COO-1199-57

Illinois State Water Survey
at the
University of Illinois
Urbana, Illinois

STUDY OF AIR POLLUTION SCAVENGING

Fourteenth Progress Report
Contract Number AE(11-1)-1199
April 1976

by

Richard G.Semonin

Sponsored by

United States Energy Research and Development Administation
Environmental Programs
Division of Biomedical and Environmental Research
Washington, D. C.

Richard G. Semonin
Principal Investigator

ABSTRACT

The field experiments were continued to estimate convective storm particulate scavenging efficiency in proximity to the St. Louis, Missouri urban-industrial complex. Complimentary studies of the urban aerosol characterization, source strength, and removal processes were also studied.

The 1975 field effort shifted emphasis from the immediate St. Louis area to the Alton-Wood River industrial complex. Along with the change in size and configuration of the network, there were increases in the numbers of most types of samplers. The new network yielded the following types of samples for analysis and interpretation: 1) 1065 total rain samples from 85 sites; 2) 68 sequential rainwater samples from 2 locations; 3) 272 wet/dry samples from 7 locations; 4) 216 air filter samples from 7 locations; 5) 36 air filter samples from aircraft; and 6) raindrop spectrometer data from 11 sites for the period 17 June-18 August. The analysis procedures require that all water samples undergo filtering for separate analyses of soluble and insoluble fractions of the elemental concentrations. This data collection effort provided a record number of samples for chemical analysis. Approximately 4000 pibals and over 370 radiosondes were released in the operational period, providing wind and thermodynamic data on 33 days. Aircraft missions were flown on 21 days, with one air tracer release of cesium on 19 July 1975. The status of the analysis of all types of data is described.

ACKNOWLEDGEMENTS

The successful operation of a field project of this magnitude requires the full cooperation of every individual involved. This has certainly been true of METROMEX from the outset and was more than true in 1975 when many people were asked to go beyond the normal routine of activities and perform added tasks. To all of our METROMEX colleagues, we extend a heartfelt thanks for enduring the hardships placed upon you by us in our pursuit of the scavenging studies and tracer experiments.

This research could not be accomplished without the total dedication of Mark Peden and his associates in the Chemistry Laboratory. This group of men and women have worked beyond expectations in performing seemingly impossible tasks. Without this sort of effort, the analysis would be hopelessly behind. The overall supervision of the field crews was superbly accomplished by Steven Hilberg. The maintainence and operation of the rawinsonde equipment was carried out in a professional manner by Anthony Raimondi. Bruce Komadina insured the operation of the raindrop spectrometers with long hours under difficult conditions. We would also like to express our appreciation to Atmospherics, Inc., specifically Tom Henderson and Don Duckering, for their untiring efforts during the 5 years of field operations, and especially for their comprehensive series of photographs and written reports of their operations and observations in the St. Louis area.

STUDY OF AIR POLLUTION SCAVENGING

Fourteenth Progress Report
Contract Number AE(ll-l)-1199

INTRODUCTION

The field efforts on this contract have been directed toward the use of tracer chemicals to study the scavenging processes in convective thunderstorms for. the past 5 years. The effort was moved in 1971 from the central Illinois area (Project ITREX) to the major field project, METROMEX, in the St. Louis, Missouri area. This project was described in great detail in the Eleventh Progress Report. The METROMEX program was envisioned as a 5-year data collection project followed by an additional period of time to analyze and catalog the data relating to the inadvertent modification of precipitation by urban influences. The Survey ERDA effort has been a vital part of this project of national importance.

The past 5 years of data collection were very fruitful, and some preliminary results have been brought together in 2 major publications; the Eleventh Progress Report under this contract, and the report C00-1199-34 listed in Appendix B of this report. Additional papers have been published and the results of specific research topics have been presented at various scientific meetings (see Appendix A).

Minor alterations occurred in field operations in the first four years as dictated by preliminary findings. However, in 1975, the final year of the field effort, major changes were incorporated into the field operations. The area of major study was moved northward to encompass the Alton-Wood River

industrial and refinery complex northeast of St. Louis, and sampling networks were enlarged (Figs. 1 £ 2).

An extensive data base of surface and upper-air measurements was acquired over the five periods of field operations. Attention has now turned toward the interpretation and analysis of the observations. Further efforts of analysis will be required to present the final results in a form useful for the prediction and assessment of the impact of our growing urban centers on the frequency, amount, and quality of precipitation.

Since a comprehensive description of the types of data gathered under the auspices of this contract has been presented in previous Progress Reports, this report will deal with the effort expended during FY-76 in the field and in analysis.

FIELD DATA COLLECTION

A summary of the Water Survey field activities in METROMEX for 1975 is presented in the enclosed report entitled "1975 Operational Report for METROMEX". The following paragraphs will expound on the portions of the data collection effort pertinent to the scavenging research.

Aircraft

The aircraft used for the tracer release flights was flown on 24 occasions during 1975 and logged a total of 73.1 hours of flight time. During the 5 1/2 week period of flight operations, one tracer mission was conducted. The remaining 23 flights were composed of second priority air sampling missions.

