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# NOAA Technical Memorandum ERL ARL-33

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

# Fiscal Year 1971 Summary Report of Division of Meteorology Support to the Environmental Protection Agency

Air Resources
Laboratory
N. CAROLINA
October 1971

# ENVIRONMENTAL RESEARCH LABORATORIES

## AIR RESOURCES LABORATORIES



NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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# FISCAL YEAR 1971 SUMMARY REPORT OF DIVISION OF METEOROLOGY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

Air Resources Laboratory
Division of Meteorology
Research Triangle Park, N. Carolina
October 1971

## DISCLAIMER

# PREFACE

Effective communication between individuals or groups is a difficult activity. This is especially true of communications about new problems and new research, since much must be left unsaid and many questions be left unanswered. Nevertheless, periodic summaries of work performed constitute valuable information sources as well as management "how goes it" tools.

The work reported herein was funded by the Environmental Protection Agency (EPA) and was done under agreement between the EPA and the Air Resources Laboratories (ARL), National Oceanic and Atmospheric Administration (NOAA) dated October 22, 1970. Although contracted studies are funded directly by the EPA, the NOAA personnel assigned to the Division of Meteorology have the responsibility for monitoring contracts.

Any inquiry on the research being performed should be directed to Mr. R. A. McCormick, Director, Division of Meteorology, Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

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# FISCAL YEAR 1971 SUMMARY REPORT OF DIVISION OF METEOROLOGY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

The following brief summaries of meteorological research and other activities present the current status of a variety of projects the Division of Meteorology (DM) is conducting for the Environmental Protection Agency (EPA).

Uniterms: Abatement, absorption, aerosol, air pollution, air quality, albedo, anticyclones, boundary layer, carbon dioxide, carbon monoxide, chemistry, contamination levels, cooling towers, diffusion, dispersion, environment, fallout, forecast, Gaussian, heat island, lasers, mesometeorology, meteorology, mixing layers, model, monitoring, oxidants, particulates, plume-rise, radar, radiation, radiometer, radiosonde, remote sensing, satellite, solar radiation, stacks, stagnation, sulfur compounds, surveys, tetroon, turbidity, trajectories, vorticity, washout, wind shear, wind tunnels.

## 1. SYNOPSIS

A Modeling Coordinating Committee (MCC) was established in March 1971 to continuously review all aspects of the air pollution modeling program of the Environmental Protection Agency (EPA). In addition to the DM strengthening its in-house capability in modeling, a Model Development Branch was established in the Division of Meteorology (DM) in the last quarter of Fiscal Year 1971.

A study is being made under contract of the feasibility of developing a mathematical-physical model of the urban boundary layer that will predict the transport and diffusion of pollutants in terms of the governing equations. A unique mathematical methodology is being developed under contract for numerical solution of a very general type of atmospheric diffusion equation that includes the effect of chemical reactions in complex systems. Space and time variability of predicted and observed air quality values are being compared in another contract.

A study is being made of the sensitivity properties and predictive accuracy of urban air pollution models of the Gaussian plume type. A major simplification of the Argonne integrated puff model is also being completed.

During Fiscal Year 1971, efforts in the development and validation of mathematical models describing the distribution of automotive generated pollutants has been directed towards determining the source of discrepancies observed when the models were evaluated against air quality. A method for predicting the properties of shear flows in turbulent motion is being applied to the prediction of turbulent atmospheric diffusion in the lower layers of the atmosphere.

Two projects regarding wind and water tunnel modeling are in progress. Determination of EPA's requirements for physical modeling facilities for simulating the diffusion of pollutants in the atmosphere is the goal of one of these projects. The other is the use of the water channel modeling facility at the French Research Laboratories at Magny les Hameaux for modeling the flow patterns in the area of the Conemaugh, Pennsylvania, power plant site; this is a U. S. - French Cooperative study of diffusion patterns of plumes from tall stacks.

The last series of field experiments in Western Pennsylvania (Large Power Plant Effluent Study, LAPPES) is planned for the fall of 1971. This study of ground level pollutant concentrations from large fossil fuel power plants with tall (800 feet) stacks has been in force since late 1967. A large volume of basic data obtained from the LAPPES project is being prepared for publication; with the exception of some short term field studies, most of the LAPPES project should be completed by the fall of 1971.

Preliminary analysis of experiments on natural precipitation washout of $SO_2$ from plumes confirms that previous gas washout models are inadequate for describing $SO_2$ washout from an elevated plume. Initial results from both laboratory and controlled field experiments are being analyzed in the development of a general model capable of describing the distribution of washout material.

Air mass trajectories over the Los Angeles Basin have been determined from tetroon flights. A helicopter followed the tetroons to determine the photochemical oxidant pollution concentration values during many of the tetroon flights.

The DM in cooperation with the National Meteorological Center (NMC) is evaluating criteria for quantifying stagnation areas. These evaluations will be used in establishing parameters for forecasting air pollution potential and describing the climatology of morning mixing heights.

Several approaches to the remote sensing of meteorological parameters within the planetary boundary layer were investigated during Fiscal Year 1971. Two of these, acoustic echo-sounding and the laser cross-beam technique, are used for obtaining wind and temperature profiles. The third, millimeter radiometric techniques, is used for obtaining mixing and temperature profiles. The Mark I Radiometric THERMASONDE$^{T.M.*}$ has been tested successfully during the past year.

A study under contract has indicated the feasibility of monitoring global albedo and atmospheric turbidity by satellite-borne instruments.

During the past year, a meteorologist was assigned to the Emergency Operation Control Center, EPA Technical Center, North Carolina. Forecasts of pollutant concentrations and field meteorological support are provided during emergency situations or episode control actions.

DM personnel have been involved with the North Atlantic Treaty Organization Committee on the Challenges in Modern Society (NATO, CCMS) air pollution project. This has included application of an urban air pollution model to Ankara, Turkey, and representation on the CCMS Panel on Modeling held October 1970 in Frankfurt, Germany.

## 2. MODEL DEVELOPMENT

### 2.1 Model Development Status

Detailed evaluation of present generation models in terms of their accuracy and sensitivity to errors and input parameters is

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*THERMASONDE$^{T.M.}$ is a trade mark by the Sperry Rand Corporation.

well under way. The next generation of models which includes more physical and photochemical reality, has been begun. Application to air pollution control activities, the design of control strategies, and the design and placement of air quality monitoring systems is rapidly increasing.

## 2.2 EPA Contractors' Information Meeting

A two-day information meeting on the EPA's modeling studies was arranged by the DM and held in Raleigh, North Carolina, in November 1970. The primary purpose of the meeting was to brief the EPA personnel on objectives and progress. Contractors and principal investigators heard included:

(1) Regional Air Pollution Analysis Model

D. Lewis, TRW, Inc.

N. Simonds, Consad Research

C. Chilton, Battelle-Columbus

(2) Sensitivity Analysis and Evaluation of Multiple Source Urban Air Pollution Models

S. Thayer, Geomet, Inc.

(3) Prediction by Numerical Models of Transport and Diffusion in an Urban Boundary Layer

J. P. Pandolfo, The Center for the Environment and Man

(4) Urban Diffusion Modeling of Carbon Monoxide

W. B. Johnson, Stanford Research Institute

(5) New York City Expressway Study

C. Simon, NYC Department of Air Resources

W. Giles, General Electric (subcontractor)

(6) Chicago Air Pollution Systems Model

J. J. Roberts, Argonne National Laboratory

(7) Air Pollution Land Use Planning Project

J. J. Roberts, Argonne National Laboratory

(8) Photochemical Model Studies of the Los Angeles Basin

A. E. Eschenroeder, General Research Corporation

(9) Development of a Simulation Model for Estimating Photochemical Pollutants

P. Roth, Systems Application, Inc.

M. Weisburd, System Development Corporation

### 2.3 EPA Modeling Coordinating Committee (MCC)

A Modeling Coordinating Committee (MCC) was established in March 1971 to review the overall needs of the EPA relating to the mathematical and physical (e.g., by hydraulic or aerodynamic techniques) modeling of ambient air quality. This committee will determine the adequacy of the entire modeling programs, both in-house and under contracts and grants, and will define areas of emphasis, gap areas, etc. It will also determine how modeling of ambient air quality is related to all major pollutants.

### 2.4 In-House Modeling Effort

A small in-house effort was devoted to improvement of a long-term air quality prediction model and application of the model for studying the sulfur dioxide ($SO_2$) and particulate pollution problems for Ankara, Turkey. This work is being done for the North Atlantic

Treaty Organization (NATO) Committee on the Challenges of Modern Society (CCMS) Air Pollution Study. The model is also being applied to recent data from St. Louis. Full documentation of these applications will be prepared in the DM.

A detailed study comparing several different photochemical-diffusion models recently developed under EPA contracts has been completed by Professor Frank Worley, Jr., from the University of Houston.

The DM has been reorganized to include a Model Development Branch. Dr. Warren B. Johnson, formerly with the Stanford Research Institute, is the Chief of that Branch.

## 2.5 Contract Effort (Mathematical Modeling)

### 2.5.1 Prediction by Numerical Models of Transport and Diffusion in an Urban Area

A 12-month contract to determine the feasibility of developing a mathematical-physical model of the urban boundary layer (i.e., its temperature, wind, and turbulence structure as compared with the surrounding rural countryside) has been awarded to the Center for the Environment and Man, Hartford, Connecticut. Most existing urban pollution models are based on the Gaussian plume representation for a single source, and it is generally agreed that an urgent need exists for a second generation of models more closely related to the physical structure of the boundary layer. The model will be of the same general type as that used for numerical weather prediction purposes; it will also be capable of predicting the spread of pollutants through advection and turbulent diffusion in an urban environment.

### 2.5.2 Determination of Space and Time Variability of Air Quality Using Connecticut Verification Data

An 8-month contract with the Research Corporation of New England, Hartford, Connecticut, will compare the space and time variability of predicted and observed air quality values. The time variability will be for periods of two hours and longer and the minimum space scale will be 5000 feet. The observations to be used for this study were obtained during the verification of a regional air quality model for Connecticut, a program sponsored by the Connecticut Research Commission with the support of the EPA. Also, a comprehensive report has been requested on the Travelers Research Corporation Regional (Connecticut) Air Pollution Model.

### 2.5.3 Sensitivity Analysis and Evaluation of Multiple Source Urban Air Pollution Models

Gaussian plume models have been used for predicting both short-term and long-term characteristics of urban air pollution distribution. Geomet, Incorporated, Rockville, Maryland, is under contract to provide a critical evaluation of the predictive accuracy of both types of models using currently available air quality data. The sensitivities of the models' predictions to errors and uncertainties in the input parameters and variables are being determined, as well as the errors arising from several mathematical approximations.

### 2.5.4 Studies of the Argonne Integrated Puff Model

A 12-month contract (inter-agency agreement with AEC) with the Center for Environmental Studies, Argonne National Laboratory (ANL), Argonne, Illinois, is concerned primarily with consolidation of earlier modeling development activities by the ANL for the EPA. Effort is being directed towards simplification of the previously developed "integrated puff" model with complete documentation of all details of the simplified version. A comprehensive comparison of "the integrated puff" model with short-term observations of air quality is included as well as a sensitivity analysis. A special feature is the development of a "calm algorithm" for the simplified version which will allow application of the model to the calm conditions that frequently occur with air pollution episodes.

### 2.5.5 Carbon Monoxide Diffusion Model Study

The Coordinating Research Council and the EPA jointly support a 12-month contract with the Stanford Research Institute (SRI), Palo Alto, California, in the development and validation of mathematical models to describe the distribution of automotive generated pollutants in urban areas. During the first year (1969-70), a diffusion model was developed to predict carbon monoxide (CO) concentrations at any point in a city using readily available meteorological and traffic data. During Fiscal Year 1971, SRI has directed its efforts towards determining the source of discrepancies observed when the model was evaluated against air quality (Continuous Air Monitoring Program) (CAMP) stations in five different cities

(St. Louis; Washington, D.C.; Chicago; Cincinnati; and Denver). A major field experiment was performed in San Jose, California, in November-December 1970. San Jose was selected for model validation to make use of the detailed computer-monitored traffic network system of the city and to provide data necessary to test the validity of the relationships between traffic and CO generation that are used with the diffusion model. Data collected in San Jose consisted of traffic counts, CO and meteorological measurements at seven fixed and two mobile stations, helicopter observations, pilot balloon wind soundings, and some lidar vertical profiles of aerosol concentration distributions. Documentation and analyses of the San Jose experiment are expected to be completed by the summer of 1971.

### 2.5.6 Urban Air Pollution Parcel Model Development

Systems, Science, and Software, La Jolla, California, has been awarded a 9-month contract to develop an urban air pollution model as an outgrowth of the development of advanced numerical techniques and economic hydrodynamic computer codes. Systems, Science, and Software has recently developed, with company funds, a sophisticated three-dimensional numerical model for simulating urban air pollution. This is a unique model in the generality with which the pollutant sources and the atmospheric transport processes may be specified. For example, the model has recently been applied with considerable success to the prediction of CO concentrations in the very complex wind field pattern that occurs in the Los Angeles Basin. The ARL at Idaho Falls provided wind field and tetroon trajectory for the test data. The mathematical structure of the model is such that it can be straightforwardly extended to include the effects of specified chemical reactions. The primary purpose of the present contract is to provide detailed documentation on the "parcel method of urban air pollution" as developed by Systems, Science, and Software, and to further develop the model so as to include photochemical reactions.

### 2.5.7 Invariant Modeling Methods

A 12-month contract was awarded to the Aeronautical Research Associates of Princeton (ARAP), Incorporated, Princeton, New Jersey, for further development of invariant modeling methods. During the past three years, as a result of a research contract supported by both NASA and the Air Force Office of Scientific Research, a new and powerful method has been developed by the ARAP for predicting the properties of shear flows in turbulent motion. This method, called invariant modeling, involves a novel scheme for closure of the heirarchy of equations describing fluid turbulence. Although in its early stages of development, the theory has been applied with very encouraging results to a study of turbulent boundary layers and to the problem of clear air turbulence in the atmosphere. In the contract, invariant modeling will be developed to the stage where it can be specifically applied to the calculation of the dispersal of an inert pollutant released into the lower layers of the atmosphere under various conditions of atmospheric stability. The theoretical results will then be compared with observational data. This entirely new approach to the theory of atmospheric diffusion does not involve the use of the eddy diffusivity concept. A unique feature of the approach is that it can be extended to include the effects of pollution concentration in a feedback mechanism coupling atmospheric radiation and turbulence fields. Also, for a multicomponent photochemical reactive system, it may be possible to include the effects of the turbulence in apparently modifying the laboratory-determined chemical reaction rates.

## 2.6 Wind and Water Tunnel Models

Two projects regarding wind and water tunnel modeling are in progress. One is an in-house study on the feasibility of modeling of diffusion in the atmospheric boundary layer. The other is a U. S. - French cooperative study wherein the French Meteorological Service has volunteered to construct a model in their water channel. This will be a model of the environs of the Conemaugh Power Plant in Western Pennsylvania which will be used for studying the diffusion patterns. The DM will supply maps, meteorological data, and $SO_2$ concentration patterns for comparison with the results of the model study.

### 2.6.1 Feasibility Study

An in-house study to determine the practicality of using physical modeling facilities for simulating the diffusion of pollutants in the atmosphere has been started. Some familiar examples of physical modeling facilities are wind tunnels, water tunnels, water tanks (still), towing tanks, and water channels. Other, somewhat unusual, facilities have also been used. The study attempts to:

(1) Evaluate the usefulness of such models from both scientific and engineering viewpoints;

(2) Determine which, if any, of these facilities could be used to meet the EPA's needs and goals;

(3) Make recommendations concerning the actions to be taken by the EPA (e.g., construct in-house facilities or use existing facilities through contracts).

Early indications are that reasonably reliable results are obtained if scale ratios are kept within the range of 1:100 and 1:500. Within this range, one can model the effects of power plants, small groups of buildings, and near-field plume rise and dispersion from such facilities. Data from several model studies have been compared with field data; the agreement is reasonably good in the regions where the flow is dominated by the presence of buildings. In regions dominated by ambient atmospheric turbulence, agreement has been poor, because the salient features of the atmospheric boundary layer were not modeled.

A primary scale of interest to the EPA is the urban area, which requires scale reductions on the order of 1:5000 to 1:20,000. Since extensive comparisons with atmospheric data have not been made, it is difficult to derive conclusions for this range. Recent studies on the effect of cross wind shear on dispersion indicate that the upper limit of the site to be modeled is about three miles (i.e., a scale reduction of about 1:30,000). Evidently, the Coriolis forces responsible for the crosswind shear cannot be ignored for larger sized regions. At present, there are no established techniques for simulating the Coriolis forces in the facilities mentioned above. A rotating tank may hold some promise, but no experiments on the scale of an urban area have been conducted. A wind tunnel with a curved test section may be a possible solution.

