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CASE STUDY OF FRONTAL BOUNDARY STUDY MISSION 03

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SUMMARY

The Frontal Boundary Study was conducted by the Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy in October and November 1989 in central Ohio. This report, which was prepared for the U.S. Environmental Protection Agency, presents the results of the aircraft and surface observations made for one precipitation event during the study, on October 10, 1989. This particular event was selected because of its relatively simple meteorological setting. Precipitation occurred mainly in the warm sector between a warm and a cold front that moved across the study area. The study area, approximately 80 x 80 km, contained a network of 36 automatic, wet-only precipitation chemistry sampling sites. PNL's Gulfstream (G-1) aircraft was used to sample trace gas concentrations aloft in the inflow region of the precipitation system.

Precipitation chemistry and rainfall rate data are presented for the October 10, 1989, event from the network of surface precipitation samplers. Trace gas concentrations and other meteorological variables measured with the G-1 during flight 03 on this date are included. Meteorological observations obtained with radiosondes and radar are also presented. These data sets can be used to evaluate air quality and wet deposition models.

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INTRODUCTION

The U.S. Department of Energy (DOE) Frontal Boundary Study (FBS) experiments were conducted at Columbus, Ohio, in October and November 1989 for the U.S. Environmental Protection Agency (EPA). One of the major objectives of the FBS was to obtain spatial and temporal data bases of precipitation amount, air chemistry, and precipitation chemistry over an area the approximate size of the regional deposition model 80- x 80-km grid. A single grid square of this size was laid out just north of Columbus (Figure 1). In addition to measurements of precipitation chemistry on a network of precipitation samplers deployed in this grid square, the Pacific Northwest Laboratory's (PNL) Gulfstream (G-1) aircraft was equipped to measure air and cloud chemistry aloft. A total of 16 flight missions (Table 1) were flown by the PNL G-1 aircraft in a variety of types of frontal storms.

TABLE 1. Dates and Times (Greenwich Mean Time) of Research Flights During the U.S. Department of Energy Frontal Boundary Study

FBS FLIGHT	DATE	DAS ON	DAS OFF	Take OFF	Land CMH	comments
fbs 01	6-Oct-89	17:20:54	20:15:48	17:26	20:17	
fbs 02	6-Oct-89	21:14:02	23:15:09	21:18	23:17	
fbs 03	10-Oct-89	08:55:28	13:09:17	9:04	13:09	
fbs 04	12-Oct-89	11:52:57	15:32:36	11:58	15:32	NOx->NOy
fbs 05	14-Oct-89	13:55:24	17:22:38	13:58	17:23	
fbs 06	16-Oct-89	15:55:30	19:04:24	16:00	19:04	
fbs 07	16-Oct-89	20:14:18	23:04:33	20:19	23:04	
fbs 08	17-Oct-89	11:56:29	15:07:21	12:03	15:07	
fbs 09	18-Oct-89	15:53:46	17:17:19	15:54	17:17	
fbs 10	23-Oct-89	14:55:12	18:06:14	14:56	18:06	NO2 invalid
fbs 11	26-OCT-89	14:59:28	18:14:46	15:07	16:20	power interupt
fbs 12	30-Oct-89	15:54:19	19:35:47	16:01	19:35	lost power runway
fbs 13	31-Oct-89	12:54:06	15:07:06	13:00	15:07	
fbs 14	31-Oct-89	16:21:24	20:11:16	16:28	20:11	
fbs 15	3-Nov-89	17:56:11	21:26:36	18:04	21:26	
fbs 16	7-Nov-89	11:56:20	16:27:44	12:03	16:27	

The field operations center for the FBS experiments was located at the Port Columbus International Airport. Meteorological equipment installed at the FBS operations center during the experiments included a weather facsimile machine, satellite imaging, dial-up weather radar, and meteorological software. Forecasts and flight objectives were determined each day at this center.

The National Weather Service (NWS) at Columbus, located only about 1.61 km from the operations center, allowed PNL meteorologists access to their office, where they made use of NWS weather charts and the continuous weather radar display. The NWS also permitted the PNL rawinsonde system to be operated on their premises. Rawinsondes were operated by PNL, Argonne National Laboratory, and Brookhaven National Laboratory personnel during the aircraft flights. A meteorological data base from these sources has been compiled for each of the FBS experiments.

The precipitation chemistry network was established to provide the necessary spatial and temporal resolution of precipitation amount and chemistry data on the sub-grid scale for deposition model evaluation. As a compromise between the desired spatial density (to document spatial variations statistically) and the areal coverage (to increase the chances for sampling scattered precipitation), a network of 36 sites with a basic site-spacing of 16 km and a higher density central area was established, covering an area 80 x 80 km. The base network is shown in Figure 2. Most of the sites were located on vegetated farm land or park areas, and all met standard criteria for location of regional or background sampling sites (Dana and Easter 1987).

The major sampling device at all sites was the computer-controlled automated rain sampler (CCARS). The CCARS is a battery-powered combination recording rain gauge and sequential chemistry sampler, capable of providing the time history of rainfall in 0.25-mm increments, and up to nine sequential samples (stages) for chemical analysis. Each CCARS was programmed to sample on a volume basis, most often for 2.5 mm per stage on the first eight stages. The final stage can contain up to 50 mm of rainfall. More detail on the operation and capabilities of the CCARS may be found in Tomich and Dana (1990).

Additional equipment was located at selected sites. Site 82 (Delaware, Ohio), which is the location of a National Atmospheric Deposition Program

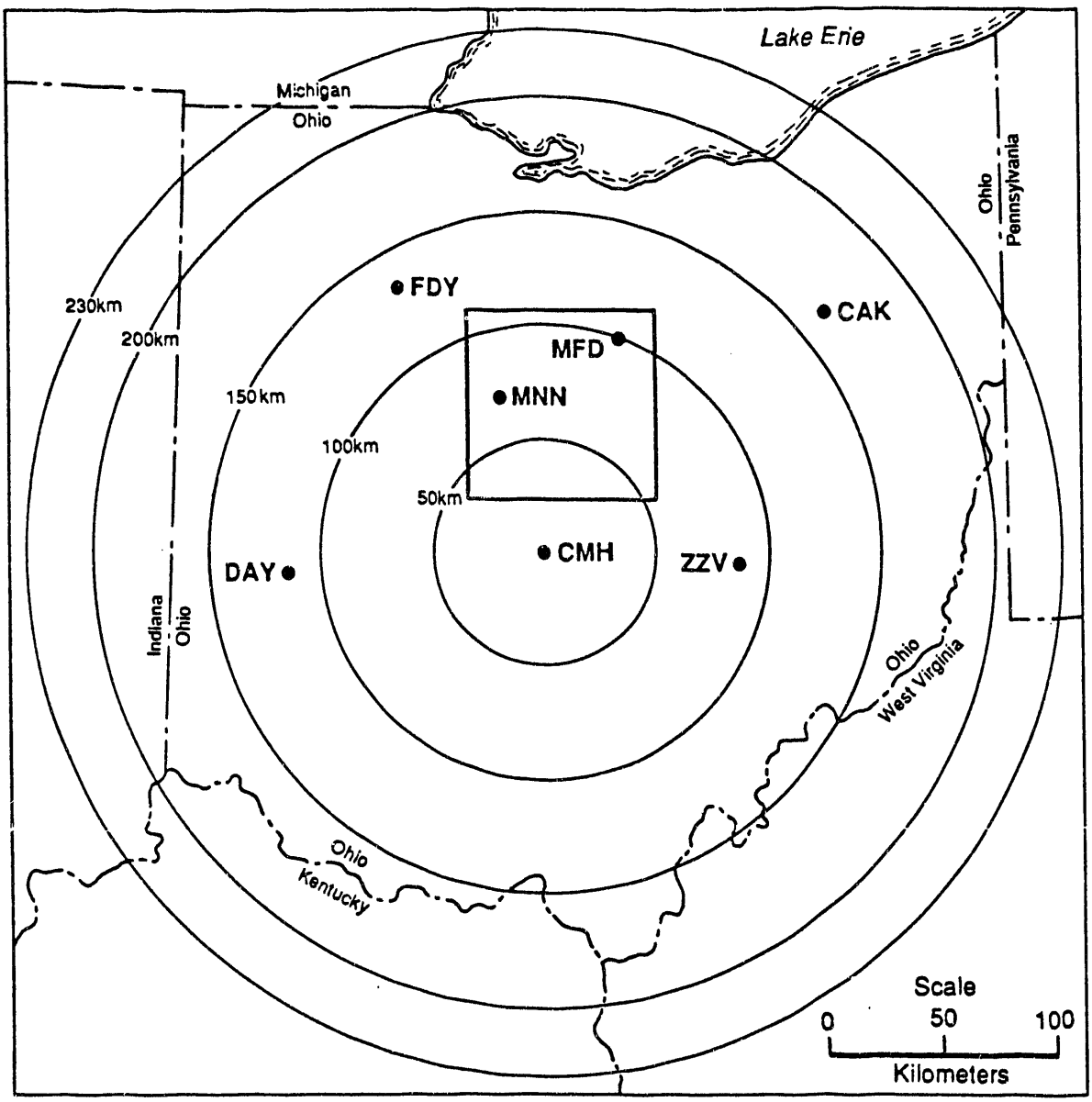

FIGURE 1. Location of the Frontal Boundary Study Precipitation Sampling Grid (square), and Selected National Weather Service Stations in Ohio. CAK-Akron, CMH-Columbus, DAY-Dayton, FDY-Findlay, MFD-Mansfield, MNN-Marion, ZZV-Zanesville

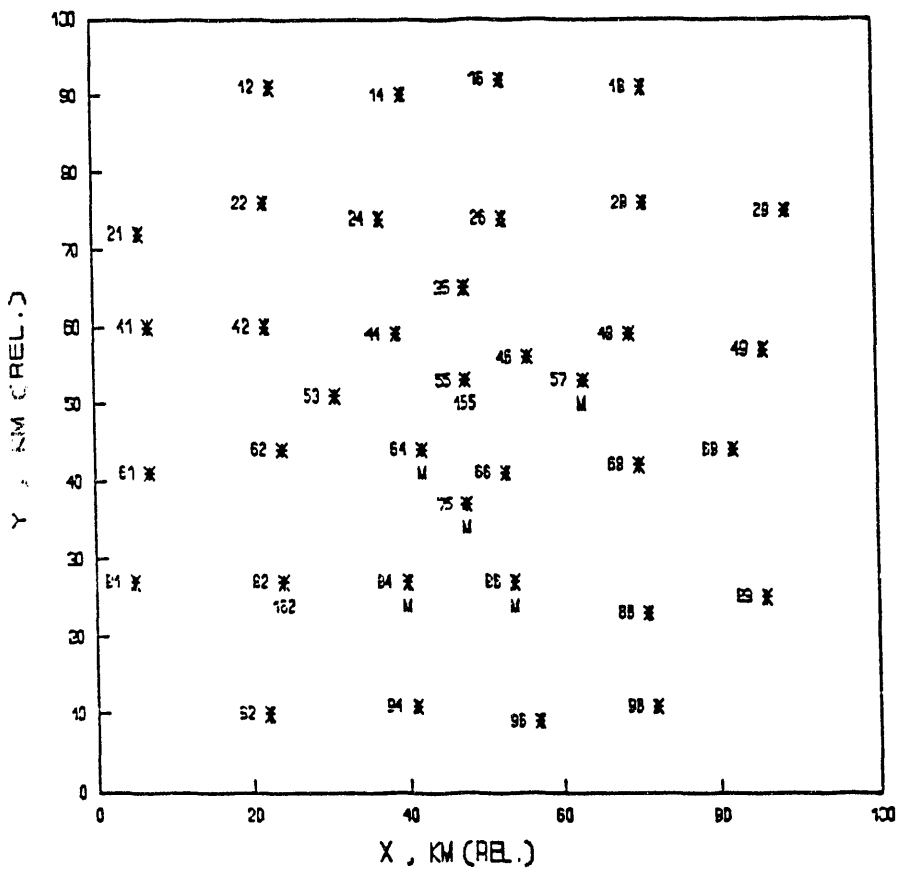

FIGURE 2. The Frontal Boundary Study Precipitation Chemistry Network

(NADP) weekly monitoring site, had two CCARS, a Belfort weighing rain gauge, an AeroChem Metrics wet-only monitoring sampler in addition to the equipment associated with the NADP site, and a funnel-and-bottle type bulk collector. Site 55 in the center of the network also had an additional CCARS. These second CCARS (designated sites 155 and 182) were either operated in the major-ion sampling mode as duplicates, or used to collect samples for hydrogen peroxide analysis (with the derivatization agent pre-administered to sample stages). Bulk collectors and simple wedge rain gauges were employed at other sites to provide duplicate measures for quality control. Aliquots from selected samples (both bulk and sequential) were treated with tetrachloro-mercurate after collection for analysis of sulfur (IV) species.

Analytical chemistry for major ions and sulfur (IV) in rain and cloud water samples and aircraft filter samples was performed at the PNL precipitation chemistry laboratory in Richland, Washington. At the time of the FBS, the laboratory routinely performed analyses for the MAP3S precipitation chemistry network. Established quality assurance/quality control procedures for that project were adhered to for FBS samples (Dana and Barchet 1989; Dana and Easter 1987).

Of the 16 missions that were flown during the FBS study, the missions of October 10, 16, and 31 and November 7 offer the most complete data sets. For this EPA study, we have chosen the experiment of October 10 (FBS 03), as being the least complex meteorologically. The synoptic situation was one in which the sampling grid was under the influence of a warm sector air mass between warm and cold fronts. This air mass produced showers and thundershowers in the vicinity of Columbus for a period of several hours. Statistically, this pattern could be expected to occur with a seasonal frequency of 4% to 6% in spring, summer, or autumn (Barchet and Davis 1984).

DATA BASE

The following sections describe the contents of the data packets compiled for this mission.

AIRCRAFT MEASUREMENTS

During the FBS series of experiments, the PNL G-1 aircraft data acquisition system was equipped to record (in volts) 24 real-time air chemistry sampling channels onto tape. An additional seven Loran navigational, air speed, and wind velocity channels were recorded (Table 2). Not all of these channels were in use during the FBS 03 experiment; Table 3 lists the operational channels that contain usable data.

When the G-1 data tapes are processed at PNL, calibrations are applied to the individual channel voltages to adjust them to appropriate units. Channels for Altitude and H_2O_2 are created during the processing. From the Latitude and Longitude channels, a plot of the flight track is created. During FBS 03, the channels for ultraviolet, CO, SO_4, NO_x, and NO were inoperable or contained uncertain data. The Loran channels for Wind Speed and Direction were not processed because data were unreliable.

Appendix A contains

- a description of the structure of the valid aircraft data contained on disks FBS03A and FBS03B, which are available from PNL
- plots of the processed aircraft data
- any aircraft data processing notes
- a table of results from analysis of the aircraft filters.

PRECIPITATION CHEMISTRY DATA

Precipitation and precipitation chemistry data from FBS are of two types: 1) rainfall timing as recorded by the CCARS, and 2) results of chemical analyses of the CCARS stages. The rainfall data consist of the timing of rainfall increments (about 0.25 mm), from which rainfall rates and rainfall amounts over any time interval may be calculated. The chemistry data

TABLE 2. Raw Data Archived in the G-1 Aircraft Data Acquisition System During the U.S. Department of Energy Frontal Boundary Study (FBS 03)

Acquisition Title	Formal Name	Status
cld.wtr	Cloud Water (g/m^3)	operational
temp.rf	Reverse Flow Temperature (deg C)	"
uv	UV Radiation(W/m^2)	inoperable
pres	Pressure (mb)	operational
temp	Temperature (deg C)	"
dew	Dew Point (deg C)	"
bscat	Aerosol Scattering ($x10^{-4}/m$)	"
o_3.a	O_3 (ppb)	"
so_2.a	SO_2 (ppb)	"
no_x	NO_x (ppb)	inoperable
no_2.stat	Status of NO_2 (volts)	"
no_2	NO_2 (ppb)	operational[a]
co	CO (ppb)	inoperable
h_2o_2.tot	Total Peroxide (perox a) (ppb)	operational
h_2o_2.org	Organic Peroxide (perox b) (volts)	"
h_2o_2.stat	Peroxide Status (volts)	"
cnc.a	CNC A (counts)	"
cnc.b	CNC B (exponent)	"
alog.20	Chan 20	inoperable
alog.21	Chan 21	"
alog.22	Chan 22	"
alog.23	Chan 23	"
no	NO (ppb)	dual with NO_2[a]
dig.in.1	Digital Input 1	inoperable
lat	Latitude (degrees)	operational
long	Longitude (degrees)	"
heading	Heading (degrees true)	unreliable
speed	True Air Speed (knots)	operational
wind.dir	Wind Direction (degrees)	unreliable
wind.speed	Wind Speed (knots)	"
warn.codes	Loran Warning Codes	operational
alt	Altitude (meters)	created
h_2o_2	H_2O_2 (ppb)	"
no_2+no	NO_2+NO (ppb)	"

(a) During FBS 03, channel input alternated between NO_2+NO and NO_2.

TABLE 3. Air Chemistry and Navigation Parameters Recorded by the G-1 Aircraft Data Acquisition System for the U.S. Department of Energy Frontal Boundary Study (FBS 03)

Formal Name	Status on 10/10/89
Latitude (degrees)	operational
Longitude (degrees)	"
Altitude (m)	created
Pressure (mb)	operational
Temperature (deg C)	"
Dew Point (deg C)	"
Aerosol Scattering ($x10^{-4}/m$)	"
O_3 (ppb)	"
SO_2 (ppb)	"
NO_2 (ppb)	"
NO_2+NO (ppb)	created
CNC A (counts)	"
H_2O_2 (ppb)	created
Cloud Water (g/m^3)	operational

are concentrations of the major inorganic species by stage, nominally 2.5 mm of rainfall. When the rainfall was intermittent, or at the end of rainfall, the stage rainfall increment was less, as small as 0.25 mm.

Because FBS 03 occurred early in the FBS series, the sampling network had not been completely installed. Thus, spatial coverage of precipitation and precipitation chemistry measurements is not as complete as for the October 17 and 31 and the November 7 events. In Appendix B, the FBS 03 data are presented in four tables:

- sampling site locations
- the rainfall data, including rainfall timing, rates, and cumulative rainfall
- precipitation chemistry data with rainfall data as above by stage
- event total precipitation and event precipitation-weighted average concentrations.

Additional tables list descriptions of the data column headings and formats for the computer files.

All data presented here have met rigid quality assurance criteria; all questionable data have been eliminated. Concentrations of all chemical species reported in the event and stage files are more than ten times larger

than detection limits and are considered accurate to ±10%. Event average concentrations for Na, Cl, Ca, and Mg are more uncertain (up to ±25%), because of the occurrence of below-detection-limit values in some samples.

METEOROLOGICAL DATA

The meteorological data base for FBS 03 is in Appendix C. Included in this appendix are

- a description of the synoptic conditions for 10 October 1989
- surface and constant pressure level charts, as available
- skew T plots of the PNL rawinsondes
- a description of the structure of the disk file(s) containing the PNL rawinsonde data, and other digitized information
- hard copies of the rawinsonde data
- a time-series diagram of clouds, weather, winds, temperatures, and precipitation that occurred at Columbus and Mansfield, Ohio
- a catalog of the color photographs of the Columbus, Ohio, weather radar monitor display during the period of the experiment.

REFERENCES

Barchet, W. R., and W. E. Davis. 1984. A Weather Pattern Climatology of the United States. PNL-4889, Pacific Northwest Laboratory, Richland, Washington.

Dana, M. T., and W. R. Barchet. 1989. The MAP3S Precipitation Chemistry Network: Data and Quality Control Summary for 1986 and 1987. PNL-6885, Pacific Northwest Laboratory, Richland, Washington.

Dana, M. T., and R. C. Easter. 1987. "Statistical Summary and Analyses of Event Precipitation Chemistry from the MAP3S Network 1976-1983." Atmos. Environ. 21:113-128.

Tomich, S. T., and M. T. Dana. 1990. "Computer-Controlled Automated Rain Sampler (CCARS) for Rainfall Measurement and Sequential Sampling." J. Atmos. Ocean. Tech. 7:541-549.

APPENDIX A

AIRCRAFT MEASUREMENTS

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AIRCRAFT MEASUREMENTS

This appendix contains the graphic plots (Figures A.1-A.16) of processed aircraft data. Plots of the aircraft flight track during FBS 03, referenced to state boundaries and the surface grid, are included. An expanded plot showing more details of the 'figure 8' pattern that was flown northeast of Columbus has time marks that are close to the time of altitude changes that were made during the flight. Aircraft direction arrows for some of the flight legs are added.

PROCESSING NOTES

NO_2+NO and NO_2 Channels

During the FBS 03 flight, the channel for NO_2 was actually used to record intervals of both NO_2+NO and NO_2, a practice not normally followed during the FBS experiments. Therefore, the aircraft data have been separated into two files, one for the periods when NO_2+NO were recorded and the other for the periods when only NO_2 was being recorded.

