551.510.42

ROYAL OBSERVATORY, HONG KONG

TECHNICAL NOTE NO. 55

SULPHUR DIOXIDE MEASUREMENTS AT KING'S PARK METEOROLOGICAL STATION IN 1979

by

E. KOO

February, 1980

SUMMARY

Sulphur dioxide levels measured at King's Park Meteorological Station in 1979 were analysed statistically and were compared with various statutory limiting levels for sulphur dioxide adopted elsewhere. Monthly mean values were determined and diurnal variations were assessed. Concentrations were found to be related to simultaneous measurements of wind. The effects of other meteorological parameters were of less significance.

CONTENTS

TABLES

FIGURES

FIGURES (cont'd)

1. INTRODUCTION

Levels of sulphur dioxide are measured at King's Park Meteorological Station with a Lear Siegler SM1000 second derivative spectrometer. Measurements are taken at 20-second intervals and have been data-logged since 4 September 1978. Preliminary monthly analyses have been prepared since then. The present study is a summary of the results of the measurements in 1979, the first full calendar year for which data is available. In assessing these results it should be borne in mind that emissions and meteorological conditions during this year may be different from those in other years.

Apart from providing summaries of the data, this study also attempts to :

a) relate the measured sulphur dioxide levels for various time intervals to air quality standards that may be established in Hong Kong in the future,

b) show the diurnal and month to month variations of sulphur dioxide levels,

c) determine the variation of sulphur dioxide levels with wind direction and speed,

d) show the diurnal variation of sulphur dioxide levels for various wind directions, and

e) consider the effects of other meteorological parameters.

The purpose of this paper is to present the results of a year's measurement of sulphur dioxide levels and no attempt has been made to provide a physical explanation of the variations of these levels.

The time used throughout this publication is Universal Co-ordinated Time (UTC) plus 8 hours.

2. INSTRUMENTATION

The Lear Siegler SM1000 ambient monitor has been designated by the U.S. Environmental Protection Agency as "an equivalent method" for measuring sulphur dioxide when the instrument is operated under the following conditions (Lear Siegler, Inc. 1976) :

Range	:	0 - 0.5 ppm (0 - 1309 $\mu g/m^3$)
Response time	:	slow (300 seconds)
Wavelength	:	299.5 nm
Operating temperature	:	20 - 30°C

The unit at King's Park however is operated at a wavelength of 218 nm at which the instrument is about three times as sensitive as at the recommended wavelength. The theory of the SM1000 and various instrumental considerations, including noise, minimum detectable concentration, zero and span drifts and data loss of the SM1000 are described in Koo (1979) and Peterson (1980). The instrument is installed in the Weather Satellite Workshop at King's Park Meteorological Station (elevation 64.8 metres above mean sea level) and has been in operation since January 1978. A MK 4 Cup Anemometer is installed above the Main Building at King's Park with the anemometer head 78.1 metres above mean sea level (Chen 1975). The anemometer is about 50 metres east of the Weather Satellite Workshop. In August 1978 a cable was laid between the cup anemometer and the Weather Satellite Workshop so that measurements of wind speed and direction together with simultaneous recordings of sulphur dioxide levels can be fed into a Memodyne data logger every 20 seconds.

3. DATA TREATMENT

Routine recordings are made on cassette tapes. In addition to the 4-hourly automatic calibrations, manual adjustment of the spectrometer is carried out whenever instrumental drift is found to be significant. Cassette tapes are read with a Memodyne 3122 Reader. The raw data is read into one of the teletype input lines of the Observatory's Eclipse S/130 computer which was installed at the Royal Observatory in July 1978. Quality control of the data is carried out on the Eclipse. The verified data is then recorded on computer compatible magnetic tapes for archiving.

The basic averaging time used in this study is three minutes. This is in line with the time scale used by the U.K. Central Electricity Generating Board in calculating ground level concentrations for determining stack heights of new power stations. It is noted, however, that in evaluating environmental air quality, arithmetic means of longer time periods are generally used (see Table 1). In this study, sulphur dioxide concentrations for longer averaging times are generated from the 3-minute means. 3-minute, 30-minute and hourly means are only included when half or more of the readings during the averaging period are available. In 1979 all daily averages were accepted, as at least 75 percent of the possible hourly values were available each day (see Table 2(d)). This 75 percent acceptance criteria has been used in the U.S. Environmental Protection Agency National Aerometric Data Bank (NADB) for assessing national progress in achieving and maintaining air quality standards (U.S. Environmental Protection Agency 1976). In this report all sulphur dioxide concentrations are rounded off to the nearest microgram per cubic metre ($\mu g/m^3$).

4. ANALYSES AND RESULTS

(I) Statistical distribution of concentrations averaged over various periods

Tables 2(a) to (d) show monthly and annual percentage frequencies of 3-minute, 30-minute, hourly and daily average sulphur dioxide concentrations occurring in 50 $\mu g/m^3$ ranges during 1979. The distributions are all left-skewed with many concentrations close to zero.

One of the more valuable functions of a continuous sampler is to determine how often air pollutant concentrations equal or exceed certain specified values. For example, one of the long term goals of the World Health Organization for limiting sulphur dioxide is that 98% of the mean daily levels should be below 200 $\mu g/m^3$. Tables 3(a) to (d) show 3-minute, 30-minute, hourly and daily sulphur dioxide concentrations equalled or exceeded for various percentages of the time. Concentrations were ranked from highest to lowest and the following equation was used to determine which observation should be selected at a particular frequency :

$$r = \frac{fn}{100} + 0.999 \qquad \text{(Pearson et al 1962)}$$

where r is the rank order of the observation truncated to give an integer value

f is the selected frequency in per cent

n is the number of observations

Analyses of air pollution data from the Continuous Air Monitoring Program (CAMP) sites in U.S.A. indicate that pollutant concentrations tend to follow a log-normal distribution for all averaging times (U.S. Department of Health, Education and Welfare 1970).

The King's Park sulphur dioxide concentrations for the four averaging times were plotted on log-normal probability paper. The results, shown in Figure 1, indicate the degree to which the 1979 data for the four averaging times departed from log-normal distribution. One of the reasons for these departures could be that, except for the daily average, data were not available for 100 per cent of the occasions (see Table 2(a) to (c)). Secondly, whenever levels above the upper instrumental limit of 1309 $\mu g/m^3$ were encountered, the compilation program approximates these levels to this upper limiting value.

(II) Estimation of annual absolute maximum concentrations for various periods

As it is recognised that under-estimation of high levels has occurred from time to time, an indication of the absolute maxima of various periods in 1979 would be useful. This was done by means of extrapolation of the frequency distribution curves in Figure 1 to the zero percentile as in Larsen (1971). It is difficult to extrapolate a distribution that is not log-normal over its whole range. Nevertheless two arbitrarily chosen points on the distribution can be used for extrapolation. One of these should be fairly close to the actual maxima but far away enough to be virtually unaffected by any inaccuracy in the measurement of high concentrations and for this purpose the 0.1 per cent frequency has been selected. For each one of the four averaging periods, a line joining the concentrations at the 20th and the 0.1 percentiles was drawn on Fig. 1 to cut the concentration axis and give an estimated maximum. These values are listed in Table 4. Larsen used this technique in evaluating annual absolute maximum concentrations

for six averaging periods for eight U.S. cities, using data from 1962 to 1968, results of which are in Table 5. For these years, the five cities, Cincinnati, Denver, Los Angeles, San Francisco and Washington all had lower hourly maximum values than Hong Kong did in 1979. Three of the five cities also had lower daily maxima than Hong Kong. Considering hourly and daily maxima only, Chicago, Philadelphia and St. Louis appear to have been more polluted than Hong Kong. One should bear in mind however that the estimations of these maxima are based on subjective inference from an assumption of log-normal distributions of pollution levels.

(III) Means, maxima and selected percentile values in each month for various time periods

The mean level for the year was 76 $\mu g/m^3$ which exceeds the World Health Organization recommended goal (60 $\mu g/m^3$) but is less than both the U.S. National Primary Standard (80 $\mu g/m^3$) and the guideline on air quality recommended by consultants from Environmental Resource Ltd. (E.R.L.) for Hong Kong of 100 $\mu g/m^3$ (see Tables 1 and 3). The median of the daily means during 1979 was 67 $\mu g/m^3$ and is less than the EEC criteria for a year.

Although the estimated absolute maximum daily concentration for 1979 was 458 $\mu g/m^3$, (see Table 4) the highest observed daily value for the year was 306 $\mu g/m^3$ on 25 September and this latter figure is less than the maximum 24-hour concentration specified in the U.S. National Primary Standard (365 $\mu g/m^3$) and also less than the guideline value recommended by E.R.L. (350 $\mu g/m^3$). In 1979, 98% of the mean daily observations were below 225 $\mu g/m^3$ and this does not meet the specified long-term goal of 220 $\mu g/m^3$ recommended by World Health Organization. The value recommended by E.R.L. which should not be exceeded on 10% of the days in a year was 200 $\mu g/m^3$. In 1979, values were above only 141 $\mu g/m^3$ on 10% of the days.

The maximum hourly value recommended by E.R.L. was 750 $\mu g/m^3$ and, except in August, October and December, this value was exceeded in every month in 1979 for a total of 22 occasions. The maximum hourly value recorded was 1209 $\mu g/m^3$ on 20 June. The estimated absolute maximum hourly concentration was 2036 $\mu g/m^3$ (see Table 4).

The mean monthly concentrations (shown in all Tables 3) were highest in March, April and May 1979 with mean monthly sulphur dioxide levels of 100 $\mu g/m^3$ or more. In each of Tables 3(a) to (d) the highest monthly value for each percentile has been underlined. Most, but not all, of these maxima occurred in March, April and May. Some maxima in the upper percentiles occurred in other months. In other words, although mean monthly levels were highest during these three spring months, higher peaks of various durations occurred in other months as well.

(IV) Diurnal variation in general

The mean diurnal variation averaged over the year shows a peak at noon and generally high levels during the whole afternoon and evening (see Figure 2).

For individual months, except July, the mean sulphur dioxide levels are very much higher during the day-time than at night (see Figure 2). However, the monthly diurnal distributions are not uni-modal, with peaks occurring mostly in the late morning and at various times in the afternoon or evening for different months.

(V) Diurnal variation for different wind directions

In Figure 2, sulphur dioxide levels with all wind directions at King's Park are grouped to obtain the monthly diurnal patterns, and possible different effects from sources lying in various directions are indistinguishable. It was therefore decided to divide each month's data into 12 subsets - one for each 30° wind sector. Results are shown in Figure 3(a) to (l). Data for winds of less than 1 knot are shown in Figure 3(m). Inspection of the figures show that the patterns of diurnal variation with winds from 080° - 100° and also from 110° to 130° are similar to the diurnal pattern for all wind directions shown in Figure 2. This is probably because winds at King's Park were prevalent from these directions about 50% of the time during 1979.

(VI) Average concentrations for various wind directions

When the 3-minute concentrations for each month are classified by wind direction in 10° sectors, average values did not peak consistently at any particular wind direction throughout 1979 (see Figures 4(a) to (m). One can conclude from these "pollution roses" that there are no dominant emission source(s) in the vicinity of King's Park that emit continuously throughout the year.

A few wind sectors from which intermittent emissions affect King's Park resulting in 3-minute concentrations in the uppermost one percentile are identified in Section (VIII).

(VII) Average concentrations for various wind speeds

Table 6 shows mean concentrations over various wind speed ranges for each month and for the whole of 1979. For most months and also for the annual average, mean concentrations increase with wind speeds up to about 10 knots, and are lowest with stronger winds. These results are reasonable, as higher winds are more effective in dispersing pollutants. Conversely, dispersion is reduced and pollutant levels tend to be higher at lower wind speeds. This general result has also been observed in various regions in U.S.A. (U.S. Environmental Protection Agency 1976). This simplified description of dispersion needs modification when a sampler is affected by factors such as a large single source, by unusual topography or by limited vertical dispersion.

(VIII) Analysis of 3-minute concentrations in the uppermost one percentile

In the preceding sections (III) to (VII), mean concentrations have been considered. In order to look at various factors associated with high concentrations of short durations, monthly analyses of the 3-minute levels in the uppermost one percentile of the year's data were carried out. The uppermost one percentile concentration in 1979 was 597 $\mu g/m^3$ and there were 1608 occasions when this value was exceeded. More than 50% of the occasions occurred in the four months of January, March, May and September.

(i) The diurnal variation of the frequency of occurrence of these high concentrations is shown in Table 7(a). The most common time of occurrence for almost all months was between 1000 and 1200 with minor peaks during the afternoon.

(ii) The frequency of occurrence of high concentrations with each 30° wind sector is shown in Table 7(b). About 70% of these occasions during the year occurred with winds from 080° to 130°. A secondary peak with about 21% of the occurrences of high concentrations was associated with winds from 230° to 280°. One can infer that major emissions contributing to high sulphur dioxide levels at King's Park were located upwind in these directions.

(iii) The wind speeds most frequently associated with high concentrations were in the range 4 to 10 knots (see Table 7(c)). The highest mean concentrations tend to occur at the upper end of this wind speed range (see monthly values in Table 6).

(IX) Other meteorological variables

Wind speed and direction were found to be the dominant meteorological factors affecting sulphur dioxide concentrations in the King's Park area. Daily values of five other meteorological parameters were correlated with mean daily sulphur dioxide levels. Correlation coefficients were all low and only relative humidity and atmospheric pressure were found to be significantly correlated with sulphur dioxide levels (see Table 8). In some studies in temperate areas daily pollution levels were found to be inversely correlated with temperature (Raynon 1972). In these temperate latitudes the number of small sources used for space heating increases as the temperature falls. However in Hong Kong, there is little small scale space heating and this may be the reason why no significant correlation was found between temperature and sulphur dioxide levels.

(X) Variation with upper air temperature

Radiosonde ascents are made twice daily at King's Park Meteorological Station at 0800 and 2000. From these ascents the stability of the lower atmosphere may be deduced from the lapse rate between the station (66 metres above mean sea level) and the standard levels of 1000 mbar and 950 mbar which are around 200 metres and 600 metres above mean sea level respectively. When the lapse rate is large the stability of the atmosphere is reduced and pollution can disperse vertically more readily. The lapse rate deduced from ascents is valid only at the time of sampling and its variation during the day is not known. Details of the variations of the strengths of the sources of sulphur dioxide emissions in Hong Kong are also not known, but they are not all constant during the day. However, daily values of sulphur dioxide were correlated with the lapse rates from the 0800 ascent, the 2000 ascent and the average of the two. As expected the correlation coefficients were found to be negative and although highly significant, were not large (see Table 9).

If an inversion is strong enough it may act as a lid, completely trapping all the polluted air underneath it. Inversions then often become visible from mountain tops in Hong Kong. Routinely, for climatological purposes, all days with inversions below 950 mbar are extracted in accordance with World Meteorological Organization practice (WMO 1960) whereby only layers with a measurable temperature increase ($\geq 0.1^{\circ}C$) and with at least a 20 mbar thickness are considered. In 1979 there were 100 such days with inversions below 950 mbar at either the 0800 or the 2000 ascent. January, March, April and December were the months with the most inversions and number of days with inversions in each month is given in Table 10. The mean daily sulphur dioxide concentration was higher on days with inversions than on days without (86 $\mu g/m^3$ against 73 $\mu g/m^3$). However, a t-test conducted with a pooled variance following Snedecor et al (1971) showed that the difference was significant only at the 0.05 level.

5. CONCLUSIONS

(a) 3-minute, 30-minute, hourly and daily averages of sulphur dioxide concentrations at King's Park Meteorological Station in 1979 were not log-normally distributed over the entire range of concentrations.

(b) In comparison with various statutory limiting levels for sulphur dioxide adopted elsewhere, the 1979 levels in Hong Kong were within some standards but exceeded others.

(c) The highest monthly mean concentrations in 1979 occurred in March, April and May but high concentrations over shorter periods occurred also in January, February, June, September and December.

(d) Wind direction and speed are the main meteorological parameters that affected sulphur dioxide levels at King's Park. The highest 3-minute concentrations occurred with east, east-southeast or westerly winds with speeds of 4 to 10 knots. These events happened more frequently between the hours 1000 to 1200.

(e) Mean daily sulphur dioxide levels were correlated with temperature lapse rates and the effect was generally statistically highly significant. Inversions also affected pollution levels but the difference caused by their presence was not shown to be significant.

REFERENCE

1. BELL, G.J., PETERSON, P. and CHIN, P.C. 1970 Meteorological aspects of atmospheric pollution in Hong Kong, Royal Observatory Tech. Note No. 29, Reprinted 1977

2. CHEN, T.Y. 1975 Comparison of surface winds in Hong Kong, Royal Observatory Tech. Note No. 41

3. KOO, E. 1979 A comparison of daily measurements of sulphur dioxide at King's Park Meteorological Station, Royal Observatory Tech. Note No. 52

4. LARSEN, Ralph I. 1971 "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards", U.S. Environmental Protection Agency, Office of Air Programs Publication No. AP-89

5. Lear Siegler, Inc. 1976 Lear Siegler SM1000 Instruction Manual

6. PEARSON, E.S. and HARTLEY H.O. 1962 Biometrika Tables for Statisticians Vol. 1, Cambridge University Press, New York.

7. PETERSON, P. 1980 Comparison between the Lear Siegler SM1000 and Monitor Labs Model 8450, Royal Observatory Tech. Note (Local) No. 27.

8. RAYNOR, Gilbert S. 1972 Urban air pollution in a suburban environment, presented in Conference of Urban Environment and Second Conference on Biometeorology, American Meteo. Society, pp. 106-109

9. SNEDECOR, G.W. and COCHRAN, W.G. 1971 "Statistical Methods", Sixth Edition, The Iowa State University Press.

10. U.S. Department of Health, Education and Welfare 1970 (second printing) "Air Quality Criteria for Sulphur Oxides", National Air Pollution Control Administration Publication No. AP.50

11. U.S. Environmental Protection Agency 1976 "Monitoring and Air Quality Trends Report - 1974", U.S. Environmental Protection Agency Publication No. EPA-450/1-76-001.