### 2.6.2 U. S. - French Cooperative Study

Mr. L. Facy, director of the Research Laboratories at Magny les Hameaux, has a water channel modeling facility in which he does model studies of air pollution at a scale ratio of about 1:10,000. The model studies are mainly concerned with the channeling of pollutants through valleys and around hills in complex terrain. Stack heights are normally scaled according to the calculated height of maximum plume rise rather than being scaled according to the actual height and then modeling the plume buoyancy. Mr. Facy is trying to use an adequate fetch of terrain upwind of the point of interest for the development of the velocity profile.

A unique feature of this facility is that ground level concentrations of pollutants are indicated by contrasting color changes on the model surface. The model is coated with a pH sensitive dye, and a weak solution of hydrochloric acid is released to simulate the stack effluent. The basic color of the model is blue. When the surface acidic concentration reaches pH 4, the surface becomes green; at pH 3 the surface becomes yellow; at pH 2 the surface becomes orange; and at pH 1 the surface becomes red. Since the pH scale is logarithmic, each color change indicates one order of magnitude change in the simulated $SO_2$ concentration. Thus, at the end of a run, ground level concentrations are vividly portrayed.

The Conemaugh site in Western Pennsylvania was chosen for a modeling study because of its complex terrain and its connection with the LAPPES project. During field experiments in the fall of 1970, meteorological and air pollution data were collected for three days with near-neutral stability and moderate-high wind speeds. The meteorological and plant output data have been sent to Mr. Facy for input to his modeling experiment. A comparison of ground level concentration patterns from the model and from the field will be made within a few months.

### 2.7 Research Grants Related to Modeling

All mathematical and physical modeling research grants are with various universities. The University of Chicago is attempting to model large scale atmospheric diffusion processes for plumes and instantaneous sources in "dishpan" experiments. Air and water tunnels are being used to study dispersion by tall stacks at Massachusetts Institute of Technology. A mathematical model of a stable-stratified atmosphere heated differentially across an infinitely long coastline is being investigated at the University of Miami.

Under the general heading of urban pollution modeling, research is being conducted at the Harvard School of Public Health, Pennsylvania State University, University of California at Davis, University of Notre Dame, and the University of California at Los Angeles. A model of negatively buoyant gas plumes is being investigated in a wind tunnel at Colorado State University. Research on an air pollution model for the Great Lakes Region has been performed at Northern Illinois University.

## 3. FIELD STUDIES OF POLLUTANT DISPERSION, TRANSFORMATIONS, AND REMOVAL PROCESSES

### 3.1 Field Studies Status

Analysis of Large Power Plant Effluent Study (LAPPES) measurements of tall stack plumes is continuing with initial results reported at the Second International Clean Air Congress in Washington, D. C., during December 1970. A final data collection period is scheduled for October and November 1971, after which the total effort will be concentrated on further analyses of measurements collected during the past four years. In addition to normal diurnal meteorological dispersion from tall stack plumes, the analyses will attempt to define plume behavior as affected by local topographic features. Final reports have been received from most contractors who participated in the LAPPES Project.

### 3.2 Large Power Plant Effluent Study (LAPPES)

Comprehensive studies of the dispersion of effluent from tall stacks have continued since the fall of 1967. These studies are conducted at a complex of three, coal-burning, mine-mouth, generating stations in western Pennsylvania. Collectively, the three stations are designed to generate 4880 megawatts of electrical power, resulting in the daily emission of more than 2000 tons of $SO_2$ into the atmosphere. The three stations, Keystone, Homer City, and Conemaugh, are located on a NW-SE line, 39 km long, about 80 km east-northeast of Pittsburgh. Each facility consists of two independent generating units, with effluent from each unit emitted from individual stacks.

The 1800 megawatt Keystone station, completed first, achieved full operation in July 1968. The Homer City station, second to reach full operation in December 1969, is capable of generating 1280 megawatts. The last to be completed, the 1800 megawatt Conemaugh station, was in operation by May 1971. The Keystone and Homer City stations have stacks 244 meters high, while the Conemaugh stacks are 305 meters high.

The LAPPES project seeks to determine the patterns of ground level concentrations from these large power plants with tall stacks. From these investigations, dispersion models will be developed which will permit the calculation of concentration patterns around large sources with tall stacks with a higher degree of confidence. Effects, both short-term and chronic, on the vegetation in the surrounding region is also under study. The vegetation studies are supported by the Agricultural Branch, Division of Health Effects Research.

Ten series of field experiments, each of one month duration, have been performed at the different plants. A fall and a spring series have been conducted each year since the inception of the study, with two additional series in March and July of 1968. The earlier series were centered at the Keystone plant. Half of the fall 1969 series and all of the spring 1970 series were centered at the Homer City plant. The last two series were conducted at the Conemaugh site. The only full series still planned is for the fall of 1971 at Conemaugh. Additional shorter-term field studies may be required to fill any specific gaps in the observational data which emerge as analyses of existent data proceed.

During field experiments, observations are made daily, unless prevented by adverse weather, power plant outage, or equipment malfunction. Extensive $SO_2$ measurements, from an instrumented helicopter, provide plume cross sections at several distances downwind by aircraft traverses through elevated plumes. Helicopter flights at tree-top level also provide $SO_2$ concentrations at near ground level; these measurements are supplemented by placing as many as ten sequential bubblers in areas where the effluent is expected to reach ground level. These portable samplers, constructed by the DM personnel, measure ground level $SO_2$ concentrations under the plume. Ambient air is bubbled through a chemical solution to obtain six consecutive 30-minute samples of the plume at 15 cm above the ground. Supporting meteorological data are provided by half-hourly pilot balloon releases to obtain wind profiles; helicopter ascents measure temperature profiles. These soundings are supplemented by standard radiosonde ascents at the start and end of each day's measurements.

A large volume of basic data obtained from the LAPPES project is being prepared for publication. The first documentation (Schiermeier and Niemeyer, 1970) contains data from the 1968 field experiments; the second documentation (Schiermeier, 1970) contains data from the 1967 and 1969 field experiments; the third documentation, containing data from the 1970 field experiments, is being published, and the final documentation will contain data from field experiments scheduled for 1971.

The most extensive analysis has been performed on the data contained in the first (1968) data volume, and has been previously reported (Pooler and Niemeyer, 1970). Partial analysis of data in the second volume tends to confirm the results previously found. During stable conditions, the wind speed imposes an upper limit on the thermal stability through the elevated layer where the plume stabilizes, such that low wind speeds and strong stability do not occur together. The principal factor causing horizontal growth of the stabilized plume is directional wind shear, however, plume spreading is less than would be expected as a result of wind shear.

Individual situations when the plume reached the ground have been analyzed in an attempt to describe the limited mixing layer situation. These times are of particular concern in that, when they occur, the highest sustained concentrations are likely to be found at ground level. Analysis is more difficult since the atmospheric structure often changes considerably during the day, and the simplified approach of assuming a gradually deepening mixing layer with a constant wind is inadequate to describe the actual structure associated with significant plume concentration at ground level. Sampling plume contact with the ground at the time and place of occurrence is difficult. An example of a day when both the meteorological and sampling data are adequate to determine plume contact with the ground is shown in figures 3-1 and 3-2. Figure 3-1 shows the $\bar{X}/\bar{Q}$ values measured by the treetop helicopter flight from stack base out to 28 km and return to 10 km. A computed curve of the maximum (centerline) relative concentration is also given. This curve was obtained by a modification under development of a method (Pooler, 1965) previously used to calculate relative concentrations with a limited mixing layer.

The calculated curve is applicable to the short sampling time which the helicopter values represent. There was a very strong inversion at about 400 meters height at the time the measurements were made. It is likely that the primary peak measured on the outbound flight at 10 kilometers was less than the maximum that occurred in that vicinity, for a well-developed mixing layer was just becoming established beneath the inversion. The values measured around 20 kilometers agree quite well with those calculated. The lower measured $SO_2$ concentration values at lesser and greater distances are believed to be the result of plume meandering. Values at distances between 10 and 20 kilometers were lower on the inbound flight than on the outbound flight.

It appears that the complete plume began to shift to a different mean azimuth during the course of the flight. Figure 3-2 illustrates

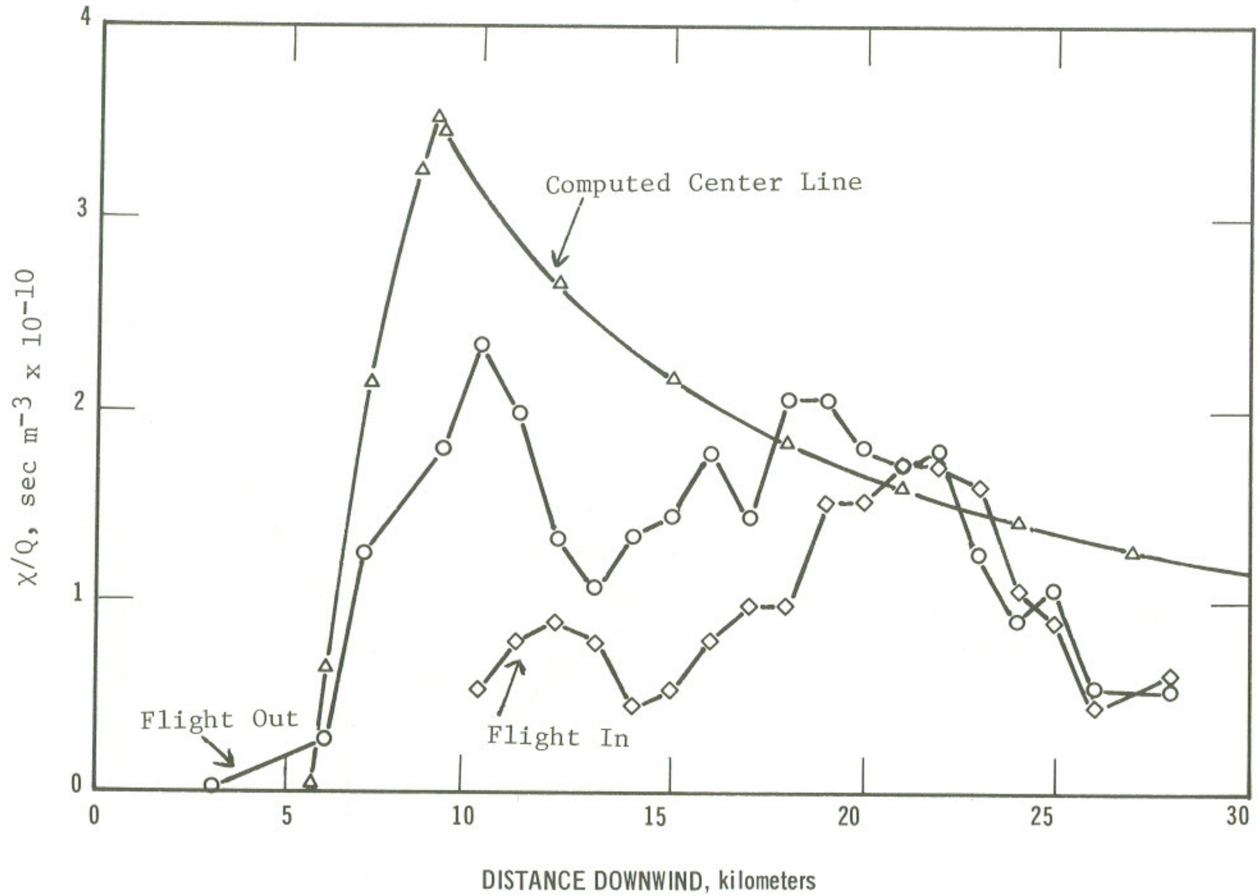


Figure 3-1. $\bar{X}/\bar{Q}$ values measured by treetop helicopter flight from stack base out to 28 km and return to 10 km.

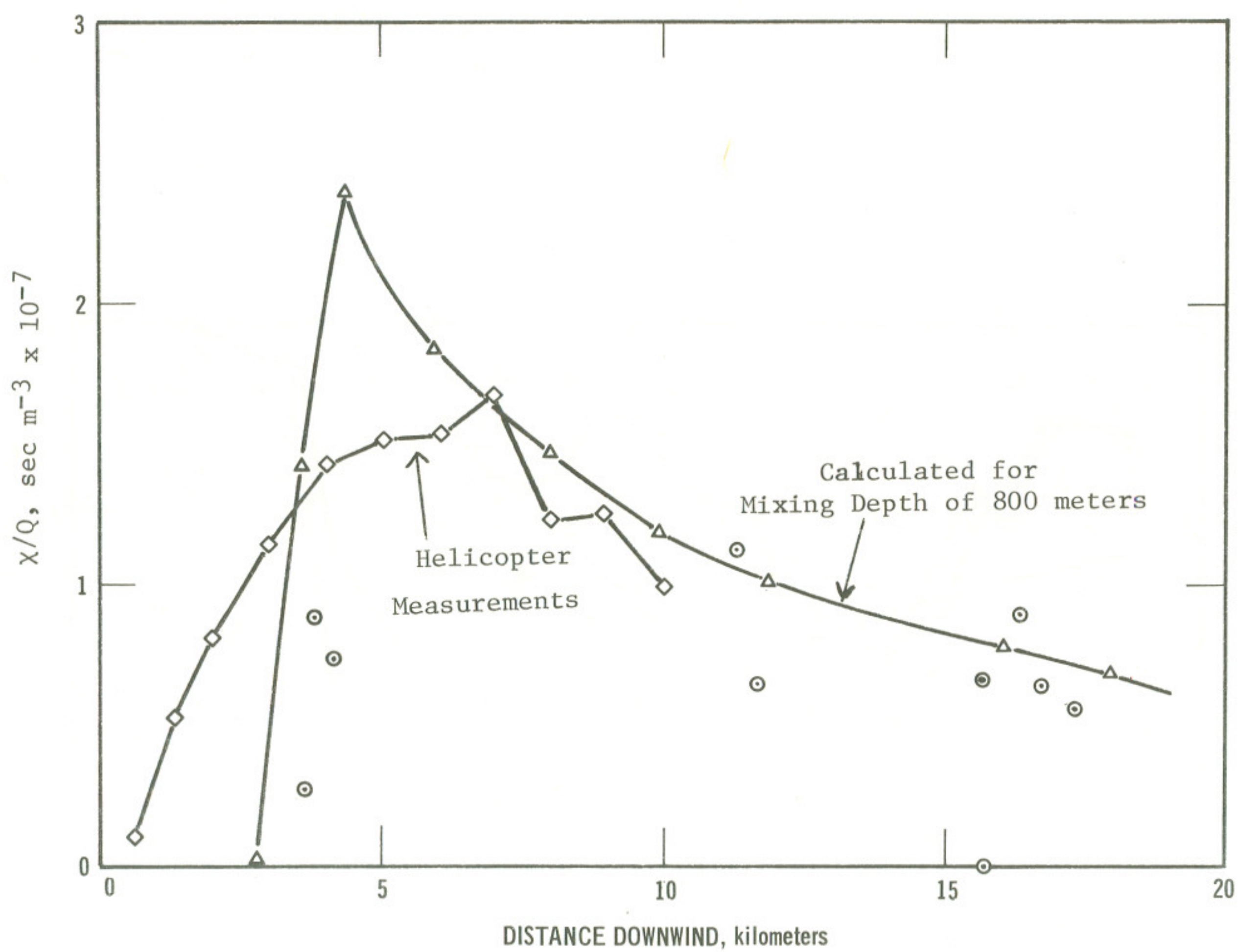


Figure 3-2. $\bar{X}/\bar{Q}$ measurements made two hours after those of Fig. 3-1 (strong inversion eliminated and surface-based mixing layer developed into overlying isothermal layer).

data about two hours later, by which time the strong inversion had been eliminated, and the surface-based mixing layer was developing into an overlying isothermal layer. The calculated curve is for a mixing depth of 800 meters, and is applicable to one-half to one hour averaging time. Observations consisted of three helicopter flights from near stack base out to 10 km over a period of about one-half hour, from which the $\bar{X}/\bar{Q}$ values shown in figure 3-2 were obtained. The highest half-hour values measured by each bubbler are indicated by circles. The background concentration on this day was of no importance as nine of the ten sampling bubblers recorded at least one zero value.

