Background Air Quality

Sandalta Trailer

May 1983 To March 1984

By

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For

Research Management Division

Alberta Environment

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ABSTRACT

The results of a baseline air quality and meteorological data collection program at a site in the Athabasca oil sands region, 65 km north of Fort McMurray, Alberta are presented. Sulphur dioxide, ozone, nitric oxide, nitrogen dioxide and meteorological parameters were monitored from May 1983 through March 1984, inclusive.

Sulphur dioxide concentrations averaged 3 ppbv over the study period. Mean ozone concentrations averaged about 27 ppbv. Nitric oxide and nitrogen dioxide concentrations averaged 0.6 ppbv and 1 ppbv, respectively.

The prevailing wind direction was southerly, parallel to the Athabasca River. The fraction of the total pollutants arriving from each direction was similar to the overall wind rose. However, the average pollutant concentrations varied only weakly with wind direction.

Two events were examined in detail. In one case, the air was transported from the Peace River region over the Oil Sands region. Sharp increases in pollutant concentrations were monitored as vertical mixing developed in the late morning hours. In the second case, the air mass source region was in the Northwest Territories and relatively low pollutant concentrations were recorded.

1. INTRODUCTION

Promet Environmental Group Ltd. reactivated and maintained an automatic air quality and meteorological monitoring station in northeastern Alberta from May 1983 to March 1984. The station was originally installed for Gulf Canada Resources Inc. in April 1981 and closed down in February 1982. The atmospheric monitoring is one component of an integrated research program on acidic deposition - vegetation response - soils interface. The data will be used with plant response data as input to a numerical model.

2. METHODS

2.1 EQUIPMENT

The air quality and meteorological monitoring station shown in Figure 1 was located in a clearing about 0.5 km^2 in size. It is adjacent to the former Gulf Sandalta camp 14 km east of Fort Mackay in the Athabasca Oil Sands region a shown in Figure 2. The following instruments were mounted on a 50 m tower: Athabasca Research Windflo 540 anemometers and wind direction vanes at 11.18 m and 46.38 m; aspirated and shielded thermocouple junctions at 9.53 m and 46.18 m to measure temperature difference; Campbell Scientific #201 temperature and relative humidity sensor at 1.5 m; Li-Cor solar radiation sensor at 4.0 m; Gill vertical propellor anemometer at 46.4 m.

A Weathertronics electrically heated tipping bucket rain/snow gauge was located on the ground about 20 m from the base of the tower.

Air quality monitoring instruments (Figure 3) included:

1. Monitor Labs 8850 SO_2 analyzer;
2. Monitor Labs 8840 $NO/NO_2/NO_x$ analyzer;
3. Monitor Labs 8550 O_3 analyzer; and
4. Monitor Labs 8500 calibrator and 8530 controller.

Figure 1. Meteorological Tower (50 m) and Trailer facing north.

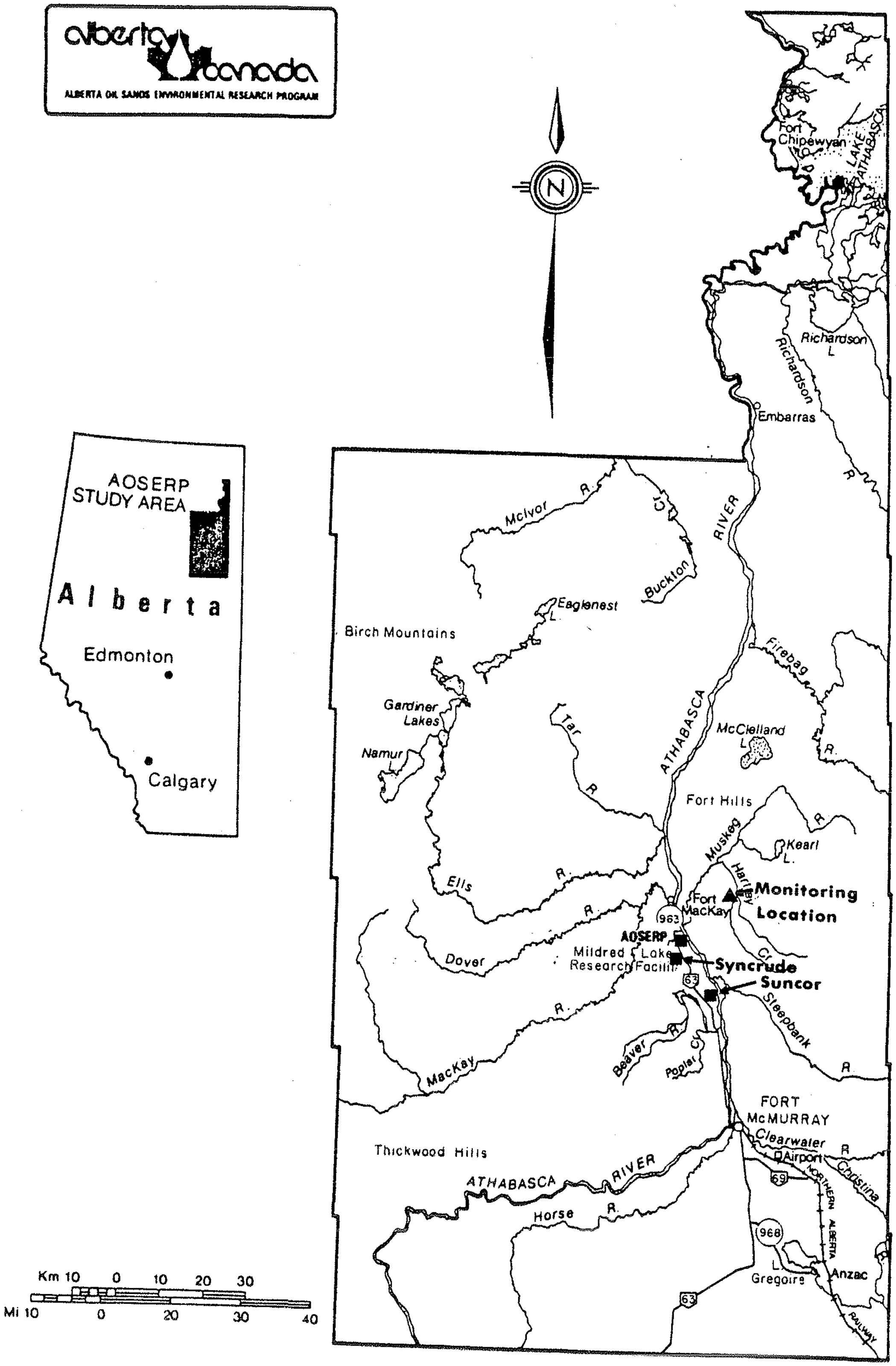

Figure 2. Location of the monitoring trailer.

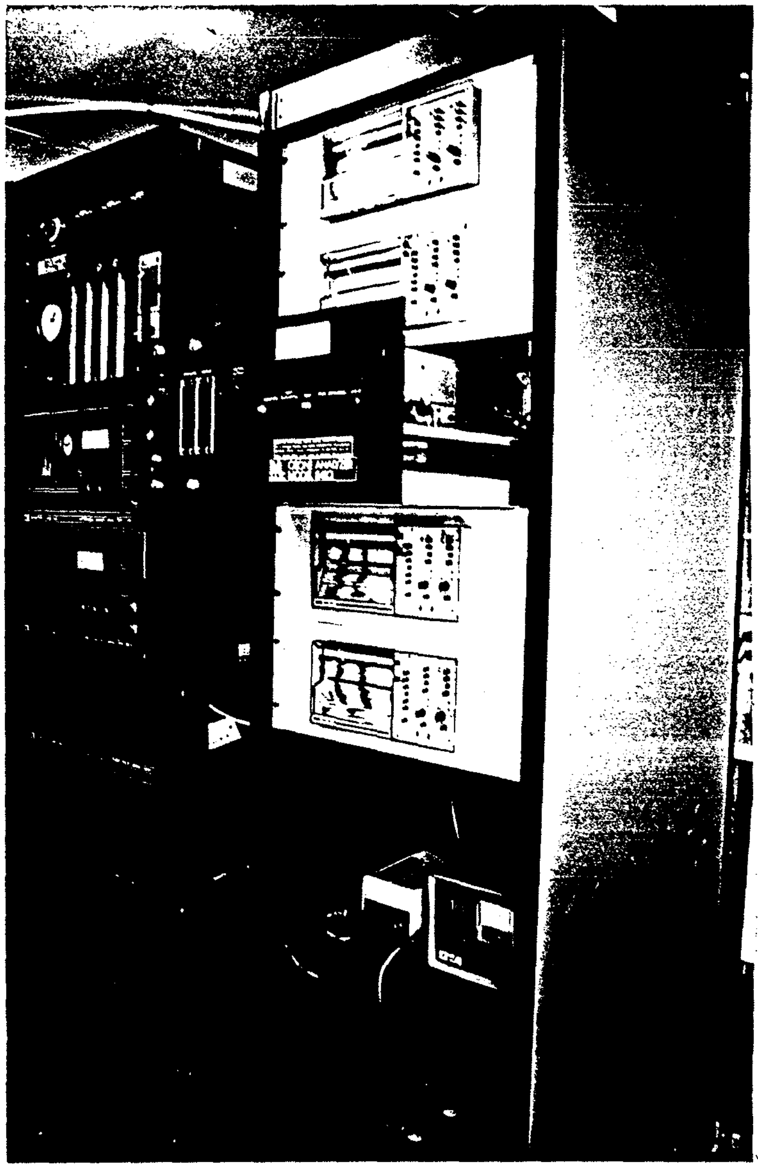

Figure 3. Air quality analyzers, calibrator and chart recorders.

2.2 DATA ACQUISITION

The meteorological and air quality variables were scanned at 10 second intervals by two Campbell Scientific CR21L microloggers. Analog and pulse signals were converted to engineering units and stored in intermediate memory for further computations every 5 minutes. Pollutant concentrations were measured at the 4.0 m and 22.0 m levels. The upper sample point is approximately 4 m above the canopy height (to the west). A teflon solenoid valve system controlled by one of the dataloggers was used to switch sampling level at 5 minute intervals. This procedure gave six data points per hour at each of the two heights above ground for each gas. Included in each 5 minutes was a 4 minute equilibration period followed by a 1 minute period in which the average concentrations were recorded by the datalogger. The equilibration period allowed the analyzers to reach over 95% response to any changes in ambient concentration at the two sampling heights. Residence time in the 12.5 mm diameter teflon sampling lines was less than 5 seconds to minimize adsorptive effects. Zero-span-zero analyzer checks were done once daily over a one hour period. Data were recorded on cassette tape with the gas concentrations and horizontal winds also recorded on charts as backup.

2.3 CALIBRATIONS

Multipoint calibrations were performed once a month on the three air quality analyzers. The analyzers were calibrated on the same range as they monitored. For NO/NO_x, O_3 and SO_2 concentration ranges to 0.5 ppm, 0.2 ppm and 1 ppm were used respectively. A permeation tube in a temperature controlled oven was used for the SO_2 calibration. Gas from a standard bottle of NO was diluted with NO scrubbed air for balancing of the NO and NO_x channels in the NO_x analyzer. Ozone from an ultraviolet lamp source was used to calibrate the O_3 analyzer and also used to produce NO_2 for calibration of the NO_x analyzer. The glassware required to produce NO_2 by gas phase titration was retrofitted to the calibrator in December 1983. Earlier attempts to use NO_2 permeation tubes were foiled by their inherent instability.

Calibrations were crosschecked semi-annually by Alberta Environment audits. Checks for correlation coefficients, zero intercept and linear regression slope were carried out on each analyzer. Although the initial audit showed a few problems existed, particularly with the ozone generator output, the second audit showed all equipment was performing exceptionally well. Alberta Environment's audits were conducted in less than ideal circumstances, as, not enough time was allowed for each calibration and when a single teflon line was used for all three analyzers, contamination problems arose. NO scavenging of O_3 during the ozone calibration impeded the response time of the analyzer and on both audit occasions, the analyzer never reached a stable level after 30 minutes.

Manufacturer's specified calibrations were used for all of the meteorological sensors. The pyranometer conversion factor was 0.0012 $MJ/m^2/mV$.

2.4 TELEPHONE INTERROGATION

The station was at a remote, unmanned location. Telephone calls were made three times a week to check equipment status and trailer interior temperature by interrogation of the dataloggers. Because of the large volume of data gathered by the CR21L micrologger systems, only the previous 8 hours or so of data was accessible over the phone. The primary means of data handling was by cassette tape rather than telephone interrogation. Manually performed, the checks provided easy access to data in final storage. Of particular interest were the analyzers' response to daily zero/span/zero routines so telephone calls were generally carried out after these calibrations.

All of the problems encountered in the eleven months of monitoring at the sites were detectable by phone. These included the 50 m wind vane being pegged against a radio antenna, trailer temperature changes, failure of the vertical anemometer, power failures, and excess noise on the NO channel of the NO_x analyzer.

Daily zero-span-zero checks using the same N.B.S. traceable reference materials as in the monthly multipoints showed consistent and accurate sensitivity and response characteristics for all three analyzers day after day. The ozone analyzer, for example, displayed a baseline consistently accurate to three decimal places for many months. Baseline values for the period October 1983 to March 1984 are given in Appendix 6.3.4.

2.5 QUALITY ASSURANCE/QUALITY CONTROL

Calibration criteria used for quality control of equipment included the following:

Slope: $0.95 \leq m \leq 1.05$ Excellent,

$0.85 \leq m < 0.95$ or

$1.05 < m \leq 1.15$ Satisfactory;

Intercept: satisfactory, if $b < 3\%$ of full scale range;

Correlation: linear, if $r^2 \geq 0.9950$.

The monthly calibration results are summarized in Appendix 6.3.

Quality assurance checks were used to assess the variability of the monthly calibrations and to modify the air quality data accordingly. For example, if the calibration changed less than 5%, no changes were made to the data set. If a shift from 6 to 14% was encountered, a ratio of conversion factors was applied. If coefficients differed monthly by over 14%, the data were discarded and a second field calibration was carried out to verify the results.

3. RESULTS

3.1 SULPHUR DIOXIDE CONCENTRATIONS

Tables 1 and 2 give the concentration statistics for SO_2. The annual means were about 3 ppbv at both levels. The vertical concentration gradients were very weak in the May through August period. On average the strongest gradients (33 pptv/m) occurred in December when there is little turbulent transfer. The Alberta standard (170 ppbv as a one hour average) was exceeded on one occasion. An hourly average concentration of 180 ppbv was recorded on 1983 October 1. The frequency distribution of SO_2 was positively skewed with most concentrations less than 10 ppbv (Figure 4).

3.2 OZONE CONCENTRATIONS

Concentration statistics for O_3 are given in Tables 3 and 4. Mean annual values were 26 to 27 ppbv. The maximum hourly average was 130 ppbv on 1983 July 31. Winds were from the south southwest and 40 ppbv of SO_2 was recorded during the same hour. Similar cases of excess ozone formation in summer has been observed from the oil sands plants by Lusis (1978) and predicted by Bottenheim (1981). The Alberta maximum permissible concentration (80 ppbv as a one hour average) was exceeded on 40 occasions. These exceedances occurred in June, July and August. Relatively high O_3 readings have been noted previously in Athabasca Oil Sands region (Strosher 1978:30). The cumulative frequency distribution (Figure 5) is approximately log normal.

Table 1. SO2 concentration statistics May 1983 - March 1984, 4 m level.

Period	Mean (ppbv)	Min (ppbv)	Max (ppbv)	S. D. (ppbv)	Range (ppbv) <20	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	Total Number
					Percent frequencies by concentration range.										
May	0.8	0.0	50.0	5.2	97.9	1.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	141
Jun	1.1	0.0	90.0	6.4	97.2	2.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	675
Jul	1.1	0.0	103.2	7.6	99.0	0.2	0.2	0.2	0.3	0.2	0.0	0.0	0.0	0.0	613
Aug	1.4	0.0	77.5	6.8	97.8	1.6	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	579
Sep	2.4	0.0	88.0	9.0	96.3	1.6	1.5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	682
Oct	4.1	0.0	189.7	13.7	94.2	3.7	0.8	0.6	0.3	0.1	0.1	0.0	0.0	0.1	710
Nov	3.7	0.0	99.2	11.9	94.2	2.4	1.9	1.3	0.1	0.0	0.0	0.0	0.0	0.0	667
Dec	1.6	0.0	70.3	5.1	99.0	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	707
Jan	2.5	0.0	72.2	7.2	96.6	2.5	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	707
Feb	5.1	0.0	125.7	13.8	92.6	3.9	1.7	1.1	0.5	0.0	0.3	0.0	0.0	0.0	662
Mar	6.5	0.0	118.5	16.3	90.4	4.8	2.0	1.4	0.8	0.6	0.0	0.0	0.0	0.0	709
Winter	3.9	0.0	125.7	11.7	94.6	2.8	1.3	0.8	0.3	0.1	0.1	0.0	0.0	0.0	3452
Summer	2.0	0.0	189.7	9.2	96.9	1.9	0.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	3400
Year	3.0	0.0	189.7	10.6	95.7	2.4	1.0	0.6	0.2	0.1	0.0	0.0	0.0	0.0	6852

Table 2. SO2 concentration statistics May 1983 - March 1984, 22 m level.

Period	Mean (ppbv)	Min (ppbv)	Max (ppbv)	S. D. (ppbv)	Range (ppbv) <20	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	Total Number
					Percent frequencies by concentration range.										
May	0.8	0.0	43.3	5.0	97.9	1.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	142
Jun	1.1	0.0	75.0	6.0	97.9	1.5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	678
Jul	1.1	0.0	120.7	7.6	98.5	0.6	0.2	0.3	0.2	0.0	0.2	0.0	0.0	0.0	616
Aug	1.3	0.0	83.8	6.5	97.6	1.9	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	594
Sep	2.6	0.0	92.5	9.2	95.6	2.3	1.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	682
Oct	4.6	0.0	184.5	14.3	93.7	3.7	1.5	0.6	0.0	0.1	0.3	0.0	0.0	0.1	710
Nov	4.0	0.0	100.5	12.8	93.6	2.8	1.9	1.0	0.4	0.1	0.0	0.0	0.0	0.0	669
Dec	2.2	0.0	70.2	6.3	97.9	1.3	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	707
Jan	2.9	0.0	83.7	7.8	96.2	2.7	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	708
Feb	5.2	0.0	154.5	14.0	92.6	4.1	1.7	1.1	0.2	0.3	0.0	0.2	0.0	0.0	662
Mar	6.5	0.0	128.3	16.0	90.6	4.2	2.4	1.4	1.1	0.1	0.1	0.0	0.0	0.0	709
Winter	4.2	0.0	154.5	12.0	94.2	3.0	1.5	0.8	0.4	0.1	0.0	0.0	0.0	0.0	3455
Summer	2.1	0.0	184.5	9.3	96.6	2.0	0.8	0.3	0.1	0.0	0.1	0.0	0.0	0.0	3422
Year	3.1	0.0	184.5	10.8	95.4	2.5	1.1	0.5	0.2	0.1	0.1	0.0	0.0	0.0	6877

Table 3. O3 concentration statistics May 1983 - March 1984, 4 m level.

Period	Mean	Min	Max	S. D.	Percent frequencies by concentration range. Range										Total Number
	(ppbv)	(ppbv)	(ppbv)	(ppbv)	(ppbv) <15	15-29	30-44	45-59	60-74	75-89	90-104	105-119	120-134	135-149	
May	39.6	10.5	59.0	12.1	6.5	13.8	34.1	45.5	0.0	0.0	0.0	0.0	0.0	0.0	123
Jun	34.7	3.0	81.7	16.4	12.4	28.1	30.9	21.3	6.7	0.6	0.0	0.0	0.0	0.0	676
Jul	49.2	5.5	130.0	20.7	3.3	15.1	29.3	20.7	20.3	8.1	2.6	0.5	0.2	0.0	615
Aug	57.0	29.5	79.2	18.3	0.0	8.3	25.0	16.7	25.0	25.0	0.0	0.0	0.0	0.0	12
Sep	20.4	0.6	44.3	10.5	32.1	46.3	21.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	635
Oct	26.4	0.4	49.4	9.6	12.1	49.0	37.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	708
Nov	19.8	1.4	53.7	8.5	32.0	54.8	12.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	668
Dec	21.0	0.2	39.7	7.8	22.2	64.7	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	612
Jan	13.9	3.3	26.7	4.6	58.3	41.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	683
Feb	16.4	4.0	24.0	4.0	32.6	67.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	641
Mar	30.5	10.3	57.0	8.7	4.6	37.6	54.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0	646
Winter	20.3	0.2	57.0	9.0	30.4	53.0	15.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	3250
Summer	32.9	0.4	130.0	18.1	14.5	34.0	30.2	12.2	6.2	2.1	0.6	0.1	0.0	0.0	2769
Year	26.1	0.2	130.0	15.3	23.1	44.3	22.5	6.0	2.9	0.9	0.3	0.0	0.0	0.0	6019

Table 4. O3 concentration statistics May 1983 - March 1984, 22 m level.

Period	Mean	Min	Max	S. D.	Percent frequencies by concentration range. Range										Total Number
	(ppbv)	(ppbv)	(ppbv)	(ppbv)	(ppbv) <15	15-29	30-44	45-59	60-74	75-89	90-104	105-119	120-134	135-149	
May	41.7	10.7	59.0	13.4	6.5	13.7	29.8	50.0	0.0	0.0	0.0	0.0	0.0	0.0	124
Jun	34.9	2.8	80.0	16.4	12.8	27.2	29.8	23.3	6.7	0.3	0.0	0.0	0.0	0.0	674
Jul	46.9	3.2	126.0	21.2	4.9	19.7	26.2	19.9	19.4	7.6	1.6	0.5	0.2	0.0	618
Aug	66.0	53.0	83.0	10.7	0.0	0.0	0.0	50.0	25.0	25.0	0.0	0.0	0.0	0.0	12
Sep	23.7	0.9	45.0	9.5	21.0	51.3	27.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	634
Oct	28.9	7.2	50.0	8.1	4.8	48.5	45.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	709
Nov	20.8	2.0	42.6	8.3	26.9	57.4	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	669
Dec	22.9	0.3	40.4	6.7	11.8	74.3	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	611
Jan	15.0	4.4	27.5	3.9	53.1	46.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	684
Feb	17.6	4.3	24.0	3.2	20.7	79.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	641
Mar	32.1	10.2	56.7	8.1	2.2	34.2	59.3	4.3	0.0	0.0	0.0	0.0	0.0	0.0	646
Winter	21.6	0.3	56.7	8.7	23.4	58.1	17.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	3251
Summer	33.9	0.9	126.0	16.9	10.5	35.8	32.3	13.0	6.1	1.9	0.4	0.1	0.0	0.0	2771
Year	27.3	0.3	126.0	14.5	17.5	47.8	24.4	6.5	2.8	0.9	0.2	0.0	0.0	0.0	6022

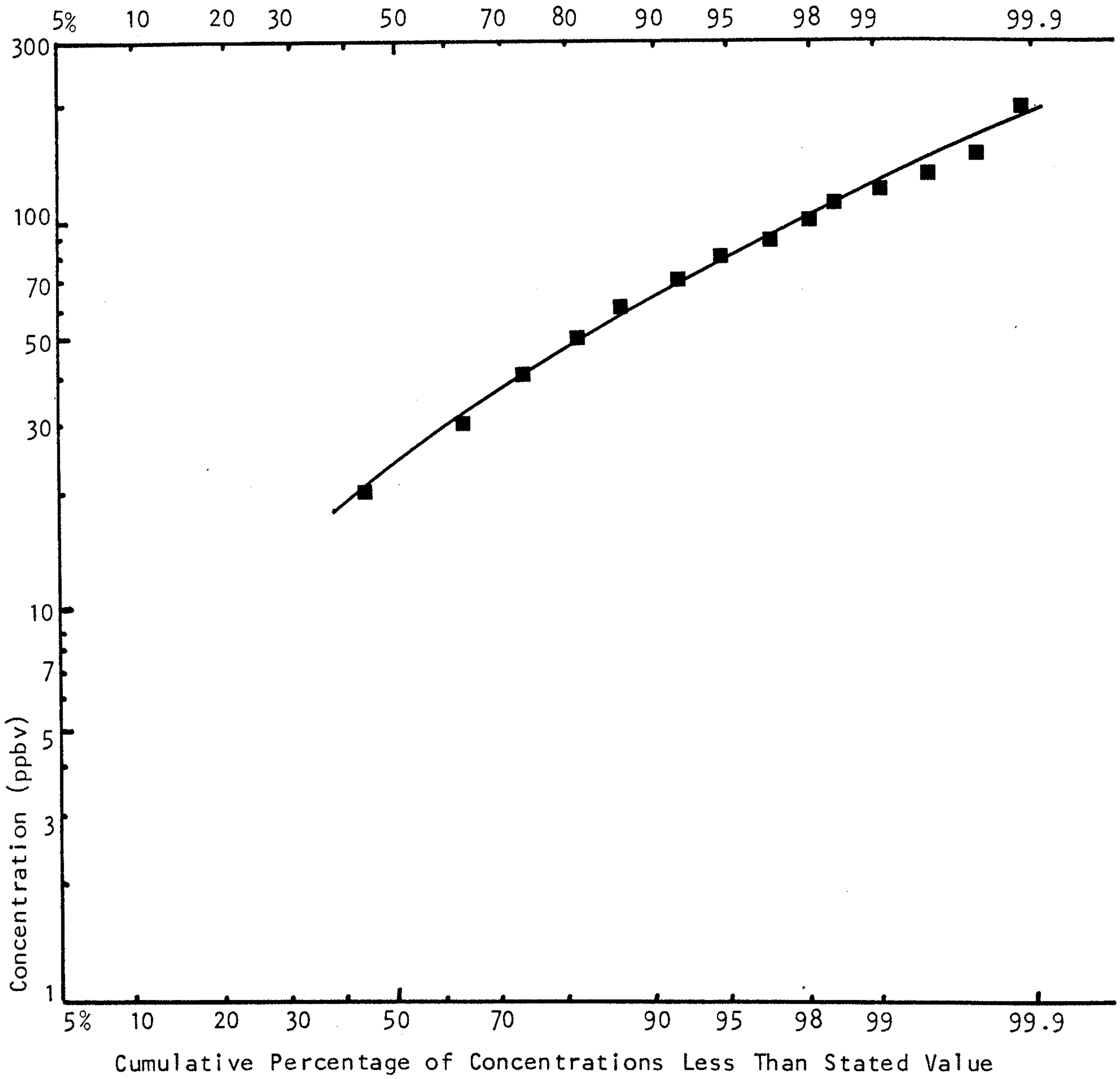

Figure 4. Cumulative frequency distribution of one hour average SO_2 concentrations. Only concentrations greater than 10ppbv are included.