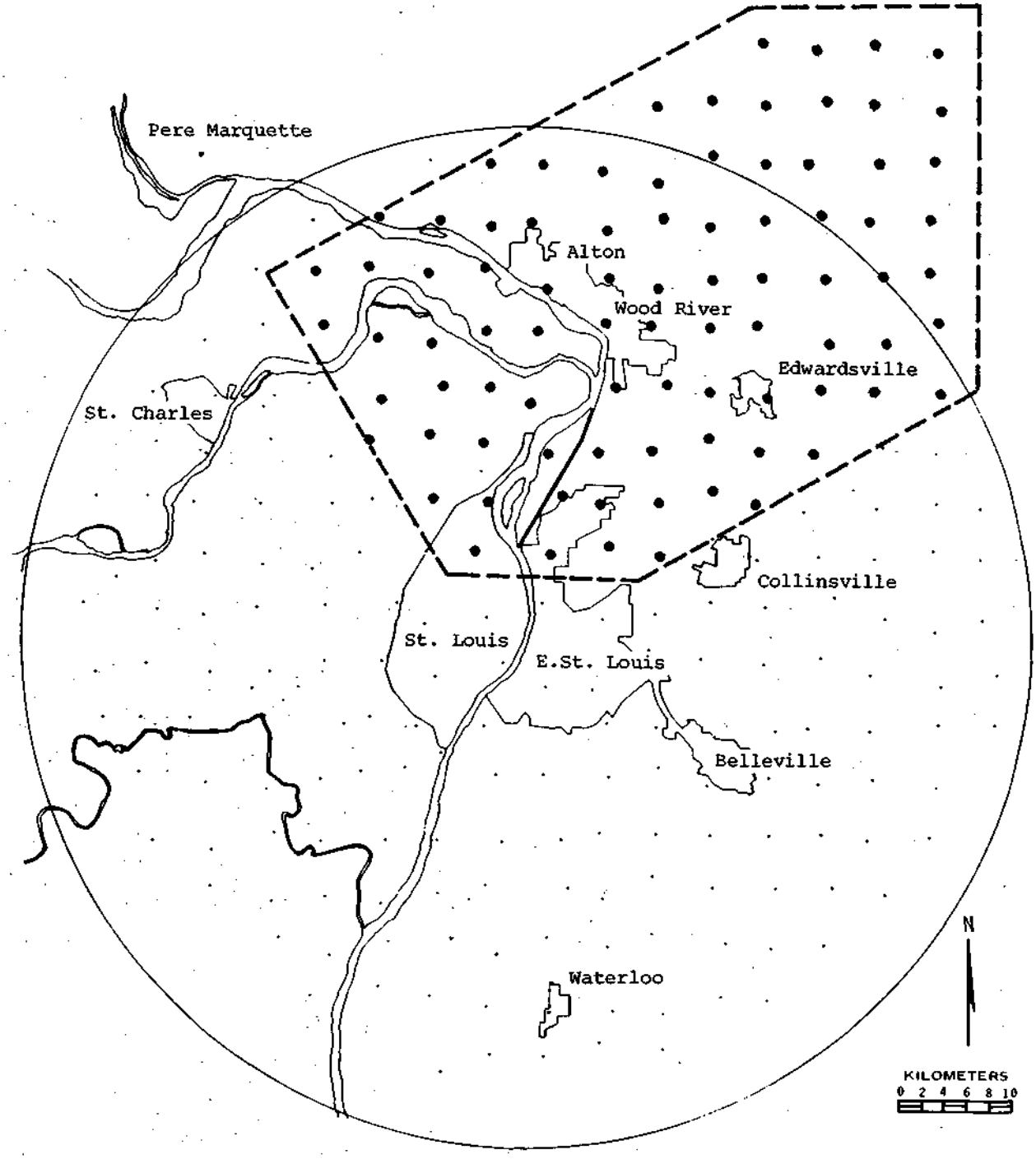

Figure 1. The 1975 tracer chemical sampling network

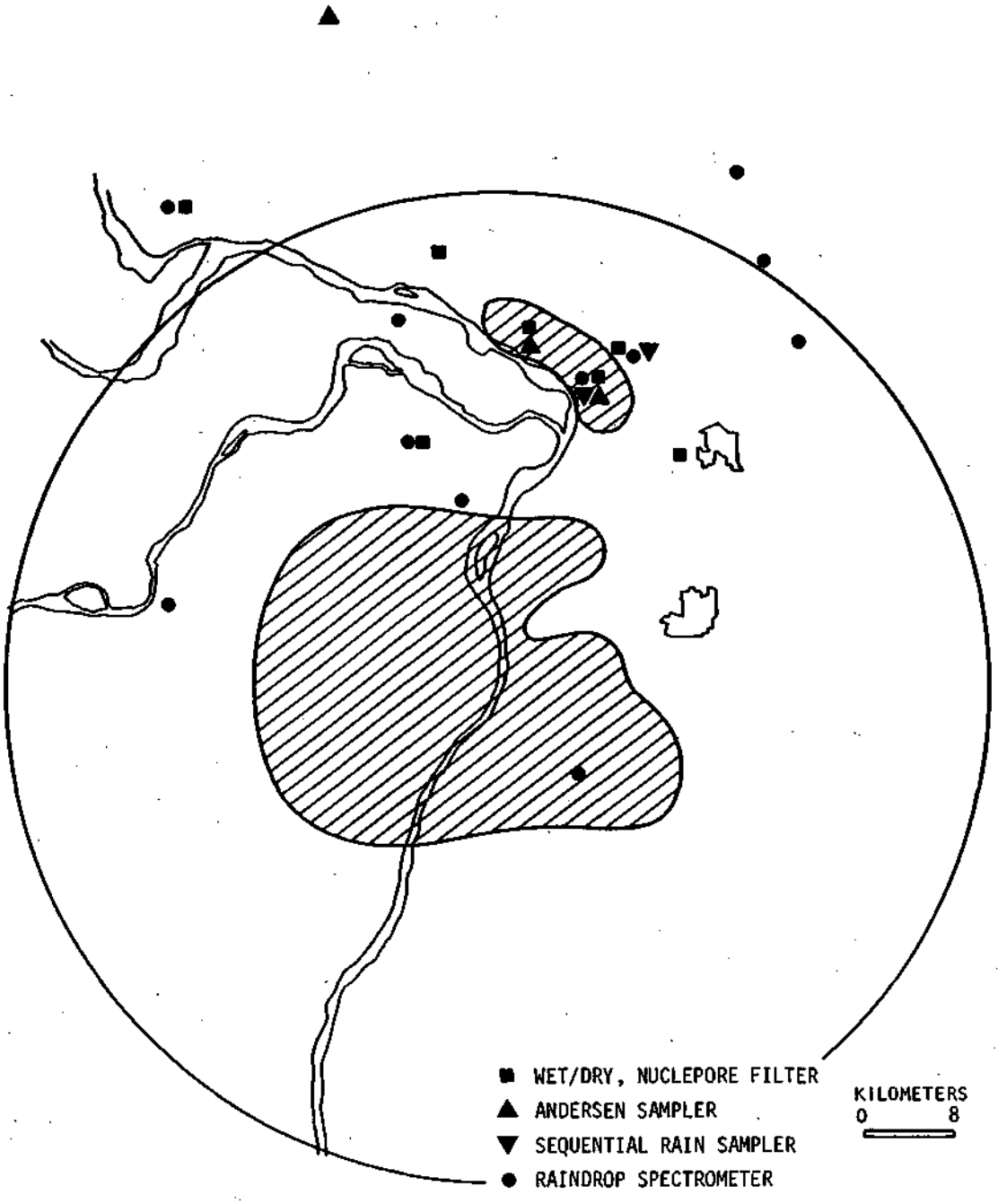

Figure 2. The 1975 rain and air chemistry sampling network

The alternate flights for the aircraft were carried out to provide data on the structure of the atmosphere prior to and during the development of convective activity which is essential to the complete understanding of storm development and structure.

Network

The instrumentation installed, maintained, and operated under funds from this contract during 1975 within the primary METROMEX research circle (Semonin and Gatz, 1974) included: 1) 90 total rainwater samplers at 85 sites; 2) 11 raindrop spectrometers; 3) 7 wet/dry samplers; 4) 2 sequential rain samplers; 5)7 air filter samplers; 6)3 rawinsondes; and 7) 11 pibal sites. A new computer-controlled 10 cm radar, operated under an NSF grant, was available at the Pere Marquette radar site to assist the aircraft on tracer missions. The operation of the network in 1975 was changed from a flexible to a fixed schedule. Operations were kept on a six-day on, one-day off schedule. This produced a total of 35 operational days from the period 4 July to 15 August (Fig. 3; Auer, 1975) and produced rain samples on 2 days and complete sets of dry samples on 11 days. Included in the samples were three tracer experiments, one by air on 19 July and the remaining two by ground release on 13 and 14 August. Since the collected samples, in general, are filtered to separate insoluable and soluable materials, the experiments produced a total of more than 2,600 samples for chemical determinations.

A total of 11 raindrop spectrometer sites were instrumented during the period 17 June through 18 August 1975, an increase of 7 samplers over the previous year. These raindrop spectrometer data are used to assess the scavenging efficiency of individual storm case studies. The distinct