The parameter used in calculating concentrations that can be varied most freely is the crosswind spread of the plume ($\sigma_y$). Analysis of selected data (wind speed less than 7 m sec$^{-1}$) indicated that plume width measured at ground level was slightly better correlated with travel time than with travel distance; a time-dependent $\sigma_y$ was used to calculate the curves for this reason. However, it appears that the wind shear between the mixed layer and the capping stable layer contributed to the horizontal spreading, and further analyses continue in hopes that plume width can be estimated from meteorological measurements with an accuracy significantly better than the usual factor of two.

### 3.3 Natural Precipitation Washout of Sulfur Dioxide ($SO_2$)

In 1970 Battelle-Pacific Northwest Laboratories, Richland, Washington, completed initial investigations of $SO_2$ washout from the plume of a large coal-fired power generation facility in western Pennsylvania (Hales, et al., 1971). Chemical analysis of precipitation collected at the ground at distances up to four miles from a power plant, emitting 11 to 23 tons of $SO_2$ an hour, showed $SO_2$ concentrations of approximately one to two percent of that predicted by pre-existing theory. No significant differences between $SO_2$ washout fluxes in rain and snow were observed; the flux of $SO_2$ washout was estimated to be proportional to the 1.23 power of the precipitation rate.

Preliminary analysis of the washout experiments indicates that the omission of certain physiochemical considerations renders preexisting gas washout models inadequate for describing the $SO_2$ washout from an elevated plume (Hales, et al. 1971). Battelle scientists suggest that the $SO_2$ concentration in precipitation tends to be in equilibrium with its instantaneous environment, but the $SO_2$ is desorbed readily below an elevated plume, in the relatively "cleaner" air. This hypothesis suggests that the $SO_2$ is efficiently removed from a plume by natural precipitation only if the plume is close to the ground. Furthermore, the effect of the absorption-desorption cycle leads to a lowering of the $SO_2$ plume, and, therefore, maximum air concentrations of $SO_2$ will occur at shorter distances from an elevated source (other things being equal) during precipitation than during non-precipitation cases. Also, for tall stack emission the maximum $SO_2$ washout is likely to occur at the distance of maximum $SO_2$ air concentration at the ground surface.

Two approaches were taken during the past year in verifying the preliminary experimental and theoretical results. $SO_2$ solubilities in precipitation and mass transfer rates have been measured both under laboratory conditions and controlled field experiments. The field experiments were conducted in February and March 1971 at a test site on the Olympic Peninsula in Washington to verify the results of the initial field investigations and theoretical implications.

Initial results from both the laboratory and controlled field experiments are being analyzed for use in a general model capable of describing the distribution of washout material.

### 3.4 Cooling Tower Study

Field work was completed during Fiscal Year 1970 on a "Cooling Tower Study" by the Illinois Institute of Technology Research Institute. A preliminary description of the results was given in the 1970 summary report. The final report (Stockham, 1971) from this contract was completed during Fiscal Year 1971.

Intermittent observations were made at the Keystone power station in Indiana, Pennsylvania, during September, November, and December 1969. Although cooling towers are potentially capable of producing fog and drizzle, of initiating clouds, and of enhancing rainfall, none of these effects were observed during this study. In addition, historical precipitation records from nine National Weather Service Stations located between 13 and 51 km from Keystone were examined for possible influence by the Keystone effluent. Only during July 1969 was there an indication of precipitation enhancement as a result of power station operation.

During the Keystone observations, the visible portion of the cooling tower plume normally rose to an altitude of less than 200 meters above the stack orifice and traveled downwind about 200 meters before evaporating. However, the dimensions of the visible plume were greatly dependent on ambient temperature and humidity. When temperatures were between 25° and 30° F and the relative humidity was high, the plume could be seen for thousands of meters. Even when the plume was visible over only a short distance, its path could be traced up to 11 km by aircraft measurements of relative humidity.

The cooling tower plume was observed to travel downwind of the plant with a vertical oscillatory motion. Using inputs from the field studies, a mathematical model indicated that a plume moisture content, at the tower exit, 50% in excess of saturation would produce the observed oscillatory pattern (Stockham, 1971).

The mixing of effluents from power station stacks and nearby cooling towers was demonstrated by the presence of acid droplets in the visible portion of the cooling tower plume and by the humidity and $SO_2$ profiles obtained along the axis of the plume path after the tower plume had evaporated.

### 3.5 Tennessee Valley Authority (TVA) Plume Study

The TVA in Fiscal Year 1971 initiated a study with the support of the DM to obtain a better understanding of the composition of plumes from large power plants and the chemical transformation of the plumes in the atmosphere. Data are being obtained on the chemical constituents of plumes including the oxides of sulfur and nitrogen. Particulate size, number, and chemical composition data are also being obtained. A report on this work is due in the summer of 1971.

### 3.6 Fate of $SO_2$ in Plume Gases

The Edison Electric Institute, the American Petroleum Institute, the Bituminous Coal Research, Inc., and the DM, EPA, are jointly sponsoring a laboratory study by Battelle-Columbus on the fate of $SO_2$ in plume gases in early plume history. During the first nine months of the contract, Battelle-Columbus constructed a model furnace and a simulated boiler and stack section. Appropriate exhaust ducting was installed to enable proper gas flows and dilutions to simulate early plume history. The data collection phase will be completed early in Fiscal Year 1972. The primary objective of the study of the fate of $SO_2$ in flue gases is to provide quantitative decay functions for $SO_2$ released into the atmosphere.

The DM is supporting Brookhaven National Laboratories (BNL) in a field study of the generation, transport, diffusion, and chemical reaction of sulfur pollutants in the atmosphere. The isotope ratio tracer method developed by BNL is being used in the study. The $S^{32}/S^{34}$ ratio technique which allows tracing sulfur compounds from individual sources has been shown to be a sensitive indicator of the chemical reactions.

BNL reports that the rate of conversion of $SO_2$ in plumes is dependent upon the prevailing meteorological conditions. The studies indicate that there is a conversion of the sulfur trioxide ($SO_3$) mist into an acid mist of $NH_4SO_4$ and that particulates are a factor in the reactions of $SO_2$ and $SO_3$ in the atmosphere. Field data were collected by BNL in November 1970 and May 1971 at Keystone.

### 3.7 Lidar Study of Plumes

A contract was awarded to the Stanford Research Institute (SRI), Menlo Park, California, in March 1970 to make two series of observations of the aerosol distribution in the lower atmosphere using an improved lidar system. The first series was made of the Homer City plume during the first two weeks of May 1970 when about 500 plume cross sections were obtained during a variety of meteorological conditions. Figure 3-3 illustrates the variations of configuration of the quasi-instantaneous plume in the upper five drawings in each column, while the lower drawings show the composite configurations. The wind speed during this period was 2 to 3 m $sec^{-1}$, and the mixing depth was about 1200 meters. The right-hand drawing shows the plume top tendency to flatten at about this height. Other sequences of observations depict the transition from the tilted, stablized plume, through the partial trapping phase as the mixing layer develops, to the phase shown by figure 3-3.

The second series were made in metropolitan St. Louis in early March 1971. These observations were of three types: (1) time

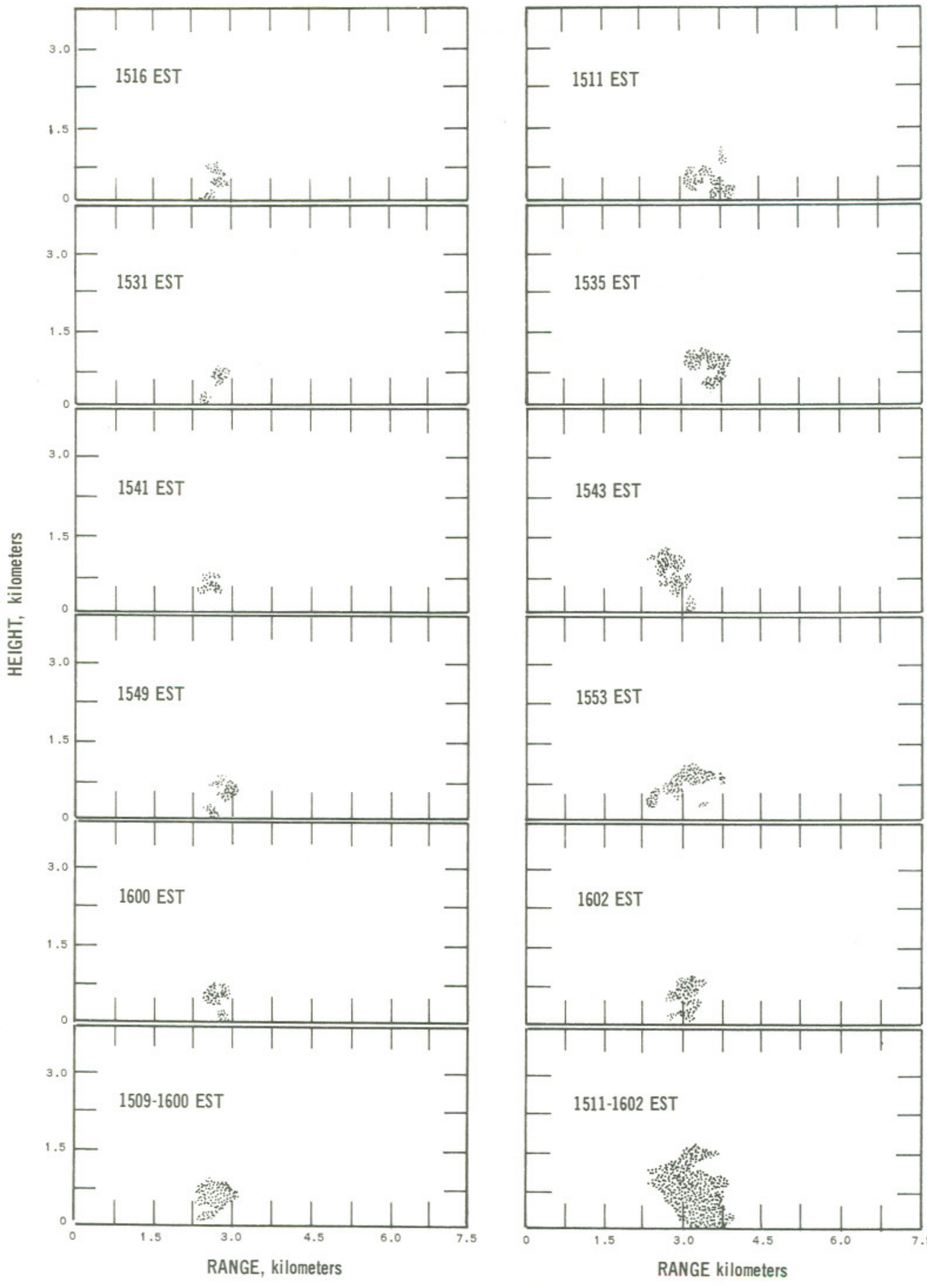


Figure 3-3. Quasi-instantaneous (15 to 30 sec) plume cross sections (top 10 dwgs.) on 11 May 1970, and corresponding 45-min composite ("average") cross sections (bottom), at downwind distances from the stack of 1 km (left) and 2.5 km (right).

sequences, in which the stationary vertically-aimed lidar obtained a sequence of observations at fixed time intervals; (2) traverses, in which the vertically-aimed lidar obtained observations at fixed intervals of travel distance by an odometer-controlled firing sequence; and (3) cross sections similar to those shown in figure 3-3, in which elevation angles were required to be greater than 20 degrees to ensure public safety. These observations are being processed and analyzed for publication.

## 3.8 Three Dimensional Trajectories in the Los Angeles Basin

In a joint research effort of several Air Resources Laboratories with the sponsorship of both the Atomic Energy Commission (AEC) and the Environmental Protection Agency (EPA), three dimensional air trajectories in the Los Angeles Basin were studied.

Transponder equipped tetroons tracked by an M-33 radar on top of Mt. Thom just north of Glendale were used in estimating low-level, three-dimensional air trajectories in the Los Angeles Basin in September and early October of 1969. An analysis of these experiments has been completed recently.

Figure 3-4 shows all trajectories of more than one hour duration grouped into 6-hour daily time periods according to the time of tetroon release. In general, the trajectories are directed east or northeastward in the afternoon due to the heating of the south-facing mountain slopes. At night the trajectories are chaotic, with air movement in various directions depending on the synoptic situation. In the evening, flights in the southern part of the basin move slowly eastward,


Figure 3-4. Tetroon trajectories of more than one-hour duration in the Los Angeles Basin during Sept-Oct 1969, grouped according to local time (PDT) of tetroon release. The numbers indicate hours since release.

whereas farther north they frequently move across the Santa Monica Mountains into the San Fernando Valley.

Tetroon flights from Redondo Beach embedded in the sea breeze almost invariably move eastward and then northeastward as they encounter the sea breeze coming in from the Long Beach area. The resulting sea breeze convergence zone moves eastward during the day, so that flights released in the early morning from Redondo Beach tend to move into downtown Los Angeles and flights released later in the day into the Azusa area, as shown by sequentially released flights 18 and 19 in the left hand diagram of figure 3-5. The flights also tend to penetrate farther to the south as the day progresses, as shown by flights 27 and 28. The right hand diagram of figure 3-5 shows, in addition, how flights released from the Long Beach area move northward or northwestward and then northeastward as they encounter the convergence zone.

Figure 3-6 presents the height traces of the tetroon flights as they are entrained into the sea breeze convergence zone. There is usually considerable upward motion upon initial contact with this zone, and the vertical oscillations tend to be relatively large as the tetroon progresses northeastward within the convergence zone.

Two flights which exhibit stagnation and near-stagnation conditions are presented in figure 3-7. Flight 36 remained nearly stationary for seven hours near Pasadena on two successive days. The enlargement shows how small cyclonic and anticyclonic loops were traced. Flight 26 exhibits seich-like eastward and westward

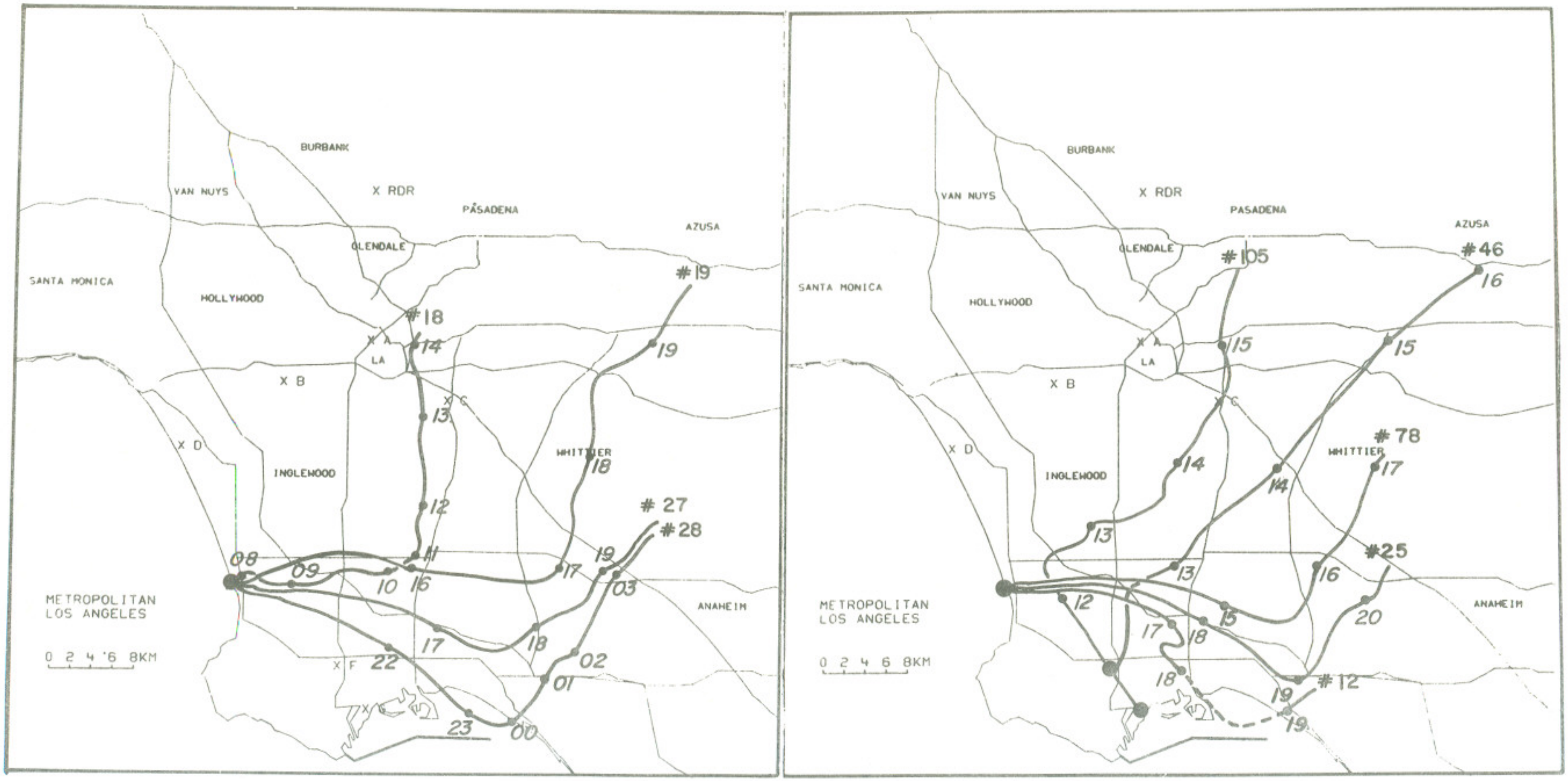


Figure 3-5. Daytime tetroon flights from Redondo Beach and Long Beach illustrating the convergence zone (trajectory turning) northeast of the Palos Verdes Peninsula. The numbers represent local time in hours.