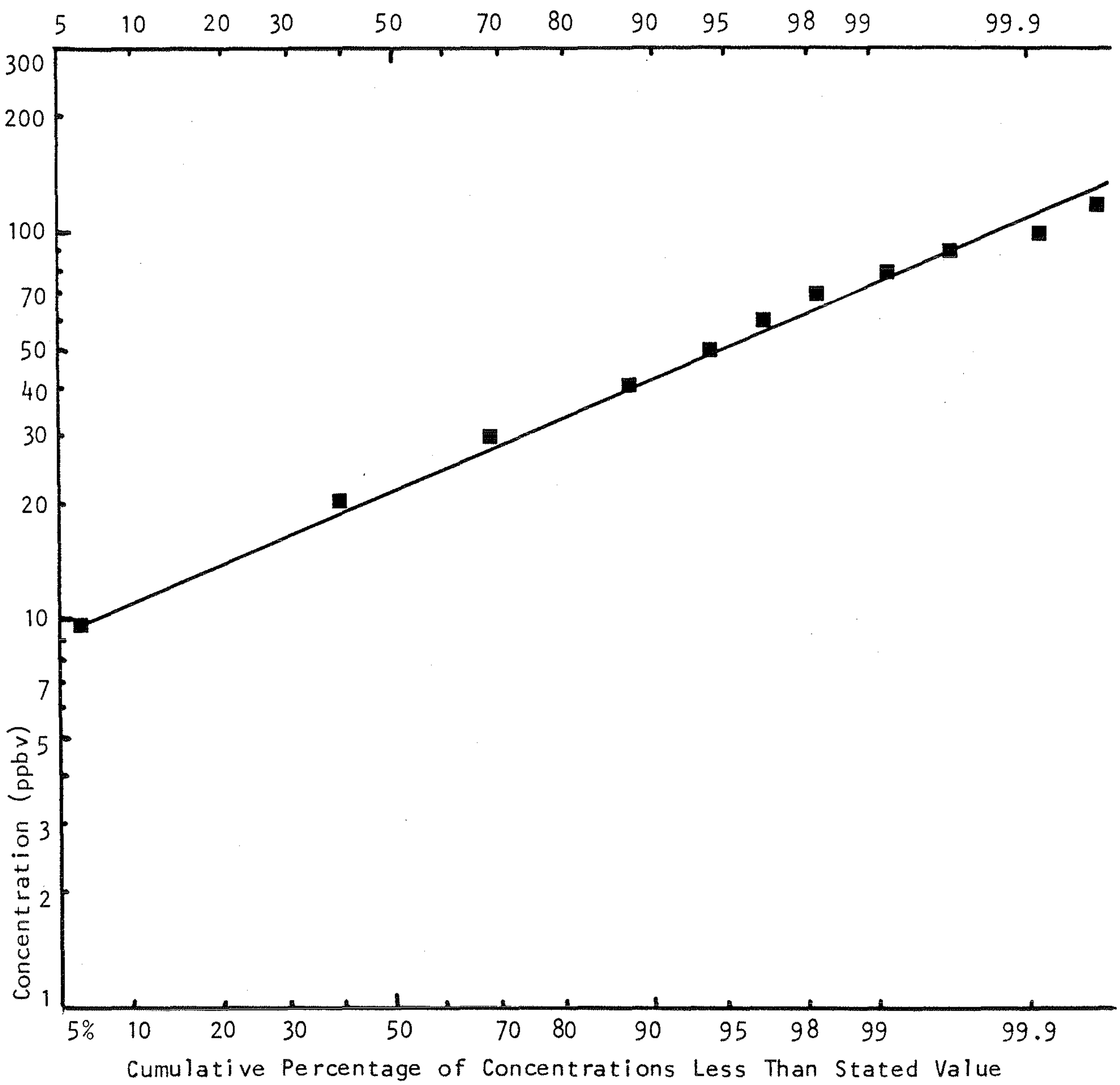

Figure 5. Cumulative frequency distribution of one hour average O_3 concentrations.

3.3 NITRIC OXIDE CONCENTRATIONS

The mean annual NO concentrations given in Tables 5 and 6 were 0.6 ppbv. The maximum hourly average concentration was 40 ppbv on 1983 October 6. The gradients of concentration with height were very weak. The frequency distribution of NO (Figure 6) was extremely positively skewed with most concentrations lower than 5 ppbv but with a few as high as 40 ppbv.

3.4 NITROGEN DIOXIDE

Mean NO_2 concentrations are given in Tables 7 and 8 by month, season and year. The mean annual concentration was about 1 ppbv. The maximum hourly average was 21 ppbv in February. Concentration usually increased with height, but the average difference between the two levels was small. The frequency distribution of NO_2 (Figure 7) was highly skewed like that of NO.

3.5 CORRELATIONS

The correlation coefficients (r) between each of the gases and the other gases and meteorological parameters are given in Tables 9 through 12. Note that the negative cosine of the hour of the day, Julian day, and wind direction is used to account for the cyclical nature of these variables. The equations used in the analysis are given in Appendix 6.1.

Table 5. NO concentration statistics June 1983 - March 1984, 4 m level.

Period	Mean	Min	Max	S. D.	Percent frequencies by concentration range.										Total Number
	(ppbv)	(ppbv)	(ppbv)	(ppbv)	Range (ppbv) <5	5 - 9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	
Jun	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	212
Jul	0.0	0.0	3.3	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	465
Aug	0.1	0.0	3.3	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	554
Sep	0.8	0.0	6.1	1.3	99.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	665
Oct	2.7	0.0	40.7	2.9	97.0	1.9	0.3	0.0	0.3	0.2	0.2	0.0	0.2	0.0	637
Nov	0.5	0.0	10.7	1.1	99.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	669
Dec	0.2	0.0	3.8	0.4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	706
Jan	0.3	0.0	3.3	0.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	703
Feb	0.2	0.0	30.6	1.5	99.1	0.6	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	653
Mar	0.2	0.0	8.8	0.7	99.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	574
Winter	0.3	0.0	30.6	0.9	99.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3305
Summer	0.9	0.0	40.7	1.9	99.1	0.6	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	2533
Year	0.6	0.0	40.7	1.5	99.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5838

Table 6. NO Concentration statistics June 1983 - March 1984, 22 m level.

Period	Mean	Min	Max	S. D.	Percent frequencies by concentration range.										Total Number
	(ppbv)	(ppbv)	(ppbv)	(ppbv)	Range (ppbv) <5	5 - 9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	
Jun	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	238
Jul	0.0	0.0	4.6	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	468
Aug	0.1	0.0	3.3	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	569
Sep	0.8	0.0	5.0	1.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	665
Oct	2.6	0.0	34.2	2.6	97.8	1.4	0.0	0.2	0.0	0.5	0.2	0.0	0.0	0.0	638
Nov	0.5	0.0	26.0	1.3	99.0	0.9	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	671
Dec	0.1	0.0	7.6	0.5	99.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	706
Jan	0.3	0.0	7.3	0.6	99.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	704
Feb	0.3	0.0	41.5	2.1	98.8	0.9	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	653
Mar	0.2	0.0	8.3	0.6	99.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	574
Winter	0.3	0.0	41.5	1.2	99.4	0.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	3308
Summer	0.9	0.0	34.2	1.8	99.5	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	2578
Year	0.5	0.0	41.5	1.5	99.4	0.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	5886

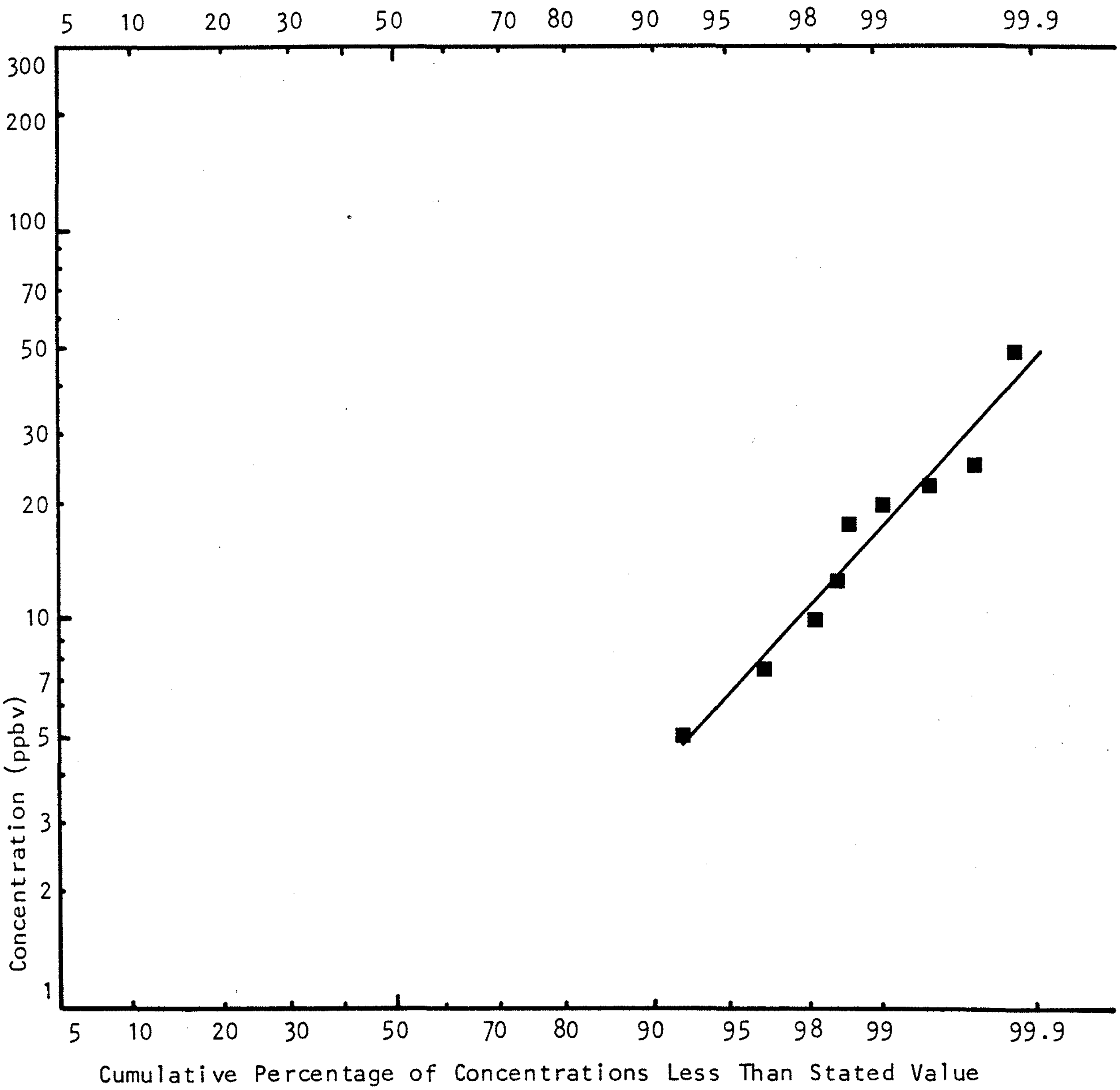

Figure 6. Cumulative frequency distribution of one hour average NO concentrations. Only concentrations greater than 2.5 ppbv are included.

Table 7. NO2 concentration statistics June 1983 - March 1984, 4 m level.

Period	Mean (ppbv)	Min (ppbv)	Max (ppbv)	S. D. (ppbv)	Percent frequencies by concentration range. Range (ppbv) <5	5 - 9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	Total Number
Jun	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	226
Jul	0.1	0.0	3.0	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	470
Aug	0.0	0.0	6.3	0.3	99.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	563
Sep	1.5	0.0	5.5	1.6	99.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	667
Oct	1.9	0.0	12.8	1.4	98.9	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	638
Nov	1.5	0.0	16.7	2.3	92.8	5.7	1.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	669
Dec	1.4	0.0	11.0	1.6	97.2	2.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	632
Jan	1.3	0.0	10.0	1.7	94.7	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	703
Feb	1.6	0.0	19.2	2.5	91.6	6.1	1.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	653
Mar	2.0	0.0	18.8	2.7	89.2	8.4	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	323
Winter	1.5	0.0	19.2	1.9	96.3	3.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2980
Summer	0.9	0.0	12.8	1.4	99.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2564
Year	1.2	0.0	19.2	1.9	96.3	3.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5544

Table 8. NO2 Concentration statistics June 1983 - March 1984, 22 m level.

Period	Mean (ppbv)	Min (ppbv)	Max (ppbv)	S. D. (ppbv)	Percent frequencies by concentration range. Range (ppbv) <5	5 - 9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	Total Number
Jun	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	245
Jul	0.1	0.0	3.2	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	473
Aug	0.0	0.0	1.3	0.1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	576
Sep	1.5	0.0	5.0	1.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	667
Oct	2.0	0.0	15.0	1.4	99.2	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	639
Nov	1.7	0.0	16.7	2.4	91.5	6.4	1.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	671
Dec	1.7	0.0	16.8	2.1	94.8	4.3	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	634
Jan	1.4	0.0	12.5	1.8	93.9	5.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	704
Feb	1.7	0.0	20.6	2.5	92.0	5.8	1.8	0.2	0.2	0.0	0.0	0.0	0.0	0.0	653
Mar	2.1	0.0	17.3	2.7	88.6	9.0	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	324
Winter	1.7	0.0	20.6	2.3	92.6	5.9	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2985
Summer	0.9	0.0	15.0	1.4	99.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2603
Year	1.3	0.0	20.6	2.0	95.9	3.2	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5585

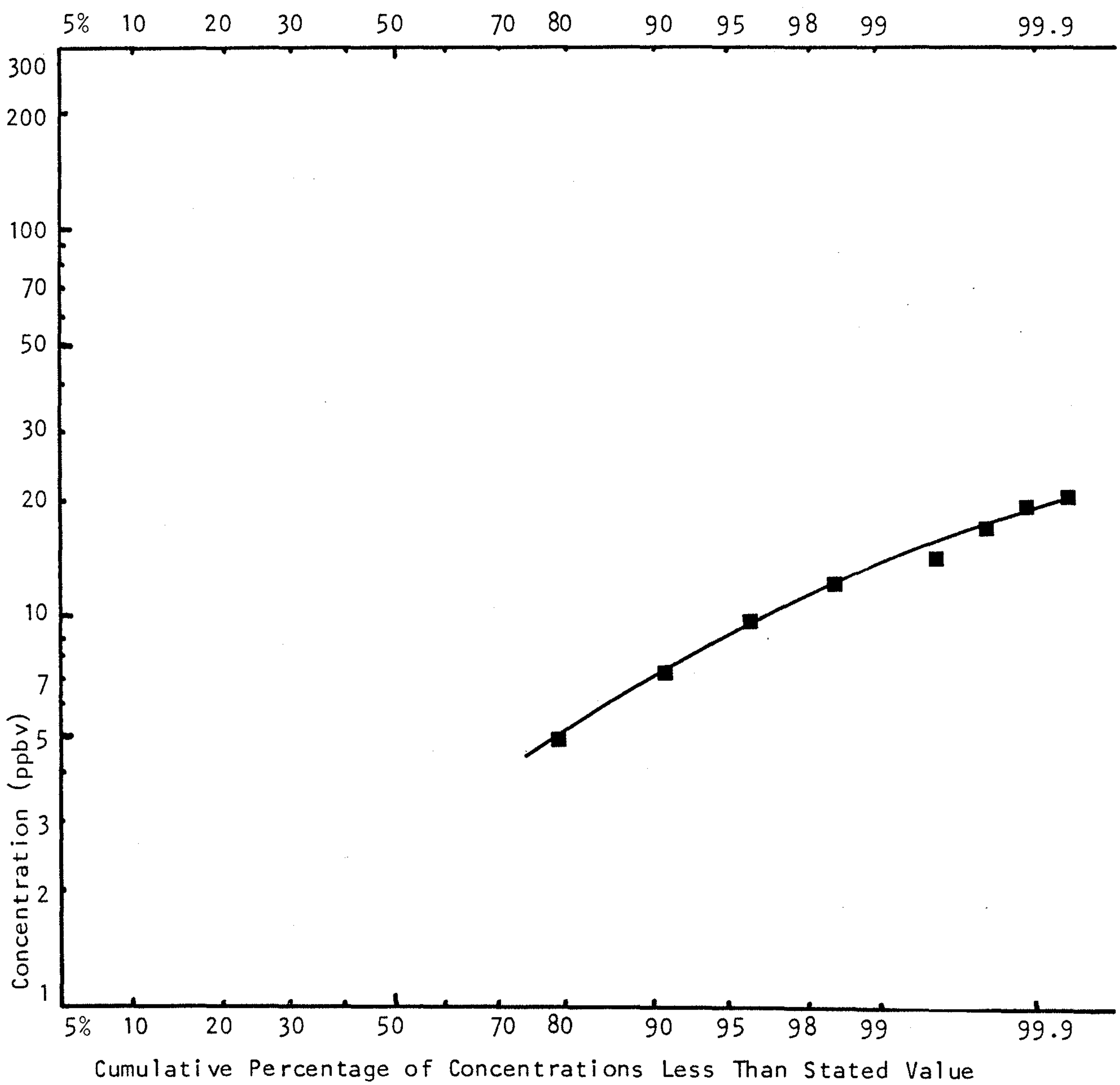

Figure 7. Cumulative frequency distribution of one hour average NO_2 concentrations. Only concentrations greater than 2.5 ppbv are included.

Table 9. Correlation coefficients between SO_2 and the other gases and meteorological parameters.

Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WINT	SUMM	YEAR
[NO]	.011	.252	.287	0.000	0.000	0.000	-.019	-.023	.095	.491	.107	.106	.179	.335	.230
[NO2]	.623	.605	.559	0.000	0.000	0.000	.040	-.009	-.047	.300	.816	.503	.638	.161	.469
[O3]	-.152	-.233	.120	0.000	.008	.151	.174	-.334	-.010	-.057	-.336	-.177	-.017	-.006	-.042
Julian Day*	-.032	-.110	.042	0.000	-.030	.068	-.093	.087	-.010	.013	-.032	.064	.120	-.130	-.088
Hour*	.197	.161	.126	0.000	.134	.182	.153	.230	.259	.237	.113	.078	.141	.208	.171
Temperature	.161	.212	.127	0.000	.024	.148	.175	.116	.142	.234	.055	.166	.178	.030	.020
Relative Humidity	.113	-.065	-.170	0.000	-.002	-.138	-.144	-.108	-.069	-.223	.095	.084	-.107	-.110	-.090
Wind Speed (10 m)	.118	.011	.071	0.000	-.009	.072	.096	.168	.060	.190	-.016	.117	.075	.105	.078
Wind Direction (10m)	.267	.248	.176	0.000	.157	.166	.118	.112	.177	.156	.241	.170	.187	.152	.161
Wind Speed (50 m)	.080	.009	-.103	0.000	-.161	-.019	-.026	-.058	-.124	-.079	-.087	.032	-.015	-.059	-.045
Wind Direction (50m)	.185	.198	.201	0.000	.155	.155	.122	.137	.161	.151	.215	.176	.173	.154	.157
Precipitation	-.032	-.029	.109	0.000	-.019	-.030	-.032	-.028	-.005	-.046	-.028	-.033	-.001	-.030	-.026
Sigma Theta (10 m)	.016	.030	.115	0.000	.018	.096	.122	.101	.099	.111	.042	-.009	.053	.075	.051
Sigma Theta (50 m)	-.029	-.019	.113	0.000	.046	.102	.158	.229	.225	.283	.107	-.008	.071	.145	.092
Temperature Diff.	-.102	-.079	-.121	0.000	-.077	-.087	-.106	-.181	-.167	-.184	-.112	-.041	-.100	-.133	-.111
Solar Radiation	.206	.179	.305	0.000	0.000	0.000	.224	.229	.202	.398	.017	.237	.253	.201	.192

* Negative Cosine of the Cyclical Variables Julian Day, Hour, and Wind Direction.

Table 10. Correlation coefficients between O_3 and the other gases and meteorological parameters.

Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WINT	SUMM	YEAR
[NO]	-.133	.013	.026	0.000	0.000	0.000	-.073	0.000	-.119	-.213	-.191	.029	-.065	-.243	-.055
[NO2]	-.320	-.183	-.049	0.000	0.000	0.000	.123	0.000	.011	-.082	-.444	-.445	-.216	-.287	-.240
[SO2]	-.152	-.233	.120	0.000	.008	.151	.174	-.334	-.010	-.057	-.336	-.177	-.017	-.006	-.042
Julian Day*	.018	.339	.527	0.000	.013	.137	-.132	.001	-.546	-.055	.035	.220	.586	.372	.564
Hour*	.079	.140	.304	0.000	.554	.414	.329	.674	.098	.154	.035	.138	.191	.240	.182
Temperature	.464	.429	.380	0.000	.901	.600	.625	.841	.162	.545	-.110	.490	.341	.609	.557
Relative Humidity	.035	-.621	-.600	0.000	-.799	-.726	-.502	-.787	-.731	-.689	-.535	.304	-.476	-.523	-.511
Wind Speed (10 m)	.533	.395	.365	0.000	.729	.651	.278	.440	.518	.402	.321	.513	.334	.369	.350
Wind Direction (10m)	-.029	.017	.151	0.000	.059	.154	-.086	-.078	.005	-.078	-.176	-.159	-.088	-.013	-.005
Wind Speed (50 m)	.382	.232	.294	0.000	.025	.441	-.017	-.703	.513	.288	.271	.410	.257	.162	.229
Wind Direction (50m)	-.079	.161	.155	0.000	.047	.075	-.091	-.410	-.063	-.066	-.114	-.144	-.087	-.049	-.041
Precipitation	.008	.015	-.029	0.000	-.013	-.135	.136	0.000	-.019	.062	-.007	.059	-.026	.129	.136
Sigma Theta (10 m)	.104	.395	.324	0.000	.657	.518	.441	.425	.505	.345	.290	.106	.247	.394	.339
Sigma Theta (50 m)	.371	.264	.165	0.000	.690	.551	.559	.688	.310	.375	.284	.436	.311	.448	.376
Temperature Diff.	-.412	-.426	-.238	0.000	-.846	-.575	-.414	-.799	-.314	-.436	-.126	-.593	-.282	-.357	-.301
Solar Radiation	.200	.269	.278	0.000	0.000	0.000	.685	.660	.155	.244	.204	.068	.360	.319	.375

* Negative Cosine of the Cyclical Variables Julian Day, Hour, and Wind Direction.

Table 11. Correlation coefficients between NO and the other gases and meteorological parameters.

Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WINT	SUMM	YEAR
[NO2]	-.191	.227	.174	0.000	0.000	0.000	-.031	-.011	.091	.137	.124	.073	.105	.365	.157
[O3]	-.133	.013	.026	0.000	0.000	0.000	-.073	0.000	-.119	-.213	-.191	.029	-.065	-.243	-.055
[SO2]	.011	.252	.287	0.000	0.000	0.000	-.019	-.023	.095	.491	.107	.106	.179	.335	.230
Julian Day*	-.196	-.162	.225	0.000	0.000	0.000	.069	.083	.191	.189	.262	-.172	.002	-.476	-.010
Hour*	-.180	.061	.016	0.000	0.000	0.000	.087	-.181	-.102	.080	.026	.053	.006	.033	.012
Temperature	-.009	.080	.233	0.000	0.000	0.000	-.044	-.175	.188	-.028	.148	.115	.117	-.332	.118
Relative Humidity	.044	.046	.049	0.000	0.000	0.000	.037	.232	.086	.064	-.163	.102	.074	.046	.019
Wind Speed (10 m)	-.081	.011	-.006	0.000	0.000	0.000	-.080	-.141	-.164	-.040	.035	.095	.015	-.025	.008
Wind Direction (10m)	-.154	.066	.115	0.000	0.000	0.000	-.019	-.122	.069	-.012	.162	.168	.064	.068	.094
Wind Speed (50 m)	-.062	.042	-.031	0.000	0.000	0.000	-.119	-.085	-.109	-.147	.057	.089	.016	-.034	.023
Wind Direction (50m)	-.092	.027	.120	0.000	0.000	0.000	.035	.023	.169	.025	.149	.217	.069	.124	.115
Precipitation	-.061	-.013	.057	0.000	0.000	0.000	-.024	.028	.032	.040	.055	-.039	-.001	-.041	-.012
Sigma Theta (10 m)	-.067	.128	.045	0.000	0.000	0.000	-.014	-.134	-.187	-.014	.151	.029	.042	-.085	-.012
Sigma Theta (50 m)	-.074	-.018	-.014	0.000	0.000	0.000	.021	-.168	-.090	.104	.068	-.049	-.019	-.065	-.026
Temperature Diff.	.252	-.045	-.022	0.000	0.000	0.000	.058	.006	.055	-.004	.248	.043	.049	.053	.050
Solar Radiation	-.082	.029	.127	0.000	0.000	0.000	-.185	-.169	-.088	.149	.173	.053	.032	-.089	.024

* Negative Cosine of the Cyclical Variables Julian Day, Hour, and Wind Direction.

