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

Fiscal Year 1972 Summary Report of Division of Meteorology Support to the Environmental Protection Agency

CHARLES R. HOSLER
HERBERT VIEBROCK, Editors

Air Resources
Laboratory
RESEARCH
TRIANGLE PARK,
N. CAROLINA
May 1973

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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FISCAL YEAR 1972 SUMMARY REPORT OF DIVISION OF METEOROLOGY SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

Charles R. Hosler
Herbert Viebrock, Editors

Division of Meteorology (EPA)

Air Resources Laboratory
Research Triangle Park, N. Carolina
May 1973

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 (EPA-IAG-0160(d)) between the EPA and the Air Resources Laboratories (ARL), National Oceanic and Atmospheric Administration (NOAA) dated May 11, 1972. Although contracted studies are funded directly by the EPA, the NOAA personnel assigned to the Division of Meteorology (DMT) 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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This report summarizes meteorological research and other projects that the Meteorology Laboratory is conducting for the Environmental Protection Agency (EPA).

Uniterms: Abatement, absorption, acoustic echo sounding, aerosol, air pollution, air quality, ammonia, boundary layer, carbon dioxide, carbon monoxide, chemistry, cooling ponds, cooling towers, diffusion, Lagrangian, lasers, maritime aerosols, mesometeorology, meteorology, mixing layers, model monitoring, oxidants, particulates, photochemical, plume rise, plume-spread, radar, radiation, radiometer, radiosonde, remote sensing, satellite, solar radiation, stacks, stagnation, tetroon, turbidity, trajectories, washout, water tunnels, wind shear, wind tunnels.

1. INTRODUCTION

In FY 1972 the EPA's Meteorology Laboratory, (ML), with its continuing programs in meteorological research on air pollution, was primarily concerned with the developing, evaluating, and using conventional air quality simulation models for stable pollutants, as well as initiating research to develop models for chemically active pollutants. The validation of an urban diffusion model that describes the distribution of automotive generated carbon monoxide (CO) was successful. Completed field studies of the Large Power Plant Effluent Study have furnished data to be used in developing dispersion models that describe sulfur dioxide (SO_2) pollutant concentration patterns, resulting from sulfur dioxide (SO_2) emitted into the atmosphere by large power plants. Studies of the natural precipitation washout of SO_2 indicated that the reversible absorption-desorption process of SO_2 in precipitation must be considered.

The development of remote sensing techniques for obtaining meteorological information important to air pollution studies focused on improving the data processing techniques for the Mark II Thermasonde, a millimeter radiometer that can provide data on mixing depths and temperature profiles within the planetary boundary layer; it is expected to be operational by early 1973. Other efforts supported the development of a portable acoustic atmospheric sounding system to provide information on wind and turbulence in the lower layers of the atmosphere.

In geophysical studies, sunglint observations from satellites, for assessing the changes in aerosol optical thickness (at wavelengths from the visible to 2.5μ) on a global scale- were determined to be feasible; the measurement of scattering in the near infrared (IR) may be possible for quantitative measurement of particulates. Studies to assess the effects of atmospheric pollution on the transfer of radiative energy and the climate of the urban boundary layer began by measuring downward directed broadband solar and terrestrial long-wave (3 to 50μ) radiation, near Research Triangle Park, North Carolina. The continued operation, since 1960, of the global atmospheric turbidity network, with 44 stations using the new dual-wavelength (0.38μ and 0.50μ) sunphotometer, is providing climatological data for determining trends in turbidity on a global scale.

In cooperation with NOAA's National Climatic Center, a compilation and analysis of climatological information on dispersion parameters, based on routine rawinsonde observations for the contiguous U. S. was prepared. It is expected that this data will be useful for site evaluation and regional-urban planning.

Operational support to other EPA laboratories consisted of technical assistance to the Office of Air Programs; provision of field teams and special forecasts to support emergency incidents; and special studies, consultation, and assistance to EPA offices and to state and local control agencies.

2. AIR QUALITY SIMULATION MODELING

2.1 Working Group on Air Quality Modeling

The Working Group on Air Quality Modeling (WGAQM), formed in March 1972, coordinates various in-house and contractual efforts on air quality simulation modeling. The WGAQM is composed of personnel from various EPA offices in North Carolina. This committee brings together those persons involved in air quality modeling and encourages the exchange of ideas on both working and developmental air quality models.

2.2 Climatological Air Quality Model Comparison

Two climatological (long-term) air quality models were evaluated. They calculate annual average pollutant concentrations and analyze the effects of various emission control plans. The two models were the Air Quality Display Model (AQDM) (TRW Systems Group, 1969) and the Climatological Dispersion Model (CDM) (Calder, 1971). Using New York City (1969) as a common base for the models, estimated annual averages of SO_2 and particulate matter at 127 receptor locations were made. Observed data were available at 75 locations for SO_2 and 114 locations for particulate matter. Point sources included in the emission inventory totaled 678, and area sources totaled 854. Area source sizes were 1 km on a side in the center of the city and increased to 10 km on a side near the region boundaries.

Results of a statistical analysis of the differences between calculated values and measured values, considering background concentrations, indicate that the CDM is better than the AQDM. It cannot be shown statistically that the variance explained is different in the two models; however, the mean square error (rms) is much less for the CDM. Table 1 shows the results.

The sensitivity of the CDM was analyzed using two sampling locations. The analysis showed that Brigg's plume rise formula reduces the computed concentrations to one-half those found using Holland's expression; that raising the nocturnal mixing height from 100 m to 150 m reduces the computed annual concentration by 5 to

10%; that assuming a wind speed of 1.5 m/sec for the first climatological wind speed class instead of 0.67 m/sec decreases the computed concentration 5 to 15%; and that using a wind profile, variable with stability, instead of the surface wind to estimate the wind speed at plume height decreases the computed concentration by 15 to 25%. The composite result of the four changes is that the computed concentration is reduced from 20 to 40%.

Table 1. Comparison of Model Estimates With Measurements

	SO_2 ($\mu g\ m^{-3}$)			Particulate Matter* ($\mu g\ m^{-3}$)		
	Measured	AQDM	CDM	Measured	AQDM	CDM
Correlation Coefficient		0.88	0.83		0.62	0.61
Mean	135	211	138	81	103	73
Largest Error (-)		-106	-137		-51	-63
Largest Error (+)		+289	+166		+115	+68
Mean Absolute Error		83	38		28	15
RMS Error		111	51		36	22
Number of observations	75	75	75	144	113	114

* A background value of 35$\mu g\ m^{-3}$ has been added to the estimates of both the AQDM and CDM before comparing them.

2.3 Ammonia Study

A study of the absorption of an ammonia (NH_3) plume into a large water body was the first attempt to analyze such an interaction of air and water pollution. It was desirable to determine whether a sewage treatment plant could pollute a large bay through the bay water absorbing a portion of the ammonia content of the plume. The lack of data on the rate of such absorption necessitated theoretical method of calculation.

A simple model was developed that incorporates the major features of atmospheric transport and diffusion of a NH_3 plume together with aqueous absorption as the plume traverses a water surface. The model is based on the concept of the deposition velocity, although empirical data concerning this is quite meager. The model was applied to the gas release from an NH_3 stripper of a hypothetical sewage treatment plant. The fraction of NH_3 absorbed after a cloud has traveled some 30 km over water was estimated as over 20%. Note that more reliable estimates can be made only after special field experiments are conducted to determine the deposition velocity.

The full derivation and complete details of the model are presented by Calder (1972).

2.4 Airport Modeling

A short-term dispersion model of airport air pollution was developed to help evaluate the necessity of installing emission control devices on aircraft. The main objective was to determine the meteorological conditions under which high ground-level pollutant concentrations will most likely result.

The model represented a variety of aircraft modes (taxiing, taking-off, climbing out, approaching, and landing), by line sources of appropriate length and orientation, for six different types of aircraft. Aircraft queuing at the end of the runway were modeled as point sources. We used 1 hour for computing average concentrations and assumed meteorological conditions remained constant. Wind direction was assumed to be parallel with the runway. A typical mix of aircraft types was used with heavy traffic conditions prevailing. Using these input parameters, we predicted concentrations of four pollutants (CO, NO_x, particulate matter, and hydrocarbons) downwind of the runway.

Calculated concentrations were within a factor of two of the observed concentrations for distances less than 10 km. Maximum concentrations for an averaging time of 1 hour occur with stable meteorological conditions and light, steady winds, The takeoff mode contributes more than 80% to the maximum oxides of nitrogen and particulate matter concentrations. With two aircraft waiting, the takeoff mode contributes the majority of the material to the CO and organic maxima. With 10 aircraft waiting, the contribution is 90%.

2.5 Averaging-Time Model

Analyses of air pollution data indicate that air quality measurements tend to fit an averaging-time mathematical model (fig. 1) having the following characteristics:

1. Pollutant concentrations are log-normally distributed for all averaging times.

2. Median concentrations are proportional to averaging time raised to an exponent ($X_{median} \alpha t^a$, where a is a function of the standard geometric deviation).

3. Maximum concentrations are approximately inversely proportional to averaging time raised to an exponent ($X_{max} \alpha \frac{1}{t^b}$, where b is a function of the standard geometric deviation).

These characteristics have been used to develop equations for calculating the geometric mean, standard geometric deviation, maximum concentration, and various percentile concentrations of air pollutants. To illustrate the predictive, as well as the interpretive value of the model, we calculated parameters for one averaging time from actual data and then used those for calculating other averaging times with the model. Maximum concentrations calculated by the model have been compared with measured values for seven gaseous pollutants obtained during continuous sampling for up to 7 years in eight cities. The model fits most urban data quite well.

