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COLD WEATHER PLUME STUDY

ATMOSPHERIC SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

COLD WEATHER PLUME STUDY

by

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ABSTRACT

There is a large array of data describing power plant pollutant transport and transformation from summer field studies. With few studies addressing these processes under winter conditions the U.S. Environmental Protection Agency (EPA) and the Electric Power Research Institute (EPRI) sponsored a joint field study in February 1981 known as the Cold Weather Plume (CWP) Study. The CWP study was based in St. Louis, MO and focused on the plume from the Kincaid power plant located southeast of Springfield, Illinois. The objective of the study was to characterize SO_x and NO_x chemistry in a power plant plume by heterogeneous and/or homogeneous mechanisms in cold weather.

Three measurement aircraft were involved along with meteorological, analytical chemistry and data base support crews. Measurements on five different days examined gaseous and aerosol plume parameters, transport and source conditions. Stability conditions varied from a well mixed atmosphere with rapid plume dispersion to a stable atmosphere where elevated pollutant values were ovserved over 100 km downwind.

This report presents the descriptive analysis of these measurements. Cross plume integrations of pollutant parameters are provided along with estimates of plume age. A complete, internally consistent data base has been established for wider use of these measurements.

This report is submitted in partial fulfillment of Contract No. 68-02-3411 by Environmental Measurements, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1980 through September 1984 and work was completed as of 15 September 1984.

CONTENTS

ACKNOWLEDGMENTS

The Cold Weather Plume Study required the cooperation of two major organizations, the U.S. Environmental Protection Agency and Electric Power Research Institute (EPRI), along with the efficient interaction of several companies in the field.

Environmental Measurements, Inc. (EMI) expresses special thanks to its subcontractors, AeroVironment, Inc. (especially Michael Chan and Brad Mueller), SRI-International (especially William Viezee and Bruce Cantrell) and Washington University Technology Associates (especially Noor Gillani and Vicky Bohm). The professional cooperation with EPRI's contractors, Meteorology Research, Inc., Battelle Columbus Laboratories and Rockwell International, contributed to the overall success of this brief field study. EMI acknowledges the valuable input from EPA's lidar aircraft operations in tracking the aerosol plume during EMI and MRI's measurements.

EMI appreciates the long hours, under extremes in weather conditions, which all personnel contributed to this study. We thank them for this effort.

SECTION 1

INTRODUCTION

Most of the field studies on chemical conversion rates for primary air pollutant emissions from power plants have taken place during summer conditions. This fact limits the application of much of the plume chemistry information to warmer times of the year, making their use inappropriate for winter conditions. The subject of this report is one attempt to improve the information on plume behavior under winter conditions - the Cold Weather Plume (CWP) Study of February 1981.

The CWP study was undertaken as a joint effort of the U.S. Environmental Protection Agency (EPA) and the Electric Power Research Institute (EPRI) because of their individual interests in winter plume phenomena. EPRI was primarily interested in the near field NO_x transformation processes for incorporation in reactive plume models while EPA was interested in the far field SO_x transformations having an impact on long range transport issues. The complementary nature of these interests led to two interrelated sets of measurements with a single general objective:

> To characterize SO_x and NO_x chemistry in a power plant plume by heterogeneous and/or homogeneous mechanisms in cold weather.

The measurements supported by each organization were planned so as to supplement their immediate needs by providing useful information for the other. Each organization assembled a group of contractors to conduct their portion of the field work.

The participating EPA organizations included Environmental Measurements, Inc. (EMI), AeroVironment, Inc. (AV), SRI-International (SRI), Washington University Technology Associates (WUTA) and EPA laboratories in Research Triangle Park and Las Vegas. The participating EPRI organizations included Battelle Columbus Laboratories (BCL), Rockwell International, and Meteorology Research, Inc. (MRI - currently Sonoma Technology, Inc.).

Subsequent sections of this report describe the organization of the project (Section 2) and the various operations which were carried out (Section 3). Section 4 covers the data base which has been established along with the access to that data base. A brief descriptive analysis of the data is presented in Section 5 to assist in future in-depth analysis. Summary and recommendations are covered in Section 6.

SECTION 2

PARTICIPANTS AND ORGANIZATION

The CWP study was carried out by a team which received its funding from two sources, the U.S.Environmental Protection Agency (EPA) and the Electric Power Research Institute (EPRI). The following table indicates which participants received funding from each group.

TABLE 2-1. COLD WEATHER PLUME STUDY PARTICIPANTS

EPA	EPRI
Environmental Measurements, Inc	Battelle Columbus Laboratories
AeroVironment, Inc.	Meteorology Research, Inc.
SRI-International	Rockwell International
Washington University Technology Associates	
Environmental Monitoring Support Laboratory:	
-Research Triangle Park	
-Las Vegas	

The responsibilities of the team members were coordinated by the Project Director, William M. Vaughan, PhD of EMI. The various subtask responsibilities are outlined in Table 2.2. These responsibilities were detailed in a Work Plan developed and circulated by EMI and BCL prior to the field study and after a preliminary planning meeting held in St. Louis in October 1980.

The coordination of these tasks was conducted primarily by phone during the preparation phase of the work. During the field study itself more intense coordination was required and was satisfied by daily meetings at the project's Mission Control Office.

This office was established on the grounds of Spirit of St. Louis Airport near the hangar used by EMI and MRI. Phone lines provided essential communication capability. Conversations were documented in a communications log book to help with the real time management of the project.

TABLE 2-2. CWP STUDY RESPONSIBILITY MATRIX

	EPA					EPRI		
Tasks	EMI	AV	SRI	WUTA	EPA	BCL	ROCK	MRI
1. Preparation of work plan	X					X		
2. Base and Field operations								
a. Selection of location	X							
b. Program management	X	O				X	O	O
c. Rapid data turnaround by EPA				X				
d. Weather forecasting			X					
e. Communication	X						X	
3. Chemical Aircraft								
a. Operation	X							X
b. Filter analysis			O		X	X	X	
c. Quality assurance	X					O		X
d. Special measurements					O	X		
4. Meteorological measurements								
a. Mobile Minisondes		X						
b. Tall Met. tower (on site)							X	
c. Double Theodolite T-sondes (on site)							X	
5. Source measurements								
a. Aerosol characteristics					X			
b. Continuous gases							X	
6. Lidar Aircraft Operations					X			
7. Data processing	X	X	X	X	X	X	X	X

X=responsible for task
O=provided support

SECTION 3

OPERATIONS

3.1 Field Sites

3.1.1 Power Plant

The power plant chosen for the study was Commonwealth Edison's Kincaid plant located in central Illinois southeast of Springfield, Illinois (See Figure 3-1). The plant was chosen, in part, because it was the site of EPRI's Plume Model Validation (PMV) study (EPRI 1981). During the CWP study, only one of the two 660 megawatt generators was operating. Its emissions were monitored before being sent up a 187 meter stack whose exit diameter was 9 meters.

Adjacent to the plant, Rockwell operated a 10 meter and a 100 meter meteorological tower and had a baseline for double theodolite tracking of pibal and temperature sonde releases. A surface meteorological station was also operated during the course of the study. The parameters reported are given in Section 3.2.

3.1.2 Mission Control

A coordinating office was set up at Spirit of St. Louis airport. There was sufficient space to hold weather briefings, conducted by the study's meteorologist, William Viezee, and to discuss each days mission plans. Data from previous missions could be displayed and discussed in order to refine future operations. Desks and phones allowed office work and field coordination to be carried out from this central facility.

Mission Control was located a short distance from the main hangar for EMI and MRI; so pilots, technicians and field engineers could easily participate in meetings. An outside electrical power drop was provided at Mission Control to allow BCL's mobile GC laboratory to operate at the center of activity (See Figure 3-2) and near the sampling aircraft.

Because Mission Control and the base of aircraft operations were far to the southwest of the study area, no elaborate

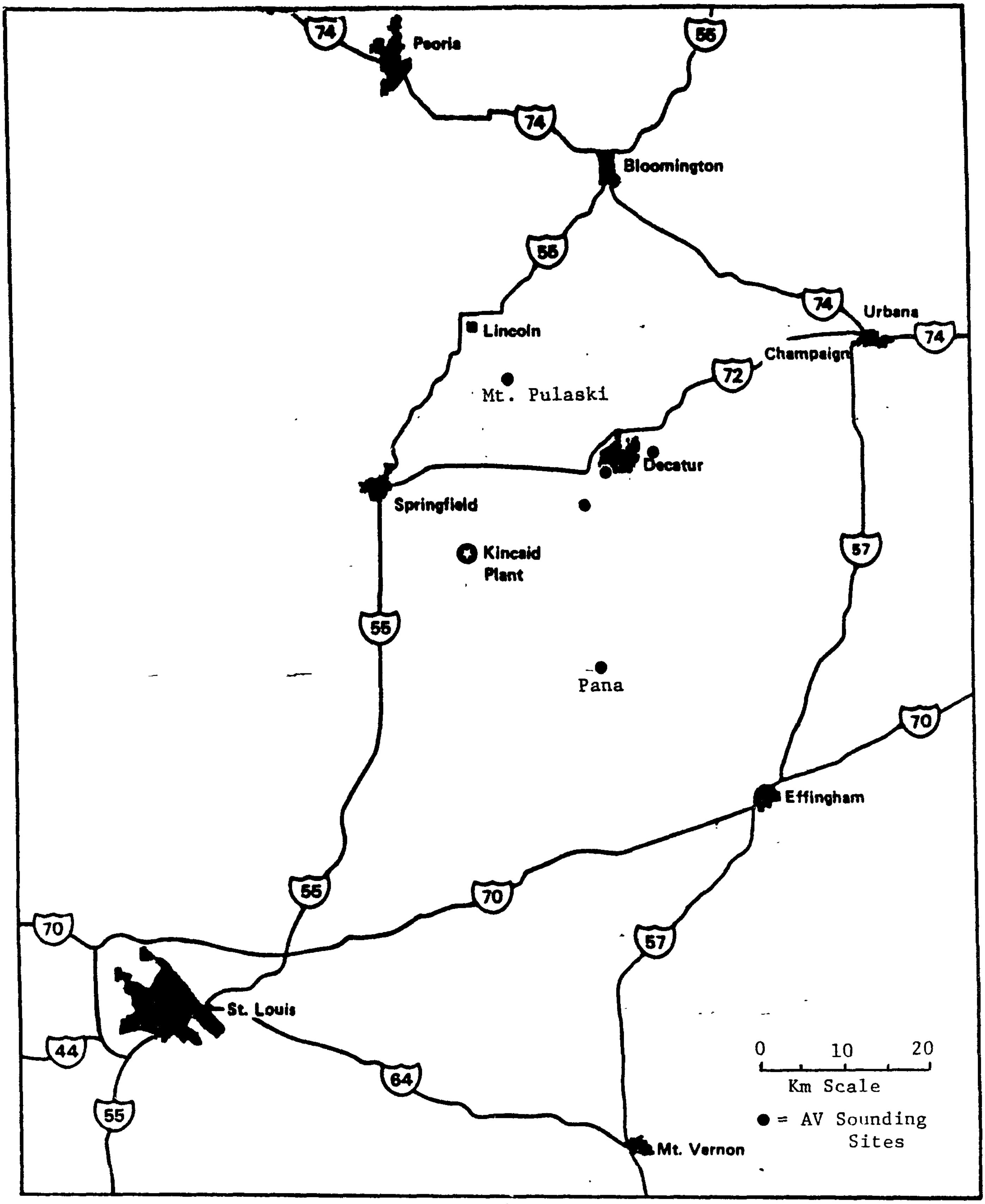


Figure 3-1. Map of the general CWP study area.

Figure 3-2. Mission Control for the Cold Weather Plume Study, with Battelle's Mobile GC laboratory (housed in the truck) operating next to it.

radio communication system was established. Flight plans were not modified much during a mission, as had been possible in previous studies where Mission Control was more centralized with respect to the measurements.

3.2 Instrumentation and Measurements

3.2.1 Aircraft Measurements

Each aircraft platform was outfitted for gaseous, aerosol and meteorological measurements in addition to recording of position and altitude. Table 3-1 gives the instrument complement for EMI's Cessna 404. Tables 3-2 - 3-4 give the complement for MRI's QueenAir. Each platform recorded the continuous measurements on magnetic tape and delivered the tapes to WUTA for rapid reading and plotting.

The details of each aircraft installation are provided in separate reports for MRI's QueenAir (L.W. Richards et al. 1981) and EMI's Cessna 404 (W.M. Vaughan et al. 1982). Additional information on EMI's platform is presented in the CHEM-1 Data Volume for the Cold Weather Plume Study (B. Vaughan et al. 1983).

In addition to the continuous measurements made on each aircraft, the tables indicate the integrated samples which were gathered for later analysis. MRI filled Teflon bags for analysis by BCL for PAN and individual C1-C10 hydrocarbon species. These analyses were carried out immediately after each flight using their mobile laboratory adjacent to Mission Control. Filter samples (Table 3-4) were analysed by Rockwell and BCL for elemental and inorganic components.

EMI's integrated cyclone filter samples were gathered under the guidance of Bruce Cantrell of SRI. He assisted in the installation of the sampling hardware and trained EMI's Paul Miller in the proper field procedures for preparing, exposing and shipping the samples for analyses. These aerosol samples (below 3.0 microns) were sent to EPA's EMSL at Research Triangle Park for analysis by ion chromatography. The special tungstic acid filters were sent to the University of South Florida for analysis of gaseous and particulate nitrogen species - ammonia, ammonium, nitric acid and nitrate.

All of EMI's measurements are presented in graphic and tabular form in the CHEM-1 Data Volume for the CWP study (B. Vaughan et al. 1983). In addition both EMI and MRI final data tapes have been incorporated in the CWP data base at the WU/EPA Special Studies Data Center at Washington University under the direction of Dr. Gillani.

TABLE 3-1. CHEM-1 INSTRUMENTATION SUMMARY FOR CWP STUDY

Category	Parameter	Instrument Make and Model	Nominal Operating Range	Sensitivity	Response Time (sec)
Air Quality Continuous Analyzers	O_3	CSI 2000	0-200 0-500ppb	3%	1
	SO_2	Meloy 285 FR and Hydride Cylinder	0-500ppb 0-100ppb 0-50ppb depending on distance.	1ppb	3
	NO/NO_x	Monitor Labs 8440E modified for fast response	0-500ppb 0-200 depending on distance.	3ppb	1
	$SO_4^=$, H_2SO_4	Meloy 285 FR modified for SO_2 scrubbing and aerosol heating	0-50ppb	1ppb	3
	b_{scat}	MRI 1567 modified for aircraft.	$0\text{-}10 \times 10^{-4} m^{-1}$	$0.1 \times 10^{-4} m^{-1}$	2
	Aitken nuclei	Environment One Aitken Nuclei Counter modified for high pressure inlet.	0-100k CN/ml	3k CN/ml	5
	Aerosol Charge Acceptance	Washington Univ.	0.01-0.1 micron		1
Batch Analyzers	Electronic Aerosol Analyzer.	Thermo-Systems, Inc.	.0032-1 micron		Time integrated.
	Optical Particle Counter	Royco 220	0.56-5.6 micron		Time integrated.

TABLE 3-1. (continued)

Category	Parameter	Instrument Make and Model	Nominal Operating Range	Sensitivity	Response Time (sec)
Air Quality Integrated Samplers	$SO_4^=$, NO_3^-, Cl^-	cyclone filter pack			
	Gaseous-Ammonia and Nitric Acid Particulate-Ammonium and Nitrate.	Tungstic Acid hollow tube pre-concentrator (Univ. of S. Florida)			
Meteorology	Temperature	Type J thermo-couple	-300 to +300°F	0-1°C	2
	Dewpoint	General Eastern 1110	-40 to 49°C	±0.5°C	3
Data Acquisition	all	Fluke 2240		-40 to +40V	1 scan/2 sec
Position	VOR	King KN53	0-360°	±1°	5
	DME	King KN62A	0-50 n.mi.	±0.1 n.mi.	1
	Altitude	Aerosonic	0-50,000 feet msl	± 50 ft.	0

TABLE 3-2.

QUEEN AIR INSTRUMENTATION
(From BCL report)

Parameter	Sampler Manufacturer and Model	Analysis Technique	Normal Measurement Ranges (Full Scale)	Time Response (to 90%)	Approximate Resolution
SO_2	Meloy 285	Flame Photometric	100, 500, 1000 ppb	30 s	1 ppb
NO/NO_x HNO_3	Monitor Labs 8440	Chemiluminescence Modified by BCL	200, 500, 1000 ppb	5 - 10 s	<5 ppb
O_3	Monitor Labs 8410	Chemiluminescence	500 ppb	5 s	5 ppb
Light Scattering	MRI 1569	Integrating Nephelometer	10^{-4} and 10^{-3} m^{-1}	<1 s	10^{-6} m^{-1}
Condensation Nuclei	Environment One Rich 100	Light Attenuation in an Expansion Chamber	10^5 cm^{-3}	3 s	10^3 cm^{-3}
Aerosol Charge Acceptance	Washington University	Aerosol Charge Acceptance	Primarily responds to .01 - .1μ particles	∿1 s	--
Broad Band Radiation	Eppley PSP	Pyranometer	0 - 1026 w/m^2 Cosine response	1 s	2 w/m^2
Ultraviolet Radiation	Eppley	Barrier-Layer Photocell	295 - 385 mμ 0 - 34.5 w/m^2 Cosine response	1 s	0.1 w/m^2
Turbulence	MRI 1120	Pressure Fluctuations	0 - 10 $cm^{2/3}$ s^{-1}	3 s (to 60%)	0.1 $cm^{2/3}$ s^{-1}
Temperature	YSI/MRI	Bead Thermister/ Vortex Housing	-55° to +45° C	5 s	0.5° C
Dew Point	Cambridge Systems 137	Cooled Mirror	-50° to +50° C	0.5 s/° C	0.5° C
Altitude	Validyne	Absolute Pressure Transducer	0 - 3000 m msl	1 s	6 m
Indicated Airspeed	Validyne	Differential Pressure Transducer	23 - 68 m s^{-1}	1 s	0.1 ms^{-1}
Position	King KX170B/ HTI DVOR	Aircraft DME/VOR	0 to 359° and 0 to 150 km from the station	1 s	1° (bearing), 0.2 km (distance)
Data Logger (includes time)	MRI Data System	9-Track Tape - 6 hour capacity in continuous operation	±9.99 VDC	Records data once per second	0.01 VDC
Stripchart Recorder	Linear Instruments	Dual Channel	0.01, 0.1, 1, 10 VDC	<1 s	--
Printer	Axiom	--	80 character lines	Prints out data every 10 seconds and at every event code or data flag change	

TABLE 3-3.

AEROSOL SIZE DISTRIBUTION MEASUREMENTS
ON QUEEN AIR
(From BCL report)

Instrument	Size Range	Method
TSI 3030[a]	0.006-0.56	Aerosol Charger/Mobility Analysis
PMS ASASP-X[b]		
Range 3	0.090-0.195	Optical Particle Counter Illumination in Laser Cavity and 35° to 120° Collection
Range 2	0.15-0.30	
Range 1	0.24-0.84	
Range 0	0.60-3.0	
PMS FSSP-100[b]		
Range 3	0.5-8	Forward Scattering Spectrometer Probe
Range 2	1-16	
Range 1	2-32	
Range 0	2-47	

[a]Automatic bag sampling system for TSI 3030; bagfill takes place in about 3 seconds and occurs automatically every 5 minutes or on command.

[b]The Particle Measuring Systems (PMS) optical particle counters can be manually set to any range, or can be set to automatically cycle through the ranges with 1 second in each range.

TABLE 3-4.

INTEGRATED SAMPLE COLLECTIONS AND ANALYSES FOR QUEEN AIR
(From BCL report)

Determination	Collection Medium	Particle Size Segregation	Nominal Flow Rate (lpm ambient)	Analysis Method
PAN C_1-C_{10} Hydrocarbons	Teflon bags	None	<1 (ram flow)	Cryogenic preconcentration/ gas chromatography
$SO_4^=$, NO_3^-	2 µm Zefluor 47 mm	Bendix 240 cyclone (2.5 µm cut)	50	Ion chromatography
Elemental Carbon	Pallflex Quartz 47 mm	Bendix 240 cyclone (2.5 µm cut)	20	GRALE: C light absorption
Elemental Composition	2 µm Teflo 25 mm	Bendix 240 cyclone (2.5 µm cut)	40	X-ray fluorescence
Total Inorganic Nitrate HNO_3 as NO_3^-	1 µm Zefluor/1 µm prewashed nylon 47 mm	None	30	EC-GC
Ammonia	2 µm Zefluor/oxalic acid impregnated glass fiber	None	10	colorimetry
Elemental Composition	2 µm Teflo after filter	Impactor (50% cut at 4, 2, 1, and 0.5 µm)	10	PIXE

3.2.2 Meteorological and Source Measurements

Rockwell's operation at Kincaid involved measurements of primary emissions using the continuous instrumentation from the PMV project and measurements of meteorological parameters. These measurements are summarized in Table 3-5.

In addition, for each day of aircraft measurements, Rockwell launched hourly temperature sonde balloons and tracked them from the double theodolite baseline adjacent to the plant. These profiles started a couple of hours before the first aircraft took off to confirm how well the transport field agreed with the forecast so that the day's mission plan could be refined. These releases continued throughout each mission. The results were reduced quickly and phoned to the Field Manager, Michael Chan, at Mission Control. At times these profiles were radioed to the aircraft when changing wind conditions moved the plume from its anticipated location. A graphical summary of these Rockwell profiles is included in Appendix A.

AV's mobile minisonde platform operated 40-100 km from Kincaid to characterize the downwind transport. Its soundings measured dry bulb and wet bulb temperature, along with pressure. The balloon tracking by single theodolite coupled with pressure readings gave wind speed and direction. AV's soundings were initiated within an hour of the first aircraft leaving Spirit of St. Louis Airport and continued almost hourly throughout each mission. These soundings were from five different locations during the course of the CWP study as shown in general in Figure 1 with details in Figure 3-3 a to c. The wind profiles from these soundings are graphically summarized in Appendix A. (The AV data are available from EMI in a format suitable for contour plotting.)

3.2.3 Teleradiometer Measurements

Toward the end of the CWP study MRI coordinated the activities of Systems Applications, Inc. (SAI) in making teleradiometer measurements at Kincaid. These measurements were actually part of EPA's VISTTA project which involved MRI and SAI in visibility measurements in the southwest. The CWP measurements were made to obtain winter readings in the midwest and worked smoothly into the CWP study. The data are indexed in C.D. Johnson et al. (1981) and interpreted along with VISTTA data in C. Seigneur et al. (1984).

3.3 Weather Forcasting

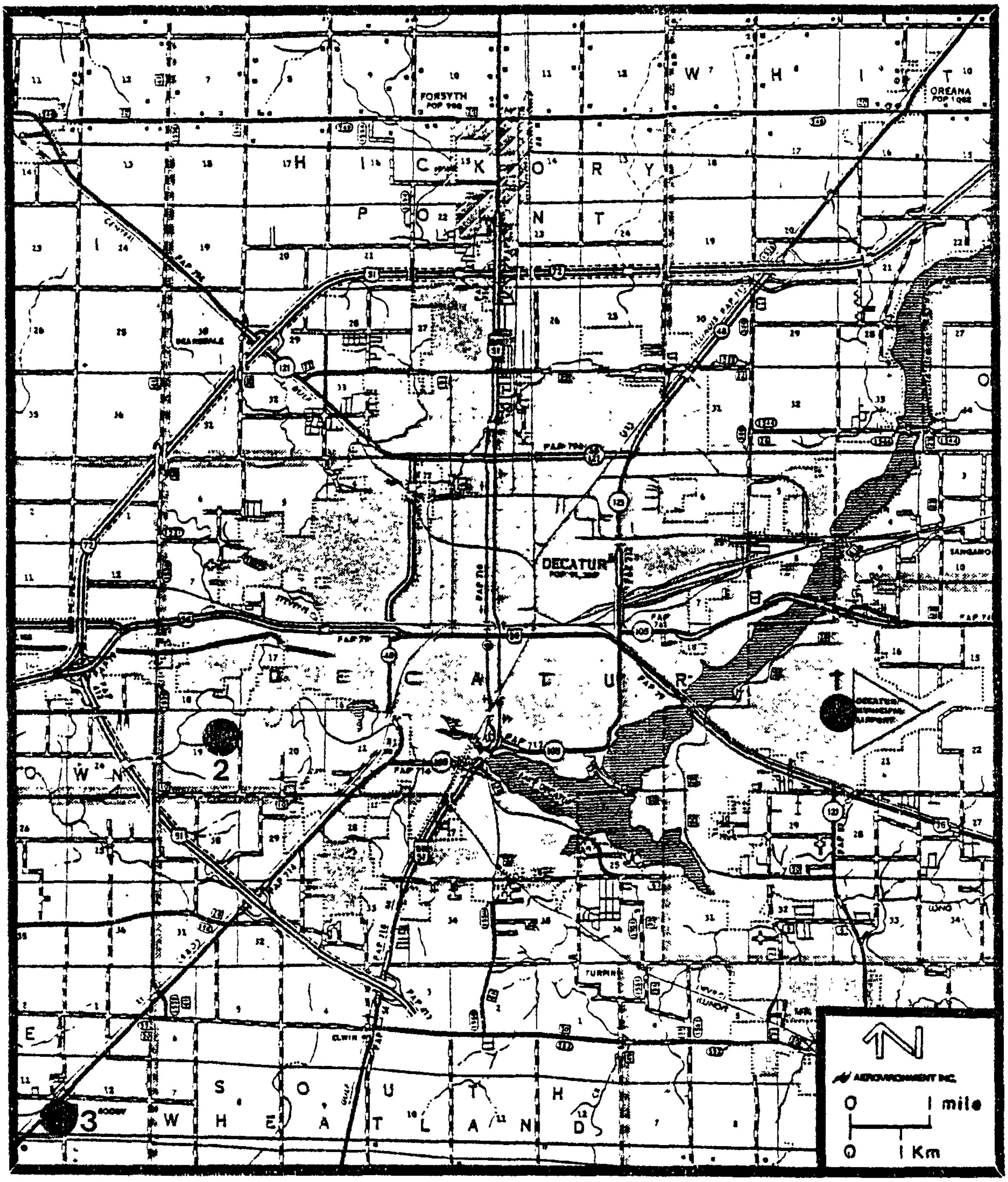
SRI provided the weather forcasting for the CWP study through the efforts of William Viezee. Mr. Viezee established

TABLE 3-5.

SOURCE EMISSIONS AND METEOROLOGICAL MONITORING DURING THE CWP STUDY[a]

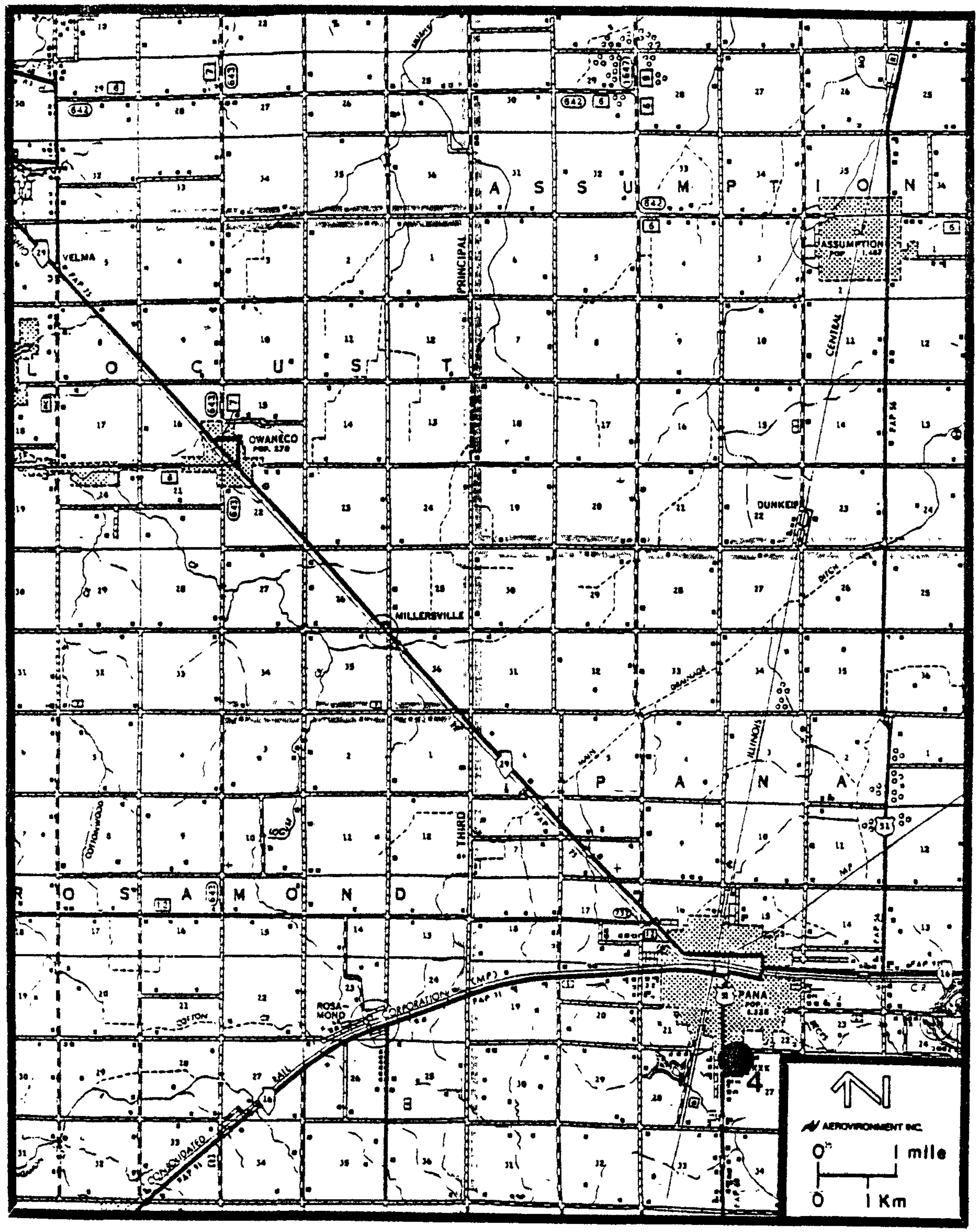
Variable	Number of Measurement Locations	Frequency of Measurements	Equipment or Method Used
Source Emissions			
SO_2 and NO	Stack	Continuous	Lear Siegler SM810
O_2	Stack	Continuous	Lear Siegler CM50
Velocity	Stack	Continuous	Kurz 455 (Hot Wire)
Temperature	Stack	Continuous	Kurz 455
Meteorological			
100 m Tower			
Wind Direction	10 m, 30 m, 50 m, 100 m	Continuous	Teledyne Geotech 15658
Wind Speed	10 m, 30 m, 50 m, 100 m	Continuous	Teledyne Geotech 15648
Temperature, T	10 m-50 m; 10 m-100 m	Continuous	Teledyne Geotech T-200
uvw Winds (Gill)	100 m	Continuous	R. M. Young 27004
Dewpoint	100 m	Continuous	Teledyne Geotech 00-200
10 m Tower			
Temperature, T	2 m-10 m	Continuous	Teledyne Geotech T-200
Surface Station			
Atmos. Pressure	1	Hourly	Teledyne Geotech 5P-100
Cloud Cover	1	Hourly	Visual Observations
Precipitation	1	Hourly	Teledyne Geotech PG2 OOH
Surface Temperature	1	Continuous	Barnes PRT-S
Net Radiation	1	Continuous	Science Associates 622-1
Solar Radiation	1	Continuous	Eppley NIP
Sky Radiation	1	Continuous	Eppley 8-48

[a]Adapted from Table 3-1, Reference 3.



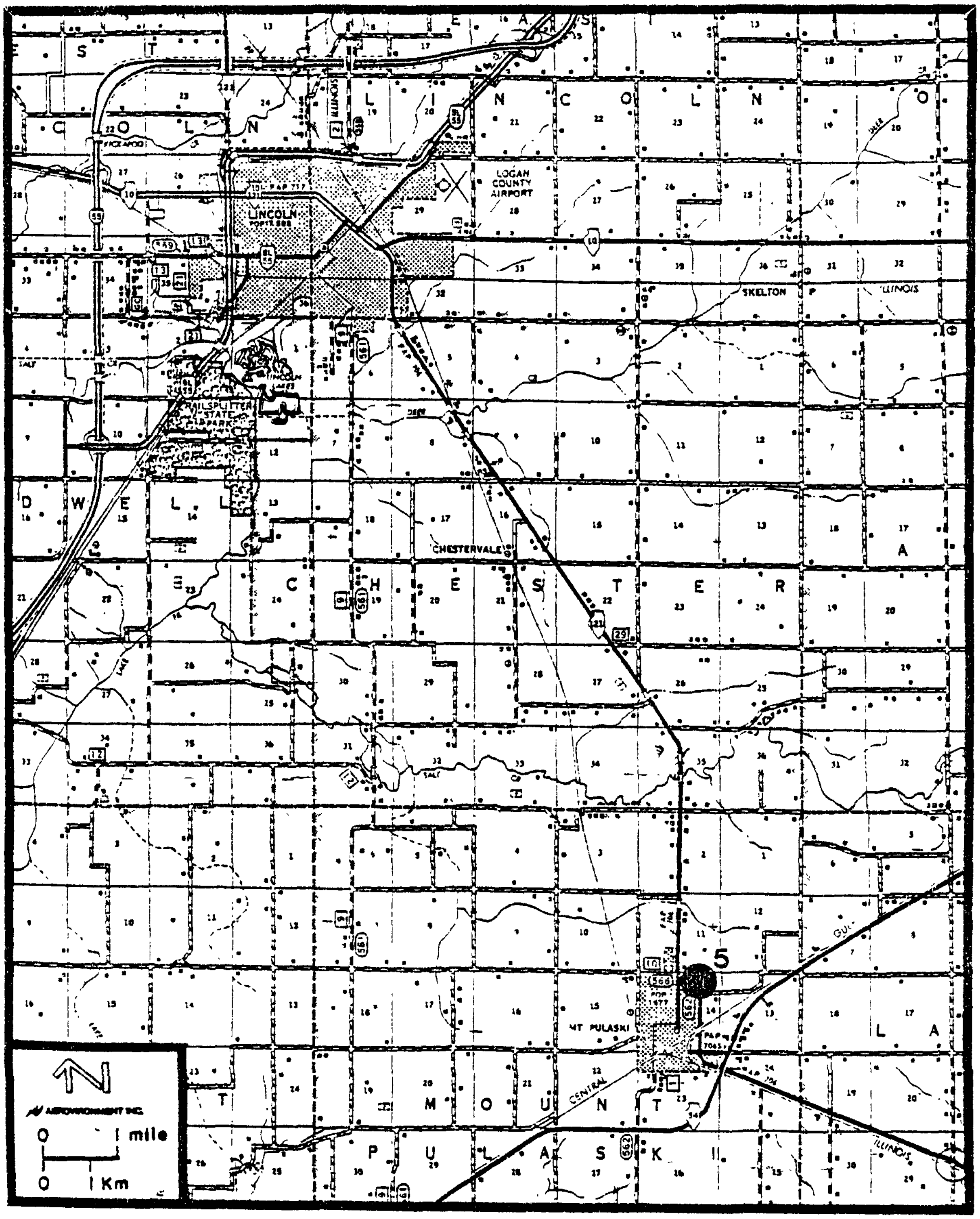
1 - Decatur, Illinois
2 - Rock Springs Center, Illinois
3 - Boody, Illinois

Figure 3-3a. Location of AV soundings during the CWP study.



4 - Pana, Illinois

Figure 3-3b. Location of AV soundings during the CWP study.



5 - Mt. Pulaski, Illinois

Figure 3-3c. Location of AV soundings during the CWP study.

a good rapport with the local National Weather Service (NWS) personnel at their St. Peters, MO office. He had access in real time to all the necessary facsimilie and modeling outputs to develop his forecasts. He would spend several hours each day at the NWS offices assimilating the latest information. Then he would drive to Spirit of St. Louis Airport to present his forcast to the afternoon briefing at Mission Control. As needed, he would return to NWS for further updates and refinements as the planned mission commenced.

After the field study he prepared an overview and description of the meteorological and transport conditions experienced during the CWP study. This summary is attached in Appendix B.

3.4 Aircraft Sampling Missions

The sampling period for the CWP study extended from 12 February through 20 February 1981. During that time EMI flew 7 flights on 5 different days. MRI flew 6 flights on 4 different days.

EMI's flight plan usually called for multiple cross plume traverses at different altitudes along with a spiral at each downwind distance. EMI's surveys extended from just under 20 km downwind to about 114 km downwind and covered plume ages from about 0.5 hr to about 5 hrs old. (Note: Plume ages used in this report for both EMI and MRI were determined by a Monte Carlo method described in Section 5). These flights and the graphic display of all measurements are described in the CWP CHEM-1 Data Volume (B. Vaughan et al. 1983). Highlights of that Data Volume are presented in Appendix C where the mission summaries, flight outline and flight maps are reproduced to assist in interpreting the descriptive analyses presented in Section 5.

MRI's flight plan usually called for the QueenAir to locate the plume and then circle within it for about an hour at one general downwind distance. In this way their measurements could reflect average plume parameters while sacrificing resolution on the vertical and horizontal extent of the plume at different altitudes.

MRI did carry out a "high resolution plume sampling mission" similar to EMI's flight plan described above. MRI also conducted a predawn flight on 20 February to investigate plume conditions under stable, non-photochemical conditions. Overall MRI ranged from about 30 to 120 km downwind in the course of its flights sampling plumes from 0.75 to 5 hrs old (See Section 5).

EPA's lidar aircraft from EMSL-LV conducted 6 flights on 5 different days. The dual frequency lidar profiled the aerosol layers in the study region with flights overlapping both EMI and MRI. The data provide an excellent picture of the vertical structure of the atmosphere during the study and are reported in the EPA-Lidar Data Volume (McElroy et al. 1982). Profiles observed ranged from single layers to complex "Z" profiles.

3.5 Data Processing, Quality Assurance and Validation

Each platform and group was responsible for its own data processing activity. These activities involved instrument calibrations, along with pre-flight and in-flight checks followed by careful examination and editing of the magnetic data tapes. EMI's processing of its CHEM-1 data followed the procedures used for the PEPE-NEROS field program and are described in detail in the CWP CHEM-1 Data Volume (B. Vaughan et al. 1983). MRI's data were processed according to their internal and PMV guidelines which are described to various degrees in several sources (EPRI, 1981; L.W. Richards, et al. 1981; and G.M. Sverdrup and C.W. Spicer 1983).

While the above procedures are fairly routine for EMI and MRI, special procedures were also set up for the CWP study to assure timely recognition of any instrument problems and to assure satisfactory intercomparison of measurements from the two monitoring platforms. This latter function focused on issues of cross-calibration of instruments by the two companies (to obtain intercomparison of instruments and techniques), parallel flyby of the aircraft (to document intercomparison while flying through the same air mass, e.g. Figure 3.4) and common QC filter samples (to compare results from different analytical laboratories). These activities have been presented in detail in the CWP CHEM-1 Data Volume (B. Vaughan, et al. 1983) and in a paper by W.M. Vaughan, et al. (1982).

Timely recognition of instrument problems was possible due to the services of Dr. Gillani of WUTA. He provided 24-hour turn around on both MRI and EMI data tapes. He took the raw tapes and converted them into strip chart format for quick appraisal of instrument operation and mission success. Several problems were corrected in timely fashion due to this service. The cross platform comparisons proved helpful in giving confidence to the overall data set.

In summary, the cross comparisons on the ground gave good results. EMI instruments were within 8-12% of the EMI calibrations when cross calibrated by the MRI crew. MRI's instruments were within 1-7% of the MRI calibrations when

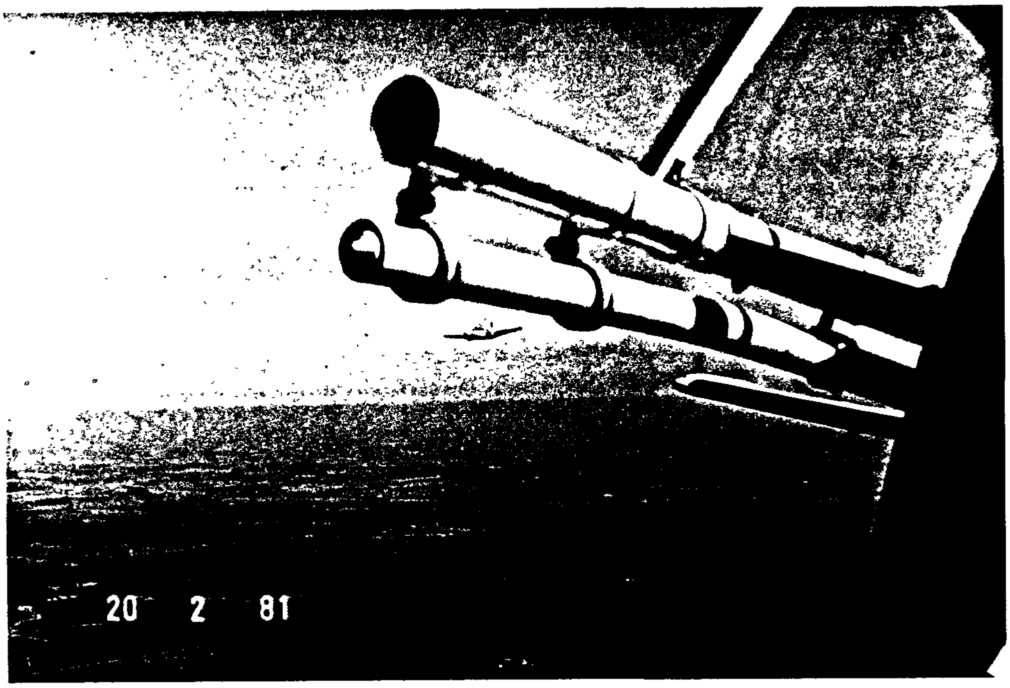


Figure 3-4. Parallel flyby on 20 February showing MRI's Queen Air in position behind CHEM-1. Aerosol intake manifold dominates the near field.

cross calibrated by EMI's technician.

The results of the parallel flybys are seen in Figure 3-5 a-g where seven parameters on 3 flybys are plotted on the same scale. Except for some offset differences on SO_2 these results are quite good.

Positional information was also carefully checked. Using known landmarks, the field notes and final positions agree quite well for EMI. MRI reports their positional resolution to be 1^o and ± 0.2 km with their on board DME/VOR instrumentation (See Table 3-2).

Additional QA support by EPA's Quality Assurance Division was planned for the source sampling equipment operated by Rockwell at Kincaid. However, a severe storm passed through the area just before the project began causing the electrical power cable to the stack elevator to be severed. With no safe and straightforward access to the stacks, no QA checks were performed there.