Table 12. Correlation coefficients between NO_2 and the other gases and meteorological parameters.

Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WINT	SUMM	YEAR
[NO]	-.191	.227	.174	0.000	0.000	0.000	-.031	-.011	.091	.137	.124	.073	.105	.365	.157
[O3]	-.320	-.183	-.049	0.000	0.000	0.000	.123	0.000	.011	-.082	-.444	-.445	-.216	-.287	-.240
[SO2]	.623	.605	.559	0.000	0.000	0.000	.040	-.009	-.047	.300	.816	.503	.638	.161	.469
Julian Day*	.172	-.084	-.113	0.000	0.000	0.000	-.412	-.070	.048	.267	-.133	-.184	.043	-.548	-.276
Hour*	.124	.103	.245	0.000	0.000	0.000	-.032	.054	-.023	-.069	.068	-.006	.104	.010	.074
Temperature	.139	.331	.386	0.000	0.000	0.000	.363	.055	.200	-.049	-.092	-.071	.130	-.342	-.121
Relative Humidity	.110	-.122	-.129	0.000	0.000	0.000	-.314	-.065	.002	.013	.117	-.121	-.075	-.010	-.021
Wind Speed (10 m)	-.002	.052	.083	0.000	0.000	0.000	-.011	-.013	-.008	-.153	-.134	-.070	-.006	-.012	-.021
Wind Direction (10m)	.329	.282	.160	0.000	0.000	0.000	.184	.027	.132	-.074	.232	.189	.238	.053	.153
Wind Speed (50 m)	.077	.087	-.153	0.000	0.000	0.000	.066	-.069	-.022	-.114	-.118	-.040	-.013	.001	-.034
Wind Direction (50m)	.198	.262	.279	0.000	0.000	0.000	.155	.023	.076	-.152	.203	.194	.213	.028	.131
Precipitation	-.032	-.044	-.004	0.000	0.000	0.000	-.061	-.006	.075	-.056	-.041	-.060	-.034	-.066	-.049
Sigma Theta (10 m)	-.029	.115	.125	0.000	0.000	0.000	.112	.002	-.033	-.070	-.019	-.123	.008	-.054	-.027
Sigma Theta (50 m)	-.130	-.065	.056	0.000	0.000	0.000	.044	.061	-.010	-.051	-.045	-.107	-.035	-.064	-.055
Temperature Diff.	-.029	-.098	-.221	0.000	0.000	0.000	.065	-.052	.042	.129	.050	.099	-.033	.071	.005
Solar Radiation	.019	.188	.481	0.000	0.000	0.000	.147	.042	-.051	.035	-.014	.127	.218	.075	.111

* Negative Cosine of the Cyclical Variables Julian Day, Hour, and Wind Direction.

Among the gases, the highest value of the correlation coefficient was 0.47 between SO_2 and NO_2. Both pollutants also were correlated with wind direction (concentrations tended to be higher with southerly winds) suggesting that they may have had a common source. The The NO_x were correlated (r = 0.16) and there was a negative correlation between NO_2 and O_3 (r= -0.24) as has been observed elsewhere (Pratt et al 1981).

Ozone was correlated with both Julian day (r = 0.56) and the hour of the day (r = 0.18). The other gases showed little relation with time of year. Sulphur dioxide concentrations were correlated with time of day (r = 0.17) to some extent with higher concentrations tending to occur at midday.

The correlation coefficient between O_3 and wind direction was nearly zero. However, there were weak positive correlations of wind direction with NO_2 (r = 0.15) and SO_2 (r = 0.16) which is consistent with transport of pollutants from the south.

Ozone was positively correlated with the temperature, the solar radiation, wind speed, and the standard deviation of wind direction; and negatively correlated with relative humidity and the vertical gradient of temperature. NO_x generally was correlated only weakly with the meteorological parameters. There was a negative correlation between NO_2 and temperature.

3.6 WIND AND POLLUTANT ROSES

As shown in Figure 8, the prevailing winds during the study period were from the south-southeast similar to the 1981 to 82 period (Morrow and Murray 1982:12). Northerly up-valley winds were not as frequent as in the previous study.

The fraction of the total pollutants arriving from each direction showed a lobed pattern similar to the overall wind rose (Figures 9 to 12, inclusive and Appendix 6.2). In contrast, the variation of average concentration with wind direction was much more uniform for all the gases (Figures 13 to 16, inclusive). Concentrations tended to be slightly higher when the winds were from up the Athabasca River valley. Ozone concentrations also tended to be slightly higher with winds from the east-southeast, whereas NO_2 concentrations were lower on average with winds from that direction.

3.7 SEASONAL VARIATIONS

The monthly means for the gas concentrations and the meteorological parameters are shown in Figure 17. Ozone concentration, solar radiation, temperature, and dewpoint followed a similar pattern over the year with the highest values in summer and lowest in winter. SO_2 and NO_2 both showed peak concentrations in October and March. The highest NO concentrations were in October. Wind speeds tended to be lowest in early winter at both the 10 and 50 m levels.

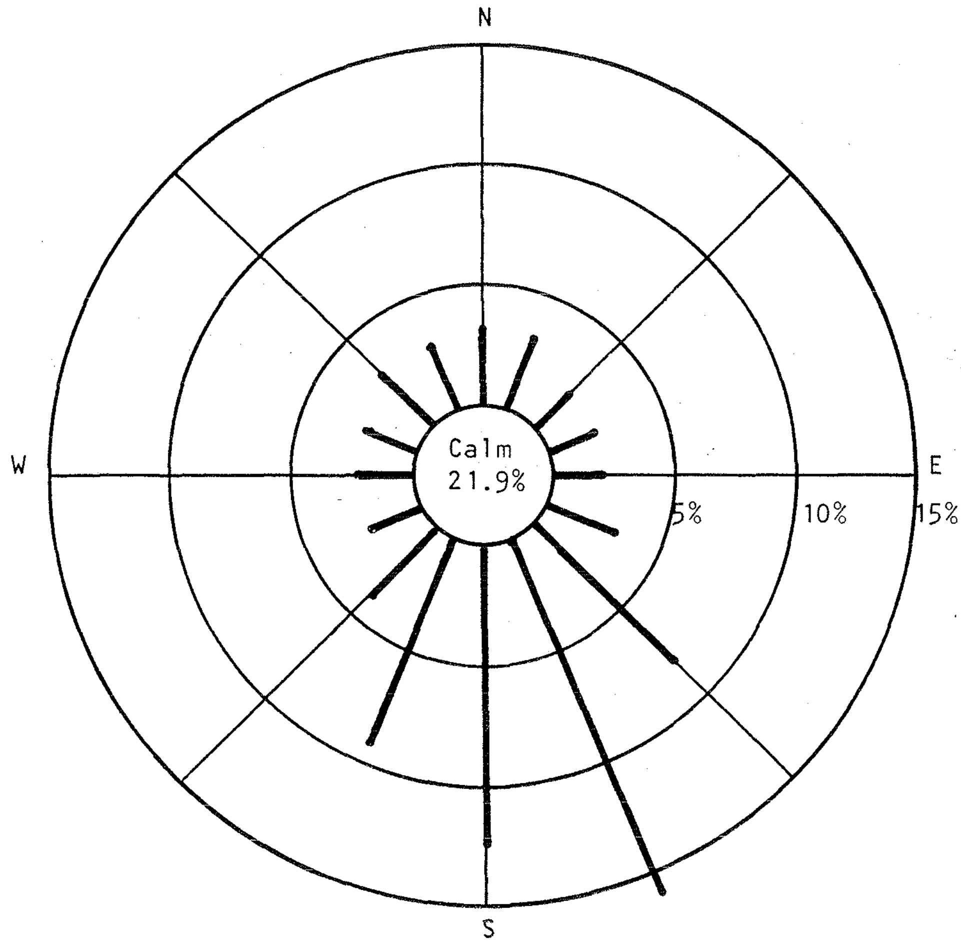

Figure 8. Sandalta 10m wind rose for May 1983 through March 1984 showing frequency of winds from a given direction.

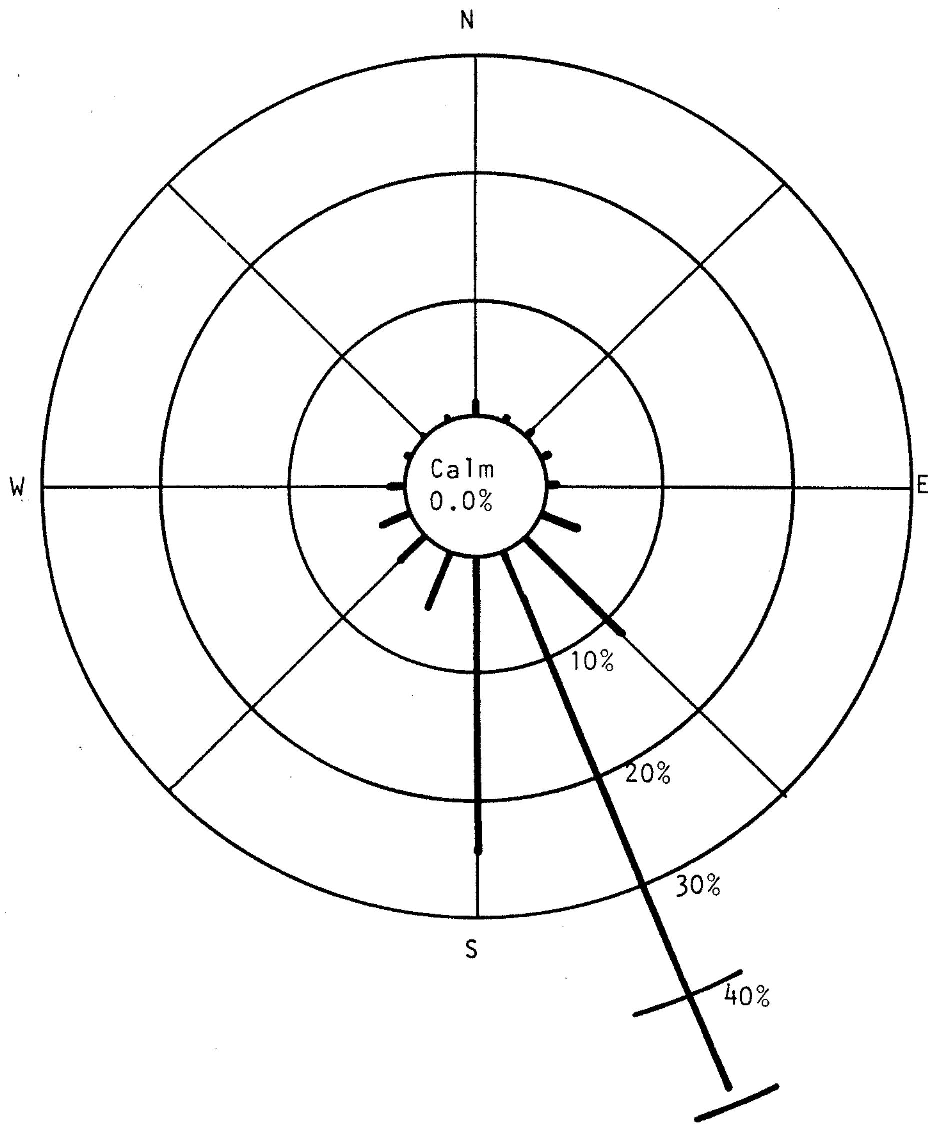

Figure 9. Pollutant rose showing frequency of 10m winds by arrival direction for SO_2. Only cases in which the concentration was above 10 ppbv are included in the analysis.

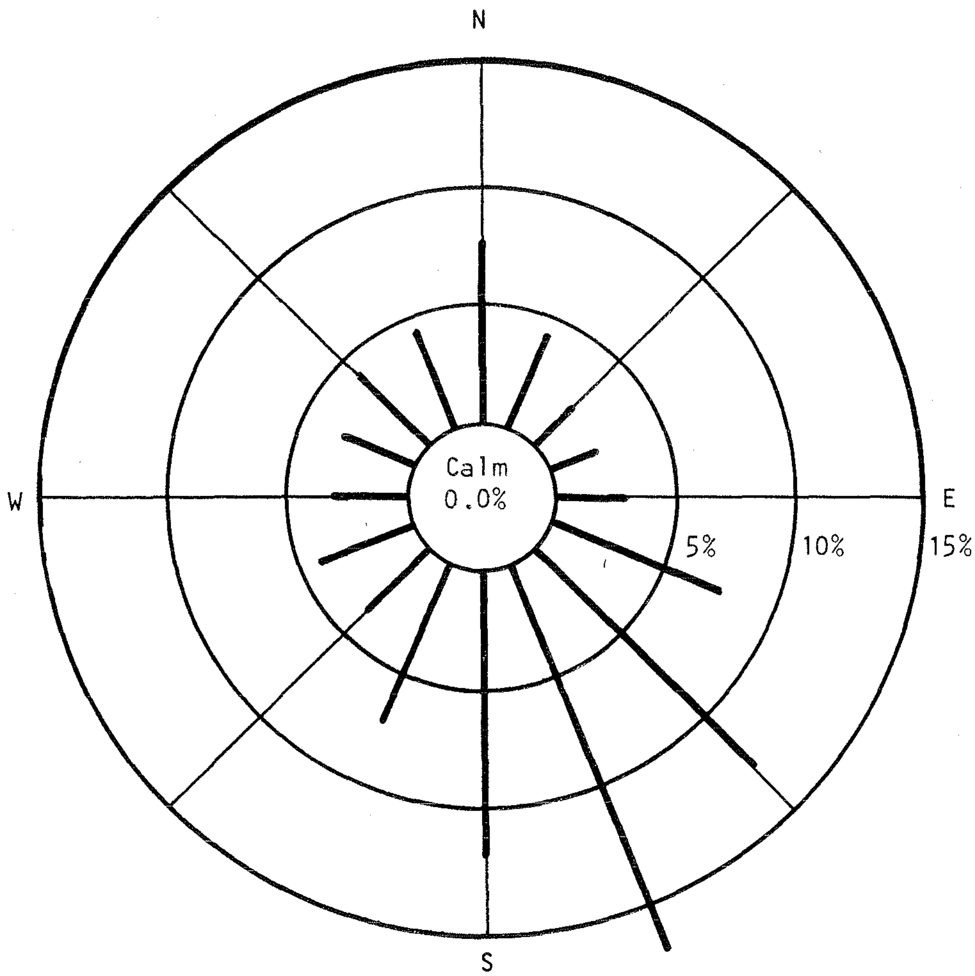

Figure 10. Pollutant rose showing frequency of 10m winds by arrival direction for O_3. Only cases in which the concentration was above 10 ppbv are included in the analysis.

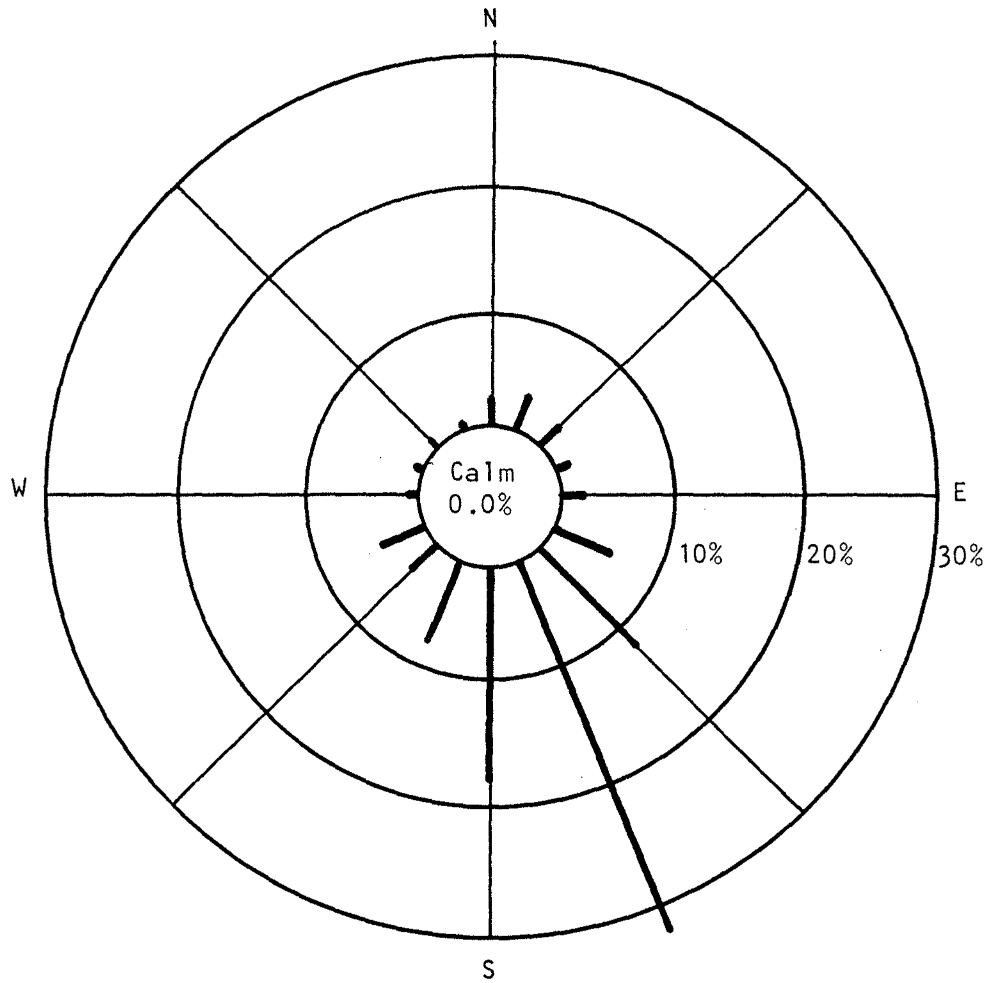

Figure 11. Pollutant rose showing frequency of 10m winds by arrival direction for NO_2. Only cases in which the concentration was above 2.5 ppbv are included in the analysis.

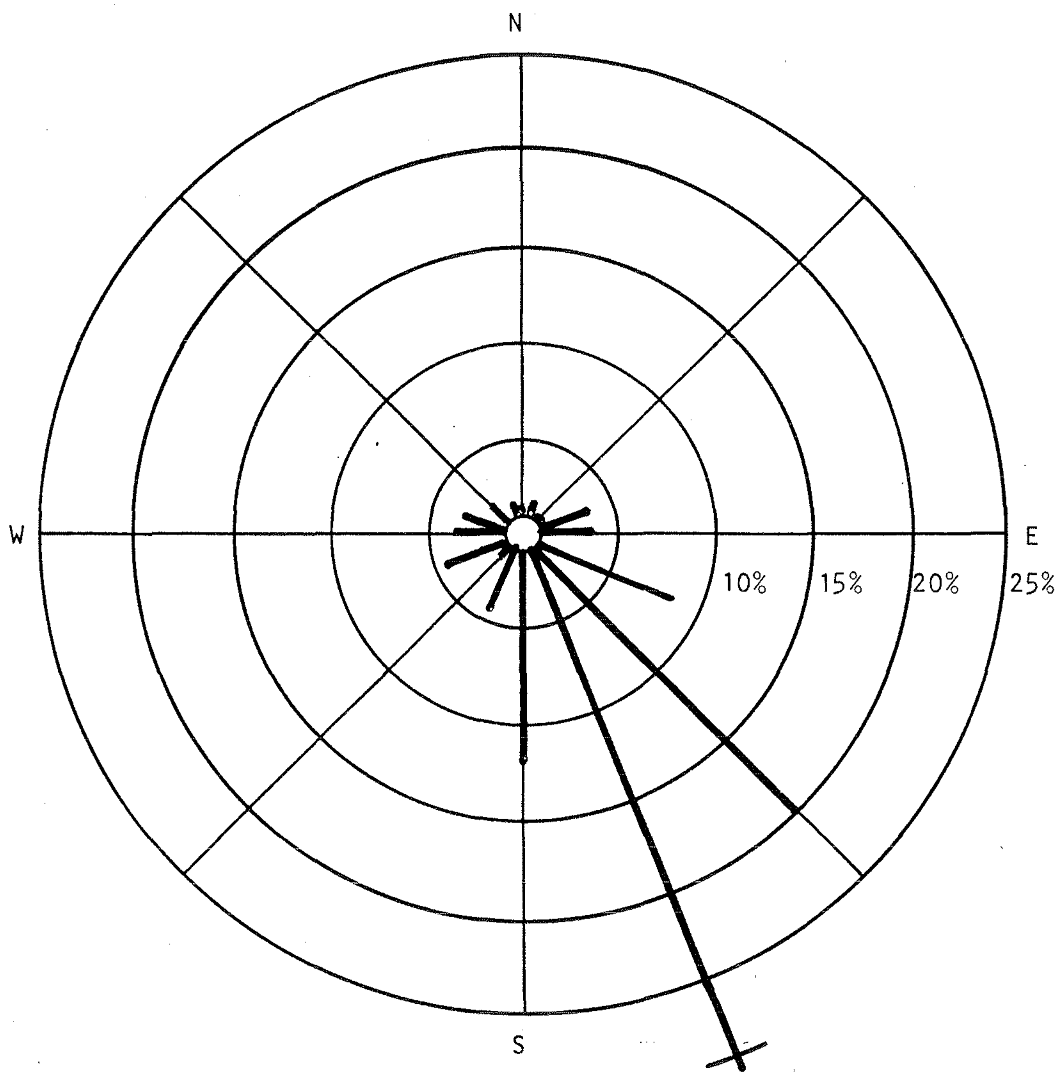

Figure 12. Pollutant rose showing frequency of 10m winds by arrival direction for NO. Only cases in which the concentration was above 2.5 ppbv are included in the analysis.

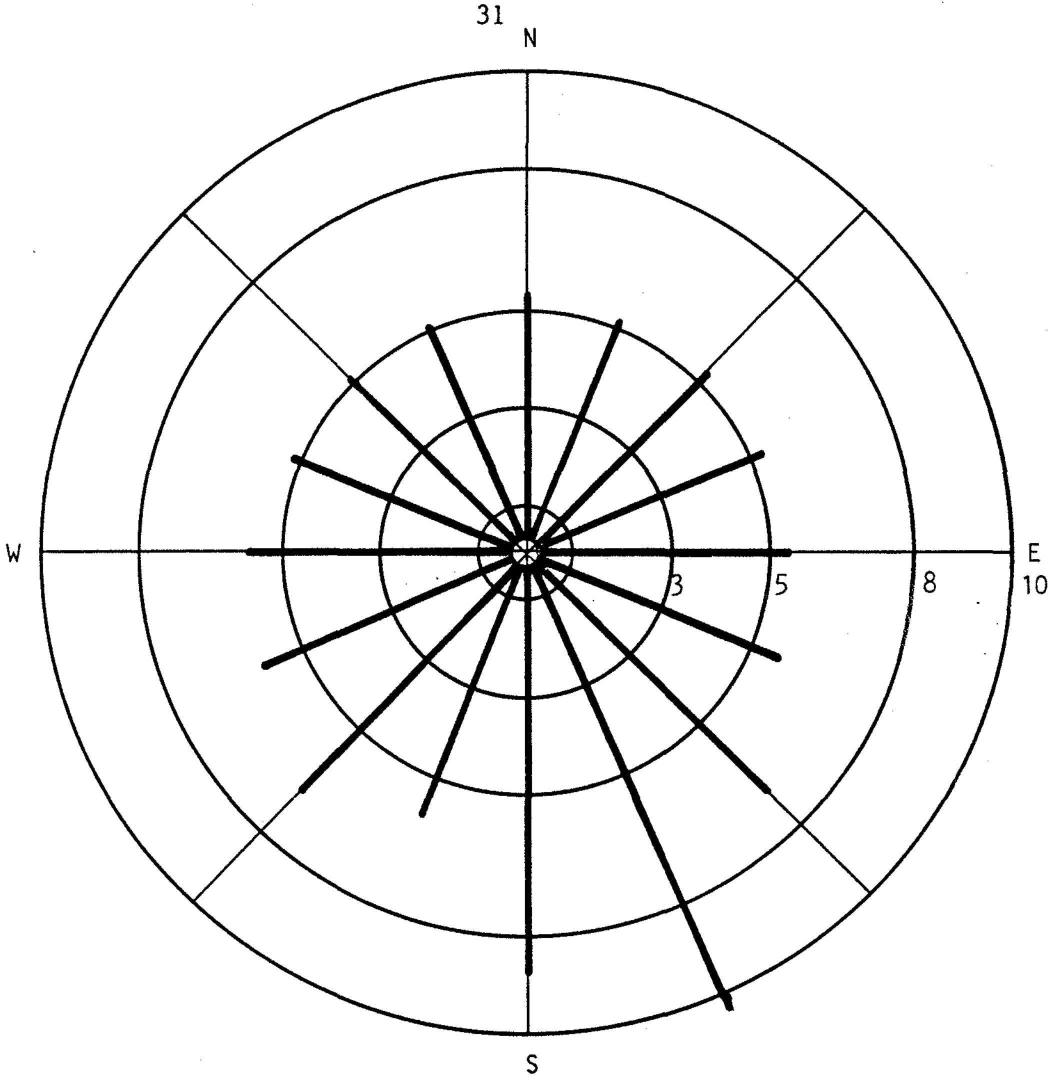

Figure 13. Pollutant rose showing average SO_2 concentration (ppbv) by arrival direction of 10m winds.