The averaging-time model has been used to estimate maximum concentrations for various averaging times. These estimates have in turn been compared with national ambient air quality standards

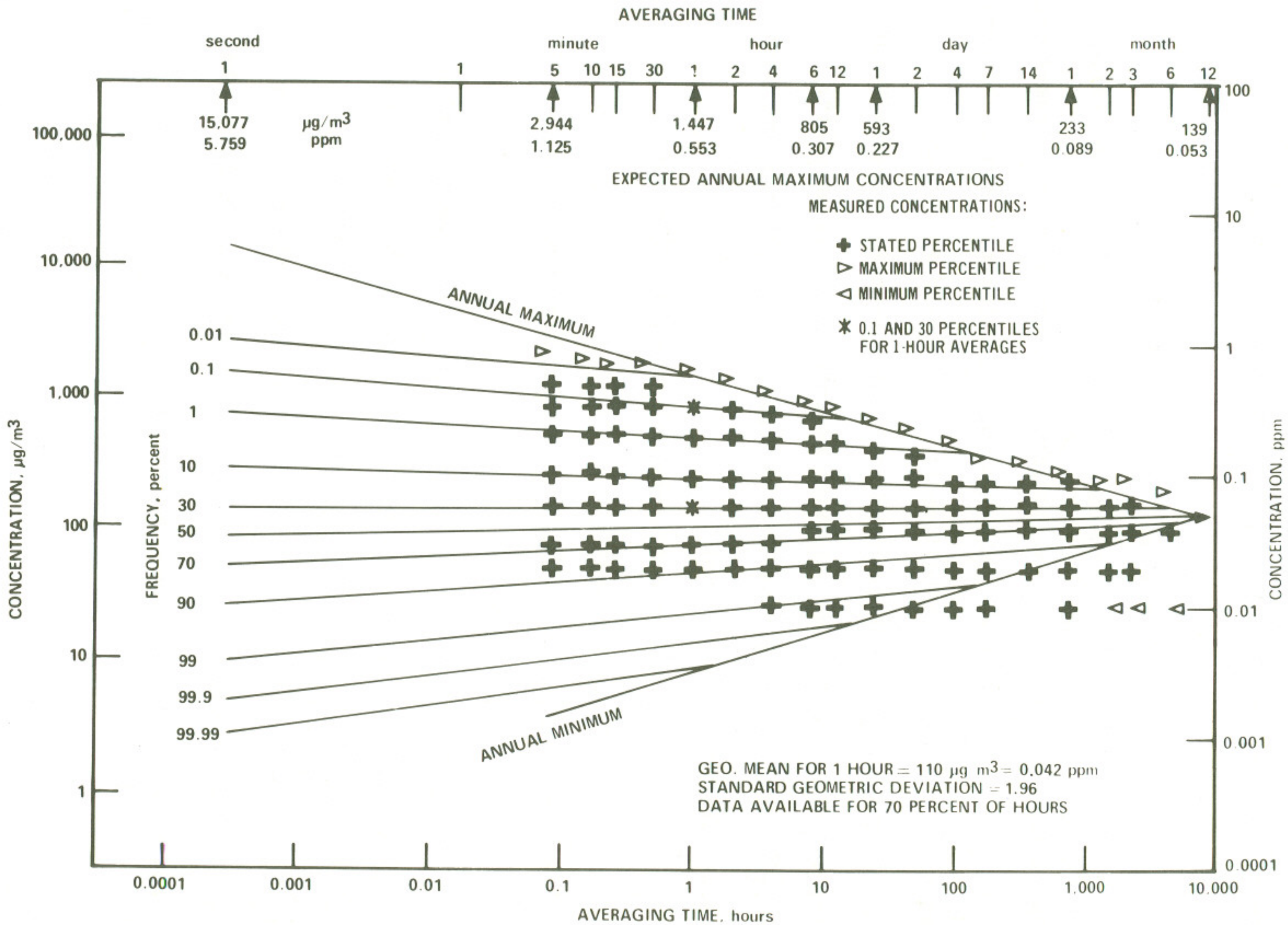

Figure 1. Plot of concentration versus averaging time and frequency for SO_2 at site No. 256, Washington, D. C., December 1, 1961, to December 1, 1968.

to determine how much reduction in pollutants might be needed to achieve the standards. The EPA publication AP-89, (Larsen, 1971), describes the averaging time model and its uses.

2.6 Gaussian Dispersion Model

Using a Gaussian dispersion model, Geomet, Inc. of Rockville, Maryland, has analyzed the variations of different model parameters. Pollutant concentrations can be calculated using both point and area sources. Gaussian distributions of plume spread in both the horizontal and vertical are used with point sources. Area sources are calculated using the narrow plume concept (i.e., only area sources directly upwind need to be considered). Calculations were made using two sets of data:

1. Chicago (1-month) SO_2 records at eight locations (hourly estimates).
2. St. Louis (3-months) SO_2 records at 10 locations (bihourly estimates).

Frequency distributions for these estimates over the period of record were compared with frequency distributions determined from observed SO_2 data. Calculations for only a portion of the total hours in the period of record were tried and found to be successful for estimating frequency distribution to deciles. Full details may be found in Koch et al. (1971).

2.7 Photochemical Dispersion Models

Three contractors, Systems Application, Inc. (SAI), General Research Corporation (GRC), and Pacific Environmental Services (PES), have been formulating and testing three distinct photochemical dispersion models. Each model differs in the chemical kinetics mechanisms and also in the handling of meteorological dispersion.

PES uses the most complex chemical kinetics, that is, a greater number of equations. SAI has the most simplified kinetic mechanism; the SAI model uses finite differences to calculate concentration variation from cell to cell. The SAI cell sizes are 2 miles by 2 miles, and there are five to 10 cells in the vertical. The PES model has one cell in the vertical, while the GRC model vertical cell size is 100 m.

Both PES and GRC use trajectory type models. These attempt to follow a parcel of air as it moves with the mean wind while allowing emissions to enter the parcel from the surface. The GRC considers the dispersion in the vertical after emission; the PES considers the emissions to mix completely within the vertical extent of the parcel immediately after emission.

All three of these models have been developed using data from the Los Angeles Basin. Each contractor will apply his model to a common data base, consisting of 6 selected days of data from the Los Angeles Basin. In addition to applying their respective models to this common base, the contractors will train ML scientists to use their respective model on computers accessible to the EPA.

2.8 Analytical/Numerical Modeling of Fluid Flow Near Buildings and in Street Canyons

The Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico, is developing and evaluating analytical/numerical techniques for describing fluid flow and pollutant patterns in street canyons and around isolated or small groups of buildings. This work is being carried out under an interagency agreement with the Atomic Energy Commission.

This study will produce a computer routine to supplement presently used dispersion models that are incapable of providing accurate pollutant concentrations near structures. The effects of heat transfer, bouyancy, and turbulence are to be included in the solution of time-varying, three-dimensional fluid flow equations. Verification is to be by comparison with experimental data. User-oriented computer program decks will be provided by LASL.

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

Systems, Science, and Software of La Jolla, California, has developed a new method for solving the atmospheric diffusion equation (K-theory). This method, called PICK, has been applied to some air pollution problems; it is based on the use of Lagrangian mass points and is one of a family of particle-in-cell techniques for solving the partial differential equations of hydrodynamics. The method can determine the three-dimensional field of pollution concentration resulting from arbitrary distribution of sources and with arbitrary three-dimensional fields of wind velocity and eddy diffusivity.

Finite-difference methods commonly used to obtain numerical solutions for such problems frequently introduce a numerical truncation dispersion of the solution that masks the physical atmospheric diffusion. This difficulty is avoided in the PICK method. Test cases for the evaluation of feasibility and accuracy and for comparison with high-order finite-difference methods were conducted with the two-dimensional computer code PICFIC.

The PICK method was used in a three-dimensional code, NEXUS, for actual air pollution studies. Although of general applicability, this code was illustrated by specific application to the simulation of CO concentrations in the Los Angeles Basin. The PICK method was also extended to include photochemical reactions, which introduce nonlinear terms into the diffusion equations for each pollutant species. The NEXUS/P code was developed to solve the set of simultaneous differential equations with the photochemical terms, and it was illustrated by application to the photochemical smog of Los Angeles.

Work on this photochemical extension of the PICK method is being continued under a new contract with Systems, Science and Software. Earlier work is reported in Sklarew et al. (1971).

2.10 Urban Boundary Layer Mathematical-Physical Model

A mathematical-physical model for predicting the wind, temperature, turbulence, and pollutant structure of the urban boundary layer is being developed by the Center for the Environment and Man (CEM) Hartford, Connecticut. Most multiple-source urban diffusion models previously developed require that the diffusion be specified *a priori* as a function of the meteorological conditions that are inputs for the model.

The CEM model numerically integrates in three-dimensions K-theory forms of the conservation equations for momentum, heat, and atmospheric water content in addition to the pollutant conservation equations. It incorporates formulas relating coefficients of turbulent transfer in the vertical to the wind and temperature fields. Therefore, it can generate wind and diffusivity fields that are physically derived and are consistent in spatial and temporal scale with the pollutant fields obtained. In principle, it provides a procedure for generating wind and diffusivity fields that are generally applicable to any geographic location, season, hour, or type of underlying surface.

Finally, there can be feed-back effects of the pollutant field, through the temperature field, on the wind and diffusivity fields. These effects may, in many actual cases, be insignificant or negligible. However, such effects may be quite significant; therefore, it is very desirable to have models capable of generating the meteorological and pollutant fields simultaneously.

Early results of this study have been encouraging and have demonstrated the feasibility of computer simulation of the temporal variation of meteorological and pollutant variables on a three-dimensional array containing several thousand grid points. At present, the basic formula and computer programs are being modified to accept an average terrain slope vector for each grid square. This model will calculate topographically induced vertical velocities and modify the calculated values of incident solar radiation at the lower atmospheric surface.

The modified simulation model will be applied to approximately 6 days of selected meteorological and air quality data from the Los Angeles Basin. The model will be evaluated upon its ability to predict the following conditions:

1. Spatial and temporal development of the mesoscale meteorological field considered in the model.
2. CO concentration field when model equations for the pollutant field are integrated simultaneously with those predicting

relevant meteorological variables.

3. CO concentration when observed meteorological fields are treated as specified inputs to the pollutant prediction model.

Work under this contract is reported in Pandolfo et al. (1971).

2.11 Invariant Modeling Applicability to Atmospheric Boundary Layer Diffusion

A contract with Aeronautical Research Associates of Princeton (ARAP), Princeton, New Jersey, represents an initial attempt to replace some of the empiricism in atmospheric diffusion calculations with a more rigorous physical description of the turbulent diffusion process in the lower atmosphere. In particular, the applicability of the method of invariant modeling of turbulent flow to the lower atmosphere is being investigated. This method, which has been successfully applied to classical shear flows (such as the free jet, the plane shear layer, and the free vortex), depends on a closure scheme for the Navier-Stokes equations at the level of the equations for the second-order correlations of turbulent fluctuations.

These correlations contain, among others, techniques responsible for the transport of momentum, heat, and matter by turbulent motion. The success of these techniques in predicting the structure of turbulence in classical shear flows, with a wide variety of geometries, suggests that the modeling might be carried over to more complicated flows in the atmosphere.

Initial tests for an atmospheric situation were made for an infinite cross-wind line source of matter in the thermally stratified lower layer of the atmosphere. These tests were quite successful. In particular, using only the mean wind and temperature profiles for the lower atmosphere and a predetermined scale length, we (the program) predicted the vertical dispersion of a pollutant release well within a factor of two of values observed downwind about 2 miles. The predictions were somewhat more exact for neutral and unstable temperature stratification than for stably stratified atmospheres.

