NOAA Technical Memorandum ERL ARL-140

METROPOLITAN TRACER EXPERIMENT (METREX)

Roland R. Draxler

Air Resources Laboratory
Silver Spring, Maryland
October 1985

UNITED STATES DEPARTMENT OF COMMERCE

Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Anthony J. Calio, Administrator

Environmental Research Laboratories

Vernon E. Derr, Director

NOTICE

Mention of a commercial company or product does not constitute an endorsement by NOAA Environmental Research Laboratories. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

CONTRIBUTING ORGANIZATIONS AND PARTICIPANTS

Tracer Sample Analysis

Raymond Lagomarsino, Freddie Thomas
Environmental Measurements Laboratory
U.S. Dept. of Energy

Russell Dietz, Robert Goodrich
Environmental Chemistry Division
Brookhaven National Laboratory

Sequential Sampler Operation

Paul Bilowus
Air Pollution Control Division
Fairfax County Health Services

Bob Judd
Air Quality Section
Prince George's County Health Dept.

Joe Rigney
Environmental Control Division
District of Columbia Dept. of
Consumer and Regulatory Affairs

Dick Wies, Francis Pluciennik
Air Management Administration
Maryland Dept. of Health and
Mental Hygiene

Passive Sampler Operation

Steve Ambrose
National Weather Service

Meteorological Towers

Harry Diamond Laboratories
U.S. Army

Washington Gas Light Company
Potomac Electric Power Company

Intensive Experiments

Ray Hosker, Robert McMillen,
Brian Templeman
Atmospheric Turbulence and Diffusion
Division, Air Resources Laboratory

Gallaudet College

Walter Hoecker, Richard Artz,
Uri Dayan
Air Resources Laboratory

Tracer Release

Integrated Systems Laboratory
National Weather Service

Paul Bilowus
Air Pollution Control Division
Fairfax County Health Services

CONTENTS

CONTENTS (cont.)

METROPOLITAN TRACER EXPERIMENT (METREX)

Roland R. Draxler

ABSTRACT. Several perfluorocarbon gas tracers were released at regular intervals for 1 year just outside of the metropolitan Washington, DC area. Continuous 8 h samples were collected at a central downtown site and two adjacent suburban locations. Monthly air samples were collected at 93 sites throughout the region at urban, suburban, and rural locations. Meteorological measurements were made on 5 towers instrumented for this experiment. The collected data can be used to quantify the errors from various dispersion modeling techniques as well as study the influence of an urban area on the dispersion of pollutants.

1. INTRODUCTION

1.1 Objectives

Transport and dispersion of pollutants over an urban area are important processes because of the concentration of pollutant sources as well as population near cities. Most past tracer studies of dispersion near urban areas have released tracer material from within rather than outside of the urban complex; many have used nonconservative fluorescent particles; and many have been conducted for a limited period of time. Furthermore, most previous experiments were constrained to limited meteorological conditions because of a fixed orientation between release and sampling locations.

The detailed objectives of the Metropolitan Tracer Experiment (METREX) are centered on two air sampling networks and 1 year of tracer releases. Monthly air samples were taken over a network of 93 samplers to provide sufficient data to determine the difference in the dispersion climatology of the urban and rural areas. More frequent sampling at three sites in the urban area provided data to evaluate the accuracy of various modeling techniques in simulating the mechanisms of transport and dispersion of pollutants. Extensive meteorological data were collected to determine model sensitivity to the use of various types of input data.

The results from this experiment provide a large data base of air concentrations and meteorological measurements to enable researchers to quantify the errors associated with various air quality models. The data are unique in that the experiment was conducted over a typical city, during all weather and climatic conditions. This permits the evaluation of dispersion models under very realistic conditions from short-term 8-h periods to annual averages.

1.2 Overview

The dispersion experiment was conducted over the Washington, DC metropolitan area using an inert, nondepositing perfluorocarbon gas for just over 1 yr (November 1983 through December 1984). During that time, 545 individual tracer

releases of 6-h duration were performed. Tracer releases occurred from near ground level or roof level from two of three suburban locations. Continuous air samples were collected every 8 h near the downtown center and at two sites at the western and eastern edges of the city. Monthly air samples were also collected at 93 sites as far as 50 km from the central downtown area.

Meteorological data were measured at five towers about 15 km apart spaced in an irregular north-south line through the city. Additional meteorological measurements were made near the surface at 11 locations, nine of which belonged to local air pollution control agencies. The other two are standard airport sites. Rawinsonde ascents were routinely made at Sterling, VA, near Dulles airport, twice daily.

During the last half of the 1-yr experiment, intensive measurements of tracer and meteorological parameters were made during one night each month. The objective was to pick synoptic situations when the urban area would have its maximum effect in altering the transport and dispersion of pollutants. These conditions included low moisture, clear skies, and light winds, resulting in a maximum difference between urban and rural temperatures. Once each month, during these conditions, the tracer was released from either northwest, within, or south of the city during the early evening hours. Rawinsondes (every 3 h) and pibals (every 1 h) were taken through the night at Dulles and National Airports, respectively. Vertical profiles of wind, temperature, and moisture were made hourly that night northwest of the city and near the downtown center using a tethersonde system.

2. TRACER RELEASE

2.1 Physical Characteristics

Three perfluorocarbon tracers, manufactured by ISC Chemicals, Ltd., were used in this study. They are all inert, nondepositing, and nontoxic. The physical properties of the three liquid compounds are given in Table 1.

Table 1.--Perfluorocarbon tracer technical data

	Perfluoro			
	Methylcyclo-pentane	Methylcyclo-hexane	Dimethylcyclo-hexane	Units
ISC name	pp½*	pp2	pp3	
Abbreviation	PMCP	PMCH	PDCH	
Boiling	48	76	102	°C
Freezing	-45	-30	-70	°C
Density	1.6	1.79	1.83	kg/l
Vapor pressure	300	141	48	mb
Heat of vaporization	85	85.9	82.9	KJ/kg
Molecular weight	300	350	400	g/mole
Purity	90	97	97	percent
Contamination	0	0.03 (pp3)	0.15 (pp2)	percent
Background	2.3	3.0	22	fl/l+

*Listed properties estimated.
+f (Femto) = 10^{-15}.

The tracer is released into the atmosphere by evaporation. The release unit has only two moving parts: a squirrel cage fan motor and a metering pump. The tracer flows in a closed circuit from the reservoir through the peristaltic pump rollers (the tubing is compressed to move the liquid) directly into the airstream on the surface of a heated disk. The disk and heater are located in a cylindrical mixing chamber. The heater, adjustable up to 600 W, maintains the temperature of the disk above the tracer's boiling point. The system's electronics control the duration of release and the duration that the system is off. Times for each on-off cycle can be set by tens/whole/tenths of an hour for each cycle. A small strip chart recorder notes when the pump and heater are on. The pump rate is preset on a calibrated dial. The airflow in the mixing chamber is controlled by baffles on the fan. The airflow should be sufficient to ensure all the vapor is diluted below the saturation mixing ratio for the expected ambient temperature without blowing the tracer drops off the heater before they vaporize. A schematic of the release unit is shown in Fig. 1.

2.2 Release Sequence

The basic experiment involved the simultaneous release of two different tracers (PMCH and PDCH) from two different locations. During the first half of the experiment (November 1983 through May 1984) the release pair was split between northwest and south of the city. The PMCH was released from the roof of our offices in Rockville, MD. The PDCH was released from the roof of a small trailer near Mt. Vernon, VA. These sites are about 17 km northwest and 15 km south of the downtown sampling location. During the rest of the experiment (June through December 1984), the PMCH site in Rockville was moved south to the roof of a small building near Lorton, VA, about 32 km southwest of the downtown sampler. The transfer of one of the release sites to the south during the summer months took advantage of the increase frequency of south winds during these months. This maximized the number of samples collected with above-background concentrations. The tracer release sites are shown in Fig. 2; the locations are given in Table 2.

Table 2.--Details of the routine tracer releases

Position	Location	Period	Height	Latitude	Longitude	Tracer
1 (1601)	Lorton	Jun-Dec	2 m	38°42'30"	77°15'19"	PMCH
2 (1602)	Rockville	Dec-May	30 m	39°02'51"	77°07'24"	PMCH
3 (1603)	Mt. Vernon	Dec-Dec	3 m	38°42'58"	77°04'40"	PDCH

The timing of each tracer release was the same for the entire experiment. Both tracers were released at the same time for 6 h starting every 36 h, regardless of the meteorological conditions. This cycle resulted in alternate day and night releases, with a 30-h period in between to permit the tracer from the previous release to clear the sampling area. Tracer releases started either at 1000 or 2200 eastern standard time (EST). The design release rate was 100 g/h for PMCH and 300 g/h for PDCH. The actual release amounts, shown in Fig. 3 and listed in Appendix B.1, on occasion varied from the calibrated settings. This was partly due to variations in the ambient temperature changing the flexibility of the tubing in the metering pump. The large release variations were due to a failure of the pump tubing and subsequent deliberate

overcompensation to maintain the same total emission. The tracer container was weighed at regular intervals to determine the exact release rate. All tabulated release amounts were adjusted by the tracer purity given in Table 1.

3. AIR SAMPLING

Automatic sequential air samples were collected at three sites shown in Fig. 2. Three 8-h samples (0000-0800, 0800-1100, 1600-2400 EST) were collected each day for the entire experiment. The passive adsorption tube samplers, used to determine monthly average tracer concentrations, were located at 93 volunteer observer sites shown in Fig. 4. Most of the sites are part of the Metropolitan Washington Cooperative Network, and some sites measure precipitation as well as temperature.

All air concentration data were first adjusted by the cross contamination of the other tracers (see Table 1); then the background value was subtracted. The air concentrations are given by the laboratory in units of femtoliters of tracer per liter of air (fl/l). The air concentration was converted to grams per cubic meter (g/m^3) by multiplying the pp½, pp2, and pp3 concentrations by 1.3×10^{-11}, 1.6×10^{-11}, and 1.8×10^{-11}, respectively. All results in this report are given in these mass units unless stated otherwise.

3.1 Laboratory Analysis

The perfluorocarbons are extremely stable nontoxic compounds, measurable at very low concentrations by gas chromatography and electron capture detection. A complete description of the technique has been given by Ferber et al. (1981)*. The atmospheric background concentrations of PMCH and PDCH are about 0.003 and 0.03 parts per trillion by volume. The tracer is recovered from the sampling tube by thermal desorption before chromatographic separation and electron capture counting. Air concentration is calculated from the recovered tracer and known air volume sampled.

3.2 Sequential Sampling

The sequential sampler consists of an air flow module (lid) and a power control module (base). The entire unit measures 36x25x20 cm and weighs 7 kg. The lid contains 23 sampling tubes filled with 150 mg of 20-50 mesh Ambersorb, which traps all perfluorocarbons in the air flowing through the tube. The base contains a constant-volume pump that draws air through each sampling tube in a sequence controlled by an internal digital clock. Flow rates, controlled by critical orifices, were set to 20 cm^3/min. The base also contains a digital printer that records the tube number, start time, stop time, and number of pump strokes (which are converted to air volume) for each sample. Controls in the base provide for automatic start at a preselected day and time for a preselected number of samples and duration of sampling (8 h per tube in this experiment). Internal rechargable batteries provide sufficient power for unattended operation for a week or more of continous sampling. After 23 samples have been collected, the lid is removed for sample analysis (in the laboratory) and a fresh lid attached in its place to continue the sampling program.

*Ferber, G.J., K. Telegadas, J.L. Heffter, C.R. Dickson, R.N. Dietz, and P.W. Krey, 1981: Demonstration of a long-range atmospheric tracer system using perfluorocarbons. NOAA TM ERL ARL-101, 74 pp.

Three units were in continuous operation for this experiment at the sites shown in Fig. 2. Each sampler was colocated at a local government air quality monitoring site. Personnel from these agencies maintained the samplers, exchanged lids, and returned them to the laboratory for analysis. The site locations are given in Table 3. The sampling data are tabulated in Appendix B.2. A time series plot of tracer concentrations is shown in Appendix A.1.

Table 3.--Sequential sampling locations

Position	Site	Operator	Latitude	Longitude
1 (1701)	Bladensburg	Prince George's County	38°56'22"	76°56'08"
2 (1702)	DC-Library	Washington, DC	38°54'14"	77°03'06"
3 (1703)	7-Corners	Fairfax County	38°52'06"	77°08'38"

3.3 Passive Sampling

The passive sampler consists of a glass tube, about 5 cm long and 4 mm in diameter; the center third of the tube is packed with Ambersorb, and a plastic cap seals both ends. When one cap is removed, the tube collects the sample air by molecular diffusion at a rate proportional to the concentration of the tracer, its diffusion coefficient in air, and the dimensions of the tube. For PMCH and PDCH the rates are 0.14 and 0.13 ml/min, respectively. To collect sufficient tracer to measure down to background, each tube must be exposed for at least 2 days.

The tubes were exposed at the 93 sites from the first of each month to the first of the following month. Sometimes tubes were changed a day or two before or after the first of the month. These dates are given in Appendix B.3.4, and the concentration data for the three tracers are given in Appendixes B.3.1 - B.3.3. A note of caution: the PMCP and PMCH concentration values for June look suspicious in that there are too many high values; however, no specific problem was identified during the passive sampler analysis. Also, in general all PMCP values appear too low; however, as before no specific problem can be identified. Summary concentration contour plots by tracer are shown in Appendix A.2. The sampler locations shown in Fig. 4 are tabulated in Table 4.

