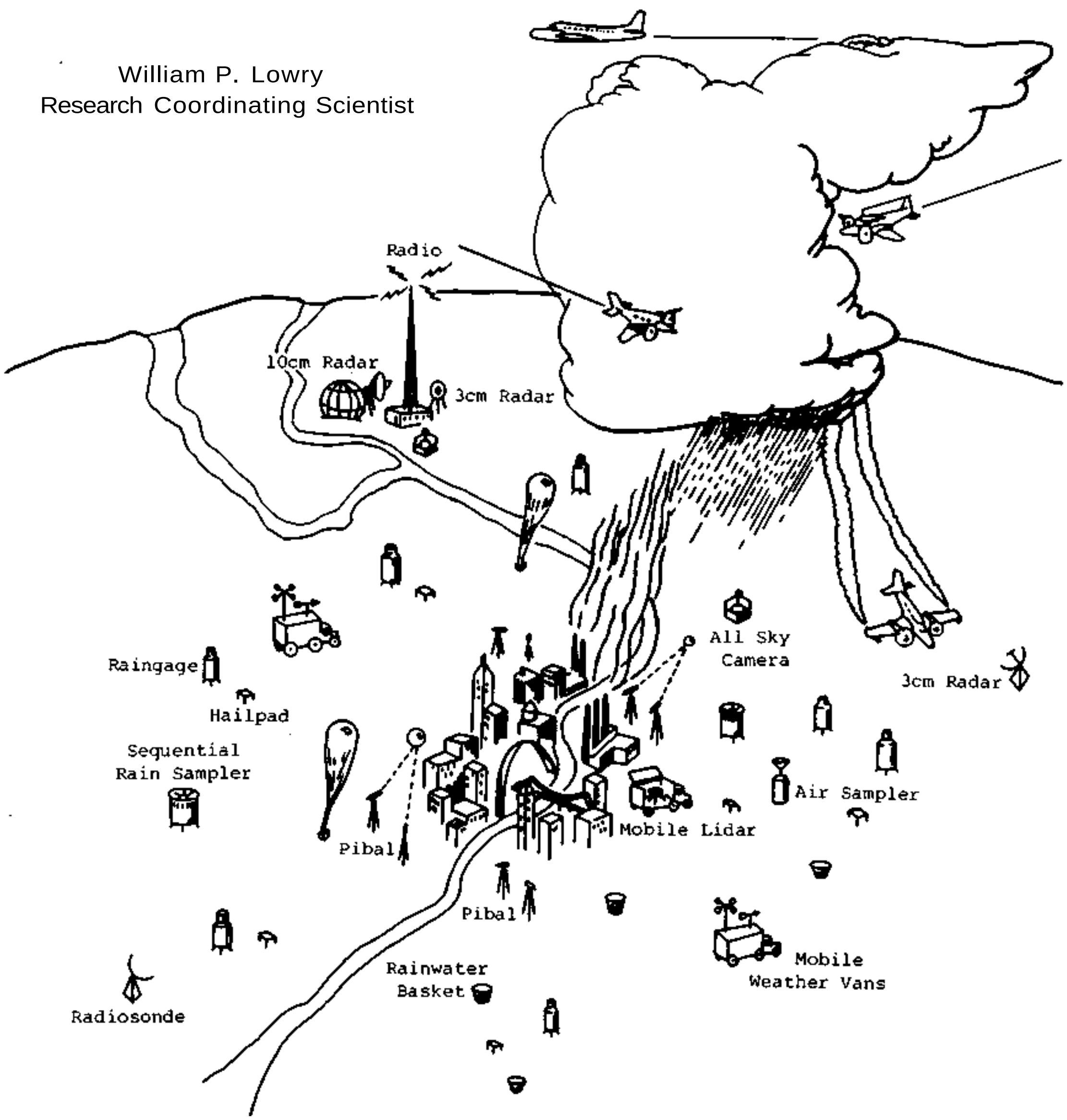
1972 OPERATIONAL REPORT
FOR
METROMEX

William P. Lowry
Research Coordinating Scientist



A Joint Program involving groups from Argonne National Laboratory, Battelle Pacific Northwest Laboratories, University of Chicago, Illinois State Water Survey, Stanford Research Institute, and University of Wyoming

Illinois State Water Survey
Urbana, Illinois 61801
April, 1973

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RESEARCH COORDINATION OF METROMEX

William P. Lowry
Illinois State Water Survey
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1. GENERAL

Project METROMEX is a federation of individual scientists with diverse sources of funding but complementary research objectives. The impetus leading to the federation grew out of a series of meetings held in the summer of 1969 among scientists from four agencies, interested in the effects of urbanization on precipitation-related processes.

The four agencies were (1) Argonne National Laboratory, (2) University of Chicago, (3) Illinois State Water Survey, and (4) University of Wyoming. The structure they developed for METROMEX has been described since then in two publications:

(a) S. Changnon, F. Huff, and.R. Semonin. METROMEX: an investigation of inadvertent weather modification. Bull. Amer. Meteor. Soc. 52(10): 958-967. October 1971, and

(b) S. Changnon, R. Semonin, and W. Lowry. Results from METROMEX. Proceedings, Conference on Urban Environment and Second Conference on Biometeorology, Philadelphia, October 31 - November 2, 1972. American Meteorological Society, Boston. pp. 191-197. 1972.

These scientists, joined in the summer field program of 1971 by scientists from Battelle Northwest Laboratories and Stanford Research Institute, completed a winter field program and a summer field program during 1972. In addition, laboratory research and mathematical modeling, as well as chemical analyses in support of the field programs, has continued throughout the year.

Six characteristics constitute the general nature of METROMEX. They are:

(i) justification for the research lies in a recognized and complex issue confronting society and mankind;
(ii) the belief that the response of science to the issue is best undertaken by task forces with complexity to match the problem;
(iii) the field projects are to be carried out at and near St. Louis;
(iv) modes of research other than collection of data in the field are essential to the project;
(v) the research is to be accomplished by relatively small, independently administered and funded groups acting cooperatively; and
(vi) the research plan is to be kept open-ended with respect to the list of participants and to the nature of the common goals.

From the outset, continuity and research planning in METROMEX have been carried out by the principal investigators assembled into the Group

Atmospheric Sciences Panel. Coordination of the work of that panel and representation of the panel to groups outside METROMEX has been accomplished through an individual acting as coordinator.

Between September 1970 and September 1972, the coordinator was elected yearly from among the members of the panel: S. A. Changnon through August 1971, and R. G. Semonin through August 197.?.

In June 1972, a grant from the National Science Foundation to the Illinois State Water Survey through the University of Illinois (GI 31+797) provided funds to search for and employ a full-time, continuing coordinator for METROMEX (to be designated Research Coordinating Scientist, RCS). In September 1972 Dr. William P. Lowry assumed that position with offices in the Water Survey and a joint appointment in the Department of Geography, University of Illinois.

During the period October-November 1972, the RCS obtained the services of three distinguished scientists as members of the METROMEX Advisory Panel. They are Drs. Barry Commoner (Washington University), Glenn Hilst (ARAP, Inc.), and James D. McQuigg (University of Missouri and NOAA).

2. CALENDAR OF FIELD OPERATIONS IN 1972.

The attached Table presents, in general terms , the' calendar of field operations conducted under METROMEX in the Greater St. Louis area during June-August 1972. Greater detail on the calendar may be found in the reports of individual cooperators to follow in this report.

Days on which prearranged observational activities were conducted simultaneously by all cooperators present are termed METRODATA Days. In 1972 there were four such scheduled days: July 20, August 4, and August 10-11. In addition, August 3 was added to the list on short notice, making a total of five days on which sets of descriptive data are especially complete. August 3 and the afternoon of August 11 exhibited convective shower activity, the other three days being generally dry and stable.

It should be noted that during these winter periods the University of Chicago group and the Illinois State Water Survey group were both making observations in the St. Louis area:

January 19 - February 4 and February 22 - March 4.

By its nature, the Chicago program consisted of "special observations" centered on flights of their Lockheed aircraft. The wintertime program of the Water Survey consisted of "regular observations" obtained from year-around operation of roughly half of the surface network of precipitation gages and hygrothermographs.

3. RELATIONSHIP TO 1971 OPERATIONS REPORT.

The 1971 Operational Report for METROMEX was much more sought after than anticipated. Thus, copies are no longer available for distribution. Because that report contains many descriptive details concerning instrumentation and aircraft capabilities, some readers of this 1972 report may wish to refer to the earlier report as background for what appears herein.

If a reader of the present report is unable to obtain access to the 1971 report and wishes to have copies of sections made and sent to him, he may make such a request of:

Dr. William P. Lowry
Research Coordinating Scientist/METROMEX
Department of Geography
University of Illinois
Urbana, Illinois 61801.

Requests for sections numbering on the order of 5 to 10 pages can be honored without difficulty. Those requesting larger sections will be asked to make copies for themselves using a loan copy of the 1971 report. To aid those formulating such a request, a facimile of the Table of Contents of the 1971 report follows.

4. SUPPLEMENTARY PUBLISHED MATERIALS ON METROMEX

As already mentioned in the introduction to this section, information about the organizational structure of METROMEX has been formally published in two papers to date (Changnon, Huff, and Semonin, 1971; Changnon, Semonin, and Lowry, 1972). Those two papers include a variety of research results as well as the organizational descriptions.

Although individual technical publications based primarily upon METROMEX results are listed in the reports of cooperators contained herein, it is useful to point out in this introductory section that clusters of these published results have appeared during 1972 in two Conference Proceedings, both published by the American Meteorological Society:

Third Conference on Weather Modification, Rapid City, South Dakota, 26-29 June, and

Conference on Urban Environments, Philadelphia, Pennsylvania, 31 October-1 November.

In addition, two informal documents are available from the RCS which present what are, in essence, status reports on the conceptual and organizational nature of METROMEX at their respective times of writing:

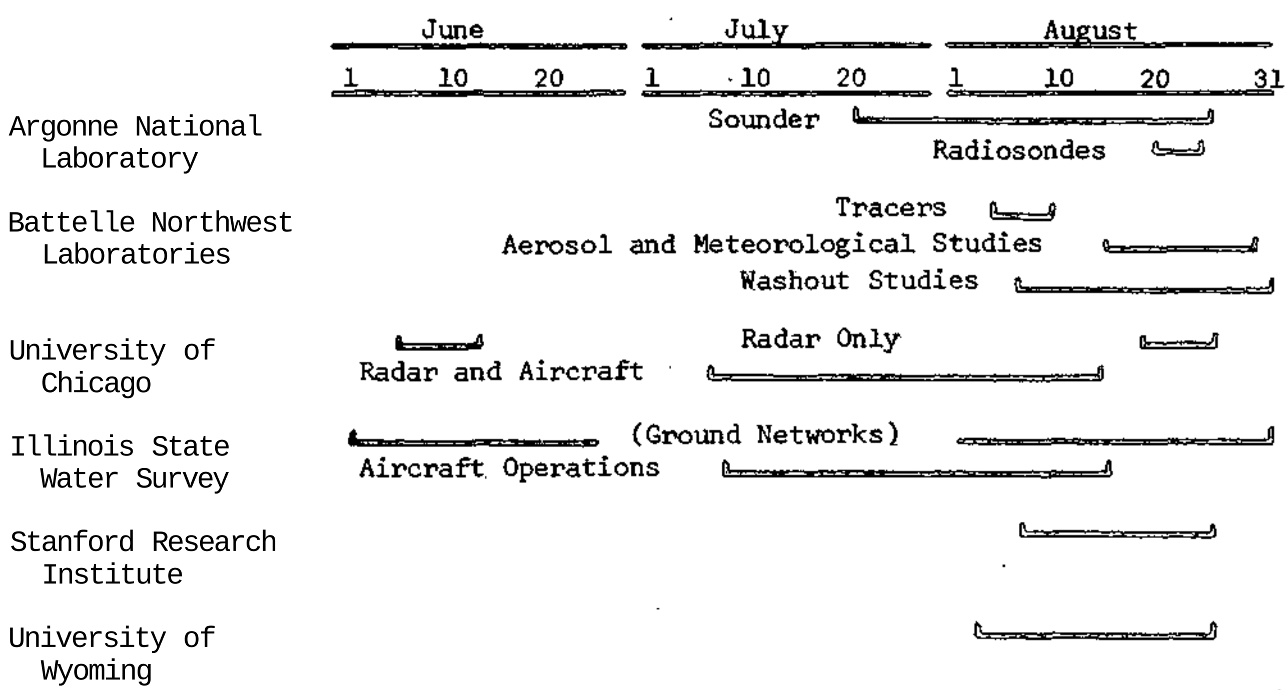
Proposed investigations of the modification of precipitation processes by urban pollution. March 17, 1970, and

Remarks of the METROMEX Research Coordinating Scientist. November 21, 1972.

Finally, information about METROMEX as it relates to other regional atmospheric investigations conducted in the Greater St. Louis area may be obtained from the St. Louis Air Pollution Studies Newsletter, to be published approximately bi-monthly beginning March 1973. Limited numbers of copies may be obtained by writing to the RCS (address in (3) above) or to:

SLAPS Newsletter
United States Environmental Protection Agency
P. 0. Box 8068, LaClede Station
St. Louis, MO 63156

CALENDAR OF METROMEX FIELD OPERATIONS IN SUMMER 1972



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Argonne Participation in METROMEX 1972*

"Acoustic Sounding of the Atmosphere"

N. A. Shaw

Argonne National Laboratory
Radiological and Environmental Research Division

INTRODUCTION;

An acoustic sounder which has been operating at Argonne National Laboratory since February 1972 was installed near St. Louis (Granite City U. S. Army Base) as a contribution to the METROMEX program, and almost continuous operation was maintained from July 20th to August 25th. The sounder can continuously monitor temperature inversions throughout the first 2 Km of the atmosphere, a feature of considerable value to the study of pollutant dispersion over a city, or for the investigation of the influence of a city on the density structure of the lower atmosphere.

In principle, the sounder is similar to sonar. A short, intense burst of acoustic energy at a frequency near 1000 Hz is transmitted vertically into the atmosphere in the form of a narrow beam. Some of this energy is scattered into almost all directions by irregularities in the refractive index of the medium caused by turbulent fluctuations in the wind and temperature fields. That small fraction of the energy directly backscattered is a function only of the intensity of the spatial temperature fluctuations which have a scale size of half the wavelength of the probing acoustic wave, in the present case approximately 15 cm. Turbulent density fluctuations of this scale may thus act as a "tracer" to reveal the presence and behaviour of much larger scale phenomena.

* Work sponsored by the D. S. Atomic Energy Commission, Division of Biomedical and Environmental Research.

For example this type of turbulence exists at the base of temperature inversions and within the ascending plumes of large convective cells. Although such regions can backscatter only a small fraction of the transmitted acoustic pulse, these weak signals may return to the acoustic antenna as an "echo" which, after amplification, can be recorded as a function of both intensity and altitude (i.e., time delay). A special facsimile recorder displays echo structures from successive audio pulses beside one another, thus providing an effective improvement in signal-to-noise ratio by means of visual integration.

When interpreting any section of an acoustic sounder record, certain limitations are apparent. Although a vertically pointing sounder produces a time cross section of the vertical structure of atmospheric turbulence, a single sounder does not distinguish between those features which are (i) localized structures undergoing simple time variations, or (ii) part of a meso- or synoptic scale phenomena moving past the sounder site. However, an analysis of several years of continuous facsimile records has established a pattern recognition inventory (Ref. 1 & 2). This enables certain characteristic patterns to be identified as time variations in local structures while others can be associated with moving systems. The facsimile records are somewhat limited by the semi-qualitative nature of the display; thus when viewing these records, emphasis should be placed upon the presence of temperature inversions (and their time history), rather than upon the intensities of the returns.

OBJECTIVES

The objectives of the acoustic sounder field experiment can be summarized as follows:

(i) To observe the time dependence and spatial variations of lower atmospheric inversion structures near a large city with a view to determining the influences of the city upon them;

(ii) To study the density structure of the lower atmosphere both upwind and downwind of the city (and perhaps observe the city "plume");

(iii) To compare the presence of temperature inversions detected by the acoustic sounder with the distribution of airborne particulates detected by the "lidar" (Stanford Research Institute); and

(iv) To study the morning break-up of a nocturnal inversion by

(a) continuously observing the changing inversion height by acoustic sounder,

(b) periodically measuring the inversion intensity and height by radiosonde flights at hourly intervals, and

(c) comparing the nocturnal inversion break-up recorded by the sounder with the development of the day-time mixing layer as detected by the lidar.

In addition, these experiments introduce a new meteorological "tool" to the METROMEX family and demonstrate its usefulness to atmospheric experiments under both fair and severe weather conditions.

Support Facilities

For supporting surface meteorological observations, the ANL team also installed a Bendix Freiz Aerovane, an hygrothermograph, and a net radiometer ((Beckmann and Whitley model. N 188-01). Radiosonde tracking and receiving equipment, provided by the U. S. Air Force Air Weather Service, was used for a program of serial radiosonde flights from the acoustic sounder site. Most of the sondes launched were modified to provide continuous temperature-altitude data, and an amplified recording feature expanded 10 C change across a 10-inch wide chart paper. For one-hour periods coinciding with the special radiosonde flights, the acoustic sounder data was also recorded on magnetic tape so that quantitative echo amplitude information could be compared with measured inversion intensities. Details of the improved sensitivity and resolution provided by the sonde and recorder modifications will be presented in another report.

On August 7th the Stanford Research Institute commenced operating a vertically pointing lidar beside the acoustic sounder at the Granite City site. The lidar transmits a short intense burst of coherent light from a laser, and detects the small amount of light backscattered by atmospheric particulates, aerosols, and cloud droplets.

It was anticipated that comparisons could be made between the presence, intensity and time history of temperature inversions(as recorded by the acoustic sounder), with the distribution of particulate matter throughout the lower atmosphere(detected by the lidar). Both of these remote sensing techniques are capable of showing, among other things, the diurnal development of the mixing layer.

Using an incremental digital data tape system, the Stanford group also recorded eleven channels of direct solar radiation, one channel of total solar intensity, and the radiation flux of the infrared spectrum. A Barnes (PRT-5), with a narrow, vertically pointing field of view, measured the radiation in a window from 9.5 to 11.5 microns. Since this instrument responded only to radiation from aerosols and atmospheric temperature variations, the data obtained are of particular interest, to the acoustic sounder observations. Other S.R.I, facilities included a Nephelometer (measuring the atmospheric scattering co-efficient for light), hygrothermographs, air filters, and a microbarograph.

Observations

The following table summarizes the operational times of the Argonne equipment:

Instrument	Installation time CD. T.	Operational hrs. (approx).	Data gaps*
Acoustic Sounder	July 20 1700 hrs to Aug. 26 1000 hrs	800	Aug. 10 1800-2050 hrs. Aug. 13 0300-0940 hrs
			Wind Direction
Aerovane	Aug. 2 1600 hrs to Aug. 25 1300 hrs	540	Aug. 18 0140-1030 hrs
			Wind Speed
			Aug. 11 1610 thru Aug. 12 0450
			Aug. 13 0318-1205 hrs.
Net Radiometer	Aug. 3 0920 hrs to Aug. 25 0819 hrs	470	Aug. 12 1610 thru Aug. 18 1025 hrs (recorded by S.R.I.)
Hygrothermograph	July 24 2130 hrs Aug. 25 1325 hrs		July 28 0600 hrs thru Aug. 1 2240 hrs

*Note: all electrical equipment failed on August 24th for a. 20 minute period due to a breakdown in the district power source.