12. World Health Organization 1972 "Air Quality Criteria and Guidelines for Urban Air Pollutants - Report of WHO Expert Committee", WHO Tech. Report Series No. 506

13. World Meteorological Organization 1960 Guide to climatological practices, WMO - No. 100.TP.44

TABLE 1. SELECTED AMBIENT AIR QUALITY STANDARDS FOR SULPHUR DIOXIDE

Reference period	Limiting level of sulphur dioxide		Source
Year	Annual arithmetic mean - 80 $\mu g/m^3$		U.S. National Primary Ambient Air Quality Standard
Day	Maximum 24-hour concentration not to be exceeded more than once a year - 365 $\mu g/m^3$		
3 hour	Maximum 3-hour concentration not to be exceeded once a year - 1300 $\mu g/m^3$		U.S. Secondary National Ambient Air Quality Standard
Year	Annual mean - 60 $\mu g/m^3$		World Health Organization Recommended long-term goals
Day	98% of observations below 200 $\mu g/m^3$		
Year	Annual arithmetic mean - 100 $\mu g/m^3$		Guidelines on air quality recommended by Environmental Resources Ltd. in Control of the Environment in Hong Kong, Sep. 1976
Day	Maximum not to exceed - 350 $\mu g/m^3$		
Day	200 $\mu g/m^3$ not to be exceeded on more than 10% of the days in the year		
Hour	Maximum not to exceed - 750 $\mu g/m^3$		
Reference period	Limiting level of sulphur dioxide	Associated concentrations of suspended particulates	EEC criteria and objectives for sulphur dioxide and suspended particulates
Year	Median of daily means - 80 $\mu g/m^3$	Annual median of daily means > 40 $\mu g/m^3$	
Year	Median of daily means - 120 $\mu g/m^3$	Winter median of daily means < 40 $\mu g/m^3$	
Winter (October to March)	Median of daily means - 130 $\mu g/m^3$	Winter median of daily means > 60 $\mu g/m^3$	
Winter (October to March)	Median of daily means - 180 $\mu g/m^3$	Winter median of daily means < 60 $\mu g/m^3$	
Day	Arithmetic mean - 250 $\mu g/m^3$	Arithmetic mean of concentration over 24 hours > 100 $\mu g/m^3$	
Day	Airthmetic mean - 350 $\mu g/m^3$	Arithmetic mean of concentration over 24 hours < 100 $\mu g/m^3$	

TABLE 2(a) PERCENTAGE FREQUENCIES OF 3-MINUTE SULPHER DIOXIDE CONCENTRATIONS OCCURRING IN THE RANGES INDICATED - 1979

Concentration range ($\mu g/m^3$)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0-49	62.88	64.56	45.13	35.58	47.51	54.39	58.45	63.43	64.49	63.49	78.99	63.96	58.55
50-99	14.34	17.09	28.09	25.72	20.69	22.98	21.08	18.81	15.29	16.07	7.88	16.29	18.70
100-149	8.50	6.46	8.74	14.64	10.90	9.94	8.50	7.80	8.22	10.05	4.46	7.16	8.79
150-199	5.08	4.40	5.05	9.39	6.45	4.60	4.05	3.53	4.59	4.71	3.30	4.87	5.00
200-249	2.52	2.10	3.40	5.06	3.95	2.82	2.31	2.19	2.39	2.12	2.01	3.29	2.85
250-299	1.53	1.48	2.54	3.23	3.55	1.73	1.40	1.20	1.18	1.42	1.22	2.10	1.88
300-349	1.10	.98	1.51	2.26	2.00	.94	1.07	.85	.62	.83	.41	.85	1.12
350-399	.99	.50	1.17	1.25	1.23	.54	.77	.54	.55	.60	.41	.55	.76
400-449	.50	.30	.95	.69	.76	.35	.59	.45	.38	.31	.29	.36	.50
450-499	.34	.25	.90	.51	.55	.28	.39	.29	.30	.18	.21	.15	.36
500-549	.28	.21	.50	.28	.46	.20	.22	.39	.29	.10	.10	.15	.27
550-599	.32	.38	.34	.24	.31	.23	.20	.14	.32	.05	.13	.10	.23
600-649	.33	.16	.33	.28	.23	.11	.19	.13	.17	.02	.14	.06	.18
650-699	.36	.15	.39	.13	.23	.17	.16	.07	.16	.01	.08	.04	.16
700-749	.25	.14	.38	.13	.29	.08	.12	.09	.17	.01	.06	.01	.14
750-799	.19	.07	.19	.11	.18	.02	.11	.04	.12	.01	.04	.01	.09
800-849	.15	.09	.14	.10	.19	.02	.11	.02	.14	.00	.06	.02	.09
850-899	.09	.21	.07	.04	.15	.06	.08	.01	.11	.00	.05	.01	.07
900-949	.08	.37	.03	.08	.11	.02	.07	.01	.10	.00	.02	.01	.07
950-999	.10	.04	.07	.06	.07	.01	.02	.00	.10	.00	.02	.01	.04
$\geq$1000	.06	.07	.07	.22	.17	.50	.10	.01	.33	.00	.11	.00	.14
Number of valid observations	13689	12192	13511	13169	13676	13240	13713	13701	13195	13669	13257	13695	160707
Percent of possible	92.0	90.7	90.8	91.5	91.9	91.9	92.2	92.1	91.6	91.9	92.1	92.0	91.7

TABLE 2(b) PERCENTAGE FREQUENCIES OF 30-MINUTE SULPHER DIOXIDE CONCENTRATION OCCURRING IN THE RANGES INDICATED - 1979

Concentration range ($\mu g/m^3$)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0-49	62.59	65.07	44.31	34.34	47.58	53.79	59.28	64.06	62.73	62.43	77.60	63.15	57.80
50-99	13.79	16.99	28.35	25.38	19.67	22.78	19.86	18.05	16.18	15.78	7.78	16.41	18.50
100-149	8.94	6.19	8.83	15.27	11.44	10.53	8.60	7.67	8.88	11.39	5.32	7.21	9.25
150-199	5.14	4.46	5.03	9.68	6.67	5.12	4.34	3.83	4.36	4.77	4.29	5.73	5.33
200-249	2.38	2.43	3.64	5.52	4.63	3.03	2.05	2.56	2.70	2.85	2.22	3.75	3.18
250-299	1.79	1.33	2.63	3.80	3.54	1.44	1.60	.98	1.35	.92	.71	1.91	1.86
300-349	1.04	.86	1.63	2.44	1.77	.79	1.29	.98	.95	1.08	.64	.57	1.18
350-399	1.34	.31	1.86	1.36	1.36	.58	.84	.68	.32	.38	.40	.64	.85
400-449	.60	.47	.85	.36	.95	.14	.68	.45	.56	.15	.24	.28	.48
450-499	.52	.16	.62	.43	.41	.50	.30	.15	.16	.23	.00	.28	.32
500-549	.52	.08	.23	.29	.48	.22	.23	.23	.32	.00	.16	.00	.23
550-599	.52	.31	.62	.22	.27	.36	.15	.23	.08	.00	.08	.00	.24
600-649	.22	.16	.46	.07	.14	.14	.30	.08	.32	.00	.08	.00	.16
650-699	.07	.16	.39	.43	.27	.00	.08	.00	.08	.00	.16	.00	.14
700-749	.00	.23	.15	.00	.20	.07	.08	.08	.32	.00	.24	.07	.12
750-799	.37	.16	.15	.00	.20	.00	.23	.00	.32	.00	.00	.00	.12
800-849	.07	.16	.23	.22	.14	.00	.00	.00	.00	.00	.00	.00	.07
850-899	.00	.16	.00	.00	.07	.00	.00	.00	.08	.00	.00	.00	.02
900-949	.07	.31	.00	.00	.07	.00	.08	.00	.00	.00	.00	.00	.04
950-999	.00	.00	.00	.07	.14	.00	.00	.00	.08	.00	.00	.00	.02
$\geq$1000	.00	.00	.00	.14	.00	.50	.00	.00	.24	.00	.08	.00	.08
Number of valid observations	1342	1277	1291	1395	1469	1387	1314	1330	1261	1299	1259	1414	16038
Percent of possible	90.2	95.0	86.8	96.9	98.7	96.3	88.3	89.4	87.6	87.3	87.4	95.0	91.5

TABLE 2(c) PERCENTAGE FREQUENCIES OF HOURLY SULPHER DIOXIDE CONCENTRATION OCCURRING IN THE RANGES INDICATED - 1979

Concentration range ($\mu g/m^3$)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0-49	62.11	64.47	44.05	34.88	46.95	51.25	56.45	63.44	62.41	61.22	77.72	62.26	57.24
50-99	13.53	16.54	28.73	23.91	18.45	25.77	21.77	18.01	15.71	16.49	7.80	16.04	18.57
100-149	9.34	6.58	8.34	15.89	12.21	10.72	9.81	7.39	9.68	12.16	6.13	9.30	9.82
150-199	4.74	5.51	5.75	10.41	7.60	5.15	4.97	5.51	4.77	5.81	4.46	4.99	5.80
200-249	3.65	1.84	3.42	5.77	5.43	2.51	2.02	2.15	2.81	1.76	1.67	3.91	3.08
250-299	.95	1.38	2.46	2.95	2.99	1.53	1.48	.67	1.40	1.35	.84	1.89	1.66
300-349	1.49	.77	1.92	2.81	2.04	.56	.67	.81	.98	.81	.28	.94	1.17
350-399	1.62	.77	1.64	.84	1.63	.97	1.21	.94	.28	.27	.00	.40	.89
400-449	.54	.31	1.09	.98	.27	.00	.27	.81	.28	.14	.28	.00	.41
450-499	.41	.15	.14	.56	.54	.28	.40	.27	.14	.00	.14	.13	.26
500-549	.68	.46	.41	.00	.41	.42	.27	.00	.28	.00	.14	.00	.25
550-599	.14	.15	.27	.14	.41	.28	.27	.00	.14	.00	.14	.13	.17
600-649	.41	.00	.96	.28	.41	.00	.00	.00	.28	.00	.14	.00	.21
650-699	.14	.31	.68	.14	.27	.00	.13	.00	.00	.00	.14	.00	.15
700-749	.00	.00	.00	.00	.00	.00	.13	.00	.14	.00	.00	.00	.02
750-799	.14	.31	.14	.00	.00	.14	.00	.00	.14	.00	.00	.00	.07
800-849	.14	.00	.00	.14	.27	.00	.00	.00	.14	.00	.14	.00	.07
850-899	.00	.15	.00	.14	.00	.00	.13	.00	.14	.00	.00	.00	.05
900-949	.00	.31	.00	.14	.14	.00	.00	.00	.00	.00	.00	.00	.05
950-999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
≥1000	.00	.00	.00	.00	.00	.42	.00	.00	.28	.00	.00	.00	.06
Number of valid observations	739	653	731	711	737	718	744	744	713	740	718	742	8690
Percent of possible	99.3	97.2	98.3	98.8	99.1	99.7	100.0	100.0	99.0	99.5	99.7	99.7	99.2

TABLE 2(d) PERCENTAGE FREQUENCIES OF DAILY SULPHER DIOXIDE CONCENTRATION OCCURRING IN THE RANGES INDICATED - 1979

Concentration range ($\mu g/m^3$)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0-49	32.26	35.71	19.35	10.00	12.90	36.67	38.71	48.39	43.33	25.81	53.33	35.48	32.60
50-99	38.71	50.00	45.16	30.00	48.39	40.00	41.94	29.03	36.67	67.74	46.67	58.06	44.38
100-149	22.58	7.14	16.13	43.33	19.35	13.33	9.68	22.58	13.33	6.45	.00	6.45	15.07
150-199	3.23	3.57	6.45	16.67	12.90	6.67	6.45	.00	.00	.00	.00	.00	4.66
200-249	3.23	.00	9.68	.00	3.23	.00	3.23	.00	3.33	.00	.00	.00	1.92
250-299	.00	.00	3.23	.00	3.23	3.33	.00	.00	.00	.00	.00	.00	.82
300-349	.00	3.57	.00	.00	.00	.00	.00	.00	3.33	.00	.00	.00	.55
Number of valid observations	31	28	31	30	31	30	31	31	30	31	30	31	365
Percent of possible	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 3(a) 3-MINUTE SULPHUR DIOXIDE LEVELS IN $\mu g/m^3$ EQUALLED OR EXCEEDED FOR VARIOUS PERCENTAGES OF THE TIME IN 1979

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
.01	1087	1175	1181	1195	1309	1309	1218	1010	1300	753	1302	934	1299
.10	983	959	977	1104	1053	1209	1008	750	1300	550	1012	658	1041
1.00	689	698	696	619	728	599	592	479	729	374	450	390	597
2.00	538	478	551	471	542	408	426	365	499	307	311	316	429
5.00	307	263	370	328	347	253	270	231	251	214	206	241	275
10.00	190	167	242	245	256	175	169	149	170	153	133	174	187
20.00	114	90	134	170	157	111	101	89	101	101	53	98	112
50.00	33	28	55	73	53	43	39	33	30	32	40	31	37
70.00	16	9	37	43	30	23	16	13	16	20	14	15	18
90.00	0	0	16	17	10	4	0	0	2	8	2	2	1
Mean Level	77	67	100	112	103	78	72	61	72	62	47	63	76
Maximum Level	1092	1221	1204	1204	1309	1309	1237	1041	1300	785	1309	967	1309

Note : The highest monthly value for each percentile has been underlined.

TABLE 3(b) 30-MINUTE SULPHUR DIOXIDE LEVELS IN $\mu g/m^3$ EQUALLED OR EXCEEDED FOR VARIOUS PERCENTAGES OF THE TIME IN 1979

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
.01	904	933	824	1095	990	1209	935	715	1300	494	1122	722	1209
.10	812	933	819	1034	974	1209	784	639	1102	452	736	480	960
1.00	593	704	644	566	672	576	533	424	711	339	401	383	555
2.00	483	437	553	432	496	381	408	337	435	293	303	290	403
5.00	314	247	368	315	341	245	275	220	253	211	201	231	269
10.00	192	165	244	248	250	171	173	152	179	152	142	180	189
20.00	119	92	138	176	157	114	103	90	107	108	57	104	117
50.00	33	27	56	76	54	45	40	33	31	32	17	32	39
70.00	17	10	39	45	30	24	19	14	16	21	9	15	19
90.00	1	0	18	21	13	8	2	2	4	10	3	5	4
Mean Level	77	67	100	112	103	78	72	61	72	62	47	63	76
Maximum Level	904	933	824	1095	990	1209	935	715	1300	494	1122	722	1300

Note : The highest monthly value for each percentile has been underlined.

TABLE 3(c) HOURLY SULPHUR DIOXIDE LEVELS IN $\mu g/m^3$ EQUALLED OR EXCEEDED FOR VARIOUS PERCENTAGES OF THE TIME IN 1979

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
.01	838	933	755	923	924	1209	856	494	1188	428	818	567	1208
.10	838	933	755	923	924	1209	856	494	1188	428	818	567	904
1.00	547	672	642	483	630	538	489	408	631	307	402	330	511
2.00	452	419	568	414	478	381	389	354	396	268	269	274	386
5.00	328	251	363	317	325	240	241	210	248	191	186	232	259
10.00	205	165	241	240	245	160	163	155	169	152	141	172	184
20.00	121	96	143	175	163	114	108	92	109	108	65	107	117
50.00	34	28	57	79	56	47	41	35	31	32	17	32	39
70.00	17	10	39	45	31	25	21	16	17	21	10	15	20
90.00	2	0	21	21	13	10	4	3	6	11	4	6	5
Mean Level	77	67	100	112	103	78	72	61	72	62	47	63	76
Maximum Level	838	933	755	923	924	1209	856	494	1188	428	818	567	1209

Note : The highest monthly value for each percentile has been underlined.

TABLE 3(d) DAILY SULPHUR DIOXIDE LEVELS IN $\mu g/m^3$ EQUALLED OR EXCEEDED FOR VARIOUS PERCENTAGES OF THE TIME IN 1979

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
.01	225	302	278	195	251	275	240	139	306	115	98	128	306
.10	225	302	278	195	251	275	240	139	306	115	98	128	306
1.00	225	302	278	195	251	275	240	139	306	115	98	128	274
2.00	225	302	278	195	251	275	240	139	306	115	98	128	225
5.00	154	175	227	182	222	167	157	126	212	109	98	115	175
10.00	148	120	215	181	193	160	122	124	138	96	91	87	141
20.00	119	75	150	149	141	122	99	112	111	83	84	84	111
50.00	74	66	75	122	83	72	59	52	60	64	48	65	67
70.00	32	46	54	86	75	49	48	33	41	55	15	49	46
90.00	18	10	35	63	44	30	22	13	19	24	11	35	19
Mean Level	77	67	100	112	103	78	72	61	72	62	47	63	76
Maximum Level	225	302	278	195	251	275	240	139	306	115	98	128	306

Note : The highest monthly value for each percentile has been underlined.