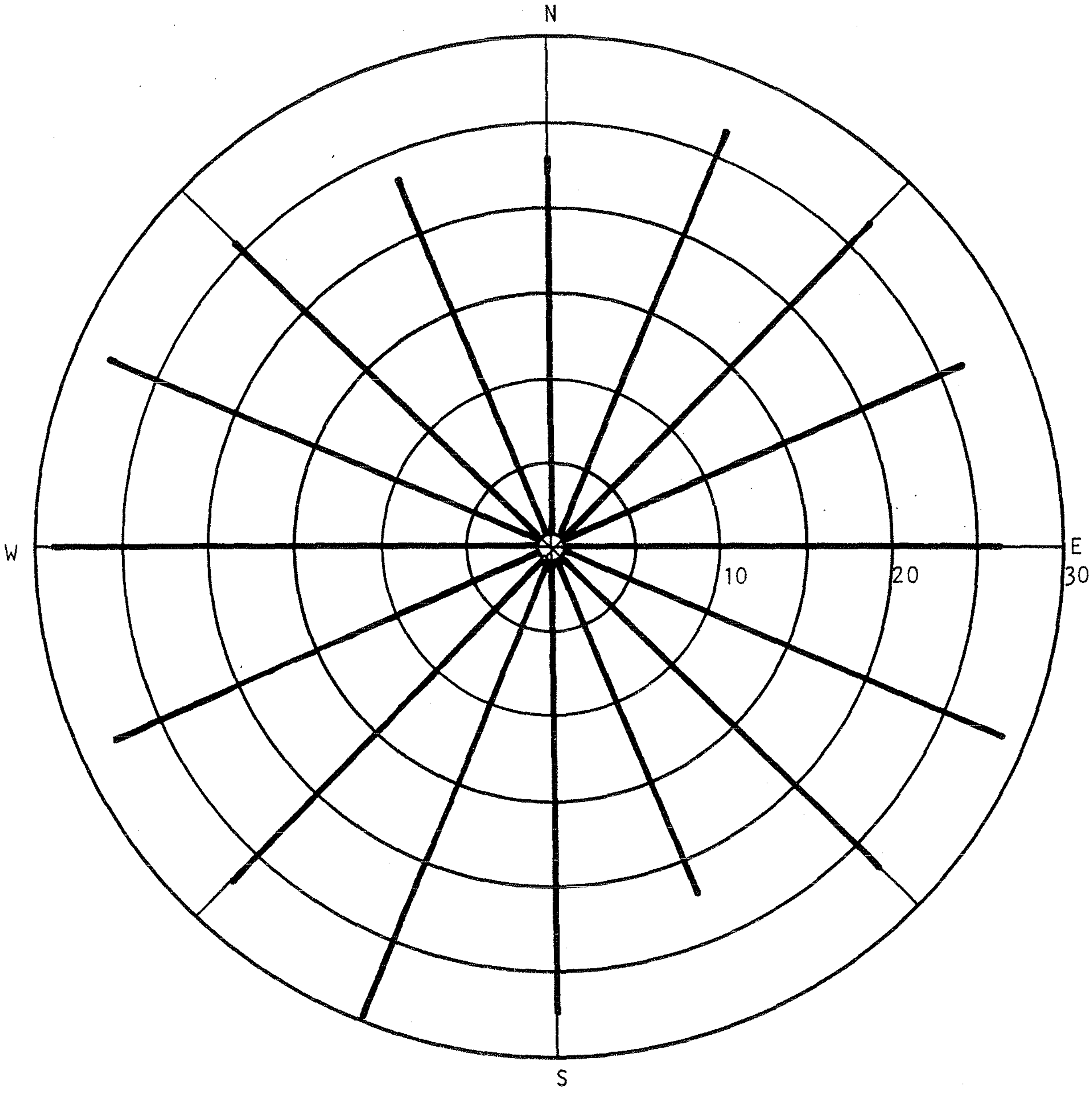

Figure 14. Pollutant rose showing average O_3 concentration (ppbv) by arrival direction of 10m winds.

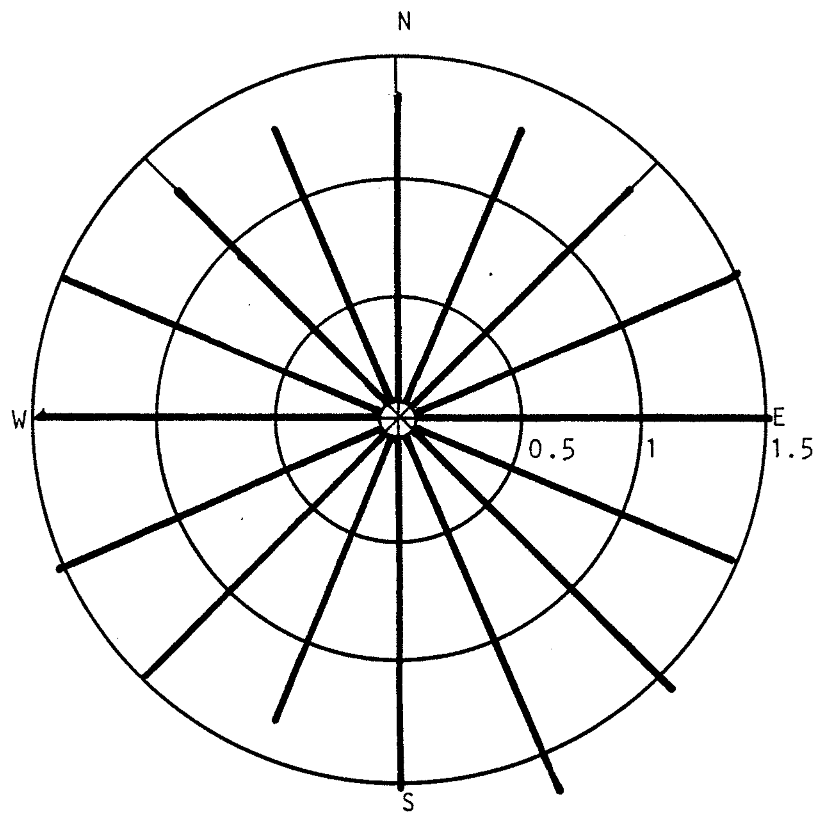

Figure 15. Pollutant rose showing average NO concentration (ppbv) by arrival direction of 10m winds.

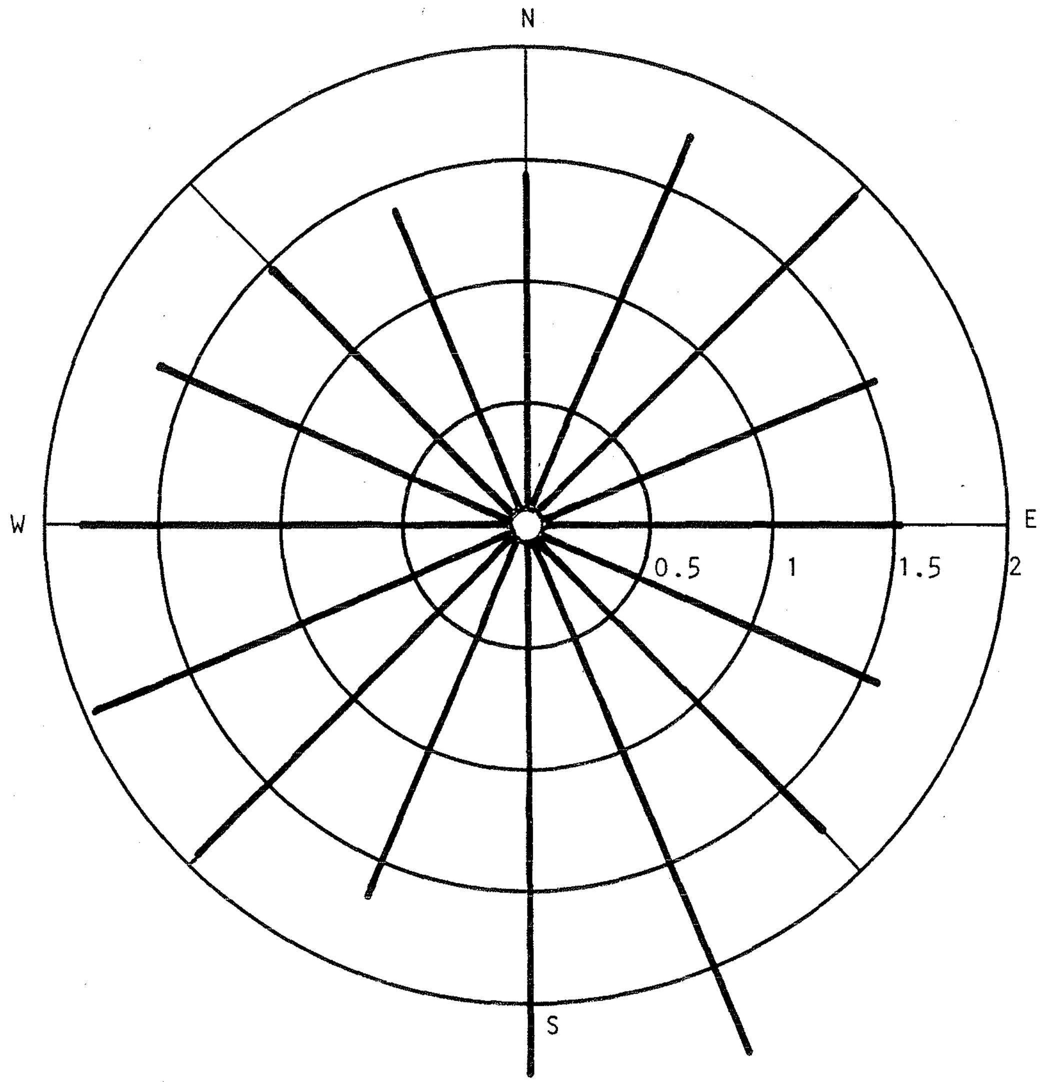

Figure 16. Pollutant rose showing average NO_2 concentration (ppbv) by arrival direction of 10m winds.

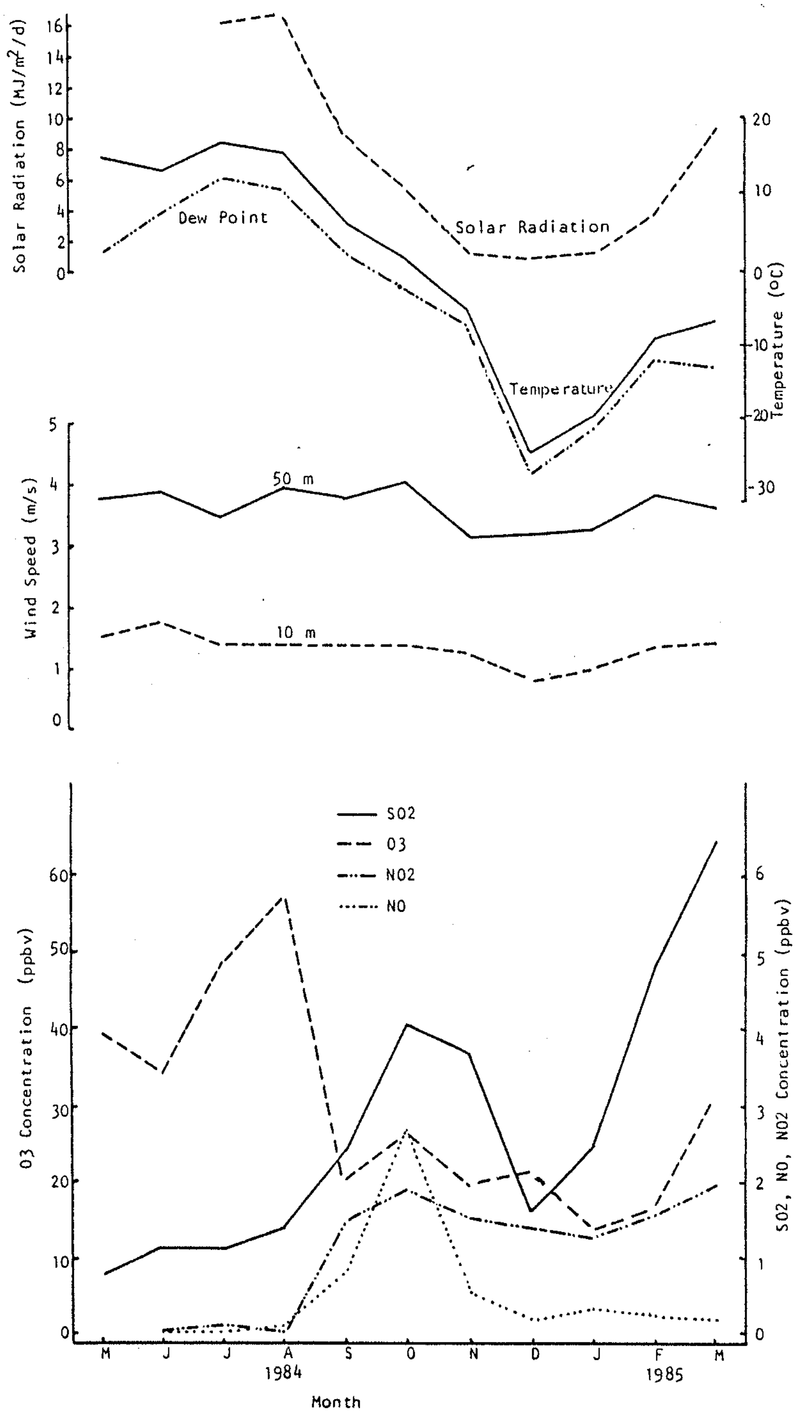

Figure 17. Mean seasonal fluctuations in pollutant concentrations and meteorological parameters from May 1983 to March 1984, inclusive. The plotted values are the means of all observations recorded during a given month.

3.8 DIURNAL VARIATIONS

Temperature, dewpoint, 10 m wind speed, O_3 and SO_2 showed diurnal cycles similar to that of the solar radiation (Figure 18). The radiation peaked three hours before the temperature and four hours before the O_3 concentrations. SO_2 concentrations were highest on average around local noon. NO_2 concentrations also had a small peak at that time. NO concentrations did not show much variation with time of day.

3.9 CASE STUDIES

Two events were selected to illustrate transport from areas with and without significant emission sources. Each event had quite a different series of pollutant concentrations as shown in Figure 19.

On 1984 October 1, a low pressure centre was moving to the northeast through the Yukon. This resulted in surface winds at the site from the southeast through southwest. Back trajectories extended through the Mildred Lake - Tar Island industrial complex and across northern Alberta to the Peace River region.

An inversion breakup fumigation resulted in mixing of pollutants from aloft to the ground after 0900 MST. After sunrise, daytime heating produced a turbulent layer of air near the ground which grew in depth to eventually entrain the elevated pollutant plumes. SO_2 and NO_x concentrations increased sharply during this event. On the other hand, the O_3 concentrations at the ground dropped during the fumigation, and peaked after the other pollutant concentrations had abated.

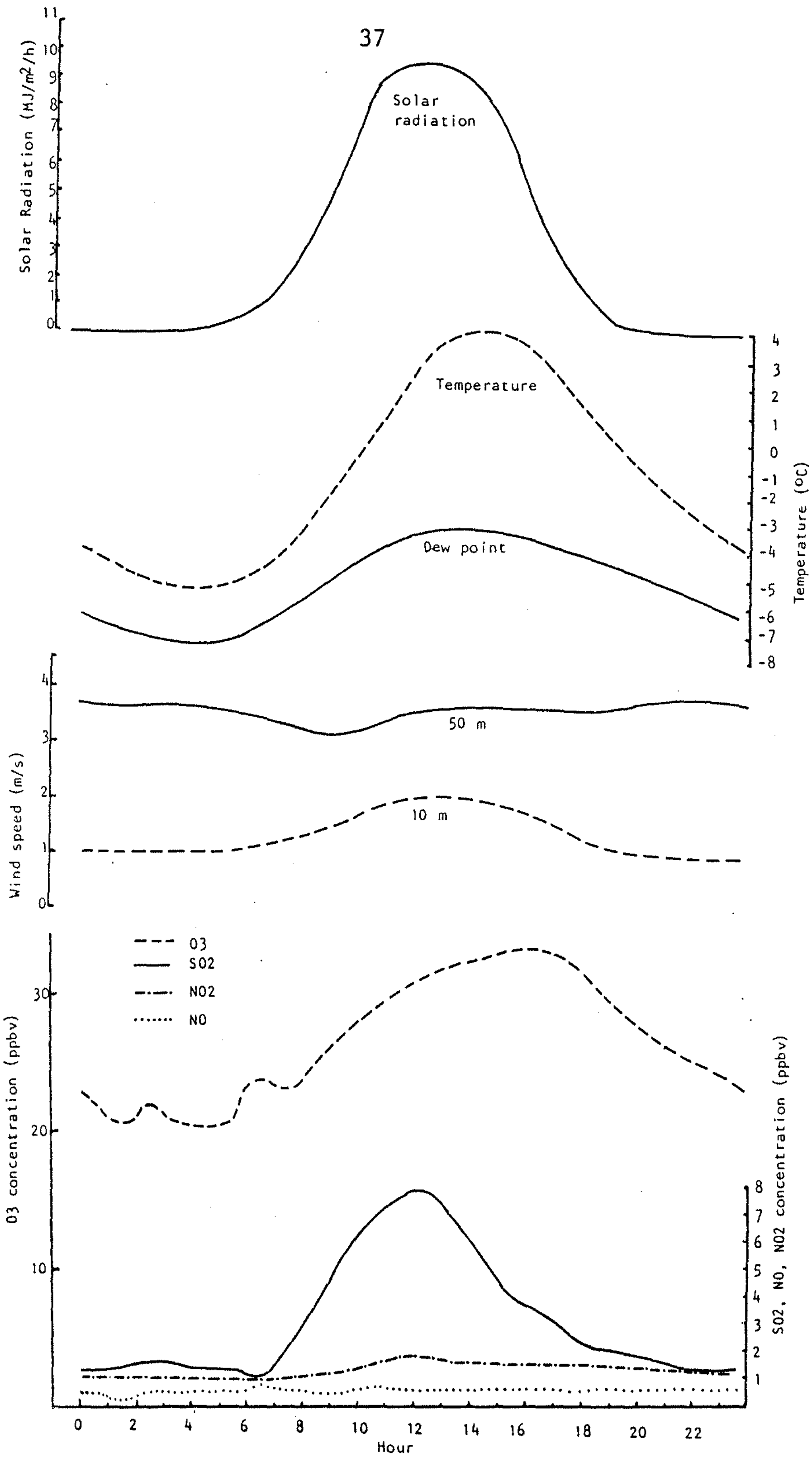

Figure 18. Mean values of the pollutant concentrations and meteorological parameters by time of day.

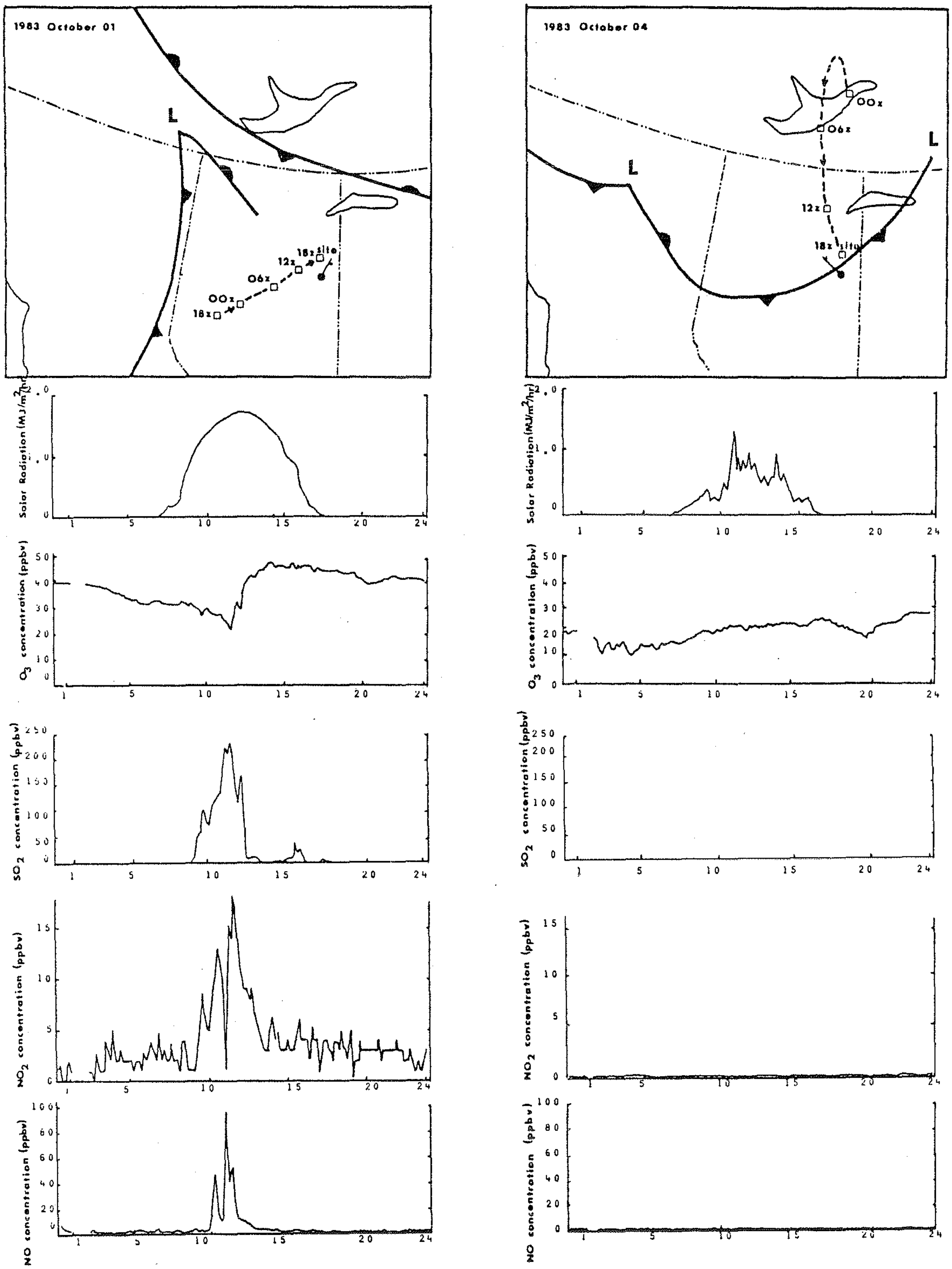

Figure 19. Surface weather maps, air parcel back-trajectories, solar radiation profiles and pollutant concentrations for 1984 October 1 and 4. On the left, is a case of transport from local oil sands sources superimposed upon long range transport from sources in northwestern Alberta. In the case on the right, clean air has moved from the north where there are no significant sources of pollutant emissions to the atmosphere.

On 1983 October 4, a cold front extended from a low pressure centre northeast of Lake Athabasca, across northern Alberta to a second low in north central British Columbia. This synoptic situation resulted in a northerly flow at the monitoring site. There are no significant pollutant emitters in the air mass source regions in the Northwest Territories. A band of cloud associated with the cold front resulted in generally cloudy skies and consequently lower solar radiation than in the 1984 October 1 event. Ozone concentrations were at a minimum just before sunrise and increased to 28 ppb in the late evening. NO_x concentrations were in the 1 to 4 ppbv range. SO_2 was below the detection limit.

4. CONCLUSIONS

The study has generated quality controlled data which are appropriate for use as air quality/atmospheric input in numerical modelling of receptor response. The continuous (5 minute average) measurements of meteorological parameters and ambient concentrations of acid forming gases can be used to assess the response of the soils and vegetation in the vicinity of the station to pollution episodes. For this reason, the air quality station was established near a biological monitoring plot.

Mean annual SO_2 concentrations were about 3 ppbv. Although there was one exceedance of the 170 ppbv (one hour average) level, most concentrations were less than 10 ppbv.

Ozone concentrations averaged about 27 ppbv over the year. Peak concentrations of up to 130 ppbv occurred in the summer due to a combination of photochemistry involving oxides of nitrogen and hydrocarbons and the mixing of elevated pollutant plumes to the ground. Such concentrations were relatively infrequent though with only 40 hours reported in excess of 80 ppbv.

Oxides of nitrogen concentrations were generally very low. Mean annual values were 0.6 and 1.3 ppbv for NO and NO_2, respectively.

The case studies showed a marked contrast between the pollutant concentrations associated with an air mass which came from a source region with no significant industrial emissions to the atmosphere compared to those observed in an air mass which traversed both regions with natural gas processing plants in northwestern Alberta and the local Oil Sands processing plants.