Negative Values

During periods when very low values of aerosol scattering, SO_2, condensation nuclei concentrations, and H_2O_2 were encountered, there were occasions when negative values were recorded by the data acquisition system. In the final processing of these four channels, all negative values were set to zero.

Averaged Aircraft Data

The plots and disk files of the valid aircraft data have been averaged over and reported at 1-s intervals. Instrument zeros, calibration excursions, and invalid data were excised from the processed data before the averaging for the disk files was done.

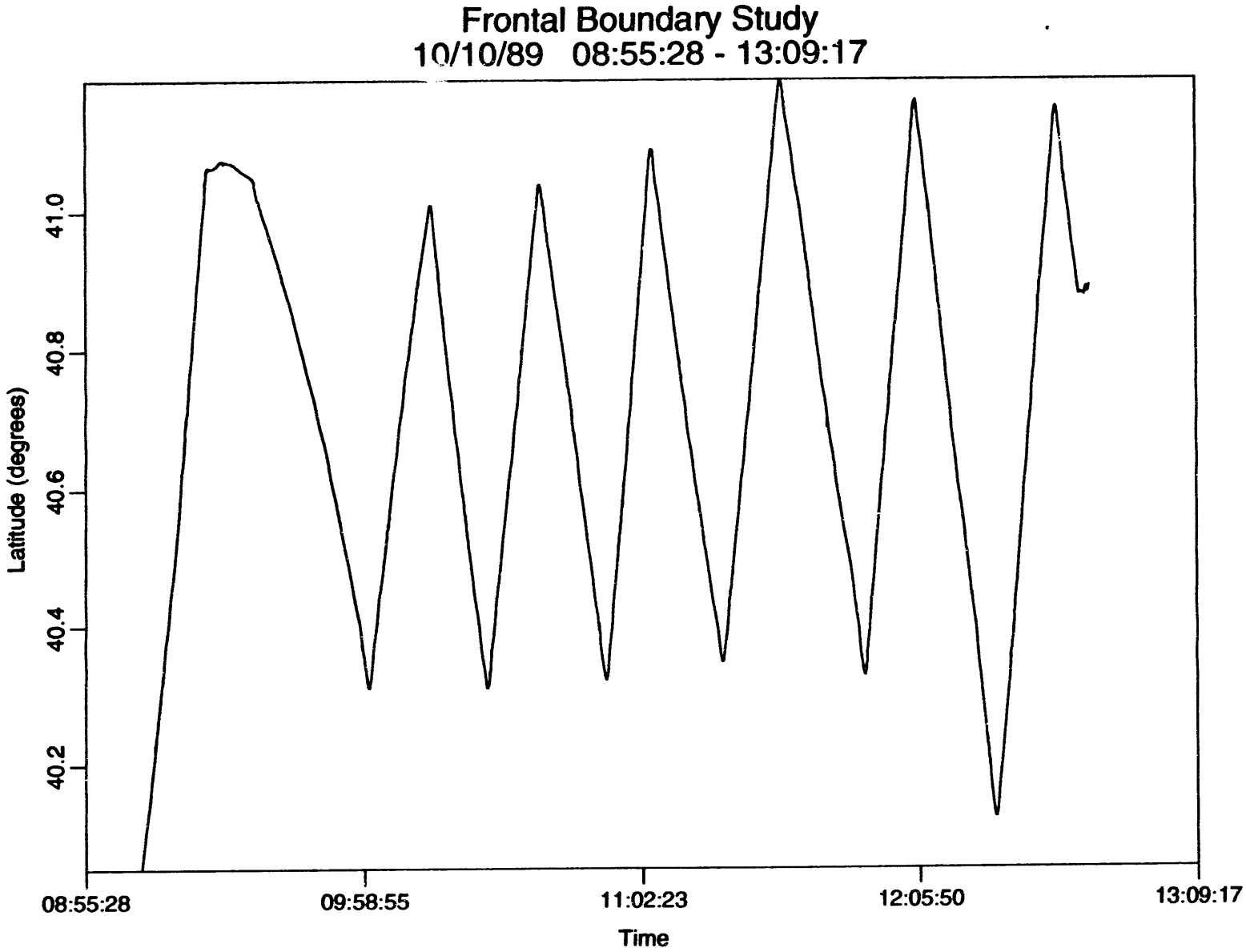


FIGURE A.1. Aircraft Latitude

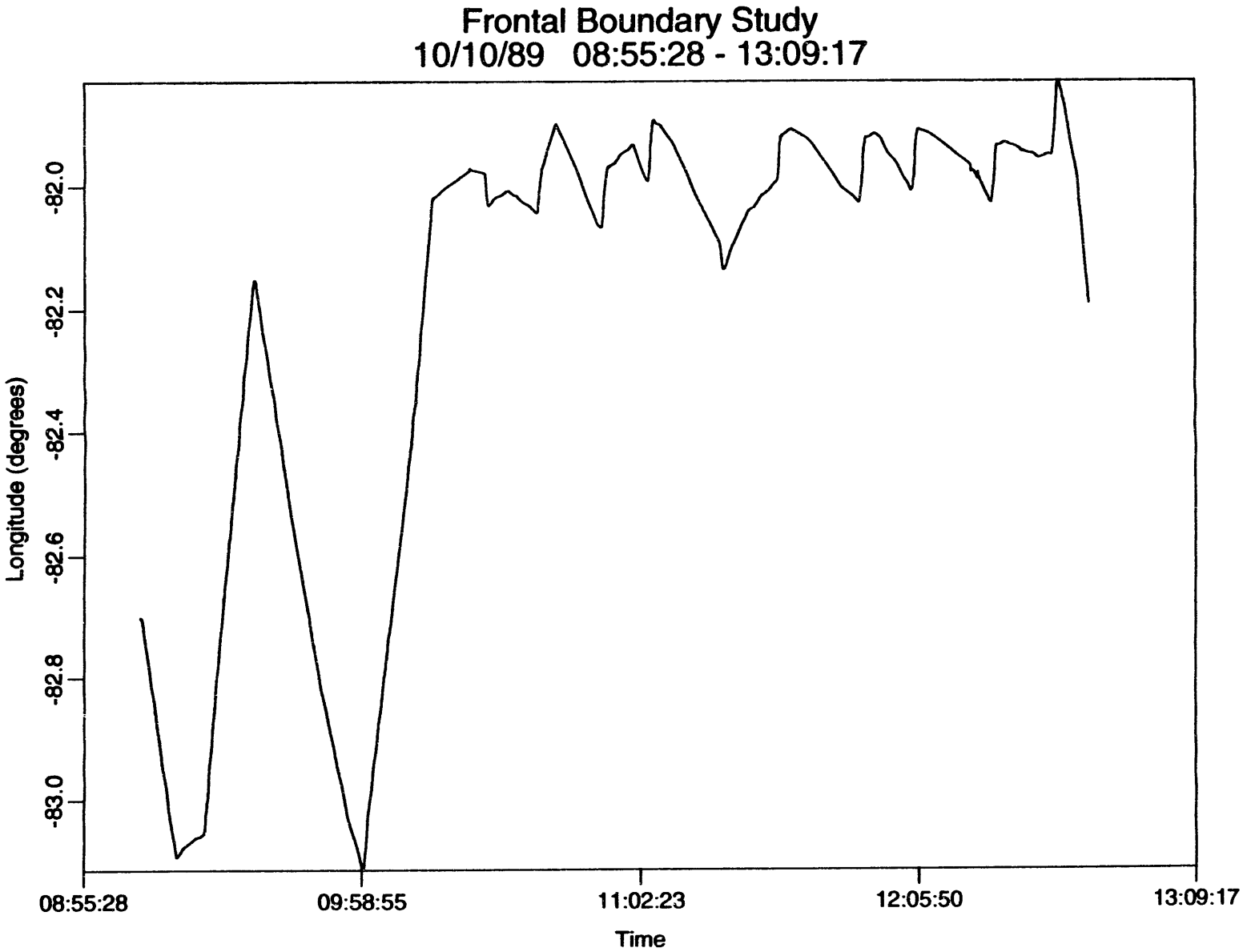


FIGURE A.2. Aircraft Longitude

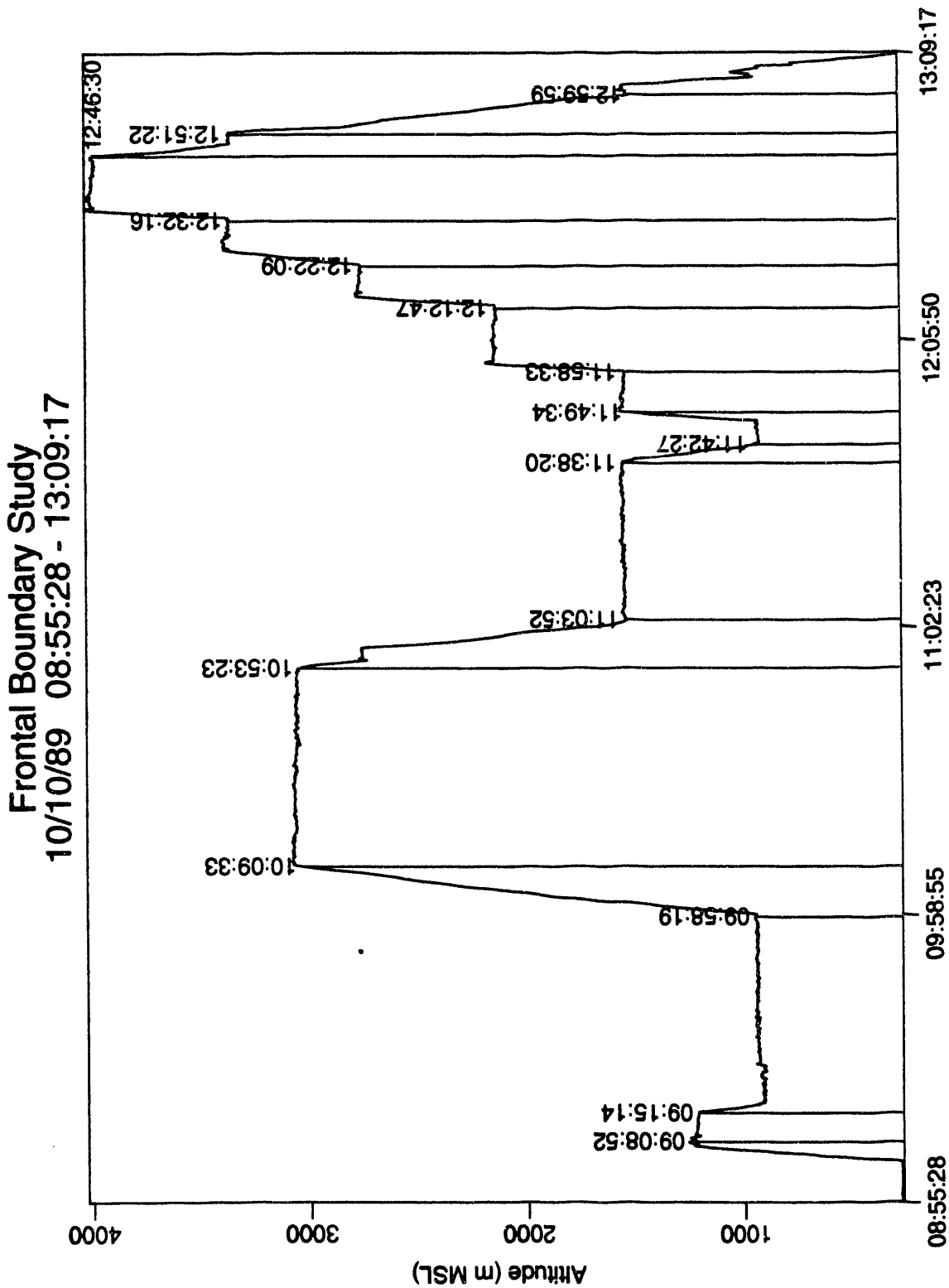


FIGURE A.3. Aircraft Altitude (m, MSL)

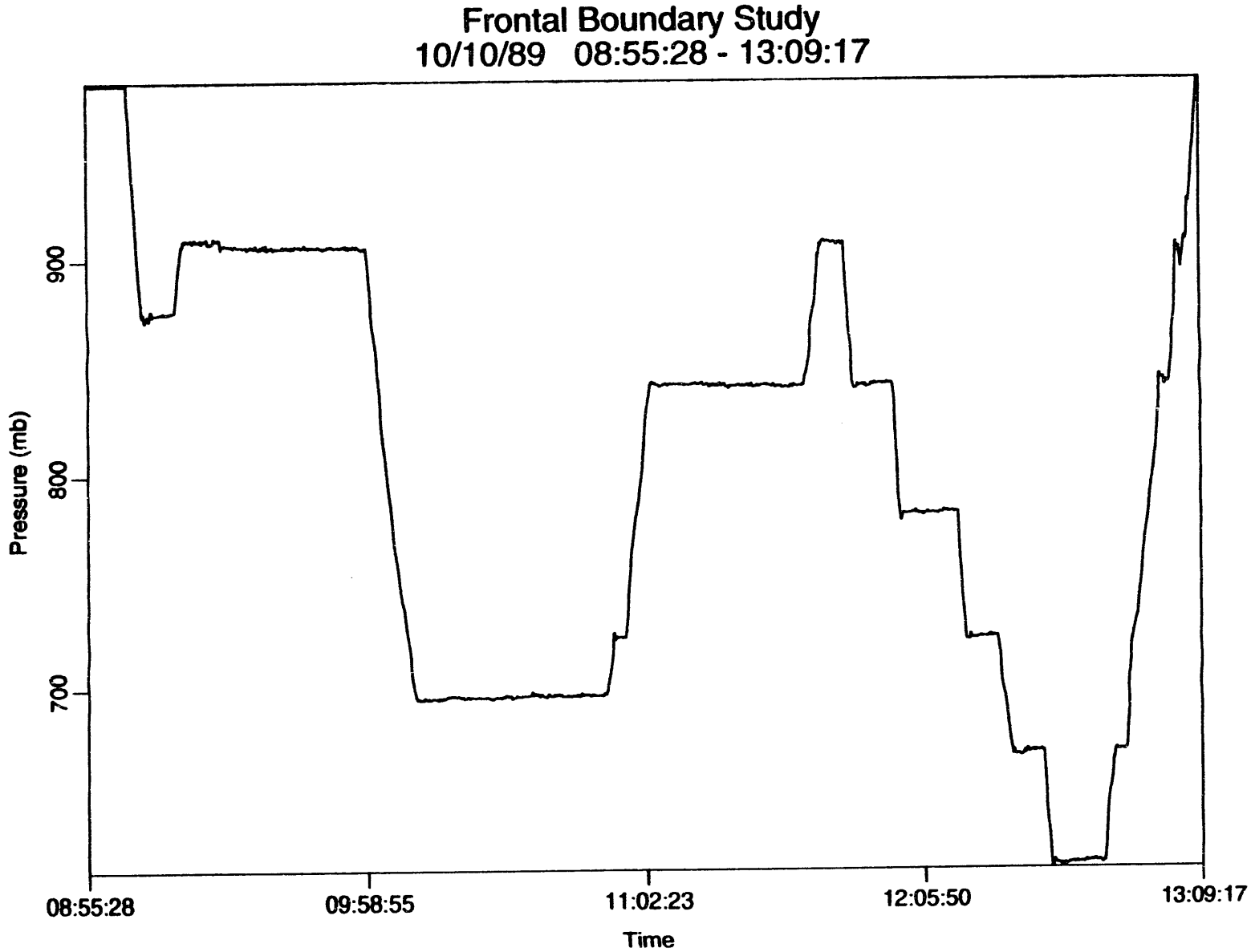


FIGURE A.4. Air Pressure (mb)

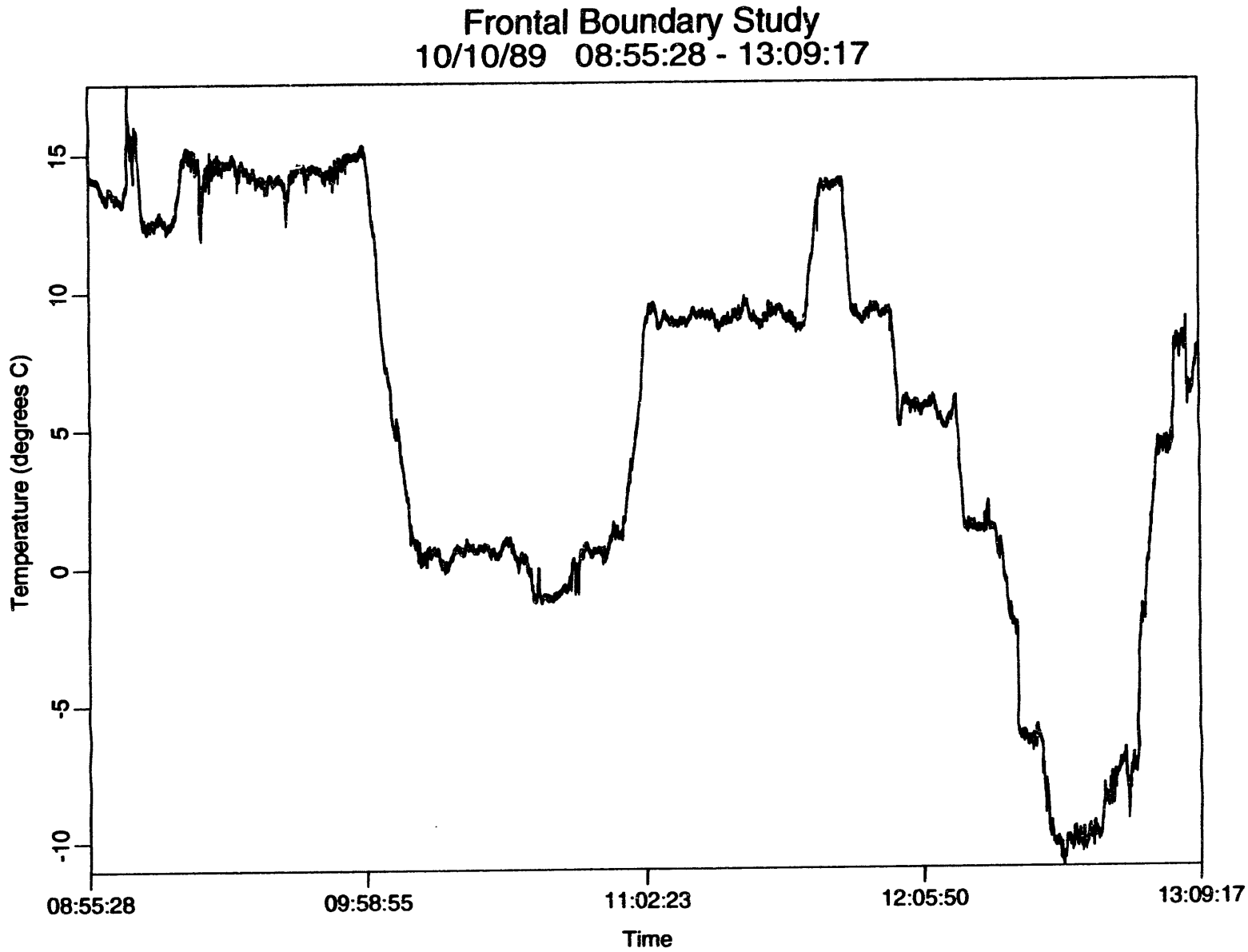


FIGURE A.5. Air Temperature (°C)