difference between the average rural drop-size distribution and the down-city distributions is striking (Semonin and Changnon, 1974) and must be evaluated for its contribution to the total downwind scavenging efficiency of modified storm events.

The network of 7 wet/dry samplers, 8 sequential rain samplers, and 7 surface air filter samplers was operated to collect data required for the determination of scavenging ratios. These samplers were in continuous operation for the period 7 July through 15 August. A total of 107 wet and 165 dry samples were obtained during the operational period along with 216 air filters, and 68 sequential rain samples. As with the network total rain samples discussed above, the wet/dry and sequential rain samples are filtered resulting in a doubling of the sample size for chemical analysis. The operations of this sub-network yielded a total of more than 650 samples for routine analysis in the chemistry facility.

Air Trajectory Program

ERDA provided for all the expendables for this operation in 1975. This observation network was also moved northward to provide support data for the rain sampling, air sampling, and tracer operations (Fig. 3). This facet of the operations was the only portion that was weather dependent, insofar that ' the daily schedule of balloon releases was determined by the type of weather expected that day. There were 33 days of upper air observations in 1975, involving the release of over 370 radiosonde flights from three sites. The ground recorders were located on a SW-NE line extending from Chesterfield, Missouri, to South Roxana, I11. to New Douglas, I11 (Fig. 3). These locations provided observations upwind, in, and downwind of the Alton-Wood River