3.4 Quality Assurance

3.4.1 Sequential sampling

The uncertainty associated with each reported air concentration (tracer volume/sampled air volume) depends primarily upon the precision and accuracy of the analytic methods used to determine tracer volume and the instrument used to determine the sample air volume. In the sequential samplers, a known volume of tracer was added to the last tube on each lid before it was sent into the field. The results for PMCH and PDCH show an analytic bias toward higher values by about 30% with a standard deviation of about 50% of the mean. The precision of the analytic method is derived from the variability of the tracer sample in the control tube. The analytic method is calibrated by passing a known sample through the analyzer several times prior to each lid to establish a correction

Table 4.--Passive sampling locations

Operator	Site No.	Lat. (deg min sec)	Long. (deg min sec)	Operator	Site No.	Lat. (deg min sec)	Long. (deg min sec)
Scace	8	391004	772503	Nat. Aboretum	561	385440	765820
Shaw	30	390907	771418	Rosenkrans	570	385552	765434
Mc Brink	31	391243	771420	Kniskern	582	385340	764904
Abrams	36	391129	770934	Hudelson	591	385413	764356
Kimmich	37	390812	771044	Adams	618	385150	771853
Hetzel	51	390959	770354	Grimes	633	385123	771158
Bryant	62	391153	765847	Pals	648	385058	770435
Knorr	68	391122	765537	US:DoC	654	385339	770203
Blaisdell	70	390808	765448	DC:Stanton Sch.	661	385233	765814
Bathgate	78	391030	765100	Aiton Sch.	667	385358	765603
Aston	80	391251	764917	Gregg	668	385137	765503
Goldstein	121	390739	771755	Burroughs	670	385237	765408
Toomey	131	390953	772407	Eskelinen	682	385103	764810
Mont. College	138	390547	770939	Myers	721	385011	771723
Resnick	145	390619	770545	WGL: Ravenswth.	727	384747	771450
Machlan	147	390607	770504	Ray	741	385059	770857
Lehnert	165	390532	765640	Lucas	751	384907	770313
Mont. County	228	390407	771549	Lacny	760	385008	765808
Freeman	241	390337	770850	Filippelli	767	384813	765600
Thompson	247	390420	770600	Alvis	773	384946	765321
Rossen	254	390417	770227	Andrews AFB	774	384802	765208
Gajary	256	390214	770128	Alex./Machnall	822	384532	771616
Ambrose	260	390147	765917	Stowe	829	384555	771304
Kennedy	278	390450	765059	Holmes	834	384807	771119
Slaughter	322	390128	771707	Best	838	384630	770832
Hexter	334	390128	771117	Bolster	843	384722	770616
Gunther	338	385936	770938	Bergman	850	384640	770338
Beaven	346	390202	770542	DC:Stanton Sch.	900	384541	772810
Terry	352	390114	770254	Ft. Belvoir	935	384253	771053
Pinkard	358	385943	770041	Bourget	938	384439	770858
WSSC: Horsepen	390	390134	764532	Lapsley	945	384318	770558
Beall	410	385815	772254	Claggett	959	384332	765914
Denis	425	385910	771545	Darby	966	384215	765641
Mitchell	438	385640	770950	Bornemann	971	384427	765403
Reeves	442	385738	770743	Green	1012	384152	772140
DC: Dalecarlia	444	385620	770647	Bado	1018	383854	771911
Goodridge	447	385957	770522	Iekel	1048	383800	770427
Burchick	452	385719	770258	MD: Judd	1101	385622	765608
Himelfarb	459	385839	770033	DC: Rigney	1102	385414	770306
WGL: Chillum	460	385707	765805	VA: Bilowus	1103	385206	770838
UM: College Pk.	467	385924	765617	CC: Bryan	1201	383615	771030
Bettendorf	471	385747	765322	CC: Davis	1202	382845	765800
Pearl	476	385937	765110	CC: McFaden/ LeDaren	1203	382300	765800
Pines	489	385837	764438				
Parkin	527	385548	771457	CC: Smith	1204	383700	765430
Jordan	539	385452	771048	CC: Welch	1205	383000	764730
DC: McMillan	556	385525	770059	CC: Potter	1206	383115	771500

factor to all subsequent PMCH and PDCH tracer volumes on that lid. The correction may vary as a result of day-to-day variations in flow rate through the analyzer as well as differences in the chromatographic column temperature. Other factors that might add to the variability are contaminants in the air sample causing interference to the integration, over-reactive catalyst beds, contamination on the detector, and samplers that have not been thoroughly cleaned of tracer from previous use being sent into the field again.

Uncertainty in reported air concentration is also related to the sampled air volume. In theory, the pumps on each instrument are to be calibrated before being sent out and when returned to the laboratory. The average of the two calibrations is then used to determine the sample air volume for that pump. In most previous experiments, the standard deviation of all the pre- and post-sampling calibrations was about 3.6% of the mean. However, during this experiment, on most occasions, a pump failed while in the field and no post-sampling calibration could be performed. It was obvious from the air concentration data that the pump calibration was changing with time before the failure, therefore a different way to correct the data was necessary.

Because of the 3-h period between tracer releases, several tubes on each sampling lid contained tracer at near atmospheric background levels. The atmospheric background of the perfluorocarbon tracers is very stable and is given in Table 5. The concentrations for each lid and for each tracer were examined to determine which tubes showed near-background air concentrations. The concentrations for each tracer were then multiplied by the correction factor, the ratio of the absolute atmospheric background to the apparent lid background. In this way all of the analytic bias and pump-volume bias were eliminated. There was of course some residual variability. The distributions of the corrections applied to PMCH and PDCH are shown in Fig. 5. The distributions for PMCH and PDCH are similar, and 80% of the applied corrections were between 0.85 and 1.15 ($\pm$15%). The distribution is not symmetric. The concentrations that had to be decreased were a result of the analytic bias, and those that were increased were probably due to pump calibration errors. There were many instances of pump failure.

Table 5.--Perfluorocarbon tracer atmospheric background (fl/l)*

PDCB	PMCP	PMCH	PDCH
0.294	2.3	3.04	21.8

*Private communication: Dr. R. Dietz, Brookhaven National Laboratory, Upton, NY (1985).

The residual error (after the background corrections) can be determined from the duplicate samples. On occasion each sequential sampling site collected duplicate air samples for 1 week. About 400 sample pairs were collected. A scatter diagram of the pairs is shown in Fig. 6. The most scatter occurs at the near-background levels of both PMCH and PDCH. The background of PDCH appears to be higher than indicated in Table 5, because of differences in calibration procedures between laboratories. The data have been corrected for this difference. No significant bias is evident, and more than 95% of all the data are within

±50% (dashed lines). A few points (four values) represent extreme mismatches (off by more than a factor of two). In these cases, no cause for the extreme differences was evident. In addition, the concentration data for one third of the experiment were examined for unrepresentative values: very high concentrations only at one site at one time or high values at times inconsistent with a tracer release. About one-third of 1% of the data were identified as suspicious; about half of these were resolved and attributed to pump failures (low air volume hence high concentration) or misplaced decimal points. Therefore better than 95% of the reported sequential sampling concentration data are reliable to within ±50% and better than 99% are reliable to a factor of two.

3.4.2 Passive sampling

The passive sampling system as well as the associated analytic techniques are somewhat different. The air volume sampled should be fairly consistent, since it is only a function of molecular diffusion and the differences due to meteorological variations will be averaged out over the course of a month. Several of the 100 tubes analyzed each month were for quality assurance. These tubes were sent out as duplicates at randomly picked sites. In addition, Brookhaven National Laboratory (BNL) inserted its own controls (tubes with no tracer concentrations, with each batch analyzed). The BNL and Environmental Measurements Laboratory (EML) analysis methods were compared by placing a passive sampling tube with each sequential sampler.

The results from the laboratory controls indicated that 65% of the tubes showed no tracer concentration. An additional 10% of the control tubes contained only 10% of the background concentration, and 20% (or 95% of all tubes) had concentrations less than twice background. This indicates that the analytic method introduces some uncertainty at low concentrations, such that there is a 25% chance that near-background concentrations are more than 10% in error.

The duplicates that were taken show a similar error distribution. The duplicates give an indication of the total accuracy of the system, sampler, and analysis. The results, shown in Fig. 7, illustrate the inherent uncertainty in air concentration data. However, as before, 95% are within a factor of two and 85% of the points are within ±50%. These results are consistent with the uncertainty in the control tubes and suggest that the largest part of the error is introduced in the analysis at the lower concentrations.

3.4.3 Sequential-passive sampler comparison

Regardless of how well the two sampling systems performed through various internal tests, it is of interest to know how well they compare with each other. The comparison of the colocated sequential and passive sampler is shown on Fig. 8, where the concentrations have background included. In general the PMCH scatter is much larger than the PDCH and appears to be slightly biased toward lower values in the passive sampler. This result is consistent with the duplicates shown in Fig. 7, where the PMCH showed much more scatter than the PDCH. The excellent performance of the sequential sampler duplicates suggests that the bias is in the passive sampler. Various applications of air concentration data usually require the background removed; hence, the apparent errors will be much larger.

The monthly averaged sequential sampler air concentration, without background and converted to mass units, is shown as Fig. 9 plotted against the

comparable passive sampler value for that site. About 47% of the values are within 50%, 71% are within a factor of two, and 96% are within a factor of ten, with several of these occurring along the abscissa. Of course it will never be known in which sampling system the extreme failures occurred, but it is probably a realistic estimate of the overall uncertainty at lower concentrations. The monthly average concentrations at the sequential sampling sites tended to be at most only several times background. However, on the positive side, the background adjustments that were made to the sequential sampling data appear to have introduced no bias.

Overall, the samplers performed quite well. The failures with the sequential sampler were primarily due to pump failures, resulting in about 10% of the scheduled samples to be missing. With the passive sampling system 11% of the scheduled samples were missing. Of those, 5% were due to lost or broken tubes and 5% were due to a failure in the analysis system.

4. STANDARD METEOROLOGICAL MEASUREMENTS

4.1 Instrumented Towers

In support of the data analysis, four microwave towers were instrumented for wind and temperature at two levels, approximately 10 and 60 m. The towers are spaced about 15 km apart in an irregular north-south line through the urban area. The tower locations are shown in Fig. 10. A fifth tower, maintained by the Fairfax County Health Department, is also included with these data. The instruments at this tower were moved during the experiment.

Our tower instrumentation consisted of a Weathertronics model 2031 3-cup anemometer that had a starting threshold of 0.24 m/s. Wind direction was measured by a Weathertronics model 2020 vane that had a threshold of 0.24 m/s, distance constant of 1.1 m, and a damping ratio of 0.4. Temperature was measured using a Campbell 101 thermistor in a naturally aspirated wooden radiation shield. The instruments were sampled every 10 s by a Campbell CR21 micrologger and half-hour averages of vector wind direction, wind speed, and temperature were written to an audio-casette tape. Tapes were changed weekly, read, and merged into a larger data base. The tower data are available from December 21, 1983, through January 2, 1985. Towers 2-5 (identified in Table 6) have about 15% of the data missing. Tower 1 has about 40% of the data missing, most if it during the summer months. The details of the instrument mountings at each tower are given in Table 6. A sample of the data is listed in Appendix B.4.

Table 6.--Meteorological tower instrumentation locations

Position	Tower	Latitude	Longitude	Base (m)	Upper (m)	Lower (m)	Azimuth of tower shadow
1	Woodbridge	38°38'45"	77°14'13"	3	61	9	080-170
2	Springfield	38°47'49"	77°10'45"	67	55	9	140-240
3	Bells Mill	39°01'49"	77°08'48"	91	65	6	085-165
4	Takoma	38°58'10"	76°59'55"	61	61	11	220-310
5*	Fairfax:1	38°51'13"	77°22'29"	120	38	10	unavailable
	Fairfax:2	38°50'23"	77°16'26"	100	38	-none-	---

*Changed sites from 1 to 2 on April 3, 1984.

4.2 NOAA Surface Observations

Standard surface observations at National Airport and Dulles Airport were obtained from the National Climatic Data Center. The data were merged by time into a single file. A sample of the data is listed in Appendix B.5. The location of each site is given in Table 7.

Table 7.--Surface weather stations

Position	Location	Latitude	Longitude
1	National	38°50'34"	77°02'07"
2	Dulles	38°56'15"	77°26'40"

4.3 Supplemental Surface Observations

Local governments maintain several air quality monitoring sites. At some of these locations meteorological data are also collected. At most sites only temperature, wind direction, and wind speed are available at either hourly or three-hourly intervals from November 1983 through December 1984. During this time, about 5% of the observations were missing. The locations and available data are summarized in Table 8. A sample of the data is listed in Appendix B.6.

Table 8.--Supplemental meteorological sites

Position	Location	Latitude	Longitude	Interval (h)
1	Takoma	38°58'30"	77°01'22"	1
2	Smith Center	39°06'48"	77°06'26"	1
3	Rockville	39°03'10"	77°07'00"	1
4	Suitland	38°51'12"	76°55'55"	1
5	Mt. Vernon	38°42'58"	77°04'40"	3
6	Occoquan	38°41'25"	77°15'35"	3
7	Lewinsville	38°55'57"	77°11'58"	3
8	Gt. Falls	38°59'45"	77°18'51"	3
9	7-Corners	38°52'06"	77°08'38"	3

4.4 Rawinsondes

Regular rawinsondes were taken at Sterling, VA, near Dulles airport. The standard observation times were at 0000 and 1200 GMT. The data are not tabulated in this report but are available from the National Climatic Data Center.

5. INTENSIVE EXPERIMENTS

Once each month starting in April 1984, PMCP tracer was released for several hours. The PMCP tracer was collected in the passive sampling tubes so

that any measured PMCP tracer for that month was only from that one release. Meteorological data and corresponding contour plots of the tracer for some of the intensive experiments are shown in Appendix A.3. All the tracer data are tabulated in Appendix B.3.1; the meteorological data are tabulated in Appendix B.7; and the tracer release times and rates are given in Table 9.

Table 9.--PMCP tracer release information

Date	Time (EST)	Location	Height (m)	Amount (kg)	Latitude	Longitude
Apr 26*	1000-1600	Rockville	30	3.86	39°02'51"	77°07'24"
May 24	2030-2215	Rockville		3.42		
Jun 26	2100-0100	Gallaudet	0.2	5.04	38°54'20"	76°59'35"
Jul 19	2100-0100	Gallaudet		3.92		
Aug 23	2100-0100	Rockville		4.53	+	
Sep 27*	1000-1400	Rockville		4.39		
Oct 25*	0730-1130	Rockville		4.36		
Nov 7	2200-0200	Takoma Park	0.2	4.41	38°59'35"	77°00'00"
Dec 7	2225-0200	Mt. Vernon	0.2	6.08	38°42'58"	77°04'40"

*No supplemental meteorology.
+Blank spaces indicate repetition for that release site.

Two tethersonde systems were operated during the intensives each month (except September and October) from May through December 1983 from about 2100 to 0400 local time (LT). One site was near the Rockville tracer release point, at Woodward High School. The other site was north of the U.S. Capitol, at Gallaudet College.