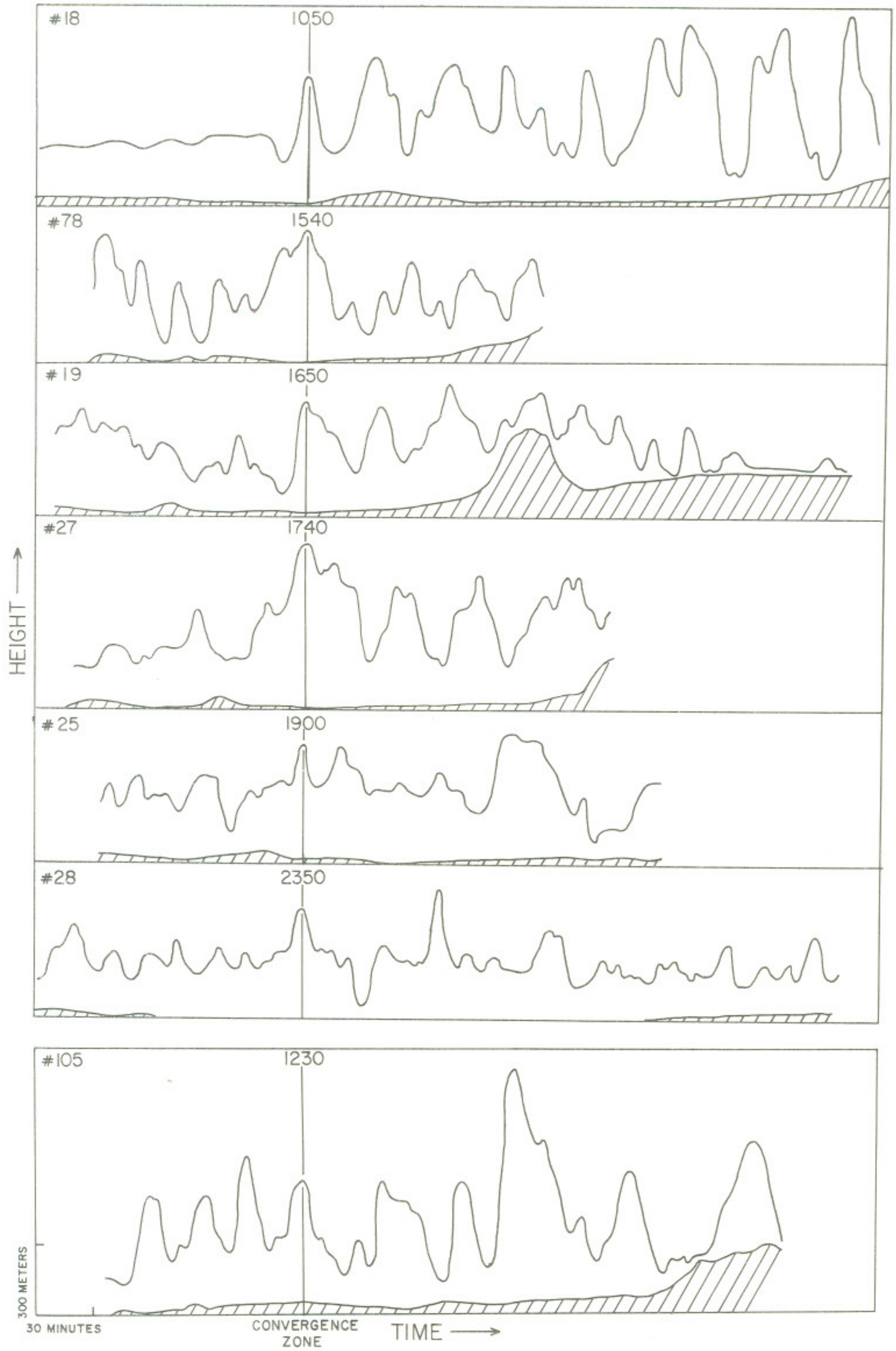


Figure 3-6. Tetroon height traces for flights entrained into the Palos Verdes convergence zone. The numbers along the vertical line indicate the local time of initial contact with this zone as determined from the horizontal turning of the trajectories.

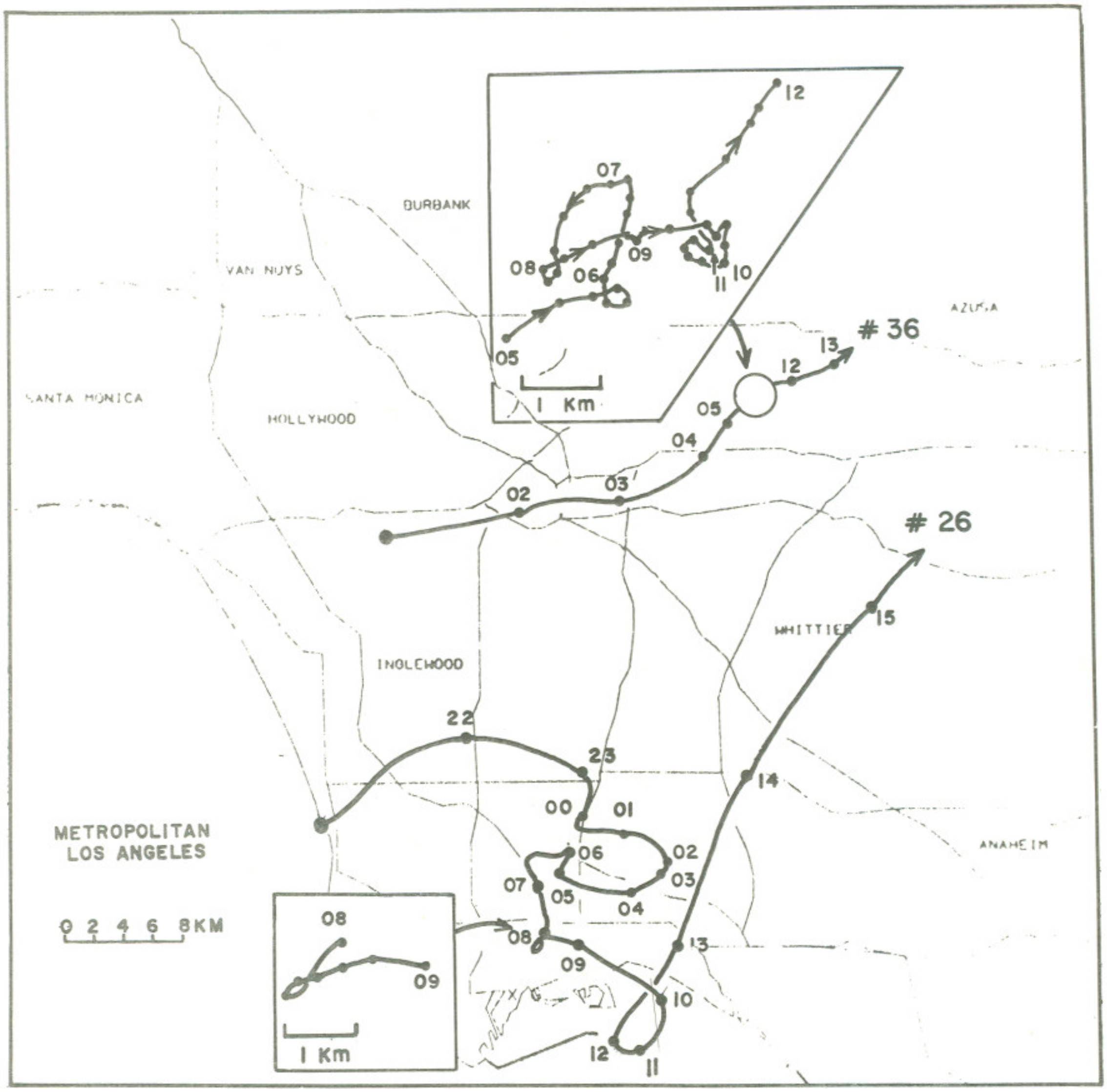


Figure 3-7. Examples of tetroon flights exhibiting stagnation and near-stagnation conditions. The trajectory segments have been expanded in scale by a factor of five. The numbers indicate local time in hours.

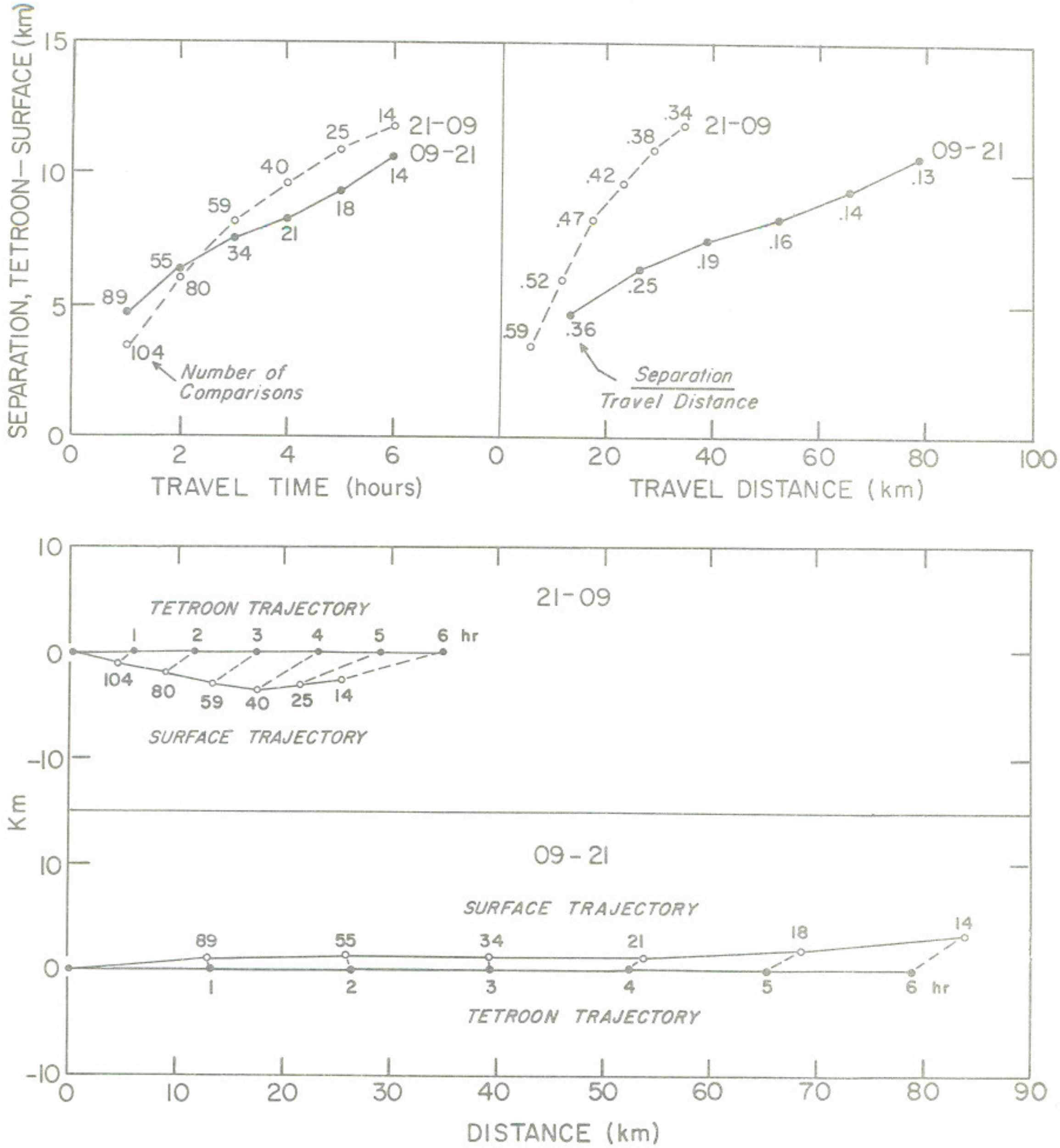


Figure 3-8. Changes in ozone (pphm) following along the tetroon trajectories (boxed numbers) in comparison with the local changes at El Monte (large boxes). The unboxed numbers along the trajectories, as well as the left-hand numbers in the El Monte boxes, represent local time in hours.

movements superimposed on a slow southward drift during the night. Near noon this flight traces out an anticyclonic loop over Long Beach Harbor before moving onshore in the sea breeze.

A helicopter followed the tetroons measuring oxidant concentration. Figure 3-8 shows how the ozone increases as the air flows northeastward from downtown Los Angeles during morning and early afternoon. In general, ozone values close to zero in the downtown area near sun-up increase to values exceeding 10 pphm as the air moves into the Pasadena area about noon. The change in oxidant value along the tetroon track should be independent of advective influences and thus represents the temporal change due to photochemical reactions on the oxidant precursors. For comparison, local changes in ozone near the surface at El Monte are presented in the large boxes in figure 3-8. These local changes, or course, include effects due to advection by the wind of already formed oxidants from other locations. At El Monte the ozone increases until about 1500 local time when the arrival of the sea breeze causes a decrease in ozone. The oxidant following the tetroon and the oxidant at a fixed point are both influenced by variations in source strength with time (i.e., the El Monte data can be affected by traffic peaking while the values along the tetroon path are also influenced by material added by the traffic and mixed upwards into the original material).

# 4. AIR POLLUTION POTENTIAL FORECASTING AND CLIMATOLOGY

## 4.1 Air Pollution Potential Forecasting and Climatology Status

The National Meteorological Center now transmits facsimile charts of stagnation areas twice daily. These areas, which are based on an index developed by the Division of Meteorology, are intended to serve as large-scale guidance to National Weather Service field stations. A quantitative evaluation of air pollution potential has been developed and is being supplied to the Emergency Operations Control Center on an experimental basis during air pollution episodes.

A rather extensive study, "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States," was completed for publication early in FY-72.

Contract work with the University of Florida to measure the daytime development and dissipation of the mixing layer (by means of an instrumented aircraft) is continuing.

### 4.2 Air Pollution Potential Forecasting

The responsibility for routine operation of the National Air Pollution Potential Forecasting Program was transferred from the DM to the National Meteorological Center (NMC) in 1967. However, the DM continues to provide input to the program through continuing research efforts.

Facsimile charts delineating stagnation areas were initiated by the NMC in September 1970, and, by February 1971, the charts were issued twice daily (at 1052Z and 2327Z) over the National Weather FOFAX circuit. The stagnation index, developed by the DM is used as guidance by National Weather Service field stations in the issuance of local statements of high air pollution potential. The

DM, in cooperation with NMC, is currently evaluating criteria for quantifying stagnation areas. More restrictive meteorological criteria will be used to delimit two or three concentric isopleths of probability of stagnation.

Normalized concentration ($\bar{X}/\bar{Q}$) was explored as a parameter for quantifying the meteorological potential for air pollution on the large-scale. The normalized concentration for a large city can be calculated by:

$$\frac{\bar{X}}{\bar{Q}} = 3.613H^{0.13} + \frac{S}{2HU} - \frac{0.088UH^{1.26}}{S}$$

where H is the mixing height (meters), U is the wind speed average (m $sec^{-1}$) through the mixing height and S is the city size or along-wind distance (meters) across the city. The advantage of $\bar{X}/\bar{Q}$ is that the mixing height and wind speed are combined for ready comparison with values for other time periods, other locations, or with climatological statistics.

Normalized concentrations for a 40-km city are calculated each day for all upper air stations in the continental United States by the NMC and transmitted to the DM via TWX. During air pollution episodes, both morning and afternoon values of $\bar{X}/\bar{Q}$ averaged for upper air stations in the forecast areas, and corresponding seasonal upper 50, 25, and 10 percentile climatological values of $\bar{X}/\bar{Q}$ are called to the Emergency Operations Control Center on a real-time basis. Figure 4-1 is a graphic presentation of $\bar{X}/\bar{Q}$ data for an episode.