Simultaneous acoustic sounder and lidar observations at the Granite City site totalled approximately 204 hours. This included 11 days during which the lidar was operated from 0700 to at least 1300. A detailed operational log of the lidar system is available from S.R.I.

The following table summarizes the launch time of the special Argonne radiosondes:

Date	Number of Sondes	Launch time (hours)
August 20	2	1000 2350
August 21	1	1300
August 22	3	0740 1115 1500.
August 23	3	0800 1030 1410
August 24	3	0700 0930 1115

To illustrate the results obtained by the acoustic sounder, Figure 1 shows a section of record taken at St. Louis on August 8th, one of the METROMEX special days. This record shows a region of strong echoes up to about 1500 feet where a stronger echo marked the base of a 4 C temperature inversion. A second weak layer was detected for several hours just above this inversion (from 0400 to 0830 hours). At 1100 the sounder indicated that the strong inversion was weakening and rising in altitude at a rate of about 400 feet per hour. By 1800 hours it had reached 4500 feet (the remaining section of record is not displayed here).

Detailed analysis of these and other sounder records is continuing, and a full report containing all the St. Louis sounder data is being prepared.

Future Plans

In 1973 Argonne will receive an additional 2 acoustic sounders from the original source (Physics Dept., RAAF Academy, University of Melbourne, Australia). With this equipment it may be possible to employ several units at St. Louis spaced in such a way as to

(1) resolve possible urban-rural differences in inversion heights,

(2) clearly differentiate between time varying structures and moving systems, and

(3) obtain a continuous three dimensional "picture" of the density discontinuities throughout the lower atmosphere.

All of the acoustic sounder results obtained in the 1972 METROMEX program were obtained from a fixed installation, a 3-m. deep hole at the Granite City site. However the sounder now operates as a mobile unit using a trailer mounted baffle or "portable hole". Thus it will be possible to obtain time-spatial cross-sections through the atmosphere, perhaps between two fixed sounder installations. (Because of excessive wind and road noise, the mobile unit must stop for several minutes to take observations at selected locations while performing a cross-town transit).

In addition, the ANL Electronics division is currently completing a digitized, double-theodolite system which features automatic recording of balloon azimuth and elevation angles in computer-compatible form on an incremental tape recorder. The same equipment records the air temperature, which is continuously transmitted from the pilot balloon by a light-weight radiosonde (403 MHZ, all solid state, an ANL modification of a Canadian design*). This system will be used in the Argonne field experiments during the 1973 METROMEX program.

CONCLUSION

Participation in the METROMEX program has proved to be a worthwhile effort for the Argonne acoustic sounder project, since the St. Louis experiment offered several advantages over routine operations at the permanent site near Chicago.

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* Developed by the Atmospheric Environmental Service of Canada, Downsville, Ontario

(a) For the first time an acoustic sounder and a lidar were operated beside one another to observe directly the influence of atmospheric inversion structures on the distribution of pollutant materials. The METROMEX program provided the opportunity for this joint ANL-SRI effort.

(b) The location and size of the City of St. Louis is more suited to the specific objectives (i), (ii), and (iii) than is the sprawling metropolis of Chicago. In particular, the presence of a large body of water near Chicago (Lake Michigan) strongly influences local weather patterns and often dominates the relatively weaker influence of the city on the lower atmosphere.

(c) The multiple radiosonde flights performed by Illinois State Water Survey offered an opportunity to compare acoustic sounder time cross sections with near-instantaneous spatial measurements of the inversion structures.

Since the goals outlined earlier in this report have only been partially accomplished, continued participation in METROMEX is desirable.

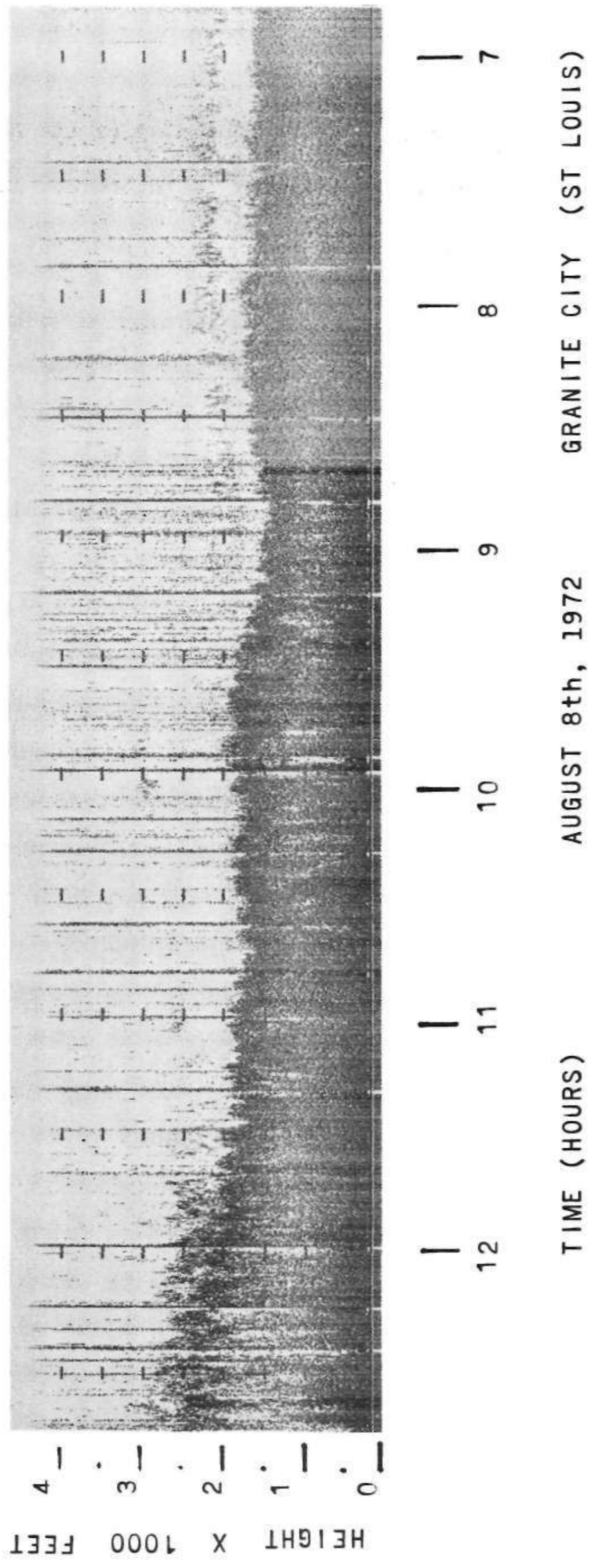
Acknowledgements

The cooperation and assistance of the Granite City U. S. Army Base, in particular that of the Facilities Engineer (Mr. Firehammer) is appreciated. Radiosonde receiving equipment was provided by the U. S. Air Force Air Weather Service through the offices of Captain D. Douglas. The Stanford Research Institute team, in the persons of Ed. Uthe, Earl Schribner, and Norman Nielsen launched radiosondes and generally assisted throughout the joint experiment. The participation of Mr. Gunther Zerbe (of Argonne) in all aspects of the sounder program is gratefully acknowledged.

References

1. Shaw, N. A. (1971) "Acoustic Sounding of Che Atmosphere", Thesis accepted for Ph.D., University of Melbourne, Australia.

2. McAllister, L.G., J.R. Pollard, A.R. Mahoney, and P.J. Shaw (1968). "Acoustic Sounding - a new approach to the study of atmospheric structure:. Proc. I.E.E.E., 57., 4, 579-587.


TIME (HOURS)
AUGUST 8th, 1972
GRANITE CITY (ST LOUIS)
7
8
9
10
11
12
HEIGHT X 1000 FEET
0
1
2
3
4

BATTELLE, PACIFIC NORTHWEST LABORATORIES

Battelle-Northwest personnel conducted three separate programs at St. Louis during the 1972 METROMEX season:

1. A tracer scavenging study of convective storms performed under AEC sponsorship by personnel of the Radiological Sciences Department.
2. An aerosol size distribution study performed for the AEC by the Atmospheric Sciences Department.
3. Measurements of rain scavenging of pollution generated by the metropolitan area, under EPA sponsorship, conducted by personnel of the Atmospheric Sciences Department.

The summaries of these activities, as prepared by the principal investigators, appear on the following pages.

Coordinator's Note: Details of operations and results may be obtained by writing to:

Dr. Jeremy M. Hales
Atmospheric Sciences Department
Battelle Northwest Laboratories
P. 0. Box 999
Richland, Washington 99352

and requesting:

Battelle, Pacific Northwest Laboratories
1972 Annual Report to the
Division of Biomedical and Environmental Research
U. S. Atomic Energy Commission.

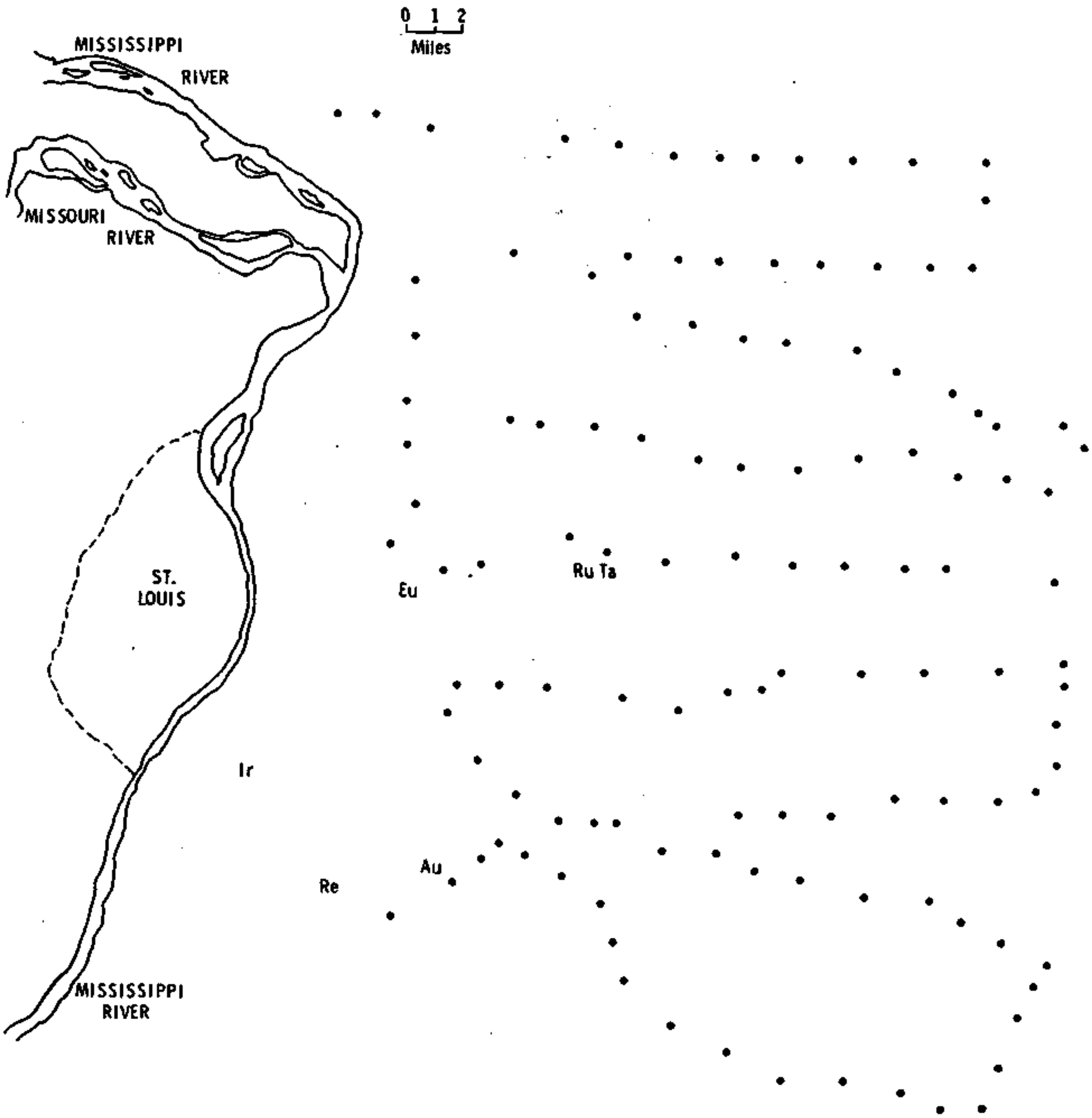
TRACER AND POLLUTION STUDIES

Scientists from the Radiological Sciences Department of Battelle-Northwest conducted two main experiments during the summer of 1972. In the first experiment, begun on August 3, six inert tracters (Eu, Ru, Ir, Ta, Re, and Au) were sequentially released at 10 to 13.5 thousand feet near the upwind edge of convective towers to measure the amount of air penetrating them and reaching the region of precipitation scavenging. The tracers were released by burning acetone-heptane solutions containing the elements in six Brad-Patton aerosol generators mounted underneath the wings of the Battelle Cessna 411. Each tracer was released over a period of two minutes. Indium and lithium were also released into the updraft of this storm at cloud base by Illinois State Water Survey personnel.

Following the tracer release, samples of precipitation were collected using a 25 mile by 36 mile network of 122 rain collectors, shown in the figure. The rain samples were frozen as quickly as possible and are now being analyzed by neutron activation. Aliquots of the samples will be sent to ISWS for indium and lithium analysis. Of the samples analyzed, those which were collected 10 to 20 miles downwind of the gold, iridium and tantalum releases generally contained measureable quantities of these tracers.

The second experiment was the measurement of the trace element composition of air filter samples to determine the contribution of the St. Louis metropolitan area to the contamination of the atmosphere. On August 7th, 8th and 9th, mobile hurricane air samplers were used to collect air samples upwind, downtown, and downwind of the city. Lundgren impactor and long-term stationary air samples were also collected. Analysis is complete by X-Ray fluorescence, but not by neutron activation. Lead concentrations typically varied from 35-71 ng m^{-3} upwind, 140-800 ng m^{-3} downtown, and on August 8, 360 and 510 ng m^{-3} at 20 miles downwind (east).

J.A. Young
T.M. Tanner
C.W. Thomas
N.A. Wogman



BATTELLE RADIOLOGICAL COLLECTION NETWORK

AEROSOL SIZE CHARACTERIZATION STUDY

The objective of the AEC sponsored Aerosol Characterization Study is to measure aerosol size distributions in conjunction with pertinent meteorological variables and trace gases for use in examining the associated interrelationships and determining the fate of these materials in the atmosphere.

Both surface and airborne measurements were obtained during the August, 1972, period. A Royco Particle Counter, combined with a multi-channel analyzer was used to measure aerosol size distributions; aircraft measurements also included use of a Sign-X SO_2 monitor and a Mee Ice Nucleus Counter. Surface measurements were conducted at Edwardsville, Illinois; airborne sampling was performed using the Battelle Cessna 411 aircraft. The table provides an operations summary for the 1972 METROMEX experiments.

A.J. Alkezweeny

AEROSOL SIZE CHARACTERIZATION STUDY
OPERATIONS SUMMARY

	Equipment Operated					
	Airborne			Surface		
Date	Royco	Sign-X	Ice Nucleus	Royco	Temp.	R.H.
8-14				1130-1215		
8-15				1000		
8-16		1430-1700		1330		
8-17				1245-1300		
8-18				0930-1630	✓	✓
8-19				0830-1430	✓	✓
8-21				0800-1600	✓	✓
8-22				1345	✓	✓
8-23				0800-1600	✓	✓
8-24				0830	✓	✓
8-25	1325-1440	✓ 1750-1900	✓	0900	✓	✓
8-26				0900-1900	✓	✓
8-27				1300	✓	✓
8-28	1230-1630	✓	✓			
8-29	1130-1520	✓	✓			

WASHOUT OF INORGANIC NONMETALLIC POLLUTANTS

Field measurements relating to a study of the washout of pollutants in the St. Louis area were conducted by Battelle-Northwest, Atmospheric Sciences Department personnel during the period August 7-31, 1972. The objective of the EPA-sponsored project was to evaluate the effectiveness of precipitation scavenging as a remover of various pollutants produced by the metropolitan area. The primary measurement emphasis was placed on chemical analysis of several chemical species in the rainwater sampled at various locations around the city, both "upstorm" and "downstorm" of the center of the city. Additional measurements included rawinsonde flights and weather radar monitoring at the National Weather Service Office at Lambert Field.

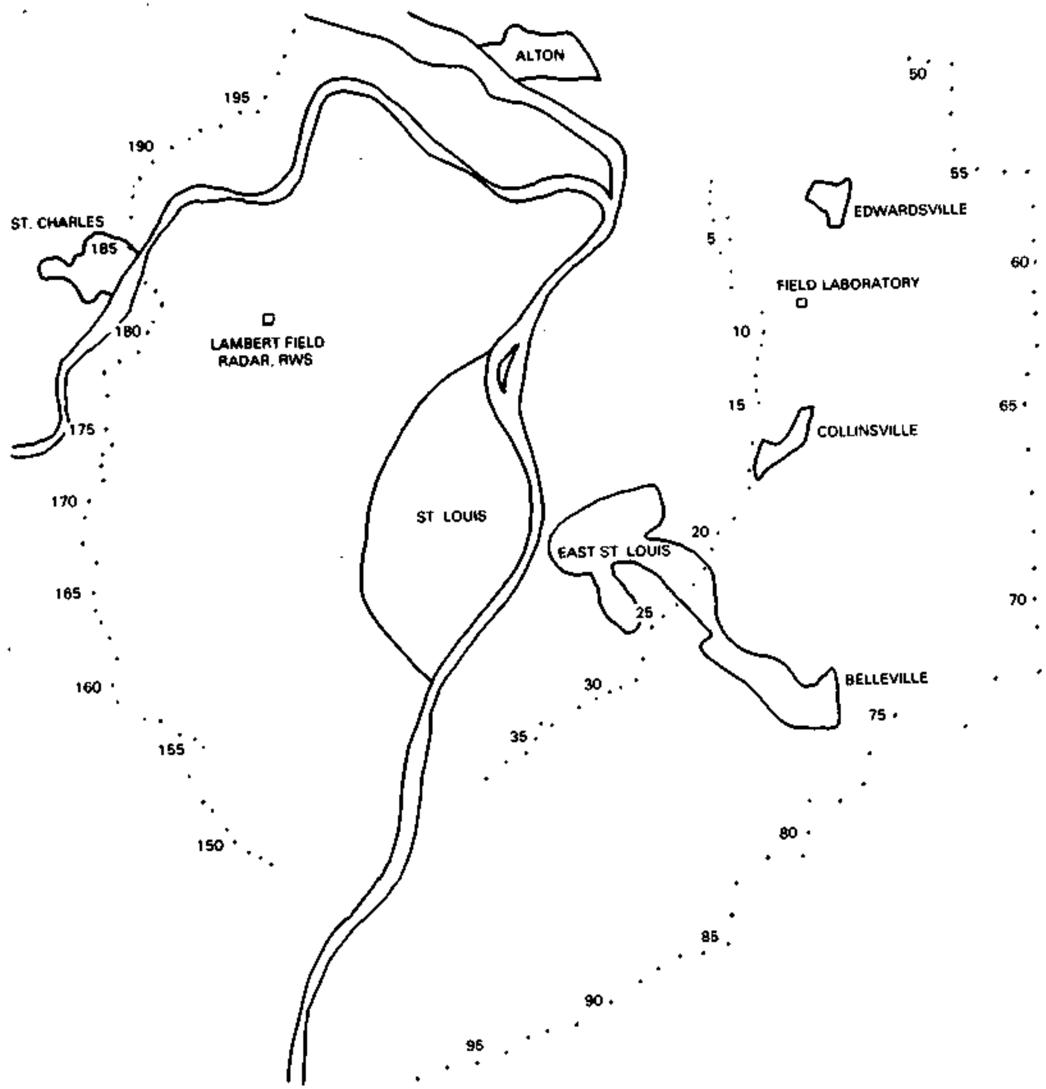
Rain was collected during five separate occasions of convective activity on the sampling network shown in the figure. Each rain collector consisted of a plastic funnel connected to a 500 ml plastic bottle. The latter was enclosed in an insulating container with dry ice. The dry ice froze the rain in a short time after collection; the freezing maintained the trace constituents in fixed chemical states and prevented their loss by desorption prior to analysis. The table is a summary of sampling activities during the August field work.