The instrument package to measure wind speed, wind direction, and wet- and dry-bulb temperatures is carried by a blimp-shaped balloon (4.9x1.1 m) inflated with helium. A small pressure sensor is used as an altimeter. Data are telemetered to a computer-monitored ground station. The balloon is raised and lowered by an electrically powered winch at hourly intervals at a rate of about 0.3 m/s to a maximum altitude of about 500 m. The tethersonde system is a commercially produced device designed at the National Center for Atmospheric Research, and manufactured by A.I.R. in Boulder, CO. The raw data were recorded at 10-s intervals. However, to facilitate data analysis these observations were averaged into 15-m layers. The pressure measurements are not referenced to an absolute value but to an arbitrary initial value at ground level. There were some occasional problems with the moisture measurements, usually a dry wick or a frozen wick. Therefore, the dew point depressions may on occasion be in error.

During the intensives, hourly single theodolite pibals were taken at National Airport from 2200-0300 LT, and rawinsondes were taken at 2100, 0000, and 0300 EST at Sterling, VA. All observations are tabulated in Appendix B.7, and selected intensives are graphically summarized in Appendix A.3.

6. DATA TAPE FORMAT

The data described in this report are available on a magnetic tape divided into several files of varying size and record length according to the data type.

A copy of the tape is available from the Computer Products Office of the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. The tape characteristics are summarized in Table 10. A detailed description of the format follows.

Table 10.--Magnetic tape characteristics (bytes)

File	Record Length	Blocksize	Description
1	20	200	Tracer emissions
2	32	4000	Sequential sampling concentrations
3	80	800	Passive sampling pp½ concentrations
4	80	800	Passive sampling pp2 concentrations
5	80	800	Passive sampling pp3 concentrations
6	80	800	Passive sampling start times
7	140	4200	Tower meteorological data
8	70	4200	NOAA surface data
9	98	4214	Supplemental surface data
10	21	2100	Intensive meteorological data

The data format has been standardized as much as possible. The format descriptors used are described below. Each letter represents one digit on the data record with the exception of the decimal point, which is implied by its position. A letter represents a data type as follows:

Y	-	Year (83/84/85)	S	-	Wind speed (m/s)
M	-	Month (00-12)	W	-	Wind direction (deg)
D	-	Day (00-31)	F	-	Wind direction fluctuation (deg)
H	-	Hour (00-23)	P	-	Pressure (mb)
M	-	Minute (00-59)	Q	-	Moisture (dew point, K unless stated otherwise)
Z	-	Height (m)			
T	-	Temperature (K unless stated otherwise)	C	-	Air concentration (g/m^3 10^{-11})
			X	-	Any other number

Data types that do not fit the standard format are discussed with the appropriate file. Spaces in the descriptions of each file mean nothing, although there may be spaces on the tape if a number does not fill its field. Each letter represents one digit and a number within parentheses before the field represents a multiplier. All times are in Eastern Standard Time. Missing data are indicated by a -1 for concentrations and 9's for meteorological variables. The order of information on a data record for several stations is in the same sequence (or position) as those stations that are identified in the various tables in the text. The file descriptions follow.

File 1 - Tracer emissions data (Appendix B.1)

	release sites		
	1601	1602	1603
YYMMDDHH	XXXX	XXXX	XXXX

The release rate for each 6-h release for the three sites is expressed in g/h. The releases are assumed to be uniform over the 6-h period. Each record is identified by the start time of the release and the rate at each of the three release sites. Of course, for any period only two sites have non-zero rates, one for PMCH (pp2) and one for PDCH (pp3). There are no missing data.

File 2 - Sequential sampling concentration data (Appendix B.2)

	sampling sites					
	1701		1702		1703	
	pp2	pp3	pp2	pp3	pp2	pp3
YYMMDDHH	CCCC	CCCC	CCCC	CCCC	CCCC	CCCC

The sequential sampling data are sorted by increasing time, and concentrations for both tracers for the three sampling sites are given on each record. The time identifies the starting time of the 8-h sample.

Files 3, 4, and 5 - Passive sampling concentration data (Appendixes B.31 - B.3.3)

Station	Latitude	Longitude	Concentration by month
XXXXX	XXX.XX	XXX.XX	14 (CCCC)

The passive sampling data are recorded as one station per record sorted by increasing station number. The position is given in hundreds of degress. The concentrations are given for the 14 months from November 1983 through December 1984.

File 6 - Passive sampling start times (Appendix B.3.4)

Station	Latitude	Longitude	Start time by month
XXXXX	XXX.XX	XXX.XX	14 (MMDD)

The format is similar to files 3, 4, and 5.

File 7 - Tower meteorological data (Appendix B.4)

YYMMDDHHMM 5(2(TTT.T SS.S WWW FF.F))

The meteorological data from the five-tower network are sorted by time with all observations from all towers on one line or data record. Each observation contains temperature, wind speed, wind direction, and standard deviation of direction for the upper level followed by the lower level for tower 1 through tower 5 (Woodbridge, Springfield, Bells Mill, Takoma, Fairfax) as indicated by the position in Table 6.

File 8 - NOAA surface data (Appendix B.5)

YYMMDDHH(EEEE) 2[PPPP TTT.T QQQ.Q SS.S WWW (LIQ)(FRZ)(CEL)(N)(X))]

The surface observations at the local airports contain only an extraction of the complete observation. These data records are also sorted by increasing time, and all observations for both stations are on one record. The special

fields include solar elevation angle (E) in degrees, current weather observations for the type of liquid (LIQ) and frozen (FRZ) precipitation in coded form*, cloud ceiling (CEL) in meters x 100, total cloud cover in tenths (N), and Turner stability category (X).

File 9 - Supplemental surface data (Appendix B.6)

YYMMDDHH 9(TTT.T SS.S WWW)

Each record of the supplemental surface data, collected by local air quality agencies, contains the temperature, wind speed, and wind direction for the nine stations as indicated by the position in Table 9 (Takoma, Smith, Rockville, Suitland, Mt. Vernon, Occoquan, Lewinsville, Gt. Falls, 7-Corners).

File 10 - Intensive meteorological data (Appendix B.7)

YYMMDDHHMM (XX) (NR)	identification record
ZZZZ PPPP TT.T SS.S WWW QQ.Q	data record

The intensive data are composed of an identification record: time of observation, station identification, and number of data records to follow. The data record consists of height, pressure, temperature, wind speed, wind direction, and dewpoint depression (°C). The station identifications (XX) are as follows:

Sterling rawinsonde	- 01
Woodward H.S. tethersonde	- 02
Gallaudet Coll. tethersonde	- 03
National Airport pibal	- 04

*See WBAN hourly surface observations reference manual (144), National Climatic Data Center.

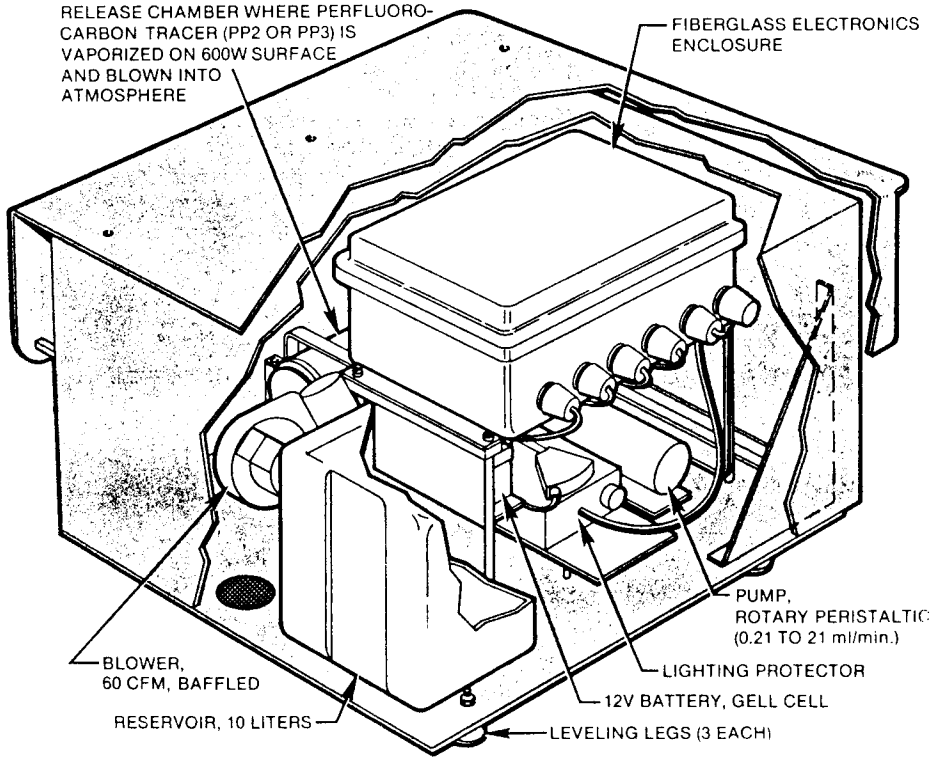

Figure 1.--Schematic of the tracer release mechanism.

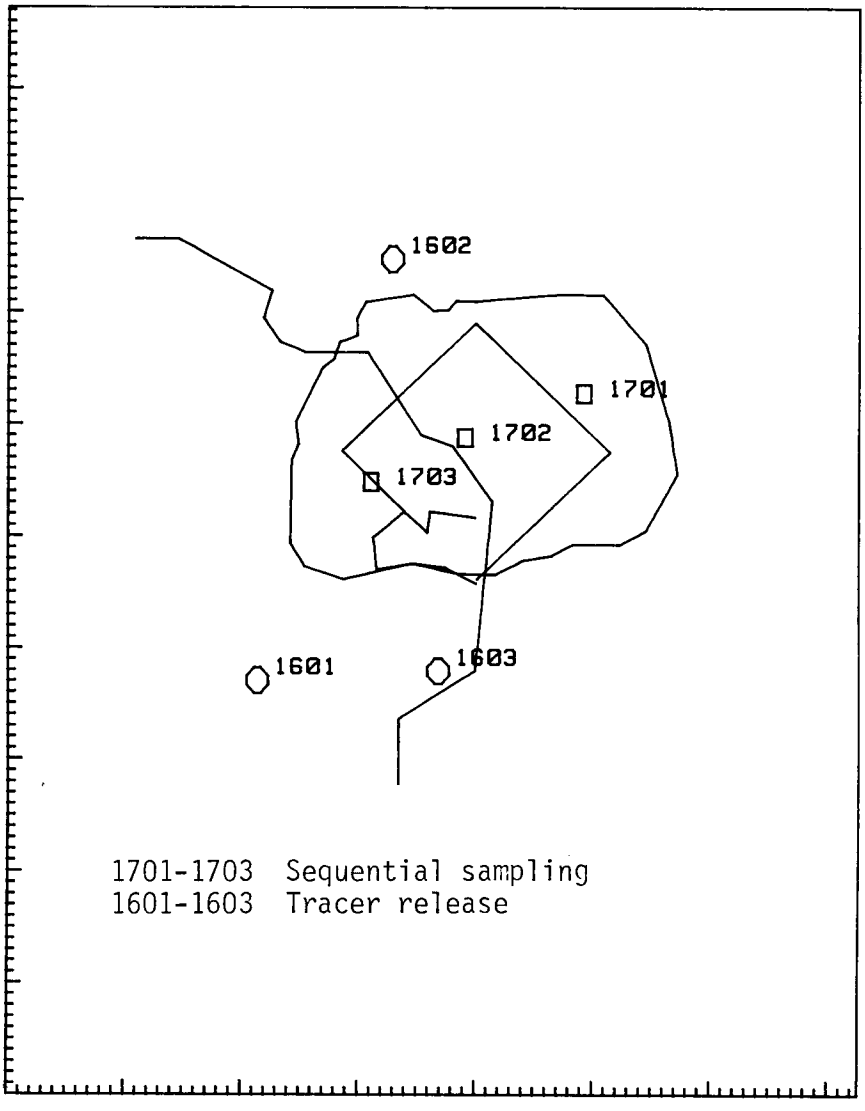

Figure 2.--Location of tracer release sites and sequential air sampling sites.

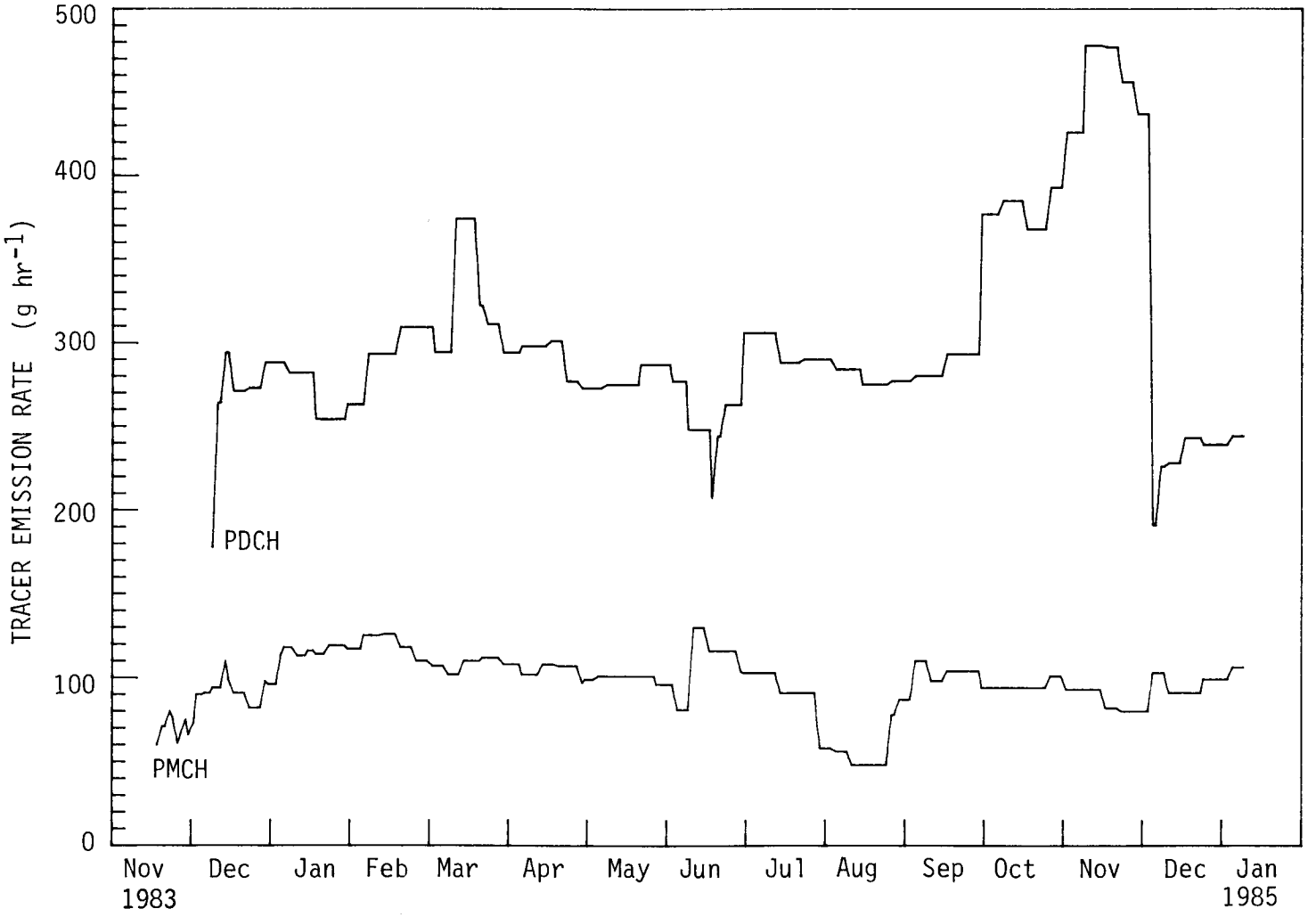

Figure 3.--Time series of PMCH and PDCH tracer release rates.