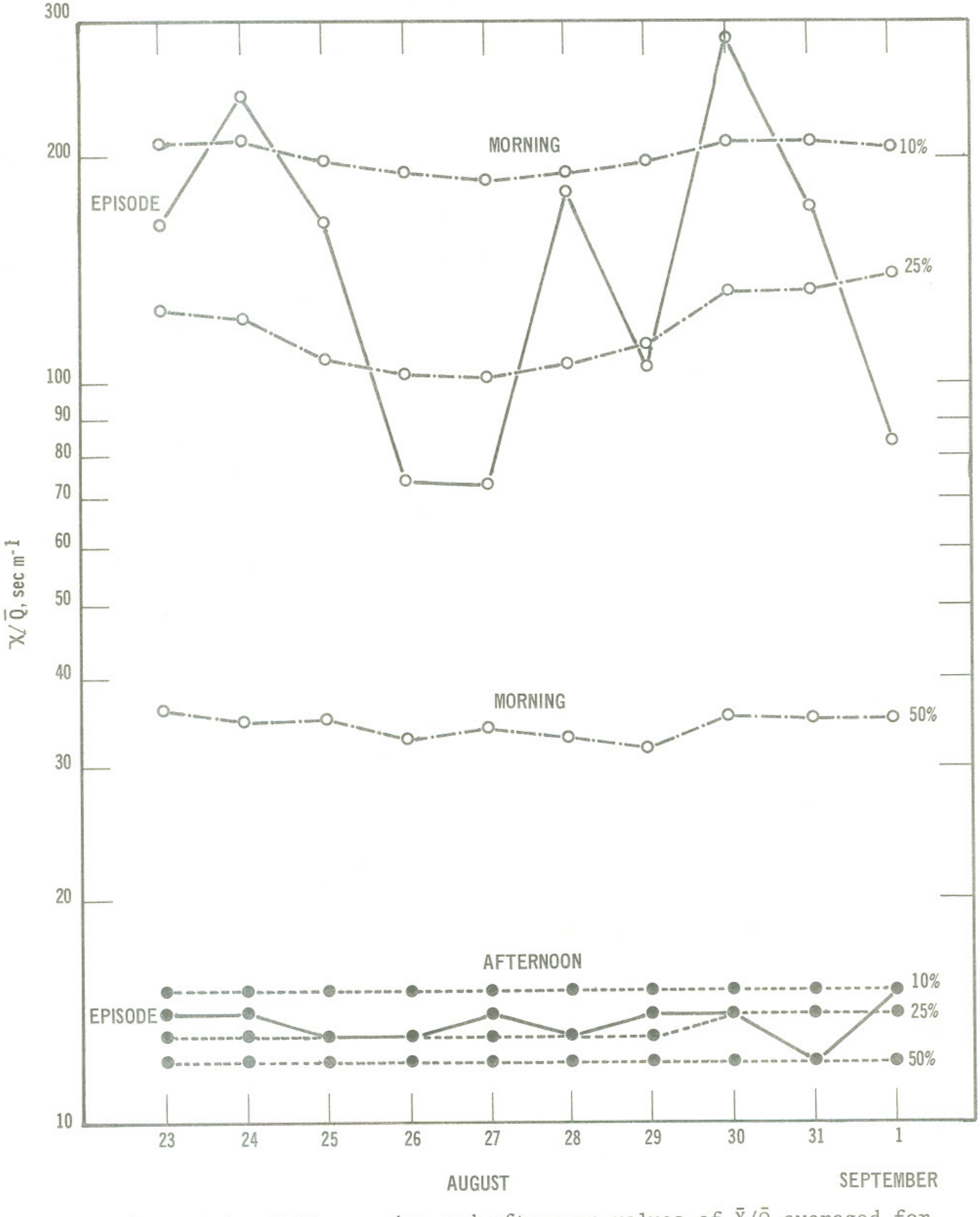


Figure 4-1. Daily morning and afternoon values of $\bar{X}/\bar{Q}$ averaged for all upper air stations in daily forecast area of high air pollution potential and corresponding upper percentile values of $\bar{X}/\bar{Q}$ based on upper-air data for five summers, 1960-1964.

Summers' (1965) model for calculating the morning mixing height over a city by simulating the heat gain to the air from the urban surface was evaluated for inclusion into the air pollution potential program. The NMC now routinely calculates morning mixing heights (and subsequently $\bar{X}/\bar{Q}$ values) using Summers' model. These parameters are not yet used in the forecast program. Further evaluation of Summers' model will include the development of criteria for air pollution potential and a climatology of morning mixing heights since these will differ from the numbers presently used in these capacities.

### 4.3 Air Pollution Potential Climatology

A draft of the study, "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States." is being cleared for publication as an EPA Technical Report. In addition to 50 isoplethed maps of mixing height, wind speed, and average normalized concentration ($\bar{X}/\bar{Q}$), data are presented on limited dispersion episodes either lasting at least two days or lasting at least five days with no significant precipitation and upper limits on mixing height and wind speed determined by the following matrix: wind speeds (m $sec^{-1}$) of 2, 4, and 6; mixing height (m) of 500, 1,000, 1,500, and 2,000. Figure 4-2 shows isolines of the total number of episode-days in five years with mixing heights 1500 m or less and wind speeds 4.0 m $sec^{-1}$ or less for episodes lasting at least two days. These limits are similar to those that have been used in the

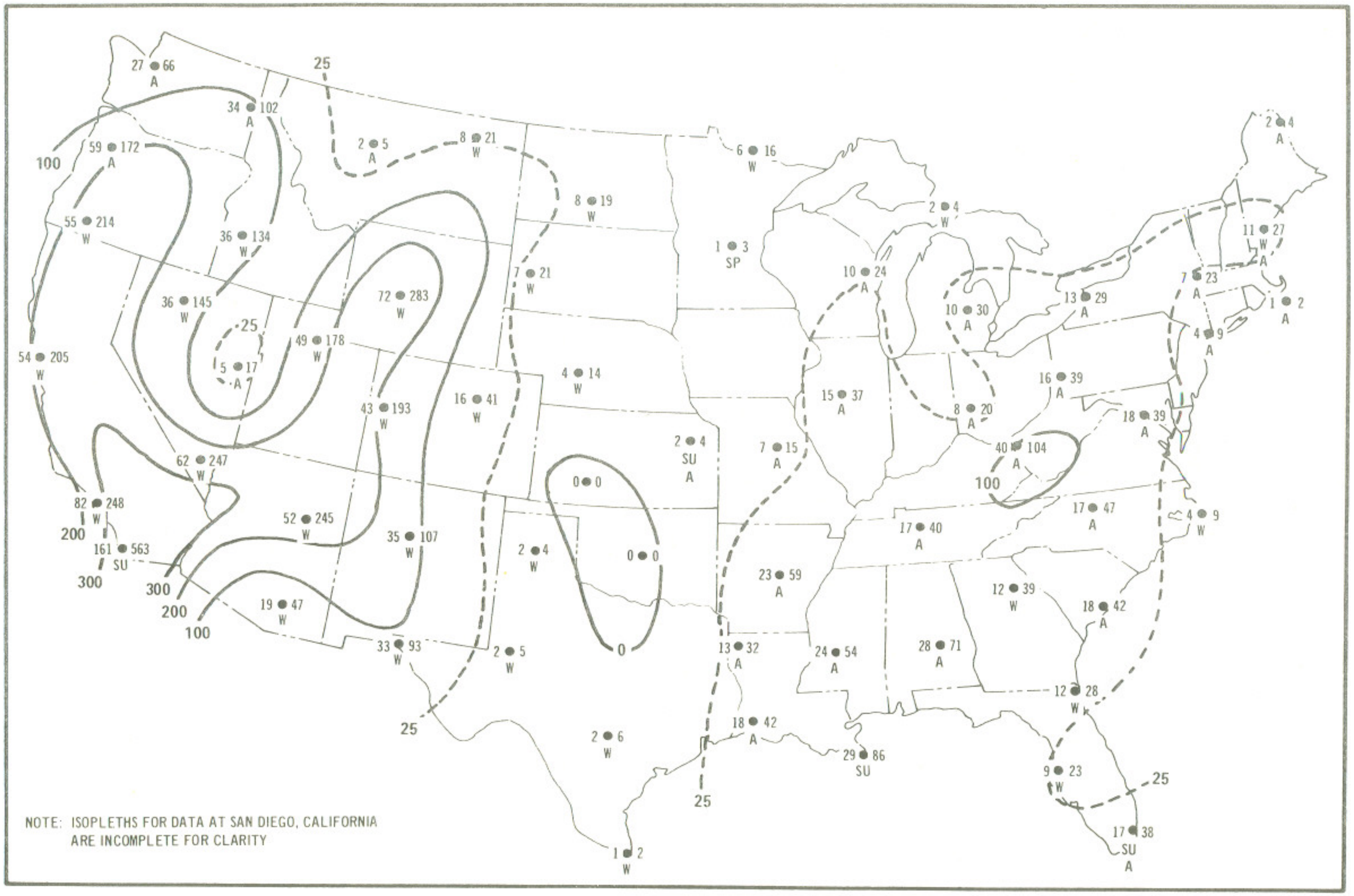


Figure 4-2. Isopleths of total number of episode-days in five years with mixing heights ≤ 1500 m, wind speeds ≤ 4.0 m $sec^{-1}$, and no significant precipitation for episodes lasting at least two days. Numerals on left and right give total number of episodes and episode-days, respectively. Season with greatest number of episode-days indicated as W(winter), SP(spring), or A(autumn).

national air pollution potential forecasting program (Gross, 1970). In the East, there is only a small area where the total episode-days exceeds 100, about one day in 18, but in the West 100 days are exceeded at most stations and 200 days are not unusual. By far the greatest number of episode-days is 563, which occured at San Diego, California, but, for clarity, the largest isopleth shown is 300. At nearby Santa Monica (Los Angeles), total episode-days are less than half those at San Diego. This disparity exists because the criterion most often <u>not</u> satisfied at both locations is afternoon wind speed. While the average afternoon wind speed at both locations is near 4.0 m $sec^{-1}$; it is slightly lower at San Diego. The season with the greatest number of episode-days in the East is generally autumn, while in the West, it is mostly winter.

Figure 4-3 is for the same conditions as figure 4-2, except that in the former the episodes had to persist for at least five days. While the isopleth patterns are similar, the frequencies of such long-duration episodes are much reduced and are almost non-existent except in the West. The greatest number of episode-days is 215: it still occurs at San Diego and is much greater than at nearby Santa Monica.

### 4.4 Mixing Height

Based on the success of the EPA's first contract with the University of Florida to measure the height of the daytime mixing

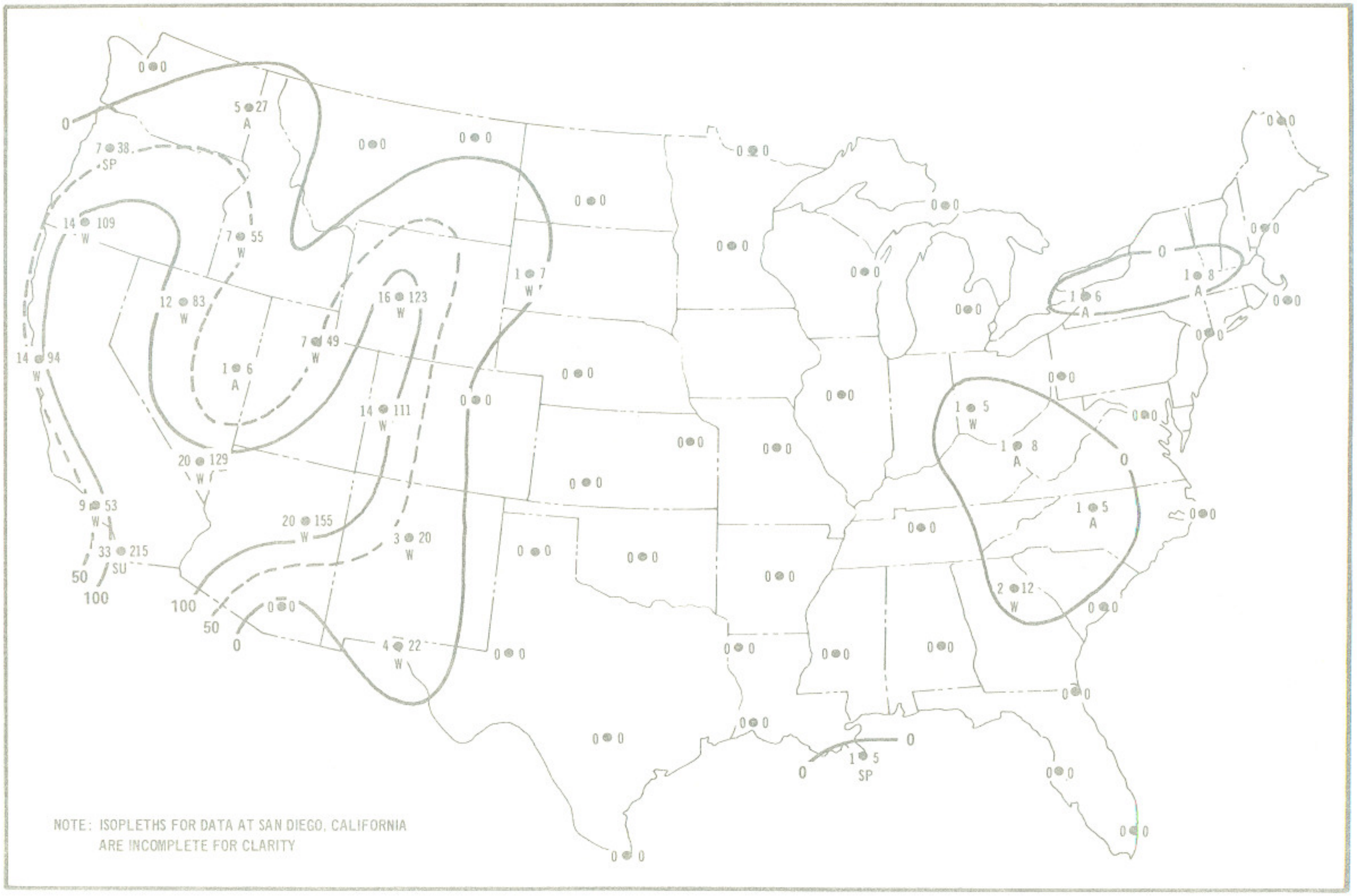


Figure 4-3. Isopleths of total number of episode-days in five years with mixing heights ≤ 1500 m, wind speeds ≤ 4.0 m $sec^{-1}$, and no significant precipitation for episodes lasting at least five days. Numerals on left and right give total number of episodes and episode days, respectively. Season with greatest number of episode days indicated as W(winter), SP(spring), SU(summer), or A(autumn).

layer by means of an instrumented aircraft (see last year's summary report), a succeeding contract has been negotiated to expand the earlier study. This contract focuses on measurements of the morning development and late afternoon dissipation of atmospheric mixing. Variations in surface terrain characteristics will be considered and attempts will be made to chart the mixing layer to its top during a stagnation episode.

One interesting aspect of the data collected to date is that, during late afternoon, just before sunset, the turbulent energy within the mid-afternoon layer (measured by the aircraft) is almost dissipated even though adiabatic lapse rate conditions persist. A final report is due in October 1971.

## 5. REMOTE SENSING DEVELOPMENT

### 5.1 Remote Sensing Status

For several years EPA has supported the development of ground-based devices capable of providing, by remote sensing techniques, reliable information to derive wind and temperature profiles within the planetary boundary layer. Feasibility studies, 1965-1967, were followed by the development and successful testing of research prototype radiometers and acoustic sounders in 1968-1970. The use of the lidar crossed-beam correlation technique has also been studied. During the past year, efforts have been focused on improving data reduction techniques applicable to an operational radiometer and to echo-sounding.

## 5.2 Remote Sensing Approach

The DM continued to provide support to the Wave Propagation Laboratory (WPL), NOAA, and to the Sperry Rand Corporation for the development of remote sensing techniques to obtain temperature and wind profiles in the planetary boundary layer. Several approaches are being studied: acoustic echo-sounding; laser cross-beam active correlation; and millimeter radiometric techniques.

## 5.3 Acoustic Echo-Sounding Technique

A description of the basic acoustic echo-sounding technique may be found in several publications (Little, 1969; McAllister, et al., 1969; Wescott, et al., 1970). Studies begun in FY 1970 were continued and expanded in FY 1971. Phase 1, the system analysis, and phase 2, an analysis of the noise interference problem, were completed. The work is reported by Simmons and Wescott (1971).