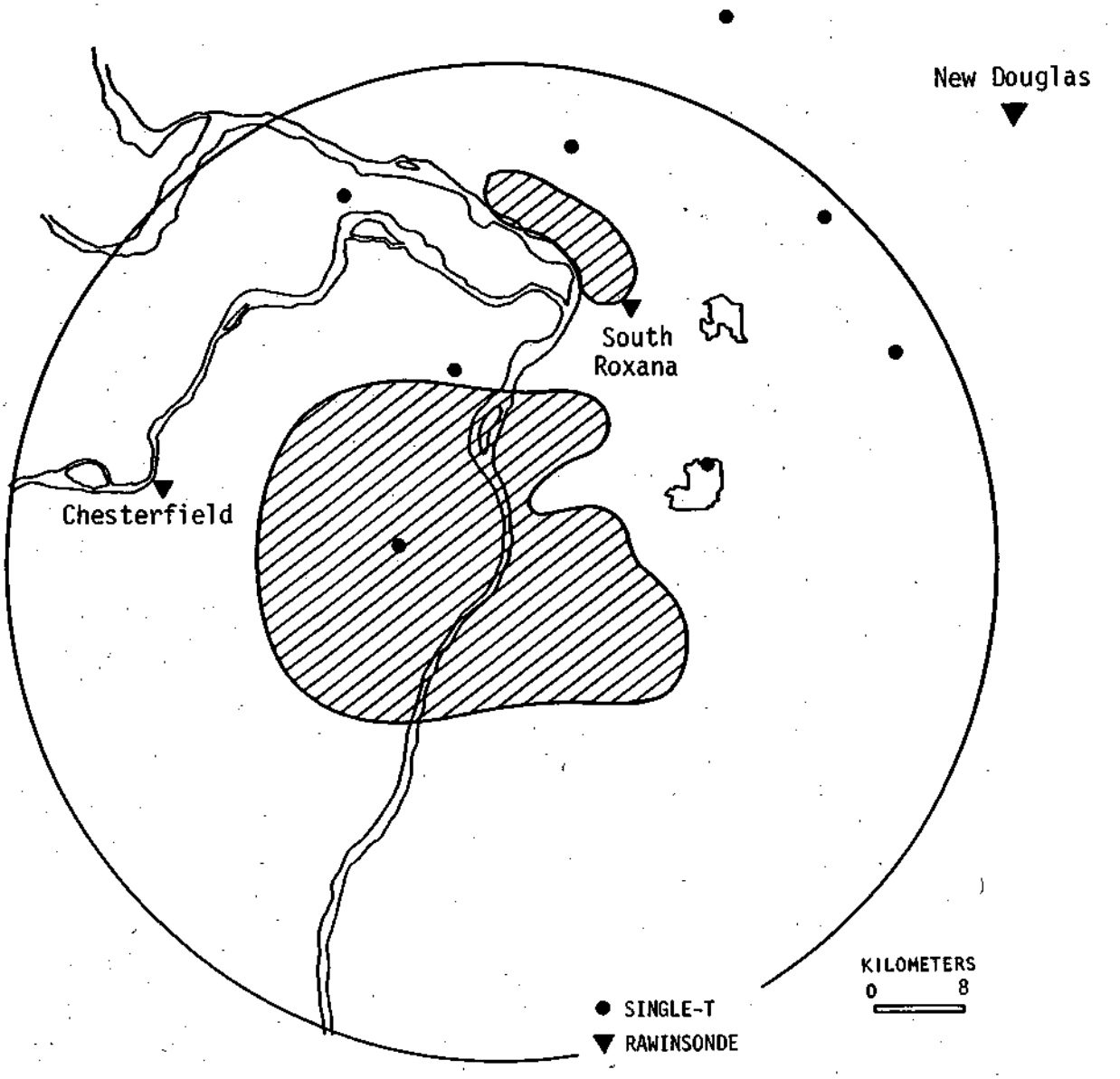

Figure 3. The 1975 air trajectory network

industrial/refinery complex. In addition to the radiosondes, approximately 4000 pilot balloons were released from an additional eight sites located within the sampling network in a manner to allow the determination of the divergence field in proximity to the Alton-Wood River area and to calculate the air trajectories near convective storms.

ANALYSIS EFFORT

The results obtained from the preliminary analysis of the data from the first 2 years of the field effort have been summarized in the report by Huff (1973). Case study analyses of several storms in the years 1972 and 1973 are discussed in a report issued in late 1975 (Changnon and Semonin, 1975).

This summary of the analysis effort contains a status report of the various data collected during the 1975 field effort, and summarizes the total data collected during the 5 years of the project.

Aircraft Data

The primary function for the aircraft services during the 5 years has been to release tracer chemicals into the updrafts of convective and other precipitating systems. These operations are entirely dependent upon the occurrence of precipitation approaching or within the sampling area, and it was necessary to have alternate missions for the aircraft for those periods of time when precipitation was not imminent.

The urban area offers the opportunity to use many of the natural and anthropogenic aerosols as tracers for the scavenging research. It is desirable, therefore, to characterize the aerosol concentration as a function

of varying synoptic weather conditions. In addition, observations of the structure of convective clouds of all types are valuable to achieve the goal of a convective cloud model for the scavenging prediction.

A very cursory examination of the 1973 and 1974 aircraft data shows that a most comprehensive set of measurements were obtained and the analysis program to examine the data in detail is under way. The measurements obtained while in flight are recorded in strip-chart form and require considerable editing, and handling before the data can be used for either case study or modeling research. The charts for the previous years of METROMEX have been partially hand-analyzed for discrete portions of the records. However, the charts are now digitized, analyzed, and the data is stored utilizing a small in-house computer system. The system in use, a WANG 720 programmable calculator with disk and tape storage capabilities, has been dedicated 50% to the digitizing of these charts. This has been completed for 1971, and the remainder of the charts are being edited and prepared for digitizing.

The aircraft data analyzed thus far have shown results which are useful for the guidance of the tracer operations as well as having direct application to the overall METROMEX studies of precipitation scavenging. An examination of a few of the variables recorded during aircraft missions has revealed the following: 1) the existence of a measurable temperature anomaly over the urban area of St. Louis at an altitude of 450 m; 2) the discernment of the urban plume by condensation nuclei concentrations which are in excellent agreement, when properly interpreted, with cloud condensation nuclei observations; 3) discrete sources of ice nuclei have been identified; and 4) the recognition that many convective storms in the area feed upon multiple updrafts which is extremely important for understanding the scavenging process in Midwest thunderstorms.