TABLE 4. ESTIMATED ABSOLUTE MAXIMUM CONCENTRATIONS IN $\mu g/m^3$ FOR VARIOUS AVERAGING TIMES OF SULPHUR DIOXIDE IN 1979

	Averaging time			
	3 minute	30 minute	1 hour	1 day
Estimated absolute maximum concentration	2481	2227	2036	458

TABLE 5. ESTIMATED ABSOLUTE MAXIMUM CONCENTRATIONS IN $\mu g/m^3$ FOR VARIOUS AVERAGING TIMES IN SOME U.S. CITIES IN 1962-68

		Averaging Time					
		5 minute	1 hour	8 hour	1 day	1 month	1 year
City	Chicago	8561	4136	2251	1649	628	367
	Cincinnati	4398	1702	785	524	157	79
	Denver	1230	576	314	236	79	52
	Los Angeles	1230	576	314	236	79	52
	Philadephia	6990	3115	1597	1126	393	209
	St. Louis	6074	2461	1152	785	236	131
	San Francisco	1466	576	262	183	52	26
	Washington	2985	1466	812	602	236	131

TABLE 6. MEAN MONTHLY AND ANNUAL SULPHUR DIOXIDE CONCENTRATION IN $\mu g/m^3$ ASSOCIATED WITH VARIOUS WIND SPEEDS

Wind speed (Knots) / Month	< 1	1–3	4–6	7–10	11–16	17–21	⩾ 22	Mean
Jan	63	61	73	97	100	19	-	77
Feb	72	59	53	74	78	10	-	67
Mar	76	77	89	121	113	92	-	100
Apr	113	117	107	119	95	34	54	112
May	89	102	99	101	79	49	14	103
Jun	58	53	64	99	130	30	20	78
Jul	90	71	67	79	51	44	43	72
Aug	56	52	60	77	71	38	5	61
Sep	51	69	85	76	49	25	20	72
Oct	48	53	64	73	72	22	25	62
Nov	32	45	49	52	41	8	10	47
Dec	40	55	56	78	84	22	23	63
Annual	64	64	70	89	87	36	16	76

TABLE 7(a) PERCENTAGE FREQUENCY OF OCCURRENCE OF THE HIGHEST 1% OF THE 3-MINUTE SULPHUR DIOXIDE CONCENTRATIONS AT DIFFERENT TIMES (1979)

Time \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0000-0059								0.1					0.1
0100-0159								0.1					0.1
0200-0259								0.6					0.6
0300-0359			0.4	0.1									0.5
0400-0459													
0500-0559													
0600-0659													
0700-0759				0.1	0.6				0.4		0.1		1.1
0800-0859		0.8			0.1	1.1	0.6	0.1	0.5		0.1		3.2
0900-0959	0.8	1.3	0.6	0.4	1.8	0.7	1.0	0.4	1.5	0.1			8.6
1000-1059	1.7	1.3	1.9	0.4	3.1	1.2	1.2		1.6			0.1	12.4
1100-1159	2.4	1.4	2.7	2.7	2.2	0.6	0.3	0.4	0.4	0.2	0.1	0.4	13.9
1200-1259	1.6		1.3	1.7	0.1		0.3	0.5	0.3	0.1	0.8		6.6
1300-1359	1.4		0.3	0.2	1.4	1.2	1.0	0.4	1.1		0.2		7.2
1400-1459	0.3		1.2	0.6	1.6	1.2	0.4	0.3	1.1		1.3		8.0
1500-1559			0.9	0.8	0.6	1.8	0.3		1.1		2.1		7.3
1600-1659		0.6	1.0	0.9	0.9	0.6	0.3	0.1	2.3	0.3		0.9	7.7
1700-1759	1.9	0.5	0.9	0.4	0.4		0.2	0.4	0.5				5.2
1800-1859	2.0	1.1	1.2	0.8	1.2		0.2	0.1				0.1	6.7
1900-1959	1.0	1.6	0.8	0.6	0.9		1.2	0.3				0.2	6.5
2000-2059	0.6	0.4	1.1				1.0						3.1
2100-2159			0.1				0.6	0.3					0.9
2200-2259	0.2						0.2	0.1					0.5
2300-2359							0.1						0.1
Total	13.9	9.0	14.4	9.6	14.7	8.4	8.5	4.0	10.7	0.6	4.6	1.6	100.0

TABLE 7(b) PERCENTAGE FREQUENCY OF OCCURRENCE OF THE HIGHEST 1% OF THE 3-MINUTE SULPHUR DIOXIDE CONCENTRATIONS IN 1979 WITH DIFFERENT WIND DIRECTIONS

Wind direction (degrees) \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
350-010			0.8	0.1	0.1		0.1		0.1				1.1
020-040					0.5		0.1	0.1	0.3	0.1			0.9
050-070	0.1		0.1	0.1	0.2			0.1	0.4		0.1		0.9
080-100	7.4	5.0	11.6	6.4	10.4	6.0	3.5	1.4	2.4			0.1	54.1
110-130	1.7	1.9	0.9	1.2	2.6	1.9	0.9	1.2	1.5	0.4	0.1	1.6	15.9
140-160	0.1			0.1	0.3	0.1	1.7						2.4
170-190				0.1	0.1	0.1	1.1						1.3
200-220	0.6				0.1		0.3	0.1	0.1		0.1		1.3
230-250	2.0	0.1	0.6	0.3		0.1	0.3	0.2	1.6	0.1	1.6		6.8
260-280	2.1	1.9	0.5	1.3	0.4	0.3	0.6	0.9	4.2		2.5		14.6
290-310				0.1				0.1	0.2		0.3		0.6
320-340								0.1	0.1				0.1
Total	13.9	9.0	14.4	9.6	14.7	8.4	8.5	4.0	10.7	0.6	4.6	1.6	100.0

TABLE 7(c) PERCENTAGE FREQUENCY OF OCCURRENCE OF THE HIGHEST 1% OF THE 3-MINUTE SULPHUR DIOXIDE CONCENTRATIONS IN 1979 WITH DIFFERENT WIND SPEEDS

Wind Speed knots \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Calm	1.4	2.1	0.3	0.5	0.5		0.4	0.7	0.2				6.0
1-3	2.6	2.2	0.5	3.0	3.2	0.3	2.0	0.5	3.5		1.4	0.1	19.4
4-6	4.7	3.1	3.9	2.4	7.8	1.4	3.1	1.8	5.0	0.4	2.6	0.2	36.3
7-10	4.4	1.2	5.9	3.6	2.9	5.4	3.1	0.8	2.1	0.1	0.6	1.3	31.3
11-16	0.8	0.3	3.7	0.1	0.3	1.2		0.3		0.1	0.1		6.8
17-21			0.1										0.1
⩾ 22													
Total	13.9	9.0	14.4	9.6	14.7	8.4	8.5	4.0	10.7	0.6	4.6	1.6	100.0

TABLE 8. CORRELATION COEFFICIENTS OF DAILY SULPHUR DIOXIDE CONCENTRATION WITH VARIOUS SURFACE METEOROLOGICAL PARAMETERS

Meteorological parameter	Correlation coefficient (r)	Level of significance (P) for n = 365
Relative Humidity	0.27	0.001
Atmospheric Pressure	-0.12	0.05
Cloud Amount	0.07	NS
Rainfall Amount	-0.07	NS
Air Temperature	0.06	NS

TABLE 9. CORRELATION COEFFICIENTS OF DAILY SULPHUR DIOXIDE CONCENTRATION WITH LAPSE RATES OF VARIOUS THICKNESSES IN 1979

Thickness between	Time(s) of ascent	Correlation coefficient(r)	Level of Significance(P)	Number of cases
(Surface-1000 mb)	0800	-0.23	0.001	312
(Surface- 950 mb)	0800	-0.15	0.010	365
(Surface-1000 mb)*	0800 and 2000	-0.29	0.001	293
(Surface- 950 mb)*	0800 and 2000	-0.27	0.001	365
(Surface-1000 mb)	2000	-0.28	0.001	294
(Surface- 950 mb)	2000	-0.27	0.001	365

* Average of lapse rate from two ascents

TABLE 10. NUMBER OF DAYS WITH INVERSIONS BELOW 950 mbar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
No. of days with inversions	13	9	16	14	10	4	2	2	5	3	7	15	100

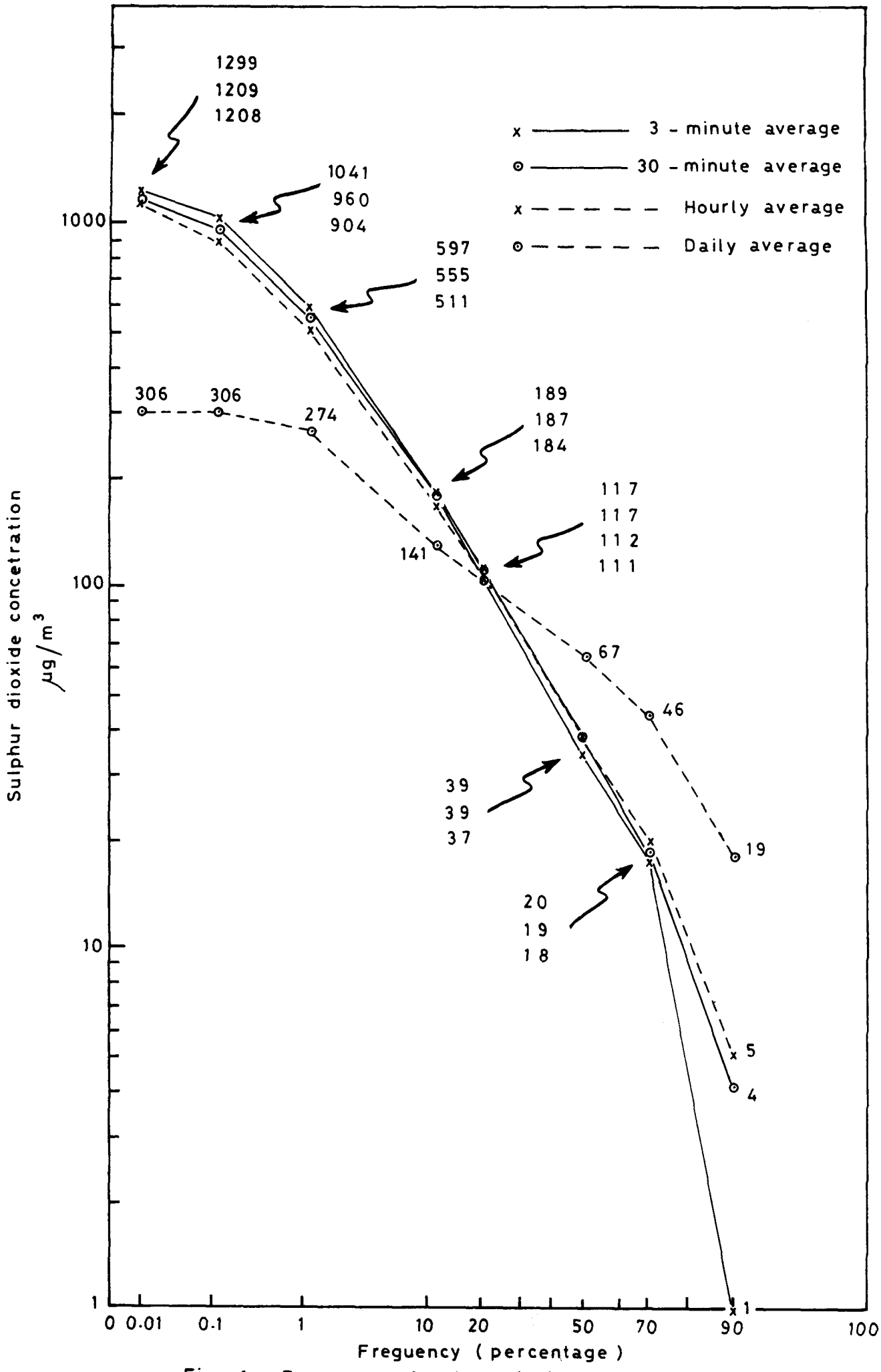

Fig. 1. Frequency of sulpur dioxide concentration equal to or exceeding specified values in 1979

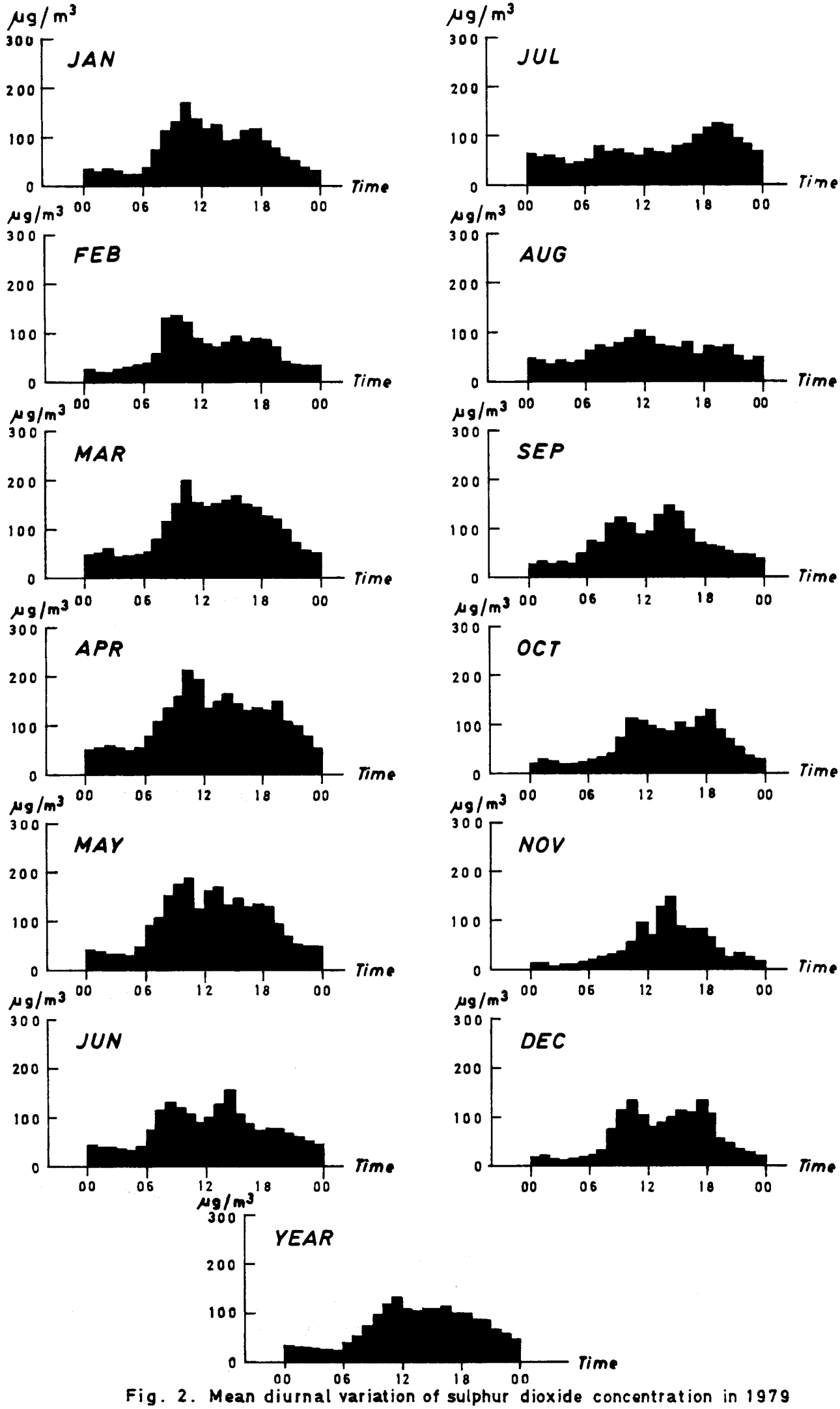

Fig. 2. Mean diurnal variation of sulphur dioxide concentration in 1979

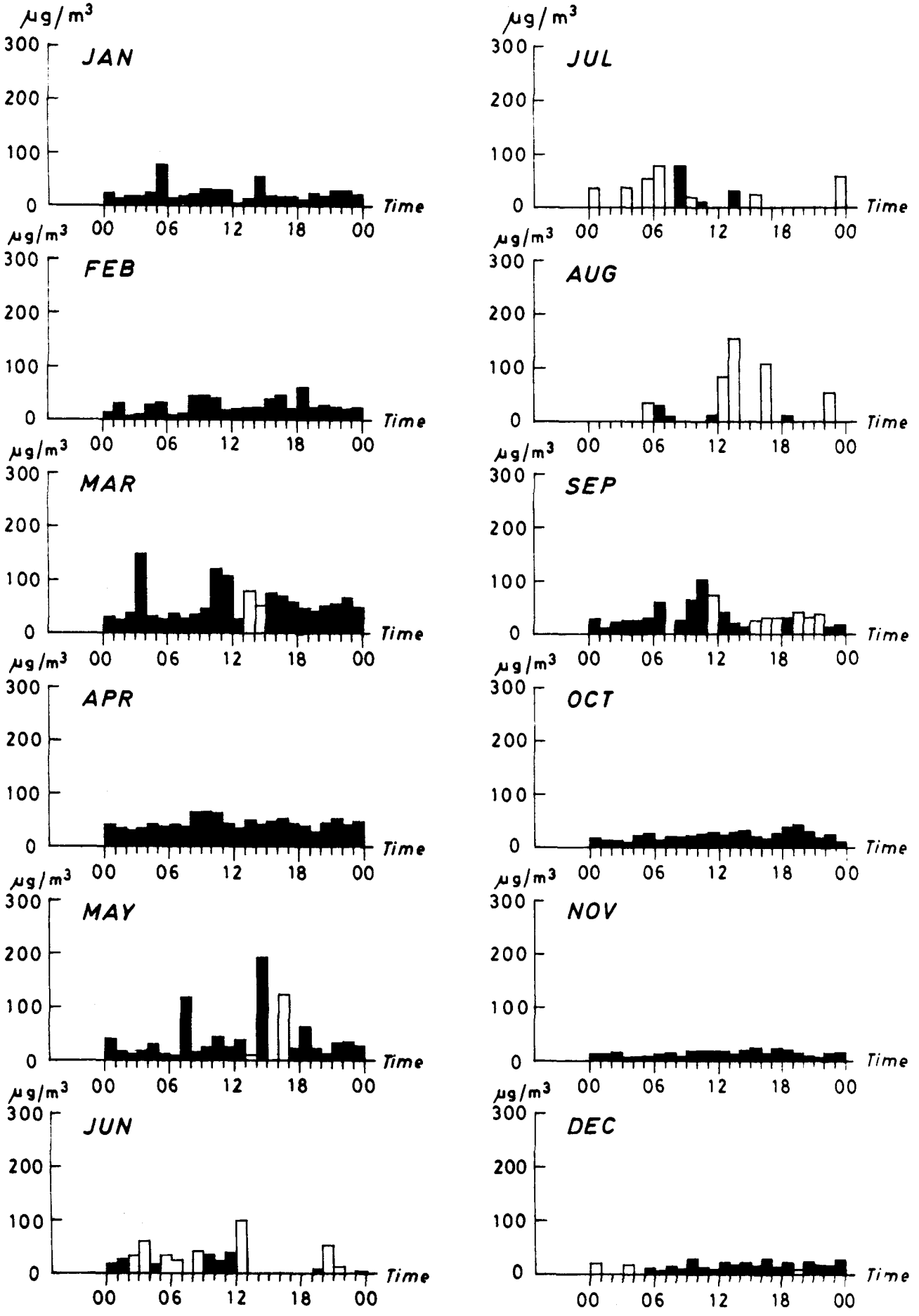

Fig. 3(a). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 350°– 010° (1979)

(Winds blew from this direction 4.1% of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