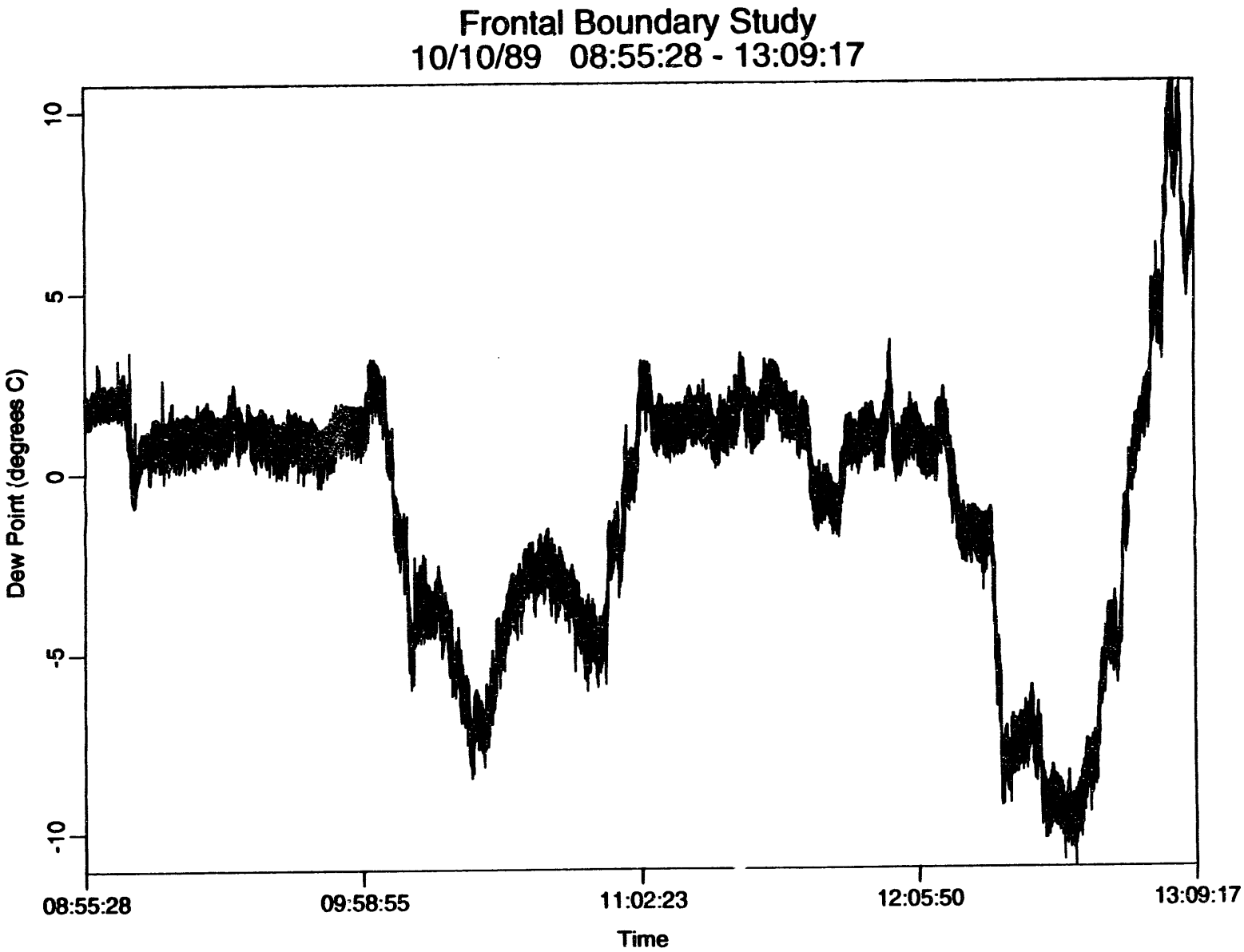


FIGURE A.6. Dew Point Temperature (°C)

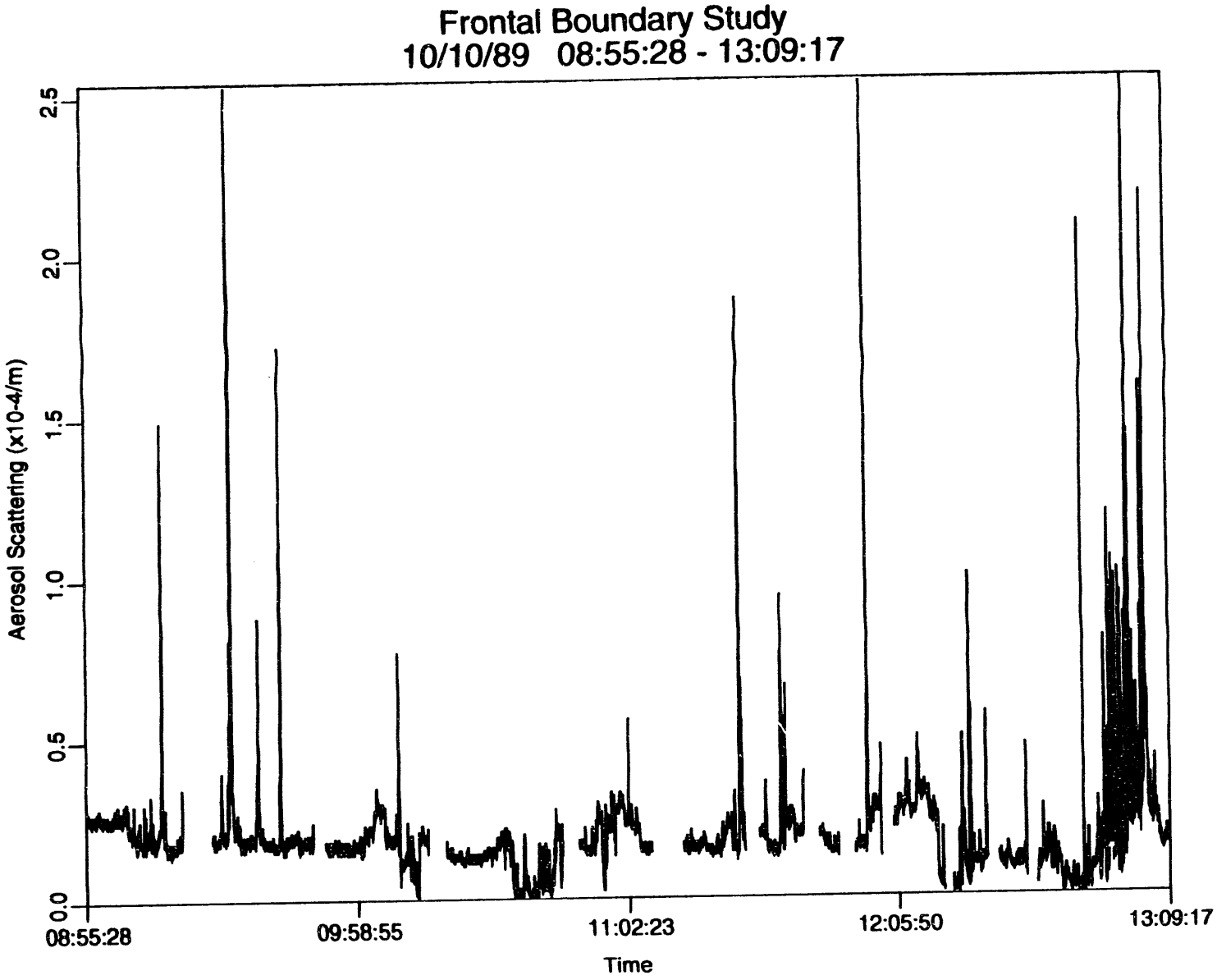


FIGURE A.7. Aerosol Scattering ($x10^{-4}m$)

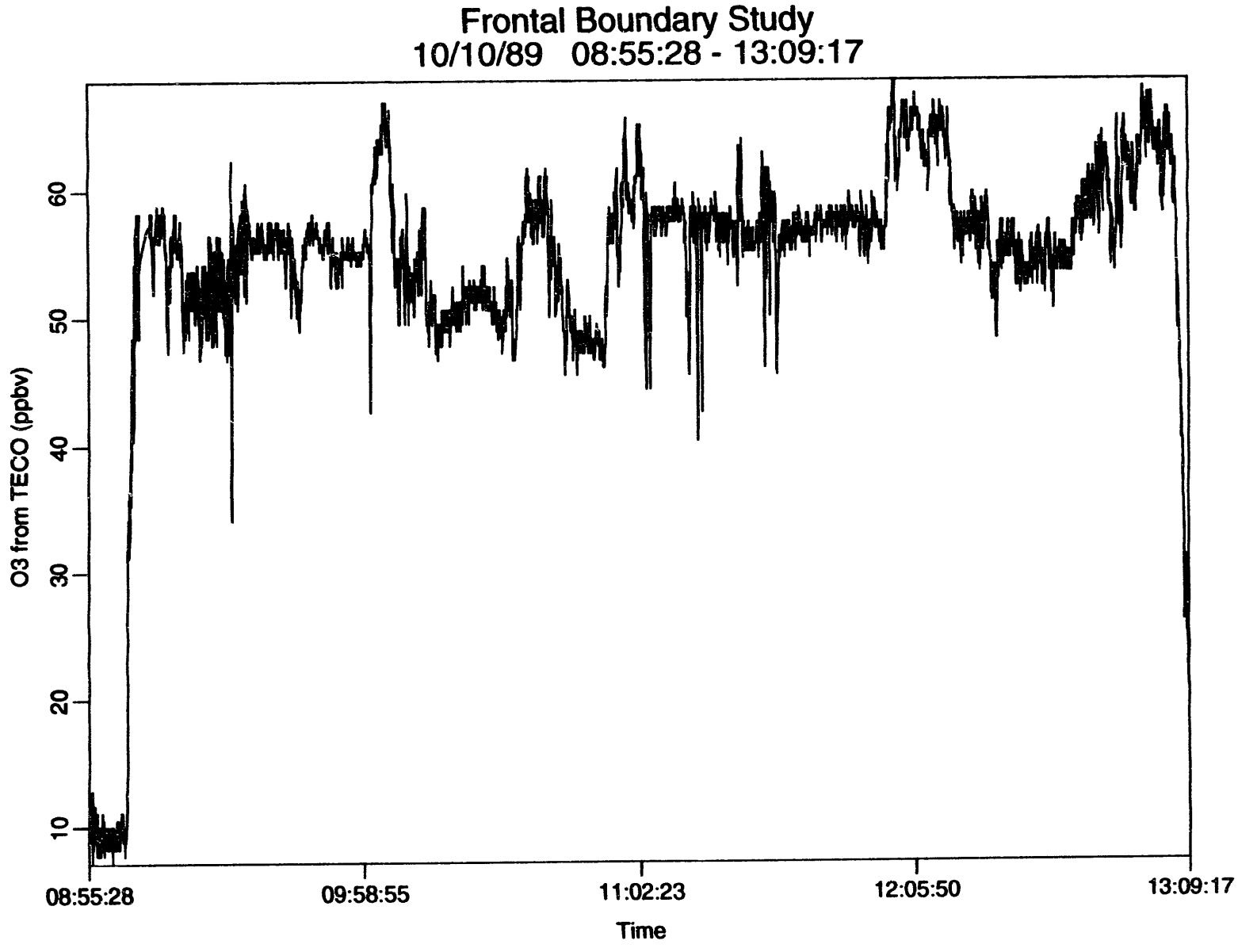


FIGURE A.8. Ozone (ppbv)

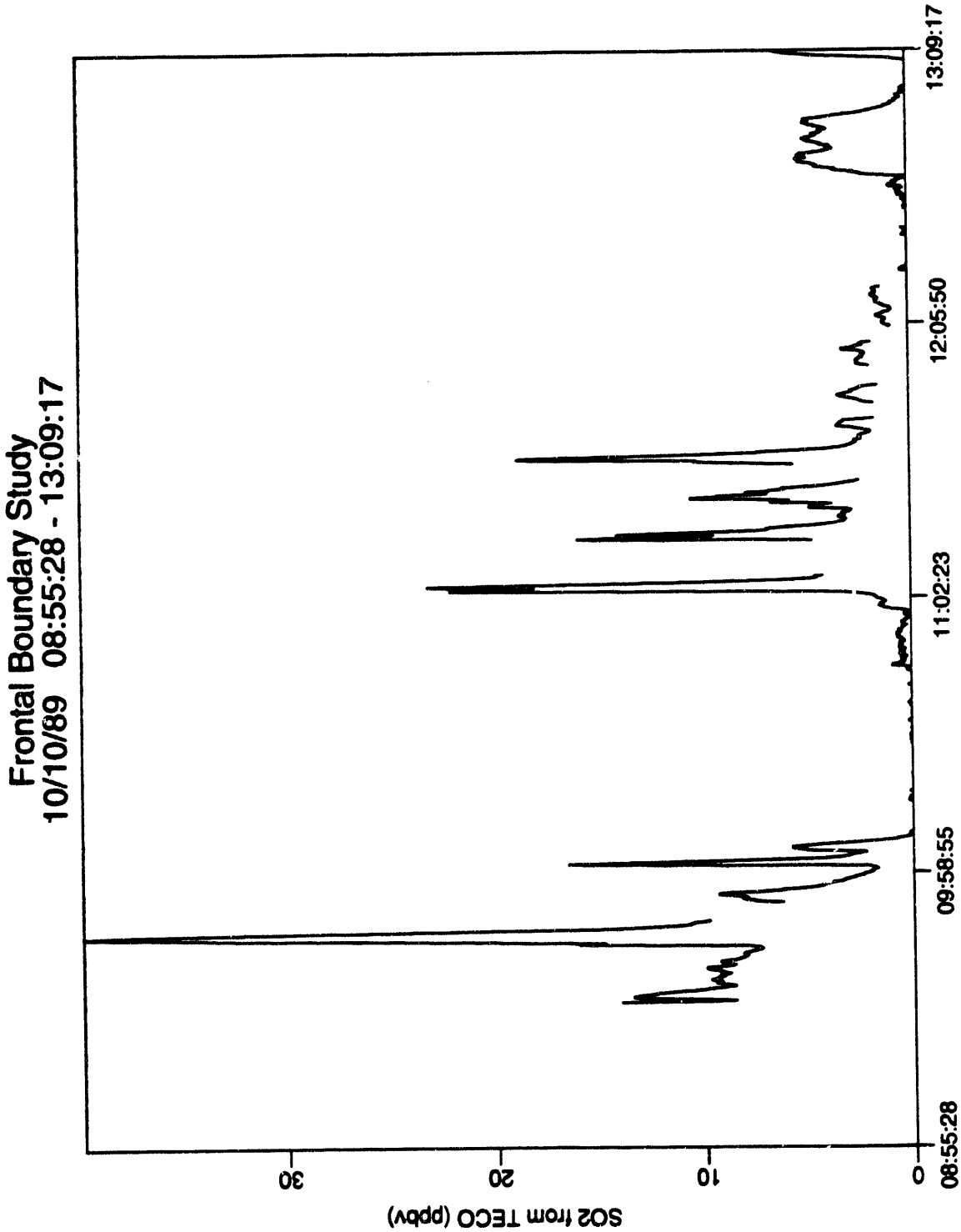


FIGURE A.9. SO_2 (ppbv)

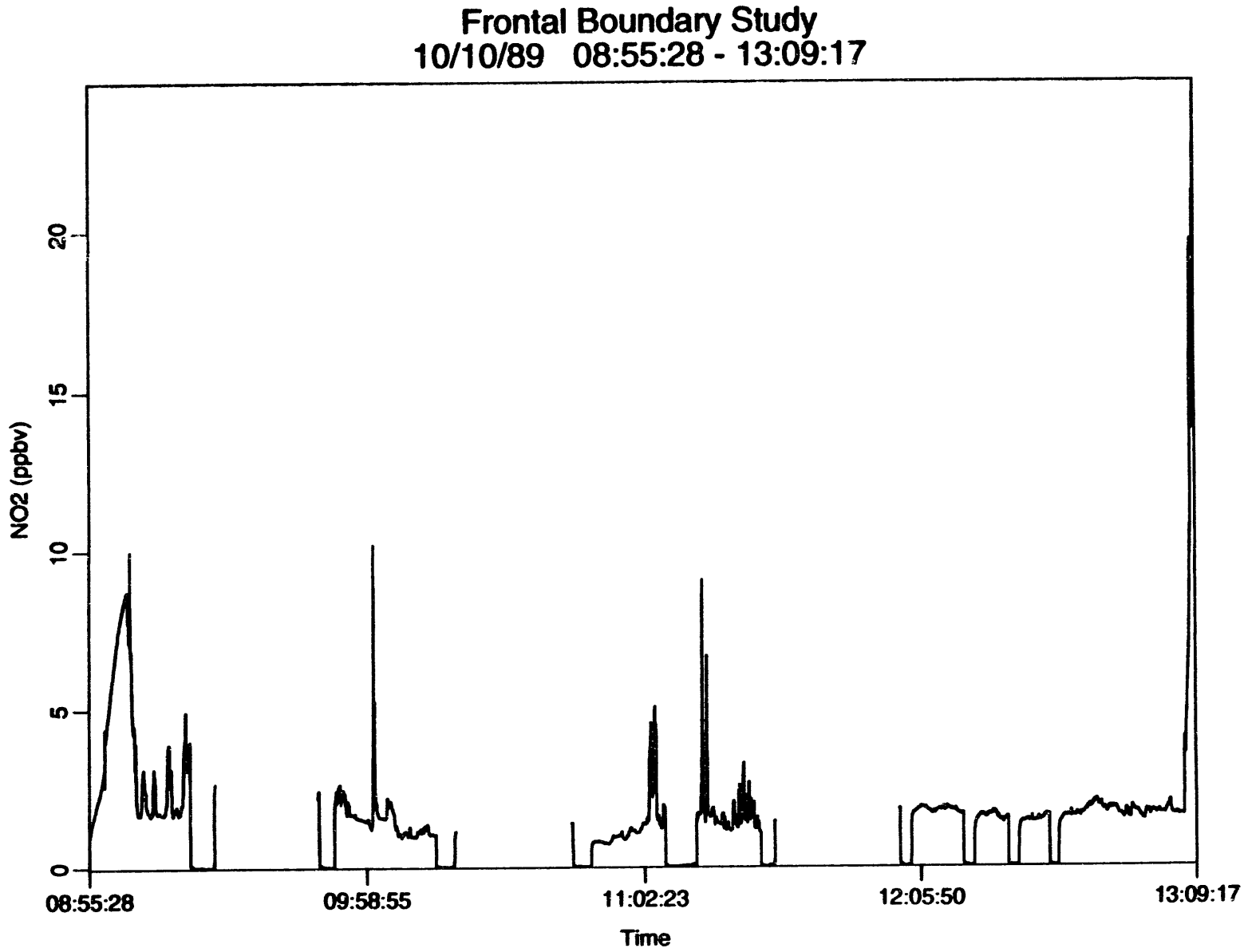


FIGURE A.10. NO_2 (ppbv)

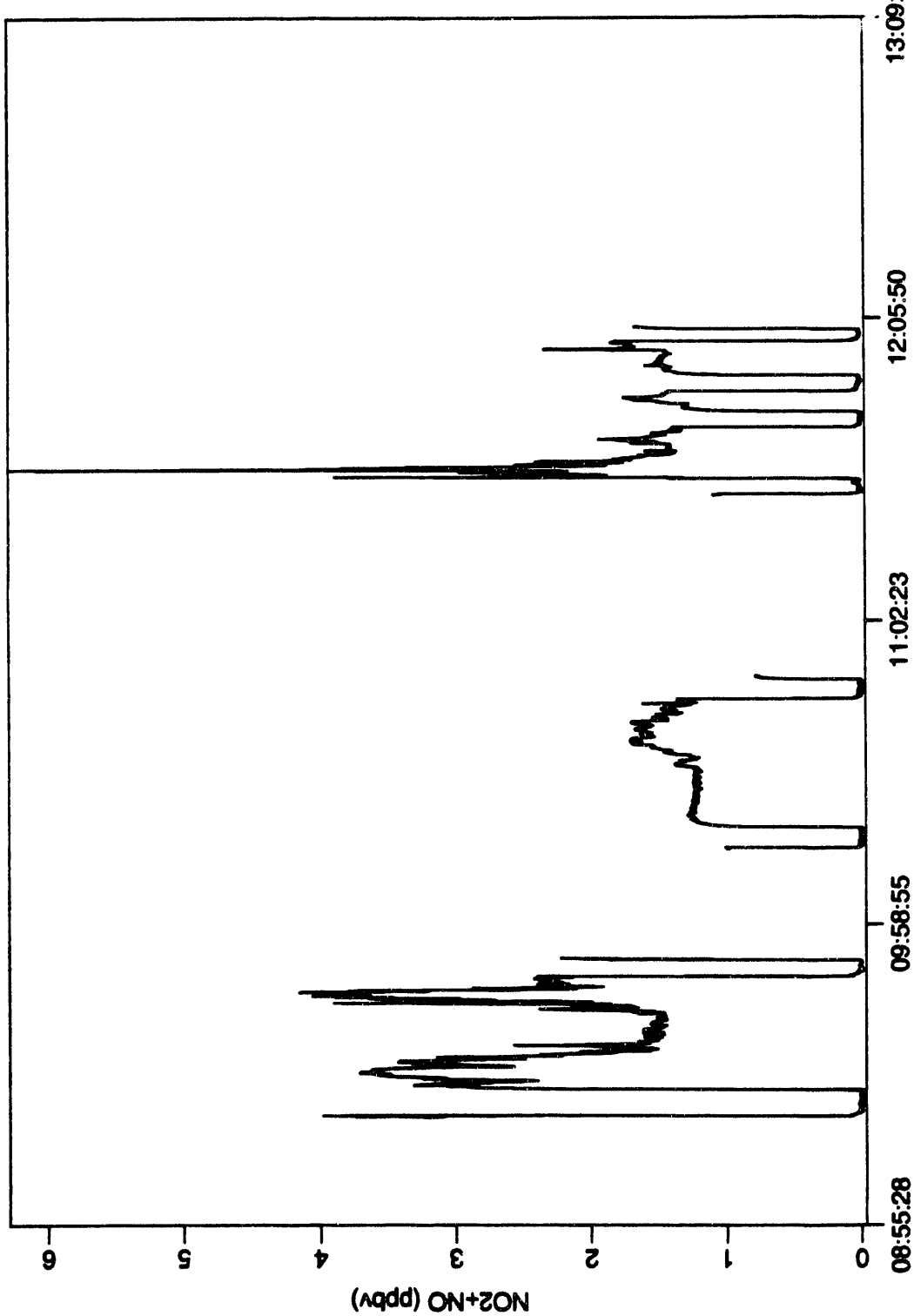


FIGURE A.11. NO_2 + NO (ppbv)