Network Data

The interpretive analysis of the chemistry data obtained from the various network operations has been directed toward their use in a limited number of case studies. To facilitate the interpretation of all of the chemistry data, the laboratory results have been formatted for computer processing to produce statistical information as well as useful data for individual storm studies. A newly acquired in-house computer system, a WANG 2200, is being used for the archiving of the chemistry data, and will be used for analysis purposes. Some examples of the results from tracer experiments have been shown by Semonin (1972, 1973) and Gatz (1974a). The results from the scavenging ratio measurements have been given by Gatz (1973, 1974a) and the utility of the data in determining the urban source strength is given below.

With the completion of the field program in 1975, all of the raindrop spectrometer data collected in the 1972-75 period will be reduced with emphasis on the following subsequent analyses: 1) the relationship between the chemistry of the sequential rain samples and the corresponding raindrop spectra parameters; 2) upwind versus downwind differences in spectra across the urban region; and 3) the relationship between spectra parameters and proximity to the main core of precipitation elements. The WANG 720 programmable calculator is dedicated 50% to the reduction and analysis of this data.

The air filter samples are collected to measure atmospheric concentrations of the same elements as measured in rain. However, these data on elemental concentrations in air can also be analyzed to provide estimates of two important parameters that relate to the source term in mass budget equations applied to atmospheric constituents.

The first of these parameters is the *source coefficient*. A source coefficient is the fraction of the total aerosol concentration at a given receptor contributed by a particular kind of source (e.g., wind-raised soil, dust or automobile exhaust). Evaluation of source coefficients for all measurable source types, both natural and man-made, at a given receptor, puts into perspective the pollution problem at that particular site, in that it indicates the relative contributions of all known sources to the total aerosol concentration. Such information makes it possible to evaluate alternate abatement strategies.

The second source parameter that may be estimated from filter measurements is the *area-wide emission rate* of the various elements measured on the filters. Knowing the emission rate (in tons/yr) of Pb, say, in the St. Louis or Alton-Wood River areas allows us to put our measurements of wet and dry deposition of Pb into perspective against the amount of Pb released. This provides the kind of information necessary to make statements about how much of a given element was released into the atmosphere in a given area in a given time, what fraction was deposited within some distance of the source, and what fraction left the area. Such information is important to assessments of elemental pathways through the environment to man. Examples of these analyses have been given by Gatz (1974b).

Air Trajectory Data

The amount of upper air data collected in 1975 was almost twice that collected in 1974. Much of this data has been checked, is now undergoing computer processing, and then will be edited. Because of the vast amount of wind data collected, the new WANG 2200 computer system described above is

being utilized to edit the wind data after the initial computer run. The computer output for the radiosonde flights consists of a listing of all measured and derived thermodynamic parameters for every contact point of the radiosonde baroswitch and significant levels between, plus a plot of the temperature and dewpoint as a function of pressure. These observations continue to be used for various case studies under investigation. Examples of their utility were given by Grosh and Semonin (1973) and in the case study report (Changnon and Semonin, 1975).

The pilot balloon observing network data are vital for the determination of the scavenging efficiency of convective storms as they traverse the research area. These data, in conjunction with the radiosonde data, are used for the calculation of the precipitation efficiency of storms as shown by Grosh and Semonin (1973). The trajectories of the airflow determined from the network measurements are also useful to separate urban-affected storms and those that can be treated as control storms. Work is now being performed to determine a method of calculating three-dimensional trajectories of air parcels. It is envisioned that analysis of this type will further help to delineate the complex air motions in and around convective storms.

Examples of the utility of the data in estimating the effect of the urban region on the airflow have been given by Ackerman (1972, 1974). The convergence of the low-level flow in response to the urban heat island and structural shape is an important concept for consideration in numerical efforts to simulate the urban environment and its effect on the atmosphere.

SUMMARY OF PROGRESS

The renovation of the two chemistry laboratories combined with the purchase of a new flameless atomic absorption module has increased both the quality control and data output capabilities of the chemistry facility. A record number of 3800 dry deposition and precipitation samples collected in the 1975 field effort were processed in the laboratory prior to atomic absorption determinations. In addition, the sizable backlog of samples that had accrued during the renovation has now been analyzed along with the bulk of the 1975 field-generated sample load. The total analytical output of the chemistry facility of 35,000 analyses during the past year has quadrupled that of the previous year's effort as a result of the improved facilities and equipment.

The capacity to analyze data collected over the past several summers of field work was increased with the acquisition of the WANG 2200 computer system, in addition to the new equipment added to the chemistry laboratory. However, because of a six month delay in funding, and thus a delay in the purchase of this equipment vital to the analysis effort, the analysis is behind schedule. Nevertheless, it is proceeding at a steady pace and it is anticipated that most of the analysis will be complete in time for inclusion in the final report on this project.

Several papers have been generated out of the analysis performed in the past year, not the least of which is the case study report released recently (Changnon and Semonin, 1975) providing an in-depth analysis of specific precipitation events in the St. Louis area. In addition, there have also been many presentations to various professional groups on the results of METROMEX.

Over the past five summers of field operations, the dry deposition of Li, Mg, K, Ca, and Zn have been measured across the rain chemistry network. The relationship between dry deposition on natural surfaces and the deposition in the plastic bottles used as samplers is unknown. However, a rough indication of elemental deposition under dry conditions has been extrapolated from the 80-site rain chemistry network to annual depositions in the St. Louis area. This information will be useful in determining mass budgets of elemental particulates released into the atmosphere in other urban-industrial areas and verification of numerical modeling efforts.

PERSONNEL

The Principle Investigator, Richard G. Semonin, has devoted 60% of the past 12 months to the conduct of this research.

REFERENCES

Ackerman, B., 1972: "Winds in the Ekman layer over St. Louis." Preprint Vol. Conf. on Urban Environ. and Second Conf. on Biometeor., Philadelphia, Amer. Meteor. Soc, 22-27.