5. REFERENCES CITED

Bottenheim, J.W., and O.P. Strausz. 1981. Development of a chemically reactive plume model for application in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by the Department of Chemistry, University of Alberta. AOSERP Report 117. 159 pp.

Lusis, M.A., K.G. Anlauf, L.A. Barrie, and H.A. Wiebe. 1978. Plume chemistry studies at a northern Alberta power plant. Atmospheric Environment 12: 2429-2437.

Murray, W.A. and T.M. Morrow. 1982. Climatological and air quality report for Gulf Sandalta 1981-1982. Prepared for Gulf Canada Resources Inc. by Promet Environmental Group Ltd. Sandalta Report No. PHASE II - 25. 225 pp.

Pratt, G.C., R.C. Hendrickson, B.I. Chevone, D.A. Christopherson, M.V. O'Brien and S.V. Krupa. 1983. Ozone and oxides of nitrogen in the rural upper-midwestern U.S.A. Atmospheric Environment 17: 2013-2023.

Strosher, M.M. 1978. Ambient air quality in the AOSERP study area, 1977. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Department of the Environment, Pollution Control Division. AOSERP Report 30. 74 pp.

Strosher, M.M. 1981. Background air quality in the AOSERP study area March 1977 to March 1980. Prepared for the Alberta Oil Sands Environmental by Alberta Department of the Environment, Pollution Control Division. AOSERP Report L 73. 84 pp.

6. APPENDIX

6.1 EQUATIONS USED IN THE STATISTICAL ANALYSIS

The mean value of a sample was calculated from:

$$\bar{x} = (\sum_{k=1}^{n} \bar{x}_k)/n$$

The standard deviation of a sample was calculated from:

$$s = (\sum_{k=1}^{n} (x_k-\bar{x}^2)/(n-1))^{\frac{1}{2}}$$

The square of the correlation coefficient, r, measures what proportion of the variation of a dependent variable, y, is accounted for by a linear relationship with the independent variable, x. The correlation coefficient was calculated from the equation:

$$r = (\sum_{k=1}^{n} x_k \cdot y_k - \bar{x} \cdot \bar{y}/n)/(\sum_{k=1}^{n} x_k{}^2 - \bar{x}^2/n)^{\frac{1}{2}} (\sum_{k=1}^{n}(y_k{}^2 - \bar{y}^2/n)^{\frac{1}{2}}$$

where n is the number of data point pairs, and k is a subscript which labels a particular pair.

The significance test for the correlation coefficient which assumes the sampling distributions are approximately normal is based on the statistic:

$$z = (n-3)^{\frac{1}{2}}(\ln((1+r)/(1-r)))$$

The minimum values of r for significance at the 0.005 confidence level are given Table 13 by gas type and time period.

Table 13. Minimum values of correlation coefficient for significance at the 0.005 confidence level.

Gas	Month											Summer[a]	Winter	Year
	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.			
NO	--	0.18	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.05	0.05	0.03
NO_2	--	0.14	0.17	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.04
O_3	0.23	0.10	0.10	0.70	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.03
SO_2	0.22	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.04	0.04	0.03

[a] Summer consists of the months May through September, inclusive; the other months are in winter.

6.2 JOINT FREQUENCIES OF GAS CONCENTRATIONS AND WIND DIRECTION

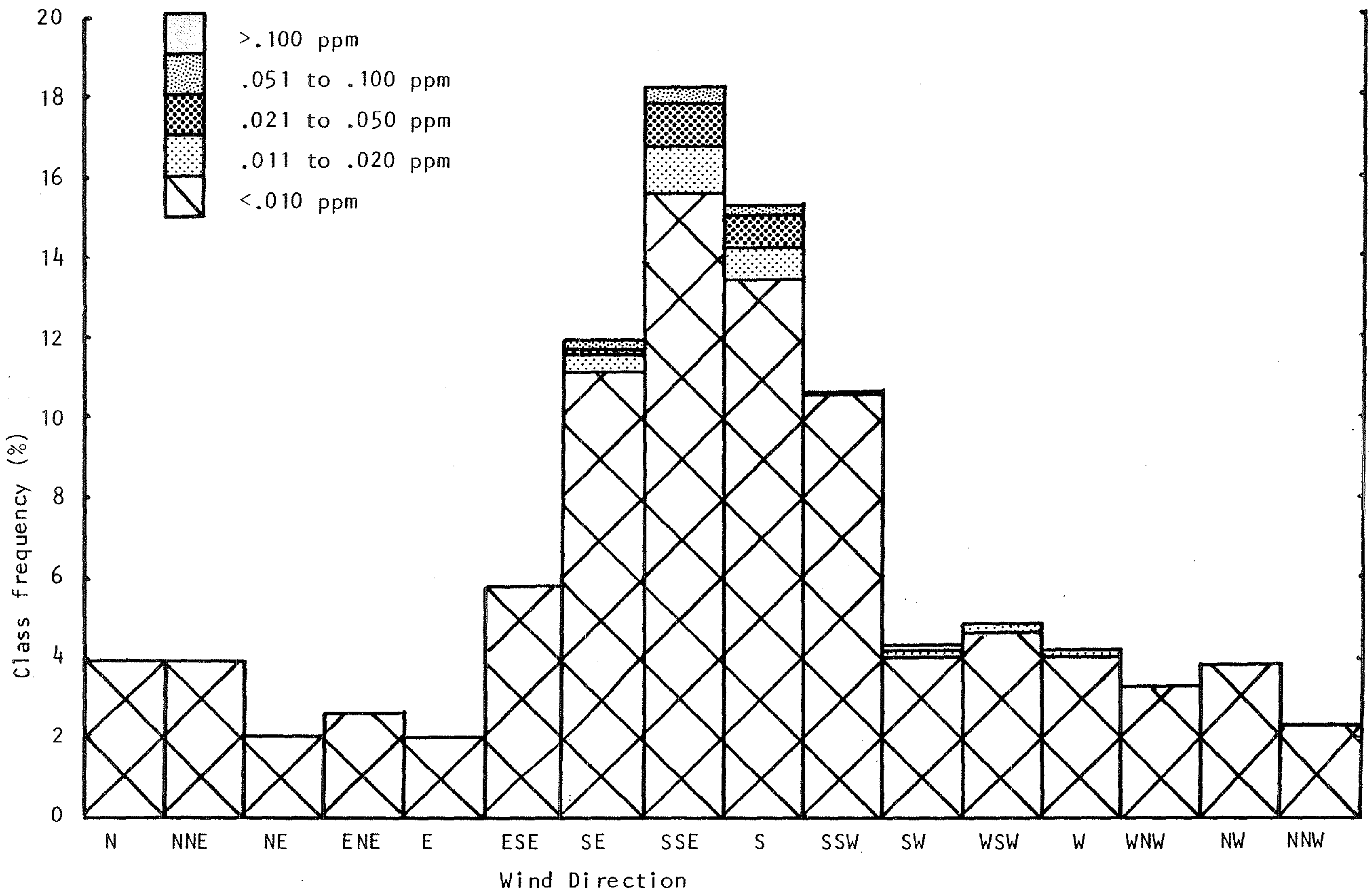

Figure 20. Frequency of occurrence of SO_2 concentration by 10 m Wind Direction for May 1983-October 1983.

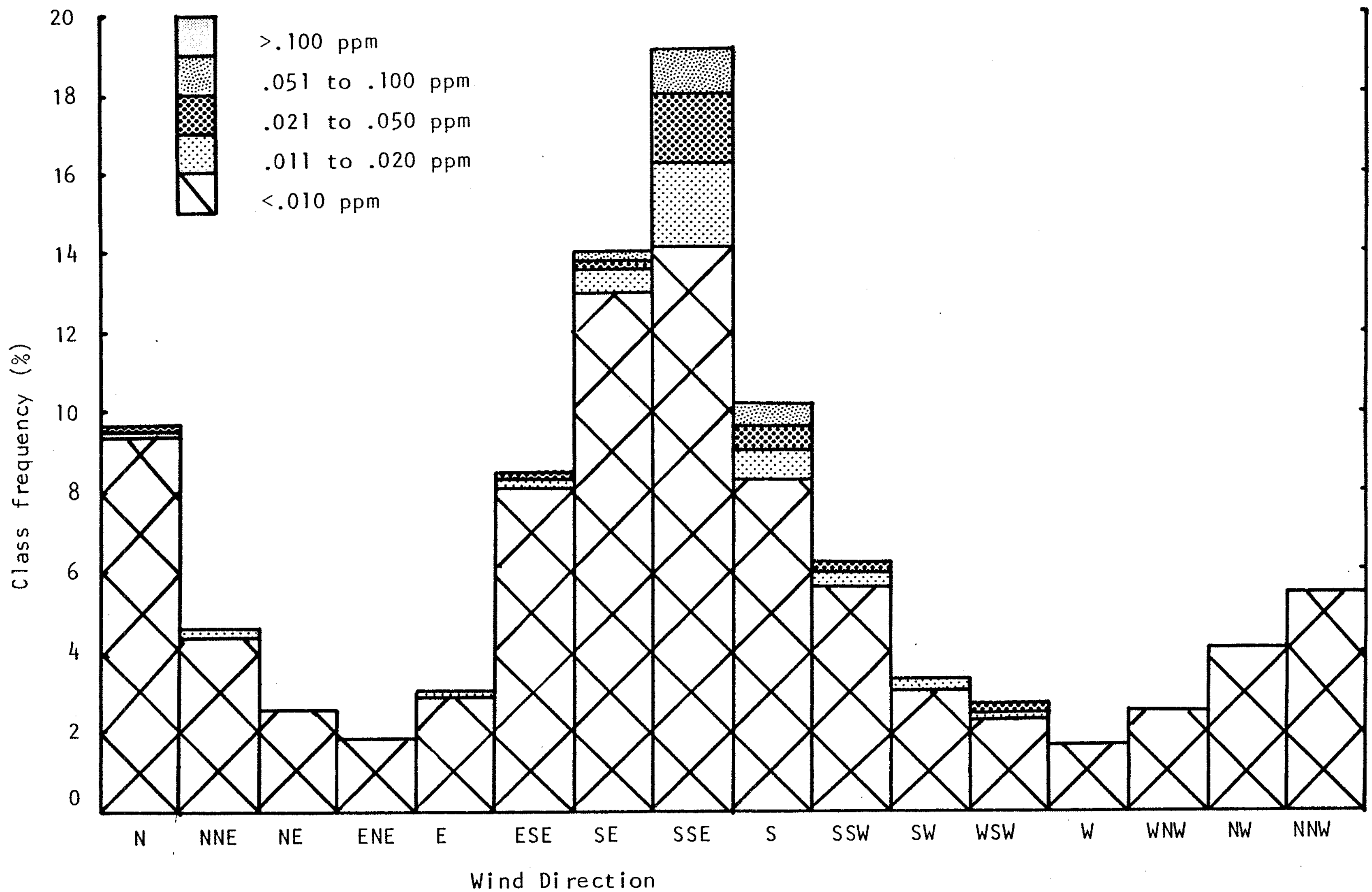

Figure 21. Frequency of occurrence of SO_2 concentration by 10 m Wind Direction for November 1983-March 1984.

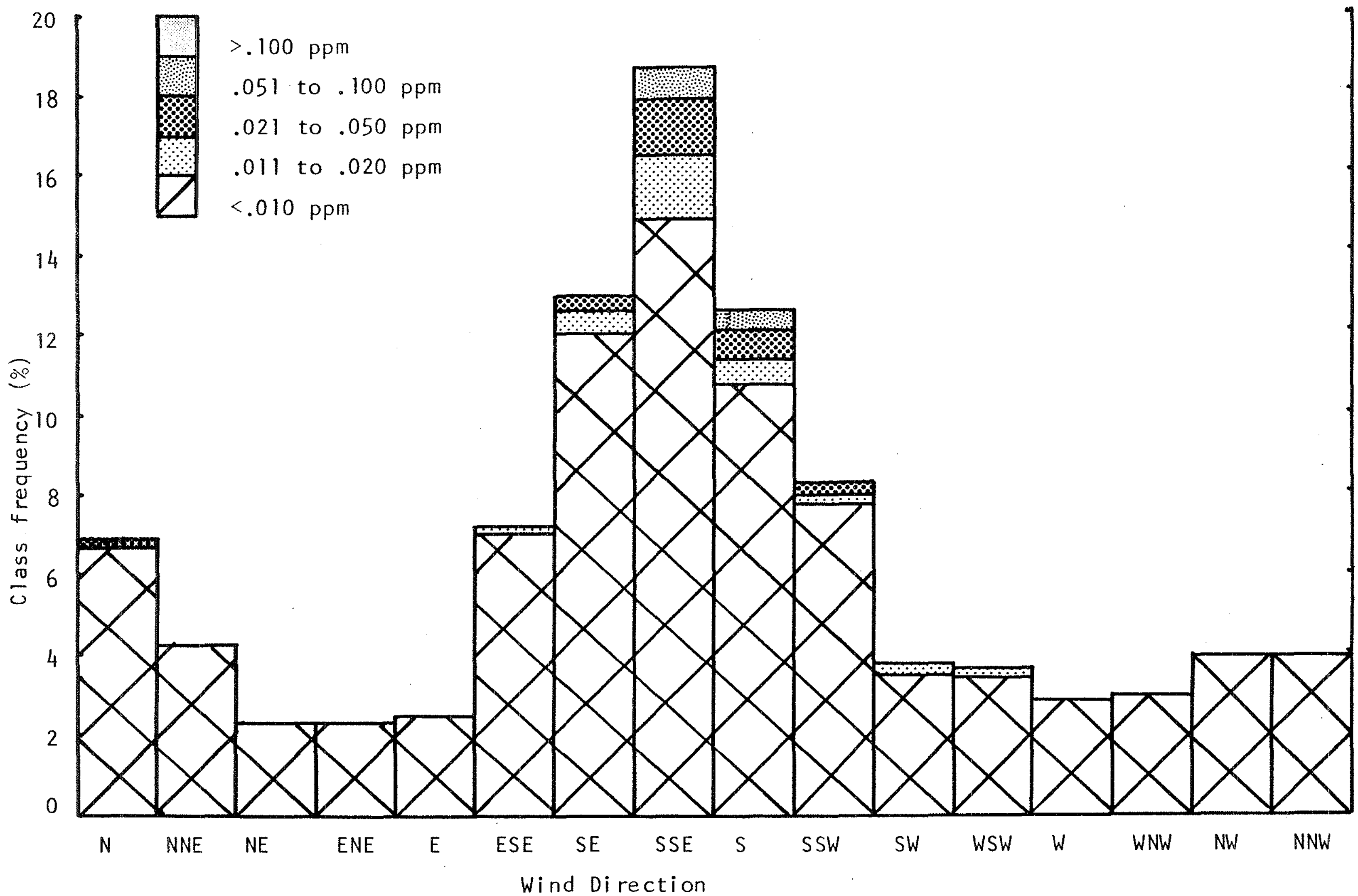

Figure 22. Frequency of occurrence of SO_2 concentration by 10 m Wind Direction for May 1983-March 1984.

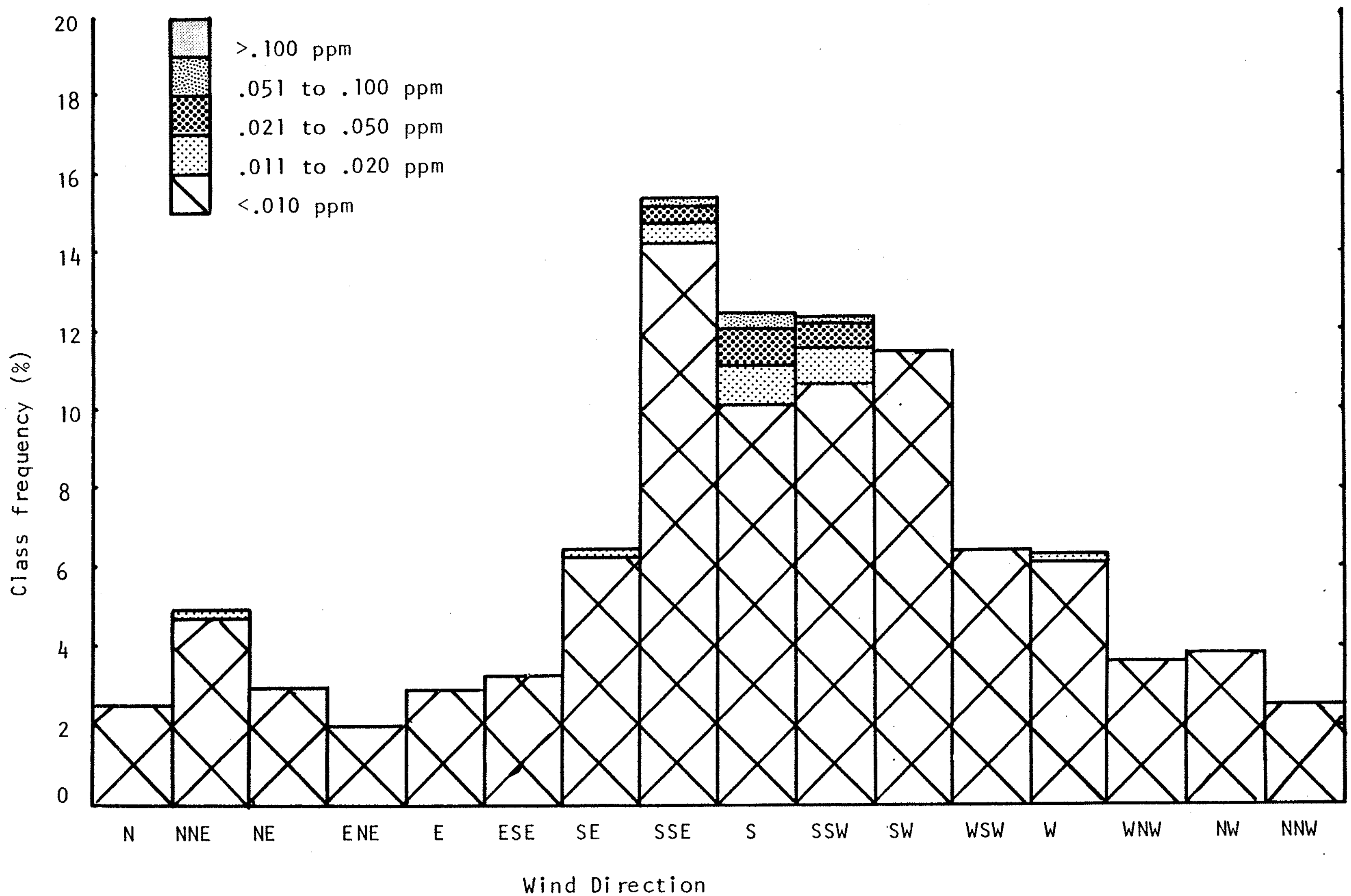

Figure 23. Frequency of occurence of SO_2 concentration by 50 m Wind Direction for May 1983- October 1983.

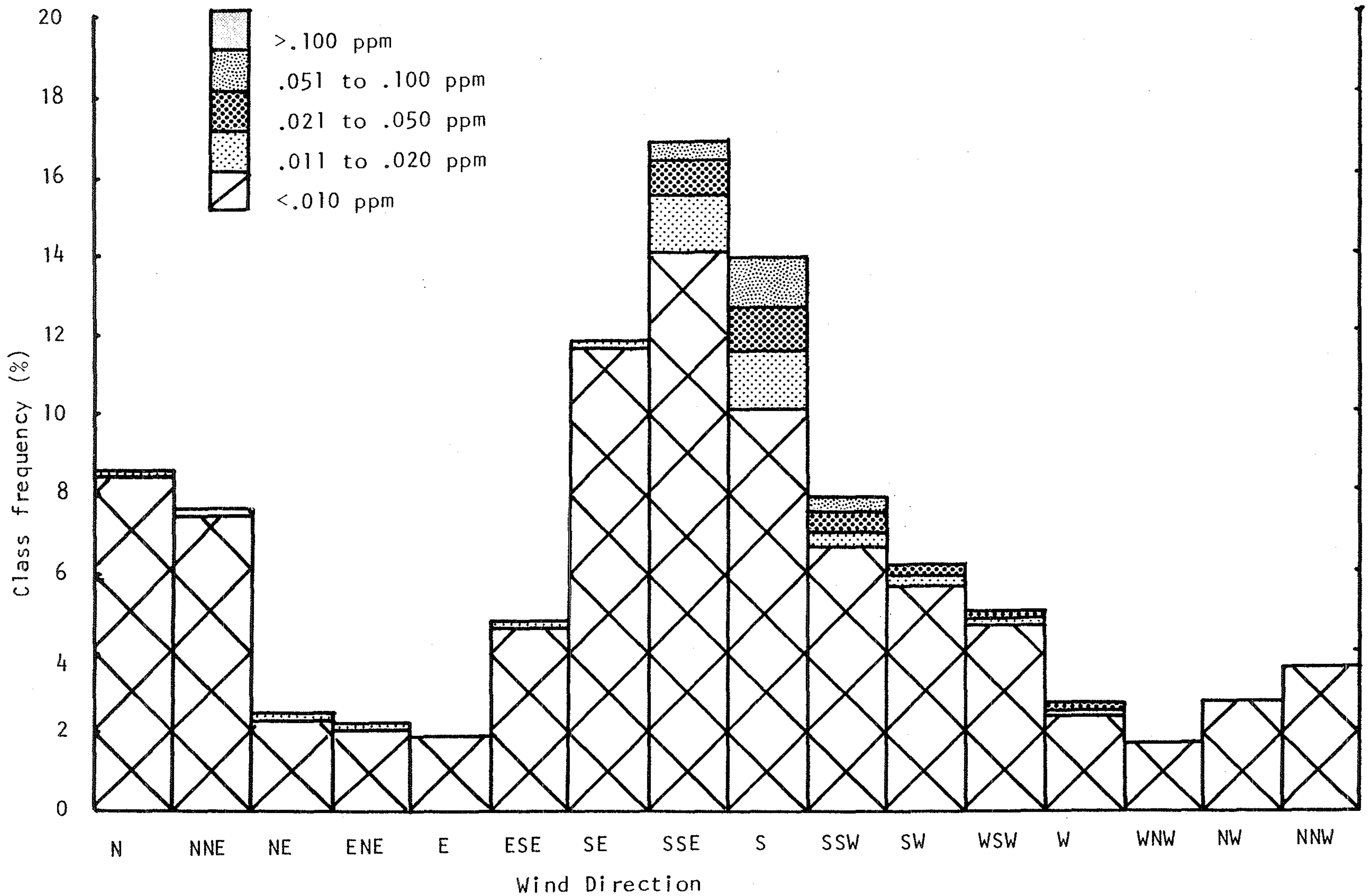

Figure 24. Frequency of occurence of SO_2 concentration by 50 m Wind Direction for November 1983-March 1984.

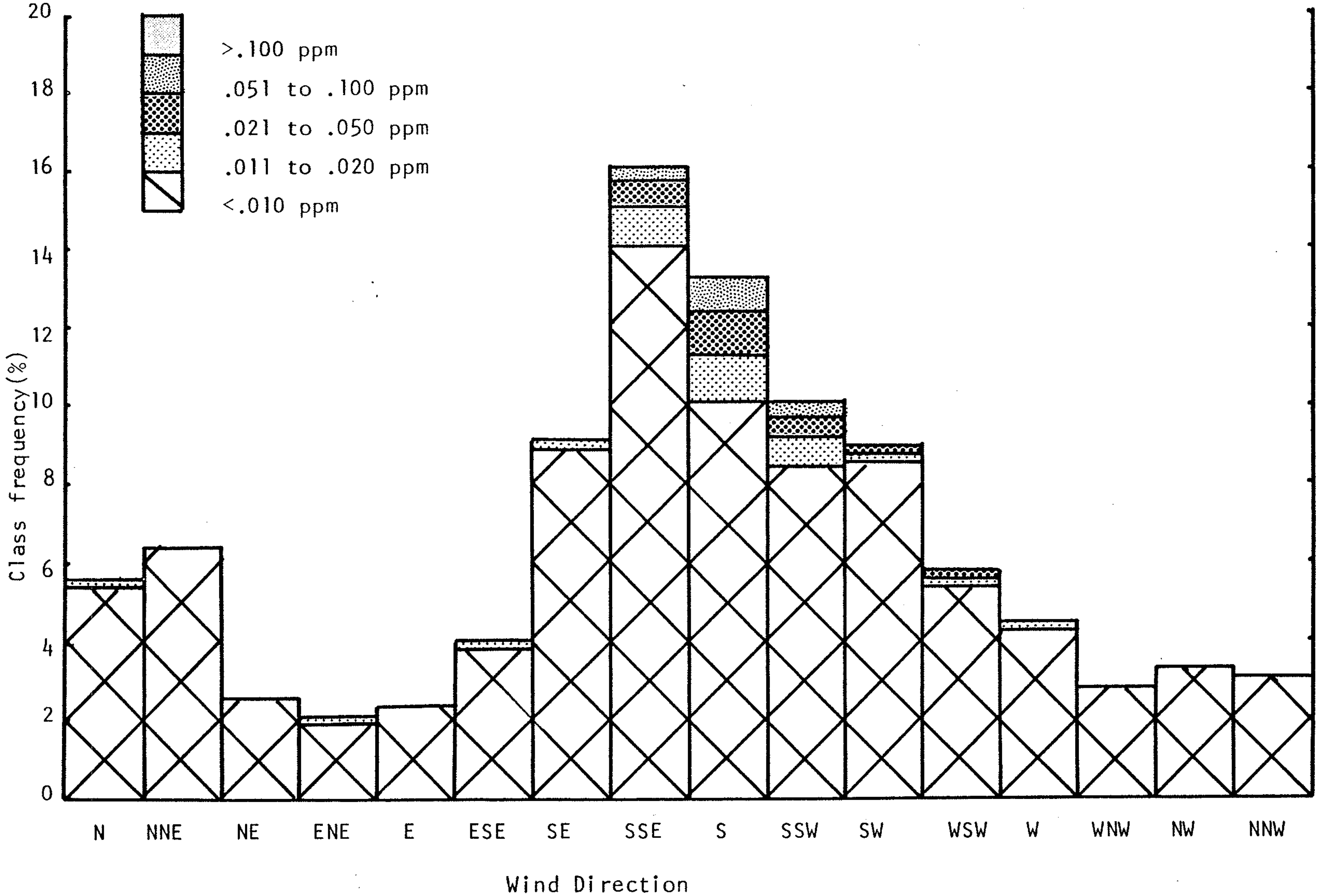

Figure 25. Frequency of occurrence of SO_2 concentration by 50 m Wind Direction for May 1983-March 1984.