Invariant modeling of atmospheric turbulence and diffusion is being extended to permit detailed analyses of the following specific problems, including comparison with appropriate observational data:

1. Diffusion in an unstable surface atmospheric layer capped by a temperature inversion, leading to the containment of airborne material in the mixed surface layer.
2. Diffusion in three spatial dimensions from a point source, for a unidirectional plane-parallel flow field.
3. Diffusion in the Ekman spiral of the planetary boundary layer.

This study will investigate in detail the significance of the Coriolis and pressure accelerations for the turbulence structure and turbulent fluxes of a pollutant.

In addition, we began a special study to assess the effects of atmospheric turbulence on the mixing and reactions among different chemical species, such as those involved in photochemical smog formation. It has been established that laboratory chemical kinetics and reaction rates may need major modifications before modeling situations of atmospheric smog; these modifications will require us to consider atmospheric turbulence of the kind already developed in the contract effort. This work shall adapt invariant modeling to include chemical reactions in the presence of turbulent mixing in a coupled analytical framework. This initial formulation of the problem will be applied to a variety of atmospheric conditions, reacting pollutants, and source locations in an attempt to define atmospheric situations where turbulent mixing significantly affects the rate of loss of primary photochemical pollutants and the rate of production of secondary ones. The initial work under this contract is reported in Donaldson and Hilst (1971).

2.12 Urban Diffusion Model for Carbon Monoxide (CO)

A mathematical model for predicting the spread of CO throughout a city and its environs has been developed by the Stanford Research Institute (SRI) for the Coordinating Research Council (CRC) and the EPA under CRC project No. CAPA-3-68.

This project was to develop a method for predicting the concentrations of automotive-generated air pollutants at any selected location in an urban area as a function of local meteorology and the distribution of pollution sources. The model is presently limited to relatively stable pollutants such as CO. In addition to predicting long-term average exposure, it can also predict - for any particular location - the percentage of time that hourly averaged concentrations greater than any specified amount can be expected. This will enable city planning organizations to predict pollution patterns that may develop in any urban region as a result of predicted growth.

The receptor-oriented working model, completed during 1970, incorporates diffusion submodels based upon both Gaussian-shaped and uniform vertical concentration profiles. Model inputs are traffic volumes on major streets and highways in the urban area, atmospheric stability, mixing depth, and wind speed and direction. Traffic volumes can be obtained from either past measurements or forecast values. Methods have been developed for estimating atmospheric stability and mixing depth from conventional (i.e., airport) hourly meteorological measurements and twice daily radiosonde data. The model can provide statistical summaries as well as hour-by-hour predictions. It has been applied to five geographically different cities (St. Louis, Chicago, Cincinnati, Denver, and Washington, D.C.).

For the initial evaluation, the field concentrations calculated by the model have been compared with those measured at Continuous Air Monitoring Program (CAMP) stations in these five cities. These comparisons demonstrated that the observed concentrations were usually higher than those predicted, particularly during peak periods. To some extent, these discrepancies were attributed to inadequate input data for the model and to inaccuracies in the CAMP data. The discrepancies also are caused by the weakness of the model in treating diffusion from nearby sources, because the CAMP stations are located at ground level alongside busy down-town streets.

During the second year of the project, San Jose, California, was added to the field program. San Jose was selected because of its size, uniform building heights, computerized traffic network, and its proximity to the Stanford Research Institute (SRI) laboratories. The principal activity in this program was the careful instrumentation of a downtown intersection and the adjacent side streets to determine the CO circulation pattern.

The San Jose study used a helicopter to measure CO concentrations at building top throughout the city. This program was very successful in extending the model to predict the CO concentrations expected at various levels between downtown buildings.

St. Louis was selected for third-year field studies to determine whether the model, as developed in San Jose, could be validated with data from a downtown section of another city where the buildings were higher than those of San Jose. These studies were completed in the late fall of 1971. The data show that a single-helix circulation is found in the deep street canyons of St. Louis, and that the simple model developed from the San Jose data is fundamentally correct for these higher buildings. The St. Louis experiment also improved a number of submodels.

When the revised model was applied in St. Louis and compared with observed hour-average CO concentrations, the root-mean-square difference between the calculated and observed values ranged from 2.6 to 3.9 ppm, depending upon the particular observation site. The model generally underestimates the concentrations below about 7 or 8 ppm and overestimates those at higher values. Median calculated values are within about 2 ppm of the observed median values. Model estimates are within 3 ppm of the observed values at the 90th and 98th percentiles. The model is described in the contractor's final report by Ludwig and Dabberdt (1972).

2.13 Fluid Model Feasibility Study

An in-house study on the use of fluid models to study diffusion in the atmospheric boundary layer has been completed. This study includes a survey of the literature on previous modeling work, a review of similarity criteria, an evaluation of existing modeling facilities, and recommendations about actions to be taken by the EPA. A draft of the study is being cleared for publication as an EPA Technical Report. A portion, "Similarity Criteria for the Application of Physical Models for the Study of Air Pollution Meteorology," was presented as a paper to the Expert Panel on Air Pollution Modeling of the Committee on the Challenges of Modern Society in Paris, France (Snyder, 1971), and a somewhat revised version has been accepted for publication in Boundary Layer Meteorology (Snyder, 1972).

Based on recommendations of this study, the EPA plans to construct physical modeling facilities at its National Environmental Research Center (NERC) in North Carolina. The first phase will be the construction of an open-return, nonstratified wind tunnel, which will be used primarily to study problems such as flow and diffusion near structures and local terrain features. The second phase will be the construction of a water channel, which will principally model flows over complex topography and over urban areas. In the future, plans are to close the return of the wind tunnel and to add heating and cooling capabilities so as to simulate stratified atmospheric flows.

The design of the initial wind tunnel will be similar to the Environmental Wind Tunnel of the Colorado State University in Ft. Collins. The test section will be 12 ft wide, 7 ft high, and 60 ft long. The speed will range from 3 to 25 ft sec^{-1}.

Construction of the wind tunnel is to begin in FY 1973. The construction of the water channel and additions to the wind tunnel are to proceed at about 1 year intervals. The selection of a location to house these facilities is in progress.

2.14 U.S. - French Cooperative Study

Mr. L. Facy, Director of the French Meteorological Research Laboratories at Magny les Hameaus, has modeled the dispersion of plumes from the Western Pennsylvania Conemaugh and Seward Power Plants with his water channel. The model study shows that the complex topography surrounding the plant has very prominent effects on plume, which is commonly diverted around hills and channeled through valleys. Colored maps depicting relative ground-level concentrations of the aerosols were received for comparison with field measurements. Unfortunately, in only one case was the wind direction the same in the model and field tests. Generally, the model results agreed in order-of-magnitude with field measurements; however, with such limited comparisons it was difficult to draw conclusions.

2.15 Grant Programs in Air Quality Modeling

Four ML research studies involving air quality-urban diffusion modeling were carried out by the following universities: The

University of California at Los Angeles; the University of Chicago; Harvard School of Public Health; and the Pennsylvania State University. These grantees were developing, improving, and evaluating computer models for predicting pollutant concentrations over an urban area.

Atmospheric transport and diffusion processes in valleys, canyons, and streets is the subject of a study by the University of Utah. This study includes numerical modeling, wind tunnel studies, and field observations.

Colorado State University is conducting a wind tunnel analysis of negatively buoyant gas plumes. Some pollution abatement equipment causes air saturated with water vapor to be emitted from fossil-fuel power plants. Evaporative cooling of the entrained water vapor causes the plume to descend. The effect of the plume on ground level concentrations is to be measured in the Colorado State University Micro-Meteorological Wind Tunnel.

A combined analytical and experimental investigation of the turbulent diffusion of pollutants in a surface layer is in progress at the University of Notre Dame.

3. ATMOSPHERIC STRUCTURE STUDIES

3.1 Large Power Plant Effluent Study (LAPPES)

Comprehensive field studies of the dispersion of effluent from tall stacks began in the fall of 1967 and concluded in the fall of 1971. These studies were conducted near three coal-burning, mine-mouth, generating stations in western Pennsylvania. Collectively, the three stations are designed to generate 4960 MW 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 ENE of Pittsburgh. Each facility consists of two independent generating units emitting effluent from stacks.

The 1880 MW Keystone Station achieved full operation in July 1968, the Homer City Station (1280 MW), in December 1969, and the last to be completed, the 1800 MW Conemaugh Station, was in full operation in 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 pattern of ground-level concentrations of pollutants released to the atmosphere from these large power plants. From these investigations, improved dispersion models will be developed.

Eleven series of field experiments, each lasting 1 month, 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 three series were conducted at the Conemaugh Plant.

During these field experiments, observations were made daily, unless prevented by adverse weather, power plant-outage, or equipment malfunction. Extensive SO_2 measurements were taken from an instrumented helicopter at several distances downwind. Helicopter flights at tree-top level also provided SO_2 concentrations near ground level; these measurements were supplemented by placing as many as 10 sequential bubblers in areas where the effluent was expected to reach ground level. These portable samplers, constructed by ML personnel, measured ground-level SO_2 concentrations under the plume. Ambient air was bubbled through a chemical solution to obtain six consecutive 30-min. samples of the plume at 15 cm above the ground.

Supporting meteorological data were provided by pilot balloon releases at half-hour intervals to obtain wind profiles. Helicopter ascents measured temperature profiles. These soundings were 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 has been or is being prepared for publication. The first document (Schiermeier and Niemeyer, 1970) contains data from the 1968 field experiments; the second (Schiermeier, 1970) contains data from the 1967 and 1969 field experiments; the third (Schiermeier, 1972) contains data from the 1970 field experiments. The final document, now being prepared, will contain data from the 1971 field experiments.

Time-height charts of winds and potential temperature for each sampling day have been drawn. These aid in selecting sampling days to be included in analyses of various categories of plume behavior. For the stable plume cases, when elevated plume cross sections were obtained at several distances, horizontal plume spread coefficients have been calculated for comparison with the shear, in the vertical, or the horizontal wind. Also, normalized vertical distributions of the crosswind integrated concentrations were calculated. For both of these analyses, the additional data (from 1967, 1969, and 1970) confirm the results previously reported, based only on 1968 data (Pooler and Niemeyer, 1970). That is, the rate of horizontal spreading of the plume is poorly correlated with wind shear. The horizontal spreading on the average is only about two-thirds that to be expected if the plume were passively fanned by the shear. The vertical distributions, while highly variable, show a skewed median distribution, with the greatest crosswind integrated concentrations in the upper portions of the stabilized plumes.

Horizontal wind data are available for most of the above plume cross sections, permitting calculation of the flux of SO_2 for each section. These flux values were normalized by the SO_2 emission rates calculated from power plant data. The plume fluxes average only a little more than half the emission rates, with a very slight decrease of flux with distance.

