in checking the turbidity instruments; data that appear suspicious usually have led to a faulty instrument.

Instrumental work has required a large amount of time. This work includes recalibrating sunphotometers; about 50 of these instruments were recalibrated during the year, either as a part of the regular annual recalibration program or following the repair of a damaged instrument. In addition, the two primary standard sunphotometers were regularly calibrated to define more accurately their constants and to keep a check on their performance. One of these standards appears to be gradually losing sensitivity in the 500-nm channel. Two other sunphotometers are being maintained as standards, and nearly 1 year of data is available for these instruments.

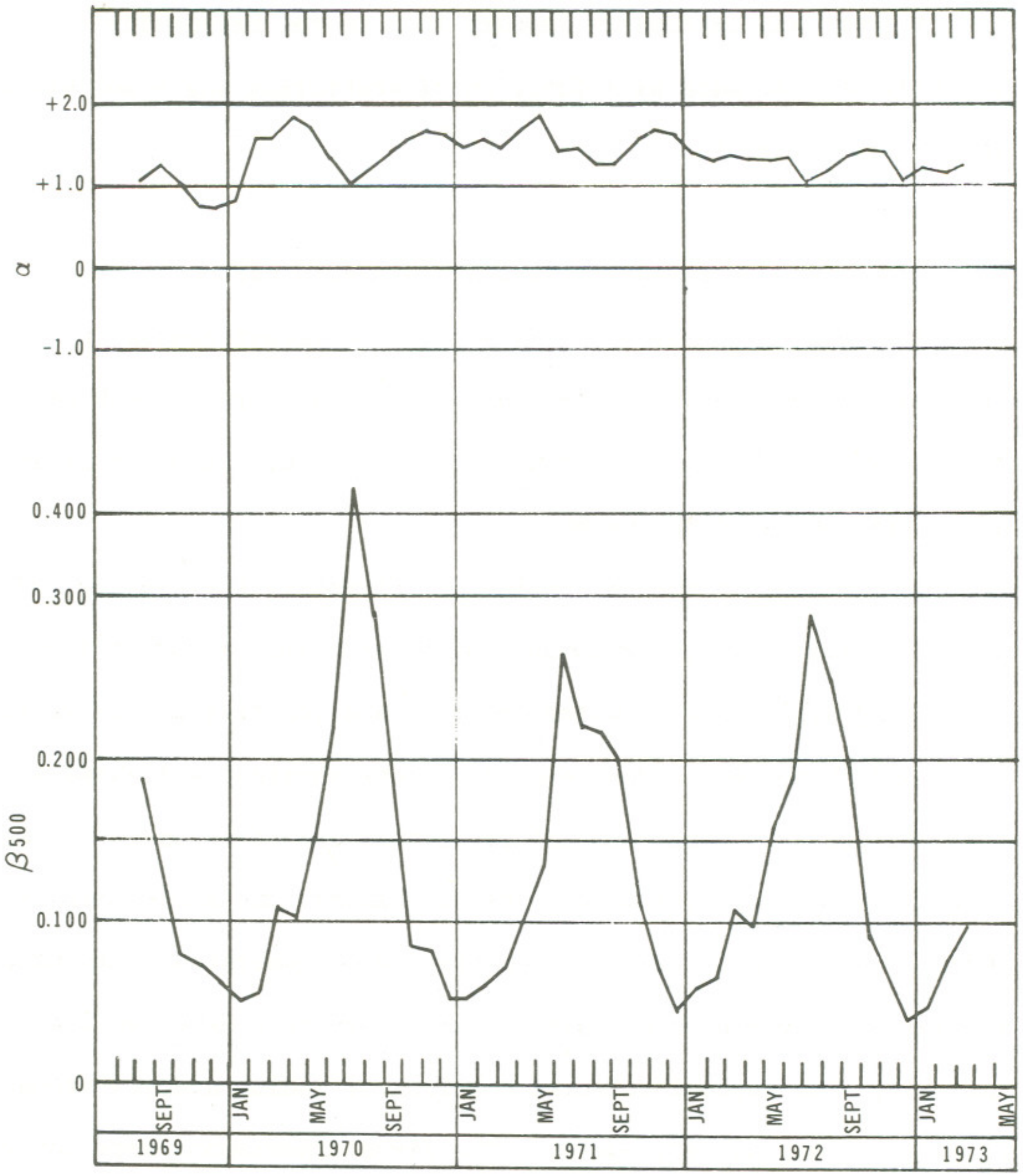

Figure 2. Monthly mean values of turbidity (β 500) and of Angstrom's wavelength exponent (α), measured at Research Triangle Park, N. C., from July 1969 through March 1973.

A grant was awarded in January 1973 to the University of Alaska to study sky radiance as a function of scattering angle and wavelength in the sun's aureole.

3.6 Pollutant Removal by Precipitation

Precipitation scavenging is a major pollutant removal process and, as a consequence, also is the cause of the "acid rain" problem. Studies of the removal of gaseous and particulate pollutants by precipitation are being sponsored by the ML.

Researchers at the University of California-Los Angeles (UCLA), under a 3-year grant, are conducting a laboratory study of the scavenging efficiency of water droplets and ice crystals of various sizes and shapes for aerosols of different physical and chemical characteristics. Three special facilities are being used: a large vertical wind tunnel, a walk-in cloud chamber, and a 35-m high rain shaft. Initial efforts were concentrated on generating a monodisperse aerosol of a hydrophobic substance sensitive to neutron activation analysis. The aerosol selected consists of indium acetylacetonate ($In\ Ac_3$) formed on NaCl nuclei. The first experiments were conducted in the vertical wind tunnel. A scavenging efficiency of 10^{-3} was measured for the collection of aerosols with a radium of 0.4 μm by a single waterdrop. This result was consistent with the theoretical computations, indicating aerosols that collide with waterdrops will stick even though the aerosols are hydrophobic. The study is continuing.