Figure 3-5a. A comparison of SO_2 from EMI (——) and MRI (---) Flybys

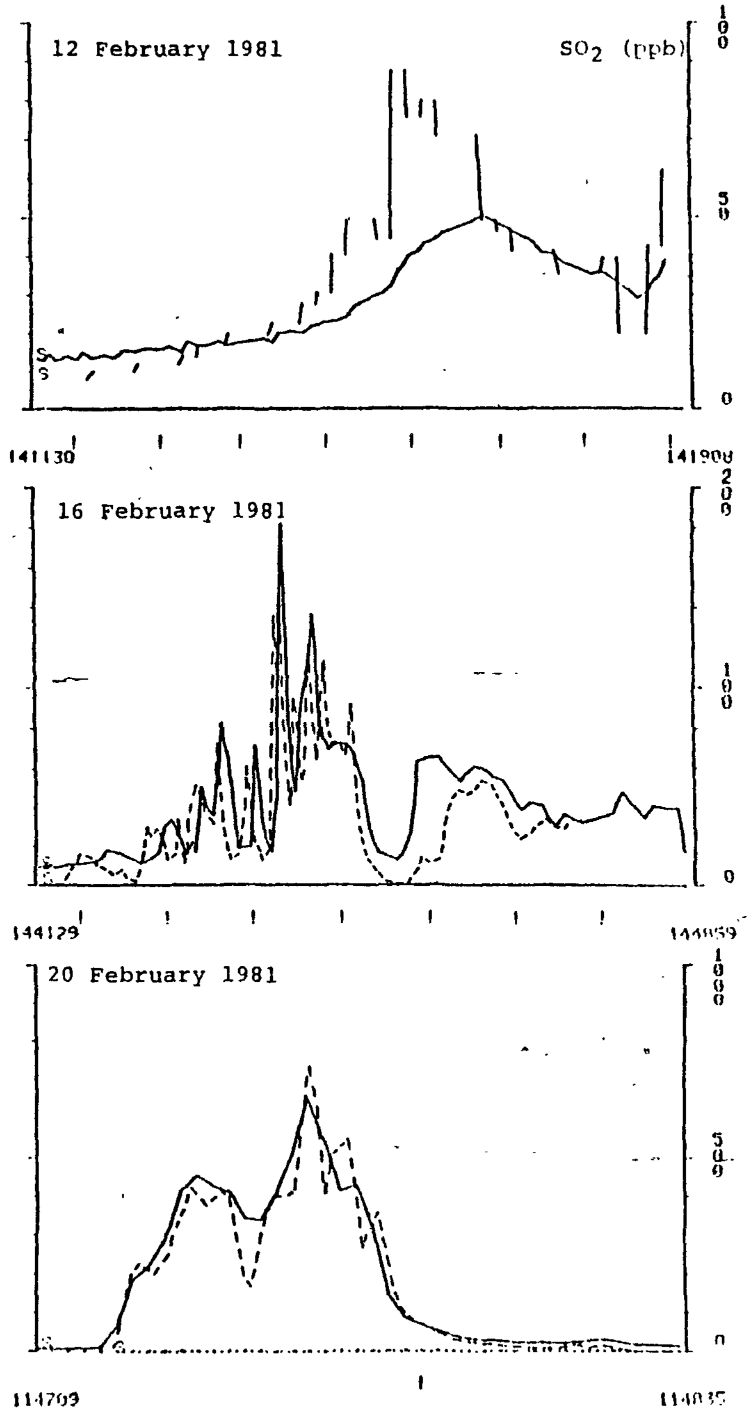


Figure 3-5b. A comparison of NO_x from EMI (—) and MRI (---) Flybys

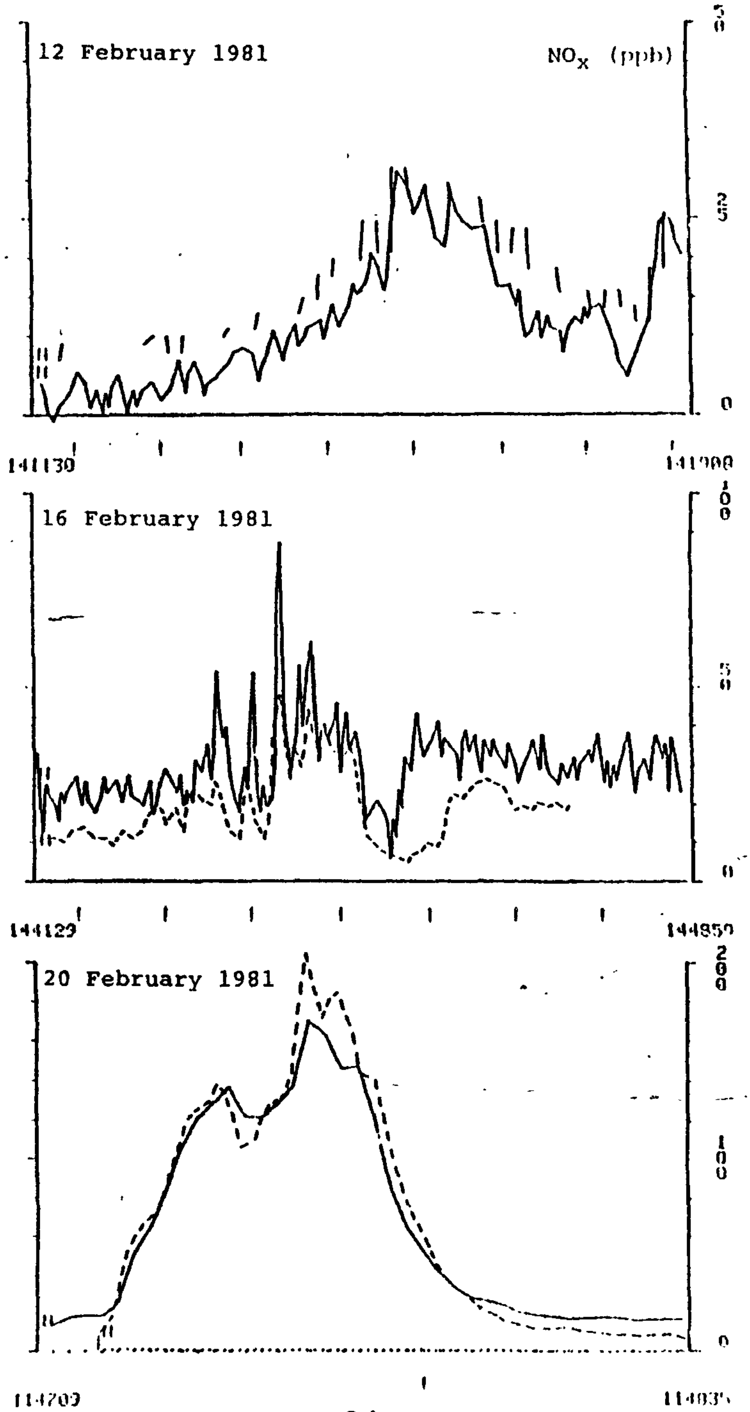


Figure 3-5c. A comparison of NO from EMI (——) and MRI (---) Flybys

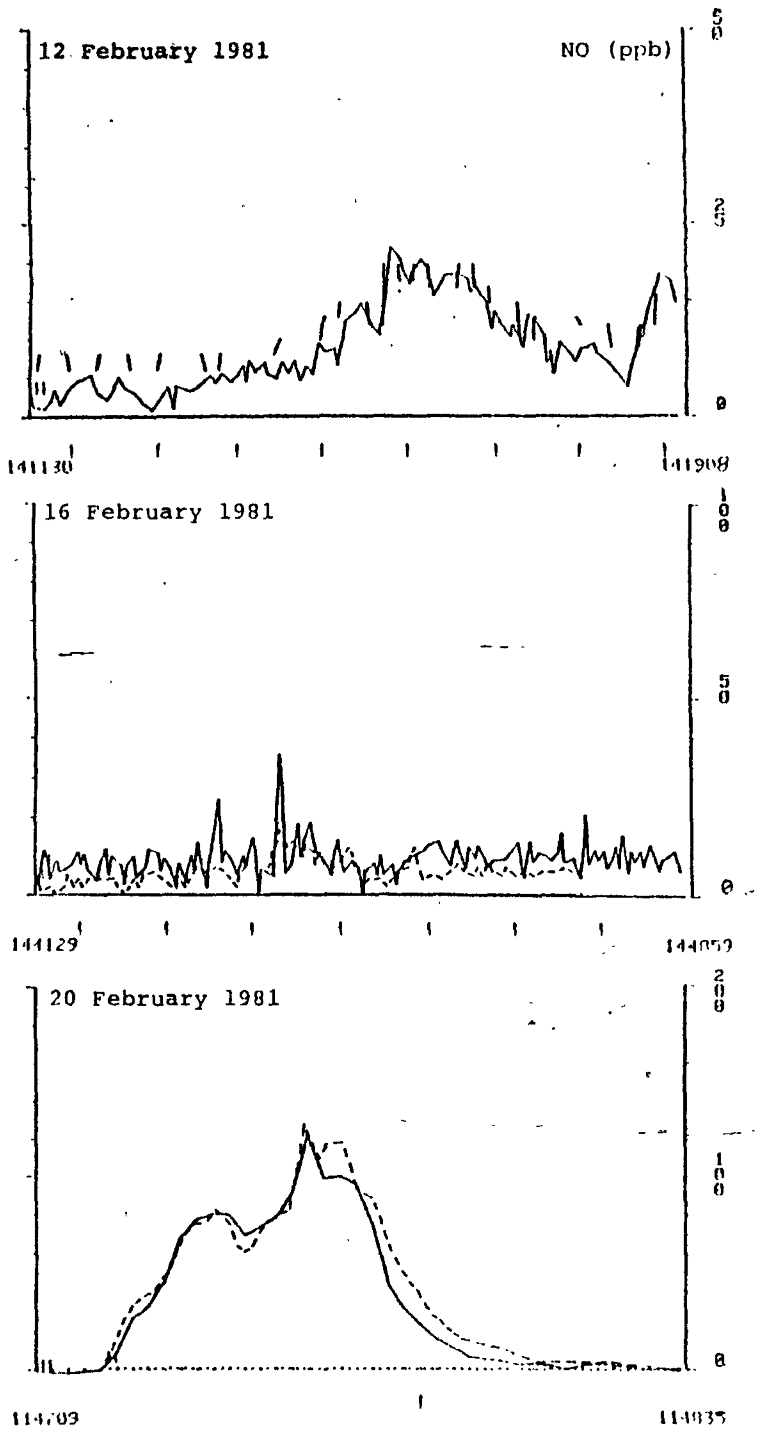


Figure 3-5d. A comparison of O_3 from EMI (....) and MRI (---) Flybys

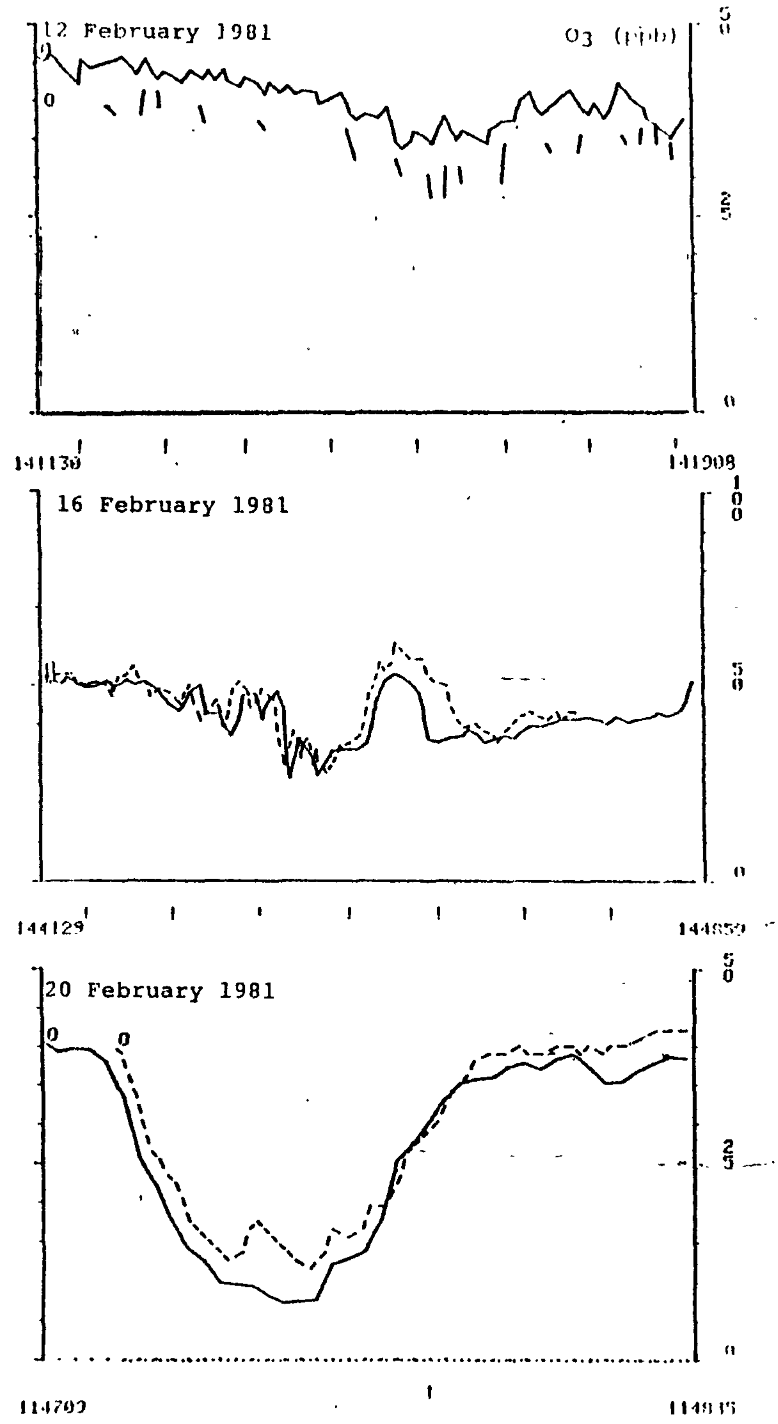


Figure 3-5e. A comparison of AHC from EMI (_) and HPI (---) flybys

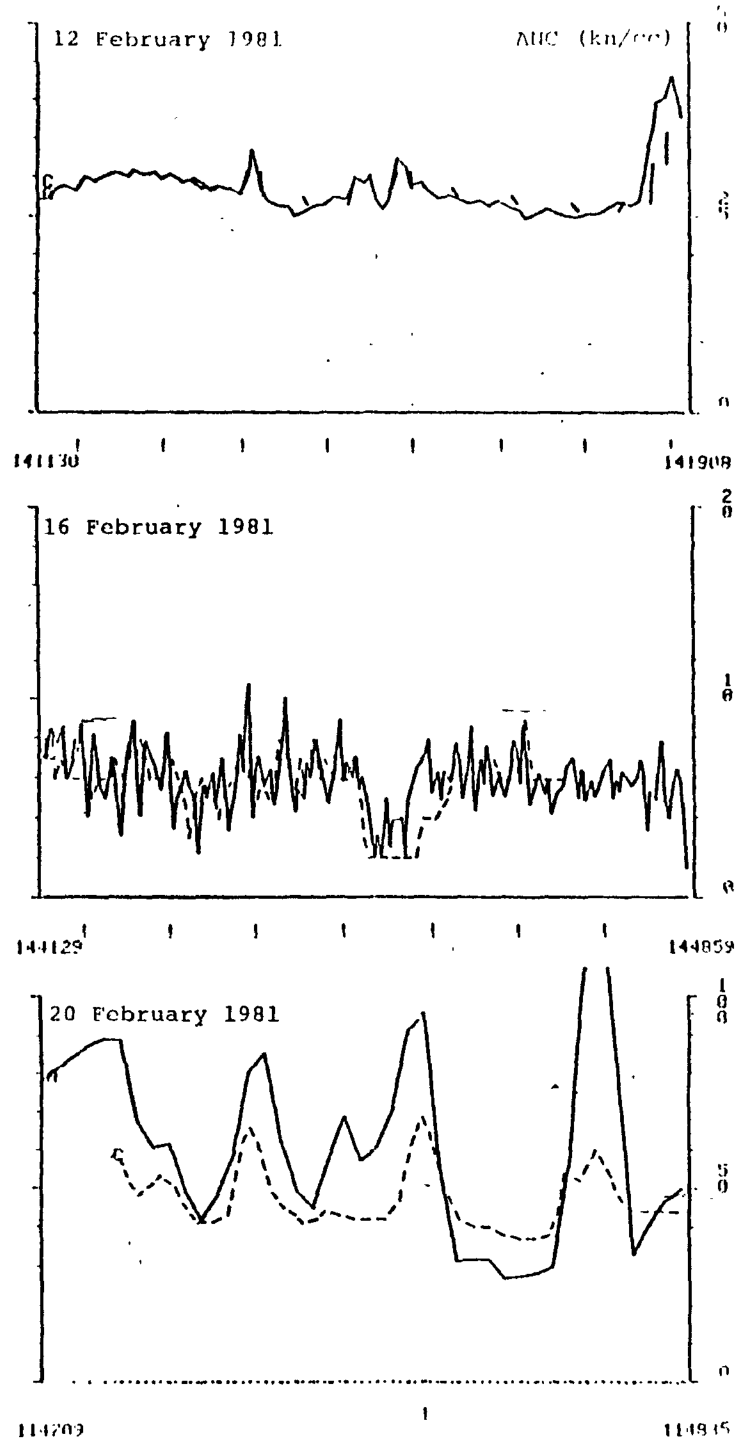


Figure 3-5f. A comparison of B_{scat} from EMI ( ) and MRI (---) Flybys

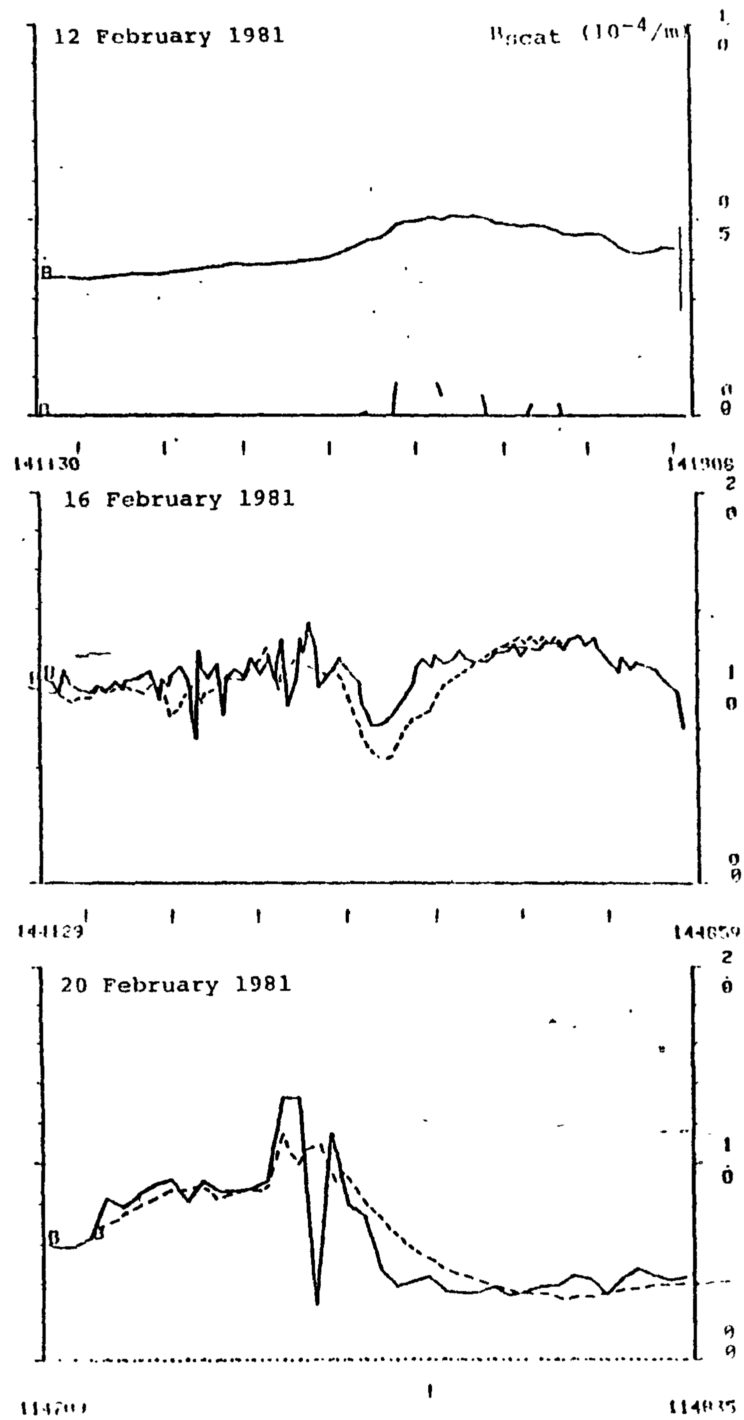


Figure 3-5g. A comparison of charge from EMI (—) and MRI (---) Flybys

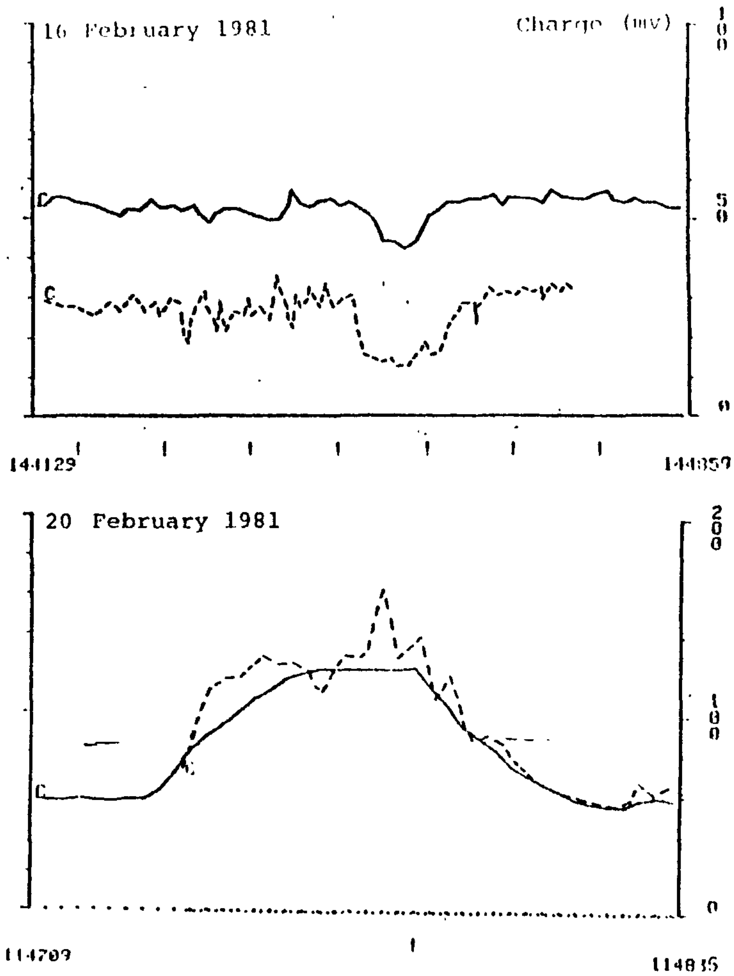
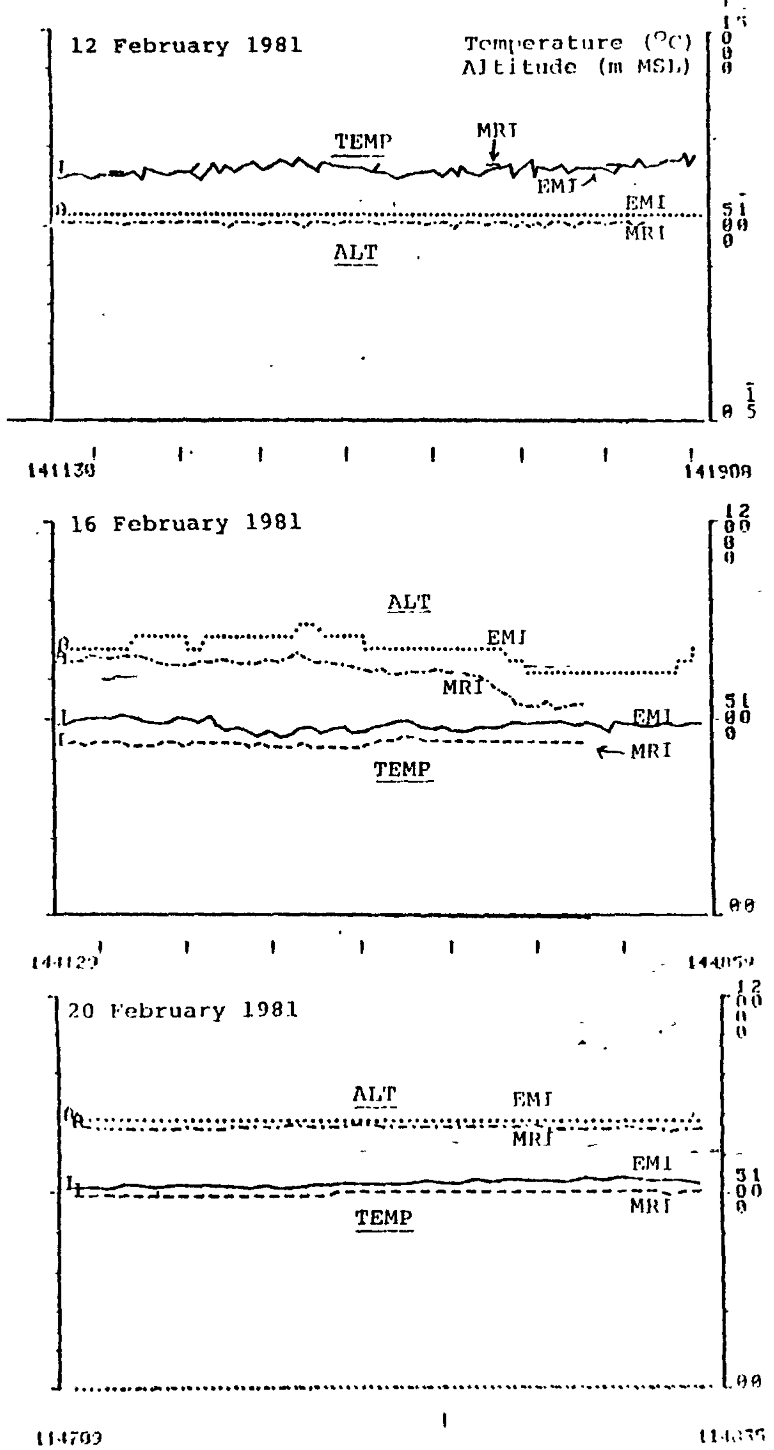


Figure 3-5h. A comparison of temperature and altitude from EMI and MRI Flybys



SECTION 4

DATA BASE

The CWP data have been incorporated into the WU/EPA Special Studies Data Center at Washington University under the direction of Dr. Noor Gillani. This data base consists of magnetic forms of the final validated data as well as hard copies of reports, articles and data volumes associated with the CWP study.

The magnetic data were submitted in STATE-10 and are now in STATE-20 format which has evolved since the mid 70's for EPA's airborne sampling programs. The format is described in Gillani, 1983.

The CWP data base is summarized in Table 4-1.

The CWP data base will be available from the following sources:

Noor Gillani, ScD
Dept. of Mechanical Engineering
Washington University
Campus Box 1187
St. Louis, MO 63130
314/889-6079

Chief, Data Management Branch
Meteorology and Assessment Division (MD-80)
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711
919/541-4545

TABLE 4-1. CWP STUDY DATA BASE SUMMARY

JOINT EPA-EPRI COLD WEATHER PLUME STUDY (CWPS 1981)

SUMMARY OF MEASUREMENTS

WU/EPA Special Studies Data Center
Washington University
St. Louis, MO

Sponsor	Organization	Data Collecting Platform		Data Description	Archive Form & Availability	
EPA	EMI	Aircraft (Cessna 404)		5 Sampling Missions		
			Continuous Data: (2 sec.)	Time, VOR/DME, (LAT/LONG), altitude, temp, dew point, SO_2, NO/NO_x, O_3, B_{scat}, ANC, Aerosol charge, $SO_4^=$, H_2SO_4 (continuous sulfate data believed to be of unacceptable quality)	Mag tapes Data Volume	✓ ✓
			Aerosol Size Distribution:	EAA (Data not processed yet) OPC (Data not processed yet)	-	
			Other Samples:	Filter samples analyzed for $SO_4^=$, NO_3^-, NH_4^+ and NH_3, HNO_3	Tabulations in Data Volume	✓
				Grab samples analyzed for detailed HC speciation	Tabulations in Data Volume	✓
	AV	Pibals Minisonde		Discrete vertical soundings during mission days altitude, wind speed/direction, temp	Mag tape Data Volume	✓ ✓
	SRI	Weather Forecast and Analysis Support		Meteorological Summary Report	Report	✓
	EPA-LV	Aircraft Lidar	Continuous Data:	Time, location, ground speed, ground temp, dual frequency lidar return (aerosol backscatter) at 20 ft. intervals (10000 ft to ground level)	Mag tapes	✓
				Flight maps, photographic data plots	Data Volume	✓
	ILLINOIS (*) STATE WATER SURVEY (Champaign, IL)	Surface station		Total incident solar radiation	Data plots Mag tape	✓ ✓

(*) Collected independent of CWPS. ISWS broad-band radiation data received in stripchart form, and subsequently digitized at WU Data Center.

(continued)

TABLE 4-1. (continued)

Sponsor	Organization	Data Collection Platform	Data Description	Archive Form &	Availability
EPRI	MRI	Aircraft (Queen Air)	Continuous Data: (1 s.) Time, location (Distance, heading from origin of each traverse), altitude, indicated air speed, temp, dew point, turbulence, UV & Broad-band Radiation, SO_2, NO, NO_x, HNO_3, O_3, Bscat, ANC, Aerosol Charge	Mag tapes Data Volume	✓ August 1984
			Aerosol Size Distribution: EAA, OPC, FSSP	Mag tapes	✓
			Other Samples: Filter Samples: $SO_4^=$, NO_3^- (Ion Chromatography) Elemental (XRF & PIXIE) Composition Total Inorg. NO_3 (EC-GC) NH_3 (Colorimetry)	Mag tape	✓
			Bag Samples: PAN, detailed HC speciation (GC)	Mag tape	✓
			5-min average data		
	ROCKWELL INTERNATIONAL	Source Monitoring	SO_2, NO, O_2, Stack exit velocity & temp	Mag tapes	✓
		Met tower (10 m) Met tower (100 m)	ΔT (2 m - 10 m) Wind speed/direction (10, 30, 50, 100 m) ΔT (10 m - 50 m, 10 m - 100 m) Dew point (100 m) u, v, w winds (100 m)	Mag tape	✓
		Surface station	T_o, Radiation (Total, net, sky - data good 1 day only)		
			Hourly data		
		Surface station	Atm. pressure, cloud cover, precip.	Mag tape	✓
		NWS Surface Obs. (Springfield)	Atm. pressure, T, dew point, wind speed/direction, ceiling height, cloud cover, precip.	Mag tape	✓

SECTION 5

DESCRIPTIVE ANALYSIS

The measurements which were made during the CWP study have undergone partial analysis to achieve a description of conditions and concentration levels in the plume and surrounding air mass. These descriptive analyses will be presented in this section with the thought that a potential user of the data can develop an interpretive analysis by applying his or her own subjective judgements, assumptions and criteria on the use of the data. It has been our intention that we would make minimum assumptions and present the potential user with a reasonable number of options in further interpreting the data. For example, EMI has presented the cross plume integrals for various parameters, including background, for various portions of complex profiles so that end users can select the portion to be used and the background to be subtracted. In addition, while MRI and BCL did undertake some interpretive analysis with their data i.e. correcting for background, establishing ratios, etc., we present their composite data and add information on plume age for further interpretation.

5.1 Meteorological Data

The CWP meteorological data gathered by Rockwell and AV and summaries by William Viezee of SRI are presented in Appendices A and B. The graphic summary of transport winds is presented in Appendix A where wind vectors versus altitude are graphically presented with time to facilitate interpretation of the changing transport conditions. Displays of Rockwell and AV data are included.

The altitude versus time profiles for four different parameters measured by AV's roving minisonde platform are available from EMI for contour plotting. The base graphics include the individual readings plotted at the reporting altitude for the time of the sounding. Since numerous subjective judgements are involved in contouring these data to show the dynamics of the atmosphere during each day for each parameter, those desiring to conduct an interpretive analysis of the data are free to supply their own assumptions to this task once they obtain a copy.

Appendix B provides the overall meteorological context of each day's mission along with maps and satellite photos and NWS soundings.

5.2 Estimation of Plume Age

For quantification of plume physical dynamics and chemical kinetics, it is necessary to estimate the transport age of the sampled plume parcels at discrete downwind locations. The estimates of plume ages at locations of aircraft traverses and orbits for all missions of both aircraft (EMI and MRI) were determined by Dr. Gillani's group at Washington University based on the use of measured winds and a plume transport simulation model.

The wind data base used for this purpose included the AV pibal data and the Rockwell T-sonde data. In each case, horizontal wind vectors (wind speed/direction) were available as a function of height at each of many soundings distributed in space and time in the general region and period of the aircraft missions. The transport simulation was based on a Monte Carlo plume transport technique previously used by White and Patterson (1983) and White et al. (1983). The method involves a trial and error approach. Corresponding to a given plume cross-sectional sampling, a release time of the sampled plume parcel is guessed, the transport simulation performed until the time of sampling at which time the location of the simulated plume is compared with the sampling location. If there is a significant descrepancy, the release time is adjusted appropriately and the simulation is repeated. This iterative procedure is repeated until the simulation matches the observation. The time from plume release to plume sampling thus provides the estimate of plume age.

In the actual transport simulation, the Monte Carlo technique is used. First, based on observed data of plume rise and vertical spread, and PBL dynamics (from aircraft soundings and lidar observations), an approximate time-height picture of plume history is reconstructed. Then, 100 "dots" representing quantized source emission are released above the source in the effective plume height layer. The transport simulation is done then in half-hour intervals. For each half hour, the measured wind vectors within ± half an hour of this time interval are selected. The subset of these vectors which correspond to the plume layer for this time interval is then collected into a "pool" of wind data. Each dot is advected according to the speed and direction of a randomly-selected wind vector out of this pool. Initially, when the plume vertical thickness is small, this pool contains very few wind vectors, and an equally small number of downwind locations to which the 100 dots can be advected. As the plume spreads vertically, there are progressively more wind vectors in the pool in each succeeding half hour. Thus, the 100 dots move forward in a dispersion cluster in successive intervals. The simulated dispersion thus includes the effect of wind shear and veer in the growing plume transport layer. The simulated dispersion provides a second dimension of information to compare with the observed plume spread (based on the aircraft traverse data).

An example of the method is shown in Figure 5-1. This shows a Monte Carlo run with a release time of 1200 on 16 February superimposed on an aeronautical sectional map with a scale of 1:500,000. Clusters of numbers 1 through 7 can be seen at different distances to the ENE of Kincaid representing the random motion of the simulated plume over 3½ hours of transport. The numbers 1 represent the plume cluster after ½ hour of transport. The numbers 2 represent the same at 1 hour, 3 at 1½ hours, and so on. The Lagrangian Monte Carlo plot is superimposed on a map showing event #3 of the EMI aircraft on February 16. This event is for the time 1407-1419. The pollutant dots numbered 4 come close to the given plume traverse, indicating about 2 hours (namely, 4 thirty minute intervals) of transport (1200 to 1400). Thus, the release time estimate of 1200 is reasonable, and the plume age estimate is about 2 hours.

Similar runs of the model and comparisons with flight maps enabled the plume ages of traverses and orbits to be determined for EMI and MRI measurements.

5.3 Aircraft Data

5.3.1 EMI's CHEM-1 Continuous Data

The CHEM-1 Data Volume presents graphic displays of all CHEM-1 measurements and should be used in conjunction with this section for further analysis and utilization of the data. In order to encapsulate the essence of these measurements, EMI carried out cross plume integrals of seven plume parameters and corrected for plume width to achieve cross plume averages. These averages were determined using annotated graphics for each event plotted in the Data Volume. For multi-lobed profiles, a traverse was broken into possible subcomponents to separate out possible inclusion of the Coffeen or Springfield plumes. The text and map sections of Appendix C will identify those times when such plume interference was possible. No background was subtracted from the integrals so the averages are plume plus background.

These cross plume averages are presented in Tables 5-1 through 5-5 for all of EMI's measurements. The traverse number is given so the flight outline and maps of Appendix C and

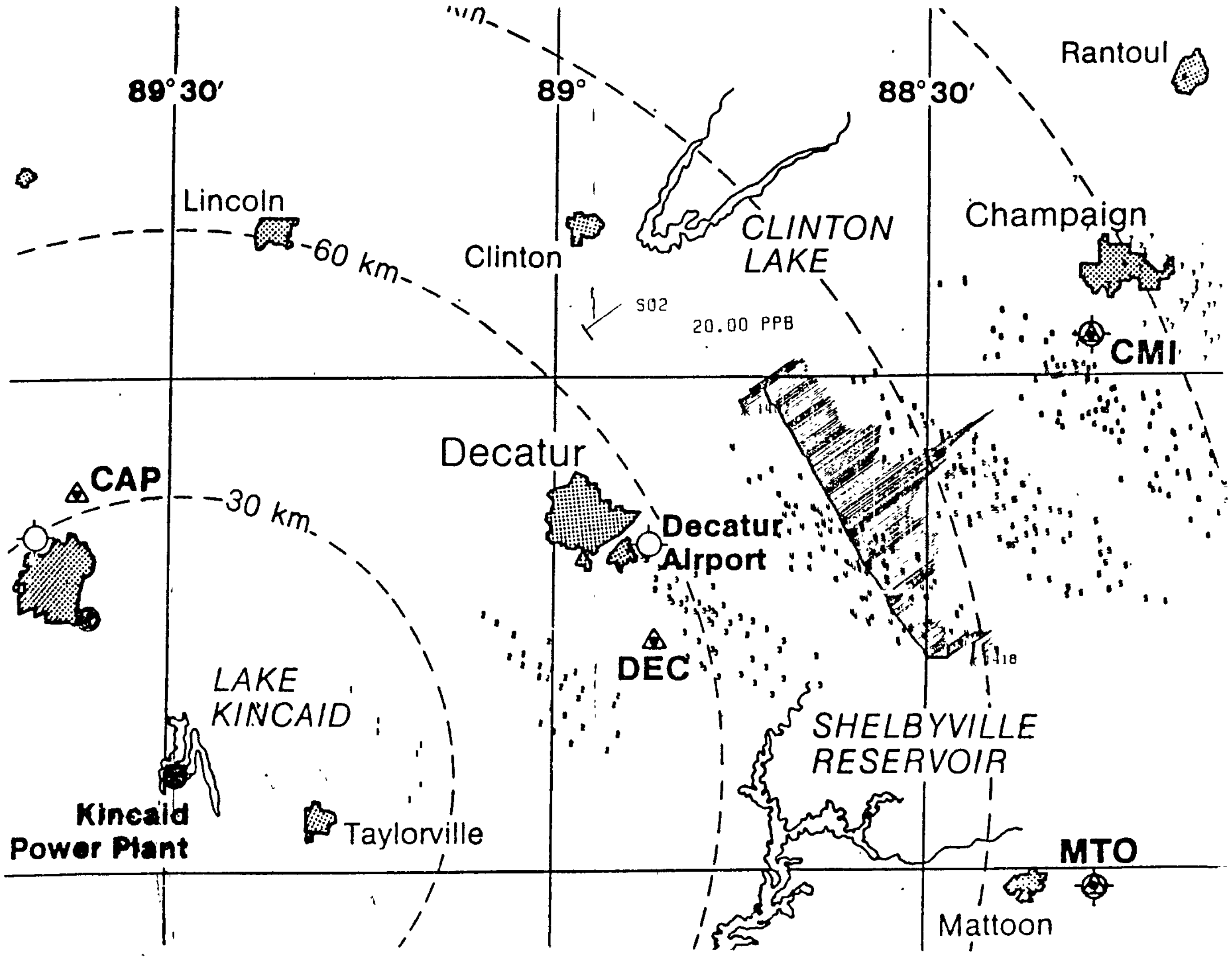


Figure 5-1. Example of plume age determination using the Monte Carlo method for CHEM-1's flight at about 1400 on 16 February.

TABLE 5-1.
CWP Traverse Summary Table - 12 February 1981
Average Concentration (Incl. Background)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
4A	23	30	100018	100154	470	92.50	0.36	35.30	18.95	17.10	2.92	81.32
4B	23	"	100018	100118	470	111.20	0.37	34.50	23.39	24.10	2.61	82.55
7A	25	30	103128	103640	470	99.50	0.46	32.50	24.28	25.60	15.37	111.18
7B	25	"	103128	103336	470	120.30	0.48	30.70	32.50	34.80	14.63	129.84
7C	25	"	103338	103644	470	83.10	0.47	34.00	18.57	18.30	15.71	98.30
7D	25	"	102624	103004	470	37.76	0.40	38.10	7.91	2.16	15.83	87.44
7E	25	"	102624	102826	470	23.34	0.36	38.10	5.31	2.16	13.15	83.40
7F	25	"	102826	102954	470	58.84	0.46	35.38	11.52	9.36	20.10	93.53
9A	31	40	104348	104756	470	103.93	0.49	32.62	24.40	23.17	23.17	103.55
9B	31	"	104348	104554	470	94.55	0.45	33.74	22.04	24.27	20.66	102.12
9C	31	"	104554	104758	470	111.96	0.52	31.56	26.82	28.46	25.94	105.14
13A	36	35	111636	111828	683	9.85	0.18	41.52	-1.03	-6.87	7.26	47.51
13B	36	"	111636	111742	683	7.44	0.18	42.54	-2.35	-8.54	6.13	47.13
13C	36	"	111742	111828	683	13.15	0.17	40.18	0.82	-4.58	8.64	48.20
15A	30	35	113810	114042	470	82.05	0.51	34.24	19.83	20.58	36.96	109.24
15B	30	"	113552	113810	470	45.55	0.42	37.54	8.92	6.09	34.45	117.94
15C	30	"	113552	114042	470	64.74	0.46	35.80	14.07	13.69	35.56	113.34
16A	30	35	114200	114442	408	79.36	0.53	33.58	18.17	22.18	38.77	138.59
16B	30	"	114144	114504	408	70.26	0.53	34.63	16.10	18.96	37.88	131.58
17A	30	35	114908	115140	408	78.11	0.55	34.40	16.97	20.19	37.08	114.73
17B	30	"	114910	114930	408	57.99	0.52	36.40	11.32	11.94	30.35	109.84
17C	30	"	114938	115140	408	83.09	0.55	33.91	18.30	22.24	38.66	115.88
18A	FERRY		115248	115348	408	79.92	0.50	34.02	17.53	21.51	49.97	114.65
18B	FERRY		115348	115520	416	31.77	0.44	36.80	10.17	12.28	50.61	113.10
18C	FERRY		115248	115520	413	51.10	0.46	35.68	12.99	16.06	50.38	113.50

(continued)

TABLE 5-1 (continued)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
20A	65	80	123302	123646	470	62.92	0.50	36.43	15.49	18.10	34.49	134.55
21A	64	80	124506	125328	562	40.78	0.38	40.04	9.56	10.65	36.06	93.41
21B	64	"	124506	125012	562	45.27	0.40	39.40	9.95	11.10	32.76	94.76
21C	64	"	125012	125328	562	33.69	0.36	41.05	8.87	9.90	41.44	91.12
25A	64	80	131604	132038	408	67.30	0.50	INVALID	10.13	7.62	29.73	118.69
27A	31	40	134320	134620	439	46.23	0.48	37.15	11.51	13.10	30.22	113.28
28A	31	40	135520	135916	591	45.43	0.45	38.04	12.62	15.43	28.83	105.43
29A	31	40	140310	140650	683	28.94	0.35	41.39	6.56	7.36	29.78	95.49
29B	31	"	140150	140310	683	18.92	0.32	43.75	2.72	1.55	25.87	100.18
29C	31	"	140150	140650	683	25.56	0.34	42.16	5.29	5.42	28.53	97.10
30A	31	40	141428	141834	530	36.20	0.46	38.35	11.86	16.27	27.15	108.30

* Uncertainty in plume ages is ±5 minutes for 30-40 min and ±15 minutes for 80 min.

TABLE 5-2.

CWP Traverse Summary Table - 13 February 1981
Average Concentration (Incl. Background)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
3A	9	45	80208	80400	630	581.39	2.03	INVALID	143.17	129.31	4.88	46.05
3B	9	"	80230	80316	630	1266.8	3.16	INVALID	292.28	262.93	8.35	68.61
4A	14	60	80554	80700	630	730.56	1.60	INVALID	167.48	187.69	3.81	65.42
5A	17	80	81148	81234	630	317.93	0.53	INVALID	108.20	126.62	2.44	18.17
6A	17	80	81902	81234	630	592.49	1.07	INVALID	148.61	178.70	2.65	26.24
11A	18	80	84258	84348	630	573.92	1.99	INVALID	211.71	237.88	13.09	185.12
11B	18	"	84258	84332	630	744.19	1.98	INVALID	336.55	333.81	19.61	262.60
12A	24	110	84956	85038	630	745.15	1.66	INVALID	275.70	275.81	12.72	84.38
13A	28	120	85512	85552	630	605.18	1.21	INVALID	140.33	169.86	9.60	34.73
14A	FERRY		90930	91116	630	398.66	0.49	INVALID	99.09	109.26	7.50	23.53
15A	FERRY		91422	91456	630	169.89	0.37	INVALID	28.28	34.73	6.02	23.28
18A	68	300	94432	94652	630	434.83	0.63	INVALID	66.71	77.30	9.53	18.23
18B	68	"	94432	94546	630	113.39	0.25	INVALID	-4.64	-10.61	7.09	3.51
18C	68	"	94546	94652	630	774.69	1.05	INVALID	141.98	170.18	12.27	34.46
18D	68	"	94112	94142	630	61.74	0.27	INVALID	6.90	5.83	2.96	3.70
19A	68	300	95002	95032	630	92.26	0.29	INVALID	17.32	27.72	8.52	68.03
19B	68	"	95210	95256	630	28.58	0.26	INVALID	4.92	7.59	3.47	2.88
21A	47	175	100138	100328	630	68.83	0.33	29.39	16.50	20.97	34.87	18.81
21B	47	"	100136	100228	630	25.69	0.28	29.80	5.67	9.91	34.29	24.33
21C	47	"	100230	100326	630	108.18	0.37	29.12	25.88	31.13	35.07	13.37

(continued)

TABLE 5-2. (continued)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
22A	50	170	101424	101558	539	143.82	0.35	24.27	36.45	48.77	21.41	18.50
23A	52	170	101634	102120	539	51.78	0.29	21.37	11.58	16.12	19.96	12.56
23B	52	"	101632	101826	539	58.54	0.29	20.46	11.84	19.18	22.32	16.00
23C	52	"	101826	102024	539	49.91	0.29	21.65	12.38	14.74	18.92	11.54
23D	52	"	102020	102120	539	39.63	0.27	22.56	8.87	12.33	17.60	7.37
24A	57	180	102134	102516	539	78.11	0.31	21.41	17.89	24.22	15.56	10.33
24B	57	"	102136	102232	539	194.77	0.38	24.54	47.19	58.06	10.78	12.08
24C	57	"	102136	102408	539	103.87	0.33	20.93	22.53	32.31	15.51	12.04
24D	57	"	102234	102410	539	48.62	0.31	18.81	9.76	16.50	17.93	12.26
24E	57	"	102512	102746	539	45.19	0.27	25.45	11.40	14.97	26.33	12.74
24F	57	"	102748	102924	539	101.82	0.35	22.66	22.72	32.28	18.97	11.56
27A	57	160	104558	104910	538	33.76	0.28	23.16	9.09	11.43	27.93	18.62
27B	57	"	105138	105356	539	239.78	0.53	18.66	60.48	74.76	27.03	35.58
29A	57	150	111022	111132	600	37.73	0.29	27.05	7.20	8.83	30.05	94.05
30A	57	150	111918	112012	600	136.32	0.42	27.42	28.29	33.04	25.53	42.17
31A	57	145	112448	112538	630	25.32	0.29	29.09	2.89	4.18	30.39	174.35
32A	57	145	113238	113354	661	23.49	0.32	29.43	2.91	1.63	45.75	21.29
33A	57	140	113924	114058	600	16.59	0.29	29.15	1.14	0.58	28.75	17.80
33B	57	"	113922	114022	600	15.61	0.28	29.11	1.09	-0.43	28.71	17.34
33C	57	"	114020	114100	600	17.03	0.29	29.30	0.58	1.89	28.19	17.37
34A	57	135	114408	114530	539	499.55	1.27	21.26	142.54	144.79	25.73	58.22

(continued)

TABLE 5-2. (continued)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
35A	57	135	115542	115634	447	17.25	0.46	27.02	4.06	6.28	27.24	29.80
35B	57	"	115732	115836	447	25.15	0.47	26.03	4.93	7.06	27.28	29.70
37A	26	45	133240	133458	528	323.48	0.97	INVALID	67.02	79.04	16.41	66.62
37B	26	"	133240	133312	528	87.26	0.39	INVALID	25.45	34.33	11.21	39.11
37C	26	"	133312	133412	528	532.75	1.32	INVALID	112.32	122.27	19.39	72.74
37D	26	"	133412	133458	528	181.07	0.92	INVALID	32.41	46.90	16.30	77.51
38A	26	45	133632	134002	443	123.28	0.58	INVALID	27.48	46.56	21.45	68.32
38B	26	"	133634	133816	448	102.74	0.62	INVALID	19.64	49.13	16.41	63.14
38C	26	"	133634	133816	436	103.70	0.44	INVALID	28.94	37.76	27.81	72.19
38D	26	"	133922	134000	436	207.41	0.92	INVALID	41.62	54.97	14.33	68.49
41A	25	45	135522	135552	589	178.33	0.42	INVALID	25.25	28.72	18.17	44.60
42A	25	45	135934	140140	528	591.02	2.09	INVALID	106.56	111.51	21.26	116.11
42B	25	"	135934	140022	528	80.00	0.42	INVALID	7.72	8.79	12.66	43.45
42C	25	"	140022	140136	528	915.14	3.24	INVALID	170.21	176.88	27.01	165.57
42D	25	"	140322	140344	528	117.81	0.42	INVALID	34.65	41.42	22.45	99.18
43A	25	45	140542	141022	465	186.08	0.88	14.10	46.29	66.21	20.17	119.84
43B	25	"	140540	140632	456	213.59	0.64	14.83	50.41	65.05	34.30	364.36
43C	25	"	140632	140812	467	44.80	0.45	17.14	21.53	33.28	17.00	73.56
43D	25	"	140812	141020	467	284.01	1.29	11.56	62.77	92.29	17.19	95.43
44A	25	45	141430	141910	436	105.27	0.72	20.82	24.19	44.34	20.91	74.81
44B	25	"	141428	141638	436	111.06	0.83	21.05	23.54	44.82	17.34	75.82
44C	25	"	141638	141820	436	61.57	0.69	21.12	15.11	31.83	19.18	65.52
44D	25	"	141820	141908	436	172.63	0.65	19.65	44.02	66.60	33.50	89.91

(continued)

TABLE 5-2. (continued)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
45A	25	45	142028	142602	371	91.98	0.65	19.27	22.24	42.87	24.43	80.16
45B	25	"	142028	142214	361	119.88	0.61	17.53	34.19	58.31	37.30	98.08
45C	25	"	142214	142358	375	57.41	0.59	19.09	14.95	31.83	21.10	70.13
45D	25	"	142358	142610	375	94.53	0.74	20.77	19.31	38.65	17.47	74.98
46A	25	45	143428	143920	406	106.30	0.61	21.47	20.15	39.27	19.95	110.42
46B	25	"	143428	143640	406	101.40	0.68	22.18	17.96	36.69	16.34	151.49
46C	25	"	143640	143830	406	62.17	0.52	22.03	12.29	29.57	17.83	62.11
46D	25	"	143830	143918	406	220.19	0.61	18.35	44.84	67.48	36.66	93.72
47A	25	45	144020	144530	467	113.41	0.54	20.48	19.84	37.47	17.12	65.37
47B	25	"	144018	144118	467	165.37	0.48	19.54	30.13	48.63	26.55	80.56
47C	25	"	144118	144242	467	46.38	0.41	20.19	7.12	19.29	14.37	56.92
47D	25	"	144220	144528	467	126.15	0.62	20.95	23.10	41.77	15.35	64.84
49A	25	45	145814	150152	528	153.38	0.37	20.65	16.48	16.78	12.11	56.33
49B	25	"	145814	145920	528	318.96	0.45	23.87	43.75	58.92	13.47	58.55
49C	25	"	145918	150150	528	81.00	0.34	19.14	2.67	-1.91	11.42	55.54
50A	25	45	150528	150856	589	103.01	0.18	29.10	9.42	0.18	9.75	35.13
50B	25	"	150526	150728	589	28.56	0.03	29.98	-6.40	-16.53	8.73	33.86
50C	25	"	150728	150858	589	198.95	0.39	27.89	32.19	22.17	11.17	36.78
51A	75	125	153046	153430	528	166.69	0.36	18.64	27.22	49.87	14.37	69.48
51B	75	"	153046	153202	528	133.90	0.15	24.30	21.30	44.12	12.55	49.99
51C	75	"	153204	153430	528	184.02	0.47	15.64	30.41	52.92	15.36	80.01
52A	75	125	154008	154438	589	32.64	0.24	27.48	24.92	34.55	9.54	42.98
52B	75	"	154008	154356	589	25.91	0.24	27.25	25.09	32.84	9.74	14.92
52C	75	"	154356	154438	589	67.93	0.24	28.73	22.80	43.63	8.06	224.43

* Uncertainty in plume ages in ±10 minutes for 45 min, ±15 minutes for 50-160 min and ±20 minutes for 170-180 min.