On the basis of previous studies, it was thought that relative humidity should be positively correlated with the "loss" of SO_2, since the sampler used does not measure sulfate (the SO_2 is thought to be converted to sulfate at higher humidities). To study the relative humidity influence, we plotted normalized flux values against relative humidity for three distances (4, 10, 16 km) at which cross sections were usually obtained. Very little influence is indicated, as shown by the 10 km data in figure 2.

Several small computer programs were written to aid in analyzing SO_2 concentrations measured by the sequential bubblers; these have been used with data from the Keystone plant. The highest half-hour SO_2 concentrations were generally found 8 to 10 km from the plant. Elevation and exposure of the sampling site, in terms of local topography and orientation of the topography relative to the plant, appeared to have no consistent influence on SO_2 concentration patterns. These results indicate that the small-scale, irregular topographic relief near the Keystone plant has no consistent effect on the mean air motion. The computer programs are being adapted to perform similar analyses of data from the Homer City and Conemaugh sampling operations. From preliminary examination of these data we anticipate that more definite topographic influences will be found.

3.2 Cooling Pond Study

A study of the heat and moisture emissions from a power plant cooling pond are being considered. The primary purpose of the study would be to obtain better heat and moisture emission data than have hitherto been available. Previous studies have primarily determined the overall heat rejection rate of such cooling facilities. Availability of resources permitting, this research will be initiated in 1973.

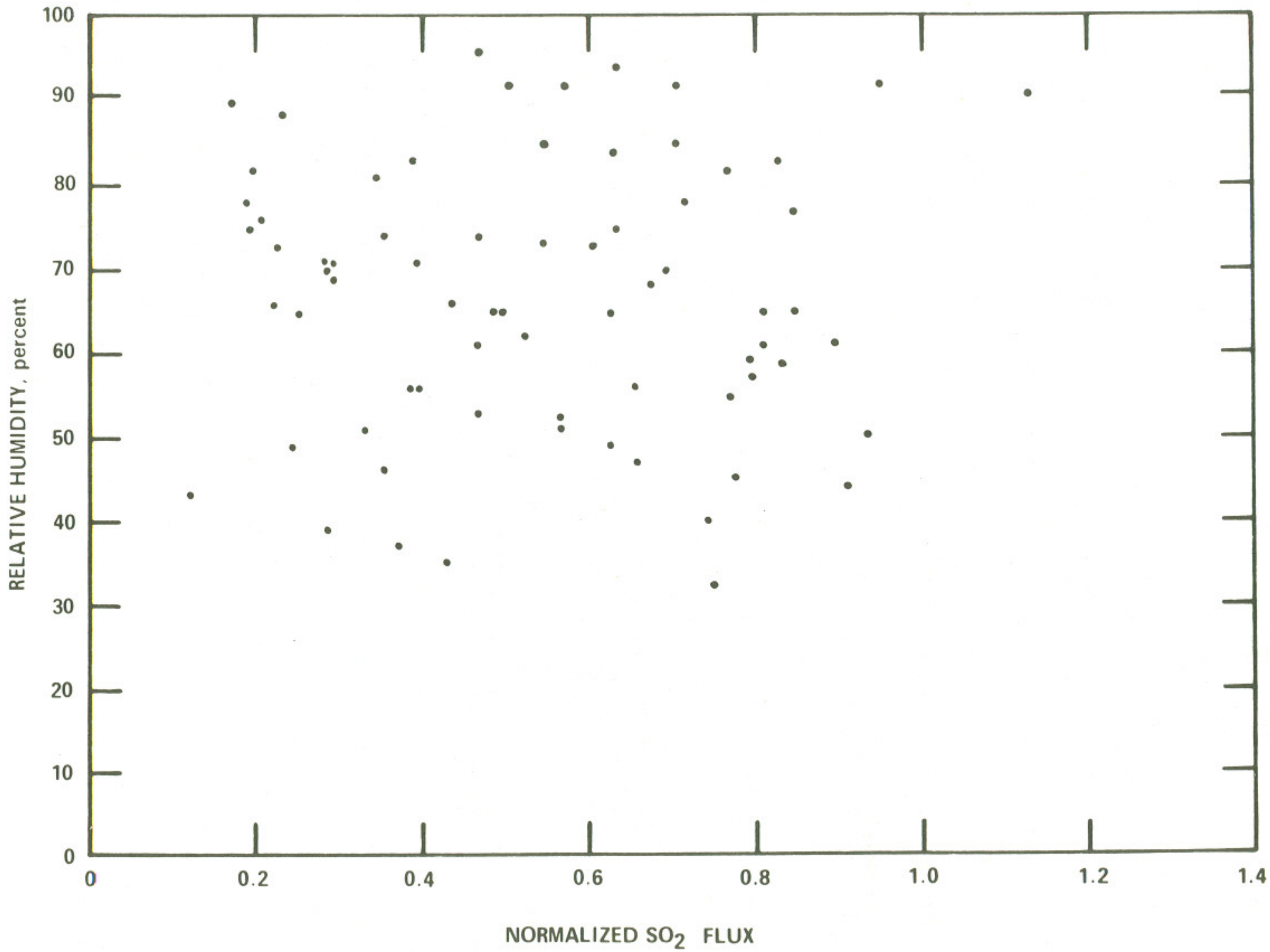

Figure 2. Normalized SO_2 flux versus mean relative humidity through the depth of a power plant plume.

3.3 Natural Precipitation Washout of Sulfur Dioxide (SO_2)

For the past 3 years, Battelle-Pacific Northwest Laboratories, Hanford, Washington, has been studying the natural precipitation washout of SO_2 from plumes. During the first year, sampling was conducted near the Keystone plant in conjunction with the LAPPES effort. Inconclusive results were obtained from that study, and subsequent theoretical analyses indicated that the relatively high elevation of the plume, together with high and varying background levels of assorted pollutants in the plant area, would make it extremely difficult to interpret any sampling results from that region.

To increase knowledge of the washout processes, Battelle then designed and studied washout from a controlled source of SO_2. This study was conducted at an airport test site at Quillayute, Washington, where background levels of SO_2 are negligible. Results of that field study, together with the development of models of the washout process, are contained in a report by Dana et al. (1972). These studies indicate that washout rates can be determined only if we consider the reversible desorption-absorption of SO_2 by precipitation. The determination of natural precipitation washout may be further improved by accounting for the equilibrium concentration of SO_2 dissolved in the drop as a function of SO_2 concentration in the air; this requires estimates of the temporal variability of the airborne SO_2 concentration.

In December 1971, a second series of field experiments was conducted at the Quillayute, Washington, site to obtain additional results under controlled conditions. Samples were obtained at greater distances (out to

300 meters, instead of 122 meters). Samples of SO_2 deposition directly onto wetted funnel surfaces were also obtained. These results are currently being analyzed. Preliminary results indicate direct deposition from the air corresponds to a deposition velocity of about 0.1 cm sec^{-1}. Such a rate could cause a significant portion of the SO_2 to be collected in rain if the SO_2 plume were confined to a shallow ground-based layer; however, for plumes from tall (>150 meters) stacks it would be only a small contribution.

In March 1972, another series of field experiments was conducted near a new power plant at Centralia, Washington. Precipitation was sampled along four arcs ranging from about 350 meters to 13 km from the plant. Samples were analyzed for SO_2, sulfate, and pH. Frozen samples were returned to the main Battelle facilities at Richland, Washington, for trace-metal analyses by atomic absorption spectrophotometry.

3.4 Urban Boundary Layer Study

An experimental and theoretical program is in progress on the structure and related dynamics of the urban planetary boundary layer. The basic premise underlying the program is that the structure of the atmosphere over a city is determined by the structure existing over the upwind area and the modifications induced primarily by the varying fluxes of heat and momentum at the earth-air interface over the urban area. An improved knowledge of this structure should allow development of improved mathematical dispersion models, since such models are inherently limited in accuracy by the validity of the boundary layer structure implicitly assumed in diffusion calculations.

Initially, the program concentrated on the nocturnal period where the heat-island phenomenon usually is developed to its maximum extent. The first experiments were conducted over metropolitan Cincinnati, Ohio. Detailed accounts of the program and its principal results were published by Clarke (1969) and Clarke and McElroy (1970).

The experimental program was then shifted to metropolitan Columbus, Ohio, a medium-sized city situated on relatively flat terrain. The Columbus studies permitted verifying, quantifying, and generalizing the Cincinnati findings so that they could be applied to other locales. A total of 12 comprehensive field investigations were spaced over three series (June 1968, September 1968, and March 1969). On each occasion, measurements normally commenced just before sunset and continued until sunrise, except for a 3-hour break beginning around midnight. The primary data obtained from the Columbus studies consist of vertical profiles of dry- and wet-bulb temperature via helicopter ascents, winds aloft by theodolite observations of slowly rising balloons, air temperature near the surface during automobile traverses, surface (skin) temperature with an infrared thermometer in a fixed-wing aircraft, and an emission inventory of artificial heat production from man's activities.

On three occasions, grab samples of air were collected at several elevations and locations during helicopter ascents and later analyzed for CO content. On one occasion, a meteorological tracer, sulfur hexa-flouride (SF_b), was disseminated and air sampled at several locations near the surface and in the vertical (via helicopter ascents) with plastic bag collectors. Also, turbulent wind fluctuations were measured with bi-directional vanes or anemometer bi-vanes at two elevations in the downtown area on building platforms, and, during the last series, "constant-level" balloons (tetroons) were flown across the metropolitan area.

Basic data reduction and processing are complete. A detailed account of the experimental program and some principal results were presented by McElroy (1971). A comprehensive summary of the results of the tetroon flights was reported by Angell et al. (1971). Additional processing and analyses of some of the data is underway to delineate more clearly the effects of the urban area. Basically, this involves grouping and averaging the individual data samples. At the conclusion of these analyses, a paper will be prepared describing the experimental program and its results.

A numerical model of the nocturnal urban boundary layer was developed from the one-dimensional, time dependent boundary layer model of Estoque (1963). The model is cross sectional and steady state and contains as dependent variables the horizontal Cartesian wind components, air temperature, and specific humidity. The model equations are closed through the use of eddy exchange coefficients that are assumed equal for heat, moisture, and momentum; the coefficient in the constant flux layer is based on the local stability and aerodynamic surface roughness while that in the transition layer is specified. The model is applied to a traverse across a city in the direction of the mean flow. The initial input data are those appropriate for the upwind rural environs.

The model simulated the thermal structure of the nocturnal boundary layer across Columbus, Ohio. Data were used for the nearly steady-state period around sunrise on two of the September dates and three March dates. In each instance, the simulations agreed well with the observed data regarding the spatial form of the surface-based thermal boundary layer across the metropolitan area. A detailed presentation of the model and its application to the Columbus experimental program is documented by McElroy (1971).