Personnel at the Battelle-Pacific Northwest Laboratories (BNW) have been investigating the scavenging of gases, particularly SO_2, by precipitation for the past 4 years. A brief review of the earlier work was reported in the Fiscal Year 1972 Summary Report (NOAA, 1973). This work, previously limited to the study of washout from power plant plumes, has been expanded to include the study of gas pollutant washout from large area sources. Field studies were conducted in the St. Louis area, in coordination with METROMEX, in August 1972. That field program was a trial run for more extensive observations to be made in the summer of 1973. Precipitation samples were collected during the passage of convective storms over St. Louis. The samples were analyzed for sulfate, sulfite, ammonium ion, nitrate, nitrite, sulfur dioxide, and pH. No sulfur dioxide or nitrite was found. Results indicated that precipitation scavenging removes essentially all the sulfate and nitrate emitted in the St. Louis area. Because this was only a preliminary field program, the conclusions are necessarily tentative.

3.7 Standard Atmospheres

The first U.S. Standard Atmosphere was published in 1958. It presented tables of the atmospheric thermodynamic parameters — temperature, density, and pressure — to 300 km (Minzner *et al.*, 1958). This was revised in 1962 and expanded in supplemental tables in 1966. The 1962 revision (NASA *et al.*, 1962) extended the U.S. Standard Atmosphere to 700 km. It depicts middle-latitude, year-round mean conditions for the range of solar activity that occurs between sunspot minimum and maximum. In 1966 (ESSA et al., 1966), additional tables were published to supplement the U.S. Standard Atmosphere, providing tabulations of atmospheric parameters, from the surface to 1,000 km, by latitude and season for lower altitudes and as a function of solar activity and angle for higher altitudes.

Revision is a continuous process. A revised U.S. Standard Atmosphere is completed and will be published in late 1973 or early 1974. The EPA was invited to join the Working Group of the U.S. Committee on Extension of the Standard Atmosphere (COESA). The ML provided representation on the Working Group and related Task Groups.

No changes were made in the thermodynamic parameters below 32 km. Studies and analysis of all available observational data show excellent agreement with the tabulated values. However, changes were made above this level, and the tables were extended to 2,000 km.

A major change was the inclusion of a chapter on atmospheric minor constituents. The objective was the preparation, where possible, of a "standard composition atmosphere." This work, relegated to a Task Group on Minor Constituents of the Atmosphere, had ML representation. It quickly became apparent to the Task Group that measurements of many trace substances in the atmosphere either did not exist or have been made only in heavily polluted areas. In addition to those substances, charged species, radionuclides, isotopes, and substances whose concentration are only inferred from numerical or chemical models have not been included.

For most of the remaining substances, statistical evaluation of the data was not appropriate, so that typical values and, when feasible, concentration ranges are given. More additional data, covering a large altitude range, exist for ozone, water vapor, and fine particles; thus, more extensive tables and charts are presented. The contribution of the ML consisted of a review and analysis of information available on SO_2, CO, and CO_2. Recommended values are given in table 5.

With its work on the new U.S. Standard Atmosphere complete, except for publication, COESA attention is being directed toward revision of the U.S. Supplemental Atmospheres published in 1966.

Table 5. Annual Mean Mixing Ratios of Sulfur Dioxide, Carbon Dioxide, and Carbon Monoxide for 45°N. All the Mixing Ratios Are Reported in Parts Per Million by Volume (ppm V)

Height (km)	Sulfur dioxide (SO_2)	Carbon monoxide (CO)	Carbon dioxide (CO_2)
Surface	1.2×10^{-3}*	0.19	322 (1970)
0-11 (troposphere)	**	0.13	322 (1970)
11-20 (lower strato-sphere)	**	0.04	321 (1970)

* tentative value; ** insufficient data.

4. REGIONAL AIR POLLUTION STUDY (RAPS)

The RAPS, a planned 5-year study in the St. Louis metropolitan area, was formally initiated in July 1972. The basic objective of the RAPS is development and validation of improved air quality simulation models that will be applied to the development of least-cost pollution control strategies and that may be further applied to land use, ecological, and total cost-effectiveness models, among others. To attain the basic objective requires an extensive base of emission, meteorological, and air quality data, together with research on the processes affecting pollutant transformations, dispersion, and ultimate fate of emitted pollutants.

The first year of effort was devoted to the setting up of plans and organization and the initiating of procurements for use in later stages of the RAPS. Most of the permanent RAPS staff — the Study Director, Research Operations Manager, Facilities Manager, and Administrative Officer — will be stationed in St. Louis for the duration of the Study; however, the Data Manager and Research Coordinator will be based at Research Triangle Park. An EPA Steering Committee, consisting of the Directors of the seven Laboratories and Divisions concerned with the Study, provides internal guidance; an ad hoc Interagency Liaison Panel of the Interdepartmental Committee for Atmospheric Sciences (ICAS) provides general guidance and coordination with other federally funded groups that are planning and performing experiments in the St. Louis area.