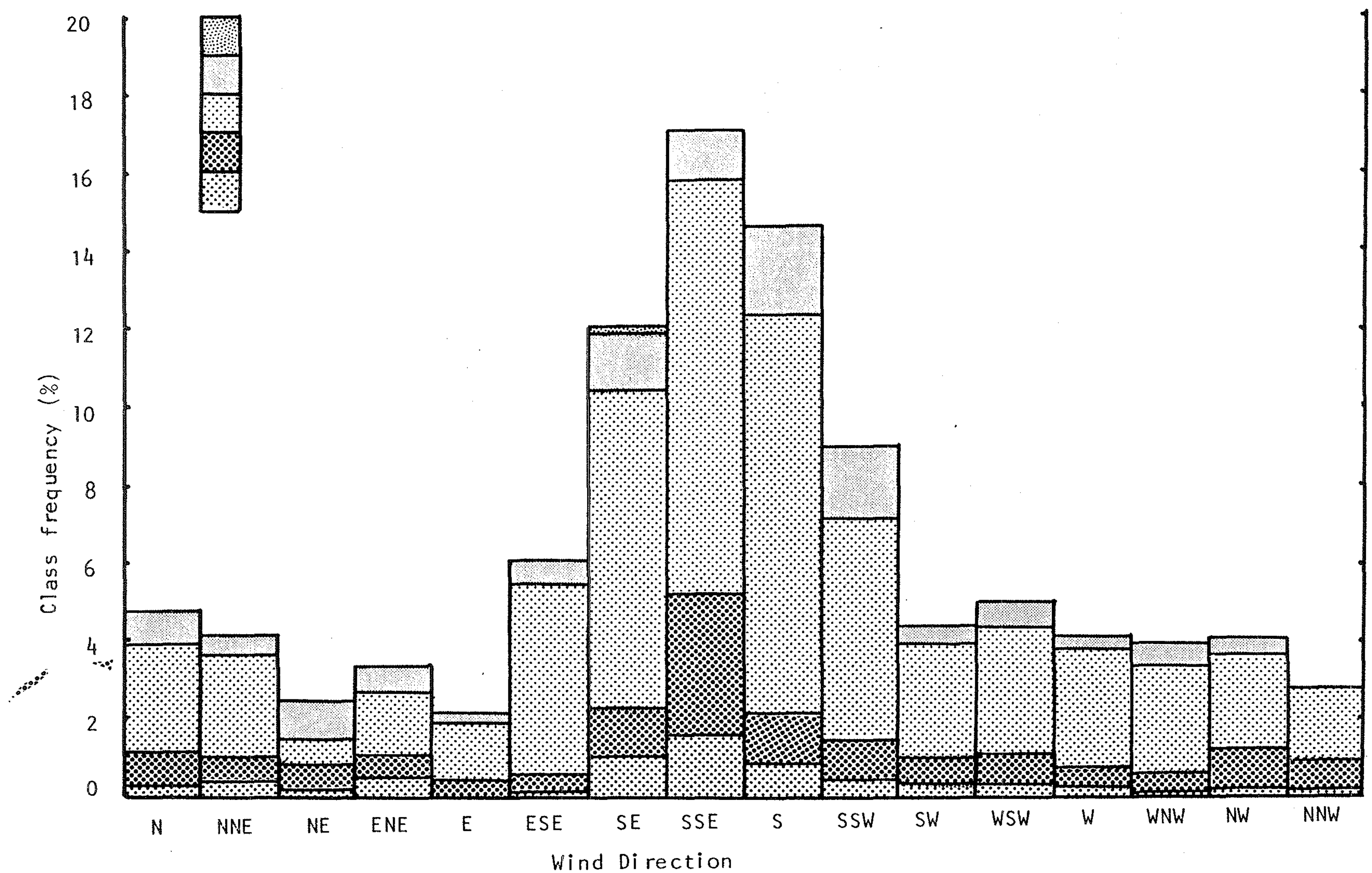

Figure 26. Frequency of occurrence of O_3 concentration by 10 m Wind Direction for May 1983-October 1983.

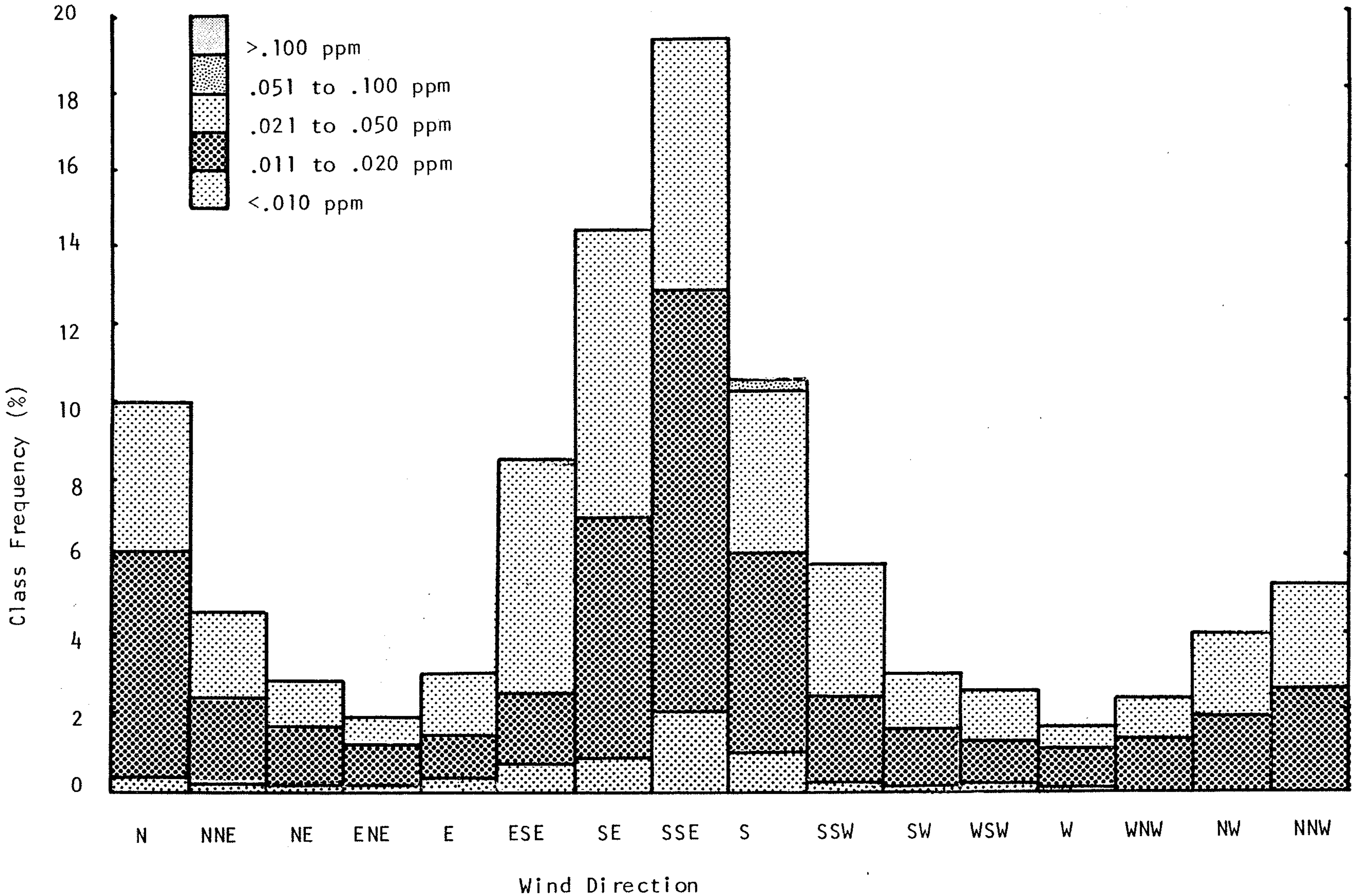

Figure 27. Frequency of occurrence of O_3 concentration by 10 m Wind Direction for November 1983-March 1984.

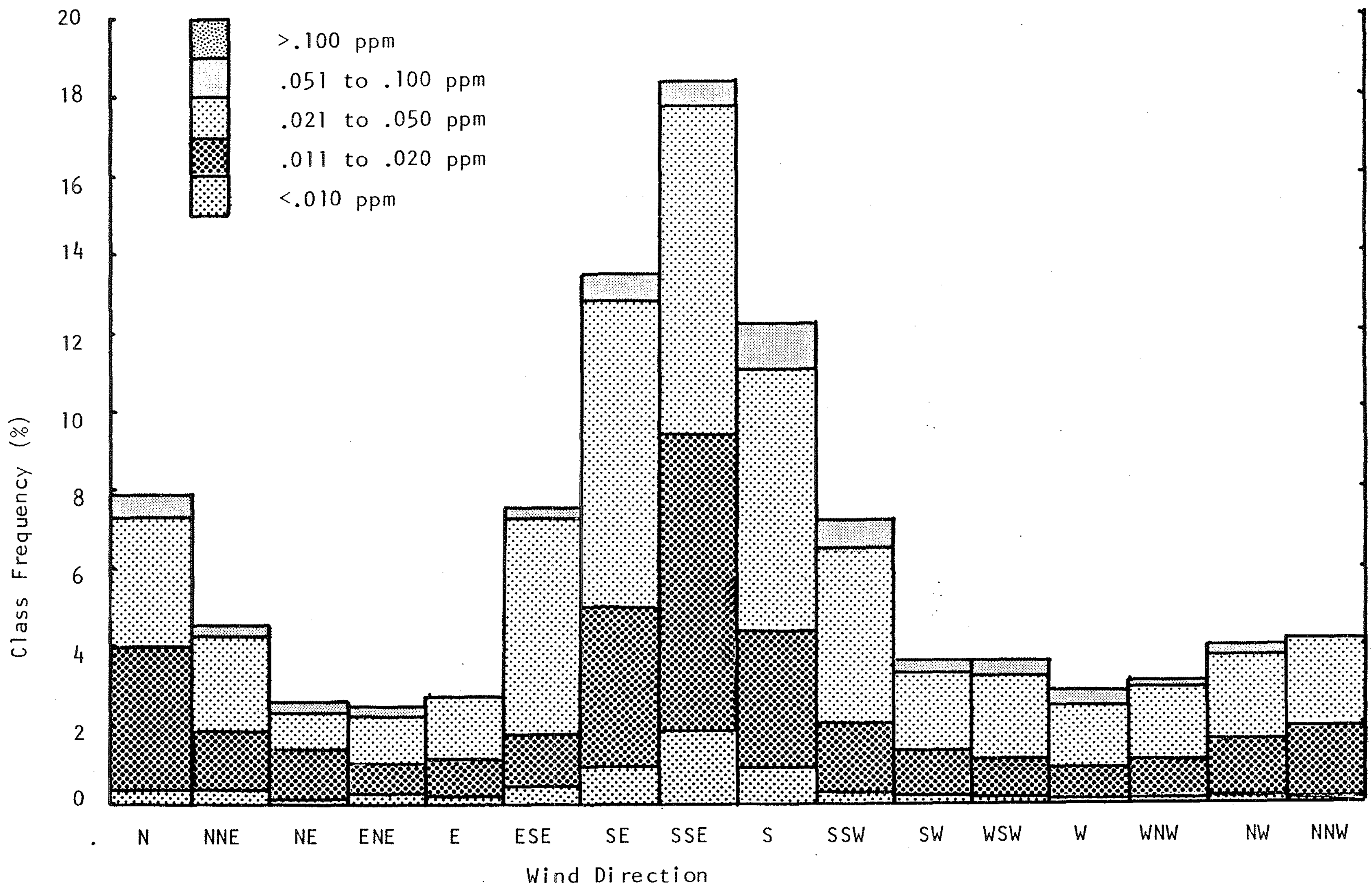

Figure 28. Frequency of occurrence of O_3 concentration by 10 m Wind Direction May 1983-March 1984.

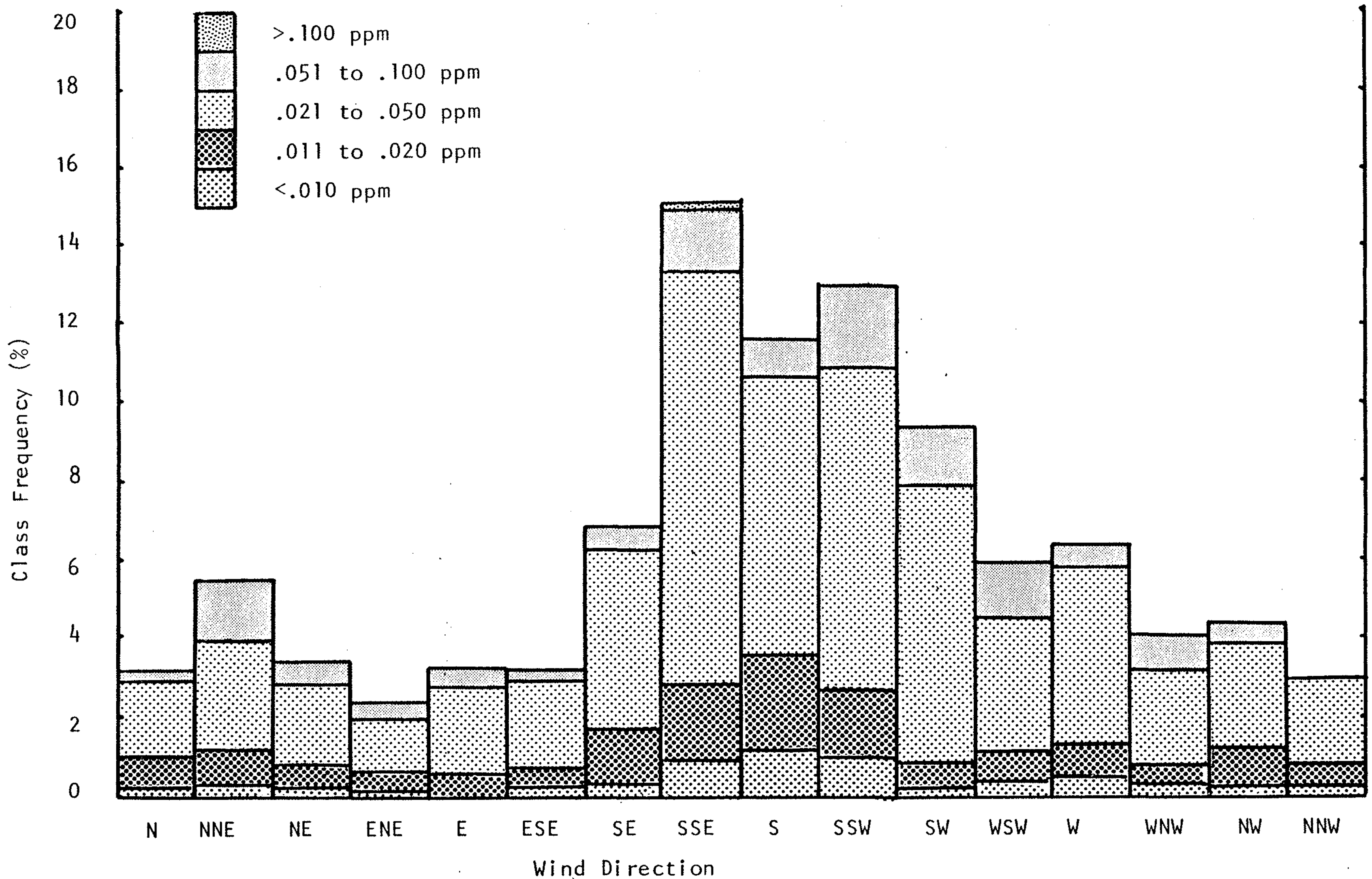

Figure 29. Frequency of occurrence of O_3 concentration by 50 m Wind Direction for May 1983-October 1983.

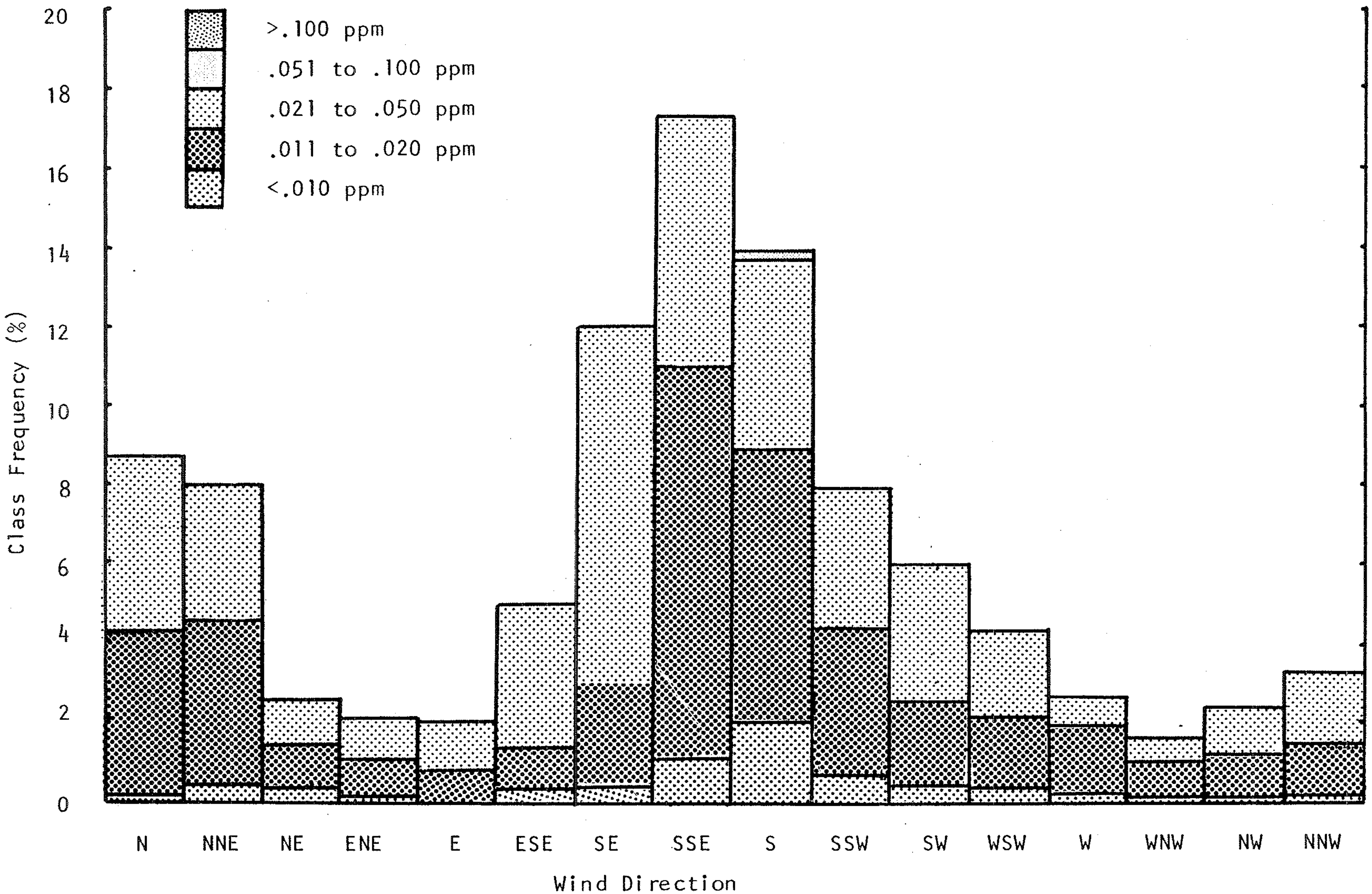

Figure 30. Frequency of occurrence of O_3 concentration by 50 m Wind Direction for November 1983-March 1984.

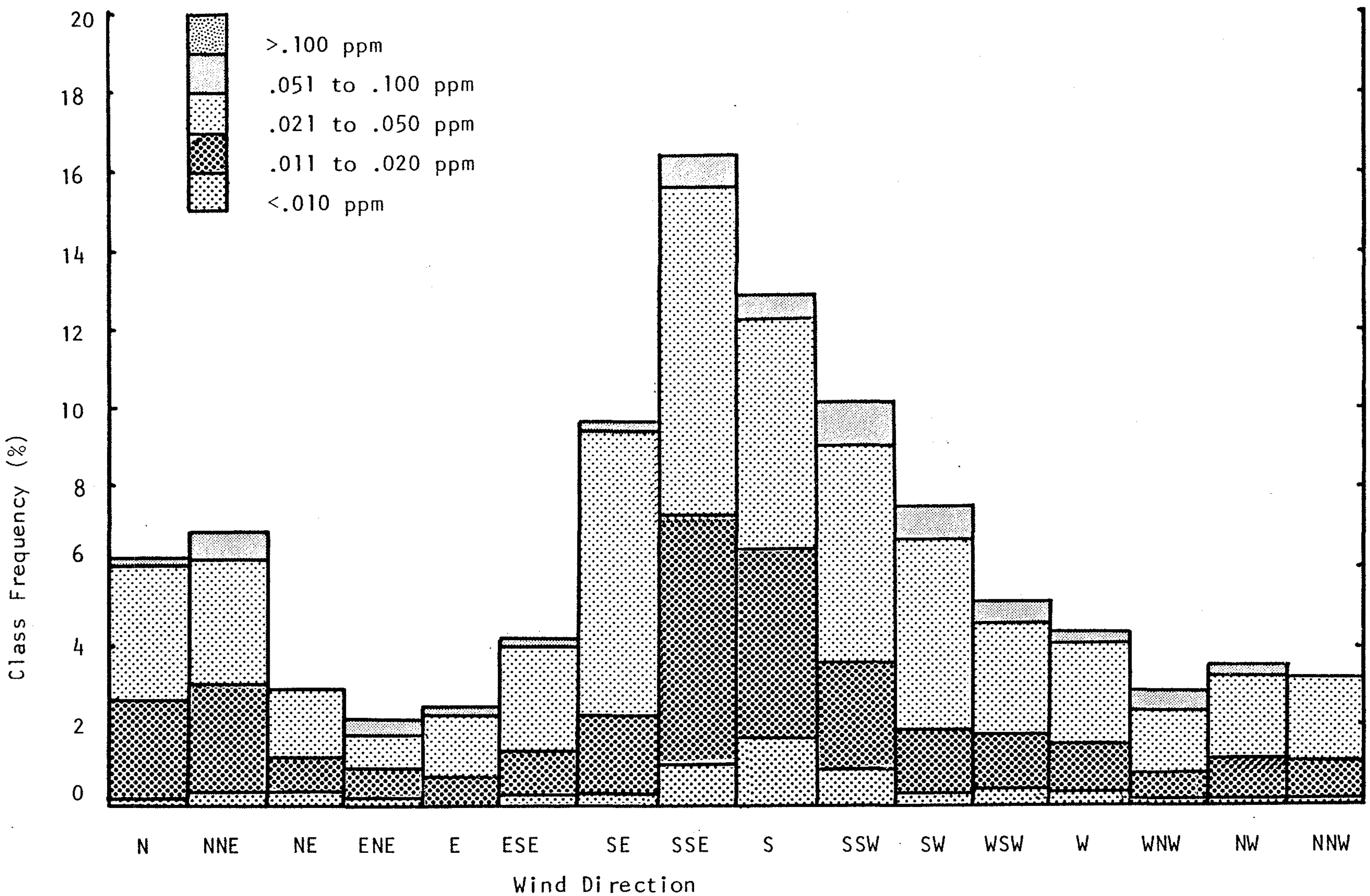

Figure 31. Frequency of occurrence of O_3 concentration by 50 m Wind Direction for May 1983-March 1984.