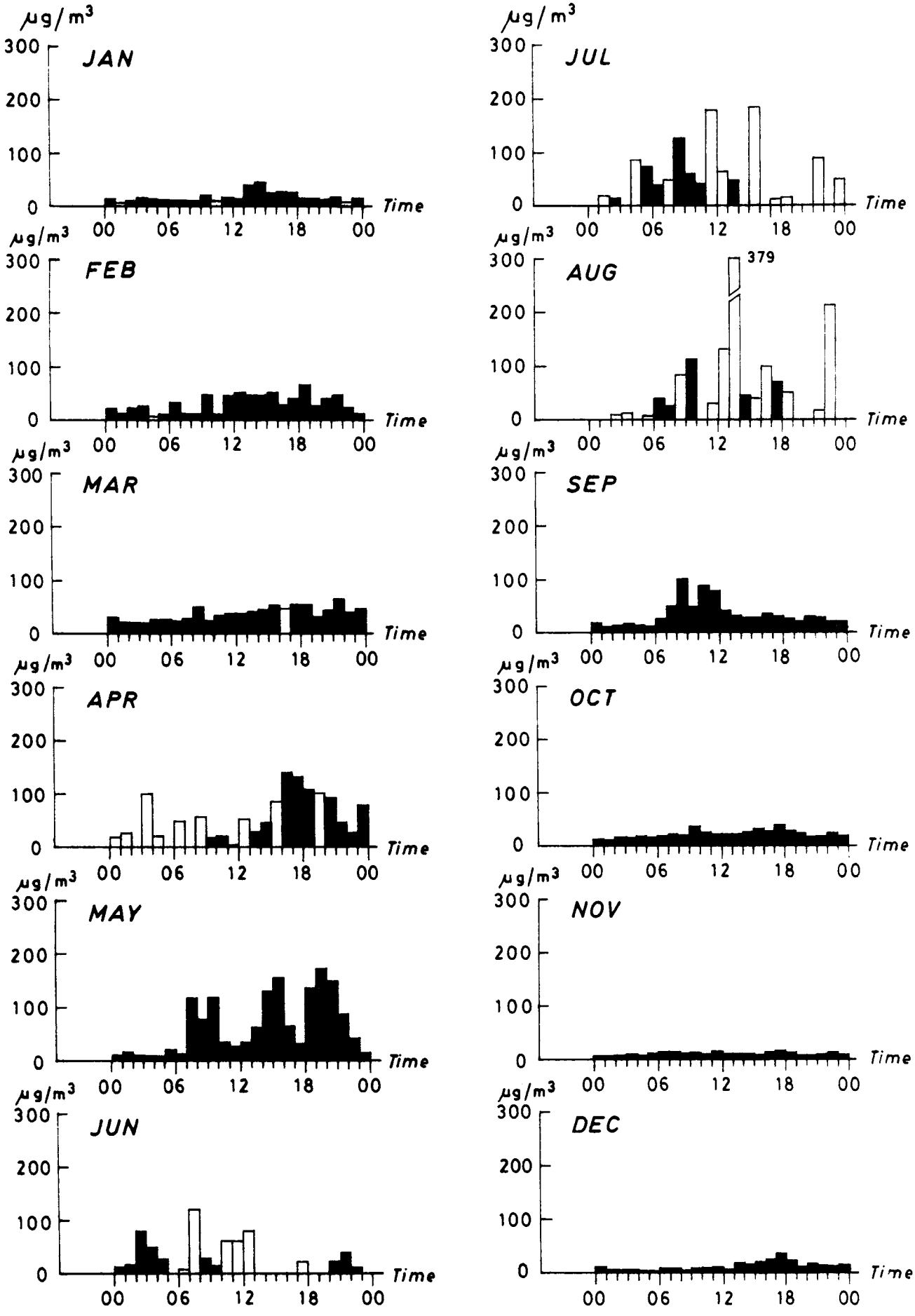

Fig. 3 (b). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 020°– 040° (1979)

(Winds blew from this direction 7.1 % of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

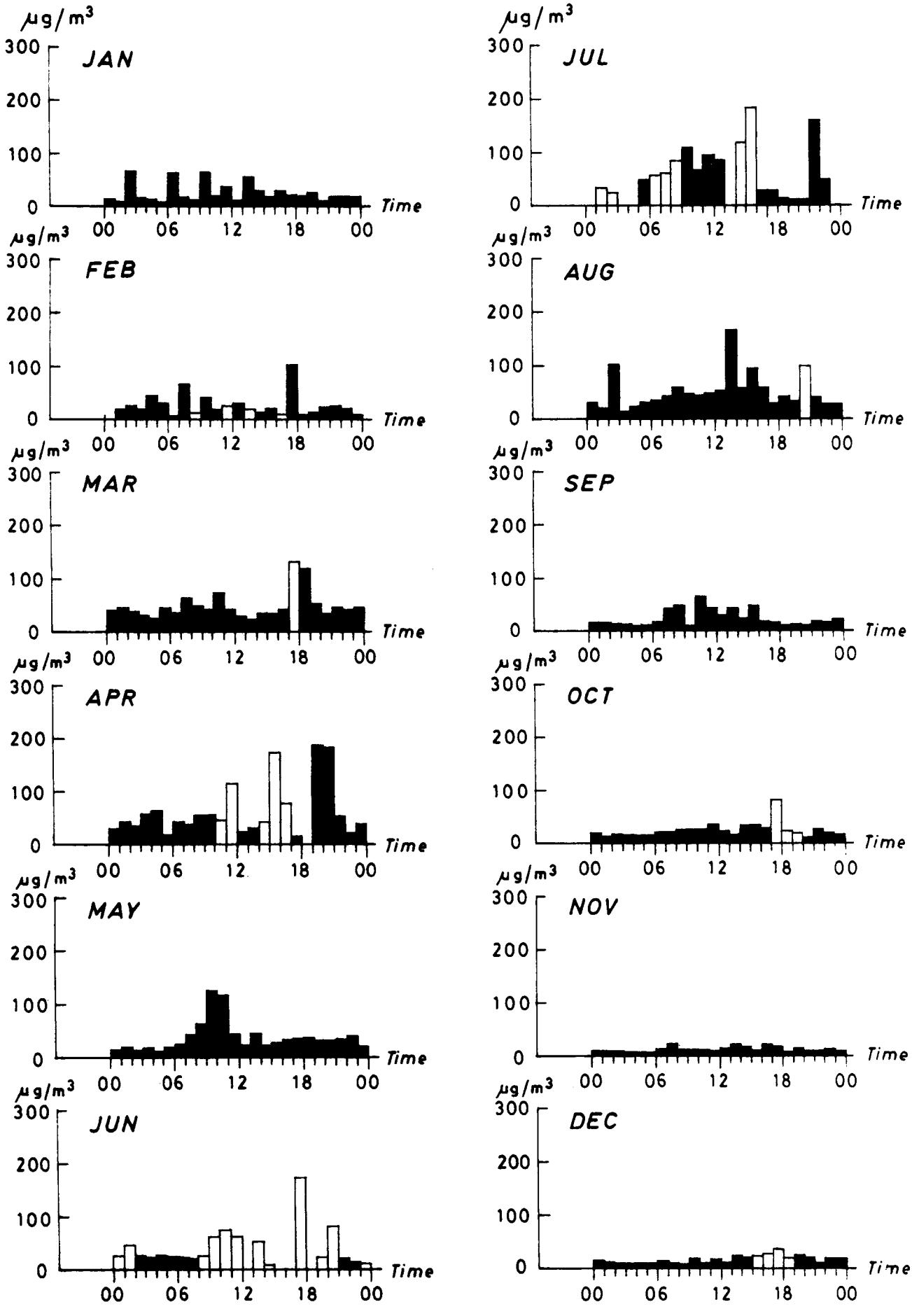

Fig. 3 (c). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 050° – 070° (1979)

(Winds blew from this direction 5.0 % of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

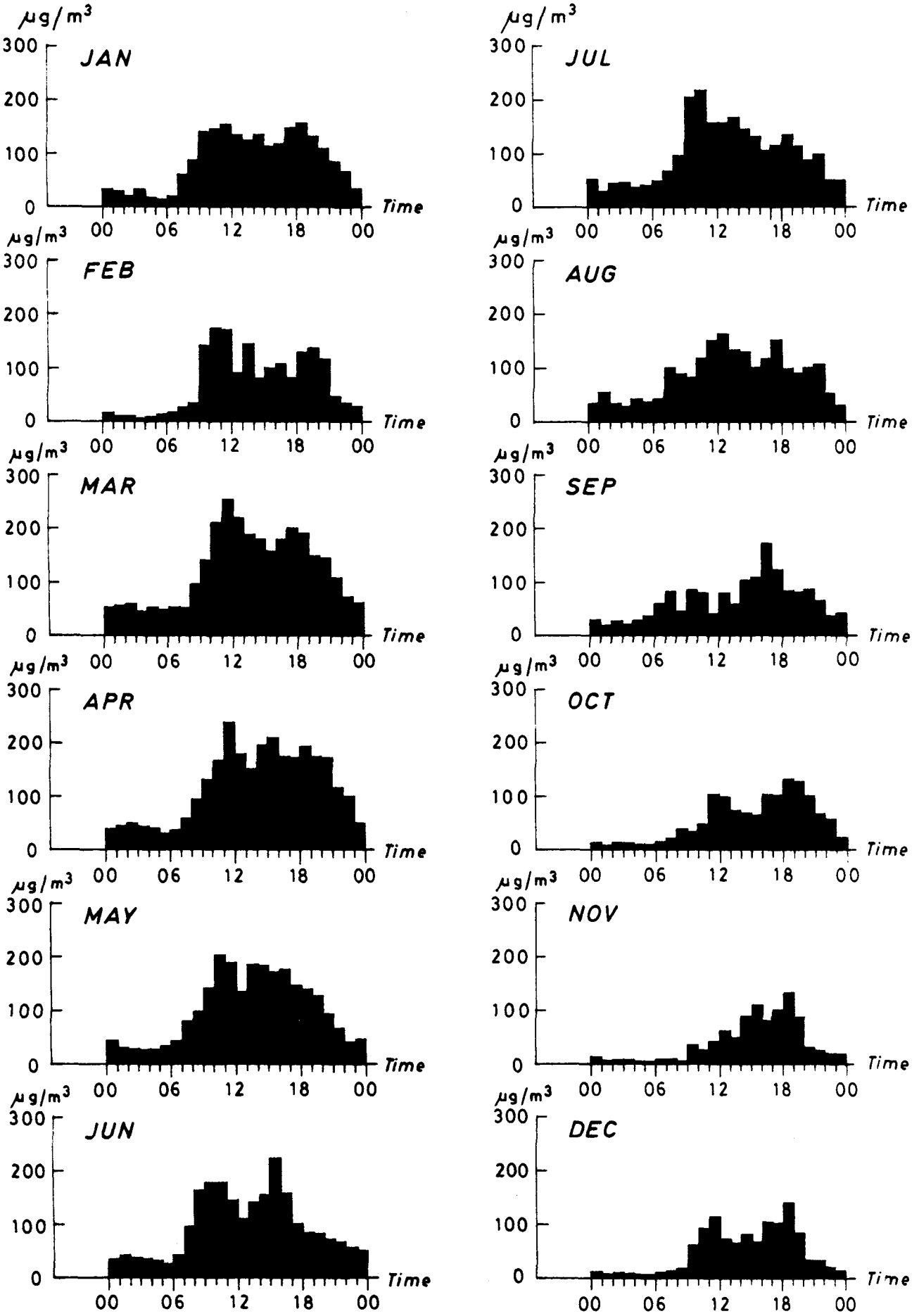

Fig. 3 (d). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 080°– 100° (1979)
(Winds blew from this direction 33.4 % of the time during the year)

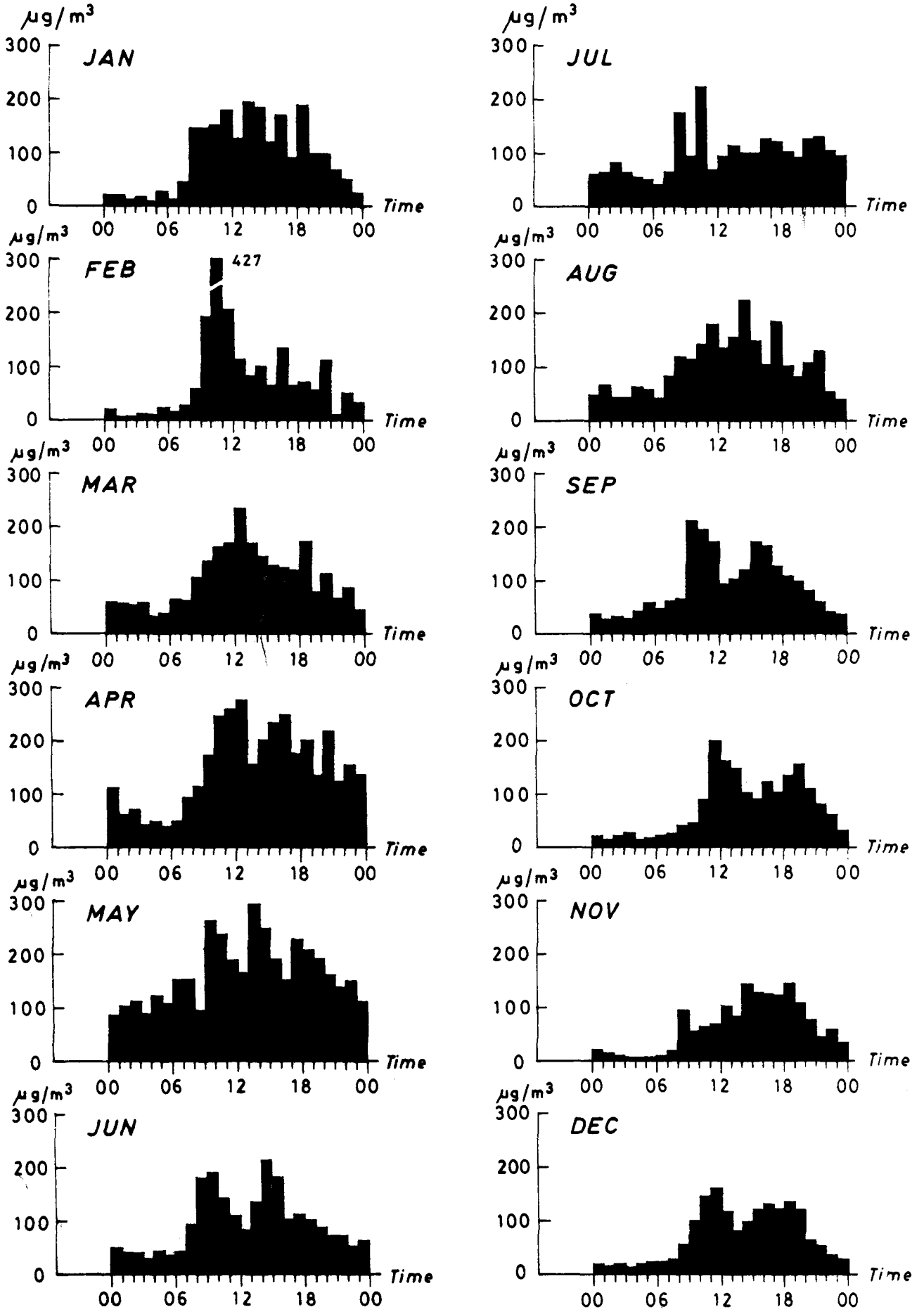

Fig. 3 (e). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 110° – 130° (1979)
(Winds blew from this direction 15.9 % of the time during the year)

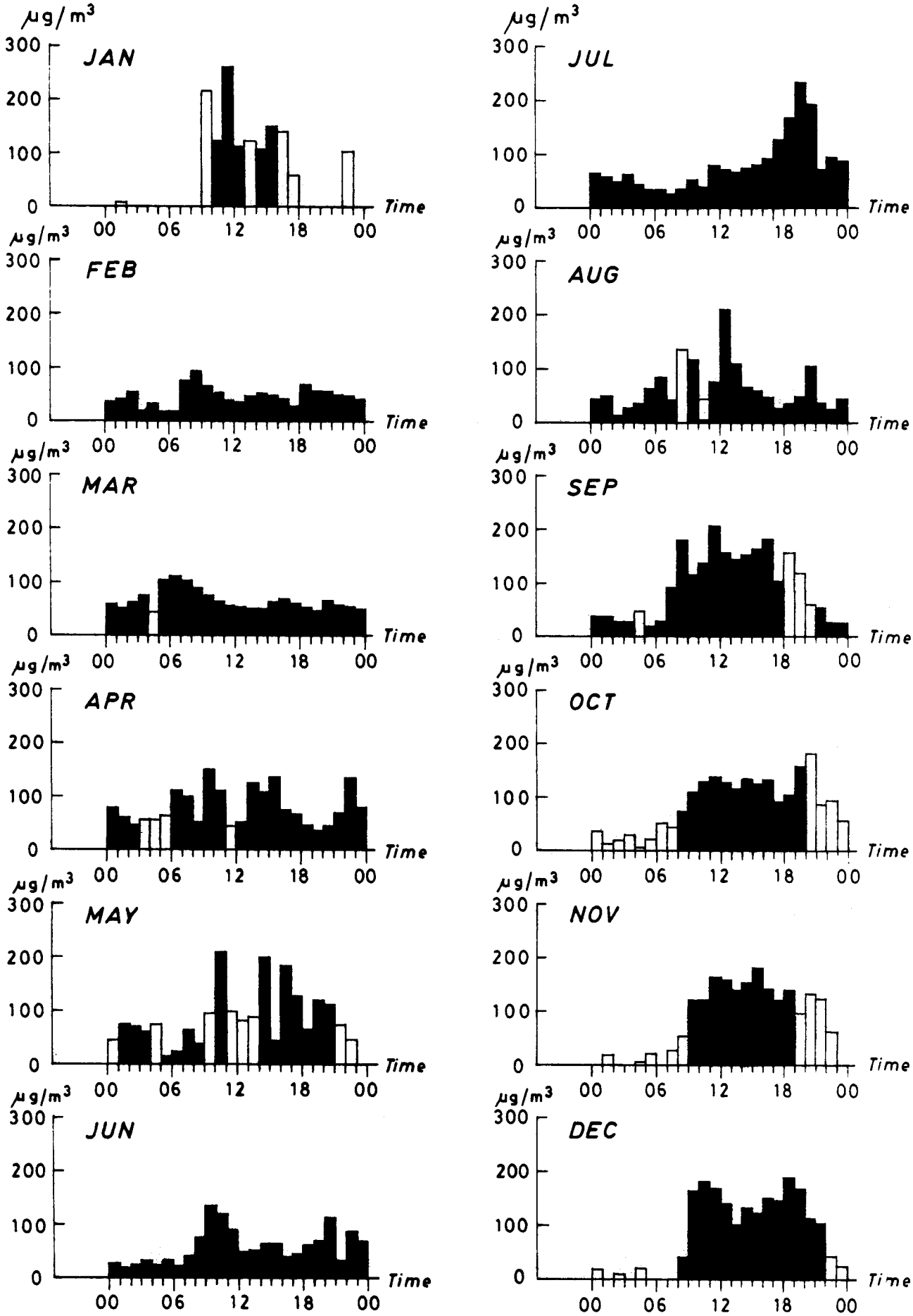

Fig. 3 (f). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 140°– 160° (1979)