TABLE 5-3. CWP Traverse Summary Table - 14 February 1981
Average Concentration (Incl. Background)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
3A	25	100	81434	81532	570	275.15	0.62	22.68	93.16	100.04	2.85	70.72
7A	25	100	85356	85424	572	431.59	0.55	23.63	82.33	124.37	2.61	63.58
8A	25	100	90158	90520	509	56.49	0.27	27.66	29.39	48.08	26.89	82.00
8B	25	"	90156	90240	500	47.51	0.29	27.48	27.73	43.57	1.21	111.23
8C	25	"	90240	90348	511	29.01	0.27	52.18	26.42	44.07	70.87	60.83
8D	25	"	90346	90528	511	57.81	0.25	27.74	31.73	49.41	6.28	85.24
9A	25	100	90856	91102	511	49.62	0.28	28.58	26.29	46.03	1.31	84.20
9B	25	"	90856	91002	511	48.80	0.28	27.97	25.51	44.54	1.32	60.56
9C	25	"	91002	91102	511	49.54	0.28	29.49	27.23	47.17	1.30	112.63
9D	25	"	91144	91608	511	95.27	0.28	21.38	44.32	67.90	1.44	61.51
9E	25	"	91608	91746	511	34.96	0.24	29.88	20.84	38.09	0.94	95.56
9F	25	"	91610	91654	511	34.27	0.24	30.04	19.22	37.70	0.94	120.28
9G	25	"	91656	91746	511	36.10	0.24	29.61	23.31	38.96	0.93	137.93
11A	64	300	93040	93622	548	20.88	0.35	36.86	18.24	31.13	1.18	61.14
11B	64	"	93704	94652	542	60.66	0.34	30.17	20.30	35.35	1.40	77.47
11C	64	"	93708	94002	542	57.73	0.38	31.33	20.86	37.03	1.50	88.01
11D	64	"	94002	94552	542	65.82	0.34	29.60	20.35	34.97	1.40	76.64
11E	64	"	94552	94650	542	38.57	0.24	30.05	18.49	32.25	1.09	52.02
13A	60	240	95524	95946	633	171.61	0.30	25.79	32.96	49.52	2.77	82.47
13B	60	"	95942	100434	633	71.10	0.25	31.92	19.37	31.14	2.01	51.61
15A	60	225	101156	101546	450	39.12	0.31	31.91	20.16	34.63	2.01	69.39
15B	60	"	101156	101402	450	32.69	0.29	31.76	21.33	35.21	1.67	55.82
15C	60	"	101400	101550	450	45.52	0.34	32.18	18.73	33.32	2.40	84.89
15D	60	"	101722	101942	453	23.78	0.32	33.22	17.27	29.10	2.08	58.59
15E	60	"	101942	102338	453	45.17	0.33	30.28	23.57	38.07	2.23	65.77
15F	60	"	101726	102338	453	37.41	0.32	31.37	21.12	34.76	2.17	62.95

(continued)

TABLE 5-3. (continued)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
17A	63	220	103244	103852	633	312.20	0.44	18.91	56.21	79.32	4.62	82.74
17B	63	"	103900	104714	574	534.31	0.90	14.75	114.30	141.27	5.42	77.46
18A	ORBIT		104744	105528	572	104.28	0.28	31.37	26.38	41.82	7.69	60.84
19A	60	210	105530	110320	572	202.56	0.49	26.62	47.67	64.61	4.05	86.59
19B	60	"	105530	105910	572	96.21	0.32	30.67	25.37	40.61	4.22	62.73
19C	60	"	105910	110144	572	425.88	0.78	19.79	95.08	116.15	4.92	135.16
19D	60	"	110142	110320	572	84.84	0.39	28.44	23.29	36.04	2.21	63.91
22A	FERRY		111508	112132	604	160.42	0.46	28.11	34.17	49.09	3.17	62.23
22B	FERRY		112134	112412	388	55.83	0.70	31.54	31.42	52.52	22.63	115.76
23A	90		131206	131258	605	88.32	0.36	9.91	-5.43	-19.50	2.00	68.39
23B	90	not	131300	131746	605	67.52	0.32	32.60	36.59	70.21	1.75	76.38
23C	90	Kincaid	131300	131436	605	87.80	0.35	31.45	45.25	80.55	1.97	71.20
23D	90		131436	131746	605	56.91	0.29	33.22	44.50	64.84	1.55	81.39
24A	90	190	131918	132114	605	75.62	0.30	31.93	46.68	65.95	1.83	73.14
24B	90	"	132116	132654	605	81.10	0.36	31.95	45.44	64.60	1.88	94.93
24C	90	"	132116	132426	605	65.29	0.34	33.16	43.81	62.53	1.72	93.55
24D	90	"	132424	132658	605	97.81	0.39	30.72	47.41	66.76	2.08	96.48
25A	92	180	132926	133232	636	296.77	0.56	25.89	75.50	105.98	3.79	96.15
25B	92	"	132924	133116	636	375.24	0.61	24.12	90.52	123.14	4.76	96.82
25C	92	"	133116	133230	636	178.41	0.48	28.68	53.79	79.95	2.39	94.69
25D	92	"	133230	133502	636	30.47	0.32	37.56	35.83	53.73	1.13	79.35
25E	92	"	133502	133832	636	25.43	0.29	36.92	32.37	55.61	1.10	62.34

(continued)

TABLE 5-3. (continued)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
26A	91	180	134032	134354	666	19.50	0.27	41.76	17.77	41.82	0.93	56.19
26B	91	"	134354	134714	666	26.68	0.30	39.87	18.52	41.27	0.92	56.41
26C	91	"	134812	135002	666	164.35	0.47	34.69	44.13	70.76	2.55	76.85
30A	90	175	140836	140958	636	424.92	0.61	27.10	94.12	126.65	6.06	90.67
31A	ZIG-ZAG		141402	141756	636	101.71	0.27	40.53	28.98	50.06	1.90	55.09
31B	ZIG-ZAG		141402	141602	636	10.45	0.15	47.14	13.09	28.71	0.72	43.20
31C	ZIG-ZAG		141600	141758	636	190.64	0.40	33.98	45.40	71.49	3.14	67.80
31D	ZIG-ZAG		142152	142618	634	109.64	0.22	46.78	27.73	50.82	1.79	51.91
31E	ZIG-ZAG		142152	142450	633	147.44	0.22	42.81	34.98	59.00	2.20	52.71
31F	ZIG-ZAG		142450	142628	636	28.15	0.22	55.35	14.03	33.06	1.00	50.33
31G	ZIG-ZAG		143108	143402	554	194.68	0.47	40.59	41.54	73.37	4.16	73.94
31H	ZIG-ZAG		143540	143752	544	479.81	0.86	31.99	110.01	152.51	14.39	120.59
31I	ZIG-ZAG		144408	144630	548	256.87	1.00	35.79	88.85	114.92	15.19	109.52
31J	ZIG-ZAG		144630	144818	586	352.33	1.26	33.83	96.09	137.86	16.84	110.44
31K	ZIG-ZAG		144818	145042	609	372.39	1.34	35.78	114.98	147.33	15.73	119.56
31L	ZIG-ZAG		145042	145256	621	478.74	1.55	36.45	118.96	146.14	19.87	144.55

* Uncertainty in plume ages in ±15 minutes for 100-190 min, ±20 minutes for 200-220 min and ±30 minutes for 225-300 min.

TABLE 5-4. CWP Traverse Summary Table - 16 February 1981
Average Concentration (Incl. Background)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
2A	81	120	135709	140159	739	33.17	0.92	49.89	7.01	28.23	5.85	46.96
2B	81	"	135711	135937	739	30.99	0.97	49.87	6.84	28.62	6.75	48.65
2C	81	"	135937	140159	739	35.57	0.87	49.89	7.17	27.65	4.91	45.35
3A	81	120	141039	141527	647	34.93	1.10	45.52	8.24	28.86	5.93	53.41
4A	81	120	142241	142739	677	26.12	1.02	46.27	7.49	27.09	5.24	49.22
5A	81	120	143109	143507	586	22.28	1.18	44.55	8.33	27.89	5.69	53.41
6A	88	140	144147	144633	694	42.69	1.05	43.01	9.14	29.95	5.93	79.63
10A	81	130	151855	151959	769	10.99	0.74	54.08	7.34	17.72	2.77	54.78
10B	81	"	151717	151923	769	6.45	0.96	56.54	6.13	16.87	3.28	40.85
10C	81	"	151925	152119	769	6.96	0.56	55.62	6.88	17.25	2.23	42.84
11A	Bkgrnd?		152415	153613	750	2.24	0.55	54.81	7.98	19.96	1.89	28.80
12A	114	185	153845	154251	767	14.55	0.83	52.63	6.94	20.18	3.50	38.32
13A	114	185	155629	155851	694	27.00	0.96	50.04	6.82	21.40	4.16	59.41
14A	114	185	160125	160201	616	15.39	1.06	53.40	6.36	18.37	6.63	130.69
15A	114	185	160715	160811	555	24.23	1.12	49.93	5.53	21.94	7.13	66.65
16A	114	185	161219	161325	494	33.44	1.25	43.66	7.16	23.06	7.94	57.20

(continued)

TABLE 5-4. (continued)

Trav #	Dwnwind (km)	Age+ (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
18A	76	145	163521	163641	677	10.39	0.97	55.92	6.88	16.75	4.03	42.08
18B	76	"	163641	164021	677	46.96	0.96	47.14	8.47	26.52	4.07	73.45
19A	76	145	164341	164627	616	14.75	1.06	54.00	7.06	17.97	3.86	92.13
19B	76	"	164343	164439	616	9.55	1.03	55.87	7.59	17.18	3.49	40.03
19C	76	"	164435	164551	616	21.72	1.07	50.90	6.84	19.91	4.13	138.76
19D	76	"	164551	164627	616	8.89	1.04	57.33	6.98	15.39	4.06	39.53
20A	ZIG-ZAG		165115	165815	677	55.54	0.96	43.71	8.70	32.27	4.26	41.91
20B	ZIG-ZAG		165819	170235	677	46.14	0.89	48.68	8.66	27.39	4.03	39.08
20C	ZIG-ZAG		170235	170623	677	33.51	0.67	50.81	7.45	23.56	3.15	32.12

* Uncertainty in plume ages in ±10 minutes for Table 5-4.

TABLE 5-5. CWP Traverse Summary Table - 20 February 1981
Average Concentration (Incl. Background)

Trav #	Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
2A	Bkgnd		105525	105903	622	5.90	0.22	35.88	-0.47	19.27	3.33	21.72
4A	72	29.5	112001	112343	622	34.20	0.55	35.02	2.52	22.10	78.17	65.17
4B	72	"	112001	112155	622	45.71	0.56	32.38	5.37	26.01	76.17	74.39
4C	72	"	112001	112047	622	25.96	0.48	34.88	1.40	20.95	61.78	84.37
4D	72	"	112047	112153	622	59.30	0.61	30.63	7.99	29.49	85.97	66.94
4E	72	"	112153	112343	622	21.63	0.55	37.87	-0.49	17.76	80.31	55.44
5A	72	29.5	112645	112905	683	72.31	0.46	33.49	10.66	33.33	55.92	57.45
5B	72	"	112643	112801	683	59.22	0.45	33.80	8.57	30.10	65.98	53.82
5C	72	"	112801	112903	683	87.82	0.48	33.27	12.67	37.17	44.04	62.17
7A	75	300	114109	114209	687	89.49	0.59	34.93	18.57	37.93	66.24	53.40
8A	73	30.0	114633	114949	683	82.20	0.53	33.48	13.96	38.01	56.68	68.93
8B	73	"	114633	114703	683	7.20	0.56	39.97	-1.69	17.45	72.28	56.65
8C	73	"	114703	114839	683	157.57	0.62	28.27	32.01	58.66	61.95	89.63
8D	73	"	114837	114947	683	11.49	0.37	37.75	6.02	18.43	38.16	49.33
9A	72	30.0	115045	115315	538	28.59	0.67	28.70	3.09	23.70	69.09	100.71
9B	72	"	115045	115141	550	17.72	0.62	27.32	2.80	20.41	56.76	57.40
9C	72	"	115143	115245	530	46.44	0.73	28.89	6.00	28.68	97.99	164.68
9D	72	"	115245	115315	530	12.61	0.68	31.02	-0.70	19.57	44.09	67.28
10A	72	30.0	115539	115937	469	13.98	0.64	27.36	2.45	21.86	50.55	72.01
10B	72	"	115539	115723	469	10.83	0.68	28.73	1.77	19.72	43.60	76.89
10C	72	"	115723	115833	469	19.86	0.63	25.24	2.93	24.26	58.75	70.62
10D	72	"	115833	115937	469	12.75	0.58	27.39	3.04	22.70	51.87	64.52

(continued)

TABLE 5-5. (continued)

Trav #		Dwnwind (km)	Age* (min)	Time (start)	Time (end)	Alt (mMSL)	SO2 (ppb)	Bscat (10^-4 *M^-1)	O3 (ppb)	NO (ppb)	NOX (ppb)	ANC (cnts)	Chrg (mv)
12A	**	116	390	121551	121905	605	13.62	0.41	34.70	1.91	21.13	86.57	50.53
13A	**	102	390	124031	124531	593	16.43	0.50	31.52	3.02	23.88	66.26	70.93
13B	**	102	"	124029	124241	592	15.68	0.51	32.56	2.37	23.08	68.47	69.02
13C	**	102	"	124239	124529	595	16.87	0.48	30.88	3.42	24.38	63.96	72.09
14A	**	102	390	125023	125251	654	17.69	0.51	30.28	4.72	27.07	64.95	77.64
15A	++	103	390++	125913	130427	543	16.48	0.53	30.81	3.78	25.45	63.37	72.68
15B	++	103	" ++	130711	131023	541	47.89	0.37	28.45	6.74	30.76	73.53	76.81
16A	++	103	390++	131537	131917	472	46.19	0.35	28.83	7.04	31.70	69.21	75.53
16B	++	103	" ++	132411	132717	471	16.06	0.48	32.15	3.42	24.23	61.08	93.71
17A	++	103	390++	133151	133457	591	13.42	0.45	34.32	2.48	22.65	57.92	87.53
17B	++	103	" ++	134003	134333	595	39.17	0.32	30.81	6.32	28.28	63.20	104.75

** Likely to be Kincaid but may also contain Springfield. USE CAUTION
++ The largest plume, to the SW, is likely to be Coffeen of 4 hours. The smaller plume, to the NE is Kincaid. (15A, 16B, 17A are Kincaid. 15B, 16A, 17B are Coffeen.)
* Uncertainty in plume ages in ±20 minutes for 295-300 min and ±30 minutes for 390 min.

graphics from the Data Volume can be linked to these values. The downwind distance of the approximate profile center from Kincaid is presented along with the Monte Carlo determination of age (See Section 5.2) to the nearest quarter hour. The time of the start and ending for the integrals is given to define the edges of the profile used in the calculations. The average altitude of each traverse is provided followed by the averages for each of the seven parameters.

There are several comments which will assist in interpreting these tables:

- Negative values occasionally appear. These result from objective processing the data uniformly and not forcing certain areas to be positive when there are no notes to carefully document a drifting instrument or an incorrect offset from calibrations. We leave it to the end user to make necessary subjective judgements on the appropriateness of the data.

- "FERRY" occasionally appears in place of downwind distance. This indicates that the averages are not from a true traverse but from encountering a plume edge while changing location. Since the values appear to be a plume graphically, we can integrate them. They represent the edge conditions intermediate between the previous and subsequent traverses.

- "INVALID" is inserted in the table when the data for that channel is judged not valid during the processing. This condition arises from instrument malfunction.

- "ZIG ZAG" designates those times when CHEM-1 zigzaged back toward Kincaid from distant surveys and repeatedly crossed the plume. Time did not permit determining the plume ages for these multiple slices but they can be estimated from the age of the last full traverse, assuming those transport conditions prevail during the zigzag survey and then scaling age to distance as seen in the flight maps of Appendix C.

- "Background" is used to indicate those averages determined outside the plume.

5.3.2 EMI's CHEM-1 Filter Data

In addition to the continuous data channels, EMI has the results of chemical analysis of the filter samples collected on CHEM-1 during the CWP study. These results for sulfate, nitrate, chloride, gaseous nitric acid, ammonia, particulate nitric acid and ammonium are presented in Table 5-6.

TABLE 5-6 CWP Integrated Filter Results

DATE/ FMU ID	START TIME	STOP TIME	% IN PLUME	VOLUME M^3	EPA ANALYSIS NITRATE UG/M^3	EPA ANALYSIS SULFATE UG/M^3	EPA ANALYSIS CHLORIDE UG/M^3	USF ANALYSIS HNO3(G) UG/M^3	USF ANALYSIS NH3(G) UG/M^3	USF ANALYSIS HNO3(P) UG/M^3	USF ANALYSIS NH3(P) UG/M^3
810212											
15	945	1002	100	1.90	1.95	2.31	0.42	17.20	1.10*	0.82	0.20*
18	1031	1151	74	2.70	3.03	3.76	0.76	6.46	0.53*	0.76	0.08*
21	1202	1222	0	2.20	1.58	1.55	0.00	1.02	0.03*	0.25	0.10*
23	1234	1323	100	2.50	3.17	4.06	0.00	9.67	0.45*	2.43	0.11*
25	1352	1418	100	2.10	3.30	4.28	0.44	7.78	0.28*	2.21	0.04*
24	1545	1613	0	3.20	1.01	0.41	0.00	0.24	<0.04*	0.25	0.11*
810213											
17	737	752	0	1.70	2.77	2.58	0.63	0.13	<0.10*	0.82	<0.10
13	827	856	63	1.60	4.49	5.74	3.29	2.87	<0.10*	0.37	0.42
16	914	1101	89	5.30	1.54	1.19	1.18	2.82	0.15*	0.34	0.15*
30	1109	1159	95	1.90	2.87	3.11	1.96	6.33	0.80*	0.80	0.30
14	1329	1427	94	3.20	5.04	11.27	2.96	2.19	0.88	0.71	0.15*
19	1434	1509	100	1.50	8.43	11.24	3.33	9.28	0.49*	2.15	<0.10
31	1543	1604	100	1.20	3.10	7.01	2.29			0.00	
32	1607	1627	0	2.20	2.36	1.64	1.50				
810214											
39	745	806	0	2.30	0.05	0.78	0.40	0.21	0.10*	0.14	<0.05
34	826	916	95	1.90	4.57	4.43	2.85	11.30	0.58	2.00	0.03*
38	937	1046	100	3.40	11.89	11.17	5.54	7.40	1.11	0.10	0.02*
35	1059	1121	100	1.00	10.66	9.95	5.41	22.30	0.56	1.00	0.03*
37	1322	1410	100	1.10	11.04	12.88	5.43	7.14	1.09	1.50	<0.05
36	1456	1516	10	2.00	11.65	7.76	2.08	8.46	0.44	2.20	0.24
810216											
44	1314	1336	0	2.40	4.75	4.11	1.90	2.44	0.75*	4.69	1.83
46	1412	1519	100	1.40	10.09	10.26	1.56	0.36	0.59*	0.70	0.43
49	1556	1613	92	0.60	8.26	11.14	0.15	2.95	LOST	5.23	1.69
51	1635	1645	100	0.90	4.95	5.08	0.00	0.59	0.82*	3.01	0.81
47	1713	1734	50	2.20	7.32	6.79	0.68	7.85	0.65*	5.67	2.02
810220											
58	1040	1100	30	2.20	0.56	0.59	4.62	0.35	1.03	1.72	0.65*
53	1120	1158	100	0.90	6.88	4.01	0.57	1.42	1.64	4.40	0.94*
52	1243	1342	100	1.00	10.66	5.72	0.79	0.67	1.72	2.57	0.30*
57	1358	1411	75	1.10	6.76	1.89	0.00	1.63	1.10*	1.22	0.32*
810221											
71	1435	1451	100	2.90	6.07	6.67	0.18				
74	1512	1542	85	3.20	6.35	7.13	0.90				

*BLANK VALUE IS 30% OR MORE OF THE ANALYTE FOUND.

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(DR. ROBERT BRAMAN)

For these data the downwind distance and ages can be estimated by comparing the Start and Stop time with the data for comparable times in Tables 5-1 through 5-5. It should be noted (as described in the CWP Data Volume) that the filters were exposed to plume conditions by EMI's field engineer during each flight. He used the strip chart display to indicate when CHEM-1 entered and left the power plant plume, using SO_2 as a marker. He would furn the filter on only while in the plume. The mass flow through the filter was recorded on the same data tape with the continuous data so that during the processing the total flow could be integrated to give the total volume sampled. That value is reported in Table 5-6. Also from the SO_2 trace and the flow trace, EMI determined, after the fact, the percent of the sample time which was in the plume. This value is also reported. Note that the overall start and stop times reported refer to the total interval for that one filter and does not refer to the multiple on-off cycles during many traverses.

5.3.3 MRI Data

EMI has extracted (with permission) pertinent tables from the CWP section of the BCL interim report (Sverdrup and Spicer, 1983) to provide a presentation of average plume parameters comparable to that of Section 5.1.

Table 5-7 presents the MRI plume parameter averages for the CWP study. Table 5-8 presents the filter and air bag sample results. MRI has subtracted their background values from the plume averages and determined some plume specific values and averages. These tabulations are presented in Tables 5-9 - 5-12, for the 13, 16 and 20 February. (12 February data was not reduced by MRI due to plume interference with the background orbit. At a later date EMI data from that day will assist in determining the proper background values to be subtracted.)

The BCL report also reports some source information on two of the sampling days. This Rockwell data is reproduced in Table 5-14.

5.3.4 EPA-Lidar Data

The EPA Lidar Data Volume (J.L. McElroy, et al.,1982) presents a valuable photographic record of the plume and ambient aerosol layering. At times the layering is quite complex (e.g. 20 February 1981). At other times the gradients of grey to black make it quite subjective to interpret. EMI tabulated the lidar profiles in terms of downwind distance and time of survey to allow some selection of lidar profiles near CHEM-1 and MRI surveys. EMI also attempted to manually quantify plume dimension and mixed height structure from this Data Volume. 13 February was done in considerable

TABLE 5-7. (TABLE 4-9. From BCL report)

SUMMARY OF CONTINUOUS AIRCRAFT DATA FROM COLD WATER PLUME STUDY
(Values shown are averages at the indicated downwind distances.)

Variable	Date/ Downwind Distance/ Start Time, CST/ Duration(s)/	February 12[a]			February 13[b]				February 16			February 20			February 20		
		30 km 1256 3600	60 km 1506 3600	Background[a] 1725 4800	28 km 0852 8580[c]	Background 0852 b	57 km 1308 4140[d]	Background 1431 3600	36 km 1200 3600	81 km 1328 3600	Background 1719 3600	58 km 0320 3600	120 km 0515 3600	Background 0619 3414	32 km 1014 3606	76 km 1153 3600	Background 1309 3600
Altitude (m-MSL)		510	507	523	476	476	460	460	510	604	767	512	499	539	506	677	620
Turbulence ($cm^{2/3}/s$)		30.2	16.3	8.5	3.2	2.8	7.2	6.4	13.3	6.9	11.0	2.0	2.6	2.1	3.7	13.3	21.0
Aitken Nuclei (No./cm^3 x 10^{-3})		32.6	22.6	9.2	13.3	11.6	20.6	18.1	12.8	8.8	7.3	7.0	2.6	1.8	61.2	48.9	28.9
O_3 (ppb)		30.3	32.9	21.4	33.0	41.4	40.6	46.0	35.0	39.3	58.0	21.4	24.4	39.3	16.1	28.2	41.9
NO_x (ppb)		33.0	21.6	19.6	67.0	2.0	59.8	8.3	31.6	25.5	10.7	164.4	24.8	10.0[f]	200.0	51.6	7.2
NO (ppb)		23.1	11.9	2.0	60.4	1.4	48.1	5.3	11.8	6.7	1.6	138.1	5.3	4.1	154.5	28.0	2.3
NO_2 (ppb)[e]		9.9	9.6	17.3	6.3	0.6	11.7	3.1	19.7	18.5	8.4	26.3	19.3	5.9[f]	45.0	23.5	4.9
SO_2 (ppb)		93.5	51.6	33.2	195.8	1.8	180.5	8.5	74.2	55.8	7.5	447.2	41.6	$\leq$2.0[f]	590.2	133.3	$\leq$2.0
Fraction of Data Within the Plume		0.99	0.93	NA	b	NA	b	NA	0.94	0.94	NA	0.58	0.83	NA	0.78	0.85	NA

[a] Significant plume interference with background sample.

[b] See text of Case Study 4 for explanation of special data reduction procedures.

[c] Calculated based on 13 traverses.

[d] Calculated based on 5 traverses.

[e] NO_2 values corrected for PAN interference.

[f] Combined data from background orbit as well as portions of plume sampling orbits which were outside the plume.

TABLE 5-8. (TABLE 4-10. From BCL report)

COLD WEATHER PLUME STUDY FILTER AND BAG DATA

Variable	Date/ Downwind Distance/ Start Time, CST/ Interval(s)/	February 12[a] 30 km 1256 3600	February 12[a] 60 km 1506 3600	February 12[a] Background[a] 1725 4800	February 13[b] 28 km 0852 8580	February 13[b] 57 km 1308 4140	February 13[b] Background 1431 3600	February 16 36 km 1200 3600	February 16 81 km 1328 3600	February 16 Background 1719 3600	February 20 58 km 0320 3600	February 20 120 km 0515 3600	February 20 Background 0619 3414	February 20 32 km 1014 3606	February 20 76 km 1153 3600	February 20 Background 1309 3600
NO_3^- < 2.5 μm[c]		0.59	0.40	0.35	0.48	0.77	-0.14	0.71	0.92	0.63	2.90	2.53	0.93	-0.19	2.04	-0.18
$SO_4^=$ < 2.5 μm[c]		5.43	3.69	3.58	2.83	7.52	3.59	6.45	0.76	3.06	2.23	0.79	0.06	8.91	3.51	0.10
NH_4^+ < 2.5 μm[c]		1.04	0.79	0.41	0.93	1.21	0.70	2.14	1.98	1.26	1.72	1.05	0.15	3.53	1.72	0.21
S < 2.5 μm[c]		4.37	1.91	1.69	1.23	1.87		3.68	3.58	2.81	1.42	0.67	0.23	5.19	2.23	0.48
Total Inorganic Nitrate[c]		1.70	3.71	3.86	1.16	1.31	2.24[f]	2.40	3.20	1.77	3.05	5.60	1.19	3.15	1.44	1.22
Total Particulate Nitrate[c]		1.57	3.14	3.72	0.98	0.67	2.20[f]	1.08	1.67	0.68	2.61	5.20	0.77	2.33	1.21	0.73
NH_3 (as NH_4^+)[c]		←	0.00	→	← 0.96	→	1.48	← 0.54	→	0.00	←	2.31	→	←	1.15	→
PAN[d]		0.1	0.1	0.3	0.1	0.1		0.1	0.3	0.7	0.1	0.2	0.1	0.5	0.1	0.1
Ethane[e]		7.7	7.3	9.7	8.0	6.9		21.3	16.8	14.5	12.4	6.7	8.1	5.6	8.9	10.9
Ethylene		7.7	5.3	4.5	11.7	9.8		18.6	9.4	5.8	5.8	6.6	3.1	3.9	7.7	4.7
Acetylene		4.1	2.8	2.4	6.2	5.2		9.9	5.0	3.1	2.6	3.5	1.5	2.1	4.1	2.5
Propane		7.4	7.0	8.2	7.4	6.6		25.5	15.3	14.6	9.9	9.6	5.4	5.3	6.7	6.1
Propene		0.6	0.2	0.2	0.1	0.6		2.6	0.6	0.2	1.1	1.0	0.1	0.1	1.0	0.1
i-Butane		2.2	2.4	2.1	2.0	1.4		12.7	7.5	5.4	12.1	16.3	4.2	4.1	3.5	3.5
n-Butane		6.8	6.9	5.8	5.0	4.6		34.3	17.9	11.0	31.8	42.8	11.1	10.8	9.2	9.2
i-Pentane		7.1	4.9	4.3	3.9	3.5		23.7	8.8	4.9	10.6	14.3	5.1	6.1	7.6	6.1
n-Pentane		3.6	2.5	2.2	2.1	1.7		12.1	4.5	2.5	5.4	7.3	2.6	3.1	3.9	3.1
2-Methylpentane		1.8	2.5	2.5	1.7	0.6		11.3	6.0	1.5	1.0	4.7	0.6	1.0	1.5	1.0
3-Methylpentane		1.0	1.9	1.0	1.7	1.1		6.4	3.6	2.3	3.3	4.5	1.3	1.4	2.5	1.1
n-Hexane		2.5	1.0	1.5	0.6	1.2		5.9	2.7	1.6	1.8	4.2	2.1	1.1	1.2	1.9
Benzene		5.0	3.6	11.0	3.3	2.6		7.3	3.8	2.8	2.6	5.3	2.3	2.3	7.3	3.4
Toluene		13.2	10.8	11.4	4.2	6.6		22.2	8.4	4.2	6.6	7.8	4.8	5.4	8.4	9.6
Ethylbenzene		2.2	1.8	1.9	0.7	1.1		3.7	1.4	0.7	1.1	1.3	0.8	0.9	1.4	1.6
m+p-Xylene		7.0	5.7	5.2	2.2	3.5		12.4	4.5	2.1	3.5	4.2	3.2	3.0	5.5	6.4
o-Xylene		3.3	2.7	1.3	1.1	1.7		5.1	1.9	1.2	1.7	1.1	2.1	1.5	3.1	2.1

[a]Significant plume interference with background sample.
[b]See text of Case Study 4, for explanation of special data reduction procedures.
[c]Units are μg-m^{-3}.
[d]Units are ppb.
[e]Units of ethane and hydrocarbons below are ppbC.
[f]Value considered to be suspect.

TABLE 5-9.

MRI Data from 13 February 1981

(TABLE 4-32. From BCL report)

PLUME CONCENTRATIONS (ppb) FOR AFTERNOON FLIGHT
ON FEBRUARY 13, 1981
(Corrected for Background)

Pollutant	Distance from Kincaid Plant 28 km	57 km
NO, ppb	58.0	42.8
NO_2, ppb	5.7	8.6
NO + NO_2, ppb	64.7	51.4
PAN, ppb	0.1	0.1
SO_2, ppb	194.0	172.0
NO_3 $\leq$2.5 μm, ppb	0.33	0.36
SO_4 $\leq$2.5 μm, ppb	0	1.00
NH_4 $\leq$2.5 μm, ppb	0.26	0.69
S $\leq$2.5 μm, ppb	1.02[a]	1.43[b]
Total inorganic nitrate, ppb	0.40[a]	0.52[a]
Total particulate nitrate, ppb	0.36[a]	0.26[a]
Total S, ppb	190.0[c]	173.4[c]
Total N, ppb	65.1[c]	52.0[c]
Monte Carlo Age, min.	80±15	90±15

[a]True background uncertain; not subtracted.

[b]Combination of plume traverse and background orbit sampling

[c]Particulate component not corrected for background.

TABLE 5-10.
MRI Data from 16 February 1981

(TABLE 4-15. From BCL report)

BACKGROUND-CORRECTED CONCENTRATIONS OF SELECTED SPECIES FOR FEBRUARY 16, 1981 FLIGHT

	36 km	81 km
Total Sulfur, ppm	67.4	48.9
$(NO + NO_2)$, ppm	21.5	15.2
Total Nitrogen, ppb	21.9	16.1
NO_3^- <2.5 μm, ppb	.03	.12
Monte Carlo Ave, min.	50±10	120±10

(TABLE 4-16. From BCL report)

SELECTED POLLUTANT RATIOS FROM FLIGHT ON FEBRUARY 16, 1981

	Sampling Distance From Stack	
Ratio	36 km	81 km
$(NO + NO_2)$ / Total Sulfur	0.319	0.311
$(NO + NO_2)$ / Total Nitrogen	0.982	0.944
Total Nitrogen / Total Sulfur	0.325	0.329
NO_3^- <2.5 μm / Total Sulfur	4.4×10^{-4}	2.4×10^{-3}
SO_2 / Total Sulfur	0.990	0.988

TABLE 5-11.
MRI Data from 20 February 1981

(TABLE 4-21. From BCL report)

PLUME CONCENTRATIONS (ppb) FOR PREDAWN FLIGHT ON
FEBRUARY 20, 1981
(Corrected for Background)

Pass	1	4
Distance From Source, km	58	120
NO, ppb	134.0	1.2
NO_2, ppb	20.4	13.4
NO + NO_2, ppb	154.4	14.c
PAN, ppb	< 0.1	0.2
SO_2, ppb	447.2	41.6
NO_3 ≤2.5 μm, ppb	1.3	0.8
SO_4 ≤2.5 μm, ppb	1.0	0.2
NH_4 ≤2.5 μm, ppb	3.7	1.5
S ≤2.5 μm, ppb	1.6	0.4
Total Inorganic NO_3, ppb	1.3	2.1
Total Particulate NO_3, ppb	1.2	2.1
Total S, ppb	448.8	42.0
Total N, ppb	155.7	16.9
Monte Carlo Age, hr.	1.25	3.0

(TABLE 4-22. From BCL report)

SELECTED POLLUTANT RATIOS FROM PREDAWN FLIGHT ON
FEBRUARY 20, 1981

Pass	1	4
Distance From Source, km	58	120
$\frac{(NO + NO_2)}{Total\ S}$	.344	.348
$\frac{(NO + NO_2)}{Total\ Nitrogen}$	.992	.864
$\frac{Total\ N}{Total\ S}$	.347	.402
$\frac{SO_2}{Total\ S}$	.996	.990
$\frac{NO_3 <2.5\ \mu m}{Total\ N}$	.0083	.0473

Table 5-12

MRI Data from 20 February 1981 afternoon flight

(Table 4-26 From BCL report)

PLUME CONCENTRATIONS (ppb) FOR AFTERNOON FLIGHT
ON FEBRUARY 20, 1981
(Corrected for Background)

Pass	1	4
Distance From Source	32 km	76 km
NO, ppb	152.2	25.7
NO_2, ppb	40.1	18.6
NO + NO_2, ppb	192.3	44.3
PAN, ppb	0.5	0.1
SO_2, ppb	575.2	133.3
NO_3 ≤2.5 μm, ppb	0.0[a]	0.0[a]
SO_4 ≤2.5 μm, ppb	2.9	1.0
NH_4 ≤2.5 μm, ppb	5.8	2.4
S ≤2.5 μm, ppb	4.6	1.6
Total inorganic nitrate, ppb	1.0	0.1[b]
Total particulate nitrate, ppb	0.8	0.2
Total S, ppb	579.8	134.9
Total N, ppb	192.8	45.3
Monte Carlo Age, hr.	2.0	5.0

[a] NO_3 ≤2.5 μm has been used in place of total inorganic nitrate for all calculations for this flight due to blank problems and inconsistencies in the total inorganic nitrate values.

[b] This value is considered unreliable.

(Table 4-27 From BCL report)

SELECTED POLLUTANT RATIOS FROM AFTERNOON FLIGHT
OF FEBRUARY 20, 1981

Pass	1	4
Distance from Source	32 km	76 km
$\frac{(NO + NO_2)}{\text{Total Sulfur}}$	0.332	0.328
$\frac{(NO + NO_2)}{\text{Total Nitrogen}}$	0.997	0.978
$\frac{\text{Total N}}{\text{Total S}}$	0.332	0.336
$\frac{SO_2}{\text{Total S}}$	0.992	0.998
$\frac{NO_3 \leq 2.5\ \mu m}{\text{Total N}}$	0.000	0.020

TABLE 5-13. Source Information on Kincaid during CWP Study.

(Table 4-17 From BCL report)

AVERAGE STACK CONCENTRATIONS AND RATIOS FOR SELECTED HOURS ON FEBRUARY 16,1981

Time, CST	SO_2 (ppm)	NO (ppm)	$[NO]/[SO_2]$
1200	1,706	499	.293
1300	1,681	486	.289
1400	1,673	477	.285

(Table 4-29 From BCL report)

HOURLY AVERAGE STACK CONCENTRATIONS AND RATIOS FOR SELECTED TIMES ON FEBRUARY 20, 1981

Time, CST	$[SO_2]$, ppm	[NO], ppm	$[NO]/[SO_2]$
0900	1876	510	.272
1000	1920	535	.279
1100	1956	544	.278
1200	2049	559	.273
1300	2075	578	.278

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detail attempting to scale from the photographs to plume dimensions using the lidar's green line (and occasionally the infrared). Attempts were made to identify the measurements for the "dense" easily measured returns from the lidar as distinguished from the "light" returns. The fact that the layers were often sloping caused even these "subjective" estimates of photographic (and hence plume) density to have a range across a traverse. It was eventually decided that this subjective attempt at quantifying plume thickness, height and width was very labor intensive and not useful without the Lidar Data Volume present to assist in interpreting it. Subsequent days were reviewed for just a verbal description of the plume with the thought that these descriptions would be better than nothing for those without access to the Lidar Data Volume. Attempts were made to include determination of mixed layer heights (i.e. top of aerosol layer) observed during the traverse. Even then ranges across the traverse reflect observations of a sloping bottom to the aerosol layer.

Those tabulations in hand written form are available from EMI. They report the quantitative determination of downwind distance (approximate minimum distance to the plant for each traverse) and the time interval of the traverse. There is also a verbal description of the aerosol profile from the traverse indicating layering, shape of layers and possible multiple plume situations. For 13 February the estimated dimensions of the plume are tabulated as well.

5.4 Radiation Data

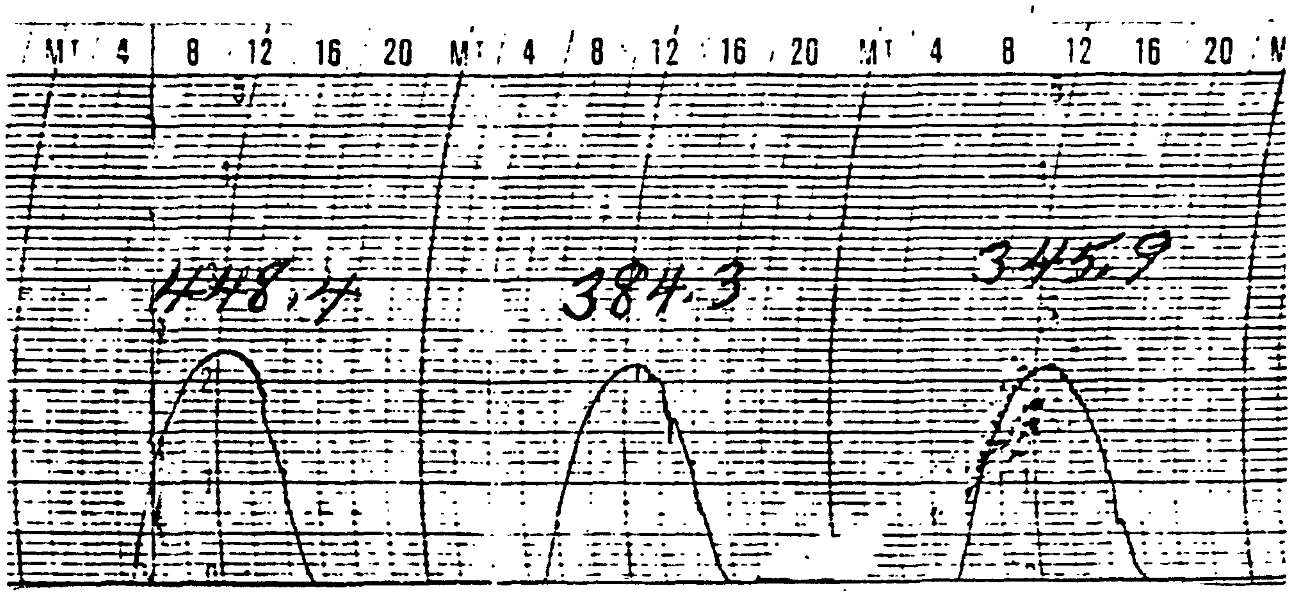
In addition to the above data gathered by the EPRI and EPA team members, EMI obtained copies of the solar radiation data during the study period measured by the Illinois State Water Survey in Champaign-Urbana. The data for the survey days are summarized in Table 5-14 and presented graphically in Figure 5-2.

Table 5-14

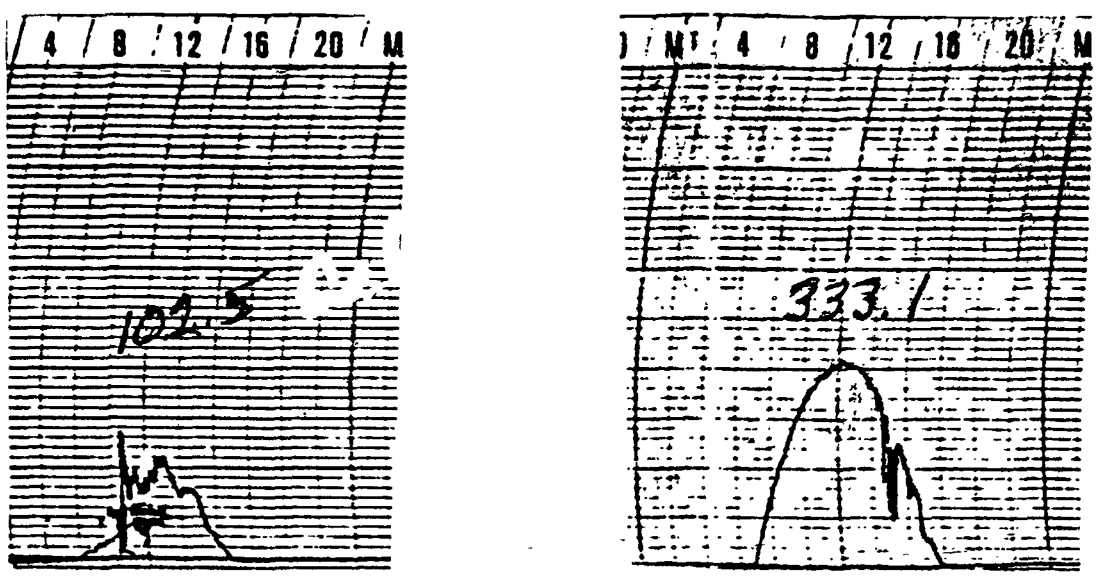
Daily Solar Radiation from Illinois State Water Survey

Date	Integral of Solar Radiation (cal/cm^2)
12 February	448.4
13 February	384.3
14 February	345.9
16 February	102.5
20 February	331.1

Argonne National labs near Chicago and north of Bloomington also measured solar radiation during February. Table 5-15 reports the results they provided.



12 February 1981 13 February 1981 14 February 1981



16 February 1981 20 February 1981

Figure 5-2. Solar radiation charts from the Illinois State Water Survey in Champaign, IL. Numbers indicate the integration under each curve in cal/cm^2/day.

TABLE 5-15. SOLAR RADIATION DATA FROM ARGONNE NATIONAL LABORATORY

ARGONNE NATIONAL LABORATORY

TOTAL RADIATION SUMMARY - FEBRUARY 1981
(WATTS/SQ. METER)

DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	DAILY AVG.
1	0	0	0	0	0	0	0	2	22	59	32	148	197	72	57	44	21	0	0	0	0	0	0	0	27
2	0	0	0	0	0	0	0	27	161	314	447	483	495	413	277	162	41	0	0	0	0	0	0	0	118
3	0	0	0	0	0	0	0	89	255	359	448	508	430	401	296	178	35	0	0	0	0	0	0	0	125
4	0	0	0	0	0	0	1	112	275	373	471	523	541	489	373	223	66	0	0	0	0	0	0	0	144
5	0	0	0	0	0	0	1	63	215	280	365	340	360	283	178	94	29	0	0	0	0	0	0	0	92
6	0	0	0	0	0	0	1	44	130	303	485	559	553	349	295	228	51	1	0	0	0	0	0	0	125
7	0	0	0	0	0	0	0	19	198	346	416	377	538	270	202	148	28	0	0	0	0	0	0	0	106
8	0	0	0	0	0	0	0	46	167	317	489	532	462	340	312	171	32	1	0	0	0	0	0	0	120
9	0	0	0	0	0	0	1	69	233	355	511	571	504	447	342	175	49	1	0	0	0	0	0	0	136
10	0	0	0	0	0	0	0	13	42	48	88	94	57	53	27	18	6	0	0	0	0	0	0	0	19
11	0	0	0	0	0	0	1	47	128	340	514	573	610	554	429	272	93	3	0	0	0	0	0	0	148
12	0	0	0	0	0	0	1	78	187	433	528	569	584	539	424	269	93	3	0	0	0	0	0	0	155
13	0	0	0	0	0	0	5	145	285	463	453	574	592	544	396	223	78	2	0	0	0	0	0	0	157
14	0	0	0	0	0	0	5	105	254	418	521	564	583	521	413	263	82	5	0	0	0	0	0	0	156
15	0	0	0	0	0	0	3	115	244	362	310	406	374	333	225	158	53	2	0	0	0	0	0	0	103
16	0	0	0	0	0	0	1	53	179	248	443	513	512	484	371	237	85	3	0	0	0	0	0	0	130
17	0	0	0	0	0	0	1	36	102	198	457	552	555	504	392	186	29	1	0	0	0	0	0	0	126
18	0	0	0	0	0	0	1	24	53	112	189	411	124	314	367	76	40	6	0	0	0	0	0	0	72
19	0	0	0	0	0	0	2	36	140	329	394	466	452	212	117	66	29	1	0	0	0	0	0	0	94
20	0	0	0	0	0	0	3	38	120	193	295	455	502	524	414	257	96	1	0	0	0	0	0	0	121
21	0	0	0	0	0	0	2	28	79	184	339	431	365	321	181	116	44	2	0	0	0	0	0	0	87
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23	0	0	0	0	0	0	0	8	30	65	93	92	105	109	63	25	7	0	0	0	0	0	0	0	25
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25	0	0	0	0	0	0	18	145	277	453	566	602	603	543	437	288	121	9	0	0	0	0	0	0	169
26	0	0	0	0	0	0	4	42	114	203	467	645	584	550	414	294	121	15	0	0	0	0	0	0	144
27	0	0	0	0	0	0	0	5	18	171	217	252	242	325	218	184	81	0	0	0	0	0	0	0	71
28	0	0	0	0	0	0	3	21	60	73	74	149	86	62	61	31	14	0	0	0	0	0	0	0	26
HOURLY AVG.	0	0	0	0	0	0	2	54	154	268	366	431	416	360	273	166	56	2	0	0	0	0	0	0	106

6. Recommendations

The presentation of data in this report is intended to give a complete picture of work completed under Contract No. 68-02-3411. The data are ready for further interpretive analysis.

It is suggested that the conversion rates of NO_x and SO_x under winter conditions be investigated for the entire data set with a common age determination as presented here. These results can extend the estimates reported by BCL in their interim report (Sverdrup and Spicer, 1983).

The parameterization of Gillani, Kohli and Wilson (1981) for summer time photochemically driven gas phase reactions can be compared to a similar parameterization based on the CWP data. The role of heterogeneous and homogeneous reactions may become more apparent in such evaluations.

With this data base brought so close to a productive analysis stage, further modeling and chemistry analysis should be supported.