Major effort during the fiscal year was devoted to procuring a prime contractor for the Study, culminating in the signing of contracts with the Rockwell International Corp., Thousand Oaks, Calif., in May 1973. Under terms of the contracts, Rockwell will install, operate, and maintain a 25-station measurement network in the St. Louis area. Stations will consist of transportable housings containing instruments for measuring CO, NO, NO_2, O_3, total hydrocarbons, non-methane hydrocarbons, total gaseous sulfur, SO_2, and H_2S; also included will be integrating nephelometers, meteorological instrumentation to measure temperature, vertical temperature difference, dewpoint, wind direction and windspeed, and three-dimensional turbulence, and sensors to measure both direct solar and total hemispheric downward-directed radiation over a variety of wavelength intervals. All these measurements, except turbulence, will be transmitted once every minute by telephone lines to a central computer facility where the data will be checked and further processed for display, storage, and later transmission to the EPA computer facility at Research Triangle Park. The network will be controlled by the central computer which will initiate commands for data polling, for remote zero and span checks on the bulk of the air quality instruments, and for operation of additional equipment — such as high-volume total particulate samplers, bags for collection of whole-air samples, and on-off commands for magnetic tape collection of turbulence data. Spare rack space and command and data channels will be available at all stations, allowing additions of equipment to the network. The contractor will also supply space and operating personnel as required for operation of special analytic equipment, such as a long-path Fourier transform spectrometer, an X-ray fluorescence analyzer, and gas chromatographs for compositional analyses of hydrocarbons. The contractor will be expected to provide a variety of supporting equipment and services for the performance of special experimental studies, most of which will be of the short-duration expeditionary type.

During the summer of 1972, several preliminary studies were performed in the St. Louis area. Differences in downward-directed radiation between a rural and an urban site were measured, and, under contract, surface albedo and thermal response of the surface were investigated; these are described in more detail elsewhere (see discussion in 2.20 and 3.4). In addition, surveys were made to determine the gaseous pollutant composition at a number of points in the region.

5. OPERATIONAL SUPPORT

5.1 Field Support to the Emergency Operations Control Center (EOCC)

Routine operations of the EOCC were phased out in 1972, shifting greater responsibilities to the EPA Regional Offices. However, a skeleton EOCC staff remains within the NERC, Research Triangle Park, to deal with accident emergencies. A team of meteorologists and meteorological technicians within the ML has been assigned responsibility for maintaining a state of readiness and for responding to emergency requests. Also, assistance was provided to the EOCC during the Regional Accidental Air Pollution Episode Workshop on February 1-2, 1973, at which the meteorological experience gained in various accident situations was discussed with representatives from the EPA Regional Offices.

5.1.1 Louisiana Chlorine Barge Incident at Morgan City

A meteorologist and meteorological technician provided field support to the EOCC in the Morgan City-Berwick, La., area on January 9-13, 1973. An accident occurred in which a barge with four chlorine tanks, each containing 275 tons of liquified gas, struck a railroad bridge and became lodged beneath it. An emergency center was established at the Berwick City Hall, with wind sensors and a pibal station placed on the roof. Forecast assistance was received from the Weather Service Forecast Office at New Orleans, La.; dispersion advice was provided from the emergency center, based on information accumulated during the Louisville, Ky., chlorine barge incident in March 1972. About 2,800 people were evacuated for about half a day as a precautionary measure while the barge was being pulled loose and towed away. In general, all operations proceeded smoothly. Wind conditions caused little concern during the critical hours because the wind direction remained northwesterly, downriver, from either of the two cities involved.

5.2 EPA Regional Offices

The 10 EPA Regional Offices supply technical assistance directly to State and local air pollution control agencies. In turn, the ML supplies assistance to these Regional Offices. With the exception of the Kansas City office, all Regional Offices have a Regional Meteorologist, although some persons performing the duties do not have this title and are not NOAA employees. Throughout most of Fiscal Year 1973, assigned NOAA meteorologists were available in seven Regional Offices: Boston, Philadelphia, Atlanta, Chicago, Denver, San Francisco, and Seattle. In March 1973, an EPA meteorologist replaced the NOAA meteorologist in Chicago as the result of a local administrative action; and in June 1973, the Regional Meteorologist in Boston resigned to join a consulting corporation.

The workloads and responsibilities of the Regional Meteorologists vary, depending upon the frequency and duration of atmospheric stagnations affecting each Region and the particular local problems associated with the geographical area in which they are located. For example, the emphasis in Atlanta has been on preparations for air stagnation episodes, whereas the greatest effort in Denver has been devoted to problems associated with large single sources of air pollution such as copper smelters and large coal-burning power plants. All Regional Meteorologists have a variety of duties, depending upon the needs of the State and local agencies. They help in determining the adequacy of air pollution control programs, participate in the development of regulations, represent the EPA at public hearings, inspect monitoring sites, and coordinate slash and agricultural burning programs. They also review environmental impact statements, requests for variances, grant applications, and contract proposals. All Regional Meteorologists are actively engaged in the application of dispersion models.

A 1-day meeting of Regional Meteorologists was held November 8, 1972, in Chicago for the purpose primarily of discussing meteorological support to the Regional EOCC. At that meeting, each Regional Meteorologist reported on his meteorological activities and his ability to respond to air pollution emergencies.

Some Regional Offices have been directly involved in field monitoring. The Atlanta office is cooperating with the Department of Interior on the Dade-Collier Training and Transition Jetport Air Pollution Study in south-central Florida. This study of a proposed international airport site focused attention on high photochemical oxidant concentrations, sometimes exceeding the National Ambient Air Quality Standard of 0.08 ppm, that can occur in this and some other nonurban areas. The Western Regional Offices have been involved in establishing sulfur dioxide monitoring networks in the vicinity of large nonferrous smelters to verify their compliance with air quality standards. Each of these networks includes at least one wind-recording station. Because smelter monitoring operations are just beginning, results are not yet available.

