PART V

ANALYSIS OF METEOROLOGICAL AND POLLUTANT CONCENTRATION DATA

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To grasp condition of meteorology and environmental concentration of particulate matter, analyses about observed data were performed. The analyses are separated into two parts. One is called short term field survey, which was carried out to measure particulate matters concentrically by many instruments and was conducted four times in a year. And the other is called long term field survey, which was carried out to obtain the annual trend of the data such as environmental condition of particulate matter.

In the analysis of short term field survey, following analyses were performed, analysis of TPM (Total Particulate Matter) and SPM (Suspended Particulate Matter) by high volume sampler or Andersen sampler, chemical analysis by XRF (X-ray fluorescence analysis) and so on.

As for the data measured in the long term field survey, following analyses were performed, such as the analysis about meteorological data and concentration of SO_2 (sulfur dioxide), analysis of SPM concentration by Beta ray dust analysers; and at the same time, the analysis of the relationship between SPM concentrations by Beta ray dust analysers and other instrument.

CHAPTER 1 ANALYSIS OF DATA IN THE LONG TERM FIELD SURVEY

In the long term field survey, following hourly data were measured for a year, wind direction, wind velocity, temperature, solar radiation, net radiation and concentration of SPM (measured by Beta ray dust analysers).

Using these hourly data, meteorology, environmental concentration, relationship between meteorological factor and environmental concentration and so on were analyzed.

V-1-1 Analysis of Meteorological Data

Atmospheric pollutants emitted from artificial sources such as factory stacks, vessels, automobiles etc. are transported and dispersed by wind. Therefore, the meteorological conditions such as wind direction, wind velocity, turbulence, solar radiation etc. are the controlling factors of diffusion phenomena.

So analyzing meteorological data in an objective area are indispensable not only to obtain meteorological conditions but also to predict future environmental concentration.

In this project, wind direction, wind velocity, solar radiation, net flux radiation, air temperature have been measured hourly, at several sites in the objective area for one year. Those hourly data were analyzed statistically by computer and following results were obtained.

V-1-1-1 Categorizing of hourly condition by seasons and hours

The meteorological and source emission conditions vary by seasons and hours. For instance, rather small number of factories are active in night time. Even the estimation of pollutant concentration aims for long term averages, such as annual or seasonal, we cannot neglect the seasonal or hourly variations of sources and also diffusion characteristics.

However it is not realistic to consider every hour to hour variation of sources in the diffusion model, so the source conditions are categorized by seasons and hours. In the previous report*, according to the statistical analysis of source conditions, meteorological conditions and environmental condition of every hour are classified into four groups by months and hours as in Table V-1-1.

In this report, the same classification was used for the analysis of meteorological data and so on.

Table V-1-1 Seasonal and hourly classification

Season / Hours	Southerly monsoon April to October	Northerly monsoon November to March
Day time	7:00 to 17:59	7:00 to 17:59
Night time	18:00 to 6:59	18:00 to 6:59

* "The Report on Environmental Effects of Coal Firing Power Stations and Integrated Steel Mill in the Republic of Singapore Volume II - Air Quality" March 1983 Japan International Cooperation Agency

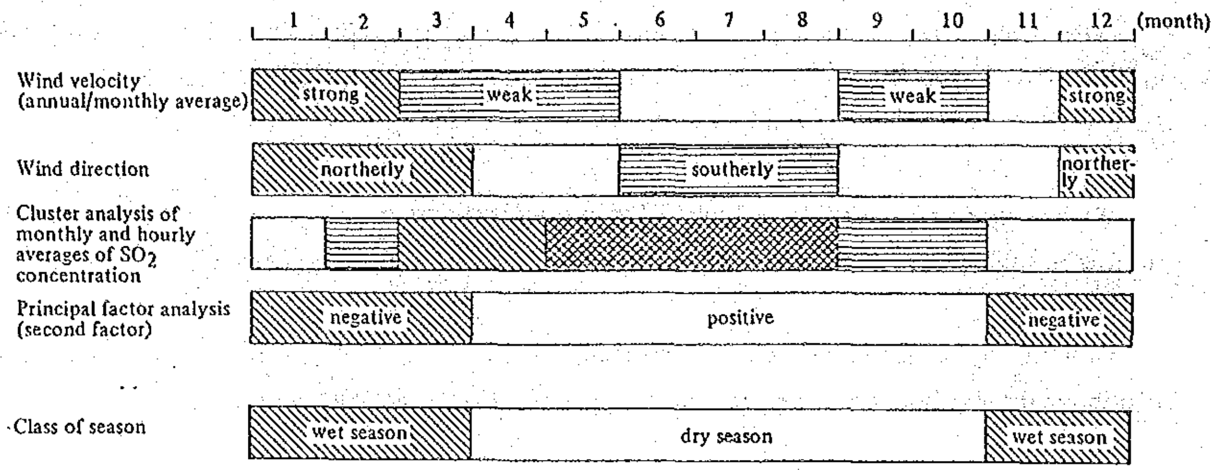


Fig. V-1-1 Monthly variation of meteorological and SO_2 concentration factors

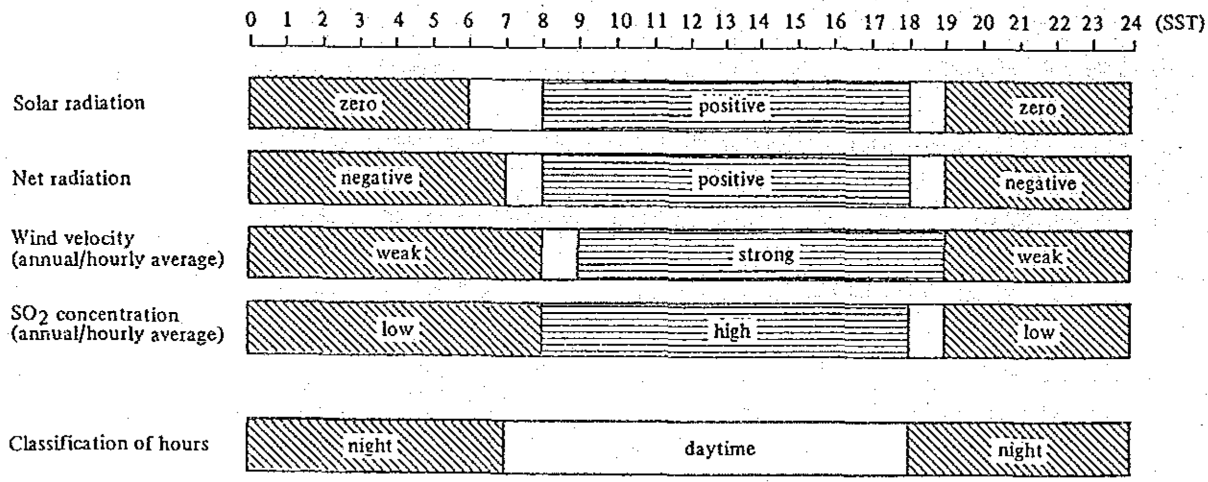


Fig. V-1-2 Diurnal variation of meteorological and SO_2 concentration factors

V-1-1-2 Monthly and hourly variations of wind velocity

Seasonal, monthly and hourly averages of wind velocity give important informations and ideas about the meteorological conditions in the objective area, such as sea breeze, topographic effect, diurnal variation etc. Fig. V-1-3 shows the monthly variations of wind velocity. Fig. V-1-4 shows hourly variations of wind velocity. At the two monitoring stations (MP1) J.T.C. Hall and (MP4) Boon Lay Apartment, previous data (July 15 1981 to July 14 1982) are also plotted by dotted line for comparison.

With respect to monthly variations, it is relatively high in wind velocity from December to February and low from March to November in MP1, MP2 and MP20. But in other stations, such a clear tendency cannot be seen.

With respect to hourly variations of wind velocity, it is relatively high in the daytime and low in nighttime. This tendency can be seen commonly in each station.

Comparing the tendency of this investigation with that of the previous investigation, both monthly and hourly variations show little difference at MP1 and MP4.

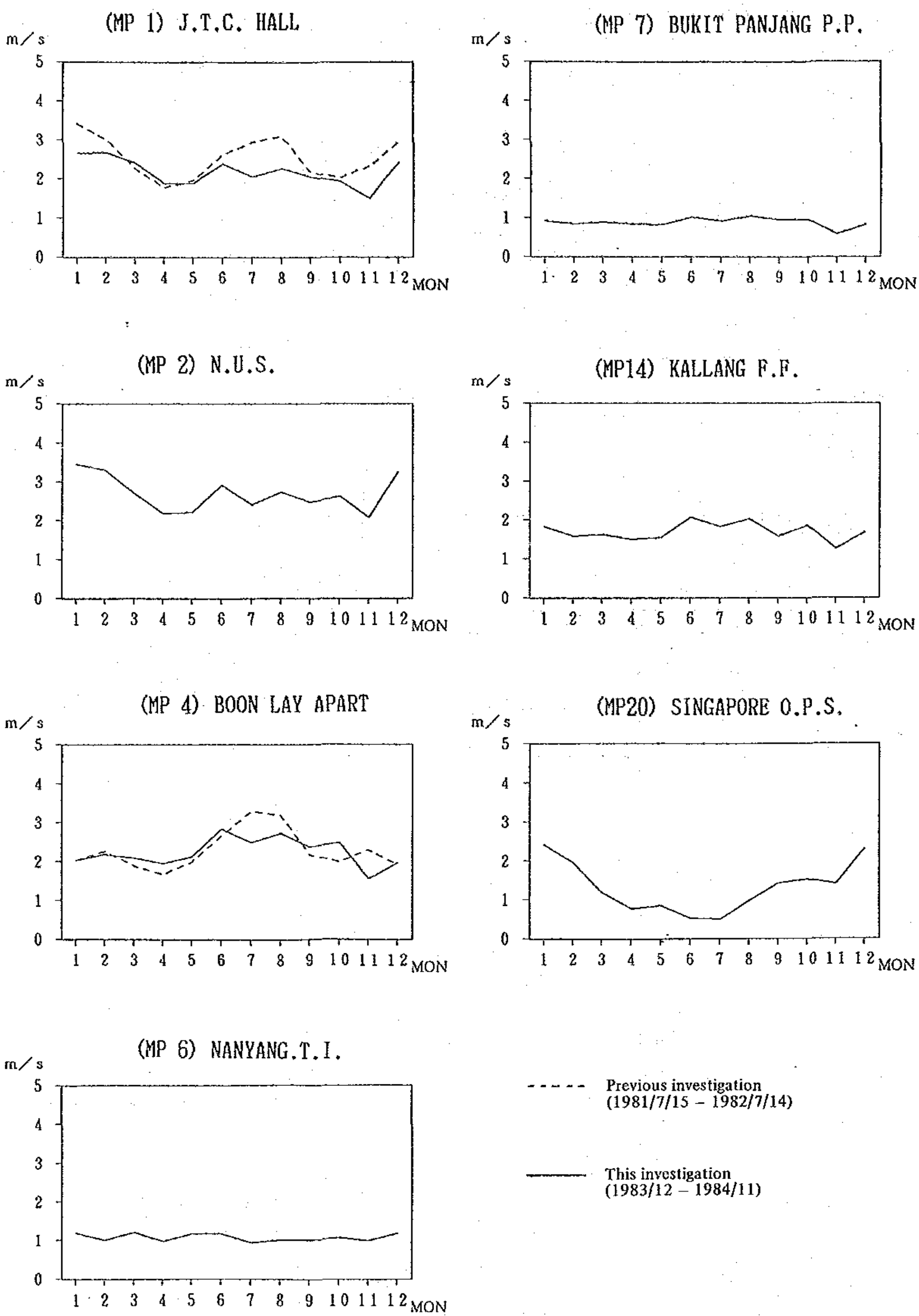


Fig. V-1-3 Monthly variations of averaging wind velocity

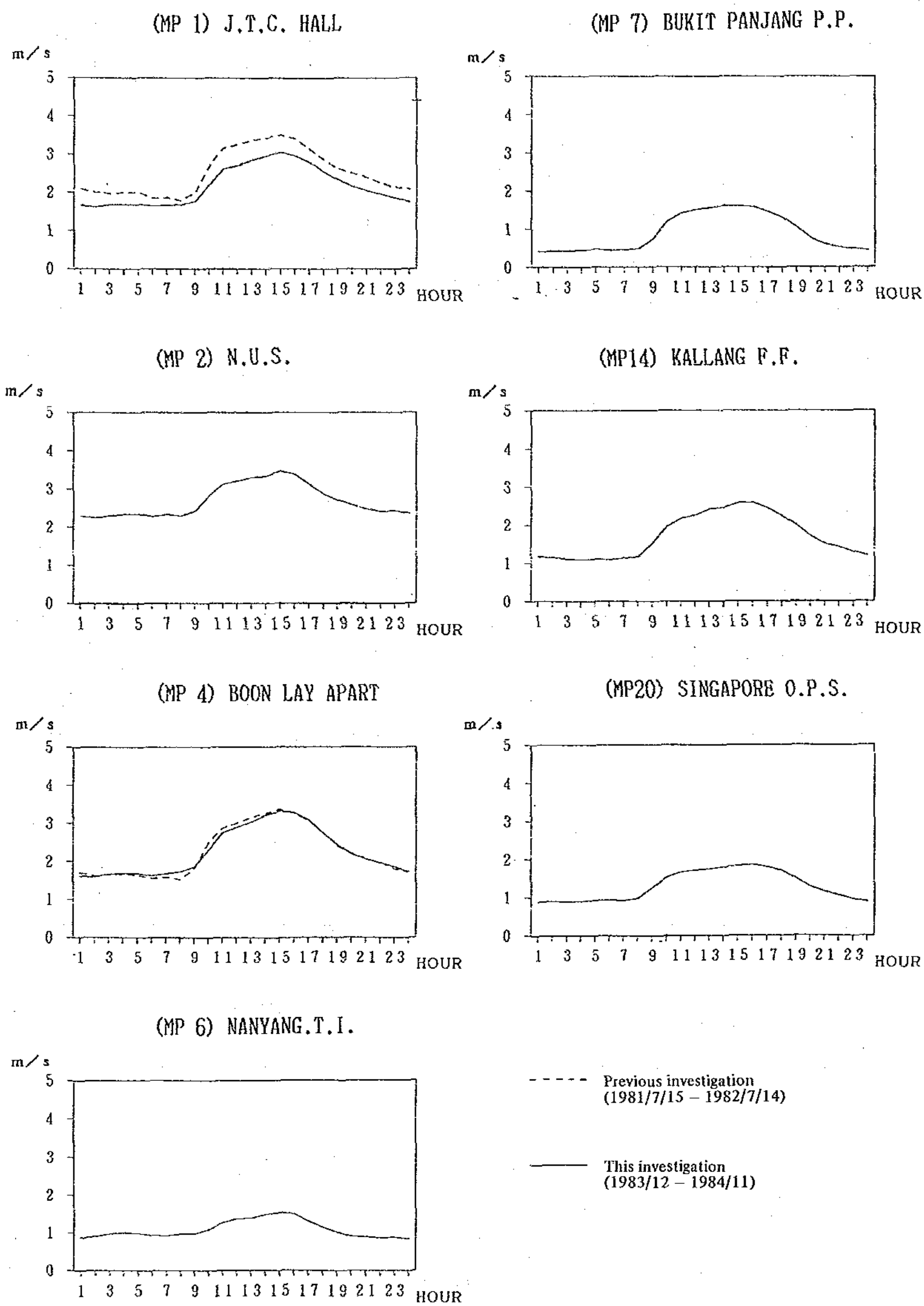


Fig. V-1-4 Hourly variations of averaging wind velocity

V-1-1-3 Frequency distribution of wind velocity

Wind velocity is analogue data and varies continuously as shown in Fig. V-1-5. At the station MP1, MP2, MP4 and MP14, there is a gentle peak around 2.0 m/s, and frequency distribution between 1.0 and 5.0 m/s is higher. And at the station MP6, MP7 and MP20, there is a sharp peak around 0.5 m/s, and frequency distribution below 3.0 m/s is higher. This tendency probably attributes to low measuring height, buildings and trees around the stations.

Modeling meteorology, wind velocity is classified into several ranks. How to classify the ranks depends on the frequency distribution of wind velocity and sensitivity of wind velocity to the equations used in the diffusion model.

In the present diffusion model, wind velocity is classified into the following seven ranks.

(1) 0 to 0.4 m/s
(2) 0.5 to 0.9 m/s
(3) 1.0 to 1.9 m/s
(4) 2.0 to 2.9 m/s
(5) 3.0 to 3.9 m/s
(6) 4.0 to 5.9 m/s
(7) 6.0 m/s and over.

In using this categorizing, frequency distribution of wind velocity ranks are shown in Table V-1-2.

Table V-1-2 Appearance frequency of each wind velocity ranks

Monitoring stations	Height of measurement (m)	Average wind velocity (m/s)	Appearance frequency (%)						
			0-0.4	0.5-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-5.9	6.0-
(MP1) J.T.C. HALL	30	2.2	2.07	9.97	35.11	29.23	17.17	6.21	0.23
(MP2) N.U.S.	30	2.7	0.94	4.52	27.28	30.84	19.70	14.93	1.79
(MP4) BOON LAY APART	46	2.2	2.05	11.04	35.44	25.05	15.53	10.34	0.55
(MP6) NANYANG.T.I.	10	1.1	11.32	36.45	44.09	7.56	0.57	0.01	0.0
(MP7) BUKIT PANJANG P.P.	10	0.9	34.58	27.14	29.39	8.67	0.23	0.0	0.0
(MP14) KALLANG F.F.	28	1.7	7.03	18.76	37.03	25.48	9.72	1.98	0.0
(MP20) SINGAPORE O.P.S.	10	1.3	20.69	26.94	29.57	15.17	5.95	1.68	0.01

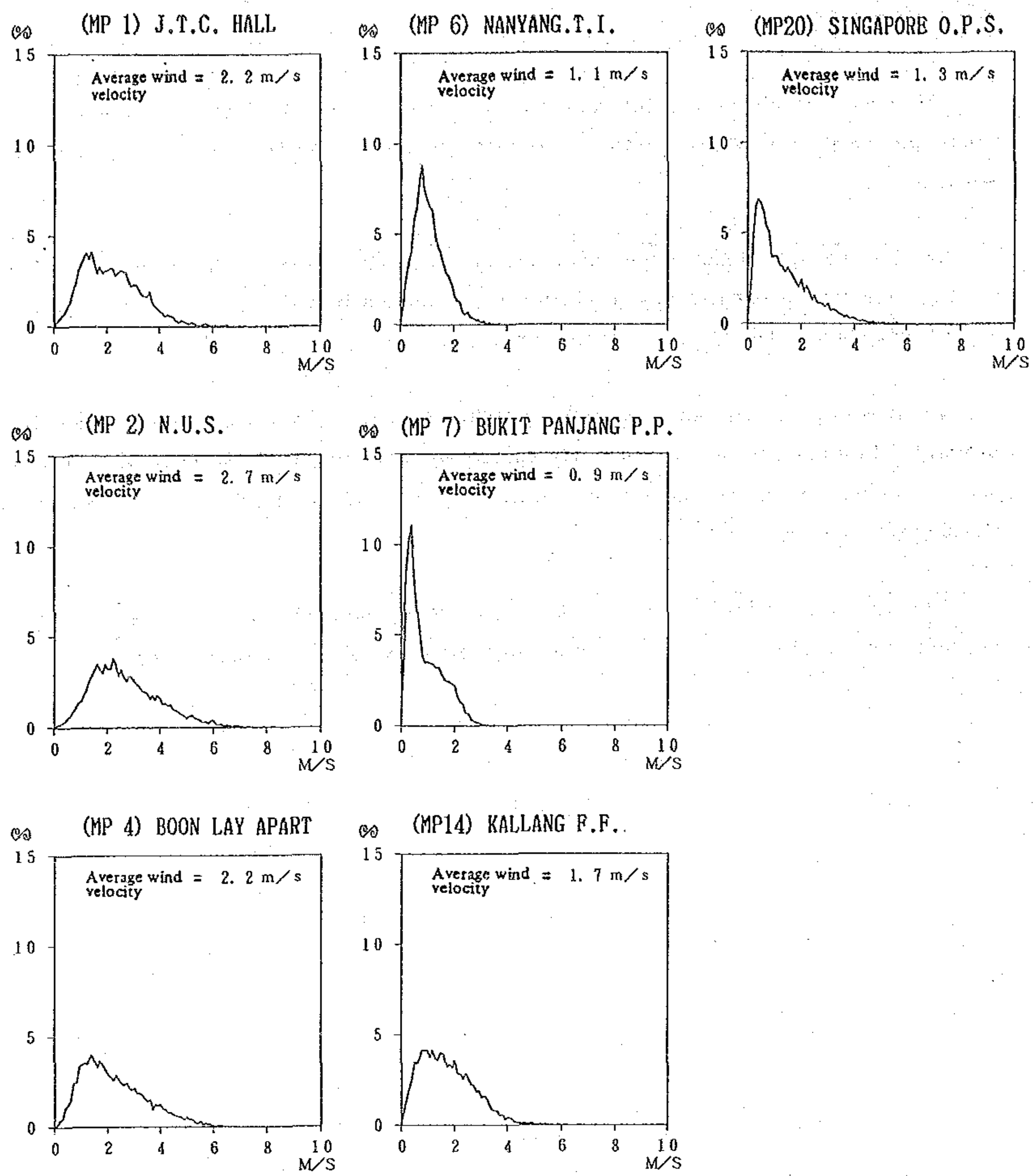


Fig. V-1-5 Frequency distribution of wind velocity

V-1-1-4 Wind rose

As a way of display of the appearance frequency of wind direction, wind rose is commonly used. Fig. V-1-6 shows the wind rose classified by time of the day and also by seasons.

In the figures, appearance frequency of each direction is shown in a solid line, average velocity in each direction is shown in a dotted line and appearance frequency of the velocity below 0.4 m/s is shown in a center circle.

Being seasonal categorizing corresponding to each monsoon, southerly winds are prevailing in a dry season and northerly winds are prevailing in a wet season. And in both seasons, effects of sea and land breeze are detectable and this tendency is clearer in a dry season than in a wet season.

The characteristics of wind at MP1 and MP4 show the same tendency with the previous investigation which was carried out from July 15 1981 to July 14 1982.

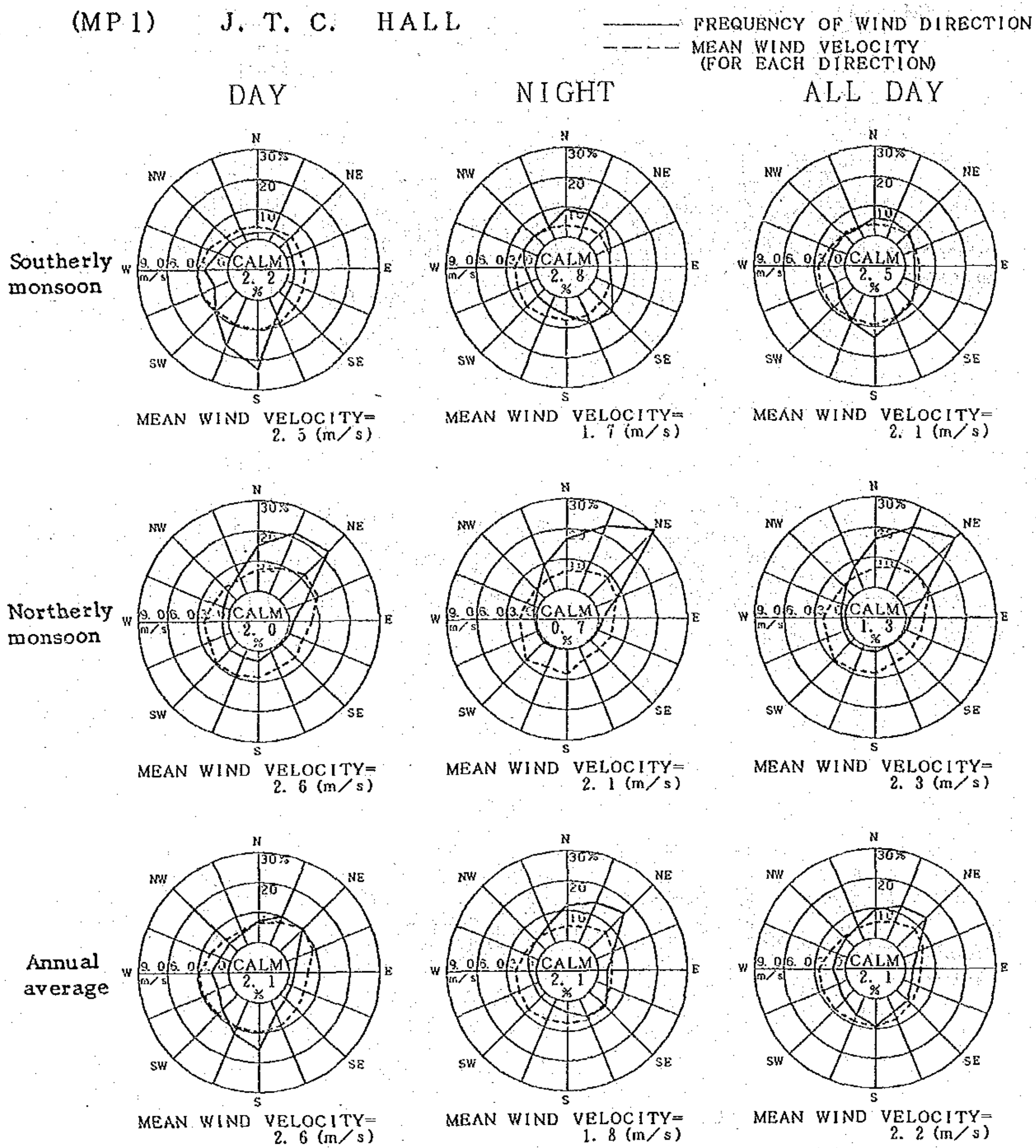


Fig. V-1-6-(1) Wind Rose of daytime and nighttime for two seasons and through the year

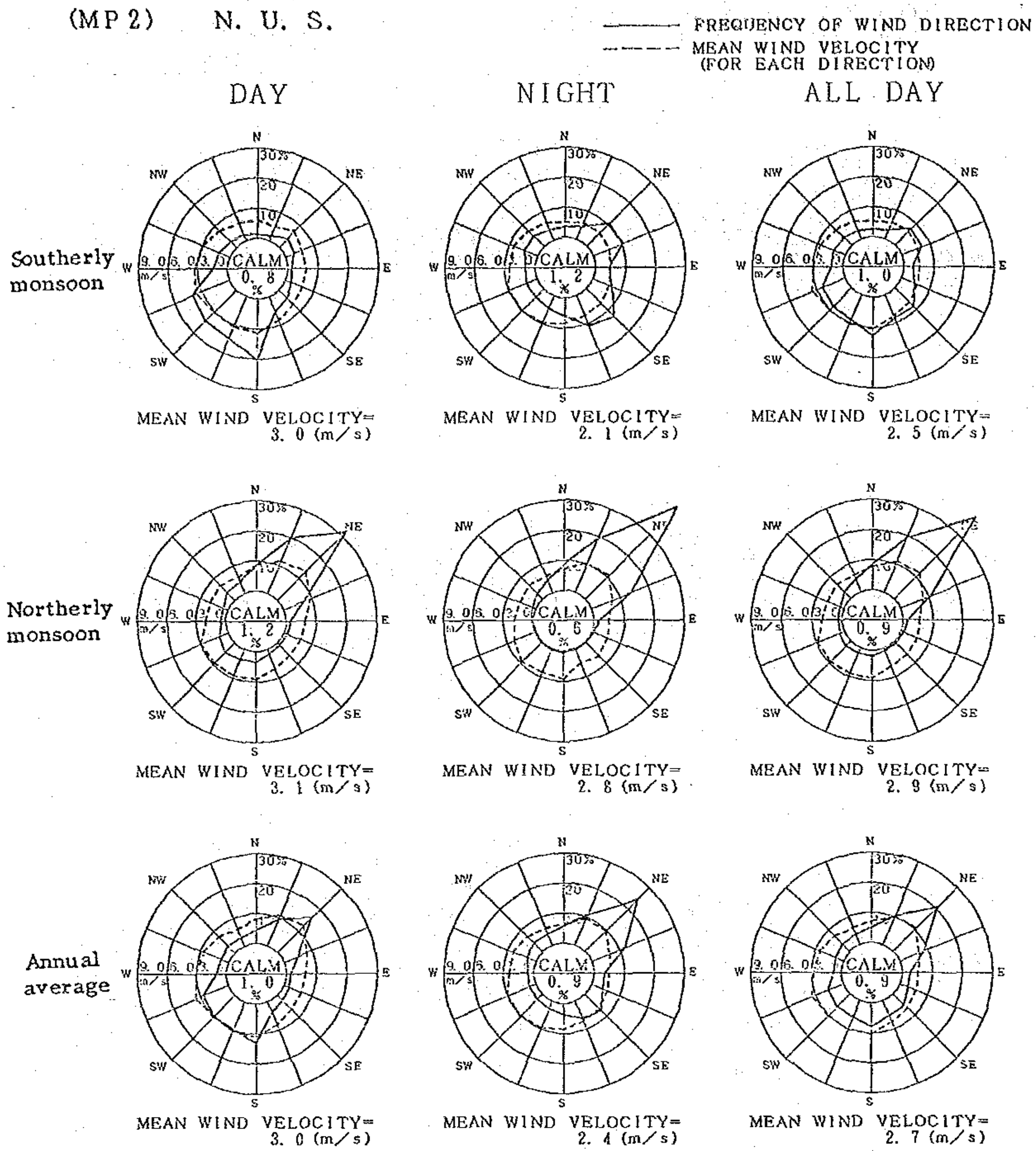


Fig. V-1-6-(2) Wind Rose of daytime and nighttime for two seasons and through the year

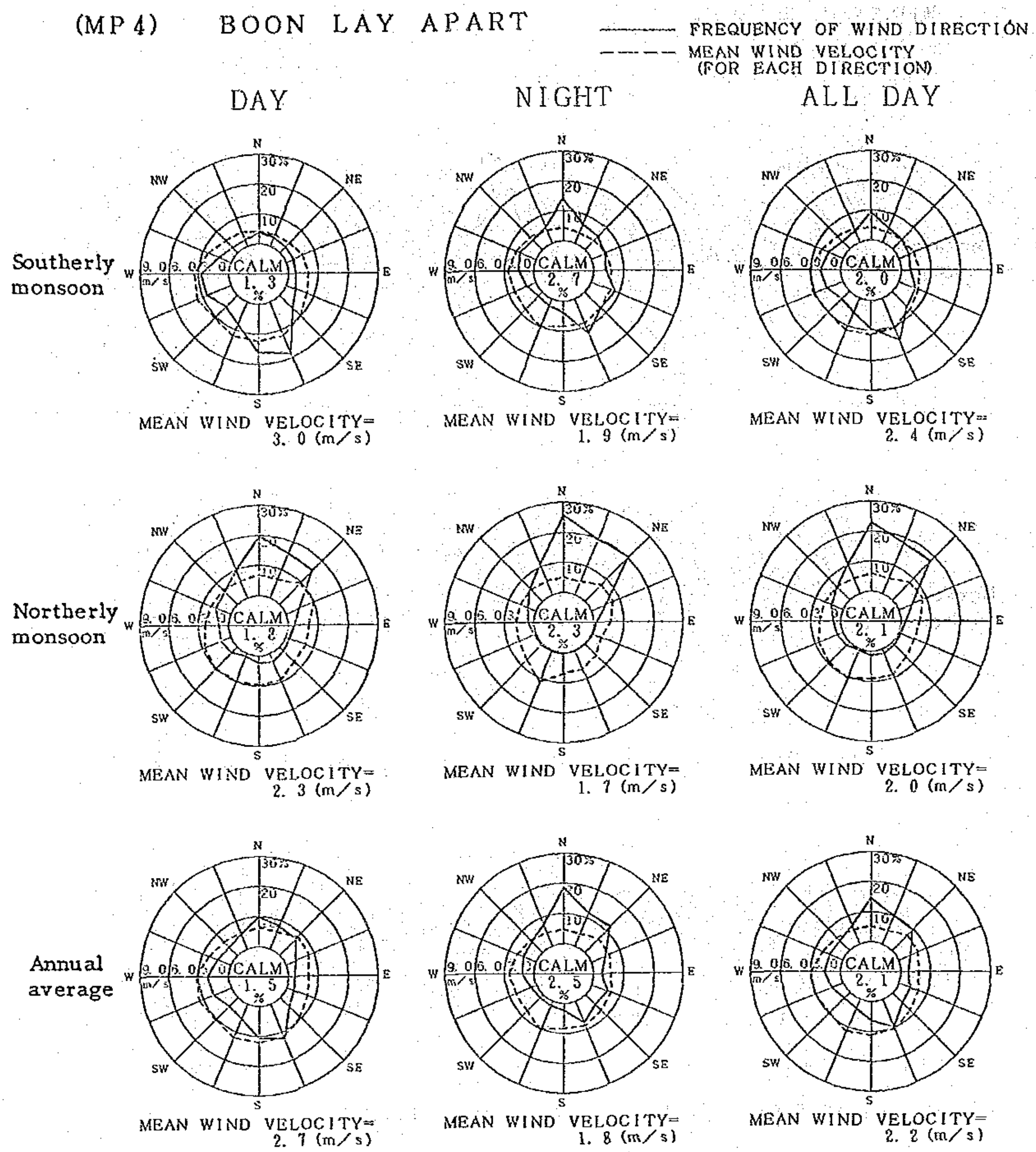


Fig. V-1-6-(3) Wind Rose of daytime and nighttime for two seasons and through the year

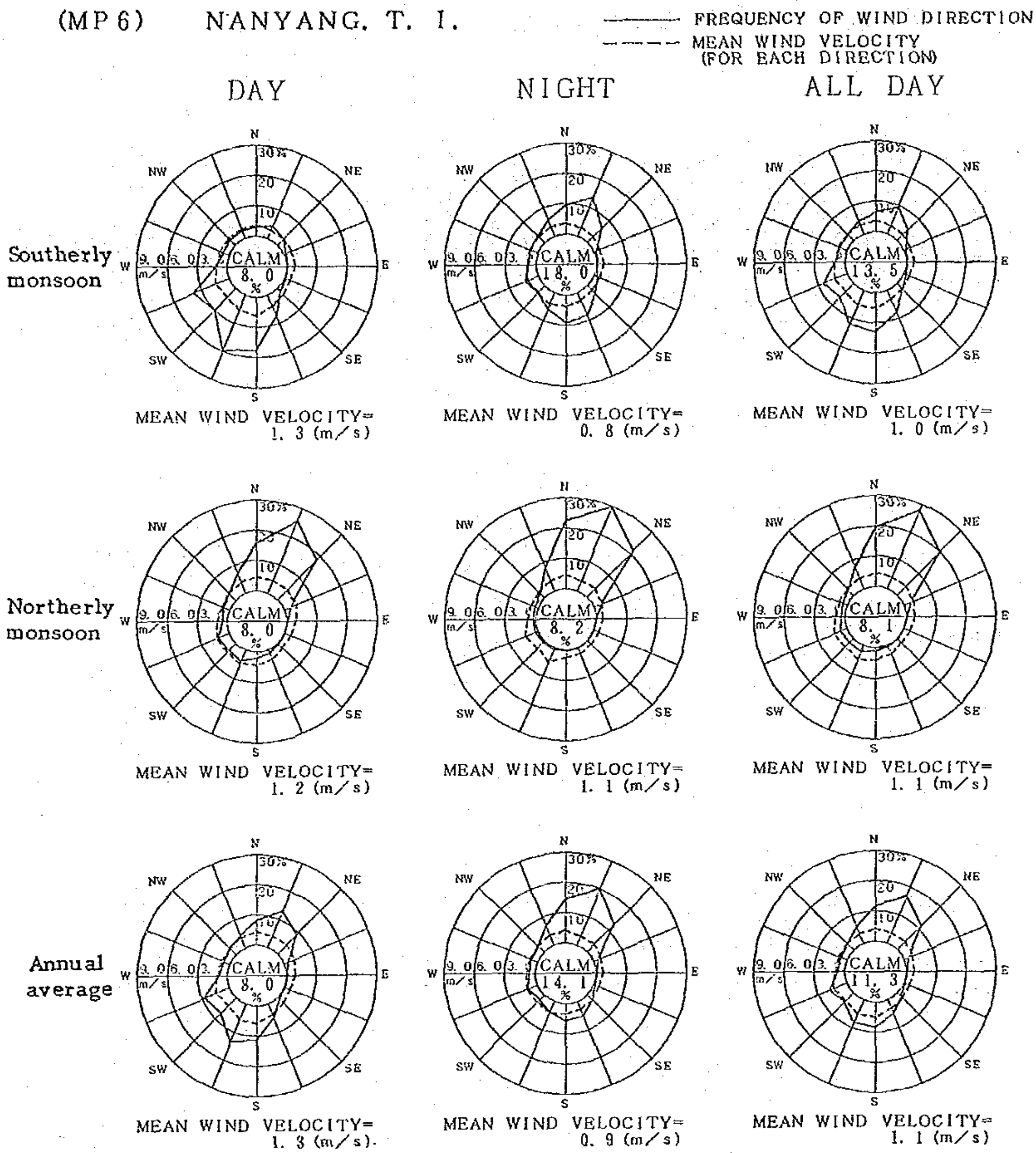


Fig. V-1-6-(4) Wind Rose of daytime and nighttime for two seasons and through the year

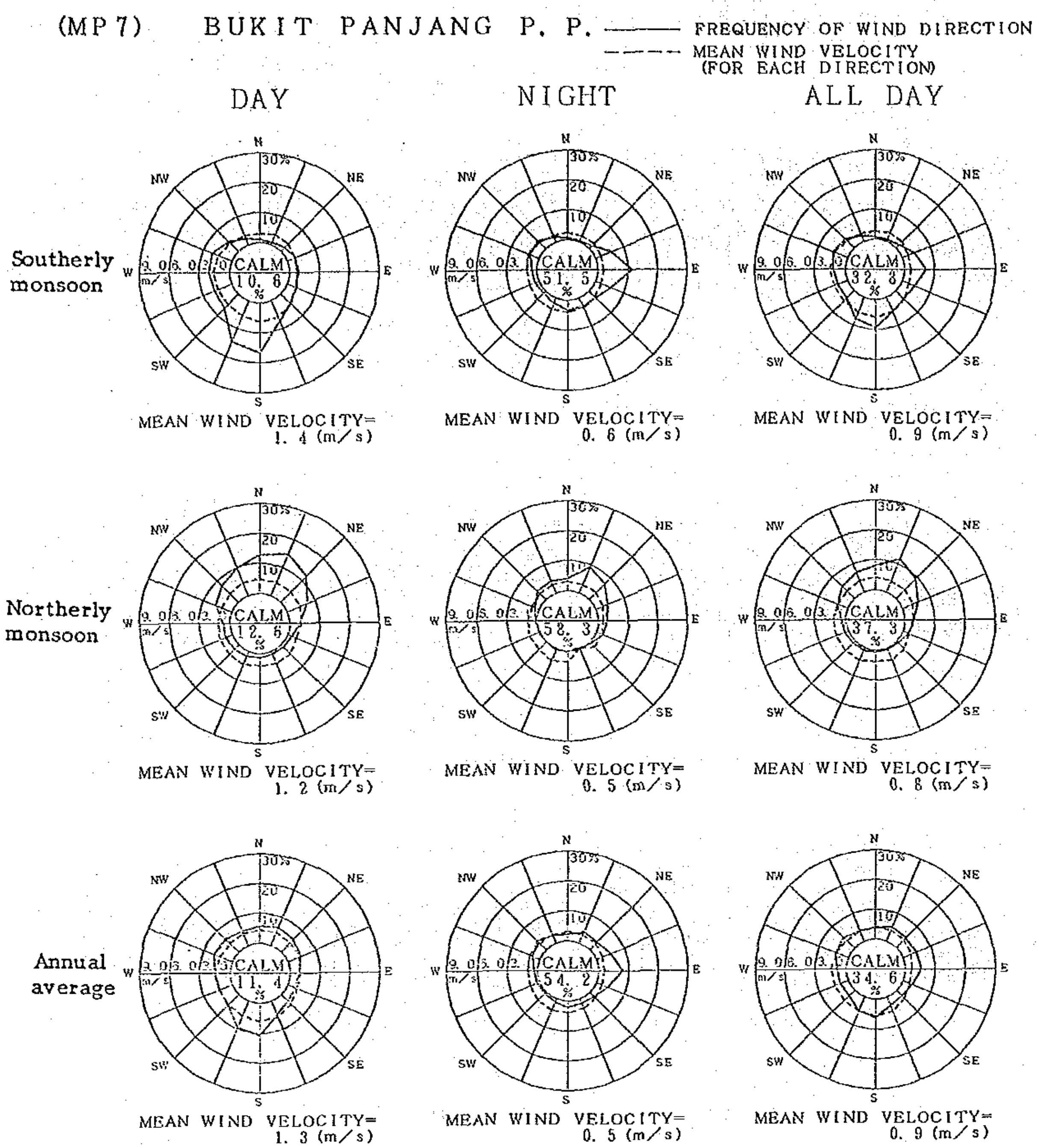


Fig. V-1-6-(5) Wind Rose of daytime and nighttime for two seasons and through the year

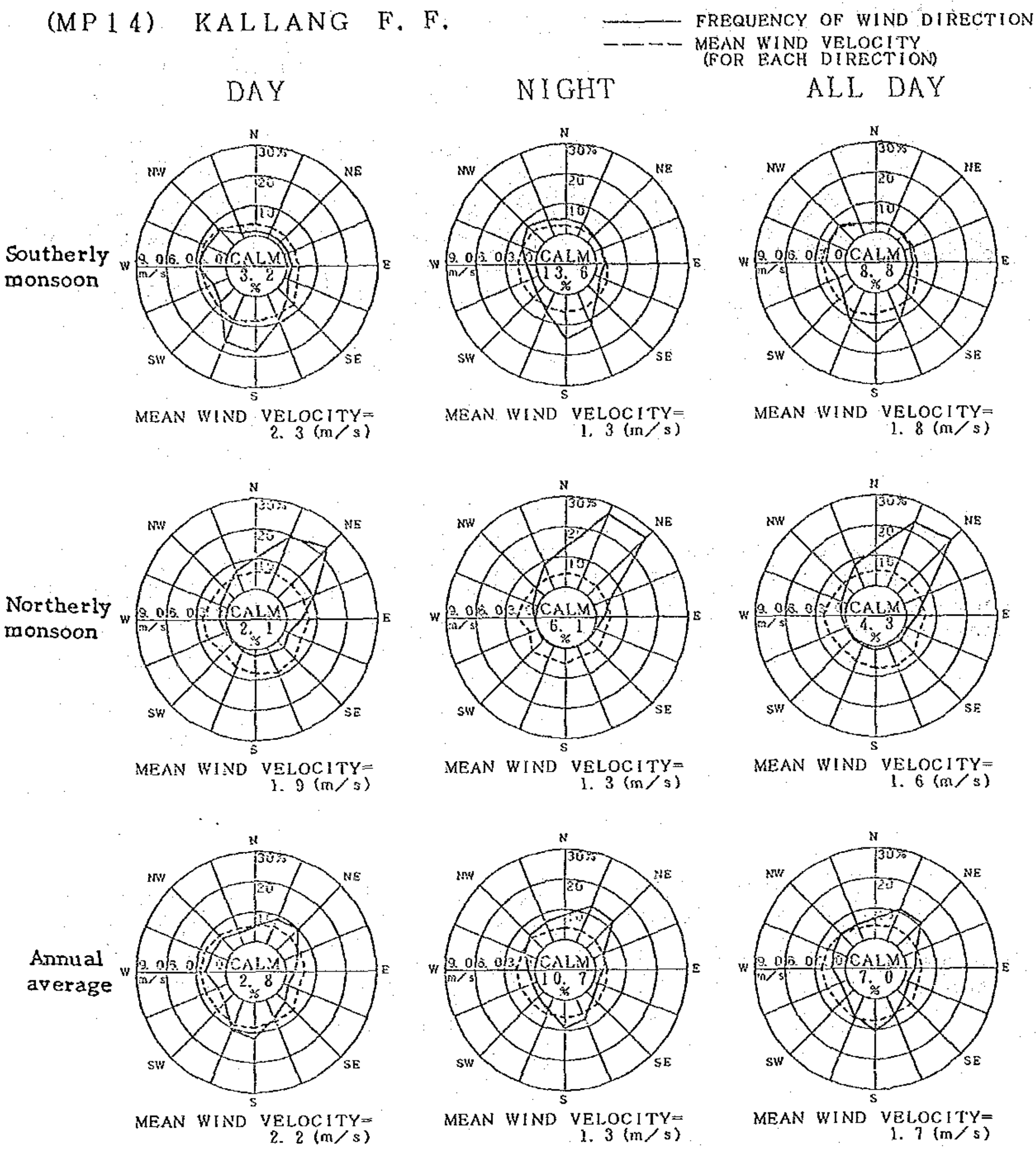


Fig. V-1-6-(6) Wind Rose of daytime and nighttime for two seasons and through the year

(MP20) SINGAPORE O. P. S.