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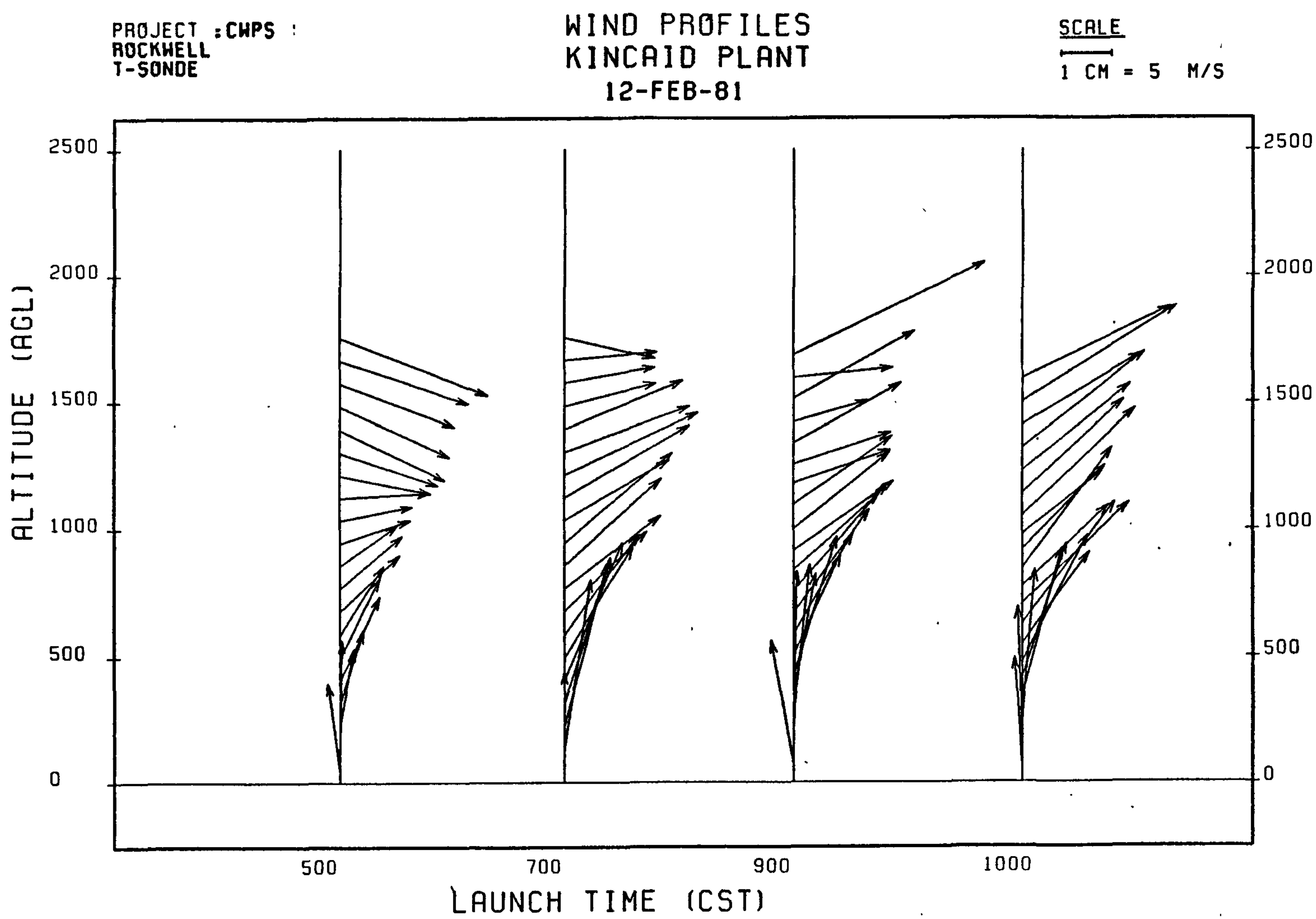
Appendix A

Graphical Summary of Wind Profiles from Rockwell and AeroVironment Soundings.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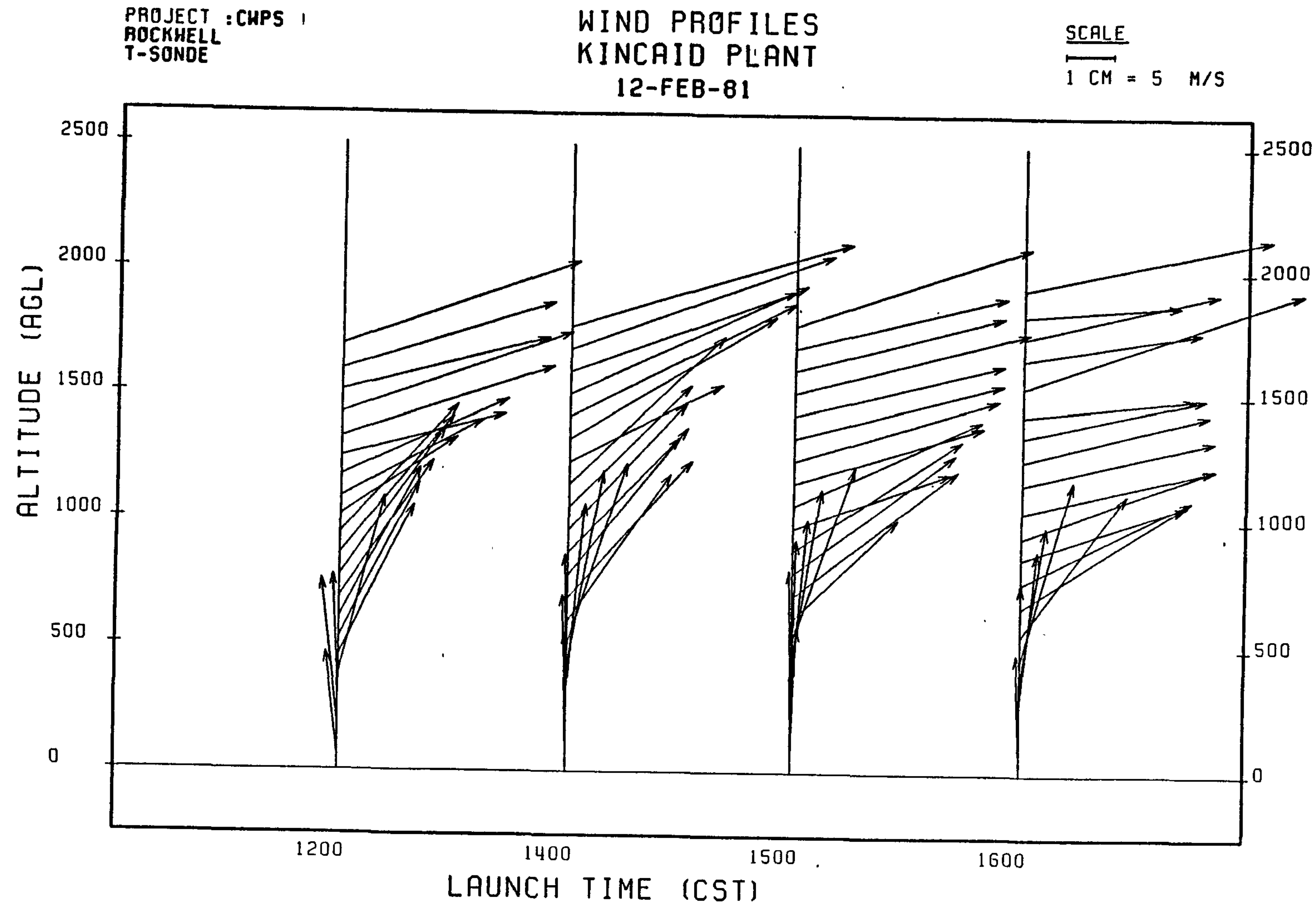
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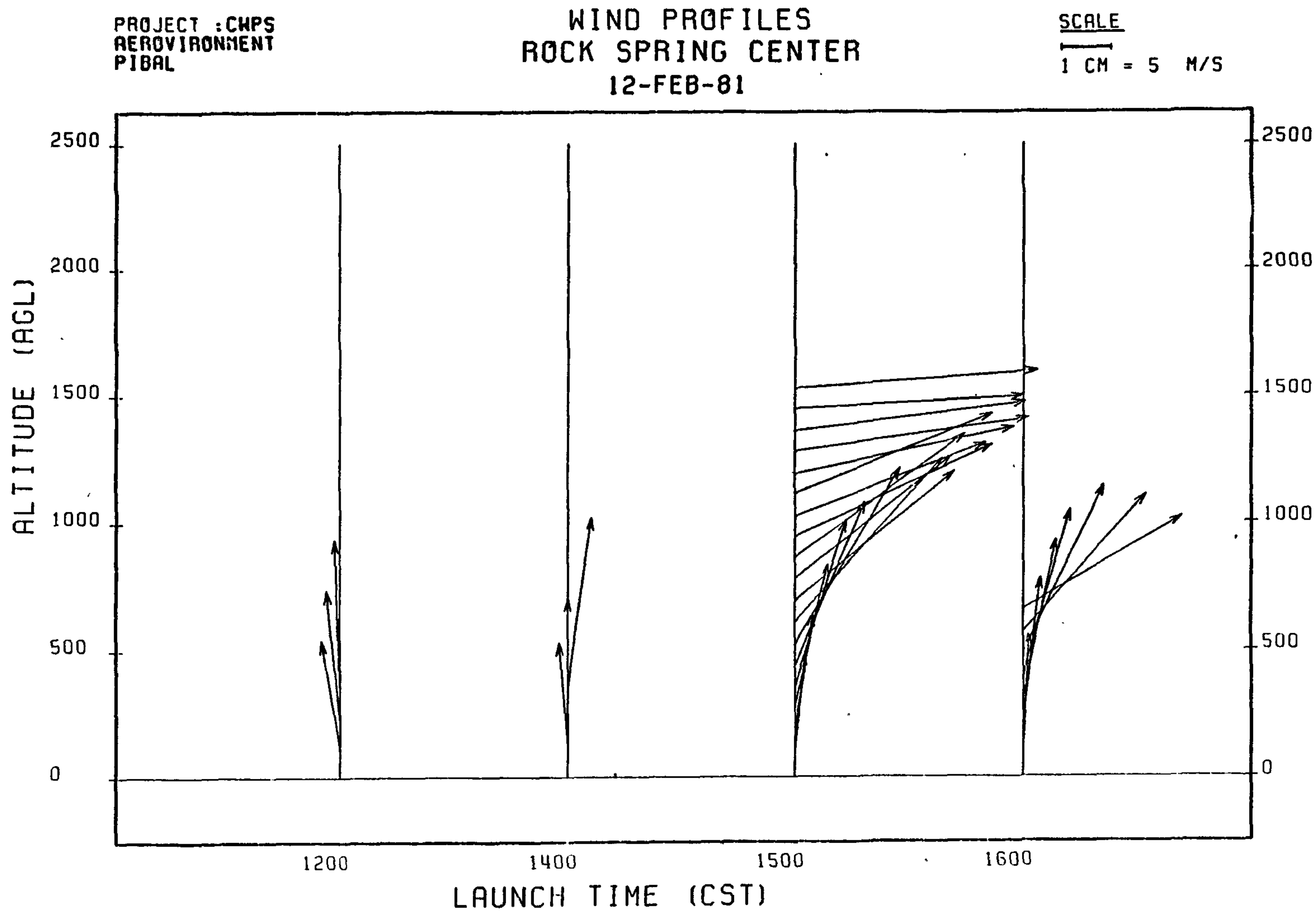
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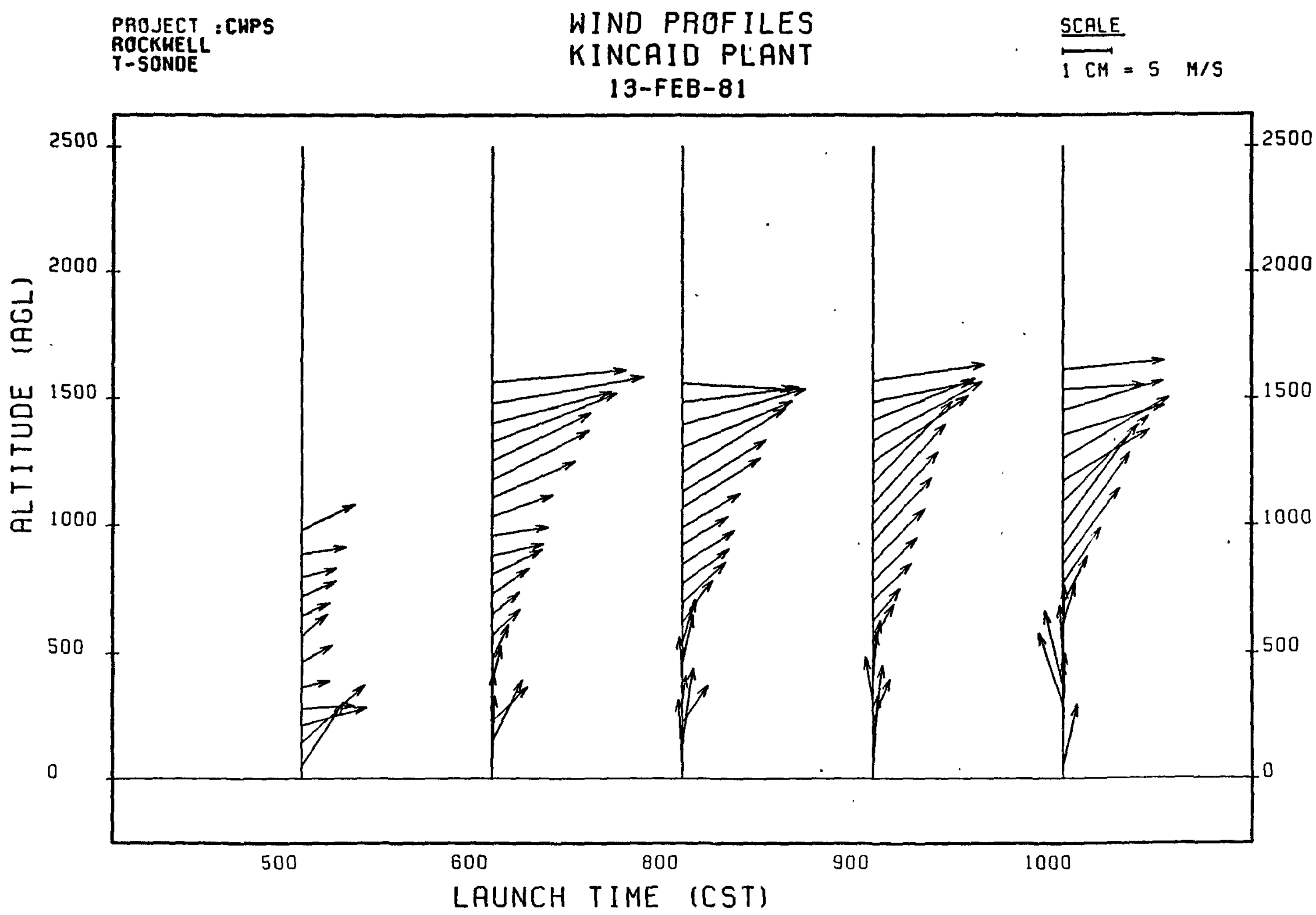
1200
1400
1500
1600
LAUNCH TIME (CST)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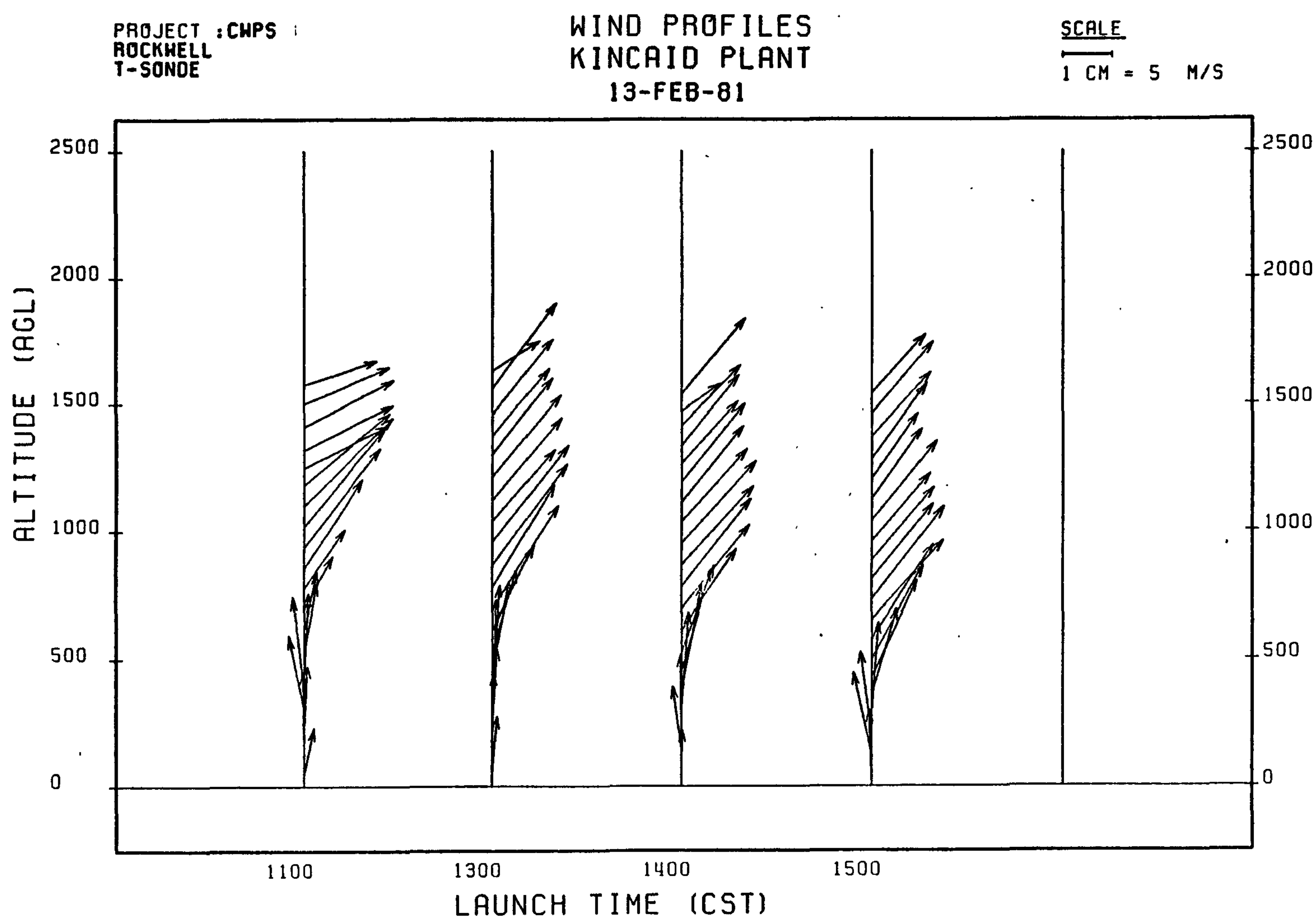
1000
LAUNCH TIME (CST)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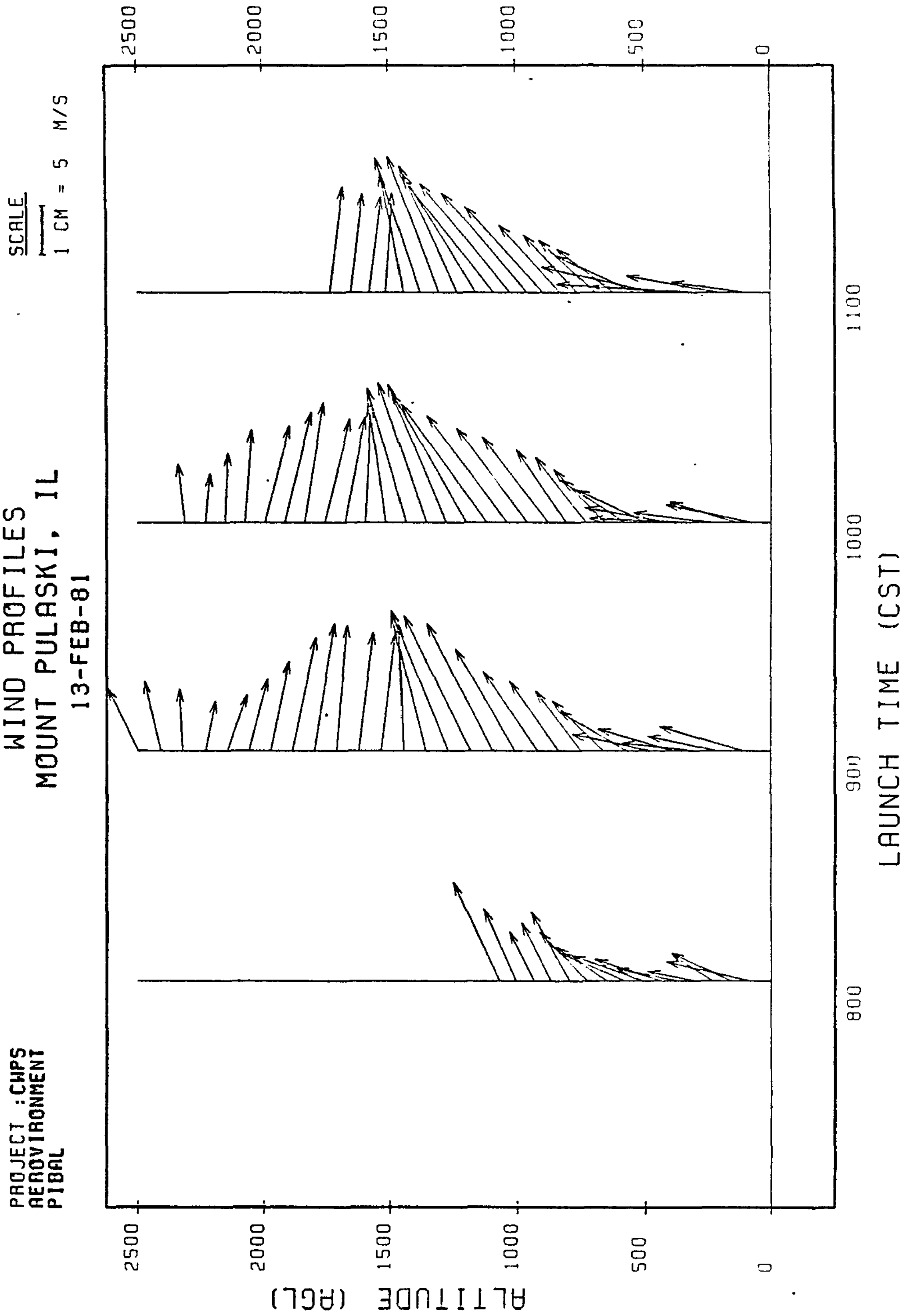
1100
1300
1400
1500
LAUNCH TIME (CST)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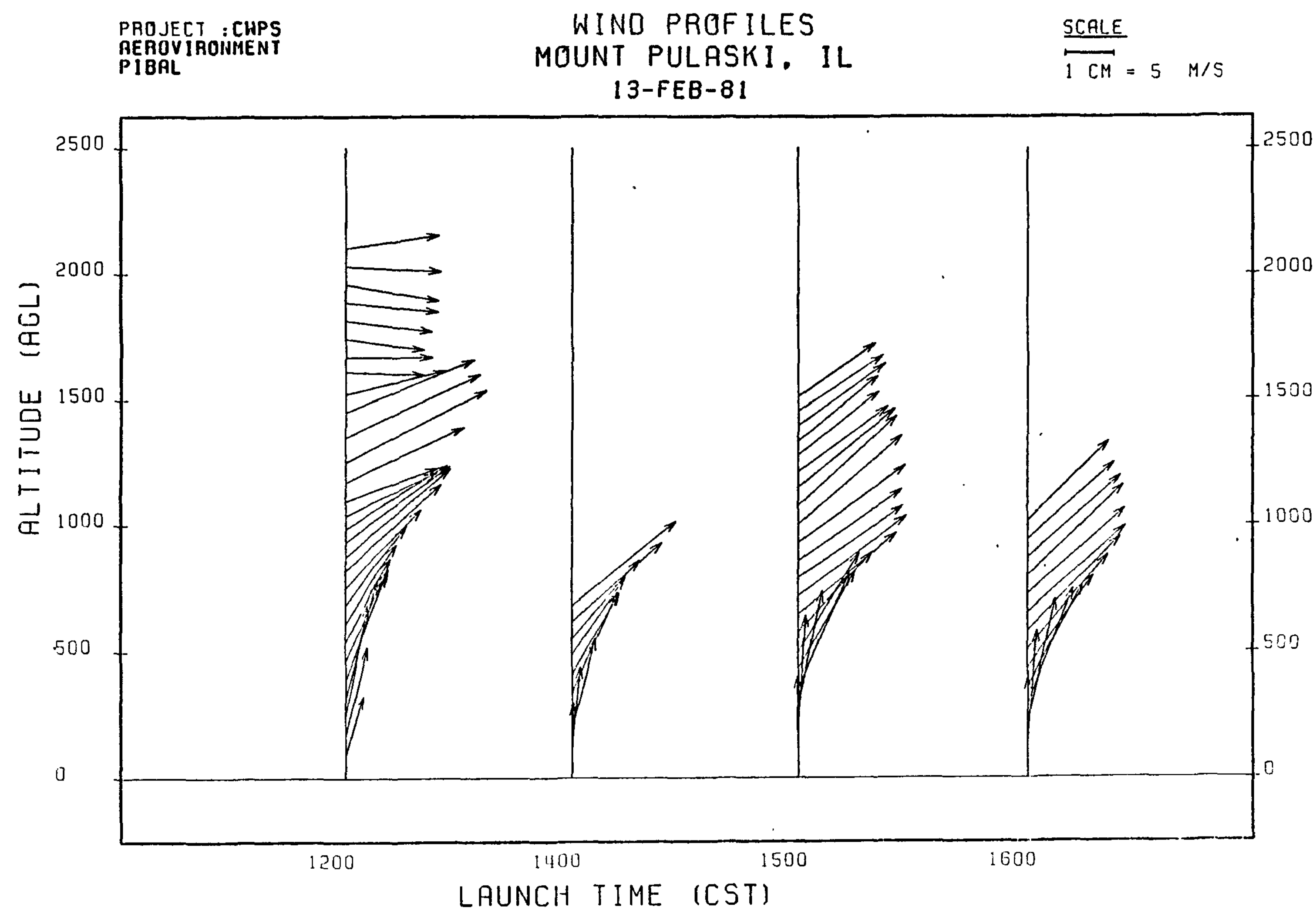
2000
2500



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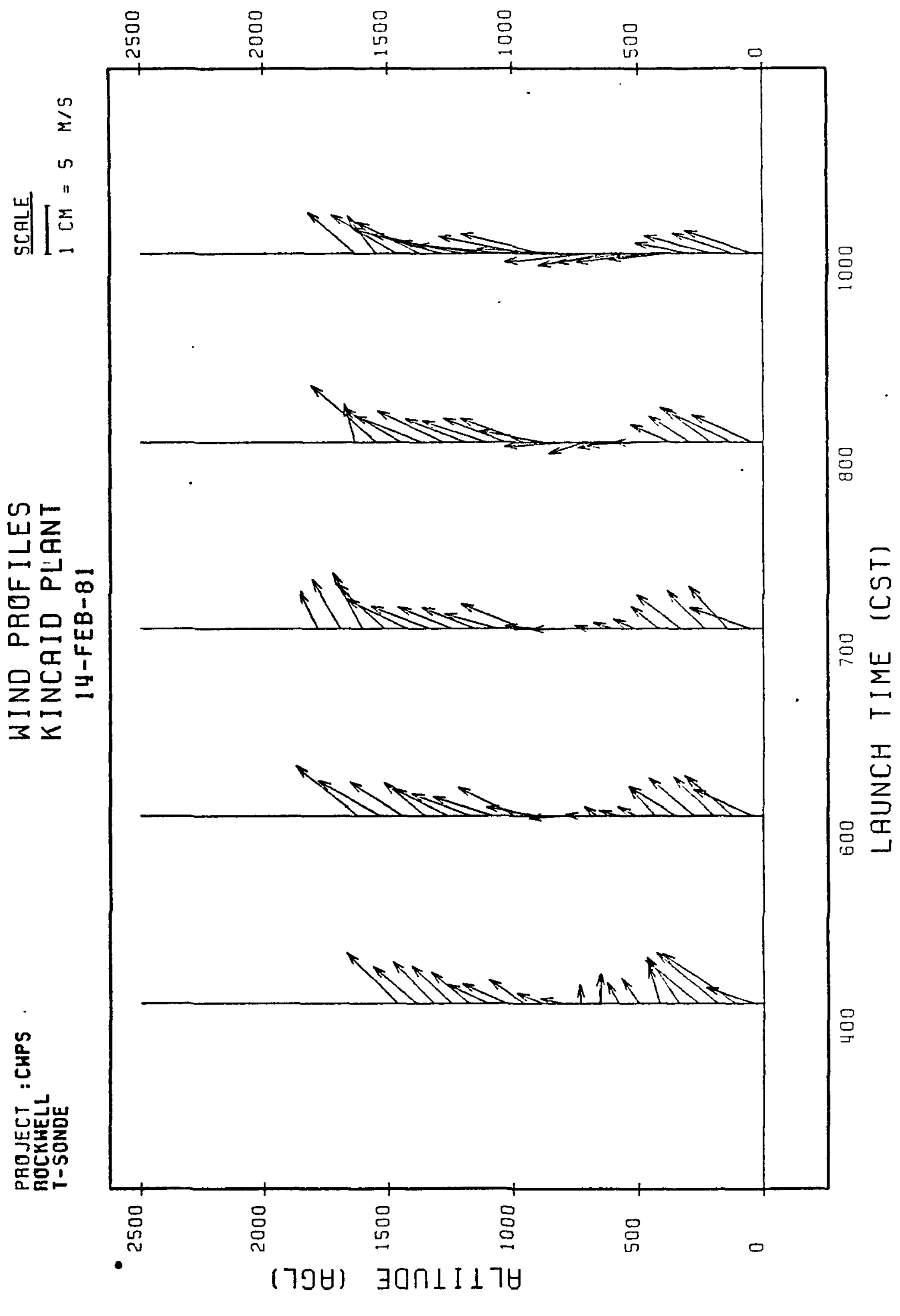
LAUNCH TIME (CST)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1000
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2000
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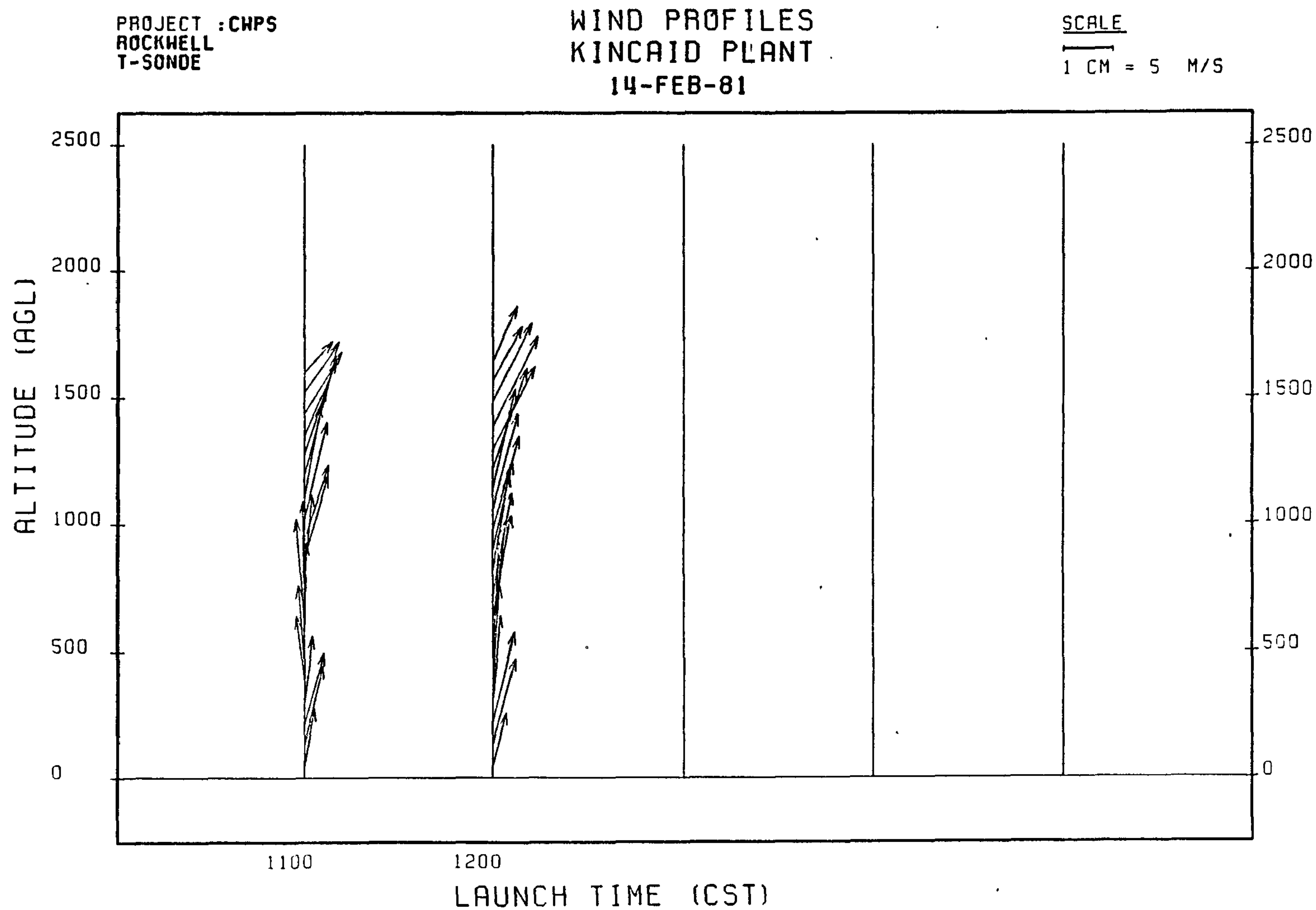
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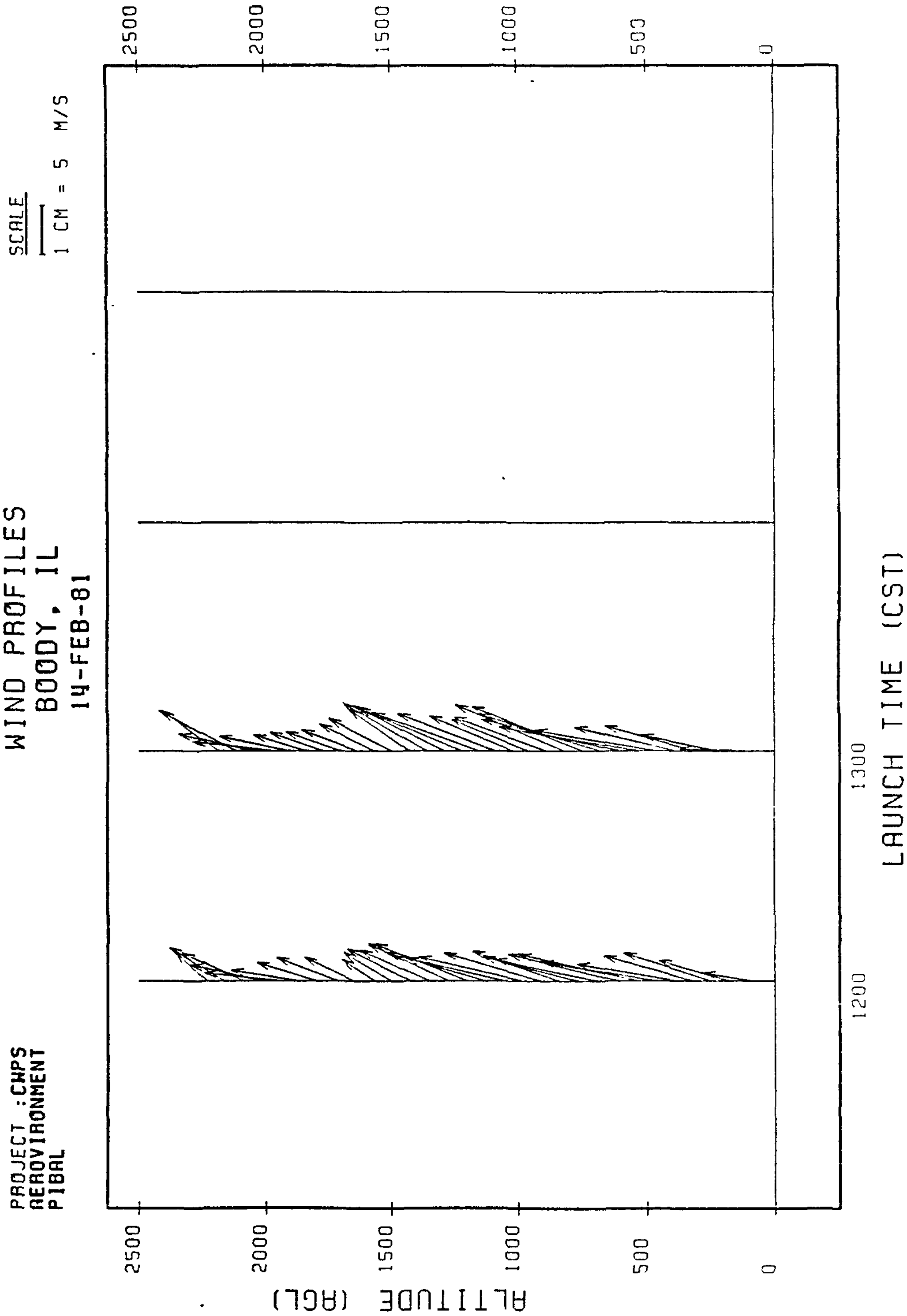
1200
LAUNCH TIME (CST)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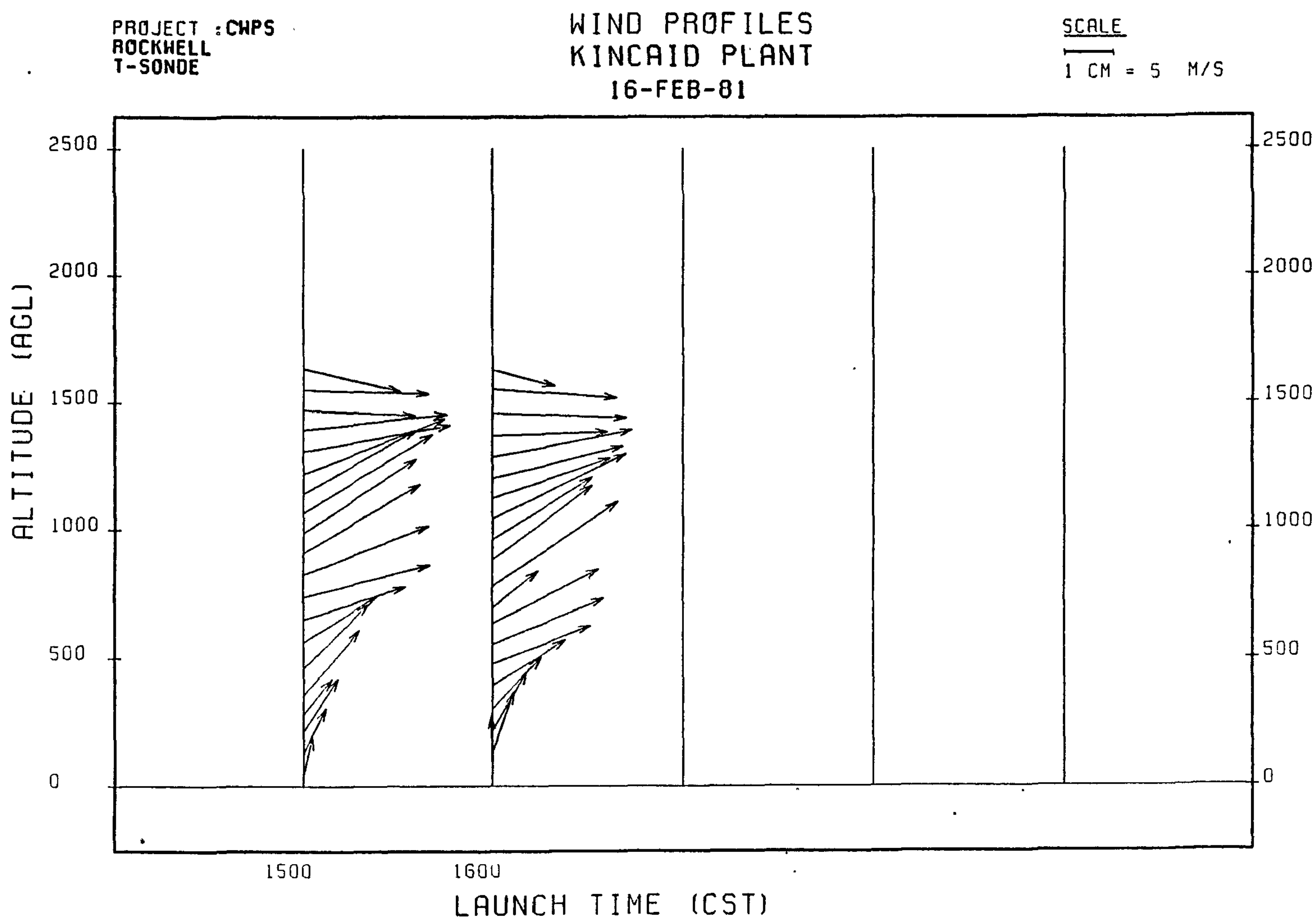
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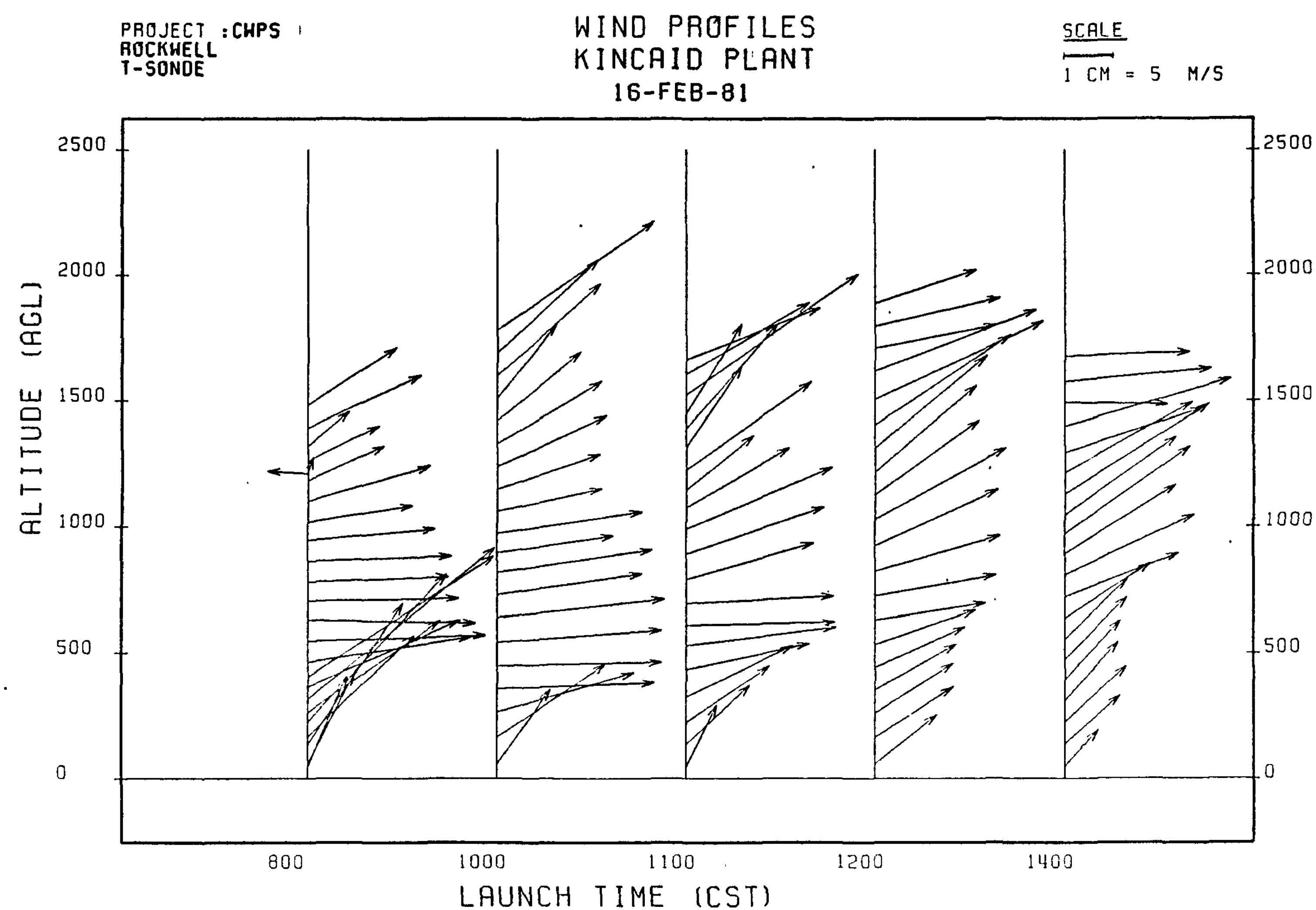
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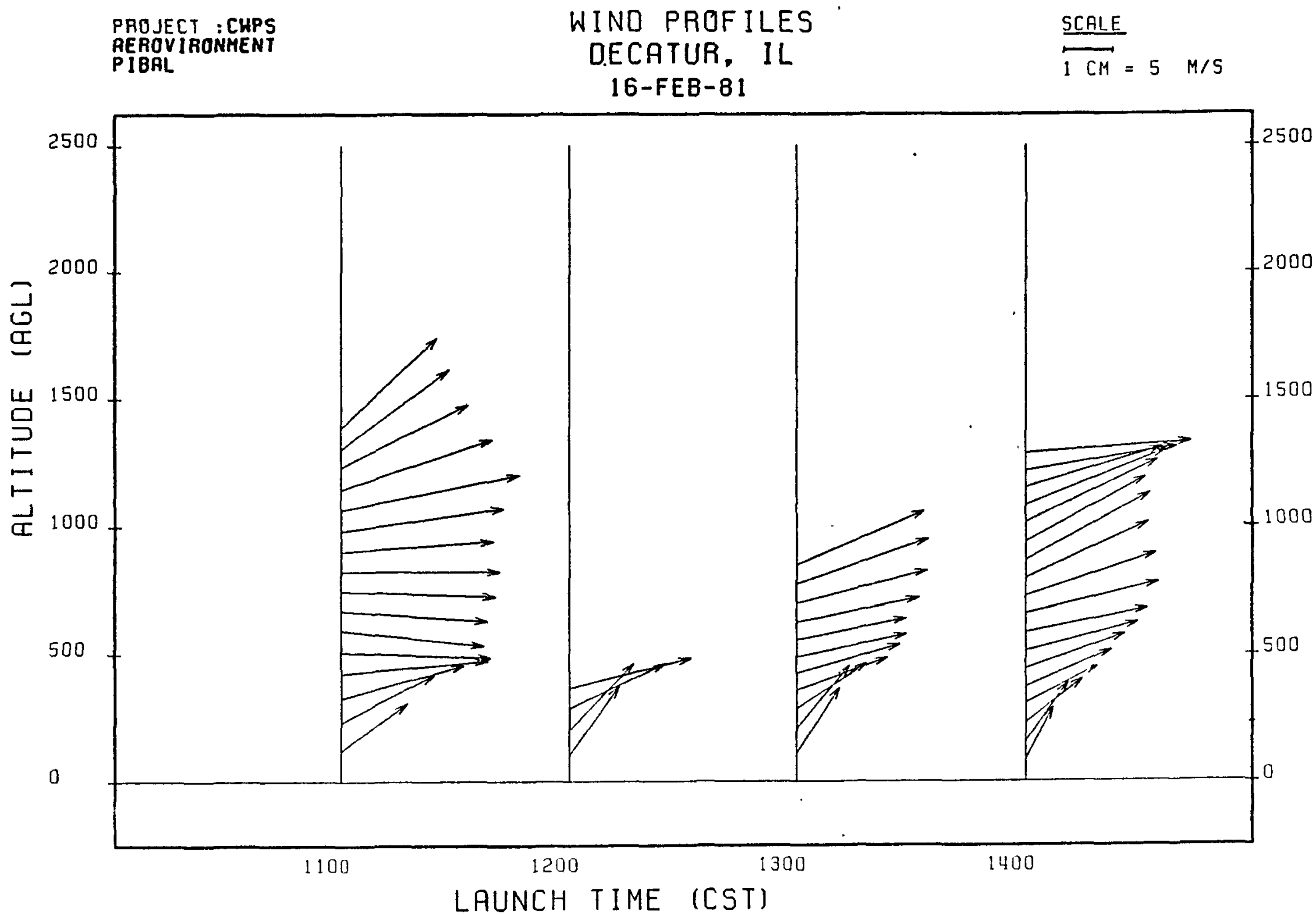
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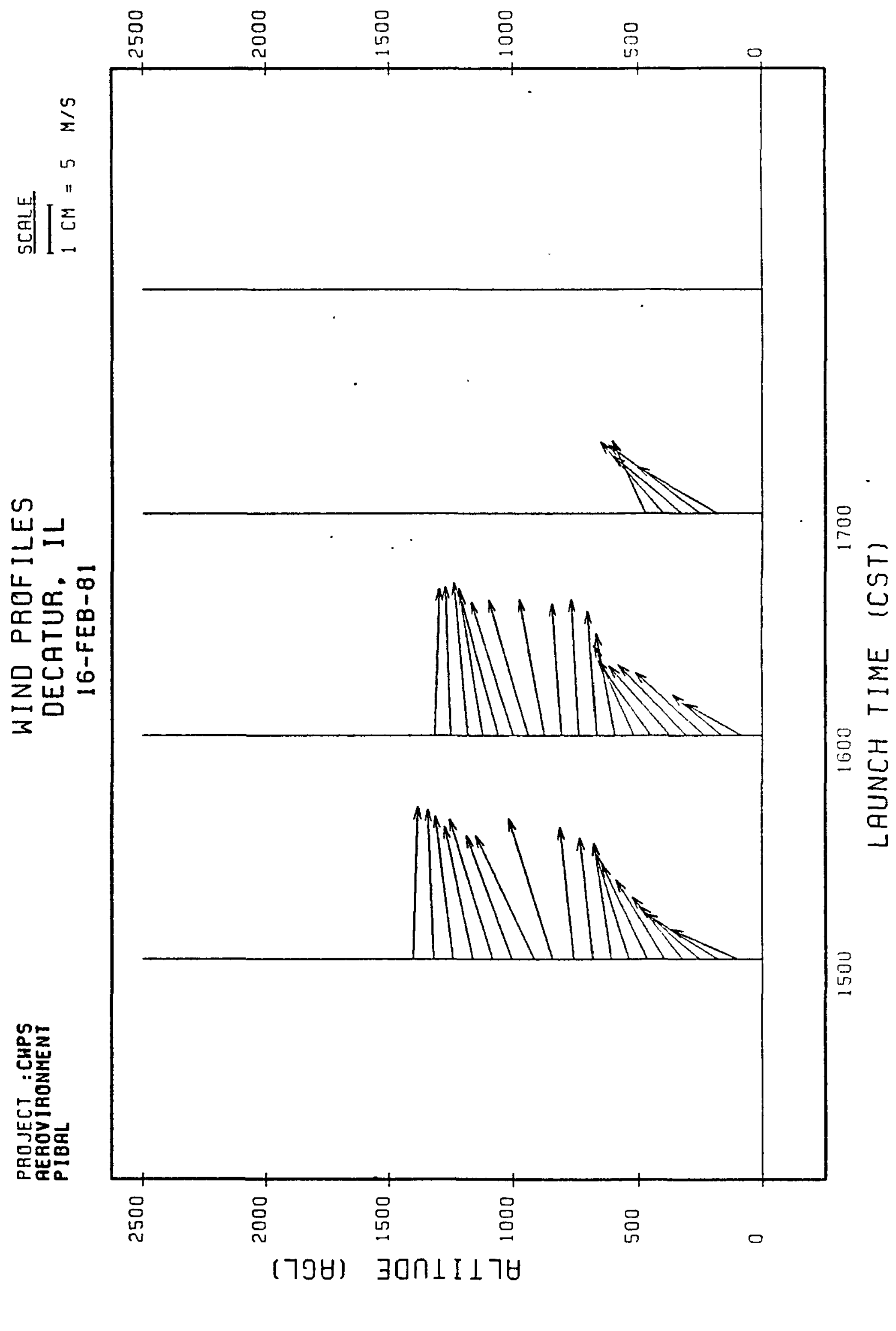
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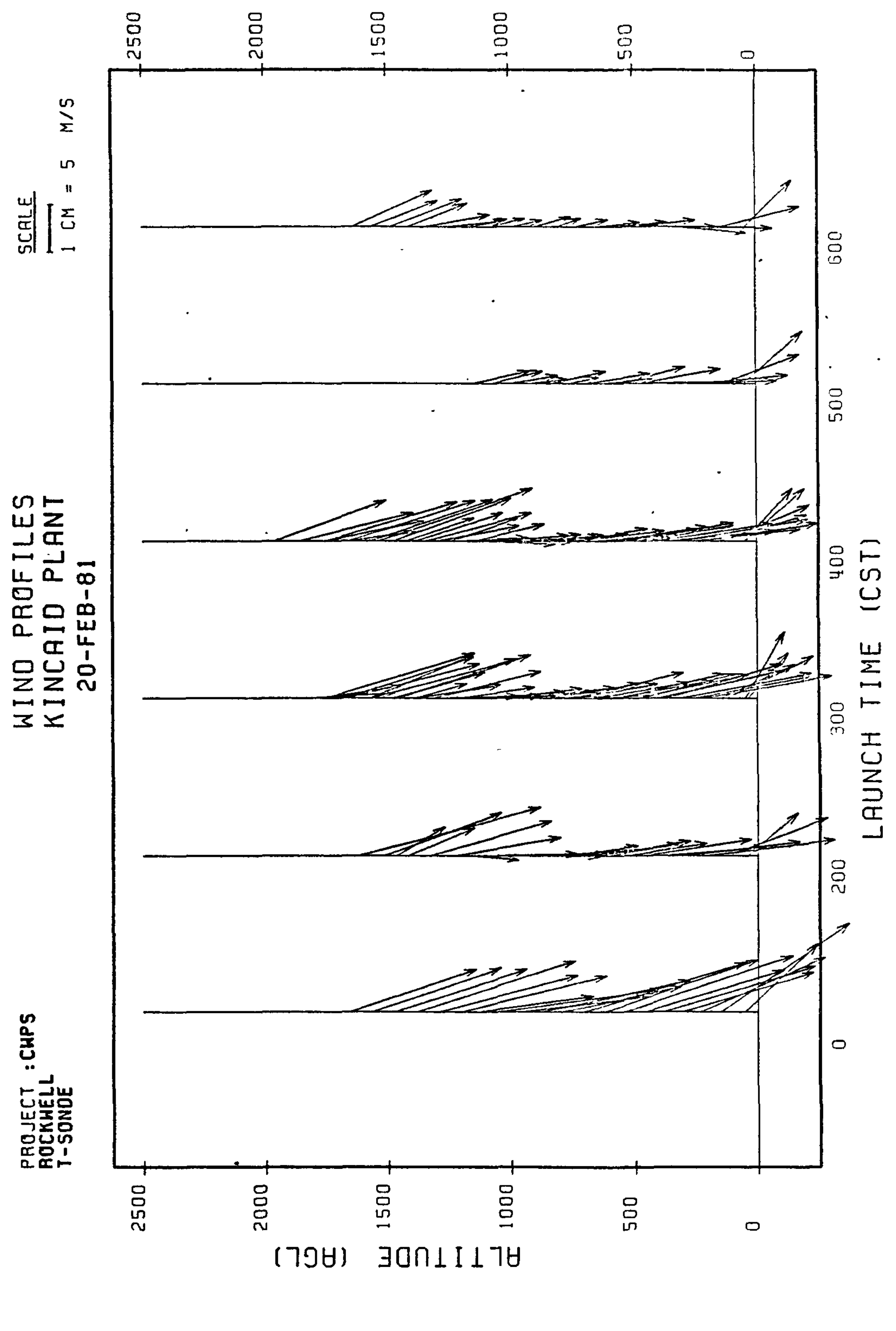
LAUNCH TIME (CST)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300
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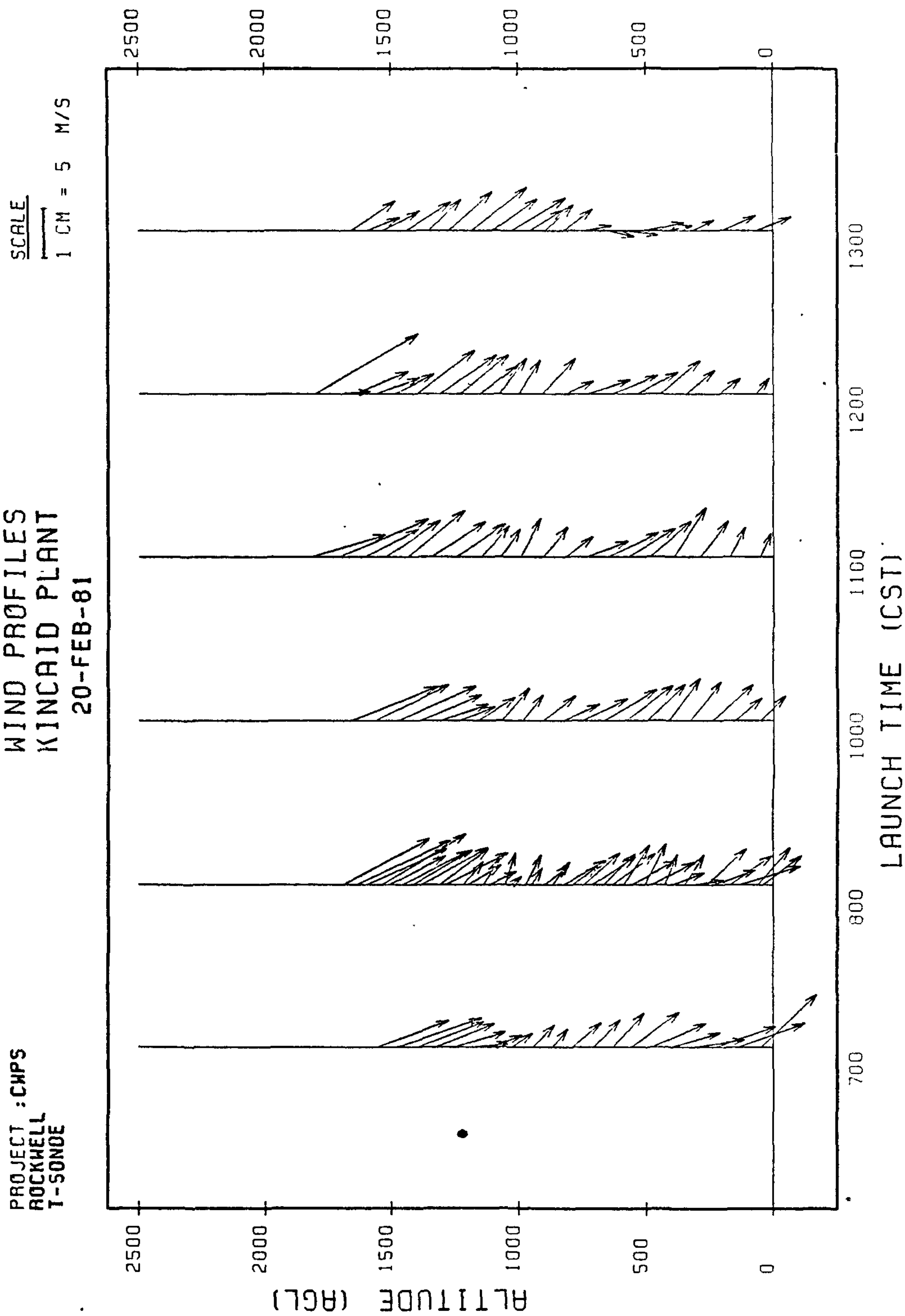
500
600
LAUNCH TIME (CST)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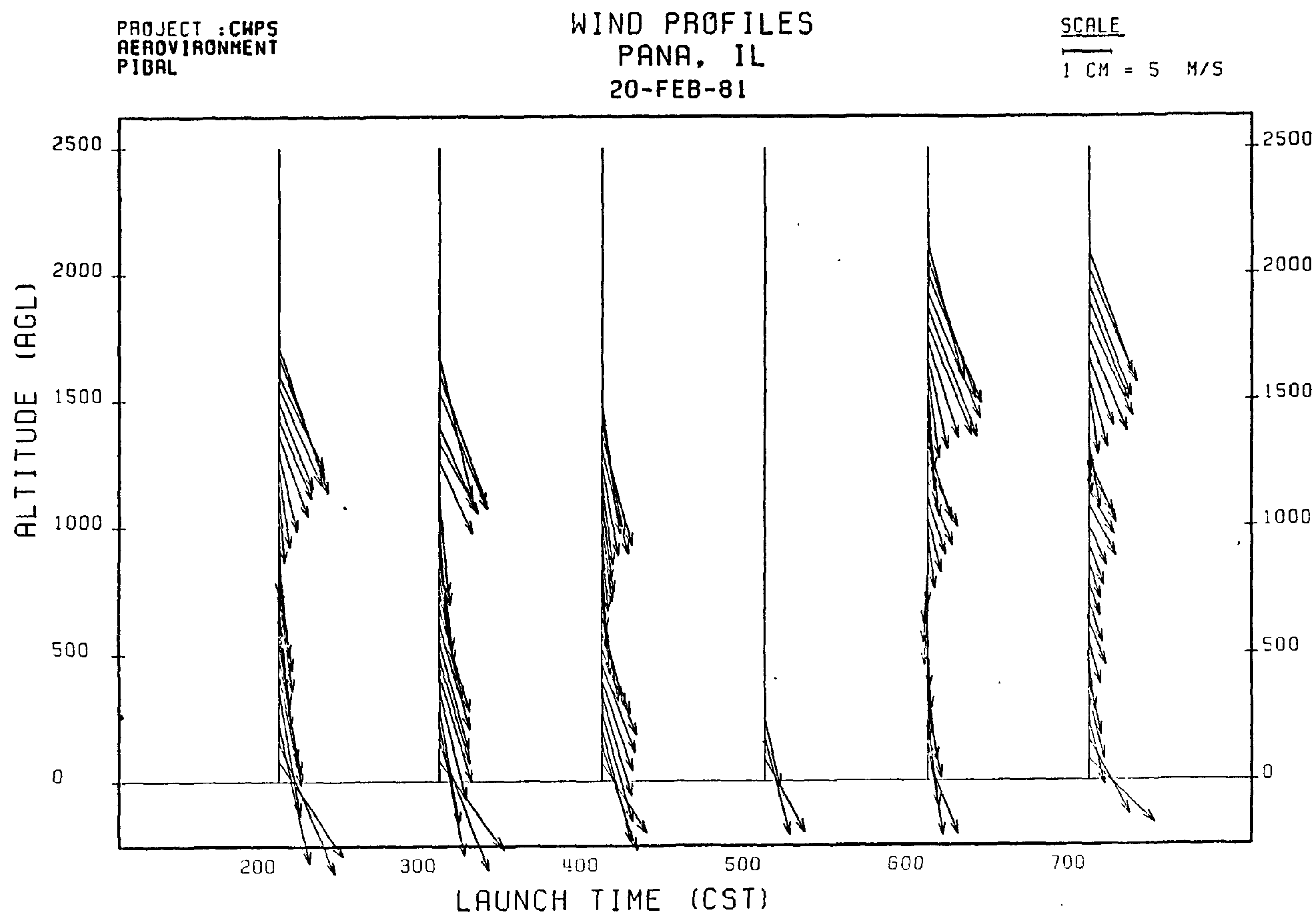
LAUNCH TIME (CST)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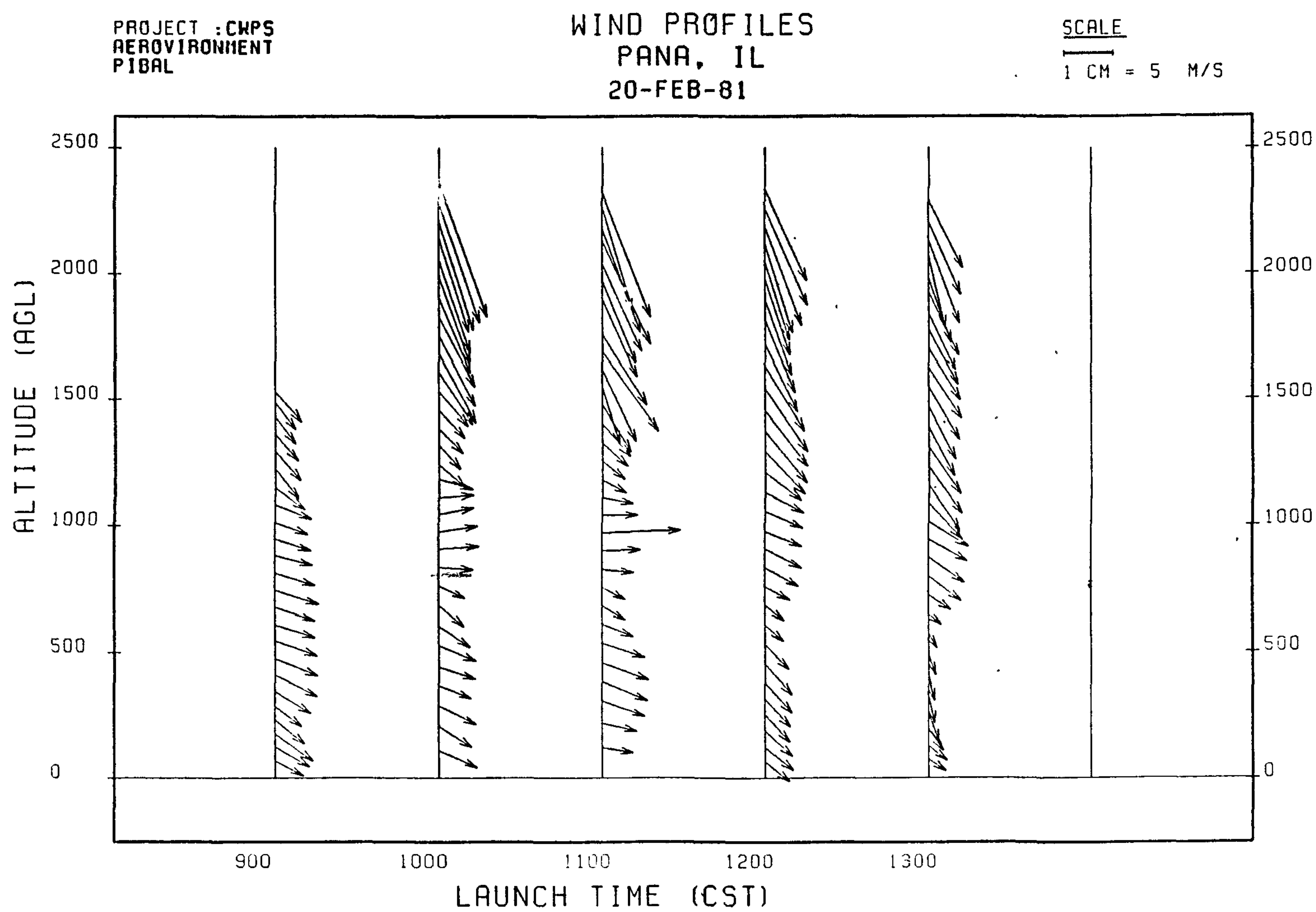
LAUNCH TIME (CST)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1500
1000
500
0
ALTITUDE (AGL)
900
1000
1100
1200
1300
LAUNCH TIME (CST)