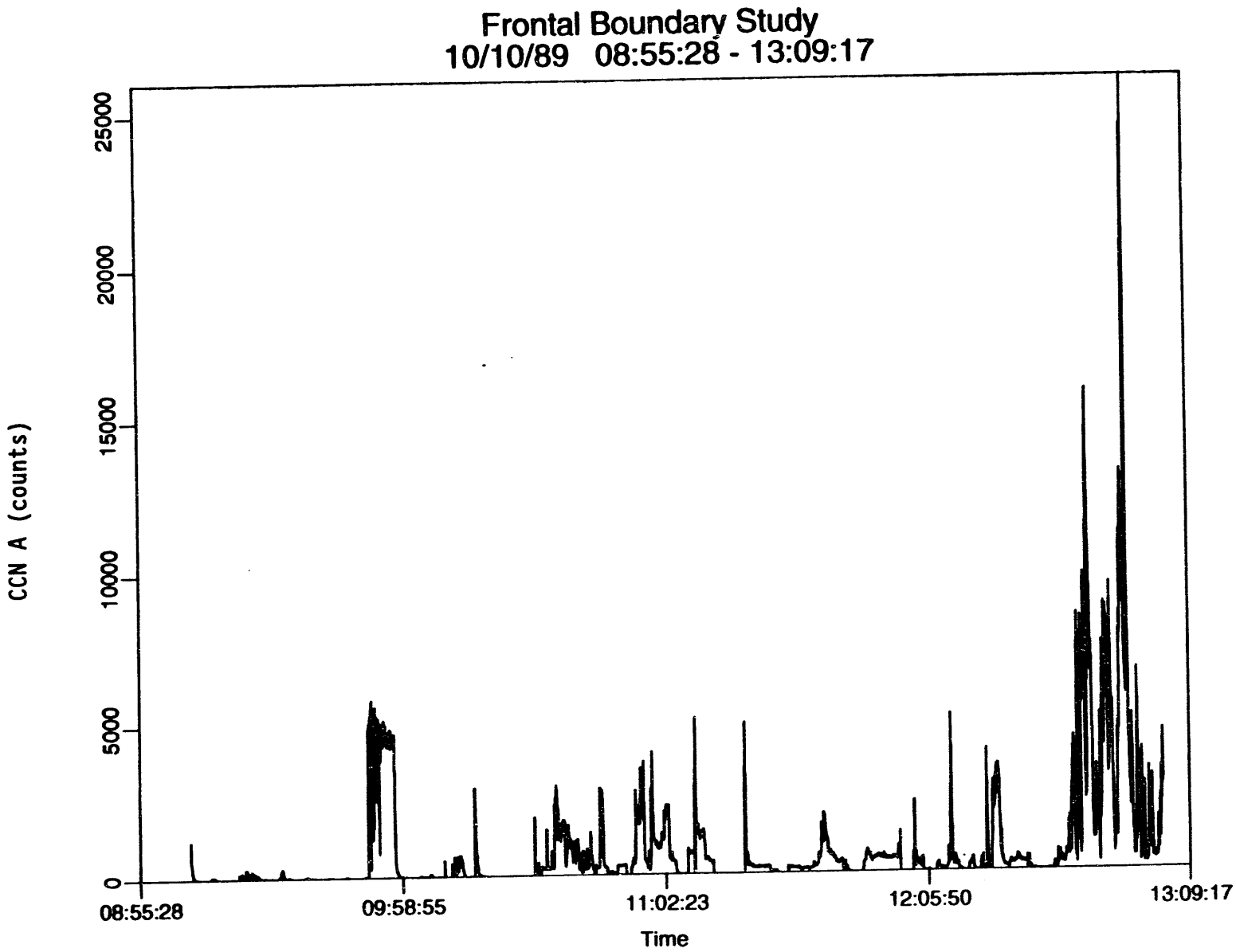


FIGURE A.12. Cloud Condensation Nuclei (counts)

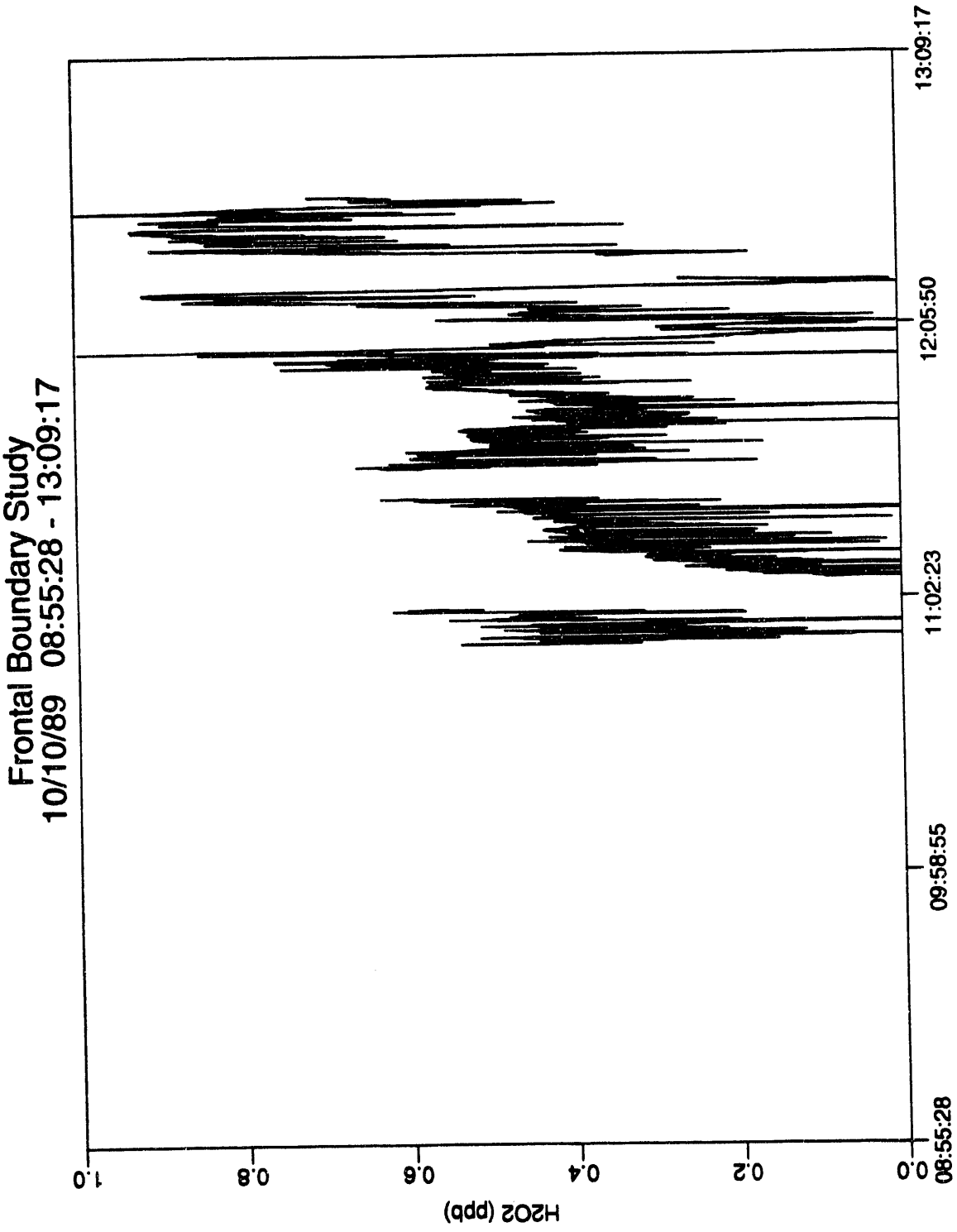


FIGURE A.13. H_2O_2 (ppb)

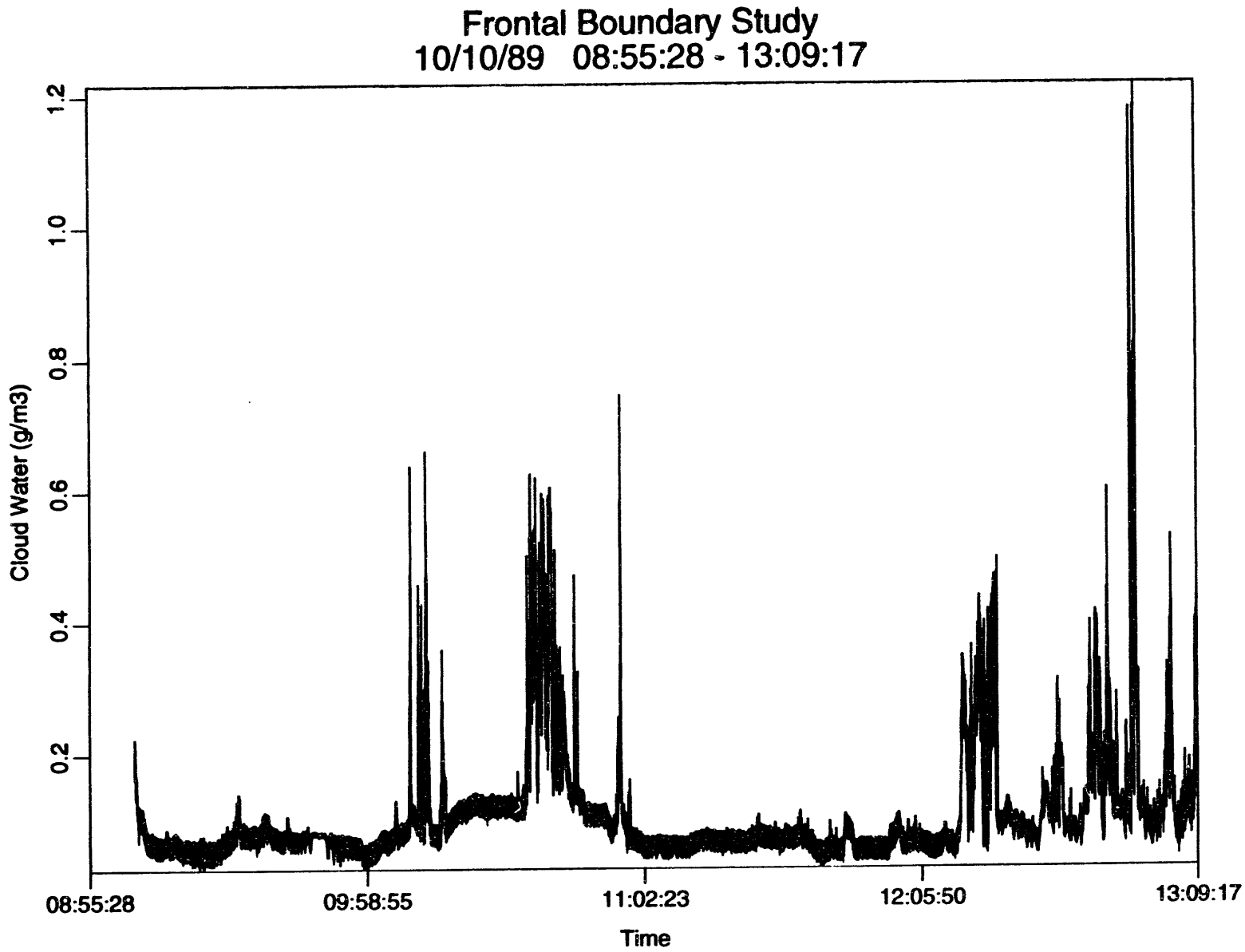


FIGURE A.14. Cloud Water (g/m^3)

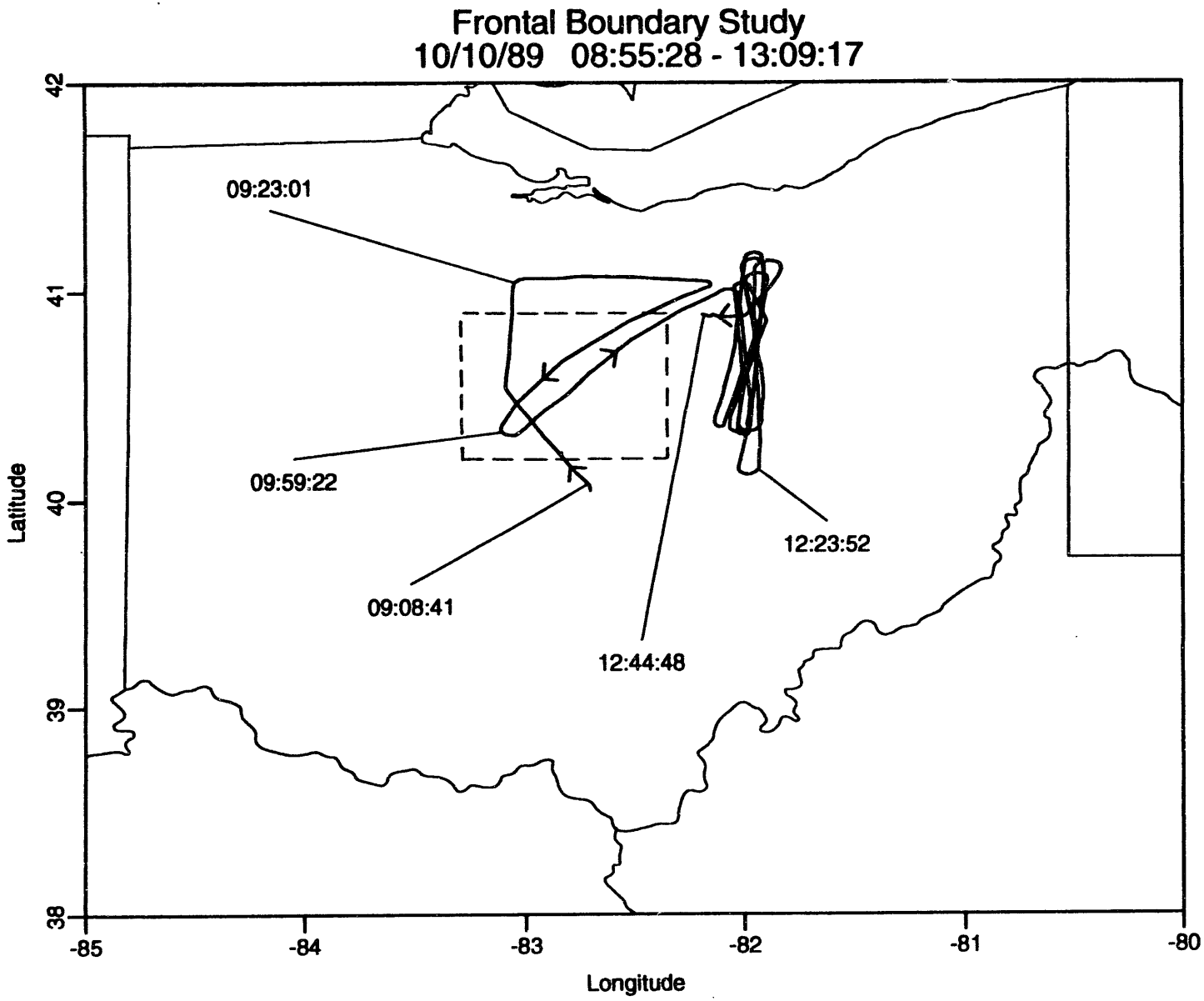


FIGURE A.15. Aircraft Flight Track

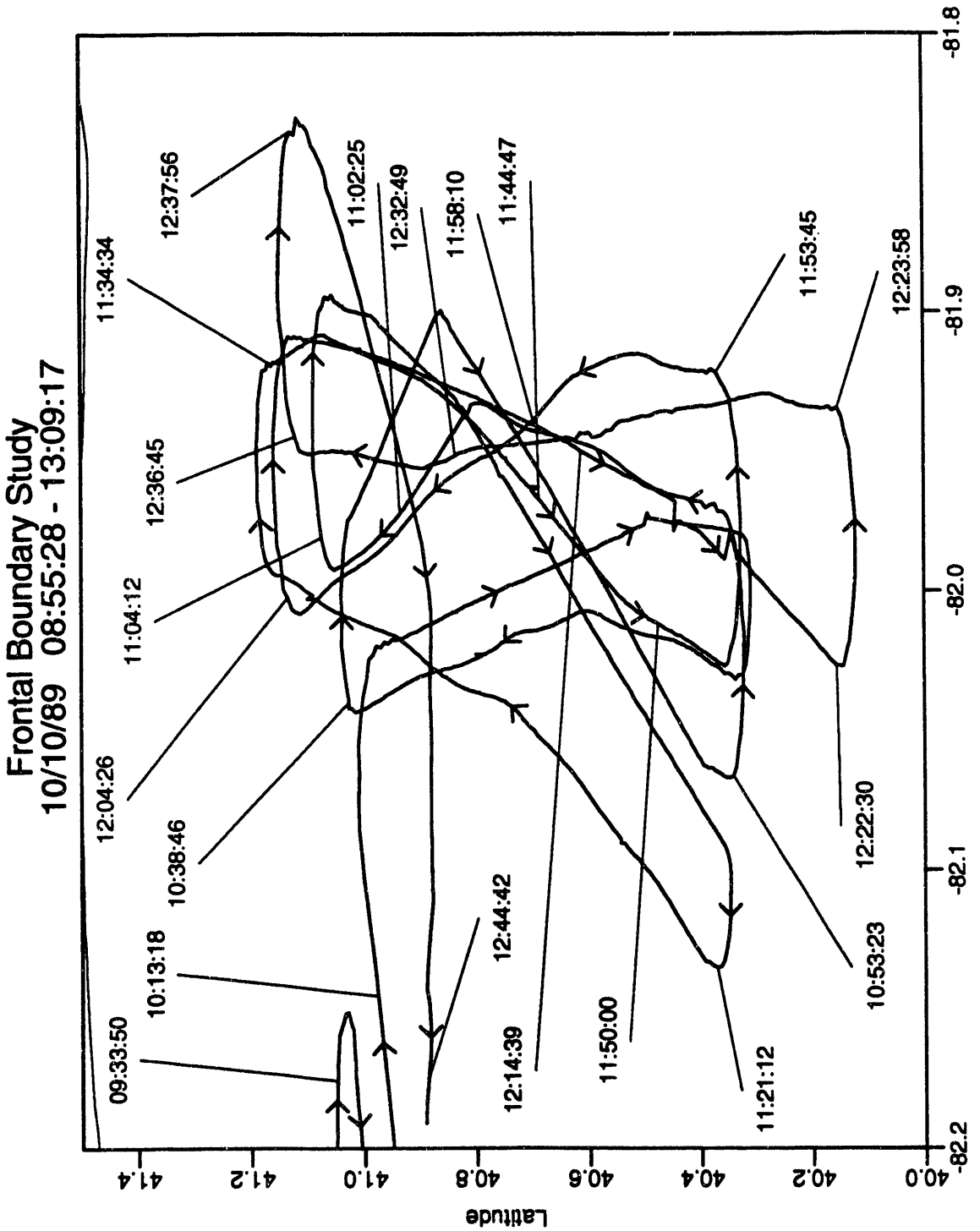


FIGURE A.16. Expanded Portion of Aircraft Flight Track

Disk File Structure

The averaged aircraft data, on two 3-1/2-in. disks in ASCII format, is available from PNL. Table A.1 provides the parameter ranges and a hard copy of a few records that show the structure of the ASCII disk files.

AIRCRAFT FILTER DATA

Table A.2 lists the aerosol and gaseous concentration data from the aircraft filter analyses.