Chemical analysis is complete for the following chemical species: $S0_2$, SO4, NH_4^+, NO_2, NO_3, and H^+. Some analyses were done on site and some at Richland, Washington; the samples were kept frozen until just before analysis. Remaining rainwater samples will be examined for trace metal concentrations.

A few intitial observations on results:

1. No significant amounts of SO_2 were found.
2. The concentrations of most species were enhanced on the first sampling line (B), but essentially to background level by the second downwind line (C), indicating a nearly complete washout of urban pollutants within these separation distances.
3. pH values were uniformly low at all locations, and varied from day to day between about 3.9 to 4.4.

M. Terry Dana
Jeremy M. Hales
John M. Thorp



BATTELLE NONMETALLIC POLLUTANT SAMPLING LAYOUT

BATTELLE WASHOUT MEASUREMENTS

Date	Run No.	Sample Line	Position Numbers*	Inclusive** Collection Time (Time of Day -CST)	Storm Path	Rawinsonde Release Time (CST)
8/12/72	1	B	19-38	0912-1433	NW to SE	--
8/17/72						1026
8/19/72	2	B	22-28	1421-1647	NW to SE	1402
8/20/72	3	A	146-153	1530-1840	NE to SW	0938, 1430
		B	1-5	1349-1649	NE to SW	--
		C	61-74	1334-1700	NE to SW	--
8/21/72	4	A	146-190	1350-2030	NW to SE	1417
		B	15-37	1455-1731	NW to SE	--
		C	65-83	1503-2001	NW to SE	--
8/25/72	5	A	154-158	0955-1705	W to E	1025, 1501
8/28/72						1053

* Sample positions used at which measurable rain fell.

** Total time from first collector out to last collector in.

UNIVERSITY OF CHICAGO IN METROMEX

1972 Operations Calender

Roscoe R. Braham, Jr.
Cloud Physics Laboratory

The overall, general objective of the University of Chicago Cloud Physics Laboratory participation in Project Metromex is to bring the tools and technical knowledge of cloud physics to bear on the assessment of cause and effect relationships connecting Urbanization to the observed Urban Weather Anomalies. Specific objectives during 1972 were:

1. Identification of urban precipitation regions within the clouds by means of our RHI radar.

2. Measurement, during selected meteorological situations, of the vertical and horizontal extent of the urban aerosol concentration, mass loading and particle size distribution. It is from this aerosol population that the cloud active nuclei emerge.

3. Quantify our knowledge of the role of cities, in particular St. Louis, in the production of cloud condensation nuclei (CCN), and to determine the . space and time scales to which these effects extend.

4. Measurement of cloud microstructure upwind, over and downwind of the city to establish the extent to which anthropogenic CCN alter cloud base particle spectra and thereby subsequently influence precipitation processes in these clouds.

5. On selected days to make vertical cross-sections of the urban heat island and associated aerosol fields and to map surface radiation fields as input to dynamical studies of sub-cloud energetics.

Field operations were conducted from our research base at the Greenville, I11. Airport during January, February, March and July and August, 1972. A summary of the daily operation of the TPS-10 ground radar and the Lodestar airplane is given in the accompanying table.

During the winter operations we had use of the NCAR QueenAir 304D equipped with a Barnes PRT-5 radiometer, state parameter sensors and an inlet tube for CCN air samples. This NCAR airplane was a very important complement to the Lodestar. It doubled our capacity for CCN measurements, provided the means for IR detection of surface temperature anomalies, and made possible coordinated two-plane studies of the heat island.

On several occasions we have had an opportunity to respond to requests from the FAA for assistance. On one occasion the FAA received a report of a light plane down in the Illinois River northwest of Pere Marquette State Park. At the FAA's request we gladly diverted from our mission for about an hour to search the river in an effort to spot the disabled aircraft. Fortunately, the report proved false. On another day, while working southeast of St. Louis we were requested by Kansas City ATC to help in probing a blind spot on their control radar. We were able to respond by working a several minute radar beam pattern into our air sampling flight.

Instrumentation on the Lockheed Lodestar was similar, in general, to that used during the preceding year although several changes in detail warrant the inclusion of the accompanying table of airplane instrumentation.

Publications and reports prepared during the year, based upon Metromex included:

Braham, R.R., Jr., 1972: University of Chicago contribution to Metromex - I. Final Report to NSF on Grant GA 28190, Department of Geophysical Sciences, University of Chicago, pp. 98.

Fitzgerald, J., 1972: A study of the initial phase of cloud droplet growth by condensation, comparison between theory and observations. Tech. Note 44, University of Chicago Cloud Physics Lab. Available from Clearinghouse of Fed. Sci. Info, accession No. PB 211252.

____________, 1972: On the computation of steady-state supersaturations in thermal diffusion chambers. J. Atmos. Sci., 29, 779-781.

____________ and P.A. Spyers-Duran, 1972: Changes in the cloud droplet size distribution associated with pollution from St. Louis. Accepted for publication in April, 1973 issue of J. Appl. Meteor.

Heymsfield, A., 1972: Ice crystal terminal velocities. J. Atmos. Sci., 29, 1348-1357.

Knollenberg, R.G., 1972: Comparative liquid water content measurements of conventional instruments with an Optical Array Spectrometer. J. Appl. Meteor., 11, 501-508.

McCarthy, J., 1972: A method for correcting airborne temperature data for sensor response time. Accepted for publication February 1973 issue of J. Appl. Meteor.

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Table . Operations Calendar, University of Chicago in Metromex - 1972

Date	Airplane	Flight No. T.O.; Lndg.	Flight Mission	CCN Samples	Ice nuclei samples
19 Jan	80F	104 1646-1727 CST	Equipment check		
	80F	104A 1737-1747	Equipment check		
20 Jan				1 ground sample	
25 Jan				1 ground sample	
26 Jan	80P	105 1337-1602	Two plane vertical cross-section over city using as end points navigation fixes	1 upwind 1 downwind 1 ground sample	
	304D	1 1336-1547	320 STL 10 dme 140 STL 40 dme		
27 Jan				1 ground sample	
28 Jan	80F	106 1234-1708	Two plane vertical cross-section over city using as end points navigation fixes	1 upwind 1 downwind 1 ground sample	
	304D	2 1400-1553	250 TOY 35 dme 070 TOY 5 dme and one plane downwind on 230 TOY .35 dme	1 upwind	

Table contd.

Date	Airplane	Flight No. T.O.; Lndg.	Flight Mission	CCN Samples	Ice nuclei samples
29 Jan	80F	107 1239-1722	Downwind sections at 15 and 45 min.	1 ground sample 1 upwind 1 downwind	
	304D	3 1237-1527	Upwind and downwind section	1 downwind 1 weak downwind close to GRE	
31 Jan	304D	4 1345-1415	CCN air samples'	1 ground sample plus 6 bag series	
	304D	5 1433-1519	CCN air samples	from about 10 upwind to	
	304D	6 1600-1645	CCN air samples	35 downwind	
1 Feb	80F	108 1035-1404	Cirrus sampling to 21 K for Heymsfield, Ph.D. thesis research	1 ground sample 1 bag at 12K	
	304D	7 1101-1504	PRT-5 map of STL	1 upwind 1 downwind	
2 Feb	80F	109 1252-1441	Box around city @ 4K for replicator and particle probes	1 ground sample	
3 Feb	80F	110 1027-1301	Box, around city @ 3K for replicator and particle probes	1 ground sample	

Table contd.

Date	Airplane	Flight No. T.O.; Lndg.	Flight Mission	CCN Samples	Ice nuclei samples
3 Feb	304D	8 1022-1051	CCN air sample	2 downwind	
4 Feb	304D	9 0914-0941	CCN air sample	1 ground sample	
	304D	10 1015-1104	CCN air sample	Series of six samples downwind perpendicular to wind	
	304D	11 1136-1211	CCN air sample		
22 Feb				Greenville ground sample	
23 Feb				Greenville ground sample 2 samples from auto exhaust leaded vs. non-leaded	
24 Feb	80F	111 1449-1616	Box around city @ 2.5K for replicator and particle probes	1 ground sample	
	304D	12 1243-1452	CCN air sample at 20K for Heymsfield thesis research	2 at 20,000 ft above middle layer cloud	

Table contd.

Date	Airplane	Flight No. T.O.; Lndg.	Flight Mission	CCN Samples	Ice nuclei samples
25 Feb	80F	112 1401-1557	Box around city @ 3.0 K plus climb to 9K for replicator and particle probes	1 ground. sample	
	304D	13 1208-1319	Planned as 2 plane with 80F. Particle probe malfunction changed to CCN samples.	1 at 12K above precipitating low cloud	
26 Feb	304D	14 1029-1130	CCN air samples	1 ground sample	
	304D	15 1142-1223	CCN air samples	series of eight air samples	
	304D	16 1248-1331	CCN air samples	downwind	
	304D	17 1438-1530	CCN air samples	1.0 K - 25 K	
27 Feb	80F	113 0003-0056	Planned cross-section over City - abort due to airplane electrical mal-function	1 ground sample	3
28 Feb	304D	18 0953-1051	CCN air samples	1 ground sample upwind downwind pair	
	304D	19 1110-1159	CCN air samples	upwind downwind pair	

Table contd.

Date	Airplane	Flight No. T.O.; Indg.	Flight Mission	CCN Samples	Ice nuclei samples
29 Feb	304D	20 2357 (28th) 0339 (29th)	PRT-5 map over city	1 ground sample	
	304D	21 1458-1558	CCN air samples .	1 upwind 1 over 1 downwind	
1 Mar	80P	114 1647-1827	Cirrus sampling to 24,000 ft for Heymsfield Ph.D. research	1 ground sample 1 bag from 23 K	
	304D	22 0952-1045	CCN air samples	1 upwind 1 over city 1 downwind	
2 Mar	80F	115 1055-1151	Cirrus sampling to 17,000 ft for Heymsfield Ph.D. research	1 ground sample	
	304D	23 1101-1209	CCN air samples	1 upwind 1 downwind	
3 Mar	80F	116 0008-0430	Two plane mission for PRT-5 map and sections through nocturnal heat	1 ground sample	51
	304D	24 0003-0335	island		
4 Mar	80F	117 0957-1155	Cirrus sampling to 27,000 ft for Heymsfield Ph.D. research		

Table contd.

Date	Radar Data	Date	Radar Data	Date	Radar Data
4 June	1500-2100 GDT	13 June	0947-1956 CDT	28 June	0936-0002 CDT
5 June	1230-1745 CDT	14 June	1132-1834 CDT	29 June	1307-2003 CDT
8 June	1015-2115 CDT	19 June	1230-2115 CDT	2 July	1215-2119 CDT
9 June	1615-2045 CDT	20 June	1302-1541 CDT	3 July	1854-2220 CDT
12 June	1045-1715 CDT	27 June	1055-2041 CDT	4 July	1006-1929 CDT

- -

Date	Radar Data	Flight No. T. O. and Lndg. times	Flight Mission	CCN Samples	Ice Nuclei samples
7 July	1042-1244	122 1705-1905	Equipment checkout, CCN samples	Upwind 5.5-1.5K Downwind 5.5-1.5K	
8 July	1641-2007	123 1531-1621	CCN samples	1 upwind 7.5-1.5K 1 downwind 7.5-1.5K	
9 July	1242-1610	124 1314-1516	TSTM Precip. Flight downwind of STL; CCN samples	1 upwind 5.5-1.5 1 downwind 5.5-1.5	
10 July	0945-1531	125 1256-1457-	Cu Cong. precip. downwind of STL; CCN samples	1 upwind 5.5-1.5 1 downwind 5.5-1.5	
11 July		126 1608-1725	Sounding and CCN samples	1 upwind 6-1.5 1 downwind 6-1.5	

Table contd.

Date	Radar Data	Flight No. T. O. and Lndg. times	Flight Mission	CCN Samples	Ice Nuclei Samples
13 July	1445-1956				
14 July	1504-1921	127 1456-1632	Aborted cloud sampling flight; CCN samples	1 up 5.5-1.5 1 dn 5.5-1.5	
15 July	0258-1922	128 1602-1717	CCN samples	1 up 3-1.5 1 city 3.2-1.5 1 dn 3-1.5	
16 July		129A 1311-1343	Equip. Checkout in 2 clds. CCN over GRE.	1 over GRE just above cloud tops	
16 July		129B 1502-1653	Sc penetrations around STL; CCN samples	1 up 4.5-1.5 1 dn 4.5-1.5	
17 July	1204-1729	130 1447-1643	Cu, Sc , CB penetrations upwind and downwind STL	1 upwind 1 downwind	
18 July	1300-2101	131 1357-1647	Frontal Cu, CB.		
20 July	1241-2045	132 1402-1658	Metrodata downwind X-section in clouds, aerosols; CCN samples	1 2.5K TOY 333/50 2 2.5K TOY 020/19 3 2.5K TOY 120/26 4-2.5K E of Nashville	
21 July		133 1402-1551	Cessna 172 flight; CCN Samples	1 upwind 5-1.5 1 downwind 5-1.5	
22 July		134 0951-1014	Equipment checkout		
22 July		135 1328-1558	Vertical soundings; CCN Samples	2 upwind 6-1.5 1 unclear 6-1.5	

Table contd.

Date	Radar Data	Flight No. T. O. and Lndg. Times	Flight Mission	CCN Samples	Ice Nuclei Samples
22 July		136 1656-1844	2 Vertical soundings, CCN samples	1 up at +? 1 dn at +? 1 rural dn GRE	
23 July		137 1338-1601	Excellent Cu upwind and down-wind cloud particle flight; CCN samples	1 MTS 090/3 5-1.5 2 I 270 & riv. 5-1.5 3 TOY 100/12 5-1.5	
23 July		138' 1715-1810	CCN samples	3 downwind 1 MTS 085/14 5-1.5 2 TOY 180/4 5-1.5 3 TOY 185/24 5.1-1.5	
24 July		139 14.57-1755	GRE-SPI-GRE Equip. pick up, CCN samples	1 MTS 360/2 5-1.5 2 TOY 240/6 5-1.5 3 Highland 5-1.5	24
25 July		140 1353-1618	Equip check		
27 July	1427-2018				
28 July	1031-1807	141 1501-1610	CCN below drizzle, Fog	1 1.5 TOY 310/20 2 1.5 TOY 226/32 3 1.5 TOY 110/15	
29 July		142 1545-1816	Sc around STL CCN samples	1 STL 036/28 5-1.5 2 1 1/2 SW JB Bridge 5-1.5 3 near GRE 2.5	13
30 July		143 1314-1506	Aerosol Calibration; upwind-downwind Sc cloud particle data; CCN samples	1 dn MTS 127/16 5-1.5 2 up STL 066/14 5-1.5	12
31 July		144 1019-1127	Runway P-Ps calibration		

Table contd.

Date	Radar Data	Flight No. T. O. and Lndg. Times	Flight Mission	CCN Samples	Ice Nuclei Samples
31 July		145 1502-1629	CCN and Millipore filters	1 MTS 020/3 5-1.5 2 TOY 360/2 5-1.5	12
2 Aug	0641-1639	146 1241-1519	CCN samples	1 TOY 238/38.5 4-1.5 2 TOY 238/38.5 4-1.5 3 TOY 302/14 4-1.5 4 TOY 302/14 4-1.5	12
3 Aug	1243-2051	147 1544-1658	Cu and TSTM at 7 K		6
4 Aug		148 1305-1708	Metrodata downwind cross-section, aerosol plumes, repllc thin stratus, formation with WYO & ISWS	1 dn Imp 2.5 1 up "test" TOY 010/22.5 2.5 1 up "test" TOY 025/22 2.5'	
5 Aug		149 1518-1633	CCN samples	1 dn STL 300/10 4-1.5 1 city Forest Park 4-1.5 1 S & up TOY 205/17.5 4-1.5	9
6 Aug	0744-2218	150 1346-1617	Probe checkout, CCN samples	1 up MTS 150/13 4-1.5 1 dn TOY 062/10 4-1.5	6
7 Aug		151 1300-1409	Post frontal Sc . replication and probe data, CCN samples	1 up STL 307/2.4 1.5 1 dn TOY 175/8.2 1.5	
8 Aug		152 0106-0234	Diurnal wave problem, cross-section cross-wind CCN samples	1 TOY 245/39 1.5 1 STL Vor 1.5 1 TOY 305, STL 075 1.5-near Alton Dam	~5
8 Aug		153 0405-0534	Diurnal wave problem, cross-wind cross-section	1 STL 195, TOY 245 1.5 1 TOY 258/25 1.5" 1 STL 075/11.8 1.5	6

Table contd.

Date	Radar Data	Flight No. T. O. and Lndg. Times	Flight Mission	CCN Samples	Ice Nuclei Samples
8 Aug		154 0714-0916	Diurnal wave problem, Soundings, cross-wind and cross-sections	No	7
10 Aug		155 1553-1838	Metrodata downwind cross-section plus diurnal wave 'problem and CCN samples	1 S dn 1/2 E JB Bridge 1.5 1' dn Eads Bridge 1.5 1 N dn TOY 305/14 1.5	7
10 Aug		156 1952-2134	Diurnal wave problem City cross-section and soundings	1 dn 1 E JB Bridge 1.5 1 City TOY 250/18 1.5 1 up Smart Field	8
10 Aug		157 2223-2404	City cross-section and diurnal wave problem	1 1 E JB Bridge 1.5 1 New F. Park TOY 250/20 1.5 1 Smart Field 1.5	
11 Aug	1132-2006	158 1357-1534	Metrodata downwind cross-section abort, CCN samples	1 MTS 180/12 1.5 1 JNC Miss-Mo Riv. 1.5 1 dn TOY 355/13 1.5	8
11 Aug		158B 1707-1739	Eq. checkout	No	
12 Aug	0939-1634	159A 1001-1140	CCN samples	1 GRE 2 1 GRE 1.5 1 GRE 1.0	
12 Aug		159B 1547-1746	Aerosol olume and CCN samples	1 up TOY 230/30 5-1.5 1 City F. Park 5-1.5 1 dn STL 060/11 5-1.5	

Table contd.