This model has demonstrated the utility of incorporating meteorological information in the deciding of urban land-use zoning and planning. Specifically, a hypothetical symmetrical city was simulated with land-use similar to that of Columbus and with initial data for Columbus under strong heat-island conditions. These "base" simulations were compared with those having alternate land-use strategies. The strategies considered include green belts between major land-use areas, major shopping centers or highrise apartment complexes within principal residential areas, and one-sided cities (e.g., lake or ocean ports). In addition, simulations were made for megalopolises each formed by linking several of the base cities.

3.5 Radiometric Thermasonde*

The ML continued to support the Sperry Rand Corporation in the development of the millimeter-wave radiometric technique for remotely measuring vertical air temperature profiles in the lowest 2.0 km of the

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*Thermasonde is a trademark of the Sperry Rand Corporation.

atmosphere. During the past year, efforts were directed to improving data processing techniques for the Thermasonde (Hosler and Lemmons, 1972). Both the Sperry Rand Research Center, Sudbury, Massachusetts, and the NOAA Wave Propagation Laboratory, Boulder, Colorado, received EPA support for investigating Thermasonde data analysis techniques; the Sperry Rand Microwave Electronics Division, Clearwater, Florida, received support for continuing the development of the Mark II Radiometric Thermasonde. The operational development of the Mark II system will culminate several years of research to provide an instrument capable of giving useful temperature profile data for assessing air pollution potential. The Mark II system prototype is expected to be completed in 1973.

During FY 1972, ML personnel participated in a 1-week experiment at Boulder, Colorado, in cooperation with NOAA and several other agencies. The Mark I Thermasonde and several other types of remote sensing systems were operated simultaneously. Later the Mark I was operated in St. Louis in support of a study by the Argonne National Laboratory. During the spring of 1972, the contractor recalibrated and modified the Mark I Thermasonde to improve its sensitivity.

4. GEOPHYSICS RESEARCH

4.1 Climatology

The ML and the National Climatic Center (NCC) have started a 5-year joint effort to compile climatological information on dispersion parameters based on analyses of routine 0000 GMT and 1200 GMT rawinsonde observations.

The NCC has written a computer program to tabulate by class intervals:

1. Frequency of inversion lapse rate by inversion thickness and base height. If there is no inversion below 3000 meters, temperature lapse rates in specified layers are used.
2. Frequency of relative humidity in specified layers by inversion thickness and base height. If there is no inversion below 3000 meters, other specified layers are used.
3. Frequency of wind speed by direction at the surface, 150, 300, 600, 900, and 1200 meters above the surface according to inversion base height and thickness, and with no inversion below 3000 meters.

The same 5-year period will be evaluated by mixing height and wind speed tabulations, so that the two sets of data will complement one another. Some data have been received from the NCC; however, these are still in the early stages of evaluation. A further application of this study will be to compare dispersion parameters derived from rawinsonde observations with Pasquill stability classes derived from simultaneous "airways" weather observations. The study "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States" has been distributed as EPA Publication No. AP-101.

4.2 Maritime Aerosols

A survey of maritime aerosols that began in late FY 1970 by the State University of New York continued during FY 1972. Although additional data are being collected in the North Atlantic, the present emphasis is on obtaining aerosol measurements from the Pacific and Indian Ocean areas.

A station was established on Pitcairn Island; initial data from this site indicate maritime aerosol concentration of 200 to 450 nuclei cm^{-3}.

The new data will permit revising and updating the preliminary North Atlantic aerosol concentration distribution chart (Hogan and Degani, 1971). Similar charts will be prepared for the Pacific and Indian Oceans.

Observations made in the North Atlantic, during the June to August 1971 cruise of the Maritime College Training Ship Empire State, indicate much higher aerosol concentrations along 40°N than measured previously. Concentration variations showed smooth diurnal trends with higher values during the day than at night; concentrations eastward from the North American continent gradually decreased.

4.3 Acoustic Radar

The NOAA Wave Propagation Laboratory (WPL) has developed a monostatic acoustic echo-sounding technique to obtain temperature and wind profile information within the planetary boundary layer. Previous work on this project has been reported by Simmons et al. (1971) and Beran et al. (1971).

During the year, WPL scientists developed a small portable sounding system and conducted field tests of the large searchlight sounder system in the Denver area. The acoustic sounder was installed near the Denver power plant and colisseum, near NOAA's Environmental Meteorological Service Unit (EMSU) site, for a comparison of acoustic data with observed verticals profiles, temperature and winds. The comparative data are being analyzed to assess the feasibility of estimating lapse rates and inversion strength.

The site was also selected for evaluating the effect of urban noises on the sounder system.

Both monostatic and bistatic acoustic echo sounding systems have been used by WPL in experiments to obtain the total wind profile within the planetary boundary layer. Preliminary results are reported by Beran and Willmarth (1971) and Beran and Clifford (1972).

A prototype acoustic sounder, termed the "Sounder-in-a-Suitcase," has been developed by WPL. This system, which is simple and lightweight, will be tested in 1972; it has the potential to enable field soundings with a minimum of equipment and transportation.

4.4 Satellite Surveillance

During the past year, the University of Wisconsin conducted several feasibility studies on the use of satellites for estimating the aerosol content and turbidity of the atmosphere. After an investigation of sunlight observations we concluded that they would be used, without absolute calibration, to determine changes in aerosol optical thickness in the visible to near 2.5 microns (μ) range to an extimated accuracy of 0.02 to 0.03 μ wherever atmospheric windows permit (McClintock et al., 1971).

On examination of the ATS-III (stationary satellite) radiance data for possible use in detecting particulate pollution started in FY 1971, and is being continued (McClintock et al., 1970; 1971). Figure 3 compares the ATS-II radiance values and surface parameters for Los Angeles, California, on April 23, 1968 (McClintock et al., 1971). As radiance values and the visibility increased from 0900 to 1400 PST, the measure of particulate

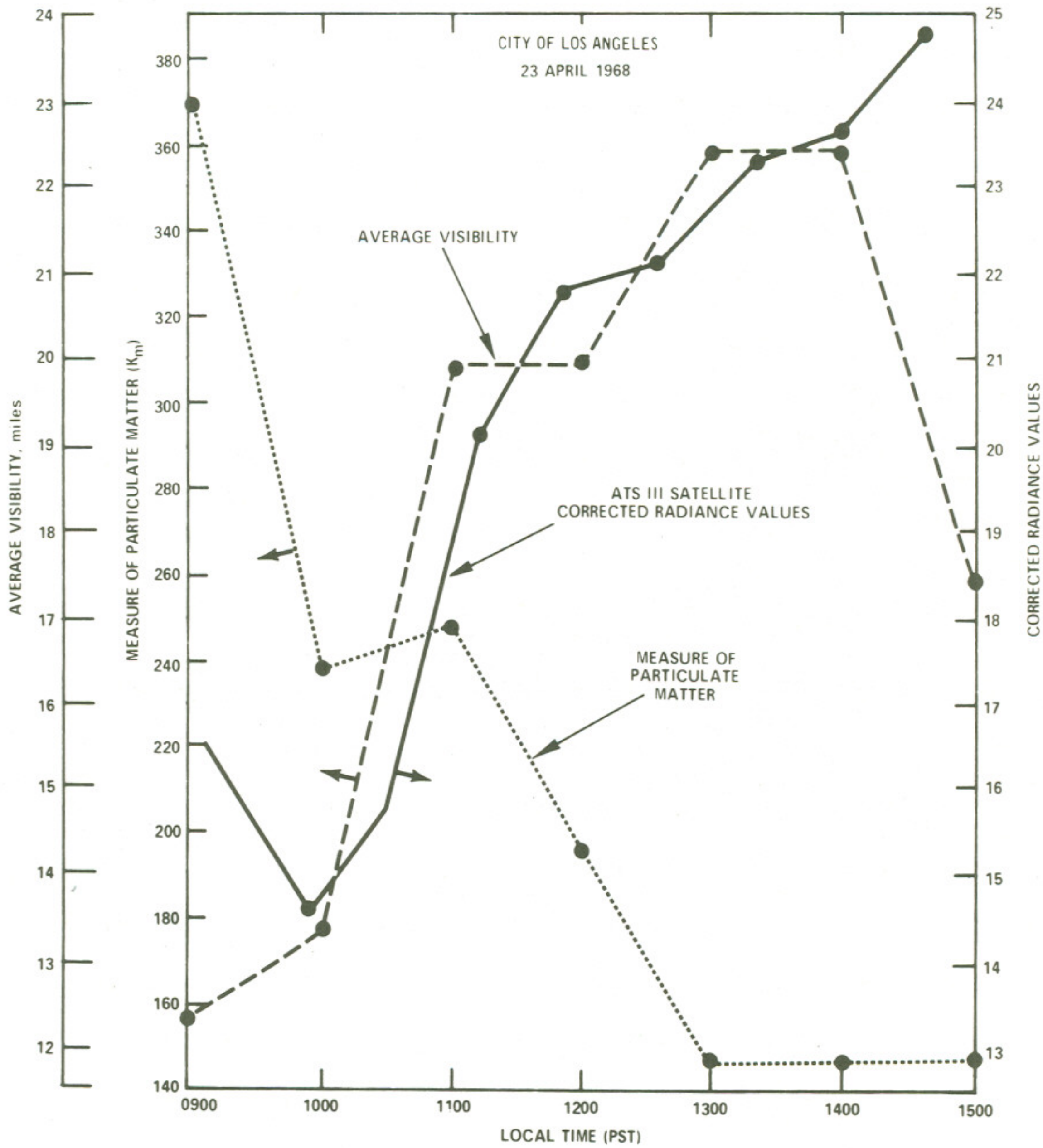

Figure 3. Ground-based data on visibility and measurements of particulate matter.

matter in the air decreased. This suggests that the technique should be examined further.

A feasibility study of the use of scattering in the near IR indicates that this approach furnishes a possibility for quantitatively measuring aerosols (McClintock et al., 1971). Satellite atmospheric polarization measurements to determine the turbidity and particle content of the atmosphere are being explored both in the field and the laboratory. A city surface of 18 blocks has been modeled to study the reflectivity of a typical area. This will provide background information for polarization studies.

4.5 Urban Radiation

Measurements of downward directed broadband solar and terrestrial long-wave (3 to 50 μ) radiation were obtained at a downtown Durham, N.C., site and at the ML facility in the Research Triangle Park (RTP), North Carolina. These two sites are approximately 4 km apart. This study will compare the incoming energy at these sites (Durham, urban - RTP, rural) and investigate the effects of atmospheric pollution on radiative energy transfer and the climate of the urban boundary layer. Radiation measurements will continue, and data analysis will begin during the coming year. In addition, upward- and downward-facing solar and long-wave sensors will be mounted on an aircraft to study the vertical variation of radiative energy over urban areas.