TABLE A.1. Structure of the G-1 Aircraft Data Channel Files on Disks FBS03A and FBS03B

```
Frontal Boundary Study  10/10/89
mission 03
data interval = 1 s
17 columns
Hour 8 10 (start and end times, GMT)
Minute 55 29
Second 28 59
-99 indicates missing or invalid data
Parameter with min value, max value, unit:
"Latitude" 40.0465 41.1878 decimal degrees
"Longitude" -83.114 -81.83 decimal degrees
"Altitude" 263.1 4024.4 meters msl
"Pressure" 614.7 982.5 millibars
"Temperature" -11 17.5 deg C
"Dew Point" -11 10.7 deg C
"Aerosol Scattering" 0 2.54 x10-4/m
"O3" 7.1 68.5 ppb
"SO2" 0 39.67 ppb
"NO2" 0.7 24.7 ppb
"NO2+NO" 1.11 6.28 ppb
"CNC" 0 26059 counts
"H2O2" 0 1 ppb
"Cloud Water" 0.02 1.22 g/m3
```

H:MM:SS	Lat	Long	Alt	Press	Temp	DP	bsc	O3	SO2	NO2	NOx	CNC	H2O2	CW
9 30 12	41.0658	-82.4503	932.9	906.5	14.5	0.6	0.20	57.5	13.46	-99.0	2.78	45.4	-99.000	0.06
9 30 13	41.0658	-82.4503	932.6	906.5	14.5	1.8	0.21	57.5	13.49	-99.0	2.81	45.4	-99.000	0.07
9 30 14	41.0658	-82.4503	932.3	906.5	14.6	1.1	0.20	57.5	13.48	-99.0	2.82	38.1	-99.000	0.08
9 30 15	41.0658	-82.4503	932.0	906.6	14.5	1.2	0.20	57.5	13.44	-99.0	2.82	38.1	-99.000	0.09
9 30 16	41.0658	-82.4503	931.4	906.6	14.6	1.5	0.20	55.2	13.45	-99.0	2.86	33.9	-99.000	0.09
9 30 17	41.0655	-82.4430	931.7	906.6	14.5	0.5	0.21	55.2	13.43	-99.0	2.89	33.9	-99.000	0.09
9 30 18	41.0655	-82.4430	931.4	906.6	14.4	1.7	0.22	55.2	13.42	-99.0	2.92	30.7	-99.000	0.09
9 30 19	41.0655	-82.4430	931.7	906.6	14.5	1.1	0.20	55.2	13.38	-99.0	2.89	30.7	-99.000	0.09
9 30 20	41.0655	-82.4430	931.7	906.6	14.5	0.9	0.20	57.5	13.32	-99.0	2.74	23.4	-99.000	0.09
9 30 21	41.0655	-82.4430	932.0	906.6	14.6	1.7	0.20	57.5	13.31	-99.0	2.59	23.4	-99.000	0.08
9 30 22	41.0655	-82.4430	932.3	906.5	14.5	0.6	0.20	57.5	13.30	-99.0	2.48	21.7	-99.000	0.06
9 30 23	41.0648	-82.4355	932.3	906.5	14.4	1.7	0.21	57.5	13.30	-99.0	2.53	21.7	-99.000	0.06
9 30 24	41.0648	-82.4355	932.9	906.5	14.6	1.4	0.20	53.6	13.27	-99.0	2.67	21.8	-99.000	0.07
9 30 25	41.0648	-82.4355	932.6	906.5	14.5	0.8	0.22	53.6	13.26	-99.0	2.76	21.9	-99.000	0.09
9 30 26	41.0648	-82.4355	932.6	906.5	14.6	1.7	0.22	53.6	13.24	-99.0	2.83	21.7	-99.000	0.09
9 30 27	41.0648	-82.4355	932.9	906.5	14.5	0.6	0.21	53.5	13.22	-99.0	2.88	21.7	-99.000	0.09

TABLE A.2. G-1 Aircraft Filter Sample Results from the Event FBS 03 Experiment

Sampling Period GMT	Alt. ft. msl	--aerosol--- $[SO_4]$ $\mu g/m^3$	$[NO_3]$ $\mu g/m^3$	$[HNO_3]$ ppb	$[NH_3]$ ppb
0922-0952	3000	3.32	0.78	0.21	0.33
1013-1043	10000	0.75	0.07	0.04	0.37
1106-1136	5000	0.35	0.21	0.08	misg
Uncertainty	±	0.08	0.04	0.01	0.5

APPENDIX B

PRECIPITATION CHEMISTRY DATA - FBS 03

APPENDIX B

PRECIPITATION CHEMISTRY DATA - FBS 03

NETWORK DESCRIPTION

Table B.1 lists the network sampling site locations and coordinates for the map of active sites in Figure B.1. Note that sites 155 and 182 are co-located with sites 55 and 82, respectively. The data file F03SILOC.TXT contains the table and F03SILOC.DOC describes the data columns.

Data Tables

1. F03MEV.TXT -- The Rainfall Data

   Table B.2 (included as F03MOV.DOC) describes the data columns and format for the rainfall data.

2. F03STMEV.TXT -- Stage Data

   Table B.3 (F03STMEV.DOC) describes the data columns and format for stage data. This table is similar to the rainfall data table. The differences:

   - The stage rainfall rate replaces the increment rainfall rate; this quantity is calculated using the time since the first rainfall increment was recorded, rather than since the actual beginning of rainfall, which is often not well defined.
   - The data rows correspond to data rows coded 2 or 3 in the rainfall data base; i.e., the end increments of stages.
   - Rainfall chemistry data are added to the data rows.

3. F03EVP.TXT -- Event Data

   Table B.4 lists the precipitation-weighted event concentrations and total rainfall, and explains the data headings and format (F03EVP.DOC). Only sites with complete event records are included.

TABLE B.1. Event FBS 03 Site Locations (File F03SILOC.TXT).

SITE	LODEG	LOMIN	LADEG	LAMIN	X	Y
12	83	4.0	40	56.7	23	91
14	82	52.2	40	55.8	40	90
16	82	43.2	40	56.9	53	92
18	82	31.2	40	56.6	71	91
21	83	15.9	40	46.2	6	72
22	83	4.8	40	48.3	22	76
24	82	54.6	40	47.2	37	74
26	82	43.3	40	47.4	53	74
28	82	30.6	40	48.6	71	76
29	82	18.1	40	48.0	89	75
35	82	46.2	40	42.6	48	65
41	83	15.6	40	39.6	7	60
42	83	4.8	40	39.6	22	60
44	82	53.0	40	39.0	39	59
46	82	41.5	40	37.8	56	56
48	82	32.0	40	39.0	69	59
49	82	20.4	40	38.4	86	57
53	82	58.8	40	34.8	31	51
55	82	46.8	40	36.0	48	53
57	82	36.4	40	36.0	63	53
61	83	15.5	40	29.4	7	41
62	83	3.5	40	31.2	24	44
64	82	51.2	40	31.2	42	44
66	82	43.3	40	29.4	53	41
68	82	31.8	40	30.0	70	42
69	82	23.4	40	31.2	82	44
75	82	46.9	40	27.0	48	37
81	83	16.4	40	21.6	5	27
82	83	3.5	40	21.6	24	27
84	82	52.5	40	21.6	40	27
86	82	42.6	40	21.6	54	27
88	82	30.6	40	19.8	71	23
89	82	20.4	40	21.0	86	25
92	83	4.6	40	12.6	22	10
94	82	51.6	40	13.2	41	11
96	82	40.8	40	12.0	57	9
98	82	30.0	40	13.2	72	11
155	82	46.8	40	36.0	48	53
182	83	3.5	40	21.6	24	27

TABLE B.1. (contd)

Header description and format.

1	2	3	4	5	6	7
SITE	LODEG	LOMIN	LADEG	LAMIN	X	Y

COL. NO.	COL. NAME	FORMAT	DESCRIPTION	UNITS
1	SITE	I7	SITE NUMBER	
2	LODEG	I7	LONGITUDE DEGREES E	DEG
3	LOMIN	F7.1	LONGITUDE MINUTES E	MIN
4	LADEG	I7	LATITUDE DEGREES N	DEG
5	LAMIN	F7.1	LATITUDE MINUTES N	MIN
6	X	I7	MAP X COORDINATE	KM
7	Y	I7	MAP Y COORDINATE	KM

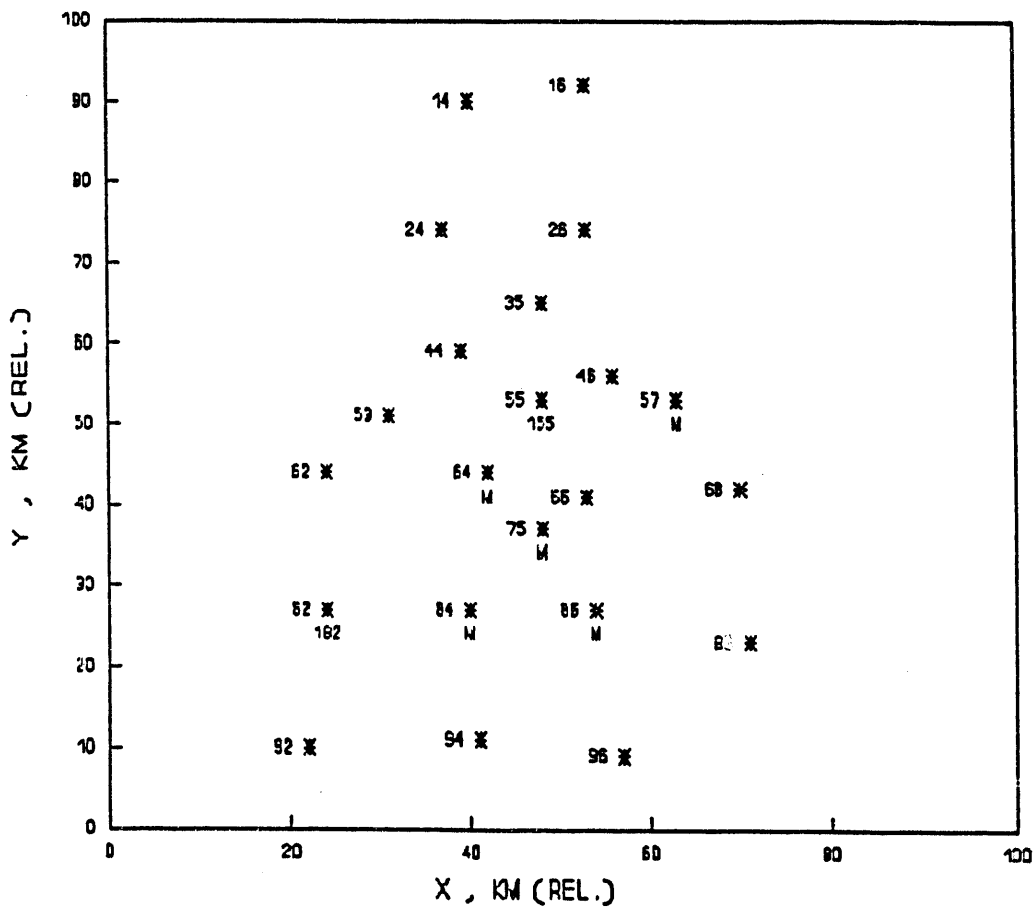


FIGURE B.1. Active Sampling Sites for Event FBS 03. "M" Indicates Site with Missing Chemistry and/or Precipitation Data

TABLE B.2. Header Explanation and Format for Rainfall Data Base F03MEV.TXT.

1	2	3	4	5	6	7	8	9
STG	DMP	DHR	TD1	DMPP	DMPJ	CUMP	SITE	CODE

COL. NAME	FOR-MAT	COL. NO.	DESCRIPTION	UNITS
STG	I7	1	CCARS STAGE NUMBER (1-9); OR, IF > 9, ROW IS A RAIN END OR RAIN RESUMPTION	-- TIME
DMP	I7	2	CCARS WITHIN-STAGE RAINFALL INCREMENT NUMBER, EXCEPT WHEN "STG" > 9	--
DHR	F7.2	3	TIME OF DAY OF END OF DMP	GMT
TD1	F7.2	4	TIME OF END OF DMP SINCE TIME OF FIRST "DMPP" RAIN RECORDED	HR
DMPP	F7.2	5	INCREMENT PRECIPITATION.	MM
DMPJ	F7.2	6	RAINFALL RATE FOR INCREMENT FOR INCREMENTS CODED 1, RATE IS MEASURED FROM TIME OF CCARS LID OPENING	MM/HR
CUMP	F7.2	7	CUMULATIVE PRECIPITATION FOR SITE	MM
SITE	I7	8	SITE NUMBER (SEE LOCATIONS FILE)	--
CODE	I7	9	1 = END OF FIRST INCREMENT OF RAIN AT SITE 2 = END OF CCARS STAGE 3 = END OF RAIN AT SITE BLANK = INTRA-STAGE RAIN INCREMENT	--

TABLE B.3. Header Description and Format for Stage Data FO3STMEV.TXT.

```
  1   2     3     4    5    6     7    8    9  10  11  12  13  14
 STG DMP   DHR   TD1 DMPP STGJ  CUMP SITE CODE SO4 NO3 NH4  Ca  H+
```

COL. NAME	FOR-MAT	COL. NO.	DESCRIPTION	UNITS
STG	I4	1	CCARS STAGE NUMBER (1-9)	--
DMP	I4	2	NUMBER OF CCARS RAINFALL INCREMENTS IN STAGE	--
DHR	F6.2	3	TIME OF DAY OF END OF STAGE	GMT
TD1	F6.2	4	TIME OF END OF STAGE SINCE TIME OF FIRST "DMPP" RAIN RECORDED	HR
DMPP	F5.2	5	LAST INCREMENT PRECIPITATION	MM
STGJ	F5.2	6	RAINFALL RATE FOR STAGE, BASED ON TD1 TIMING	MM/HR
CUMP	F6.2	7	CUMULATIVE PRECIPITATION FOR SITE	MM
SITE	I4	8	SITE NUMBER (SEE LOCATIONS FILE)	--
CODE	I4	9	2 = END OF CCARS STAGE 3 = END OF RAIN AT SITE	--
SO4,	I4	10-14	STAGE CONCENTRATIONS OF CHEMICAL SPECIES 0 = AT OR BELOW DETECTION LIMIT -99 = MISSING OR NO-RAIN PERIOD	uM

TABLE B.4. Event Data for File F03EVP.TXT

1	2	3	4	5	6	7	8	9	10	11	12
SITE	X	Y	P	SO4	NO3	H	NH4	Cl	Na	Ca	Mg
14	40	90	11.3	34	53	51	48	9.6	2.4	12.6	2.9
16	53	92	8.2	40	53	52	59	15.2	1.4	19.7	5.3
24	37	74	6.5	41	54	36	85	13.0	3.5	17.5	4.3
26	53	74	8.4	31	39	43	47	10.7	1.0	11.9	3.0
35	48	65	7.5	32	43	32	40	11.3	3.1	20.9	5.2
44	39	59	6.3	33	44	39	35	12.3	3.1	18.4	5.0
53	31	51	7.4	39	52	17	43	10.5	1.6	30.6	11.5
55	48	53	9.2	33	41	33	38	8.8	1.9	16.1	4.5
62	24	44	7.6	36	47	21	41	9.6	1.7	28.1	8.4
66	53	41	12.1	31	34	38	43	9.7	1.1	11.5	2.7
68	70	42	7.3	29	29	26	44	5.5	1.2	10.7	3.3
82	24	27	8.0	39	49	57	51	5.6	2.1	15.8	2.6
88	71	23	9.6	29	35	41	42	3.8	1.9	9.0	2.0
92	22	10	14.6	36	44	39	56	2.9	0.7	13.6	3.2
94	41	11	11.6	34	37	38	49	4.1	1.6	9.6	2.5
96	57	9	9.4	35	38	3	78	5.5	6.3	17.2	3.1

Header description and format for event data F03EV.TXT

1	2	3	4	5	6	7	8	9	10	11	12
SITE	X	Y	P	SO4	NO3	H	NH4	Cl	Na	Ca	Mg

COL NO	COL NAME	FORMAT	DESCRIPTION	UNITS
1	SITE	I5	SITE NUMBER	
2	X	I5	MAP X COORDINATE	KM
3	Y	I5	MAP Y COORDINATE	KM
4	P	F5.1	EVENT PRECIPITATION	MM
5	SO4	I5	SULFATE CONCENTRATION	uM
6	NO3	I5	NITRATE CONCENTRATION	uM
7	H	I5	HYDROGEN CONCENTRATION	uM
8	NH4	I5	AMMONIUM CONCENTRATION	uM
9	Cl	F5.1	CHLORIDE CONCENTRATION	uM
10	Na	F5.1	SODIUM CONCENTRATION	uM
11	Ca	F5.1	CALCIUM CONCENTRATION	uM
12	Mg	F5.1	MAGNESIUM CONCENTRATION	uM

APPENDIX C

METEOROLOGICAL DATA

APPENDIX C

METEOROLOGICAL DATA

The following information is presented in this appendix:

- a narrative of the synoptic conditions over Ohio on 10/10/89
- a map (Figure C.1), showing the sequential 3-hourly surface frontal positions for the period 0000-2100 GMT, 10/10/89
- contour plots of 850, 700, 500, and 300 mb constant pressure surfaces for 10/10/89 (Figures C.2-C.8)
- Table C.1, a composite time-series table showing
  - precipitation periods and hourly amounts at Columbus (CMH) and Mansfield (MFD), Ohio, and composite precipitation periods for the north and south grid sites
  - hourly determinations of sky cover, cloud type, cloud base height, and precipitation type for CMH and MFD, and the average height of the precipitation cells as determined by the CMH radar
  - hourly wind velocities at CMH and MFD
  - a time box identifying rawinsonde release times, radar image recordings, and the G-1 aircraft flight period
  - a legend to interpret the meteorological symbols and abbreviations

  (The meteorological information in Table C.1 has been digitized and put on an enclosed disk. The structure of this file is shown in Table C.2.)
- skew T plots of the rawinsonde data for 0730, 1000 and 1400 GMT (Figures C.9, C.10 and C.11). Hard copy and ASCII disk files of the edited rawinsonde data are included in this packet. Table C.3 describes the structure of the rawinsonde files. A cross section of the potential temperature structure from Atlantic City, New Jersey, to Topeka, Kansas, using 1200 GMT rawinsonde data, is shown in Figure C.12.
- a set of photographic prints, made at approximately 15-min intervals, of an enlarged portion of the northern sector of the monitor screen for the CMH weather radar. A catalog of the prints, and a brief guide to interpreting the photographs is included.

Synoptic Weather Pattern and Conditions for October 10, 1989
Columbus, OH FBS Experiment No. 3

The warm front from a weather system that was located west of Ohio early in the day, passed through the Columbus area at about 0600 GMT (0200EDT), and by 2100 GMT was located from southern Lake Huron to western Lake Ontario (Figure C.1). The cold front (at 0600 GMT) was located along a line extending from near Chicago, Illinois, southwestward across the state, then north of St. Louis, Missouri, to the panhandle of Texas. The low pressure center associated with this weather system was located over eastern Wisconsin at this time. Aloft, a trough of low pressure extended from Lake Superior to Arkansas.

During the day the low moved eastward to be over Lake Huron by 2100 GMT, and at that time the cold front had just passed Columbus. The cold front was weakening and becoming hard to identify south of Ohio. Thus, from about 0600 GMT until 2100 GMT the Columbus area was experiencing weather associated with the warm sector, between the warm and cold fronts of this system.

No precipitation from the overrunning cloudiness in advance of the warm front was reported at Columbus, but light rain showers did begin at Columbus in the warm sector air at 1020 GMT. These showers were indicated on the Columbus weather radar as a wide band of mostly level 1 echoes that approached Columbus from the west. These showers were confined to the warm sector air. Following this first major band of precipitation, subsequent radar echoes showed a continuing series of narrow bands of showers and thundershowers that developed in western Ohio and that would then move eastward over the Columbus area. This weather pattern persisted until shortly after noon local time (1725 GMT). A few thunderstorms embedded within these precipitation bands were evident from the Columbus weather radar. Based on radar observations, the precipitation that fell on the sampling grid occurred before the arrival of the cold front. The cold front passed Columbus at about 2030 GMT.

From 0900 to 1315 GMT, one research aircraft flight was made over and near the sampling network; the aircraft took air samples at 3000, 5000, and 10000 feet MSL. In addition, a stepped-profile from 3000 to 13000 feet was flown.

On the surface network, sequential samples were collected at 23 sites; precipitation amounts at the sites averaged 10 mm during the period 0800-1700 GMT.