Work continues on obtaining the horizontal wind components when the system is used in the Doppler mode; on perfecting and testing a lightweight acoustic shield for the antenna to prevent noise pollution and interference; on further evaluation of echo-sounder and tower data from the Haswell 1969 field experiment; and on obtaining additional data during various meteorological conditions.

## 5.4 Cross-Beam Active Correlation Technique

The cross-beam active correlation technique employs the measurement of scattered energy from a pulsed laser beam using two telescopes to view a common atmospheric cell. By correlating the two observations, it is possible to determine the horizontal wind. The basic concept is outlined in Fisher and Damkevala (1969) and Little, et al. (1970).

During FY 1971, work continued on perfecting the technique developed in FY 1970 and obtaining additional field data for analysis.

## 5.5 Radiometric THERMASONDE

Since 1965 the DM has supported research by Sperry Rand Corporation in the development of equipment and data analysis techniques for remotely measuring the vertical temperature profile in the lower 2.0 km of the atmosphere. The technique used a radiometer to measure radiation emitted from oxygen molecules in the atmosphere; the radiation intensity is proportional to the temperature of the molecules. The radiometer is operated at a fixed frequency of 54.5 gHz. Height information is obtained either by making measurements at different antenna elevation angles or by scanning the antenna continuously in elevation angle from 0° to 90°, in which case the radiometer output is a plot of antenna brightness temperature versus elevation angle which must be converted to air temperature versus height above surface. Papers by Mount (et al., 1970) fully describe the technique, and the DM annual reports for 1970 and earlier years outline the technical and economic reasons why such a technique is desirable and describe the earlier research efforts.

In 1969, the DM acquired an operational prototype radiometer (the Mark I Radiometric THERMASONDE) and conducted tests using data analysis techniques then available. These tests demonstrated the excellence of the Mark I itself, however the data analysis techniques proved to be inadequate, especially for the measurement of elevated inversions. Consequently, efforts during the past year were focused primarily on the development of better data analysis techniques, although the Mark I radiometer was modified slightly to improve its sensitivity. Efforts in both these areas have been successful; the Mark I sensitivity was improved by a factor of approximately two; analysis techniques have been developed to the extent that radiometric data can be converted to useful vertical temperature profiles.

One manual and three computerized data analysis techniques were developed. The manual technique, the most successful to date, is a library recognition technique requiring a matching of computer-generated overlays to the observed radiometric data. Each overlay is a plot of antenna brightness temperature versus antenna elevation angle and represents what a radiometer operating in a fixed frequency-continuous elevation angle scan mode would have measured had it been looking at the atmospheric temperature versus height profile from which the overlay was computed. Thus, when an overlay is found which matches a measured radiometric trace, the atmospheric temperature-height profile which produced the real data is presumed to be identical to the profile from which the overlay was calculated.

The library contains overlays generated from a wide variety of temperature height profiles, but a consideration of only those profiles containing temperature inversions will illustrate the usefulness of the library technique. At present the library contains overlays generated from inversion-containing profiles with inversion-base heights limited to the following: 0, 0.1, 0.3, 0.5, 0.75, 1.0, and 1.5 km; thus, when an inversion-containing profile is measured by the radiometer, the height of the inversion base is restricted to one of the above height classifications. This is demonstrated by figure 5-1, which plots inversion base height, as determined by the radiometric technique versus inversion base height determined by radiosonde, where height is determined by radiosonde forced into the nearest library height classification. Radiometer and radiosonde measurements are made simultaneously. Figure 5-1 represents the results of such comparisons where the inversion-base heights range from 0. to 1.5 km. The number near each circle represents the number of comparisons available at that particular height. An analysis of each of these cases proved that the temperature gradient below the inversion was accurately measured, and that in no case did the radiometric technique fail to detect the presence of an inversion when one existed.

These data were obtained from several locations; San Jose, California; St. Louis, Missouri; and Raleigh, North Carolina; during field experiments in FY 1971. A clear majority of the data, however, is from Raleigh, N. C.

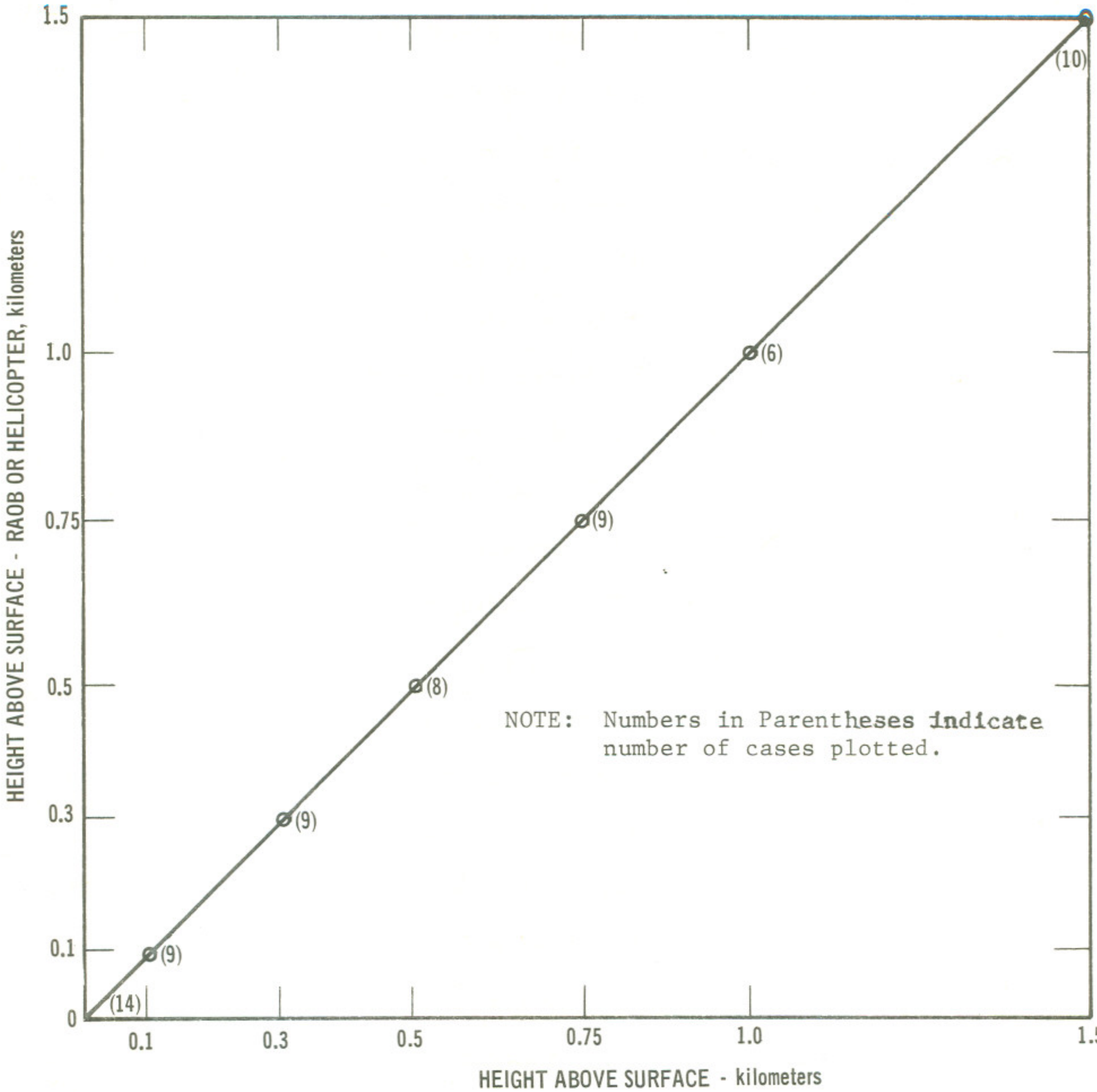


Figure 5-1. Heights of bases of stable layers, Mk I Radiometer versus radar or helicopter observation.

During FY 1972, the Mark I radiometer will be involved in several studies at the following locations: Boulder, Colorado; St. Louis, Missouri; and White Sands Missile Range. Only the Boulder experiments will be concerned with the actual radiometry; in the other cases the Mark I will be used to provide atmospheric temperature profiles as part of the data necessary in studies of other phenomena.

The development of an improved fully automatic radiometric sounding system (Mark II) is being supported by the EPA.

# 6. GEOPHYSICAL STUDIES

## 6.1 Geophysical Studies Status

In the ten years since the DM became actively interested in atmospheric turbidity, a measurement network of some 40 stations, mostly in the U.S., has been developed and maintained, data reports and analyses have been published, and instrument development has been vigorously pursued. The global network is currently being expanded and the stations are being equipped with improved dual-wavelength sunphotometers. This work is generating international interest.

A field study of the differences in radiation energy budgets between urban and rural locations has reached the stage where instruments are being tested and calibrated. Field measurements will begin in FY-72. This study is expected to provide important insight into the influences of pollution on urban climate with more general applications to the larger scale geophysical problem of scattering and absorption in the troposphere and stratosphere.

Research contracts are in progress for the following purposes: (1) to determine the light scattering properties of various aerosols pursuant to evaluating the feasibility of using lidar to measure particulate concentrations, (2) to measure Aitken nuclei along the shipping routes of the major oceans, and (3) to consider the feasibility of monitoring global albedo and atmospheric turbidity from satellites.

A completed contract has recommended a five-year research program on the long-term aspects of air pollution. Areas of high priority include: (1) acid precipitation, (2) a stratospheric content of particles and trace gases, (3) $CO_2$ partition between atmosphere, biosphere, and hydrosphere, and (4) climatic theory and modeling. These recommendations reflect an increasing world-wide concern about possible long-term effects of pollution. To the extent permitted by resources, EPA's activities in the geophysical area will be increased, in terms of both current and recommended studies.

## 6.2 A Five-Year Research Program on the Long-Term Effects of Air Pollution

In 1970, a survey of the problem areas and a broad delineation of the lines on which useful research could be pursued by the EPA on problems of long-term geophysical and biological effects of air pollution was conducted by Dr. G. D. Robinson of the Center for the Environment and Man, Inc., Hartford, Connecticut (Robinson, 1970). In following up the initial critical review and in considering the deliberations and findings of the MIT Study of Critical Environmental Problems, held in July 1970 (Man's Impact on the Global Environment - Assessment and Recommendations for Action, MIT Press, 1970), Dr. Robinson has prepared a five-year research program design on the Long-Term Effects of Air Pollution, for the EPA's consideration.

Selected high priority research areas recommended for the EPA's initiation or support include:

a. Acid precipitation problems

b. Lower stratosphere particle and trace gas content

c. Initial survey of $CO_2$ partition between the atmosphere, oceans, and biosphere

d. Initial survey of climatic theory and modeling.

Additional work areas and projects are recommended for the EPA's cooperation with other agencies and for encouraging support. Publication of this study is expected soon.

## 6.3 Turbidity Network

A program to measure the atmospheric turbidity coefficient at a network of stations in the U.S. was begun in 1960. A summary of these measurements covering the period 1961 through 1966 has been published (Flowers, McCormick, and Kurfis, 1969). The present emphasis is to determine the world-wide background of turbidity as a basis for the study of long-term-trends in turbidity. Arrangements have been made for turbidity measurements to be taken at 14 overseas Air Weather Service stations in 12 foreign countries and, in cooperation with the National Weather Service, at 10 U.S. sites designated as Regional Monitoring Stations. All of these stations belong to the WMO network of stations for measuring background pollution. The WMO has accepted the United States' (NOAA's NCC) offer to collect and publish world-wide-turbidity data. An improved two-wavelength sunphotometer which was developed by the DM is being manufactured for use at these background stations. Although plans were made to begin the expanded program of observations by early 1971, unexpected delays in the manufacturing of the instrument have moved the starting date to late in 1971.

The dual-wavelength sunphotometers will provide turbidity coefficients at both 380 and 500 nm wavelengths from which Angstrom's wavelength exponent, $\alpha$, will be calculated. These measurements have been made at Cincinnati and Raleigh over several years. Both locations show the same variation in the monthly mean values of $\alpha$: high values in spring and fall and low values in summer and winter. The wavelength exponent, $\alpha$, is related to the particle size distribution so that large values indicate a relative preponderence of small particles and small values an abundance of large particles, at least over the size range $0.1\mu < r < 1.0\mu$. The reasons for this variation are probably related to the sources and production rates of the various size particles, the relative humidity of the air mass and the tropospheric circulation. Usually, high $\alpha$ values are associated with low turbidity values and low $\alpha$ values with relatively high turbidity values, although there are exceptions. For example, at Raleigh, $\alpha$ values with low turbidity values tend to occur when the low level circulation is easterly; this is consistent with the known particle size distribution of maritime air. Further analysis will require data from more locations, particularly in determining whether the observed annual variation is general.

## 6.4 Urban Radiation

Last year's report described a planned experiment involving measurements of the all-wave radiation energy budget in both an urban and a nearby rural area. This project will investigate the dependence of urban-rural radiation differences on atmospheric pollution and urban morphology. Instruments and data acquisition equipment were obtained during the year and their initial testing, calibration, and intercomparison completed. Simultaneous measurements at the urban and rural sites were expected to begin in FY 1972.

## 6.5 Laser Scattering

The feasibility of using lidar (laser detection and ranging) for measuring relative particulate concentrations has been established. The quantitative application of the lidar technique for obtaining absolute particulate concentrations is limited by the accuracy with which the optical characteristics of the aerosol, and the effect of the relative humidity of the atmosphere, are known. Theoretical analyses are not far enough advanced to be able to predict the light scattering from natural aerosols because of their polydispersity and their irregular shapes. It is necessary to study the effects of humidity to the extent that backscatter is dependent on the particle size distribution which is in turn dependent on relative humidity.

A research contract was awarded the Center for Environment Studies of the Pennsylvania State University to experimentally investigate light scattering phenomena so as to determine the influences of particle size distribution, relative humidity, and angle of polarization of laser light with respect to the plane of scattering. In addition, measurements of back scattering from actual atmospheric aerosols using both the laboratory apparatus and a prototype lidar probe will be made in an urban area with high pollution levels. Measurements thus far have shown that backscatter from hygroscopic particles is roughly constant below about 50% relative humidity but increases quite sharply above 50 to 60% relative humidity reaching six times the dry scattering at 90% relative humidity. Future work will involve using the General Electric Company's lidar to determine the effects of angle of polarization and field measurements of atmospheric aerosols over Philadelphia.

### 6.6 Maritime Aerosols

In late FY 1970, a contract, "Comprehensive Survey of Maritime Aerosols," was negotiated with the State University of New York at Albany. This contract continued into the current year. The study consists of oceanic observations of Aitken nuclei over the Atlantic, Pacific, and Indian Oceans. Graduate officers from the New York State Maritime College on board U.S. merchant ships have been employed to make the nuclei measurements.

A summary of all pertinent data obtained from the North Atlantic shows that continental-produced nuclei fields extend eastward from the coast of North America to the vicinity of Bermuda and west of Europe to the vicinity of the Azores, areas of predominately clear weather. These fields are less extensive in the more northern latitudes and off the coast of Africa. Two areas of very low concentrations were found in mid-ocean, at 20° to 30° N. and north of 40°N., separated by a band of higher concentrations.

## 6.7 Satellite Surveillance

During the year, the EPA continued its contract with the Space Science and Engineering Center of the University of Wisconsin to study the feasibility of monitoring global albedo and atmospheric turbidity with satellite-borne instruments. The study of turbidity observations has emphasized the use of sunglint from the ocean surface to measure atmospheric transmission. Two assumptions are implied by this technique: the sea surface is a mirror of imperfect, but determinable, reflectivity; the solar radiation transmitted down and reflected back up through the atmosphere by this mirror contains the record of the optical effects of atmospheric constituents.

During the year several basic questions have been considered: What effect do atmospheric constituents, primarily gaseous pollutants and particles, have on the transmission of solar radiation? What factors (e.g., surface wind speed, sun-satellite geometry, solar radiation, wavelength, and sea salinity) influence the properties of the mirror. What background sources (e.g., skylight, light reflected by particles in the sea, light reflected by whitecaps, and black body radiation from the earth) interfere with the primary sunglint radiation? Methods are being considered to process historical data from the Applications Technology Satellite. Methods to display reflected radiance data from the Los Angeles and surrounding area have been perfected so that urban-rural turbidity time variations can be studied.