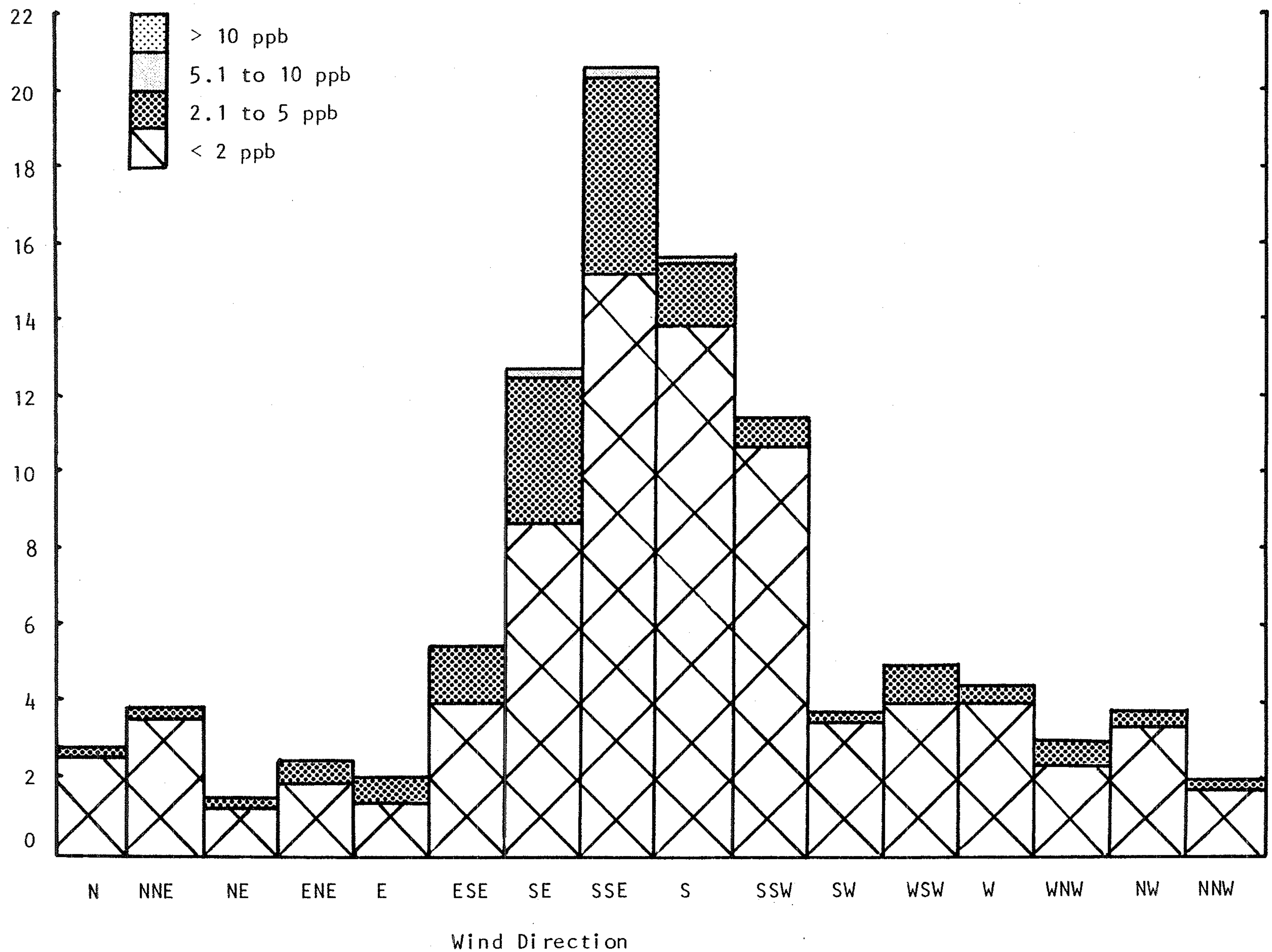

Figure 32. Frequency of occurrence of NO concentration by 10 m Wind Direction for June 1983-Octoboer 1983.

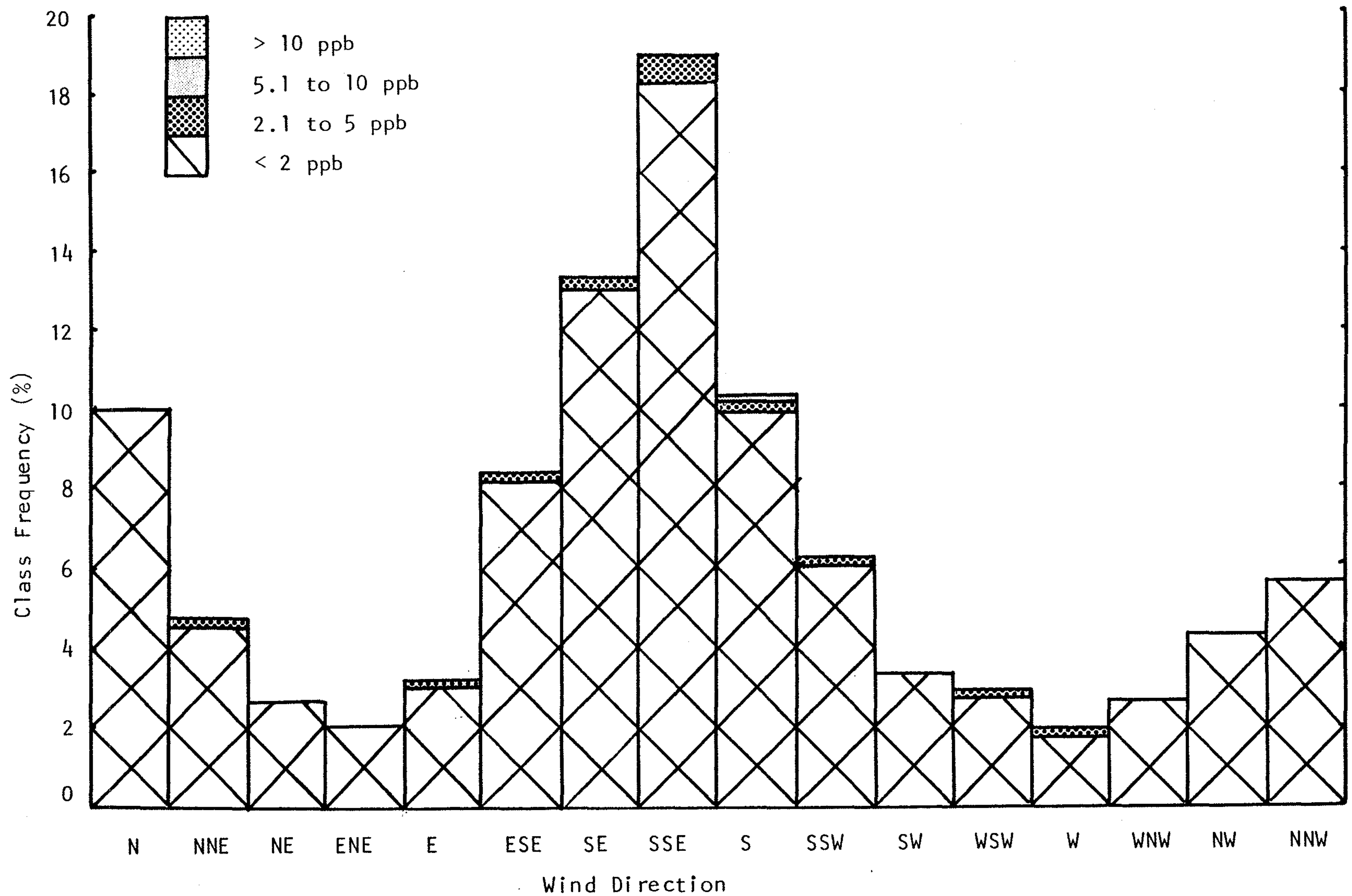

Figure 33. Frequency of occurrence of NO concentration by 10 m Wind Direction for November 1983-March 1984.

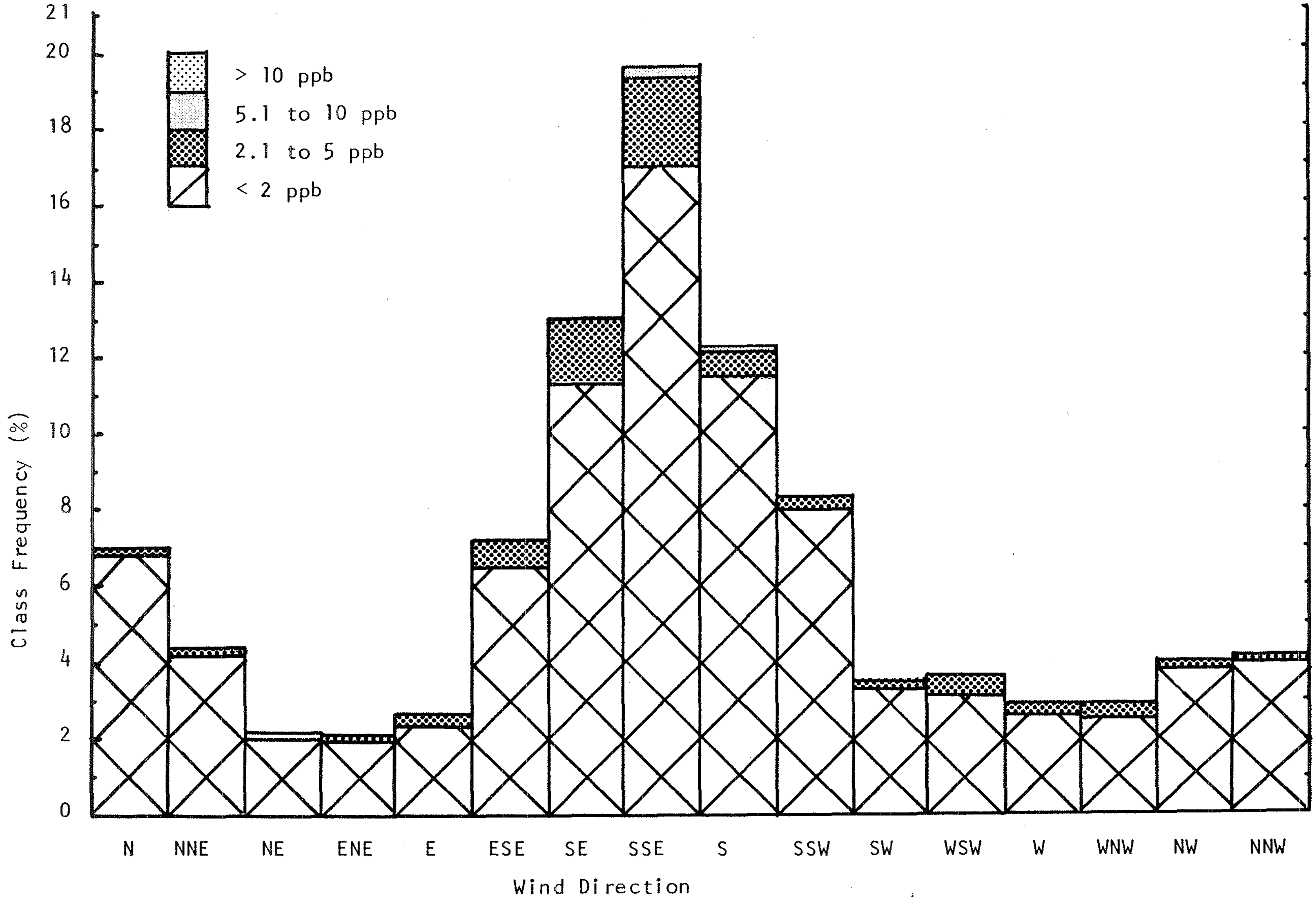

Figure 34. Frequency of occurrence of NO concentration by 10 m Wind Direction for June 1983-March 1984.

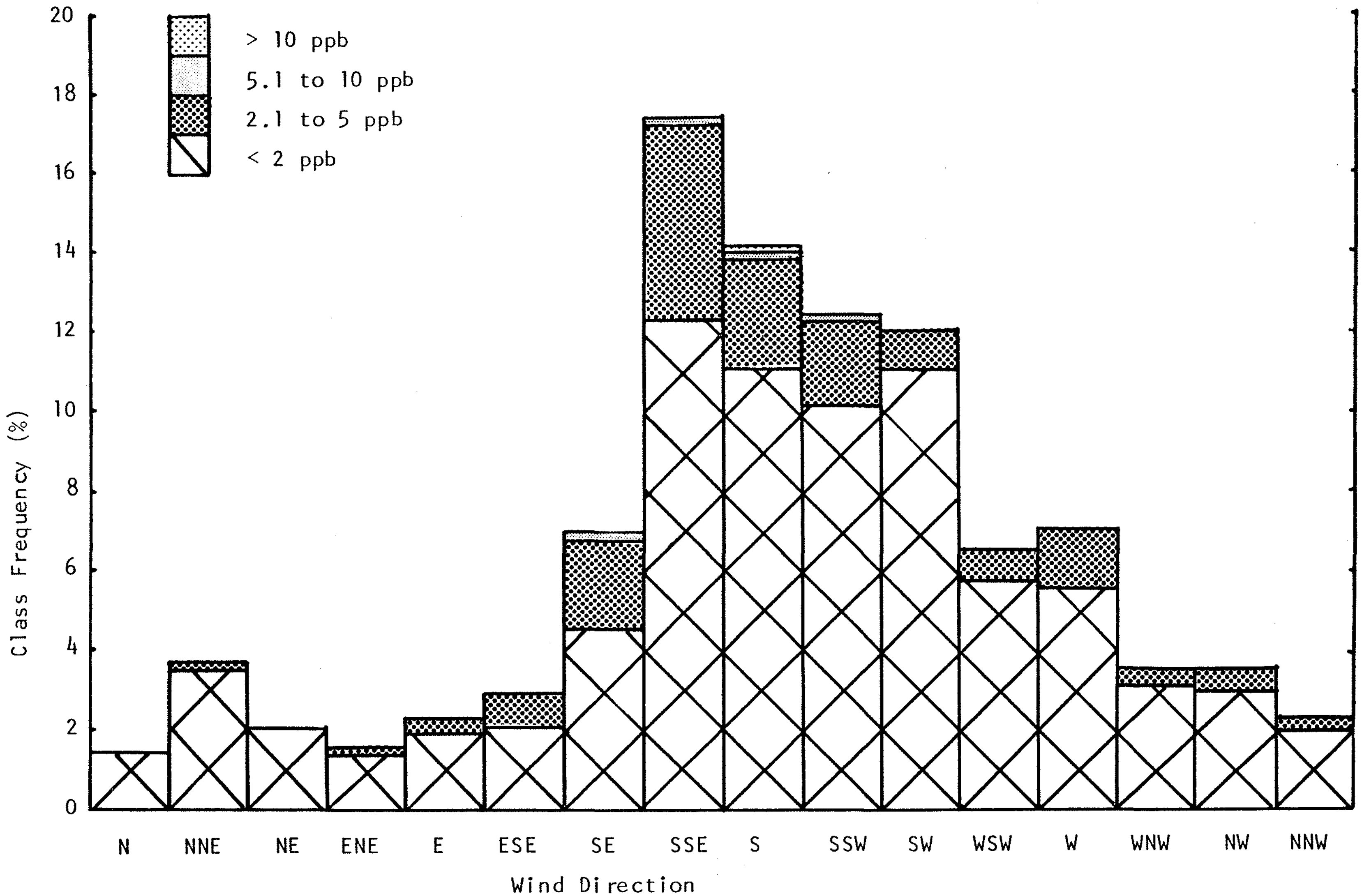

Figure 35. Frequency of occurrence of NO concentration by 50 m Wind Direction for June 1983-October 1983.

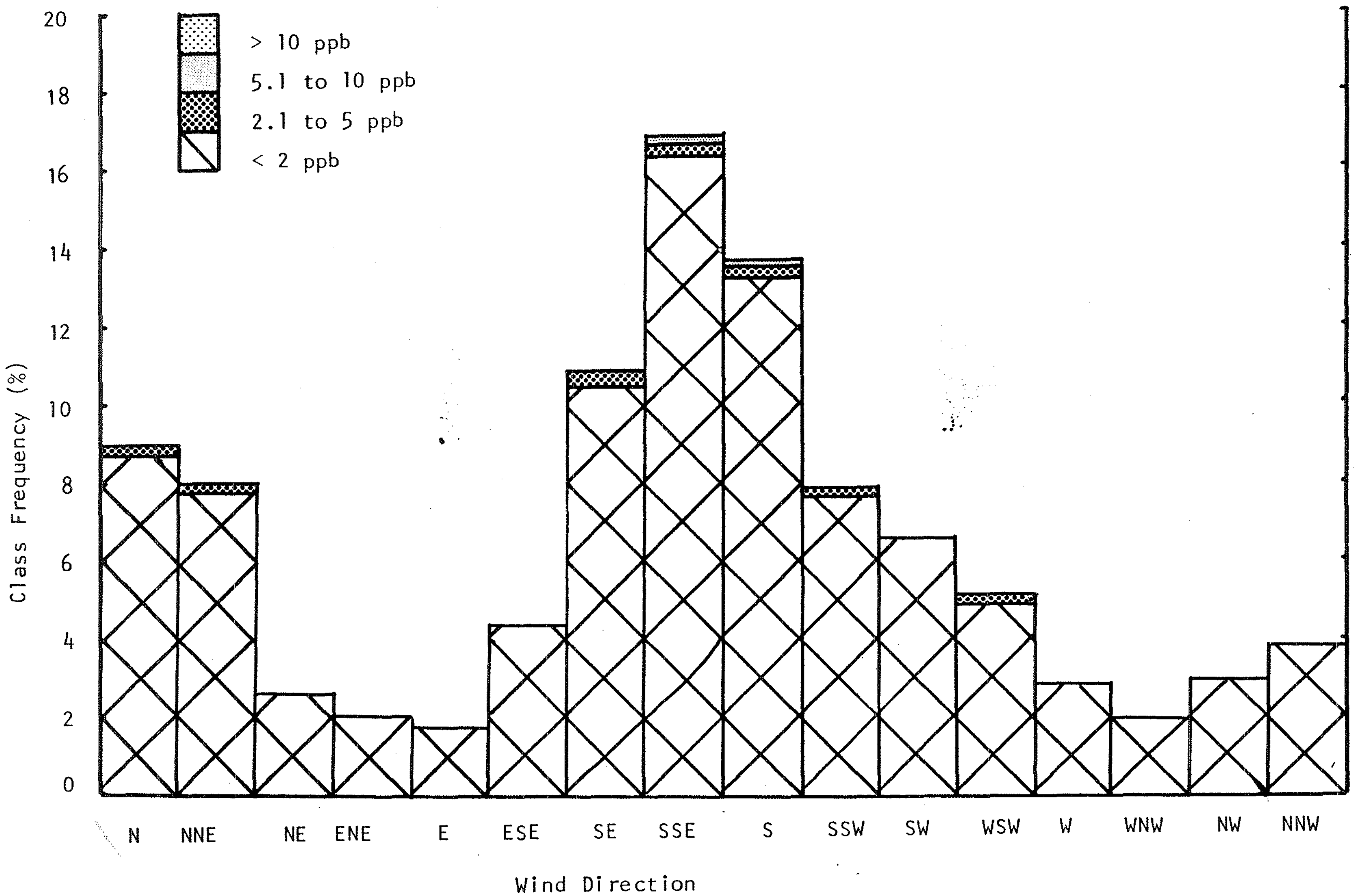

Figure 36. Frequency of occurrence of NO concentration by 50 m Wind Direction for November 1983-March 1984.

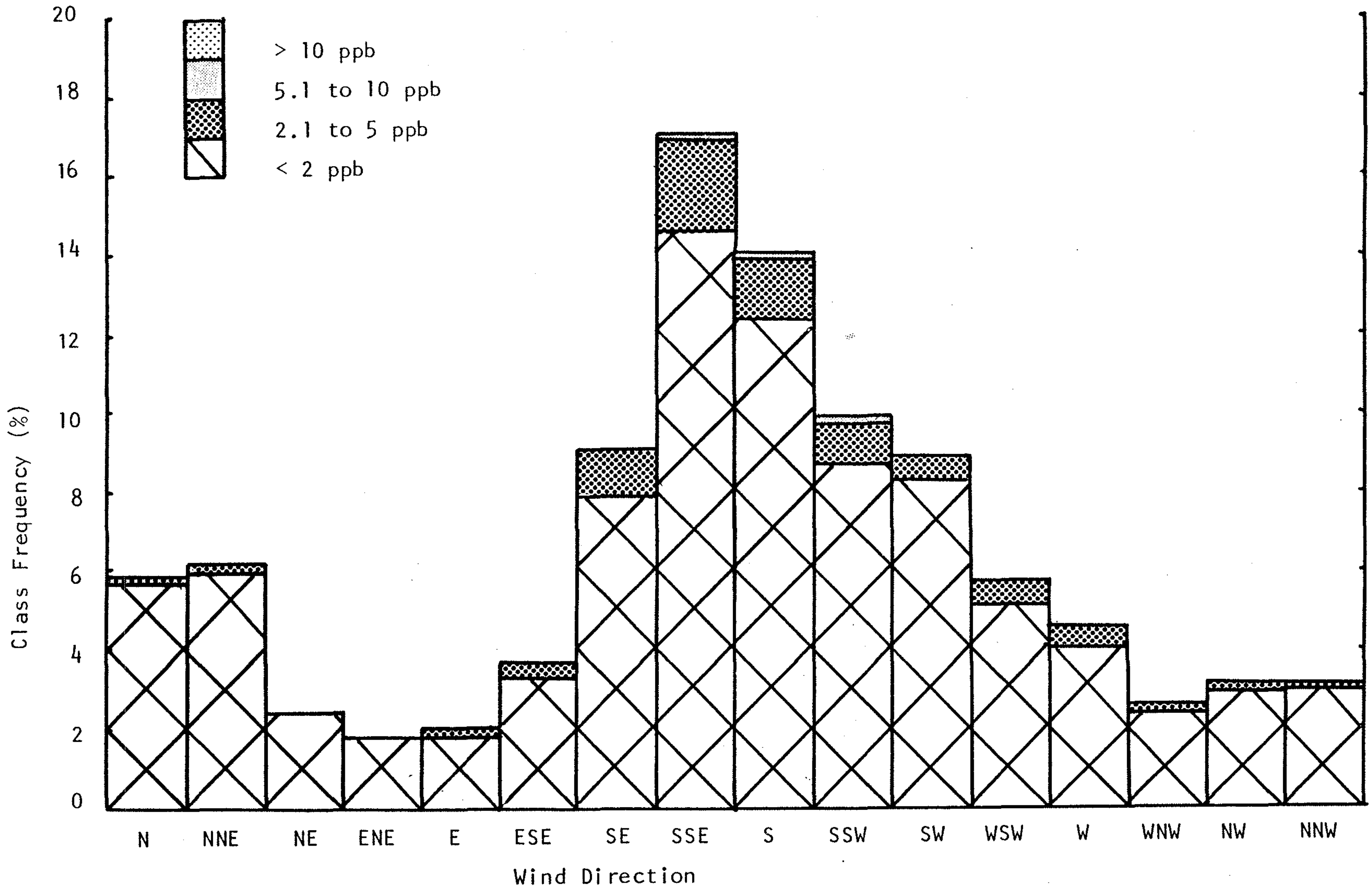

Figure 37. Frequency of occurrence of NO concentration by 50 m Wind Direction for June 1983-March 1984.

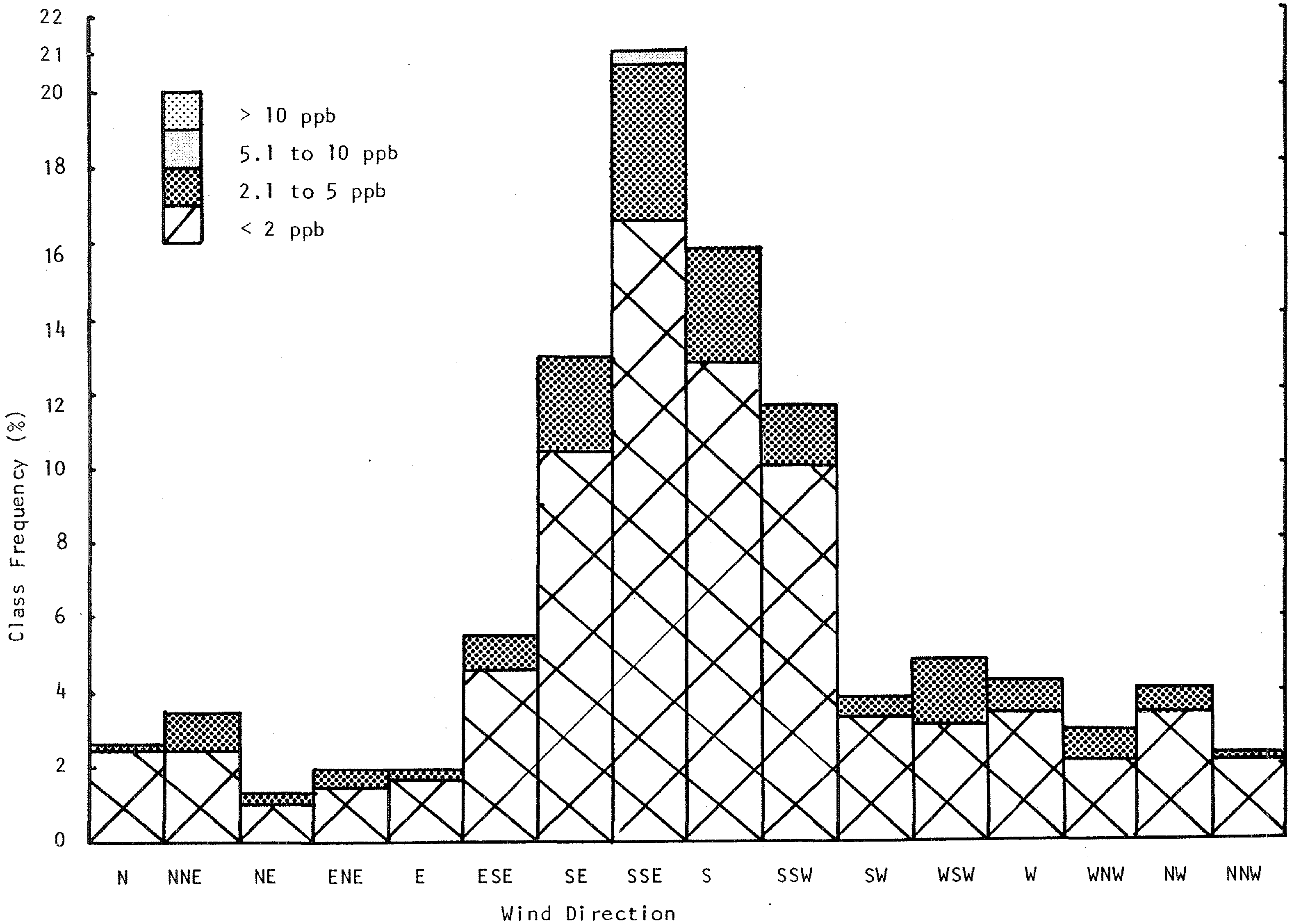

Figure 38. Frequency of occurrence of NO_2 concentration by 10 m Wind Direction for June 1983-October 1983.