P. L. Finkelstein, the Regional Meteorologist, Region III, received his doctorate in 1973.

5.3 Office of Air Quality Planning and Standards (OAQPS)

Three meteorologists are assigned to the Source Receptor Analysis Branch and two to the Monitoring and Reports Branch of OAQPS to provide meteorological support to air pollution control operations. Assistance was also given to enforcement offices of the EPA.

5.3.1 Source Receptor Analysis Branch

5.3.1.1 Major Sulfur Dioxide Sources in Complex Terrain

A staff report on estimated impact of smelting operations on SO_2 concentrations in the Rocky Mountain area was completed in August 1972.

Work continued on providing estimates of SO_2 concentrations in complex terrain from smelters and power plants. A number of lawsuits have been filed against EPA by these industries, contesting the procedures used for obtaining dispersion estimates where the plume is intercepted by high ground. Consequently, it has been necessary to examine and test alternative procedures that have been proposed.

One of the Branch meteorologists has worked with the Regional Meteorologists in the Western States and with the Quality Assurance Environmental Monitoring Laboratory to select SO_2 sampling sites, making a trip to the Four Corners area of New Mexico for this purpose.

5.3.1.2 Fuel Distribution Study

Recent studies on the impact of State Implementation Plans (SIP) have indicated a potential nationwide low-sulfur coal deficit in 1975. The deficit will be most acute in 12 States with high coal-consumption rates. One means to alleviate the deficit would be to grant variances to large non-urban power plants, provided ambient air quality standards are not violated. Initially, the 24-hour single source model (JCHCRS1) was applied to three Air Quality Control Regions (AQCR) in Indiana. The results of this study indicated that most large power plants could be permitted to burn coal at their 1970 sulfur levels temporarily without violating either annual or 24-hour primary air quality standards.

Also, an additional five AQCR's were modeled, involving 16 large power plants. The results indicate that five of these plants could be granted a full variance without exceeding ambient air quality standards.

Two additional plants could be given limited variances (some sulfur reduction would be required, but not to the extent required by the SIP). The remaining nine plants could not be granted variances. The report on this project, "Fuel distribution study for five Midwest AQCR's," is in preparation.

5.3.1.3 Intermittent Control Systems (ICS)

During the past fiscal year, intermittent control of pollution sources in place of continuous control with emission control devices emerged as a major issue, principally because: (a) Some stronger evidence of the potential reliability of intermittent control systems became available; and (b) for certain sources, constant control systems may be inadequate or unavailable, thereby preventing timely attainment of air quality standards. Investigation of intermittent control by the OAQPS, with assistance from ML personnel, revealed that an ICS is a viable control measure, but only for large, isolated, elevated sources of SO_2.

Meteorologists assigned by the ML assisted the OAQPS in the following specific activities:

(1) Informal evaluation of proposals from specific and group sources so as to utilize intermittent control in place of the SIP requirements.

(2) Technical evaluation of proposals received in response to a Request for Proposal for an investigation of the reliability of the ICS.

(3) Visiting facilities currently using intermittent control to assess their ICS programs.

(4) Drafting of a staff paper on intermittent control systems which included the following subjects:

(a) Theory and operation of the ICS,

(b) Reliability,

(c) Enforcement,

(d) ICS and the SIP, and

(e) Various related topics.

(5) Drafting of proposed revisions and additions to the Code of Federal Regulations (40 CFR 51) that would provide for the use of supplementary control systems (SCS) in carefully selected situations.

5.3.2 Monitoring and Reports Branch

5.3.2.1 Air Quality Trend Reporting

The Monitoring and Reports Branch, Monitoring and Data Analysis Division, has the responsibility for assessing and reporting trends in air quality. The Branch utilizes data available in the National Aerometric Data Bank (NADB) for analyses that provide information necessary to trigger actions to assure that National Ambient Air Quality Standards are achieved in 1975 (or 1977, if an extension is granted). A ML meteorologist is assigned to the Branch to take into account meteorological factors in the interpretation of air quality trends. Efforts in analyzing data for the first report by the Branch have been focused on isolating meteorological parameters that can cause anomalous short-term trends (within 4 years or less). Heating-degree days and

and rainfall have thus far been associated with anomalous short-term trends. In the Western States during the 1968-71 time frame, a trend toward increasing suspended particulate levels, reversing an established long-term trend (1960-71), was found to be associated with a preponderance of decreased rainfall during the same period. The first semiannual report of the Branch is to be issued in mid-1973. Later efforts may include national trend analyses of airport visibility (an air quality component) and development of indices to adjust air quality trend lines for the effect of anomalous meteorology.

5.3.2.2 Delmarva Power Plant

ML meteorologists played an active part for the Government in a lawsuit initiated by Getty Oil Company against the EPA concerning a power plant the Company operates in Delaware. The Company claimed that an EPA-approved State regulation, requiring the use of lower sulfur fuel, should not be enforced at the Company's Delmarva Power Plant because measured air quality in the county in which the plant is located did not violate SO_2 air quality standards. A ML meteorologist provided an affidavit to the court stating a professional opinion, based on dispersion estimates, that short-term, 24-hour SO_2 standards could be violated at locations where monitors were not in existence. The court's decision was in favor of the EPA.

5.3.2.3 Hazardous Pollutant Monitoring Guides

National Emission Standards for Hazardous Air Pollutants were issued in April 1973. ML meteorologists have been involved in the development of emission limitations for mercury and beryllium on the basis of dispersion considerations. Some large sources of beryllium will have the option of monitoring the ambient air to assure that a concentration of 0.01 $\mu g/m^3$ over a 30-day average is not exceeded. To permit the EPA Regional Offices to evaluate monitoring networks for these large beryllium sources expeditiously, a ML meteorologist has prepared two in-house guides: (1) Preliminary evaluation of sampling networks for beryllium extraction plants, and (2) Guidelines for design of beryllium air monitoring networks.