Ackerman, B., 1974: "METROMEX: Wind fields over St. Louis in undisturbed weather." Bull. Amer. Meteor. Soc, 55(2), 93-95.

Auer, August H., Jr., 1975: 1975 Operational Report for METROMEX. University of Wyoming, 47 pp.

Changnon, S. A., Jr., and Semonin, R. G., editors, 1975: Studies of Selected Precipitation Cases from METROMEX. Illinois State Water Survey Rept. of Invest. No. 81, Urbana, 329 pp.

Gatz, D. F., 1973: "Scavenging ratio measurements." In Huff, F. A., Ed., Summary Report of METROMEX Studies, 1971-1972. I11. State Water Survey Rept. of Invest. No. 74, 133-144.

Gatz, D. F., 1974a: "METROMEX: Air and rain chemistry analyses." Bull. Amer. Meteor. Soc, 55(2), 92-93.

Gatz, D. F., 1974b: "Relative contributions of different sources of urban aerosols: Application of a new estimation method to multiple sites in Chicago." Atmospheric Environment.

Grosh, R. C. and R. G. Semonin, 1973: "Moisture budgets and wind fields of thunderstorms passing over an urban area in the Midwest." Preprint Vol. Eighth Conf. on Severe Local Storms, Denver, Amer. Meteor. Soc., 130-137.

Huff, F. A., Editor, 1973: Summary Report of METROMEX Studies, 1971-1972. Illinois State Water Survey Rept. of Invest. No. 74, Urbana, 169 pp.

Semonin, R. G., 1972: "Tracer chemical experiments in Midwest convective clouds." Preprint Vol. Third Conf. on Weather Mod., Rapid City, Amer. Meteor. Soc, 83-87.

Semonin, R. G., 1973: "METROMEX chemical tracer studies." In Huff, F. A., Ed., Summary Report of METROMEX Studies 1971-1972. Illinois State Water Survey Rept. of Invest. No. 74, 125-129.

Semonin, R. G. and S. A. Changnon, Jr., 1974: "METROMEX: Summary of 1971-1972 results." Bull. Amer. Meteor. Soc. , 55(2), 95-100.

Semonin, R. G., and D. ,F. Gatz, 1974: Study of Rainout of Radioactivity in Illinois. Twelfth Progress Report to the U. S. Atomic Energy Commission, Contract AT(11-1)-1199, 21 pp.

APPENDIX A

Presentations
1971 - 1975

APPENDIX A
ERDA-1199
Presentations

"METROMEX Research Results", R. G. Semonin, Southwest Illinois Planning Commission and East-West Gateway Commission, St. Louis, July 1975.

"METROMEX Overview", R. G. Semonin, Federal Interdepartmental Committee on Atmospheric Science, St. Louis, August 1975.

"Temporal and Spatial Variability of Rainwater pH", R. G. Semonin, Conference on Metropolitan Physical Environment, Syracuse, August 1975.

"Wet Deposition Estimation Using Scavenging Ratios", D. F. Gatz, Symposium of Atmospheric Contribution to the Chemistry of Lake Waters, International Association of Great Lakes Research, Longford Mills, Ontario, September 1975.

"Methodology and Results of Insoluble Deposition Determinations in Project METROMEX", M. E. Peden, American Geophysical Union, Madison, September 1975.

"Tracer Rainout from a Pre-Frontal Thunderstorm System", N. J. Doesken, American Geophysical Union, Madison, September 1975.

"Comparison of Urban and Rural Diurnal Temperature and Moisture Cycles", S. D. Hilberg, American Geophysical Union, Madison, September 1975.

"Preliminary Results of Analysis of Terrain Effects Upon Rainfall in St. Louis", J. P. Vogel and F. A. Huff, American Geophysical Union, Madison, September 1975.

"Surface Effects from Thunderstorms", J. L. Vogel, Ninth Severe Local Storms Conference, American Meteorological Society, Norman, October 1975.

"The Past, Present, and Future of METROMEX", R. G. Semonin, Lab. for Atmospheric Research, U. of I11., Urbana, October 1975.

"Applications of Flameless Atomic Absorption to the Analysis of Metals in Environmental Precipitation and Dry Deposition Samples", M. E. Peden, WMO Expert Meeting on Wet and Dry Deposition, Toronto, November 1975.

"Metal Concentrations in Atmospheric Aerosol In and Near St. Louis", D. F. Gatz, 68th Annual Meeting of the American Institute of Chemical Engineers, Los Angeles, November 1975.

"Inadvertent Weather Modification", R. G. Semonin, Dept. of Electrical Engineering, U. of I11., Urbana, November 1975.

"Air and Precipitation Chemistry: Tools for the Atmospheric Scientist", R. G. Semonin, Northern Illinois University, DeKalb, January 1976.

"Acid Rain Measurements in METROMEX", R. G. Semonin, U. S. Department of Agriculture, Washington, D. C., February 1976.

"Weather and Man's Activities", R. G. Semonin, St. Joseph College, Rensselaer, March 1976.

"METROMEX: Past, Present, Future", R. G. Semonin, St. Louis University Chapter, AMS, St. Louis, April 1976.

APPENDIX B
ERDA-1199
Reports, Reprints, and Preprints

COO-1199-1 Huff, F. A., 1963: Study of rainout of radioactivity in Illinois. First Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 58 p.

COO-1199-2 Huff, F. A., 1964: Study of rainout of radioactivity in Illinois. Second Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 6l p.

COO-1199-3 Huff, F. A., 1965: Radioactive rainout relations on densely gaged sampling networks. Water Resources Res., 1,(1), 97-108.