Date	Radar Data	Flight No. T. O. and Lndg. Times	Flight Mission	CCN Samples	Ice Nuclei Samples
13 Aug		160 1412-1726	Cumulus cld flight, Rural vs. city penetrations at 12K, 10K; CCN samples	1 dn STL Vortac 5-1.5 1 city Forest Pk. 5-1.5 1 up TOY 195/12 5-1.5	
14 Aug		161 1529-1905	Flyup with ISWS Cu at 19K over STL, CCN samples	1 ? STL 040/11 5-1.5 1 city Forest Pk. 5-1.5 1 ? JB Bridge 5-1.5	
18 Aug	1352-1829				
19 Aug	1338-2056				
20 Aug	1300-2057				
21 Aug	1524-2156				
22 Aug	1119-2128				
24 Aug	1211-1645				
25 Aug	1153-2221				

Instrumentation in University of Chicago Lockheed Lodestar - 9980F

Parameter

Aerosol and nuclei sampling

1. Aerosol spectrometer I
   Open cavity laser scattering probe with pulse-height scaling into eight size classes, each 0. 2 µ m wide. Range - 0. 2 to 1.6 (µ m dia; Sampling cross-section - 0. 2 mm^2 ; Sampling rate - 0. 25 1 min^{-1}

2. Aerosol spectrometer II SASOL
   Open cavity laser scattering probe with pulse-height scaling into 15 size classes, each 0. 1 µ m wide. Range - 0. 1 to 1. 5 µ m dia; Sampling cross-section - 0. 3 mm ; Sampling rate - 0.4 1 min^{-1}

3. Aerosol spectrometer III LASOL
   Open cavity laser scattering probe with pulse-height scaling into 15 size classes, each 0. 1 µ m wide. Range - ' 1 to 15 µ m dia; Sampling cross-section - 1.6 mm^2; Sampling rate - 2.0 1 min^{-1}.

4. Manifold of 24 millipore filters, sequentially exposed upon command and replacement in flight. Sampling volume - 30 1 min^{-1}; Sampling duration - selectable, usually 1-3 mins; Sampling interval - selectable

5. Sampling tube and sampling station
   3 inch dia tube opening ahead of prop-line and well outside boundary layer of plane, leads directly into aft fuselage where samples may be collected. Normal flow through tube ca 150 1 sec" .

Cloud Particle Sampling

1. Cloud scattering probe SCA
   Laser forward scattering probe with pulse-height scaling into 15 size channels each 2 µ m wide. Range - 2 to 30 µ m dia; Sampling cross-section 0. 1 mm2; Sampling rate - 5 to 10 cm^3 sec^{-1}

2. Cloud Array Probe OPA
   Optical array probe with direct read-out into 14 size classes, each 20 µ m wide. Range - 20 to 280 µ m dia; Sampling cross-section increases from 0. 28 mm^2 for 20 µ m particles to 9. 1 mm^2 for 160 µ m particles and decreases to 1. 3 mm^2 for 280 µ m dia particles.

3. Continuous Formvar Replicator
   16 mm transparent tape with precoated Formvar ribbon which is resoftened just prior to exposure. Slit width: 4 mm.

Tape speed - 15 to 30 cm sec"[1] adjustable; Sampling rate - ca 20 cm^3 per meter of flight; Range - ca 3 to 100 µm drops, up to several mm crystals.

Precipitation Particle Sampling	1. Precipitation array probe PPT Optical array probe with direct readout into 15 size clases, each 200 µm wide. Range - 200 µm to 3 mm dia; Sampling cross-section -9.6 cm^2 for 200 µm dia particles decreasing linearly to 4. 7 cm^2 for 3 mm dia particles.
	2. Lead foil sampler - see Note 1. Strip of wide dead-soft lead foil mounted on 80 mesh wire cloth backing exposed to airstream through wide aperture. Range - approximately 200 µm to 4 µm drops and 100 µm to 5 mm graupels; Sampling cross-section 2 cm^2.
	3. Sampling tube and sampling station See item 5 under aerosol sampling. Tube is particularly useful for sampling graupels, snow-pellets and compact crystals.
Liquid Water Content	1. Johnson - Williams heated wire Range - up 6.0 gm m^3. Max range is function of TAS and PA. Response limited to drops dia ≤ ca 30 µm dia; Sampling area - 0. 14 cm^2
	2. Liquid water content is automatically computed from size spectra obtained with scattering and array probes as those data are machine reduced.
	3. Australian paper-tape - see Note 1.
Air Tempera- **ture**	1. Total temperature RSMT Rosemount 102E2AL non-deiced
	2. Reverse Flow III Platinum resistance element, **230** ohm nom. in bridge circuit with range switching
	3. Reverse Flow I Same as above except operational amplifier without range switching.
Air Density	Pace P1 (0-15 psi) variable reluctance sensor close coupled to CD 32 carrier-demodulator with temperature sensor to allow correction for temperature coefficient.
Humidity	1. Cambridge Frostpoint Hygrometer Model 137-C3 with 137-S10 sensor
	2. Wet bulb Platinum element, 230 ohm nom. , in wetted wick

optical radiation	Upward and downward facing, hemispherical viewing pyranometers; Moll-Gorczynski type
Airspeed	Pace P1 (± 2 psi) variable reluctance system
Radar	Bendix RDR 1B-1 , 3-cm, nose mounted, 360 deg. "horizontal" scan, 3. 9 deg. horiz. , 3.9 deg. vert. ; 40 KW Peak Pwr.
Airspeed Attitude	Standard aircraft gyros
Magnetic Heading	C-2, Gyrosyn compass
Position indicators	Dual OMNI with OBI; dual ADF; DME; ATC beacon
Time synchronization	Crystal oscillator, temp. com. $1/10^{8}$, with binary freq. 2^{21}, counted down to hours, minutes and seconds; also used to trigger driving circuits for counters and cameras.
Data recording	1. Multichannel analog and digital magnetic tape system adapted from NCAR ARIS model 2. 2. Oscillograph recorder, Honeywell Visicorder Model 1108. 3. Tape printer. Sample, hold and print system for inflight recovery of particle counts from any one (selectable) of the particle systems, without interfering with normal particle recording in ARIS system. 4. Photobox with 16 mm time-lapse photography of plane's attitude, altitude, airspeed and position. 5. Uher voice-activated magnetic tape recorder for plane's intercom.
Cloud photography	1. 16 mm Flight Research Multidata camera in lapse time model facing forward. 2. Hand held 35 mm cameras
Communications	Dual VHF Collins 51V; Dual UHF Collins 51U; Multicom transceiver for plane to Project radar

Note 1. Available as back-up to particle systems, not normally used.

ILLINOIS STATE WATER SURVEY IN METROMEX

Richard G. Semonin and Stanley A. Changnon, Jr.
Atmospheric Sciences Section

1. Introduction

The interest of the Water Survey in inadvertent weather modification is the outgrowth of many years of climatological research pertinent to the Illinois weather as related to the industrial and agricultural demand for weather information. Stanley A. Changnon, Jr., and Richard G. Semonin are the principal investigators for the Survey research.which is sponsored by the State of Illinois, National Science Foundation, and the U. S. Atomic Energy Commission. The major goals of the Survey reflect the historical interest of the Survey research group in the areas of rainfall, climatology, cloud physics, atmospheric chemistry, and severe weather.

2. Goals

The major research goals of the Water Survey's participation in METROMEX include: 1) the study of severe local weather phenomena in summer so as to describe the temporal-spatial relationships of these events in the St. Louis urban area with special reference to their relationships under varying synoptic weather conditions; 2) the study of raingage and radar data to assess the magnitude and location of urban related precipitation changes with specific reference to time-space analyses of rainfall and synoptic weather analyses ; 3) the study of upper air data with specific reference to the alterations of the boundary layer flow induced by the urban area and the possible effects of this alteration upon storm dynamics; 4) the study of the urban aerosol (both with regard to its size distribution and chemical constitution) with emphasis on its relation to removal processes and its importance to cloud microphysics;

and 5) an atmospheric tracer project involving placement of a tracer chemical into convective storms, and subsequent analysis to determine the temporal and spatial distribution of the tracer at the surface following its interaction with the precipitation process.

The overriding goal of the Water Survey research is to study, understand, and evaluate the urban-induced rainfall increases with respect to the quality and quantity of the water resources of the State of Illinois. As a specific example, the primary ground-water supply area for the urban-industrial complex in Illinois east of St. Louis is located where the rainfall increases have occurred, and this ground-water area depends heavily. upon rainfall recharge.

3. Facilities

All of the facilities and instrumentation utilized in the 1971 operations (and described in the 1971 Metromex Operational Report) were utilized in 1972. Moreover, there was a broadening of our goals and an increase in effort, personnel, and facilities. The broadening of the Water Survey goals to include the air motion studies of Dr. Bernice Ackerman, and the aerosol chemistry studies of Dr. Donald Gatz necessitated the addition of new equipment and facilities. The results from the 1971 experimental season also demonstrated that the basic research circle should be expanded to the east and northeast, and that the existing circular (52-mile diameter) network of raingages, hail indicators, and hygrothermographs should be supplemented with more equipment. The preliminary chemistry analyses also dictated that a larger network of rainwater samplers would be necessary to better define the areal extent of the tracer chemical deposition.

Research Area Expansion. The raingage and hailpad network was extended in the downwind area from St. Louis to include an additional 1700 square miles with one gage per 81 square miles. The gage separation in the extension of the research circle averages 9 miles which is three times the distance between gages in the original 2200 square mile circular area centered in St. Louis (see Fig. 1). This enlarged network was desired to permit the delineation of the rainfall and any possible alterations in the more distant downwind areas of St. Louis. This facility also allows a better definition of the storm intensity at the boundaries of the 1971 circular network.

Raindrop Size and Charge Measurement. In addition to the 2 raindrop spectrometers that were installed in 1971, 6 units were designed and built at the Water Survey, and were then incorporated in the network for 1972. The data recording system is composed of a stereo cassette recorder with a capability of operating unattended for up to 18 hours of continuous rain. These instruments were distributed in the network as shown in Fig. 2. Two of the locations also were used to obtain the charge of individual raindrops on the second channel of the stereo system.

Chemical Sampling. The total rainwater collector network was expanded from the 60 sites in 1971 to the present 81 locations shown in Fig. 3. The additional collectors were placed both upwind and downwind of the 1971 network in order to provide an increased coverage of urban and rural areas.

A substantial increase in Water Survey 1972 operations was the inclusion of a program of washout ratio(*) measurements. The net effect of this program on the over-all METROMEX operations was small, however, because the effort was largely a continuation of that begun in 1971 METROMEX by Argonne National Laboratory. The main features of the work remained essentially the same in 1972 with one exception: collection of filter samples aloft using U. S. Air Force RB-57C aircraft was not a part of the 1972 operations. All

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(*) The washout ratio is the ratio of the concentration of a substance in precipitation (μg/g), to that in air (μg/g).

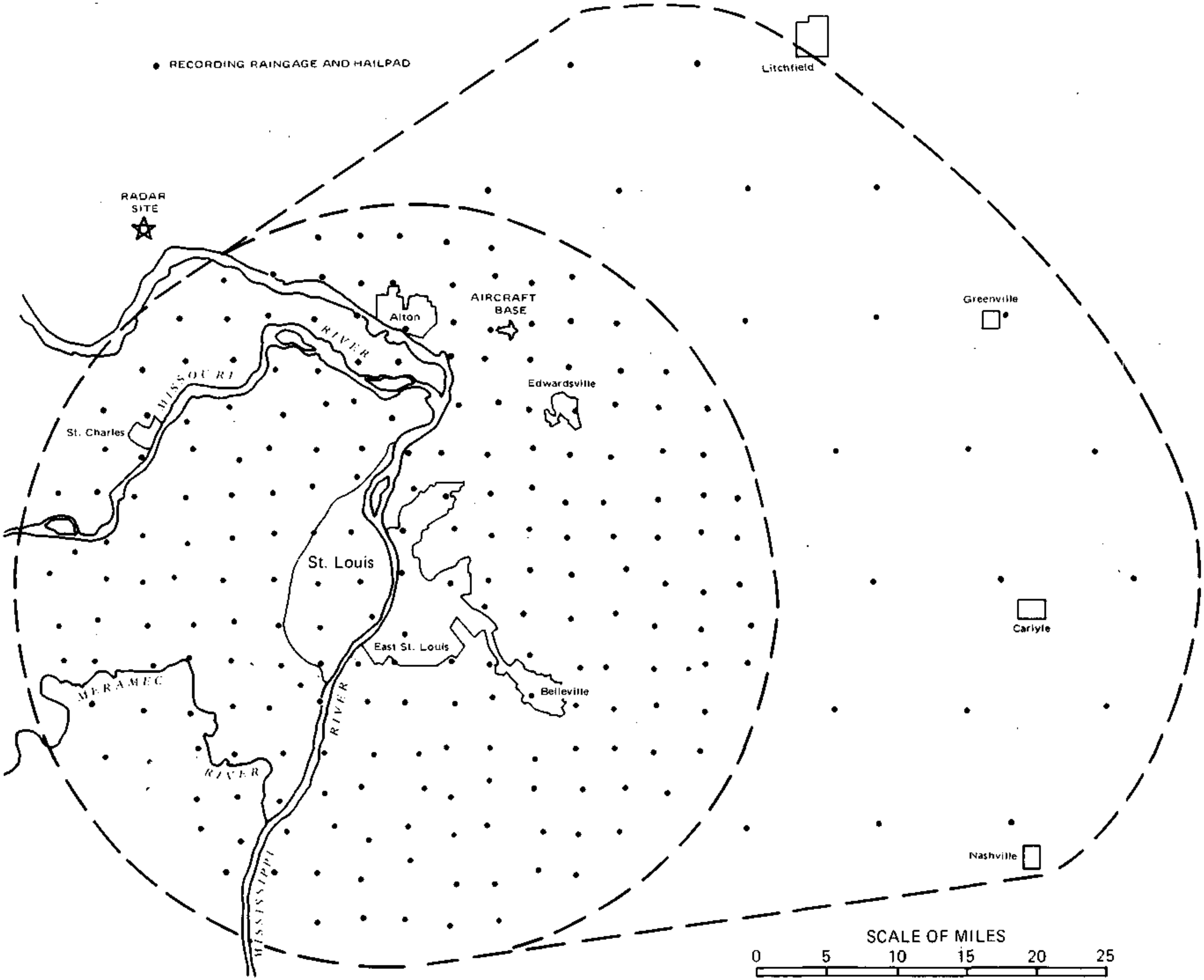

Figure 1. Expanded METROMEX-1972 recording raingage network

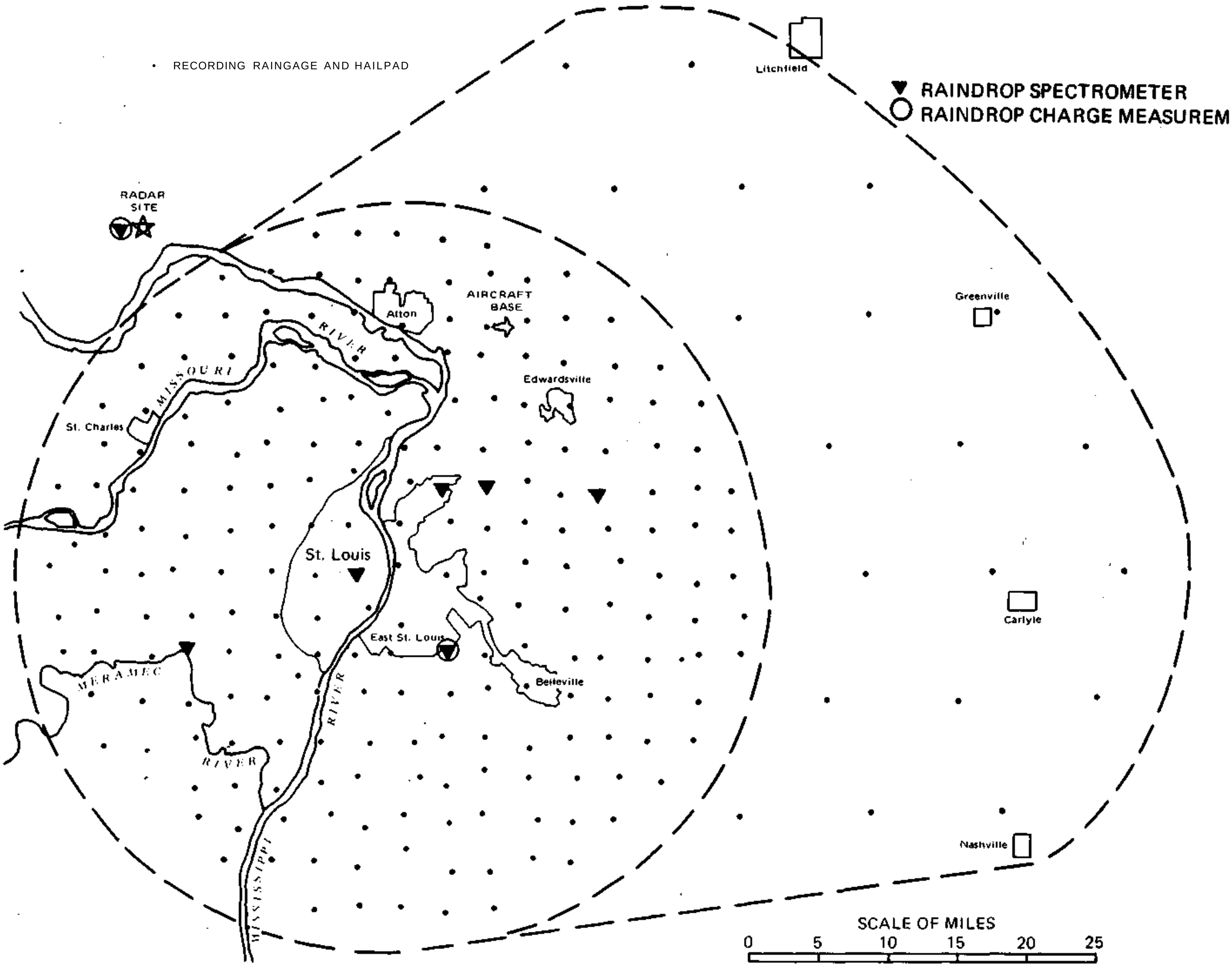

Figure 2. Raindrop size and charge instrument network

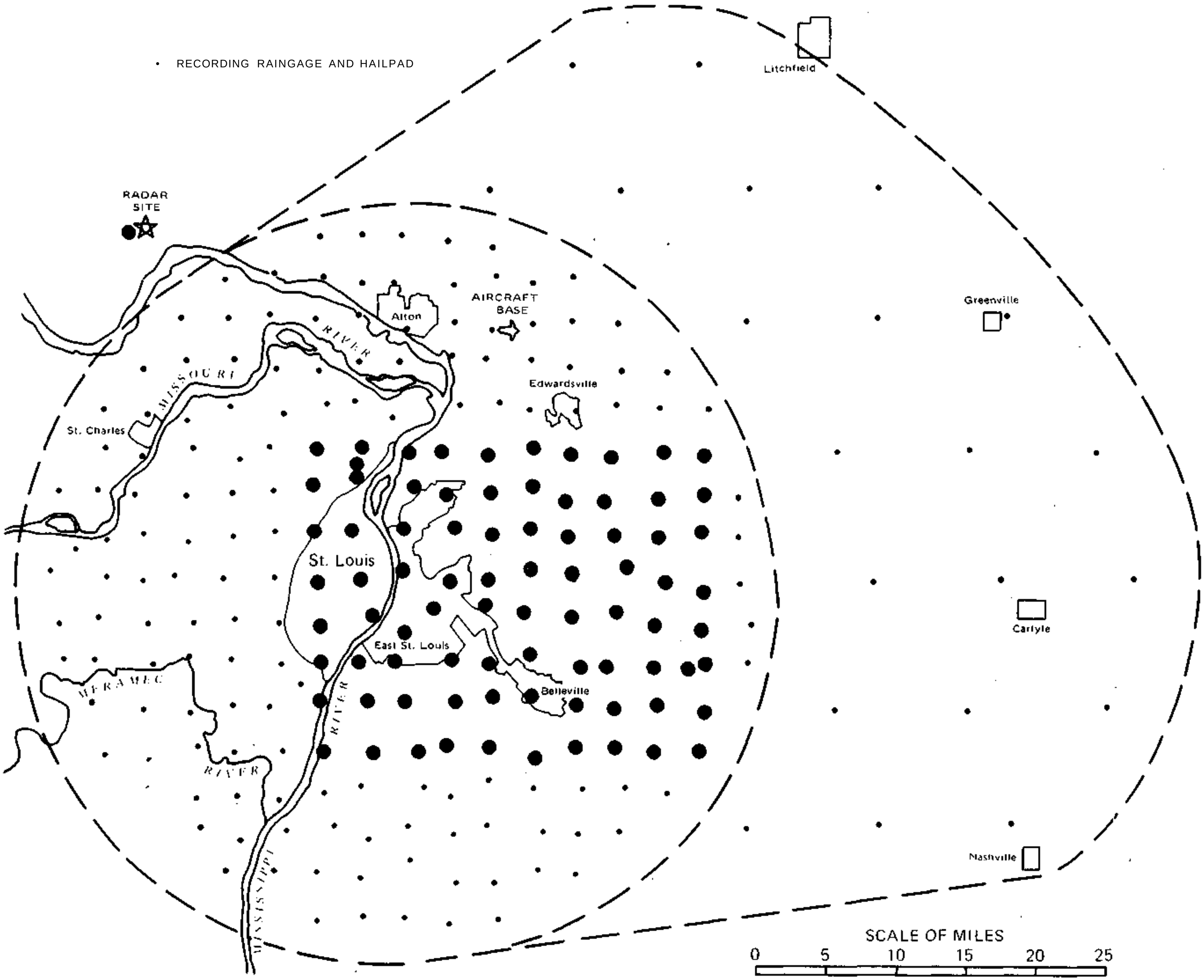

Figure 3. The expanded total rainwater sampling network

other sampling instrumentation was retained in 1972, and a high-volume (20 cfm) 5-stage Andersen impactor was added.