(Winds blew from this direction 5.1 % of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

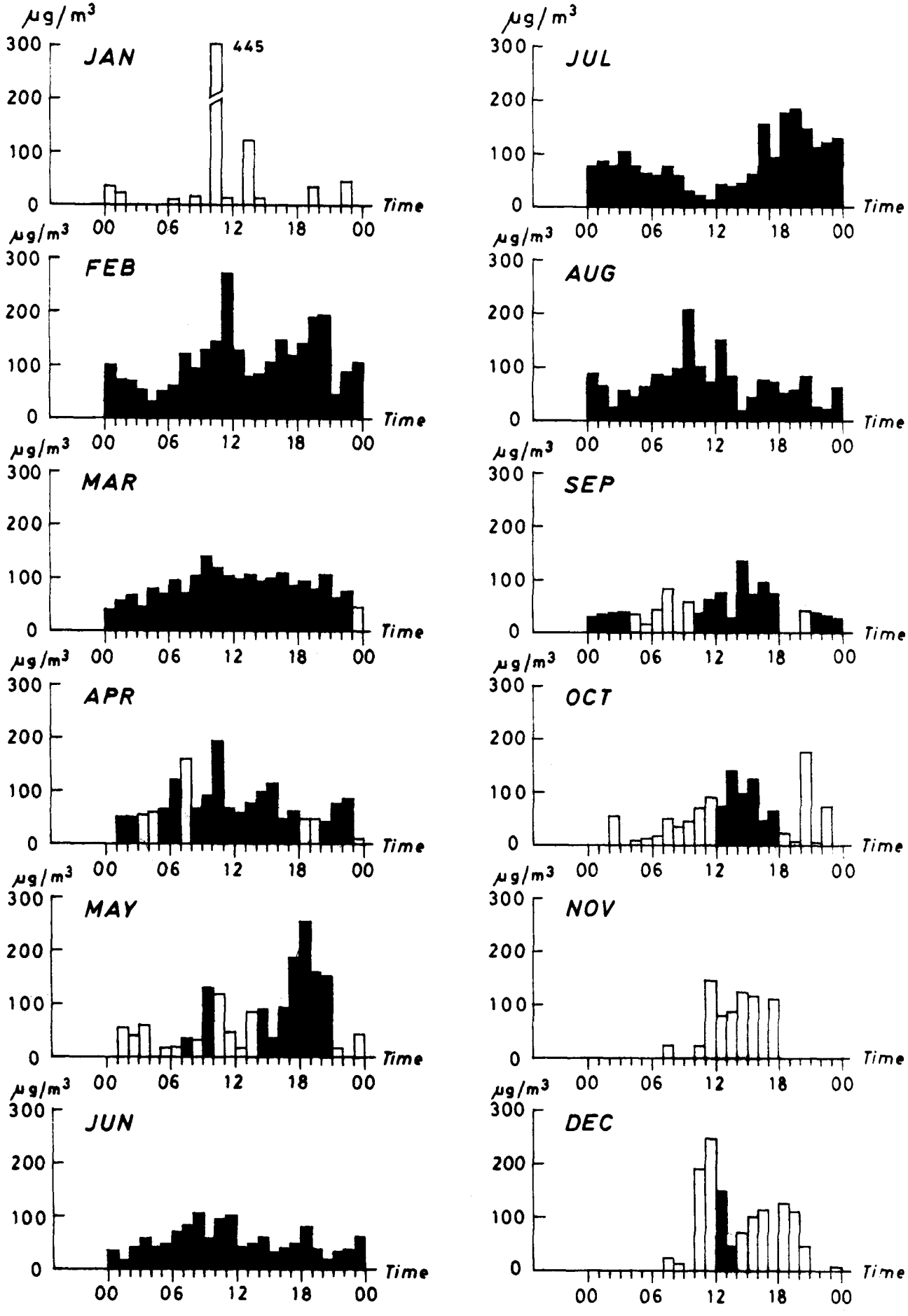

Fig. 3(g). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 170° – 190° (1979)

(Winds blew from this direction 2.7% of the time during the year)

Note: The white entries denote means obtained from 5 or fewer observations

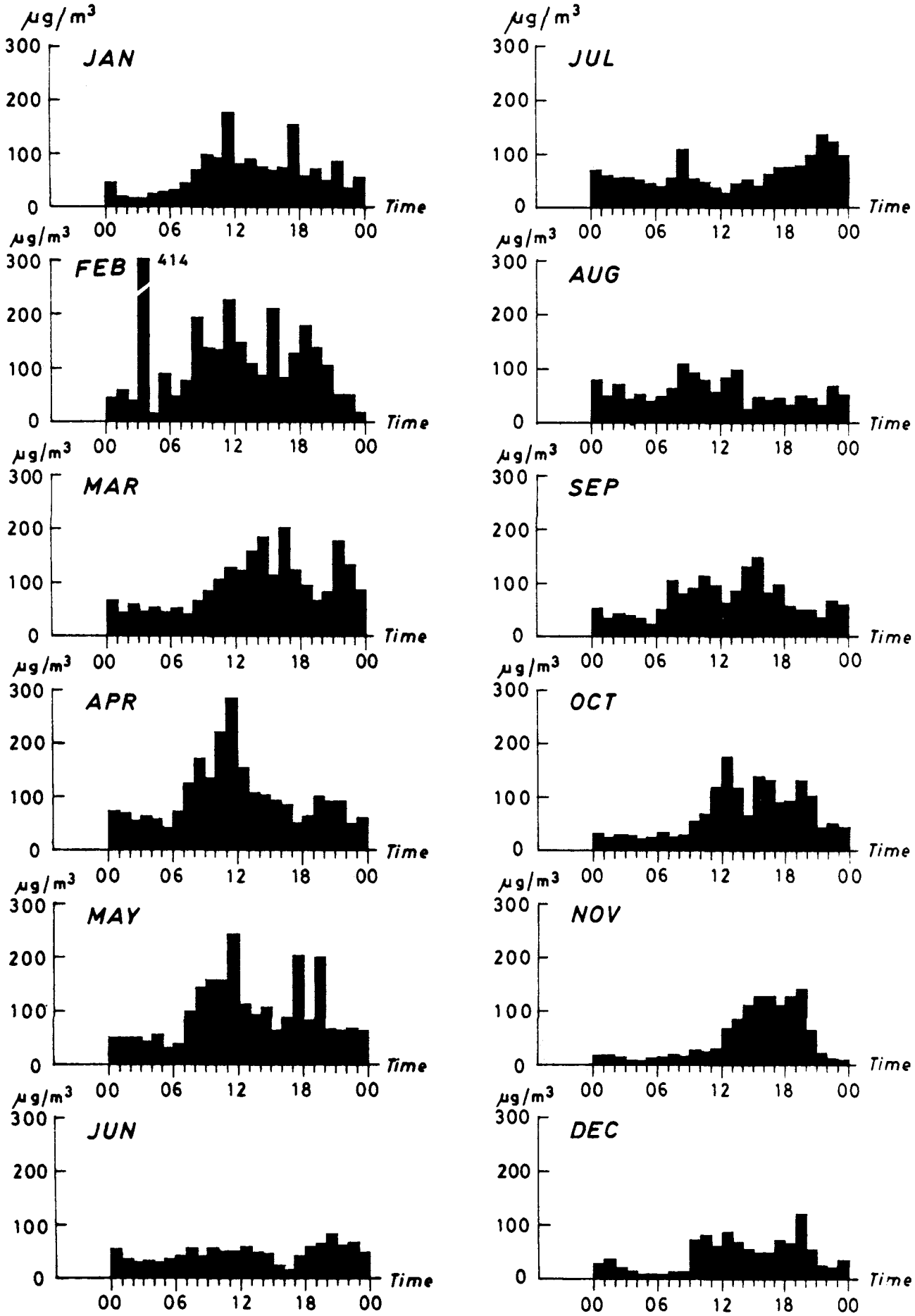

Fig. 3 (h). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 200° – 220° (1979)
(Winds blew from this direction 2.8 % of the time during the year)

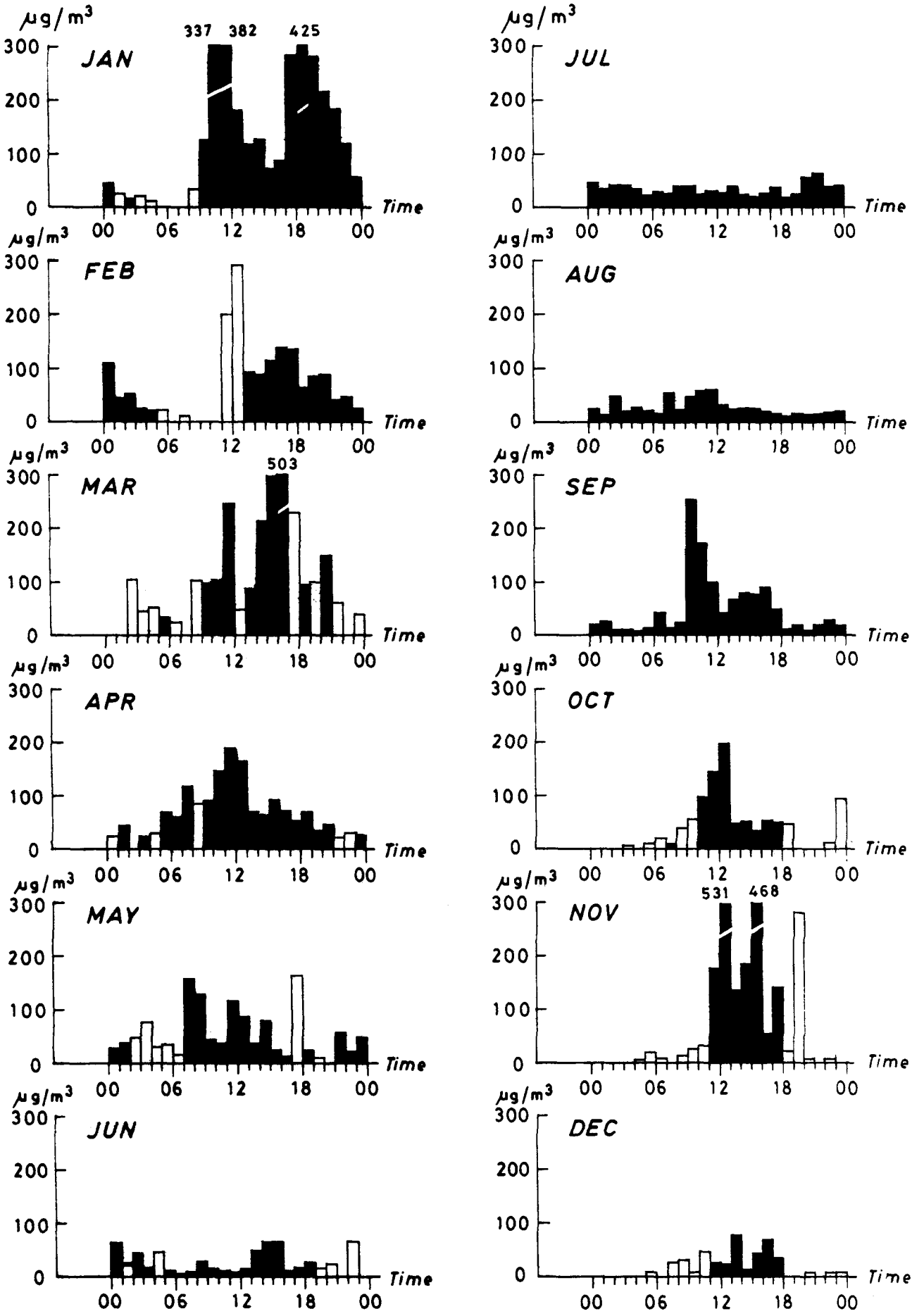

Fig. 3 (i). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 230° – 250° (1979)

(Winds blew from this direction 5.7% of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

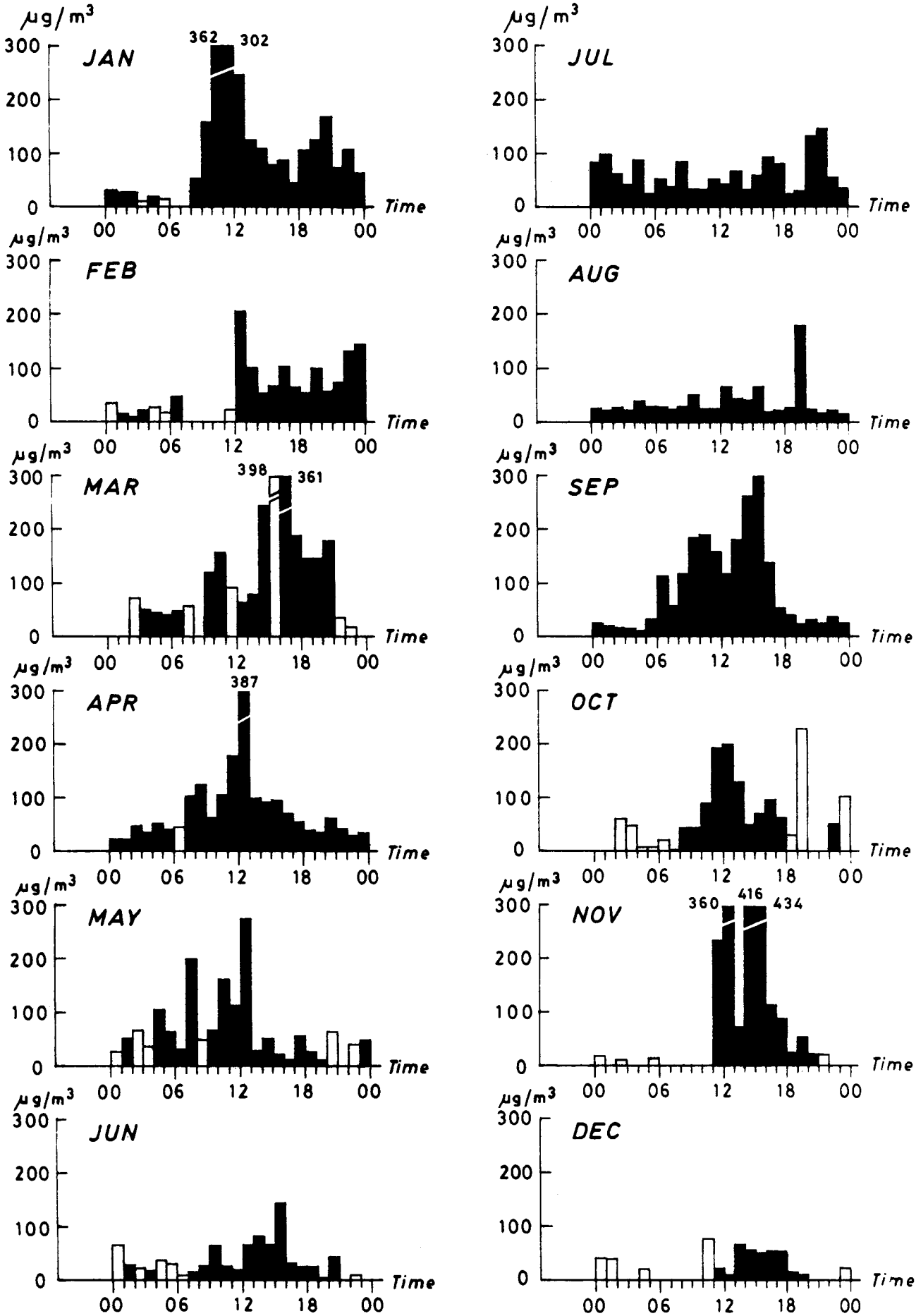

Fig. 3 (j). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 260°– 280° (1979)

(Winds blew from this direction 5·4 % of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