5.3.2.4 Review of Impact Statements

During the fiscal year, approximately 60 draft Environmental Impact Statements (EIS) were reviewed to insure that meteorological factors are properly considered. Final EIS's were also reviewed as received. A guide for air quality review of EIS's was prepared for use in Regional and other EPA offices. It was found that the reported frequencies of occurrence of Pasquill stability classes vary widely, depending on the method used for determining the stabilities. Consequently, information on stability in different parts of the United States is being accumulated, and the development of a climatology of the frequency of occurrence of Pasquill stability classes throughout the conterminous United States has been proposed.

5.4 Human Studies Laboratory

A meteorologist and a meteorological technician are assigned to the Human Studies Laboratory (HSL) to offer assistance and guidance in the design, operation, and analysis of data from studies involving meteorological data, instruments, or climatological information. The following are examples of work performed in support of the HSL.

Community Health Environmental Surveillance Study (CHESS) programs in New York City, in the Southeastern United States (Birmingham, Ala., and Charlotte, N.C.), and in Los Angeles were given daily summaries of possible atmospheric stagnation conditions. When an Air Stagnation Advisory was issued for an area that includes a CHESS city and was forecasted to persist 48 hours or longer, a procedure was initiated by the HSL to survey the affected population by means of telephone and medical questionnaires adapted to a counting procedure that allows for rapid computer analysis.

Results from several CHESS operations are given in the paper by Nelson et al. (1973). In two high air pollution episodes in New York City during the summer of 1970 and in one episode in April 1971 in the Southeast, it was found that cough, chest discomfort, and restricted physical activity were statistically significant in New York City when the 24-hour SO_2 and particulate concentrations attained levels of 340 and 172 $\mu g/m^3$, respectively, and were similarly found in the Southeast when the 24-hour particulate concentrations were 179 to 186 $\mu g/m^3$, even with very low SO_2 levels of less than 20 $\mu g/m^3$. These exposures were below the maximum 24-hour national primary standard (not to be exceeded more than once a year) of 365 $\mu g/m^3$ for SO_2 and of 260 $\mu g/m^3$ for particulate.

A prototype, continuous aerometric monitoring station was installed at Chapel Hill, N.C., to determine the best possible instrumentation for temperature, dewpoint, windspeed, and wind direction to be included in the design of the forthcoming Community Health Air Monitoring Program (CHAMP). The CHAMP will function as part of the more comprehensive CHESS program. With pollutant and meteorological data provided by the CHAMP's instrumentation, CHESS will determine relations between air pollution and human health problems such as asthma, bronchitis, heart disease, and other chronic respiratory problems. The CHAMP instrumentation will replace that now operating at four CHESS cities — New York (four sites), Birmingham (four sites), Charlotte (two sites), and Los Angeles (seven sites) — and will be used as initial installation at two future CHESS cities — Salt Lake City, Utah (four sites) and St. Louis (two sites). Continuous values of temperature, dewpoint, windspeed, and wind direction, along with pollutant concentrations of SO_2, NO, NO_2, O_3, CO, and total suspended particulate, will be automatically recorded and transmitted back to HSL at Research Triangle Park.

Additional assistance, that is, the collection of climatological temperature, was given the HSL in support of an asthma study in southern California. Also, maintenance for four hygrothermographs in laboratories at Research Triangle Park and two Aerovane wind systems at Chattanooga, Tenn.

Besides direct support of the HSL projects, studies were conducted on topics utilizing data accumulated during various health investigations. Work continues on nationwide mortality statistics as they relate to influences of extreme maximum and minimum temperatures. An expected daily mortality rate was computed for each of 422 regions throughout the United States for the years from 1962 to 1966, and the actual number of daily deaths was then compared as a ratio to the expected. Regions with daily mortality ratios of 1.50 or greater were noted, and prevalent atmospheric conditions were observed to determine any relationship between the two events. Consequently, two extreme heat waves were investigated — New York City on July 4, 1966, and St. Louis on July 13, 1966 — and one cold wave in the Southeastern United States on January 30, 1966. An article on these three events is now being prepared for publication; its content will discuss synoptic conditions related to the excess mortality and the particular causes of death.

Another study in progress concerns atmospheric conditions prevalent during extremely high concentrations of NO and NO_2 observed at Chattanooga. Concentrations of these pollutants will be identified and the associated weather conditions analyzed.

5.5 Quality Assurance and Environmental Monitoring Laboratory (QAEML)

A meteorologist is assigned to the Quality Assurance and Environmental Laboratory to assist with the correlation and interpretation of air quality data, to review monitoring results, and to provide advice on the location and exposure of air sampling instruments.

Further study was made of the ozone data gathered during June, July, and August of 1971 at a number of cities east of the Rockies because of unexplained high ozone concentrations. Chemiluminescent-type samplers were located downwind (with respect to the prevailing winds) of the center of each city and at a distance of 5 mi, more or less, depending on the availability of sites.