Appendix B

Meteorological Summary Report: Cold Weather Plume Study - St. Louis, Mo.

DESCRIPTIVE SUMMARIES OF METEOROLOGICAL DATA COLLECTED DURING THE EPA/EPRI COLD WEATHER PLUME STUDY OF FEBRUARY 1981

GENERAL

During the period 9 through 20 February 1981, SRI International provided weather support for the Cold Weather Plume (CWP) study at St. Louis, Missouri. Mr. William Viezee of SRI prepared meteorological analyses and forecasts for EMI from an office at the National Weather Service Forecast Office (NWSFO) located in St. Charles, Missouri. He collected and archived a large volume of relevant weather observations, weather charts, and weather-satellite photographs during that period.

Daily weather briefings were held at the Spirit of St. Louis Airport to support the scheduling of aircraft flights to and from the Kincaid Power Plant in Illinois.

Figure 1 shows the location of the Kincaid Power Plant and the nearby weather reporting stations that were most frequently consulted to identify atmospheric conditions.

This report presents a descriptive summary of pertinent weather information for each day of the study period based on the meteorological data and guidance that were collected by SRI at the NWSFO.

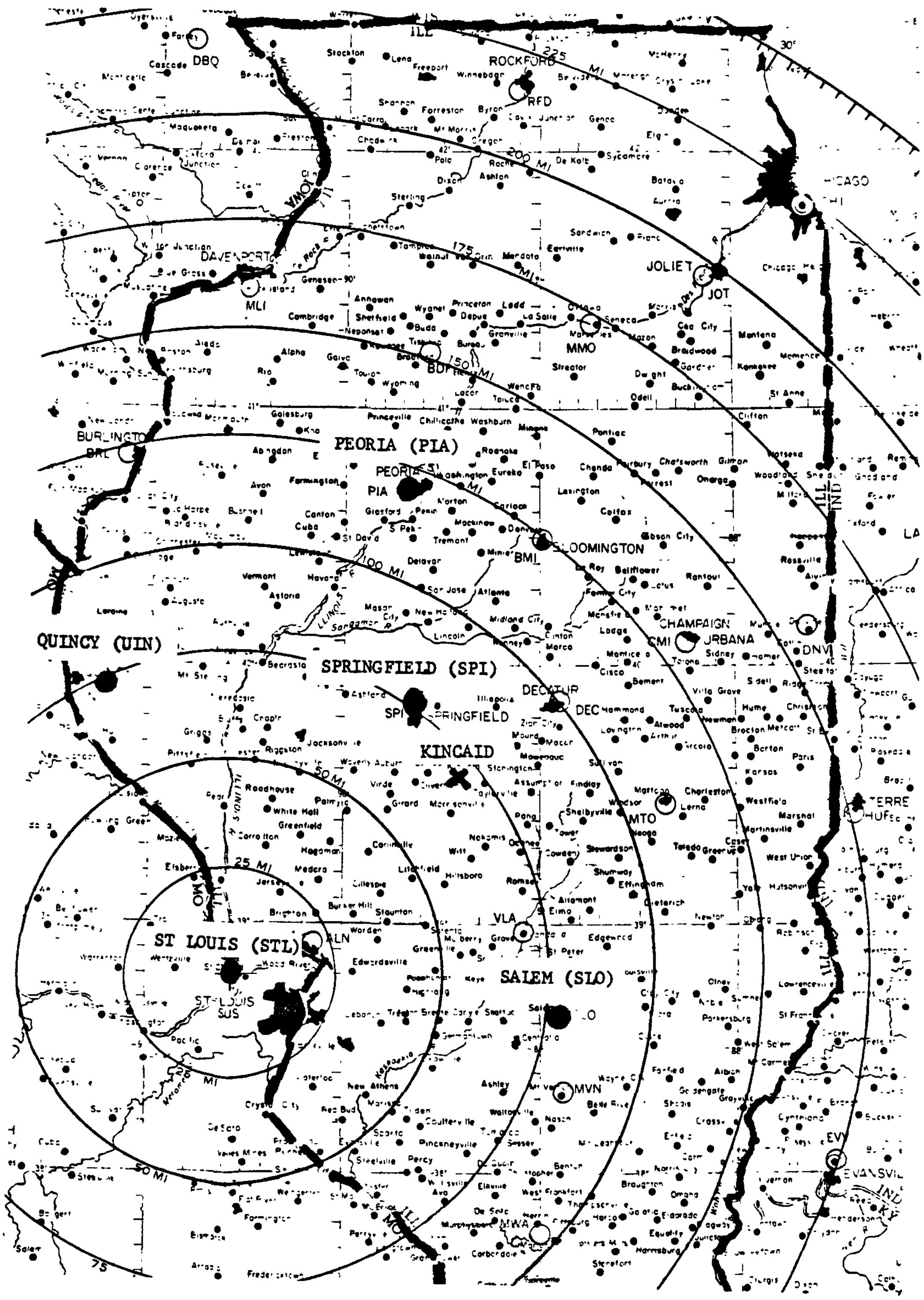

Figure 1. Location of principal weather reporting stations in relation to the Kincaid Power Plant in Illinois.

Monday, 9 February

On this day, weather conditions were good in the area of St. Louis and the Kincaid Power Plant. At 10 o'clock in the morning, St. Louis reported scattered high-altitude cirrus clouds. Springfield, Illinois, near Kincaid, reported broken clouds near 7000 ft. Winds were light (<15 knots), and the maximum surface temperature ranged from the mid-30's to the low 40's. No aircraft flights were made.

The weather outlook for Tuesday was for a snow storm approaching Missouri and Illinois from the southwest. This snow storm is shown in Figure 2 on the radar-echo summary chart for Monday afternoon 1735 CST, and in Figure 3 on the satellite cloud photograph at 1430 CST. These radar and satellite data indicate extensive cloud cover in Texas, Oklahoma, and Arkansas which was predicted by the National Weather Service (NWS) to move northeast into southern MIssouri on Monday night. The NWS winter storm warning issued at 1700 CST is quoted below.

> "Winter storm warning tonight and early Tuesday. Snow tonight ....Locally heavy at times....Accumulating to 4 inches or more before diminishing to flurries Tuesday....The low tonight around 20. Windy and turning sharply colder Tuesday....Afternoon temperatures in the teens. Clearing and very cold Tuesday night with the low 5 to 10 below. Sunny and cold Wednesday.... The high around 10 above.
> Winds....Northeasterly 10 to 20 MPH tonight.... North 15 to 30 MPH and gusty Tuesday."

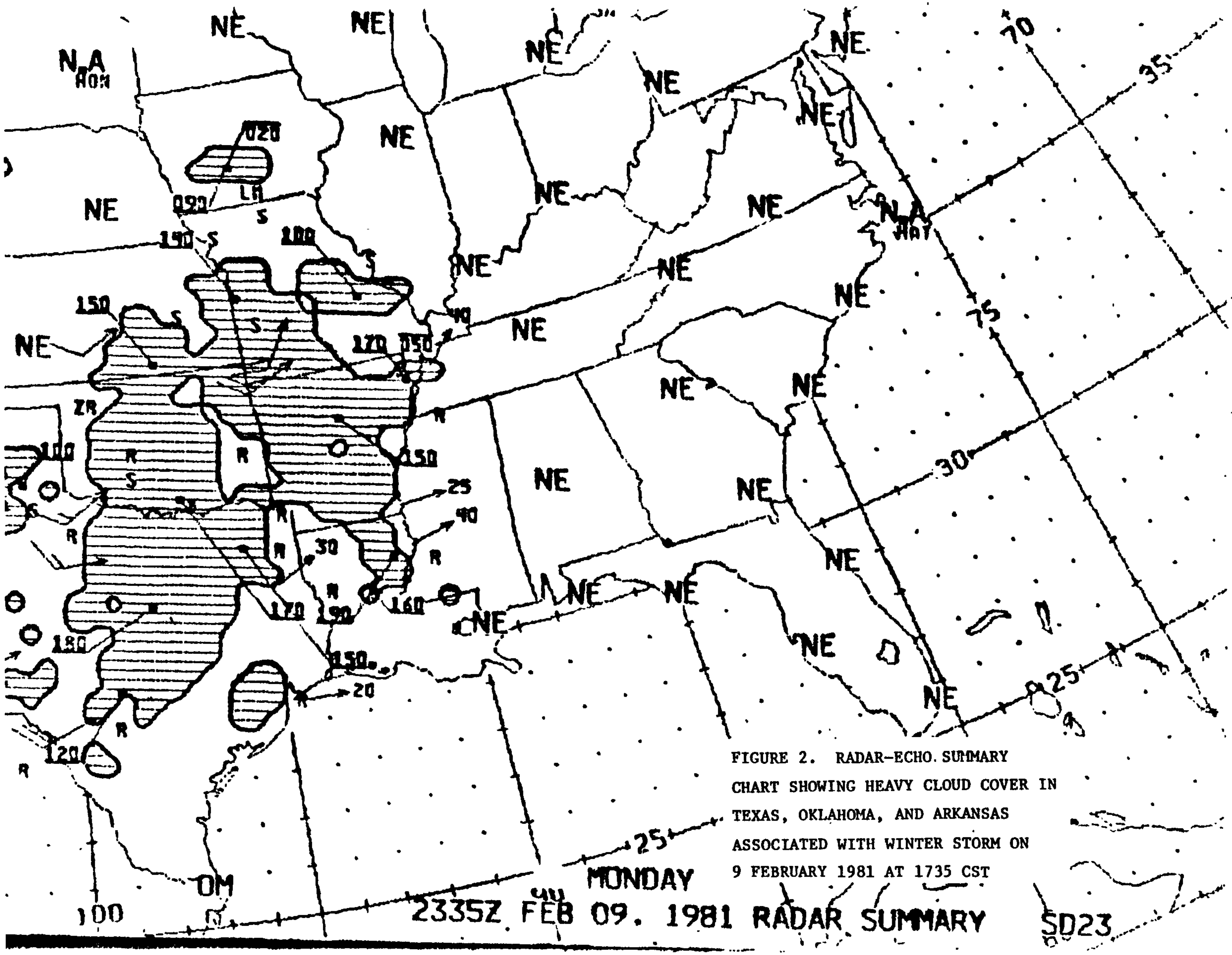

FIGURE 2. RADAR-ECHO SUMMARY CHART SHOWING HEAVY CLOUD COVER IN TEXAS, OKLAHOMA, AND ARKANSAS ASSOCIATED WITH WINTER STORM ON 9 FEBRUARY 1981 AT 1735 CST

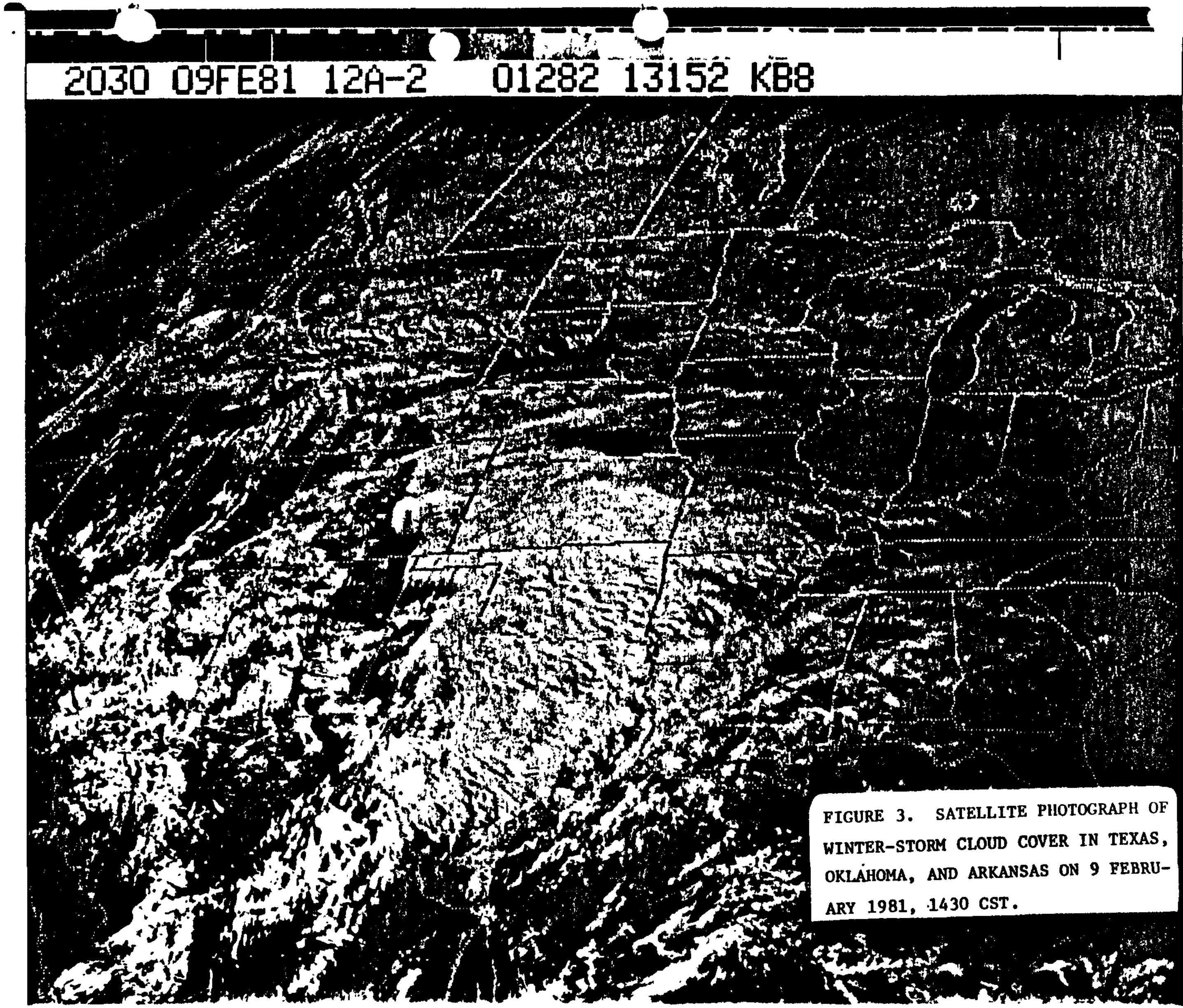

FIGURE 3. SATELLITE PHOTOGRAPH OF WINTER-STORM CLOUD COVER IN TEXAS, OKLAHOMA, AND ARKANSAS ON 9 FEBRUARY 1981, 1430 CST.

Tuesday, 10 February

A severe winter storm prevented aircraft flights from St. Louis to the Kincaid area. Figure 4 shows the 850-mb contour analysis at 1800 CST. The low-pressure center is located in northeastern Illinois. Very cold air and strong northerly winds (35-45 knots) are observed behind this low-pressure center. At 1400 CST, Peoria, Illinois reported an obscured cloud base at 300 ft with 1/2 mile surface visibility in snow and fog. Springfield, Illinois, near the Kincaid plant reported an obscured cloud ceiling at 100 ft with a surface visibility of 3/8 mile in light snow and fog. A thunderstorm was reported in the area.

The weather outlook for Wednesday called for clear and cold conditions with strong northerly winds. The boundary-layer winds predicted in Missouri and Illinois for Wednesday morning 0600 CST were northwest at 35 knots.

Wednesday, 11 February

At 0900 CST on Wednesday morning, winds were northwest at 35-40 knots near the 300-ft level at the Kincaid plant. At 0750 CST, St. Louis weather was clear with west-northwest surface winds at 24 knots gusting to 32 knots. These windy conditions prevailed throughout the day, and no aircraft flight missions could be scheduled.

Thursday, 12 February

On this day, the winds in the boundary layer were still strong. Figure 5 shows the wind flow near 5000 ft MSL (850-mb) at 0600 CST and at 1800 CST. Winds are generally west to southwest at 25-35 knots in Missouri and Illinois.

Figure 6 shows vertical profiles of the wind from ground-level to 10,000 ft MSL at Peoria, Illinois, during early morning (0600 CST) and late afternoon (1800 CST). The winds from ground-level to 5,000 ft MSL show a significant increase in speed from morning to afternoon. At 1800 CST, the winds at all altitudes range from 30 to 40 knots.

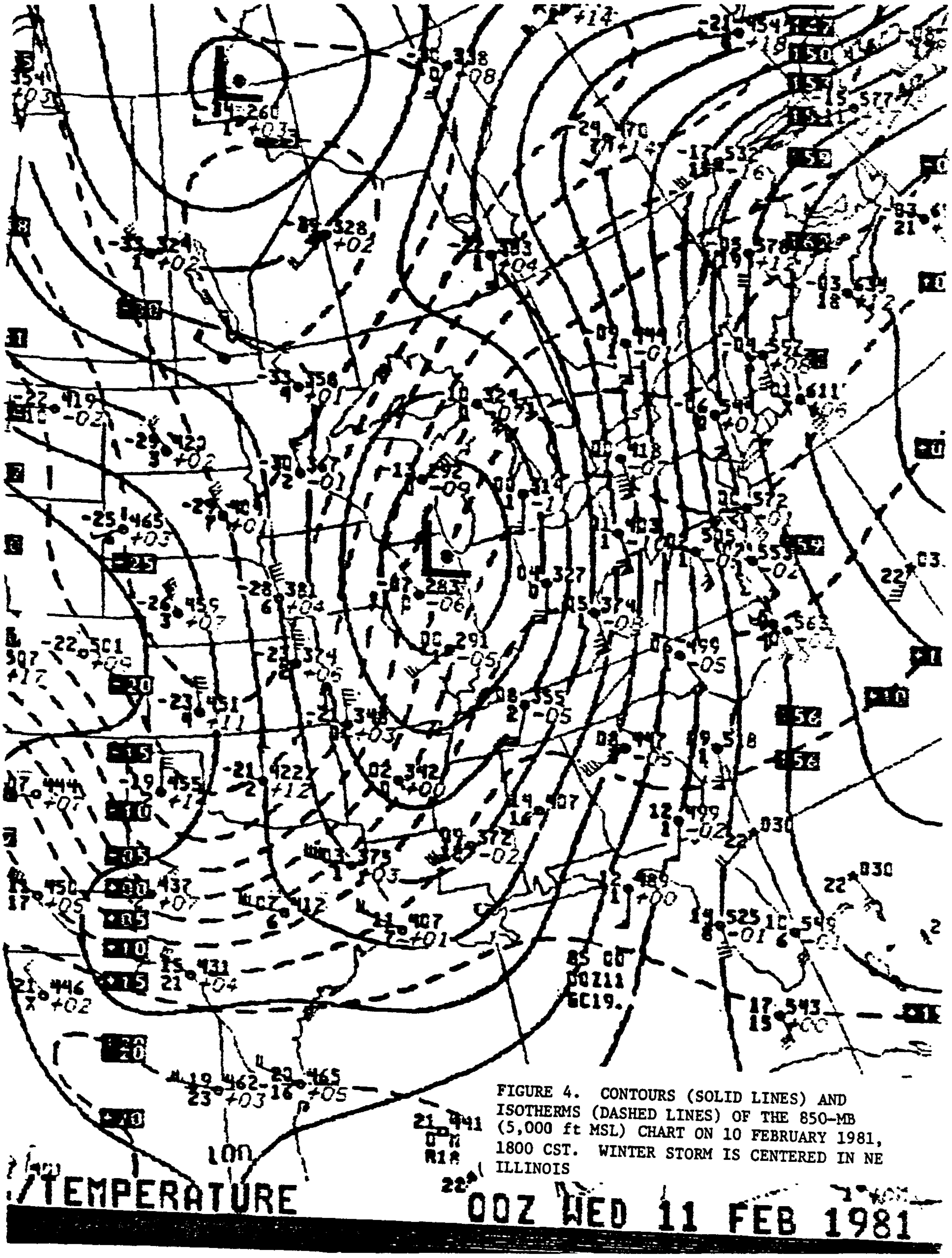

FIGURE 4. CONTOURS (SOLID LINES) AND ISOTHERMS (DASHED LINES) OF THE 850-MB (5,000 ft MSL) CHART ON 10 FEBRUARY 1981, 1800 CST. WINTER STORM IS CENTERED IN NE ILLINOIS

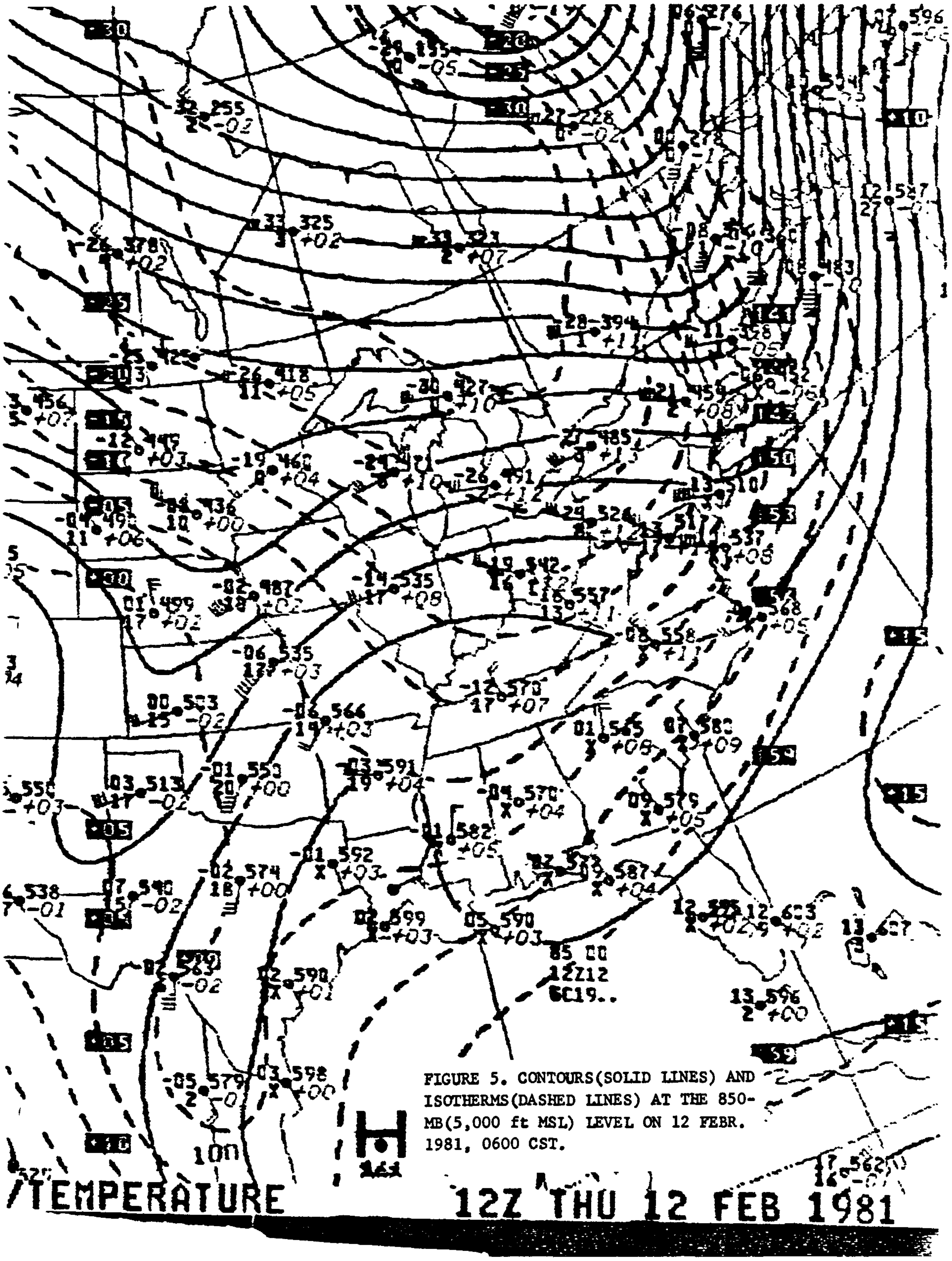

FIGURE 5. CONTOURS(SOLID LINES) AND ISOTHERMS(DASHED LINES) AT THE 850-MB(5,000 ft MSL) LEVEL ON 12 FEBR. 1981, 0600 CST.

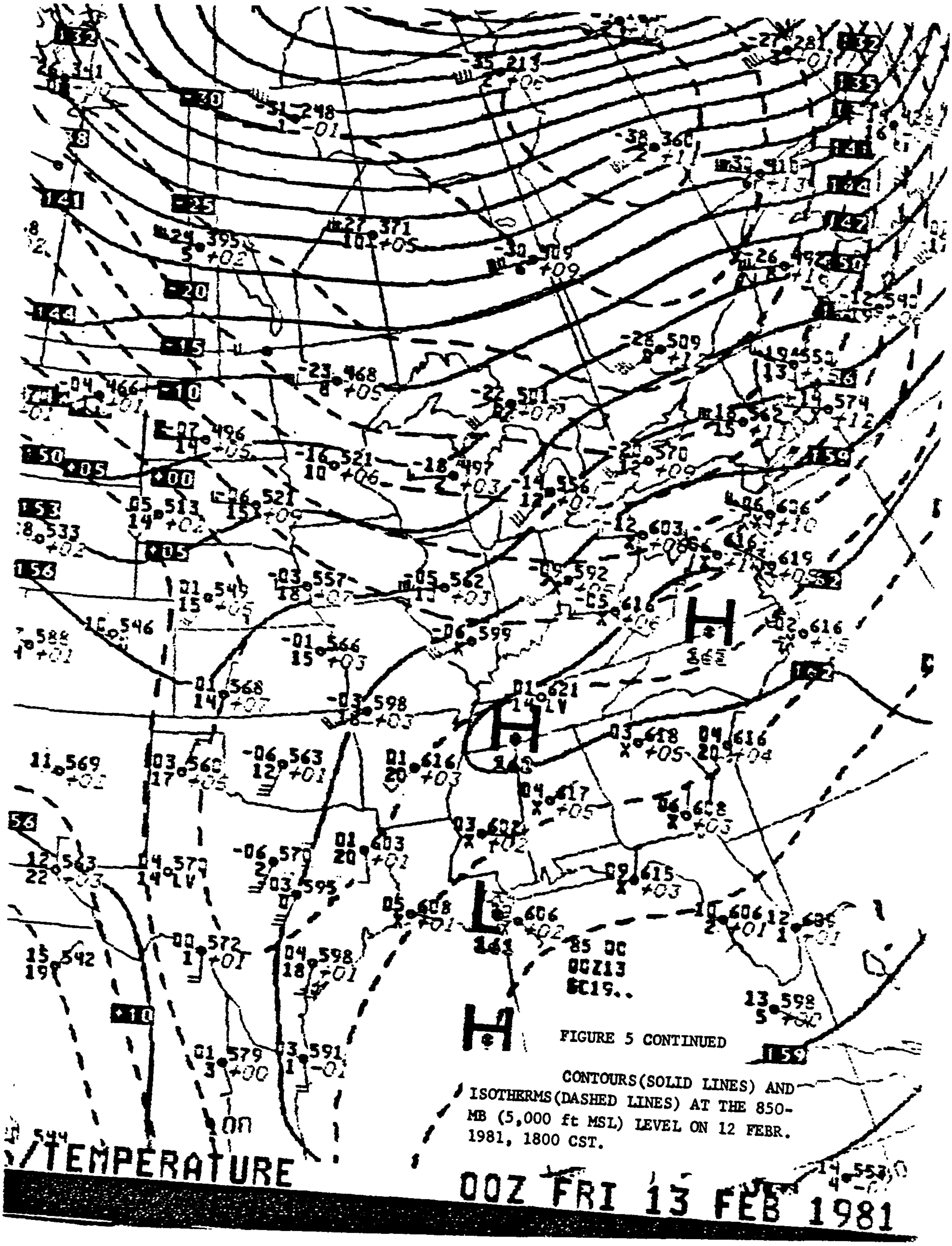

FIGURE 5 CONTINUED

CONTOURS (SOLID LINES) AND ISOTHERMS (DASHED LINES) AT THE 850-MB (5,000 ft MSL) LEVEL ON 12 FEBR. 1981, 1800 CST.

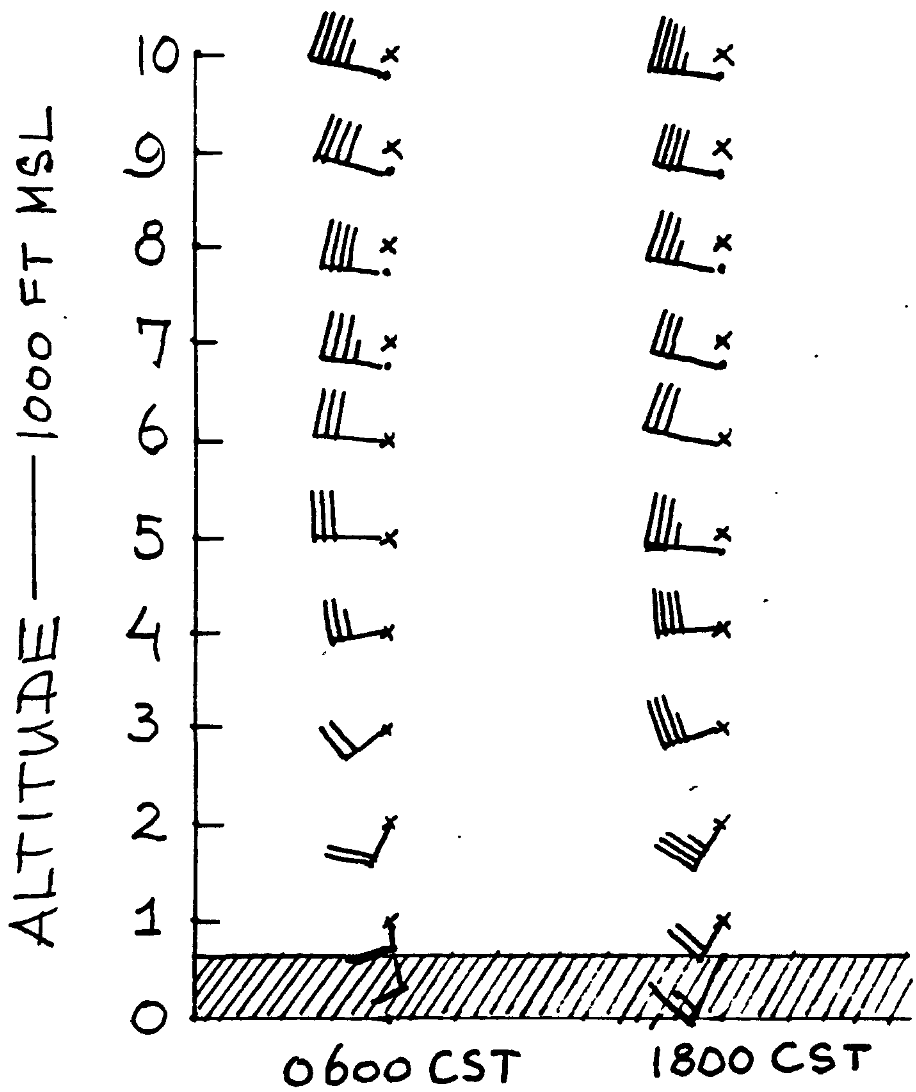

Figure 6. Vertical wind profiles at Peoria, Illinois on Thursday, 12 February 1981 showing wind speeds between 35 and 40 knots between ground-level and 5000 ft MSL.

(Wind direction is plotted to 36 compass points; barb is 10 knots, half barb is 5 knots)

Figure 7 represents a time section of the vertical temperature structure at Peoria, Illinois. It shows a significant warming from morning (0600 CST) to afternoon (1800 CST), with a temperature inversion from ground-level to close to 6,000 ft MSL.

Figures 8 and 9 show air-parcel trajectories predicted by the LFM-II numerical prediction model of the National Meteorological Center. These trajectories cover the 24-hour period of 12 February, 0600 CST to 13 February, 0600 CST. At Peoria and St. Louis, air parcels at 5,000 ft arrive from the area of Oklahoma and Texas, while near the surface they originate from southern Arkansas and northern Mississippi. These southerly trajectories are responsible for the rapid warming apparent in the temperature data of Figure 7.

Surface winds remained strong during the afternoon. Springfield, Illinois, reported southerly winds at 25 knots with gusts to 31 knots at 1500 CST. The outlook for Friday was good with southerly winds of decreasing speed.

Friday, 13 February

Friday the 13th happened to be a good day. A plume sampling flight was made to the Kincaid plant. The general wind flow conditions at 850-mb (5,000 ft MSL) are shown in Figure 10. The winds are southwesterly throughout the area of interest--i.e., Missouri and Illinois. Figure 11 shows the cloud conditions observed at 1600 CST. Scattered-to-broken cirrus clouds (20,000 to 25,000 ft) are present around Kincaid. Figure 12 gives a more detailed look at the wind structure between ground-level and 10,000 ft MSL at Peoria, Illinois, during early morning (0600 CST) and late afternoon (1800 CST). Winds are relatively light (10-25 knots), and have decreased from the previous day.

Figure 13 shows the temperature distribution and the location of low-level temperature inversions. At 1800 CST, an inversion layer extends from ground-level to about 3,000 ft MSL. A shallow inversion is present at 8,000 ft MSL.

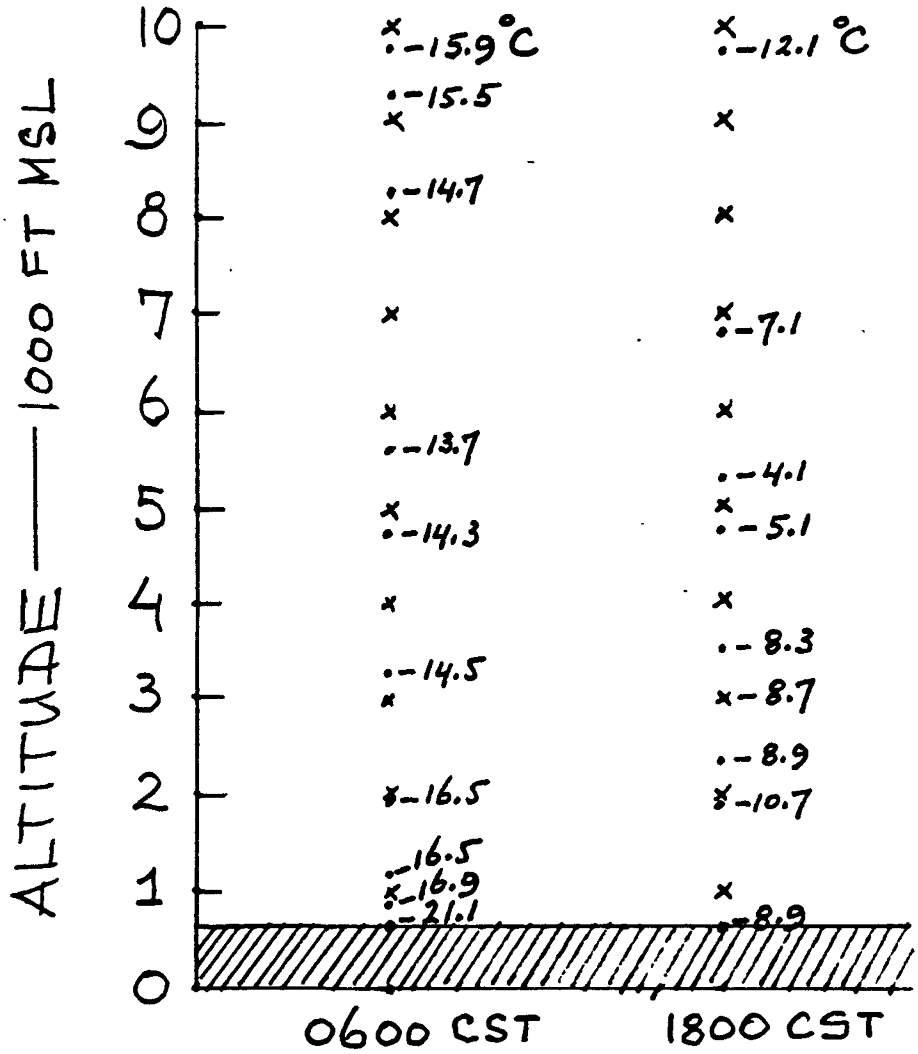

Figure 7. Vertical temperature profiles at Peoria, Illinois on Thursday, 12 February 1981 showing temperature increase with height (inversion) from ground-level to about 6000 ft MSL. Note large warming trend for the 12-hour period from early morning to afternoon. (Temperatures in degrees Centigrade)

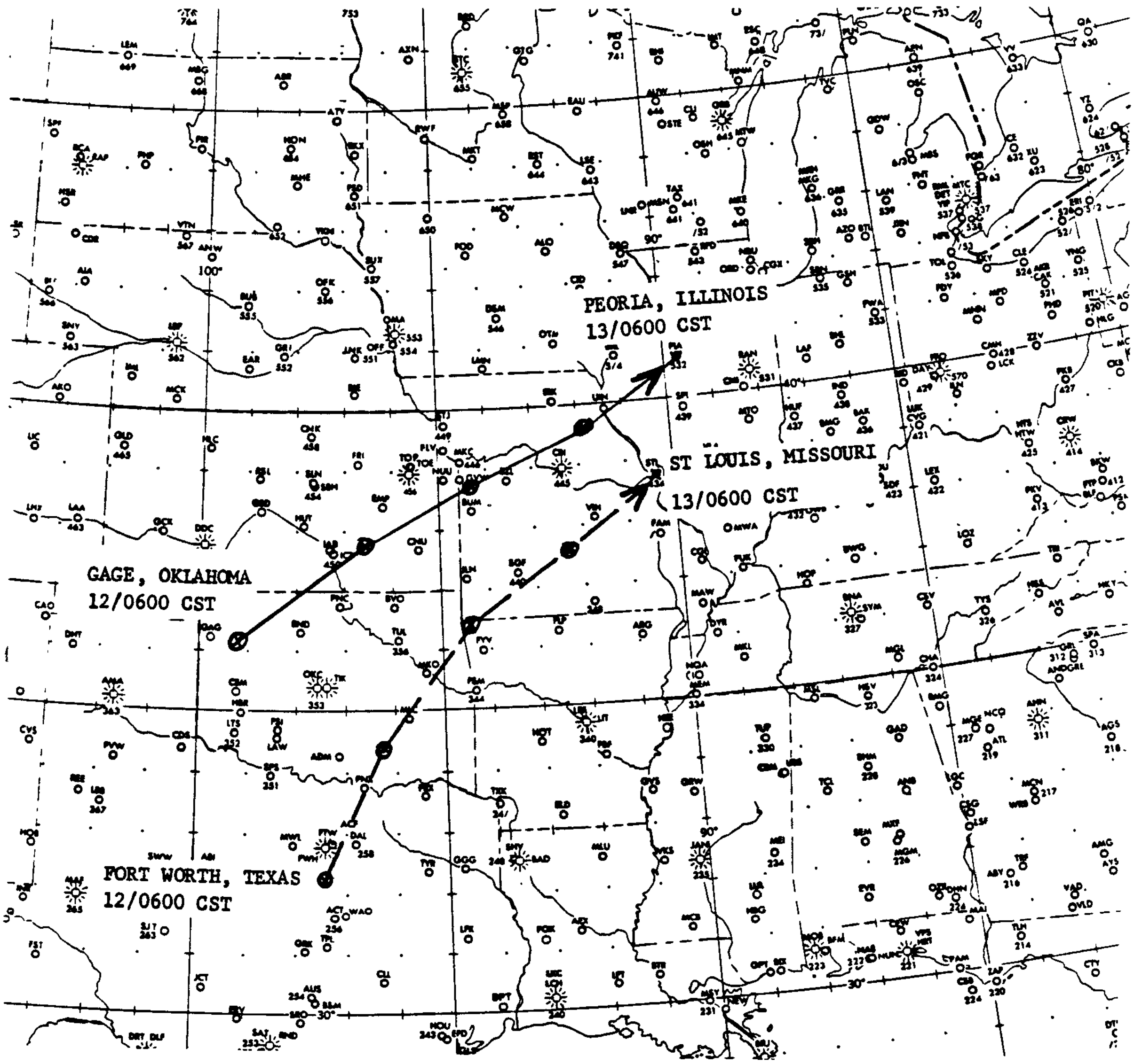

Figure 8. 24-Hour predicted air-parcel trajectories at 5000 ft altitude (about 850-mb) terminating at Peoria, Illinois, and at St Louis, Missouri. Air-parcel positions are indicated at 6 hour intervals. 24-Hour period represents 12 February,0600 CST to 13 February,0600 CST.