Two of the sampling sites used in 1971 (Tyson and Coldwater Creek) were not used in 1972. A high-volume filter sampler and a sequential rain sampler were added to the Centreville site in 1972. The locations of this 1972 chemical sampling equipment is shown in Fig. 4.

These samplers were supplemented by 2 wet-dry samplers provided to the project by the AEC Health and Safety Laboratory through the courtesy of Dr. H. Volchok. The air sampling equipment and the sequential rain samplers were loaned to this project by Argonne National Laboratory through the kind assistance of Dr. H. Moses.

All of this instrumentation is used to complement the AEC-sponsored tracer and precipitation scavenging work.

Hygrothermograph Network. The 7 station network in 1971 was found to be inadequate for mesoscale weather analyses. Therefore, it was expanded to 26 sites in 1972 with the continuous measurement of temperature and relative humidity at each site. The complement of instruments was composed of 4 units from the Environmental Protection Agency, 3 from Argonne National Laboratory, 1 from the National Center for Atmospheric Research, and 18 from the Water Survey.

These were installed to supplement the existing network of stations employed by the Illinois EPA and the St. Louis County Air Pollution Network. The location of the 1972 METROMEX network of hygrothermograph instruments is shown in Fig. 5.

Upper Air Observations. The 1972 project involving boundary layer measurements was an extension of the 1971 airflow program carried out by Argonne National Laboratory. The primary changes from 1972 were the addition of three

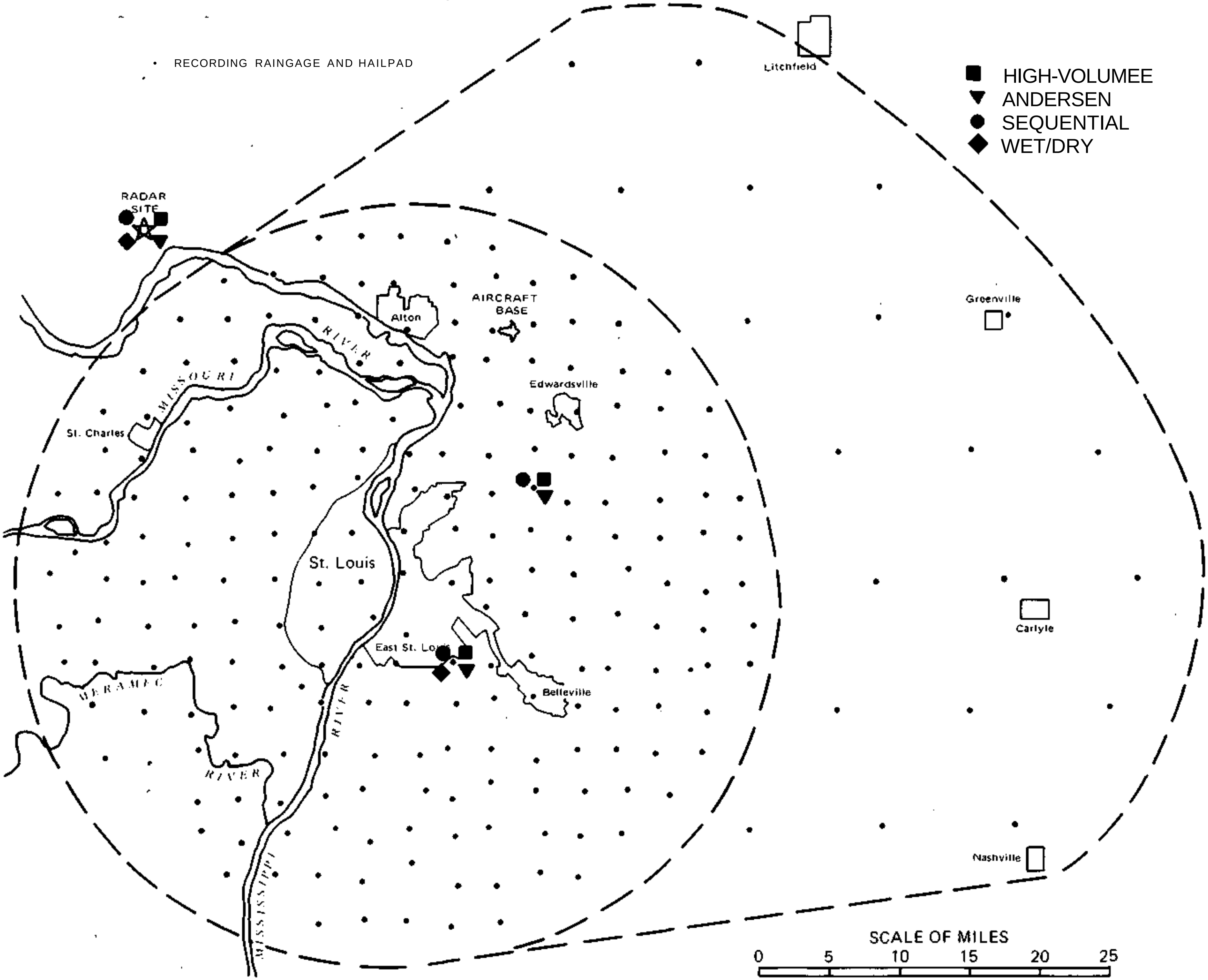

Figure 4. Aerosol and sequential rainwater sampling locations for washout ratio determinations

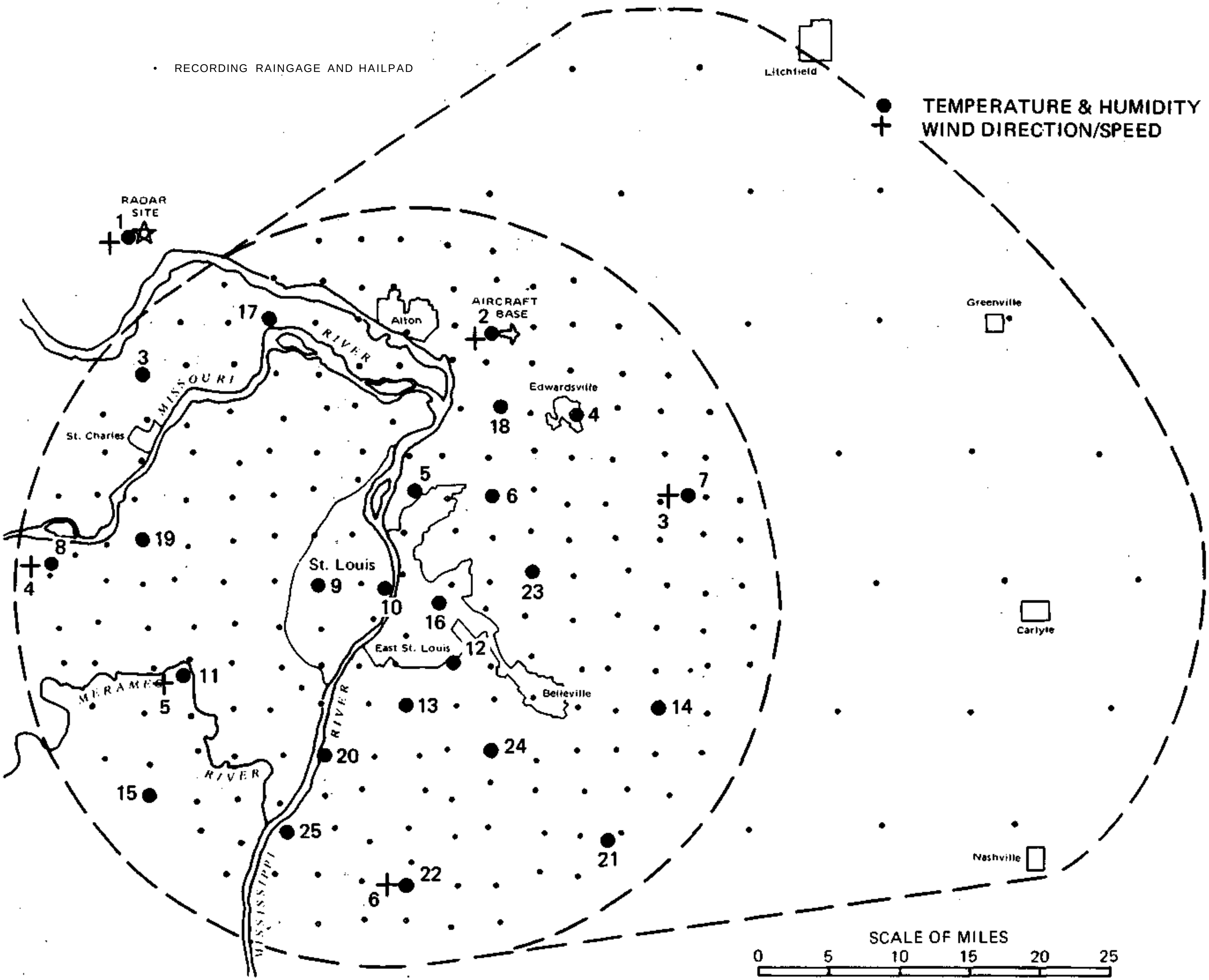

Figure 5. Hygrothermograph and wind instrument locations - 1972

radiosonde stations to the pibal network and a minor reduction in the number of pibal stations.

The locations of the pibal and radiosonde stations are shown in Fig. 6. The radiosonde stations, located at Monsanto Research Park (1), St. Louis University (2) and Scott AFB (3) provided data enabling development of cross-sections across the study area. As in 1971, a variable array of seven to eight pibal stations was used, depending on the objective of the day's operation. Field measurements were made on eighteen occasions between July 17 and August 10.

There were three main types of operations depending on the weather and the Metromex experiment to be supported. These, listed in order of priority, were as follows.

A. Convective Shower and Tracer Experiments

This operation was designed to support the Survey's tracer experiments. The objective was to provide low-level wind data for trajectory analysis and temperature-moisture profiles for determining the boundary layer stability and the evolution of the thermodynamic structure as cloud systems developed and moved through the urban area.

Number of operations: 6, on tracer release and convective shower days.

Time: Approximately 1400-1900

Observations:

7 sites: Double theodolite pibals at 1/2 hour intervals, tracked to 3500 m.

3 sites: Radiosondes with single theodolite tracking of balloon at 1 hour intervals. Radiosondes were tracked to about 600 mb, with one per day from site 2 tracked to tropopause. Five to six releases scheduled from each site, with one fewer from central city (Site 2).

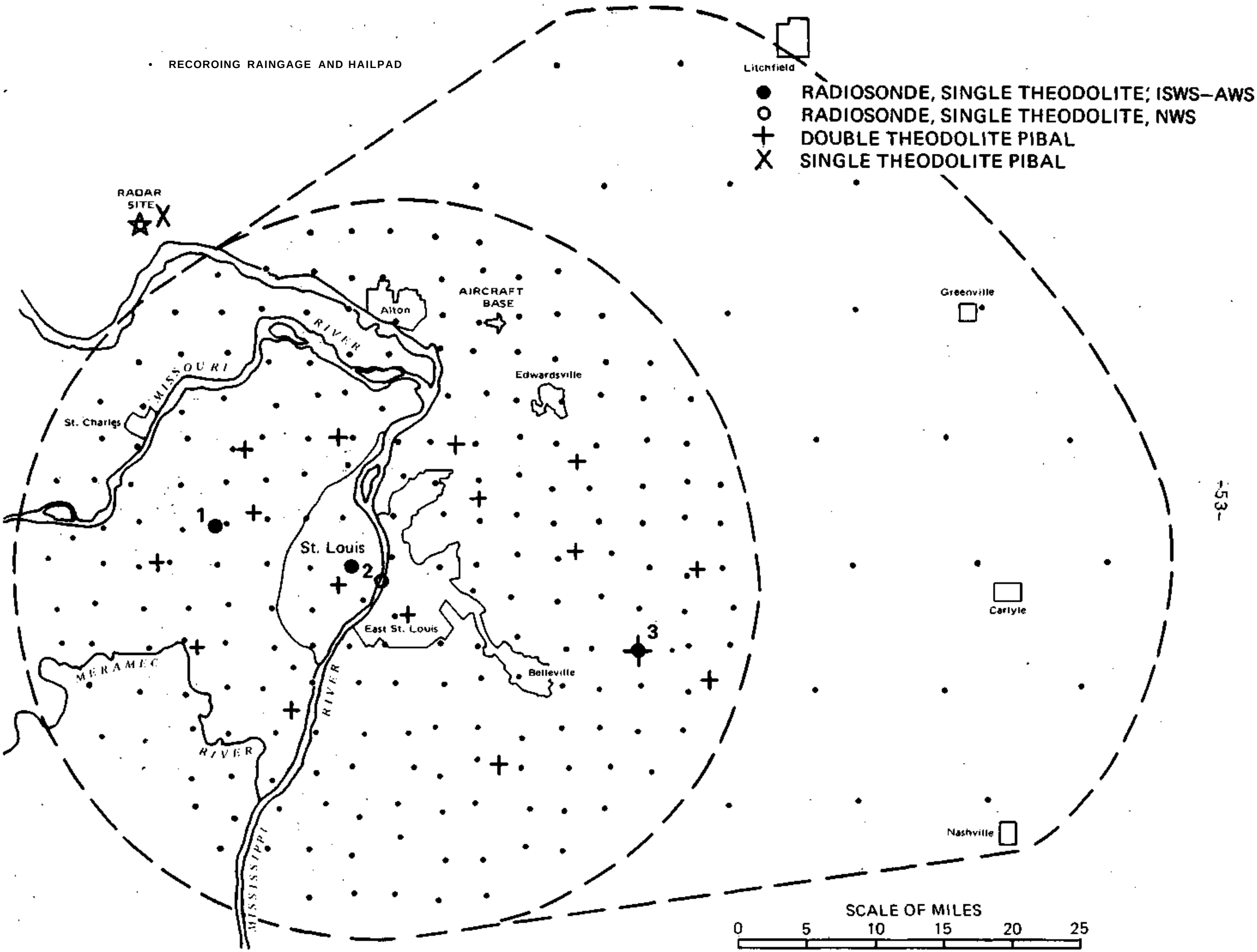

Figure 6. Upper air observation network for METROMEX-1972

Site Array: Selected to maximize data for trajectory analysis over the rainwater sampling area.

B. Nighttime Urban Circulation

Airflow measurements made in 1971 indicate that the urban effect may be more extensive than originally anticipated. Wind observations were made on an expanded array this year with coordinated radiosonde ascents from three sites.

Number of operations: 5 nights. Weather conditions - light ambient winds, clear or minor cloud cover.

Time: 2140-0100. (one experiment 2340-0300).

Observations:

7 to 9 sites: Double theodolite pibals at 20-min intervals, tracked to about 2 km.

3 sites: Radiosondes at 1 1/2 to 2 hour intervals, tracked to about 600 mb. Two or three releases scheduled from each site.

Site Array: Selected to permit detection of inflow (outflow)from city and calculation of divergence for city and country areas.

C. Urban Plume (Metrodata Days)

These operations were during the day when no convective showers were present. As it turned out, all scheduled Metrodata days fell on days suitable for this experiment. The objective was to determine streamlines and trajectories over the metropolitan area in support of the plume tracing by the Metromex aircraft.

Number of operations: 4

Time: Approximately 1220-1530 or 1400-1700.

Observations:

<u>7 or 8 sites</u>: Double theodolite pibals at 20 minute intervals, tracked to about 2 km.

<u>2 or 3 sites</u>: One radiosonde release at each site, tracked to burst. During operations scheduled 1220T1530, no release at site 2 - the EMSU sounding serves as central point on cross-section.

<u>Site Array</u>: Sites lined up along the wind, across the metropolitan area.

Once again the Air Weather Service provided the personnel and equipment for the observations and the Atomic Energy Commission provided the support for expendables and miscellaneous expenses.

<u>Radar Data Collection</u>. In addition to the digitization of the FPS-18 (PPI) radar data, that from the TPS-10 (RHI) was also recorded digitally during 1972. This type of data recording was desired to aid the analysis of the radar data. It is anticipated that most of the magnetic tapes acquired during the past summer will be processed at the NCAR computer center where the digital data will be retrieved in the form of contoured plots of echo intensity.