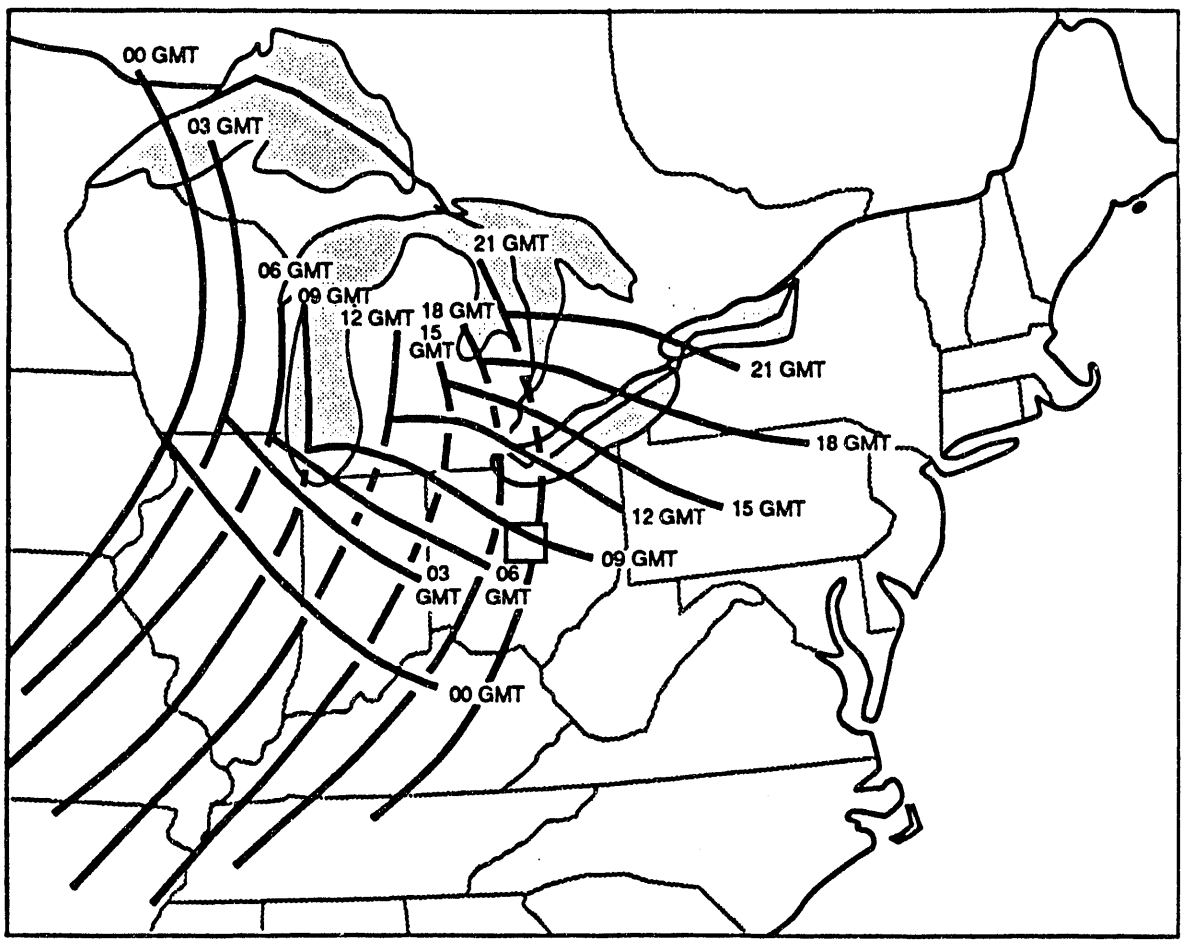


FIGURE C.1. Three-Hourly Sequential Positions of the Midwest Frontal System on October 10, 1989

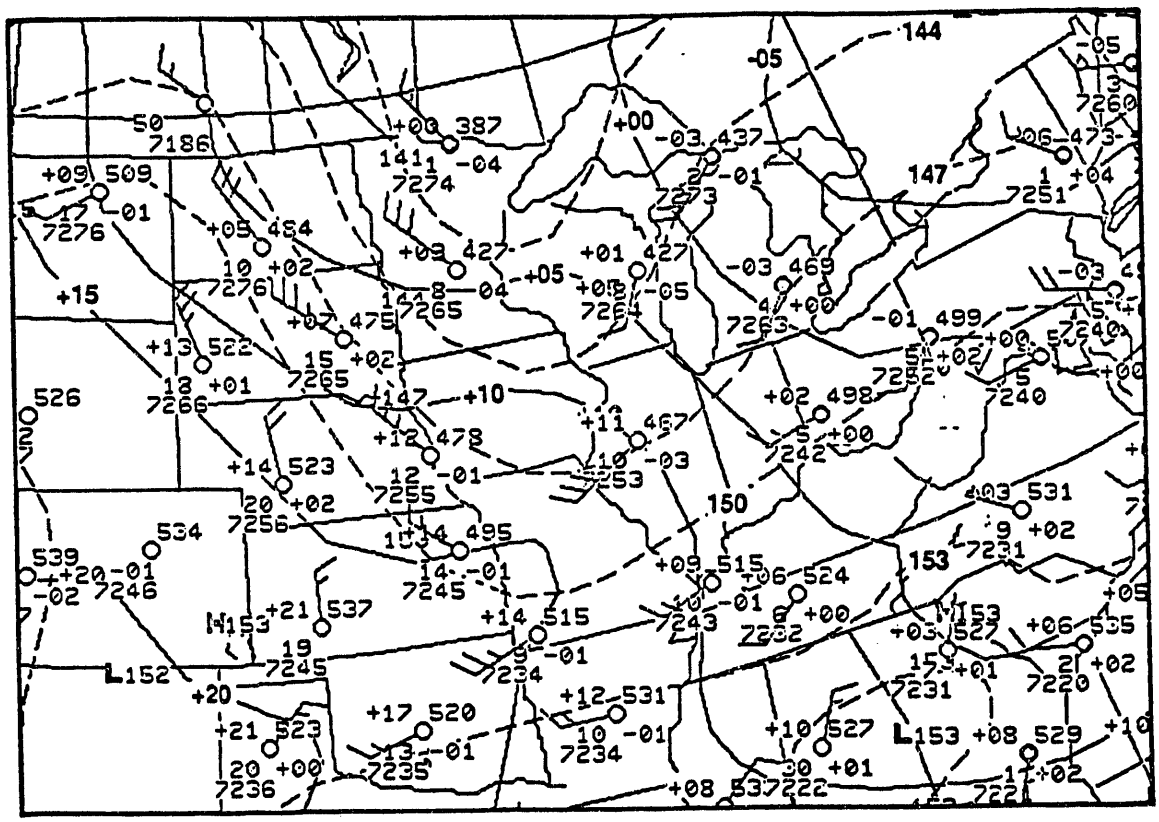


FIGURE C.2. Contour Plot of 850-mb Height (m*10, dashed line) and Temperature (°C, solid line) at 0000 GMT, October 10, 1989

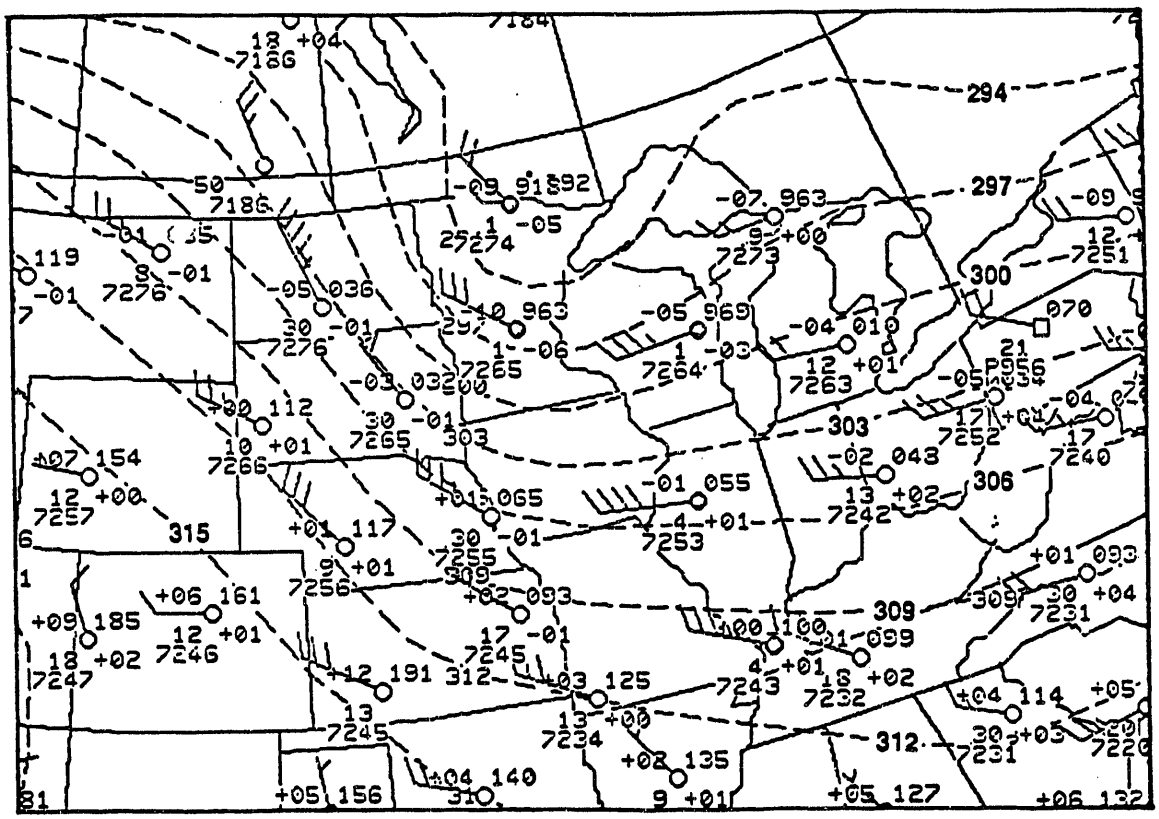


FIGURE C.3. Contour Plot of 700-mb Height (m*10, dashed line) at 0000 GMT, October 10, 1989

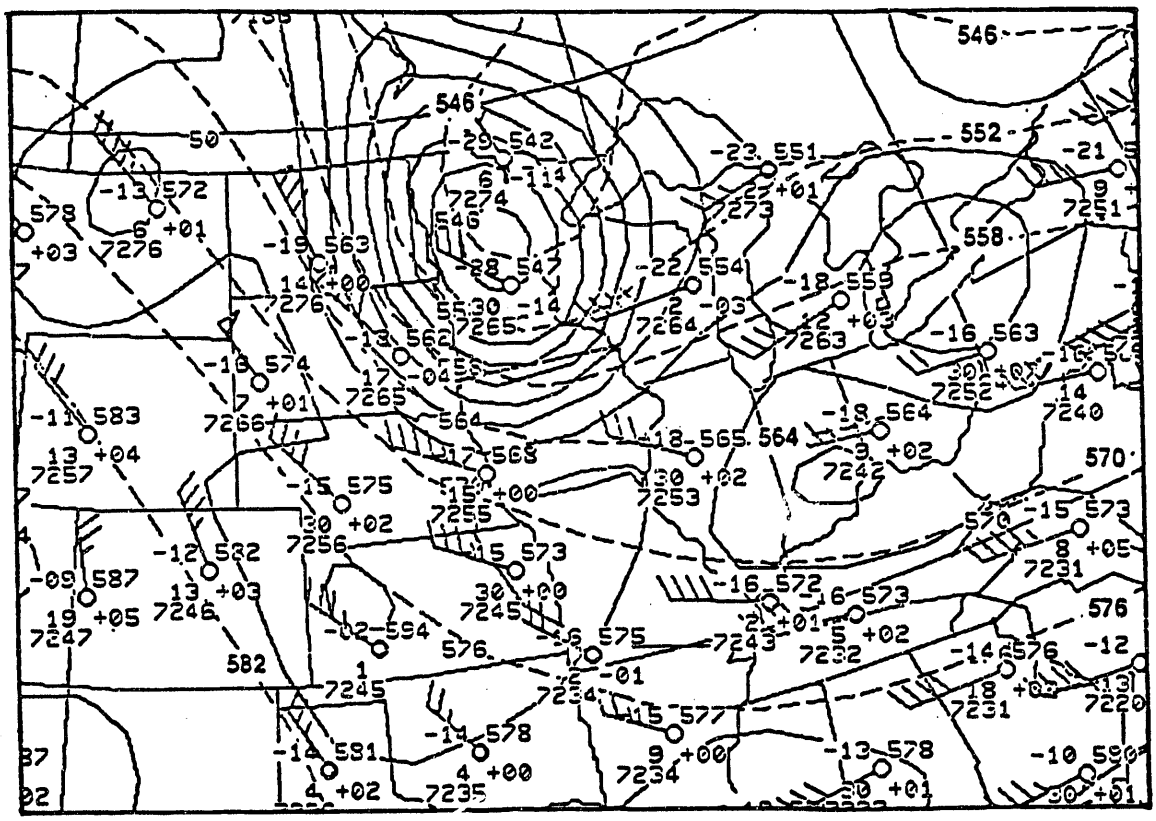


FIGURE C.4. Contour Plot of 500-mb Height (m*10, dashed line) and Vorticity (s^{-1}, solid line) at 0000 GMT, October 10, 1989

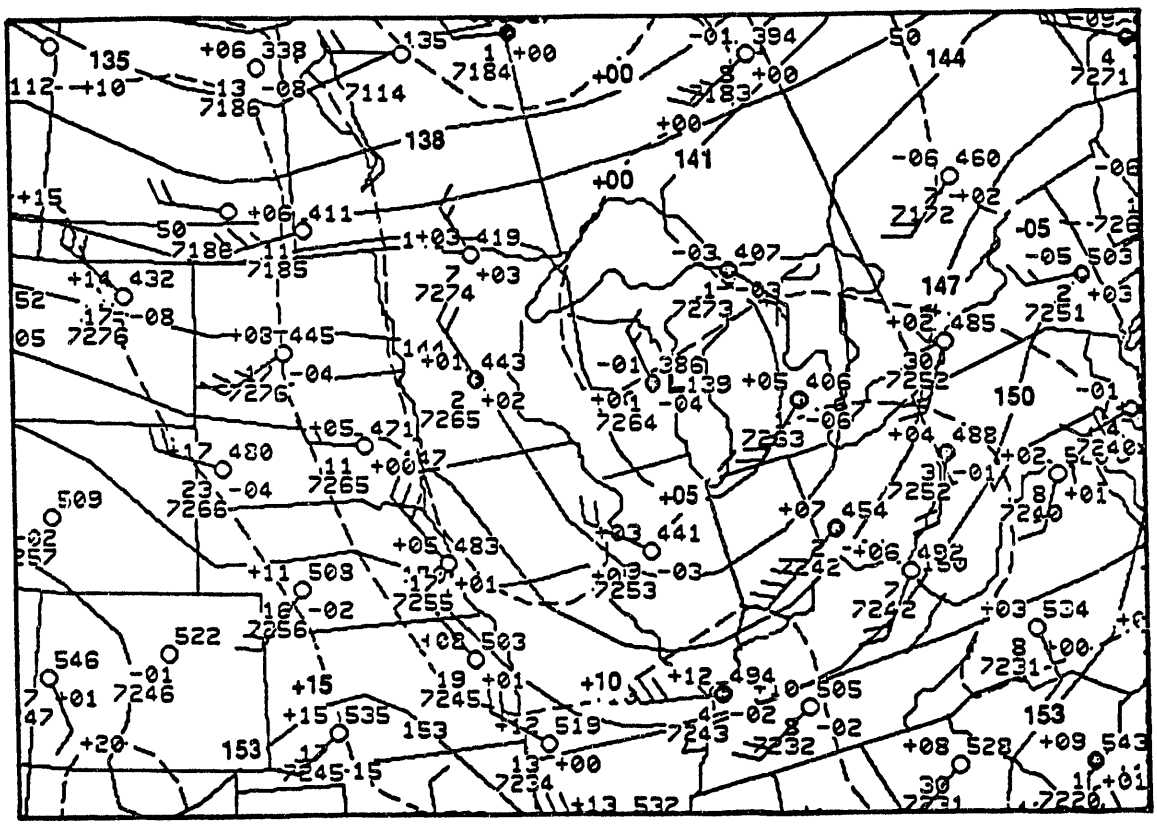


FIGURE C.5. Contour Plot of 850-mb Height (m*10, solid line) and Temperature (°C, dashed line) at 1200 GMT, October 10, 1989

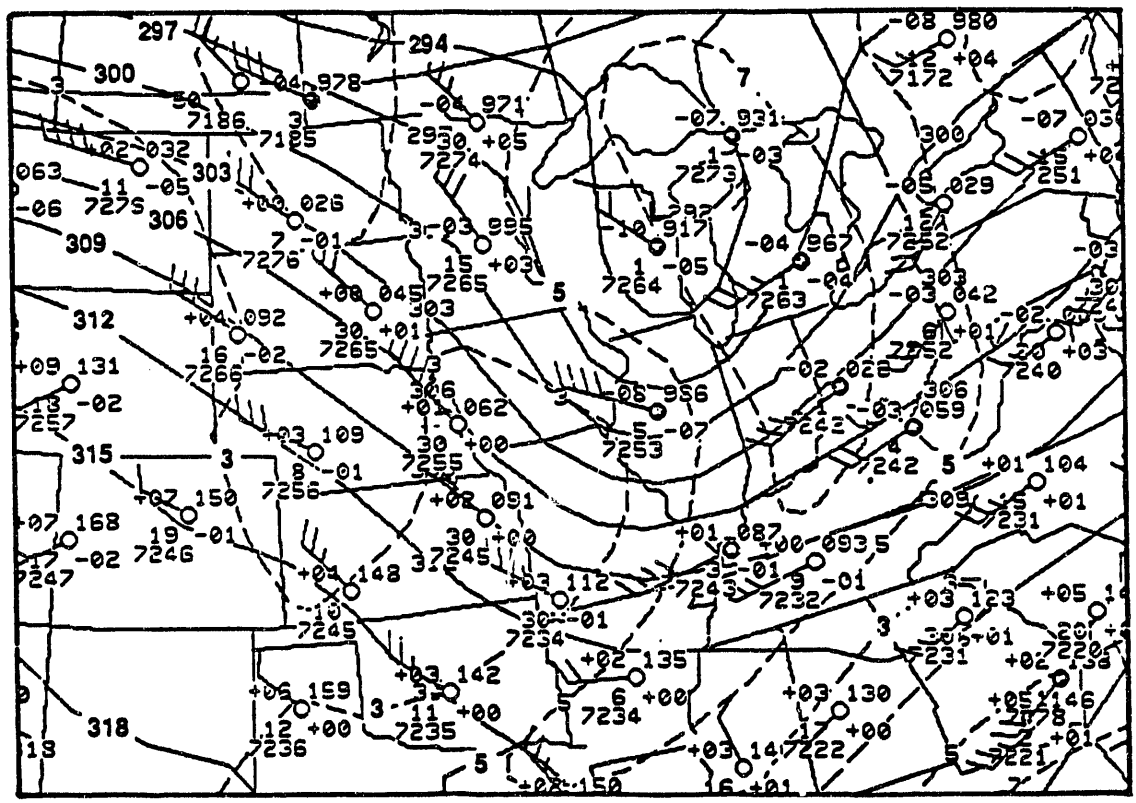


FIGURE C.6. Contour Plot of 700-mb Height (m*10, solid line) and Mean Relative Humidity (*10%, dashed line) at 1200 GMT, October 10, 1989

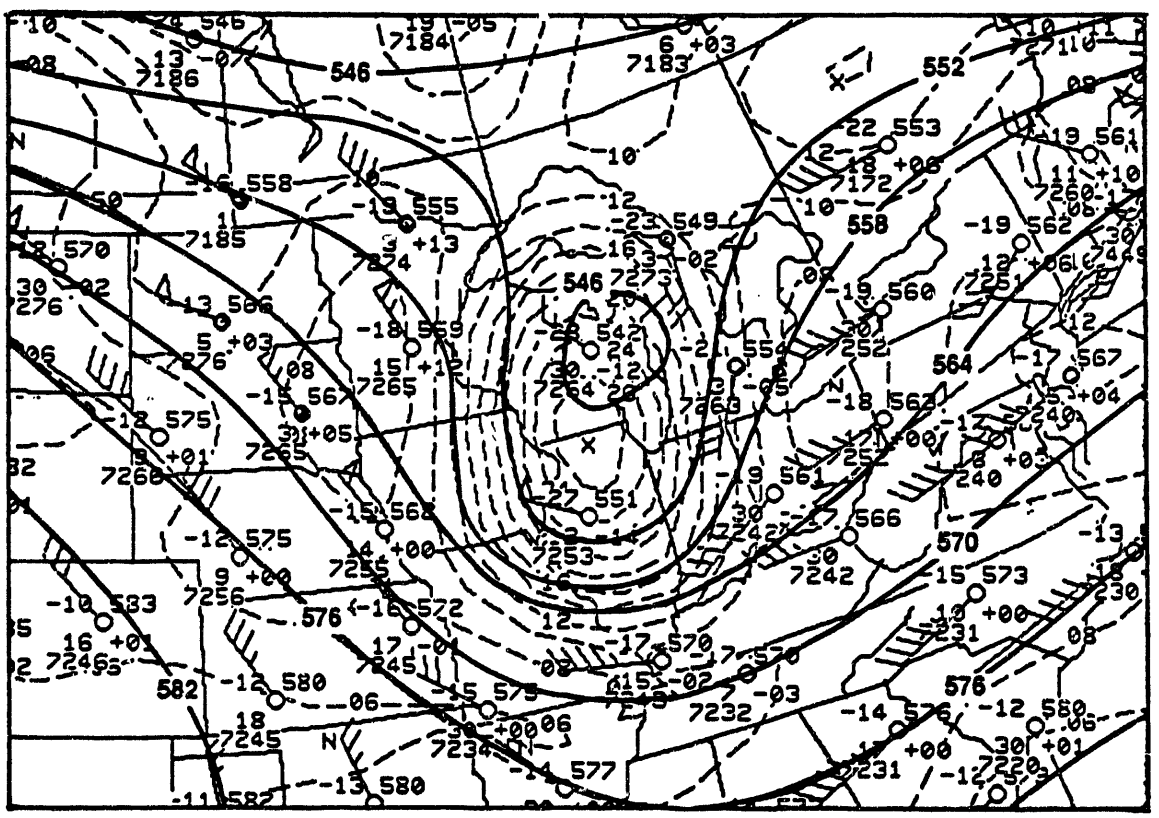


FIGURE C.7. Contour Plot of 500-mb Height (m*10, solid line) and Vorticity (s^{-1}, dashed line) at 1200 GMT, October 10, 1989