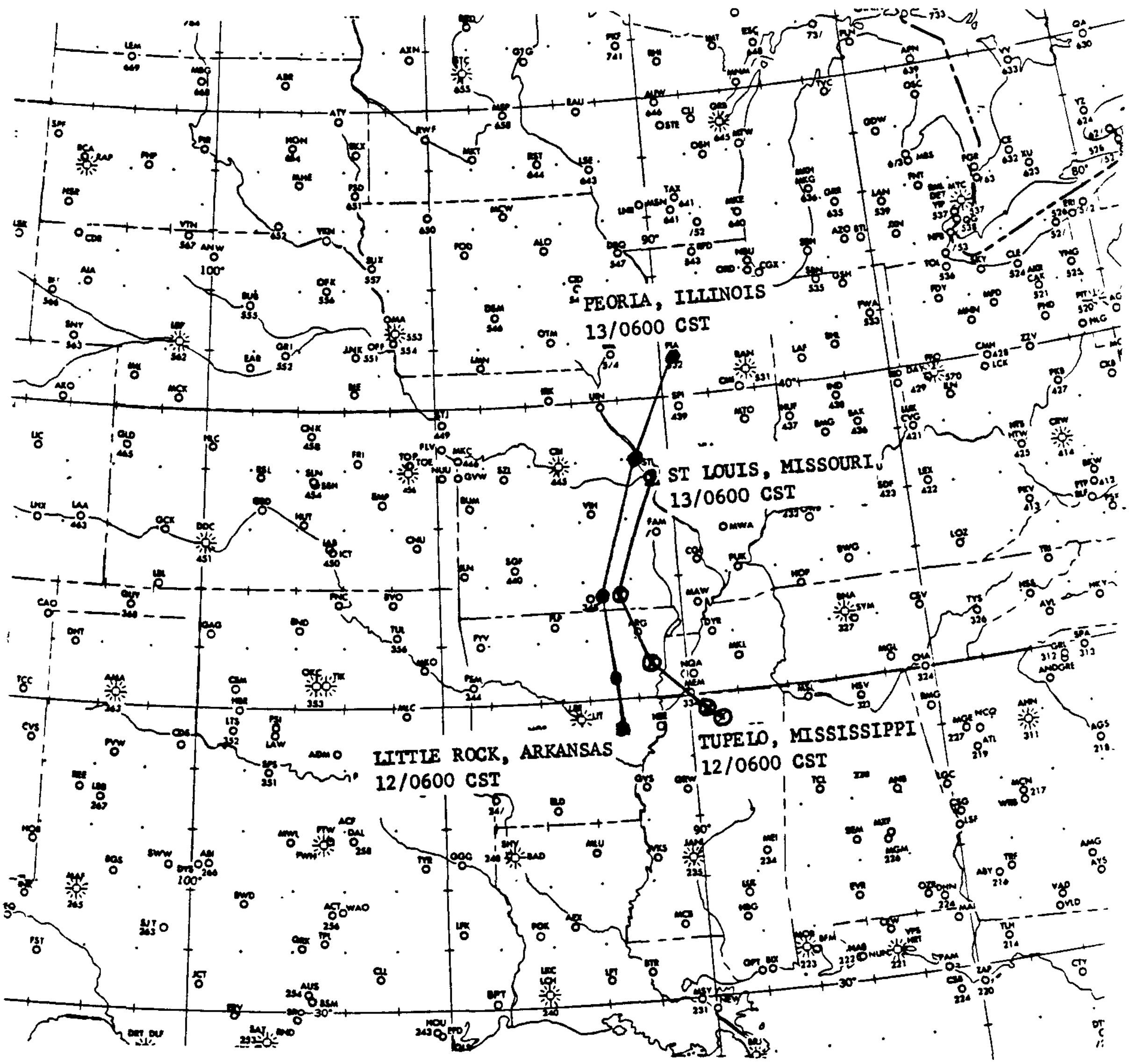

Figure 9. 24-Hour predicted air-parcel trajectories at the surface terminating at Peoria, Illinois, and at St. Louis, Missouri. Air-parcel positions are indicated at 6 hour intervals. 24-hour period extends from 12 February, 0600 CST to 13 February, 0600 CST.

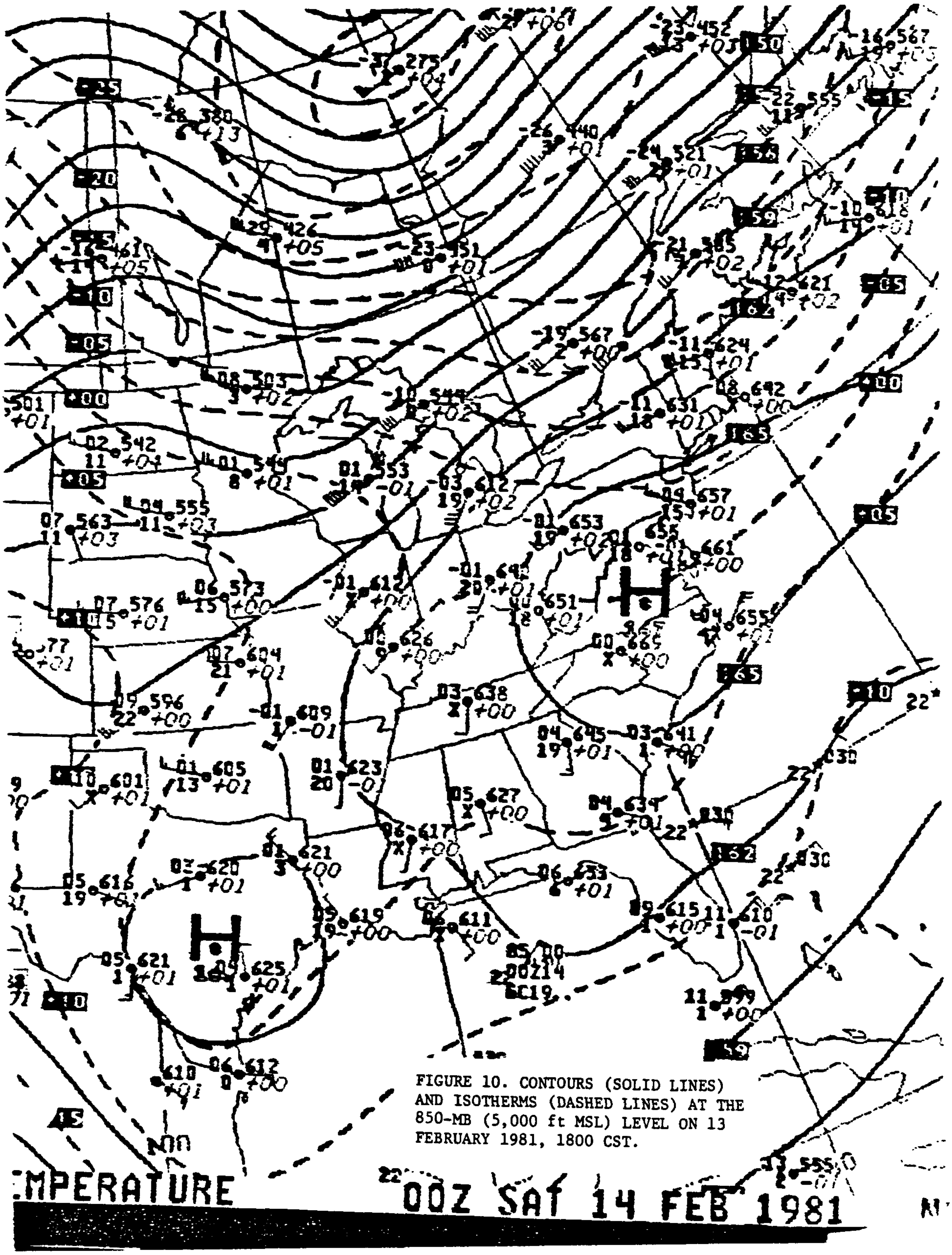

FIGURE 10. CONTOURS (SOLID LINES) AND ISOTHERMS (DASHED LINES) AT THE 850-MB (5,000 ft MSL) LEVEL ON 13 FEBRUARY 1981, 1800 CST.

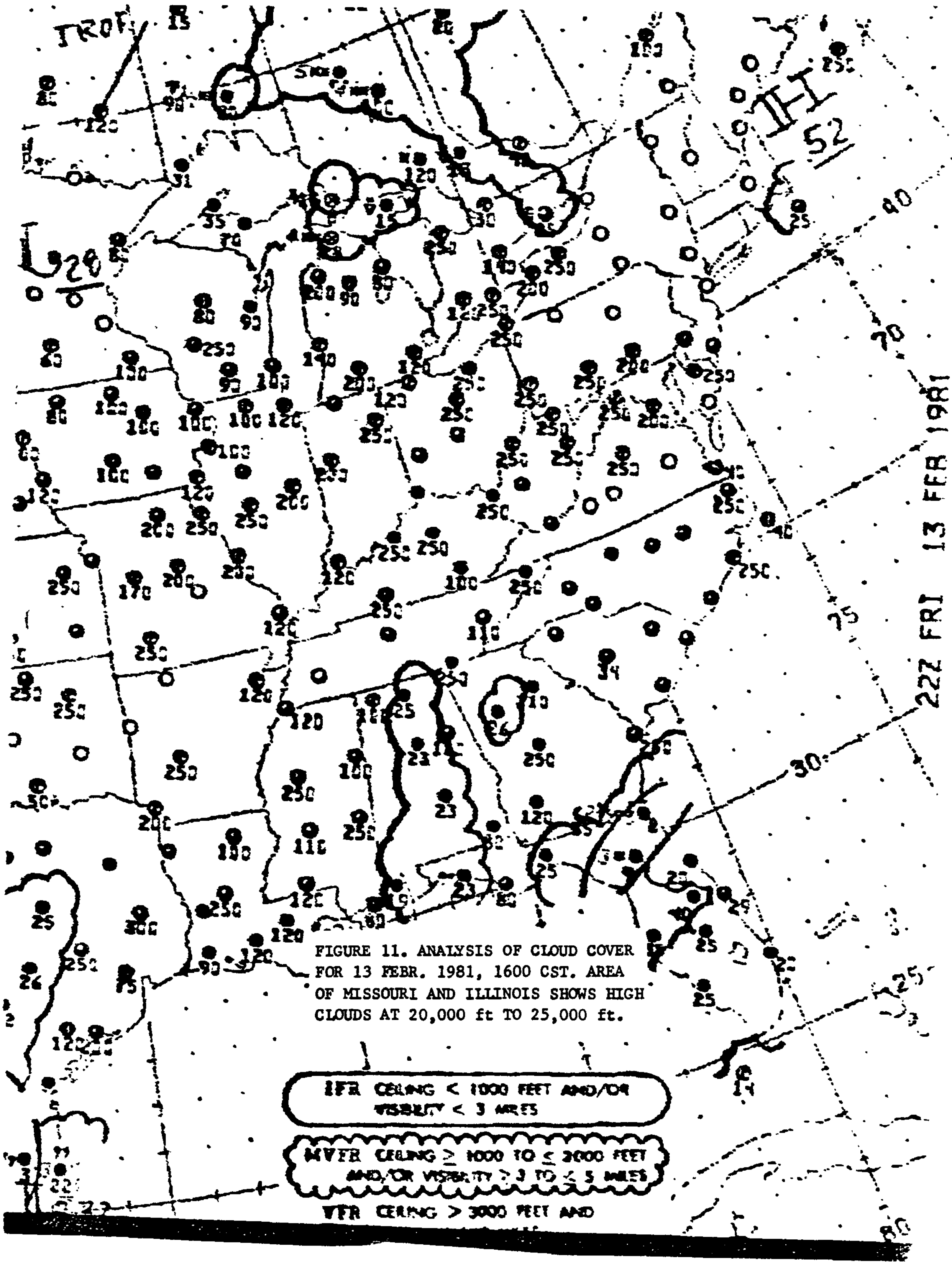

FIGURE 11. ANALYSIS OF CLOUD COVER FOR 13 FEBR. 1981, 1600 CST. AREA OF MISSOURI AND ILLINOIS SHOWS HIGH CLOUDS AT 20,000 ft TO 25,000 ft.

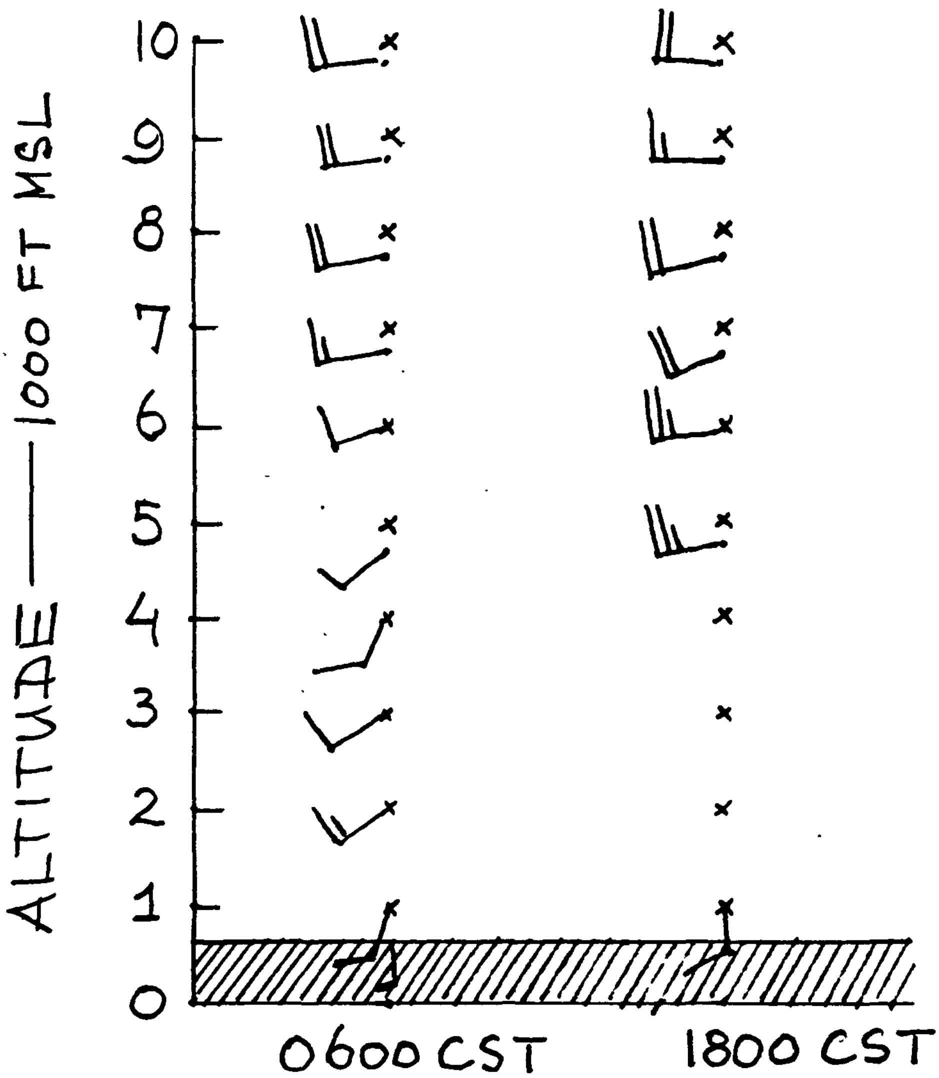

FIGURE 12. Vertical wind profiles at Peoria, Illinois on Friday, 13 February 1981 showing significant decrease in wind speed from previous day.
(Wind direction is plotted to 36 compass points; full barb is 10 knots, half barb is 5 knots.)

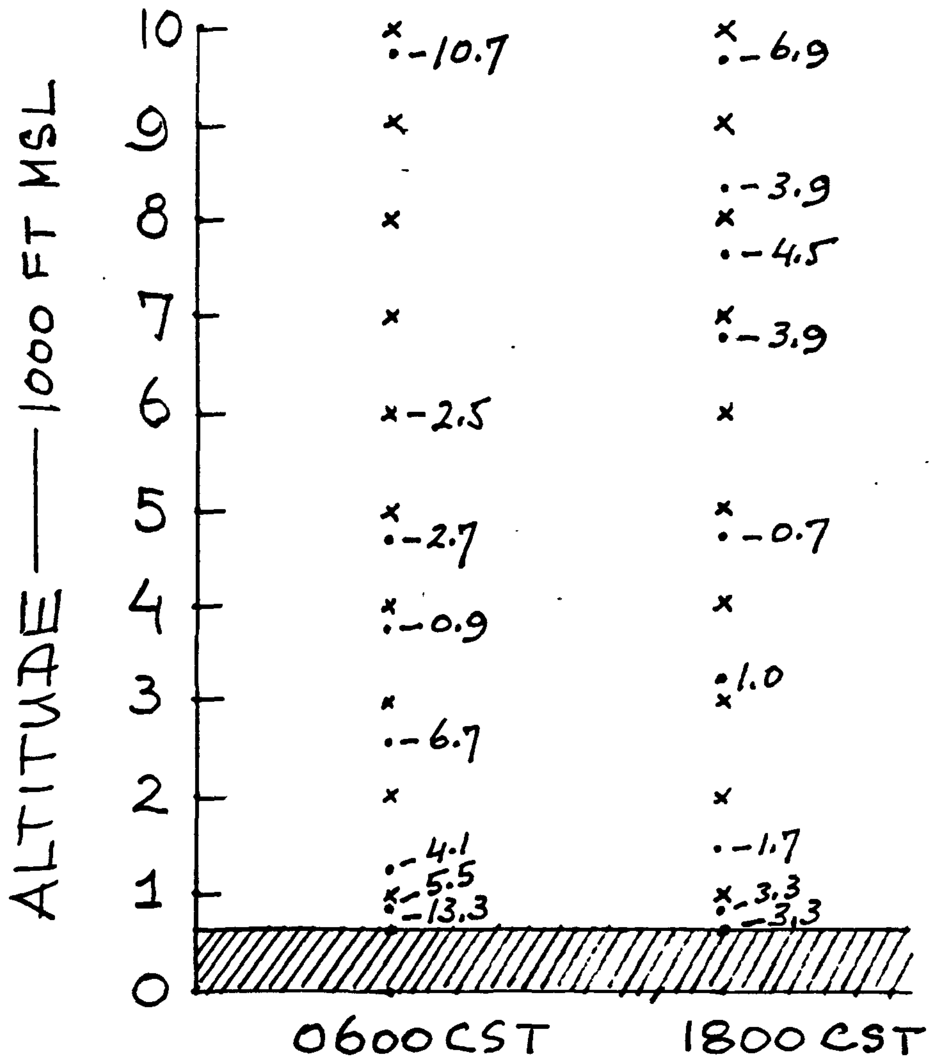

Figure 13. Vertical profiles of temperature (°C) at Peoria, Illinois on Friday, 13 February 1981 showing ground inversions at both indicated times, and elevated inversion near 3,000 ft MSL. Note that general warming of the airmass continues from morning to afternoon.

Air-parcel trajectory information at the 5,000 ft altitude, and near ground-level is illustrated in Figures 14 and 15. Trajectories are drawn for air parcels that terminate at Peoria, Illinois, and at Indianapolis, Indiana. Interpolating between the two trajectories drawn at each level shows that air parcels near the Kincaid Power Plant arrived from southerly and southwesterly directions, and originated in an area extending from Kansas to northern Arkansas to Kentucky.

Maximum surface temperatures recorded on 13 February are printed on the chart of Figure 16. Temperatures ranged from the high 20's to the high 30's in the area of the Kincaid Plant in Illinois.

The forecast called for good weather conditions on Saturday but increasing wind speeds on Sunday.

Saturday, 14 February

On Saturday, surface weather conditions were dominated by southerly winds on the backside of a 1045-mb high-pressure system centered on the East Coast. Only scattered cirrus clouds were observed in Missouri and Illinois. Figure 17 shows a satellite photograph in the visible part of the electro-magnetic spectrum. Snow cover is clearly seen extending through the area of interest.

The general wind flow at 850-mb (5,000 ft altitude) for late afternoon (1800 CST) is given by the contour chart of Figure 18. Winds are south to southwest at 15 knots in the area of Missouri and Illinois. Stronger winds are evident to the west of Missouri and are associated with an approaching low-pressure trough. Thus, wind speeds should increase with time as the low-pressure trough moves eastward.

Figure 19 shows vertical profiles of the wind from ground-level to 10,000 ft MSL at Peoria, Illinois on Saturday morning (0600 CST) and Sunday morning (0600 CST). The increase in wind speed is very evident in the observations. On Sunday morning, winds are southwesterly at 30-35 knots from ground-level to 6,000 ft MSL.

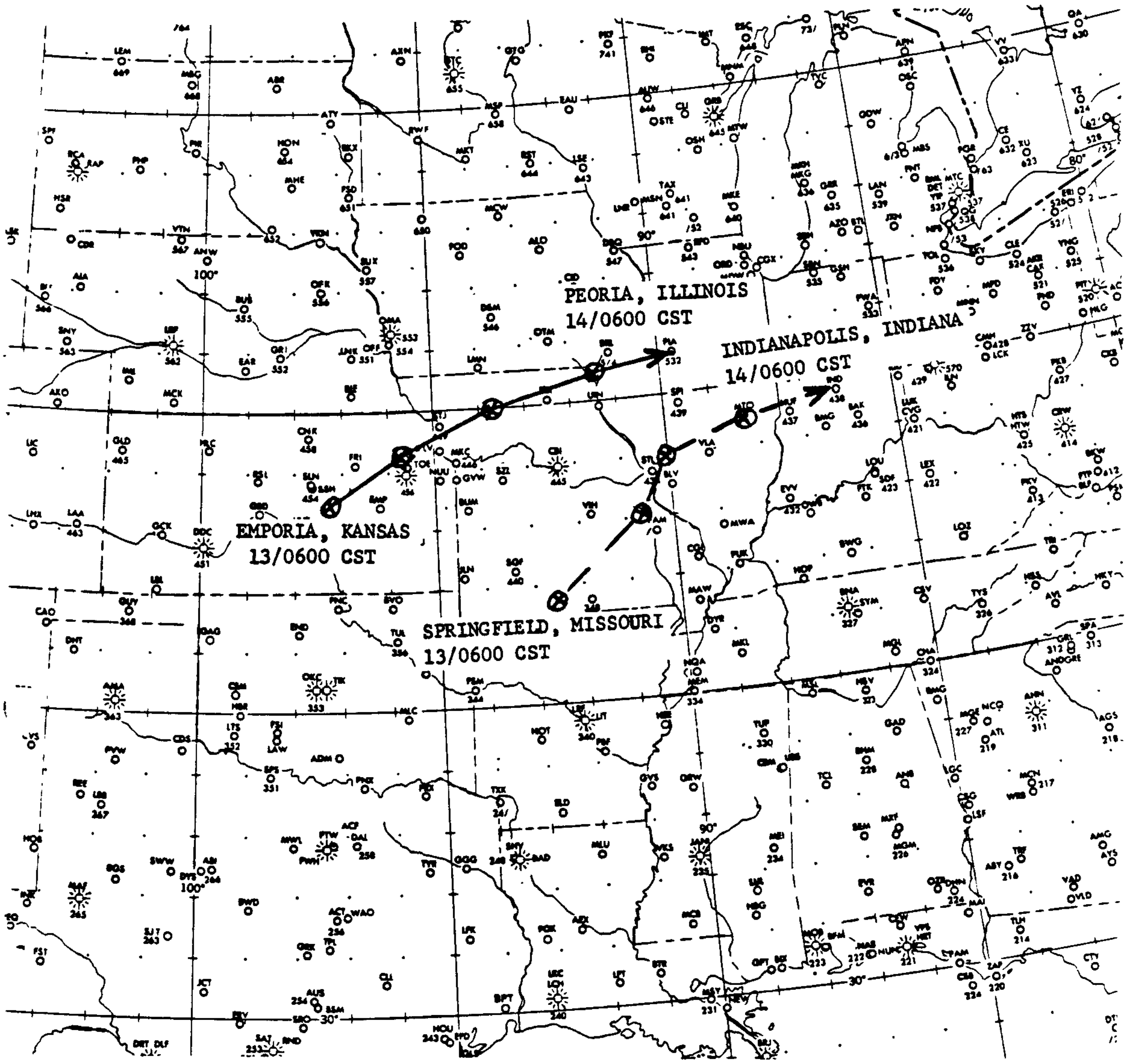

Figure 14. 24-hour predicted air-parcel trajectories at 5,000 ft altitude (about 850-mb) terminating at Peoria, Illinois, and at Indianapolis, Indiana. Air-parcel positions are indicated every 6 hours for the period 13 February 0600 CST to 14 February 0600 CST.

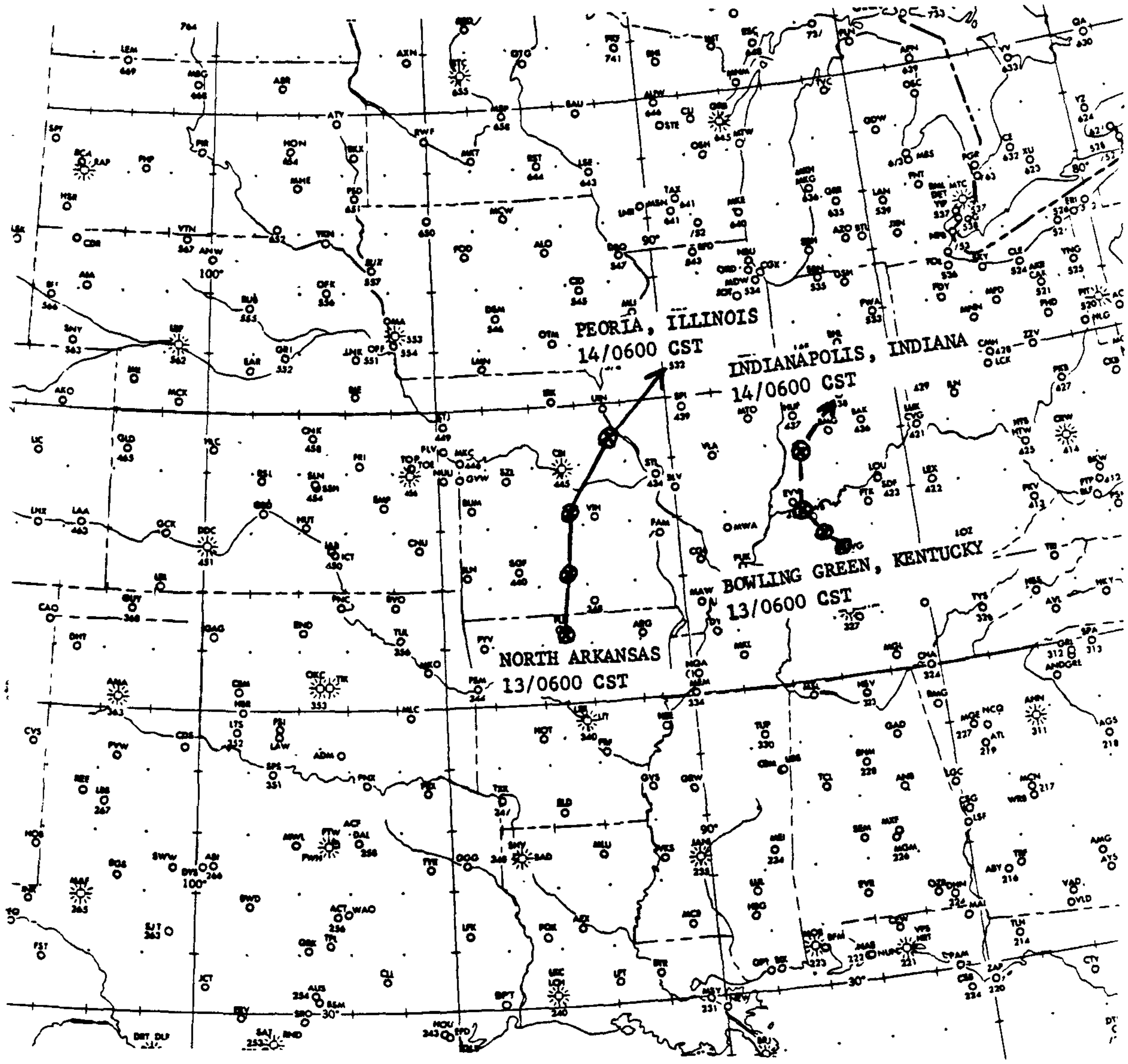

Figure 15. 24-hour air-parcel trajectories terminating at Peoria, Illinois, and at Indianapolis, Indiana, near ground-level during the period 13 February, 0600 CST to 14 February, 0600 CST.

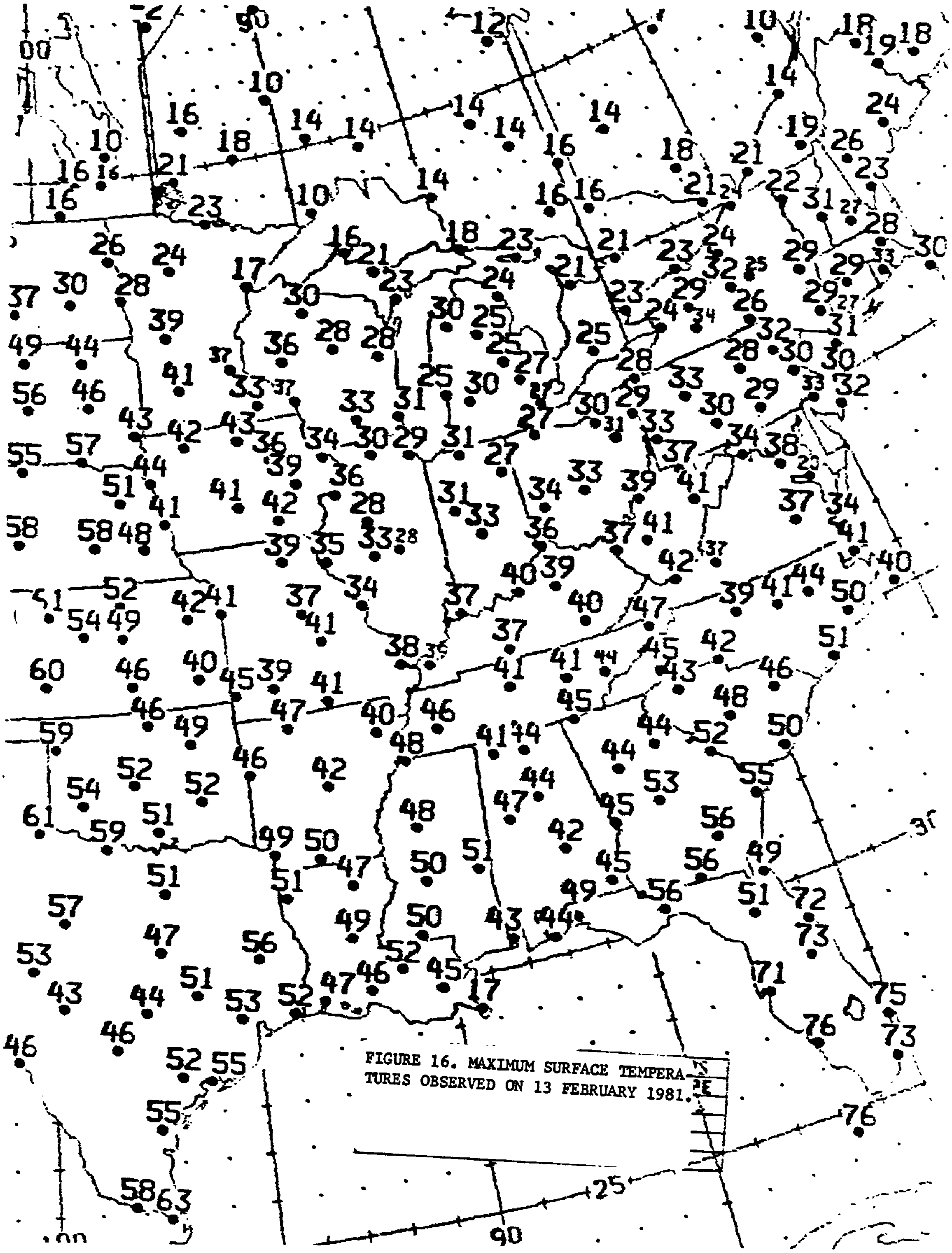

FIGURE 16. MAXIMUM SURFACE TEMPERATURES OBSERVED ON 13 FEBRUARY 1981.

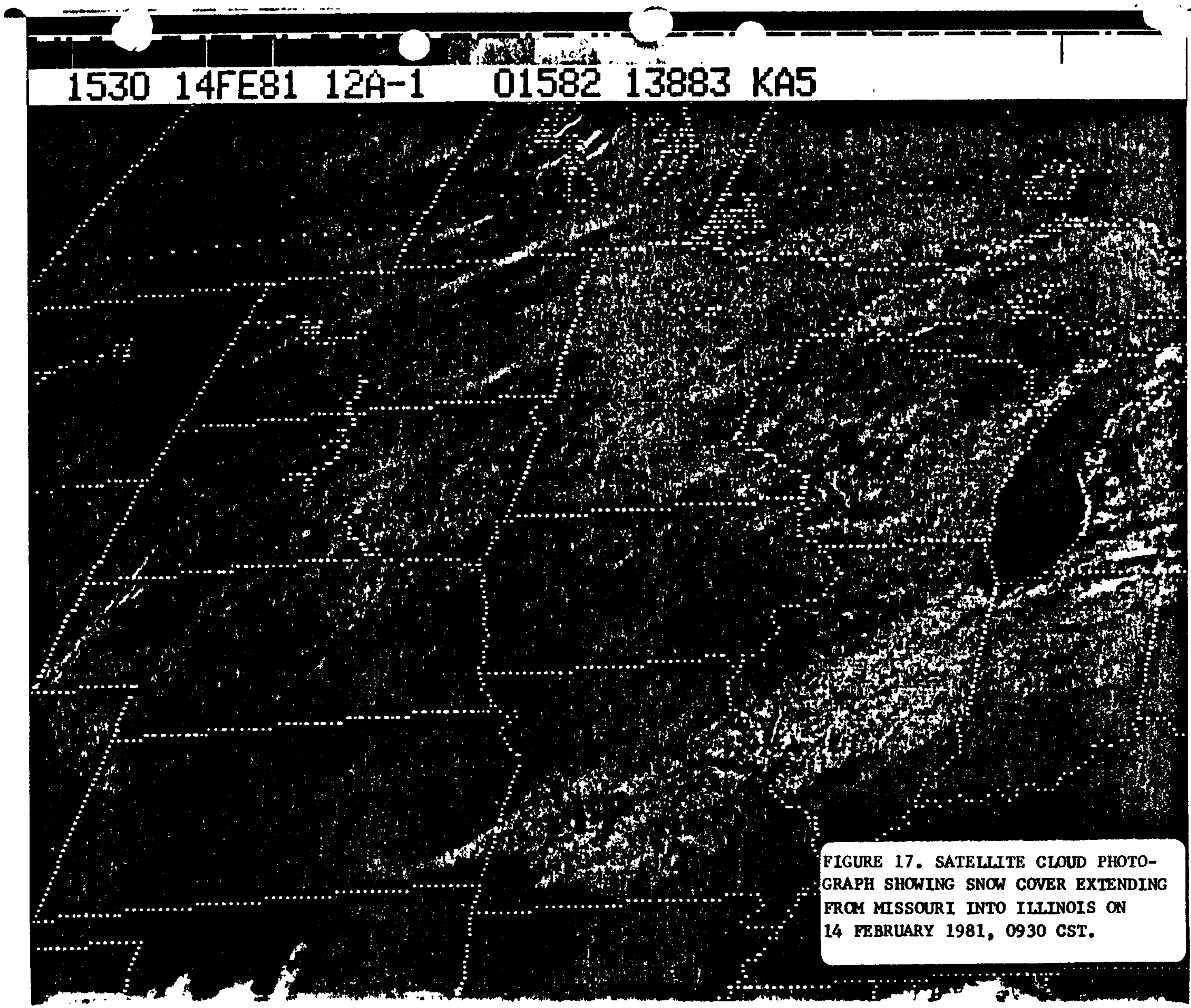

FIGURE 17. SATELLITE CLOUD PHOTOGRAPH SHOWING SNOW COVER EXTENDING FROM MISSOURI INTO ILLINOIS ON 14 FEBRUARY 1981, 0930 CST.

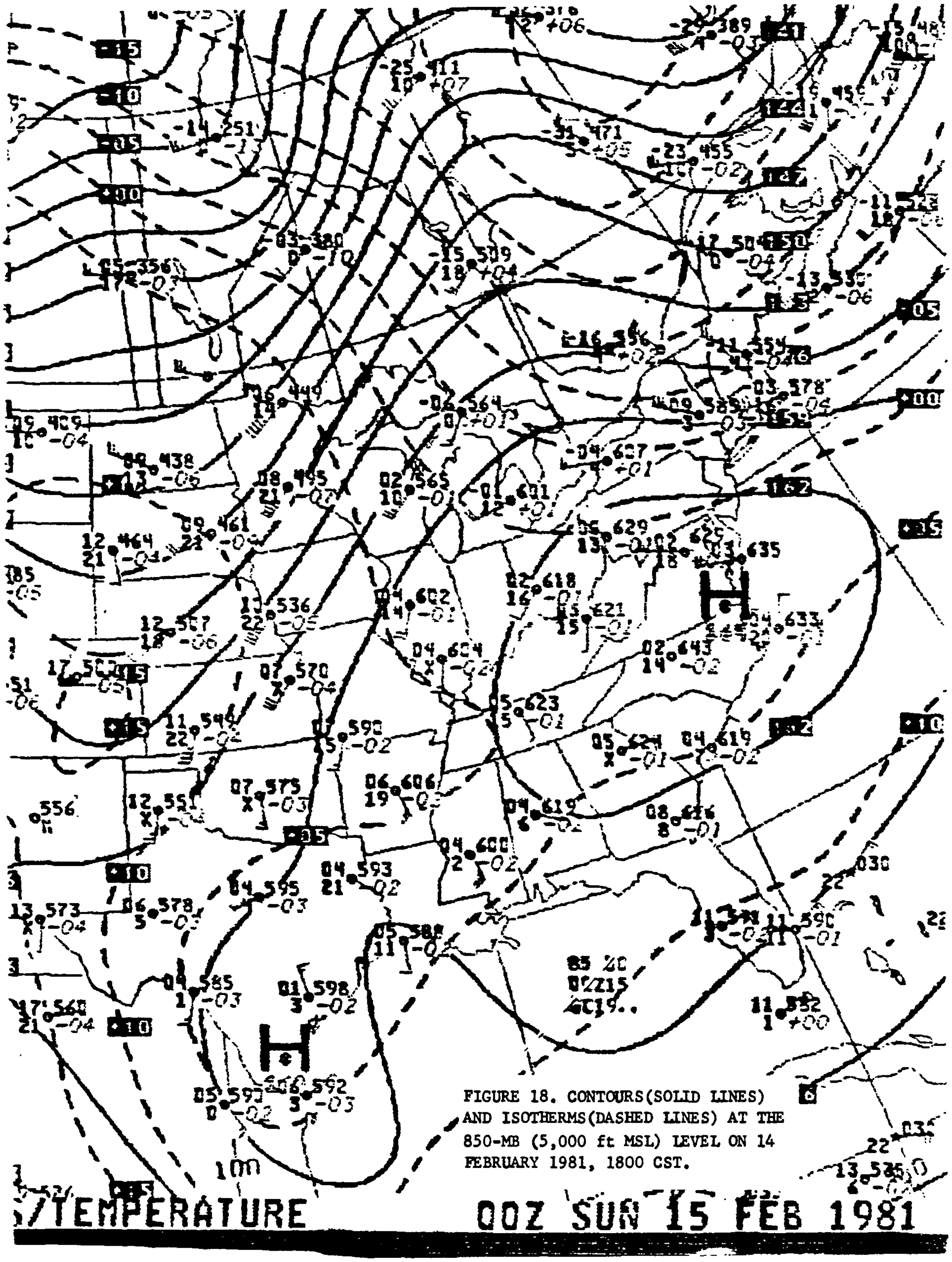

FIGURE 18. CONTOURS(SOLID LINES) AND ISOTHERMS(DASHED LINES) AT THE 850-MB (5,000 ft MSL) LEVEL ON 14 FEBRUARY 1981, 1800 CST.

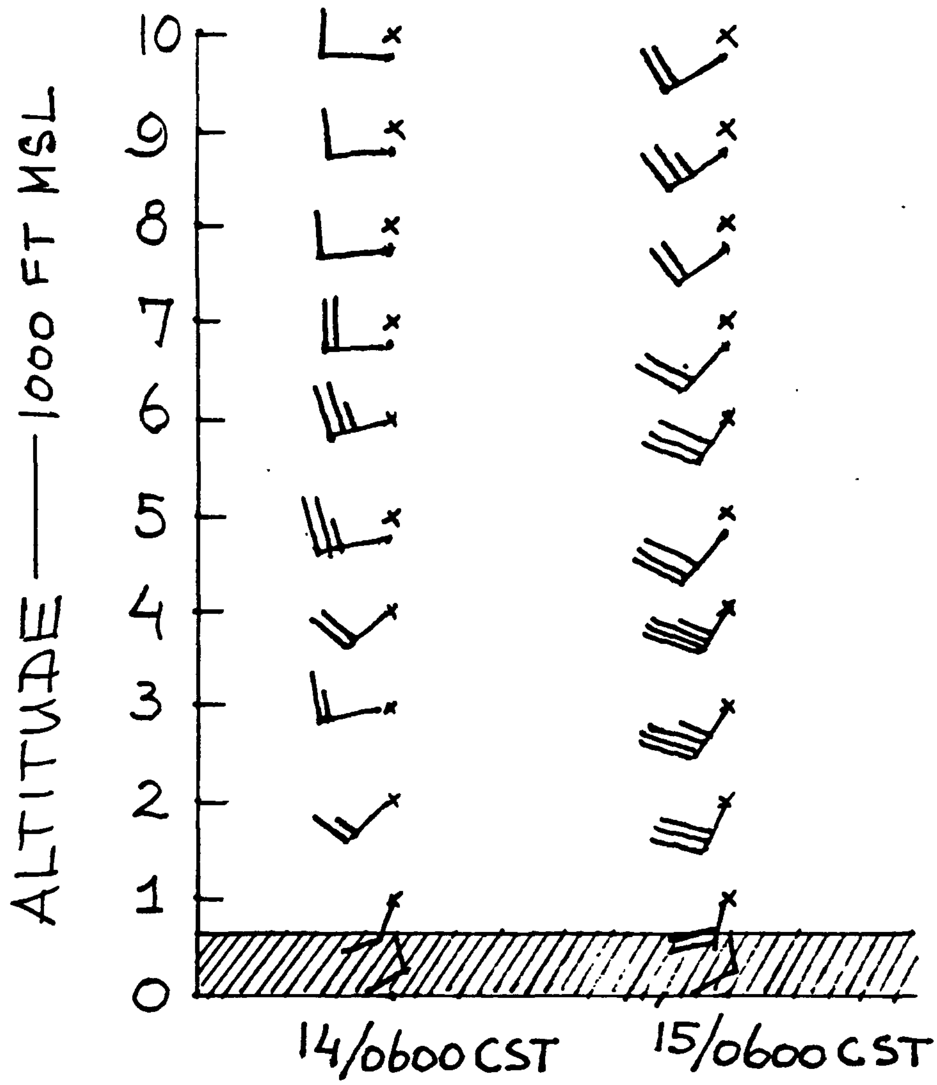

Figure 19. Vertical wind profiles from radiosonde ascents made at Peoria, Illinois on 14 February, 0600 CST and on 15 February, 0600 CST. Data show increase in the wind speed from 20-25 knots on 14 February to 30-35 knots on 15 February.

Figure 20 presents air-parcel trajectories for the 24-hour period of 14 February, 0600 CST to 15 February, 0600 CST. Air parcels terminate at St. Louis, and at Peoria. Trajectories are for the 850-mb level which is near the 5,000 ft altitude. It is seen, that air-parcels at this altitude originate from the area of Little Rock, Arkansas. The trajectories are predicted by the LFM-II numerical model.

Figure 21 shows 24-hour predicted air-parcel trajectories near the surface for St. Louis and Peoria. Air-parcels originate from the area of Memphis, Tennessee.

Figure 22 presents the analysis of observed cloud cover at 1200 CST. In the area of interest between St. Louis and Peoria, skies are clear for all practical purposes.

Maximum surface temperatures in Missouri and Illinois on 14 February ranged from the mid-40's to the high 30's as shown in Figure 23.

Sunday, 15 February

No aircraft flights were carried out on this day. Southerly surface winds prevailed throughout the area of interest. Temperature and moisture increased in the boundary layer, and early-morning low-cloud cover was observed. For example, at 0700 CST, Springfield, Illinois reported a cloud ceiling of 1800 ft with a southerly wind at 15 knots.

The outlook for Monday was for early morning fog or low clouds, and increasing southwesterly winds during the afternoon.

Monday, 16 February

On this day, the area of the Kincaid Power Plant reported early morning fog that lifted into low-level stratus clouds around 1000 CST. Figure 24 shows the surface visibility and cloud ceiling conditions in Missouri and Illinois at 1000 CST. Missouri reports only middle and high clouds, but Illinois has low-surface visibility in fog. Inside the scalloped line in Illinois, visibility is between 3 and 5 miles. Inside the solid line, visibilities are reported below 3 miles with cloud ceiling below 1000 ft. These restricting weather conditions improved toward the afternoon.