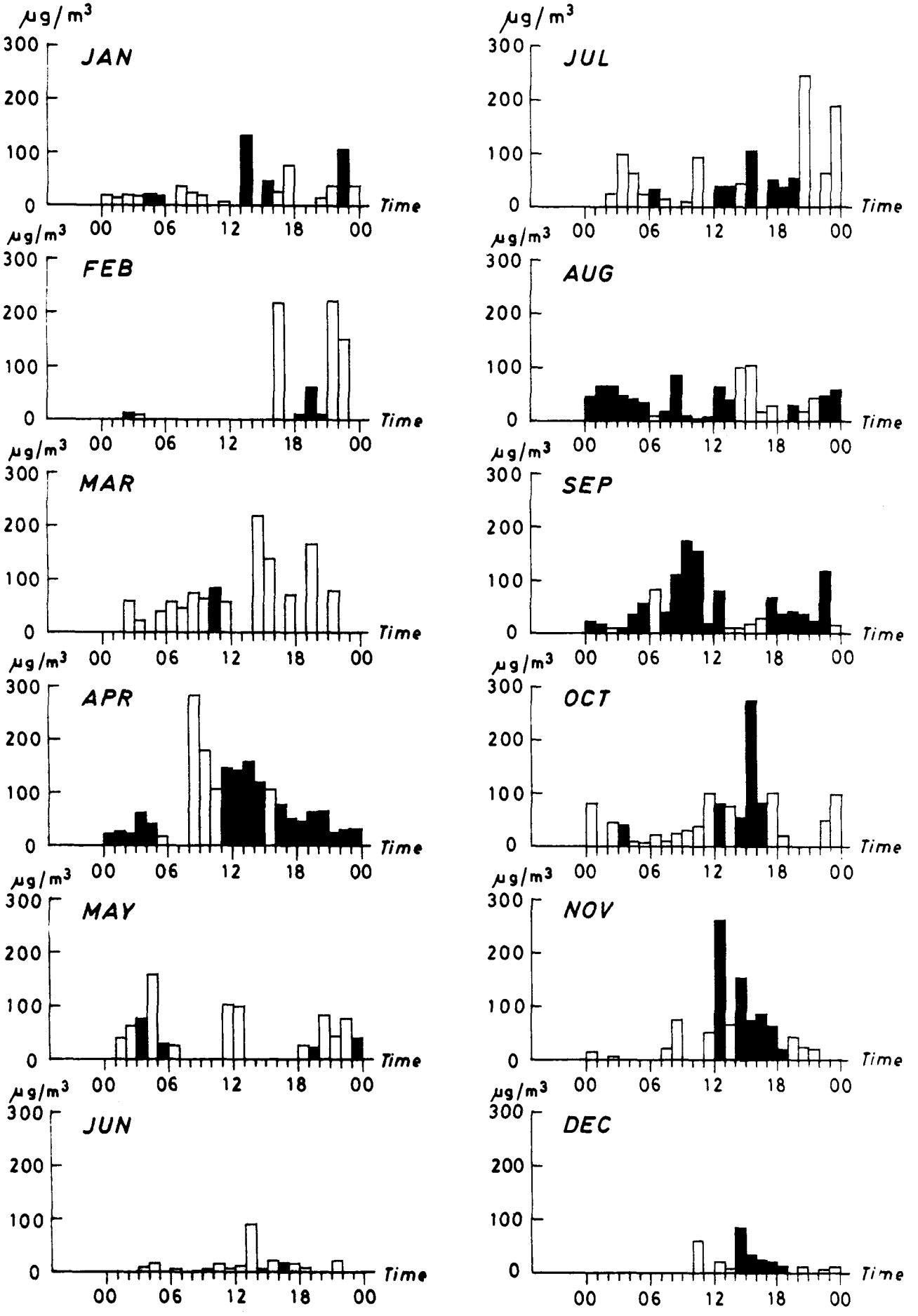

Fig. 3 (k). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 290° – 310° (1979)

(Winds blew from this direction 1·1 % of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

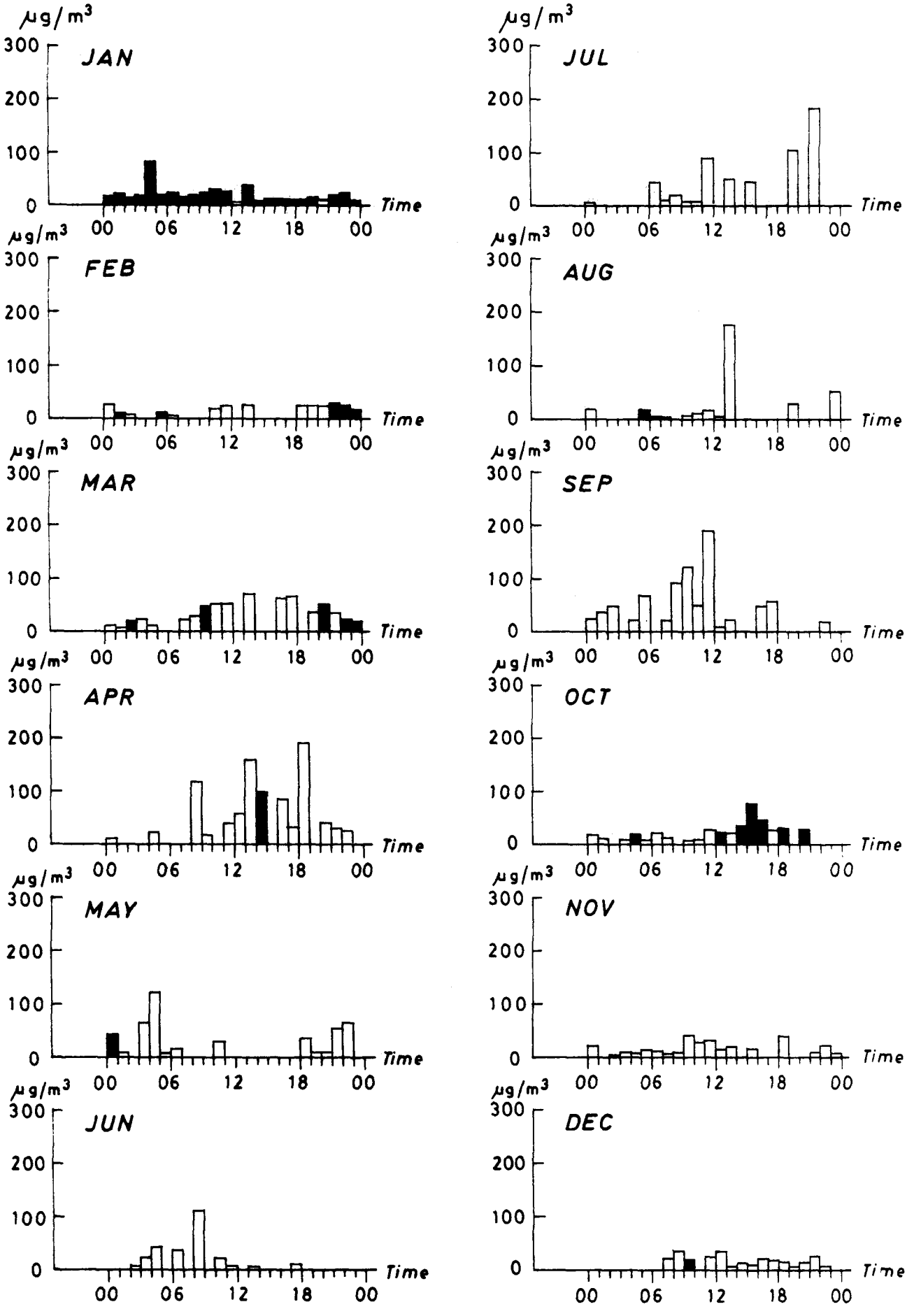

Fig. 3(I). Mean monthly diurnal variation of sulphur dioxide concentration with winds from 320°–340° (1979)

(Winds blew from this direction 0.6% of the time during the year)

Note: The white entries denote means obtained from 5 or fewer observations

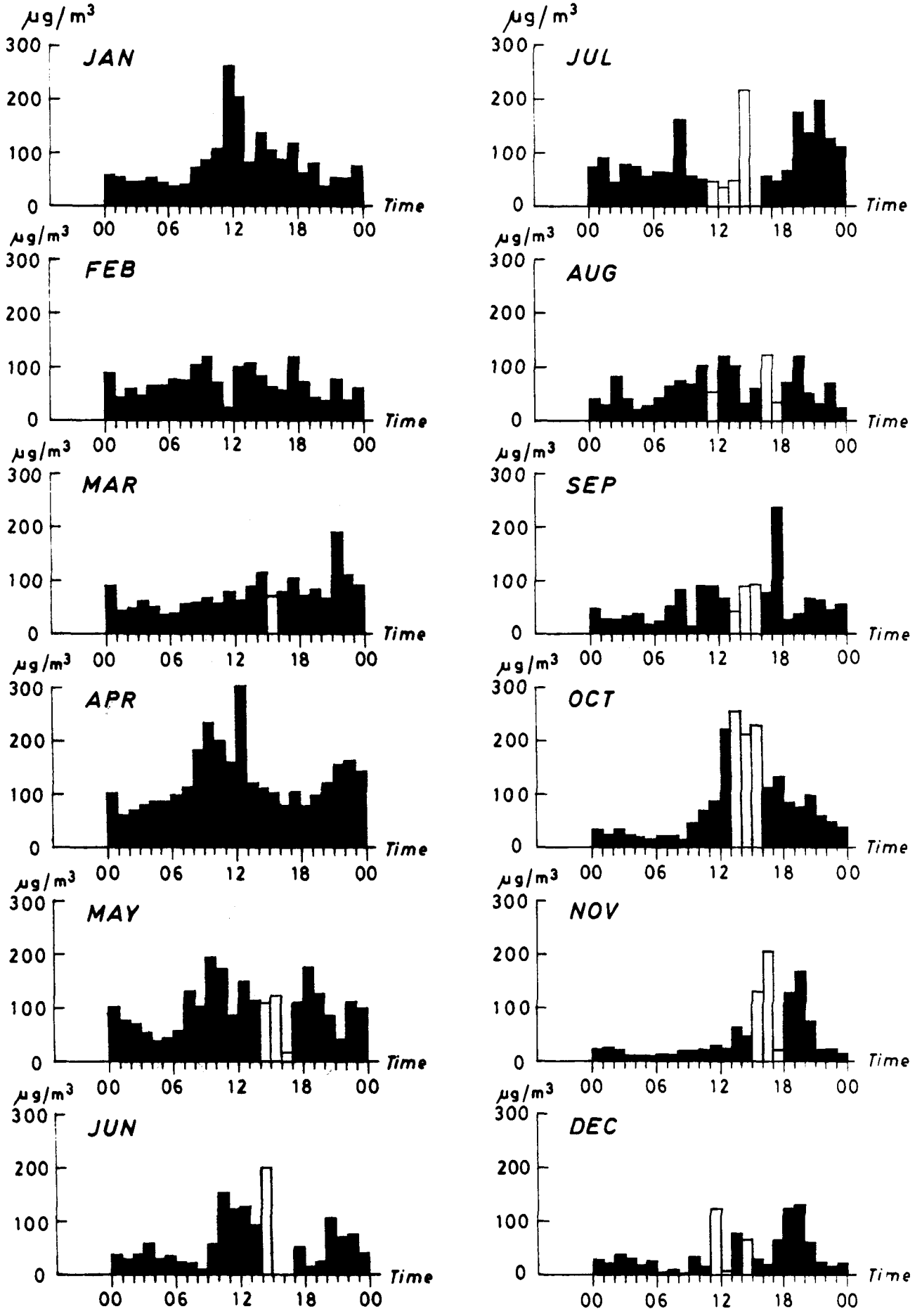

Fig. 3(m). Mean monthly diurnal variation of sulphur dioxide concentration with calm winds (1979)

(This occurred 11.1% of the time during the year)

Note : The white entries denote means obtained from 5 or fewer observations

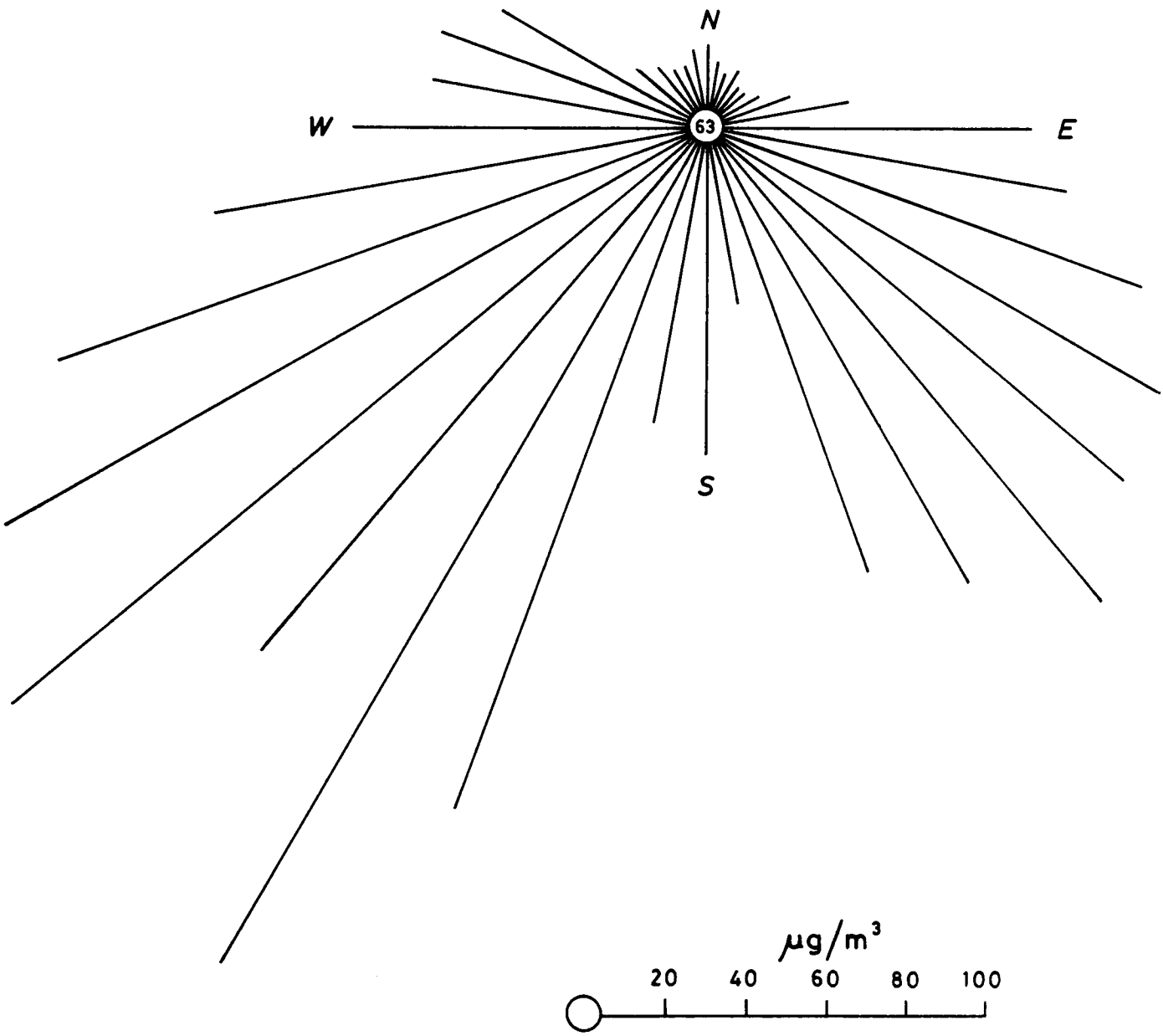

Fig. 4(a). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in January 1979.

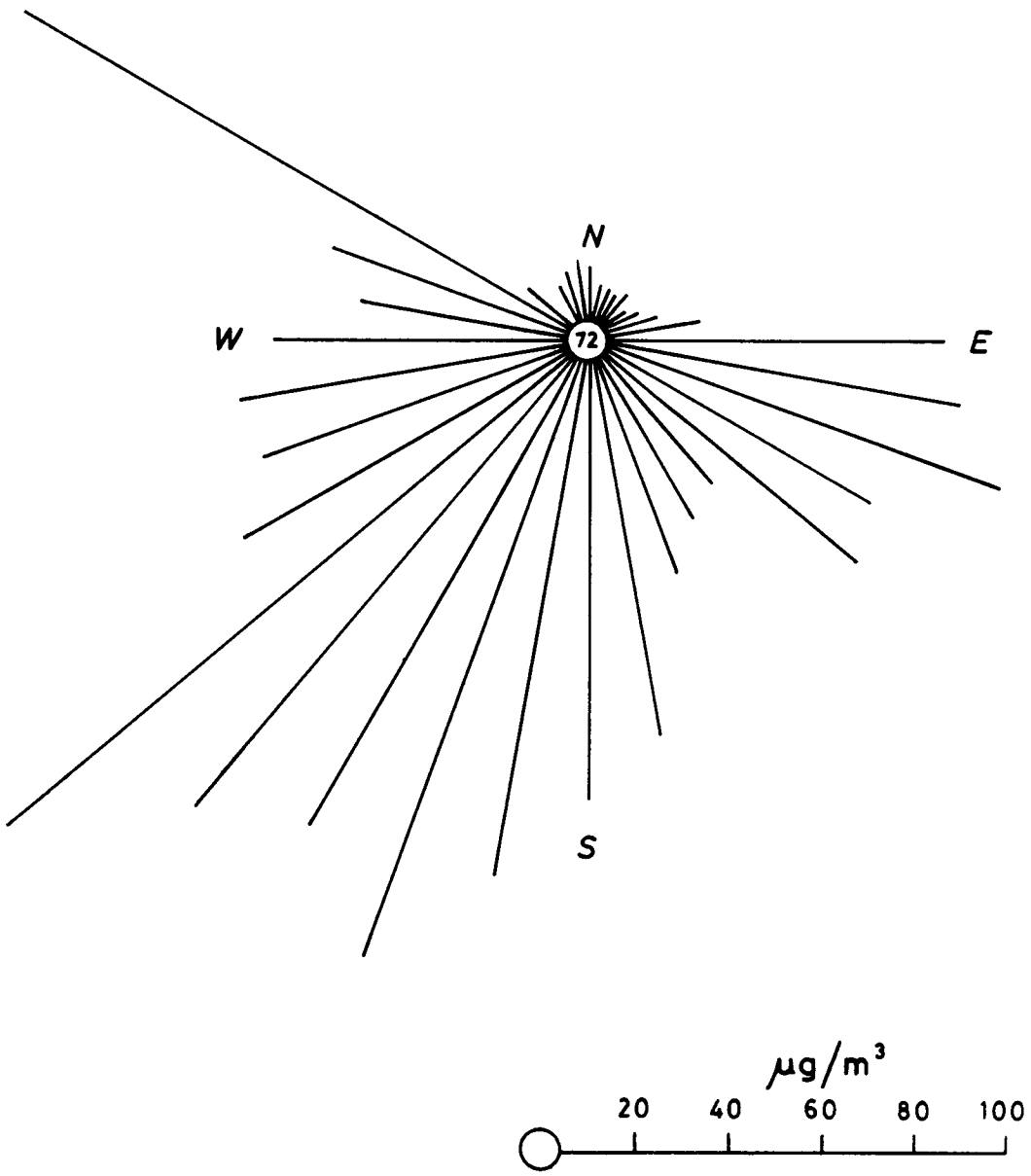

Fig. 4(b). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in February 1979.