——— FREQUENCY OF WIND DIRECTION
– – – – MEAN WIND VELOCITY (FOR EACH DIRECTION)

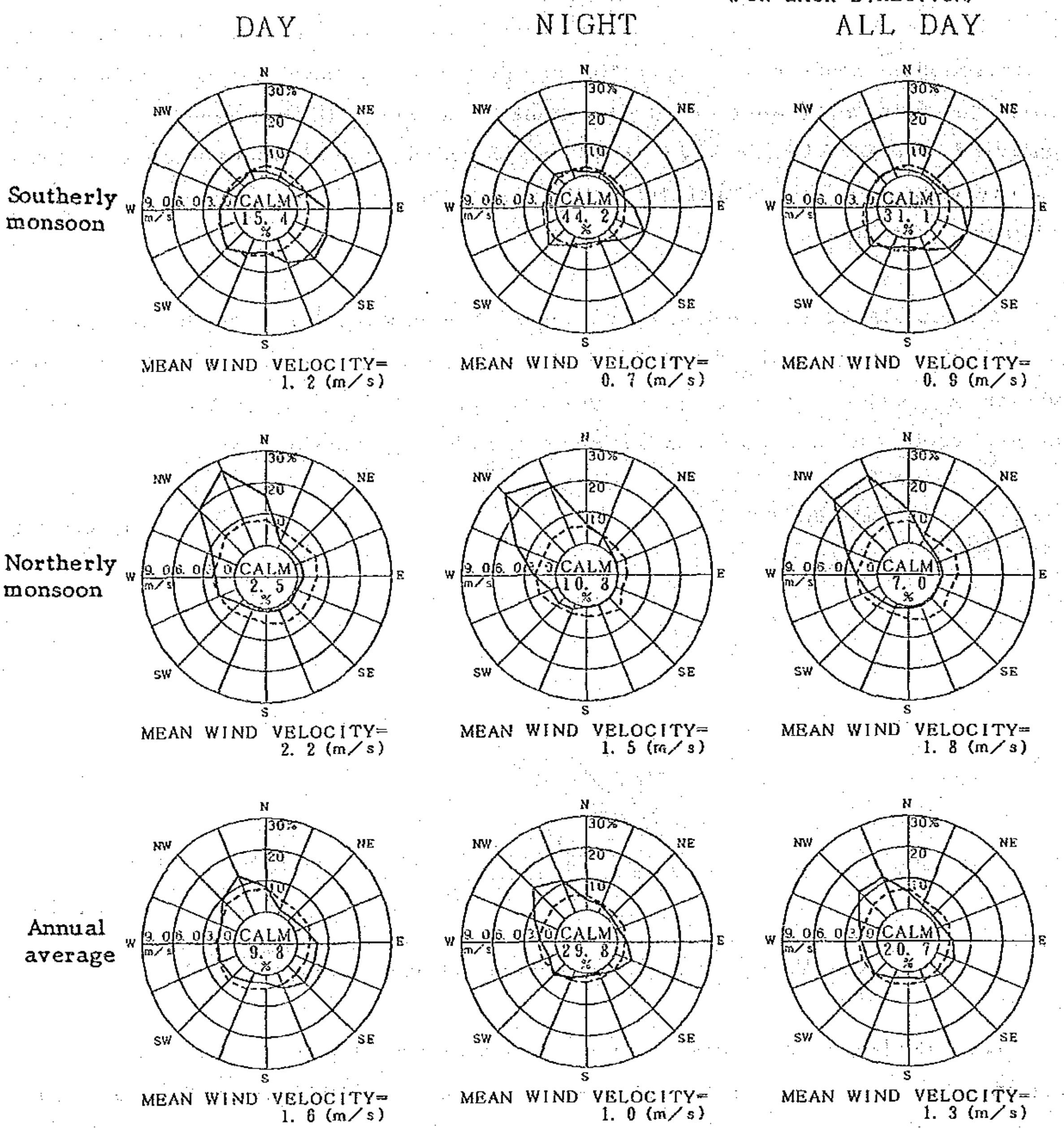


Fig. V-1-6-(7) Wind Rose of daytime and nighttime for two seasons and through the year

V-1-1-5 Cross correlation of wind vectors of different stations

Like the objective area - 60 km from east to west and 40 km from north to south, the meteorological conditions seem not to be the same. So based on the hourly wind data (wind direction, wind velocity), the resemblance of wind data between two stations were analyzed. One of the basic way is to take cross correlations of wind vectors of every hour for every station. The cross correlations of wind vectors of every hour are calculated the following procedures.

We consider stations A and B, and denote the wind vector of station A at time i by $\vec{V}_{Ai}$ and for station B, $\vec{V}_{Bi}$ as Fig. V-1-7. Next we calculate the angle of the two wind vectors $\vec{V}_{Ai}$ and $\vec{V}_{Bi}$ for each time series, and denote it by θ_i. Then the cross correlation of wind vectors for station A and B is given by following equation.

$$r(A, B) \doteqdot \frac{\sum_i \vec{V}_{Ai}\, \vec{V}_{Bi} \cos\theta i}{\sum \vec{V}_{Ai}\, \vec{V}_{Bi}}$$ Equation V-1-1

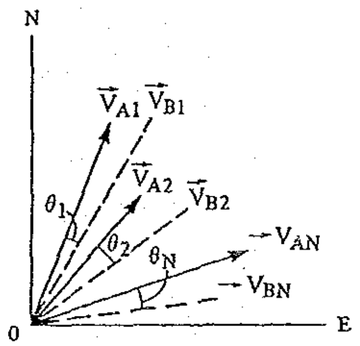


Fig. V-1-7 Wind vectors between station A and station B

The calculated cross correlations for all stations are shown in Table V-1-3. From the results, it is clear that the correlations are high except MP20, which locates north-east part in the objective area.

Table V-1-3 Cross correlation of wind vectors for different stations

Monitoring stations	MP1	MP2	MP4	MP6	MP7	MP14	MP20
(MP1) J.T.C. HALL	1.000	0.951	0.931	0.940	0.891	0.888	0.401
(MP2) N.U.S.	0.951	1.000	0.893	0.911	0.850	0.887	0.326
(MP4) BOON LAY APART	0.931	0.893	1.000	0.919	0.885	0.819	0.536
(MP6) NANYANG.T.I.	0.940	0.911	0.919	1.000	0.857	0.852	0.397
(MP7) BUKIT PANJANG P.P.	0.891	0.850	0.885	0.857	1.000	0.822	0.511
(MP14) KALLANG F.F.	0.888	0.887	0.819	0.852	0.822	1.000	0.331
(MP20) SINGAPORE O.P.S.	0.401	0.326	0.536	0.397	0.511	0.331	1.000

V-1-1-6 Cluster analysis based on cross correlation of wind vectors

The cluster analysis is an analytical method to classify a set of variables into several clusters. It is commonly used in biology and natural history in order to classify samples. In this study, observational stations are classified by Furthest Neighbour Method in which cross correlations are used as the measure of the distance. The algorithm is as follows:

(1) First we define d_{ij} as the measure of the neighbouring factor between stations i and j as follows:

$$d_{ij} = (1 - r_{ij})$$

where r_{ij} is the cross correlation.

(2) Using the initial measures of distance defined above, clustering is started and the neighbouring two stations are grouped. These groups are new clusters.

(3) The measures of distance are again calculated between new clusters. And clustering is again done for the newly calculated measures. These procedures are repeated until all samples are gathered into one cluster.

For the renewal of distance between new clusters, several methods are proposed. In this study, the Furthest Neighbour Method in which the furthest distance of the clusters are used, is applied (Fig. V-1-8).

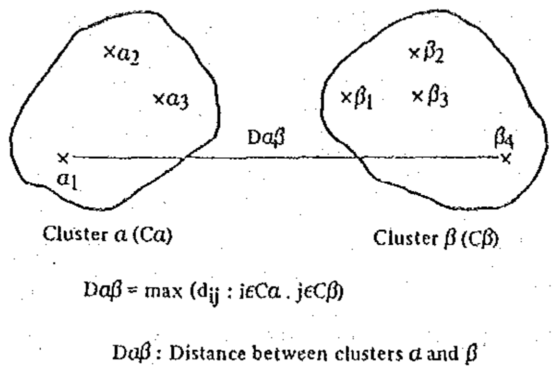


Fig. V-1-8 Distance between cluster α and β.

The result of the cluster analysis is shown in Fig. V-1-9. From this figure, it is clear that the monitoring stations are classified into two groups by correlation coefficients. The first group is from MP1 to MP14. And another group is MP20. It implies that the wind field is different in west of Singapore from the east.

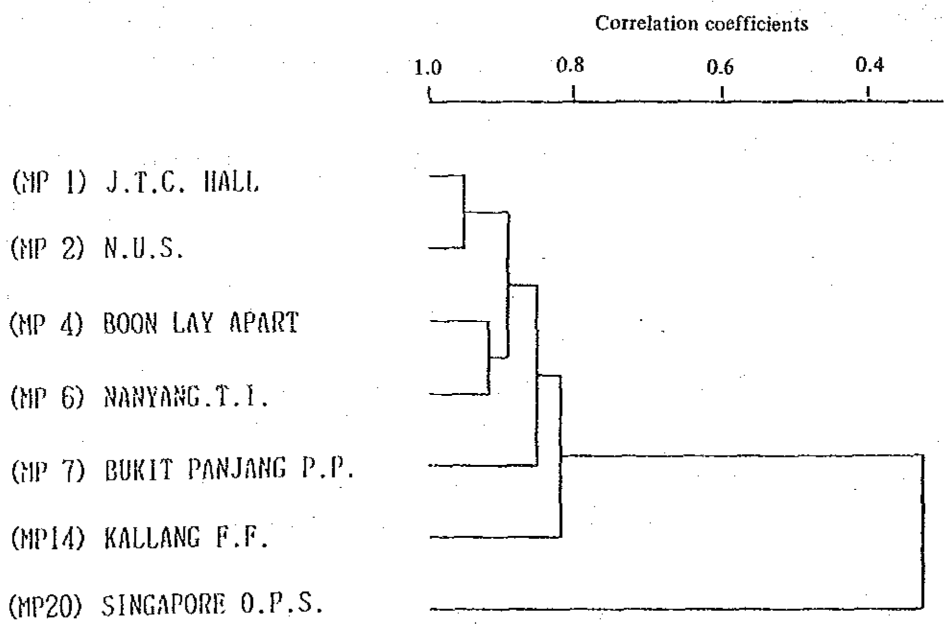


Fig. V-1-9 Result of clustering correlation coefficients

V-1-1-7 Principal component analysis based on cross correlation analysis

The principal component analysis is a method in which variables X_1, X_2, X_3 ... X_p are summed up to mutually independent components.

In the principal component analysis, principal components Z_k are represented by weighed averages of variables as follows:

$$\left.\begin{aligned} z_1 &= \ell_{11}x_1 + \ell_{12}x_2 + \cdots + \ell_{1p}x_p = \sum_{i=1}^{p} \ell_{1i}x_i \\ z_2 &= \ell_{21}x_1 + \ell_{22}x_2 + \cdots + \ell_{2p}x_p = \sum_{i=1}^{p} \ell_{2i}x_i \\ &\cdots\cdots \\ z_k &= \ell_{k1}x_1 + \ell_{k2}x_2 + \cdots + \ell_{kp}x_p = \sum_{i=1}^{p} \ell_{ki}x_i \\ &\cdots\cdots \\ z_m &= \ell_{m1}x_1 + \ell_{m2}x_2 + \cdots + \ell_{mp}x_p = \sum_{i=1}^{p} \ell_{mi}x_i \end{aligned}\right\} \quad \text{Equation V-1-2}$$

where,

$$\ell_{k1}^2 + \ell_{k2}^2 + \cdots + \ell_{kp}^2 = \sum_{i=1}^{p} \ell_{ki}^2 = 1 \quad (k = 1, 2, \cdots, m) \qquad \text{Equation V-1-3}$$

Coefficients ℓ_{ki} are decided as to satisfy following conditions:

(a) In the first principal component Z_1, the coefficients $\{\ell_{1i}\}$ (i = 1, 2, ... p) are settled as the variance of Z_1 takes the maximum.

(b) The coefficients of $\{\ell_{2i}\}$ in the second component Z_2 are decided as the variance of Z_2 takes maximum under the condition of no correlation with Z_1.

(c) The coefficients of $\{\ell_{ki}\}$ in the k th components Z_k are decided as the variance of Z_k takes maximum under the condition of no correlation with Z_1, Z_2, ... Z_{k-1}.

In this study, regarding wind data of each monitoring station as the variables, the principal components are derived from cross correlation of wind vectors.

The results are shown in Table V-1-4 and V-1-5. Table V-1-4 shows the eigen vectors (ℓ_{ki}) and eigen values. The eigen values λ_k represent the variances of the principal components Z_k, and the rate of the variance to the total variance (in this case seven) is called contribution. The contribution of the first component Z_1 is 0.81 ($\lambda_1/7$) and it means that 81 percent of informations included in variables is contained in Z_1.

The contribution of second principal component is 0.836/7 = 0.12 and the summed contribution of the first and second principal components becomes 0.93. This means that 93 percent of total informations is explained by the two components. Factor loading $r(Z_k, x_i)$ is equal to the cross correlations of variables x_i, and expressed by the equation.

$$r(Z_k, x_i) = \sqrt{\lambda_k}\ \ell_{ki} \qquad \text{Equation V-1-4}$$

Fig. V-1-10 shows the distributions of factor loading of the first and second component for every station. At MP20, factor loading of first and second component are different from that of other monitoring stations. This indicates that monitoring stations are divided into two groups - MP20 and other monitoring stations. The result of principal component analysis agrees with the result of the cluster analysis. And also this result agrees with the results of the previous investigation, which had been showed that the characteristic of wind data had been divided into two parts - the west part of Singapore and the east part of Singapore.

Table V-1-4 Eigen vectors and eigen values

Monitoring stations	Principal components				
	1	2	3	4	5
MP1 J.T.C. HALL	0.410	0.125	-0.126	-0.077	-0.188
MP2 N.U.S.	0.399	0.217	-0.032	-0.199	-0.691
MP4 BOON LAY APART	0.404	-0.077	-0.391	-0.106	0.000
MP6 NANYANG.T.I.	0.401	0.113	-0.339	-0.251	0.658
MP7 BUKIT PANJANG P.P.	0.393	-0.073	0.021	0.906	0.042
MP14 KALLANG F.F.	0.383	0.201	0.833	-0.162	0.222
MP20 SINGAPORE O.P.S.	0.214	-0.934	0.144	-0.184	-0.061
Eigen values	5.658	0.836	0.179	0.146	0.082

Table V-1-5 Loading factors

Monitoring stations	Principal components				
	1	2	3	4	5
MP1 J.T.C. HALL	0.976	0.114	-0.053	-0.029	-0.054
MP2 N.U.S.	0.950	0.198	-0.014	-0.076	-0.197
MP4 BOON LAY APART	0.962	-0.070	-0.165	-0.041	0.000
MP6 NANYANG.T.I.	0.955	0.104	-0.143	-0.096	0.188
MP7 BUKIT PANJANG P.P.	0.935	-0.067	0.009	0.346	0.012
MP14 KALLANG F.F.	0.912	0.184	0.352	-0.062	0.064
MP20 SINGAPORE O.P.S.	0.510	-0.854	0.061	-0.070	-0.017

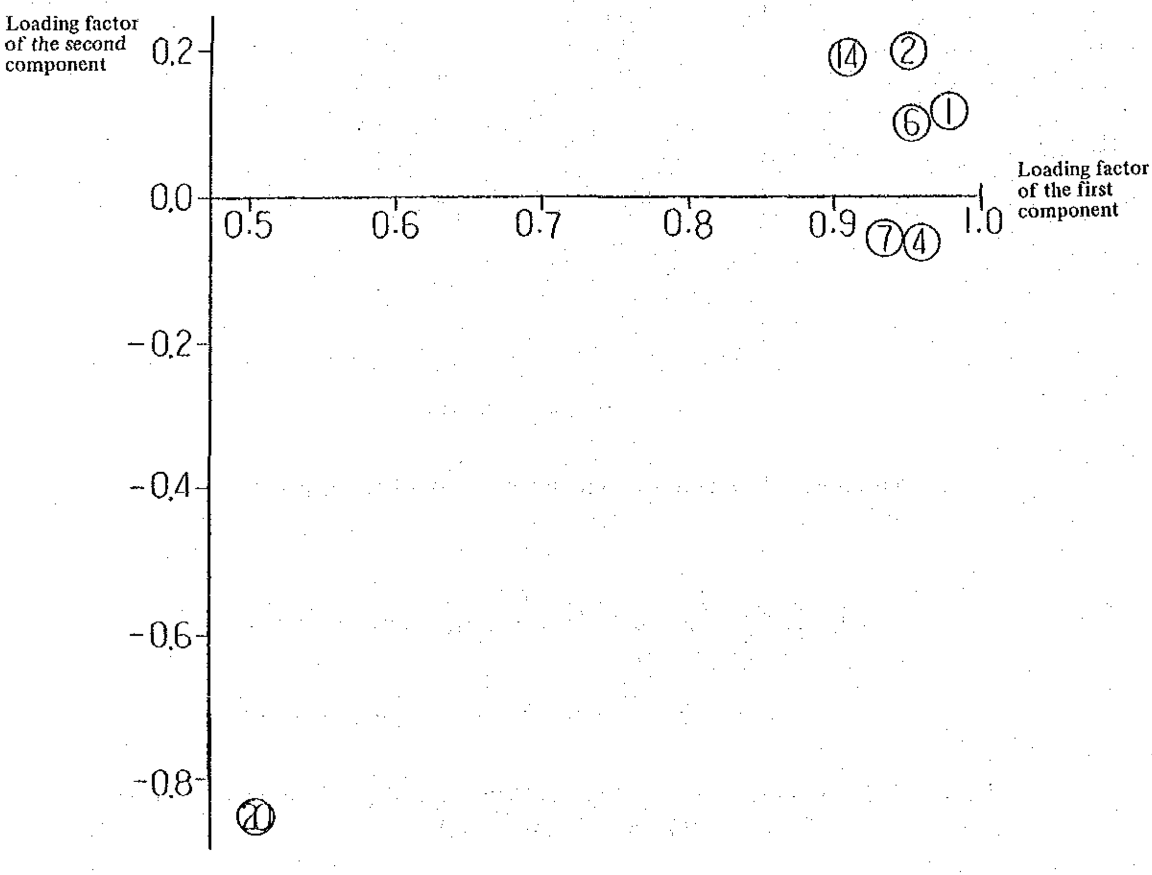


Fig. V-1-10 Results of analyzing principal components

V-1-1-8 Atmospheric stability

Atmospheric stability is the index of thermal stability of atmosphere, and it is related to vertical temperature profiles as in Fig. V-1-11.

In unstable condition, the lapse rate of the air temperature is larger than the dry adiabatic lapse rate, and colder air mass in upper level descends and warmer air mass in lower level ascends to upper layer. Then thermally induced air mass mixing occurs. This is called unstable. On the other hand, when the lapse rate is smaller than the dry adiabatic, lower air mass is heavy and light in upper level. Therefore, air mass mixing is restrained, and this condition is called stable.

Plume diffusion of different stability conditions are typically illustrated as in Fig. V-1-12.

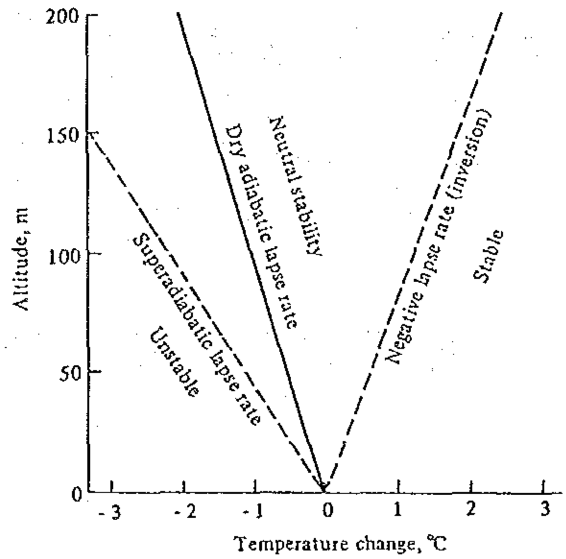


Fig. V-1-11 Atmospheric air-temperature lapse rates

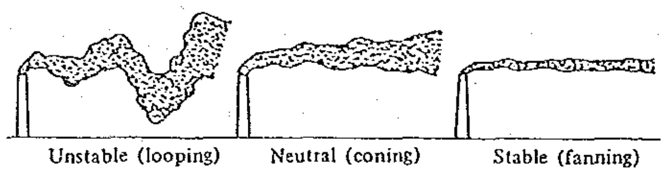


Fig. V-1-12 Characteristic forms of smoke plumes from chimneys (Church 1949 and Slade 1968)

The best way of classification of thermal stability is the method by temperature lapse rate. However, it is not easy technically and also financially to take temperature profile for a long period. Therefore, more convenient methods were proposed and used. One of the common methods of the stability classification is the so-called Pasquill's stability, in which, classifications are done by low level wind velocity, solar radiation and the rate of cloud cover in night time, and this method is adopted in Meteorological Agency of England.

In this report, Japanese MITI's (Ministry of International Trade and Industry) classification which is modified Pasquill's method as shown in Table V-1-6 is adopted. According to this method, we calculated the appearance frequency of atmospheric stability, as shown in Table V-1-7. The frequency distributions of atmospheric stability at MP1 and MP4 in the present survey show almost the same pattern as those of the previous survey.

Table V-1-6 Stability classification systems by MITI's

Wind velocity (m/s) about 10 m above ground		Solar radiation				Net radiation	
		Upper: (cal/cm^2 · hr), lower: (W/m^2)					
Rank of wind velocity	Represent-ative wind velocity	- 50 - 580	49 - 25 579 - 290	24 - 13 289 - 151	12 - 0 150 - 0	0 - -2.9 0 - -34	-3.0 - -35 -
0.0 - 0.3	0.0	CA	CB	CC	CC	CC	CD
0.4 - 0.9	0.6	A	B	B	D	E	F
1.0 - 2.9	2.0	B	B	C	D	E	F
3.0 - 4.9	4.0	B	C	C	D	D	E
5.0 - 7.9	6.5	C	D	D	D	D	D
8.0 -	10.0	D	D	D	D	D	D

* "The manual predicting environmental concentration in the atmosphere at the prior investigation of industrial pollution"

Table V-1-7 Frequency distributions of stability categories

(Unit %)

Monitoring stations	Calm				Windy					
	CA	CB	CC	CD	A	B	C	D	E	F
(MP1) J.T.C. HALL	0.14	0.35	1.54	0.01	0.40	19.29	13.14	23.02	40.06	2.05
(MP2) N.U.S.	0.06	0.13	0.73	0.01	0.33	17.10	14.23	30.97	34.46	1.98
(MP4) BOON LAY APART	0.11	0.25	1.66	0.01	0.70	18.07	13.29	23.97	39.60	2.34
(MP6) NANYANG.T.I.	0.54	0.99	9.46	0.26	2.53	23.38	5.69	15.56	39.18	2.41
(MP7) BUKIT PANJANG P.P.	0.31	1.13	31.47	1.37	1.33	24.19	4.84	13.38	20.56	1.42
(MP14) KALLANG F.F.	0.13	0.28	6.52	0.11	0.63	22.37	10.30	17.57	39.66	2.43
(MP20) SINGAPORE O.P.S.	0.64	1.22	17.97	0.65	3.02	20.50	7.33	15.48	31.04	2.15

V-1-1-9 Temperature

As mentioned before, vertical temperature profile is closely related to atmospheric stability and plume diffusion. In this study, the air temperature at two different levels (1.5 m and 30 m above ground) were continuously measured at MP1.

Fig. V-1-13 shows the monthly variations. In every month, the temperature at 30 m was higher than that of 1.5 m.

Fig. V-1-14 shows the hourly variations at two levels. The difference was very small in daytime, but in nighttime the temperature at 30 m level becomes 0.7^{o}C higher than 1.5 m level. This tendency is adverse to general tendency. This is probably due to the difference of the conditions of measuring points. The lower measuring point is located above lawn and higher one is located above concrete. So in the daytime, the radiation heat of upper point is higher than that of lower point, and the temperature of upper point becomes higher.

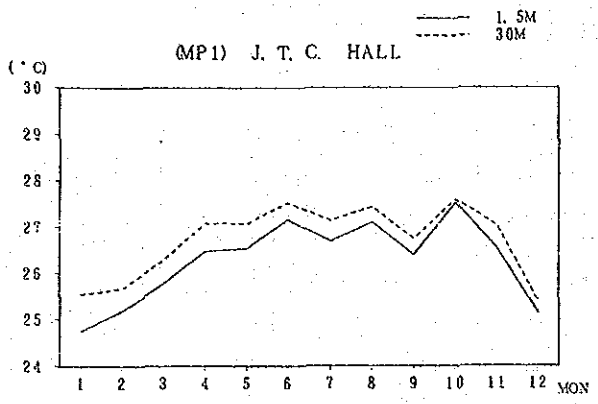


Fig. V-1-13 Monthly variations of temperature

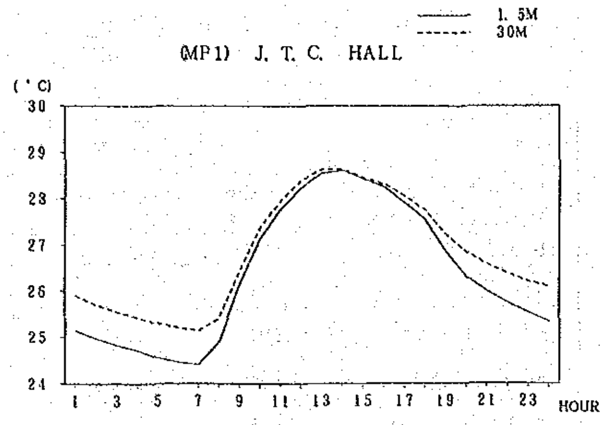


Fig. V-1-14 Hourly variations of temperature

Table V-1-8 shows the daytime and nighttime averages of temperature for two seasons and one year. For the annual averages, the temperature of 30 m level was about 0.4°C higher than that of 1.5 m level.

The temperature difference between 30 m and 1.5 m (T_{30} - $T_{1.5}$) classified by wind velocity rank and the net radiation is shown in Table V-1-9. It shows that the greater the difference of temperature between 30 m and 1.5 m, the more stable the atmospheric stability is. So it means that temperature gradient corresponds to atmospheric stability.

Table V-1-8 Average temperature classified by season and day/night

(Unit; °C)

Height	Southerly Monsoon			Northerly Monsoon			Yearly Average		
	Day time	Night time	Through day	Day time	Night time	Through day	Day time	Night time	Through day
30 m above ground	28.0	26.5	27.2	27.3	25.0	26.0	27.8	26.0	26.8
1.5 m above ground	28.0	25.9	26.8	27.0	24.3	25.5	27.6	25.3	26.4
30 m - 1.5 m	0.0	0.6	0.4	0.3	0.7	0.5	0.2	0.7	0.4

Table V-1-9 Temperature difference ($T_{30} - T_{1.5}$) classified by wind velocity and net radiation

Ranks of net radiation flux (cal/cm^2 hr)	Windy (u ≧ 0.5 m/s)			Calm (u ≦ 0.4 m/s)		
	Hours	Average temperature difference (°C)	Standard deviation (°C)	Hours	Average temperature difference (°C)	Standard deviation (°C)
-3.0 and below	198	0.98	0.59	3	1.87	0.19
-2.9 ~ 7.9	4832	0.50	0.53	107	0.85	0.60
8.0 and over	2168	0.09	0.57	48	0.37	1.01

V-1-2 Analysis of SO_2 Concentration

To clarify the variations of SO_2 concentration in space and time, and also its dependence on meteorological conditions, SO_2 data were analyzed. The data were the SO_2 concentration, wind direction, wind velocity and etc.

V-1-2-1 Monthly variations of SO_2 concentration

In Fig. V-1-15, monthly variations of SO_2 concentration are shown. At MP1 and MP4, the results of previous investigation (which was conducted from July 15 1981 to July 14 1982) are also plotted by dotted line. At MP1, MP2, MP14 and MP20, there are two peaks, one is between March and May and the other is between September and November. At MP4, MP6 and MP7, SO_2 concentrations between March and October are higher than the concentrations between November and February. This is probably due to the relation among the locations of emission sources, monitoring stations and also the direction of prevailing wind.

V-1-2-2 Hourly variations of SO_2 concentration

In Fig. V-1-16, hourly variations of SO_2 concentration are shown. At MP1 and MP4, the results of previous investigation are also plotted. At every station, concentration in daytime is higher than in nighttime. Especially, this tendency at MP4, MP6 and MP7 is clear. This is due to the prevailing wind in daytime (southerly wind) and the locations of monitoring stations. At MP1 and MP4, there are no clear difference between the previous investigation and this investigation.

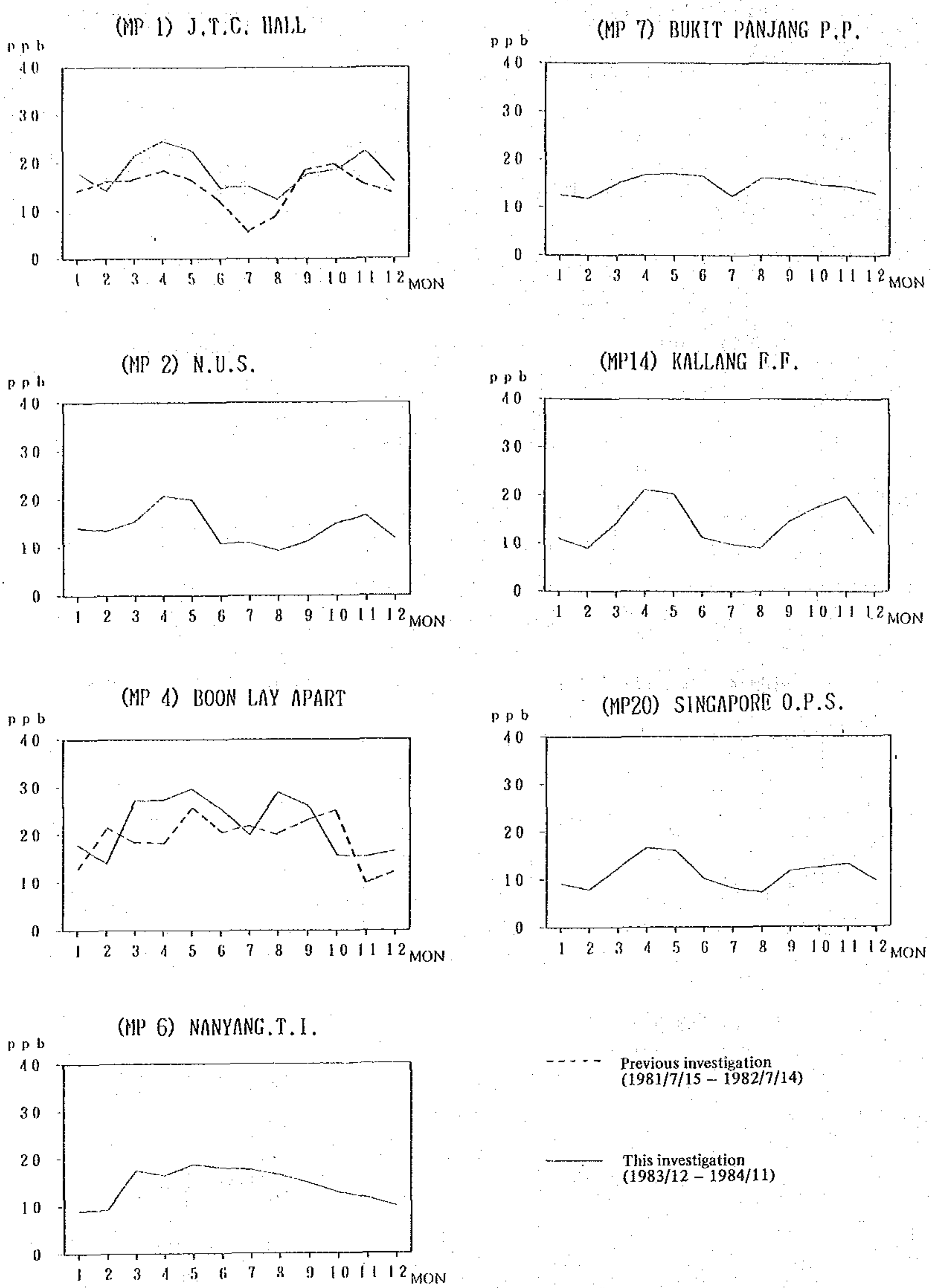


Fig. V-1-15 Monthly variations of SO_2 concentration

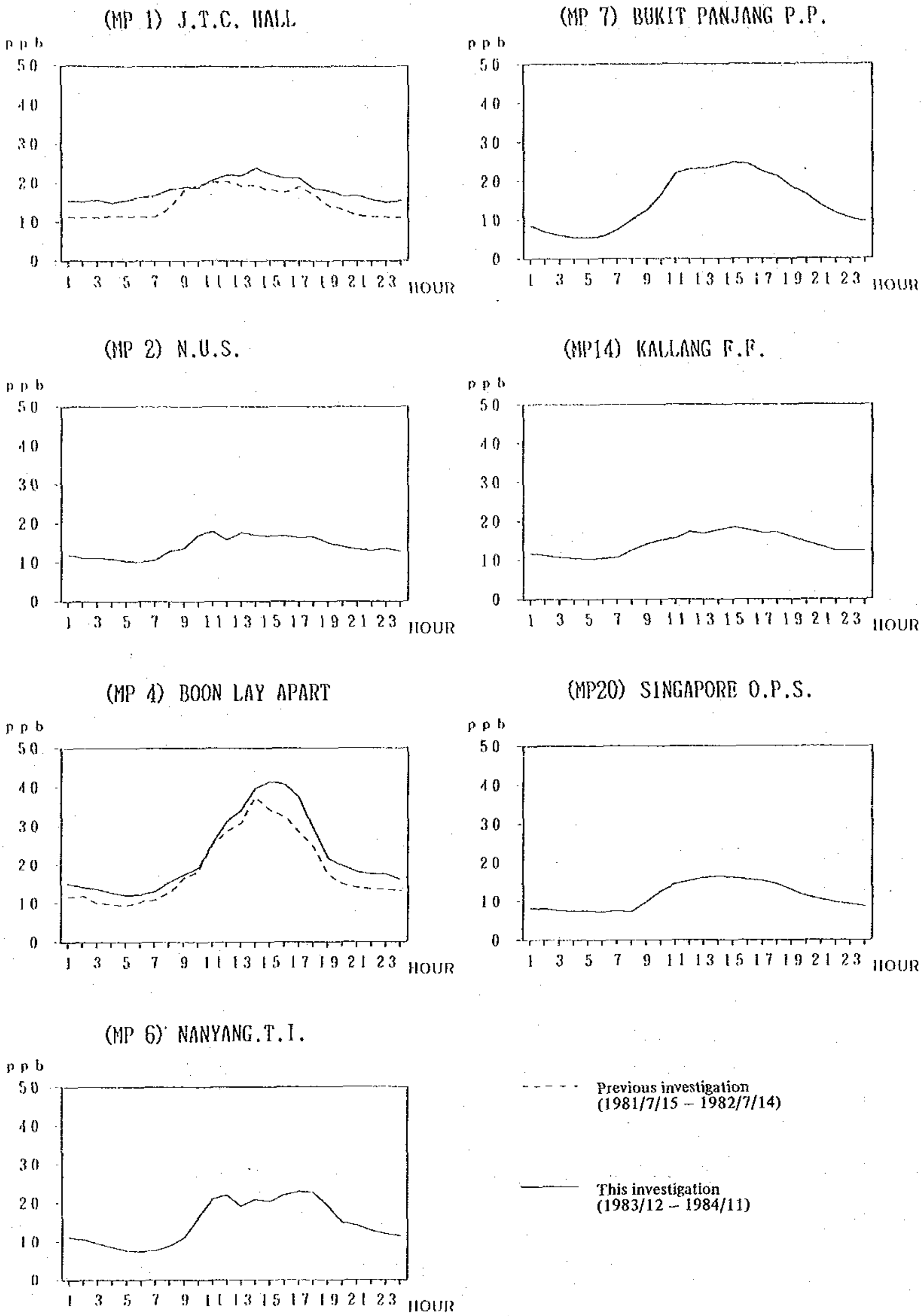


Fig. V-1-16 Hourly variations of SO_2 concentration

V-1-2-3 Frequency distribution of SO_2 concentration

R. I. Larsen (1969) has found out from statistical analysis of concentration data of atmospheric pollutants that the frequency distribution of pollution follows a log normal profile, and he has proposed following mathematical model:

$$f(c) = \frac{1}{\sqrt{2\pi}\, Sg} \exp\left\{-\frac{(\ell n C - \ell n mg)^2}{2Sg^2}\right\} \qquad \text{Equation V-1-4}$$

where the symbols are;

f(c): frequency occurrence of concentration level c

mg : Arithmetic mean of concentration and denoted by

$$mg = \exp\left(\frac{\sum_{i=1}^{n} \ell n Ci}{n}\right)$$

Sg : Arithmetic standard deviation of concentration

$$Sg = \exp\sqrt{\frac{\sum_{i=1}^{n} (\ell n Ci - \ell n mg)^2}{n}}$$

Fig. V-1-17 shows cumulative frequency distributions of hourly and daily averaged SO_2 concentration plotted in log normal charts. The cumulative frequency distribution is calculated by accumulating the frequency of concentration level C from lower level and evaluate the frequency by C.

For the hourly data, lines are almost straight and clear, log normal profiles are obtained for hourly averages. For daily averages, even some of the lines show slight kinks at low and high level, the frequency distributions follow nearly log normal profiles.

The gradients of the lines are equal to Sg, the standard deviations of concentration, and Sg is larger for slower slope. And the concentration at cumulative frequency of 50 percent is equal to the arithmetic mean mg. Assuming the log-normal profile, the value of Sg is calculable from the curve by the following equation:

$$Sg = \exp\left\{\frac{\ell n(Ca/Cb)}{Za-Zb}\right\} \qquad \text{Equation V-1-5}$$

where, the symbols are as follows;

Ca, Cb: Concentration level at cumulative frequency a and b, respectively.

Za, Zb: Standard deviation number of concentration at cumulative frequency a and b, respectively.

R. I. Larsen adopted 99.9 percent and 50 percent as a and b, where the profiles follow log-normals well. Then, Za and Zb are equal to 3.09 and 0.52, respectively, the arithmetic standard deviation of hourly concentration, if SO_2 calculated by Equation V-1-5 for seven stations, are shown in Table V-1-10. These values are slightly larger than the values commonly obtained in Japan.

Table V-1-10 Arithmetic standard deviation of hourly SO_2 concentration

Monitoring stations	Arithmetic standard deviation
(MP1) J.T.C. HALL	2.03
(MP2) N.U.S.	2.30
(MP4) BOON LAY APART	2.81
(MP6) NANYANG.T.I.	2.54
(MP7) BUKIT PANJANG P.P.	2.30
(MP14) KALLANG F.F.	1.96
(MP20) SINGAPORE O.P.S.	2.26

The relation of cumulative frequency distribution is effectively used to estimate the concentration corresponding to cumulative frequency of a value and vice versa.

The values of daily average concentration at cumulative frequency 98 percent (the highest value of concentration data set in which highest 2 percent are excluded) are shown in Table V-1-11, together with the highest values corresponding to 100 percent of the hourly averages.

Table V-1-11 Values of 98% cumulative of daily average and the maximum values of hourly data

(unit; ppb)

Monitoring stations	Values of 98% cumulative daily average	Maximum values of daily average data	Maximum values of hourly data
(MP1) J.T.C. HALL	33	45	190
(MP2) N.U.S.	27	42	198
(MP4) BOON LAY APART	54	78	430
(MP6) NANYANG.T.I.	37	46	215
(MP7) BUKIT PANJANG P.P.	28	35	172
(MP14) KALLANG F.F.	29	36	164
(MP20) SINGAPORE O.P.S.	23	33	157

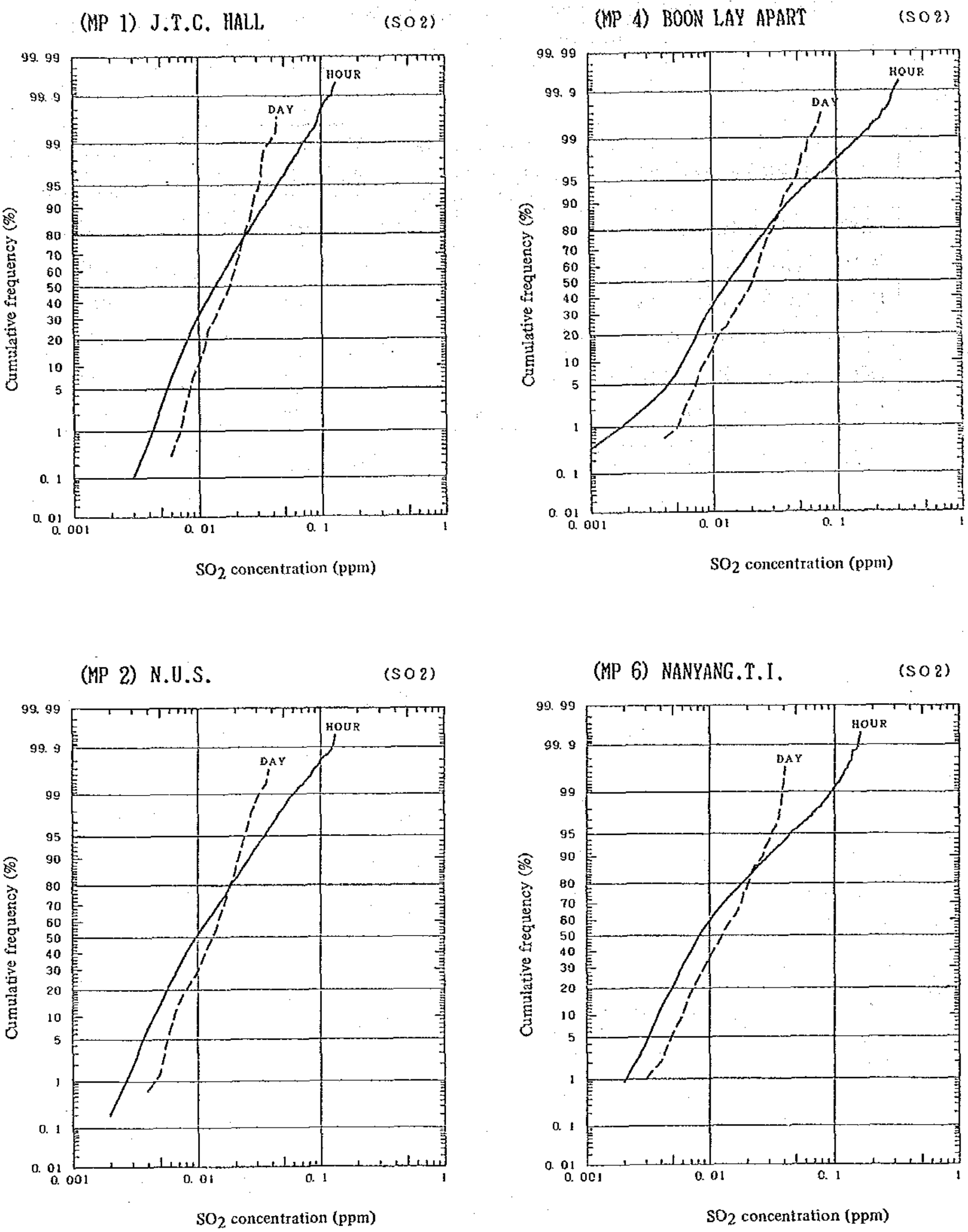
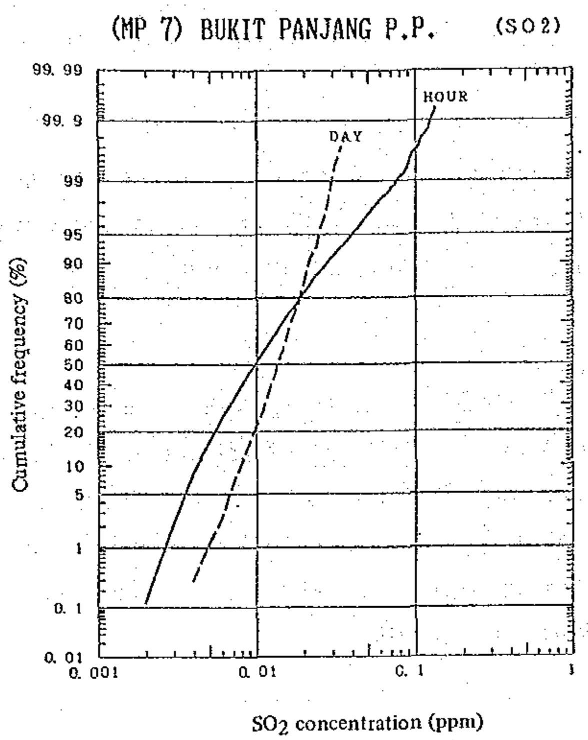
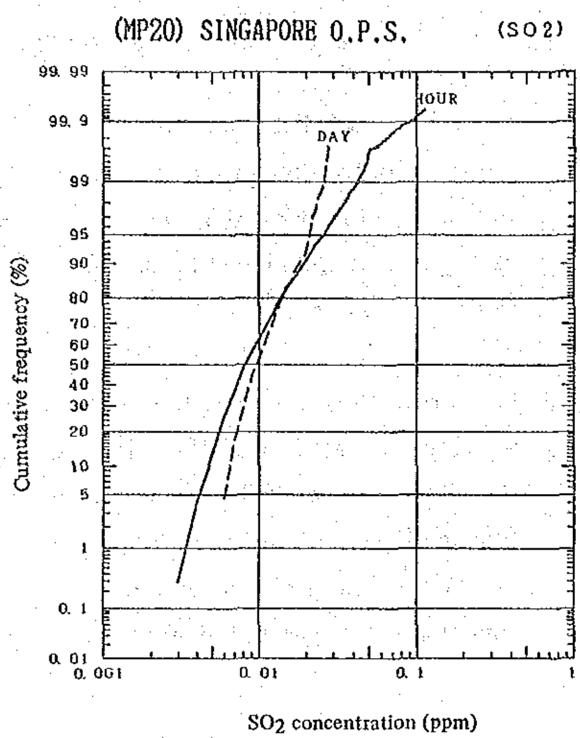


Fig. V-1-17-(1) Cumulative frequency distribution of hourly and daily average SO_2 concentration





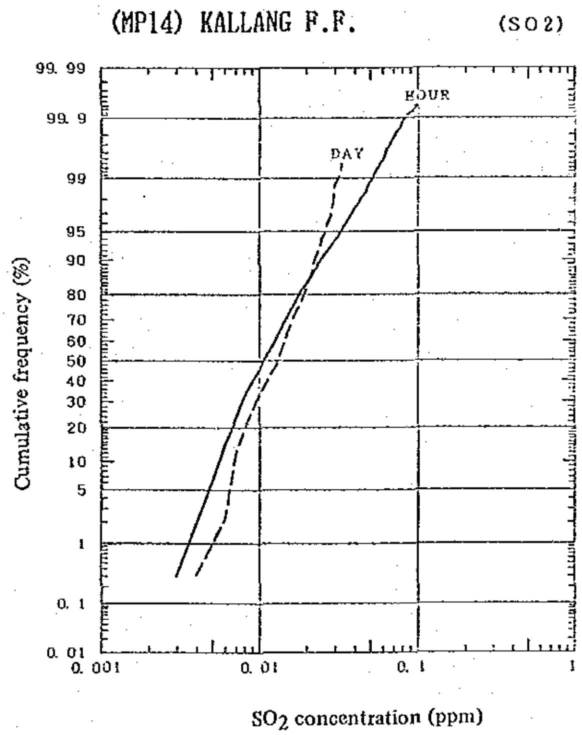


Fig. V-1-17-(2) Cumulative frequency distribution of hourly and daily average SO_2 concentration

V-1-2-4 Dependence of SO_2 concentration on wind direction and wind velocity ranks

The wind direction and wind velocity is the most important controlling factors for environmental concentration. The SO_2 concentration data were analyzed and averages as for each wind direction together with wind velocity ranks were calculated. The results are shown in Fig. V-1-18. In each wind direction, average concentrations for six velocity ranks are plotted.