4. Water Survey Operations Calendar

The record of equipment operations and data availability is shown in Fig. 7. A solid, slashed, or dashed line indicates the continuous collection of data for the calendar period indicated. In the case of the chemistry, the vertical bar indicates the termination of an individual sample or the beginning of a new one. Solid circles represent specific operations or data collection within a 24-hour period, and a star in the aircraft category shows the dates of tracer release. The numbers associated with the raindrop spectrometers, hygrothermographs,

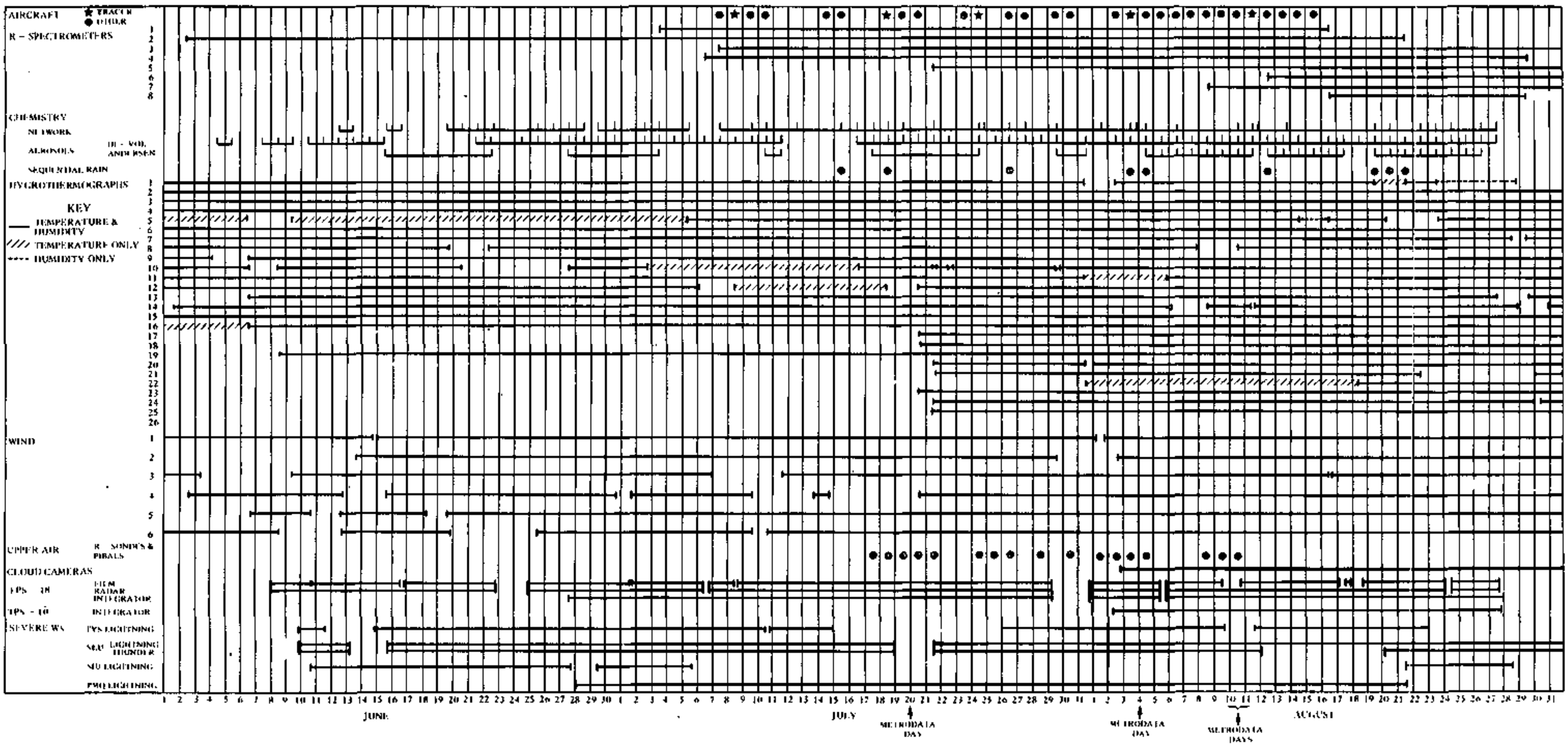

Figure 7. Calendar of Water Survey field operations for Metromex 1972.

and wind instruments refer to the locations shown in Figs. 2 and 5, respectively.

The Metrodata Days are indicated at the bottom of the Fig. 7. These were days on which all participating groups attempted to collect simultaneous data to better describe the atmosphere on space and time. This was as a priority over each group's individual research goals.

As in the previous summer experiments, the raingage network and hailpad network were operated continuously throughout the 3-month period. The enlargement of the research area to encompass 21 additional raingages and hailpads to the east and northeast of the research circle is described in another section of this report.

Routine hourly weather observations were taken at the Pere Marquette (PMQ) field headquarters during the entire summer. A Gardner condensation nucleus counter was also used at PMQ to obtain hourly measurements.

1. Illinois State Water Survey Publications and Releases Concerning Metromex

Changnon, S. A. Jr., 1971: The 1971 Operational Report for Metromex. Illinois State Water Survey, Urbana, 93 pp.

Changnon, S. A., 1972: Field study of urban effects on precipitation and severe weather at St. Louis. Annual Report NSF GA-28189X, I11. State Water Survey, 20 pp.

Semonirt, R. G., 1972: Study of rainout of radioactivity in Illinois. 11th Interim Progress Report to AEC, AT(11-1)-1199, I11. State Water Survey, Urbana, 11 pp.

1972 Published Papers

*Ackerman, B., 1972: Winds in the Ekman layer over St. Louis, Preprints Conf. on Urban Environments, AMS, Boston, 22-27.

*Beebe, R. C, and G. M. Morgan, 1972: Synoptic analyses of summer rainfall periods exhibiting urban effects. Preprints Conf. on Urban Environments, AMS, Boston, 173-176.

*Changnon, S. A., 1972: Urban effects on thunderstorm and hailstorm frequencies. Preprints Conf. on Urban Environment, AMS, Boston, 177-184.

Changnon, S. A., 1972: Can Weather Modification Usefully Augment the Water Resources of the Humid Midwestern United States? Proceedings International Symposium on Water Resources Planning, Int. Assoc. Hydrological Sciences, Mexico City, 32 pp.

"Changnon, S. A., 1972: Inadvertent weather and precipitation modification by urbanization. Journal Irrigation £ Drainage Div., ASCE, 12 pp.

*These publications were also presented orally at a conference.

*Changnon, S. A., R. G. Semonin, and W. P. Lowry, 1972: Results of Metromex. Preprints Conf. on Urban Environments, AMS, Boston, 191-197.

*Gatz, D. F., 1972: Washout ratios in urban and non-urban areas, Preprints Conf. on Urban Environments, AMS, Boston, 124-128.

Huff, F. A., and S. A. Changnon, 1972: Climatological assessment of urban effects on precipitation at St. Louis. J. Appl. Meteoro., 11, 823-842.

*Schickedanz, P. T., 1972: The raincell approach to the evaluation of rain modification experiments. Preprints 3rd Conf. on Wea. Mod., AMS, Boston, 88-95.

"Semonin, R. G., 1972: Tracer chemical experiments in midwest convective clouds. Preprints 3rd Conf. on Wea. Mod., AMS, Boston, 83-87.

1972 Oral Presentations

Ackerman, B., "Boundary Layer Studies at St. Louis." Invited Talk presented to the Greater St. Louis Chapter of American Meteorological Society, March 1972.

Cataneo, R., "Effects of Large Urban Areas Upon Weather." University of Illinois Graduate Student Seminar, April 1972.

Changnon, S. A., "Water Survey's Metromex Program." Invited Talk presented to the Greater St. Louis Chapter of American Meteorological Society, May 1972.

Changnon, S. A., "Inadvertent Weather and Precipitation Modification and Hydrologic Implications." Invited Paper presented at ASCE Water Resources Conference, January 1972, Atlanta, Ga.

Changnon, S. A., "Planned and Inadvertent Rain Enhancement in Illinois." Talk presented to Directors of Soil and Water Conservation Districts in Southern Illinois at Mt. Vernon, Illinois, March 1972.

Changnon, S. A., "Urban Effects on Weather." Invited Lecture for Fluid Mechanics Summer Program at Colorado State University, July 1972, Ft. Collins, Colo.

Changnon, S. A., "Metromex and the Survey's Atmospheric Science Program." Talk presented to State Board of Natural Resources at Pere Marquette Park, May 1972.

Changnon, S. A., and F. A. Huff, "Hydrologic Implications of Inadvertent Precipitation Modification." Invited Paper presented at 1972 Annual Meeting of American Geophysical Union in April, Washington, D. C.

Changnon, S. A., and R. G. Semonin, "Metromex and the Water Survey." A joint presentation at a Seminar for the Illinois State Water Survey staff, May 1972.

Changnon, S. A., and R. G. Semonin, "A Description of the Goals and Activities of Metromex." Joint talk given at the Chemist-Meteorologist Workshop, January 1972.

Huff, F. A., "Urban Effects on Rainfall." Invited Paper presented at meeting of New Mexico Section of ASCE, Santa Fe, October 1972.

Huff, F. A., "Results of Our Studies of Urban Effects on Rainfall." Seminar for staff of the Illinois State Water Survey, November 1972.

Jones, D. M. A., "Metromex and Its Influence on You." Invited Talk to Eastern Illinois Section of Highway Engineers, Paris, Illinois, November 1972.

Semonin, R. G., "Description of Metromex." Presented to Interdepartmental Committee on Atmospheric Sciences in Washington, June 1972.

Semonin, R. G., "Trace Metals in Rainwater." Paper presented at 1972 Annual Meeting of A.G.U. in April, Washington, D. C.

Semonin, R. G., "Rain Scavenging." Lead Project Seminar, University of Illinois, January 1972.

Semonin, R. G., and S. A. Changnon, "The Water Survey's Goals, Instrumentation, and Findings for Metromex." Joint talk given at St. Louis planning meeting at EPA in Research Triangle, North Carolina, April 1972.

Staff (Changnon, Semonin, Cataneo, Jones), "Results from 1972 Metromex-Water Survey Reports." A series of talks presented at St. Louis Air Pollution Studies Meeting in St. Louis, November 1972.

Wilson, J. W., "La Porte and Metromex - Two Studies of Inadvertent Weather Modification." Seminar at Northeastern Illinois University of Chicago, February 1972.

1972 Releases to News Media

Two Metromex-related 5-minute radio tapes were made by Changnon. One for the Illinois Agricultural Association in March 1972 for distribution and playing on their statewide radio programs. A second was made for WILL radio (University of Illinois) in September 1972. This tape was distributed to 21 stations for use in the series "Your University Reports."

Changnon was involved in three television programs concerning discussions of Metromex. The first was in St. Louis (December 1971) and was a 5-minute live interview. A second was a video-tape interview (5 minutes) done by the Illinois Agricultural Association for distribution and presentation on 6 stations. Finally, Metromex was discussed on a "talk show" on ABC-TV in Chicago in September.

SRI OPERATIONAL REPORT

Edward E. Uthe

The SRI 1972 METROMEX program is designed to improve our understanding of the interactions between the concentration and behavior of particulate, cloud, and precipitation elements and atmospheric processes important to climatic modification by urban areas.

The SRI field program extended from 7 through 25 August; The experimental elements are shown in Figure 1. The primary data-gathering instrument was the SRI Mark IX mobile lidar system shown in Figure 2. The lidar was used to derive intensity-modulated displays of the vertical aerosol structure similar in format to the example presented in the 1971 operational report (also see Uthe, 1972A; Collis and Uthe, 1972). Unfortunately, the lidar was not operating in a mobile configuration and, therefore, the downwind structure of the urban plume was not mapped as well as was planned. A summary of the lidar data collection is given in Table 1. A limited supply of an interim report that presents all the lidar data collected is available (Uthe, 1972B).

In addition to the lidar observations of aerosol structure, other data were collected (Figure 1) that greatly aid the study of atmospheric processes related to the development of precipitation and severe weather. In particular, supplementary data were collected to:

- Extend the lidar observations in a quantitative sense.
- Derive or verify relationships governing the interaction of urban aerosols with the transfer of solar and terrestrial radiation (and resulting surface and atmospheric heating).

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*This program is funded by the National Science Foundation, Environmental Systems and Resources, Weather Modification Program under NSF Grant GI-34770.

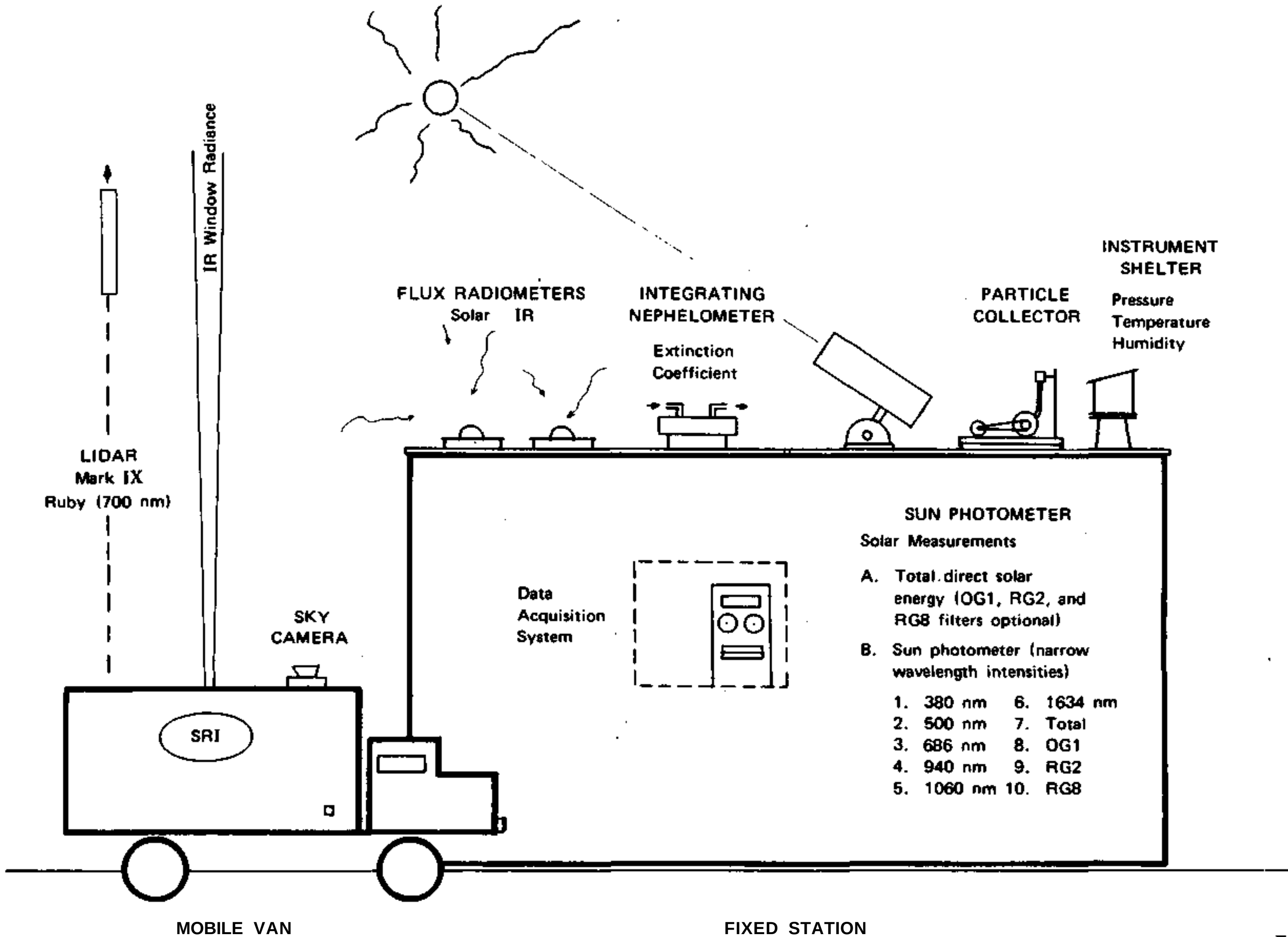
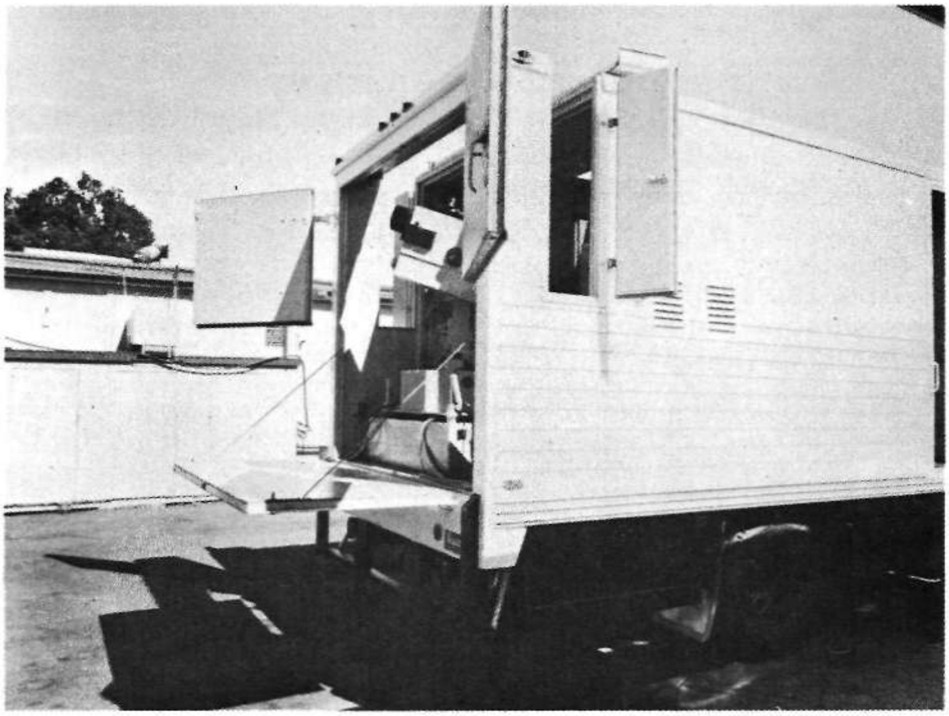
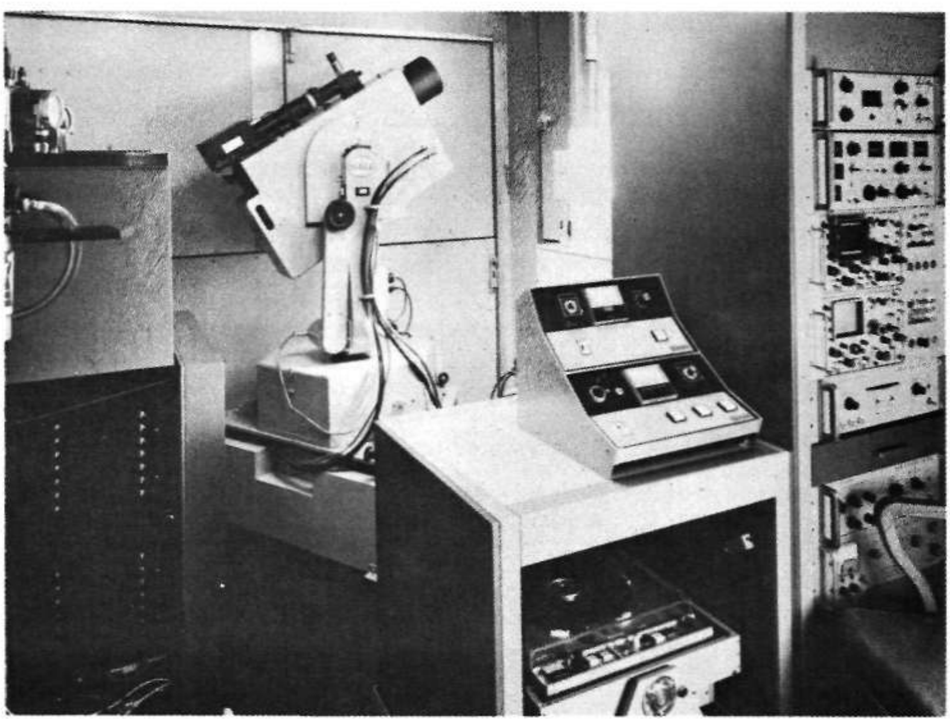


FIGURE 1 METROMEX 1972 RADIATION/AEROSOL EXPERIMENT



(a) MARK IX LIDAR VAN



(b) MARK IX LIDAR AND ASSOCIATED RECORDING AND DISPLAY ELECTRONICS **SA-1976-1**

FIGURE 2 THE SRI MARK IX LIDAR SYSTEM

Table 1

MARK IX DATA SUMMARY—ST. LOUIS 1972

Date	Time	No. of Shots	Rate (pulses/min)	Location
Aug. 7	0708 - 1313 1440 - 1533	1020	3	Granite City Army Depot
	2315 - 0247 (8 Aug)	560	3	St. Louis University
Aug. 8	0700 - 1328	410	3	Granite City Army Depot
Aug. 9	0602 - 1833 1935 - 2028	2240	3	Granite City Army Depot
	2209 - 2302 0125 - 0133 (10 Aug)	160	20	Granite City Army Depot
Aug. 10	0700 - 1420	1120	3	Granite City Army Depot
	1635 - 2213	800	3	Granite City Army Depot
Aug. 11	0648 - 1734	2080	3	Granite City Army Depot
	2306 - 2352	240	3	Granite City Army Depot
Aug. 14	0704 - 2320	3040	3	Granite City Army Depot
Aug. 15	0655 - 1837	1920	3	Granite City Army Depot
Aug. 16	0700 - 1520	1440	3	Granite City Army Depot
Aug. 17	0038 - 1755	2800	3	Granite City Army Depot
Aug. 18	0648 - 1925	1920	3	Granite City Army Depot
Aug. 19	1608 - 2339	1920	5	Granite City Army Depot
Aug. 20	0847 - 2204	2080	3	Granite City Army Depot
Aug. 21	2347 - 1549 (20 Aug)	3200	3	Granite City Army Depot
	1639 - 1648	118	10	Granite City Army Depot
	1713 - 1745	160	5	Granite City Army Depot
	1801 - 1823	250	10	Granite City Army Depot
	(Note - receiver gain reduced 4 dB at 1812)			
	1835 - 1910	320	10	Granite City Army Depot
	1910 - 2139	480	3	Granite City Army Depot

Table 1 (Concluded)

Date	Time	No. of Shots	Rate (pulses/min)	Location
Aug. 22	0935 - 2300	4180	5	Granite City Army Depot
Aug. 23	1135 - 2110	2400	5	Granite City Army Depot
Aug. 24	0825 - 1004	320	5	Granite City Army Depot
	1128 - 1233	320	5	Monsanto Plant (Lindberg and Olive Blvd.)
	1245 - 1309	2	5	U.S. 244 and Olive
	1331 - 1339	160	20	Blvd.
	1440 - 1723	640	5	Granite City Army Depot
Aug. 25	0202 - 0826		3	Granite City Army Depot
	0827 - 1500	1600	5	Granite City Army Depot

- Investigate urban effects on thermal stability and convection.