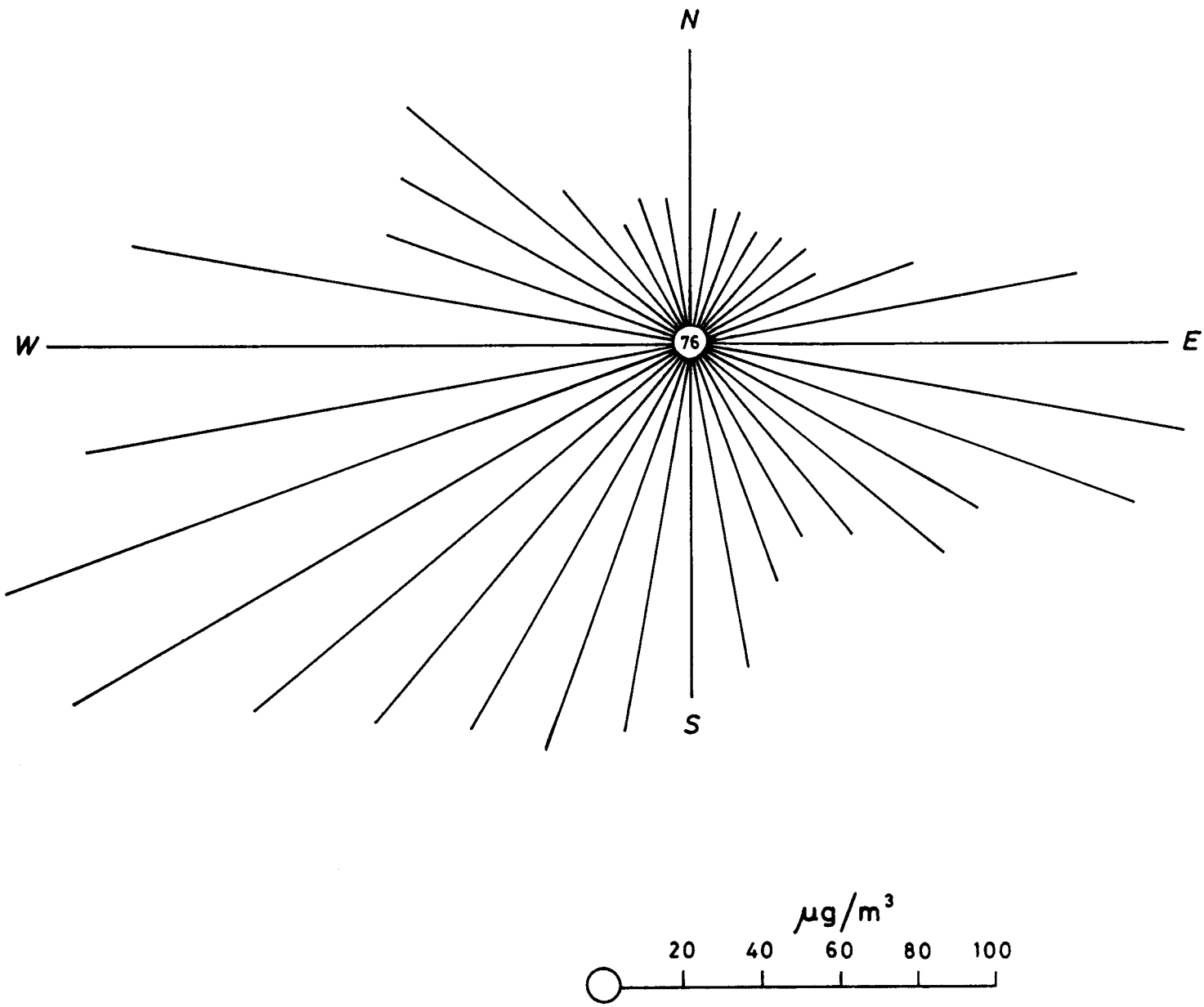

Fig. 4(c). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in March 1979.

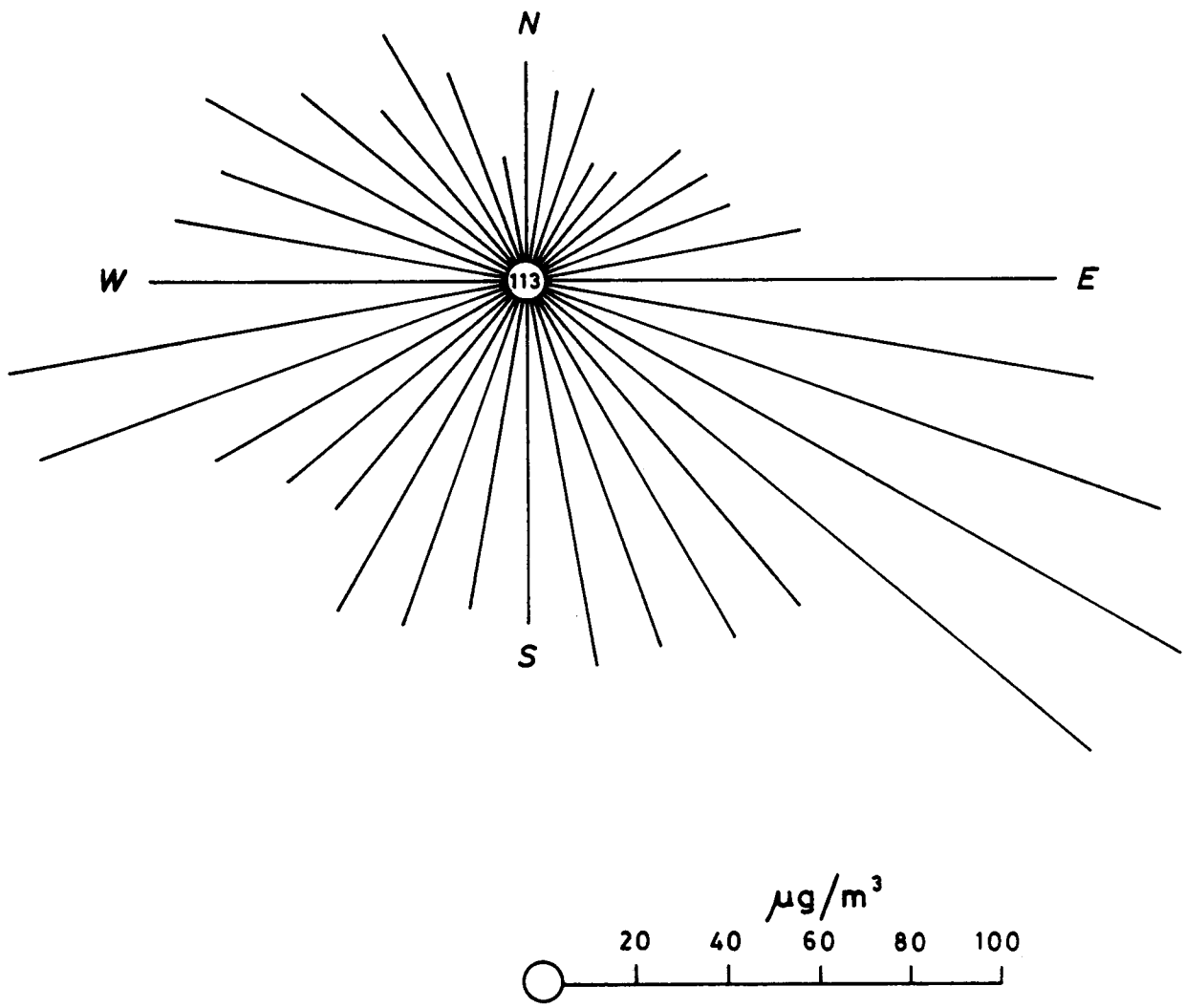

Fig. 4(d). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in April 1979.

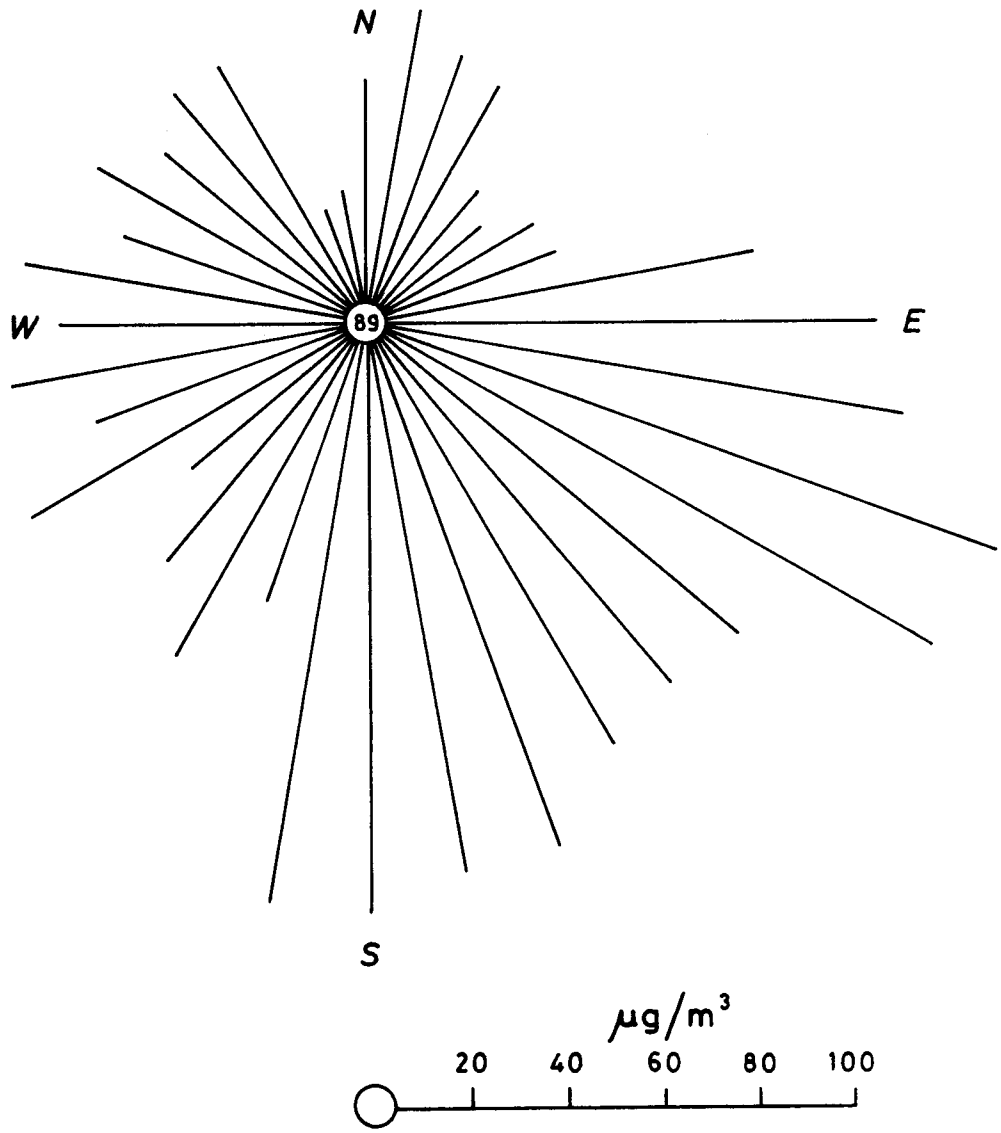

Fig. 4(e). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in May 1979.

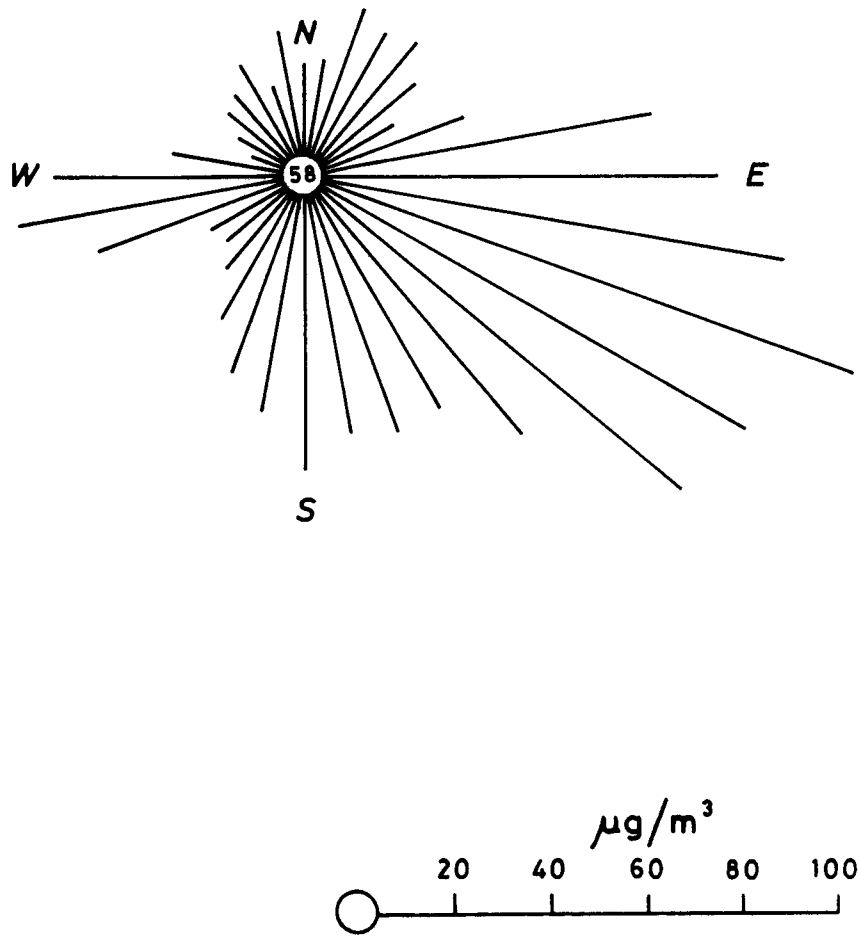

Fig. 4(f). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in June 1979.

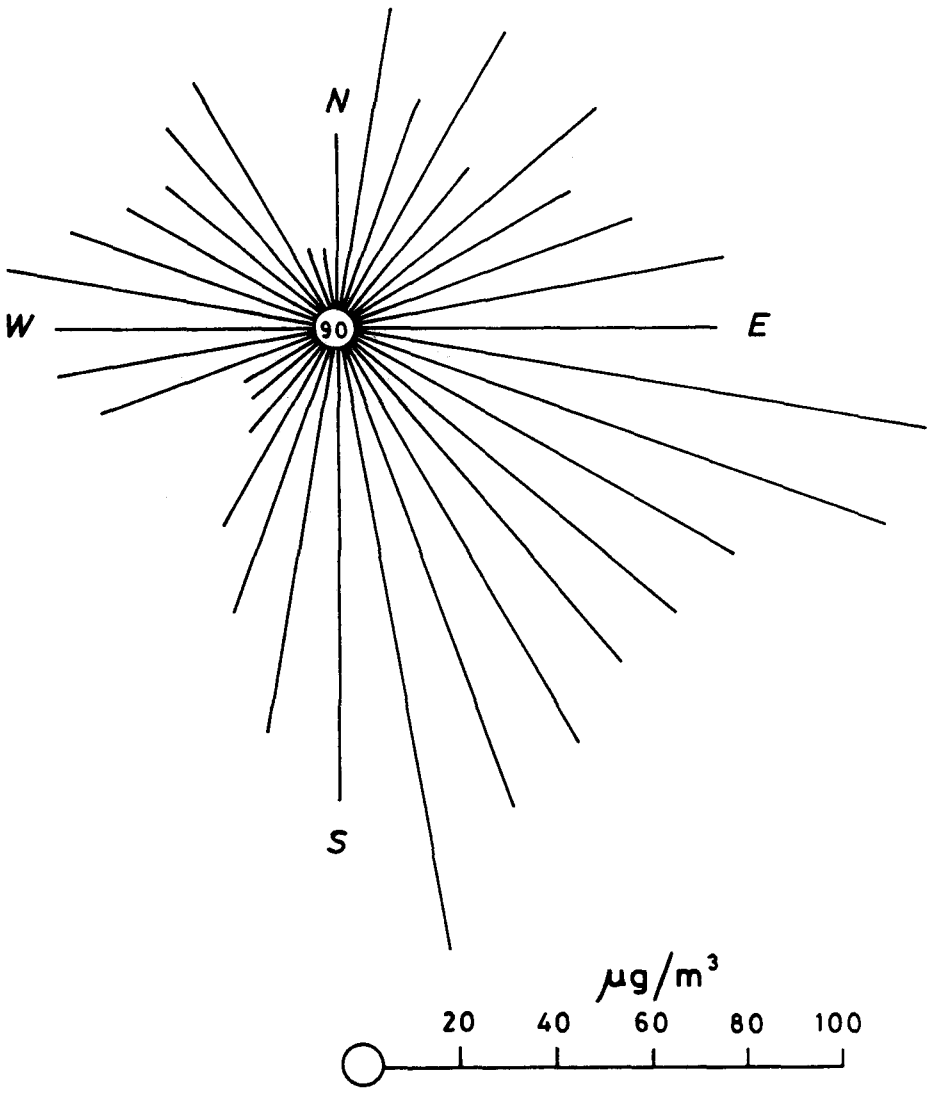

Fig. 4(g). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in July 1979.

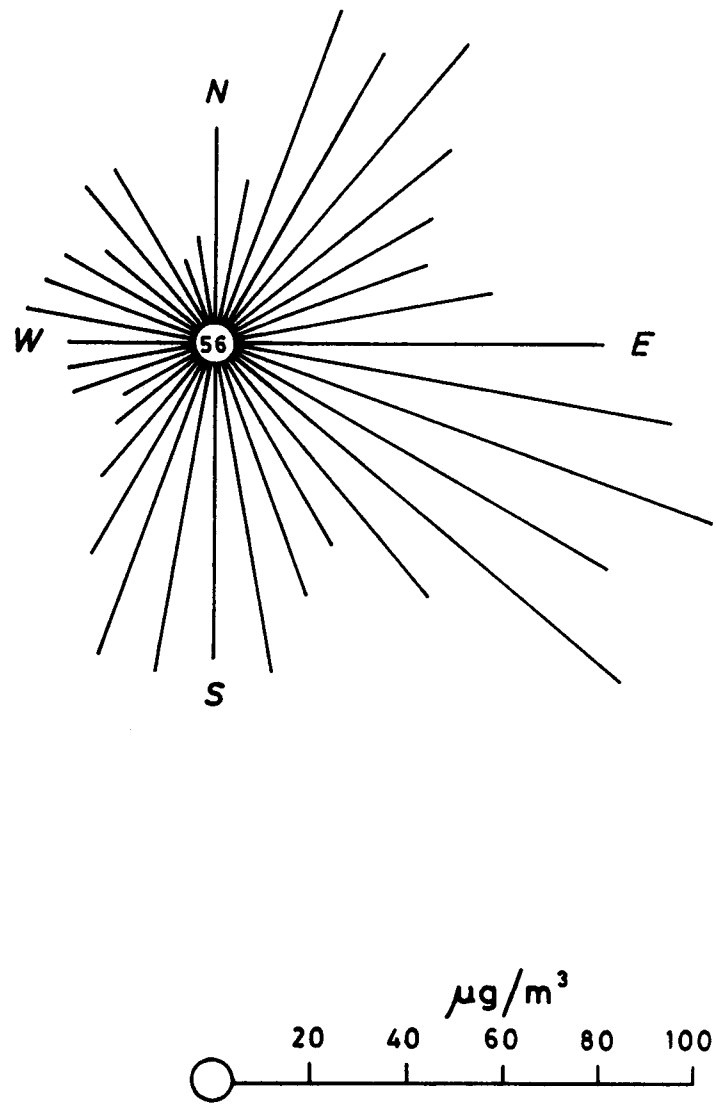

Fig. 4(h). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in August 1979.