From these results, the wind directions in appearing relatively high concentration can be seen. At MP1, the directions are SW and WSW. At MP4, the direction is S. At MP6, the direction is SSE. At MP7, the directions are SSW and SW. These characters are reasonable from the view of the locations of emission sources and monitoring stations. For MP14 and MP20, of which not any large emission sources exist around, dependences of concentration on wind direction and velocity are very small.

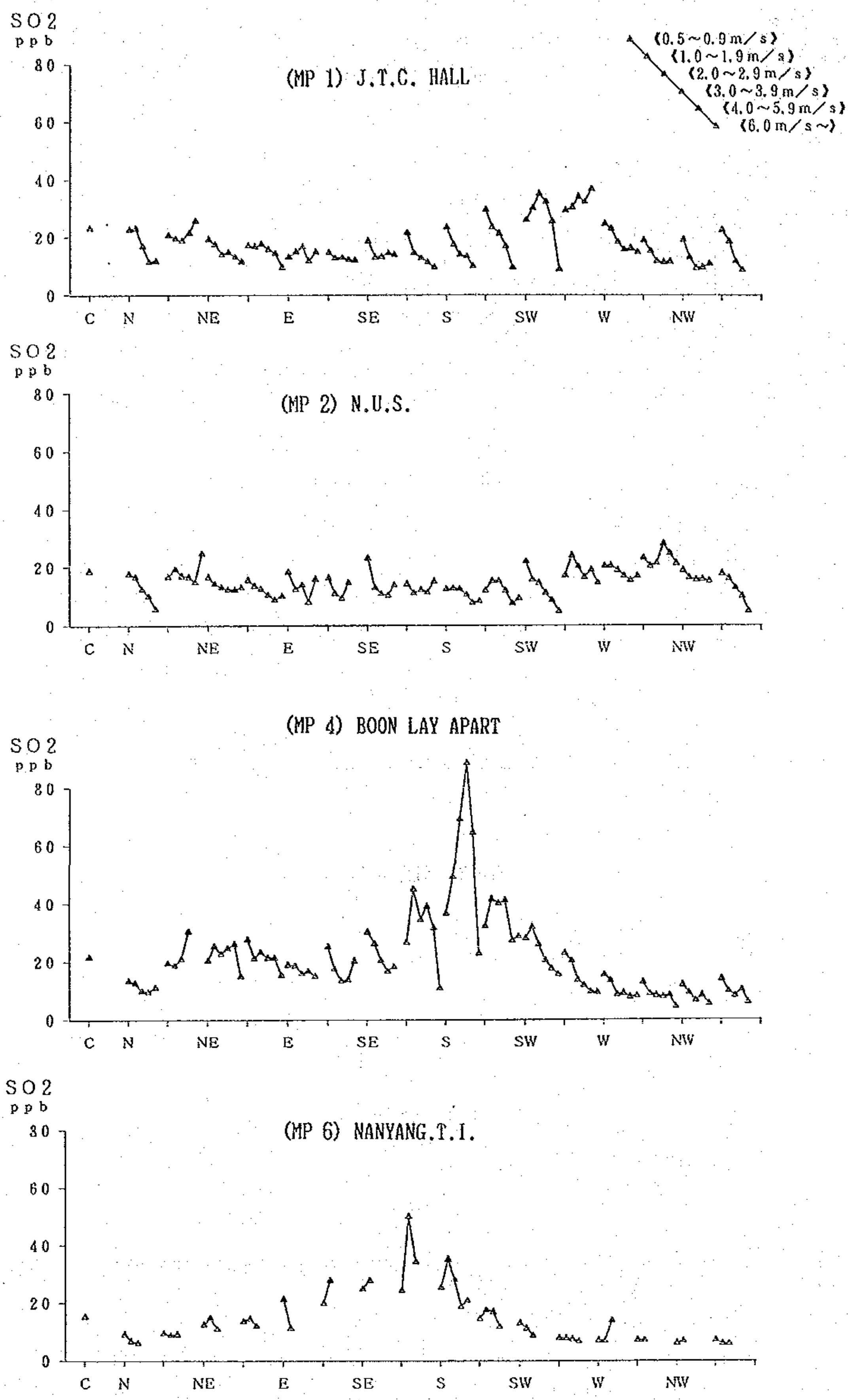


Fig. V-1-18-(1) Average SO_2 concentration for wind direction and velocity ranks

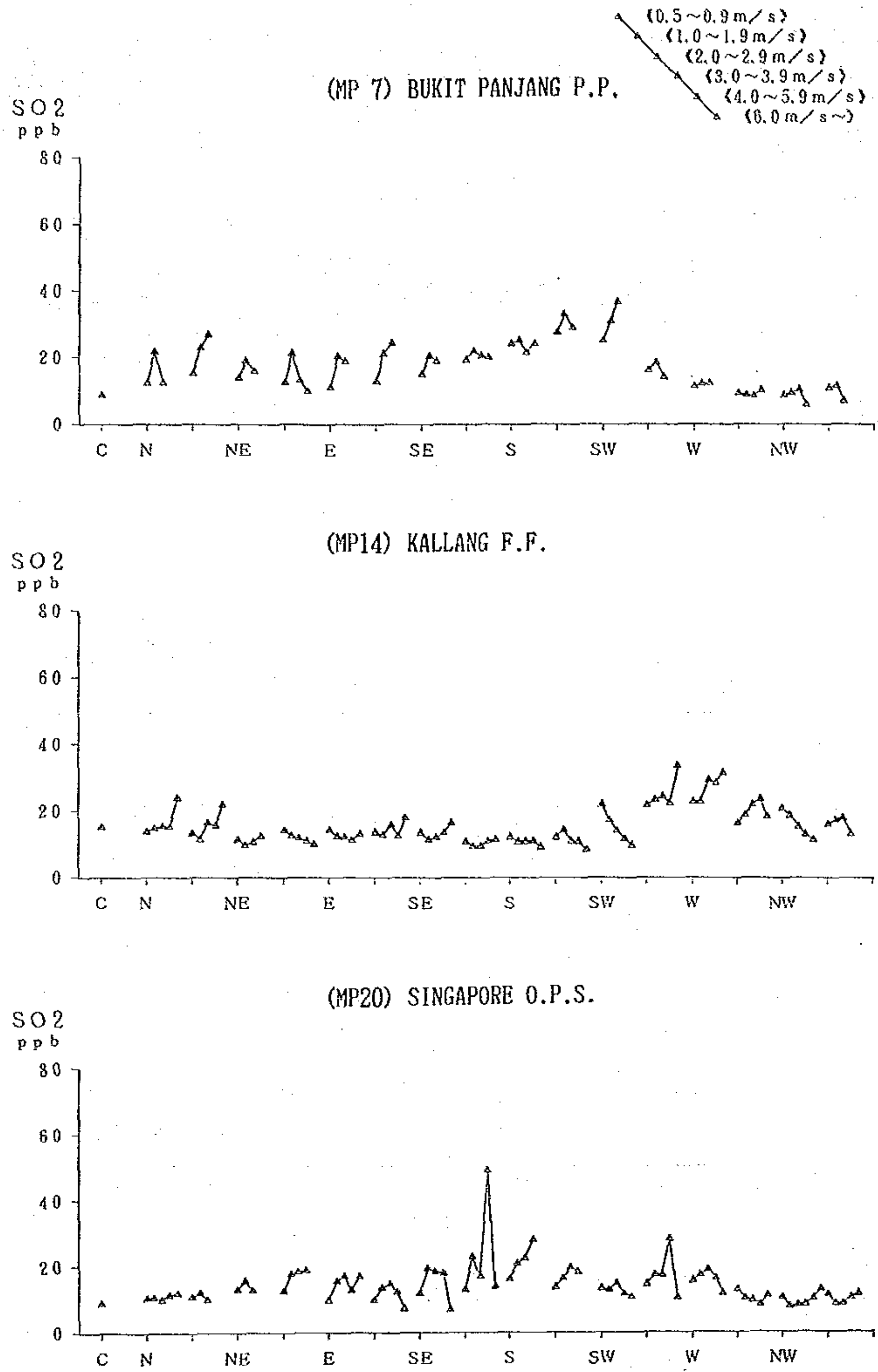


Fig. V-1-18-(2) Average SO_2 concentration for wind direction and velocity ranks

V-1-3 Analysis of SPM (Suspended Particulate Matters) Concentration by Beta ray Dust Analysers

To grasp the characteristics of spatial and time series variations of SPM concentration and the relation between the meteorological conditions and environmental concentration of SPM, the following data analysis were performed - the analysis of SPM concentration, the analysis of relation between SPM concentration and meteorological factors and so on.

V-1-3-1 Monthly variations of SPM concentration by Beta ray dust analysers

Fig. V-1-19 shows the monthly variations of SPM concentration at each monitoring station. At each monitoring station, relatively high concentration continues from March through May and from October through November. The tendency is resemble closely with that of SO_2.

V-1-3-2 Hourly variations of SPM concentration by Beta ray dust analysers

Fig. V-1-20 shows the hourly variations of SPM concentration. At each station, there appears the relatively higher concentration in nighttime than in daytime. The tendency of SPM is adverse to that of SO_2. The appearance of relatively high concentration at 9 o'clock is commonly seen at each station. At each station, the hourly variations do not show the seasonal different pattern.

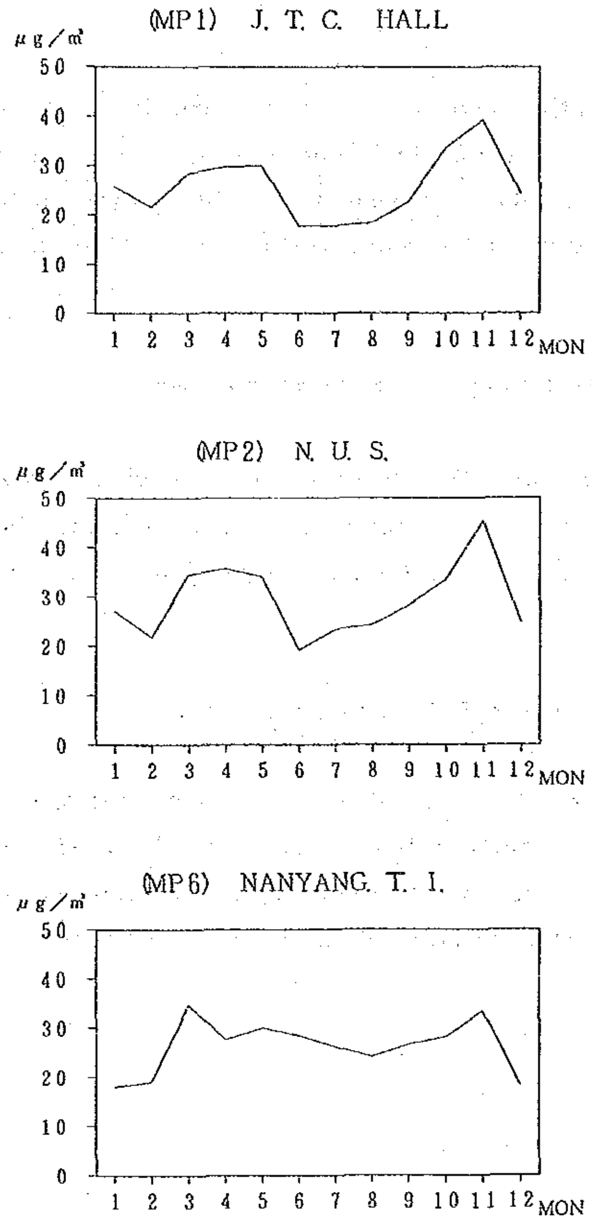


Fig. V-1-19 Monthly variations of SPM concentration

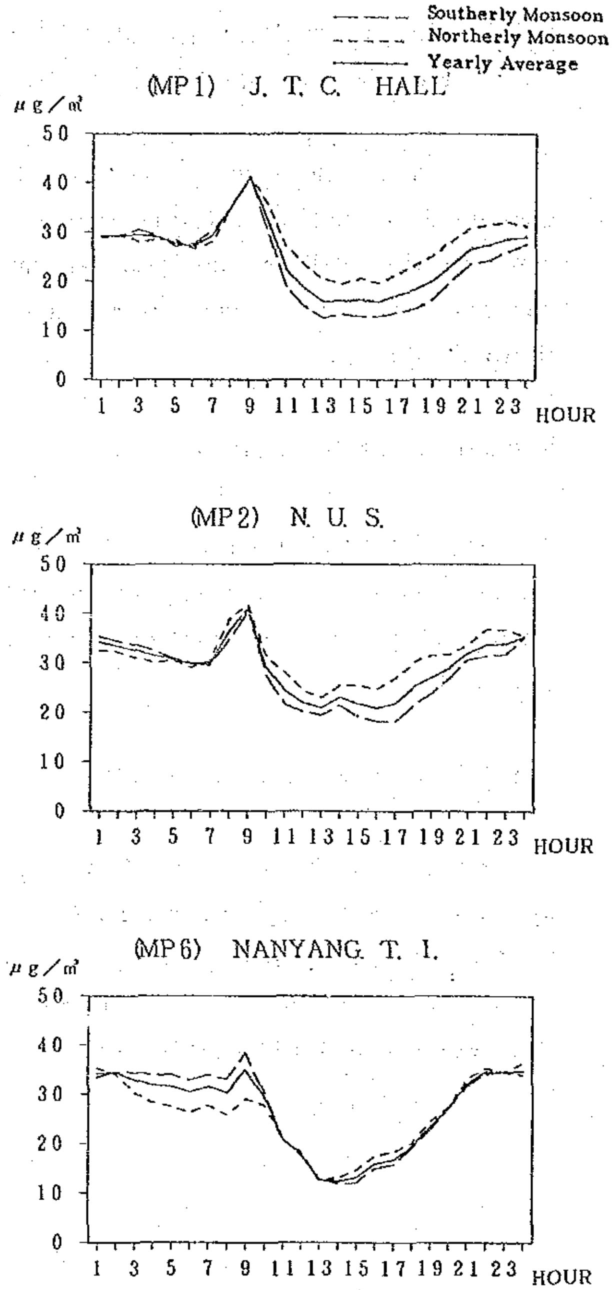


Fig. V-1-20 Hourly variations of SPM concentration

V-1-3-3 Weekly variations of SPM concentration by Beta ray dust analysers

Table V-1-12 and Fig. V-1-21 show weekly variations of SPM concentration. From the result, the relatively low concentration appears on Sunday, which seems to be caused by the decrease of traffic on Sunday. Then we consider the ratio (γa), which is calculated SPM concentration on Sunday divided by the average concentration of weekday.

At MP1, MP2 and MP6, each value (γa) is 0.796, 0.847 and 0.917. And also, on Monday and Saturday, SPM concentration is slightly lower.

Table V-1-12 Weekly variations of SPM concentration by Beta ray dust analysers

(Unit; $\mu g/m^3$)

Monitoring stations	Average concentration							Aver-age	γa
	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.		
(MP1) J.T.C. HALL	20.6	23.4	27.7	25.9	28.9	27.7	21.7	25.2	0.796
(MP2) N.U.S.	25.2	26.7	30.2	31.3	31.9	31.6	26.8	29.1	0.847
(MP6) NANYANG.T.I.	24.7	23.2	28.1	27.3	30.1	27.4	25.6	26.6	0.917

* γa = (SPM concentration of Sunday/average concentration of weekday)

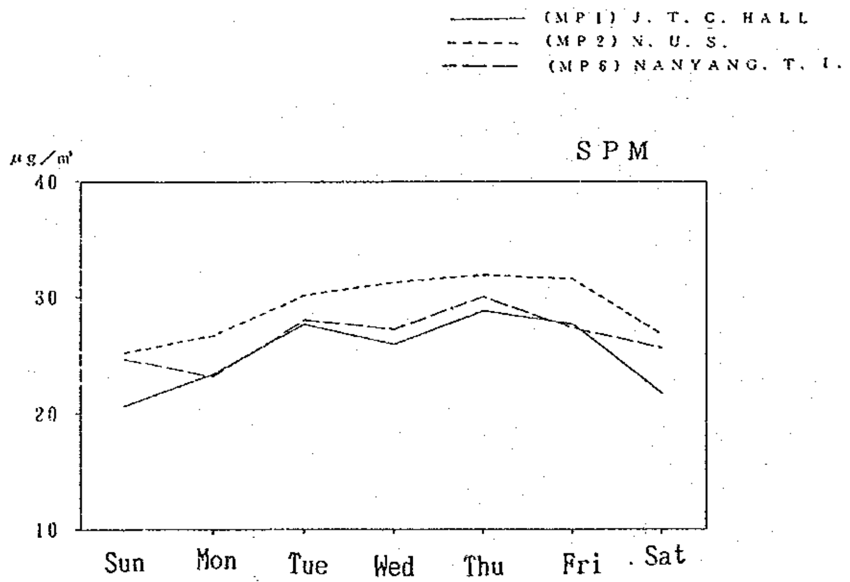


Fig. V-1-21 Weekly variations of SPM concentration by Beta ray dust analysers

V-1-3-4 Frequency distribution of SPM concentration by Beta ray dust analysers

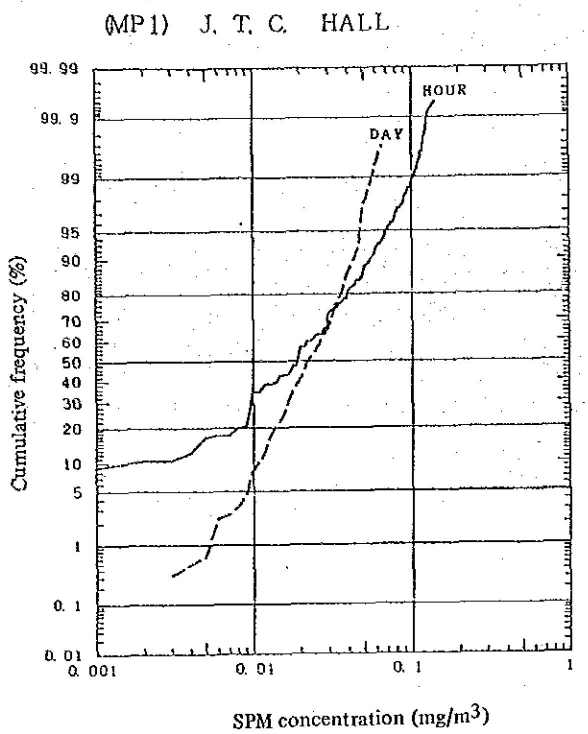
Cumulative frequency distribution of SPM concentrations hourly and daily averaged are shown in Fig. V-1-22.

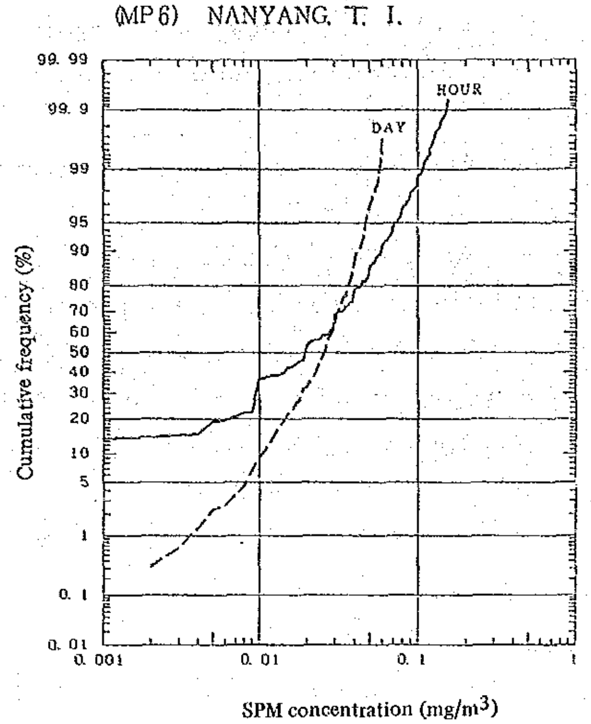
Geometrical standard deviations (Sg) of hourly data calculated by Equation V-1-5 are shown in Table V-1-13. Comparing with Sg of SO_2, Sg of SPM is lower than that of SO_2. This shows that the gradient of cumulative frequency curve of SO_2 is gentle and the variation of SO_2 concentration is greater than that of SPM concentration.

Table V-1-13 shows the values of 98 percent cumulative of daily average, maximum of the hourly values and maximum of daily average values.

Table V-1-13 Values of 98% cumulative of daily average concentration the maximum of daily average concentration, etc.

Monitoring Stations	Geometrical standard deviation	98% cumulative of daily average (μg/m^3)	Maximum value of daily average (μg/m^3)	Maximum value of hourly data (μg/m^3)
(MP1) J.T.C. HALL	1.76	50	76	160
(MP2) N.U.S.	1.79	61	89	185
(MP6) NANYANG.T.I.	1.80	52	68	190





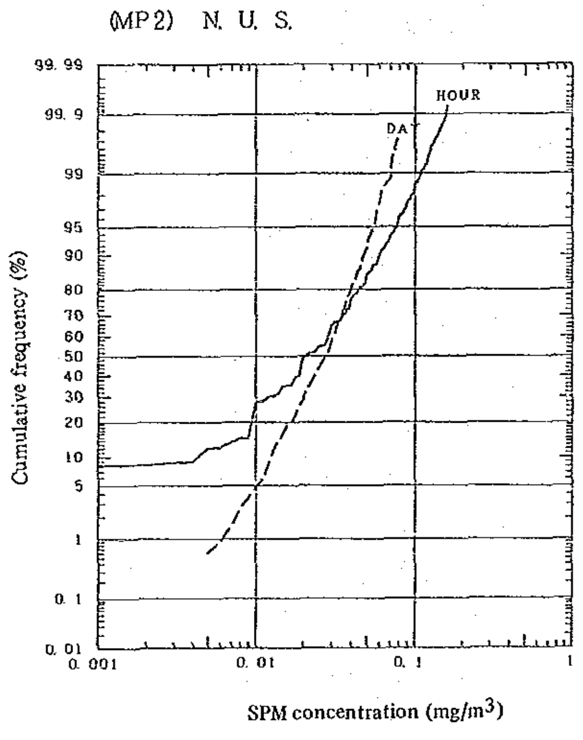


Fig. V-1-22 Cumulative frequency distribution of hourly and daily average SPM concentration

V-1-3-5 Dependence of SPM concentration by Beta ray dust analysers on wind directions and wind velocity ranks

Fig. V-1-23 shows average concentration of SPM on wind direction and wind velocity.

At each station, relatively high concentration appears in northerly wind and relatively low concentration in southerly wind. This tendency is opposed to the tendency of SO_2. But it does not always show that there is a main source to the north because there are many kinds of source. And there is other tendency that the greater wind velocity is, the lower the concentration of SPM is.

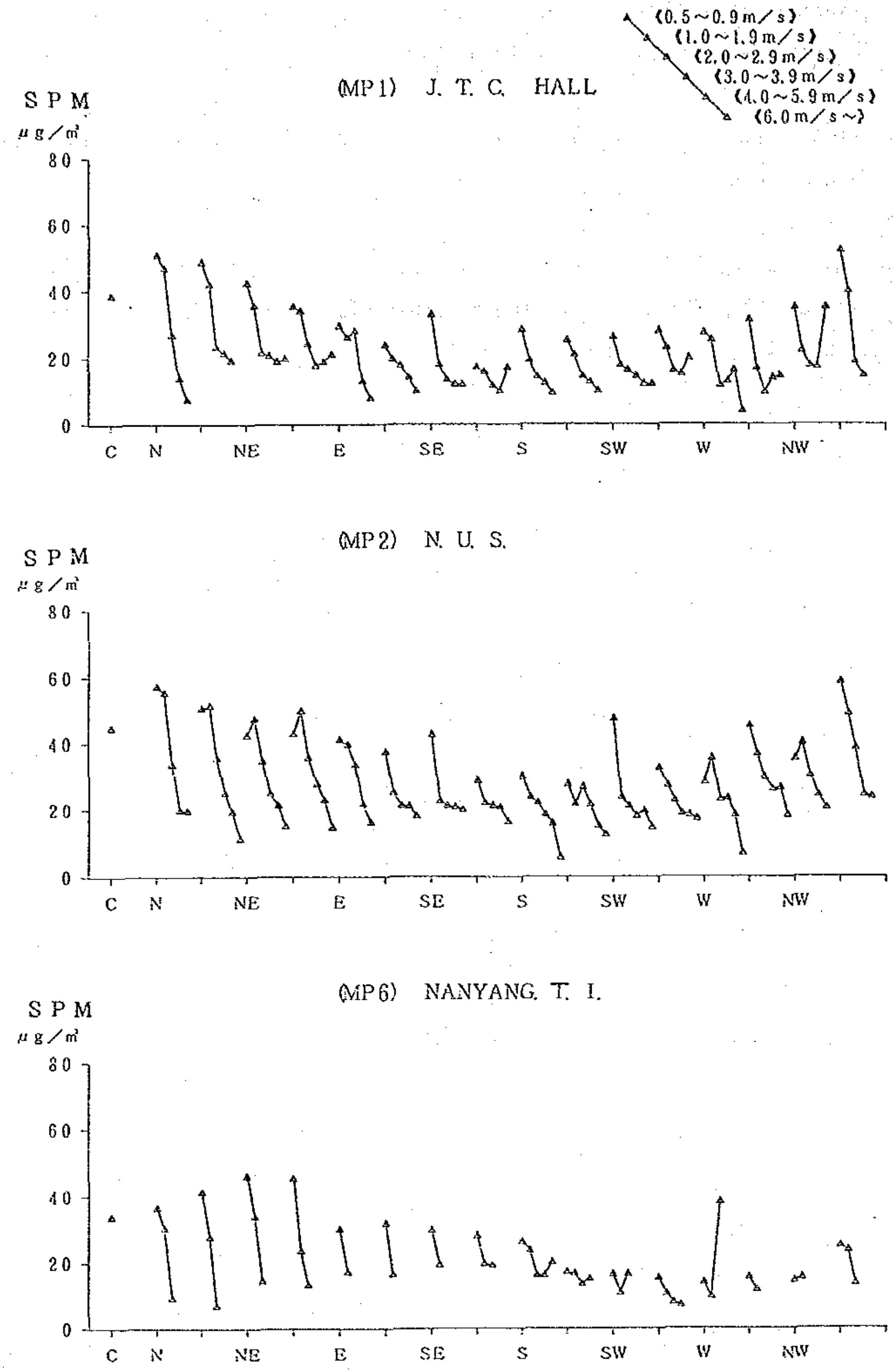
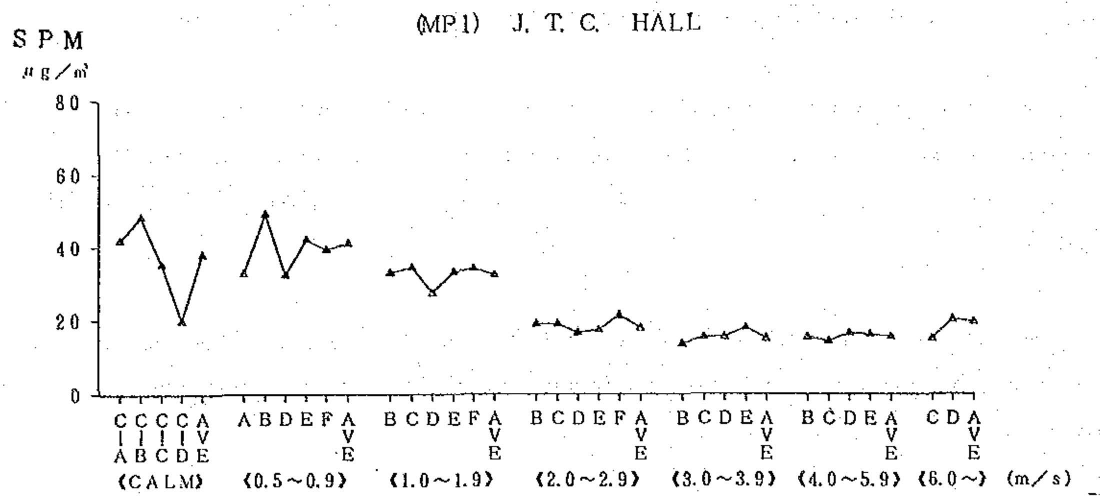


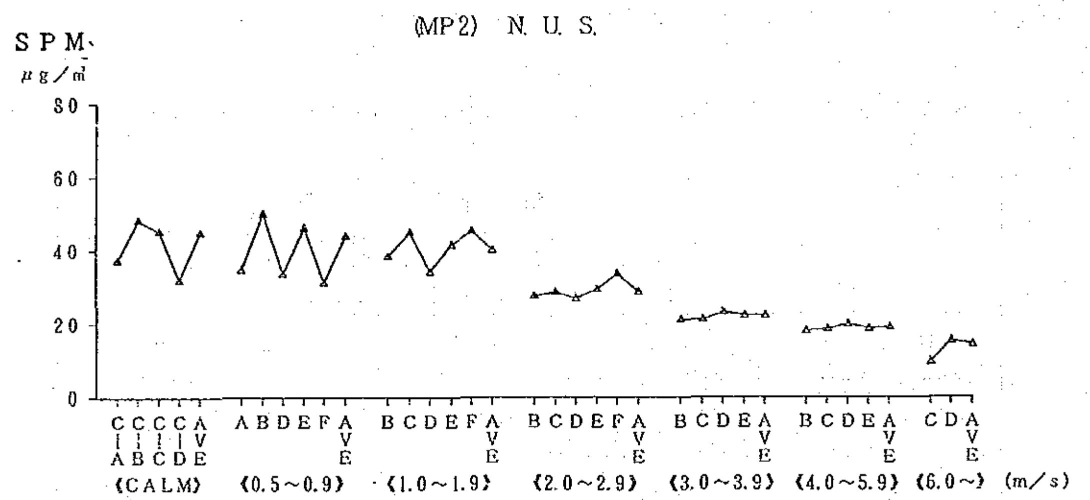
Fig. V-1-23 SPM concentration on wind direction and wind velocity ranks

V-1-3-6 Dependence of SPM concentration by Beta ray dust analysers on wind velocity ranks and atmospheric stability

Fig. V-1-24 shows the average concentration of SPM for wind velocity and atmospheric stability.

From this figure, it is clear that the greater the wind velocity is, the lower the concentration of SPM become. But the relationship between the concentration and the atmospheric stability is not clear.





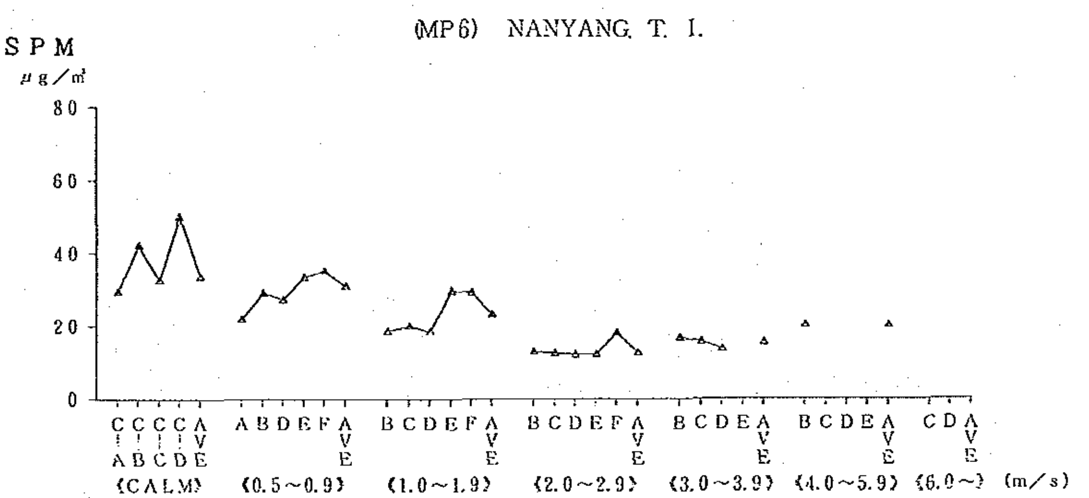


Fig. V-1-24 SPM concentration on wind velocity ranks and atmospheric stability

V-1-3-7 Correlation of SPM concentration between monitoring stations

Table V-1-14 shows correlation coefficients of SPM concentration (measured by Beta ray dust analysers) between monitoring stations. The coefficient calculated by yearly averaged data between MP1 and MP2 is relatively high (0.616), other coefficients are relatively low.

The reason seems that the distance between MP1 and MP2 is closer than that of others and the variation patterns of average concentration for wind direction of MP1 and MP2 are resemble. (See Fig. V-1-23)

Fig. V-1-25 shows the relationship between concentrations of monitoring stations. In these figures, numeral mean the number of data in each concentration rank.

Table V-1-14 Correlation coefficients of SPM concentration between monitoring stations

Monitoring stations	Southerly Monsoon (April - October)	Northerly Monsoon (November - March)	Yearly average
(MP1) —— (MP2) J.T.C. HALL N.U.S.	0.640	0.576	0.616
(MP1) —— (MP6) J.T.C. HALL NANYANG.T.I.	0.488	0.406	0.451
(MP2) —— (MP6) N.U.S. NANYANG.T.I.	0.391	0.371	0.378

Y : (MP2) N.U.S.

μ g / m³

Y = 0.6625 X +12.3647
EFFECTIVE CASES = 7510
CORRELATION COEFFICIENT = 0.616
STANDARD DEVIATION = 19.19

Y \ X	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199
190 - 199																				
180 - 189												1			1					
170 - 179											1	2								
160 - 169				1			1				1									
150 - 159									1	1	1	1					1			
140 - 149				3			1		1		1	1								
130 - 139							1	1	1	3	1									
120 - 129				1	1		3	5	4	6	3	4	2							
110 - 119	1				3	4	4	5	4	3	1	1	1		1					
100 - 109		2	1	2	8	6	8	11	5	11	3	3	4		1					
90 - 99		4	4	4	12	12	11	13	6	6	8		1							
80 - 89	3	3	10	16	12	24	18	22	15	10	10	4	1							
70 - 79	3	15	17	29	30	26	30	15	12	4	2	5	2		1					
60 - 69	6	31	44	55	53	52	29	18	14	12	5	2	4			1				
50 - 59	25	66	82	77	66	60	30	20	13	3	3	2	5							
40 - 49	69	147	160	137	81	66	39	16	11	3		1	1							
30 - 39	156	282	255	172	105	54	34	15	13	9	4	1	1							
20 - 29	286	452	280	185	76	55	20	13	2	3	1		1							
10 - 19	510	643	372	181	68	37	13	5	3		2	1	1							
0 - 9	443	413	167	58	23	10	4	1		1	1									

X : (MP1) J.T.C. HALL μ g / m³

Fig. V-1-25-(1) Frequency in each concentration rank of SPM

Y : (MP6) NANYANG.T.I.

μ g / m³

Y = 0.4857 X 114.7855
EFFECTIVE CASES = 6845
CORRELATION COEFFICIENT = 0.451
STANDARD DEVIATION = 21.92

Y \ X	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199
190 - 199				1																
180 - 189																				
170 - 179										1										
160 - 169										1						1				
150 - 159		1		1				1												
140 - 149				1				2			1	1	1							
130 - 139			1					2	2	1	1									
120 - 129		2	1	2	4	1	1	3			2	2					1			
110 - 119	2		2	4	2	4	4	1	5	2	1	2	2							
100 - 109	5	1	3	4	6	9	13	7		3		1	2							
90 - 99	2	8	4	8	12	13	5	5	1	4		2								
80 - 89	2	10	17	20	12	18	12	7	9	1	3	3	3							
70 - 79	6	20	27	26	27	19	9	17	9	4	2	3	2		1					
60 - 69	13	41	57	42	34	35	19	13	11	7	5	2	2		1					
50 - 59	33	96	80	79	46	43	30	13	21	6	10	2	4							
40 - 49	67	145	135	86	55	40	34	22	12	13	8	3	2		1					
30 - 39	128	232	174	105	87	57	35	21	10	9	3	3	2							
20 - 29	221	303	197	140	75	49	28	14	9	11	5	1	2							
10 - 19	419	515	297	174	64	46	25	13	7	2	4									
0 - 9	530	503	239	121	56	34	13	7	5	2	1									

X : (MP1) J.T.C. HALL

μ g / m³

Fig. V-1-25-(2) Frequency in each concentration rank of SPM

Y = 0.3773 X +15.8024
EFFECTIVE CASES = 7356
CORRELATION COEFFICIENT = 0.378
STANDARD DEVIATION = 22.57

Y : (MP6) NANYANG.T.I. (μg/m³)

X : (MP2) N.U.S. (μg/m³)

Y \ X	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199
190 - 199					1															
180 - 189																				
170 - 179				1																
160 - 169					1		1													
150 - 159				1		1				2	2									
140 - 149			1	1		1	1			1	1									
130 - 139	1						1	1	1	2	1									
120 - 129		2	3	3	1	2		2	4		1					1				
110 - 119	3	1		2	4	6	4	4	2	1	2	2			1			1		
100 - 109	2	3	3	5	6	7	6	7	8	3	3	1	1		1					
90 - 99	3	6	7	13	7	6	7	3	4	4	4		1							
80 - 89	3	9	9	16	26	14	11	8	7	5	4	2	5		1					
70 - 79	8	22	24	27	23	21	21	11	12	6	2	1	2			1		1	1	
60 - 69	15	46	32	41	40	45	38	12	9	5	3	4	4	3	1	1	1			
50 - 59	32	92	66	92	58	40	45	32	17	9	6	3	2		1			1	1	
40 - 49	60	118	119	128	90	63	32	20	15	12	6	5	6			2				
30 - 39	93	243	175	135	93	73	51	28	19	8	5	6	1	2	1		1			
20 - 29	172	271	230	182	112	69	32	27	27	14	9	4	2	2						
10 - 19	314	474	350	245	143	71	46	27	14	12	5	1					1			
0 - 9	376	499	329	174	108	48	31	10	8	3	4	1	1	1	1					

Fig. V-1-25-(3) Frequency in each concentration rank of SPM

V-1-3-8 Analysis of high concentration of SPM by Beta ray dust analysers

To grasp the meteorological conditions and SO_2 concentration at high concentration of particulate matter, analysis of high concentration of SPM was performed with hourly data and daily averaged data.

(1) Analysis of high concentration of hourly data

We put in order the highest 50 hours of SPM concentration and meteorological conditions (wind direction, wind velocity, atmospheric stability, SO_2 concentration etc.) in Table V-1-15. The conditions of appearance of high concentration are following - for monthly high concentration appear in May and November, for hour from 8 to 9 o'clock and from 21 to 4 o'clock, for wind direction northerly wind and for wind velocity below 2 m/s. At MP1 and MP2, when the SPM concentration is high, SO_2 concentration is apt to be high. But MP6 does not show such tendency.

(2) Analysis of high concentration of daily average data

We put in order the highest 20 days of SPM concentration and meteorological conditions in Table V-1-16. And the frequency of highest concentrations in each month are shown in Table V-1-17. For month, relatively high concentrations are apt to appear in May and November. At every station, when the SPM concentration is high, SO_2 concentration is apt to be high.

Table V-1-15 The highest 50 hours of SPM concentration and meteorological conditions

(MP1) J. T. C. HALL

Rank-ing	Date hour	SPM (μg/m³)	SO_2 (ppb)	RS	WD	WS (0.1m/s)	ST
1)	11 6 19	160	42	464	NNW	7	E
2)	5 4 1	150	33		NNE	9	E
3)	11 6 20	148	31		N	8	E
4)	11 13 23	142	39		NNE	6	E
5)	4 26 22	140	27		NE	16	E
6)	5 26 3	140	37		N	11	E
7)	5 9 4	128	41	496	NNE	11	E
8)	6 12 9	128	18		NNE	10	C
9)	11 13 22	128	27		NNW	5	E
10)	4 5 2	125	49	299	W	8	F
11)	5 8 22	125	37		NNE	15	E
12)	5 22 1	125	43	415	N	12	E
13)	11 9 21	125	56	195	NNW	11	E
14)	4 17 22	124	45	374	NE	11	E
15)	5 22 2	124	63	136	N	11	E
16)	9 21 3	124	29		NNW	14	B
17)	5 4 3	122	26		NNE	12	E
18)	9 23 8	122	36		N	9	B
19)	5 14 24	120	29		NNE	10	E
20)	5 25 21	120	22		ENE	12	E
21)	5 26 4	120	33		N	10	E
22)	5 26 10	120	25		C	2	C-B
23)	6 8 9	120	28		NNE	7	B
24)	7 26 7	120	46	352	C	4	CC(D)
25)	8 23 9	120	28		N	11	B
26)	9 21 4	120	21		NNE	11	E
27)	9 27 23	120	51	277	N	10	E
28)	10 6 3	120	41	496	NNW	12	E
29)	11 8 7	120	53	167	NNW	14	E
30)	3 20 9	120	23		C	3	CC(D)
31)	11 9 9	118	24		N	10	B
32)	11 4 3	116	24		NNW	10	E
33)	4 5 1	115	33		NNW	10	E
34)	4 26 3	115	28		NNW	13	E
35)	5 4 2	115	25		N	12	E
36)	5 22 3	115	59	167	N	13	E
37)	6 8 8	115	34		N	8	B
38)	6 13 8	115	32		N	9	B
39)	8 22 23	115	16		NNE	9	E
40)	4 18 1	112	34		N	6	E
41)	4 27 9	112	46	352	NNW	11	B
42)	5 4 4	112	24		NNW	8	E
43)	11 11 2	112	19		NNE	7	E
44)	3 29 3	112	38		NNW	5	E
45)	4 3 22	110	28		NNE	10	F
46)	4 17 24	110	33		N	12	E
47)	4 26 21	110	36		NNE	19	E
48)	4 26 23	110	25		NNE	14	E
49)	5 9 8	110	31		NNW	9	B
50)	6 13 9	110	28		NNE	10	B

(MP2) N. U. S.

Rank-ing	Date hour	SPM (μg/m³)	SO_2 (ppb)	RS	WD	WS (0.1m/s)	ST
1)	3 29 3	185	33	440	C	1	CC(N)
2)	11 6 20	184	41	245	NNE	15	E
3)	4 27 9	175	28		NNW	13	B
4)	3 29 4	172	28		ENE	13	E
5)	10 10 9	170	28		NNE	14	B
6)	11 6 21	170	25		ENE	20	E
7)	11 4 4	160	28		NNW	15	E
8)	11 6 24	160	53	119	NNE	15	E
9)	3 29 9	160	39	278	NNW	25	B
10)	3 29 2	158	36	349	C	3	CC(N)
11)	5 9 8	155	21		N	9	B
12)	10 10 8	154	56	95	NNE	14	C
13)	5 8 21	152	17		N	18	E
14)	4 18 4	150	31		N	18	B
15)	11 6 19	150	32	475	N	10	E
16)	11 6 22	145	21		ENE	18	E
17)	3 29 1	145	26		WNW	11	E
18)	3 24 8	144	45	184	N	18	D(D)
19)	5 25 24	142	***		***	***	***
20)	11 4 5	142	14		NNW	16	E
21)	5 26 1	140	***		***	***	***
22)	3 28 6	140	32	475	NNW	20	E
23)	4 27 14	138	36	349	SW	44	B
24)	11 19 8	138	16		NNW	11	C
25)	7 13 16	135	73	49	SSW	31	C
26)	11 7 8	135	32	475	N	14	C
27)	3 30 23	135	17		NE	10	E
28)	5 8 23	132	23		ENE	23	E
29)	11 7 2	132	62	73	NNE	13	E
30)	7 24 9	130	22		NNW	16	B
31)	9 9 4	130	17		N	17	E
32)	5 3 9	128	27		NNE	18	C
33)	5 8 24	128	25		NE	22	E
34)	5 22 3	128	86	29	N	16	E
35)	4 18 3	126	16		NNE	8	E
36)	5 4 4	125	12		SE	8	E
37)	5 7 23	125	14		NE	22	E
38)	5 22 1	125	95	22	NNE	12	E
39)	11 7 5	125	23		N	17	E
40)	11 29 21	125	28		NE	19	E
41)	5 8 22	124	16		NE	21	E
42)	5 15 9	124	28		NNW	25	C
43)	4 26 24	122	18		NE	20	E
44)	5 19 9	122	32	475	ENE	12	B
45)	7 13 17	122	46	173	SSW	31	C
46)	11 9 23	122	35	382	NNE	7	E
47)	11 15 23	122	18		ENE	15	E
48)	3 28 24	122	23		C	2	CC(N)
49)	5 22 9	120	36	349	NE	18	B
50)	5 26 2	120	***		***	***	***

(MP6) NANYANG. T. I.