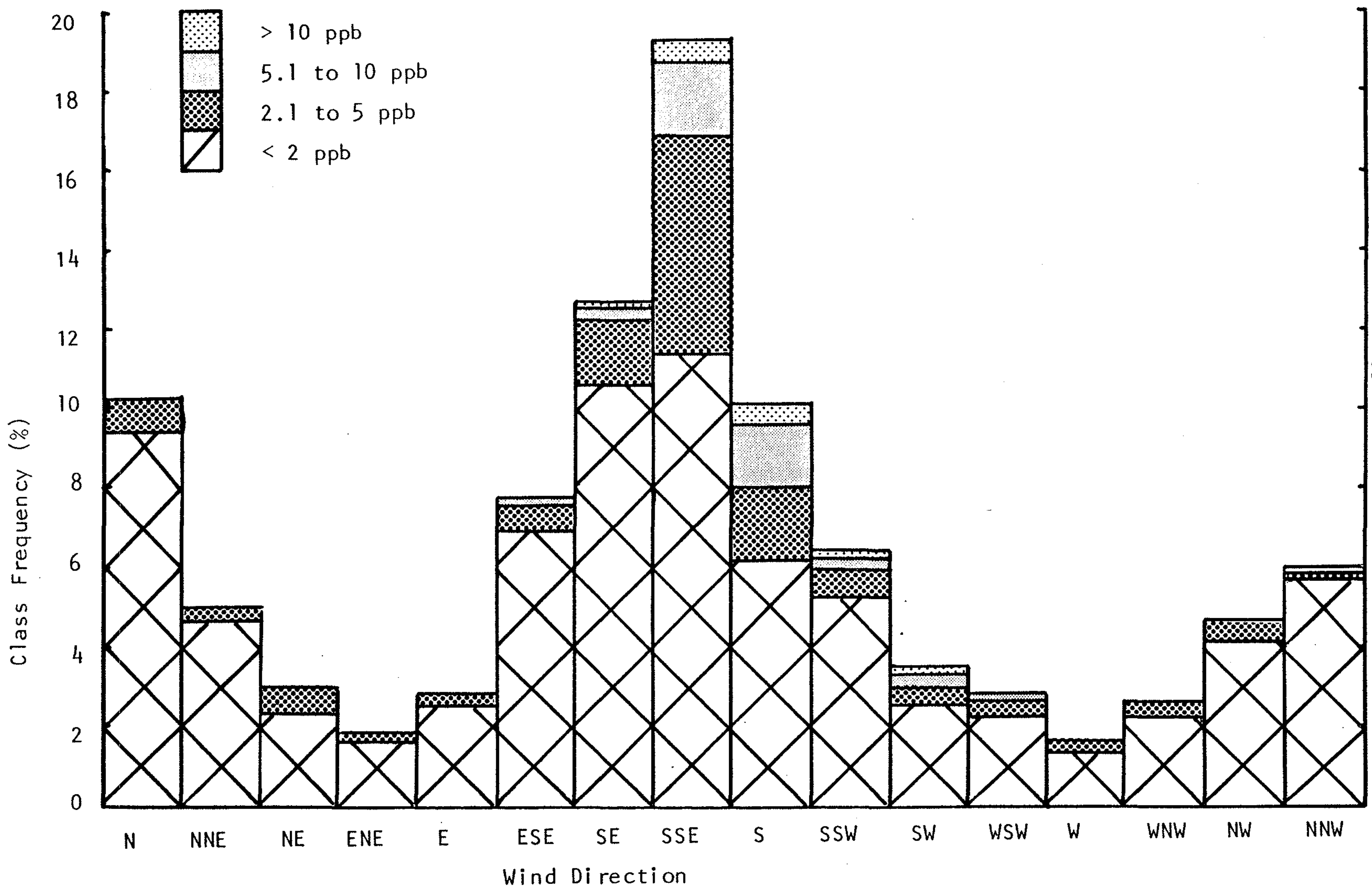

Figure 39. Frequency of occurrence of NO_2 concentration by 10 m Wind Direction for November 1983-March 1984.

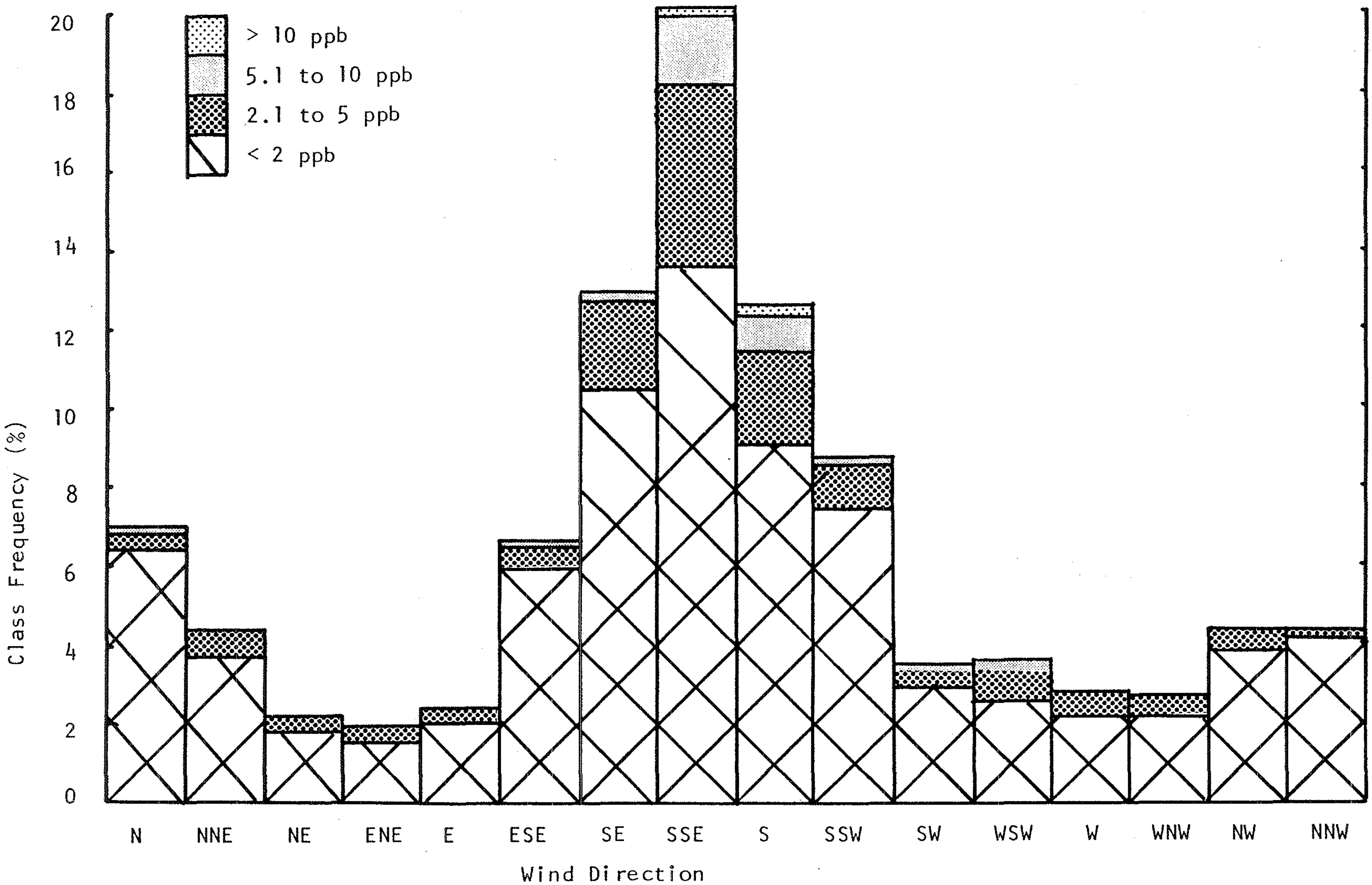

Figure 40. Frequency of occurrence of NO_2 concentration by 10 m Wind Direction for June 1983-March 1984.

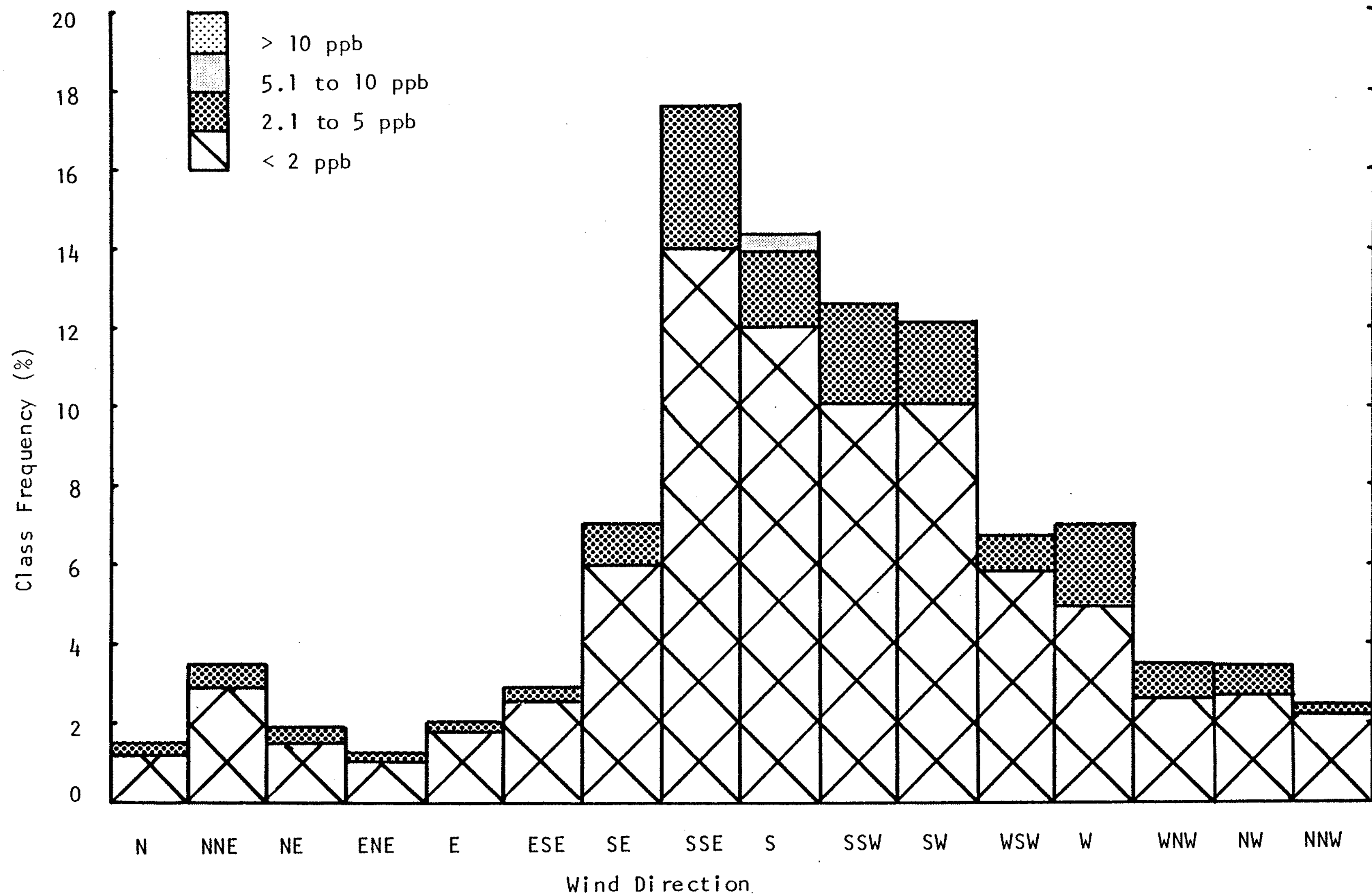

Figure 41. Frequency of occurrence of NO_2 concentration by 50 m Wind Direction for June 1983-October 1983.

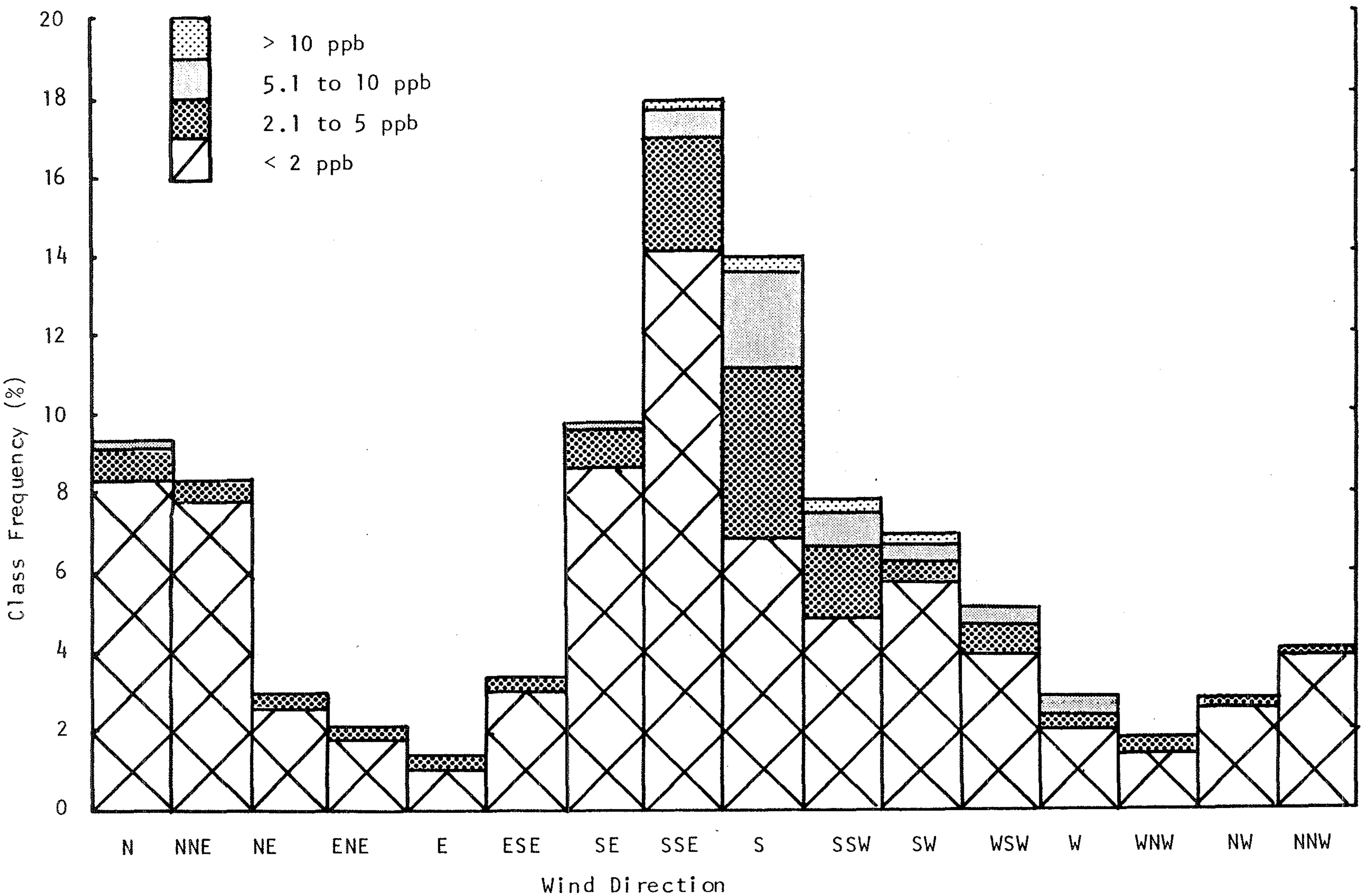

Figure 42. Frequency of occurrence of NO_2 concentration by 50 m Wind Direction for November 1983-March 1984.

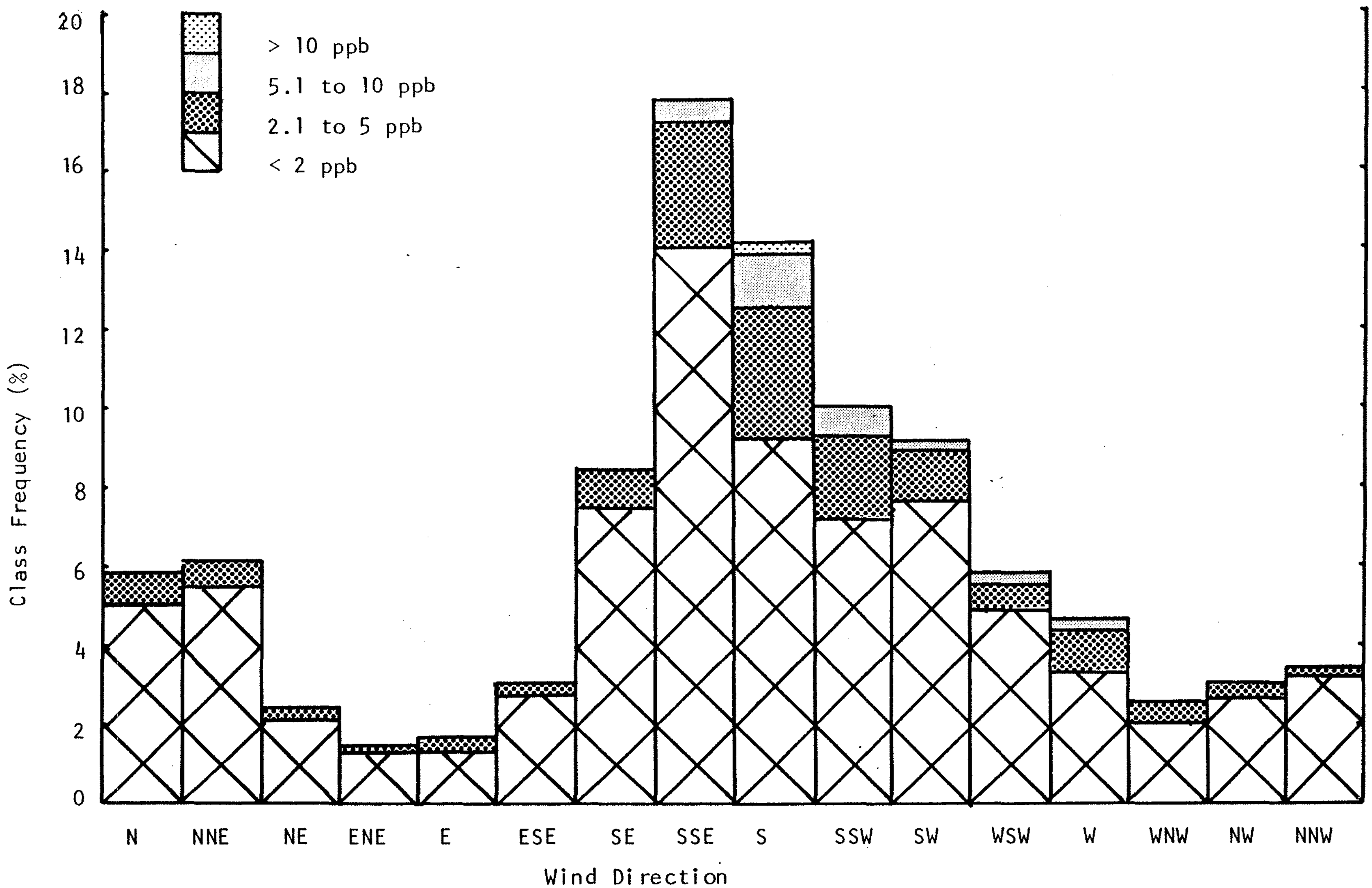

Figure 43. Frequency of occurrence of NO_2 concentration by 50 m Wind Direction for June 1983-March 1984.

6.3 MONTHLY CALIBRATIONS

6.3.1 $NO/NO_2/NO_x$ Calibration Summary

Date		Correlation Coefficient	Slope	Intercept	Comments
1983-5-26	NO	1.00	1.10	-0.003	
	NO_x	1.00	1.05	0.014	
	NO_2[a]				
1983-6-23	NO	0.9853	0.812	0.078	mixer card
	NO_x	0.9947	0.756	0.099	exchanged
	NO_2[a]				for repair
1983-7-29	NO	0.9979	1.02	-0.004	
	NO_x	1.000	0.85	0.058	
	NO_2[a]				
1983-8-28	NO	0.9994	1.00	0.000	original mixer
	NO_x	0.9959	0.954	0.019	card replaced
	NO_2[a]				
1983-9-17	NO	1.000	1.04	0.003	
	NO_x	0.9999	1.03	0.000	
	NO_2[a]				
1983-11-1	NO	0.9999	0.910	0.012	
	NO_x	0.9999	0.999	0.014	
	NO_2[a]				

continued . . .

[a] not available until 1983-12-7.

6.3.1 NO/NO_2/NO_x Calibration Summary (Continued)

Date		Correlation Coefficient	Slope	Intercept	Comments
1983-12-7	NO	1.00	0.9996	0.001	GPT glassware
	NO_x	0.9999	1.02	-0.006	installed in
	NO_2	1.00	1.00	-0.003	calibrator
1984-1-4	NO	0.9998	0.992	0.005	
	NO_x	0.9999	1.01	-0.006	
	NO_2	0.9999	1.01	-0.005	
1984-2-1	NO	0.9999	1.10	-0.019	
	NO_x	0.9998	0.970	-0.002	
					calibration
1984-2-1	NO	1.0	1.00	-0.002	repeated after
	NO_x	1.0	0.99	-0.005	adjusting span
					amplifier.
1984-2-2	NO	1.0	1.03	-0.013	
	NO_x	0.9999	1.02	-0.009	
	NO_2	0.9991	0.963	0.014	
1984-2-2	NO_2	0.9995	1.05	-0.004	
1984-2-3	NO	1.0	1.05	-0.012	
	NO_x	0.9999	1.02	-0.002	
	NO_2	0.9991	1.06	-0.003	
1984-3-5	NO	0.9999	1.15	-0.01	
	NO_x	0.9998	1.15	-0.007	

continued . . .

6.3.1 $NO/NO_2/NO_x$ Calibration Summary (Concluded)

Date		Correlation Coefficient	Slope	Intercept	Comments
1984-3-5	NO	0.9999	1.06	-0.02	calibration repeated to
	NO_x	0.9999	1.06	-0.02	balance $NO-NO_x$ set up to 1:1
1984-3-6	NO	0.9999	1.00	-0.007	
	NO_x	0.9999	1.03	-0.01	
	NO_2	0.9994	0.97	0.006	

6.3.2 Ozone Calibration Summary

Date	Correlation Coefficient	Slope	Intercept	Comments
1983-5-26	0.9992	0.882	0.006	
1983-6-23	0.9999	1.02	0.002	
1983-7-29	0.9972	0.928	0.018	
1983-9-1	0.9862	0.881	0.003	
1983-10-2	0.9996	0.989	0.002	
1983-11-1	1.000	0.971	0.003	
1983-12-7	0.9995	0.846	0.035	
	0.9985	0.888	0.008	
1984-1-5	0.9997	0.860	-0.004	
1984-1-5	0.9999	1.01	-0.005	new O_3 source in calibrator
1984-2-1	0.9994	0.92	-0.003	
1984-3-5	0.9999	0.88	-0.001	
1984-3-6	0.9998	1.62	0.001	
	0.9996	0.98	0.002	

6.3.3 Sulphur Dioxide Calibration Summary

Date	Correlation Coefficient	Slope	Intercept	Comments
1983-5-26	0.9993	0.904	0.034	
1983-6-23	0.9969	0.8342	0.052	
1983-7-29	0.9999	0.787	0.038	
1983-9-1	0.9999	0.9996	-0.006	
1983-9-17	1.000	1.056	-0.010	
1983-10-2	1.000	1.04	-0.004	
1983-11-1	1.000	1.02	-0.007	
1983-12-7	1.000	1.024	-0.098	
1984-1-4	0.9997	0.98	-0.004	
1984-1-5	0.9998	0.980	0.003	
1984-2-1	0.9999	1.02	-0.009	
1984-3-5	0.9998	1.05	0.000	