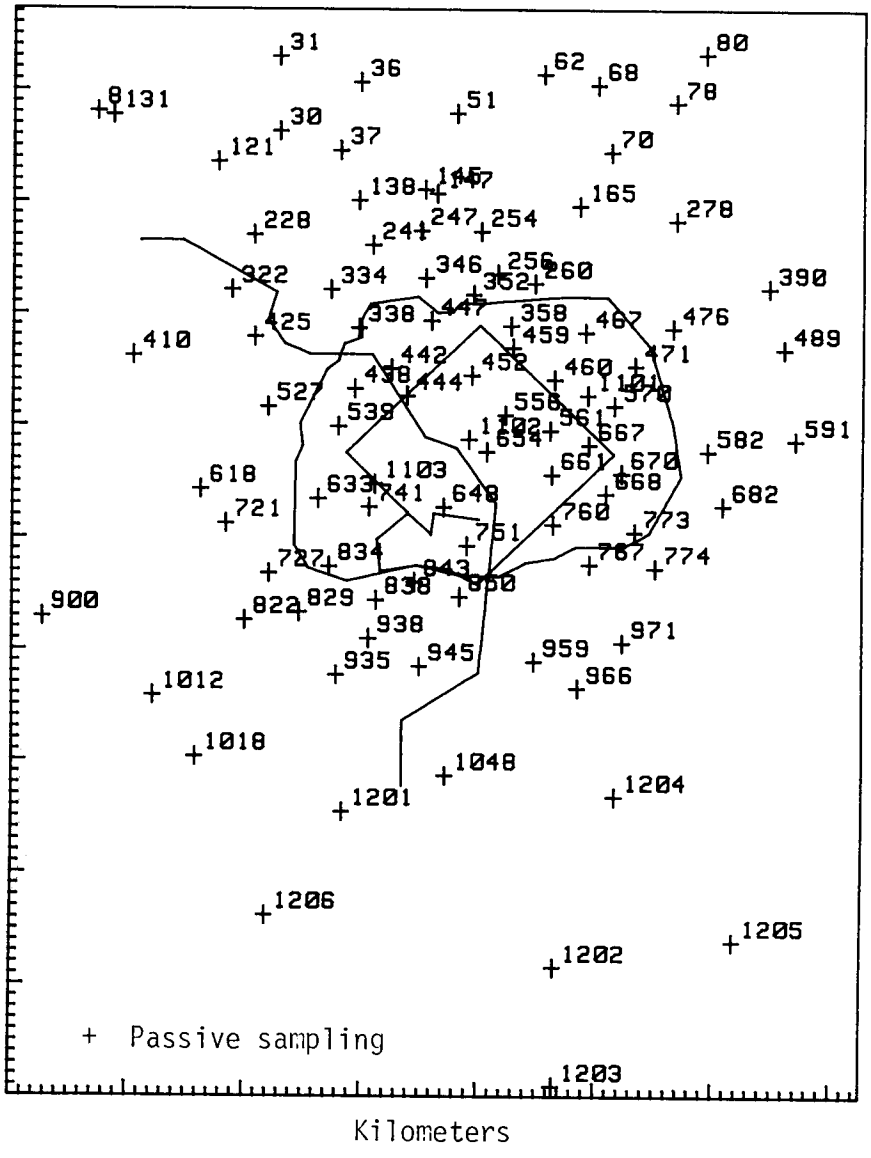

Figure 4.--Location of passive tracer sampling sites.

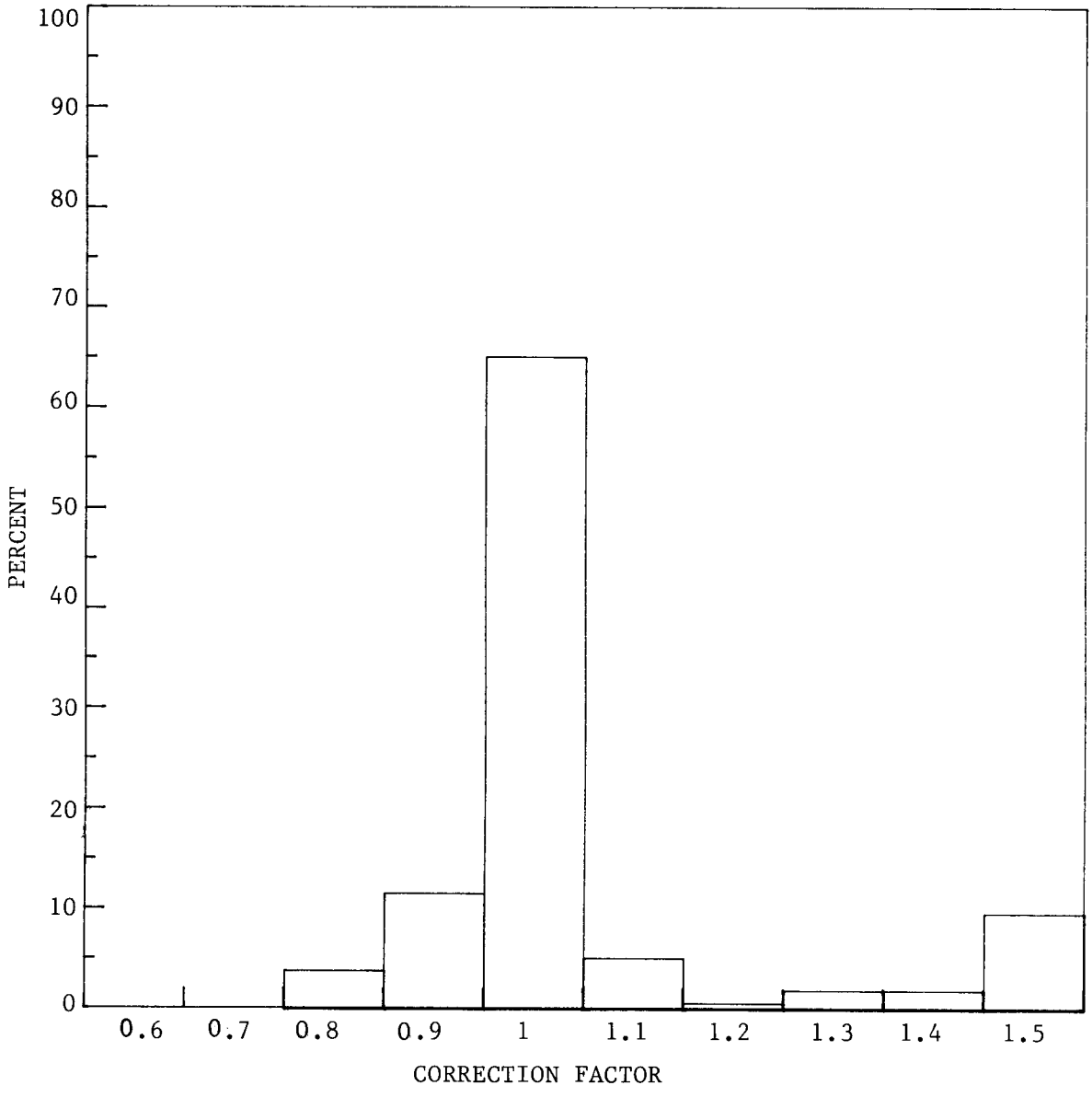

Figure 5.--Distribution of sequential sampler correction factors.

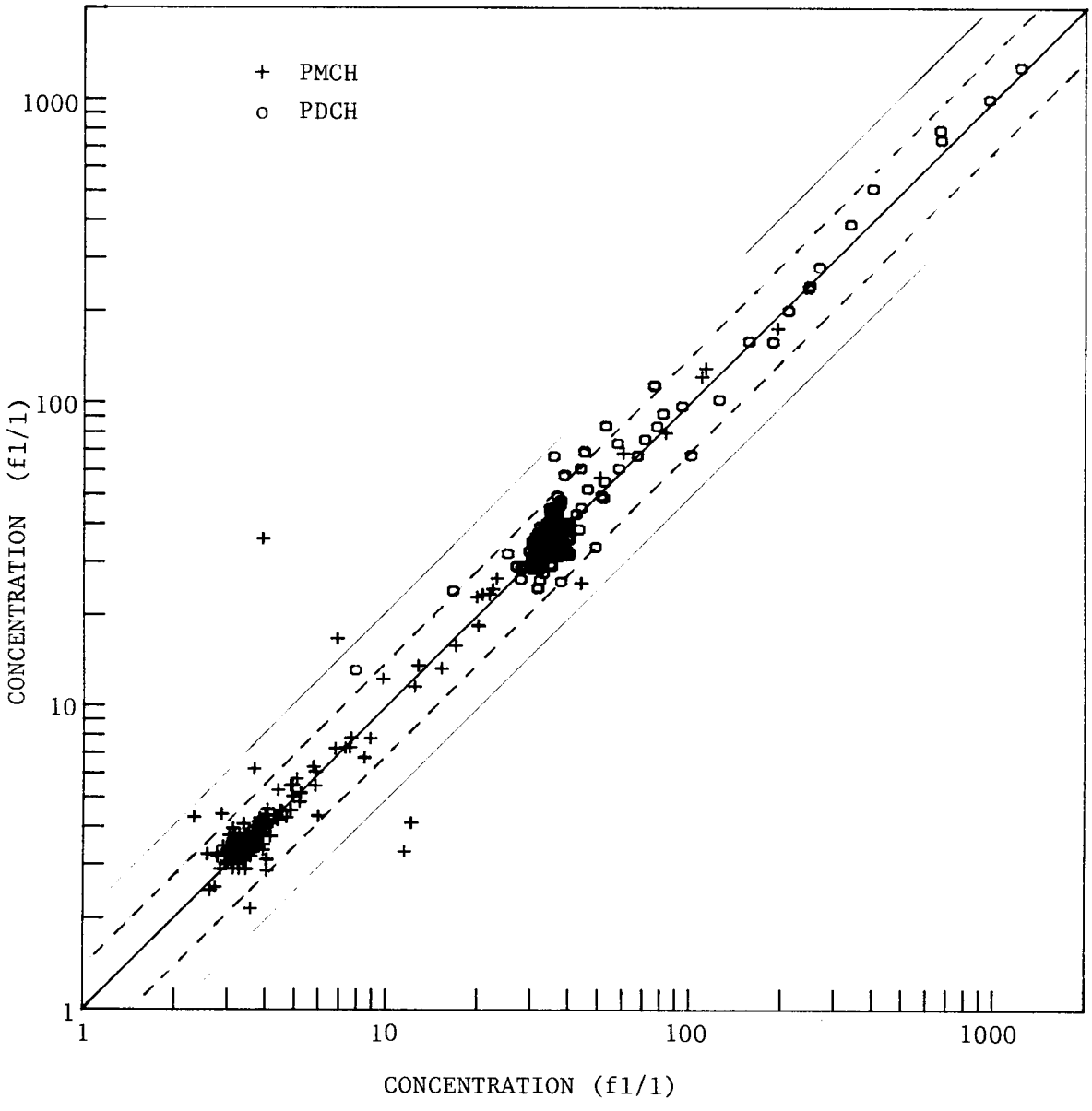

Figure 6.--Sequential sampler duplicate samples.