Rank-ing	Date hour	SPM (μg/m³)	SO_2 (ppb)	RS	WD	WS (0.1m/s)	ST
1)	1 4 19	190	10		NE	13	E
2)	5 3 24	170	16		N	12	E
3)	5 4 1	160	15		NNE	10	E
4)	6 9 9	160	18		ESE	5	B
5)	10 25 6	160	8		NNW	12	E
6)	4 12 23	155	19		C	3	***
7)	8 22 22	155	17		N	6	E
8)	9 8 23	155	18		NE	9	E
9)	9 8 22	152	31		NNE	6	E
10)	9 8 24	150	15		NNE	6	E
11)	1 23 21	150	12		NE	8	E
12)	6 9 7	145	8		NE	6	D(D)
13)	8 23 9	145	11		N	10	B
14)	5 3 23	140	31		C	4	CC(N)
15)	8 22 23	140	12		NNE	6	E
16)	8 23 1	140	10		NNE	7	E
17)	10 4 21	140	16		NE	9	E
18)	10 25 5	138	8		NNW	13	F
19)	4 15 17	135	135	19	SSW	13	D(D)
20)	1 8 12	132	14		NE	22	B
21)	5 25 22	130	30		NE	6	E
22)	8 22 24	130	9		NNE	7	E
23)	8 23 3	130	11		C	4	CC(N)
24)	8 23 7	130	7		NNE	8	D(D)
25)	10 25 4	130	8		NNW	16	E
26)	10 31 2	130	11		NNE	9	E
27)	11 3 22	128	12		NNE	9	E
28)	11 6 19	128	13		N	12	E
29)	3 9 10	128	11		NNE	15	B
30)	6 17 6	125	12		NNE	5	D(D)
31)	8 23 5	125	9		NNE	7	E
32)	10 25 3	125	7		NNW	18	E
33)	11 28 2	125	7		NNE	10	***
34)	3 20 10	125	90	96	N	7	B
35)	11 9 3	124	17		NNE	9	E
36)	7 29 22	122	22		NNE	8	E
37)	10 4 22	122	14		NE	12	E
38)	6 4 1	120	19		SE	6	E
39)	6 8 8	120	7		N	9	B
40)	6 23 21	120	15		NE	9	E
41)	7 28 23	120	10		NE	7	E
42)	8 23 8	120	8		N	8	B
43)	10 25 7	120	8		N	14	D(D)
44)	11 6 18	120	16		N	7	E
45)	11 9 9	120	16		N	12	B
46)	11 30 24	120	8		NNE	9	E
47)	1 2 3	120	6		N	17	E
48)	6 19 12	118	5		WSW	25	B
49)	11 12 24	116	9		N	13	E
50)	5 3 21	115	18		N	15	E

* Ranking of SO_2 is object to the highest 500 hours of concentration.

Note:
SO_2; SO_2 concentration
SPM; SPM concentration
WD; Wind direction
WS; Wind velocity
ST; Atmospheric stability
RS; Ranking of SO_2
(D); Daytime
(N); Nighttime

Table V-1-16 The highest 20 days of SPM concentration

Ranking	(MP1) J.T.C. HALL				(MP2) N.U.S.				(MP6) NANYANG. T. I.			
	Date	SPM (μg/m³)	SO_2 (ppb)	Ranking of SO_2	Date	SPM (μg/m³)	SO_2 (ppb)	Ranking of SO_2	Date	SPM (μg/m³)	SO_2 (ppb)	Ranking of SO_2
1)	11/6	76.3	34.1	6	11/6	88.8	22.8	24	8/23	67.8	26.4	32
2)	11/9	65.8	22.1		3/29	77.9	20.5	39	3/20	61.0	28.0	25
3)	4/5	58.9	39.0	4	4/27	71.6	31.8	4	4/3	58.7	37.3	9
4)	11/13	56.2	24.2		7/13	71.2	24.9	14	6/7	58.1	22.0	48
5)	5/8	54.7	27.6	31	5/8	70.6	15.9		10/31	57.3	28.1	24
6)	4/27	52.1	43.4	2	11/7	64.7	25.0	13	3/11	55.3	27.4	29
7)	4/26	51.3	29.2	22	11/4	61.7	20.5	40	5/26	53.5	27.8	26
8)	11/7	49.9	34.6	5	11/9	60.8	16.3		4/7	52.3	29.1	22
9)	12/28	49.9	20.9		4/5	60.3	—		5/2	51.5	13.7	
10)	11/11	49.4	17.5		4/26	60.3	19.7		9/8	50.9	22.7	43
11)	12/29	48.9	18.0		3/28	59.9	14.9		3/13	50.0	39.4	3
12)	5/14	48.6	20.2		10/10	58.0	22.9	23	10/4	49.8	—	
13)	5/18	48.6	33.1	9	5/7	57.6	22.3	26	6/8	48.7	38.9	5
14)	3/20	48.5	31.7	17	8/23	57.6	17.4		11/13	48.5	21.1	
15)	5/26	48.5	17.9		11/29	57.2	21.0	37	11/1	47.8	23.0	41
16)	4/15	48.0	29.8	21	11/1	56.9	17.3		3/30	47.7	15.4	
17)	5/3	47.7	26.3	45	5/11	55.9	18.5		5/25	47.7	21.3	
18)	5/11	47.5	22.5		11/18	55.1	12.9		6/12	47.5	37.5	8
19)	3/28	47.5	20.6		5/3	54.4	23.4	20	5/3	47.1	18.8	
20)	11/10	47.2	20.7		4/18	53.2	18.7		10/25	47.0	7.5	

Note:
- SPM; Daily average concentration of SPM
- SO_2; Daily average concentration of SO_2
- Ranking of SO_2 is object to the highest 50 days of concentration.

Table V-1-17 Frequency of highest concentration of SPM by month

Month	MP1	MP2	MP6	Total
Jan				
Feb				
Mar	2	2	4	8
Apr	4	4	2	10
May	6	4	4	14
Jun			3	3
Jul		1		1
Aug		1	1	2
Sep			1	1
Oct		1	3	4
Nov	6	7	2	15
Dec	2			2
Total	20	20	20	60

V-1-3-9 Correlation between SPM concentration and SO_2 concentration

Table V-1-18 shows correlation between SPM concentration and SO_2 concentration for seasonal and yearly averaged data. For yearly averaged data, correlation coefficients are low, for example, the value at MP1 is 0.340. Fig. V-1-26 shows the relationship between SPM concentration and SO_2 concentration. In these figures, numeral mean the number of data in each concentration rank.

Table V-1-18 Correlation coefficients between SPM concentration and SO_2 concentration at each station

Monitoring stations	Southerly Monsoon (April - October)	Northerly Monsoon (November - March)	Yearly average
(MP1) J.T.C. HALL	0.363	0.309	0.340
(MP2) N.U.S.	0.318	0.281	0.303
(MP6) NANYANG.T.I.	0.123	0.231	0.157

(MP1) J.T.C. HALL

Y = 0.5543 X +15.0237
EFFECTIVE CASES = 7537
CORRELATION COEFFICIENT = 0.340
STANDARD DEVIATION = 21.33

Y : SPM μg / m³

Y \ X	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199	200-209	210-219
190 - 199																						
180 - 189																						
170 - 179																						
160 - 169					1																	
150 - 159				1																		
140 - 149			1	3																		
130 - 139																						
120 - 129		1	10	3	6	3	1															
110 - 119		2	11	10	5	1																
100 - 109		5	18	13	9		2															
90 - 99		7	28	25	9	3		2														
80 - 89		26	38	30	13	3																
70 - 79	2	39	64	29	17	6	2	1														
60 - 69	5	72	97	35	16	15	3		1	2										1		
50 - 59	16	167	125	52	19	7	8	3	4		2		2	1								
40 - 49	52	241	123	63	21	17	8	4	2	5												
30 - 39	170	443	169	60	31	15	9	3	3	6	1			1								
20 - 29	346	662	207	91	39	22	8	4	4	2		2		1								
10 - 19	729	905	237	97	43	22	16	10	4	7	2		1		1							
0 - 9	613	687	148	35	17	10	9	3	2	1												

X : SO2 ppb

X axis; SO_2 concentration
Y axis; SPM concentration

Fig. V-1-26-(1) Frequency in each concentration rank at MP1

(MP2) N.U.S.

Y = 0.6025 X +20.7344
EFFECTIVE CASES = 7571
CORRELATION COEFFICIENT = 0.303
STANDARD DEVIATION = 23.37

Y : SPM $\mu g / m^3$

Y \ X	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199	200-209	210-219
190 - 199																						
180 - 189				1	1																	
170 - 179			4																			
160 - 169			1	1		1																
150 - 159		1	1	3		1																
140 - 149		1	2	1	1																	
130 - 139		3	2	2			1	1														
120 - 129		10	7	7	1	1			1	1												
110 - 119		9	14	1	3		1						1									
100 - 109	2	30	20	11	4	1							1									
90 - 99	9	44	22	9	5	1	1													1		
80 - 89	19	76	29	11	7	3	2	2	3								1					
70 - 79	29	82	43	13	9	5	1	1														
60 - 69	66	139	75	26	5	6	4	1	2	1			1									
50 - 59	142	185	75	25	11	5	3	1		1		1										
40 - 49	270	270	110	51	18	10	1	1	2	2	1			1								
30 - 39	503	389	140	41	18	10	5	1	1	1		1	1							1		
20 - 29	728	462	123	52	15	9	5	2	3	1	1	1		1								
10 - 19	1012	618	141	37	23	8	5	4	2		2		1									
0 - 9	728	295	59	14	8	2		2														

p p b

X : SO2

X axis; SO_2 concentration
Y axis; SPM concentration

Fig. V-1-26-(2) Frequency in each concentration rank at MP2

(MP6) NANYANG.T.I.

Y = 0.2186 X +23.3193
EFFECTIVE CASES = 7476
CORRELATION COEFFICIENT = 0.157
STANDARD DEVIATION = 24.25

Y : SPM
μ g / m³

Y \ X	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199	200-209	210-219
190 - 199		1																				
180 - 189																						
170 - 179		1																				
160 - 169	1	2																				
150 - 159		5		1																		
140 - 149	1	4		1																		
130 - 139	4	3		1										1								
120 - 129	8	11	1							1												
110 - 119	14	15	4																			
100 - 109	16	22	11	2	2	1	1				1		1									
90 - 99	16	27	10	5	2	1	2	1	2													
80 - 89	47	50	10	8	1	1	2			3	1			1		1						
70 - 79	69	68	15	9	11	1	3	2	2	1		2	1	1								
60 - 69	144	92	26	7	4	8	5		4	3		2		1		1						1
50 - 59	205	156	56	21	17	7	8	4	6	2	2	1	1	1								
40 - 49	304	172	72	33	28	13	12	9	2	9	1	2		2		1	1			1		
30 - 39	452	241	103	56	17	14	7	8	13	7	6	5	3	2								
20 - 29	635	287	102	50	28	20	12	5	3	5	4	3	3	1	1	1					1	
10 - 19	1029	439	151	59	30	13	10	7	8	1	1	1		1		1						
0 - 9	1128	383	87	28	21	8	5	3	1	2		2	1				1					

p p b

X : SO2

X axis; SO_2 concentration
Y axis; SPM concentration

Fig. V-1-26-(3) Frequency in each concentration rank at MP6

CHAPTER 2 DATA ANALYSIS DURING SHORT TERM FIELD SURVEYS

The short term surveys were performed in December 1983, in March 1984, from June to July 1984, and in September 1984. In these terms, the ambient concentration of particulate matter were measured by high volume sampler and Andersen sampler. Using these data, analysis of ambient concentration of particulate matter were performed. At the same time, using the data of SPM (measured by Beta ray dust analysers), analysis of SPM concentration during each short term survey were performed.

V-2-1 Analysis of TPM, SPM Concentration of High Volume Sampler

At twenty monitoring stations, daily average concentration of TPM and SPM were measured. In each short term survey, TPM was measured for fourteen days and SPM was measured for twelve days. Among these data, there are a few data which are low confidence because of shortness of measuring time. With respect to analysis of the diurnal variations, such data are considered to be effective. On the other hand, for calculating the correlation coefficients, such data are considered not to be effective.

V-2-1-1 Seasonal variations of TPM and SPM concentration by high volume sampler

Table V-2-1 shows the average concentration of TPM and SPM in each short term survey. The values were averaged of twelve days. Fig. V-2-1 shows the spatial distributions of TPM and SPM concentration for each survey.

From these figures, the relatively high concentration of TPM appeared at MP7 and MP17. This may be due to the reason that these monitoring stations are located near the road of heavy traffic.

Except these two stations, differences of concentration between stations are little. In the south or south-west part of the objective area, the relatively high concentration appear at the 2nd field survey, which was conducted in March 1984.

Table V-2-1 TPM and SPM concentration in each short term field survey

Monitoring stations	TPM (μg/m³)					SPM (μg/m³)				
	1st survey	2nd survey	3rd survey	4th survey	Average	1st survey	2nd survey	3rd survey	4th survey	Average
MP 1	60.3	99.3	51.9	62.9	68.6	28.5	47.0	25.4	34.6	33.9
MP 2	54.9	64.4	51.0	42.4	53.2	34.9	31.3	25.8	26.1	29.5
MP 3	52.7	79.8	60.6	73.8	66.7	28.0	42.6	21.7	33.0	31.3
MP 4	79.7	91.5	65.0	60.5	74.2	40.4	52.1	29.6	36.0	39.5
MP 5	78.5	95.4	67.0	72.0	78.2	41.8	43.2	21.7	31.1	34.5
MP 6	54.1	86.9	67.7	57.0	66.4	33.2	44.8	28.9	27.0	33.5
MP 7	102.2	144.2	145.8	146.2	134.6	51.1	63.6	55.4	51.8	55.5
MP 8	43.0	77.0	91.8	67.1	69.7	29.3	39.0	42.8	34.6	36.4
MP 9	49.0	90.8	101.9	91.3	83.3	26.8	47.5	42.1	43.0	39.9
MP10	50.5	65.3	54.2	45.9	54.0	28.0	33.1	28.4	22.6	28.0
MP11	55.1	81.2	97.1	78.1	77.9	33.3	39.6	49.0	39.4	40.3
MP12	61.7	96.8	56.6	60.9	69.0	27.3	34.6	20.5	27.0	27.4
MP13	40.2	75.5	58.6	55.7	57.5	21.1	39.9	27.9	31.9	30.2
MP14	52.9	74.4	63.0	62.9	63.3	25.6	41.7	31.1	34.7	33.3
MP15	39.8	56.1	37.8	44.9	44.7	20.1	28.9	16.2	23.6	22.2
MP16	44.5	83.1	85.4	76.3	72.3	20.5	43.0	34.7	37.9	34.0
MP17	103.2	120.1	67.2	81.7	93.1	39.5	53.6	36.7	41.3	42.8
MP18	56.7	63.9	59.4	73.8	63.5	31.1	30.1	27.3	41.0	32.4
MP19	67.8	61.7	59.0	61.7	62.6	32.5	29.9	29.5	31.1	30.8
MP20	41.5	54.1	81.9	76.1	63.4	17.0	24.0	24.3	32.5	24.5

Note: Concentration is average values of 12 days.

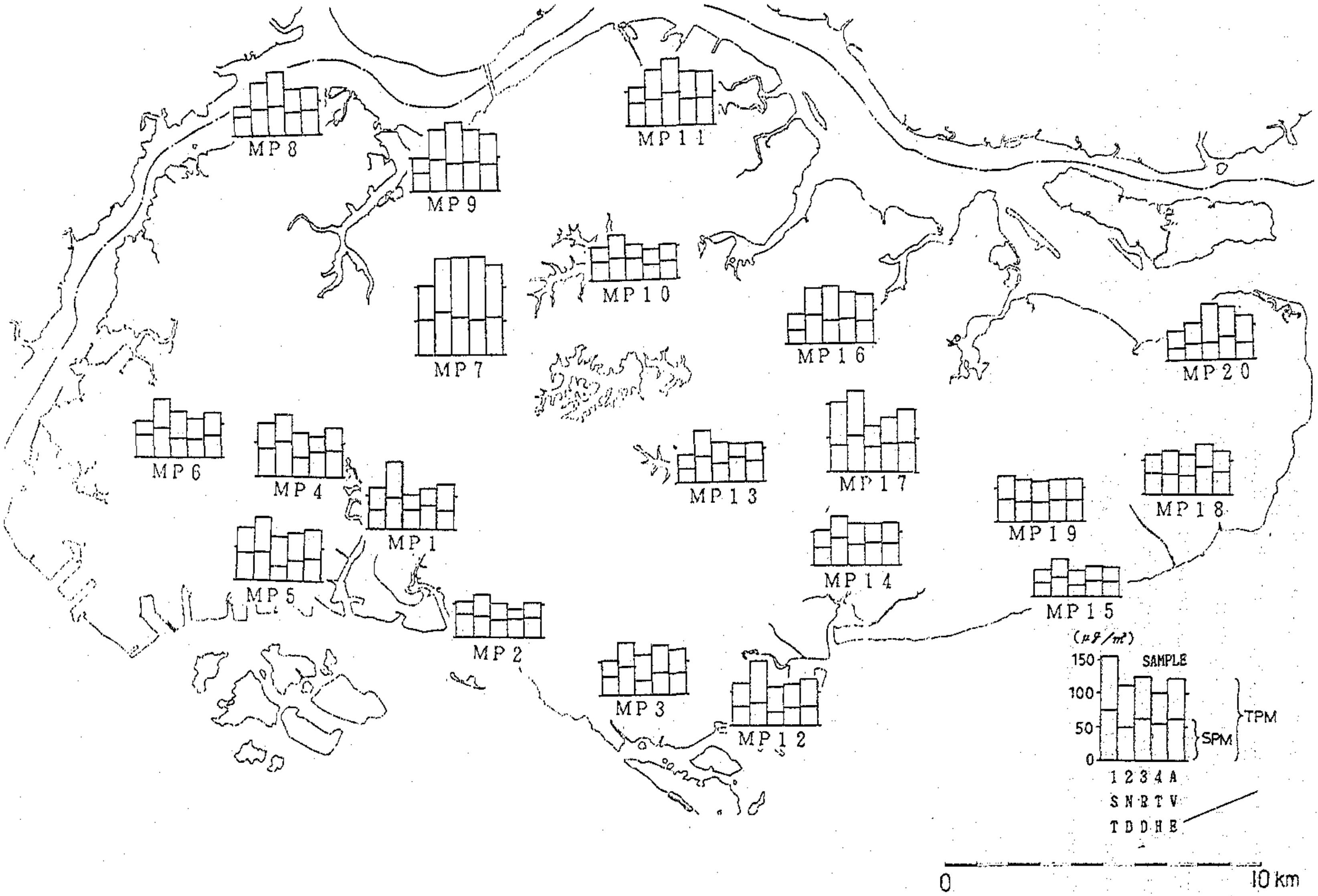


Fig. V-2-1 Spatial distributions of TPM and SPM concentration for each short term field survey

V-2-1-2 The diurnal variations of TPM and SPM concentration by high volume sampler

Fig. V-2-2 shows the diurnal variations of TPM and SPM concentration by high volume samplers. In these figures, three lines show the time series of TPM, SPM concentration and the ratio (SPM concentration/TPM concentration). And at MP1, MP2 and MP6, SPM concentration which are measured by Beta ray dust analysers are also plotted. From these figures, SPM concentrations by high volume samplers show almost the same value as measured by Beta ray dust analysers. And the ratios (SPM concentration/TPM concentration) vary from 30% to 70%.

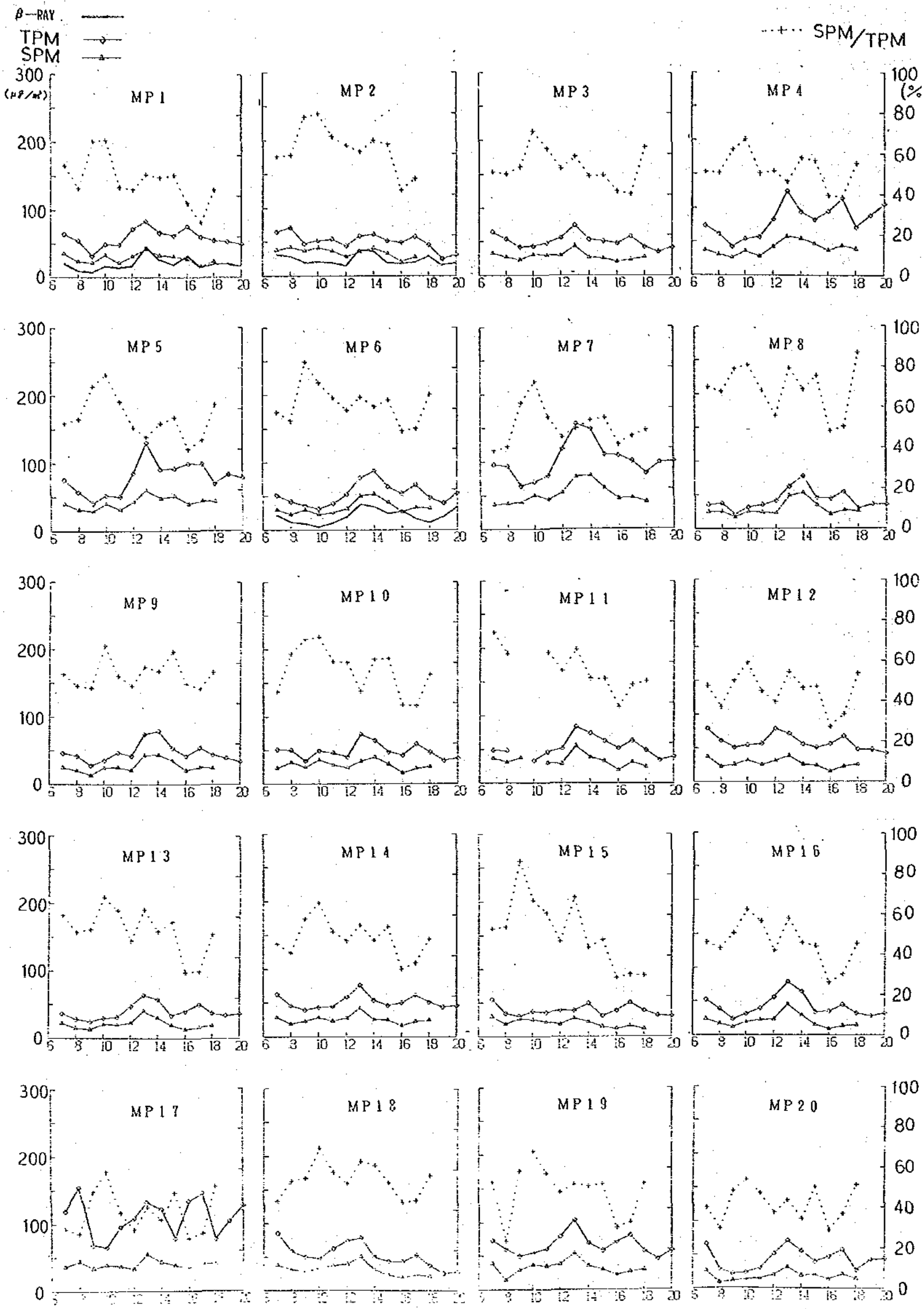


Fig. V-2-2-(1) Diurnal variations of TPM, SPM concentration (1st survey)

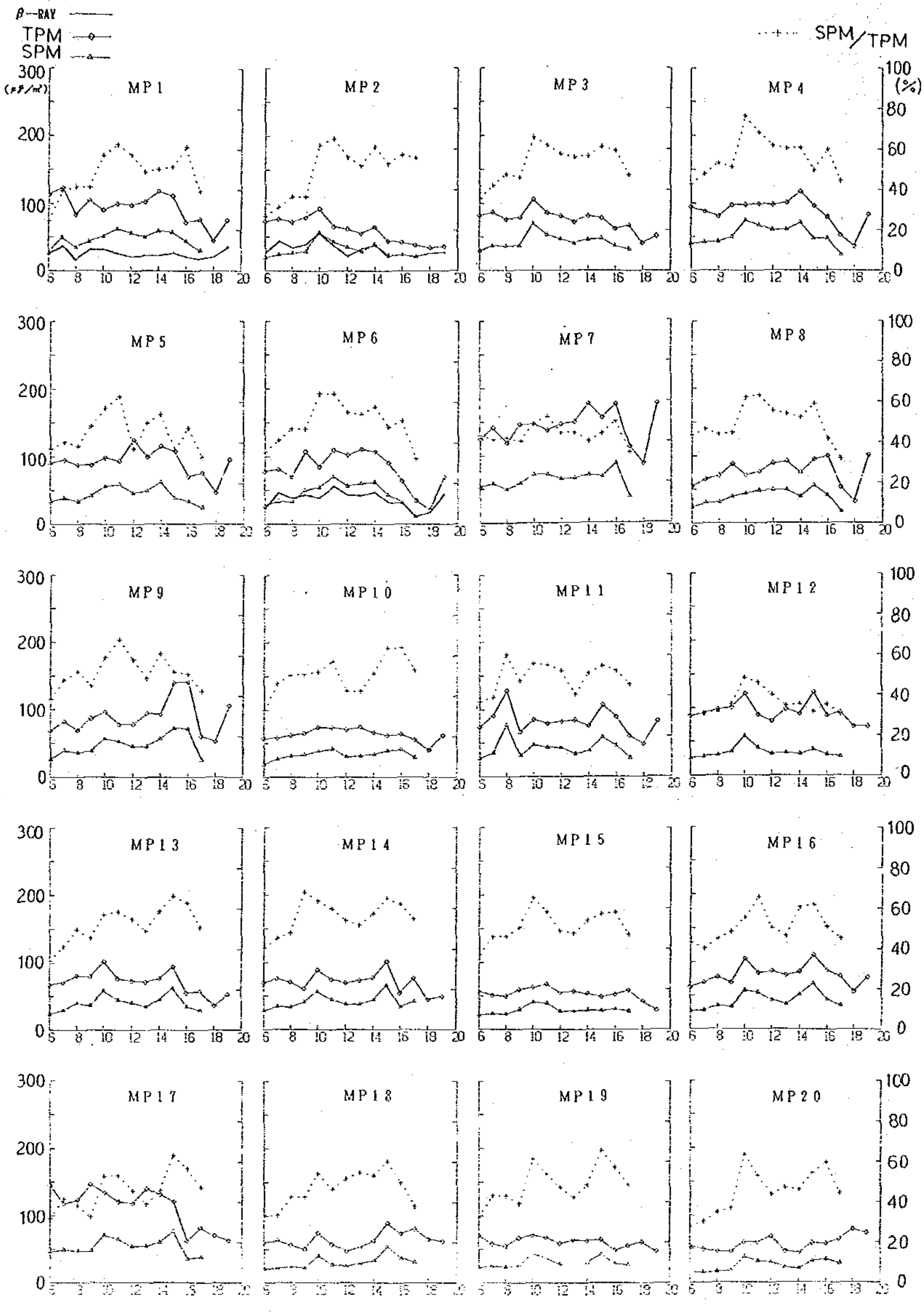


Fig. V-2-2-(2) Diurnal variations of TPM, SPM concentration (2nd survey)

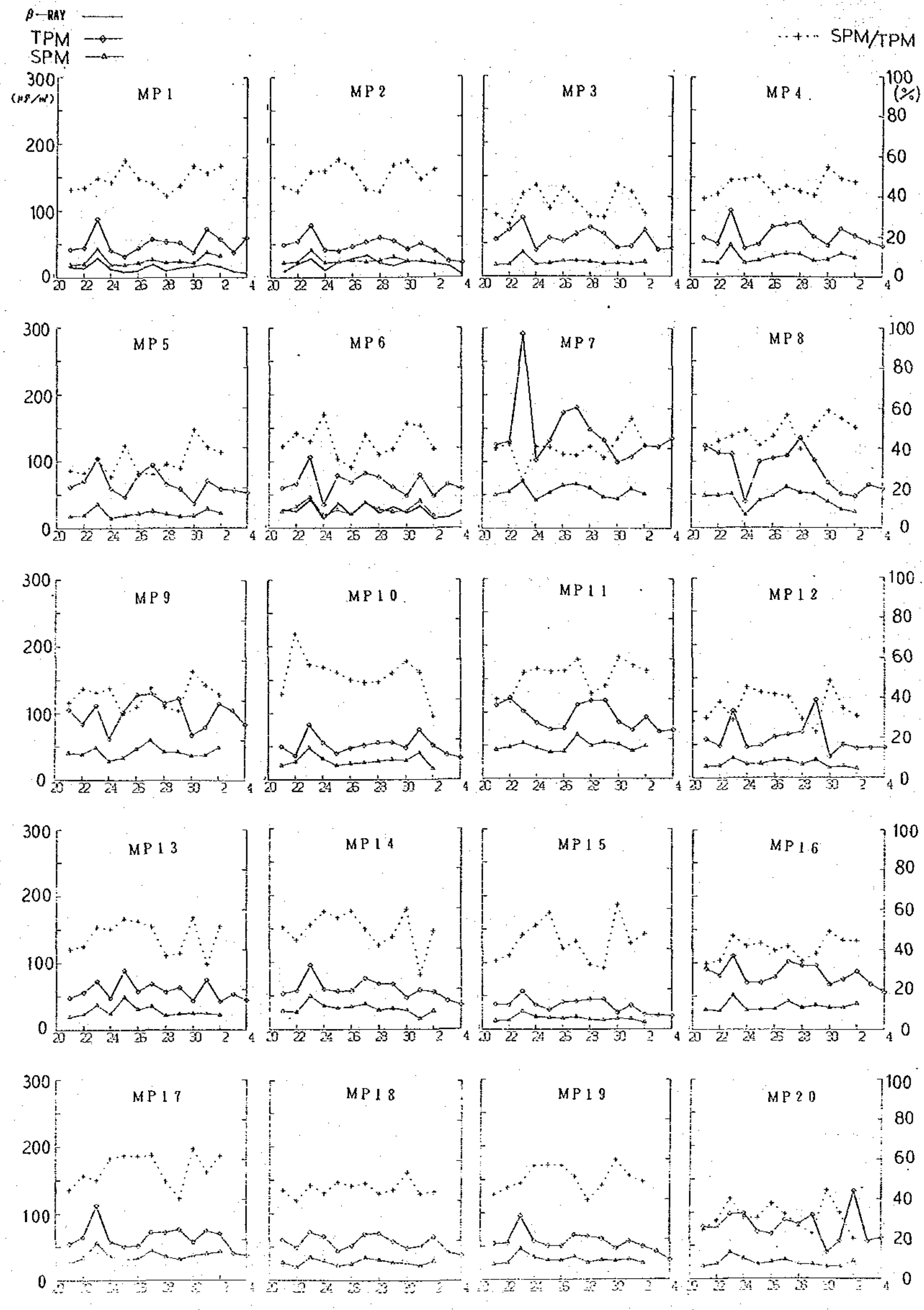


Fig. V-2-2-(3) Diurnal variations of TPM, SPM concentration (3rd survey)

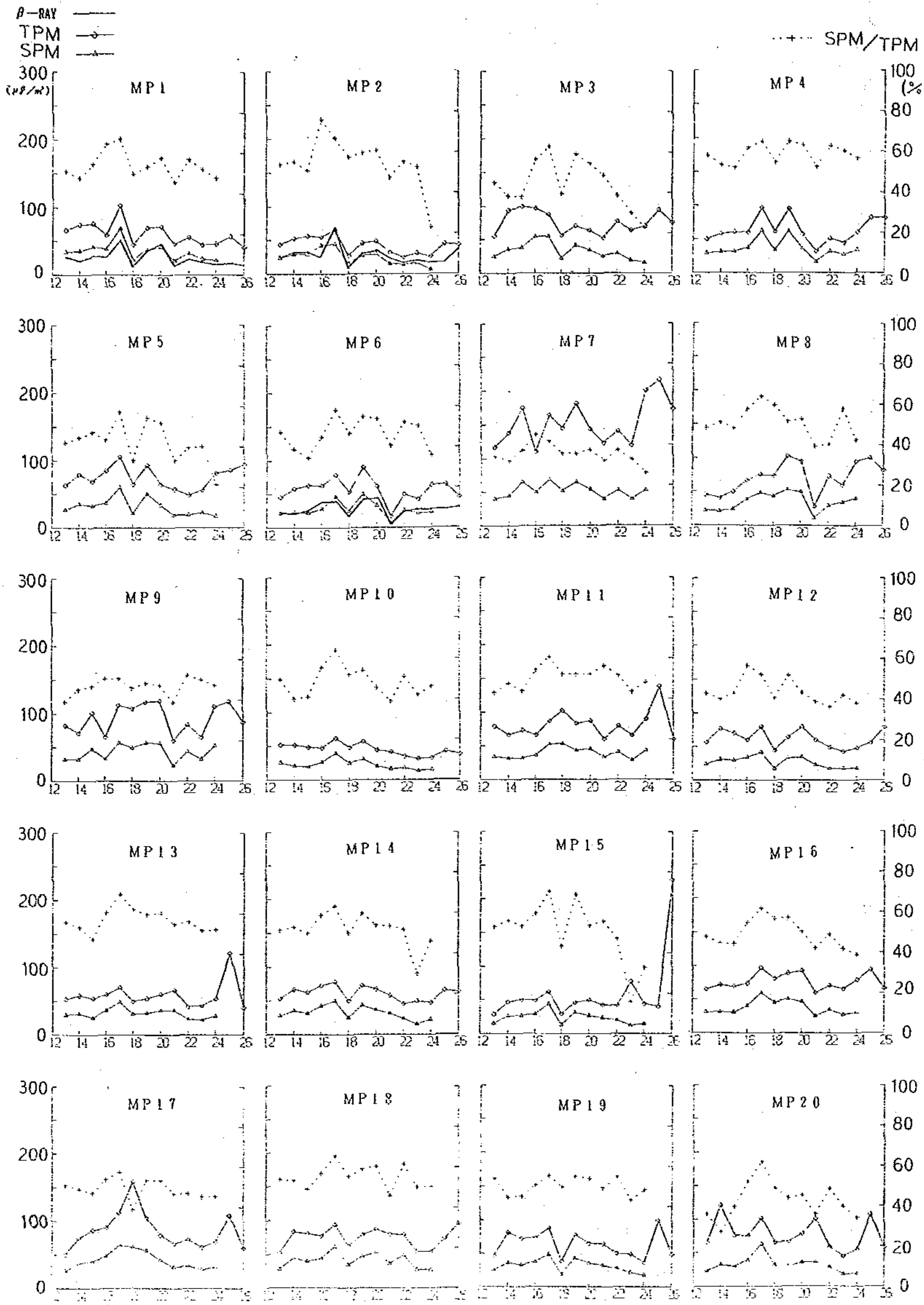


Fig. V-2-2-(4) Diurnal variations of TPM, SPM concentration (4th survey)

V-2-1-3 Correlation among the stations on the concentration of particulate matters

As described in PART II, the particulate matters in the ambient air are originated from various sources and the spatial distributions of the sources are widespread.

The particulate matters emitted from sources are transported by wind and diffused. So the variation patterns of the concentration at different points show the contributing emission source to some extent. Namely if the variation patterns are same, the contributing emission source considered to be the same.

Then, in this section, using the cluster analysis and the principal component analysis, we analyzed the resemblance of concentration in different stations or different surveys.

Table V-2-2 shows the correlation coefficient matrix among the stations. From these tables, we can see the tendency that the coefficients of SPM is higher than that of TPM. Using these correlation coefficients, cluster analysis (maximum algorithm) and principal component analysis were performed. The results from these analysis are shown in Figs. V-2-3, V-2-4, Table V-2-3.

From these results, there are no resemblance. So the sources of TPM and SPM are considered to be different at each stations and each short term survey.

Table V-2-2-(1) Correlation coefficients of different stations (1st survey)

(Unit 0.01)

TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		14	70	83	90	69	85	67	63	56	70	48	79	77	37	75	74	39	82	84
2	14		53	15	9	24	24	35	38	55	24	25	11	25	42	37	61	39	21	32
3	70	53		70	71	59	70	54	63	72	70	75	68	90	48	86	69	79	89	88
4	83	15	70		97	84	82	79	75	73	87	32	90	83	44	72	83	22	86	82
5	90	9	71	97		83	87	75	73	68	85	31	87	81	33	72	75	24	85	82
6	69	24	59	84	83		91	94	93	75	94	13	88	65	44	75	67	12	64	73
7	85	24	70	82	87	91		89	88	72	91	30	90	71	31	88	66	33	77	81
8	67	35	54	79	75	94	89		94	80	88	9	96	56	45	76	68	11	62	65
9	63	38	63	75	73	93	88	94		88	93	6	85	63	41	82	58	21	63	68
10	56	55	72	73	68	75	72	80	88		83	17	78	72	48	79	61	29	69	63
11	70	24	70	87	85	94	91	88	93	83		23	93	76	30	85	70	25	80	72
12	48	25	75	32	31	13	30	9	6	17	23		36	71	51	60	63	90	68	70
13	79	11	68	90	87	88	90	86	85	78	93	36		83	49	88	76	31	86	79
14	77	25	90	83	81	65	71	56	63	72	76	71	83		57	86	75	65	95	90
15	37	42	48	44	33	44	31	45	41	48	30	51	49	57		49	66	39	44	67
16	75	37	86	72	72	75	88	76	82	79	65	60	88	86	49		66	66	87	86
17	74	61	69	83	75	67	66	68	58	61	70	63	76	75	66	66		42	82	87
18	39	39	79	22	24	12	33	11	21	29	25	90	31	65	39	66	42		63	68
19	82	21	89	86	85	64	77	62	63	69	60	68	86	95	44	87	82	63		87
20	84	32	88	82	82	73	81	65	68	63	72	70	79	90	67	86	87	68	87	

SPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		23	70	60	65	49	62	57	60	42	62	71	76	75	47	74	55	63	71	85
2	23		40	-10	-15	8	10	29	21	79	54	47	26	28	69	36	19	42	18	-5
3	70	40		42	50	34	40	46	49	44	77	89	82	91	61	89	76	90	82	73
4	60	-10	42		95	88	87	87	88	40	53	32	81	61	-4	65	82	28	54	73
5	65	-15	50	95		80	80	77	83	31	55	40	79	70	-4	63	84	30	61	78
6	49	8	34	88	80		89	91	88	47	69	27	78	56	11	65	73	26	53	65
7	62	10	40	87	80	89		92	89	63	62	27	85	59	14	71	75	39	58	55
8	57	29	46	87	77	91	92		97	71	66	30	85	56	17	74	80	37	50	58
9	60	21	49	88	83	88	89	97		63	63	32	84	58	13	72	78	35	55	66
10	42	79	44	40	31	47	63	71	63		62	36	58	43	40	57	54	42	33	12
11	62	54	77	53	55	69	62	66	63	62		77	79	85	77	84	76	77	73	68
12	71	47	89	32	40	27	27	30	32	36	77		70	88	84	76	54	83	84	74
13	76	26	82	81	79	78	83	85	84	58	79	70		88	42	96	92	74	84	80
14	75	28	91	61	70	56	59	56	58	43	85	88	88		57	88	84	80	93	81
15	47	69	61	-4	-4	11	14	17	13	40	77	84	42	57		56	21	74	59	40
16	74	36	89	65	63	65	71	74	72	57	84	76	96	88	56		86	88	83	77
17	55	19	76	82	84	73	75	80	78	54	76	54	92	84	21	86		65	78	71
18	63	42	90	28	30	26	39	37	35	42	77	83	74	80	74	68	65		77	63
19	71	18	82	54	61	53	58	50	55	33	73	84	84	93	59	83	78	77		81
20	85	-5	73	73	78	65	55	58	66	12	68	74	80	81	40	77	71	63	81	

SPM / TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		85	60	86	76	83	68	70	50	71	71	79	76	85	81	75	68	58	75	59
2	85		79	93	91	90	82	81	45	90	61	84	77	92	82	84	87	76	81	77
3	60	79		65	76	67	63	75	57	55	47	84	80	79	48	87	79	80	75	77
4	86	93	65		87	80	76	73	55	89	36	76	69	83	56	69	83	68	74	66
5	76	91	76	87		82	80	69	41	83	43	70	65	80	61	71	83	61	71	74
6	83	90	67	80	82		78	78	35	71	44	94	64	88	77	75	82	63	81	80
7	68	82	63	76	80	78		53	58	70	-7	64	54	85	57	66	81	75	75	72
8	70	81	75	73	69	78	53		58	54	49	92	77	78	52	77	86	67	67	79
9	50	45	57	55	41	35	58	58		32	38	79	67	67	17	57	64	61	62	62
10	71	90	55	89	83	71	70	54	32		30	50	58	72	62	62	79	64	51	44
11	71	61	47	36	43	44	-7	49	38	30		56	85	62	83	74	21	24	41	32
12	79	84	84	76	70	94	64	92	79	50	56		86	89	60	87	83	77	85	83
13	76	77	80	69	65	64	54	77	67	58	85	86		85	69	95	64	72	75	67
14	85	92	79	83	80	88	85	78	67	72	62	89	85		75	90	88	60	88	85
15	81	82	48	56	61	77	57	52	17	62	83	60	69	75		76	49	52	56	40
16	75	84	87	69	71	75	66	77	57	62	74	87	95	90	76		70	84	79	69
17	68	87	79	83	83	82	81	86	64	79	21	83	64	88	49	70		74	80	91
18	58	76	80	68	61	63	75	67	61	64	24	77	72	80	52	84	74		63	52
19	75	81	75	74	71	81	75	67	62	51	41	85	75	88	56	79	80	63		85
20	59	77	77	66	74	80	72	79	62	44	32	83	67	85	40	69	91	52	85	

Table V-2-2-(2) Correlation coefficients of different stations (2nd survey)

(Unit 0.01)

TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		36	39	67	59	60	19	-8	-5	-4	26	5	28	33	-14	-18	67	-22	55	-42
2	36		81	45	22	37	-13	-28	-37	28	-10	16	55	0	28	-21	69	-46	58	-33
3	39	81		47	44	36	-5	-27	-20	41	15	41	75	48	39	24	58	-9	71	11
4	67	45	47		71	91	58	37	21	59	30	11	50	17	10	16	68	-40	59	-38
5	59	22	44	71		68	31	21	0	44	32	4	48	43	-10	31	51	-29	37	13
6	60	37	36	91	68		46	49	12	70	22	3	43	8	24	9	67	-56	56	-31
7	19	-13	-5	58	31	46		71	77	38	49	10	10	-3	-21	44	-12	10	-9	-29
8	-8	-28	-27	37	21	49	71		76	50	52	16	14	-11	-19	45	-11	-7	-19	-10
9	-5	-37	-20	21	0	12	77	76		14	74	45	18	19	-36	65	-31	51	-20	-8
10	-4	28	41	59	44	70	38	50	14		18	14	45	8	52	41	31	-38	37	5
11	26	-10	15	30	32	22	49	52	74	18		46	42	49	-51	61	-4	36	-7	2
12	5	16	41	11	4	3	10	16	45	14	46		79	74	-5	68	24	57	37	-5
13	28	55	75	50	48	43	10	14	18	45	42	79		69	9	59	58	11	59	-5
14	33	0	48	17	43	8	-3	-11	19	8	49	74	69		-6	67	24	57	41	28
15	-14	28	39	10	-10	24	-21	-19	-36	52	-51	-5	9	-6		-7	20	-23	56	30
16	-18	-21	24	16	31	9	44	45	65	41	61	68	59	67	-7		-19	60	3	37
17	67	69	58	68	51	67	-12	-11	-31	31	-4	24	58	24	20	-19		-50	82	-58
18	-22	-46	-9	-40	-29	-56	10	-7	51	-38	36	57	11	57	-23	60	-50		-17	31
19	55	58	71	59	37	56	-9	-19	-20	37	-7	37	59	41	56	3	82	-17		-5
20	-42	-33	11	-38	13	-31	-29	-10	-8	5	2	-5	-5	28	30	37	-58	31	-5	

SPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		58	69	78	81	84	66	83	69	63	69	46	65	53	54	70	71	38	62	46
2	58		92	86	82	70	42	44	32	50	36	85	60	44	82	53	59	18	65	60
3	69	92		80	73	66	51	63	54	63	66	93	82	69	82	76	79	49	87	79
4	78	86	80		95	93	66	71	51	49	44	66	58	35	64	55	64	19	55	39
5	81	82	73	95		93	53	61	40	42	31	57	51	35	62	51	66	11	51	33
6	84	70	66	93	93		57	79	44	47	38	51	51	32	56	49	64	7	45	31
7	66	42	51	66	53	57		73	88	68	70	42	44	25	51	57	32	45	46	42
8	83	44	63	71	61	79	73		77	67	78	52	71	55	48	71	69	49	62	49
9	69	32	54	51	40	44	88	77		82	90	46	71	58	48	81	50	77	66	55
10	63	50	63	49	42	47	68	67	82		76	62	73	63	77	80	45	64	71	68
11	69	36	66	44	31	38	70	78	90	76		55	85	72	46	88	67	79	80	67
12	46	85	93	66	57	51	42	52	46	62	55		76	70	86	66	70	48	85	72
13	65	60	82	58	51	51	44	71	71	73	85	76		90	59	92	86	77	90	69
14	53	44	69	35	35	32	25	55	58	63	72	70	90		56	87	82	83	92	74
15	54	82	82	64	62	56	51	48	48	77	46	86	59	56		64	49	37	76	76
16	70	53	76	55	51	49	57	71	81	80	88	66	92	87	64		79	85	92	78
17	71	59	79	64	66	64	32	69	50	45	67	70	86	82	49	79		57	85	63
18	38	18	49	19	11	7	45	49	77	64	79	48	77	83	37	85	57		78	66
19	62	65	87	55	51	45	46	62	66	71	80	85	90	92	76	92	85	78		83
20	46	60	79	39	33	31	42	49	55	68	67	72	69	74	76	78	63	66	83	