4.6 Aerosol Long-Wave Radiation

ML is investigating the effect of atmospheric aerosols on long-wave (3 to 5 μ) energy received at the earth's surface. The basic experiment consists of three parts:

1. Measurement of incoming long-wave radiation
2. Calculation of expected incoming long-wave radiation for a dust-free atmosphere
3. Measurement of atmospheric turbidity with a sunphotometer.

The premise of this study is that the observed energy minus the calculated long-wave energy is dependent on the atmospheric aerosol content (as indicated by turbidity). Radiation data will be analyzed to determine the validity of this premise. When the sky is cloud free, which eliminates cloud influence, radiation and atmospheric turbidity will be measured independently at the ML facility in RTP.

4.7 Atmospheric Turbidity

The network of stations, where turbidity is measured with the Volz sunphotometer at 0.5 μ wavelength, continued in operation in 1971-1972. In addition, the new dual-wavelength sunphotometers (0.5 μ and 0.38 μ) have been placed at 44 stations around the world (fig. 4). The new instruments will provide turbidity coefficients and Angstrom's wavelength exponent, α, at these two wavelengths. The main objectives of the expanded network are to provide a turbidity climatology over the world and to provide data for determining long-term trends of turbidity.

The responsibility for collecting, processing, and publishing the network turbidity data was turned over to the National Climatic Center (NCC) of NOAA in March 1972.

5. OPERATIONAL SUPPORT

5.1 Routine Meteorological Support of the Emergency Operations Control Center (EOCC)

The EOCC was established to meet EPA's responsibilities under Section 108 k of the Air Quality Act of 1967 (the EOCC is now operating under Section 303 of the Clean Air Act of 1970) to help prevent imminent and substantial air pollution. The ML provides a meteorologist and a meteorological technician to the EOCC for daily operations.

Routine support includes surveillance of the entire U.S. for general conditions of high air pollution potential, and the preparation of summaries of current and forecast conditions. The meteorological potential for air pollution was evaluated quantitatively for areas where air quality data indicate increased concentrations and also where local atmospheric stagnation advisories had been issued by the National Weather Service (NWS). To do this a very simple dispersion model calculated theoretical city-wide average concentrations as a function of mixing height and wind speed and compared the results with available climatological values.

A technique using conventional diffusion formulations is being developed to estimate real-time pollutant concentrations during air pollution episodes. Such estimates will aid in the deciding on control tactics. In this system, the concentrations will be estimated for a limited number of receptor locations near the anticipated maximum concentration and at air quality sampling locations. The system will also identify how much each source contributes to the calculated concentrations. Averaging times will

Figure 4. Dual-wavelength sunphotometers around the world.

vary between 3 and 24 hours. Forecast meteorological input information for this system may be forthcoming from the Air Force boundary layer model, which is being evaluated by the National Meteorological Center.

As necessary during air pollution incidents, ML meteorologists serve as members of EOCC field teams (see sec. 5.5, EOCC Field Support).

The national High Air Pollution Potential Forecast (HAPPF) program, initiated by ML in 1960 and transferred to ESSA in 1967 as an operational forecast program, was replaced in September 1971 by the NWS's local Air Stagnation Advisory (ASA) program. In this program, ASA responsibility for the entire U.S. is delegated to 46 NWS Forecast Offices, 18 of them with Environmental Meteorological Service Units (EMSU). The ML is preparing a report on the HAPPF program, including a brief history of its development and a summary of advisories issued.

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

Special field support is given to the EOCC as required during actual air pollution emergencies.

5.2.1 Quitman, Mississippi

On October 21-23, 1971, a meteorologist visited oil fields near Quitman, Mississippi, as part of an EOCC team responding to complaints about gaseous emissions. The team concluded that an air pollution emergency did not exist, although an odor problem and low-level SO_2 were present. The strongest concentrations of odors seemed to be associated with cold air drainage. As a result of the team's recommendations, an EPA petroleum engineer visited the area to advise the state of Mississippi about control devices and operating procedures in the oil fields. Some technical support was also given to state officials for upgrading their air monitoring program in and around the oil fields.

5.2.2 Birmingham, Alabama

Air quality conditions in Birmingham began to deteriorate on November 1, 1971, when a 24-hour sampling period indicated particulate concentrations of 500 $\mu g\ m^{-3}$. Measurements of particulate concentrations in North Birmingham were 771 $\mu g\ m^{-3}$ on November 16 and 758 $\mu g\ m^{-3}$ on November 17th.

A temporary Restraining Order was issued for specific operations of 27 corporations by a U.S. District Judge at 1:45 a.m., November 18. The ML meteorologist helped prepare the affidavit that resulted in the shutdown. He provided advice on the duration of the stagnation conditions and on the probable concentrations to be expected when industrial operations were resumed. The NWS Forecast Office in Birmingham also provided meteorological support during the episode. The ASA was canceled at 8:00 a.m., November 18, and the Restraining Order was requested to be lifted at 9:00 a.m., November 19.

5.2.3 Clairton, Pennsylvania

The Clairton, Pennsylvania, Coke Works were suspected as causing ambient air concentrations of SO_2 and/or particulate matter exceeding Federal Standards. Consequently, a meteorologist visited the Clairton area on February 6, 1972, to assist the EOCC position five sampling stations and a wind recording station. Although two of these stations were placed where maximum pollutant concentrations were expected, about 1 month of measurements failed to show that emergency levels of SO_2 or particulate matter were being approached. Therefore, the monitoring effort was discontinued in view of expected favorable dispersion conditions in the spring. The local agency is continuing surveillance of pollution levels and wind conditions in the area.

5.2.4 Louisville, Kentucky

A towing accident on the Ohio River, March 19, 1972, left a barge containing four 165-ton tanks of liquid chlorine lodged in a precarious position near a floodgate entrance to the lower McAlphine Dam. Since this dam is located in the heart of metropolitan Louisville, a massive release of chlorine gas would have created a major emergency.

The Office of Emergency Planning (OEP) declared an emergency on March 23 at a meeting in Washington, D. C.; a ML meteorologist participated in the meeting. A ML meteorologist arrived in Louisville later the same day and met with the Meteorologist-in-Charge of the NWS Forecast Office to implement emergency meteorological support efforts. Air monitoring equipment and technicians arrived by Coast Guard aircraft, and the ML meteorologist assisted in the placement of four chlorine continuous monitoring stations. One of these was on the dam with an intake hose above the barge. The recorder was read remotely through a telescope placed at another station on the river bank. During critical phases of the operation, samplers in automobiles were used; these were positioned according to expected wind conditions.

The following meteorological services were provided by the NWS during this incident:

1. Hourly wind forecasts for the coming 2-hour period. (These wind forecasts and other special forecasts as required were furnished by a local teletype network connected to Coast Guard Emergency Operations Center and Kentucky and Indiana Civil Defense Headquarters.)

2. Special surface wind observations from the barge site.

3. Daily weather briefings at OEP operations office.

4. Environmental Meteorological Support Unit (EMSU) services. (This included twice daily rawinsonde observations made at the University of Louisville.)

5. Pilot balloon observations four times daily at the barge site.

During the operation, the ML provided two meteorologists and two technicians. The two technicians assisted with the upper wind soundings and the weather watch that was maintained in the Coast Guard Emergency Operations Center. The two meteorologists provided services to the Louisville Civil Defense Headquarters, which served the Mayor of Louisville and the County Judge, Jefferson County. Wind direction and speed and estimates of the radial distances of possible effects of chlorine concentrations were continuously updated. The Chemical Corps U.S. Army provided two monitoring instruments in helicopters strategically stationed and on call, as needed. The Civil Air Patrol (CAP) provided two airplanes for observations. A Chemical Corps officer and crew of enlisted men were available in the Civil Defense Headquarters to plot information concerning any actual chlorine cloud. About 60 fire stations were alerted to report on chlorine; actual observations were expected from police and other sources.

On April 2, the barge secured, chlorine transfer operations began; this permitted the meteorologists to end direct support to the Civil Defense Headquarters on April 4. However, before leaving, they provided the Civil Defense Office with simple tables for determining distances at which various effects might occur, assuming different possible accidents and meteorological conditions. The NWS continued to provide hourly forecasts and other weather services until the chlorine either was safely transferred or was disposed of by reacting it with sodium hydroxide and flushing it into the river.

5.2.5 Southeast Chicago - Northwest Indiana

On complaints of a local citizens group, the EOCC sought to determine whether pollutant concentrations in the southeast Chicago - northwest Indiana area were exceeding levels constituting an imminent and substantial danger to health. Special meteorological and air quality was sampled from July to November 1971. Although data have not been completely evaluated, preliminary results indicate that SO_2 and particulate concentrations are below the level that endangers health.

5.3 EPA Regional Offices

Meteorologists have been selected, trained, and been assigned by NOAA to the following seven EPA Regional Offices:

Region I - Boston, Massachusetts

Region III - Philadelphia, Pennsylvania

Region IV - Atlanta, Georgia

Region V - Chicago, Illinois

Region VIII - Denver, Colorado

Region IX - San Francisco, California

Region X - Seattle, Washington

The NOAA meteorologist provides technical support and consultation to the Regional Office and meteorological assistance to state and local air pollution control agencies. Specifically, the meteorologist will:

1. Advise on the adequacies of air pollution control plans and programs
2. Provide information for EPA grant programs
3. Serve as a focal point in the Regional Office during air pollution episodes or emergencies
4. Provide advice with respect to meteorological field observations as necessary
5. Perform air pollution studies and prepare reports from estimates of plume rise, atmospheric dispersion, and climatological data.

Regional meteorologists have visited control agencies within their Region to become familiar with local control programs. Their work has consisted of reviewing state implementation plans, impact statements, research proposals, and standards of performance for new, stationary, air pollution sources. They have calculated plume rise and dispersion for selecting sites of power plants, participated in public hearings, and given meteorological support to various special studies. For example, it was necessary to calculate particulate concentrations that might result from controlled burning of 4000 acres of scrub oak before the construction of a waste water management project.

Regional meteorologists provide advice on air stagnation situations and emergencies; this requires a daily awareness of meteorological conditions and a close liaison with the NWS's EMSU's and the EPA's EOCC. It is anticipated that EOCC responsibilities will be decentralized and shifted to the Regional Offices.

5.4 Applied Technology Division (ATD)

5.4.1 Control Agency Procedures Branch (CAPB)

In the summer of 1971, results of a telephone survey by the meteorologist assigned to the Control Agency Procedures Branch (CAPB) were used to compile a Directory of Meteorologists Employed at State and Local Air Pollution Control Agencies. This directory was issued in September 1971. A new and expanded directory was issued in May 1972. The new listing includes air pollution meteorologists at federal agencies.