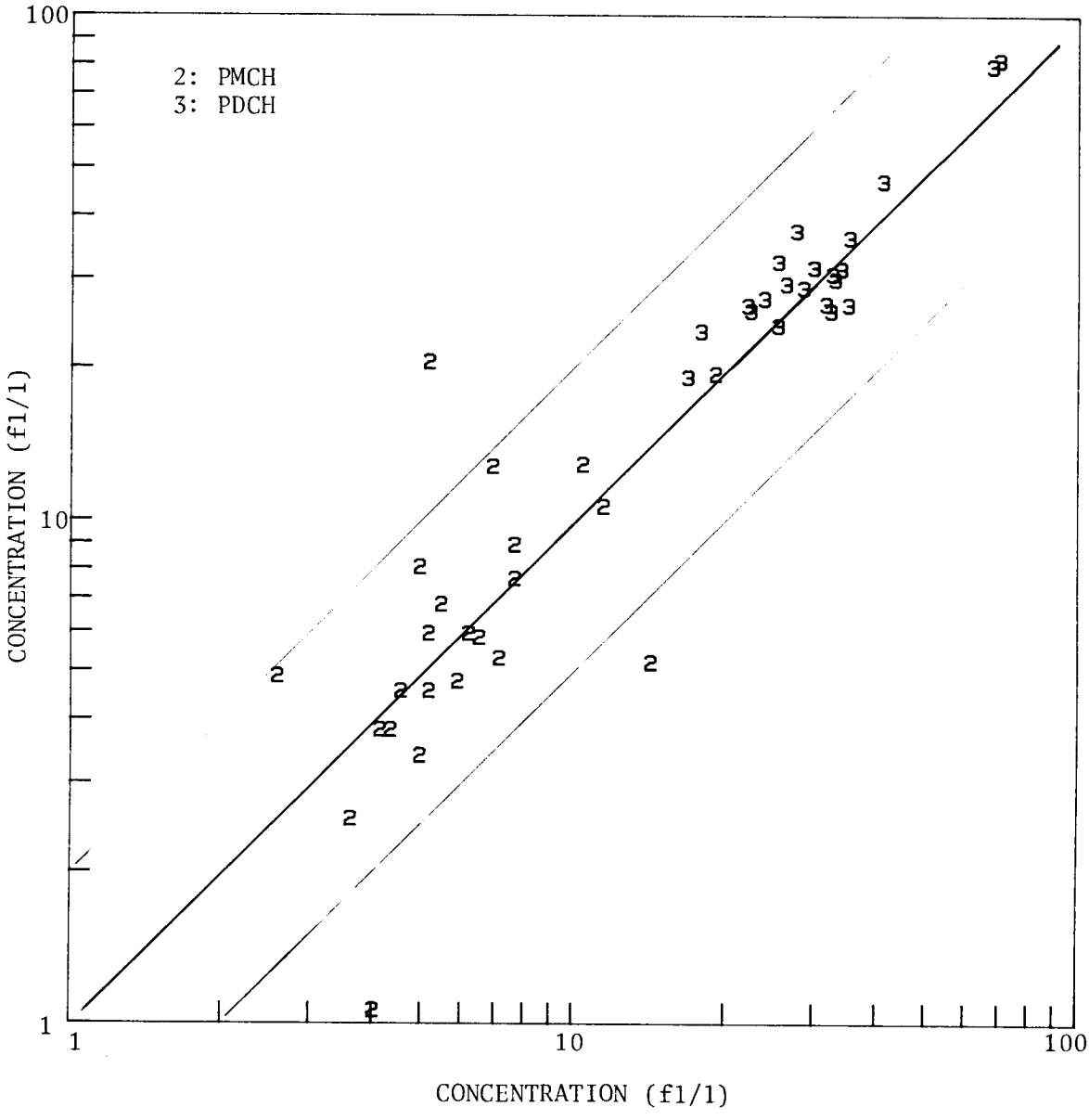

Figure 7.--Passive sampler duplicate samples.

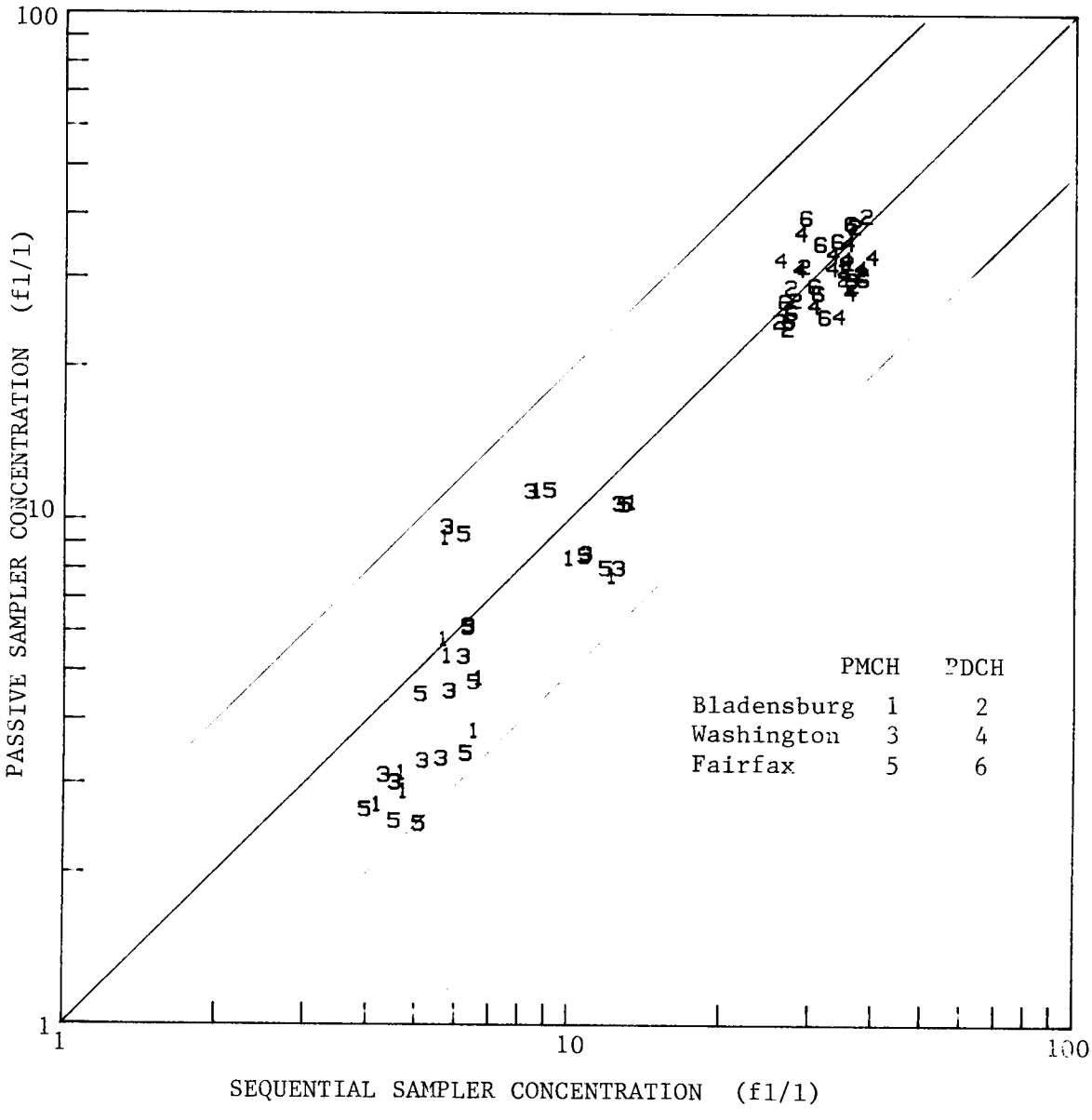

Figure 8.--Sequential-passive sampler comparison, including tracer background.

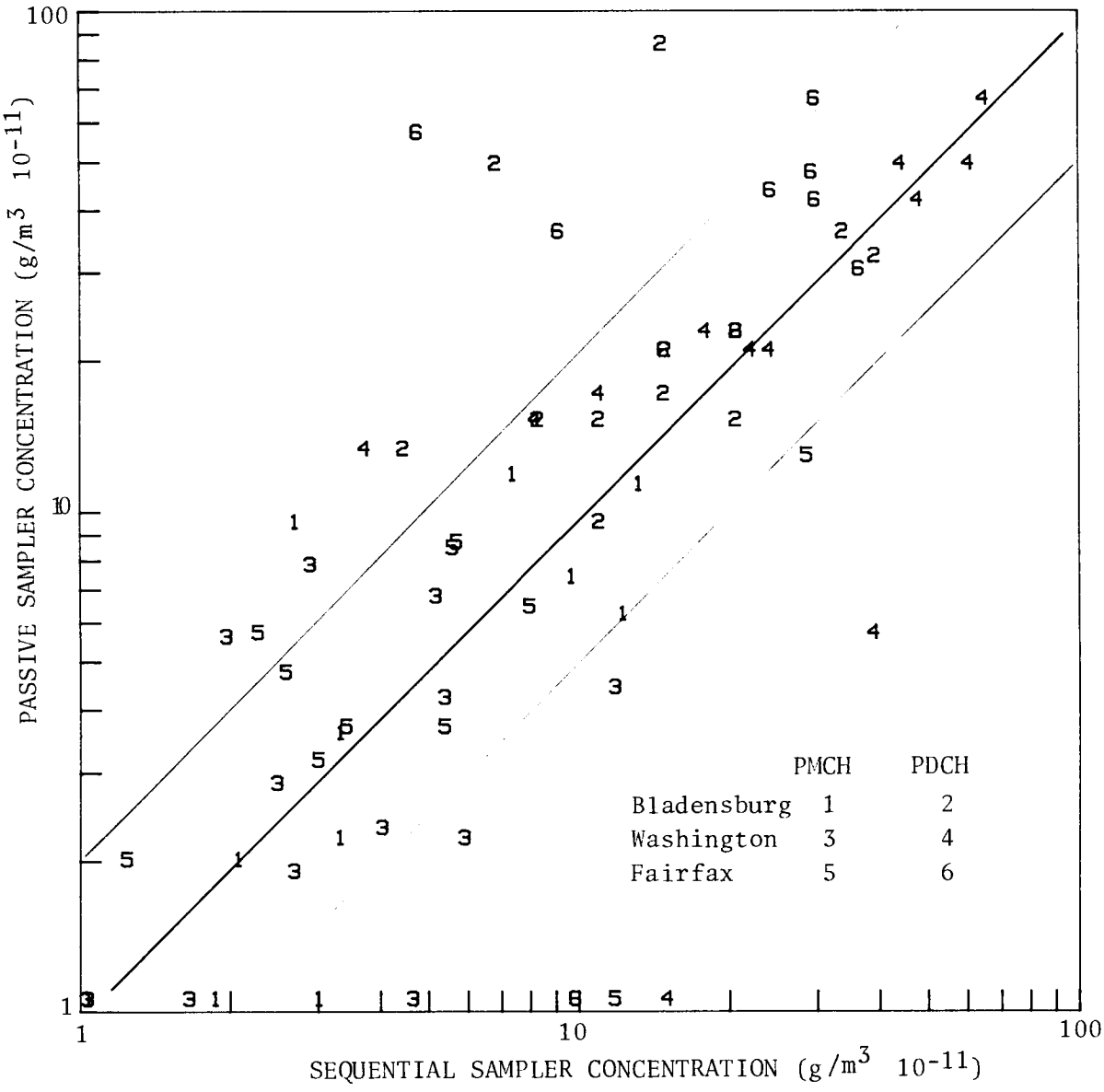

Figure 9.--Sequential-passive sampler comparison, not including tracer background.

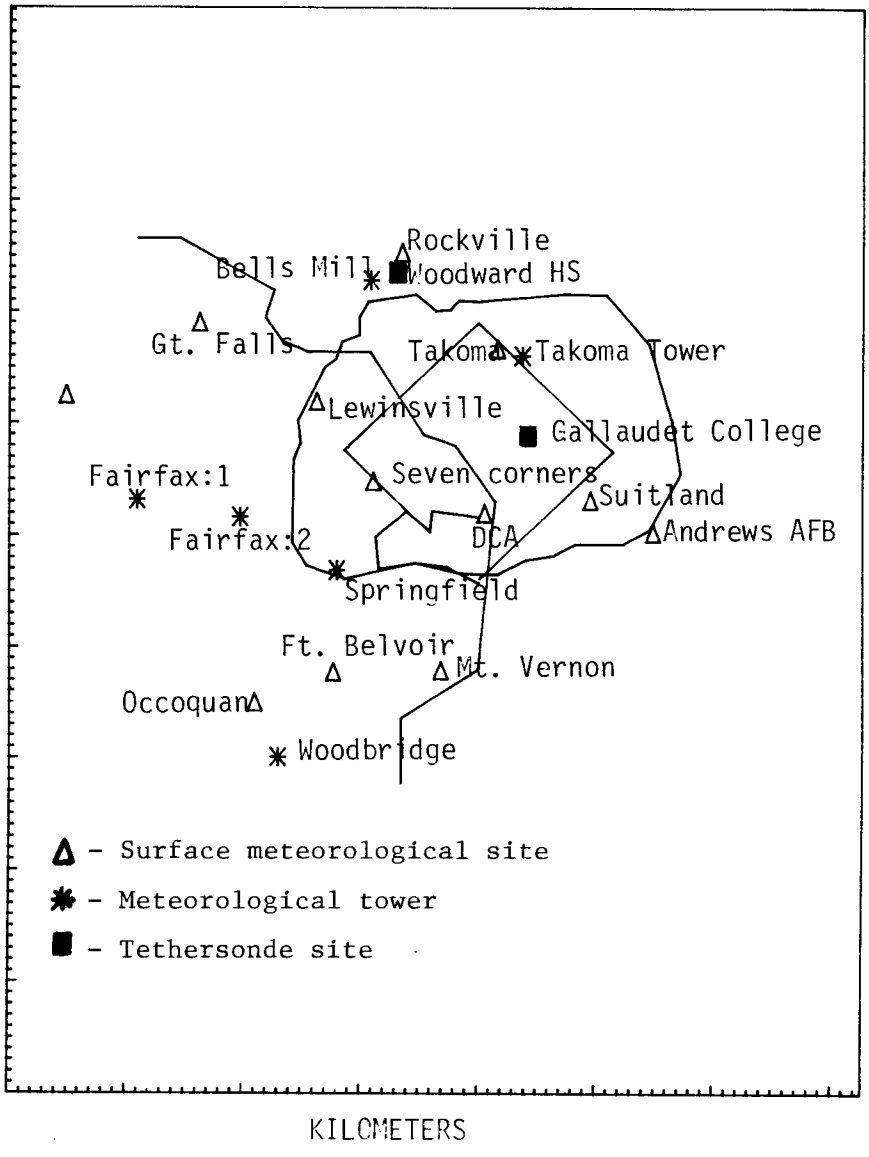

Figure 10.--Meteorological measurement sites.

APPENDIX A - SELECTED GRAPHIC DATA SUMMARY

A.1 - Time Series of Sequential Air Samples for PMCH (PP2) and PDCH (PP3)

A.2 - Air Concentration Contours (PMCH and PDCH) Averaged From December 1983 Through May 1984 and June 1984 Through December 1984

Tracer release sites are marked with an (X).