SPM / TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		84	93	81	58	82	68	61	82	62	84	71	84	63	83	69	72	72	74	81
2	84		89	72	52	68	40	48	73	54	81	64	83	59	77	75	72	70	73	88
3	93	89		82	56	83	62	70	78	61	87	71	89	68	89	77	79	87	85	94
4	81	72	82		79	95	71	73	82	24	67	92	54	45	77	57	40	61	51	75
5	58	52	56	79		82	63	61	69	23	43	77	32	43	64	60	18	35	26	53
6	82	68	83	95	82		71	84	90	28	69	86	59	49	75	70	40	69	49	71
7	68	40	62	71	63	71		67	59	28	49	70	42	27	58	50	46	41	45	51
8	61	48	70	73	61	84	67		76	13	55	72	45	34	59	70	42	65	48	68
9	82	73	78	82	69	90	59	76		38	76	77	66	39	69	78	51	56	55	64
10	62	54	61	24	23	28	28	13	38		73	18	83	74	75	59	81	47	82	62
11	84	81	87	67	43	69	49	55	76	73		67	89	80	89	83	77	69	84	83
12	71	64	71	92	77	86	70	72	77	18	67		40	48	72	57	34	42	45	70
13	84	83	89	54	32	59	42	45	66	83	89	40		71	82	79	89	82	90	84
14	63	59	68	45	43	49	27	34	39	74	80	48	71		81	64	56	62	67	71
15	83	77	89	77	64	75	58	59	69	75	89	72	82	81		75	77	69	88	91
16	69	75	77	57	60	70	50	70	78	59	83	57	79	64	75		69	68	70	75
17	72	72	79	40	18	40	46	42	51	81	77	34	89	56	77	69		63	96	79
18	72	70	87	61	35	69	41	65	56	47	69	42	82	62	69	68	63		70	79
19	74	73	85	51	26	49	45	48	55	82	84	45	90	67	88	70	96	70		87
20	81	88	94	75	53	71	51	68	64	62	83	70	84	71	91	75	79	79	87	

Table V-2-2-(3) Correlation coefficients of different stations (3rd survey)

(Unit 0.01)

TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		76	55	82	72	64	67	-1	24	88	13	71	16	76	59	65	92	54	79	29
2	76		74	80	74	76	81	54	32	63	52	69	31	86	89	79	87	51	91	11
3	55	74		65	56	64	73	57	59	24	59	73	37	71	54	82	71	49	68	50
4	82	80	65		82	80	83	42	61	67	20	88	30	80	73	77	75	58	77	17
5	72	74	56	82		70	83	36	49	51	25	85	32	81	76	72	66	54	77	26
6	64	76	64	80	70		79	55	47	48	13	80	74	73	66	60	64	17	71	-11
7	67	81	73	83	83	79		46	52	51	20	93	49	89	76	74	76	49	87	24
8	-1	54	57	42	36	55	46		59	-18	63	56	44	35	56	57	14	13	33	-12
9	24	32	59	61	49	47	52	59		1	34	57	38	44	39	69	23	38	27	38
10	88	63	24	67	51	48	51	-18	1		-11	61	9	64	56	44	80	49	73	13
11	13	52	59	20	25	13	20	63	34	-11		35	-10	35	43	69	33	45	33	31
12	71	89	73	88	85	80	93	56	57	61	35		46	92	92	85	78	61	91	28
13	16	31	37	30	32	74	49	44	38	9	-10	46		49	39	23	24	-13	40	-9
14	76	86	71	80	81	73	89	35	44	64	35	92	49		84	82	86	68	96	37
15	59	89	54	73	76	66	76	56	39	56	43	92	39	84		73	69	52	85	10
16	65	79	82	77	72	60	74	57	69	44	69	65	23	82	73		75	75	77	49
17	92	87	71	75	66	64	76	14	23	80	33	78	24	88	69	75		59	91	35
18	54	51	49	58	54	17	49	13	38	49	45	61	-13	68	52	75	59		65	67
19	79	91	68	77	77	71	67	33	27	73	33	91	40	96	85	77	91	65		29
20	29	11	50	17	26	-11	24	-12	38	13	31	28	-9	37	10	49	35	67	29	

SPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		63	72	82	90	69	56	-10	41	67	23	28	13	24	48	80	84	38	64	53
2	63		83	70	70	60	48	36	25	76	27	65	29	65	72	74	61	41	78	60
3	72	83		89	85	61	73	31	54	56	36	71	43	77	77	88	84	62	82	80
4	82	70	89		93	74	83	30	59	62	35	61	29	48	64	83	82	60	71	58
5	90	70	85	93		84	83	21	52	67	23	57	36	40	65	80	83	39	73	59
6	69	60	61	74	84		69	37	35	73	35	50	34	26	63	63	67	24	67	36
7	56	48	73	83	83	69		54	69	34	23	74	42	39	49	58	57	33	50	47
8	-10	36	31	30	21	37	54		57	1	48	55	22	36	17	28	1	25	13	5
9	41	25	54	59	52	35	69	57		-7	68	45	13	38	11	68	49	59	24	38
10	67	76	56	62	67	73	34	1	-7		12	45	10	31	74	51	59	23	77	44
11	23	27	36	35	23	35	23	48	68	12		32	-2	45	22	64	50	71	35	36
12	28	65	71	61	57	50	74	55	45	45	32		56	80	81	54	45	46	78	72
13	13	29	43	29	36	34	42	22	13	10	-2	58		50	57	30	29	1	51	36
14	24	65	77	48	40	26	39	36	38	31	45	80	50		79	67	55	67	79	86
15	48	72	77	64	65	63	49	17	11	74	22	81	57	79		61	66	45	96	77
16	80	74	88	83	80	63	58	28	68	51	64	54	30	67	61		88	74	76	72
17	84	61	84	82	83	67	57	1	49	59	50	45	29	55	66	88		60	78	75
18	38	41	62	60	39	24	33	25	59	23	71	46	1	67	45	74	60		53	64
19	64	78	82	71	73	67	50	13	24	77	35	78	51	79	96	76	78	53		83
20	53	60	80	58	59	36	47	5	38	44	36	72	36	86	77	72	75	64	83	

SPM/TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		76	39	76	76	1	21	39	19	-15	68	39	82	24	82	80	65	55	72	30
2	76		45	54	52	-11	-10	27	-8	-8	53	50	62	51	63	64	37	60	72	28
3	39	45		63	28	38	6	53	49	8	79	54	73	34	60	69	55	53	75	77
4	76	54	63		77	49	24	54	58	12	77	50	75	20	92	89	65	58	69	56
5	76	52	28	77		12	37	37	34	-3	47	19	48	-4	65	69	35	58	39	38
6	1	-11	38	49	12		34	56	83	40	31	34	11	-11	35	35	15	-4	24	27
7	21	-10	6	24	37	34		27	32	0	11	23	-3	-49	12	2	22	-18	17	-10
8	39	27	53	54	37	56	27		71	2	78	47	48	-5	40	68	42	44	52	39
9	19	-8	49	58	34	83	32	71		29	48	35	37	-3	46	53	41	20	34	52
10	-15	-8	8	12	-3	40	0	2	29		-14	40	-5	-1	9	-1	-8	-10	17	49
11	68	53	79	77	47	31	11	78	48	-14		54	87	24	73	88	74	67	79	56
12	39	50	54	50	19	34	23	47	35	40	54		62	53	67	36	78	49	86	52
13	82	62	73	75	48	11	-3	48	37	-5	87	62		81	87	83	87	67	87	62
14	24	51	34	20	-4	-11	-49	-5	-3	-1	24	53	81		50	20	47	56	51	33
15	82	63	60	92	65	35	12	40	46	9	73	67	87	50		81	79	65	81	56
16	80	64	69	89	69	35	2	68	53	-1	88	36	83	20	81		59	63	70	59
17	65	37	55	65	35	15	22	42	41	-8	74	78	87	47	79	59		49	79	44
18	55	60	53	58	58	-4	-18	44	20	-10	67	49	67	56	65	63	49		60	61
19	72	72	75	69	39	24	17	52	34	17	79	86	87	51	81	70	79	60		60
20	30	28	77	56	38	27	-10	39	52	49	56	52	62	33	56	59	44	61	60	

Table V-2-2-(4) Correlation coefficients of different stations (4th survey)

(Unit 0.01)

TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		88	55	69	65	61	23	8	39	78	9	85	56	70	68	56	82	67	78	55
2	88		66	56	66	53	3	-7	17	78	-16	85	64	87	66	40	77	62	86	58
3	55	66		38	48	50	19	-3	-3	31	-27	48	18	51	66	14	46	51	63	36
4	69	56	38		86	92	57	60	68	70	47	43	29	67	51	81	92	40	52	14
5	65	66	48	86		78	46	38	42	69	21	51	58	89	60	66	83	35	61	37
6	61	53	50	92	78		62	71	71	55	46	41	12	64	48	79	80	32	44	0
7	23	3	19	57	46	62		59	77	11	52	14	4	32	32	51	35	9	3	-10
8	8	-7	-3	60	38	71	59		77	0	68	-2	-15	29	21	78	38	4	-10	-44
9	39	17	-3	68	42	71	77	77		34	84	28	10	25	20	83	56	18	2	-14
10	78	78	31	70	69	55	11	0	34		18	67	58	70	27	48	89	48	69	56
11	9	-16	-27	47	21	46	52	68	84	18		-11	-13	-15	-23	67	42	-13	-36	-30
12	85	85	48	43	51	41	14	-2	28	67	-11		73	78	72	46	59	80	85	76
13	56	64	18	29	58	12	4	-15	10	58	-13	73		73	59	35	49	59	66	77
14	70	87	51	67	89	64	32	29	25	70	-15	78	73		78	58	78	61	90	48
15	68	66	66	51	60	48	32	21	20	27	-23	72	59	78		50	77	80	76	44
16	56	40	14	81	66	79	51	78	83	48	67	46	35	58	50		73	44	33	11
17	82	77	46	92	83	80	35	38	56	89	42	59	49	78	77	73		61	75	28
18	67	62	51	40	35	32	9	4	18	48	-13	80	59	61	80	44	61		83	69
19	78	86	63	52	61	44	3	-10	2	69	-36	85	66	90	76	33	75	83		72
20	55	58	36	14	37	0	-10	-44	-14	56	-30	76	77	48	44	11	28	69	72	

SPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		84	82	73	88	69	68	37	46	79	35	86	69	76	87	71	87	80	82	81
2	84		93	62	83	57	53	39	33	71	21	93	69	88	81	57	82	60	80	70
3	82	93		65	85	62	58	31	23	74	19	89	67	90	90	63	88	78	90	78
4	73	62	65		88	97	80	76	73	83	60	65	54	76	70	88	91	63	67	54
5	88	83	85	88		83	68	50	46	86	33	90	69	93	88	78	96	72	89	72
6	69	57	62	97	83		75	83	76	76	58	63	45	69	63	88	86	65	63	45
7	68	53	58	80	68	75		60	84	62	57	57	38	54	67	72	79	63	56	51
8	37	39	31	76	50	83	60		82	48	72	34	32	52	29	82	63	41	24	25
9	46	33	23	73	46	76	84	82		44	76	32	25	35	35	74	58	47	25	27
10	79	71	74	83	86	76	62	48	44		57	73	74	73	72	85	98	60	70	75
11	35	21	19	60	33	58	57	72	76	57		20	52	23	28	81	67	47	17	50
12	86	93	89	65	90	63	57	34	32	73	20		76	94	92	64	88	75	93	75
13	69	69	67	54	69	45	38	32	25	74	52	76		78	77	69	74	65	71	90
14	76	88	90	76	93	69	54	52	35	73	23	94	78		92	65	91	65	93	72
15	87	81	90	70	88	63	67	29	35	72	28	92	77	92		65	93	86	97	85
16	71	57	63	88	78	88	72	82	74	85	81	64	69	65	65		93	73	61	70
17	87	82	88	91	96	86	79	63	58	98	67	88	74	91	93	93		76	89	77
18	80	60	78	63	72	65	63	41	47	60	47	75	65	65	86	73	76		83	81
19	82	80	90	67	89	63	56	24	25	70	17	93	71	93	97	61	89	83		77
20	81	70	78	54	72	45	51	25	27	75	50	75	90	72	85	70	77	81	77	

SPM/TPM

St.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		83	63	72	64	57	88	56	65	75	49	73	63	68	54	69	77	75	49	85
2	83		65	63	46	41	88	62	55	75	51	83	68	70	44	73	81	65	40	68
3	63	65		56	77	62	74	40	6	59	68	75	74	91	90	78	90	60	67	60
4	72	63	56		56	87	51	39	63	72	40	56	63	71	48	62	66	83	68	67
5	64	46	77	56		62	66	51	29	42	25	63	45	68	87	63	78	61	40	45
6	57	41	62	87	62		48	48	41	66	45	41	74	61	56	71	63	81	69	68
7	88	88	74	51	66	48		54	44	63	48	74	59	58	61	75	73	61	44	78
8	56	62	40	39	51	48	54		39	56	24	65	61	53	48	67	69	45	2	57
9	65	55	6	63	29	41	44	39		48	22	33	27	44	14	37	31	59	11	59
10	75	75	59	72	42	66	63	56	48		59	66	85	71	43	87	78	81	71	85
11	49	51	68	40	25	45	48	24	22	59		41	80	70	46	63	70	54	55	67
12	73	83	75	56	63	41	74	65	33	66	41		58	82	74	70	82	45	33	58
13	63	68	74	63	45	74	59	61	27	85	80	58		71	50	89	89	79	70	80
14	68	70	91	71	68	61	58	53	44	71	70	82	71		91	69	90	59	48	58
15	54	44	90	48	87	56	61	48	14	43	46	74	50	91		63	79	43	38	40
16	69	73	78	62	63	71	75	67	37	87	63	70	89	69	63		93	80	66	82
17	77	81	90	66	78	63	73	69	31	78	70	82	89	90	79	93		77	67	71
18	75	65	60	83	61	81	61	45	59	81	54	45	79	59	43	80	77		76	75
19	49	40	67	68	40	69	44	2	11	71	55	33	70	48	38	66	67	76		59
20	85	68	60	67	45	68	78	57	59	85	67	58	80	58	40	82	71	75	59	

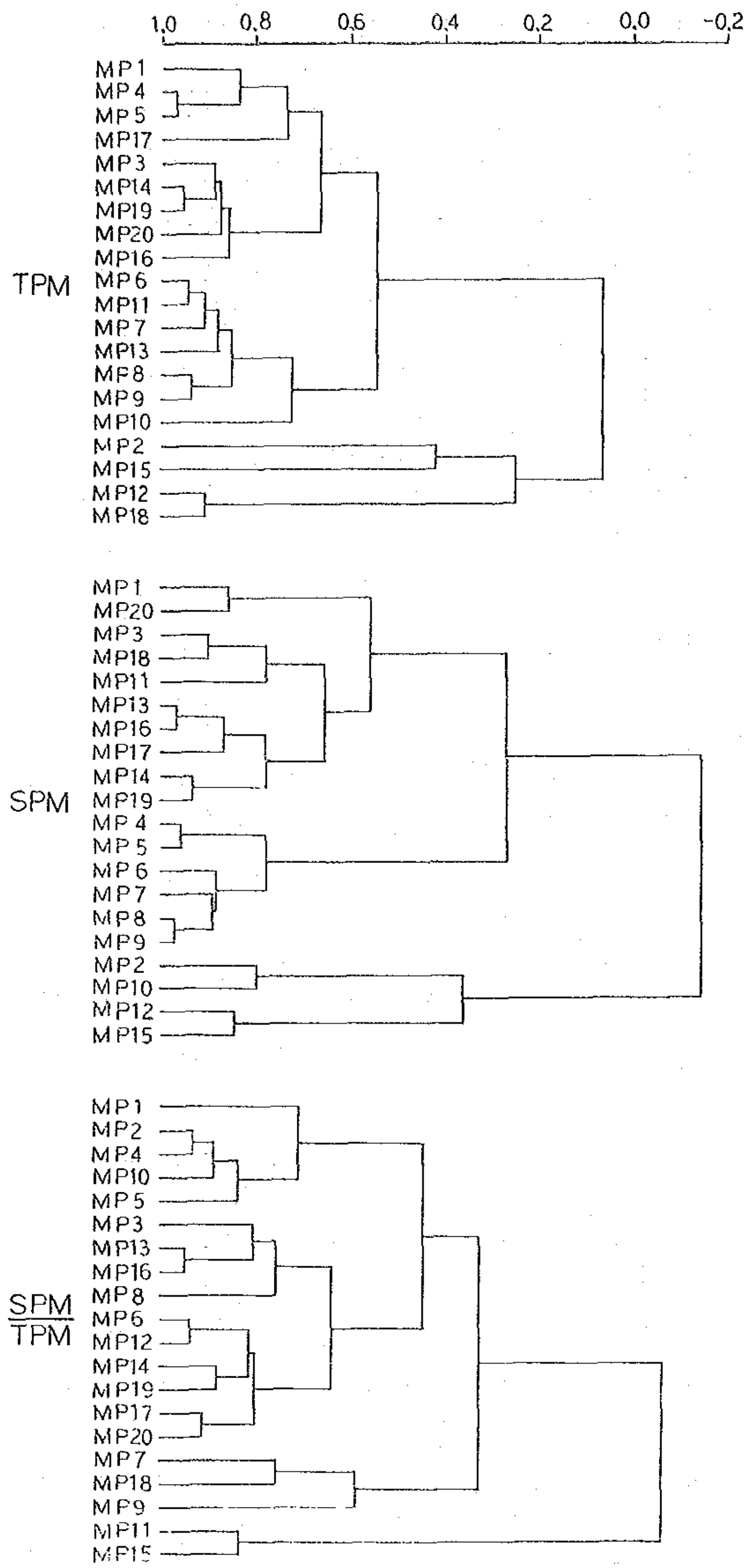


Fig. V-2-3-(1) Results of clustering and correlation coefficients (1st survey)

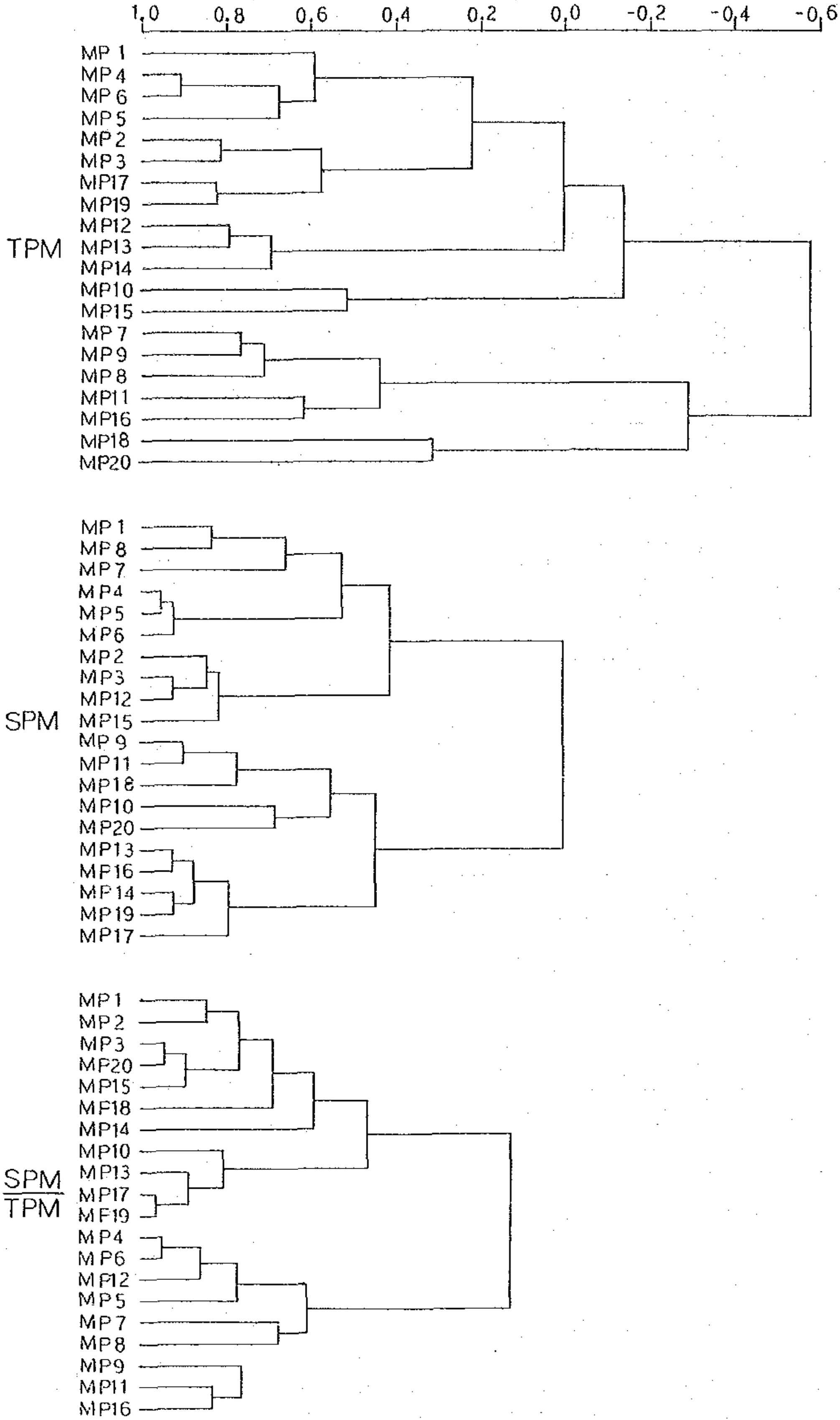


Fig. V-2-3-(2) Results of clustering and correlation coefficients (2nd survey)

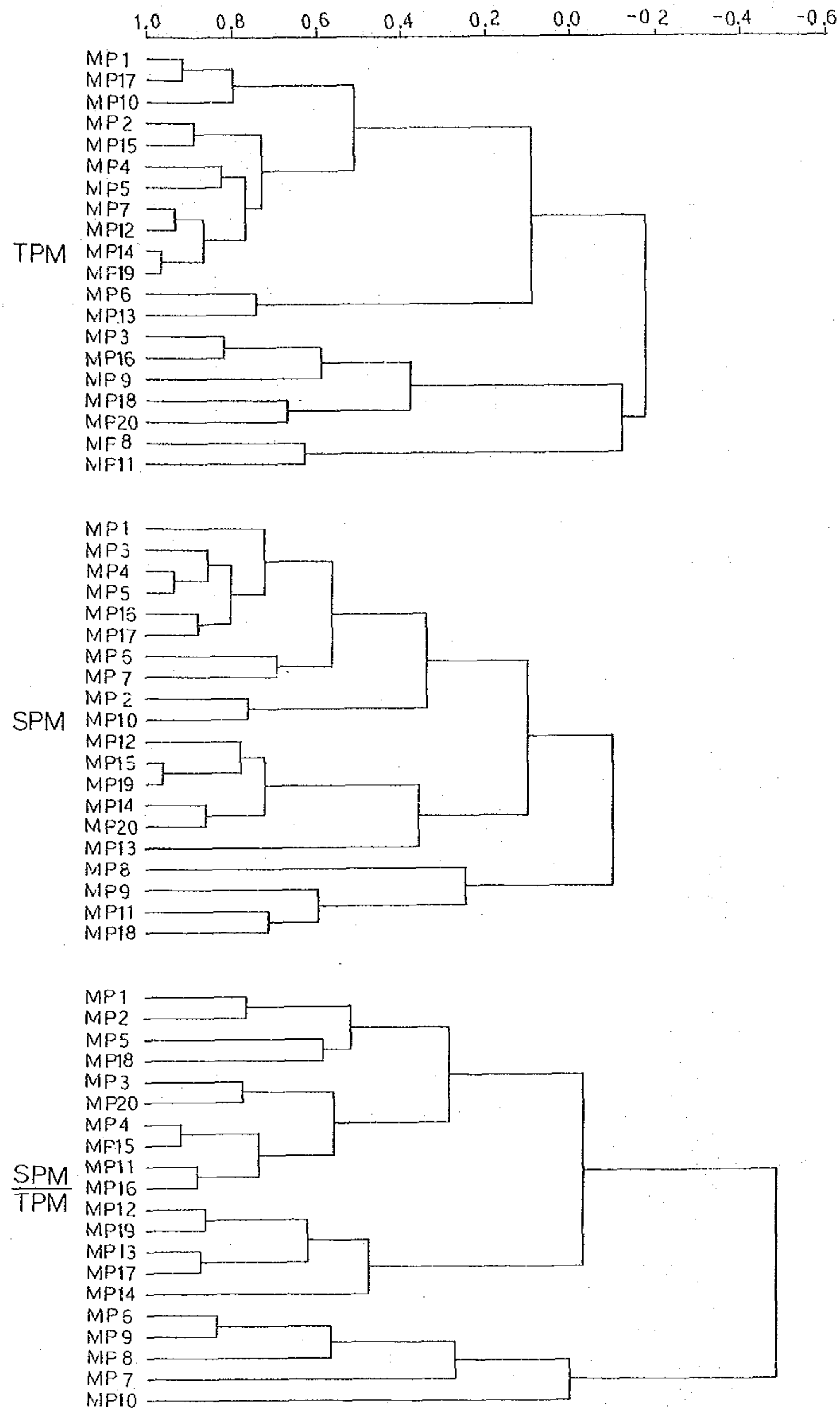


Fig. V-2-3-(3) Results of clustering and correlation coefficients (3rd survey)

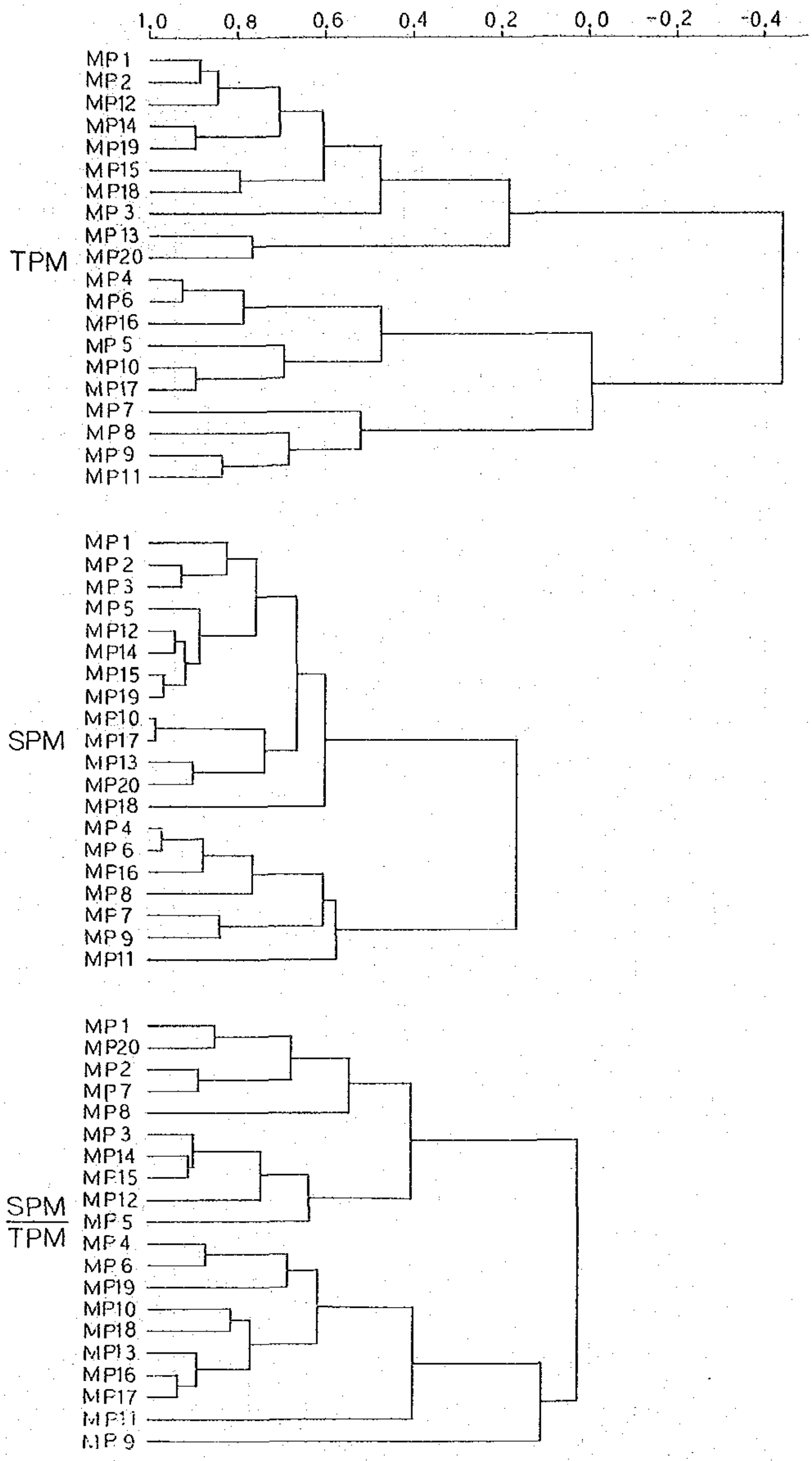


Fig. V-2-3-(4) Results of clustering and correlation coefficients (4th survey)

Table V-2-3-(1) The results from the principal component analysis (1st survey)

TPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.231	0.008	-0.254	0.101	0.248	0.853	0.014	-0.305	0.093	0.188
2	0.102	-0.162	0.695	-0.060	0.442	0.378	-0.265	0.833	-0.055	0.335
3	0.236	-0.233	0.044	-0.245	0.131	0.871	-0.381	0.053	-0.227	0.099
4	0.246	0.127	-0.159	0.219	0.197	0.909	0.208	-0.190	0.204	0.149
5	0.242	0.131	-0.242	0.113	0.252	0.894	0.215	-0.290	0.104	0.191
6	0.234	0.257	0.057	0.054	-0.133	0.864	0.420	0.068	0.050	-0.101
7	0.247	0.158	-0.067	-0.166	0.011	0.910	0.258	-0.081	-0.154	0.009
8	0.227	0.265	0.174	0.026	-0.101	0.838	0.433	0.209	0.024	-0.076
9	0.230	0.244	0.199	-0.181	-0.186	0.850	0.399	0.239	-0.168	-0.141
10	0.224	0.120	0.297	-0.186	-0.035	0.826	0.196	0.356	-0.172	-0.026
11	0.246	0.201	-0.013	-0.170	0.004	0.909	0.329	-0.016	-0.158	0.003
12	0.143	-0.500	-0.140	0.042	-0.052	0.529	-0.819	-0.167	0.039	-0.040
13	0.253	0.132	-0.115	0.052	-0.205	0.934	0.216	-0.137	0.048	-0.155
14	0.246	-0.162	-0.139	-0.003	-0.075	0.909	-0.264	-0.167	-0.002	-0.057
15	0.153	-0.184	0.291	0.591	-0.525	0.564	-0.301	0.349	0.548	-0.397
16	0.252	-0.066	0.021	-0.290	-0.243	0.929	-0.108	0.025	-0.269	-0.184
17	0.231	-0.106	0.133	0.410	0.371	0.852	-0.174	0.159	0.380	0.281
18	0.139	-0.477	-0.002	-0.331	-0.146	0.514	-0.780	-0.003	-0.307	-0.111
19	0.250	-0.127	-0.200	-0.053	0.108	0.921	-0.207	-0.239	-0.049	0.082
20	0.252	-0.157	-0.068	0.142	-0.059	0.931	-0.257	-0.082	0.131	-0.045
Eigen values	13.626	2.678	1.435	0.860	0.573					

SPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.224	-0.046	-0.132	0.466	-0.580	0.803	-0.085	-0.181	0.362	-0.403
2	0.095	-0.305	0.528	0.065	-0.112	0.339	-0.559	0.725	0.050	-0.078
3	0.233	-0.222	-0.122	-0.295	-0.213	0.836	-0.407	-0.168	-0.229	-0.148
4	0.219	0.317	-0.051	0.046	-0.020	0.786	0.581	-0.070	0.036	-0.014
5	0.221	0.278	-0.162	0.012	-0.098	0.790	0.510	-0.223	0.009	-0.068
6	0.215	0.276	0.103	0.203	0.433	0.772	0.506	0.141	0.157	0.301
7	0.225	0.251	0.150	0.057	0.017	0.804	0.460	0.206	0.045	0.012
8	0.230	0.234	0.244	0.046	-0.010	0.825	0.429	0.336	0.036	-0.007
9	0.231	0.244	0.164	0.086	-0.070	0.826	0.446	0.226	0.067	-0.048
10	0.170	-0.034	0.546	-0.092	-0.280	0.610	-0.062	0.749	-0.072	-0.195
11	0.246	-0.140	0.119	0.103	0.445	0.883	-0.257	0.164	0.080	0.309
12	0.211	-0.316	-0.149	0.145	-0.034	0.757	-0.580	-0.205	0.112	-0.024
13	0.273	0.041	-0.016	-0.126	-0.050	0.980	0.075	-0.022	-0.098	-0.035
14	0.256	-0.117	-0.157	-0.132	0.055	0.917	-0.215	-0.216	-0.103	0.039
15	0.144	-0.419	0.102	0.366	0.307	0.517	-0.769	0.141	0.284	0.213
16	0.265	-0.077	-0.005	-0.190	-0.018	0.950	-0.141	-0.007	-0.148	-0.012
17	0.252	0.099	-0.024	-0.472	0.082	0.903	0.182	-0.032	-0.366	0.057
18	0.212	-0.287	-0.079	-0.261	-0.025	0.758	-0.526	-0.108	-0.203	-0.017
19	0.240	-0.117	-0.217	-0.060	0.135	0.859	-0.214	-0.298	-0.047	0.094
20	0.234	0.020	-0.341	0.310	-0.020	0.839	0.037	-0.469	0.241	-0.014
Eigen values	12.834	3.361	1.886	0.602	0.483					

SPM / TPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.230	0.169	0.180	0.071	0.347	0.871	0.224	0.214	0.062	0.263
2	0.256	0.016	0.211	0.013	-0.050	0.970	0.021	0.251	0.011	-0.038
3	0.224	-0.031	-0.208	-0.116	-0.410	0.851	-0.040	-0.248	-0.101	-0.312
4	0.233	-0.128	0.195	-0.073	0.355	0.884	-0.170	0.232	-0.063	0.270
5	0.230	-0.107	0.231	0.077	-0.006	0.872	-0.141	0.275	0.067	-0.005
6	0.238	-0.035	0.180	0.349	-0.138	0.902	-0.047	0.214	0.303	-0.105
7	0.214	-0.354	0.141	-0.132	-0.007	0.811	-0.469	0.167	-0.114	-0.005
8	0.225	-0.000	-0.170	0.190	-0.076	0.853	-0.000	-0.202	0.165	-0.058
9	0.171	-0.093	-0.486	-0.238	0.558	0.650	-0.124	-0.578	-0.207	0.424
10	0.202	-0.112	0.421	-0.296	0.156	0.767	-0.148	0.500	-0.257	0.118
11	0.152	0.649	-0.053	0.044	0.139	0.575	0.859	-0.063	0.038	0.106
12	0.247	0.029	-0.250	0.142	0.005	0.936	0.038	-0.297	0.123	0.004
13	0.230	0.269	-0.198	-0.182	0.024	0.872	0.355	-0.235	-0.158	0.018
14	0.258	0.015	-0.020	-0.010	0.042	0.977	0.020	-0.024	-0.008	0.032
15	0.194	0.366	0.328	0.008	-0.144	0.736	0.484	0.390	0.007	-0.109
16	0.241	0.192	-0.113	-0.197	-0.285	0.912	0.254	-0.134	-0.170	-0.216
17	0.238	-0.278	-0.022	0.099	0.008	0.903	-0.367	-0.026	0.086	0.006
18	0.212	-0.122	-0.097	-0.546	-0.304	0.804	-0.162	-0.115	-0.474	-0.231
19	0.230	-0.069	-0.119	0.223	0.021	0.872	-0.091	-0.142	0.194	0.016
20	0.220	-0.179	-0.211	0.445	-0.074	0.833	-0.237	-0.251	0.385	-0.056
Eigen values	14.387	1.751	1.413	0.752	0.577					

Table V-2-3-(2) The results from the principal component analysis (2nd survey)

TPM

St.	Eigen values and eigen vectors 1	2	3	4	5	Factor loading 1	2	3	4	5
1	0.246	-0.100	0.079	0.395	-0.262	0.632	-0.217	0.141	0.564	-0.300
2	0.231	-0.248	-0.093	0.053	0.267	0.594	-0.537	-0.166	0.075	0.306
3	0.288	-0.099	-0.267	-0.065	0.008	0.740	-0.215	-0.478	-0.092	0.009
4	0.341	-0.025	0.225	0.018	-0.064	0.874	-0.054	0.402	0.026	-0.073
5	0.280	0.017	0.078	0.003	-0.554	0.717	0.037	0.140	0.005	-0.634
6	0.321	-0.059	0.265	-0.104	-0.073	0.825	-0.128	0.474	-0.148	-0.084
7	0.135	0.256	0.340	-0.032	0.065	0.346	0.555	0.607	-0.045	0.075
8	0.097	0.275	0.350	-0.186	0.115	0.250	0.597	0.626	-0.265	0.132
9	0.057	0.408	0.161	0.027	0.196	0.147	0.885	0.288	0.039	0.225
10	0.246	0.024	0.124	-0.475	0.080	0.630	0.052	0.221	-0.678	0.091
11	0.150	0.342	0.044	0.170	-0.101	0.385	0.741	0.079	0.243	-0.115
12	0.179	0.239	-0.298	0.094	0.354	0.460	0.517	-0.532	0.134	0.406
13	0.317	0.097	-0.228	0.008	0.154	0.815	0.210	-0.408	0.012	0.176
14	0.192	0.197	-0.359	0.125	-0.226	0.493	0.426	-0.642	0.179	-0.259
15	0.076	-0.204	-0.137	-0.507	0.144	0.196	-0.442	-0.246	-0.724	0.165
16	0.139	0.379	-0.153	-0.192	-0.031	0.358	0.822	-0.273	-0.274	-0.036
17	0.306	-0.230	-0.008	0.187	0.113	0.785	-0.498	-0.015	0.267	0.129
18	-0.091	0.329	-0.302	0.121	0.055	-0.232	0.713	-0.540	0.172	0.063
19	0.295	-0.163	-0.178	-0.044	0.058	0.757	-0.354	-0.319	-0.063	0.067
20	-0.089	0.101	-0.266	-0.406	-0.479	-0.228	0.219	-0.476	-0.579	-0.548
Eigen values	16.587	4.698	3.199	2.038	1.310					

SPM

St.	Eigen values and eigen vectors 1	2	3	4	5	Factor loading 1	2	3	4	5
1	0.226	0.163	0.245	0.196	-0.311	0.818	0.268	0.327	0.202	-0.194
2	0.209	0.288	-0.279	-0.162	0.183	0.754	0.473	-0.373	-0.167	0.114
3	0.253	0.102	-0.223	-0.047	0.231	0.914	0.167	-0.299	-0.049	0.144
4	0.216	0.359	0.064	0.021	0.253	0.779	0.589	0.085	0.022	0.158
5	0.199	0.393	0.019	0.131	-0.041	0.717	0.645	0.025	0.135	-0.026
6	0.197	0.380	0.146	0.164	-0.233	0.712	0.624	0.195	0.169	-0.146
7	0.190	0.060	0.425	-0.351	0.339	0.686	0.098	0.568	-0.362	0.211
8	0.226	0.053	0.312	0.153	-0.103	0.616	0.087	0.417	0.158	-0.064
9	0.219	-0.167	0.371	-0.156	0.156	0.792	-0.275	0.496	-0.161	0.097
10	0.225	-0.117	0.127	-0.357	-0.470	0.812	-0.191	0.169	-0.368	-0.293
11	0.231	-0.235	0.217	0.025	0.187	0.834	-0.385	0.290	0.026	0.116
12	0.229	0.044	-0.326	-0.161	0.269	0.828	0.073	-0.435	-0.166	0.168
13	0.251	-0.146	-0.074	0.203	0.074	0.908	-0.240	-0.099	0.210	0.046
14	0.222	-0.257	-0.191	0.247	-0.196	0.801	-0.422	-0.255	0.255	-0.122
15	0.218	0.103	-0.229	-0.426	-0.324	0.789	0.168	-0.307	-0.440	-0.202
16	0.255	-0.184	0.023	0.077	-0.100	0.920	-0.302	0.030	0.079	-0.063
17	0.231	-0.005	-0.132	0.473	0.062	0.836	-0.008	-0.176	0.488	0.039
18	0.188	-0.408	0.050	0.044	0.171	0.680	-0.669	0.066	0.045	0.107
19	0.255	-0.149	-0.190	0.050	0.031	0.920	-0.245	-0.254	0.052	0.019
20	0.216	-0.165	-0.224	-0.213	-0.161	0.782	-0.270	-0.300	-0.220	-0.100
Eigen values	13.060	2.692	1.787	1.064	0.389					

SPM / TPM

St.	Eigen values and eigen vectors 1	2	3	4	5	Factor loading 1	2	3	4	5
1	0.250	-0.014	0.016	0.110	0.251	0.928	-0.022	0.014	0.092	0.188
2	0.235	0.059	0.058	-0.227	0.373	0.871	0.097	0.052	-0.189	0.279
3	0.263	0.024	0.155	-0.060	0.175	0.975	0.040	0.140	-0.050	0.131
4	0.225	-0.290	-0.044	-0.031	0.322	0.835	-0.473	-0.040	-0.026	0.241
5	0.176	-0.340	-0.410	-0.052	-0.169	0.654	-0.556	-0.372	-0.043	-0.126
6	0.232	-0.289	0.028	-0.105	-0.037	0.859	-0.472	0.025	-0.088	-0.027
7	0.179	-0.243	0.030	0.665	-0.081	0.663	-0.396	0.028	0.554	-0.061
8	0.197	-0.269	0.362	-0.003	-0.419	0.730	-0.439	0.328	-0.003	-0.313
9	0.226	-0.196	0.085	-0.005	-0.120	0.836	-0.319	0.077	-0.004	-0.090
10	0.178	0.378	-0.324	0.223	-0.155	0.659	0.618	-0.294	0.186	-0.116
11	0.248	0.122	-0.109	-0.052	-0.042	0.917	0.199	-0.099	-0.044	-0.032
12	0.208	-0.316	-0.200	0.040	0.203	0.771	-0.516	-0.181	0.033	0.152
13	0.238	0.254	0.118	-0.039	0.003	0.882	0.416	0.107	-0.032	0.002
14	0.197	0.196	-0.471	-0.311	-0.167	0.729	0.321	-0.428	-0.259	-0.125
15	0.254	0.066	-0.246	0.056	0.035	0.941	0.108	-0.223	0.047	0.026
16	0.230	0.029	0.040	-0.133	-0.555	0.852	0.047	0.036	-0.111	-0.415
17	0.211	0.303	0.190	0.341	0.012	0.783	0.495	0.172	0.284	0.009
18	0.215	0.083	0.397	-0.359	-0.057	0.798	0.135	0.360	-0.299	-0.043
19	0.228	0.271	0.094	0.215	0.033	0.845	0.442	0.085	0.179	0.025
20	0.251	0.071	0.075	-0.108	0.166	0.930	0.116	0.068	-0.090	0.125
Eigen values	13.719	2.668	0.823	0.694	0.559					

Table V-2-3-(3) The results from the principal component analysis (3rd survey)

TPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.232	-0.319	0.018	-0.022	0.024	0.806	-0.494	0.027	-0.024	0.021
2	0.266	-0.005	0.057	0.328	-0.078	0.925	-0.007	0.083	0.348	-0.068
3	0.231	0.193	-0.145	-0.087	-0.362	0.802	0.298	-0.213	-0.092	-0.312
4	0.259	-0.048	0.076	-0.095	0.389	0.899	-0.074	0.115	-0.100	0.335
5	0.245	-0.030	0.049	-0.092	0.288	0.852	-0.047	0.072	-0.098	0.248
6	0.230	0.096	0.354	-0.077	-0.053	0.800	0.149	0.520	-0.081	-0.046
7	0.261	0.020	0.116	-0.139	-0.002	0.907	0.030	0.171	-0.148	-0.002
8	0.143	0.520	0.077	0.226	0.114	0.498	0.804	0.114	0.240	0.098
9	0.160	0.341	-0.105	-0.450	0.361	0.555	0.527	-0.154	-0.477	0.311
10	0.185	-0.450	0.089	0.063	0.100	0.641	-0.696	0.130	0.067	0.086
11	0.124	0.315	-0.372	0.443	-0.138	0.433	0.488	-0.547	0.471	-0.119
12	0.280	0.035	0.056	-0.018	0.097	0.971	0.054	0.082	-0.019	0.084
13	0.121	0.220	0.418	-0.328	-0.424	0.421	0.340	0.615	-0.348	-0.365
14	0.274	-0.066	0.013	-0.049	-0.166	0.953	-0.101	0.018	-0.052	-0.143
15	0.249	0.041	0.081	0.253	0.127	0.864	0.064	0.120	0.269	0.110
16	0.259	0.124	-0.221	0.012	0.069	0.900	0.192	-0.325	0.012	0.059
17	0.253	-0.225	-0.035	0.092	-0.270	0.878	-0.348	-0.051	0.098	-0.233
18	0.189	-0.128	-0.409	-0.040	0.171	0.658	-0.198	-0.601	-0.042	0.147
19	0.269	-0.132	0.035	0.113	-0.194	0.936	-0.204	0.051	0.120	-0.167
20	0.097	-0.061	-0.511	-0.436	-0.275	0.339	-0.094	-0.751	-0.463	-0.237
Eigen values	12.080	2.389	2.159	1.127	0.743					

SPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.223	-0.211	-0.371	0.059	-0.139	0.758	-0.321	-0.516	0.076	-0.138
2	0.240	-0.128	0.065	-0.011	0.318	0.816	-0.194	0.091	-0.014	0.315
3	0.279	-0.005	0.017	0.019	-0.126	0.950	-0.008	0.024	0.025	-0.125
4	0.265	-0.022	-0.207	-0.101	-0.081	0.903	-0.033	-0.288	-0.128	-0.080
5	0.261	-0.134	-0.223	-0.173	-0.137	0.888	-0.204	-0.310	-0.221	-0.136
6	0.222	-0.135	-0.186	-0.284	0.245	0.754	-0.205	-0.259	-0.363	0.243
7	0.222	0.106	-0.101	-0.414	-0.210	0.755	0.161	-0.140	-0.528	-0.208
8	0.104	0.412	0.105	-0.416	0.397	0.353	0.627	0.146	-0.530	0.393
9	0.168	0.456	-0.228	-0.093	-0.198	0.570	0.694	-0.317	-0.119	-0.196
10	0.196	-0.378	-0.060	0.020	0.447	0.668	-0.574	-0.083	0.025	0.444
11	0.144	0.418	-0.119	0.233	0.310	0.490	0.636	-0.165	0.297	0.307
12	0.232	0.097	0.338	-0.189	0.036	0.788	0.148	0.470	-0.241	0.037
13	0.130	-0.054	0.386	-0.295	-0.388	0.444	-0.082	0.536	-0.377	-0.385
14	0.220	0.143	0.397	0.197	-0.028	0.749	0.218	0.552	0.251	-0.028
15	0.245	-0.189	0.300	0.034	0.091	0.834	-0.288	0.417	0.044	0.090
16	0.268	0.100	-0.147	0.160	-0.033	0.912	0.151	-0.204	0.204	-0.033
17	0.256	-0.068	-0.181	0.190	-0.166	0.871	-0.104	-0.251	0.242	-0.165
18	0.191	0.292	-0.029	0.387	0.038	0.651	0.444	-0.041	0.494	0.038
19	0.266	-0.165	0.187	0.112	0.072	0.904	-0.250	0.260	0.143	0.071
20	0.237	-0.005	0.199	0.284	-0.213	0.806	-0.007	0.277	0.362	-0.211
Eigen values	11.574	2.313	1.936	1.626	0.983					