The meteorologist visited the Department of Ecology of the State of Washington and the Puget Sound Control Agency as a part of a CAPB team evaluating the effectiveness of the state and local air pollution control agencies. They suggested how the meteorological programs throughout the state could be improved.

5.4.2 Air Quality Management Branch (AQMB)

The Air Quality Management Branch (AQMB) focuses on the daily operational needs of the Applied Technology Division of Air Programs, EPA. Four meteorologists are assigned to the AQMB to test mathematical diffusion models used in plans and control strategies for specific cities, such as New York or Philadelphia. A major task in FY 1972 was estimating average concentrations for various periods near 12 major smelters in the western United States. These meteorologists have also evaluated environmental impact statements, studied the effectiveness of meteorological control procedures, estimated pollutant concentrations from assorted single air pollution sources.

A final report to be used in Section III of the Glacier National Park Study was submitted to the Division of Stationary Source Enforcement in September 1971. The report, which describes the geography and climatology of the Flathead River drainage area, analyzed the region's air pollution meteorology. The meteorological analysis helped explain the distribution of contaminants from the Columbia Falls Aluminum Plant, which showed that the highest fluoride concentration of the day is usually carried into the National Park between 9:00 a.m. and noon on a typical summer morning. The report contains an analysis of wind data from three stations operated in the Glacier National Park from June through December of 1970.

As a followup on the Grant County, West Virginia - Garrett County, Maryland, Air Pollution Abatement Activity - called the Mt. Storm Action - several members of the EPA staff, including an ML meteorologist, were subpoenaed by the litigants in a suit against the Virginia Electric Power Company. The meteorologist's deposition presented the meteorological aspects of the problem and information on the distribution and likely concentrations of pollutants emanating from the power plant (APTD 0656).

At the request of EPA Region II, the New York - New Jersey - Connecticut Air Quality Control Region (AQCR) was modeled using the Air Quality Implementation Planning Program. A summary of the anticipated reductions in surface concentrations of SO_2 and of particulate matter that will result from emission standards being implemented was supplied to EPA Region II headquarters and internally to the Plans Management Branch, Standards Development and Implementation Division (PMB/SDID). Several emission configurations were used to test a variety of strategies for achieving air quality standards. The study is continuing with updated emission inventories and new control strategies. Similar studies of Washington, D. C., Philadelphia, Chicago, Buffalo, Boston, and Louisville are being carried out.

A staff paper "Criteria for Evaluating an Intermittent Control System" was prepared and is being reviewed. The paper was based on the experience of TVA and several nonferrous smelters in maintaining ground-level concentrations of SO_2 at acceptable levels by reducing emissions during adverse meteorological conditions. This paper was used to develop the EPA policy on implementation of control procedures for large, cost-to-control sources of SO_2.

Approximately 100 Environmental Impact Statements concerning various governmental and industrial projects have been reviewed to ensure that meteorological factors are properly considered. An analysis of the imposition of emission standards for beryllium and mercury on ambient air quality was provided to the Hazardous Pollutant Standards Branch. An anlysis of the adequacy of 400-foot stacks at the San Juan Power Plant was prepared for the Bureau of Reclamation.

The impact of SO_2 emissions from 15 of the largest nonferrous smelters was analyzed. The results were used to determine the degree of control needed to achieve daily and annual air quality standards. A modified version of the Air Quality Display Model was used for all calculations. The primary modification causes the plume centerline to remain horizontal, relative to mean sea level, in the stable atmosphere regardless of terrain. An assumed limited mixing height was used to calculate the maximum 24-hour contamination levels.

5.5 Division of Health Effects Research (DHER)

Community Health and Environment Surveillance Study (CHESS) programs, now operating in New York City and in the southeastern United States (Birmingham-Charlotte-Greensboro), require continuous monitoring of atmospheric conditions. When an ASA for an area including a CHESS city is forecast to persist 48 hours or longer, a procedure is initiated by the DHER to survey the affected population by telephone and marked sensing questionnaires.

Experience from previous studies prompted the design of a basic all-purpose questionnaire that was both medically complete and adaptable to data processing. A computer program is available which analyzes all medical aerometric and temperature data and presents results as statistical summaries capable of revealing occurrences of significant respiratory symptoms with the population. Sampling was performed in November 1971 for stagnation episodes in New York City and Birmingham, Alabama. During a particularly clean period of low air pollution, sampling was conducted again in January 1972 in New York City to serve as a control study.

A new CHESS program was begun in the Los Angeles area to study health effects of ambient oxidant concentrations on school children. Occurrences of lower respiratory infection will be compared among three communities representing high-middle-low oxidant environments. An important factor in the selection of the three communities was a climatological survey to ensure similarity of temperature regimes, since previous investigations by DHER have established the significance temperature has on respiratory diseases such as bronchial asthma. The Los Angeles area presented a special problem due to maritime influence along the coast and higher temperatures inland. Combined climatological and aerometric surveys led to the selection of the communities of Glendora-Anaheim-Vista as the high-middle-low comparison oxidant environments.

Another CHESS program was begun in St. Louis, Missouri, during the spring of 1972. A climatological survey is now in progress to aid in selecting high-middle-low pollution environments.

A prototype continuous aerometric recording station for the forthcoming 16-site Community Health Ambient Monitoring Program (CHAMP) was installed at Chapel Hill, North Carolina. As part of the program, hourly values of temperature, dew point, and wind speed and directions are recorded and transmitted to a central location for processing. The services of a meteorological technician were given to the Bio-Environmental Measurements Branch of DHER to assist in the selection of meteorological instruments considered to be the most reliable.

The Epidemiology Branch of DHER is continuing a study of nationwide mortality statistics as influenced by maximum and minimum temperatures. As expected,daily mortality is computed for each of 422 regions over the United States, and the observed mortality is compared as a ratio. In a preliminary study, regions having observed mortality ratios of 1.50 or more were listed for June and July 1966, which included periods of severe heat waves in the eastern United States. On July 13, 1966, a mortality ratio of 5.24 was found for St. Louis coincident with a maximum temperature of 105°F and a minimum of 85°F; this increase of five times the expected mortality for a July day in St. Louis had been the subject of several medical papers. The present study will investigate trends on mortality ratios in regions surrounding St. Louis (in Illinois and Missouri) to determine the extent of excess deaths caused by the heat wave; consideration will be given to prevailing weather conditions. Mortality ratios observed during periods of cold wave conditions are also under study.

5.6 Division of Air Surveillance (DAS)

A meteorologist is assigned to the Division of Air Surveillance (DAS) to assist with the correlation and interpretation of air quality data, to review reports of monitoring results, and to advise on the location and exposure of air sampling instruments. The following are examples of the results of work performed at the request of the DAS:

The report prepared for the EPA by the Air Pollution Control District, County of Los Angeles (April 1971), analyzes periods when meteorological conditions may have been suitable for additive effects of aircraft emissions to a known background. Many observations have shown concentrations of CO above the 8-hour standard at points along the airport boundary. A number of such cases were analyzed, and we found that the high CO concentrations usually occurred with advection from the city sources rather than from the airport.

Concentration of SO_2 in Ankara, Turkey, measured during December 1970 and January 1971 as part of a cooperative study with the United States, were analyzed for a possible relationship between measured concentrations and meteorological parameters. As expected, wind speed had a negative correlation. However, wind direction and temperature seemed to have little effect on day-to-day concentrations. This suggests that the cause of the air pollution is largely home heating rather than industrial sources and that the effects of increased combustion during periods of low temperature may be off-set by greater dispersion during periods of cold weather.

The EPA supplied a group of cities east of the Rocky Mountains with CO and O_3 monitors. The CO instrument was located in the area of heaviest traffic and the O_3 instrument 4 to 16 kilometers (x to y km) downwind (based on direction of prevailing winds). Measured CO concentrations were dependent on the site; therefore, comparisons between cities are invalid. Ozone instrument siting is believed to be less sensitive to small variations in location. Concentrations of ozone are being examined relative to concurrent meteorological conditions.

5.7 Division of Stationary Source Enforcement (DSSE)

Meteorologists supporting the Division of Stationary Source Enforcement (DSSE) participated in preparation of a technical report and oral presentation in connection with an abatement conference on air pollution in the Mt. Storm, West Virginia - Luke, Maryland area. Principal investigations involved:

1. Assessing the contribution of SO_2 emissions from the Mt. Storm power plant to Christmas tree damage in the area.

2. Evaluating the extent that other sources, including a large kraft pulp mill at Luke, Maryland, contributed concentrations of air pollution.

The Abatement Conference convened at Potomac State College in Keyser, West Virginia, May 11-14, 1971. Dispersion calculated by meteorologists supplemented air quality measured in the area; these provided a basis for recommendations for control measures by the EPA Administrator on October 14, 1971.

Meteorologists had participated in abatement conferences on air pollution problems in the area of Parkersburg, West Virginia, in 1967 and 1969. One provision of the previous recommendations involved correcting a downwash problem at a power station operated by the Union Carbide Corporation. Union Carbide submitted plans in April 1971 for a tall stack to be installed that would substantially reduce downwash. Meteorologists evaluated the plan which considered flow characteristics around the plant due to buildings and valley topography. A single 120-m stack was agreed upon and subsequently constructed.

The DSSE was formed by EPA during 1971 and given responsibilities for enforcing provisions of the Clean Air Act Amendment of 1970. The main activity of DSSE has been to ensure that standards, being promulgated by the EPA, contain adequate provisions for enforceability, including Standards of Performance for New Stationary Sources, National Emission Standards for Hazardous Air Pollutants, and Implementation Plans to meet National Air Quality Standards. Since these Standards and Implementation Plans are just now being put into effect, there have been few enforcement actions during the past year.

In a related activity, the EPA requested that the DSSE recommend water pollution enforcement actions that could significantly change atmospheric emissions. Two methods have been proposed for steel production facilities to dispose of liquid wastes (from their coking operations), which exceed allowable water discharge limits and air pollutants may not be completely eliminated by water-steam treatment: incineration, and evaporation (quenching of hot coke with waste contaminated water). Meteorologists have calculated the dispersion to estimate the impact on the air environment that would result from these methods.

Hazardous Emission Standards were developed with the help of meteorologists, who provided dispersion estimates of maximum emissions for certain categories of sources of beryllium and mercury covered by the standards. A long-term variation of the Pasquill-Gifford dispersion formula was used. Ambient air emission concentrations, not to be exceeded over any 30-days, were set as goals to form the basis for dispersion estimates. Maximum allowable emissions were calculated for least favorable meteorological conditions at representative source locations. These results should assure that the ambient air emission concentration goal will not be exceeded near any source.

5.8 Manpower Development Staff (MDS) Institute for Air Pollution Training (IAPT)

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

The basic course, "Air Pollution Meteorology," is recommended for meteorological technicians and for scientists and engineers having little or no training in meteorology. There were eight presentations during the year, including one at the State University of New York at Buffalo. In all, 237 persons received certificates of completion.