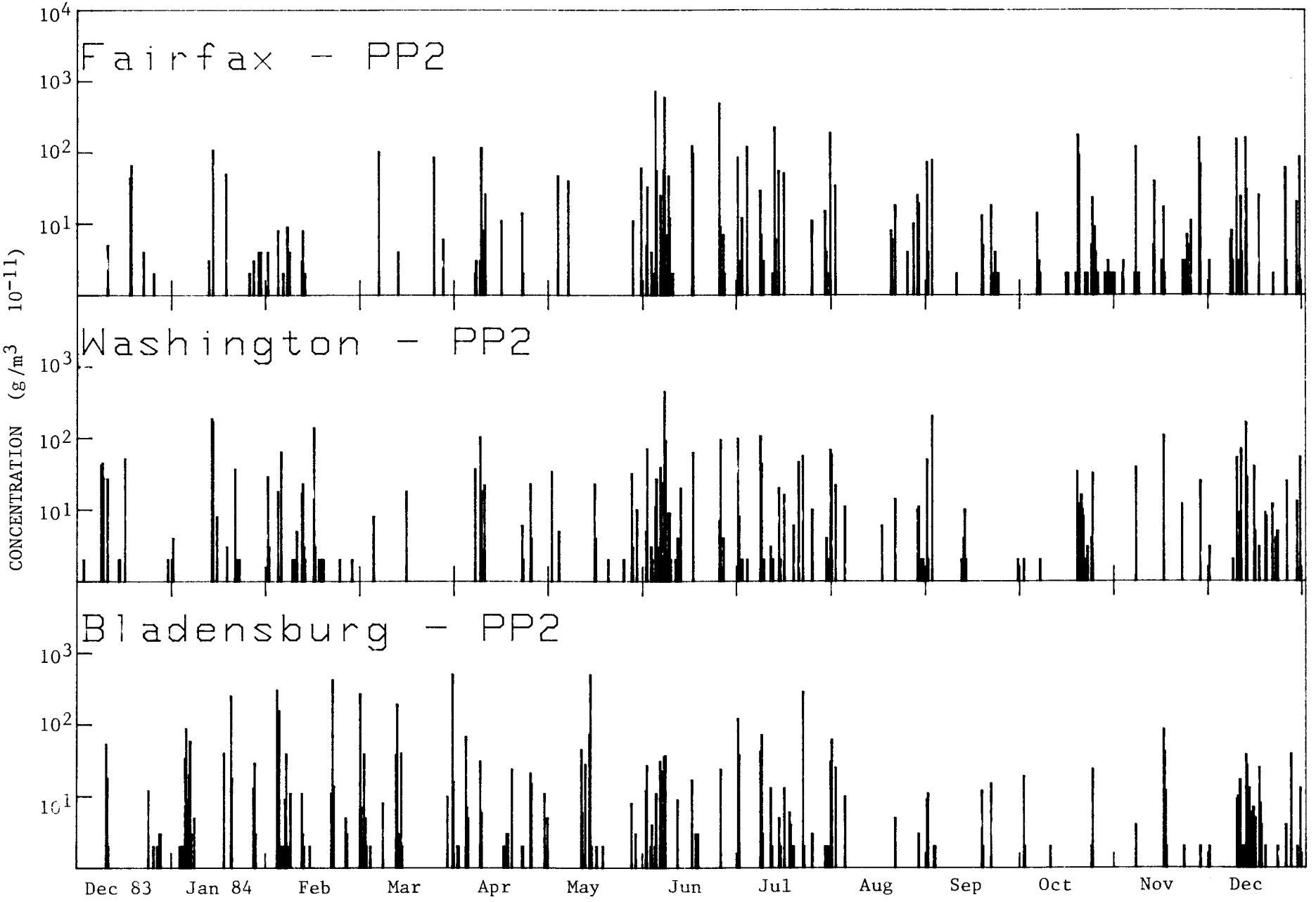

Figure A.1.1--Time series of sequential air samples for PMCH (pp2) at all three sites.

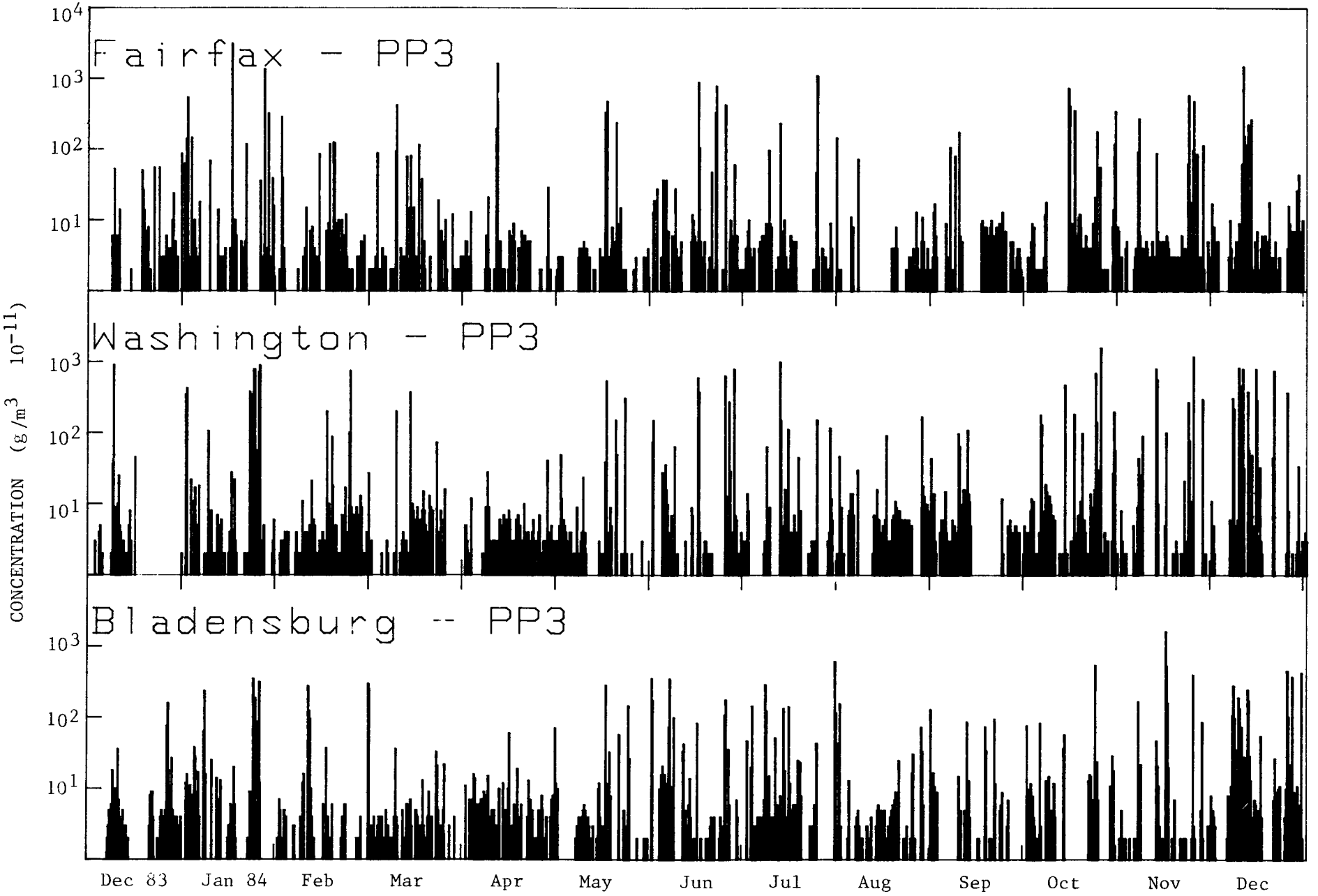

Figure A.1.2--Time series of sequential air samples for PDCH (pp3) at all three sites.

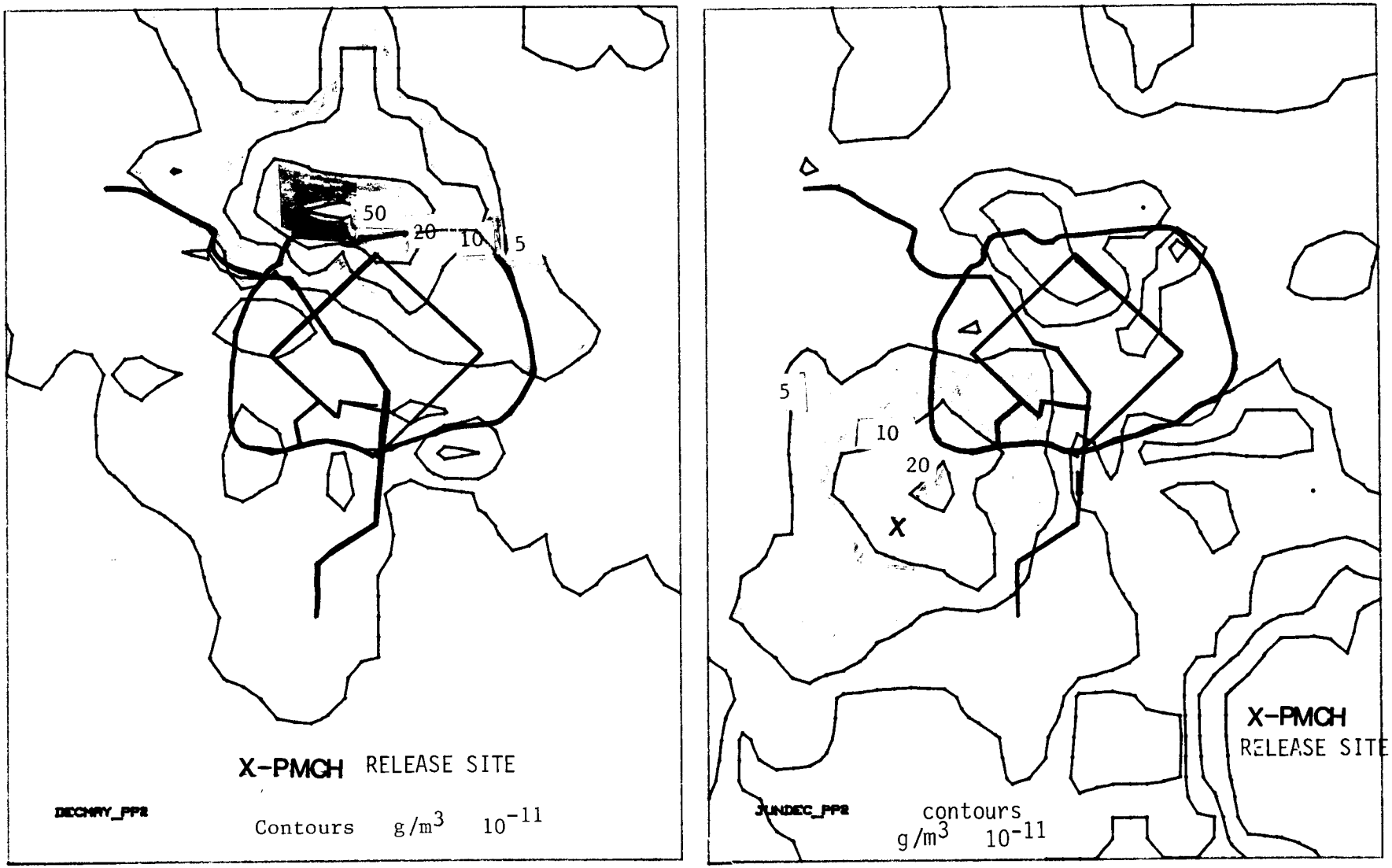

Figure A.2.1--Air concentrations of PMCH from the monthly sampling network, averaged between December 1983 through May 1984 (left) and June 1984 through December 1984 (right).

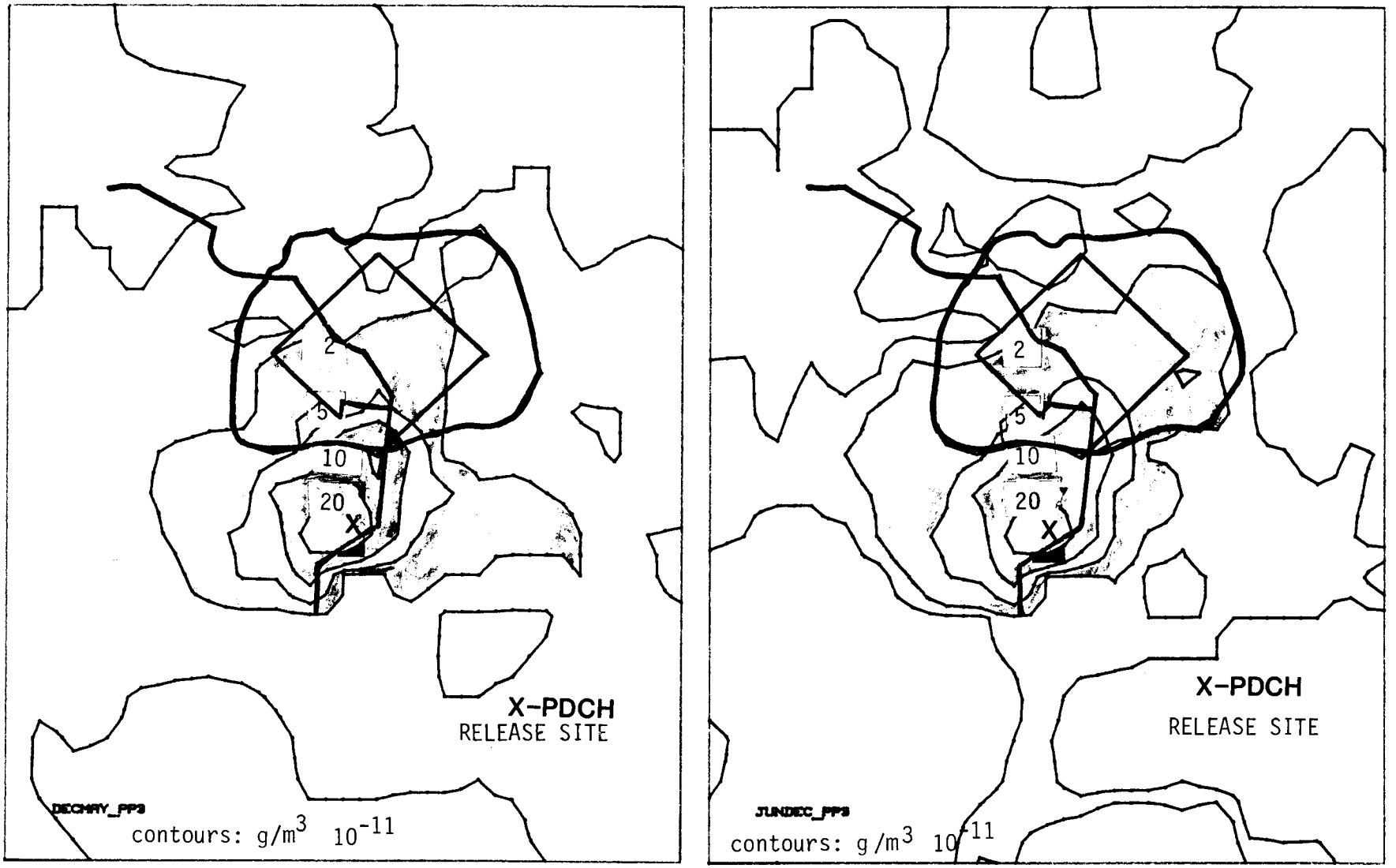

Figure A.2.2--Air concentrations of PDCH from the monthly sampling network, averaged between December 1983 through May 1984 (left) and June 1984 through December 1984 (right).