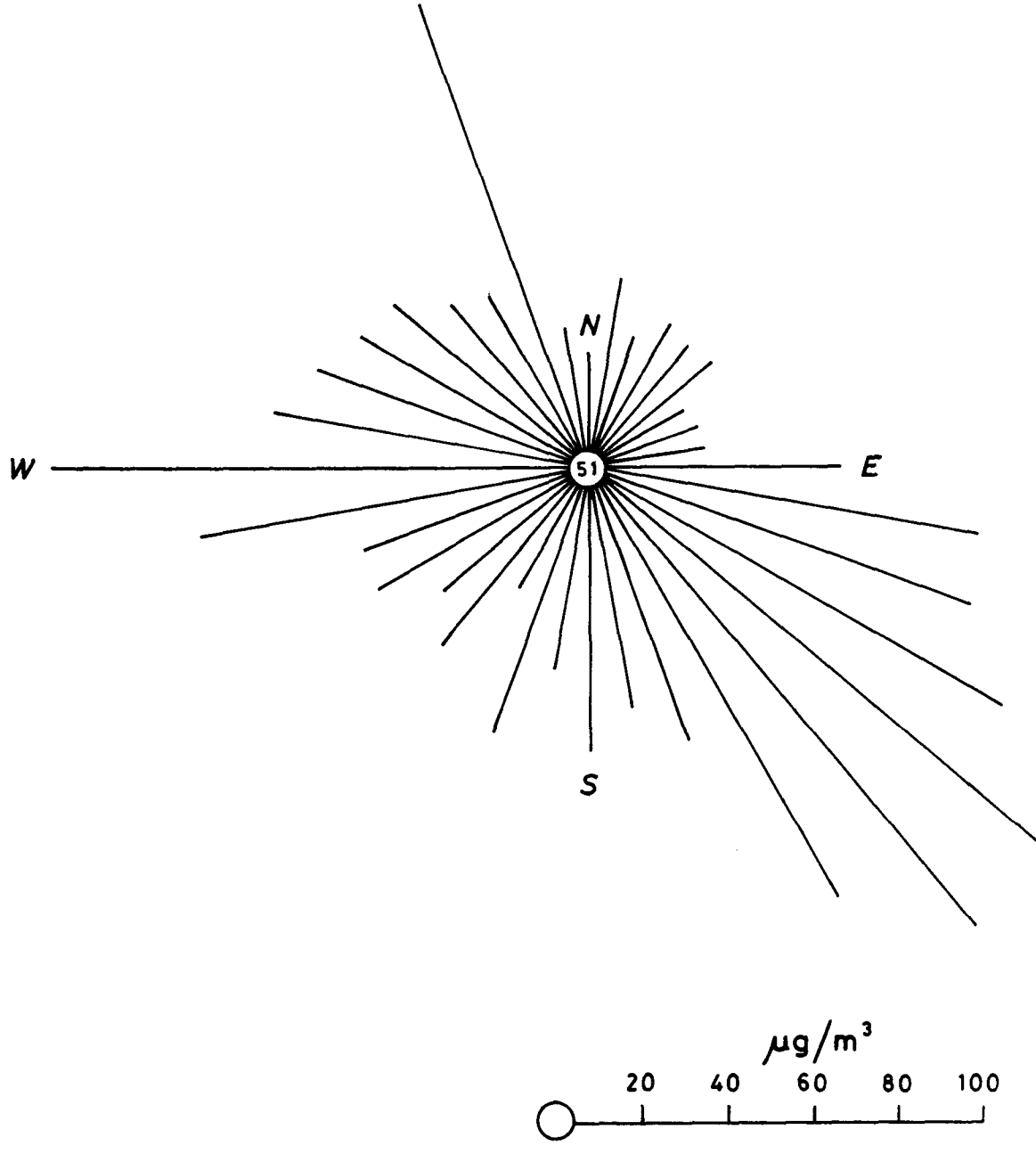

Fig. 4(i). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in September 1979.

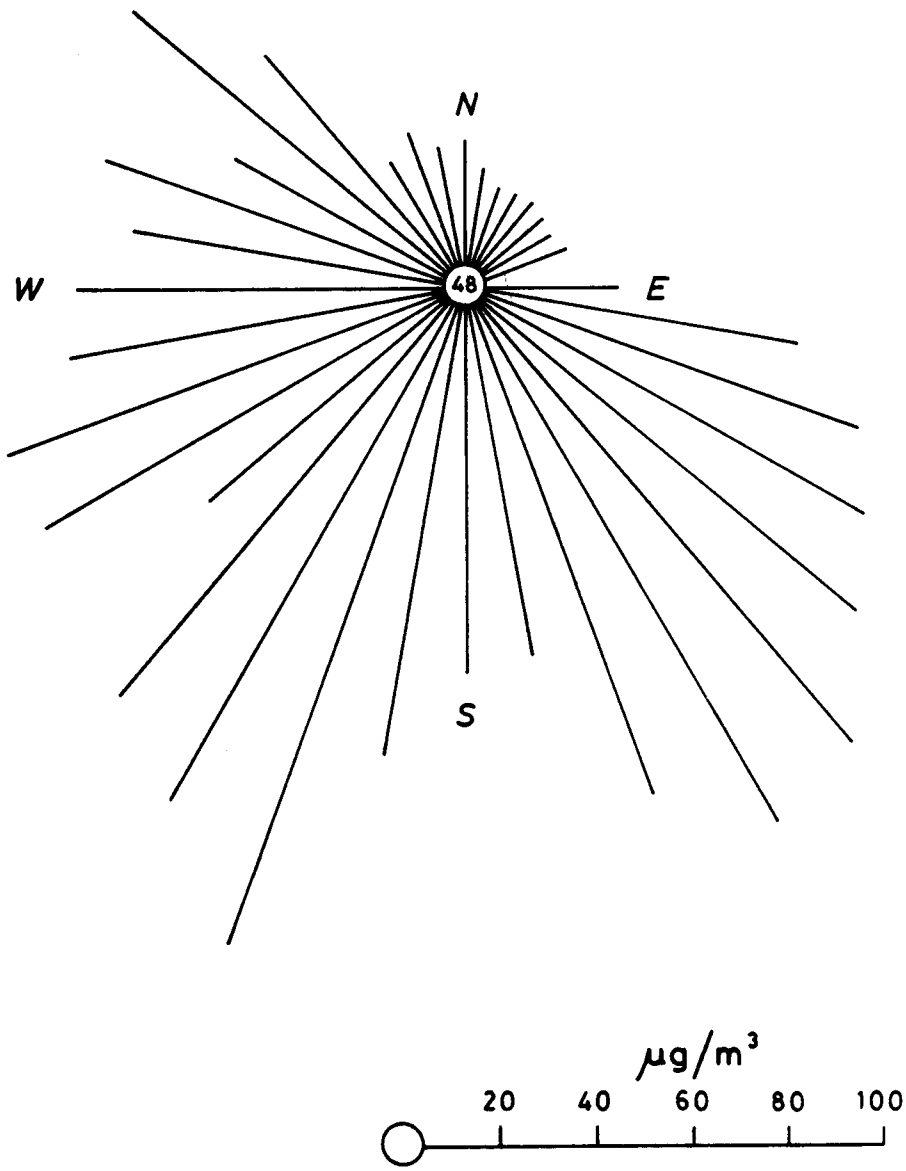

Fig. 4(j). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in October 1979.

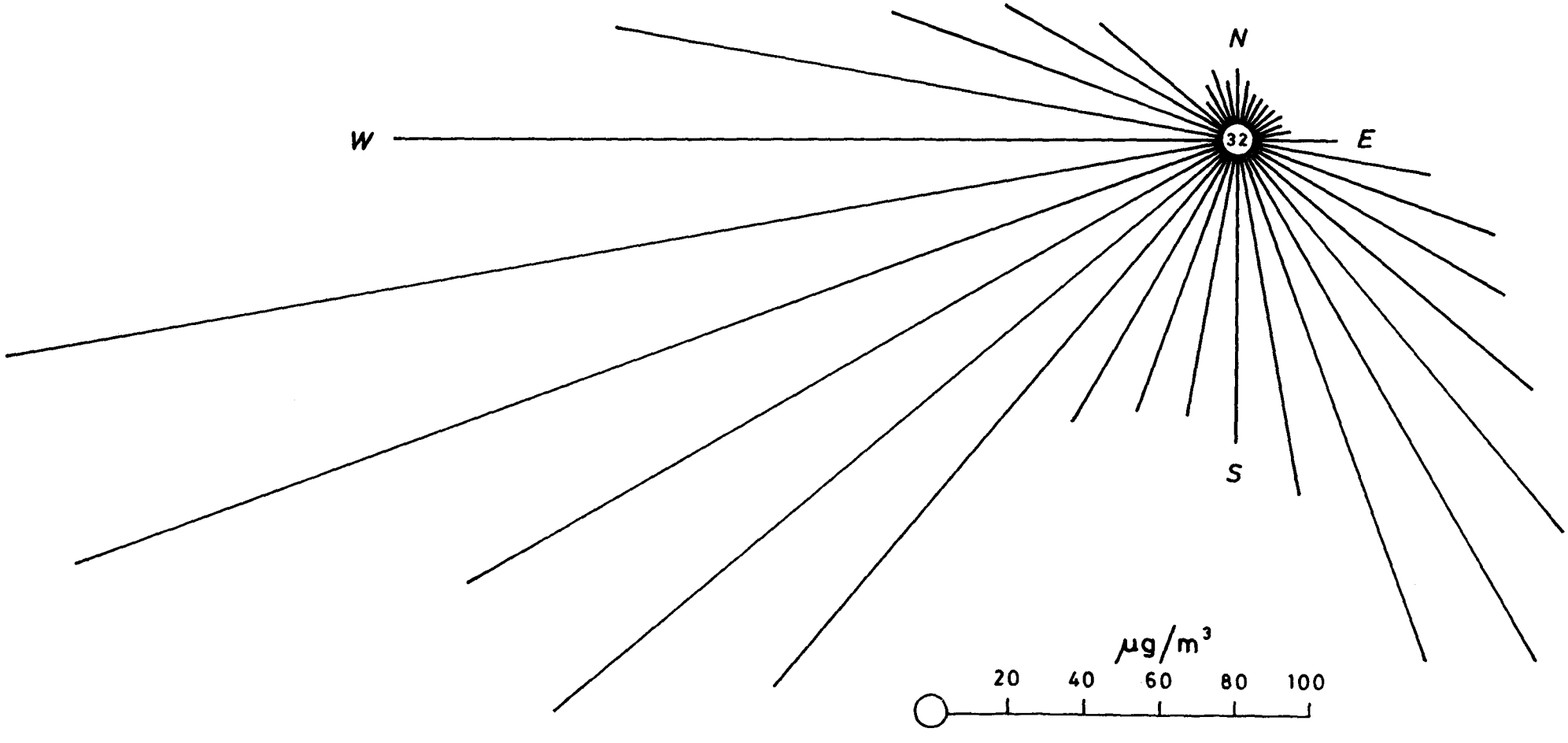

Fig. 4(k). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in November 1979.

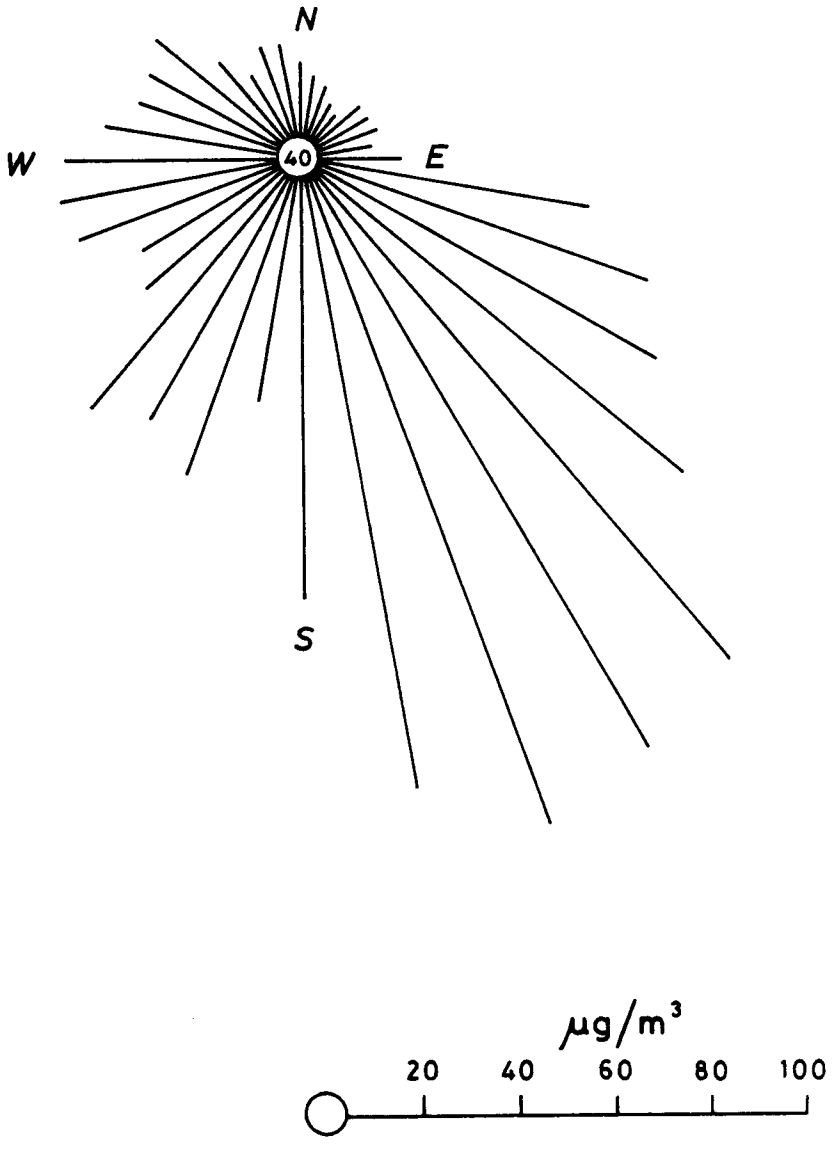

Fig. 4(l). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in December 1979.

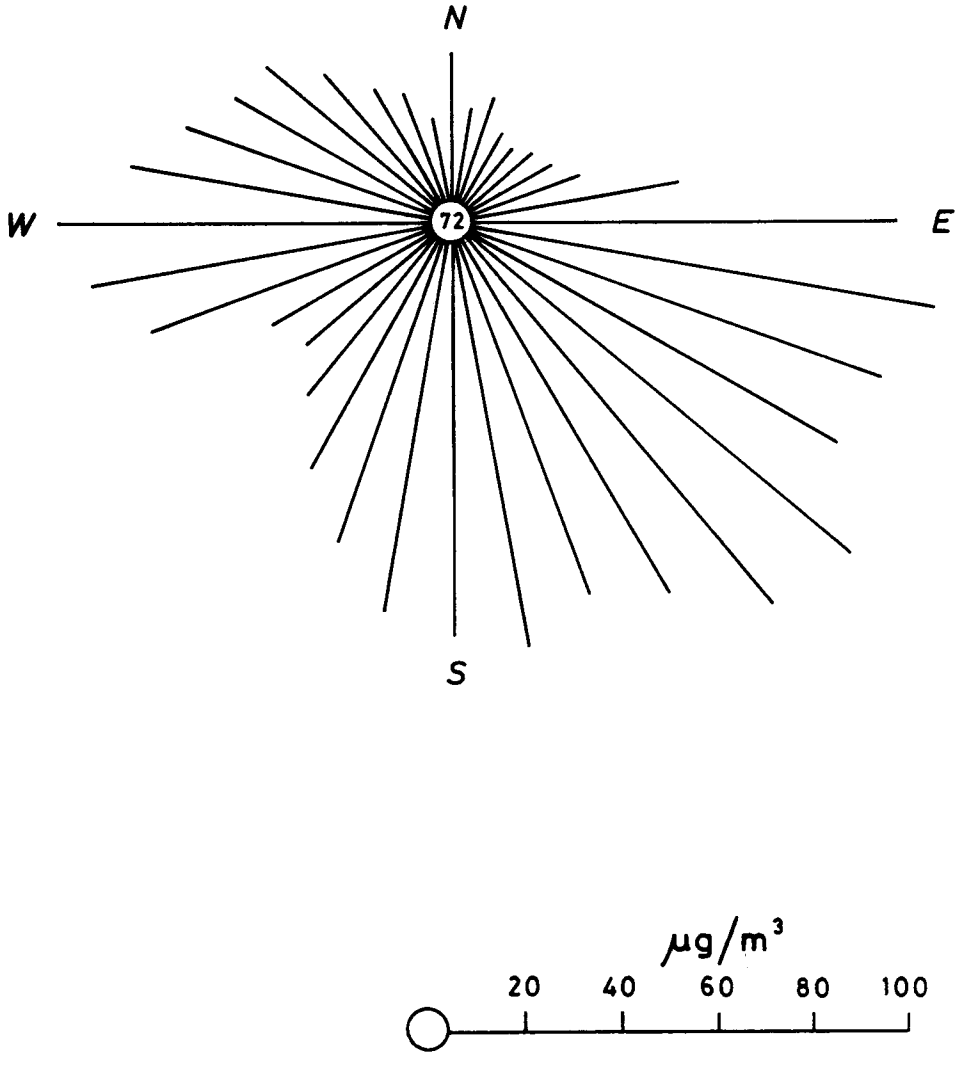

Fig. 4(m). 3-minute mean sulphur dioxide concentration associated with winds from each 10° sector in the year 1979.