SPM/TPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.247	-0.140	-0.321	-0.123	0.148	0.794	-0.235	-0.454	-0.137	0.158
2	0.208	-0.289	-0.101	-0.042	0.203	0.669	-0.484	-0.143	-0.047	0.218
3	0.243	0.058	0.167	0.172	-0.174	0.779	0.098	0.235	0.192	-0.186
4	0.277	0.108	-0.147	0.048	0.176	0.891	0.181	-0.207	0.054	0.191
5	0.198	0.035	-0.397	0.079	0.416	0.636	0.059	-0.560	0.089	0.446
6	0.113	0.476	0.133	0.020	-0.049	0.362	0.799	0.187	0.023	-0.052
7	0.045	0.335	-0.311	-0.526	-0.003	0.145	0.561	-0.440	-0.588	-0.003
8	0.204	0.268	-0.071	0.161	-0.313	0.655	0.449	-0.100	0.180	-0.336
9	0.171	0.430	0.081	0.141	-0.110	0.549	0.720	0.114	0.158	-0.118
10	0.028	0.244	0.431	-0.089	0.576	0.090	0.406	0.609	-0.100	0.618
11	0.279	0.022	-0.083	0.136	-0.293	0.896	0.037	-0.117	0.152	-0.314
12	0.224	0.018	0.300	-0.445	-0.000	0.718	0.031	0.423	-0.497	-0.000
13	0.291	-0.173	0.059	-0.025	-0.137	0.935	-0.291	0.084	-0.028	-0.147
14	0.143	-0.373	0.365	-0.057	-0.097	0.459	-0.625	0.515	-0.064	-0.104
15	0.287	-0.042	-0.029	-0.109	0.139	0.921	-0.070	-0.040	-0.122	0.149
16	0.280	0.028	-0.163	0.278	0.029	0.898	0.047	-0.230	0.311	0.032
17	0.250	-0.054	0.032	-0.333	-0.257	0.803	-0.091	0.045	-0.372	-0.276
18	0.229	-0.202	0.008	0.249	0.055	0.734	-0.340	0.012	0.278	0.059
19	0.281	-0.066	0.114	-0.238	-0.027	0.902	-0.111	0.161	-0.266	-0.028
20	0.215	0.075	0.304	0.274	0.233	0.691	0.126	0.429	0.307	0.250
Eigen values	10.304	2.811	1.992	1.249	1.151					

Table V-2-3-(4) The results from the principal component analysis (4th survey)

TPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.273	0.063	0.076	-0.093	-0.304	0.888	0.135	0.089	-0.097	-0.267
2	0.264	0.163	-0.010	-0.222	-0.085	0.858	0.350	-0.011	-0.231	-0.075
3	0.178	0.128	-0.521	-0.143	-0.281	0.579	0.276	-0.608	-0.149	-0.247
4	0.256	-0.206	-0.030	-0.213	0.030	0.833	-0.443	-0.034	-0.221	0.026
5	0.263	-0.073	-0.044	-0.213	0.451	0.853	-0.156	-0.051	-0.221	0.397
6	0.237	-0.240	-0.206	-0.196	-0.059	0.770	-0.518	-0.241	-0.204	-0.052
7	0.124	-0.290	-0.175	0.247	0.122	0.403	-0.625	-0.205	0.257	0.108
8	0.098	-0.392	-0.160	0.191	0.124	0.318	-0.844	-0.186	0.199	0.109
9	0.154	-0.359	0.166	0.197	-0.171	0.500	-0.772	0.194	0.205	-0.150
10	0.244	0.044	0.360	-0.406	-0.066	0.794	0.095	0.421	-0.422	-0.058
11	0.049	-0.403	0.335	0.012	-0.220	0.161	-0.868	0.391	0.012	-0.193
12	0.255	0.168	0.130	0.221	-0.167	0.827	0.361	0.152	0.230	-0.147
13	0.202	0.189	0.326	0.241	0.424	0.658	0.407	0.381	0.251	0.373
14	0.280	0.071	-0.103	-0.022	0.421	0.910	0.153	-0.121	-0.023	0.370
15	0.244	0.097	-0.338	0.341	0.054	0.791	0.208	-0.395	0.354	0.047
16	0.225	-0.259	0.125	0.197	0.003	0.732	-0.558	0.146	0.205	0.003
17	0.288	-0.085	0.043	-0.194	-0.085	0.936	-0.182	0.050	-0.201	-0.074
18	0.225	0.160	-0.016	0.396	-0.324	0.730	0.345	-0.019	0.412	-0.285
19	0.259	0.224	-0.082	-0.016	-0.017	0.842	0.482	-0.096	-0.019	-0.015
20	0.165	0.298	0.281	0.184	-0.024	0.536	0.642	0.328	0.192	-0.021
Eigen values	10.554	4.639	1.364	1.082	0.773					

SPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.240	-0.102	0.010	-0.186	-0.184	0.899	-0.172	0.010	-0.156	-0.124
2	0.224	-0.187	0.147	0.153	0.216	0.840	-0.314	0.151	-0.128	0.144
3	0.233	-0.223	0.106	-0.026	0.033	0.873	-0.375	0.109	-0.023	0.022
4	0.236	0.194	0.200	0.121	-0.214	0.884	0.327	0.206	0.101	-0.143
5	0.252	-0.069	0.186	0.128	-0.181	0.947	-0.117	0.192	0.107	-0.121
6	0.225	0.236	0.256	0.090	-0.097	0.845	0.397	0.264	0.075	-0.065
7	0.205	0.210	0.171	-0.467	-0.154	0.769	0.353	0.176	-0.390	-0.103
8	0.163	0.402	0.126	0.267	0.461	0.610	0.676	0.130	0.223	0.309
9	0.158	0.429	0.103	-0.274	0.197	0.594	0.721	0.107	-0.229	0.132
10	0.235	0.022	-0.128	0.297	-0.556	0.881	0.038	-0.132	0.248	-0.372
11	0.147	0.395	-0.481	0.017	0.010	0.553	0.665	-0.496	0.015	0.007
12	0.238	-0.212	0.107	0.029	0.182	0.894	-0.357	0.110	0.024	0.122
13	0.209	-0.135	-0.468	0.233	0.212	0.783	-0.227	-0.483	0.194	0.142
14	0.240	-0.157	0.168	0.262	0.310	0.901	-0.264	0.173	0.219	0.208
15	0.244	-0.195	0.009	-0.213	0.041	0.914	-0.327	0.010	-0.178	0.028
16	0.236	0.227	-0.170	0.112	-0.027	0.886	0.382	-0.175	0.094	-0.018
17	0.268	0.031	-0.014	0.097	-0.185	1.007	0.052	-0.014	0.081	-0.124
18	0.222	-0.051	-0.151	-0.480	0.187	0.832	-0.086	-0.156	-0.402	0.125
19	0.234	-0.237	0.098	-0.114	0.008	0.879	-0.399	0.101	-0.096	0.005
20	0.219	-0.155	-0.451	-0.121	0.005	0.822	-0.261	-0.465	-0.101	0.004
Eigen values	14.068	2.831	1.063	0.699	0.449					

SPM / TPM

St.	Eigen values and eigen vectors					Factor loading				
	1	2	3	4	5	1	2	3	4	5
1	0.241	-0.100	-0.243	0.022	0.263	0.866	-0.134	-0.310	0.023	0.232
2	0.231	-0.029	-0.278	-0.241	0.206	0.830	-0.039	-0.355	-0.256	0.182
3	0.239	0.315	0.209	-0.017	0.165	0.858	0.423	0.266	-0.018	0.146
4	0.222	-0.231	0.030	0.381	0.084	0.798	-0.310	0.038	0.406	0.074
5	0.204	0.297	-0.048	0.422	-0.041	0.732	0.399	-0.061	0.450	-0.036
6	0.215	-0.166	0.197	0.371	-0.277	0.774	-0.223	0.251	0.395	-0.245
7	0.228	0.066	-0.222	-0.120	0.282	0.821	0.088	-0.282	-0.128	0.249
8	0.181	0.087	-0.358	-0.100	-0.658	0.650	0.117	-0.456	-0.106	-0.581
9	0.140	-0.373	-0.419	0.225	0.160	0.503	-0.502	-0.533	0.239	0.142
10	0.242	-0.217	0.034	-0.160	-0.089	0.869	-0.291	0.044	-0.171	-0.079
11	0.189	-0.025	0.279	-0.400	0.164	0.679	-0.034	0.355	-0.426	0.145
12	0.224	0.259	-0.231	-0.096	0.089	0.803	0.348	-0.295	-0.102	0.078
13	0.244	-0.094	0.208	-0.258	-0.277	0.875	-0.126	0.265	-0.275	-0.244
14	0.243	0.217	0.019	0.055	0.109	0.873	0.292	0.024	0.059	0.096
15	0.205	0.455	0.053	0.228	0.018	0.735	0.611	0.068	0.243	0.016
16	0.255	-0.016	0.065	-0.140	-0.243	0.917	-0.021	0.083	-0.149	-0.214
17	0.267	0.154	0.058	-0.095	-0.092	0.960	0.207	0.074	-0.102	-0.082
18	0.237	-0.276	0.097	0.176	-0.054	0.850	-0.371	0.124	0.188	-0.048
19	0.189	-0.176	0.475	0.071	0.190	0.680	-0.236	0.606	0.076	0.168
20	0.237	-0.247	-0.053	-0.159	0.010	0.852	-0.332	-0.068	-0.169	0.009
Eigen values	12.901	1.806	1.623	1.135	0.780					

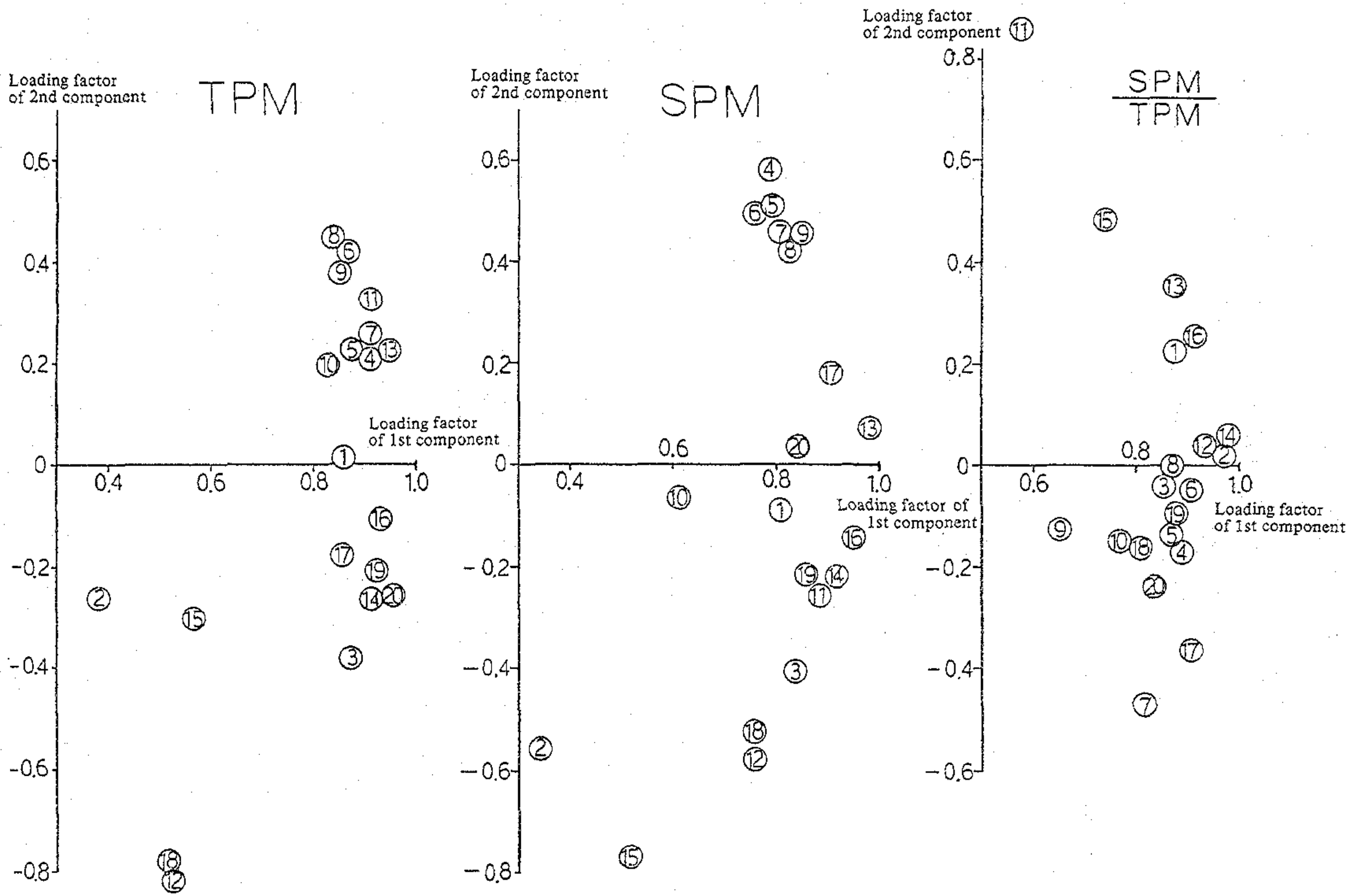


Fig. V-2-4-(1) The results of the principal component analysis (1st survey)

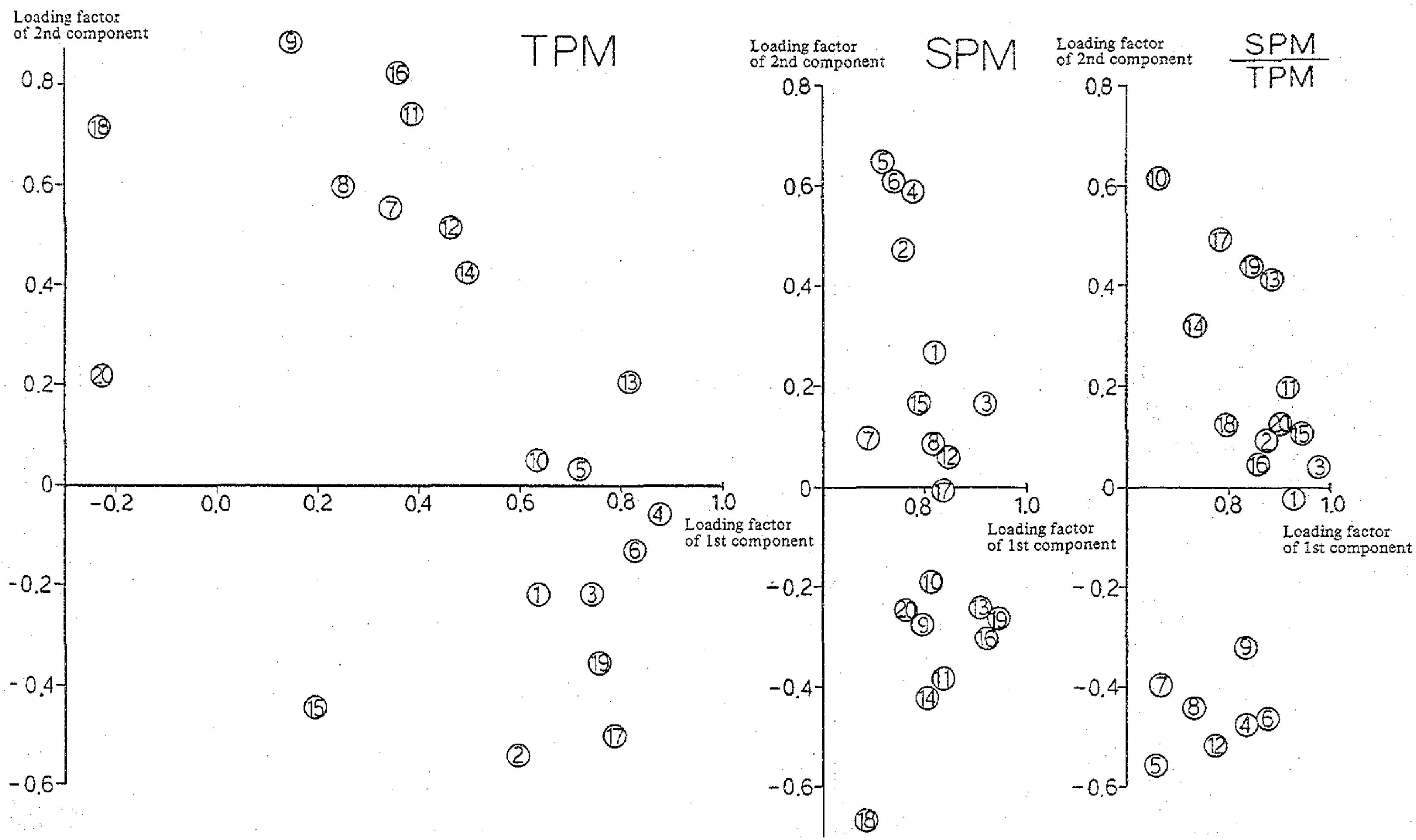


Fig. V-2-4-(2) The results of the principal component analysis (2nd survey)

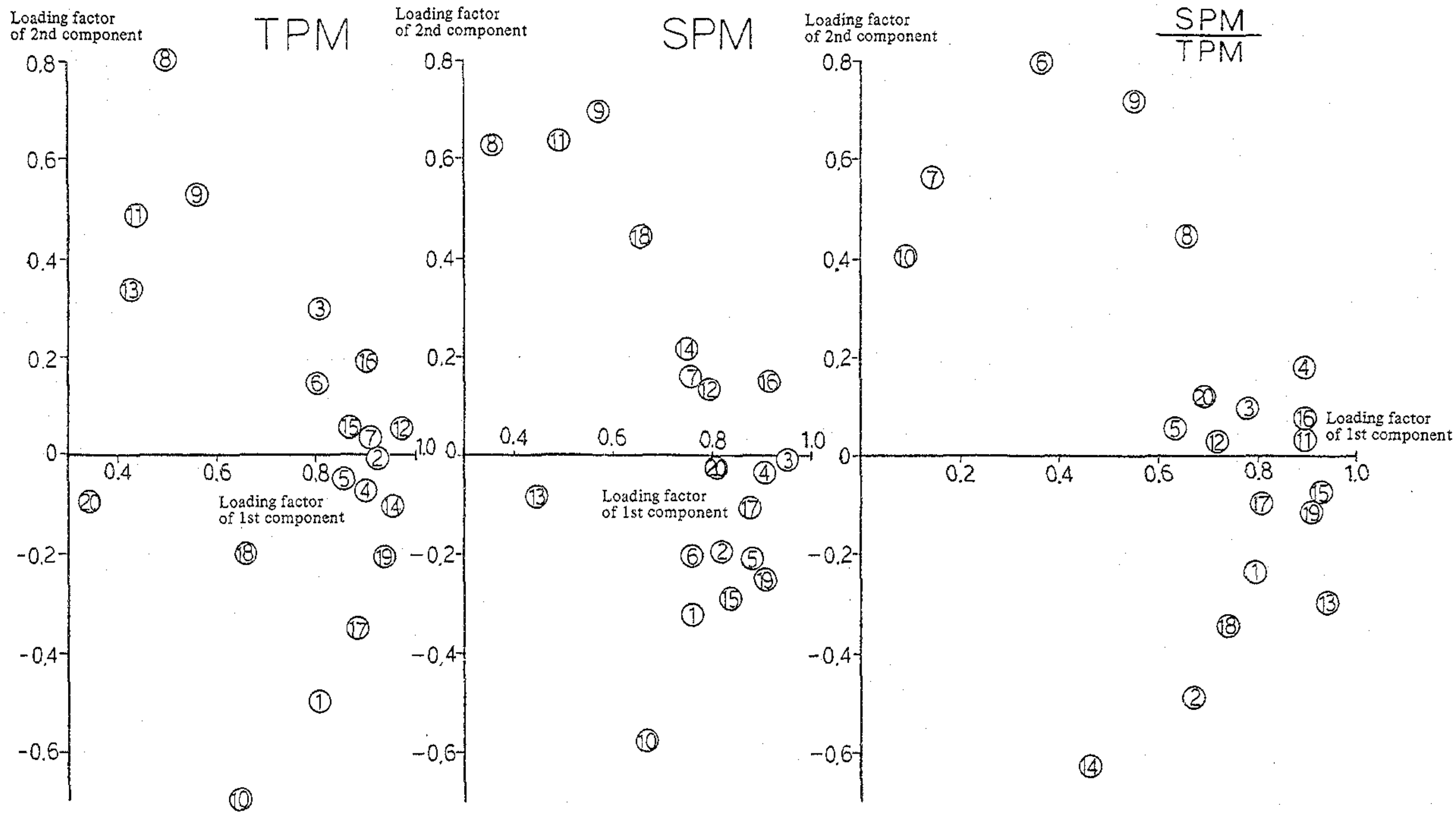


Fig. V-2-4-(3) The results of the principal component analysis (3rd survey)

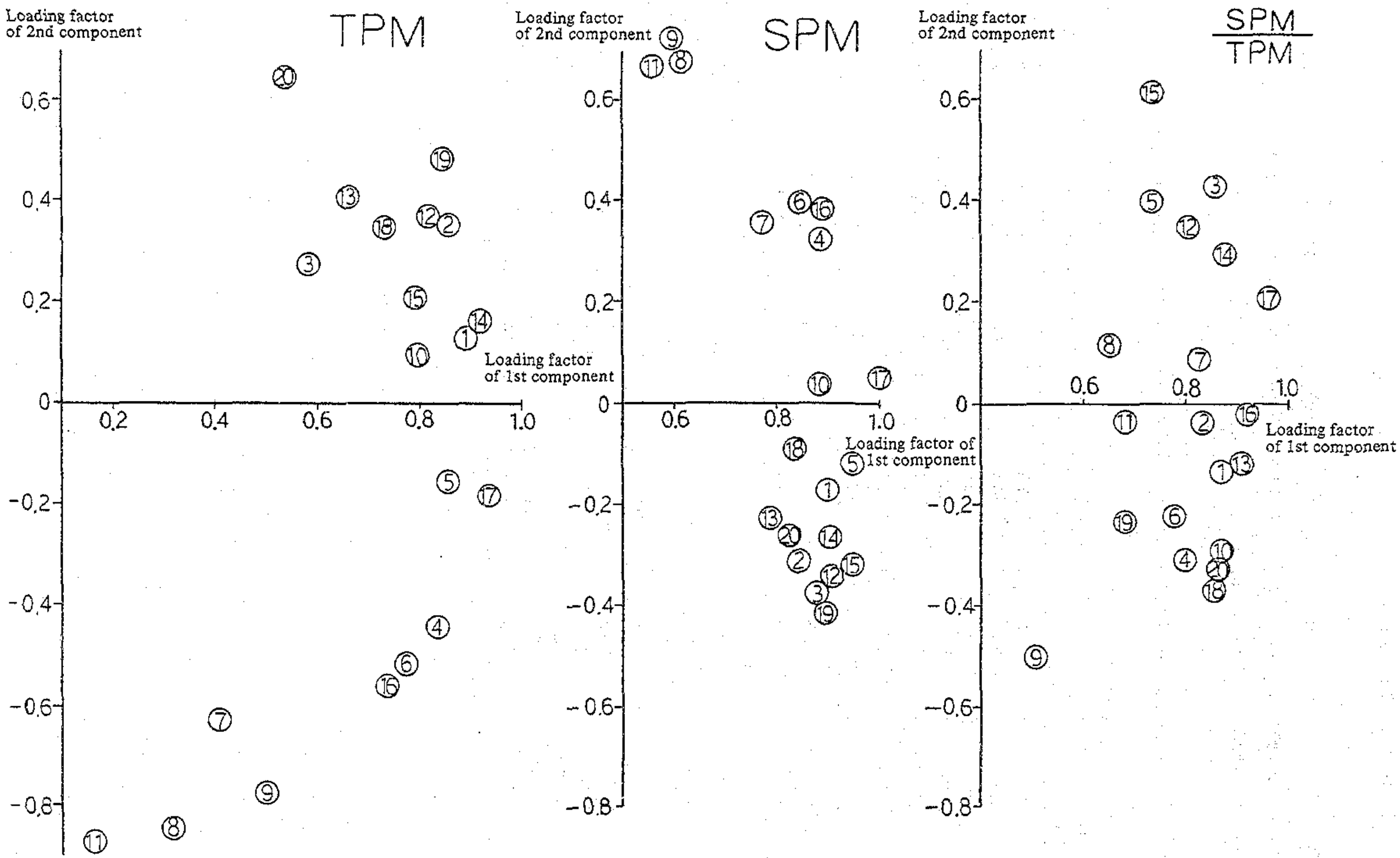


Fig. V-2-4-(4) The results of the principal component analysis (4th survey)

V-2-1-4 Correlation between TPM concentration and SPM concentration measured by high volume sampler

Fig. V-2-5 shows the scatter grams of TPM and SPM for each short term survey. From these figures, the correlations between TPM and SPM are relatively high and at the same station, the correlation shows the seasonal variation.

Table V-2-4 Correlation coefficients of TPM and SPM concentrations at each station

Monitoring stations	1st survey	2nd survey	3rd survey	4th survey	Average
MP1	0.616	0.376	0.950	0.958	0.835
MP2	0.544	0.545	0.847	0.939	0.686
MP3	0.698	0.732	0.671	0.680	0.722
MP4	0.840	0.820	0.937	0.982	0.857
MP5	0.872	0.612	0.773	0.837	0.742
MP6	0.908	0.918	0.839	0.905	0.862
MP7	0.844	0.861	0.789	0.712	0.652
MP8	0.880	0.825	0.905	0.914	0.860
MP9	0.948	0.906	0.793	0.964	0.883
MP10	0.558	0.532	0.840	0.892	0.783
MP11	0.785	0.816	0.572	0.867	0.809
MP12	0.583	0.693	0.797	0.890	0.768
MP13	0.780	0.833	0.894	0.897	0.884
MP14	0.685	0.823	0.752	0.972	0.860
MP15	0.211	0.716	0.643	0.875	0.750
MP16	0.895	0.926	0.749	0.917	0.868
MP17	0.407	0.481	0.812	0.987	0.682
MP18	0.845	0.804	0.912	0.917	0.855
MP19	0.577	0.417	0.848	0.952	0.737
MP20	0.893	0.728	0.559	0.643	0.662

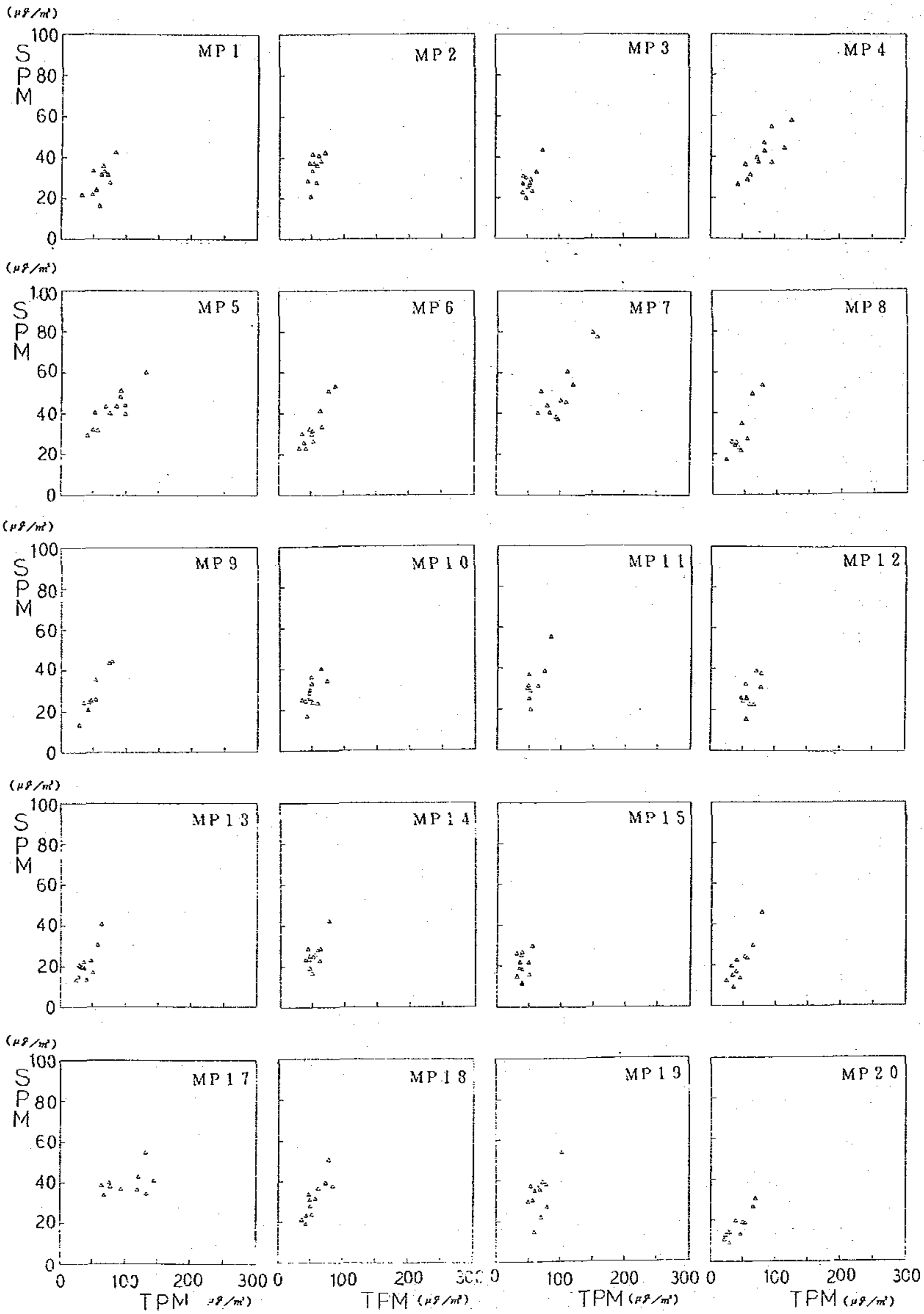


Fig. V-2-5-(1) Scatter grams of SPM and TPM concentration (1st survey)

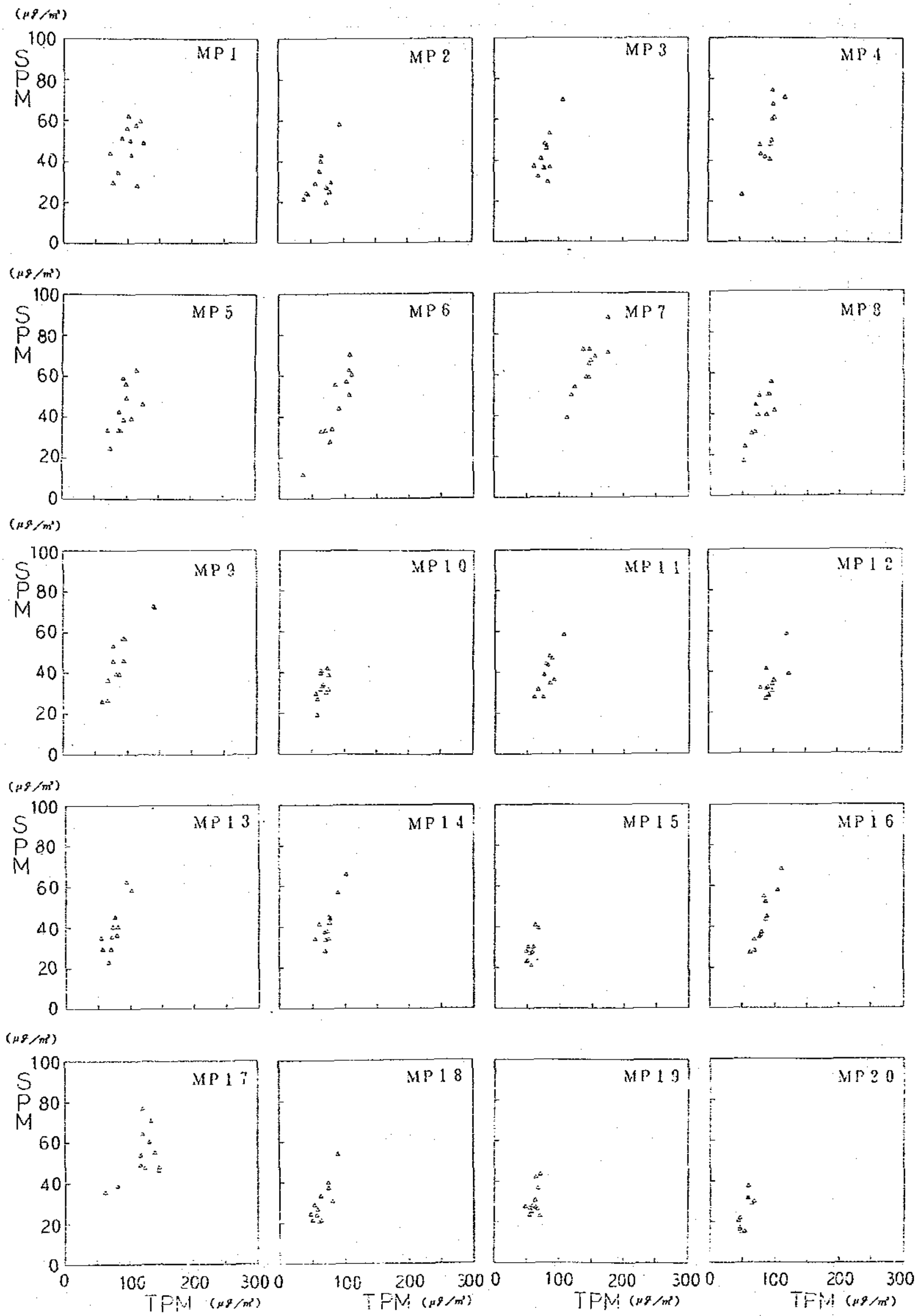


Fig. V-2-5-(2) Scatter grams of SPM and TPM concentration (2nd survey)

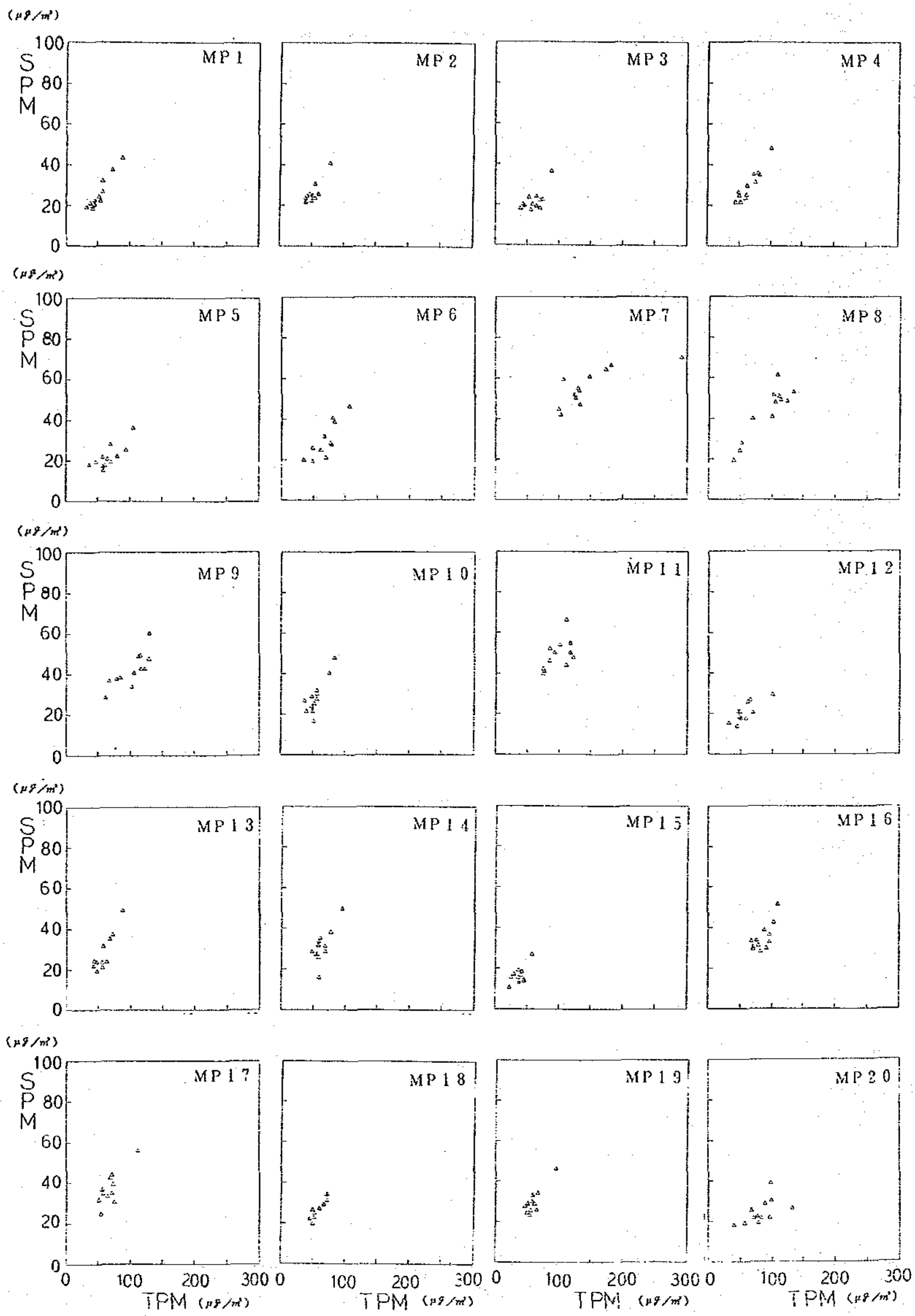


Fig. V-2-5-(3) Scatter grams of SPM and TPM concentration (3rd survey)

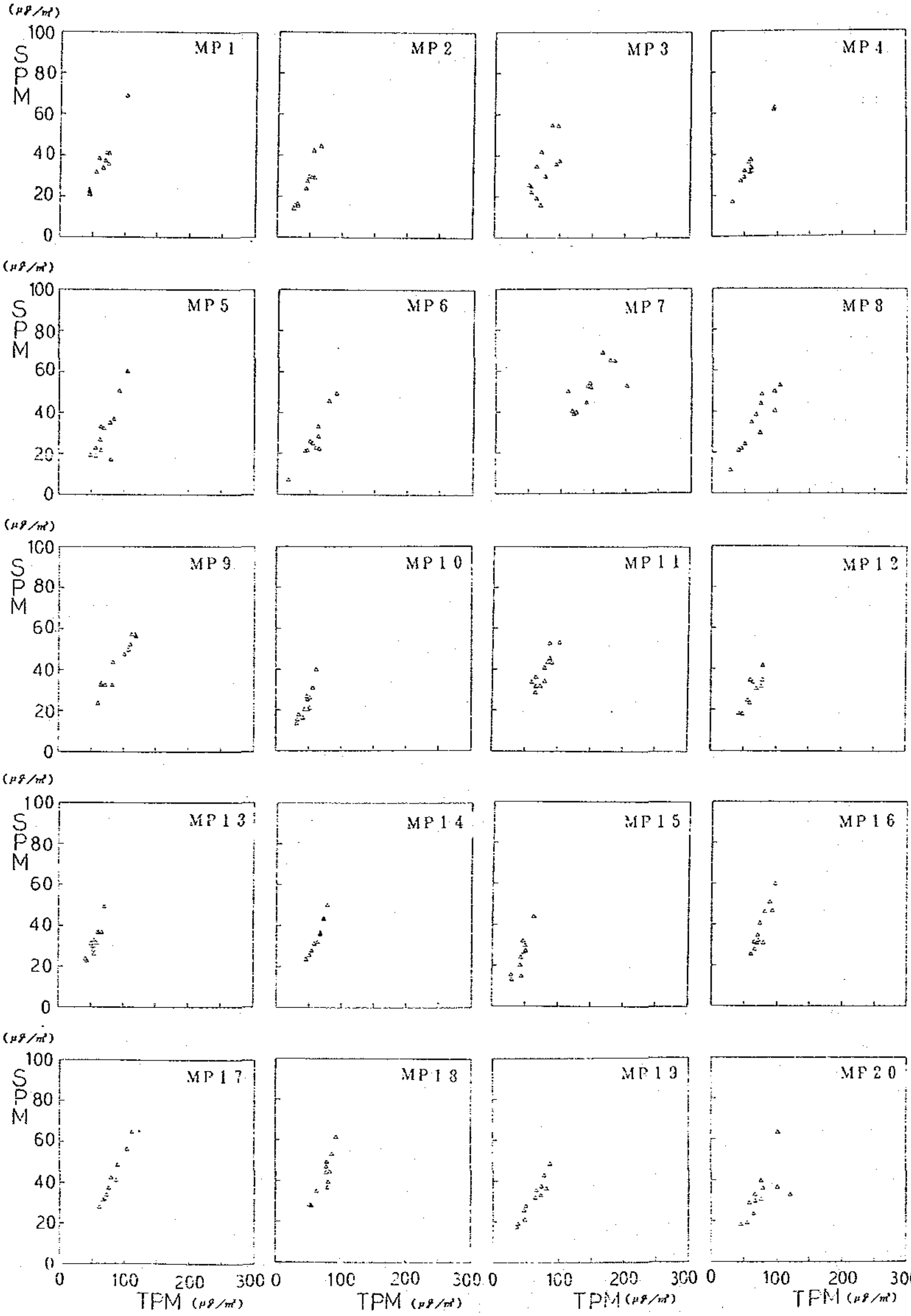


Fig. V-2-5-(4) Scatter grams of SPM and TPM concentration (4th survey)

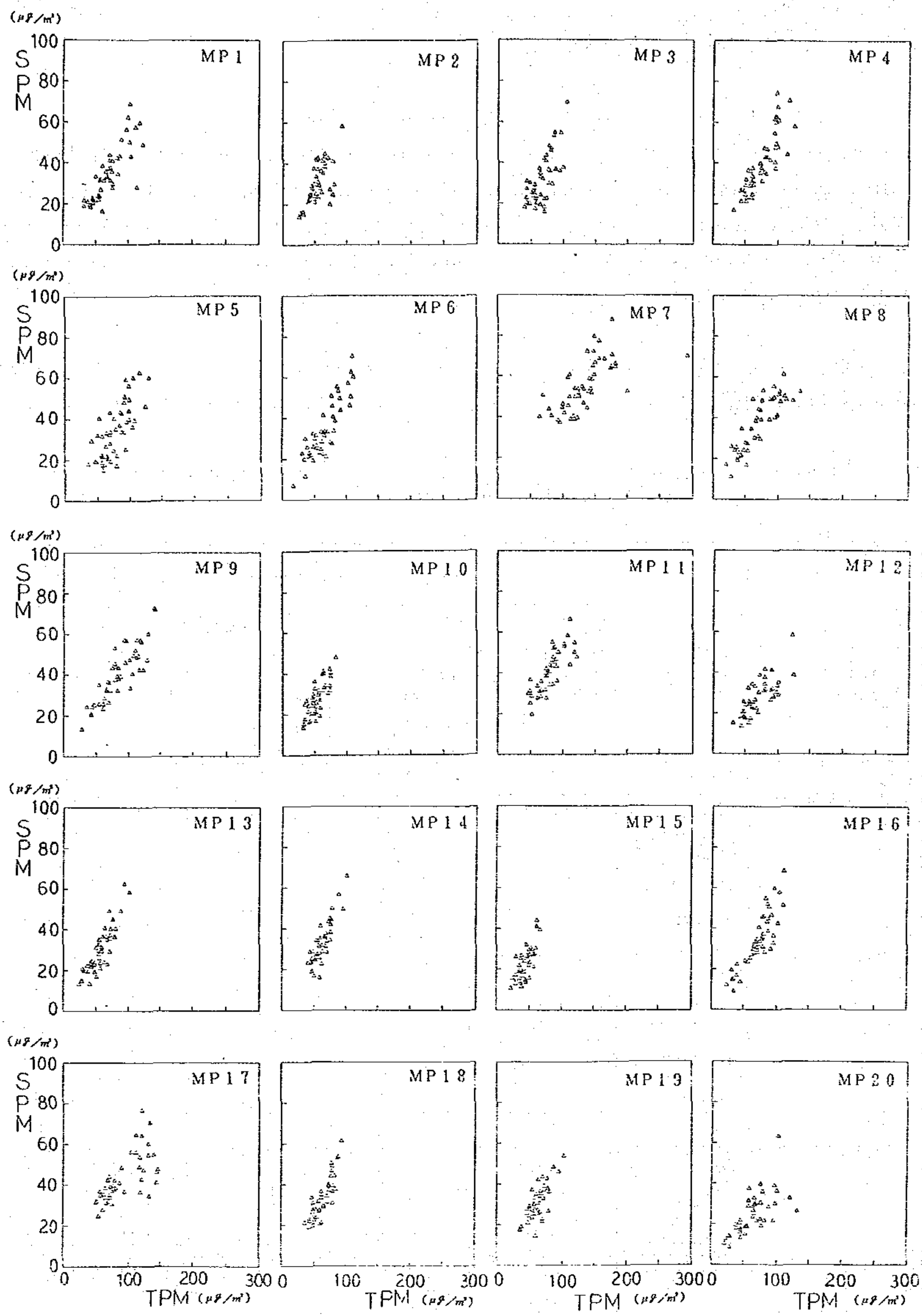


Fig. V-2-5-(5) Scatter grams of SPM and TPM concentration (Average)

V-2-1-5 Comparison between the concentrations measured by high volume sampler and by Beta ray dust analysers

Table V-2-5 shows the comparison between the concentrations measured by high volume sampler and by Beta ray dust analysers. In this table, average concentration is calculated using the data for twelve days. The values of SPM by high volume sampler are slightly higher than the values by Beta ray dust analysers. Table V-2-6 shows the comparison between the daily averaged concentration measured by high volume sampler and by Beta ray dust analysers.