The fixed-station data recording was conducted at a site where the Argonne National Laboratories were recording the surface wind and the vertical atmospheric structure by using an acoustic sounder and radiosonde probes. A complementary SRI program was also being conducted during this period (9, 11, and 14 August) to investigate the role of surface geophysical characteristics in determining urban-rural differences in the surface energy budget. As a part of this study, aircraft observations of: (1) ambient wet- and dry-bulb temperatures, (2) downwelling and upwelling solar radiation, (3) surface radiative temperature, and (4) panchromatic surface photographs were made at two-to-three-hour intervals.

The supplementary data were collected by using a digital data-acquisition system to sample each sensor at one-minute intervals during the complete experimental period. This continuous record of data was recorded on magnetic tape for rapid computer processing and display. Figure 3 presents an example of a computer generated time plot of various supplementary data for 14 August. The mixing-layer depth as derived from the lidar observations has been included.

Although a quantitative cause and effect analysis has not been performed on these data, several interesting features are readily apparent. For example, an increase in the diffuse component of the solar flux occurs at the time of increased mixing-layer depth. The ratio of direct-to-diffuse solar energy is less in the afternoon hours than in the morning hours, indicating a greater afternoon aerosol density or an aerosol layer extending to greater heights. We plan to relate this ratio to the total aerosol concentration and vertical distribution as inferred from the lidar backscatter signatures. The near-surface aerosol content (scattering coefficient) shows a decrease from 0800 to 1000 CDT corresponding to an increase in the wet bulb depression (dry minus wet bulb temperatures), indicating a decrease of hygroscopic particle size (to be verified from inferences of particle size by using the solar spectral measurements). The aerosol density increases from 1000 to 1200 CDT as the mixing depth remains constant. A gradual decrease in near-surface aerosol density (1200-1400 CDT) accompanies the rapid rise in mixing depth. From 1600

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*Dabberdt, W. F. and P. A. Davis: Geophysical Characteristics and Energy Budget of the Urban Surface, EPA Contract No. 68-02-1015 (1972).

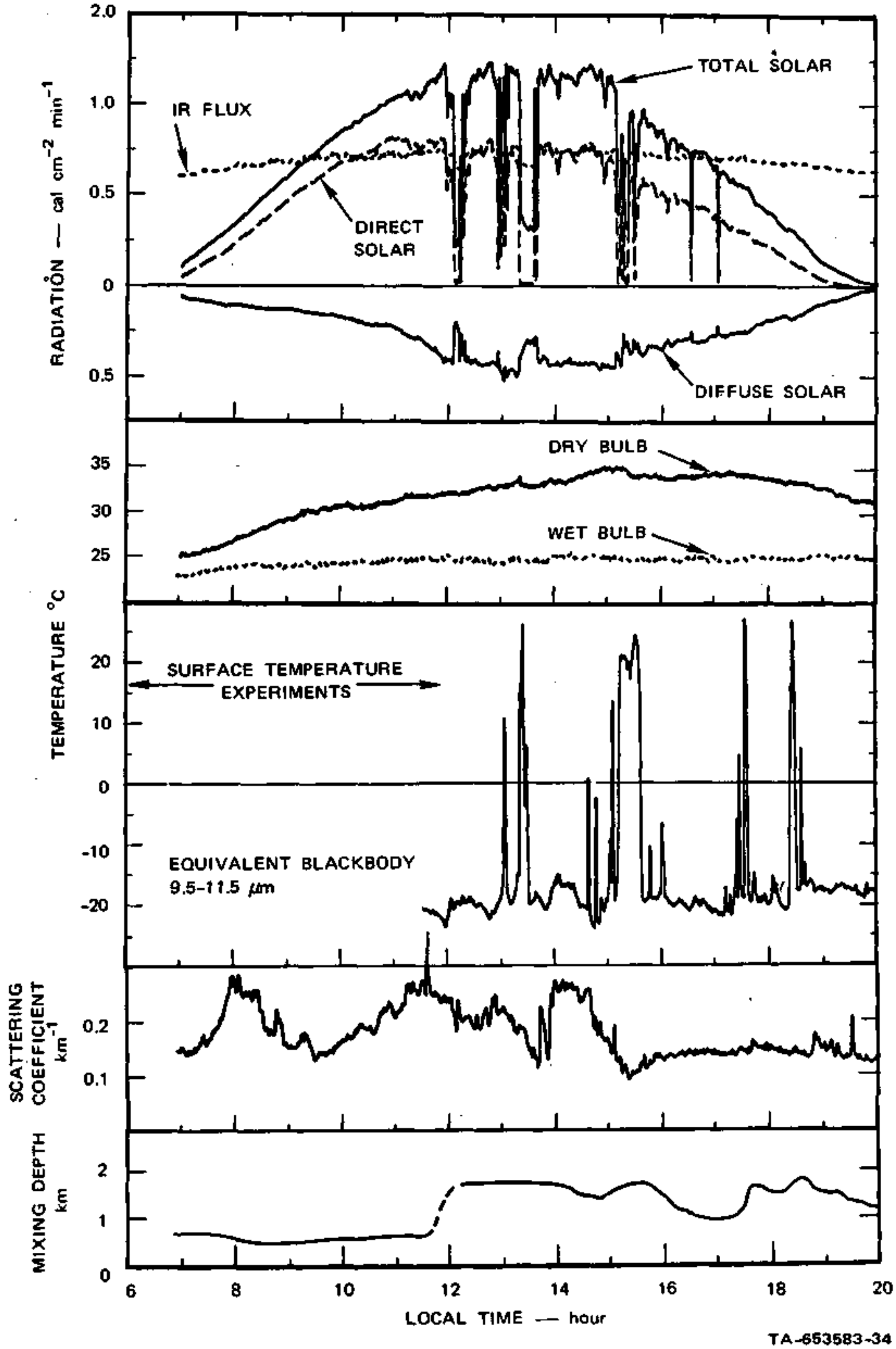

FIGURE 3 METEOROLOGICAL, RADIATIVE AND AEROSOL PARAMETERS OBSERVED DURING 14 AUGUST 1972

to 2000 CDT the near-surface aerosol is constant (and does not show an increase at the time of the expected traffic peak near 1700 CDT) at its lowest concentration during the day, although the diffused solar energy is at its greatest intensity. (This implies an aerosol layer extending to greater heights—verified from the lidar observations.) The equivalent blackbody temperature (9.5- to 11.5-μm wavelength) at times when clouds were absent within the radiometer field of view «-15° C) seems to be well correlated with the near-surface aerosol content. Unfortunately, at the time of the mixing-depth rise, the radiometer was being used to investigate surface temperature (pointed downward). The effective cloud base temperature of the clouds' that totally obscured the direct sunlight was in excess of 20° C. The opaque cloud at 1100 CDT was observed to be developing over a highly industrialized area, and pollutants from a complex of stacks were observed to enter the cloud base (this was recorded photographically but is not presented here).

A preliminary analysis has been performed on the multiwavelength solar intensity measurements from 0700-1100 CDT on 14 August; the results are presented in Figures 4 and 5. The intensity (I) in each spectral interval (λ) during this time period (t) can be represented by the expression:

$$Kt,\lambda) = I_o (\lambda)\exp[-u(t,\lambda)\ m(t)] \quad ,$$

where I_o is the light intensity at the top of the atmosphere, u is the optical depth along a vertical ray path, and m(t) (the optical airmass) is the ratio of the optical depth along a ray path from the sun to the vertical optical depth. It can easily be shown that, if observed $\ell n I$ is plotted as a function of computed m for a time period of constant optical depth, a straight line is obtained with a slope of -u and an intercept of $\ell n I_o$ (the value observed at the top of the atmosphere). Hence the instrument is calibrated for optical depth evaluation at times of varying atmospheric densities. This analysis of the sunphotometer data, as well as of the Epply pyrheliometer data, is shown in Figure 4. Since the pryheliometer had been calibrated by Epply standards, and since the total solar intensity at the top of the atmosphere is well known (i.e., the intercept is known), the validity of the assumption of a constant optical depth during the 0700-1100 time period (required for calibrating the sunphotometer) can be evaluated from the actual intercept. This technique indicates that the wavelength-integrated vertical optical depth was increasing over this time period.

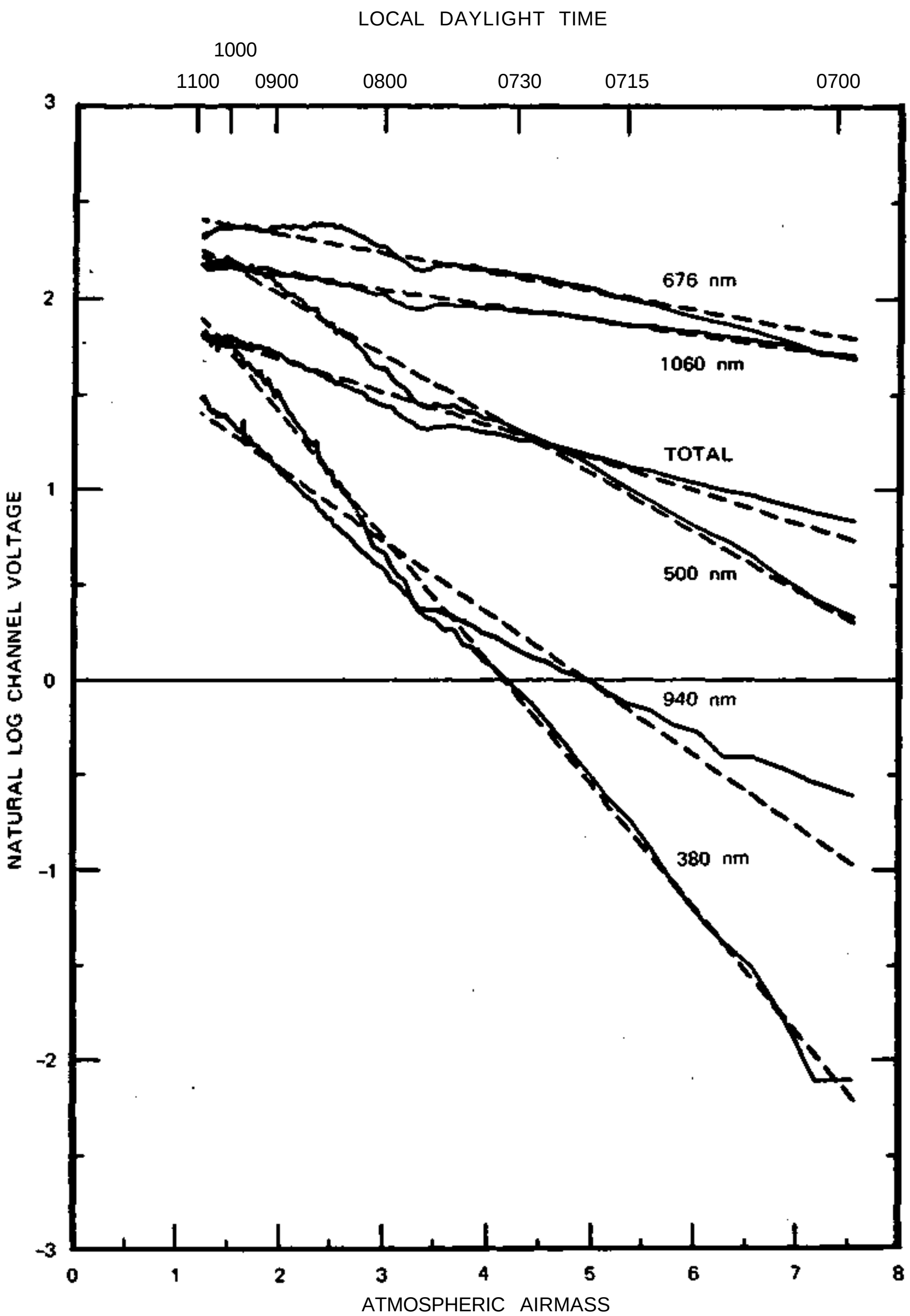

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FIGURE 4 CALIBRATION PLOT FOR SUNPHOTOMETER DATA—14 AUGUST 1972

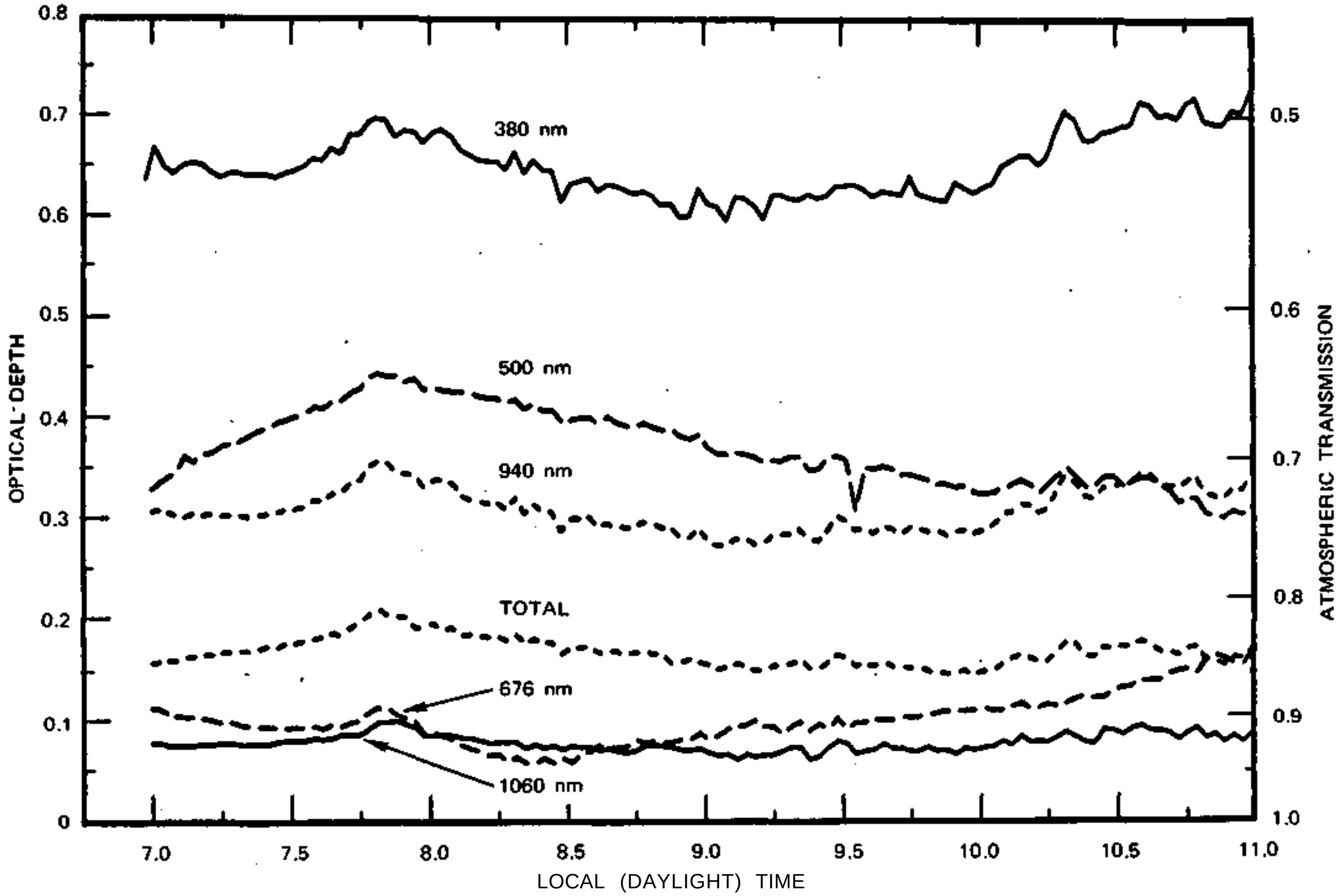

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FIGURE 5 OPTICAL DEPTH AT VARIOUS WAVELENGTHS AS A FUNCTION OF TIME FOR 14 AUGUST 1972

For the purpose of illustration, the intercept of a least-squares line has been assumed as the calibration constant; the resulting optical depths are presented in Figure 5. It can be seen that $u_{380} > u_{500} > u_{676}$, as would be expected. Also $u_{940} > u_{676}$ since the 940-nm interval is in a water-vapor band. The optical depth again decreases in the 1060-nm window region. The peak in optical depth at ≈0800 CDT is well related to the near-surface aerosol content (Figure 3), as might be expected because of the shallow (≈500-m) mixing-layer depth. An increase in u_{380} can be observed from 1000 to 1100 CDT. This could be related to the formation of NO_2 some 2 hours after peak traffic flow—possibly the peak observed in the optical depths at 0800 CDT—and to the sensitivity of the 380-nm interval to this gas.

We plan to explore the quantitative use of these data to derive vertically integrated concentrations of NO_2, water vapor, and suspended particulate matter and to infer information on the particle size distribution, either by use of a formal mathematical inversion technique or from wavelength-particle size relationships, all as a function of time. These data will thus provide a much needed input to the study of atmospheric processes important to climatic modification, especially by radiative means.

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Uthe, E. E., 1972A: Lidar observations of the urban aerosol structure. Bull. Amer. Met. Soc, 53, 358-360.

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METROMEX, 1972:

University of Wyoming Participation

by

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Department of Atmospheric Resources
University of Wyoming,
Laramie, Wyoming

Introduction

During the month of August, 1972, the Department of Atmospheric Resources, College of Engineering, University of Wyoming, completed its second phsse of the METROMEX field operation. The principle objectives of the University of Wyoming group during the 1972 METROMEX operations were:

A. Meso-scale Circulation Features

1. Observe and analyze the kinematics of the general meso-scale motion over an urbanized area and numerically model the meso-scale motions associated with an urban atmosphere; and
2. Make observations leading to the formation of a relationship between the modification of air destined to enter thunderstorms from the horizontal flow of the sub-cloud region and the variations and the character of the cloud and its product.