A.3 - Intensive Experiments: Temperature Profiles and PMCP Concentration Contours for August and November of 1984

The time of each sounding is noted near each profile.

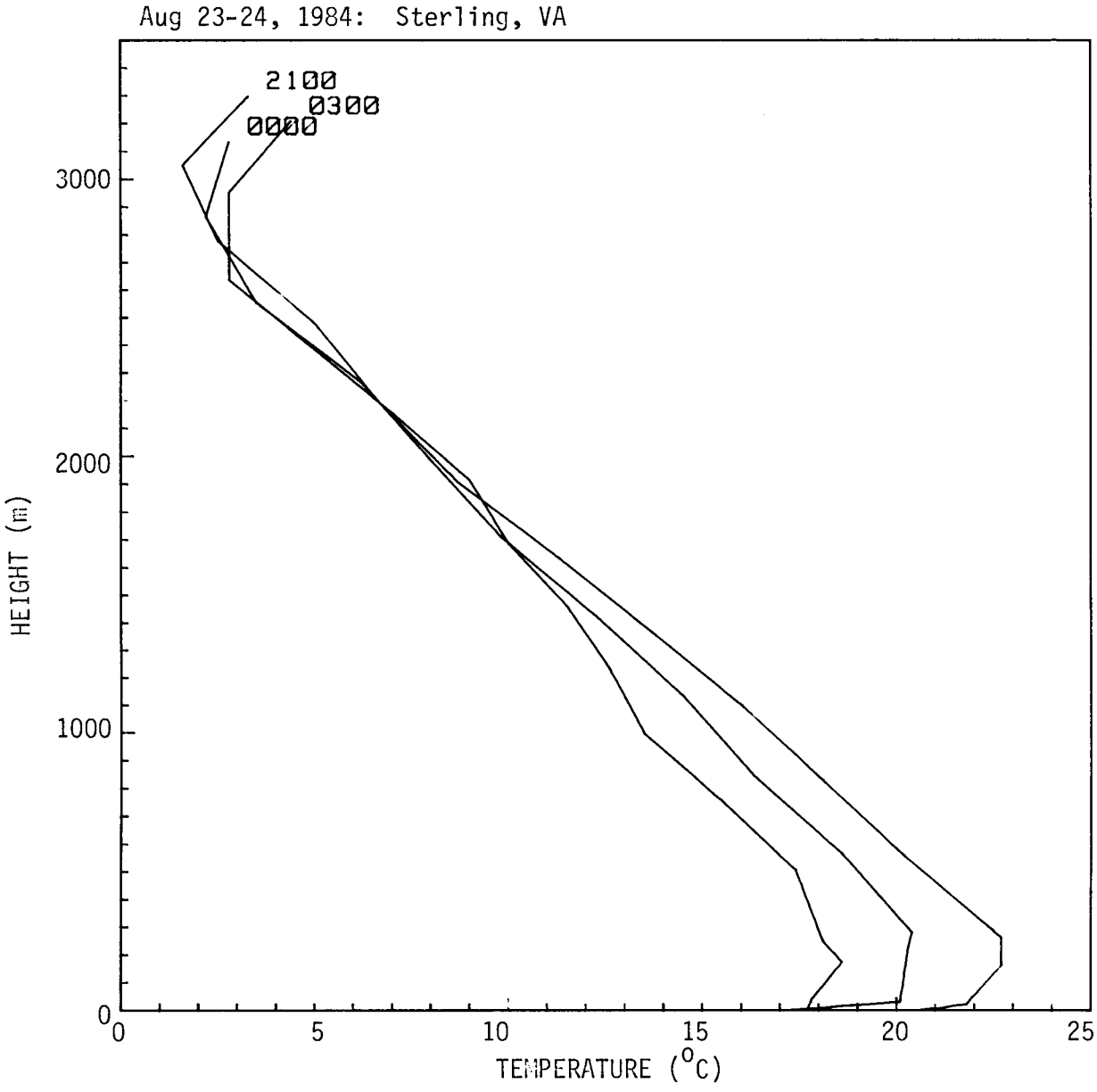

Figure A.3.1--Rawinsonde temperature profiles for the 23 August intensive experiment.

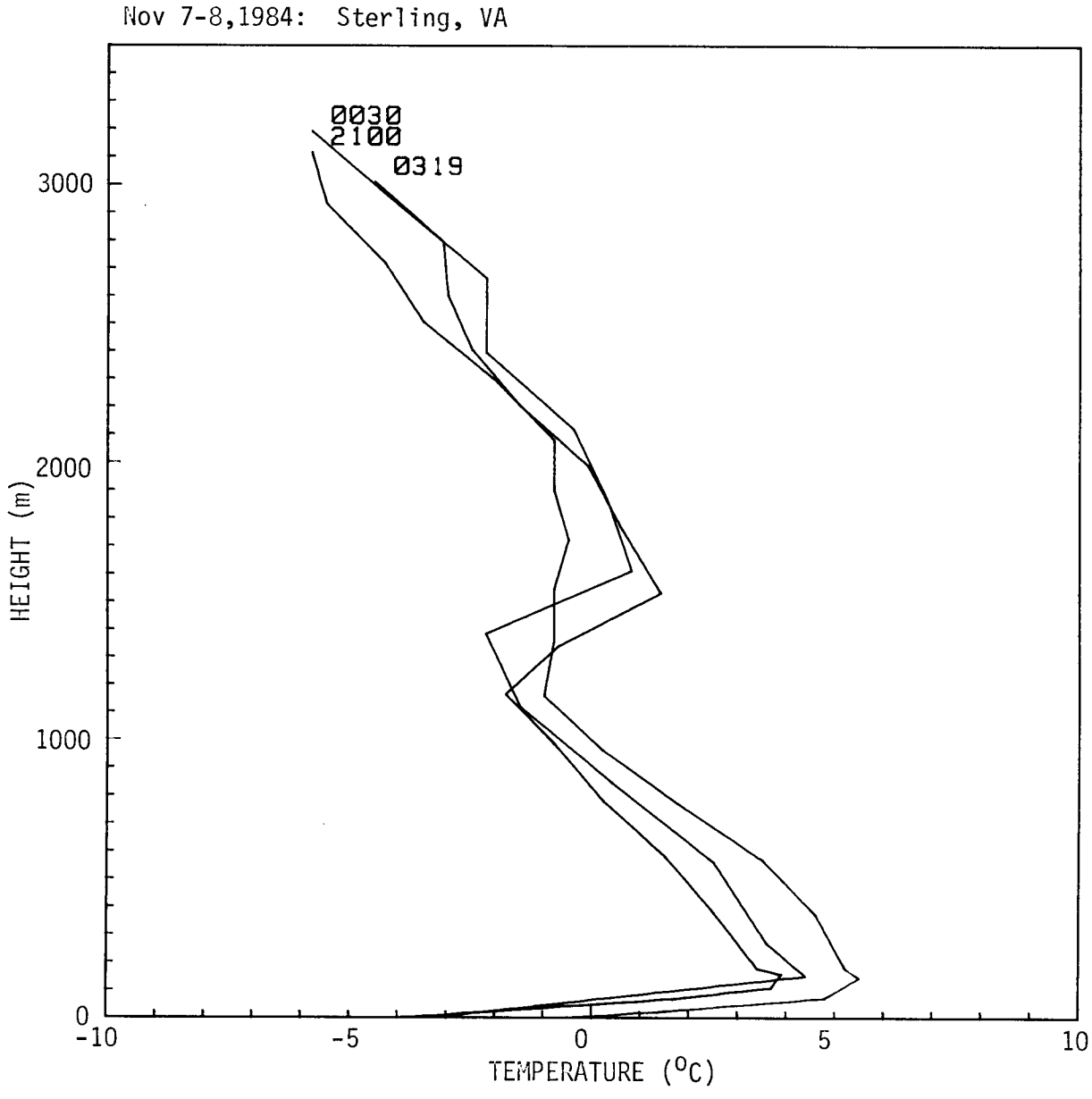

Figure A.3.2--Rawinsonde temperature profiles for the 7 November intensive experiment.

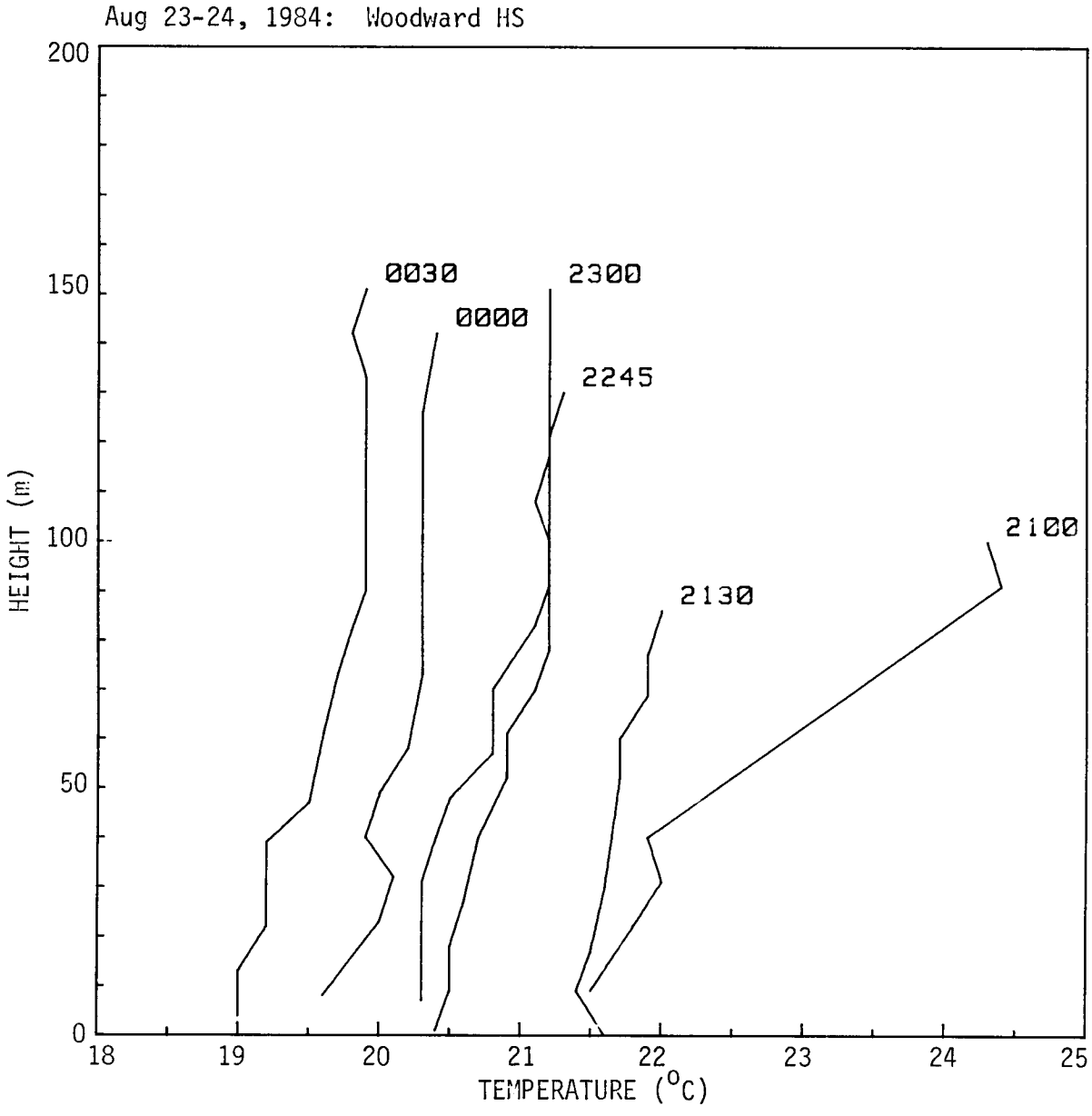

Figure A.3.3--Tethersonde temperature profiles at the suburban site for the 23 August intensive experiment.