Figs. V-2-6, V-2-7 show the scatter grams. Using the 24 hours data from eleven o'clock (measured by Beta ray dust analysers), we calculated the daily averaged value.

Table V-2-5 Comparison between the concentrations measured by high volume sampler and Beta ray dust analysers

Monitoring Stations	Survey	Average concentration			Correlation coefficient	
		TPM concentration (A) (high volume sampler) (μg/m³)	SPM concentration (B) (high volume sampler) (μg/m³)	SPM concentration (C) (Beta ray dust analysers) (μg/m³)	between A and C	between B and C
(MP 1) J.T.C. HALL	1st survey	60.3	28.5	19.9	0.815	0.684
	2nd survey	99.3	47.0	25.5	0.378	0.335
	3rd survey	51.9	25.4	15.3	0.683	0.814
	4th survey	62.9	34.6	26.6	0.848	0.892
	Average	68.6	33.9	21.8	0.645	0.699
(MP2) N.U.S.	1st survey	54.9	34.9	25.6	0.645	0.550
	2nd survey	64.4	31.3	34.0	0.823	0.665
	3rd survey	51.0	25.8	22.2	0.550	0.278
	4th survey	42.4	26.1	28.2	0.808	0.780
	Average	53.2	29.5	27.5	0.645	0.581
(MP6) NANYANG.T.I.	1st survey	54.1	33.2	19.1	0.807	0.815
	2nd survey	86.9	44.8	38.8	0.823	0.851
	3rd survey	67.7	28.9	27.9	0.802	0.821
	4th survey	57.0	27.0	27.8	0.761	0.853
	Average	66.4	33.5	28.4	0.711	0.689

Table V-2-6-(1) Comparison between the concentration measured by high volume sampler and Beta ray dust analysers

(MP1) J.T.C. HALL (unit; μg/m³)

1st survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
12/7	64.8	35.7	20.4
8	54.7	24.1	10.5
9	32.2	21.6	6.3
10	49.2	33.3	16.3
11	48.6	21.7	14.6
12	72.1	31.4	16.2
13	83.3	42.3	44.6
14	66.7	32.9	26.3
15	62.3	31.4	17.9
16	75.4	27.6	29.7
17	59.8	16.1	15.9
18	54.6	23.6	19.8
19	52.7	-	19.3
20	49.0	-	17.5
Average	60.3	28.5	19.9

2nd survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
3/6	112.9	27.9	25.4
7	123.4	48.9	36.7
8	83.4	34.6	17.3
9	104.5	43.2	32.3
10	90.1	51.3	31.6
11	99.6	62.1	25.8
12	97.8	56.2	22.6
13	102.6	50.1	21.8
14	118.2	59.4	23.5
15	111.6	57.3	29.0
16	71.9	44.0	22.7
17	75.7	29.6	17.5
18	44.9	-	20.5
19	74.9	-	36.6
Average	99.3	47.0	25.5

3rd survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
6/21	41.9	18.3	15.7
22	45.0	20.1	14.6
23	87.3	43.3	29.1
24	41.1	19.5	11.6
25	32.3	18.9	8.2
26	44.7	22.1	10.2
27	57.1	26.7	19.6
28	53.8	21.9	8.5
29	52.1	23.9	14.6
30	37.7	21.0	16.0
7/1	72.2	37.7	19.4
2	57.4	32.0	16.2
3	37.9	-	7.0
4	59.6	-	5.5
Average	51.9	25.4	15.3

4th survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
9/13	66.1	33.7	25.1
14	74.6	35.6	20.0
15	75.2	40.9	28.9
16	59.5	38.5	28.0
17	102.7	68.9	50.9
18	45.0	22.4	12.4
19	69.5	37.2	36.2
20	71.3	41.1	44.7
21	45.5	20.7	14.8
22	55.5	31.6	23.3
23	44.6	23.2	19.7
24	45.9	21.9	15.0
25	56.9	-	18.7
26	41.1	-	15.6
Average	62.9	34.6	26.6

Table V-2-6-(2) Comparison between the concentration measured by high volume sampler and Beta ray dust analysers

(MP2) N.U.S. (unit; μg/m^3)

1st survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
12/7	65.1	38.2	33.4
8	71.4	42.4	29.9
9	47.6	37.2	21.3
10	52.1	41.6	22.0
11	53.9	37.0	20.5
12	44.3	28.4	13.9
13	59.0	36.1	39.9
14	61.4	41.0	36.6
15	51.7	33.4	20.5
16	49.2	20.8	19.1
17	57.9	27.7	20.7
18	45.8	-	29.2
19	25.3	-	17.0
20	31.3	-	18.7
Average	54.9	34.9	25.6

2nd survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
3/6	73.3	19.8	29.1
7	77.6	24.7	45.7
8	73.3	27.1	35.7
9	80.0	29.5	40.7
10	93.0	57.9	55.2
11	65.8	43.0	39.5
12	62.6	35.3	21.6
13	56.0	29.2	33.3
14	65.2	40.0	39.3
15	44.9	23.9	21.9
16	42.5	24.4	24.7
17	38.3	21.4	21.5
18	34.5	-	24.8
19	36.6	-	27.8
Average	64.4	31.3	34.0

3rd survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
6/21	49.1	22.3	10.1
22	55.0	23.7	22.5
23	77.7	40.9	28.8
24	41.7	22.2	10.6
25	40.1	23.6	22.0
26	46.6	25.5	28.0
27	53.5	23.6	37.9
28	60.2	25.7	21.3
29	54.9	30.6	16.4
30	42.5	24.6	24.5
7/1	51.0	24.9	24.8
2	40.1	21.6	19.5
3	24.1	-	17.3
4	22.3	-	3.3
Average	51.0	25.8	22.2

4th survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
9/13	43.9	23.8	28.2
14	52.8	29.3	32.9
15	56.8	29.1	33.1
16	55.3	42.2	26.6
17	66.2	44.5	69.3
18	27.1	15.6	6.9
19	45.9	27.5	30.8
20	48.5	29.6	35.7
21	31.5	15.0	24.1
22	25.0	13.9	15.7
23	30.7	16.2	19.1
24	25.4	-	15.4
25	44.2	-	15.9
26	42.8	-	35.7
Average	42.4	26.1	28.2

Table V-2-6-(3) Comparison between the concentration measured by high volume sampler and Beta ray dust analysers

(MP6) NANYANG.T.I. (unit; μg/m^3)

1st survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
12/7	51.2	29.8	21.5
8	42.2	22.7	12.0
9	36.0	29.9	8.8
10	31.2	22.7	5.2
11	39.2	25.6	10.9
12	52.9	31.3	18.1
13	77.2	50.7	37.5
14	87.2	53.2	34.7
15	64.1	41.2	23.9
16	53.8	26.3	27.6
17	66.7	33.4	17.3
18	48.0	32.1	11.3
19	40.0	-	19.0
20	54.4	-	34.6
Average	54.1	33.2	19.1

2nd survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
3/6	77.7	27.5	24.2
7	81.1	33.7	47.3
8	70.5	33.2	38.7
9	107.2	50.4	45.3
10	85.4	55.2	40.2
11	109.2	70.2	55.9
12	102.8	56.9	43.6
13	111.0	60.2	44.0
14	107.6	62.4	47.7
15	91.1	43.8	33.3
16	64.1	32.7	32.0
17	35.5	11.5	13.7
18	21.4	-	18.9
19	69.7	-	43.5
Average	86.9	44.8	38.8

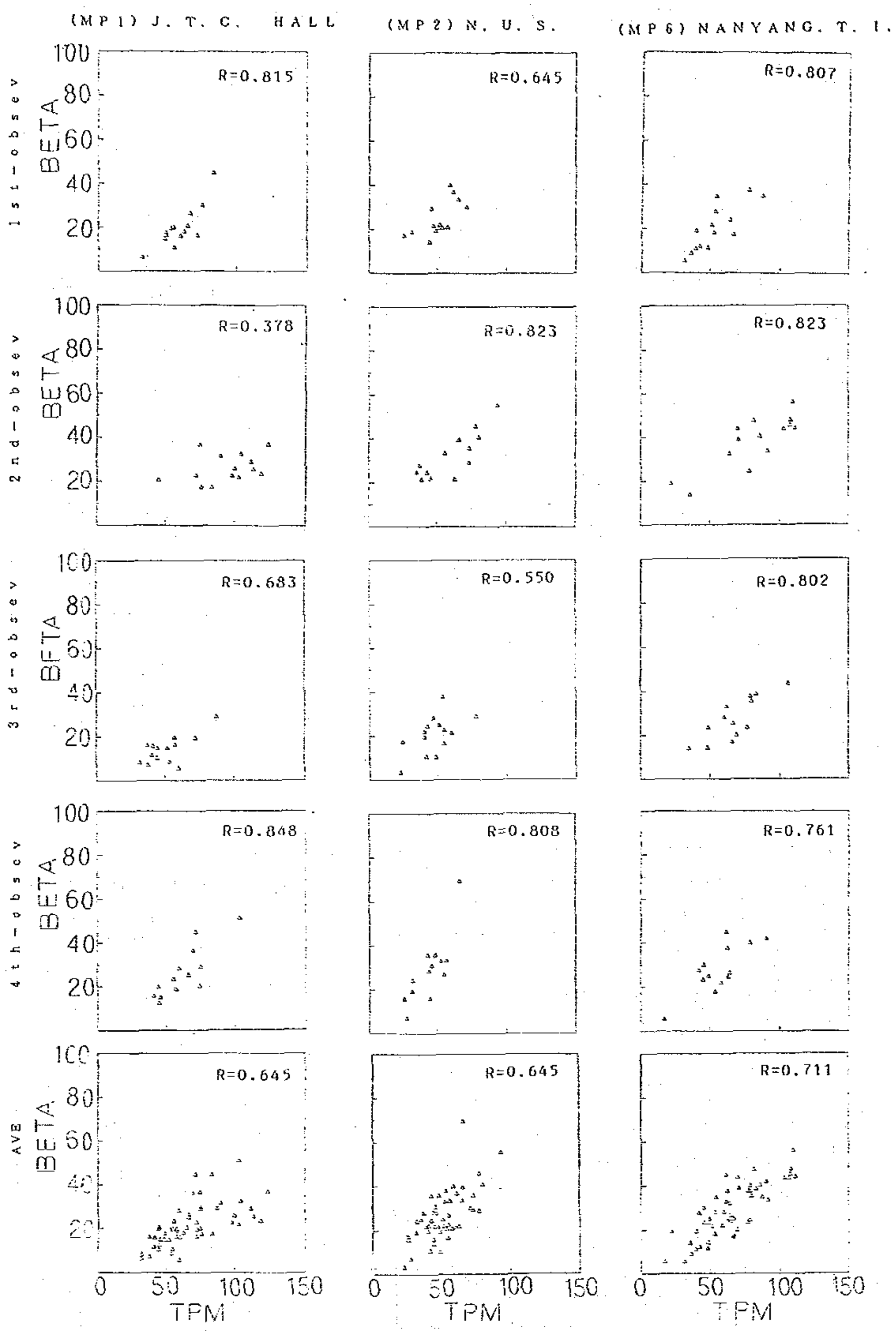
3rd survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
6/21	60.2	24.6	27.9
22	66.5	31.4	25.0
23	106.2	46.1	43.3
24	34.9	19.8	13.8
25	78.5	27.2	37.4
26	69.1	21.0	19.8
27	82.5	38.4	38.4
28	76.4	28.1	23.3
29	61.9	24.6	32.8
30	48.8	25.6	23.2
7/1	79.4	40.5	35.2
2	48.5	19.2	14.1
3	66.0	-	16.7
4	-	-	25.4
Average	67.7	28.9	27.9

4th survey

Date	High volume sampler		Beta ray dust analysers
	TPM	SPM	SPM
9/13	45.3	21.5	23.0
14	58.4	22.8	21.8
15	63.5	22.1	24.4
16	62.5	28.2	37.4
17	78.5	45.8	39.8
18	53.5	25.0	17.7
19	89.8	49.5	41.7
20	61.5	33.1	44.8
21	16.7	6.8	5.2
22	49.3	25.8	24.8
23	42.0	21.2	27.3
24	63.0	22.6	25.1
25	64.2	-	26.4
26	45.5	-	29.8
Average	57.0	27.0	27.8

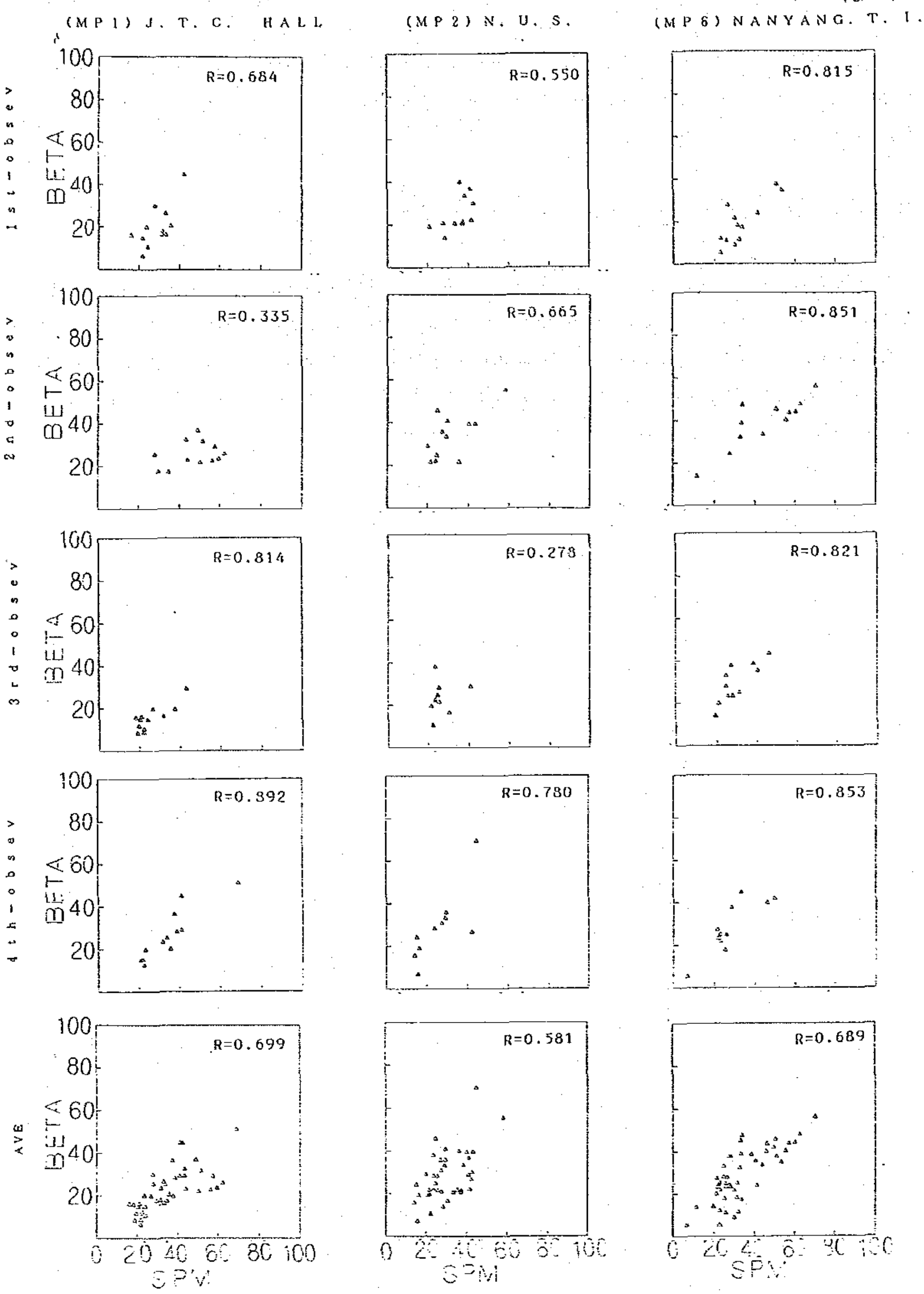
(Unit: $\mu g/m^3$)



X axis; TPM concentration by high volume sampler
Y axis; SPM concentration by Beta ray dust analysers

Fig. V-2-6 Scatter grams

(Unit: μg/m³)



X axis; TPM concentration by high volume sampler
Y axis; SPM concentration by Beta ray dust analysers

Fig. V-2-7 Scatter grams

V-2-2 Analysis of TPM Concentration Measured by Andersen Sampler

At MP1, MP2 and MP6, we measured the size distribution of TPM using Andersen sampler. And, we compared these data with the data measured by high volume sampler or by Beta ray dust analysers.

V-2-2-1 TPM concentrations for the ranks of particle size

Table V-2-7 shows the size distribution of TPM measured by Andersen sampler. The seasonal variations of size distribution were shown in Fig. V-2-8. Fine particles below 2.1 μm dia occupy about 60%, coarse particles between 2.1 μm and 11 μm dia occupy about 30%, and gigantic particles above 11 μm dia occupy about 10%. In the 3rd survey, the density of gigantic particles become slightly higher.

Table V-2-7 Size distributions measured by Andersen sampler

(unit; μg/m^3)

Particulate size			1st survey			2nd survey			3rd survey			4th survey		
Classify	Stage	Rank (μm)	MP1	MP2	MP6	MP1	MP2	MP6	MP1	MP2	MP6	MP1	MP2	MP6
	0	11 -	4.63	1.90	2.29	4.94	2.68	4.35	3.31	1.79	4.66	3.78	2.12	3.61
Coarse	1	7.0 - 11	2.34	1.12	1.14	1.72	1.55	1.88	2.09	1.30	2.27	1.58	0.79	1.39
	2	4.7 - 7.0	4.01	1.82	2.70	3.09	2.73	3.34	3.75	2.67	4.20	3.01	2.28	2.54
	3	3.3 - 4.7	3.60	2.84	4.54	5.82	2.35	6.22	3.53	4.81	6.72	5.09	2.07	4.36
	4	2.1 - 3.3	2.34	2.16	2.59	4.33	3.92	4.25	5.11	3.59	4.90	3.80	3.56	3.35
Fine	5	1.1 - 2.1	5.08	2.33	2.78	3.50	2.84	4.88	3.25	2.52	3.71	3.85	2.65	3.42
	6	0.65 - 1.1	1.75	2.94	2.66	2.25	1.29	2.78	1.08	1.18	2.04	2.84	1.37	2.26
	7	0.43 - 0.65	0.93	3.16	4.00	5.34	1.86	7.36	2.27	3.51	5.50	4.37	1.26	5.32
	8	- 0.43	15.29	11.09	10.46	18.39	20.39	17.54	15.91	10.95	13.74	16.99	15.70	12.83
Total			40.0	29.4	33.2	49.4	39.6	52.6	40.3	32.3	47.8	45.3	31.8	39.1

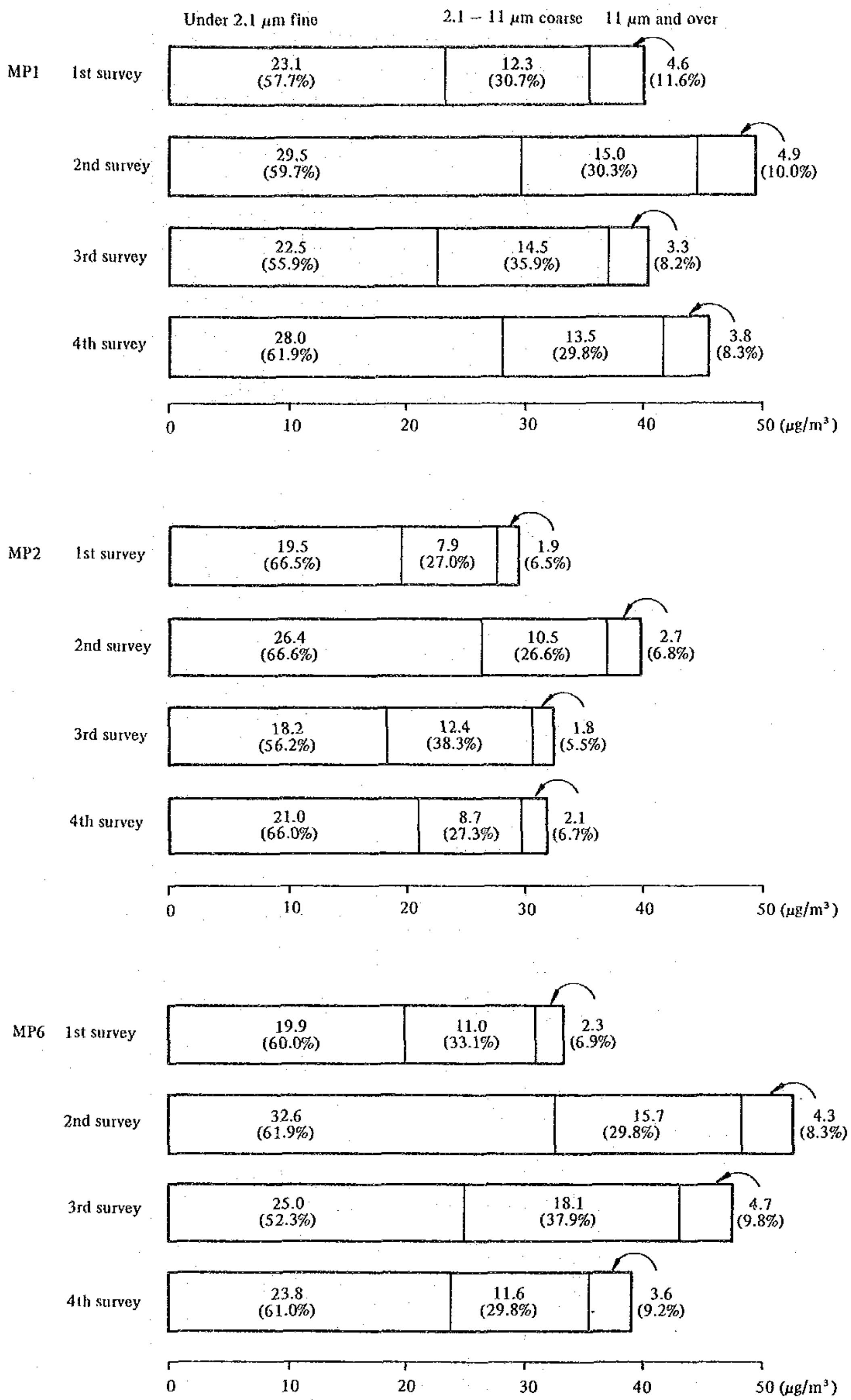


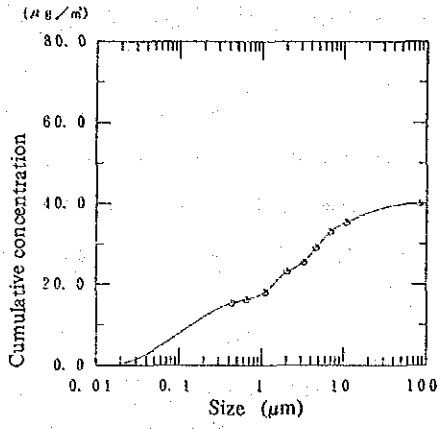
Fig. V-2-8 Seasonal variations of the concentration of particulate matter by particulate size

V-2-2-2 Size distribution of TPM concentration measured by Andersen sampler

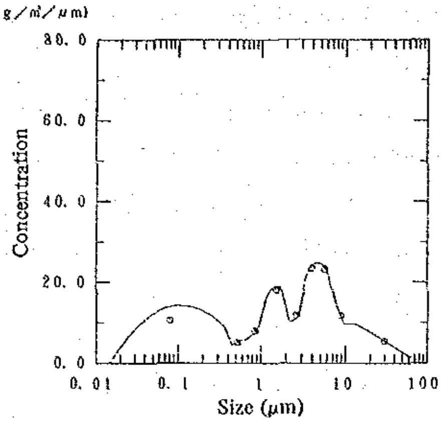
Fig. V-2-9 shows the size distribution of TPM concentration and cumulative concentration. These figures were made by following procedure; as shown in Table V-2-7, we classify particle size in nine parts (i.e., stage 0 - stage 8). The cumulative concentration curve in each stage is closely resembled by the cubic polynominal using discrete data.

The curve showing size distributions is calculated by differentiating the cumulative concentration curve. In the figures of the size distribution of TPM concentration, there are two peaks - one is in about 0.4 μm dia and another is in about 4 μm dia. These results are generally seen.

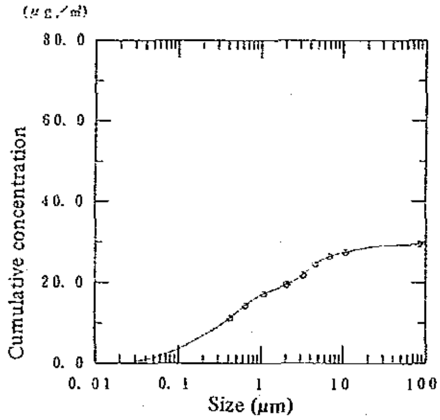
(MP 1)
J.T.C. HALL



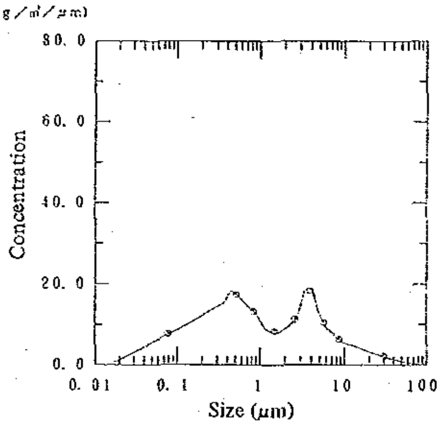
SAMPLING TIME = 291.4 H
AIR VOLUME = 513.9 m³
TOTAL CONC = 40.0 μg/m³



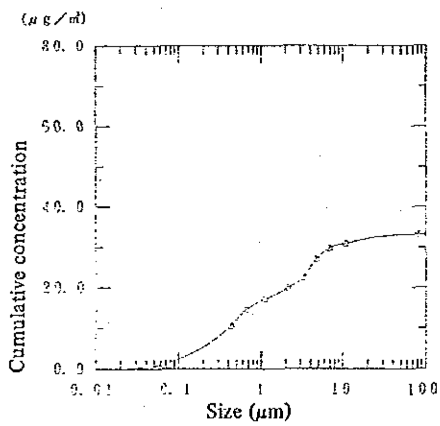
(MP 2)
N.U.S.



SAMPLING TIME = 288.2 H
AIR VOLUME = 510.3 m³
TOTAL CONC = 29.4 μg/m³



(MP 6)
NANYANG.T.I.



SAMPLING TIME = 283.3 H
AIR VOLUME = 510.6 m³
TOTAL CONC = 33.2 μg/m³

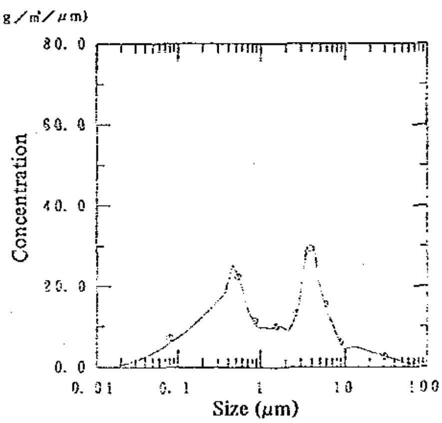
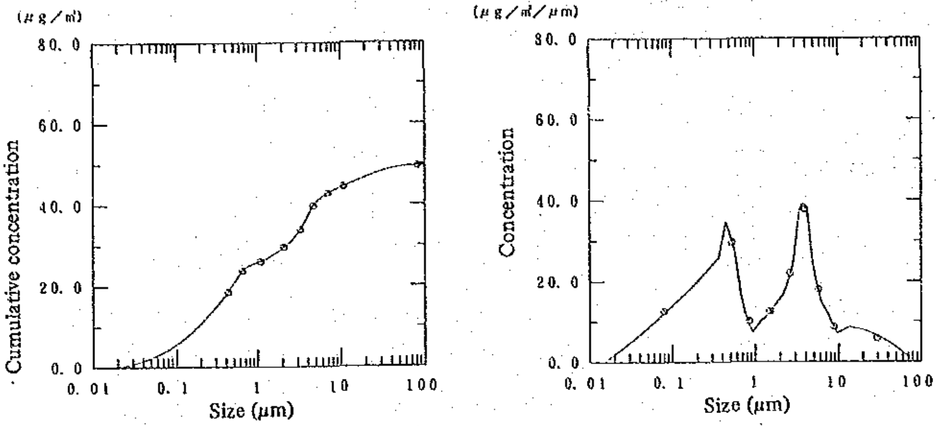


Fig. V-2-9-(1) Cumulative concentration and size distribution of TPM (1st survey)

(MP 1)

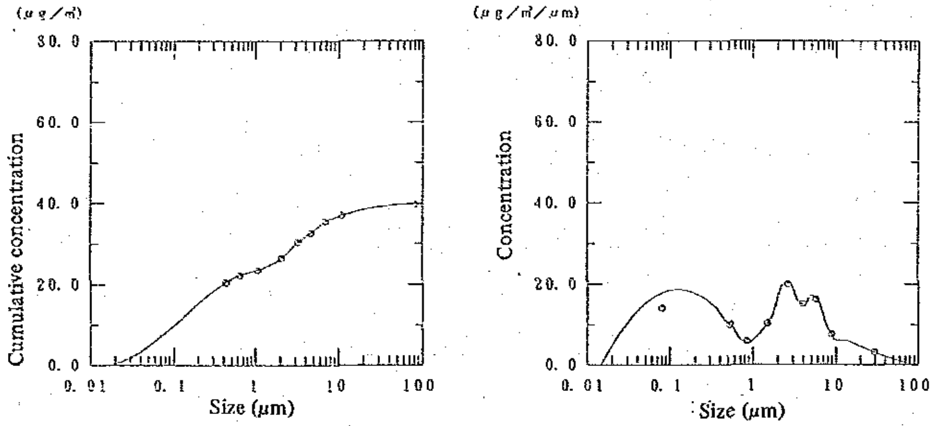
J.T.C. HALL



SAMPLING TIME = 288.5 H
AIR VOLUME = 466.0 m³
TOTAL CONC = 49.4 μg/m³

(MP 2)

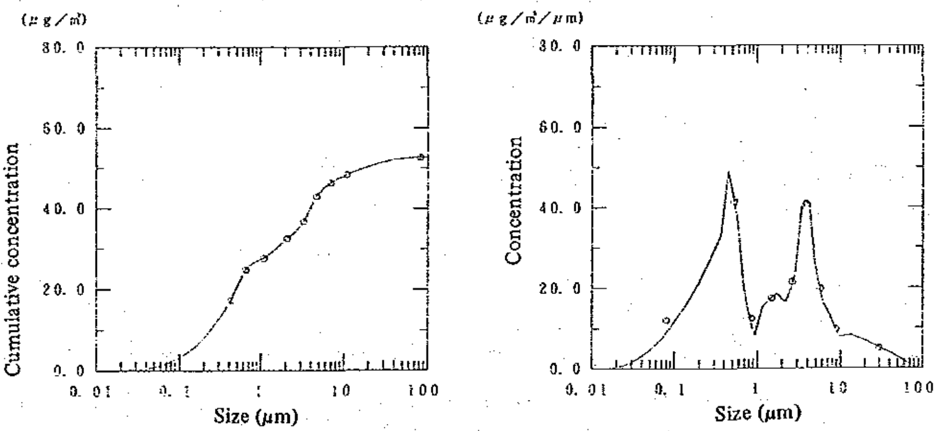
N.U.S.



SAMPLING TIME = 234.6 H
AIR VOLUME = 387.9 m³
TOTAL CONC = 39.6 μg/m³

(MP 6)

NANYANG.T.I.

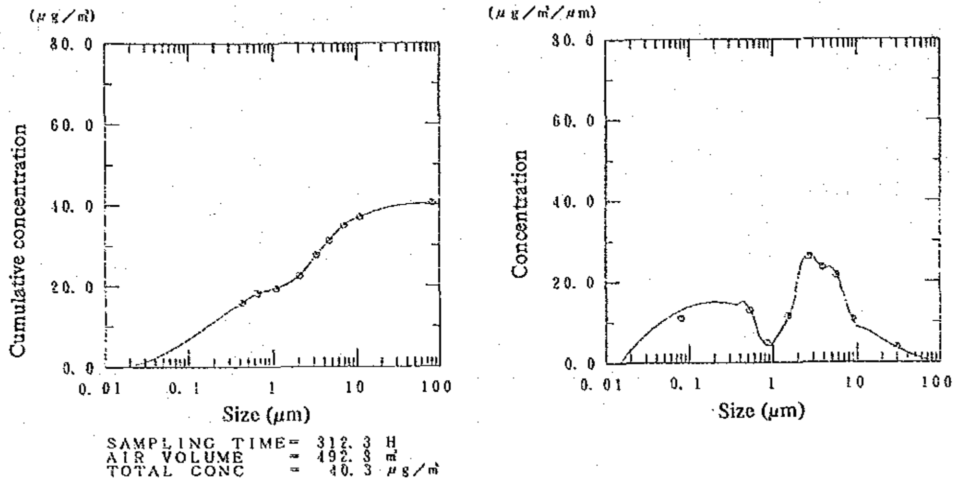


SAMPLING TIME = 336.2 H
AIR VOLUME = 511.4 m³
TOTAL CONC = 52.5 μg/m³

Fig. V-2-9-(2) Cumulative concentration and size distribution of TPM (2nd survey)

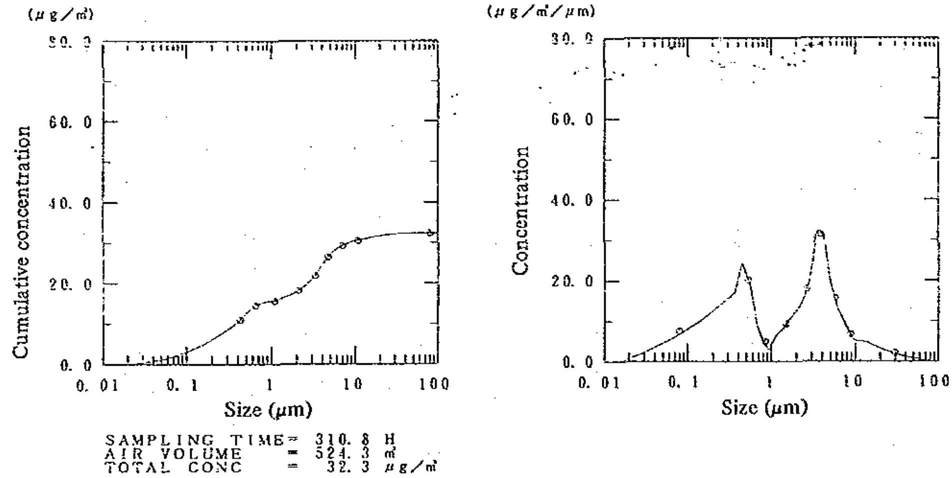
(MP 1)

J.T.C. HALL



(MP 2)

N.U.S.



(MP 6)

NANYANG.T.I.

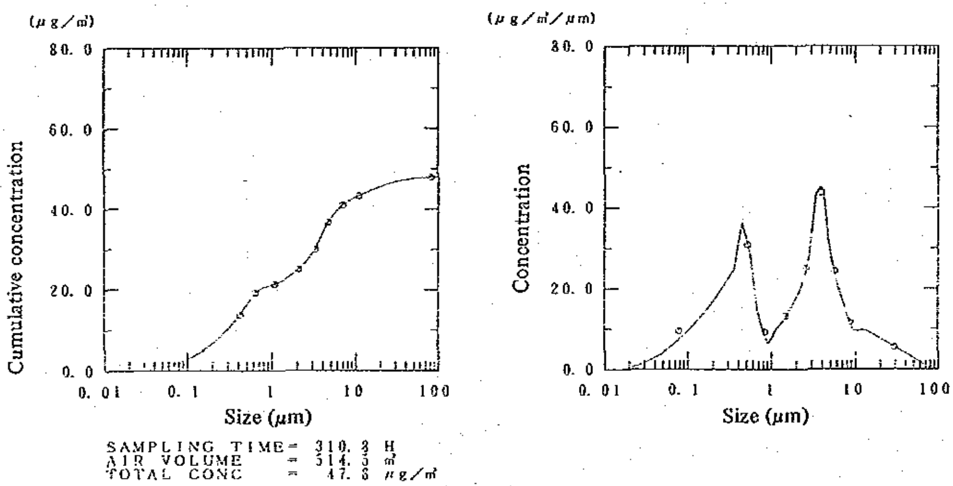
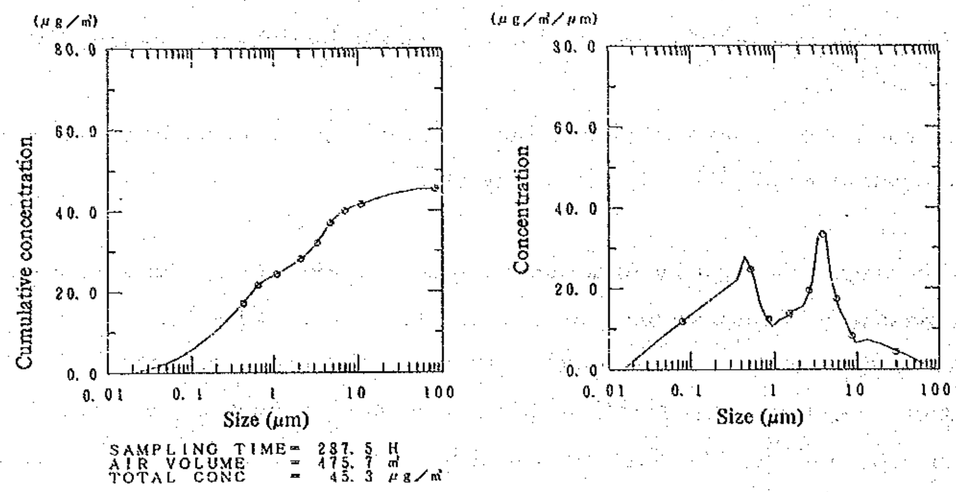


Fig. V-2-9-(3) Cumulative concentration and size distribution of TPM (3rd survey)

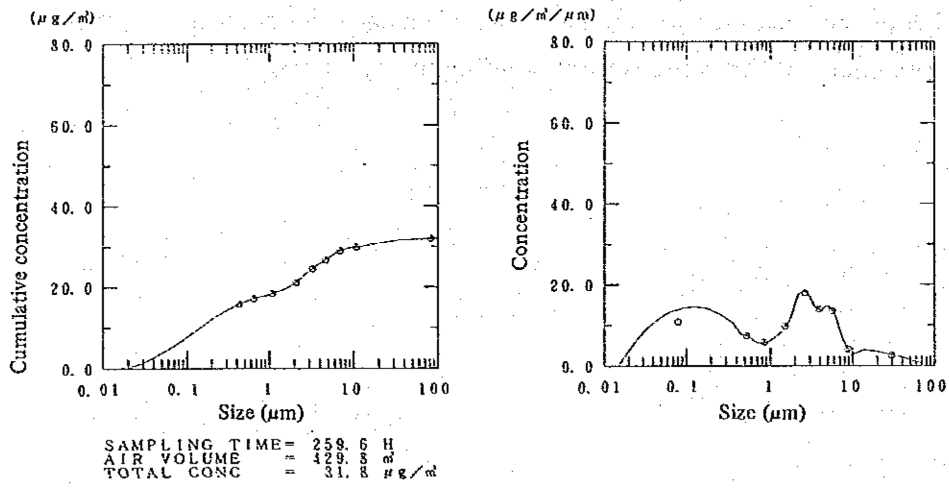
(MP 1)

J.T.C. HALL



(MP 2)

N.U.S.



(MP 6)

NANYANG.T.I.

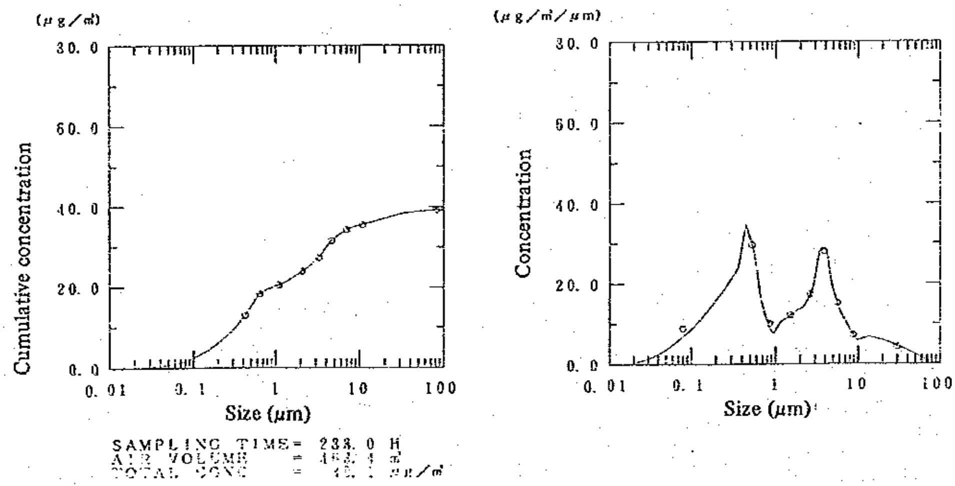


Fig. V-2-9-(4) Cumulative concentration and size distribution of TPM (4th survey)

V-2-2-3 Comparison of concentrations measured by different instruments

Table V-2-8 shows the concentrations which are measured by Andersen sampler, high volume sampler and Beta ray dust analysers.

The data measured by Andersen sampler are averaged values for about ten days. The data measured by high volume sampler are daily averaged value, and the data measured by Beta ray dust analysers are hourly values. So in order to coordinate the measurement duration, we used the duration when the measurements by Andersen sampler were performed. And for the data measured by Andersen sampler, we used the data less than 11 μm dia.

From the results, the concentration measured by Andersen sampler are slightly higher than the concentration measured by other instruments.

Table V-2-8 Comparison of particulate matters concentrations measured by several instruments

(MP1) J.T.C. HALL (μg/m³)

Survey	Duration	Andersen sampler	High volume sampler		Beta ray dust analysers
			TPM	SPM	
1st survey	12/9 - 12/21	35.3	58.8	28.2	20.4
2nd survey	3/8 - 3/20	44.4	89.6	48.8	25.1
3rd survey	6/21 - 7/4	37.0	50.8	25.4	14.7
4th survey	9/13 - 9/25	41.5	62.9	34.6	26.6
Average		39.6	65.5	34.3	21.7

(MP2) N.U.S (μg/m³)

Survey	Duration	Andersen sampler	High volume sampler		Beta ray dust analysers
			TPM	SPM	
1st survey	12/9 - 12/21	27.5	48.3	33.7	23.3
2nd survey	3/10 - 3/20	36.9	53.9	34.4	31.0
3rd survey	6/21 - 7/4	30.5	49.0	25.8	21.8
4th survey	9/14 - 9/25	29.7	42.3	26.3	28.1
Average		31.2	48.4	30.1	26.1

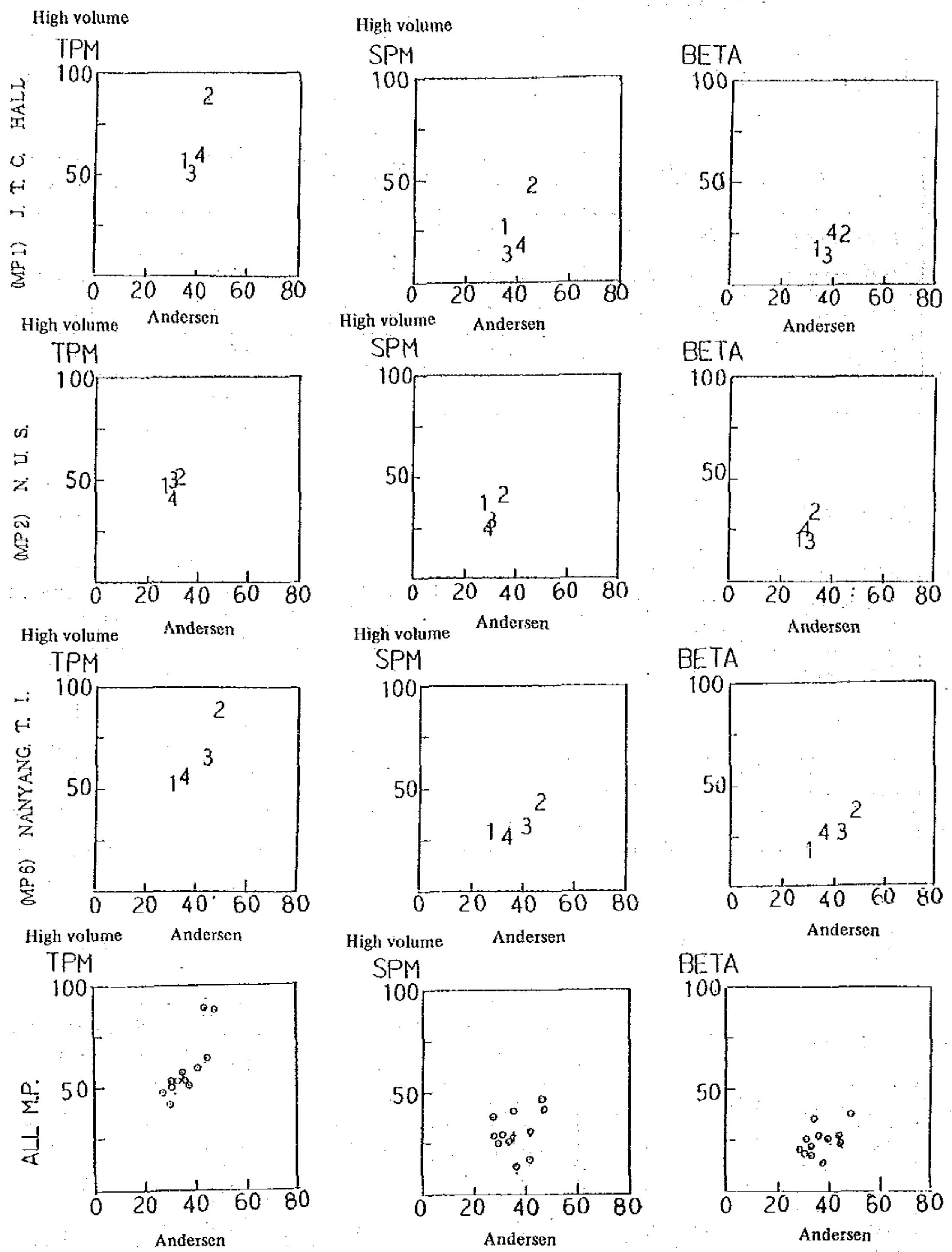
(MP6) NANYANG.T.I. (μg/m³)

Survey	Duration	Andersen sampler	High volume sampler		Beta ray dust analysers
			TPM	SPM	
1st survey	12/9 - 12/21	30.9	54.2	34.6	20.7
2nd survey	3/6 - 3/20	48.3	81.0	44.8	37.7
3rd survey	6/21 - 7/4	43.1	67.6	28.9	27.0
4th survey	9/13 - 9/25	35.5	57.0	27.0	27.8
Average		39.5	65.0	33.8	28.3

Notes:

1) The concentration measured by Beta ray dust analysers is averaged using 24 hours data from 11 A.M.
2) The concentrations measured by Andersen sampler show the concentration below 11 μm diameter

(Unit: $\mu g/m^3$)



Notes:

1) X axis; the concentration measured by Andersen sampler
Y axis; the concentration measured by high volume sampler or Beta ray dust analysers

2) The numbers in the figures correspond to short term survey

Fig. V-2-10 Scatter gram of particulate matter concentration measured by different instruments

V-2-3 Analysis of SPM Concentration by Beta Ray Dust Analysers

We analyzed the relationship between the meteorological factors and the SPM concentration during each short term field survey.