B. Nucleus Concentrations

1. Establish quantitatively the. production of cloud, Aitken and ice nuclei by an urban environment.

C. Cloud and Precipitation Processes

1. Investigate the transfer processes of the urban aerosol to the cloud particle;
2. Determine the affects of urban-produced cloud nuclei on the structure of the cloud;
3. Investigate the coalescence mechanism of precipitation associated with the polluted conditions; and
4. Investigate the evolution of resulting cloud particles into precipitation.

As would be expected, considerable administrative, organizational and technical background preparation needed to be accomplished prior to the initiation of the field programs; it was felt that this advance preparation greatly enhanced the achievement of the objectives of this study during August 1972.

Foremost in this preparation was the activity leading to the filing of a waiver under FAA regulation Part 91.63 concerning the low-level aircraft flights over metropolitan areas. Paramount in the University of Wyoming's airflow and modeling studies is the collection of temperature data at various altitudes, including levels less than 1,000 ft above the terrain, to serve the needs of input and/or verification. Also, programs involving aerosol sampling dictate flights at low levels. In this regard, early in November 1971, following the selection of a flight path over the metropolitan area to satisfy the data collection requirements, letters were sent to some 25 local municipalities requesting permission to fly at altitudes less than 1,000 ft over their domain; by February 1972, all 25 municipalities had responded affirmatively to our request. The official waiver under Part 91.63 was filed with the St. Louis FAA office and permission was granted for low-level flights during the month of August 1972.

Since air-to-ground radio communications between aircraft, mobile units and the Pere Marquette headquarters (operated by the Illinois State Water Survey) is imperative in our field program, the Department of Atmospheric Resources petitioned the FCC for temporary authority to use our assigned 154.100 mHz state government radio frequency in the greater St. Louis areas; permission for such radio usage was granted for the period 15 July-15 September 1972-74.

Facilities

A. During the 1972 METROMEX period, the University of Wyoming operated a Queen Air aircraft (N10UW) (see Figure 1). This aircraft is equipped with an L-band transponder, dual navigation and communications equipment, radar altimeter, ADF, ILS with glide slope, distance measuring equipment, IVSI rate of climb indicators, and a two-axis auto-pilot with couplers. The aircraft is also equipped with a. digital data acquisition system (Figure 2), which is especially suited for airborne atmospheric research. The data system is a versatile, high resolution system which records analogue and digital input data on one-half inch IBM computer compatible magnetic tape. The aircraft operational parameters recorded are heading, indicated air speed, pressure altitude, manifold pressure, VOR azimuth and DME position, vertical acceleration, roll rate, pitch rate, and rate of climb; meteorological parameters recorded are temperature, dew point, liquid water content, turbulence, flow through membrane filters, and time. The. aircraft was also equipped with an onboard digital computer (Figure 2) which made possible real-time determination of ambient temperatures, potential temperatures, dew point, specific humidity, vertical velocity (updrafts) and time. Figure 3 shews the cockpit of the Queen Air with the respective locations of the digital computer real-time display of the meteorological parameters and the scope of the RCA AVQ-55 (Bright Scope) X-band airborne radar system.

Figure 1. Queen Air aircraft, operated by the Department of Atmospheric Resources, University of Wyoming, during METROMEX 1972.

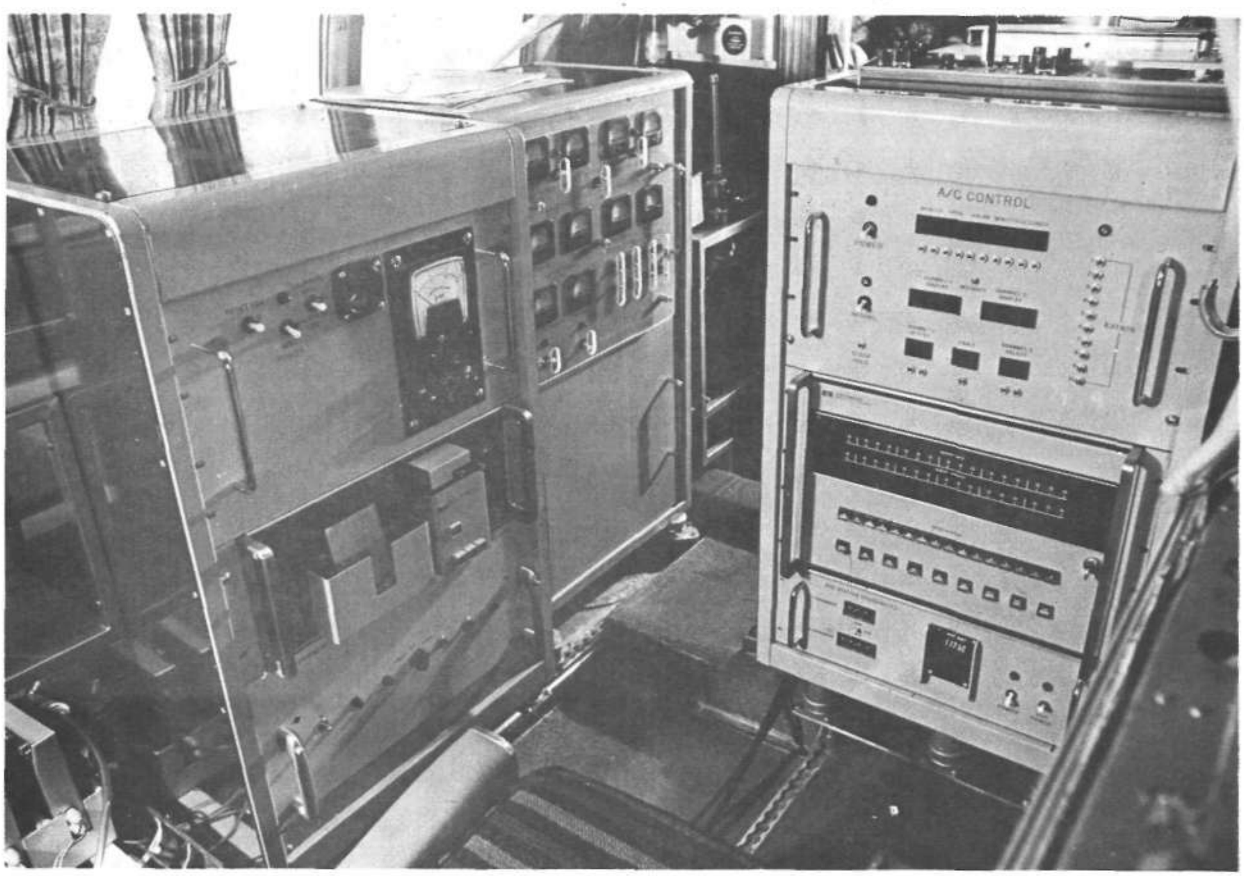

Figure 2. Interior cabin of the University of Wyoming research aircraft showing the digital data acquisition system and digital computer.

Figure 3. Cockpit of the University of Wyoming research aircraft showing aviation and navigational displays, X-band radar scope, and digital computer real-time display of meteorological parameters.

The temperature, dew point, pressure, transducers, as well as the indicated air speed and heading systems, installed in the University of Wyoming aircraft were calibrated against those of the NCAR Buffalo on an intercomparison flight conducted on 13 June 1972. Mr. Claude E. Duchon, Department of Meteorology of the University of Oklahoma (under contract with the National Hail Research Experiment) (NCAR) , analyzed these data and his results are presented in Table 1. In addition, a comparison flight was flown with the University of Chicago aircraft while in St. Louis during August 1972.

The types of sensors employed within this airborne meteorological system and their range, accuracy and resolution had been previously discussed in Table 1 of the 1971 operational report for METROMEX.

B. Mobile Meteorological Systems. Two carryall type trucks have been equipped for measurements of meteorological and precipitation parameters. Each mobile unit is capable of measuring temperature, dew point, wind speed and direction, ice nuclei measurements by air filter samples, raindrop size distribution, rate of rainfall, and, as well, has the capability of collecting rain and hail precipitation samples and launching pilot balloons.

The types of sensors employed within this mobile meteorological system and their range, accuracy, and resolution have been previously discussed in Table 3 of the 1971 operational report for METROMEX.

C. Upper Air Soundings. Three sources of upper air (temperature, humidity and pressure) data were earmarked for our participation: NOAA-operated radiosonde station at the St. Louis river front (sunrise and 1800Z if conditions warranted); University of Wyoming aircraft soundings in the vertical; and University of Wyoming-operated radiosonde station at Pacific, Missouri.

The choice of Pacific, Missouri (30 miles west-southwest of St. Louis) as a radiosonde launch site was premised on the argument that this location was representative of environmental conditions upwind from the St. Louis urban complex, while the St. Louis riverfront radiosonde should give conditions representative within the center of the. urban complex. Local NOAA officials have expressed complete cooperation in the exchange of radiosonde data. In addition, arrangements were made with the local NOAA officials to supply special radiosonde releases from the St. Louis riverfront Arch during "off hours" in order to supplement the nocturnal urban airflow studies.

Pilot balloon (pibal) observations were also an integral part of the data required for the verification of airflow and cumulus modeling programs. In this regard, pibal data gathered by Wyoming personnel, complimented by releases by NOAA personnel at St. Louis Lambert Field, were acquired during the field program. During the month of August 1972, a total of 153 pibals and 28 radiosondes were released in connection with the University of Wyoming's involvement in Project METROMEX.

Table 1. Results of comparison flights between NCAR Buffalo (N326D) and Wyoming Queen Air (N10UW), 13 June 72.

	Pressure, mb			Temperature, C			Dew Point, C			Remarks
Time	326D	10UW	Diff.	326D	10UW	Diff.	326D	10UW	Diff.	
1102	568.6	567.7	0.9	—3.9	-4.1	-0.2	-6.1	-6.1	0.0	/-(J)
1110	568.8	568.1	0.7	-3.8	-4.1	-0.3	-5.8	-5.9	-0.1	
1114	568.8	567.9	0.9	-3.3	-3.6	-0.3	-7.3	-7.6	-0.3	
Average			0.83			-0.26			-0.13	

	Indicated Airspeed, kts.			True Airspeed, kts.			Compass True Heading Degrees		
Time	326D	10UW	Diff.	326D	10UW	Diff.	326D	10UW	Diff.
1102	138.5	135.3	3.2	178.0	174.7	3.3	062.7	060.4	2.3
1110	136.4	133.2	3.2	175.3	171.9	3.4	338.5	335.7	2.8
1114	140.1	137.0	3.1	180.2	176.9	3.3	339.8	336.4	3.4
Average			3.16			3.33			2.83

D. Other Facilities. Other cloud physics instrumentation utilized in METROMEX 1972 has been previously outlined in the 1971 operational report for METROMEX and will not be repeated here.

E. Calendar of Operations. The Department of Atmospheric Resources of the University of Wyoming participated in Project METROMEX during 31 July-25 August 1972. A summary of operations involving Wyoming personnel and equipment is to be found in Table 2.

The. 1972 METROMEX field operation provided much better opportunities for studying the development of convective cloud activity over the metropolitan area than did the 1971 season. Several outstanding examples of preferred convective cloud development over the metropolitan area were observed during August 1972.

While the presence of more convective weather in the St. Louis area during 1972 placed more emphasis on that type of data collection, attempts were still made to delineate information regarding the low-level airflow over the St. Louis area, with emphasis on boundary layer wind profile as well as turbulence spectra below 2,000 ft msl.

Preliminary Findings

For the most part, the preliminary findings to date relating to condensation nuclei, appear to parallel those results found in 1971.

Perhaps the most outstanding feature of the August 1972 research was the detailed investigation of two moderate thunderstorms which moved across the St. Louis area on 3 August and 21 August. The storms were observed by all University of Wyoming field equipment beginning at a position about 10 miles west of the metropolitan area to their subsequent dissipation about 30 miles downwind of the metropolitan area. A very preliminary analysis at this time suggests that there may have been some enhancement of the thunderstorm updraft over and to the east of the downtown district of St. Louis. Visual evidence, as well as precipitation data acquired by the mobile meteorological unit, suggested heavy rainfall associated with the strong updraft of a point about 10 miles downwind of the industrial complexes of metropolitan St. Louis.

An additional case study of the variable mixing layer depth has been examined. In this study particular emphasis was given to observations extending through two consecutive night time periods. These data confirm the earlier findings that the maximum doming of the inversion which caps the mixing layer occurs during mid-day. The night-time inversion structure aloft exhibited only small meso-scale distortions.

Table 2. METROMEX Data Summary, August 1972

Date	Aircraft Flight, CDT	Purpose of Flight	UW Pibal Data	UW Radiosondes
2	1600-1709 1929-2024	Cu Penetration CB Study	1700 Market St. & U.S. 40, CVM	0645 PAC 1245 PAC
3	1525-1935	CB Study		1200 PAC 1800 PAC
4	1105-1220 1356-1550 1610-1655	Nuclei Budget Metrodata Calibration	1200 Weiss Airport 1410 Arch 1525 Weiss Airport 1600 CVM	0645 PAC 1230 PAC
5	-	-	-	-
6	-	-	-	-
7	-	-	-	0630 PAC
8	0600-0728 1700-1851	Airflow Airflow	0600 Arch, St. Peters, PAC 0820 I-55 & I11 143 0848 St. Charles, PAC 0930 St. Charles, PAC 1015 St. Charles, PAC 1050 Troy, PAC	0645 PAC 1230 PAC 1730 PAC
9	2300-0156	Airflow	2300 Arch, PAC	0630 PAC
10	0855-1056 1410-1710 2255-0101	Airflow Airflow Airflow	0000 Hamel, Weiss Airport, Arch 0100 Arch, Hamel	0800 PAC 0945 PAC 1730 ARCH 1830 PAC 2340 ARCH
11		"	-	0000 PAC
12	-	-	-	-
13	-	-	-	-
14	1200-1358 1515-1650	Cu Penetration Cu Penetration	1330 I-270 & U.S. 67, CVM 1400 Forest Park, PAC 1620 I-55-70 & St. Clair St. 1638 I-70 & Lucas and Hunt Road, PAC 1710 Carondelet Park, CVM 1715 I-270 & I11 203, PAC 1720 Weiss Airport 1728 I-244 & Ross Ave. 1750 Weiss Airport, PAC	0630 PAC 1200 PAC 1700 PAC
15	-	-	-	0700 PAC
16	-	-	-	0645 PAC
17	1032-1229	Airflow	1030 I11 111 & I-270, Arch, PAC, I-244 & Lackland 1100 " " " 1130 " " " 1200 " " " 1230 " " " 1300 " " " 1400 I-44 Laclede Sta. Rd.	0645 PAC
18	-	-	-	0800 PAC
19	-	-	-	-
20	-	-	-	-
21	1445-1855	CB Study	1530 I-244 & U.S. 40 1550 Arch, PAC 1555 I-244 & U.S. 40 1730 Troy, CVM	0700 PAC 1245 PAC
22	1200-1334 1525-1940	Cu Penetration Cu Penetration	1000 I-270 & Mo 140, I-270 & I11 3 1752 St. Charles, PAC	0700 PAC 1645 PAC
23	-	-	-	0630 PAC
24	-	-	-	0645 PAC 1230 PAC
25	1630-1832	CB Study	1345 Weiss Airport 1630 CVM	0645 PAC 1300 PAC

Results

Four project reports in association with the sponsored research activities within Project METROMEX have been prepared to date. These titles appear below with a list of authors and abstracts.

Auer, Jr., A. H., 1972: An estimate of the production of cloud and Aitken nuclei by the St. Louis Metropolitan Area (METROMEX). Preprints of the Third Conference on Weather Modification, Rapid City, South Dakota, 79-82.

ABSTRACT. It is a problem of some practical interest to determine to what extent human activities contribute to the total production of Aitken nuclei and particularly of cloud nuclei, that is, those condensation nuclei which are activated in natural cloud formation. The production of cloud and Aitken nuclei by the City of St. Louis have been established quantitatively by measuring the mean concentration in vertical columns, upwind and downwind of the metropolitan area.

The mean concentration of cloud nuclei (active at supersaturations from 0.2% to 3.5%) and Aitken were measured on 5 and 8 occasions, respectively, during August 1971, under the auspices of Project METROMEX. Besides these nuclei concentrations, mean wave-speed over the metropolitan area and the area of production also serve as input to the budget computation.

These production rates are compared with rates from other metropolitan areas and suggest that seasonal and degree-of-urbanization variations may exist.

Lawson, R. P., 1972: Urban-induced influence on convective cloud activity. M.S. thesis, Department of Atmospheric Resources, College of Engineering, University of Wyoming, Laramie, Wyoming, 168 pp.

ABSTRACT. Three case study days (9, 13 and 23 August 1971) of project METROMEX were selected on the merit of available data to investigate possible urban-induced influences on convective cloud activity. Data included observations from meteorologically equipped aircraft and mobile units, radiosondes and pilot balloons, lidar, surface temperature and dew point recording network, radar and 35-mm photographs.

Analyses of the data revealed regions where convective cloud activity was inhibited by the presence of an elevated thermally stable layer, while simultaneously, other regions showed cumulus development. Using a dimensional similitude of analysis of a fluidal model, it was found that the atmospheric system may be capable of exhibiting elevated warming via turbulent entrainment of warm air downward through the elevated stable layer. Aerosol heating was also considered as a mechanism which may produce elevated heating.

Subsequent daytime elevated warming at and immediately beneath the elevated stable layer was found to shrink the potential mixing layer depth, inhibiting convective cloud activity. This relationship between mixing layer depth and convective cloud activity is consistent with other Project METROMEX synoptic analyses for dry summers.

Spangler, T. C., 1972: Dynamically induced meso-scale variations of the urban mixing layer depth. M.S. thesis, Department of Atmospheric Resources, College of Engineering, University of Wyoming, Laramie, Wyoming, 94 pp.

ABSTRACT. The dynamical effects of an urban surface on the airflow above it could be an important factor in the meso-scale precipitation pattern. In order to evaluate the dynamical influences of an urban area, local variations in the mixing layer depth over metropolitan St. Louis are investigated. Variations in the height of a temperature inversion capping a deep mixing layer are used to measure the urban effect on the mixing layer depth. Case studies employing aircraft, pilot balloon and radiosonde data collected in Project METROMEX show that the St. Louis urban area produces a doming of the inversion layer over the city during the morning hours on certain summer days. It is concluded from observational and numerical modeling studies that the urban surface influence did not contribute significantly to the formation of the inversion dome but rather that a major influence existed within the upper regions of the mixing layer.

Spangler, T. C. and R. A. Dirks, 1972: Meso-scale variations of the urban mixing layer depth. Preprints of the Conference on Urban Environment and Second Conference on Biometeorology, Philadelphia, Pennsylvania, 37-42.

ABSTRACT. Local variations in mixing layer depths are suggested as an important factor in the occurrance of meso-scale anomalies in convective precipitation. Results of the METROMEX experiment show that the St. Louis urban area produces a domed mixing layer during certain summer days. The apparent development of this feature during the morning hours and the observed temperature and wind field within the mixing layer permit a qualitative evaluation of causal mechanisms. Implications to the modification of convective clouds by urban areas and air pollution potential forecasting are discussed.

Future Research Plans

Inadvertent weather modification has been shown to exist climatologically (and now possibly on a case study basis) and some possible physical linkups have been indicated. However, no comprehensive investigation has been undertaken to describe and indicate the various physical processes that lead to the observed affect. Therefore, the research goals and operational plans for August 1973 will essentially be the same as have been put forward in 1971-72.

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