COO-1199-4 Huff, F. A. and G. E. Stout, 1965: Distribution of radioactive rainout in convective rainfall. J. Appl. Meteorol., 3(6), 707-717.

COO-1199-5 Huff, F. A., 1965: Study of rainout of radioactivity in Illinois. Third Progress Report to U. S. Atomic Energy Commission. Contract AT(ll-l)-1199, 66p.

COO-1199-6 Huff, F. A., 1965: Radioactive rainout relations in convective rainstorms. Res. Report No. 1 to U. S. Atomic Energy Commission. Contract AT(ll-l)-1199, 131 p.

COO-1199-7 Feteris, P. J., 1965: 1964 Project Springfield studies. Res. Report No. 2 to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 20 p.

COO-1199-8 Huff, F. A. and W. E. Bradley, 1965: Study of rainout of radioactivity in Illinois. Fourth Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 20 p.

COO-1199-9 Stout, G. E. and F. A. Huff, 1967: Rainout characteristics for hydrological studies. Symposium on Isotopes in Hydrology. Vienna, 6l-72.

COO-1199-10 Bradley, W. E. and P. J. Feteris, 1966: Study of rainout of radioactivity in Illinois. Fifth Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 2b p.

COO-1199-11 Bradley, W. E. and G. E. Martin, 1967: An airborne precipitation collector. J. Appl. Meteorol., 6(4), 717-723.

C00-1199-12 Huff, F. A. and G. E. Stout, 1968: Relation between Ce^{144} and Sr^{90} rainout in convective rainstorms. Tellus, 20(1), 82-87.

COO-1199-13 Huff, F. A. and G. E. Stout, 1967: Time distributions of radioactivity and chemical constituents in rainfall. Proc. USAEC Meteorol. Info. Meeting, Chalk River,Canada, 503-513.

COO-1199-14 Huff, F. A., W. E. Bradley, and P. J. Feteris, 1967: Study of rainout of radioactivity in Illinois. Sixth Progress Report to U. S. Atomic Energy Commission. Contract AT(ll-l)-1199, 19 p.

COO-1199-15 Wilson, J. W. and P. T. Jones III, 1968: Tracing tropospheric radioactive debris by isentropic trajectories. Res. Report No. 3 to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 33 p.

COO-1199-16 Lyons, W. A. and J. W. Wilson, 1968: The control of summertime cumuli and thunderstorms by Lake Michigan during non-lake breeze conditions. Satellite and Mesometeorol. Res. Paper Ho. 74 to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 32 p.

COO-1199-17 Wilson, J. W. and W. E. Bradley, 1968: Study of rainout of radioactivity in Illinois. Seventh Progress Report to U.S. Atomic Energy Commission. Contract AT(11-1)-1199, 64 p.

COO-1199-18 Stout, G. E., 1969: Study of rainout of radioactivity in Illinois. Eighth Progress Report to U. S. Atomic Energy Commission. Contract AT(ll-l}-1199, 49 p.

COO-1199-19 Semonin, R. G., 1970: Study of rainout of radioactivity in Illinois. Ninth Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 55 p.

COO-1199-20 Semonin, R. G., 1971: Study of rainout of radioactivity in Illinois. Tenth Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 56 p.

COO-1199-21 Adam, J. R. and R. G. Semonin, 1970: Collection efficiencies of raindrops for submicron particulates. Proc. Symposium on Precip. Scavenging, Richland, Wash., 151-159.

COO-1199-22 Adam, J. R. and R. G. Semonin, 1970: A technique for the experimental measurement of collection efficiency. Proc. Conf. Cld. Phys., Ft. Collins, Colo., 139-140.

COO-1199-23 Semonin, R. G. and J. R. Adam, 1971: The washout of atmospheric particulates by rain. Proc. Conf. Air Pollution Meteorol., Raleigh, N. Car., 65-68.

COO-1199-24 Changnon, S. A., Jr., F. A. Huff, and R. G. Semonin, 1971: METROMEX: an investigation of inadvertent weather modification. Bull. Am. Meteorol. Soc., 52(10), 958-967.

COO-1199-25 Cataneo, R., J. R. Adam, and R. G. Semonin, 1971: Interaction between equal-sized droplets due to the wake effect. J. Atmos. Sci., 28(3), 416-418.

COO-1199-26 Cataneo, R. and D. L. Vercellion, 1972: Estimating rainfall rate-radar reflectivity relationships for individual storms. J. Appl. Meteorol., 11(1), 211-213.

COO-1199-27 Semonin, R. G., 1972: Tracer chemical experiments in Midwest convective clouds. Proc. Third Conf. Weather Mod., Rapid City, S. Dak. , 83-87.

COO-1199-28 Semonin, R. G., 1972: The use of chemical and biological tracers in cloud physics. Intern. Conf. Cld. Phys. , London.

C00-1199-29 Semonin, R. G., 1972: Study of rainout of radioactivity in Illinois. Interim Eleventh Progress Report to U. S. Atomic Energy Commission. Contract AT(ll-l)-1199, 12 p.

C00-1199-30 Adam, J. R., R. Cataneo, D. F. Gatz, and R. G. Semonin, 1973: Study of rainout of radioactivity in Illinois. Eleventh Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 157 p.

C00-1199-31 Henderson, T. J. and D. W. Duckering, 1973: Final Report METROMEX 1973: A summary of operations conducted by Atmospherics Incorporated during the period 7 July through 19 August 1973, 51 pp.

C00-1199-32 Changnon, S. A., Jr., R. G. Semonin, and W. P. Lowry, 1972: Results from METROMEX. Preprint Vol. Conf. on Urban Environ. and Second Conf. on Biometeor., Philadelphia, Amer. Meteor. Soc, 191-197.