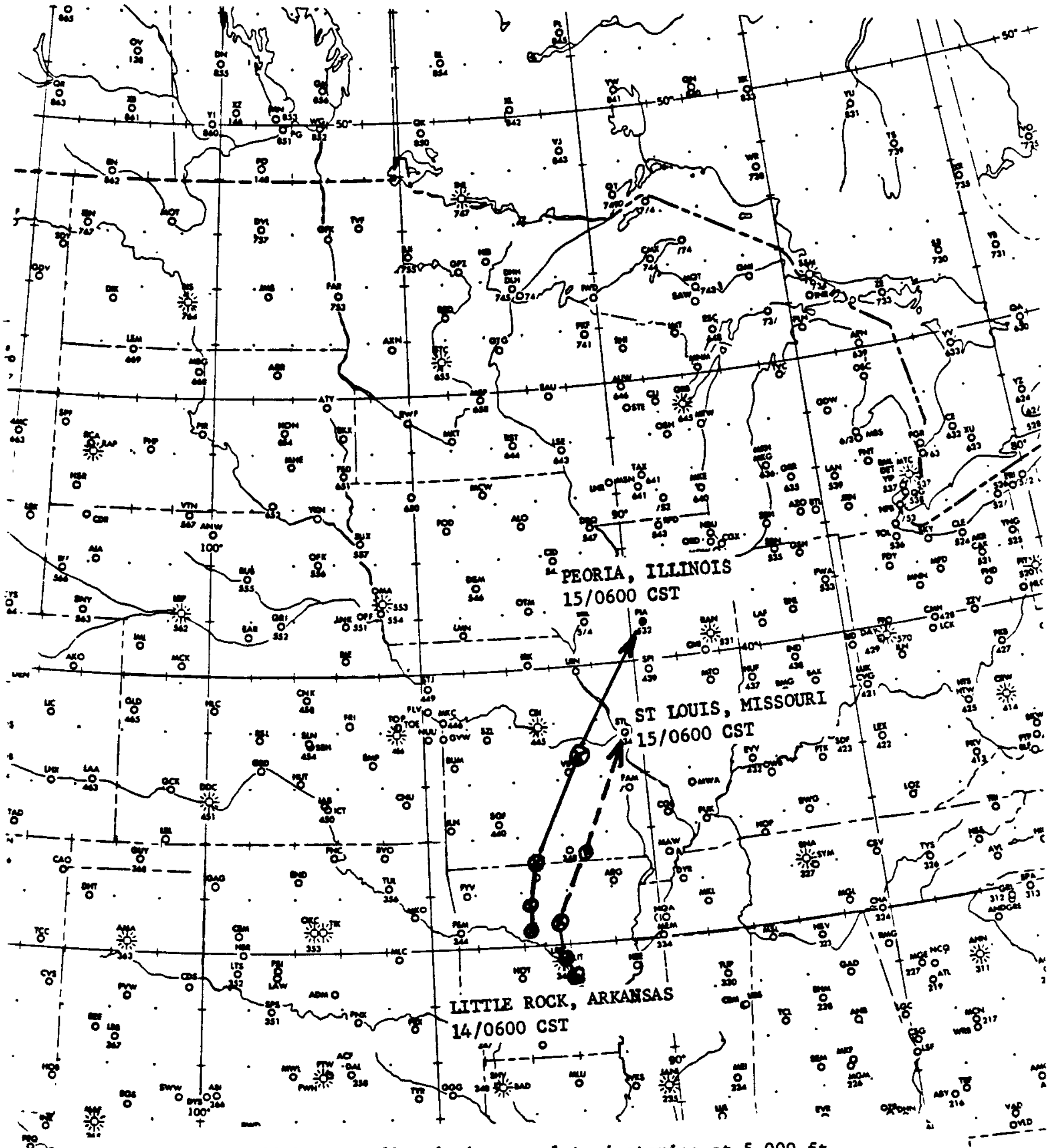

Figure 20. 24-hour predicted air-parcel trajectories at 5,000 ft (about 850-mb) terminating at Peoria, Illinois, and at St. Louis, Missouri. Air-parcel positions are indicated at 6-hour intervals. 24-hour period represents 14 February, 0600 CST to 15 February, 0600 CST.

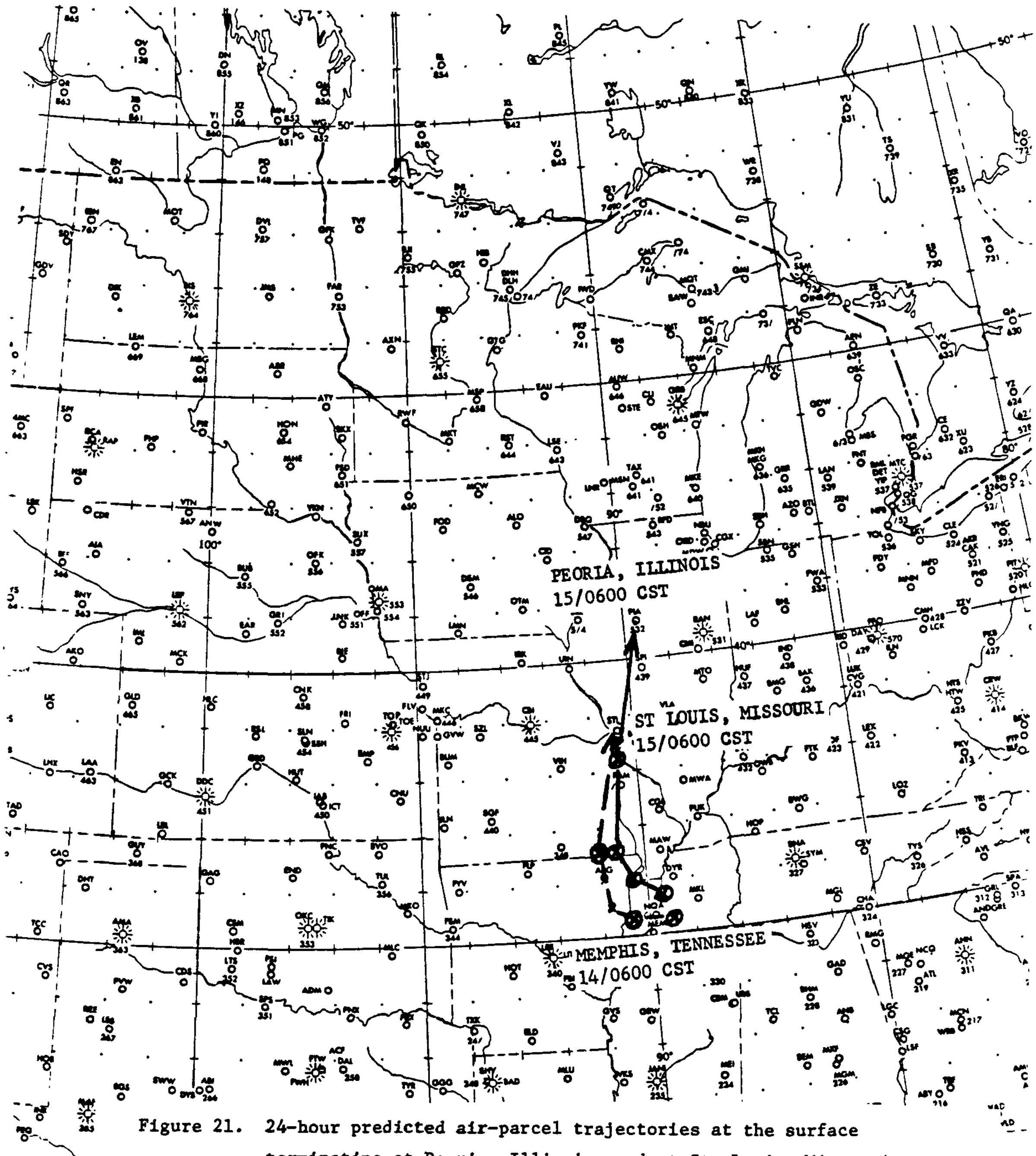

Figure 21. 24-hour predicted air-parcel trajectories at the surface terminating at Peoria, Illinois, and at St. Louis, Missouri. Air-parcel positions are indicated at 6-hour intervals. 24-hour period extends from 14 February, 0600 CST to 15 February, 0600 CST.

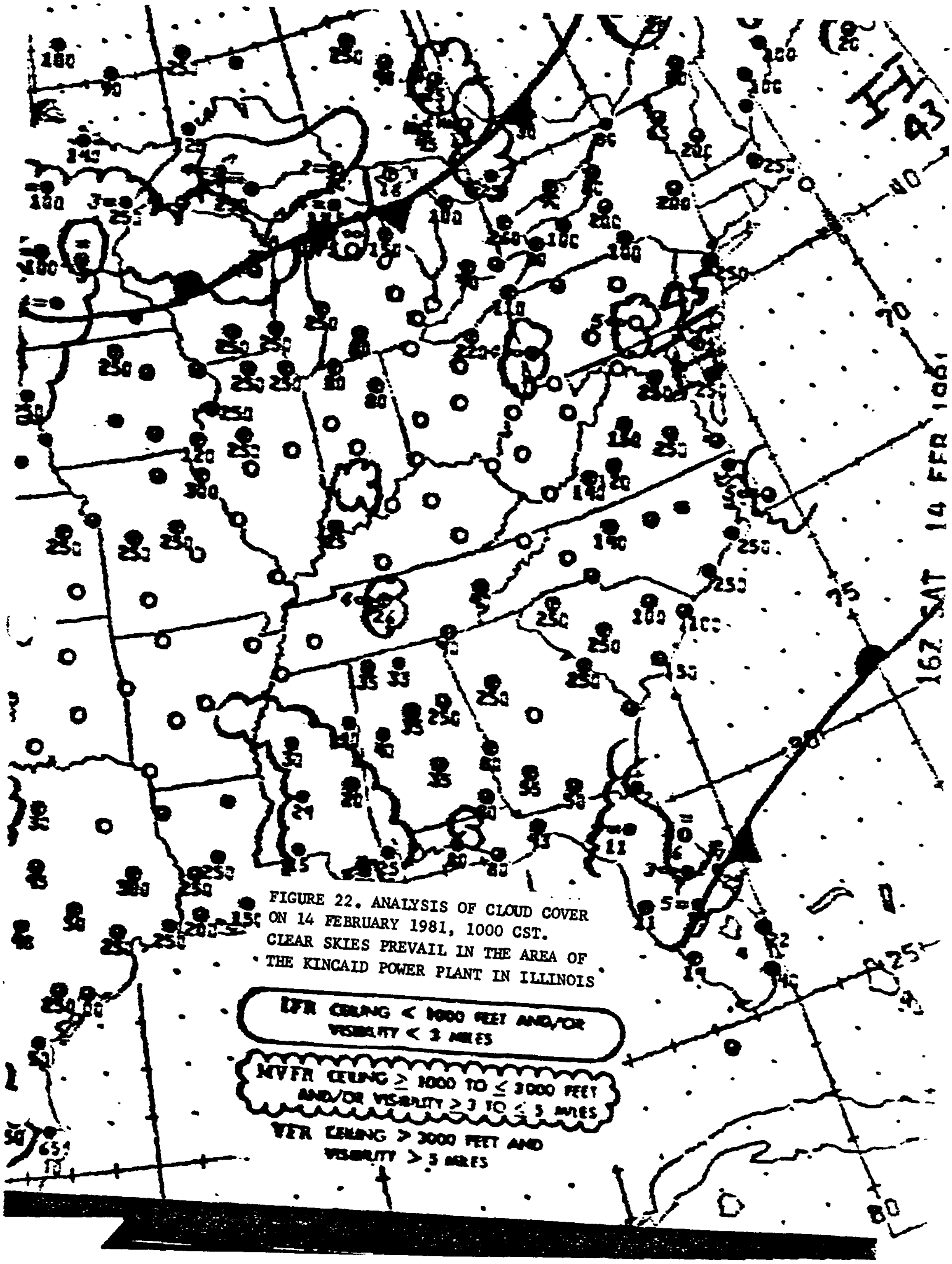

FIGURE 22. ANALYSIS OF CLOUD COVER ON 14 FEBRUARY 1981, 1000 CST. CLEAR SKIES PREVAIL IN THE AREA OF THE KINCAID POWER PLANT IN ILLINOIS

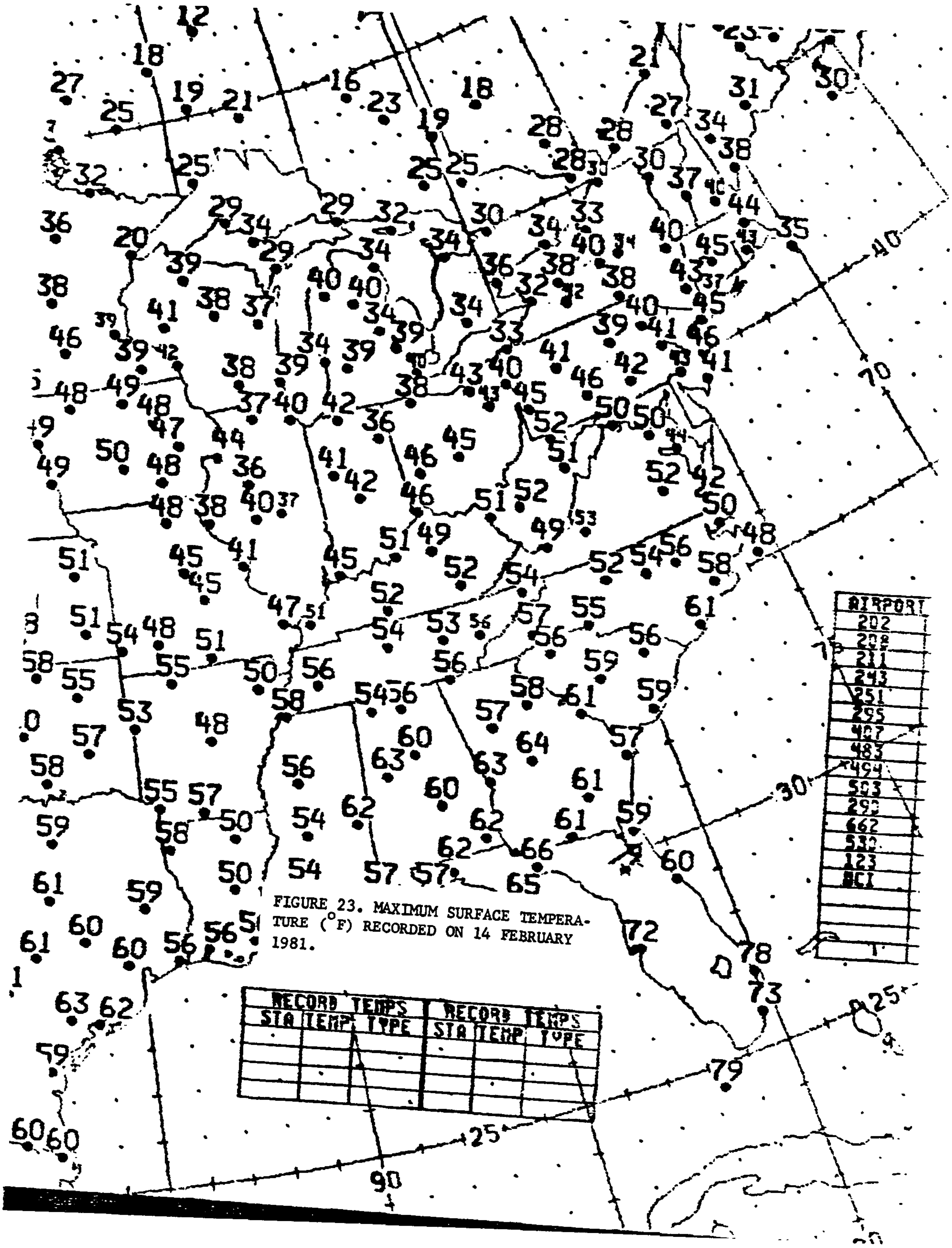

FIGURE 23. MAXIMUM SURFACE TEMPERATURE (°F) RECORDED ON 14 FEBRUARY 1981.

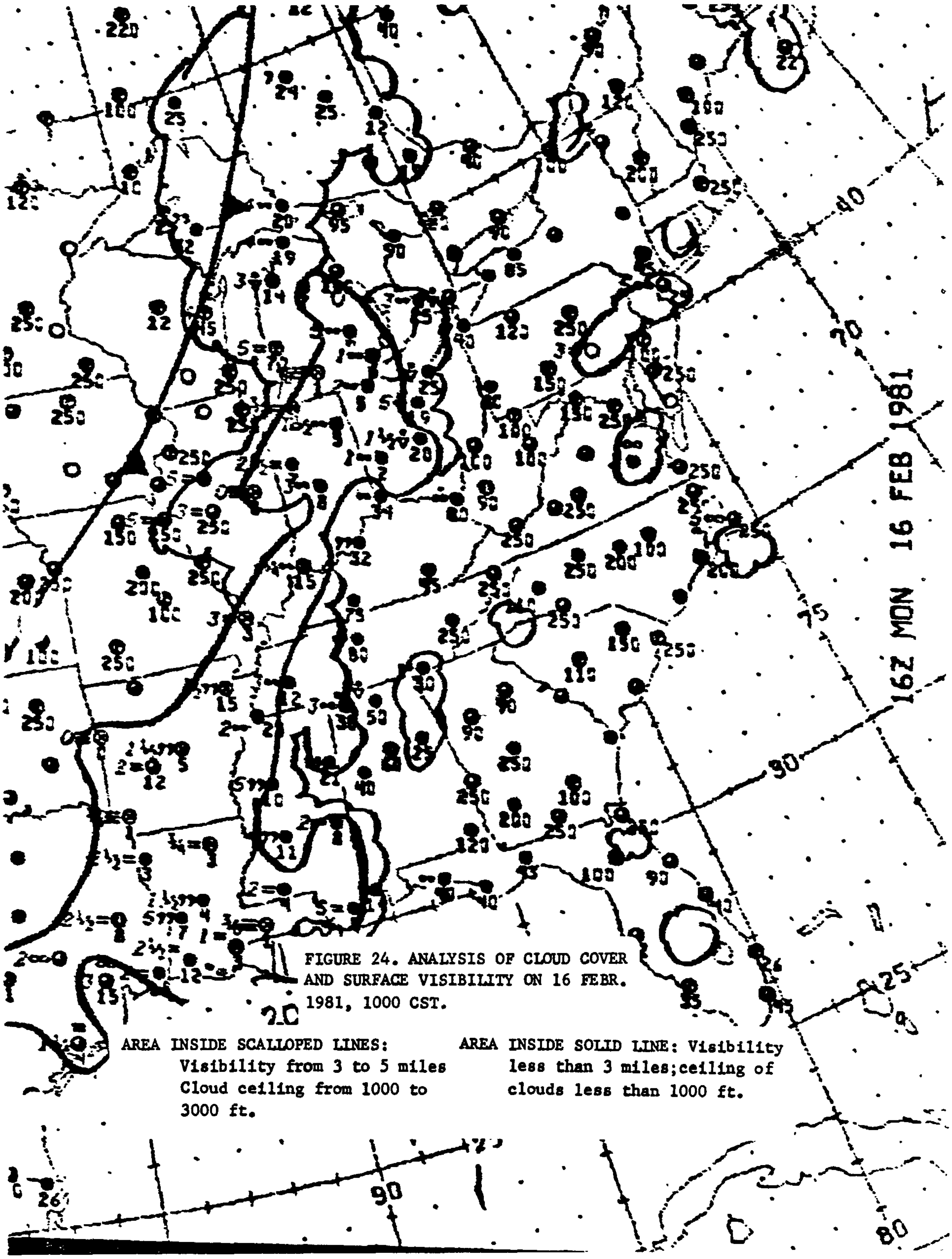

FIGURE 24. ANALYSIS OF CLOUD COVER AND SURFACE VISIBILITY ON 16 FEBR. 1981, 1000 CST.

AREA INSIDE SCALLOPED LINES: Visibility from 3 to 5 miles Cloud ceiling from 1000 to 3000 ft.

AREA INSIDE SOLID LINE: Visibility less than 3 miles; ceiling of clouds less than 1000 ft.

Figure 25 shows the contour chart at 850-mb (5,000 ft MSL) at 0600 CST. The contour spacing is relatively small in Illinois which means that the wind speed is relatively high (35-40 knots indicated on the chart).

Figure 26 illustrates the wind structure from ground-level to 10,000 ft MSL at Salem, Illinois (see Figure 1) for 0600 CST and 1800 CST. Wind speeds at this location decreased from morning to afternoon. Winds below 4,000 ft MSL are southerly. Above this altitude, they shift to southwest and west.

Figure 27 presents the vertical profile of temperature and humidity at Salem obtained at 1800 CST. Inversions in the temperature profile are evident below 5,000 ft MSL (850-mb) with high relative humidity. This low-level moist layer is associated with the early morning fog and stratus conditions. Above 850-mb, the air is quite dry.

Figure 28 shows air-parcel trajectories (5,000 ft altitude) for the 24-hour period of 16 February, 0600 CST to 17 February, 0600 CST that terminate at Peoria, Illinois, and at Indianapolis, Indiana. The position of the air parcels are indicated at 6-hourly intervals. The air that arrives at Peoria originates from the area of Hutchinson, Kansas, while that arriving at Indianapolis comes from a southwesterly direction near Joplin, Missouri.

Figure 29 shows similar trajectories at ground-level. At this level, air parcels arrive from a more southerly direction. By interpolating the predicted trajectories of Figures 28 and 29, an estimate can be made of the area of origin of air parcels near the Kincaid Power Plant on early Tuesday morning 17 February.

Figure 30 shows the maximum surface temperatures that were recorded on Monday. Temperatures in Missouri and Illinois range from about 50° to 60°F.

Tuesday, 17 February

Dense fog covered the target area of Kincaid during the morning hours. On this day, the Kincaid Power Plant was shut down and no aircraft flights could be scheduled.

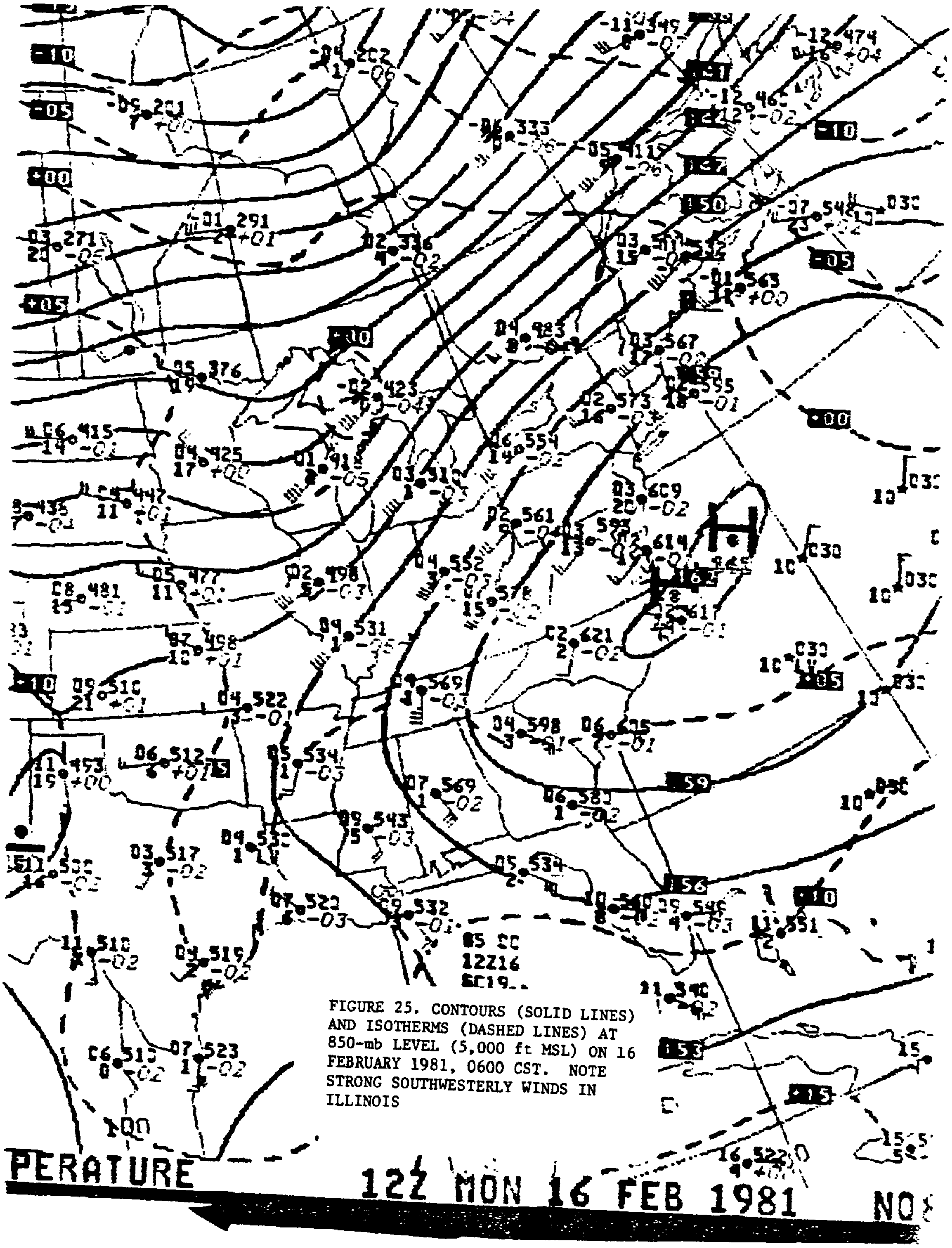

FIGURE 25. CONTOURS (SOLID LINES) AND ISOTHERMS (DASHED LINES) AT 850-mb LEVEL (5,000 ft MSL) ON 16 FEBRUARY 1981, 0600 CST. NOTE STRONG SOUTHWESTERLY WINDS IN ILLINOIS

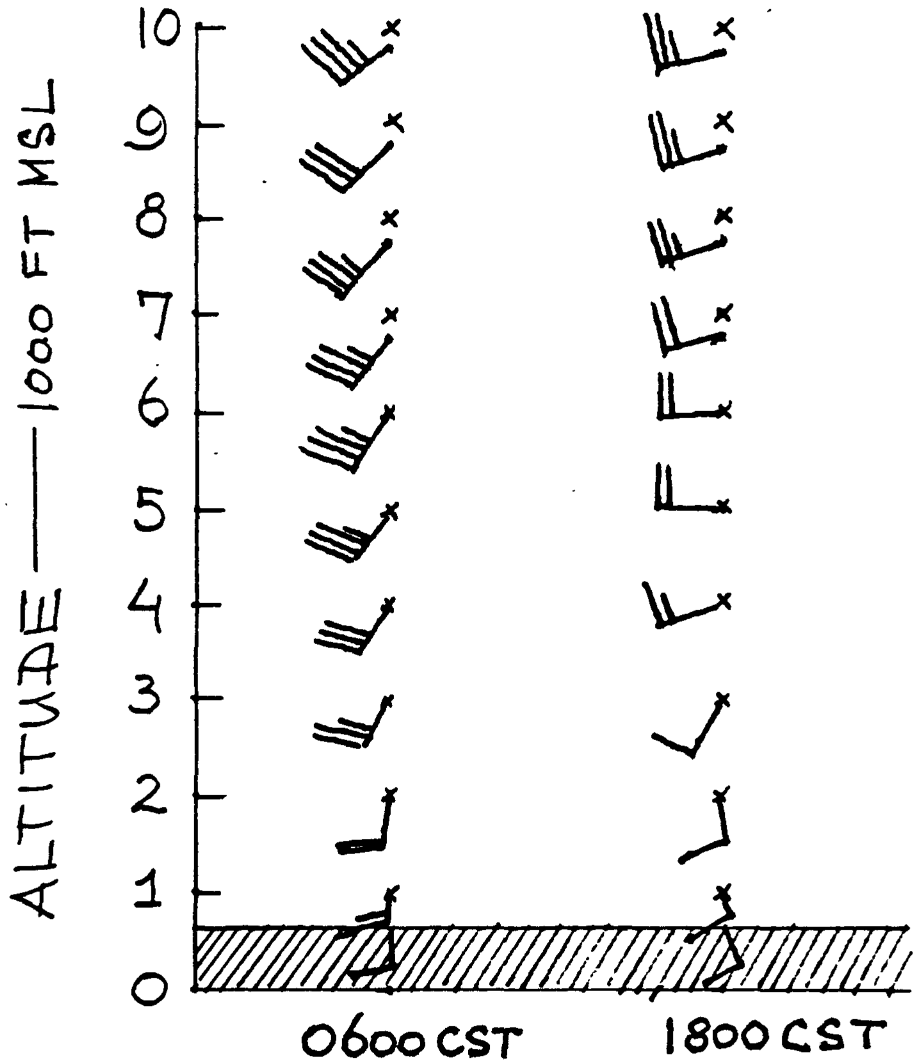

FIGURE 26. Vertical profiles of the wind from ground-level to 10,000 ft MSL at Salem, Illinois on Monday morning (0600 CST) and late afternoon (1800 CST), 16 February 1981. The winds show a significant decrease in speed from morning to afternoon, and are more westerly in direction above 3,000 ft MSL.

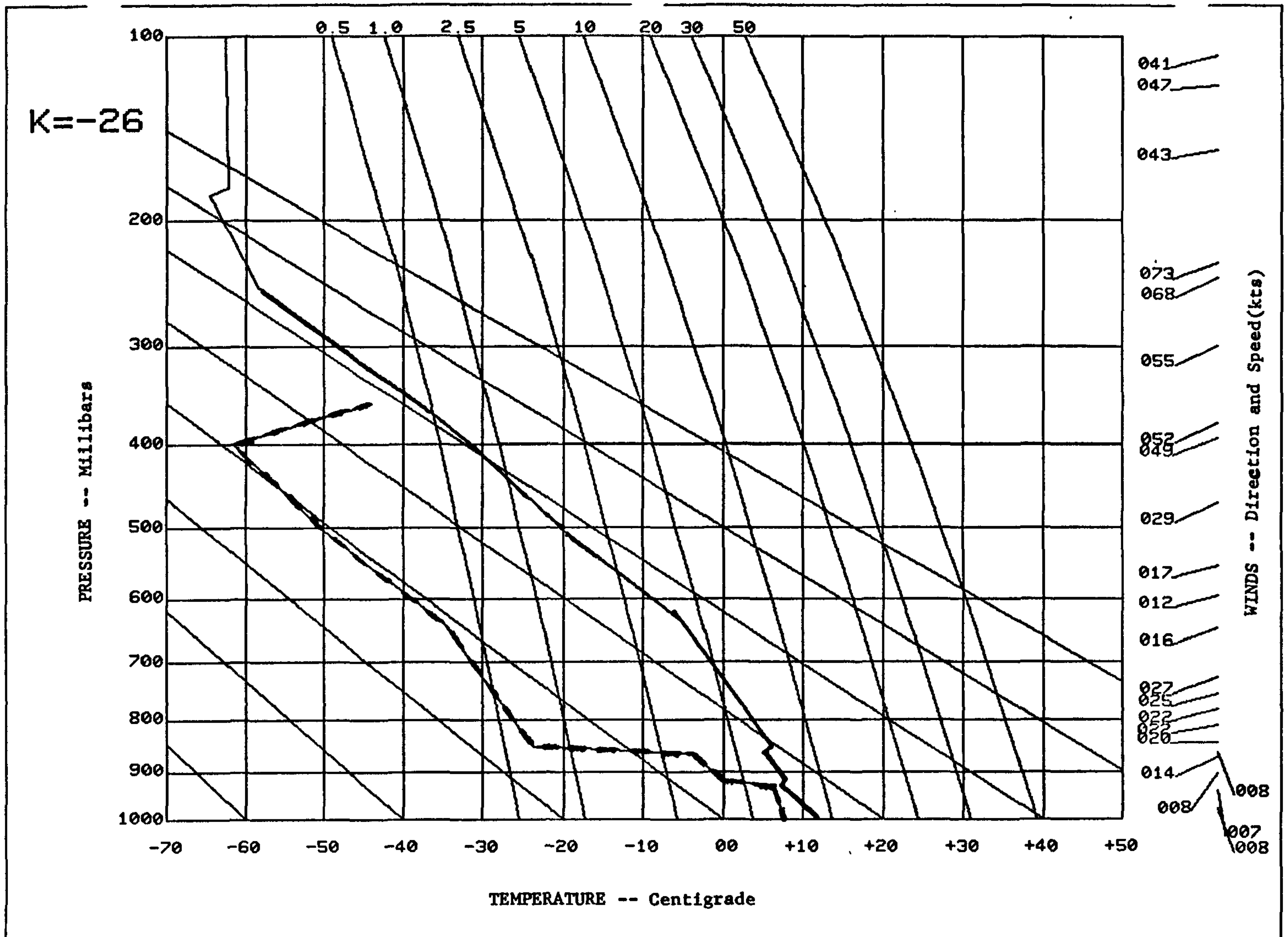

FIGURE 27. Radiosonde ascent for Salem, Illinois made on 16 February 1981, 1800 CST. Temperature profile is shown by solid line, dewpoint by dashed line. Note temperature inversions below 850-mb with dry air above this level.

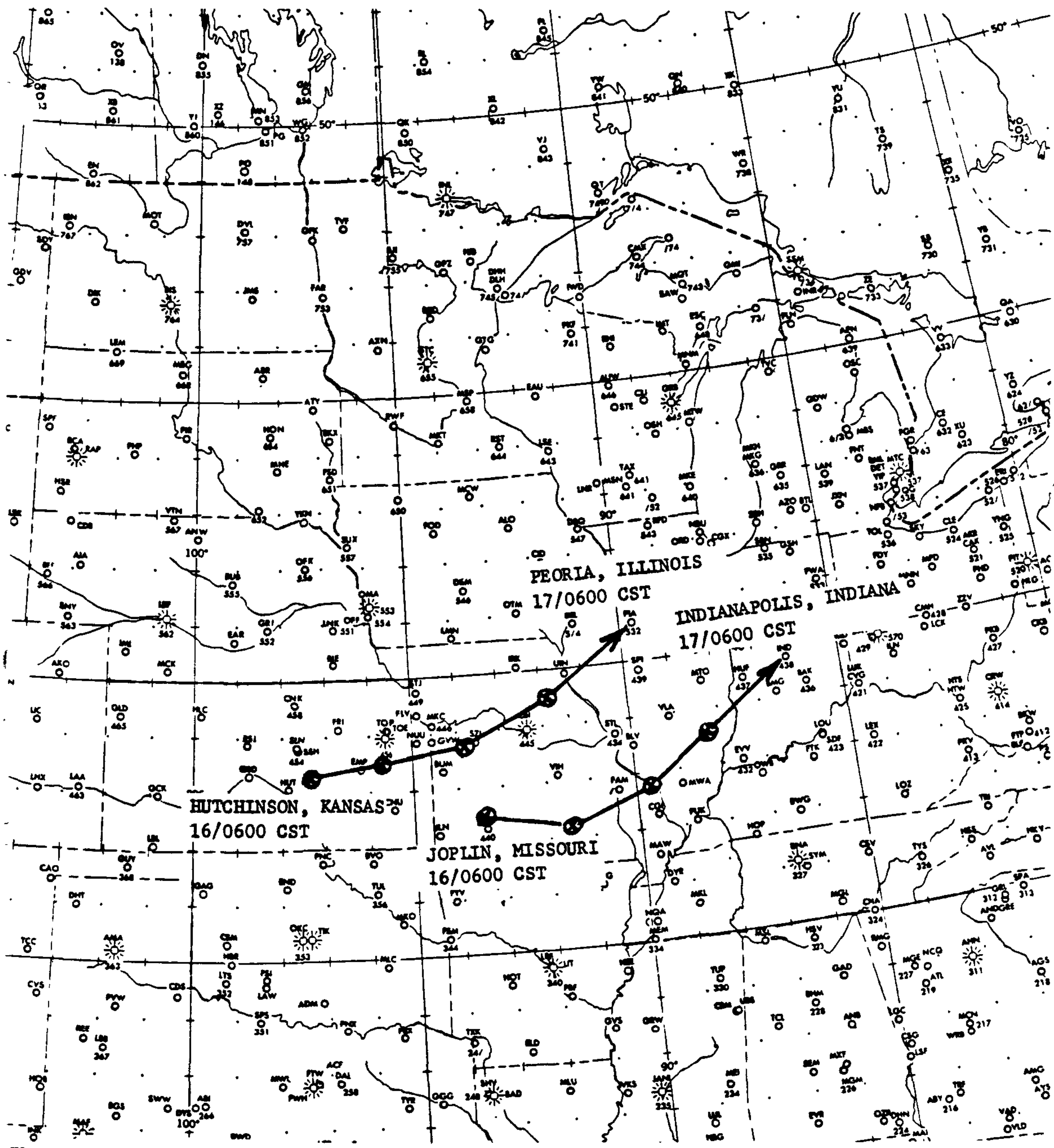

FIGURE 28. Air-parcel trajectories at the 5,000 ft altitude that terminate at Peoria, Illinois and at Indianapolis, Indiana on 17 February 1981,0600 CST. The area of origin of the air parcel 24 hours earlier is indicated for each location. The position of the parcels is shown at 6-hourly intervals.

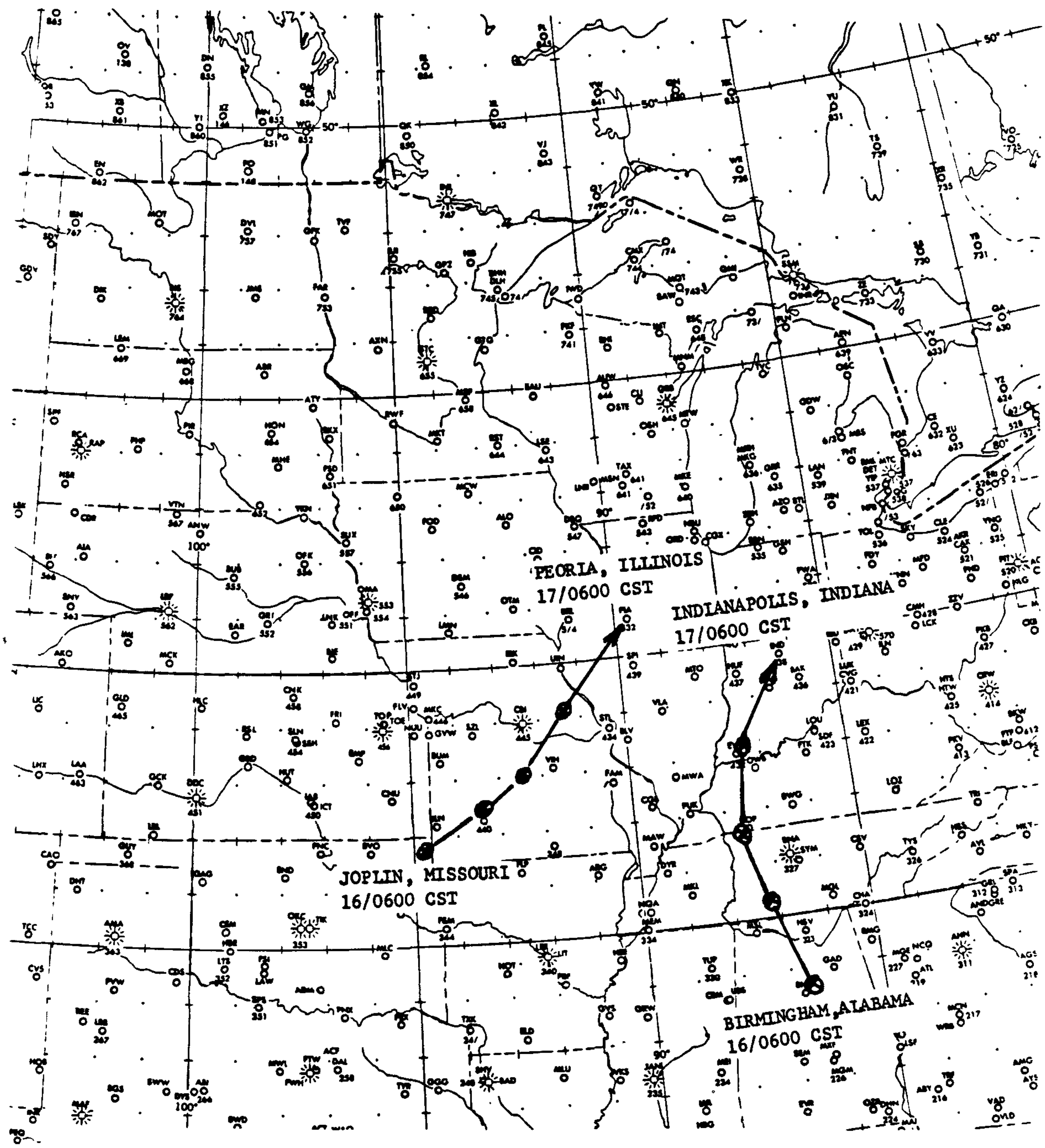

FIGURE 29. Air-parcel trajectories near ground-level that terminate at Peoria, Illinois and at Indianapolis, Indiana on 17 February 1981, 0600 CST. The origon of the air parcel 24 hours earlier is indicated as southwestern Missouri and northern Alabama.

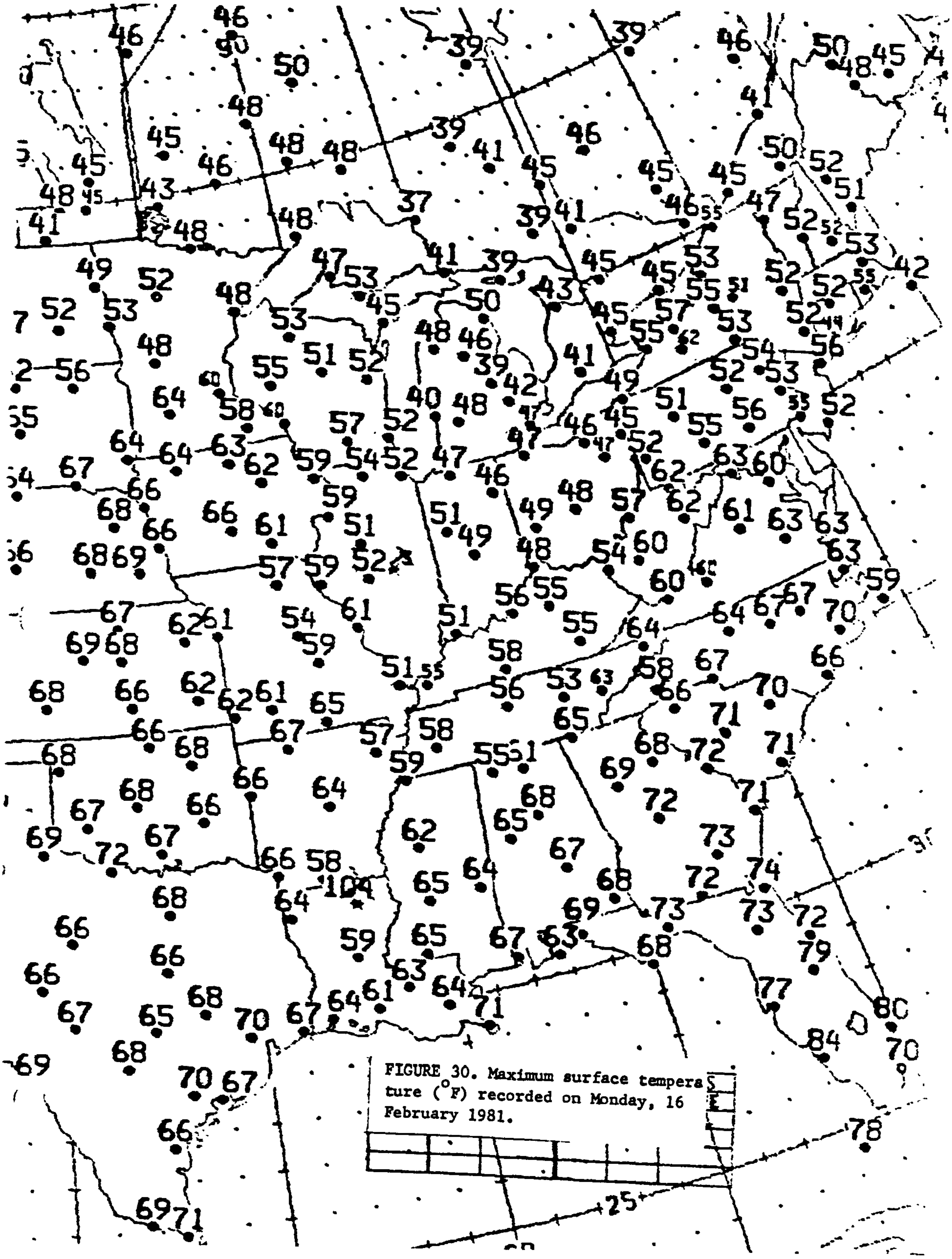

FIGURE 30. Maximum surface temperature (°F) recorded on Monday, 16 February 1981.

Wednesday, 18 February

No aircraft flights were planned because of the continued shutdown of the Kincaid Plant.

Weather conditions remained the same as the previous day with fog and low clouds during the morning and afternoon. Surface observations at Springfield, Illinois, reported 300 ft scattered clouds with 2 to 3 miles surface visibility in light fog at 0900 CST, and 2500 ft broken clouds with 8 miles visibility at 1400 CST.

The maximum surface temperature in the St. Louis area was around 71°F.

Thursday, 19 February

Kincaid Plant down. No aircraft flights planned.

Friday, 20 February

On this day, good weather conditions prevailed in the area between St. Louis and the Kincaid Power Plant in Illinois. At 0700 CST, Springfield reported nearly clear-sky conditions with 15 miles surface visibility, a surface temperature of 35°F, and light northwesterly winds. The conditions around Peoria were similar.

Figure 31 shows a satellite cloud photograph at 0800 CST. No significant cloud cover is observed in Missouri and Illinois.

Figure 32 shows the vertical profile of the wind from Peoria to Salem at 0600 CST. The wind direction is northwest to north with speeds ranging from 20 to 30 knots.

Figure 33 shows the vertical temperature structure from Peoria to Salem at 0600 CST. Ground inversions are present during these early morning hours.

Air-parcel trajectories near the 5,000 ft level are shown in Figure 34. The trajectories are for the 24-hour period of 19 February, 1800 CST to 20 February, 1800 CST. Air parcels that arrive in the Kincaid area originate from Iowa and southern Minnesota.

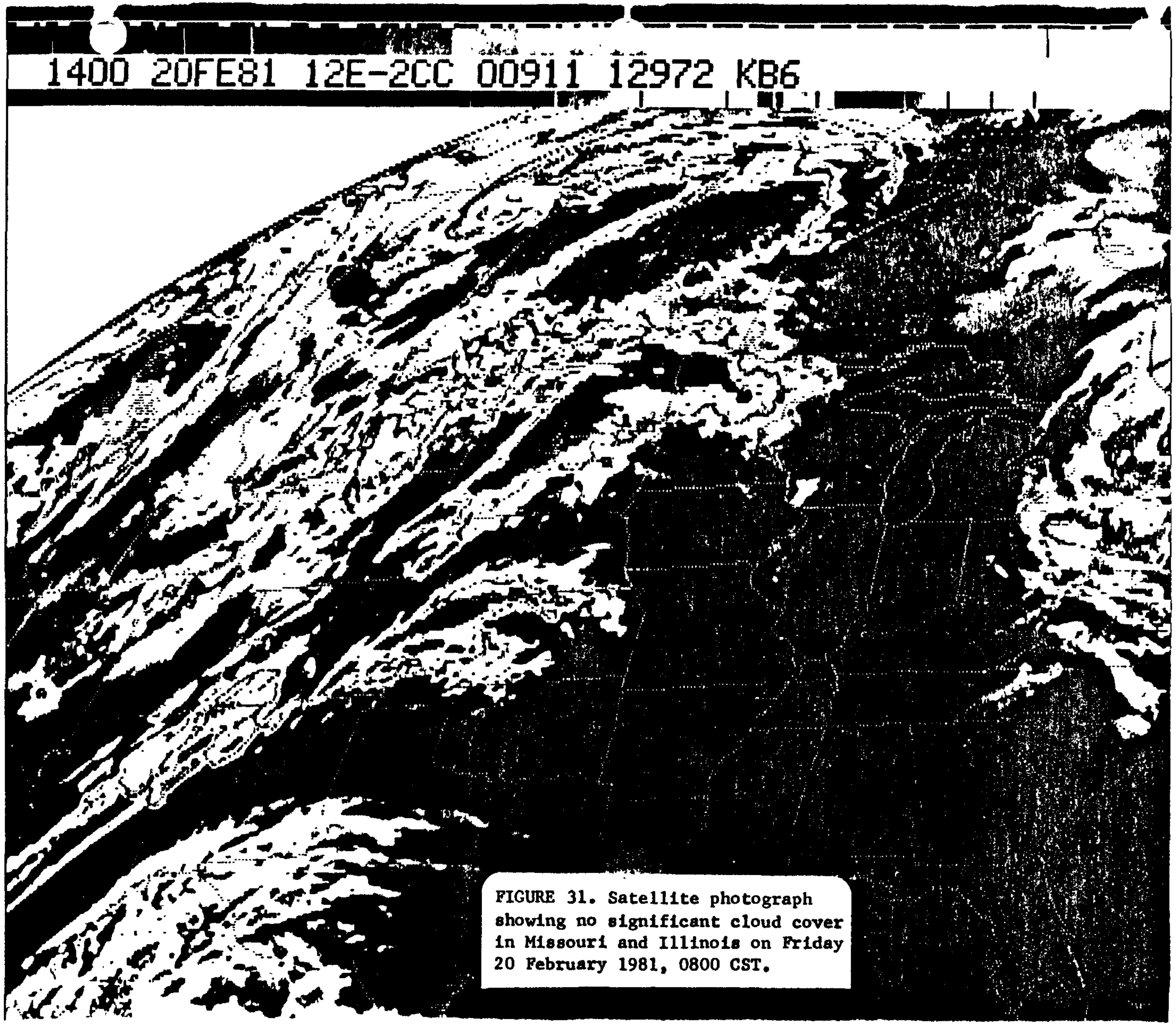

FIGURE 31. Satellite photograph showing no significant cloud cover in Missouri and Illinois on Friday 20 February 1981, 0800 CST.