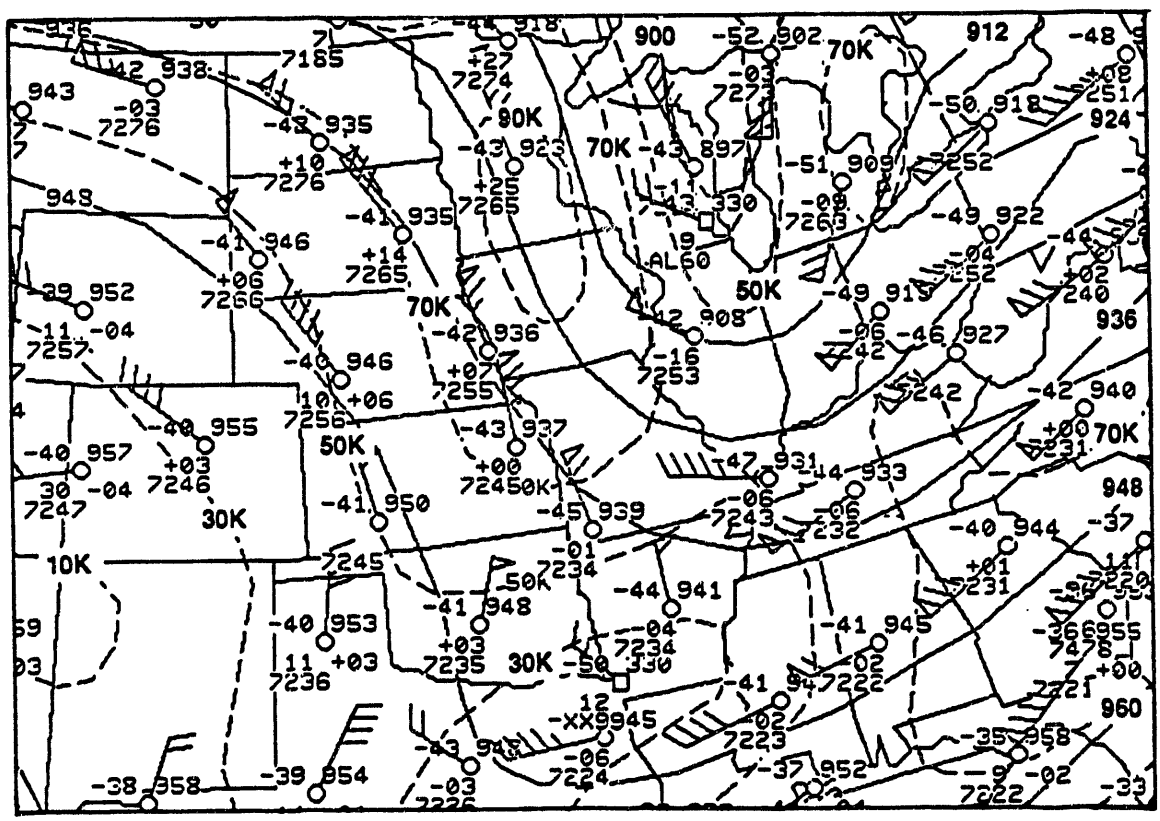
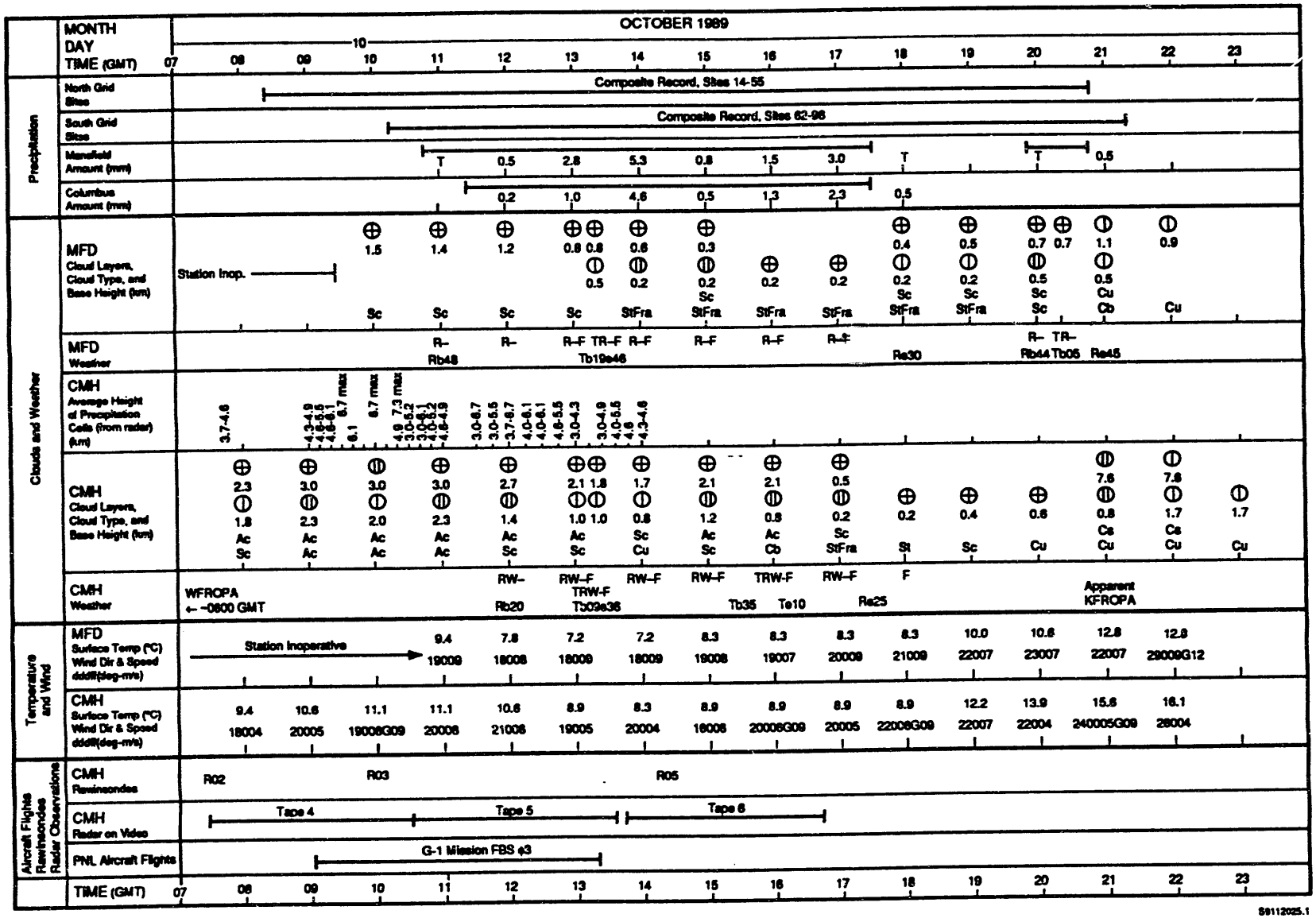


FIGURE C.8. Contour Plot of 300-mb Height (m*10, solid line) and Wind Speed (K=kts, dashed line) at 1200 GMT, October 10, 1989

TABLE C.1. Composite Time Series of Meteorological and Field Experiment Events on October 10, 1989



DESCRIPTIVE LEGEND OF SYMBOLS AND ABBREVIATIONS IN TABLE C.1

CATEGORY: CLOUD LAYERS, CLOUD TYPE

SYMBOL	MEANING
◑	1 to 5 tenths sky cover
◍	6 to 9 tenths sky cover
⊕	10 tenths sky cover
X	Sky obscured
St	Stratus clouds
Sc	Strato-cumulus clouds
StFra	Stratus-fractus clouds
Cu	Cumulus clouds
CuFra	Cumulus-fractus clouds
Cb	Cumulo-nimbus clouds
Ac	Alto cumulus clouds
As	Alto stratus clouds
Cs	Cirro stratus clouds
Ci	Cirrus clouds

CATEGORY: WEATHER

SYMBOL	MEANING
F	Fog
R	Rain
RW	Rain shower
T	Thunderstorm without precipitation
TRW	Thundershower
b	Minute after the hour that precipitation began
e	Minute after the hour that precipitation ended
- +	Precipitation intensity (- = light, = moderate, + = heavy)
WFROPA	Warm front passage
KFROPA	Cold front passage
LTGIC	Lightning in cloud
LTGCG	Lightning cloud to ground

CATEGORY: TEMPERATURE & WIND

SYMBOL	MEANING
G	Wind gust, i.e. 09G12 = speed 09m/s, gusts to 12m/s

CATEGORY: RAWINSONDES, RADAR OBSERVATIONS & AIRCRAFT FLIGHTS

SYMBOL	MEANING
R nn	PNL Project FBS sequential rawinsonde number
Tape nn	PNL recorded weather radar audio/video tape number
G-1	PNL Gulfstream G-1 aircraft flight period

FBS 03 HOURLY WEATHER, COLUMBUS AND MANSFIELD, OHIO

ID	YRMODA	TM-Z	CEILG	-	S	K	Y	-	T	R	L	A	F	DRSP	GUST	DB C	T	HT	T	HT	T	HT	LOW	HIGH	MAX	PCPN
CMH	891010	0745																					3.7	4.6		
CMH	891010	0800	2.3	2	8									18004		9.4	3	1.8	7	2.3						
CMH	891010	0900	2.3	5	8									20005		10.6	7	2.3	7	3.0			4.3	4.9		
CMH	891010	0912																					4.6	5.5		
CMH	891010	0920																					4.6	6.1	6.7	
CMH	891010	0930																							6.7	
CMH	891010	0940																					6.1		7.3	
CMH	891010	0950																							6.1	
CMH	891010	1000	3.0	2	5									19006	9	11.1	7	2.0	7	3.0					6.7	
CMH	891010	1010																					4.9		7.3	
CMH	891010	1022																					4.9		7.3	
CMH	891010	1028																					7.3			
CMH	891010	1030																					4.6	5.2		
CMH	891010	1040																					4.9	5.2	7.6	
CMH	891010	1050																					4.2	5.2	7.3	
CMH	891010	1100	2.3	5	8									19009		11.1	7	2.3	7	3.0			4.6	4.9	6.7	
CMH	891010	1130																					3.0	5.2	7.6	
CMH	891010	1145																					3.0	5.5	7.6	
CMH	891010	1200	1.4	5	8					4				21006		10.6	3	1.4	7	2.7			3.7	6.7	7.6	.2
CMH	891010	1215																					4.0	6.1	7.3	
CMH	891010	1232																					4.0	6.1	6.7	
CMH	891010	1245																					4.6	5.5	7.3	
CMH	891010	1300	2.1	2	8					4			1	19505		8.9	3	1.0	7	2.1			3.0	5.2	7.3	1.0
CMH	891010	1310	1.8	2	8				1	4			1													
CMH	891010	1320																					3.0	4.9	7.3	
CMH	891010	1333																					4.0	5.5	6.7	
CMH	891010	1347																					4.6		7.0	
CMH	891010	1400	1.7	2	8					4			1	20004		8.3	4	.8	3	1.7			4.3	4.6	7.0	4.6
CMH	891010	1500	1.2	5	8					4			1	16006		8.9	3	1.2	7	2.1						.5
CMH	891010	1600	0.8	5	8				1	4			1	20006	9	8.9	5	.8	7	2.1						1.3
CMH	891010	1700	.2	5	8					4			1	20005		8.9	2	.2	3	.5						3.0
CMH	891010	1800	.2	8									1	22006	9	8.9	2	.2								.5
CMH	891010	1900	.4	8										22007		12.2	3	.4								
CMH	891010	2000	.6	8										22004		13.9	4	.6								
CMH	891010	2100	.8	5	5									24005	9	15.6	4	.8	9	7.6						
CMH	891010	2200		2	2									26004		16.1	4	1.7	9	7.6						
CMH	891010	2300		2										28003		13.9	4	1.7								
MFD	891010	1000	1.5	8													3	1.5								
MFD	891010	1100	1.4	8						1				19009		9.4	3	1.4								50.0
MFD	891010	1200	1.2	8						1				18008		7.8	3	1.2								.5
MFD	891010	1300	.8	8						1			1	18009		7.2	3	.8								2.8
MFD	891010	1320	.8	2	8				1	1			1	19009												
MFD	891010	1400	.2	5	8					1			1	18009		7.2	2	.2	2	.6						5.3
MFD	891010	1500	.2	5	8					1			1	19008		8.3	2	.2	3	.3						.6
MFD	891010	1600	.2	8						1			1	19007		8.3	2	.2								1.5
MFD	891010	1700	.2	5	8					1			1	20009		8.3	2	.2								3.0
MFD	891010	1800	.4	2	8									21009		8.3	2	.2	3	.4						50.0
MFD	891010	1900	.5	2	8									22007		10.0	2	.2	3	.5						
MFD	891010	2000	.5	5	8					1				23007		10.6	3	.5	3	.7						50.0
MFD	891010	2012	.7	8					1	1				23008												
MFD	891010	2100		2	2									22007		12.8	5	.5	4	1.1						.5
MFD	891010	2200		2										29009	12	12.8	4	.9								

Digitized Form of Weather Parameters in TABLE C.1.

TABLE C.2. Structure, Read Format, and Symbolic Interpretation of Electronic File Containing Hourly Weather Observations Taken at Columbus and Mansfield, Ohio, on October 10, 1989

COLUMNS	VARIABLE	FORMAT	EXPLANATION	UNITS
1	Blank			
2-4	Station id	A3	Columbus = CMH, Mansfield = MFD	alpha
5-10	Date	I6	Date = YR MO DA	
11-15	Time	I5	GMT-24 hour clock	
16-20	Ceiling	F5.1	Height of lowest cloud layer with > 5/10 sky coverage.	km
21-25	Cloud layers	I5	blank=clear 1=thin scattered 2=scattered; (1 to 5 tenths sky covered) 4=thin broken 5=broken; (6 to 9 tenths sky covered) 7=thin overcast 8=overcast; (> 9 tenths sky covered) 1 in Col.25=Sky partly obscured; fog,snow 2 in Col.25=Sky totally obscured " "	
26	Thunderstorm	I1	1=thunderstorm, 3=tornado 2=heavy thunderstorm	
27	Rain	I1	1=light (.2 to 2.7 mm/hr) 2=moderate (2.8 to 7.6 mm/hr 3=heavy (more than 7.7 mm/hr) 4=light rain shower 5=moderate rain shower 6=heavy rain shower 7=light freezing rain 8=moderate " " 9=heavy " "	
28	Drizzle	I1	4=light drizzle 5=moderate drizzle 6=heavy drizzle 7=light freezing drizzle 8=moderate " " 9=heavy " "	
29	Frozen precip.	I1	1=light ice pellets 2=moderate " 3=heavy " " 4=light hail 5=moderate " 6=heavy " 7=light soft hail 8=moderate " 9=heavy "	
30	Fog	I1	1=fog 2=ice fog 3=ground fog	
31-35	Wind vel.	I5	Dir = 1 min. avg to nearest 10° deg. Speed = 1 minute average	deg m/s
36-40	Wind gust	I5	Speed 3m/s > avg during past 10 min.	m/s
41-45	Temperature	F5.1	Ambient temperature	°C
46	1st cld lyr	I1	Type of cloud (lowest cloud layer) 1=fog 6=alto stratus 2=stratus 7=alto cumulus 3=stratocumulus 8=cirrus 4=cumulus 9=cirro stratus 5=cumulonimbus	
47-50	1st lyr ht	F4.1	Height of lowest cloud base	km
51	2nd cld type	I1	Type of cloud (second cloud layer)	
52-55	2nd lyr ht	F4.1	Height of second cloud layer base	km
56	3rd cld type	I1	Type of third cloud layer	
57-60	3rd lyr ht	F4.1	Height of third cloud layer base	km
61-65	Radar ht	F5.1	Radar ht of avg lowest rain cell tops	km
66-70	Radar ht	F5.1	Radar ht of avg highest rain cell tops	km
71-75	Radar ht	F5.1	Radar ht of maximum rain cell tops	km
76-80	Amount	F5.1	Hourly precipitation amount 50=trace (< .2 mm)	mm

---

999 = Missing data

Read Format:

FORMAT(1x,A3,I6,I5,F5.1,I5,5I1,2I5,F5.1,3(I1,F4.1),4F5.1)

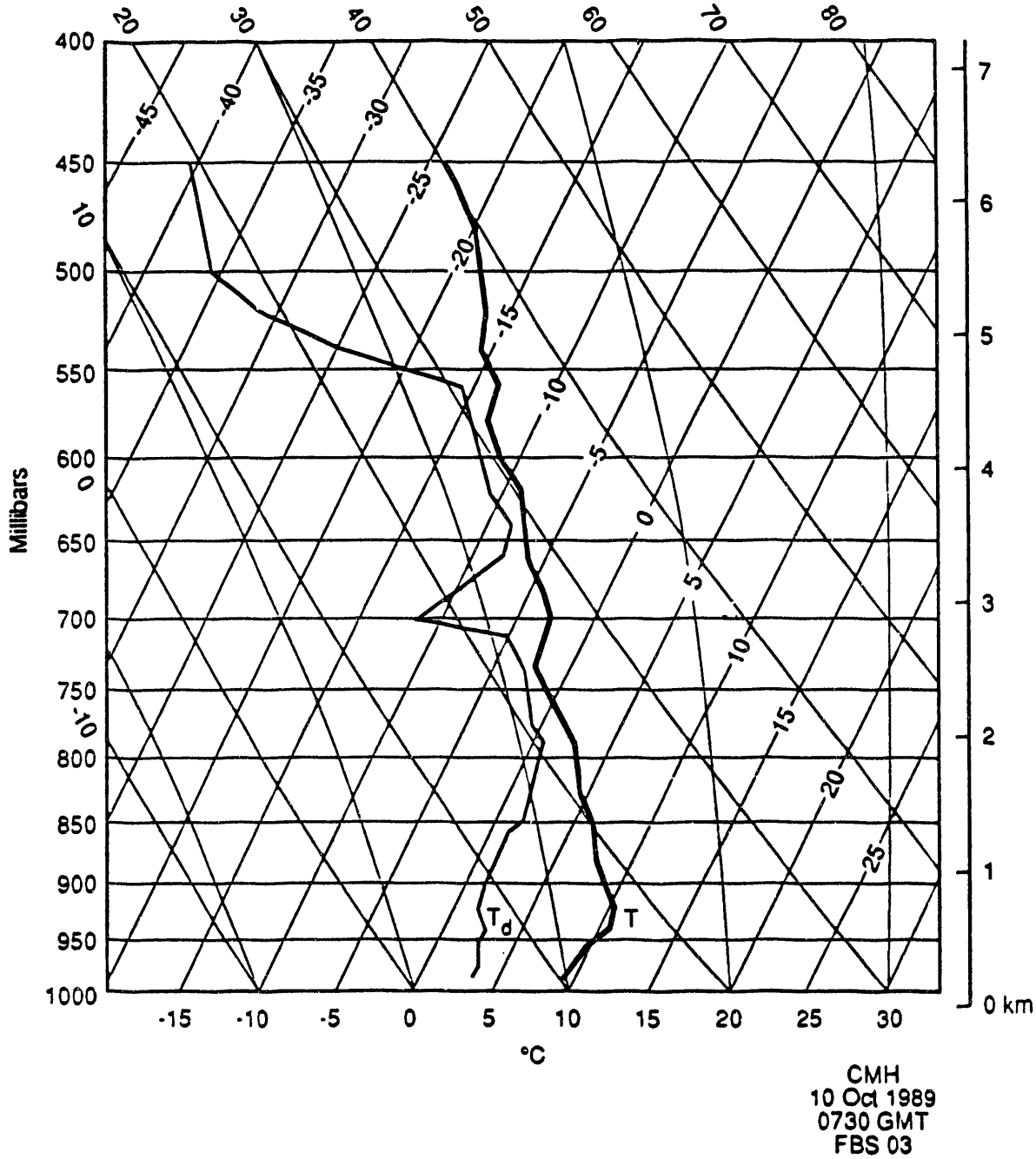


FIGURE C.9. Plot of Columbus, Ohio, Rawinsonde Taken at 0730 GMT, October 10, 1989