It was expected that the highest concentrations of ozone would be found when winds brought air from the city toward the sampler. This proved to be true in general, but there were exceptions which raised questions as to other sources of ozone. At New Orleans, the sampler was located on the north side of the city, not far from the shore of Lake Pontchartrain. The highest ozone concentration occurred with winds from across the lake, which is about 25 mi wide at that point, and its source has not been determined. At Houston, Tex., the sampler was located 6 mi northwest of the center of the city. The highly industralized ship canal area is to the east and south. However, the highest average hourly concentration during the hours of 1200 and 1500 occurred with northerly winds. The concentration with east winds was also high. Because the prevailing winds were southeasterly, the greatest amount of ozone undoubtedly came from the east and southeast, but a significant amount also came from unidentified sources north and northwest. The sampler for Rochester, N.Y., was 10 mi east of the center of the city and showed the greatest concentration of ozone occurred with winds from Rochester. However, northwest through northeast winds, coming from Lake Ontario and reaching the sampler after only a short passage across land, frequently carried high concentrations. There were similar unexplained high ozone concentrations at Omaha, Nebr., Milwaukee, Wis., and other cities.

Miami reported the lowest average and peak values of any of the cities in the study (except for San Juan, P.R.). However, in 1972, during another study, at a point 40 mi west of Miami at the Dade-Collier Training and Transition Jet Port, there was a period of almost 1 week when the hourly values were so high that they exceeded the National Air Quality Standard for hours at a time. That Jet Port study was begun in March 1972, and data were made available through August 1972.

Ozone concentrations, in general, follow a daily trend related to the amount of sunlight available, with the highest concentrations found around noon or soon afterward and with the low concentrations found at night. However, during the period from May 20-27, 1972, concentrations were consistently high with winds more consistently westerly than usual. No source appears to the west; moreover, there have been other periods of westerly winds with no high concentrations. In fact, if transport were involved, easterly winds would be more likely to bring ozone because of the higher density of traffic around Miami and the east coast of Florida. Further investigation revealed this episode, as measured at the Jet Port, coincided with a previously noted period of widespread haze and smoke that covered southern Florida from May 21-27; it appeared that the source of the ozone was at a much greater distance, perhaps from States as far distant as Pennsylvania and Ohio.

Although the ozone concentrations were much higher in Miami in May 1972 than for the same period during the preceding year, apparently some of the ozone which had survived the long trip was destroyed by nitrogen oxides and other pollutants in the Miami atmosphere. The highest daily average ozone concentration reported in Dade County was 0.040 ppm on May 22. At the Jet Port, the hourly ozone concentration on that day did not drop below 0.070 ppm during the entire 24-hour period and was above the National Air Quality Standard of 0.080 ppm for 13 hours, reaching 0.105 ppm during the hours of 0900 and 1000.

Another case of high ozone concentrations occurring in a rural area is described in a report by F. Vukovich (1973). At the Garrett County Airport, Md., between August 4 and September 24, 1972, approximately 11 percent of the hourly ozone concentrations exceeded the 0.080 ppm National Air Quality Standard. During one period, the Standard was exceeded for 26 consecutive hours. Again, although not as well verified, it seemed that the high ozone concentrations were associated with airmasses which had passed over urban industrial regions.

The QAEML meteorologist has served as a member of a Task Force convened by the Director, NERC, Research Triangle Park, to review and evaluate the effects of altitude as a variable in relation to air pollution problems. Also, he is one of the participants in a study of observed particulate concentrations in England. Prevailing winds and observed particle sizes indicate significant transport of particulates coming from continental Europe into England.

The Field Monitoring and Instrument Evaluation Branch, QAEML, is routinely assisted to assure the quality of data being received from wind stations in the Smelter Ambient Air Monitoring Project. Measurements of SO_2 are being made at 12 nonferrous smelters spread throughout Montana, Idaho, Utah, Nevada, Arizona, and New Mexico. Several sampling sites are found in the vicinity of most of the smelters. At one site, a continuous monitor determines peak values of SO_2 and the times of its occurrence. At other locations, there are only SO_2 bubblers to determine 24-hour SO_2 average concentrations. Windspeed and wind direction are measured at one site for each smelter, and instrument records and data compilations are systematically checked to assure data quality.

5.6 Control Programs Development Division (CPDD) Air Pollution Training Institute

Two meteorologists are assigned to the Air Pollution Training Institute: one serves as Chief of the Air Quality Management Section; the other is assigned to the Laboratory and Surveillance Section. Blocks of instruction are developed and presented on all aspects of air pollution meteorology required to support the curriculum of the Institute. Most instruction is presented in intensive short courses, usually of 1-week duration.

The basic course, "Air Pollution Meteorology," is recommended for meteorological technicians and for scientists and engineers having little or no training in meteorology. There were three course presentations during the fiscal year; in all, 79 persons received certificates of completion. The course manual was reprinted in 1973, incorporating certain revisions and updates of material.

The second course, "Diffusion of Air Pollution — Theory and Application," is designed primarily for meteorologists working in air pollution control. Other scientists and engineers who have completed the basic course may also enroll. This course was presented once to 25 students at Research Triangle Park.

The third short course, "Meteorological Instrumentation in Air Pollution," is basically for engineers and technical personnel responsible for designing, procuring, and maintaining air pollution monitoring networks that include meteorological sensors. A 1-m cross-section wind tunnel is being used for demonstrations and experiments in a new laboratory. Twelve persons attended the single presentation of the course.

To support the National Weather Service (NWS) and its Focal Point Meteorologist program, the Institute, in cooperation with the NWS National Meteorological Center (NMC) and the Weather Analysis and Prediction Division, continued a 2-week training program in air pollution. NWS meteorologists responsible for preparing air stagnation advisories receive 7 class days of instruction on air pollution and meteorological topics at Research Triangle Park; then, they travel to Suitland, Md., for 3 days of discussion and familiarization with NMC guidance materials, forecast research programs, and NWS policy in support of environmental pollution programs. Seventeen meteorologists attended this course in August 1972.