## 7. OPERATIONAL SUPPORT

### 7.1 Bureau of Air Pollution Sciences (BAPS)

The Bureau of Air Pollution and Sciences (BAPS) develops air quality criteria and evaluates State standards, collects and analyzes air quality and emission data (Division of Atmospheric Surveillance), and conducts research on the effects of air pollutants on people, animals, plants, and property (Division of Effects Research).

Estimates of the maximum concentrations of candidate pollutants for control as hazardous air pollutants under Sec. 112 of the Clean Air Act as amended in 1970 were made for the largest known sources in the U.S. These estimates for nine different pollutants and discussion of the methods used in making the estimates were included in two internal reports.

Short-term dispersion models are being developed to determine maximum concentrations of air pollutants resulting from aircraft emissions. Estimates for averaging times of one hour or longer are desired. Models have been developed for the determination of relative concentrations from takeoff roll, landing roll, and waiting aircraft for any stability, wind speed, and mixing height for wind direction parallel to the runway in use, for six aircraft types. Models for approach and takeoff will be developed next.

A literature survey was made on transport and dispersion as specifically related to fluorides. A short section was prepared for a lead criteria draft entitled, "Influence of Lead on Visibility, Weather Modification, and Global Climate." A draft of a fluorides criteria was reviewed and comments made. A number of miscellaneous estimates of dispersion and transport were made during the year.

### 7.1.1 Division of Atmospheric Surveillance (DAS)

An analysis of St. Louis air quality resulted in an internal report entitled: "The Variation in Magnitude and Location of the Daily Maximum $SO_2$ Concentration During a Winter Season as Revealed by a 40 Station Measurement Network."

Another study showed that the highest average oxidant was received at the Chicago Continuous Air Monitoring Program (CAMP) station when the winds were from the east, off of Lake Michigan. That is, the air that has been least affected by the other pollutants in the Chicago air retained the most oxidant. In an effort to more closely examine the oxidant concentrations, the 1967 data from the Chicago CAMP Station were considered by wind direction, for two times of year, for two wind speed classes, and by time of day. The meteorological data used were from Midway Airport, about 15 km southwest of the CAMP station.

During the cooler part of the year, October to April, it is not expected that oxidant will be synthesized by the action of solar radiation on automobile exhaust gases. However, oxidant continues to be present in measurable amounts according to the CAMP records. Mean concentrations for each direction are highest with east and northeast winds and are 1.3 to 1.4 times higher during the hours from 0800-1600 than from 1700-0700. The maximum mean concentration from a direction is 0.04 ppm from the east during the period 0800-1600 with winds greater than ten knots. The conjecture is that the differences from daytime to nighttime concentrations are due to the differences in vertical mixing to the surface of the ozone aloft rather than due to photochemical generation of oxidant.

During the warmer months, May through September, the time periods considered were: 0100-0500, 0600-0900, 1000-1400, 1500-1900, and 2000-0000. During this time of year some differences are shown with wind speed. With winds ten knots or less, the maximum mean concentration of 0.06 ppm occurs during the period 1000-1400 with winds from both the west and east-southeast. With winds over ten knots (implying a shorter time of travel over any built-up area) the maximum mean concentration of 0.06 ppm occurs during the period 2000-0000 with the wind from the southeast with only slightly lower concentrations during the same period with winds from the east and east-northeast.

Since $SO_2$ apparently aids in destroying ozone, mean concentrations of $SO_2$ were also determined for each direction. Directions with the highest $SO_2$ concentrations had lowest oxidant concentrations, especially during the winter months. During the summer, $SO_2$ concentrations are considerably lower.

Mean concentrations of CO as a function of wind direction will be determined for conformity with distribution of maximum Chicago vehicular traffic. This will partially indicate the representativeness of the airport winds for the CAMP station. Local emissions of CO will overshadow the distant sources. Because of the reaction time in the production of photochemical oxidant, the oxidant at the CAMP station would be expected to be the result of more distant emitters of photochemical precursors (hydrocarbons and nitric oxides). Therefore the CO concentrations by direction will not be a direct indicator of the auto exhaust emissions most responsible for oxidant formation.

A study was also made relating wind direction and average oxidant at the CAMP (Continuous Air Monitoring Program) station in Washington, D. C. Data used were restricted to times when the wind speed was more than ten knots.In both 1967 and 1968 the highest average values were found to come from the south-southeast. That is the direction of the least population. In all other directions, Washington is surrounded by suburbs which may decrease background oxidant flowing into the urban area.

A similar study for Denver showed the average oxidant values to be almost the same for most directions; however, for the south and south-southwest directions big differences were observed. In both 1967 and 1968 the winds from these southerly directions were very low in oxidant. This is the direction of the main industrial area of Denver.

### 7.1.2 Division of Effects Research (DER)

A two-station meteorological network recording hourly temperature, humidity, barometric pressure, and wind was installed and operated as part of a five station air quality network in

New Cumberland, West Virginia, from November 1969 to June 1970 in support of an asthma study. During FY 1971 these data were reduced, quality controlled, tabulated and presented to the principal investigators in the DER for inclusion in their analysis. The main purpose was to identify parameters, meteorological or aerometric, that showed significant correlation with asthma attack rates of people living in New Cumberland. Analysis of these data, based on 238 reporting days, indicated that both air pollution ($SO_2$ and particulates) and temperature affect asthma attack rate, with the pollution effect separable from the temperature effect. It will, therefore, continue to be necessary to obtain temperature data in addition to air pollution data for future asthma studies.

Based on experience gained in the New Cumberland study, a new study of lower respiratory infection in children five to seven years old was begun in the New York City area. Occurrences of infection are reported in areas of high air pollution (Bronx), medium (Queens), and low (Riverhead, Long Island). In support of this study, temperature data are routinely compiled and presented to the principal investigators for inclusion in their statistical summarization and analysis.

Two wind-recording systems are operated and maintained in support of a Community Health and Environmental Surveillance Study (CHESS) in Chattanooga, Tennessee.

Experience gained with use of digital wind systems has served as a basis for guidance to the Aerometry Section of the DER in specifying instrumentation for 16 recording sites by the forthcoming

Community Health Ambient Monitoring Program (CHAMP). Parameters to be monitored include hourly values of temperature, dewpoint, wind speed, and wind direction. These will be recorded in digital form on magnetic tape.

A wind system was installed and operated in Cincinnati in support of a short sampling study on asbestos effects.

The Epidemiology Section of the DER has undertaken a study of nationwide mortality statistics and the relationship of meteorological parameters, particularly temperature. The mortality statistics used are daily by counties. The list of climatological stations in the U.S. reporting daily maximum and minimum temperatures was inspected to select 424 sites representative of areas of available mortality statistics. Coordination with the National Climatic Center at Asheville, North Carolina, will result in acquiring data on magnetic tape for these sites for the period from 1962 through 1966.

A preliminary study by the Epidemiology Section was concluded this fiscal year concerning excess deaths resulting from elevated temperature found in a summertime urban heat island. Mortality statistics for portions of a study area were compared for an urban region and the surrounding suburbs. The mortality effects of both flu epidemics and regional temperatures were removed from these statistics before comparison. During a heat wave on July 4, 1966, mortality data for the 18 counties around New York City revealed deaths more than doubled in the central core (heat-island) of Manhattan, Bronx, Queens, Brooklyn, and Newark, and less than doubled in the cooler suburbs. Temperatures, especially night time minima (81°F) were 10°F higher in the heat-island. Statistical analysis indicated only part of the excess deaths could be explained by differences of income, age, or levels of air-conditioning.

There were 1,020 deaths in the 18 county area on July 4, 1966. Of these 481 were the normal expectation for a July day. For the excess of 539, an area wide suburban maximum of 103°F would have predicted 361, leaving the remaining 178 deaths attributable to higher temperatures in the core area.

Preliminary to the establishment of a Community Health and Environmental Surveillance Study in the Salt Lake City area, a climatological study was made. The wind flow is greatly influenced by the topography, in particular by the alignment of the Jordan Valley and by the proximity of the wind flow to the canyons on the west slopes of the Wasatch Mountains. Differential heating results in up-slope winds during the afternoon and down-slope winds at night. The mountain-valley wind regime has important effects on the air pollution situation for this area. Pollutant sources to the north and northwest of the city will have an effect about 25 percent of the time, and sources to the south and southeast affect the city about 50 percent of the time.

Salt Lake City ranks high in the nation for total hours of inversion occurrence as revealed by radiosonde measurements. Inversions occur on about 80 percent of the mornings throughout the year, with the highest frequency in summer, 90 to 95 percent. Computation of morning urban mixing depths revealed all monthly averages to be less than 400 meters with the wind speeds through the morning mixing depth less than four meters per second for six months of the year.

Climatological upper wind records for 1960 through 1964 indicate that the mountain-valley regime observed at the surface is also evident aloft. Data were available for two times of day for each season for three heights above the surface. The effect of the mountain-valley winds aloft is greatest in summer and least pronounced in winter. Figure 7-1 shows the wind statistics for the winter season.

A climatological study similar to that for Salt Lake City was conducted for the El Paso area. Using the results of the climatology, an international sampling project for the El Paso area is being planned.

## 7.2 Meteorology Branch, Division of Abatement (DA)

### 7.2.1 Abatement Actions

New Cumberland, West Virginia - Knox Township, Ohio

Meteorologists prepared analyses of the impact of the Toronto Power Plant on air quality of New Cumberland. The analyses in conjunction with the advice of control engineers and medical doctors, formed the justification for the official recommendation that six uncontrolled boilers of the power plant cease operation. Meteorologists participated in numerous meetings and discussions among industry, State, and Federal Air Pollution Control officials

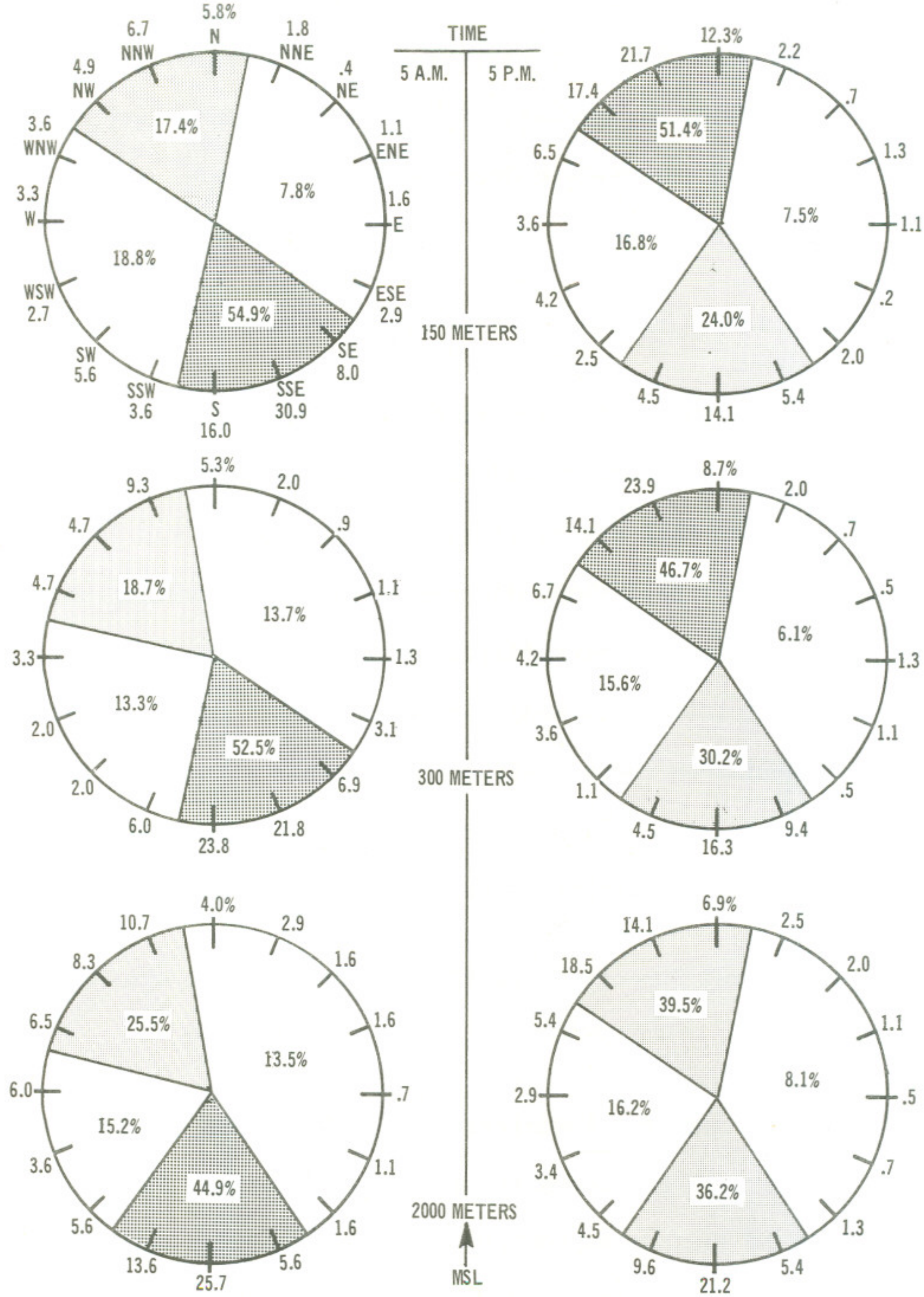


Figure 7-1. Winter wind direction frequencies at 5 a.m. and at 5 p.m. for three levels - Salt Lake City.

concerning the effectiveness of control devices, availability of alternative fuels and timing of control action. Meteorological judgments were offered as appropriate. The boilers in question were placed on "cold reserve" on December 31, 1971, three years earlier than first proposed.

Mt. Storm, West Virginia - Garret Co., Maryland

Meteorologists made extensive analyses of the impact of a power plant on the tree nursery industry in the two counties. The major difficulty was that extensive damage to the trees was found and attributed to air pollution, but the levels of contamination measured were not known to be sufficiently high to cause the damage observed. Meteorologists made numerous analyses of short-term levels of contamination under a variety of weather situations in an attempt to explain the damage. The analyses and findings were presented at a formal interstate abatement conference in May 1971.

### 7.2.2 Meteorological Support to Emergency Operations Control Center (EOCC)

The Emergency Operations Control Center (EOCC) was established within the EPA to meet its responsibility under Section 108K of the Air Quality Act of 1967 (the EOCC is now operating under Section 303, Air Quality Act of 1970) to take steps to prevent imminent and substantial endangerment to the health and welfare of persons from air pollution. The DM provides operational support to the EOCC.

The meteorologist assigned to the EOCC defines the necessary meteorological parameters and develops forecast techniques for episode control actions. Meteorologist from the DM also participated in the EOCC's episode control workshops and served in an advisory capacity at meetings between the EOCC and a contractor (Argonne National Laboratory) working on diffusion modeling for episode control actions.

In addition to routine meteorological surveillance, augmented meteorological support was provided to EOCC on five instances where air pollution constituted or was feared to constitute an immediate endangerment to health:

Galaxy, Maryland

This situation involved a solvent recovery plant located in a narrow valley. The sampling program contracted for was costly because of the nature of the contaminants. A meteorologist operated on-site with the EOCC project engineer to help select the place and time that sampling was conducted and to optimize effectiveness and minimize cost of the sampling effort.

Shreveport, Louisiana

The State gave a contractor a variance from air pollution laws to burn a substantial amount of debris from a land clearing operation near a residential area, a rest home and schools. Local residents appealed to the Federal Government. The meteorologists, as a part of a team which included engineers and medical doctors, cooperated in developing a position for the EPA Administrator to take with the Governor of Louisiana. The position described probable air quality concentrations and the consequent health effects which could result from the proposed open burning. The matter was resolved when the contractor removed the debris, which contained substantial quantities of poison ivy, from the area.

Jackson, Mississippi

An accident during an oil drilling operation about 20 miles from Jackson, Mississippi allowed a large quantity of hydrogen sulfide ($H_2S$) to be released without control. Meteorologists worked with the EOCC to identify the probable areas where unacceptable levels of $H_2S$ might occur, appropriate areas to locate samplers and times when local residents might need to be evacuated. Data were provided to the Mississippi Air and Water Control Commission. The oil well was eventually plugged.

Chattanooga, Tennessee

A local stagnation contributed to levels of particulate matter pollution which exceeded Tennessee air quality standards. Meteorologists accompanied a team of engineers, lawyers, and sampling technicians to the area. They provided special atmospheric soundings, calculations of the impact of proposed emergency reductions of emissions and testified at a hearing to justify the control actions taken by the local air pollution control agency.

St. Louis, Missouri

An accident in the Illinois portion of the St. Louis Air Quality Control Region wrecked and ignited a freight car loaded with toxic chemicals. Meteorologists provided estimates of the degradation of air quality and helped estimate the areas subject to contamination levels which might endanger health. The fire was extinguished and emissions controlled before emergency action was initiated by the EOCC. The initial information concerning the incident was received by the EOCC through the NOAA Environmental Meteorological Support Unit, St. Louis.