V-2-3-1 Dependence of SPM concentrations by Beta ray dust analysers during the short term field survey on wind directions

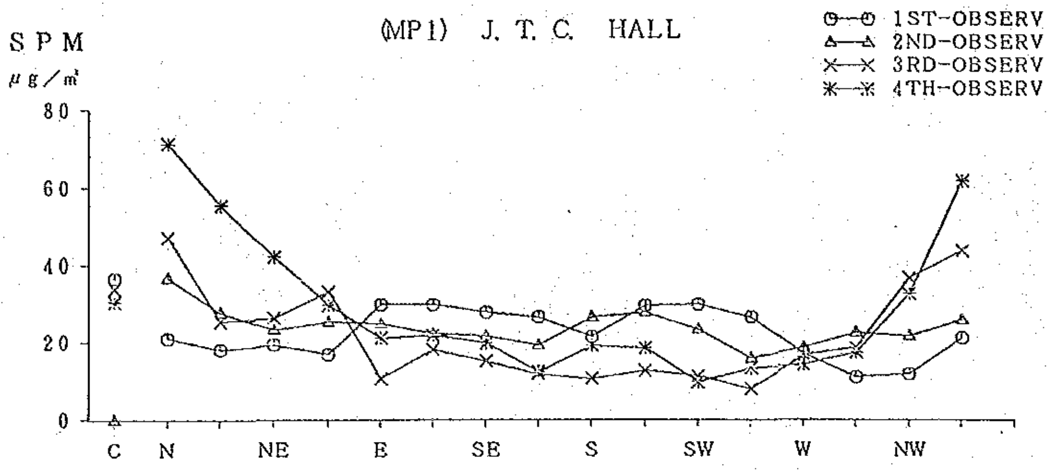
Table V-2-9 and Fig. V-2-11 show the average concentration during each short term field survey by wind directions. Fig. V-2-12 shows the SPM concentration by wind directions at three monitoring stations. And Fig. V-2-13 shows wind rose during the short term field survey.

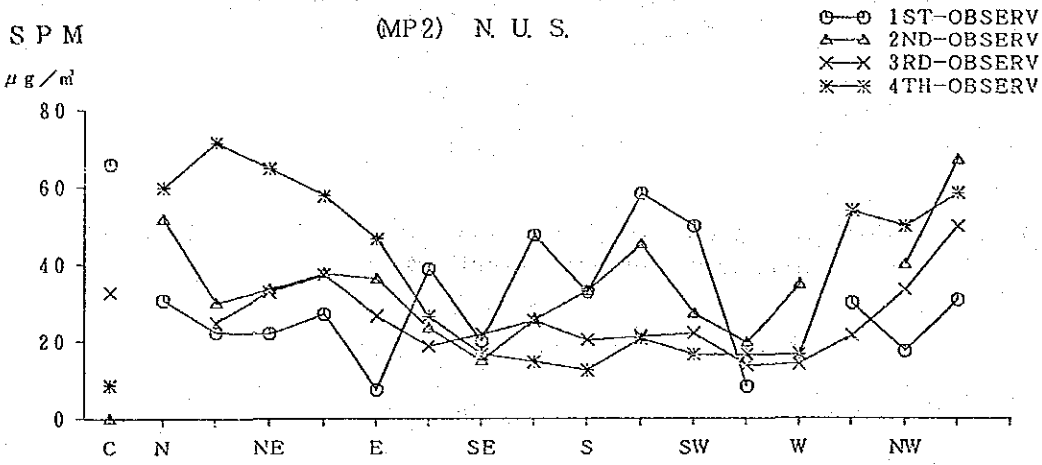
From Fig. V-2-13, the dominant wind direction in each survey are following; the direction is N in the 1st survey, the direction is NE in the 2nd survey and the direction is S both in the 3rd and 4th survey. But at MP20, the characteristics of wind direction are different from other stations. From these figures, relatively high concentration of SPM appears in the north wind direction at the 3rd and 4th survey.

n = The numbers of case
AVE = Average ($\mu g/m^3$)
SIG = Standard deviation ($\mu g/m^3$)

Table V-2-9 Dependence of SPM concentration during short term field survey on wind directions

Monitoring stations	Survey	Item	CALM	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
(MP1) J.T.C. HALL	1st survey	n	5	46	58	77	14	1	2	1	3	5	5	3	3	4	5	18	38	288
		AVE	36.8	21.2	18.2	19.5	17.0	30.0	30.0	28.0	26.7	21.6	29.6	30.0	26.7	17.3	11.2	12.0	21.2	19.9
		SIG	30.6	21.2	17.2	17.4	8.9	0.0	10.0	0.0	4.7	5.3	13.9	22.9	17.0	19.3	9.4	14.1	19.6	18.2
	2nd survey	n	0	23	32	74	42	10	5	7	9	14	19	12	11	5	3	4	2	272
		AVE	0.0	36.8	27.8	23.3	25.4	25.0	22.4	21.7	19.3	26.6	27.7	23.5	15.9	18.8	22.7	21.8	26.0	25.3
		SIG	0.0	25.1	13.2	13.6	14.2	12.2	8.6	20.7	15.7	19.7	24.2	13.0	8.1	8.8	17.9	6.3	16.0	16.7
	3rd survey	n	5	6	5	7	3	7	24	49	46	58	33	18	10	8	4	2	3	288
		AVE	34.0	47.5	25.6	26.4	33.3	10.7	18.3	15.2	11.8	10.6	12.7	11.4	8.1	16.8	18.8	37.0	44.0	15.3
		SIG	33.8	14.8	7.7	12.4	16.7	6.8	12.1	10.7	8.1	9.0	9.6	15.4	5.9	9.7	8.9	7.0	27.3	13.8
	4th survey	n	9	16	15	9	14	8	13	18	24	29	29	34	11	10	16	18	14	287
		AVE	30.6	71.7	55.8	42.3	29.7	21.3	22.0	19.9	12.5	19.3	18.6	9.7	13.5	14.4	17.5	32.7	62.1	26.6
		SIG	29.5	21.9	27.8	16.9	18.0	11.4	14.9	10.4	8.2	14.7	11.0	7.6	13.2	18.3	14.0	27.0	33.7	25.1
	Average	n	19	91	110	167	73	26	44	75	82	106	86	67	35	27	28	42	57	1135
		AVE	33.1	35.7	26.5	22.7	24.9	20.2	20.4	17.1	13.4	15.6	19.0	13.5	13.8	16.3	17.1	23.0	32.6	21.7
		SIG	31.1	28.8	21.6	16.4	15.0	12.1	12.9	12.2	9.8	13.8	16.0	13.6	11.6	15.0	13.5	22.5	29.8	19.5
(MP2) N.U.S.	1st survey	n	1	35	51	109	16	2	5	1	2	10	4	4	5	0	3	15	24	287
		AVE	66.0	30.8	22.3	22.1	27.2	7.5	38.8	20.0	47.5	32.7	58.3	50.0	8.4	0.0	30.0	17.3	30.8	25.6
		SIG	0.0	15.1	14.6	16.0	11.1	7.5	7.4	0.0	7.5	16.0	14.5	13.7	4.3	0.0	21.4	16.9	17.3	17.1
	2nd survey	n	1	5	17	77	71	14	10	8	9	14	22	18	9	8	0	1	4	288
		AVE	0.0	51.8	30.0	33.3	37.6	36.1	23.5	14.9	25.7	33.0	45.0	27.1	19.6	34.6	0.0	40.0	67.0	34.0
		SIG	0.0	20.3	12.8	17.0	18.8	17.6	23.9	11.5	21.9	20.0	30.9	21.4	15.5	18.4	0.0	0.0	33.1	21.3
	3rd survey	n	3	0	2	5	8	3	18	70	37	57	24	30	18	2	7	3	1	288
		AVE	32.7	0.0	25.0	32.8	37.3	26.7	18.7	21.8	25.4	20.3	21.2	22.0	13.7	14.0	21.4	33.3	50.0	22.2
		SIG	26.6	0.0	5.0	10.0	12.2	4.7	14.4	13.6	10.8	11.3	8.0	16.2	7.7	4.0	12.4	24.7	0.0	13.4
	4th survey	n	5	8	9	23	7	9	14	30	25	24	28	50	26	10	9	3	8	288
		AVE	8.8	60.0	71.7	64.8	57.7	46.6	26.5	16.6	14.6	12.4	20.6	16.5	16.4	16.5	53.9	50.0	58.5	28.2
		SIG	4.7	29.8	29.5	21.5	17.3	21.1	22.6	12.6	9.3	9.5	21.1	16.6	8.1	12.9	19.8	21.6	34.1	26.5
	Average	n	10	48	79	214	102	28	47	109	73	105	78	102	58	20	19	22	37	1151
		AVE	20.8	37.8	29.7	31.0	37.3	36.4	24.2	19.9	22.3	21.4	29.6	21.3	15.4	23.5	38.2	25.0	41.2	27.5
		SIG	24.2	22.3	22.6	21.2	18.5	20.2	19.9	13.4	13.9	14.7	24.9	18.7	9.8	17.4	23.4	22.1	27.8	20.6
(MP6) NANYANG. T. I.	1st survey	n	30	62	57	47	1	0	0	1	0	4	4	7	2	3	8	17	40	283
		AVE	29.1	13.9	24.2	28.8	30.0	0.0	0.0	0.0	0.0	31.3	14.8	11.0	0.0	5.0	8.4	8.2	10.2	19.0
		SIG	19.5	13.8	14.5	25.3	0.0	0.0	0.0	0.0	0.0	8.2	7.6	9.7	0.0	4.1	5.1	5.0	10.4	17.9
	2nd survey	n	13	15	52	72	25	5	0	1	5	12	31	11	13	3	2	5	6	271
		AVE	30.8	26.7	40.3	47.8	48.4	36.8	0.0	9.0	52.2	41.4	34.8	19.3	19.6	11.7	14.0	37.6	31.2	38.7
		SIG	21.4	17.9	21.6	23.1	19.0	4.1	0.0	0.0	23.1	18.9	27.0	20.2	12.2	8.5	14.0	20.4	12.4	23.4
	3rd survey	n	43	6	12	9	2	0	3	15	38	78	39	19	16	1	2	1	3	287
		AVE	35.1	51.5	39.8	62.8	46.0	0.0	28.0	27.3	25.9	27.7	16.7	10.4	17.6	10.0	28.5	28.0	58.7	27.9
		SIG	18.7	14.6	19.9	33.9	36.0	0.0	4.9	8.6	15.1	15.8	13.4	7.5	22.8	0.0	6.5	0.0	29.6	20.2
	4th survey	n	42	21	25	10	2	1	1	8	16	30	27	33	26	7	10	9	19	287
		AVE	36.0	54.5	50.4	56.0	26.0	30.0	45.0	36.9	29.0	20.1	13.6	8.9	9.7	16.4	8.0	18.4	38.5	27.8
		SIG	14.2	21.2	17.4	18.1	4.0	0.0	0.0	24.4	14.4	14.4	12.9	7.7	10.1	17.3	5.6	16.7	23.5	22.3
	Average	n	128	104	146	138	30	6	4	25	59	124	101	70	57	14	22	32	68	1128
		AVE	33.6	26.1	35.7	42.9	46.1	35.7	32.3	28.5	29.0	27.3	21.3	11.2	13.8	12.5	10.5	16.3	22.1	28.2
		SIG	18.1	23.5	20.7	26.7	20.7	4.5	8.5	17.5	17.3	16.6	20.5	11.4	15.9	13.7	9.0	16.4	22.3	22.1





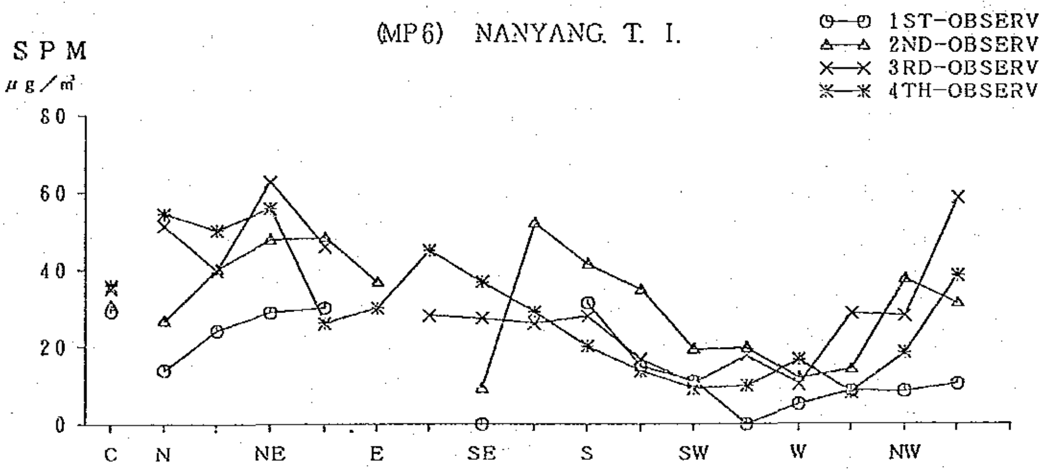


Fig. V-2-11 Dependence of SPM concentration during the short term field survey on wind directions

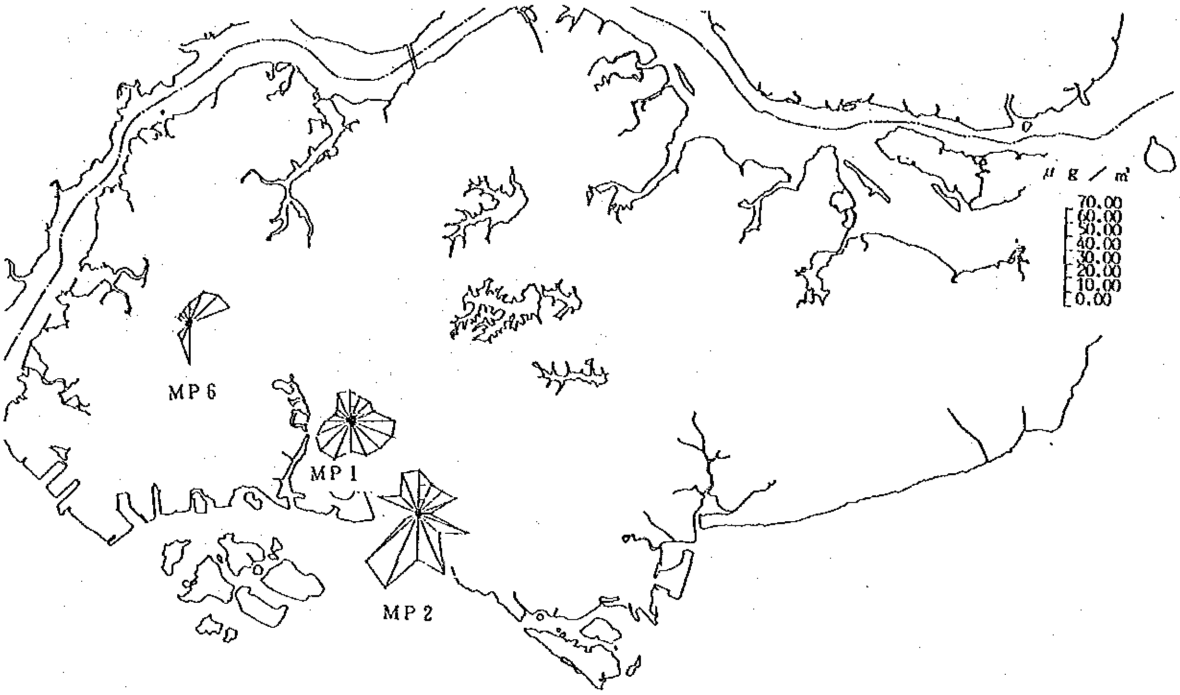


Fig. V-2-12-(1) Dependence of SPM concentration during the 1st short term field survey on wind directions

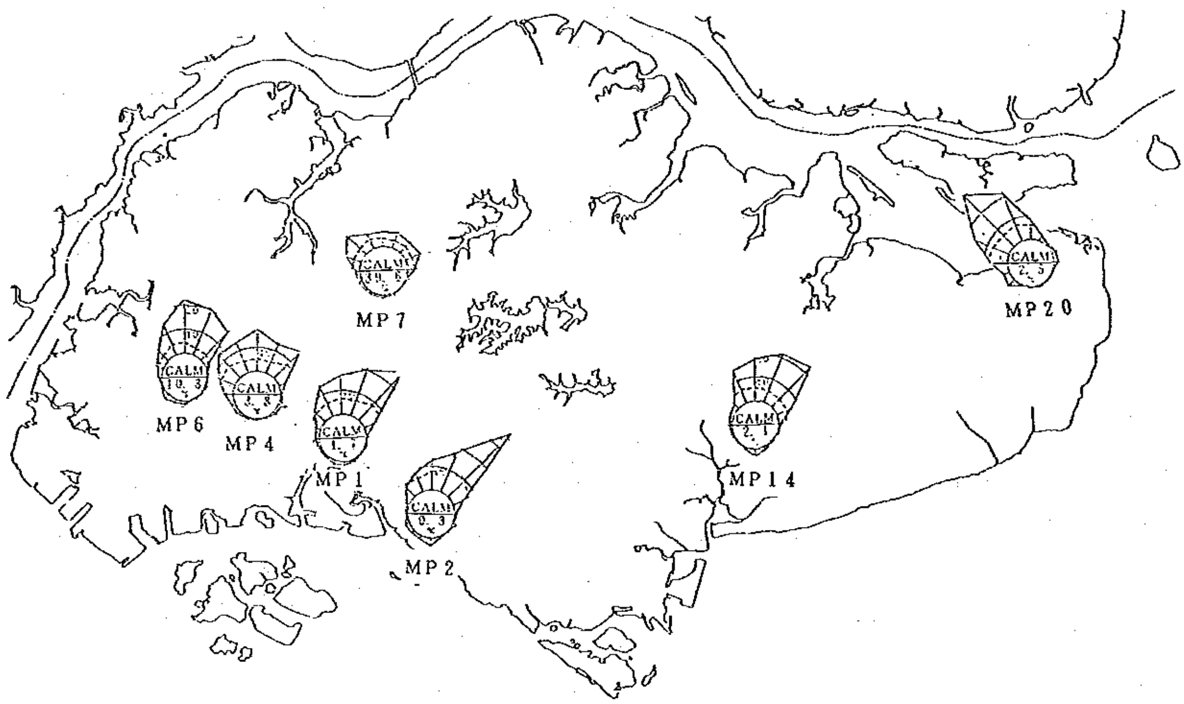


Fig. V-2-13-(1) Wind rose during the 1st short term field survey

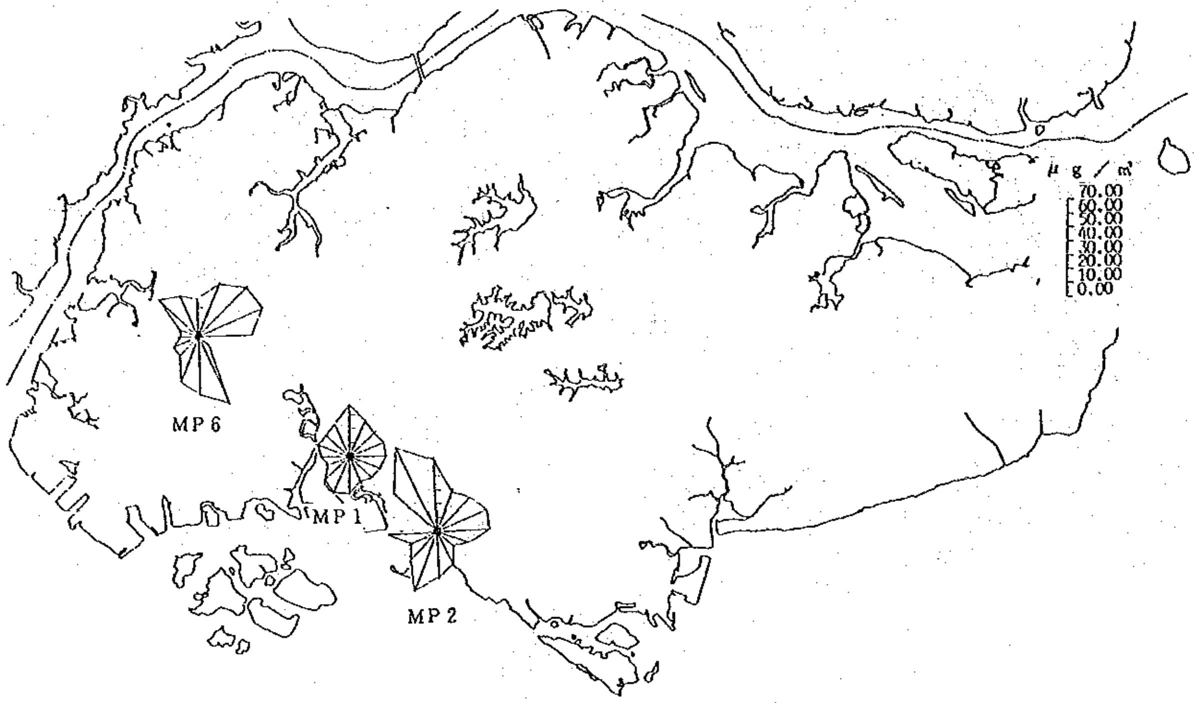


Fig. V-2-12-(2) Dependence of SPM concentration during the 2nd short term field survey on wind directions

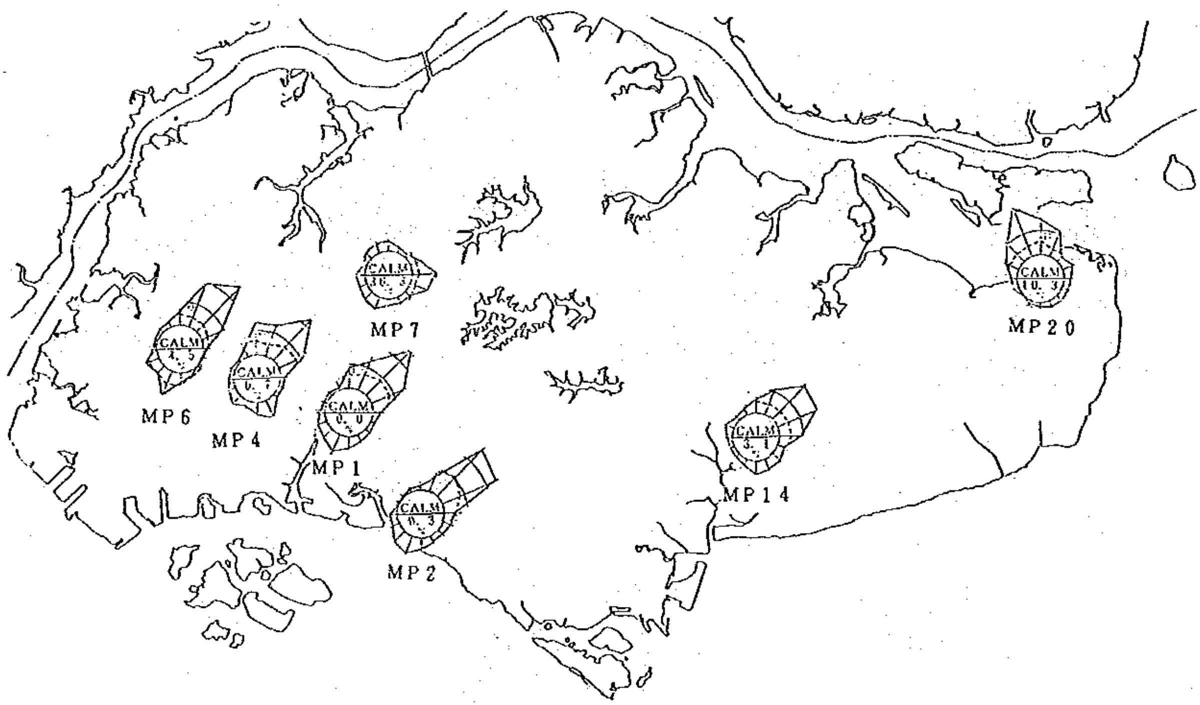


Fig. V-2-13-(2) Wind rose during the 2nd short term field survey

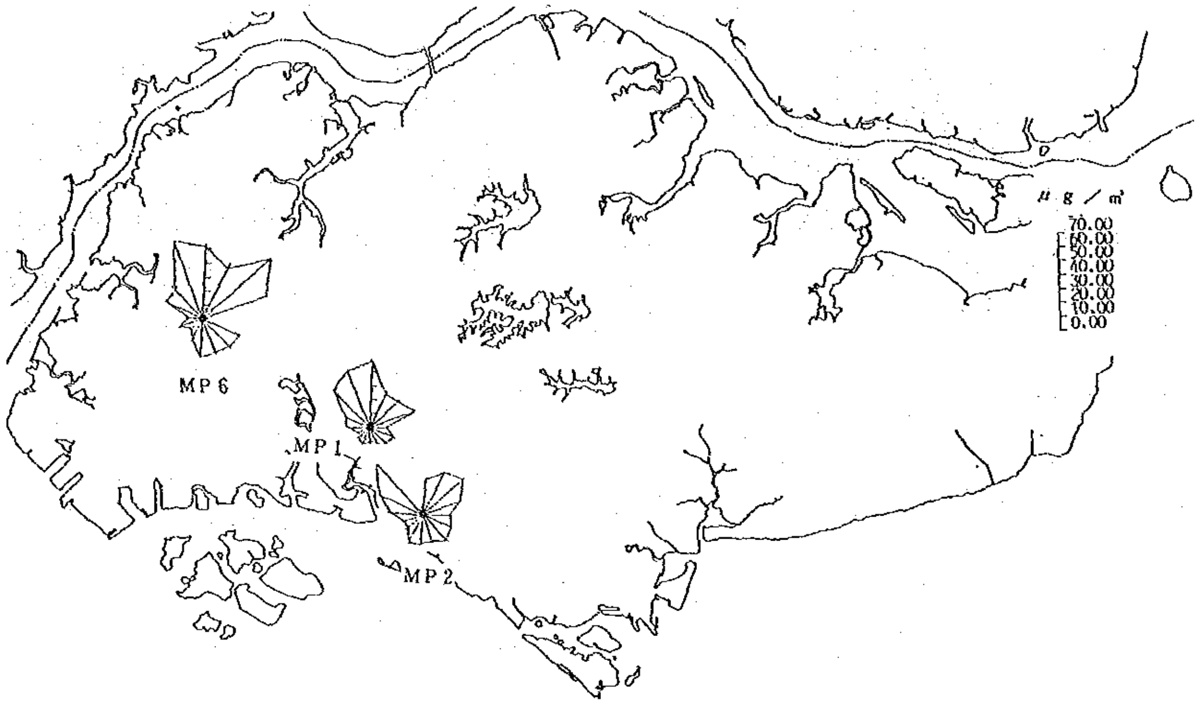


Fig. V-2-12-(3) Dependence of SPM concentration during the 3rd short term field survey on wind directions

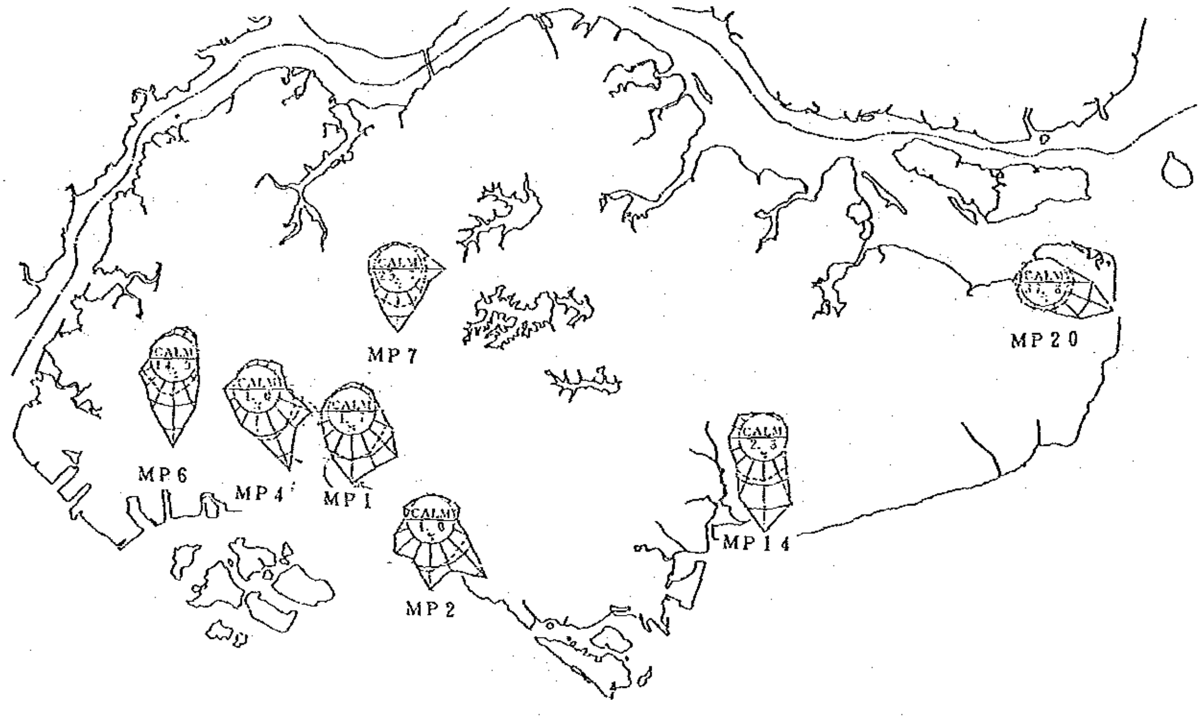


Fig. V-2-13-(3) Wind rose during the 3rd short term field survey

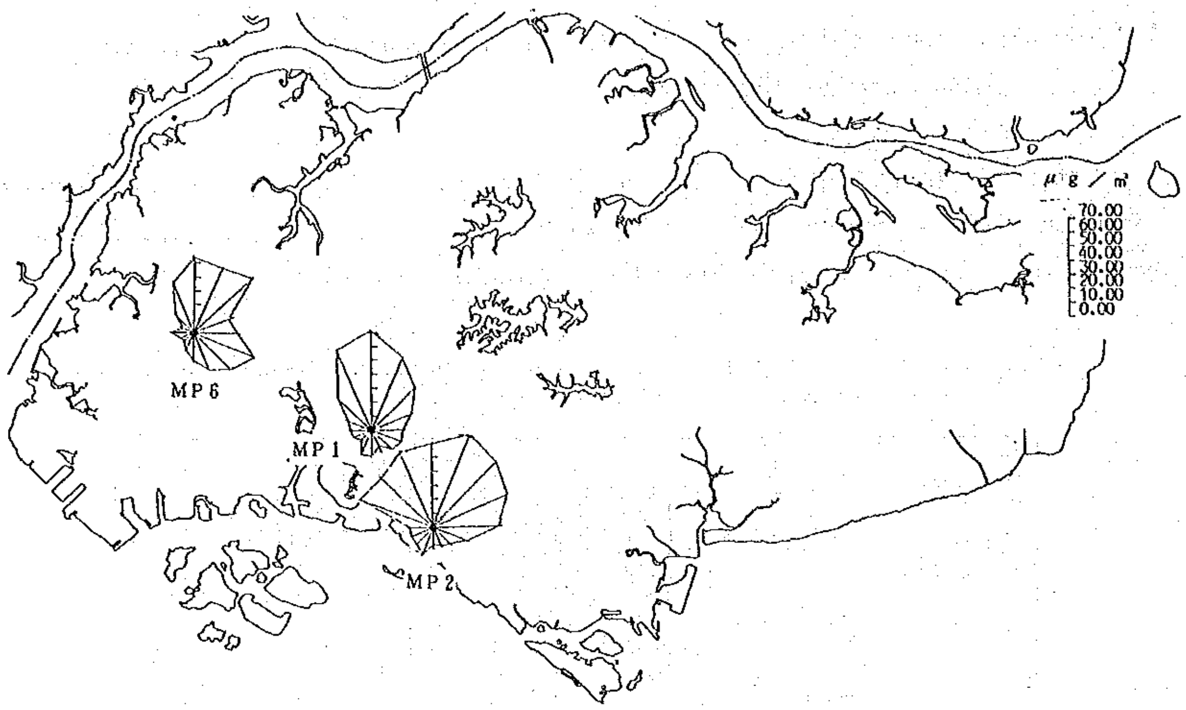


Fig. V-2-12-(4) Dependence of SPM concentration during the 4th short term field survey on wind directions

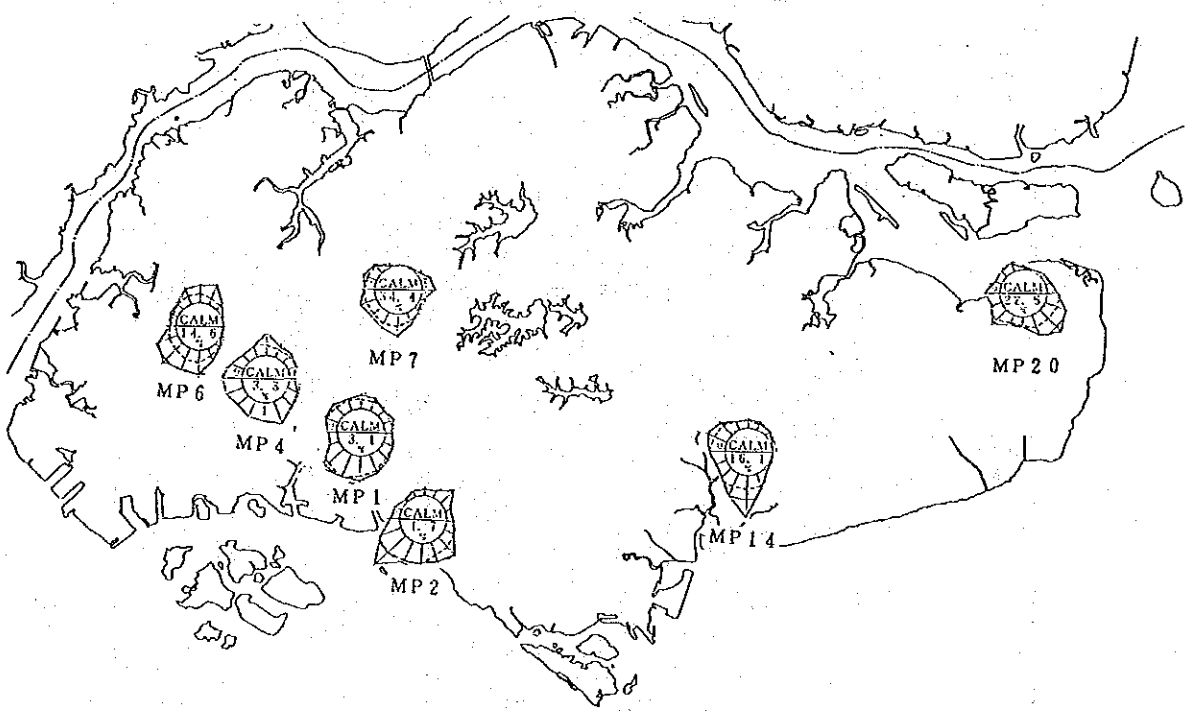


Fig. V-2-13-(4) Wind rose during the 4th short term field survey

V-2-3-2 Dependence of SPM concentrations during the short term field survey on wind velocity ranks

Table V-2-10 and Fig. V-2-14 show the dependence of SPM concentration during each short term field survey on wind velocity ranks. The results show the tendency that the greater the wind velocity is, the lower the SPM concentration is.

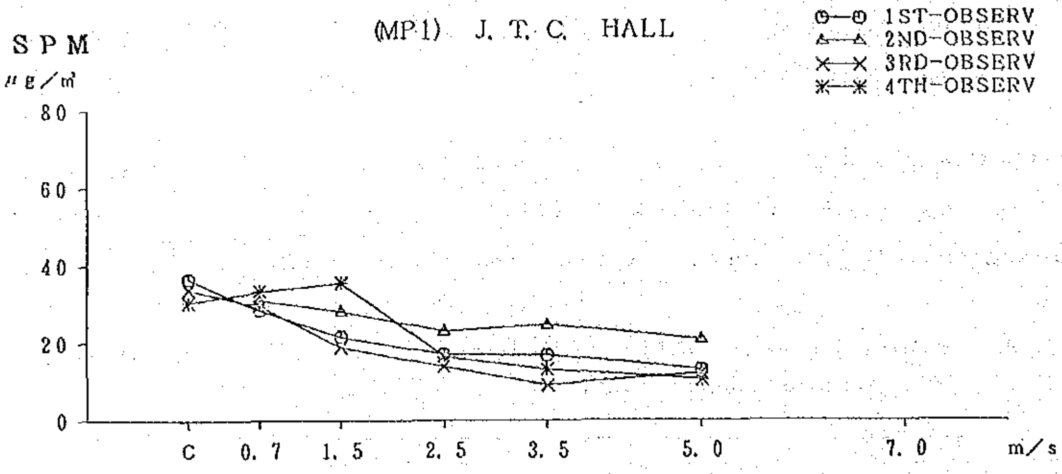
Table V-2-10 Dependence of SPM concentration during the short term field survey on wind velocity ranks

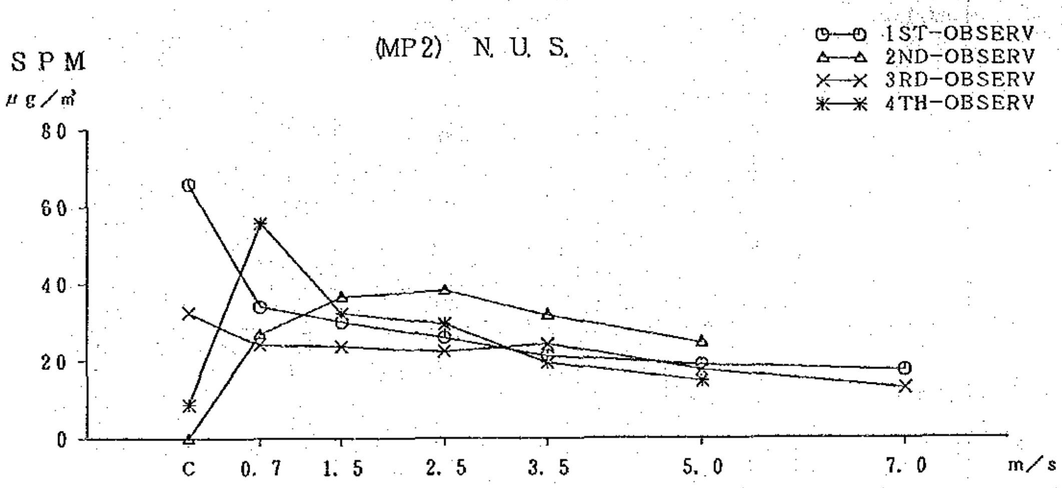
Monitoring stations	Survey	Item	Wind velocity ranks 0 -0.4	0.5 -0.9	1.0 -1.9	2.0 -2.9	3.0 -3.9	4.0 -5.9	6.0 m/s over	Ave
(MP1) J.T.C. HALL	1st survey	n	5	20	108	107	37	11		288
		AVE	36.8	28.6	21.9	17.1	16.9	13.2	-	19.9
		SIG	30.6	28.0	20.2	13.1	13.6	9.6		18.2
	2nd survey	n		12	79	116	52	13		272
		AVE	-	31.3	28.5	23.2	24.8	20.9	-	25.3
		SIG		15.1	20.6	13.3	17.6	9.9		16.7
	3rd survey	n	5	18	63	117	61	24		288
		AVE	34.0	29.8	19.1	14.1	9.2	12.3	-	15.3
		SIG	33.8	23.4	13.5	10.7	7.4	8.5		13.8
	4th survey	n	9	44	112	74	43	5		287
		AVE	30.6	33.7	35.9	16.6	13.2	10.6	-	26.6
		SIG	29.5	28.4	28.5	13.6	10.1	8.1		25.1
	Average	n	19	94	362	414	193	53		1135
		AVE	33.1	31.5	27.2	17.9	15.8	14.4	-	21.7
		SIG	31.1	26.1	23.2	13.1	14.0	9.8		19.5
(MP2) N.U.S.	1st survey	n	1	15	65	106	64	34	2	287
		AVE	66.0	34.2	30.2	26.1	21.2	18.9	17.5	25.6
		SIG	0.0	19.2	18.1	16.9	14.1	13.9	7.5	17.1
	2nd survey	n	1	13	52	108	85	29		288
		AVE	0.0	26.9	36.5	38.2	31.8	24.6	-	34.0
		SIG	0.0	26.6	24.4	20.1	20.1	13.3		21.3
	3rd survey	n	3	9	55	116	53	45	7	288
		AVE	32.7	24.2	23.8	22.4	24.3	17.6	12.9	22.2
		SIG	26.6	13.1	15.0	12.4	14.4	9.4	9.9	13.4
	4th survey	n	5	11	113	84	45	30		288
		AVE	8.8	55.7	32.3	29.5	19.5	14.7	-	28.2
		SIG	4.7	39.5	26.8	27.4	18.3	11.9		26.5
	Average	n	10	48	285	414	247	138	9	1151
		AVE	20.8	35.3	31.0	28.9	25.2	18.7	13.9	27.5
		SIG	24.2	28.9	23.0	20.2	17.9	12.5	9.6	20.6
(MP6) NANYANG.T.I.	1st survey	n	30	132	104	17				283
		AVE	29.1	22.7	12.3	14.1	-	-	-	19.0
		SIG	19.5	18.8	14.1	11.1				17.9
	2nd survey	n	13	71	172	15				271
		AVE	30.8	43.9	36.6	44.3	-	-	-	38.7
		SIG	21.4	22.8	22.9	28.5				23.4
	3rd survey	n	43	91	121	22	9	1		287
		AVE	35.1	32.9	24.1	15.5	23.3	20.0	-	27.9
		SIG	18.7	23.7	17.4	10.4	13.7	0.0		20.2
	4th survey	n	42	108	121	16				287
		AVE	36.0	31.9	23.3	12.2	-	-	-	27.8
		SIG	14.2	23.0	23.1	9.3				22.3
	Average	n	128	402	518	70	9	1		1128
		AVE	33.6	31.2	25.7	20.6	23.3	20.0	-	28.2
		SIG	18.1	23.0	22.0	20.3	13.7	0.0		22.1

n; The numbers of cases

AVE; Average ($\mu g/m^3$)

SIG; Standard deviation ($\mu g/m^3$)





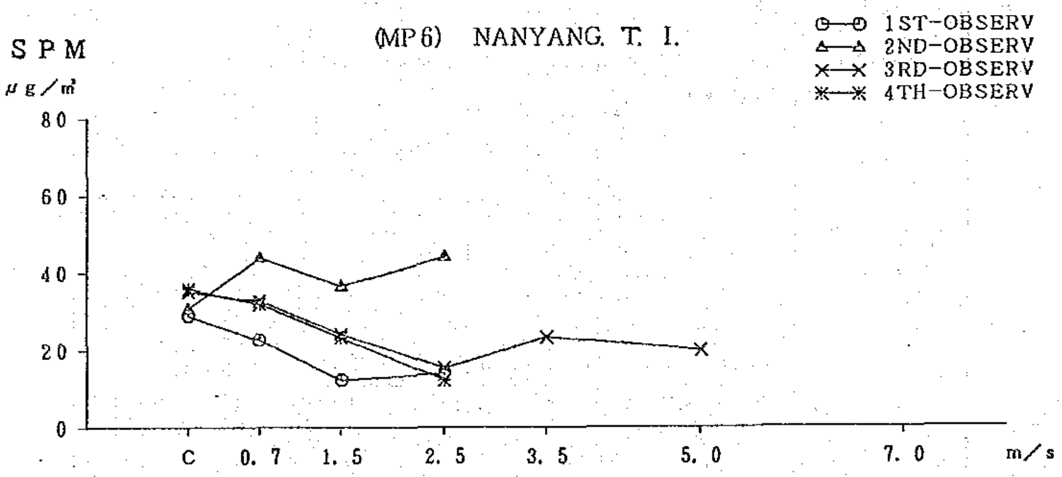


Fig. V-2-14 Dependence of SPM concentration during short term field survey on wind velocity ranks