A narrated slide sequence entitled, "Effective Stack Height," has been completed and is being incorporated into an instructional package on this topic. The package is designed primarily for engineers and scientists and requires an in-depth study of Briggs' (1969) publication, Plume Rise, and related papers. An audio tape cassette and set of lecture notes on Plume Rise, made during a classroom presentation by Dr. G. A. Briggs, is included in the package, together with three problem sets and recommendations for calculation procedures prepared by the ML's Model Application Branch. The package is designed so that is requires 4 to 8 hours of student time to complete.

A self-instructional cassette tape and booklet on air pollution meteorology, part of a nine-component course, has been prepared. The meteorology portion requires about 2 hours to complete.

Numerous seminars, lectures, and informal talks were presented to various professional organizations, university classes, civic groups, and schools. The senior meteorologist accepted a 2-month World Health Organization (WHO) appointment as a consultant in environmental health; he traveled to Nagpur, India, to develop an air pollution training program for the Central Public Health Engineering Research Institute. A 324-page training manual (Dicke, 1973) was compiled, and a 1-week long training course was conducted in Bombay as part of this WHO project.

Several man-weeks were spent assisting the Federal Highway Administration in preparing and presenting materials on air pollution meteorology topics, such as selection of meteorological sensors, instrument exposure, and data reduction techniques for highway environmental impact projects, in conjunction with three 2-week training courses for State highway engineers.

5.7 Radiochemistry and Nuclear Energy Research Laboratory

The series of field studies being conducted in the vicinity of the Oyster Creek Nuclear Power Station, N.J., reported in the Fiscal Year 1972 Summary Report, has continued. A meteorologist assisted a team from the EPA Radiochemistry and Nuclear Energy Research Laboratory during monitoring operations on August 22-24, 1972, on December 11-14, 1972, and on April 2-4, 1973. The stack from which the ventilating air and the off-gases from the reactor are expelled is 117 m (384 ft) high. Estimates of the distances to which maximum concentrations could be expected were made, and advice was given for locating portable sampling equipment in or beneath the stack plume. Wind and temperature gradient information were available from a 122-m (400-ft) meteorological tower near the stack, and upper wind information was determined from pilot and ceiling balloons. During the April 1973 observations, a U.S. Coast Guard helicopter was used to make radiological determinations within the plume. Results of this work are being reported by the Radiochemistry and Nuclear Energy Research Laboratory.

5.8 Special Assistance to State of West Virginia

At the request of the Director of the West Virginia Air Pollution Control Commission, a statement pertaining to SO_2 concentrations from the Mitchell and Kammer power plants, Moundsville, W. Va., was presented to the State Commission on December 7, 1972. The Mitchell plant has a 366-m (1,200-ft) stack, whereas the Kammer plant has two 183-m (600-ft) stacks, with a 305-m (1,000-ft) stack under consideration. The plants are located sufficiently close together to be considered as a single source, and the combined rate of emission is 1,600 tons of SO_2 per day. It was concluded that emissions from the 183-m stacks at the Kammer plant could cause ambient air standards to be exceeded on the hill and ridge tops directly downwind, but the probability of emissions from the proposed 305-m stack at the Kammer plant and the 366-m stack at the

Mitchell plant exceeding standards is too low to be of practical significance. However, it was pointed out that marginal conditions for injury to sensitive vegetation occur at distances of 4 to 30 mi (6.2 to 48.3 km), potentially affecting an area of 2,800 sq. mi.

5.9 Assistance to Other Federal Agencies

The Special Projects Branch of the ML answers inquiries and provides technical assistance to other Government agencies according to need. Among the agencies receiving assistance were the Department of the Treasury (reports and advice on dispersion modeling for possible sulfur dioxide emission tax), Office of Science and Technology (advice on environmental monitoring), and Department of Defense (reports on air pollution conditions and monitoring stations in the Washington, D.C., area).

5.10 Interagency Coordination Committees

The Chief, Special Projects Branch, serves as the representative of the ML on the NOAA-EPA Coordination Group. This committee has been primarily concerned with determining priorities for NOAA Environmental Meteorological Support Units (EMSU) in major cities. Recently, the committee has been concerned with a national reduction of EMSU services because of economy measures being taken by NOAA. The Branch Chief also serves as the alternate EPA representative on the Interdepartmental Committee for Meteorological Services and on its new Subcommittee for Atmospheric Quality Meteorological Services, which will include representation from all Federal agencies concerned with air quality. This subcommittee is presently engaged in drafting a Federal Plan stating the meteorological requirements of the agencies concerned.

On December 14, 1972, the National Communications System/Weather Communications Coordinating Committee was given a briefing on the EPA meteorological communications requirements. This briefing covered the EPA organizational structure, Regional Office facilities, computer modeling hookups, and EPA data storage and retrieval systems for air pollution source inventories (NEDS), air quality data (SAROAD), and water quality data (STORET).

6. INTERNATIONAL ACTIVITIES

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

Mr. R. A. McCormick (Chairman), Mr. K. L. Calder, and Dr. W. B. Johnson, Jr. attended the Third Meeting of the Expert Panel on Air Pollution Modeling, held in Paris on October 2-3, 1972. One major aim of the NATO/CCMS air pollution project is to keep the users of air quality simulation models informed of the current state of the art. To provide an opportunity for an informal give-and-take on information of the widest possible basis, participation at the meeting was broadened to include representation from countries not members of NATO. Thus, 11 countries were represented at the meeting — the United States, Federal Republic of Germany, Turkey, Italy, France, the Netherlands, Norway, Sweden, Denmark, United Kingdom, and Canada. Among the topics discussed were air quality modeling efforts for St. Louis and New York City in the United States, Ankara in Turkey, Cologne, Frankfurt, and Dusseldorf in Germany, Milan in Italy, Stockholm in Sweden, Oslo in Norway, London and Manchester in the United Kingdom, and for the Netherlands. In addition, a number of general questions connected with simulation modeling and atmospheric dispersion were considered. The EPA made a contribution to the CCMS pilot study by compiling and publishing the proceedings of this meeting as a permanent record of the material discussed (NATO/CCMS, Air Pollution, Modeling, No. 14).