The course, "Diffusion of Air Pollution - Theory and Application," is designed primarily for meteorologists working in air pollution control. Other scientists and engineers who have completed the basic course may also enroll. This course was presented to a total of 76 students: once at Fleet Weather Central, Norfolk, Virginia, for military weather officers; and once at Research Triangle Park, North Carolina.

The third short course is "Meteorological Instrumentation in Air Pollution." This is for engineers and technical personnel responsible for designing, procuring, and maintaining air pollution monitoring networks that include meteorological sensors. A new manual has been written, and a 1-m cross-section wind tunnel is to be installed in a new laboratory early in 1973. Twenty persons attended the single presentation of the course.

To support the NWS and Focal Point Meteorologist program, the institute, in cooperation with NOAA's National Meteorological Center and the Weather Analysis and Prediction Division, began a 2-week training program in air pollution. NOAA meteorologists responsible for preparing air stagnation advisories receive 7 days of instruction on air pollution and meteorological topics at the Research Triangle Park, then they travel to Suitland, Maryland, for 3 days of discussion and familiarization with NMC guidance materials, forecast research programs, and NWS policy in support of environmental pollution programs. Thirty-four meteorologists attended these courses during the past year.

An automated slide show entitled, "Effective Stack Height" has been completed. The sequence is designed primarily for engineers and scientists or as introductory material for meteorologists before they study in-depth Briggs' (1969) publication. A video tape and set of lecture notes based on Plume Rise was completed and circulated to all NOAA Air Resources Laboratories.

A section on air pollution meteorology, which had been part of a computer assisted instruction course, has been rewritten into programmed instruction (PI). Extensive revisions have been initiated and a printed version is being validated by students. The PI manual required about 3 hours of study to complete.

Numerous seminars, lectures, and informal talks were presented to various professional organizations, university classes, civic groups, and schools. The senior meteorologist accepted a short-term World Health Organization appointment as a Consultant in Environmental Health and traveled to Czechoslovakia to present the meteorology portion of a week-long seminar on air quality management. One man-week was spent with the State of California Division of Highways and the Federal Highway Administration advising them on meteorological sensors, instrument placement exposure, and data reduction techniques for highway research projects.

5.9 Southwest Energy Study

The Southwest Energy Study, under the sponsorship of the Department of Interior, is a comprehensive examination of existing and proposed coal-fired steam electric generating plants in the Southwest which use coal from the Colorado Plateau and adjacent areas. The environmental impact of the existing power plants and related facilities, as well as potential impact of additional power installations, is the primary concern of the study.

The ML has provided air pollution climatological data and other input to the Southwest Energy Study Report of the Meteorology Work Group. The ML furnishes a meteorologist for liaison between the Meteorology Work Group and EPA engineers and scientists who gather facts about power plant design and are responsible for evaluating the environmental impact.

A ML meteorologist participated in the second annual meeting of the Colorado Plateau Environmental Advisory Council, Flagstaff, Arizona, on September 2, 1971. At this meeting, which dealt with the environmental impact of specific power plants, EPA estimates of the impact of power plant emissions on visibility were discussed.

5.10 Radiochemistry and Nuclear Engineering Division

The Radiochemistry and Nuclear Engineering Research Division (RNERD), National Environmental Research Center, Cincinnati, Ohio, is conducting a series of field studies near the Oyster Creek Nuclear Power Station, New Jersey. A ML meteorologist assisted a radiological team during a 2-day investigation in January 1972 and a meteorologist and a technician participated in a 3-day period of observations during April 1972. Meteorological forecasts and observations from a 130 m meteorological tower and from pilot balloon soundings were used to position observers with radiological instruments where the plume from the power reactor stack could be sampled and the radiation measured. During the April investigation, an airplane from EPA Las Vegas National Environmental Research Laboratory facility was used to measure external radiation and collect gas samples. These observations were used to define plume height, lateral and vertical dispersion coefficients, and the centerline concentration of radioactive noble gases. RNERD will prepare a report on the study.

5.11 NOAA/EPA Coordination Group

The NOAA/EPA Coordination Group, including representatives from the ML, meets once every 2 months. The group is concerned primarily with the development and coordination of NOAA Environmental Meteorological Support Unit (EMSU) activities.

In response to a letter from the Chairman of the Fairbanks, Alaska, North Star Borough, concerning the need for an EMSU in Fairbanks, a ML meteorologist visited Alaska during the first week of January 1972. In

Fairbanks air pollutants have been increasing, especially exhaust products from automobiles. As a result of the Alaskan visit, an EMSU meteorologist has been assigned to Fairbanks, and all Alaskan Air Stagnation Advisory messages related to the EPA Emergency Operations Control Center are routinely transmitted to the National Meteorological Center (NMC). The NMC representative who made the trip to Fairbanks is developing the necessary air pollution forecast guidance material for Alaska.

6. INTERNATIONAL AFFAIRS

6.1 Global Monitoring Design Study

Dr. James Peterson of the ML served as consultant to the Commission on Monitoring of the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) from June 28 through August 11, 1971. The Commission, working in Stockholm, Sweden, was asked to design a global environmental monitoring system for consideration at the 1972 U.N. Conference on the Environment. A report, "Global Environmental Monitoring," was published in late 1971.

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

The Second Meeting of the Expert Panel on Modeling of NATO/CCMS was held July 26-28, 1971, in Paris. Modeling experts from the United States, Germany, Turkey, and France attended the meeting. Those attending from the ML included Mr. R. A. McCormick (Chairman), Mr. K. L. Calder, Dr. W. H. Snyder, and Dr. F. A. Worley, Jr. (on leave from the University of Houston), all representing the U.S. Topics that were discussed included: current status of the Ankara and Frankfurt air pollution modeling studies; hydraulic and aerodynamic modeling of air pollution problems; and, modeling air pollution in the presence of physical and chemical transformations. A number of detailed technical papers were presented at the meeting and published as Proceedings No. 5 on Air Pollution by the NATO/CCMS.

ML Committee members visited the Laboratories of the National Meteorological Office, Paris, at Magny Les Hameaux. During the visit, Dr. L. Facy hosted a tour and discussed his water channel modeling experiments.

6.3 World Meteorological Organization (WMO)

The U.N. World Meteorological Organization (WMO) Executive Committee Panel on Meteorological Aspects of Air Pollution met at the National Environmental Research Center, Research Triangle Park, North Carolina, from April 10-14, 1972. This panel reviewed the progress nations of the world have made in following up previous recommendations of the WMO. The panel also worked out details of a global air pollution monitoring network (fig. 5). They presented their recommendation as part of the U.N. Conference on Human Environment at Stockholm in June 1972. Mr. R. A. McCormick, Director of the ML, was a member of the panel and served during the year before this meeting as the Panel Chairman.

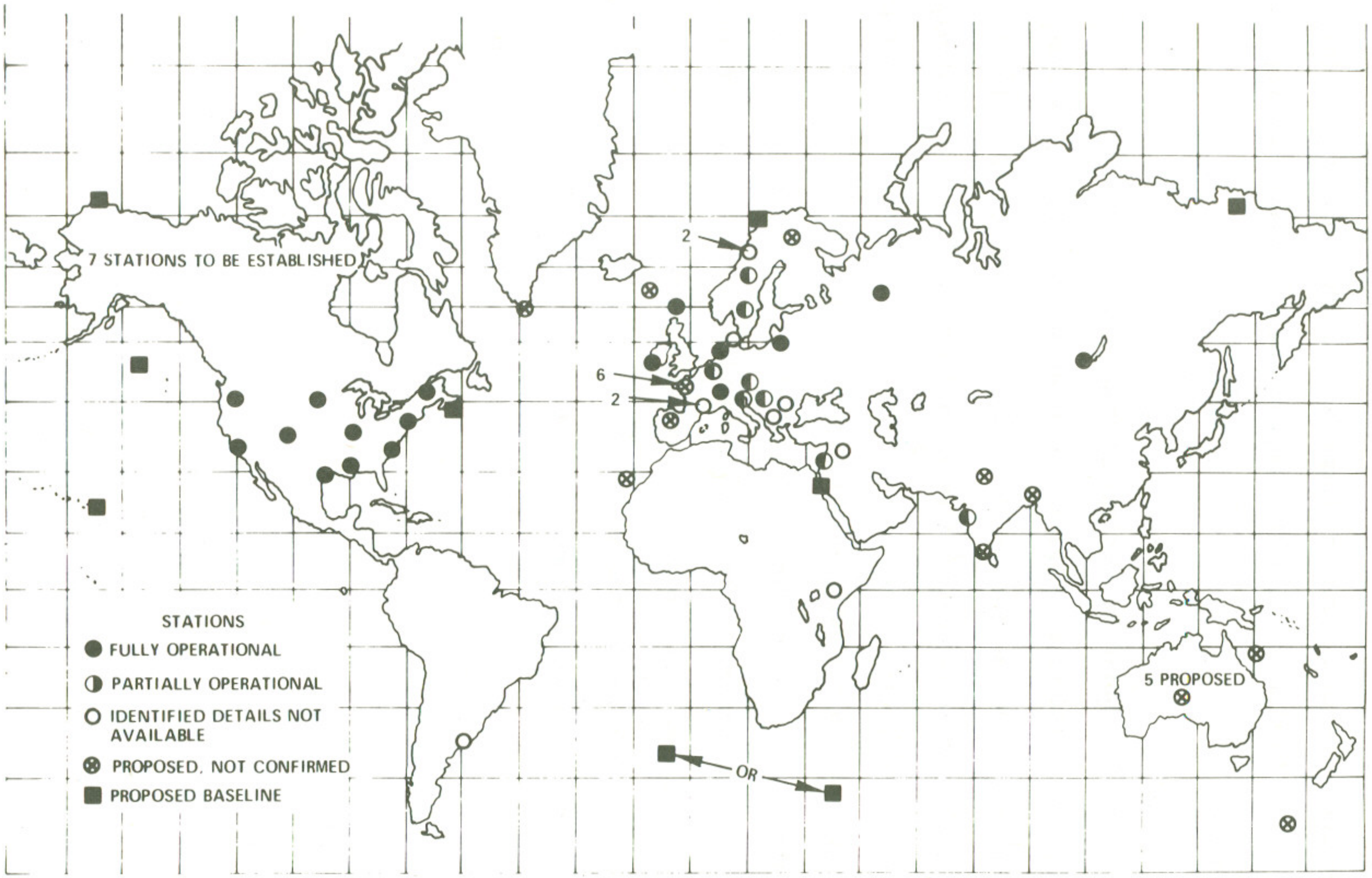

Figure 5. The World Meteorological Organization Air Pollution Network.

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