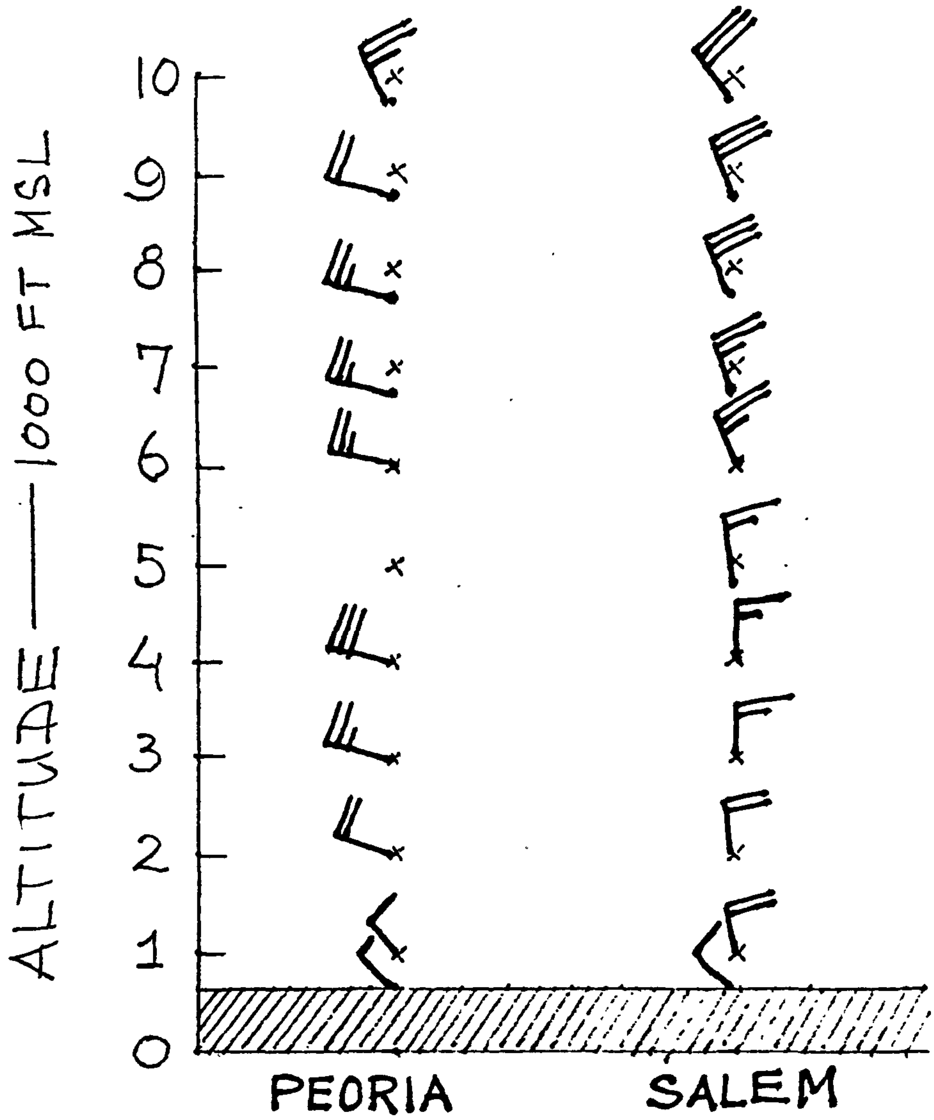

FIGURE 32. Vertical profiles of the wind from Peoria, Illinois to Salem, Illinois on 20 February 1981, 0600 CST.

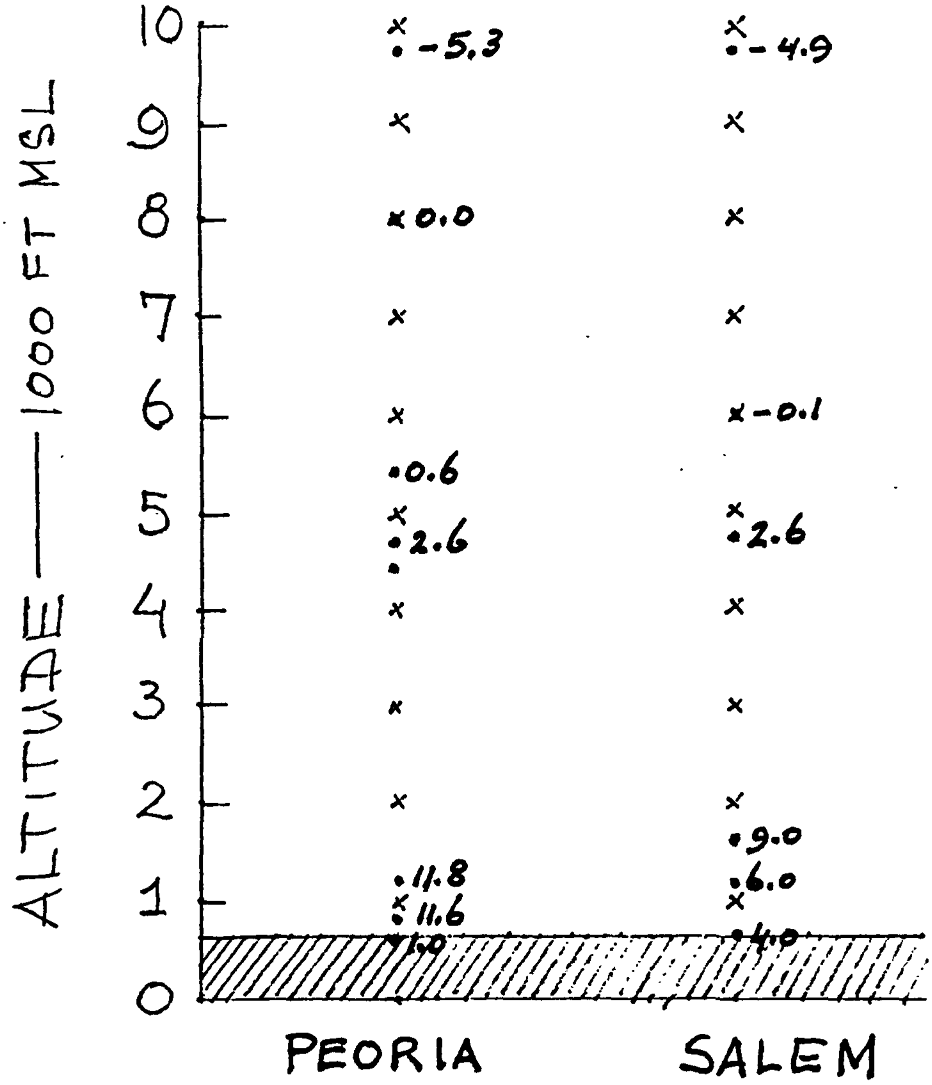

FIGURE 33. Ambient air temperature (°C) from Peoria, Illinois to Salem, Illinois on 20 February 1981, 0600 CST.

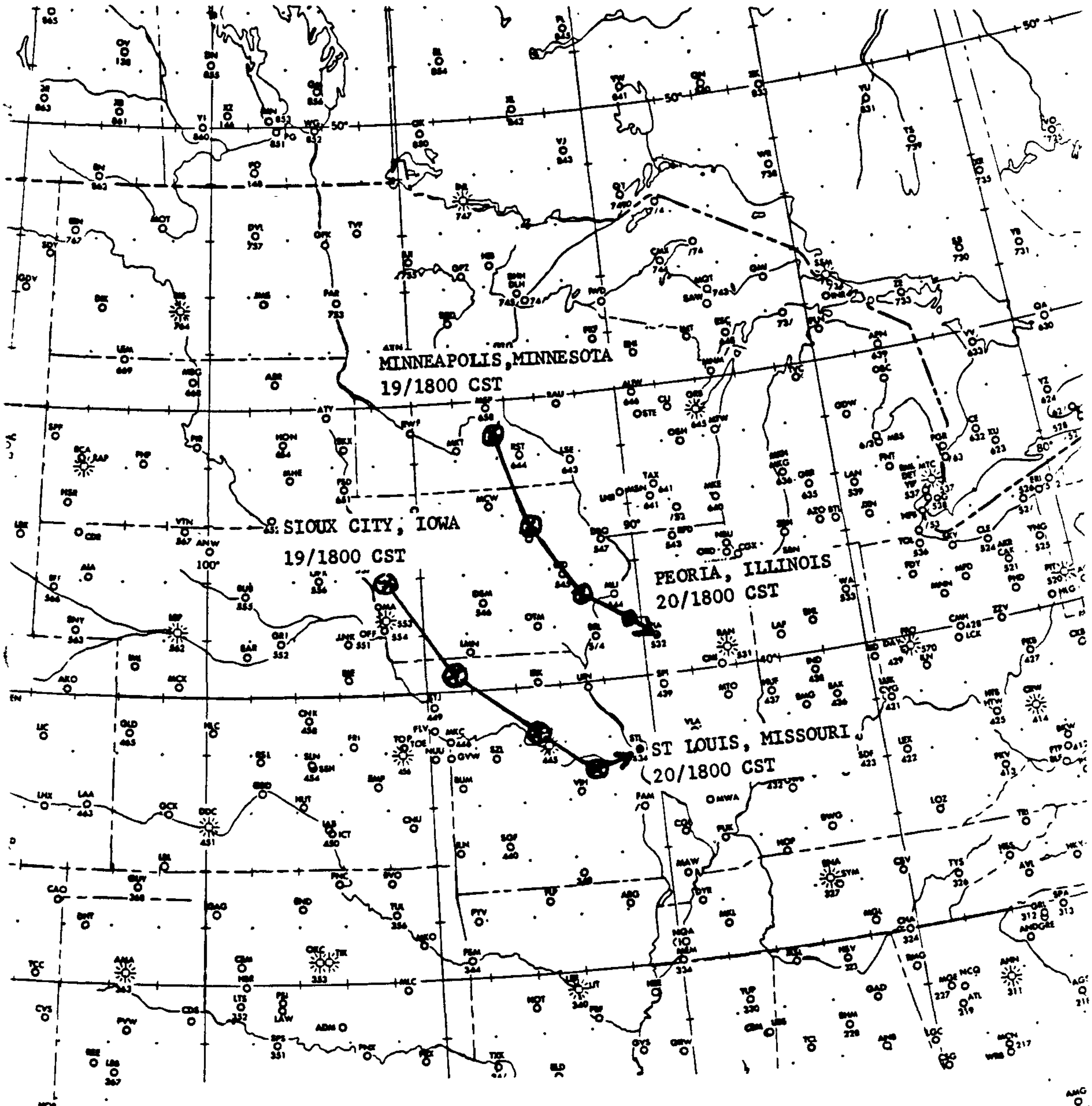

FIGURE 34. Air-parcel trajectories at the 5,000 ft level that terminate at Peoria, Illinois and at St. Louis, Missouri, on 20 February 1881, 1800 CST. The locations of origin of the air parcels 24 hours earlier is indicated. The position of the parcels is shown at 6-hourly intervals.

Appendix C

EMI Mission Highlights from the
CHEM-1 Data Volume
for
Cold Weather Plume Study.

CWP CHEM-1 MISSION SUMMARY

Date: 12 February 1981

Measurement Interval: 0945-1425 CST   Flight Hours: 5.7 hrs

Objective: Study of the Kincaid Plume under stable transport in the morning and, due to increased wind turbulence, well-mixed transport in the afternoon.

Activities: Take-off was close to 0915. CHEM-1 ferried to a point (A) about 10km S of Kincaid. From there CHEM-1 flew approximately parallel to the plume's trajectory at 1500ft. MSL to a point about 20km NNE of Kincaid (B). At that point a wide orbit was flown (B-C) to complete the background filter. (Data plots indicate that an SO_2 plume was encountered, possibly the Coffeen plume.)

The first cross-plume pass to locate the plume centerline was flown at 1500ft. MSL from about 23 km NNE of the stacks (C) to approximately 30km NNW of Kincaid (D). CHEM-1 then ferried to E, F and G while planning the series of traverses at 30km downwind.

CHEM-1 observed SO_2 levels in the vicinity of the Springfield Municipal Power Plant plume transport. It penetrated this same plume at 1500ft MSL at the west end of the traverse from G to about 30km NE of Kincaid. After an orbit and ferry from H to I, a traverse was completed to J. The peak SO_2 value was observed near the midpoint of this traverse, just N of Dawson, IL (K); so a spiral was executed there from 1000 to 5000ft. MSL. CHEM-1 then ferried to a point approximately 32km N of Kincaid (L). A 2200ft. MSL traverse was completed from L to M with very little SO_2 observed. It was decided that more consistent downwind distances could be maintained north of the plant using U.S.36 as a visual marker. Traverses were completed along this route after ferrying to O, near Illiopolis.

O to P was flown at 1500ft. MSL, where the SO_2 was again clearly observed. P to Q was flown at 1300ft. MSL, followed by a westbound survey at 1200ft. MSL back from Q to P.

CHEM-1 then ferried from point P to the vicinity of Mason City, IL (X), where a long background orbit was completed. From X, CHEM-1 flew a traverse at about 1500ft. MSL to near Beason, IL (T) at a downwind distance of about 65km. Two more traverses using T and S as endpoints were flown at 1800 and 1300ft. MSL respectively, with a spiral near the midpoint (U) from 1000 to 3000ft. MSL. Levels of

SO_2 were generally less than 100ppb at this downwind distance due to the excessive plume dispersion associated with very strong southerly winds. The plume was ill-defined at this distance. This observation was confirmed by EPA Lidar.

CHEM-1 then ferried to the CAP VOR (V) and flew 4 traverses between V and O at 1400, 1900, 2200 and 1700ft. MSL. A well-coordinated parallel flyby was completed at this 30km distance with MRI. CHEM-1 then ferried to Springfield at 1700ft. MSL in a parallel traverse with MRI for a landing to conclude the mission.

TABLE 5-1. FLIGHT OUTLINE

12 FEBRUARY 1981 FLIGHT 1 (0945-1425CST)
EMI

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
1	F	0920-0945	KSUS-A		No magnetic data
2	F	0945-0954	A-B	622-470	CF#15 (events 2–4)
3	O	0954-0959	B-C	470	SO_2 plume seen (Coffeen?)
4	T	0959-1003	C-D	470	
5	F	1003-1014	D-E-F	470	
6	F	1014-1026	F-G	470	CF#18 (events 6–17)
7	T	1026-1037	G-H	470	
8	F-O	1037-1043	H-I	470	
9	T	1043-1048	I-J	470	
10	F	1048-1054	J-K	470-318	
11	S	1054-1106	K	378-1540	
12	F	1106-1116	K-V-L	1540-683	
13	T	1116-1124	L-M	683	Probably outside mixing layer
14	F	1124-1134	M-N-O	549	
15	T	1134-1141	O-P	470	
16	T	1142-1146	P-Q	409	
17	T	1147-1152	Q-P	409	
18	F	1152-1200	P-R	409-927	
19	F-O	1200-1231	R-X	897-592	Bg CF#21

12 FEBRUARY 1981, CONT.

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
20	T	1231-1242	X-U-T	470	CF#23 (events 20–25)
21	T	1243-1254	T-S	561	
22	F	1254-1258	S-U	561-318	
23	S	1302-1307	U	318-927	Ozone instrument problem
24	F	1307-1314	U-S	927-409	Ozone instrument problem
25	T	1314-1325	S-T	409	Ozone instrument problem
26	F	1325-1343	T-V	409-836	Ozone instrument problem
27	T	1343-1350	V-O	439	No valid data from 1347-1350
28	T	1351-1359	O-V	592	CF#25 (events 28–30)
29	T	1401-1409	V-O	683	
30	T	1410-1419	O-V	531	MRI flyby
31	F	1419- ?	V-KSPI		No continuous data; CF#24 (events 31–32)
32	F	1540- ?	KSPI-KSUS		No continuous data

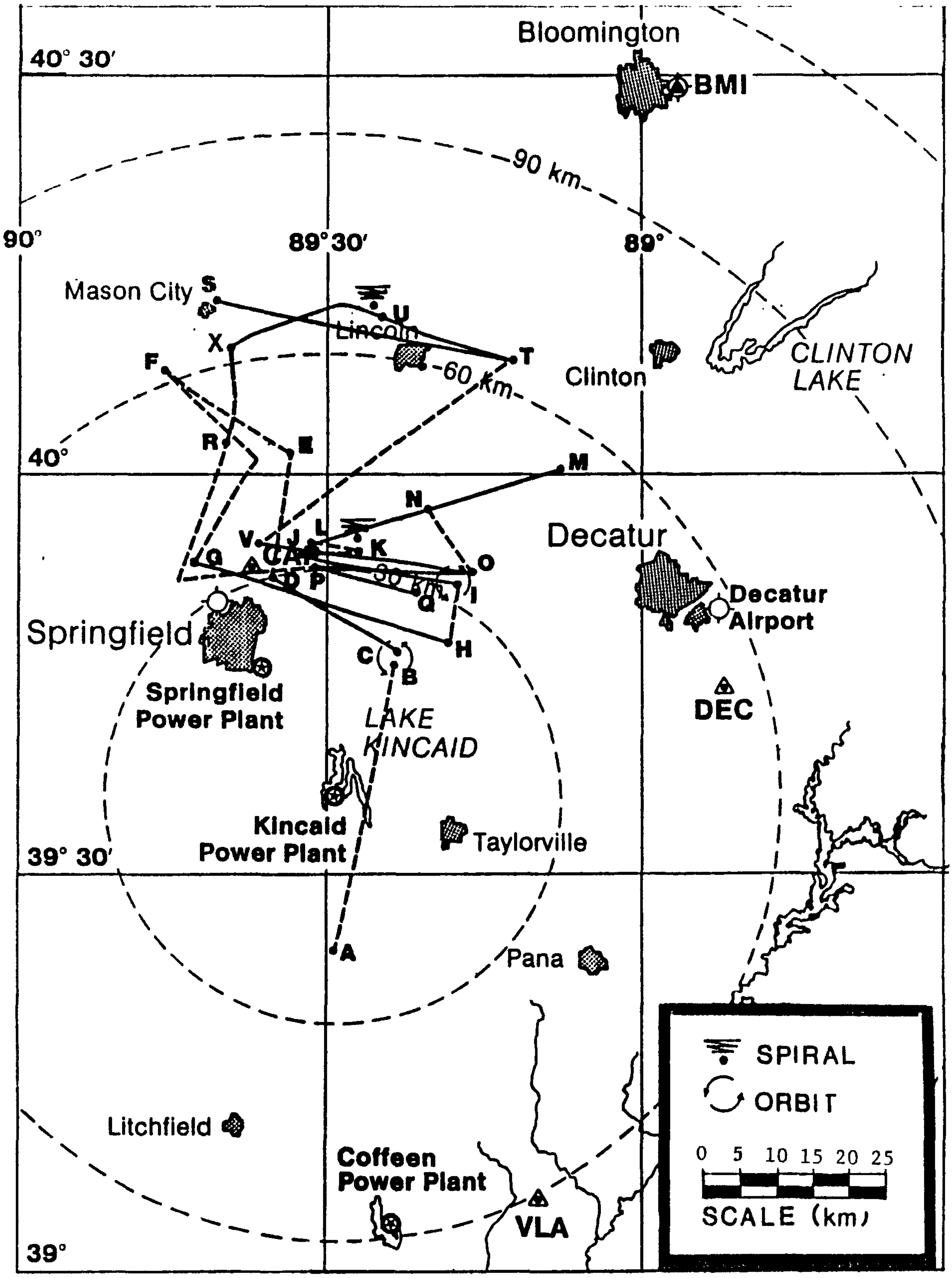

Figure 5-1. Flight Map for 12 February 1981, Flight 1.

CWP CHEM-1 MISSION SUMMARY

Date: 13 February 1981 (2 missions)

Measurement Interval I: 0746-1201 CST   Flight Hours: 4.5 hrs

Objective: Plume flux measurement in the Kincaid plume.

Activities: After a take-off at approximately 0720, CHEM-1 flew upwind of Kincaid and gathered background data and filter samples from 0746 through 0755. The plume was observed to be quite broken and poorly defined. At 2500ft. MSL CHEM-1 passed over the plume material. The first cross-plume traverse occurred about 10km downwind from C to D.

CHEM-1 zigzagged across the plume from D to K (about 27km downwind), characterizing the plume while also waiting for the transport to stabilize. Several multi-modal profiles were observed in this time frame. A spiral at G was carried out, showing a narrow plume between 550 and 700m MSL.

After the zigzag pattern, CHEM-1 traveled to its first assigned distance of about 60km downwind. There were several traverses in this general area. It was difficult to locate a consistent plume profile, and readings of high aerosol to the east of the anticipated plume transport direction confused the search for the Kincaid plume in its vertically narrow and horizontally shifting configuration. This time frame will require examination for the possibility that the observations to the east were due to the Coffeen plume. (MRI was characterizing the plume at 30km during this time interval.)

CHEM-1 ferried to Springfield for fuel and lunch to conclude the morning.

TABLE 5-2. FLIGHT OUTLINE

13 FEBRUARY 1981 FLIGHT 1 (0746-1201CST)
EMI

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
1	F	0746-0755	A-B	905	CF#17
2	F	0755-0802	B-C	783	
3	T	0802-0805	C-D	631	
4	T	0805-0810	D-E	631	
5	T	0810-0815	E-F	631	
6	T	0815-0821	F-E	631	
7	F	0821-0827	E-G	631-417	
8	S	0827-0832	G	417-1060	CF#13 (events 8-13)
9	T	0835-0838	G-H	925	No plume found
10	T	0838-0842	H-G	844	No plume found
11	T	0843-0847	G-I	631	
12	T	0847-0852	I-J	631	
13	T	0852-0857	J-K	631	
14	F	0857-0911	K-L-M-N	631	CF#16 (events 14-21)
15	F	0911-0923	N-O-P	631	
16	T	0924-0928	P-Q	631	No plume found
17	Bg	0928-0940	Q-R-S	631	
18	T	0940-0948	S-T	631	
19	T	0948-0956	T-U	631	
20	F	0956-0959	U-V	631	
21	T	0959-1008	V-W	631	
NO EVENT		1008-1013			SO_2 500ppb Data lost

TABLE 5-2. (cont.)

13 FEBRUARY 1981, FLIGHT 1, CONT.

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
22	T	1013-1016	Q-X	539	CF#16 (events 22–27, NO EVENT 1058-1102)
23	T	1016-1021	X-Y	539	
24	T	1022-1030	Y-Z	539	
25	F	1030-1036	Z-AA	509	CF#16
26	T	1036-1045	AA-Y	509	No plume found
27	T	1046-1056	Y-BB	539	
NO EVENT		1058-1102			SO_2 900ppb Data lost
28	F	1102-1108	CC-DD	539-600	No plume found
29	T	1108-1117	DD-BB	600	CF#30 (events 29–36)
30	T	1117-1122	BB-EE	600	
31	T	1122-1128	EE-Z	631	
32	T	1130-1135	Z-DD	661	CF#30
33	T	1137-1141	DD-Z	600	
34	T	1143-1148	Z-EE	539	
NO EVENT		1149-1154		479	Magnetic data lost Manual data show double plume: 700ppb, 100ppb SO_2
35	T	1155-1159	BB-N	448	
36	S	1159-1201		448-844	

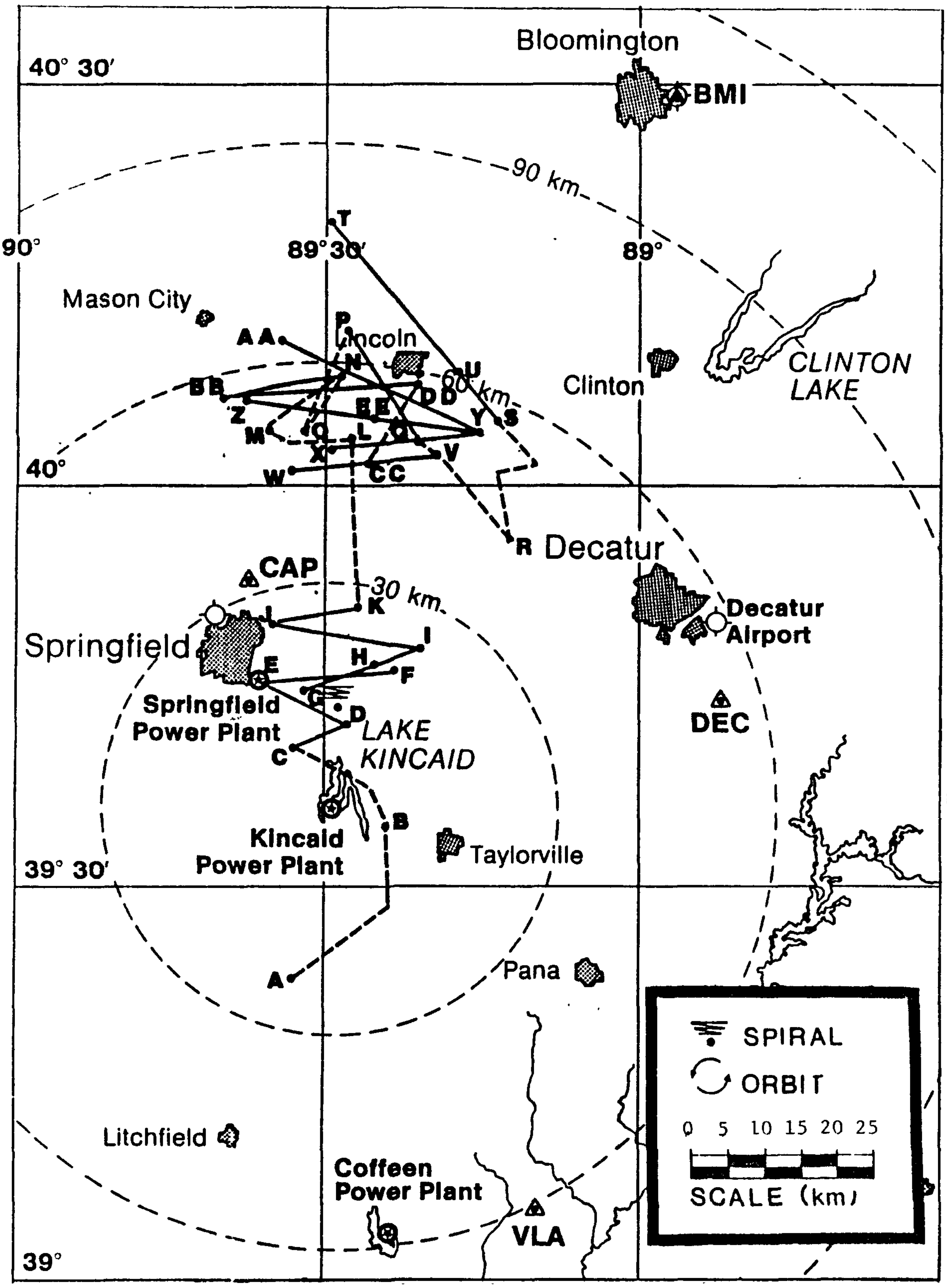

Figure 5-2. Flight Map for 13 February 1981, Flight 1.

CWP CHEM-1 MISSION SUMMARY

Date: 14 February 1981 (2 missions)

Measurement Interval I: 0746-1124 CST   Flight Hours: 4.4 hrs

Objective: Study of the Kincaid plume under stable transport conditions.

Activities: Take-off for EMI was at approximately 0715. CHEM-1 ferried to point C some 26km NE of Kincaid and flew a traverse from C to D (about 26km N of Kincaid) at 1700ft. MSL at a downwind distance of 25km. A marked SO_2 profile was observed. CHEM-1 then ferried to near the midpoint of the traverse (E) and spiralled up from 1200 to 3000ft. MSL. CHEM-1 ferried back to point D and traversed the same route as before, extending the east endpoint to near Blue Mound, IL about 34km ENE of Kincaid (F) at 2200ft. MSL. The Cofeen plume was characterized to the east of Kincaid's plume. Three more traverses were flown over this route (D-F) at altitudes of 1900, 1500, and 1700ft. MSL respectively, observing the plumes in a narrow altitude range.

CHEM-1 next ferried to Mason City, IL (G) and traversed from G to the vicinity of Clinton, IL (H) at 1800ft. MSL at a downwind distance of 60km. (At this distance a distinct layering was observed only in the narrow band of actual plume altitude. Several passes were made looking for the Kincaid plume before this condition was evident.) The Springfield plume was sampled at this distance.

CHEM-1 then ferried to a point (I) aproximately 12km ESE of Clinton (H). CHEM-1 traversed from I to Lincoln, IL (J) at 2100ft. MSL. A traverse from K to L was flown at 1500ft. MSL. From L CHEM-1 ferried to Monticello, IL (N) and flew a traverse from N to O at 2000ft. MSL. Another traverse was flown from O to a point near Kenney, IL (P). The multi-lobed plume seen in these traverses was enough to the east that probably both Kincaid and Coffeen were sampled. CHEM-1 then ferried to a point near Beason, IL (Q) and spiralled up from 1000 to 2500ft. MSL, but observed no plume, since the Kincaid plume was horizontally and vertically narrow at this distance.

CHEM-1 then ferried to Bloomington for lunch and refueling.

CWP CHEM-1 MISSION SUMMARY

Date: 14 February 1981 (2 missions)

Measurement Interval II: 1318-1515 CST   Flight Hours: 2 hrs

Objective: Continuation of the stable plume scenario.

Activities: CHEM-1 took off from Bloomington at 1300. It flew a set of 3 traverses between a point 4km SW of Bloomington (S) and a point 40km W of Bloomington (T) at 2000, 2100 and 2200ft. MSL. A narrow and concentrated SO_2 plume (levels above 1100ppb) was observed near Hopedale (U) and confirmed by EPA Lidar. It was less than 500 feet thick and only a few km wide even at about 110km downwind. CHEM-1 seemed to be characterizing the upper portion of this narrow lidar profile.

CHEM-1 ferried to a point near Hopedale (U) and spiralled up from 1000 to 3000ft. MSL. CHEM-1 then ferried from U to a point near Minier (V) and flew 2 traverses between V and T at 2300 and 2100 respectively.

CHEM-1 concluded the mission by flying a zig-zag pattern from W back to the Kincaid stacks, confirming the identity of the narrow plume observed earlier, and then returned to Spirit of St. Louis Airport (KSUS).

TABLE 5-4. FLIGHT OUTLINE

14 FEBRUARY 1981
EMI

FLIGHT 1 (0746-1124CST)
FLIGHT 2 (1318-1515CST)

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
1	Bg	0746-0811	A-B	908	CF#39 (events 1–2)
2	F	0811-0814	B-C	908-542	
3	T	0814-0819	C-D	572	
4	F	0819-0824	D-E	572-390	
5	S	0826-0830	E	390-969	CF#34 (events 5–9)
NO EVENT		0830-0835		969-664	No continuous data
6	T	0835-0845	D-F	664	Altitude drop at Coffeen plume
7	T	0848-0857	F-D	572	
8	T	0857-0907	D-F	496	Coffeen again
9	T	0907-0918	F-D	511	Coffeen again; 30 sec. gap
10	F	0918-0930	D-G	511	
11	T	0930-0947	G-H	542	Probably Springfield too; CF#38 (events 11–17)
12	F	0948-0955	H-I	633	
13	T	0955-1005	I-J	633	Coffeen(?) & Kincaid
14	F	1005-1010	J-K	633-450	
15	T	1010-1024	K-L	450	Coffeen(?) & Kincaid
16	F	1024-1032	L-M-N	633	
17	T	1033-1048	N-O	633	30 sec. gap
18	O	1048-1055	O	572	Some plume; not pure background.

TABLE 5-4. (cont.)

14 FEBRUARY 1981, FLIGHTS 1 & 2, CONT.

EVENT NO.	TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
19	T	1055-1104	O-P	572	CF#35 (events 19–22)
20	F	1104-1109	P-Q	572-329	
21	S	1109-1112	Q	329-755	
22	F	1112-1124	Q-Blmngtn.	755-0	Diagonal crossing of Coffeen(?)
Mission II					
23	T	1312-1318	R-S	606	
24	T	1318-1328	S-T	606	CF#37 (events 24 through NO EVENT 1400-1403)
25	T	1329-1339	T-S	636	
26	T	1340-1350	S-T	667	
27	F	1351-1354	T-U	453-301	
28	S	1354-1359	U	301-941	
NO EVENT		1400-1403		941-697	
29	T	1403-1408	V-T	697	
30	T	1408-1410	T-W	636	
31	Zig-zag	1410-1454	W-Kincaid	636-545	CF#36
32	F	1454-1528	Kincaid-KSUS	606	

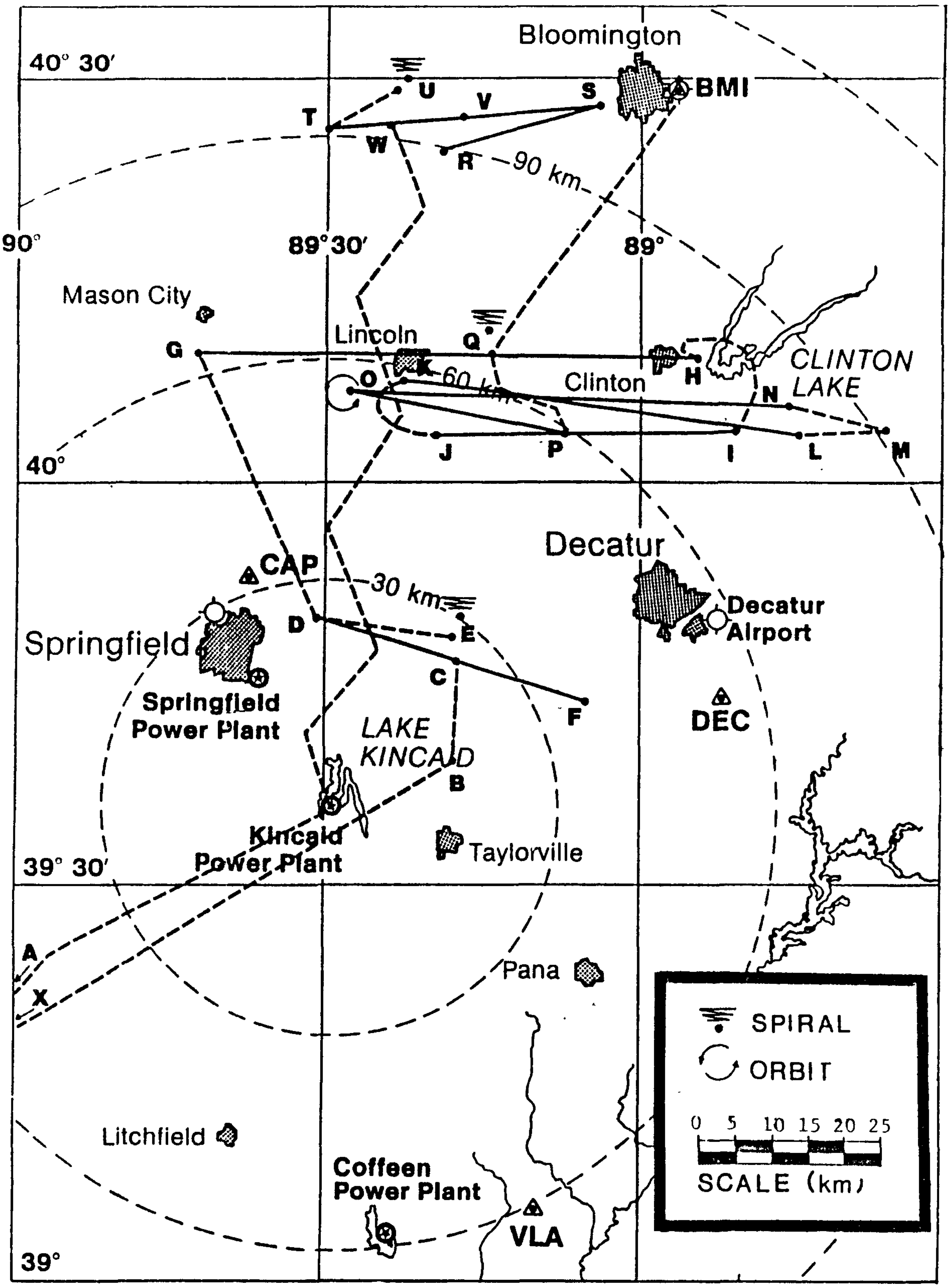

Figure 5-4. Flight Map for 14 February 1981, Flights 1 and 2.

CWP CHEM-1 MISSION SUMMARY

Date: 16 February 1981

Measurement Interval: 1310-1734 CST   Flight Hours: 4.6 hrs

Objective: Study of Kincaid plume under stable conditions with transport winds out of the southwest.

Activities: EMI took off at about 1230. CHEM-1 ferried, gathering background data out to point D about 90km E of Kincaid. It flew a traverse at 2400ft. MSL from D to point E about 78km NE of Kincaid. This traverse and subsequent surveys in this region utilized the 324^{o} radial from Mattoon. Again the plume was in a relatively thin layer and difficult to locate consistently. CHEM-1 reversed direction back towards point D at 2200ft. MSL, eventually stopping at Arthur, IL (F). Two additional traverses between F and E at 2200 and 1900ft. MSL were completed. CHEM-1 then rendezvoused with MRI near point G and flew a parallel traverse with them to Bement, IL (H). CHEM-1 ferried back to near the midpoint (J) of that traverse and spiralled up from 1100 to 3000ft. MSL. CHEM-1 then ferried back to G and, based on SO_2 information from the spiral, flew another traverse from G to E at 2450ft. MSL.

Next CHEM-1 ferried to the CMI VOR (L) and flew two traverses between L and a point about 115km ENE of Kincaid (M) at 2200 and 2300ft. MSL. Then CHEM-1 flew three traverses between point L and a point near Villa Grove, IL (N) at 2000, 1800, and 1600ft. MSL. The plume had shifted toward the north by this time and was centered over the Champaign-Urbana airport. It was also quite low at this distance where ground fog was forming, preventing lower altitude surveys. The Champaign-Urbana tower cooperated well with CHEM-1 but would not allow it over the airport airspace, much less allow it to fly at the lower altitudes needed for complete characterization at this distance. (MRI landed at Champaign-Urbana after the earlier flyby and was socked in by the ground fog during this period.)

CHEM-1 then ferried back to point G and flew a traverse from G to a point about 80km NE of Kincaid (P) at 2200ft. MSL. Next CHEM-1 traversed from P back to point Q at 2000ft. MSL. CHEM-1 concluded the mission by flying a zig-zag pattern back to the Kincaid stacks. By the time CHEM-1 approached the stacks, there was no plume to observe since in mid-afternoon the plant had gone down due to mechanical problems. Hence, a complete in-plume zig-zag was not possible.

CHEM-1 returned to Spirit of St. Louis airport, gathering background data on the way.

TABLE 5-5. FLIGHT OUTLINE

16 FEBRUARY 1981 FLIGHT 1 (1310-1734CST)

EMI

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
1	F	1310-1351	A-B-C-D	739	CF#44
2	T	1351-1407	D-E	739	
3	T	1407-1419	E-F	647	
4	T	1420-1429	F-E	678	
5	T	1431-1438	E-F	586	
6	T	1440-1447	G-H	678	Fly-by with MRI
7	F	1447-1457	H-I-J	678-342	CF#46 (events 3-10)
8	S	1458-1503	J	342-921	
9	F	1504-1512	J-G	921-769	
10	T	1512-1523	G-E	769	
11	Bg	1523-1536	E-K-L	744	
12	T	1538-1548	L-M	728	
13	T	1550-1559	M-L	708	
14	T	1559-1604	L-N	617	CF#49 (events 13-16)
15	T	1605-1611	N-L	556	30 sec. gap
16	T	1611-1616	L-N	495	
17	F	1616-1628	N-O-G	495-678	
18	T	1628-1642	G-P	678	
19	T	1643-1649	P-Q	617	CF#51 (events 18-20)
20	Zig-zag	1649-1716	Q-Kincaid	678-586	
21	F	1716-1734	Kincaid-R	769	CF47

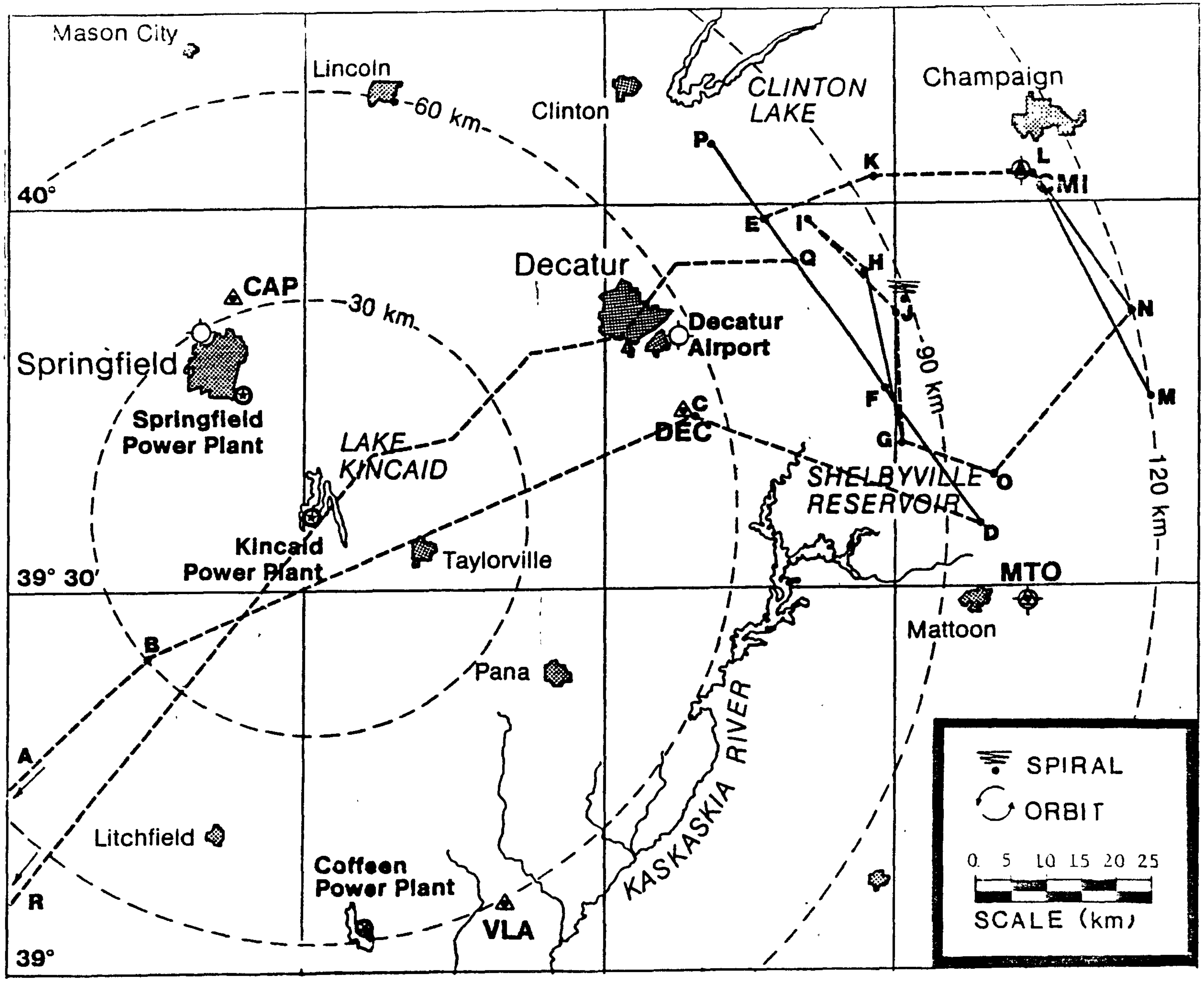

Figure 5-5. Flight Map for 16 February 1981, Flight 1.

CWP CHEM-1 MISSION SUMMARY

Date: 20 February 1981

Measurement Interval: 1035-1415 CST   Flight Hours: 3.7 hrs

Objective: Characterization of Kincaid plume during the transition from stable to well-mixed conditions with transport winds out of the NW (after two earlier missions by MRI starting at 0200 CST).

Activities: Take-off was at 1030. CHEM-1 ferried to a point (C) near Staunton, IL and orbited in the background, awaiting word on MRI's status. Then it flew to D approximately 66km SE of Kincaid near the Vandalia (VLA) VOR, gathering background data on the way. From there CHEM-1 flew a traverse at 2100ft. MSL toward the east just upwind of the Coffeen power plant to a point near Moccasin, IL (E). From point E CHEM-1 flew a traverse back towards C at 2300ft. MSL, ending at F. Having observed a clear SO_2 profile, CHEM-1 then ferried back to the midpoint of the E-F traverse to G and spiralled up from 800 to 3000ft. MSL. From G CHEM-1 ferried to Beecher City, IL (E) and flew a parallel traverse with MRI from E to G at 2200ft. MSL at the maximum SO_2 level. CHEM-1 then flew a traverse back to E at 1800ft. MSL. Next a traverse was flown from E to F at 1600ft. MSL, completing this 65km characterization. These traverses encountered a well-defined plume and characterized it at several altitudes.

CHEM-1 then ferried to a point (K) about 120km downwind of Kincaid near Flora, IL, trying to keep track of the edge of the plume on the way. It flew a traverse from K to a point (L) near Effingham, IL at 2000ft. MSL. From L CHEM-1 ferried to point M, also near Effingham, and flew a traverse roughly paralleling I-57 to point N near Salem, IL at 2000ft. MSL. From N CHEM-1 flew a traverse back toward the BIB VOR at 2200ft. MSL to point O. From O CHEM-1 flew a traverse back toward Salem to point P at 1800ft. MSL. Two more traverses were flown between O and P at 1600 and 2000ft. MSL. (On none of these traverses this far downwind was any clear Kincaid plume observed. SO_2 profiles were observed but are not clearly interpreted without trajectory analysis. It is possible, in retrospect, that the move to 120km was too long in light of the time that the transport wind had been established at 315°. Hence these EMI surveys may well have preceded the actual plume transport to the area.) This concluded the mission, and CHEM-1 returned to the Spirit of St. Louis Airport (KSUS).

TABLE 5-6. FLIGHT OUTLINE

20 FEBRUARY 1981 FLIGHT 1 (1035-1415CST)

EMI

EVENT NO.	EVENT TYPE	TIME	ROUTE	ALTITUDE (m MSL)	COMMENTS; CYCLONE FILTER NO.
1	F	1035-1053	A-B-C	470-896	} CF#58 (events 1-3)
2	Bg&O	1055-1101	C	622	
3	F	1101-1118	C-D	622	
4	T	1120-1124	D-E	622	} CF#53 (events 4-10)
5	T	1126-1130	E-F	683	
NO EVENT		1130-1135		683-226	
6	S	1135-1140	G	287-896	
7	T	1141-1144	G-E	683	
8	T	1146-1150	E-G	683	MRI fly-by
9	T	1151-1154	G-E	531	
10	T	1154-1200	E-F	470	
11	F	1200-1215	F-I-J-K	653	1204-1209 No tape
12	T	1216-1229	K-L	592	
NO EVENT		1229-1223			
13	T	1233-1246	M-N	592	Interpret with caution; see summary text
14	T	1248-1255	N-O	653	Interpret with caution; see summary text
15	T	1257-1312	O-P	546	Interpret with caution; see summary text. CF#52 (events 13-17)
16	T	1313-1328	P-O	470	Interpret with caution; see summary text
17	T	1330-1344	O-P	592	Interpret with caution; see summary text
18	F	1345-1415	P-Q-R-KSUS	927-165	CF#57

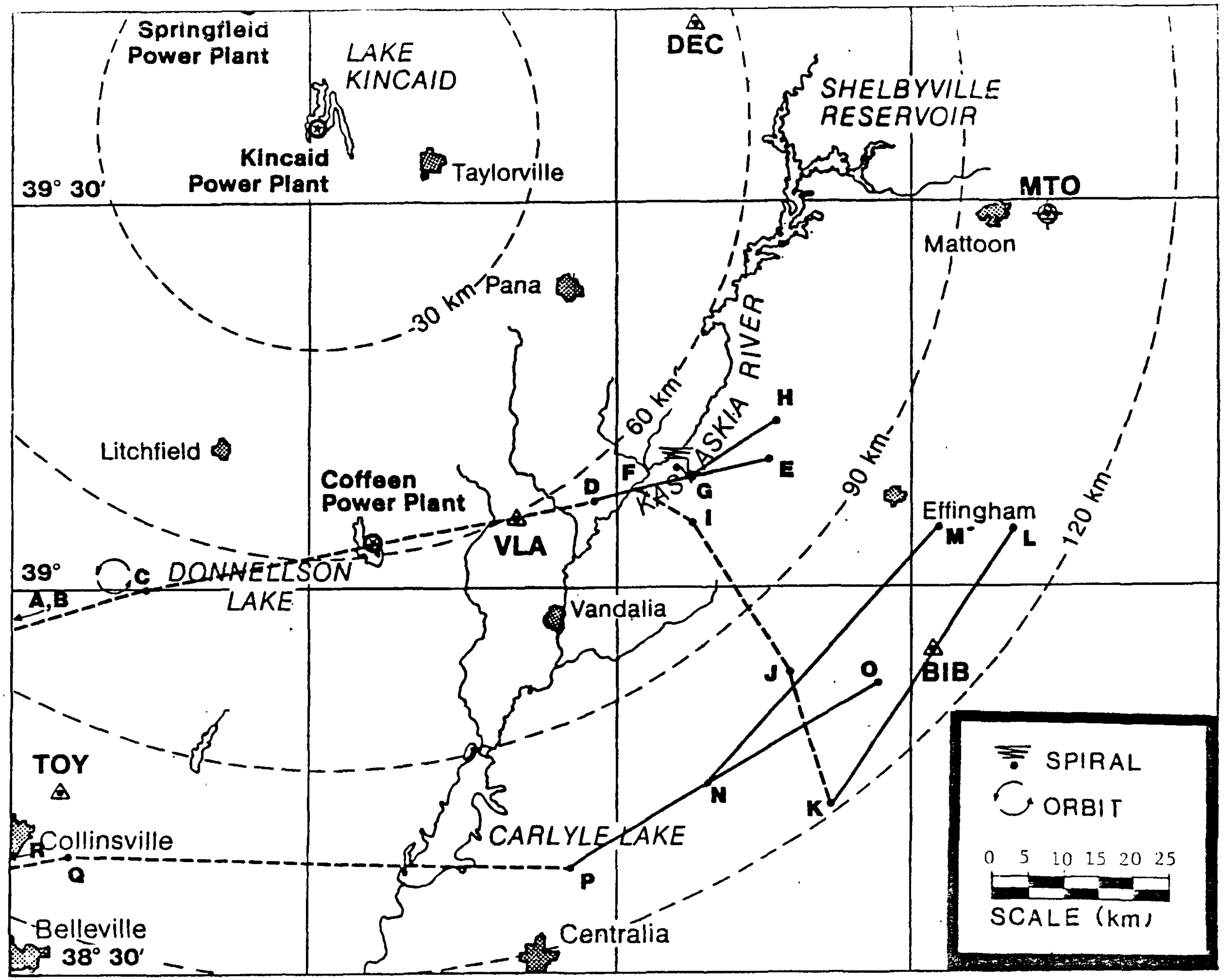

Figure 5-6 Flight Map for 20 February 1981, Flight 1.