Encouraged by the success of the above meeting, a Fourth Meeting of the Expert Panel on Air Pollution Modeling was held at Oberursel, Germany, on May 28-30, 1973. Again participants at the meeting included countries of Western Europe, the United States, Canada, and Australia. The meeting was organized as a series of five workshop sessions, aimed at a free and open exchange of ideas and attitudes on topics currently of major significance in air pollution modeling activities. The five workshop sessions held are as follows:

(a) Applications of modeling and users needs;

(b) Validation of air quality simulation models;

(c) Role of regional air pollution studies in model development;

(d) Role of empirical/statistical modeling of air quality; and

(e) Simplicity versus sophistication in air quality modeling.

Approximately 50 experts participated, including Mr. K. L. Calder, Mr. D. B. Turner, and Dr. D. G. Fox of the ML.

6.2 World Meteorological Organization (WMO)

During the week of December 11-15, 1972, Mr. G. C. Holzworth participated in meetings of the Working Group on Applications of Meteorology and Climatology to Environmental Problems, Commission for Special Applications of Meteorology and Climatology at the WMO headquarters in Geneva, Switzerland. The objective of the Working Group was to prepare a report on the involvement of the WMO in meteorological applications to environmental problems and to establish guidelines for international activity and participation. Some of the topics considered were: man's impact on local and regional climate, applications of climatology in local and regional land use planning, development of natural resources, environmental effects of energy production and use, and worldwide environmental monitoring.

6.3 World Health Organization (WHO)

Mr. J. L. Dicke served as environmental health consultant to the Central Public Health Engineering Research Institute, Nagpur, India, during the spring of 1973. This 6-week assignment, under the auspices of the WHO Southeast Asia Regional Office, was for the purpose of advising on air pollution survey work, assisting in the preparation of a training program, and providing the training expertise in meteorological aspects of air pollution. Two main accomplishments of the assignment were development of an air pollution control training program and the presentation of a 6-day training course at Bombay.

From May 6-19, 1973, Dr. J. L. McElroy served as a WHO consultant on meteorological aspects of air pollution modeling at the Polish Environmental Pollution Abatement Centre, Katowice, Poland. The trip was sponsored by the UNDP/WHO Project Poland. Following his assignment in Poland, Dr. McElroy visited the research laboratories of several institutions in Western Europe.

6.4 U.S. — U.S.S.R. Environmental Agreement

Under a recent U.S. — U.S.S.R. agreement on mutual exchange of information relating to environmental pollution problems, a U.S.S.R. group visited the NERC at Research Triangle Park, N.C., on May 14-16, 1973. The first day of the visit was spent in the ML and was devoted to discussions on air pollution potential forecasting, numerical modeling of air pollution dispersion, and physical modeling of air pollution dispersion. Other discussions held later were related to air pollutant source inventories and emission factors; air pollution instrumentation research and development, photochemical pollutants, and aerosols life cycle; EPA field programs, data management, and quality control; and industrial instrumentation and methodology research.

The members of the exchange group were:

Aleksander Zaitsev,
Chief, Meteorology Laboratory
Main Geophysical Observatory
Leningrad, U.S.S.R.

Igor M. Nazarov,
Geophysics Section Chief
Institute of Applied Geophysics
Moscow, U.S.S.R.

Anastasia Shitskova,
Director, Moscow Research Institute of Hygiene
Moscow, U.S.S.R.

6.5 Miscellaneous

Dr. G. Griffing spent 8 days in Poland during January 1973 to discuss with Polish scientists the possibility of their submitting research proposals under P.L. 480 funds. He visited the Environmental Pollution Abatement Centre at Katowice and the National Institute for Hydrology and Meteorology at Warsaw. He also participated in a WHO-sponsored workshop on Air Pollution Information Systems while at Katowice.

Dr. R. E. Ruff presented a paper, "Application of adaptive pattern classification to the derivation of relationships between air quality data," at the WHO International Symposium on Air Quality Monitoring Networks and Data Analysis, held June 4-8, 1973, at Bilthoven, the Netherlands.

Preceding his participation at the NATO/CCMS meeting at Oberursel, Germany, Dr. D. G. Fox presented a paper, "The pseudospectral approximation for limited area modeling," at the WMO/IAMAP Symposium on Mesoscale Meteorological Systems and Fine Mesh Modeling at Bracknell, England. He also visited several research laboratories in England and France.

Mr. K. L. Calder attended a meeting of the Main Committee 2 of the VDI Commission on Clean Air Relating to Calculation Methods and Models for the Dispersion of Pollutants in the Atmosphere, held November 20-21, 1972, at Dusseldorf, Germany. This meeting was attended by about 108 invitees from nine countries — Federal Republic of Germany, the United States, France, Austria, Sweden, Norway, the Netherlands, Switzerland, and Hungary. Mr. Calder presented a paper, "Modeling air pollutant concentrations near highways," that had been prepared by Messrs. R. C. Sklarew, D. B. Turner, and J. R. Zimmerman of the ML. The papers and discussion of the meeting will be officially published as a VDl report.

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