COO-1199-33 Grosh, R. C. and R. G. Semonin, 1973: Moisture budgets and wind fields of thunderstorms passing over an urban area in the Midwest. Preprint Vol. Eighth Conf. on Severe Local Storms, Denver, Amer. Meteor. Soc, 130-137.

COO-1199-34 Huff, F. A., Editor, 1973: Summary Report of METROMEX Studies, 1971-1972. Illinois State Water Survey Rept. of Invest. No. 74, Urbana, 169 pp.

C00-1199-35 Gatz, D. F., 1972: Washout ratios in urban and non-urban areas. Preprint Vol. Conf. on Urban Environ. and Second Conf. on Biometeor. , Philadelphia, Amer. Meteor. Soc, 124-128.

C00-1199-36 Lowry, W. P., 1973: 1973 Operational Report for METROMEX. Illinois State Water Survey, Urbana, 63 pp.

C00-1199-37 A collection of papers, 1974:

Staff: METROMEX: An overview of Illinois State Water Survey Projects.

Huff, F. A. and P. T. Schickedanz: METROMEX: Rainfall analysis.

Gatz, D. F.: METROMEX: Air and rain chemistry analysis.

Ackerman, B.: METROMEX: Wind fields over St. Louis in undisturbed weather.

Semonin, R. G. and S. A. Changnon, Jr.: METROMEX: Summary of 1971-1972 results.

Bull. Amer. Meteor. Soc., 55(2), 89-100.

C0O-1199-38 R. G. Semonin and D. F. Gatz, 1974: Study of Rainout of Radioactivity in Illinois. Twelth Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 21 pp.

C0O-1199-39 Henderson, T. J. and D. W. Duckering, 1972: Final Report METROMEX 1973: A summary of operations conducted by Atmospherics Incorporated during the period 5 July through 15 August 1972, 34 pp.

C00-1199-40 Ackerman, B., 1974: Wind fields over the St. Louis metropolitan area. J. Air Poll. Cont. Assoc, 24, 232-236.

C0O-1199-41 Rattonetti, A., 1974: Determination of soluble Cadmium, Lead, Silver, and Indium in rainwater and stream water with the use of flameless atomic absorption. Anal. Chem., 46, 739-742.

C0O-1199-42 Ackerman, B., 1974: Wind profiles and their variability in the planetary boundary layer. Prep. Vol. Symp. on Atmos. Diffusion and Air Poll., Santa Barbara, Amer. Meteor. Soc, 19-22.

C0O-1199-43 Gatz, D. F., 1974: St. Louis air pollution: Estimates of aerosol source coefficients and elemental emission rates. Prep. Vol. Symp. on Atmos. Diffusion and Air Poll., Santa Barbara, Amer. Meteor. Soc, 109-114.

C00-1199-44 Ackerman, B., 1974: Spatial variability of the wind velocity in the lowest 500 meters. Prep. Vol. Sixth Conf. on Aerospace and Aeronautical Meteorol. , El Paso, Amer. Meteor., Soc, 325-328.

C00-1199-45 Cataneo, R., 1974: Operational aspects of Project METROMEX - an inadvertent weather modification study. Prep. Vol. Fourth Conf. on Wea. Mod. , Ft. Lauderdale, Amer. Meteor. Soc, 379-381.

C0O-1199-46 Semonin, R. G. and S. A. Changnon, Jr., 1974: METROMEX: Lessons for precipitation enhancement in the Midwest. Prep. Vol. Fourth Conf. on Wea. Mod., Ft. Lauderdale, Amer. Meteor. Soc, 353-357.

C00-1199-47 Braham, R. R., Jr., 1974: 1974 Operational Report for METROMEX. Univ. of Chicago, 39 pp.

C0O-1199-48 Gatz, D. F. , 1975: Relative contributions of different sources of urban aerosols: Application of a new estimation method to multiple sites in Chicago. Atmos. Environ., 9, 1-18.

C00-1199-49 Henderson, T. J. and D. W. Duckering, 1975: Final Report METROMEX 1974: A summary of operations conducted by Atmospherics, Incorporated during the period 7 July through 17 August 1974, 48 pp.

COO-1199-50 Semonin, R. G. , 1975: Study of rainout of radioactivity in Illinois. Thirteenth Progress Report to U. S. Atomic Energy Commission. Contract AT(11-1)-1199, 24 pp.

COO-1199-51 Henderson, Thomas, Jr., and Donald W. Duckering, 1976: METROMEX 1975: A summary report, 53 pp.

C00-1199-52 Hall, N. D., and K. V. Beard. 1975: Electrostatic force between a conducting sphere and dialectic sphere. Pure and Applied Geophysics, 113, 515-524.

C00-1199-53 Grover, S. N., and K. V. Beard, 1975: A numerical determination of the efficiency with which electrically charged cloud drops and small raindrops collide with electrically charged spherical particles of various densities. Journal of Atmos. Sciences, 32. 2156-2165.

COO-1199-54 Vogel, J. L., 1975: Surface effects from thunderstorms. Prep. Vol. Ninth Severe Local Storms Conf., Norman, Amer. Meteor, Soc., 113-119.

COO-1199-55 Auer, August H., Jr., 1975: 1975 Operational Report for METROMEX, University of Wyoming, 47 pp.

C00-1199-56 Changnon, S. A., Jr., and R. G. Semonin, editors, 1975: Studies of selected precipitation cases from METROMEX. Illinois State Water Survey Rep. of Invest. No. 81, Urbana, 329 pp.

C00-1199-57 Semonin, R. G., 1976: Study of air pollution scavenging. Fourteenth Progress Report to the Energy Research and Development Admin. Contract AE(11-1)-1199, 23 pp.