7.2.3 Support of Local Agencies

Expansion of Consolidated Edison's Astoria Power Plant, New York City

Analyses were made of the impact of an addition to the Astoria Power Plant in New York City on the City's capability of achieving air quality standards. Consolidated Edison had proposed the construction of a 1600 megawatt addition to the Astoria plant, concurrent with converting all coal units to fuel oil with a maximum of 0.37% sulfur content. The analyses involved using the diffusion model to estimate the contribution of the power plants to ambient $SO_2$ concentrations. Diurnal and seasonal variations in emissions and meteorology were considered. For computational purposes, the power production day was divided into three time-periods:

1) 3 a.m. through 8 a.m. - Maximum

2) 9 a.m. through 8 p.m. - Minimum

3) 9 p.m. through 2 a.m. - Transitional

Three seasons were used:

1) Winter (December, January, February)

2) Summer (June, July, August)

3) Spring-fall (March, April, May, September, October, November)

Stability wind roses were determined for the same periods from three-hour National Weather Service data from LaGuardia International Airport for 1969.

The 1969 emissions for each plant were computed for each time period in each season from the diurnal power production curves provided by the Consolidation Edison Co., the total seasonal fuel usage of each plant, and the sulfur content of the fuels used. The expected emissions under the plan proposed by consolidated Edison were computed by converting coal usage to oil usage, using the amount of oil required to produce the same amount of electrical power produced by the coal. Then all the oil was assumed to contain 0.37 percent sulfur. Otherwise, 1969 fuel usage and diurnal power production curves were used.

The results of the modeling indicated that a reduction of about 35 to 50 percent in the $SO_2$ contribution by the power plants was likely. This equates to about 20 to 30 percent reduction in the ambient annual $SO_2$ levels in Queens, the Bronx, portions of Brooklyn, and mid-Manhattan. Alternate plans were proposed and modeled, including an 800 megawatt addition to Astoria instead of the 1600 megawatt addition. In each case, it was determined that a reduction was not likely to be sufficient to permit timely achievement of the proposed air quality standards.

Super Incinerators, New York City

An analysis was made of the likely impact on air quality by the construction of four super-incinerators (up to 5000 tons per day of refuse) in New York City. The portions of the city most vulnerable to degradation of air quality from the incinerators were identified using a frequency-of-occurrence model. The analysis revealed that control devices for gaseous pollutants, particularly hydrochloric acid, would be in order. Engineers determined that high efficiency control mechanisms for particulate matter could probably keep particulate matter contamination within acceptable limits.

State of Arizona

Meteorologists attended and helped prepare material for hearings conducted by the State of Arizona on ambient air and emission standards for $SO_2$. These hearings were concerned almost solely with the copper smelting industry, which is by far the most significant source of $SO_2$ in the state.

La Cygna Power Plant, Kansas

Investigations were made of the impact of a proposed power plant on air quality near La Cygna, Kansas. The plant will use coal with a very high sulfur content (4-6%). Control engineers used the data to select appropriate control devices for the facility.

Navajo Power Plant, Page, Arizona

Numerous studies were made of the impact of the Navajo Power Plant. Data were used to assist in determining optimum configuration of this facility. Extensive use was made of a staff study prepared in 1967 and published in 1968 by the DA meteorologists.

7.2.4 National Emission Standards

The Clean Air Act requires that emission standards be developed for pollutants from major classes of stationary sources. For some of these classes, especially $SO_2$ control from power plants, the feasibility and degree of emission control possible is being questioned. Thus, it was desirable to estimate how much control was necessary to meet the air quality standards. Ground-level concentrations were estimated for a range of sources using various types of fuel and varying stack characteristics. The calculations were made for the meteorological conditions which cause the highest concentrations from sources with tall stacks, (e.g., limited mixing, inversion-breakup fumigation, light-wind fumigation). The estimates were used to indicate the degree of control necessary. They will form part of the technological basis for the selection of appropriate emission standards.

## 7.3 Division of Control Agency Development (DCAD)

DCAD provided meteorological technical assistance to numerous State and local air pollution control agencies and to other EPA facilities.

7.3.1 Coal-Burning Power Plants, St. Louis, Missouri

At the request of the Missouri Air Conservation Commission, estimates were made of the annual average concentrations from eight coal-burning power plants in the St. Louis area. Also, one-hour estimates were made of air pollution concentrations from the Sioux Power Plant, a 1,000 megawatt plant on the north side of the City. Findings were presented by meteorologists who participated in hearings July 22-23, 1970. As a follow-up, new area-wide estimates were being prepared for evaluating control plans of power plants through the year 1973.

7.3.2 Proposed Chemical Plant, Hilton Head Island, South Carolina

A study was made of the air pollution climatology of the site of a proposed chemical plant near Hilton Head Island, South Carolina at the request of the State air pollution control agency. Upper wind observations were made in the vicinity at two locations for approximately one week. The study showed the difficulty of applying a diffusion model to an area made up of broken areas of water and land. Local concern about the environmental impact of the plant has resulted in cancellation of plans for construction.

7.3.3 Agricultural and Silvacultural Burning and Sugar Industries, State of Florida

A meteorologist participated in two meetings in Florida. One meeting presented the technical aspects of the combined problems of the forestry and citrus industry, and the other meeting considered problems of the sugar cane industry. Primarily, local agencies have been advised with respect to the possible use of meteorology and Federal meteorological resources available. Further action will depend upon the requests of the agencies for assistance.

7.3.4 Miami Jetport

Federal and local environmental agencies have joined in a cooperative study of the proposed Miami Jetport. The site under consideration is the same as for the Miami Training and Transition Airport. A meteorologist visited the area February 8-10 for the purpose of determining the best location for air-monitoring stations. The meteorological study to be undertaken by EPA will depend on local plans.

7.3.5 Puerto Rico

A meteorologist visited Puerto Rico in August for the purpose of determining the meteorological requirements of the Commonwealth air pollution control agency and for firsthand information on the future environment impact of a refinery under construction at Yabucoa, Puerto Rico. At the request of the agency, an independent evaluation was made of an environmental report that had been prepared on the refinery area.

7.3.6 Large Power Plants - Southwestern United States

Interest has continued in the Four Corners Power Plant, New Mexico. A summary of the air pollution climatology of the Four Corners

Air Pollution Control Region was prepared, and a meteorologist participated in the pre-consultation meeting in Sante Fe that considered the boundaries of the Region. Also, various kinds of evaluations have been made pertaining to the impact of some other large power plants in the arid regions of the Southwestern United States. The State of Arizona has requested an estimate of the mutual effect of the Navajo and Kaiparowits power plants which may share the same Colorado River valley area about 50 miles from the Grand Canyon National Park. Diffusion estimates were also made for the Reid Gardner power plant in the Las Vegas area at the request of the Clark County, Nevada agency.

7.3.7 Allegheny County, Pennsylvania Airport

Airway observations from the Allegheny County, Pennsylvania Airport were examined for the purpose of determining the possible effect of coke-oven operations on visibility. Consideration was given to a possible study that would lead to a more effective control program in the area. However, the available data did not conclusively show the effect of any particular source on the airport. The valley configuration and periods of light variable winds make difficult the tracing of pollution to its source when visibility at the airport is low.

7.3.8 Other Technical Assistance

(1) Generalized air pollution climatologies were written for about 15 air quality control regions. These were prepared in

anticipation of the needs of certain States preparing regional plans.

(2) A meteorologist visited Little Rock, Arkansas, and advice was given to the State Pollution Control Commission pertaining to the feasibility of a diffusion model for two large aluminum ore refineries that are sufficiently close together to cause a mutual effect on the surrounding area.

(3) Climatological information and diffusion calculations were used in a situation where the burning of black liquor (a waste product) was being considered in lieu of disposal in the ocean near Fernandino Beach, Florida.

(4) Diffusion calculations were made for ammonia emissions from a sewage treatment lagoon for the purpose of estimating possible transfer of ammonia to the water of Tampa Bay, either by contact or by precipitation.

(5) Mr. Dennis Lunderville, Meteorologist, Air Pollution Control Board of the State of Tennessee, was given on-the-job training for a week. Emphasis was placed on the application of diffusion calculations.

(6) Thirty-eight proposals dealing with a proposed study for modeling aircraft and automotive emissions in the vicinity of airports were evaluated for the Department of Transportation, FAA.

### 7.3.9 Current Activities and Plans

Support is being given to an EPA project that will locate monitoring stations in approximately 30 cities for the purpose of obtaining baseline data for oxidants, nitrogen oxides, and hydrocarbons. Climatological information is being supplied and meteorologists and meteorological technicians will make site visits as required.

Wherever possible, future technical assistance is to be supplied directly by EPA regional offices. Consequently, steps are being taken that may result in the assignment of meteorologists to selected regional offices. These meteorologists would be expected to work closely with State and local agencies and give various kinds of meteorological support to the Regional Air Pollution Control Directors.

Field support is also to be given by the DM in air pollution emergencies. A light airplane instrumented for temperature soundings and limited air sampling is available, and a meteorologist and certain technicians are alerted for possible service during air pollution episodes or accident situations.

### 7.3.10 Associated Technical Assistance Activities

Technical assistance efforts and support to other air pollution control activities have produced the four computer programs described below. All are written in Fortran IV. Inquiries concerning these programs should be made to the DM.

(1) FREQ2 - computes either (A) concentrations resulting from single - or multiple source-receptor combinations or (B) frequency of occurrence of concentrations above selected levels of interest, or both. Stability roses are required for the (B) option.

(2) ROSEX - computes either (A) stability rose aloft for a station having a surface stability rose and an upper wind rose or (B) "downtown" stability rose for a station having an "airport" stability rose and a "downtown" wind rose. Output acceptable to FREQ2.

(3) ROSES - draws wind roses, including scales and legend, for eight, sixteen, or thirty-six pointed roses. Input is the same format required by FREQ2 or ROSEX (requires plotter).

(4) ROSEALL - computes from the raw data (A) wind roses (B) stability roses for data in any format, on tape, card or disk. Number of directions, speed categories, etc., all optional. Can be used for weather roses and weather-stability roses.

## 7.4 Office of Manpower Development (OMD) Institute for Air Pollution Training

Two meteorologists assigned to the Institute in the Laboratory and Surveillance Section develop and present blocks of instruction dealing with the meteorology of air pollution. This is accomplished through the presentation of intensive short courses, usually one week in duration.

The basic course, "Air Pollution Meteorology," is recommended for scientists and engineers having little or no training in meteorology and for meteorological technicians. There were four course presentations during the year, attended by 146 persons.

"Diffusion of Air Pollution - Theory and Application" is the course 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 twice to a total of 74 students; once at the National Weather Service Central Region Headquarters and once in the Institute facility at the Research Triangle Park.

The third short course is "Meteorological Instrumentation in Air Pollution." This course is for engineers and technical personnel responsible for designing, procuring and maintaining air pollution monitoring networks that include meteorological sensors. Thirty-two persons completed the two presentations of this course.

A section on air pollution meteorology has been incorporated into a computer assisted instruction (CAI) mode course currently being validated. The CAI course contains nine sections dealing with specific air pollution subjects and is designed with the freshman or sophomore college student in mind. The meteorology section should require a minimum of two hours at the computer terminal.

Numerous seminars and informal talks were presented to various professional organizations, civic groups and schools. In addition, two man-weeks were spent at the State of California Air Resources Board in a career development capacity, and one man-week was spent at the State of California Division of Highways in an advisory capacity.

# 8. INTERNATIONAL AFFAIRS

## 8.1 North Atlantic Treaty Organization Committee on the Challenges in Modern Society (NATO CCMS)

Air pollution technicians from the United States arrived in Ankara, Turkey, on September 15, 1970, to help install an air quality network and began the collection of pollution sources information and meteorological data required as input for the air pollution assessment of Ankara. Particular emphasis was placed on the collection of data from the winter season of 1970.

The Expert Panel on Modeling of the CCMS held its first meeting on October 9, 1970, in Frankfurt, Germany. Modeling experts from the United States, Germany, Turkey, and France attended the meeting. Mr. Robert A. McCormick chaired the meeting, and Mr. K. L. Calder presented a detailed technical paper on a climatological urban air pollution model that was proposed for application in the Ankara study. The Panel endorsed the use of the climatological model for this purpose. In subsequent meetings from October 12 through October 14, 1970, Mr. McCormick and Mr. J. Zimmerman attended a CCMS meeting in Frankfurt where the German delegation presented plans for the air quality study of the city of Frankfurt which they will undertake as part of the CCMS pollution project.

## 8.2 World Meteorological Organization (WMO)

On March 22 through 26, 1971, Mr. Robert A. McCormick attended the second meeting of the Executive Committee Panel on Meteorological

Aspects of Air Pollution, of which he is Chairman, at WMO headquarters in Geneva. The primary purpose of the meeting was to approve Part I of the WMO Operations Manual for the global network for monitoring background air pollution levels and to plan for the preparation of Part II. Part I provides for the measurement of turbidity (NOAA archiving) and the chemical analysis of precipitation (EPA archiving) and dry fall-out at the regional and baseline stations. Part II will cover the sampling and analysis of gases and particulate matter and further steps to be taken in implementing the WMO network.

On April 12, 1971, a paper by Mr. McCormick was presented to the 6th Congress in Geneva on "WMO's Plans for Monitoring of Background Atmospheric Pollution."

In April 1971, Dr. James Peterson, at the request of WMO, began a two to three month assignment at WMO headquarters in Geneva. The purpose of the assignment was to assist the WMO Secretary in preparing the working documents on air pollution to be presented at the 1972 UN Conference on the Environment to be held in Stockholm.

8.3 Organization of Economic Cooperative Development (OECD)

On September 14 and 15, 1970, Mr. Robert A. McCormick attended a meeting of the Study Group on Models for Prediction of Air Pollution, of which he is Chairman, at OECD headquarters in Paris. This meeting was called for a final critical review and approval of the report "Models for the Prediction of Air Pollution" prepared by Professor James Mahoney of Harvard University for the Study Group.

This report examines critically the present experience with urban diffusion modeling techniques, advises on further research possibilities, and examines the operational requirements for models. It is expected that the OECD will de-restrict the report, and steps will then be taken to have it published in the open literature.

Mr. George Holzworth attended the second meeting of the Planning Group on Mass Transport of Air Pollutants held at the OECD Headquarters in Paris October 11 through 16, 1970. The main purpose of the meeting was to review the study plan submitted by Mr. J. Nord (Norway). The study plan is to survey sulfur emissions in northern Europe and Scandanavia, establish a comprehensive daily sampling network for sulfur in air and precipitation, establish an International Center to coordinate the field activities, and conduct the necessary studies. The U.S. role in this project is in an advisory capacity only with no active participation by funding or assignment of personnel. The U.S. recommendation that large-scale tracer experiments be included as part of the study program was rejected as too expensive.

The third meeting of the Planning Group was held in Paris, June 9-11, 1971, for developing further details on the study project. A report on the study plan to be distributed by July 1, 1971, will include pollution sampling and chemical analyses procedures and the following schedule of Phases: 1971, Preparatory; 1972, Pilot when all participating countries should be collecting some samples; 1973-1974, Operational (if needed); 1975 concluding when final report is prepared. A Project Steering Committee, operating under guidance of the Air Management Sector Group, will supervise the project and recommend on continuation in 1973-1974. International funding for the Central Project Unit; the modeling, interpretation, coordination unit; will be allocated among participating countries on the basis of an established OECD formula.

### 8.4 Global Monitoring Design Study

On June 8 and June 28, 1971, R. A. McCormick and J. T. Peterson, respectively, joined the working group of the Monitoring Commission of the International Council of Scientific Unions (ICSU) Scientific Committee on Problems of the Environment (SCOPE) in Stockholm. Mr. McCormick and Dr. Peterson served as consultants to the working group in the preparation of their report on the design of a Global Environmental Monitoring (GEM) system. This report is to serve as the SCOPE input to the 1972 UN Conference on Human Environment, also to be held in Stockholm.

### 8.5 Study on Man's Impact on Climate

On June 28, 1971, Mr. R. A. McCormick joined the three-week Study on Man's Impact on Climate (SMCC) at Lidingo, Sweden. This study was the follow-up of the Study on Critical Environmental Problems (SCEP) held at Williams College, Massachusetts, in the summer of 1970. The primary purpose of SMIC was to arrive at an international assessment of present knowledge about inadvertent climate modification. This assessment will also serve as an input to the 1972 UN Conference on Human Environment.

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