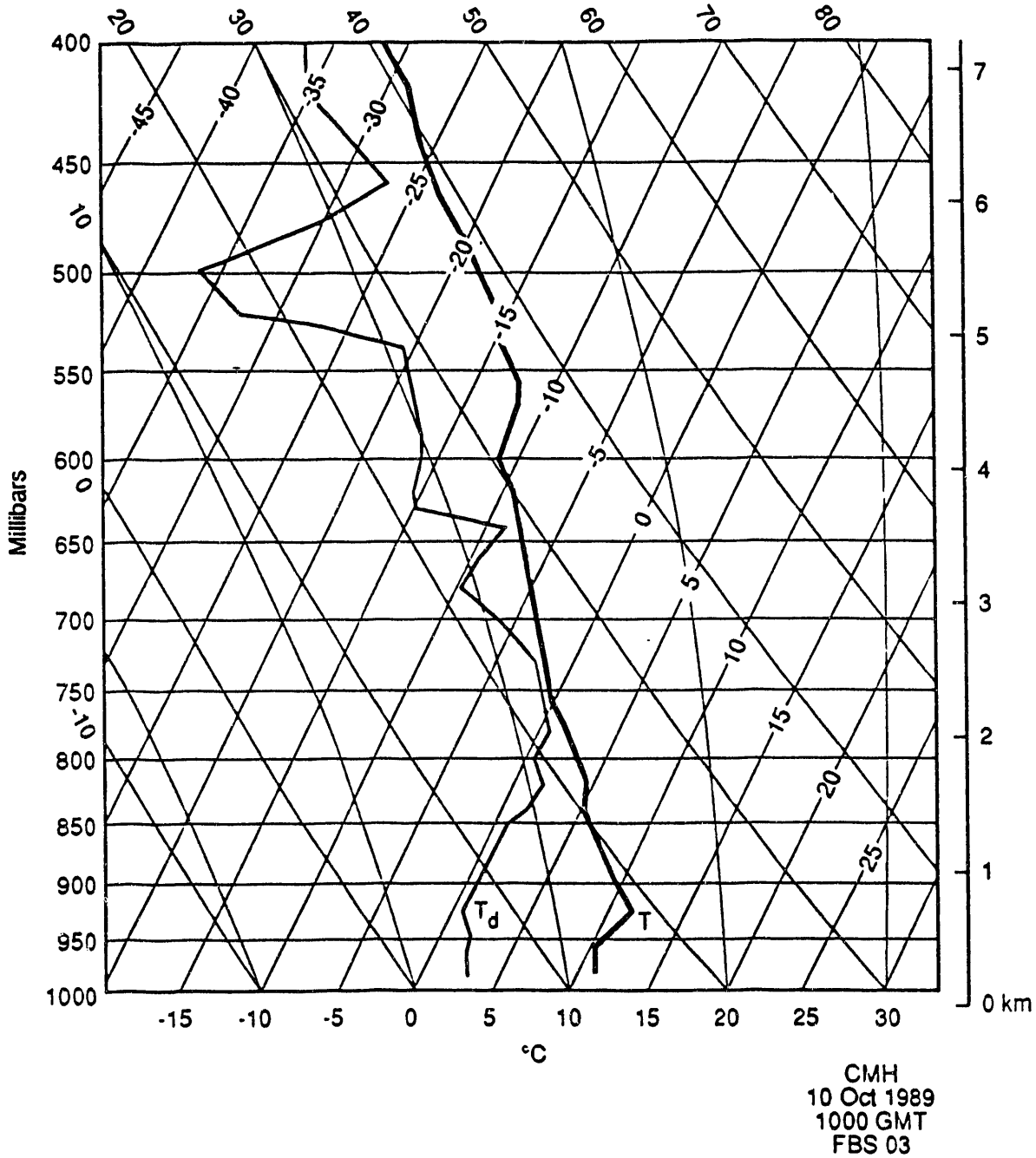


FIGURE C.10. Plot of Columbus, Ohio, Rawinsonde Taken at 1000 GMT, October 10, 1989

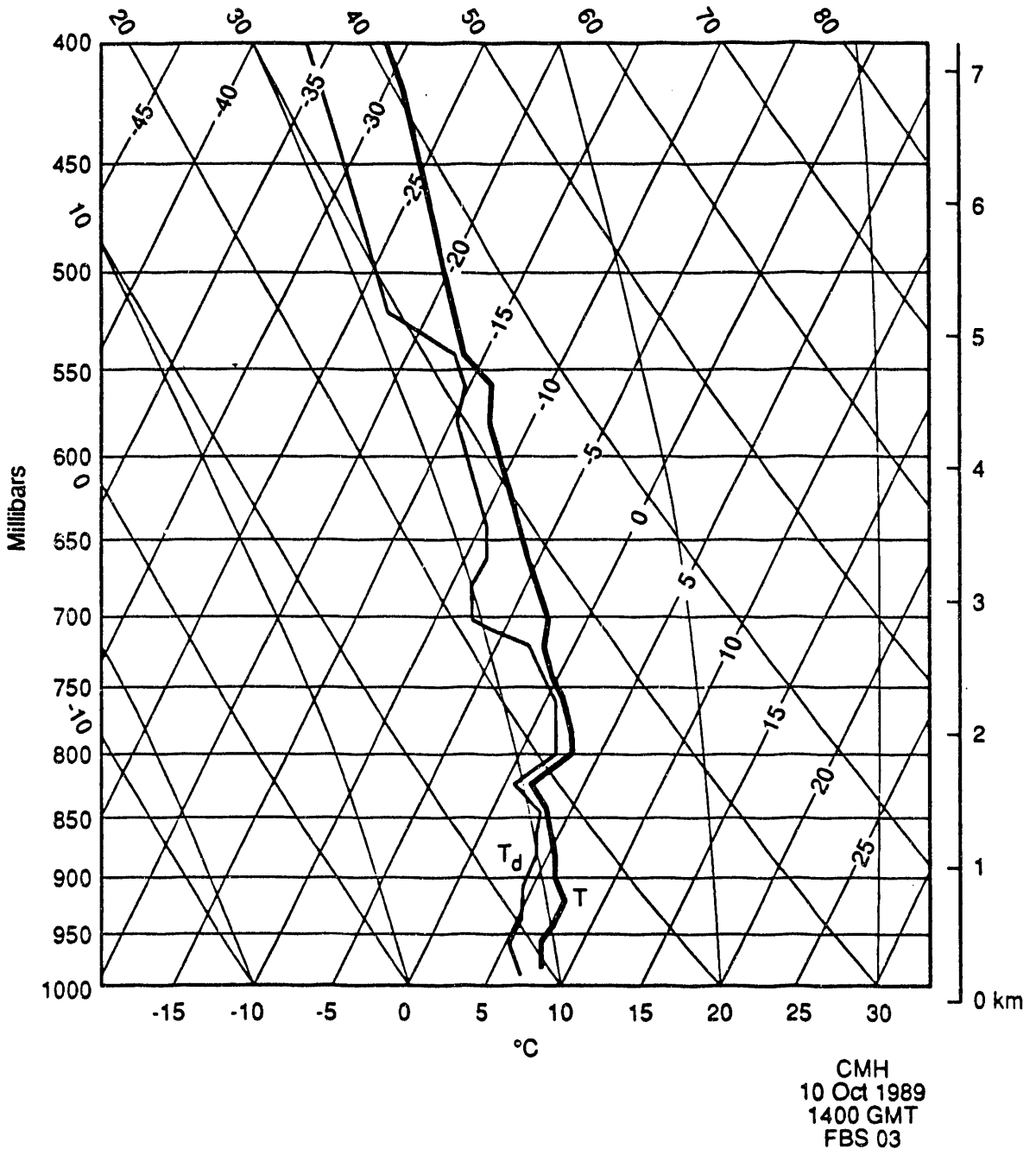


FIGURE C.11. Plot of Columbus, Ohio, Rawinsonde Taken at 1400 GMT, October 10, 1989

TABLE C.3. Structure of the Rawinsonde Data Files

FBS OCT 1989 RAWINSONDE DATA FILE DOCUMENTATION AND FORMAT

DATE	FBS NO.	RELEASE TIME(GMT)
Oct. 10	R02	0730
Oct. 10	R03	1000
Oct. 10	R05	1415

PARAMETER LIST

DATE	Date/Station Id.
TMDAY	Time (GMT)
PR=MB	Pressure (mb)
DT=DC	Dry Bulb Temperature (deg. C)
RH=PC	Relative HUmidity (%)
PT=DC	Potential Temperature (deg. K)
DW=DC	Dew Point Temperature (deg. C)
PHT=M	Balloon height (meters, MSL)
AZ=DG	Azimuth (degrees, true north)
EL=DG	elevation angle (degrees from horizontal)
BS=MS	Wind Speed (meters/second)
BD=DG	Wind Direction (degrees, true north)
HS=M	Mean Wind Height (meters, MSL)
AR=MS	Balloon Ascent(+)/Descent(-) (meters/second)

DATE	TMDAY	PR=MB	DT=DC	RH=PC	PT=DC	DW=DC	PHT=M	AZ=DG	EL=DG	BS=MS	BD=DG	HS=M	AR=M
101011	095855	966.4	11.58	57.6	287.53	3.50	246.	170.50	0.00	8888.88	8888.9	8889.	8888.88
101011	095923	982.6	10.90	88888888	285.48	88888888	269.	79.92	25.02	0.00	263.0	255.	1.05
101011	095928	983.4	11.23	58.2	285.74	3.32	262.	79.92	25.02	0.00	263.0	255.	-1.46
101011	095943	982.4	10.90	56.9	285.49	2.70	270.	79.92	25.02	0.00	263.0	255.	0.58
101011	095947	984.5	10.90	57.0	285.32	2.72	253.	79.92	25.02	0.00	263.0	255.	-3.62
101011	095952	984.6	10.87	56.7	285.28	2.63	252.	79.92	25.02	0.00	263.0	260.	-0.23
101011	095957	949.1	10.99	56.1	288.42	2.58	252.	79.92	25.02	0.00	263.0	260.	8888.88
101011	100002	980.0	11.02	57.0	285.82	2.83	252.	79.92	25.02	0.00	263.0	260.	8888.88
101011	100007	985.9	11.32	56.8	285.62	3.06	240.	79.92	25.02	0.00	263.0	260.	-0.79
101011	100011	980.1	11.31	57.2	286.09	3.16	289.	79.92	25.02	0.00	263.0	260.	10.29
101011	100016	984.4	11.11	57.2	285.54	2.96	254.	73.60	25.02	0.00	263.0	260.	-7.49
101011	100021	985.1	11.01	57.1	285.38	2.84	247.	59.50	25.02	0.00	263.0	249.	-1.31
101011	100026	984.5	10.97	57.1	285.39	2.82	252.	55.90	25.02	0.00	263.0	249.	1.01
101011	100030	985.4	10.94	57.1	285.29	2.80	245.	38.48	25.02	0.00	263.0	249.	-1.57
101011	100035	981.2	10.87	57.3	285.57	2.76	281.	29.81	32.19	0.00	263.0	249.	7.57
101011	100045	988.9	11.06	57.0	285.12	2.87	215.	29.81	40.23	0.00	263.0	249.	-6.83
101011	100050	982.9	11.05	56.6	285.61	2.77	266.	26.73	40.23	0.00	263.0	257.	10.76
101011	100054	978.4	10.80	56.5	285.72	2.49	304.	9.96	40.46	0.00	263.0	257.	8.00
101011	100059	975.2	10.57	56.7	285.76	2.34	331.	9.98	40.46	0.00	263.0	257.	5.67
101011	100104	972.1	10.37	56.5	285.82	2.11	358.	9.96	40.42	0.00	263.0	257.	5.53

Note: Missing data are indicated by 88888888, 8888.88, 8889., etc.

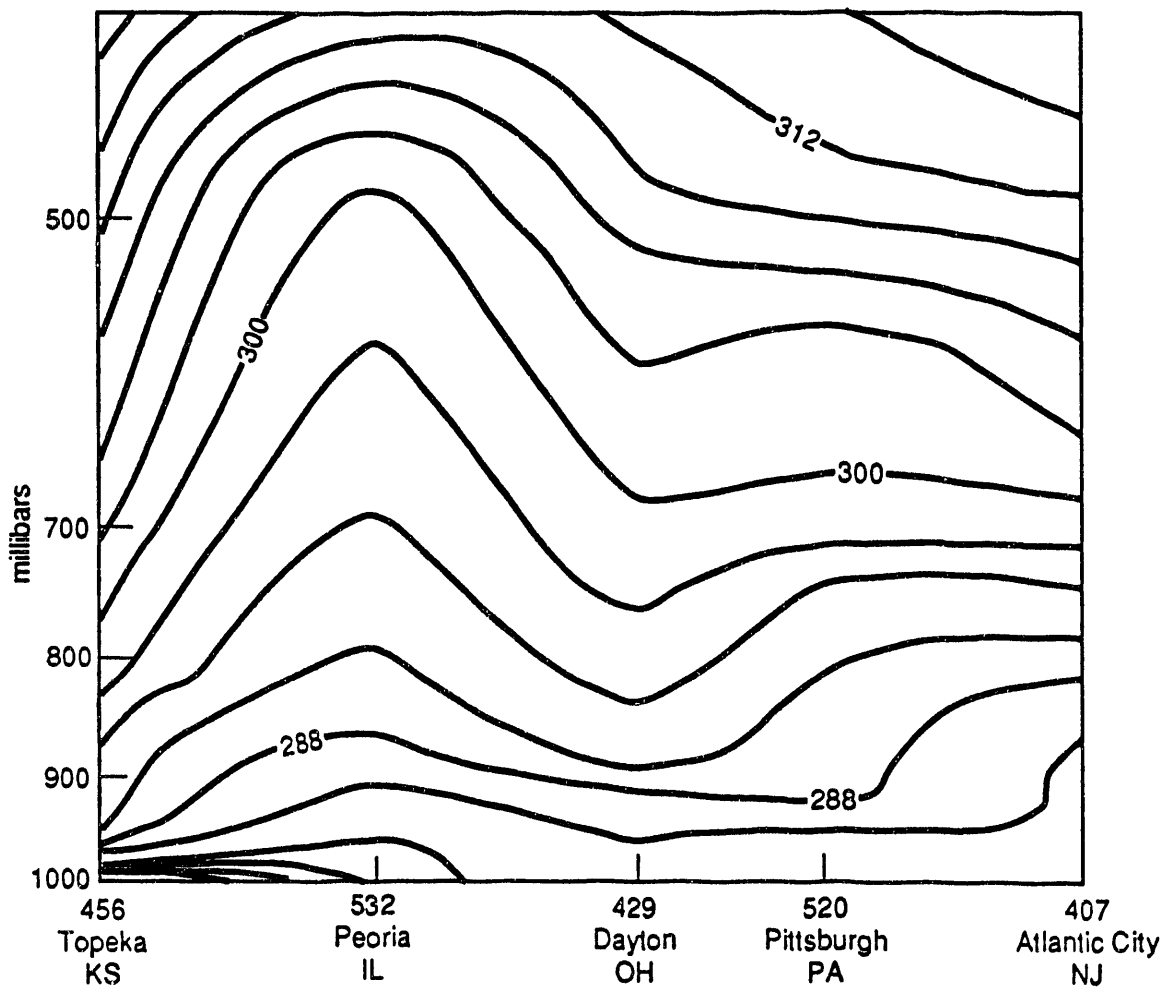


FIGURE C.12. Cross Section of Potential Temperature (°K) from Atlantic City, New Jersey, to Topeka, Kansas, for 1200 GMT, October 10, 1989

COLUMBUS, OHIO WEATHER RADAR
CATALOG OF SELECTED PHOTOGRAPHS
OCTOBER 10, 1989

GMT+	REMARKS
1122	Reference photo. Has background and range rings.
0720	No level 1 blanking. No range rings unless indicated.
0746	"
0801	"
0815	"
0831	"
0844	"
0858	"
0915	"
0930	"
0942	"
0959	"
1015	"
1043	After 1043 GMT, second photo has level 1 blanked.
1058	
1122	
1124	
1132	
1148	
1200	
1214	
1230	
1245	
1259	
1318	
1331	
1344 #1	No zoom. Incomplete sweep.
1344 #2	
1402	Antenna elevation raised to 1.7^0.
1415	Note level 3 echo just south of grid.
1429	
1445	
1459	
1514	
1530	Background on.
1544	No photo with level 1 blanked.
1559	
1613	
1629	
1640	
1644	
1646	Last photo of series.

Notes:
1. Range ring spacing is 25 nautical miles.
2. GMT+ is transmission time of 2 minute antenna sweep.
3. See accompanying pages for more information on print interpretation.

COLUMBUS, OHIO WEATHER RADAR
CATALOG OF SELECTED PHOTOGRAPHS
OCTOBER 10, 1989

TAPE COUNTER	GMT+	LVL 1	LVL 2	REMARKS (GMT+ is transmission time of 2 min. scan) (LVL 2 = Level 2 & greater. Lvl 1 = all levels)
	0720	*		Zoom No range rings
	0746	*		" "
	0801	*		" "
	0815	*		" "
	0831	*		" "
	0844	*		" "
	0858	*		" "
	0915	*		" "
	0930	*		" "
	0942	*		" "
	0959	*		" "
	1015	*		" "
	1043	*	*	" " El. 0.7
	1058	*	*	" " 0.3
	1122	*	*	" "
	1122			" Background and range rings only
	1124	*	*	" No range rings
	1132	*	*	" "
	1148	*		" " End of first roll
	1148	*	*	" "
	1200	*	*	" "
	1214	*	*	" "
	1230	*	*	" "
	1245	*	*	" "
	1259	*	*	" "
	1318	*	*	" "
	1331	*	*	" "
	1344	*		Full scale; ~200^0 sweep
	1344	*	*	Zoom No range rings
	1402	*	*	" " El. 1.7
	1415	*	*	", Level 3 echo north of CMH
	1429	*	*	" " End of second roll
	1429	*		" "
	1445	*	*	" "
	1459	*	*	" "
	1514	*	*	" "
	1530	*	*	" " Background on
	1544	*		" "
	1559	*	*	" "
	1613	*	*	" "

COLUMBUS, OHIO WEATHER RADAR
CATALOG OF SELECTED PHOTOGRAPHS
OCTOBER 10, 1989

TAPE COUNTER	GMT+	LVL 1	LVL 2	REMARKS (GMT+ is transmission time of 2 min. scan) (LVL 2 = Level 2 & greater. Lvl 1 = all levels)	
	1629	*	*	Zoom	No range rings
	1640	*	*	"	"
	1644	*	*	"	"
	1646	*	*	"	" End of third roll

RADAR PRINT INTERPRETATION

There is a colored header on each print that contains the following information:

Top Line (left to right)

CMH	Station i.d.; CMH = Columbus, Ohio
10/10	Current month/day GMT
hh:mm	Transmission time hour:minute GMT
Color bars	
Light green	Level 1, lightest precipitation echo.
Dark green	Level 2
Light yellow	Level 3
Dark yellow	Level 4
Light red	Level 5
Dark red	Level 6, heaviest precipitation echo.
EL: dd.d	Radar antenna elevation angle above the horizontal. Normal elevation is ~00.5°.
88:88	Not used.
R:nmi	Distance to outside range ring in nautical miles from CMH. For nearly all the included photographs R=100, and that will be the ring segment most often shown.

Second Line(left to right)

MnDnInDIA	Memory bank and display status information.

GENERAL INFORMATION

The print for 1122 GMT is a reference print that has no precipitation echoes, but rather shows portions (at the zoom scale), of the 25, 50, 75, and 100 n. mi range rings, and the location (+) of the following Ohio stations:

TOL = Toledo	21G = Marblehead	27G = Lorain
CLE = Cleveland	FDY = Findlay	(A)OH = Lima
MFD = Mansfield	MNN = Marion	

For the radar photo record between 1043 to 1646 GMT on October 10, 1989, usually a pair of prints are included. One print will show the echoes from all precipitation intensities, Levels 1 through 6. (Level 1 echoes may include precipitation that does not reach the ground.) The second print of the pair has the Level 1 echoes blanked out to more easily show where the cells of greater than Level 1 intensity were located. Except for the radar sweep of 1415 GMT, where a Level 3 cell north of CHM made a very brief appearance, all radar echoes in the photographic record period were Level 1 or Level 2.

Grease pencil lines were drawn on the monitor screen to approximately outline the 80- x 80-km surface sampling grid. The lines may not show in dark areas of the prints, but the western boundary of the grid can be seen on the print for 1015 GMT, and the entire grid can be faintly seen on the 1058 GMT Level 2-6 print. The Level 1-6 print for 1245 GMT shows the grid against an echo background. There are some slight differences in scale of the prints because camera to screen distance was not always quite the same between photographic sessions.

One of the photographs for the 1344 GMT sweep is at non-zoom scale. Though the radar antenna sweep was not complete for this particular image, the full precipitation echo pattern north and west of CMH is shown out to 100 n. mi. and the banding of the precipitation cells is evident. The yellow Level 3 echoes at the center of the scan are the results of ground clutter at CMH.

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