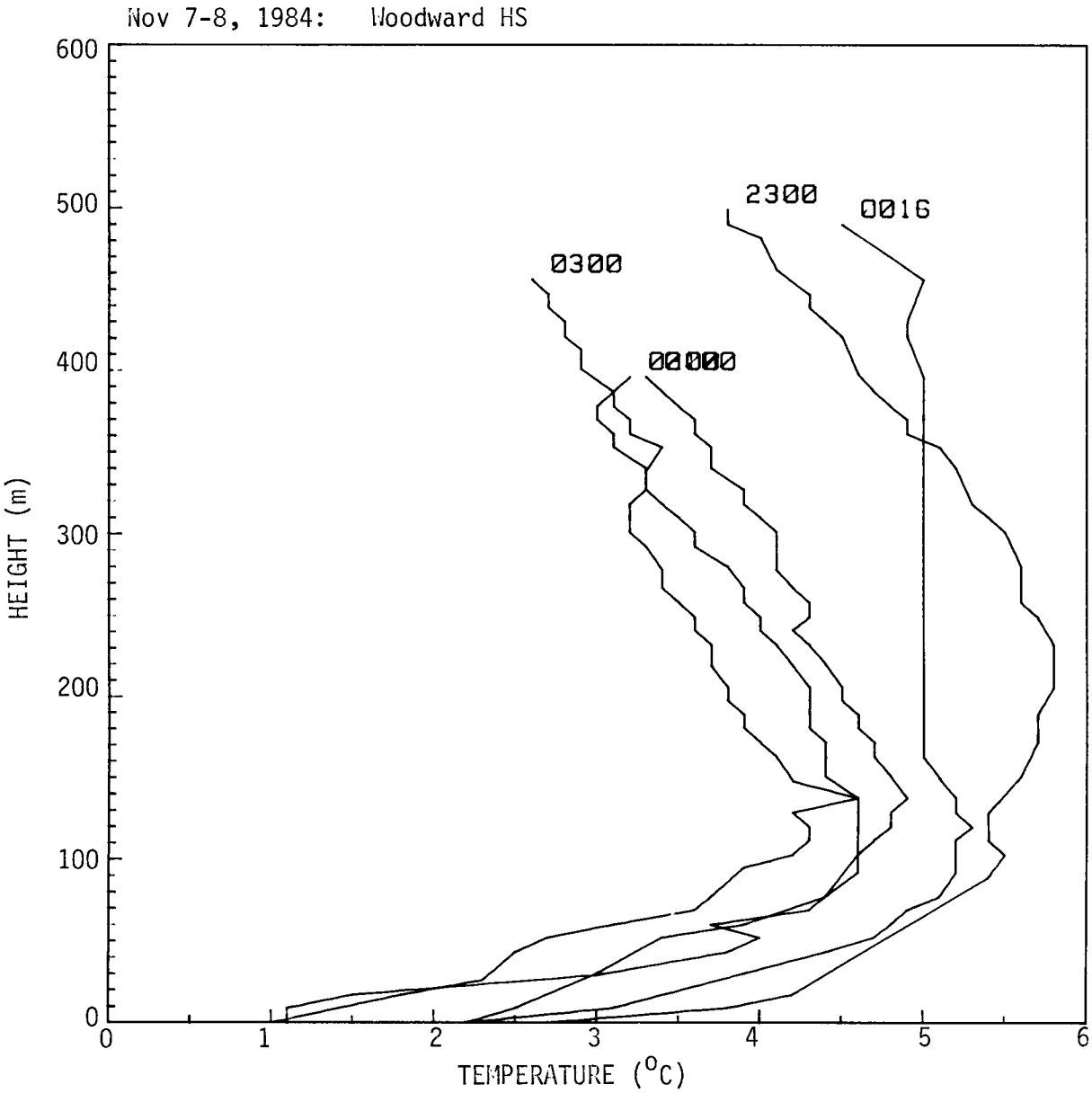

Figure A.3.4--Tethersonde temperature profiles at the surburban site for the 7 November intensive experiment.

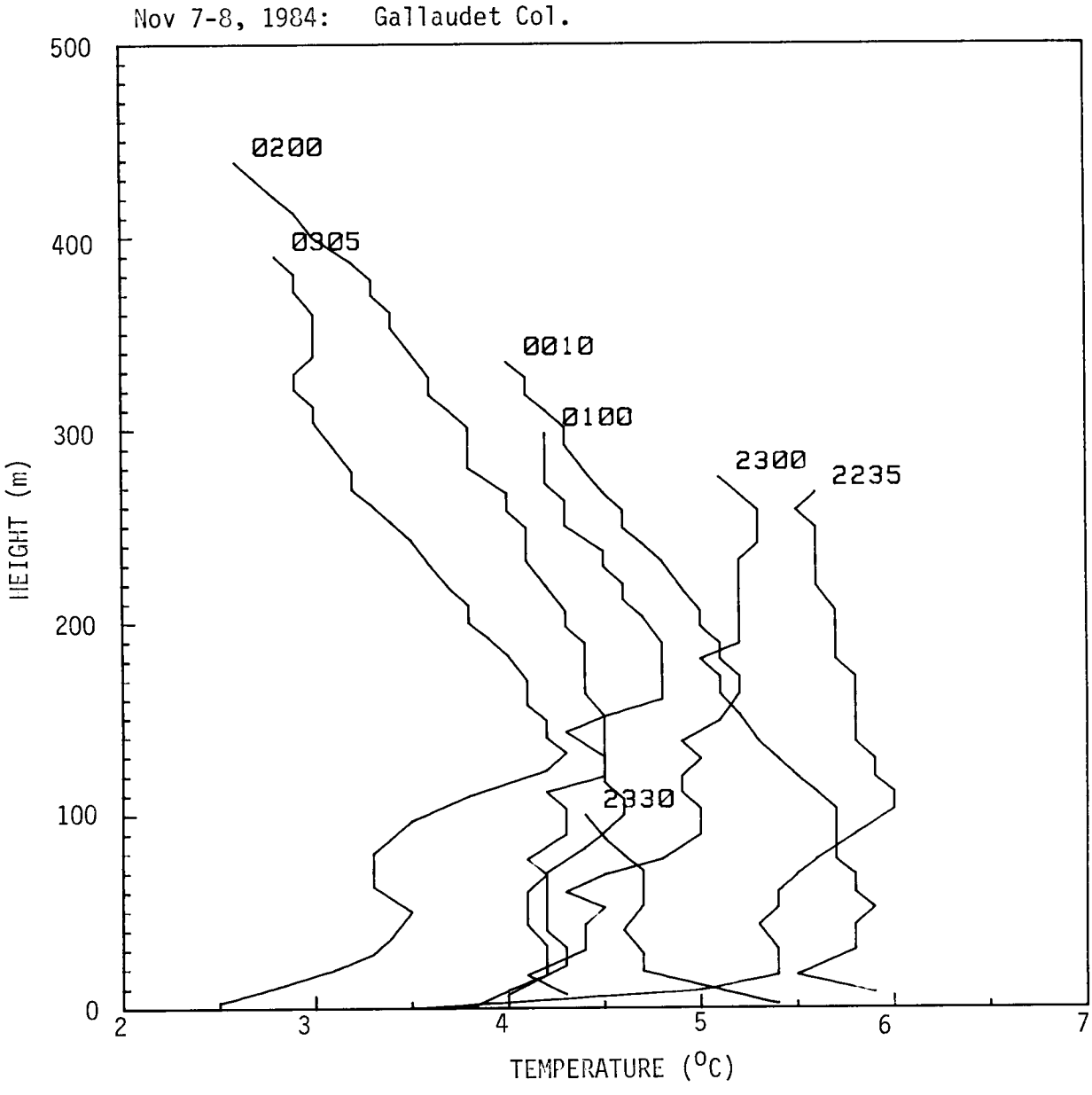

Figure A.3.6--Tethersonde temperature profiles at the downtown site for the 7 November intensive experiment.

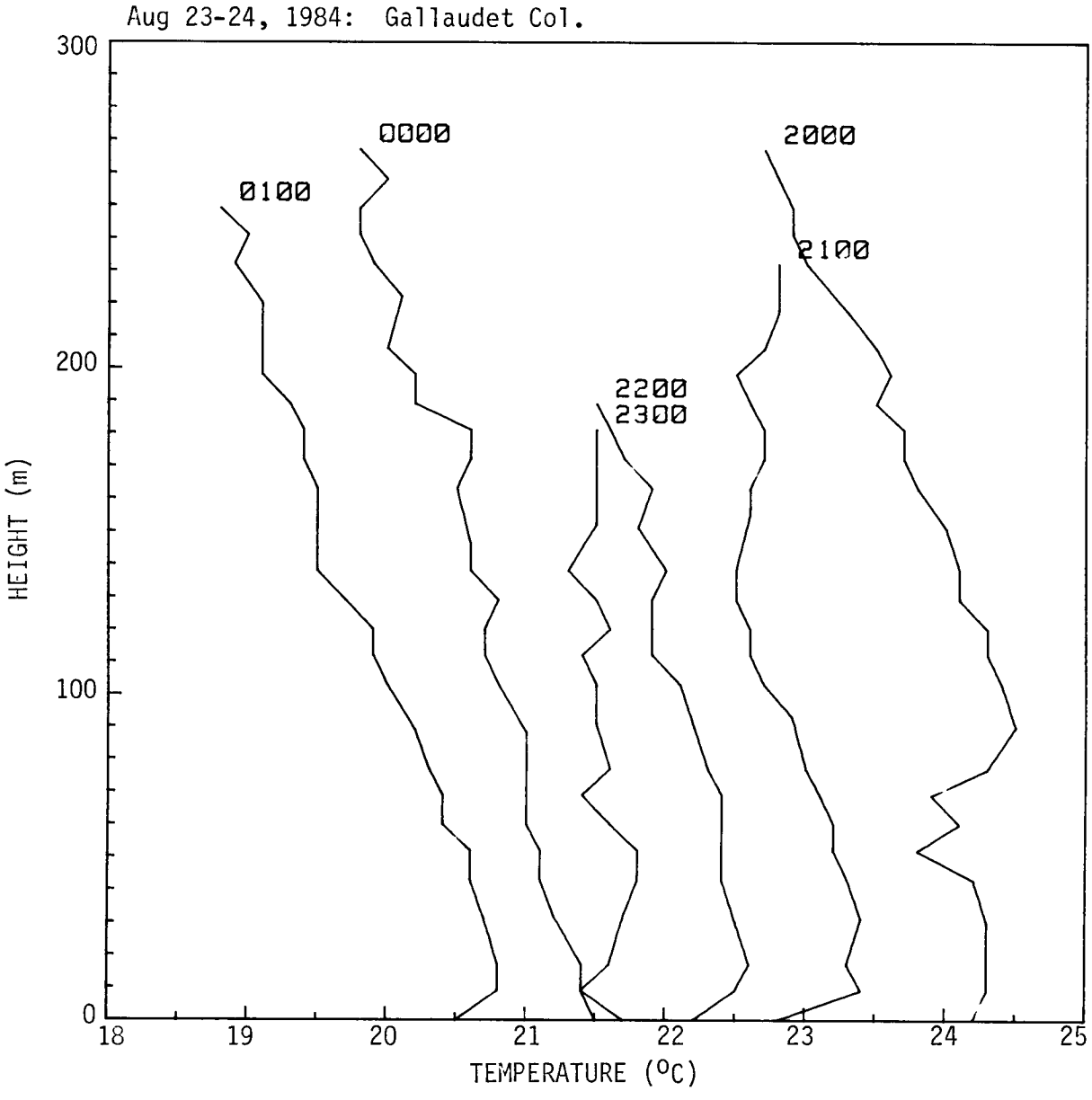

Figure A.3.5--Tethersonde temperature profiles at the downtown site for the 23 August intensive experiment.

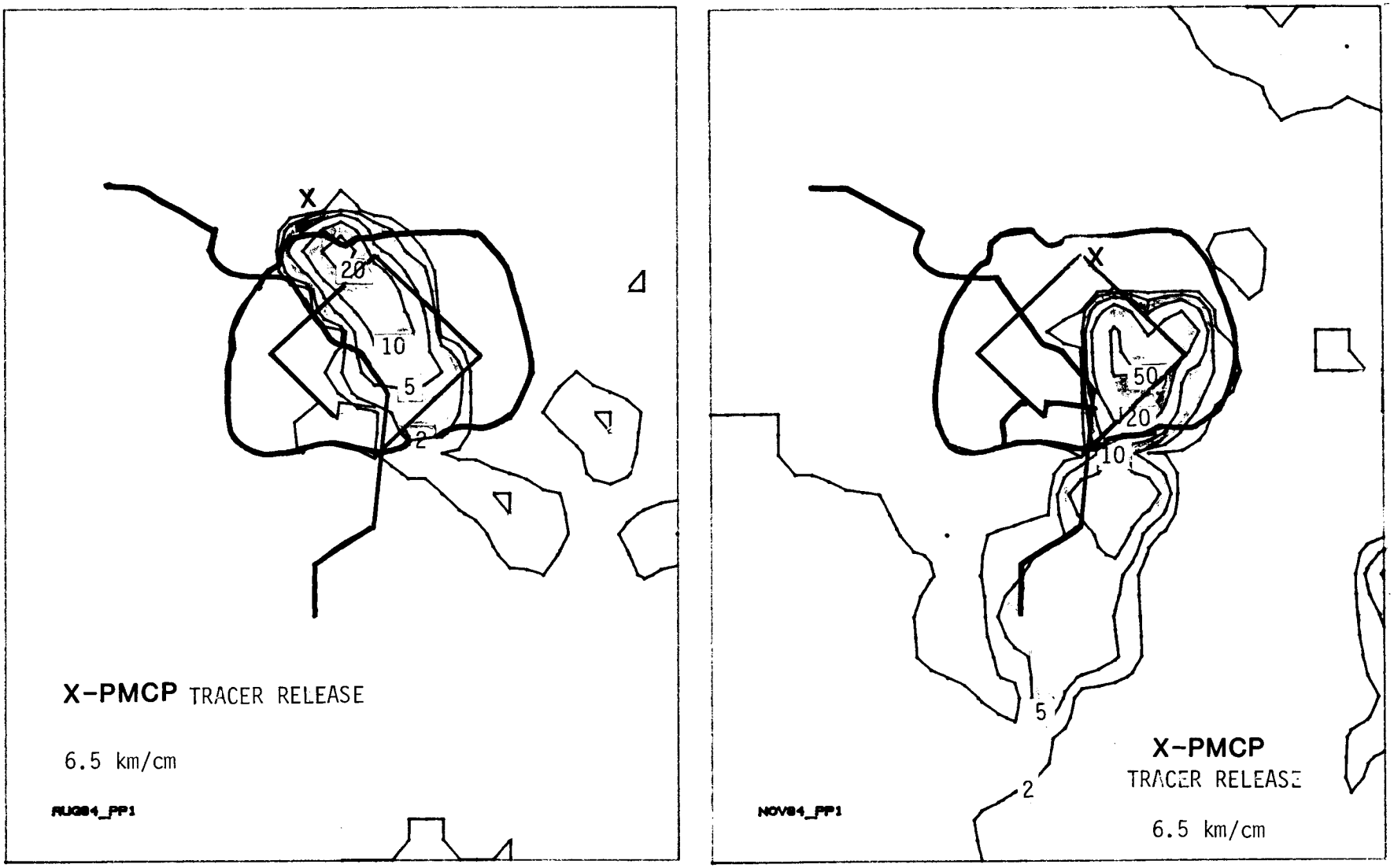

Figure A.3.7--Concentration contours for the monthly average value of PMCP for the August (left) and November (right) intensive experiments.