HONG KONG OBSERVATORY

Technical Note (Local) No. 72

REGIONAL TEMPERATURE VARIATION IN WINTER OF HONG KONG

by

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1. INTRODUCTION

Hong Kong, though small (about 1,000 square kilometres), can sometimes experience large regional variation in meteorological elements such as temperature. Topography and proximity to the sea partly account for such variations. Anthropogenic factors such as urbanization also contribute to temperature differences between urban and rural areas. At times, meteorological conditions can play an important role in short-term temperature changes.

Apart from the Hong Kong Observatory, there is a need to forecast the minimum temperature at various locations in Hong Kong particularly in the New Territories where low temperatures in winter may affect crops and fish farming.

With the setting up of automatic weather stations at various parts of the territory, temperature data are now available at these locations. Empirical and statistical methods are applied to analyse these data to obtain a general picture of the regional temperature variation pattern.

In this study, only the daily minimum temperature in the winter months are investigated. The winter months in this note are referred to December, January and February. Minimum temperatures from selected automatic weather stations are compared with those recorded at the Hong Kong Observatory. Regression analysis are made to each selected automatic weather station against the Hong Kong Observatory under northerly surges. Forecast equations based on regression analysis are then obtained.

It is hoped that results from this study can provide useful information in predicting minimum temperatures during winter for various parts of Hong Kong. Town planners and power utilities companies may found such information useful in estimating power consumption.

2. SOURCE OF TEMPERATURE DATA

The Hong Kong Observatory operates a network of automatic weather stations (AWS) in various parts of Hong Kong. These stations were set up to meet the increasing demand for regional meteorological data. An AWS measures wind, dry-bulb and wet-bulb temperatures, dew point, relative humidity, atmospheric pressure and rainfall and the data are transmitted to the Hong Kong Observatory at one-minute intervals via telephone circuits. The meteorological data acquired by the AWS were compiled in a format similar to those of a manned weather stations. A system of quality checks is implemented on a non real-time basis and the data are then stored on magnetic tapes after processing.

Air temperatures are measured by platinum resistance thermometer at the automatic weather stations. The minimum of these one-minute temperature data transmitted to the Hong Kong Observatory on a day is regarded as the daily minimum temperature recorded for that day.

In this study, computer programs were written to analyse daily minimum temperature data in December, January and February from records of selected automatic weather stations at the Hong Kong Observatory, Sha Tin, Lau Fau Shan, Ta Kwu Ling, Tuen Mun, Wong Chuk Hang, Waglan Island, Tai Po Kau and Sai Kung. These stations were chosen because of their longer recording periods. Also, they are located in relatively densely populated areas and on the whole can provide a wide coverage over the territory. Details of the positions, elevations and date of first operation of these stations are listed in Table 2.1. A Hong Kong map showing their locations can be found in Figure 2.1.

3. STATISTICAL ANALYSIS OF TEMPERATURE DATA

3.1 Mean daily minimum temperature

Mean daily minimum temperature for December, January and February of each year from 1991 to 1995 are compiled. The averages of these monthly means over the five years are then computed and listed in Table 3.1.

From the table, January is the coldest month among the three with all nine stations having the lowest mean minimum temperatures. February is in general colder than December with eight stations recording lower readings. The only exception is the station Ta Kwu Ling for which the average minimum temperature in February is slightly higher than that of December.

Rough sketches of the distribution of these averages on mean daily minimum temperature for each month are given in Figures 3.1, 3.2 and 3.3. The three temperature distribution patterns are rather similar. In general, those stations located at the southern part of the territory recorded higher temperatures. Topography in Hong Kong may be one of the factors contributing to this. The high mountains in Hong Kong such as Tai Mo Shan, Tate's Cairn are mainly east-west oriented and thus shelter the northerly winds in winter. The highest reading recorded is at the Hong Kong Observatory. Urbanization seems to be the cause for that since the Observatory is situated at the centre of the urban areas. The next higher temperatures recorded are Waglan Island and Wong Chuk Hang. Ta Kwu Ling, a station in the rural area of the northern part of the New Territories, has the lowest readings among the nine stations. As compared to the station Tai Po, temperatures of Sha Tin are slightly lower in all the three months. The difference in the averages between the Hong Kong Observatory and Ta Kwu Ling are 3.4, 3.3 and 1.7 degrees for December, January and February respectively.

3.2 Percentage of days with daily minimum temperature below specified values

Tables 3.2, 3.3 and 3.4 show the percentage of days in the five years 1991 to 1995 with daily minimum temperatures below specified values for December, January and February respectively.

In December, as much as 40 per cent of Ta Kwu Ling's daily minimum temperature but only about 10 per cent of that of the urban areas are below or equal to 12 degrees. It is seldom for stations to record temperatures below or equal to 4 degrees. For January, the percentage increases to over 50 at Ta Kwu Ling and Lau Fau Shan and over 40 for Sha Tin, Tuen Mun, Tai Po Kau and Sai Kung. There are still about 30 per cent of days for stations like Tuen Mun, Sha Tin, Lau Fau Shan and about 40 per cent for Ta Kwu Ling having temperatures below or equal to 10 degrees. Temperatures less than or equal to 4 degrees is not seldom for Ta Kwu Ling. There is one occasion

at Ta Kwu Ling having recorded sub-zero temperature in this five-year period. In February, the order of stations to have percentage of days with minimum temperatures below or equal to 12 degrees is slightly different from that of December and January. The percentage for Wong Chuk Hang is smaller than Waglan Island and that of Sai Kung is higher than Tai Po Kau and Tuen Mun. It is rare that the stations recorded temperatures below or equal to 6 degrees.

The lowest daily minimum temperature recorded by various stations in 1991 to 1995 for December, January and February can be found in Table 3.5. The lowest temperature is -0.4 degrees recorded at Ta Kwu Ling on 29 January 1993.

3.3 Deviation of daily minimum temperature from the Hong Kong Observatory

It is interesting to note the difference between the daily minimum temperature recorded by the Hong Kong Observatory with respect to other stations. Table 3.6 shows the maximum, mean and standard deviation of the difference at each station. It can be clearly seen that the mean temperature deviations for all the stations except Lau Fau Shan and Ta Kwu Ling are within two degrees. The distribution of temperature deviations of Ta Kwu Ling and Sha Tin stations are more dispersed as compared to other stations. Although the mean deviations of the stations are all within three degrees, there are occasions that the deviation can be quite large. As indicated in the table, the maximum difference can reach 11.2 degrees.

The percentage of days with the deviation within specified values for the years 1991 to 1995 are shown in Table 3.7. For Waglan Island and Wong Chuk Hang, the majority of the days are having daily minimum temperatures deviations between zero and two degrees. There are still a substantial portion, about 20 and 25 per cent respectively, that the temperatures recorded at the two stations are higher than the Hong Kong Observatory. Deviations greater than or equal to four degrees are rare.

The remaining six New Territories stations except Ta Kwu Ling have over 80 per cent of days with minimum temperature deviations between zero and four degrees. About half of the days at Tai Po Kau, Tuen Mun and Sha Tin and 60 per cent at Sai Kung are within a couple of degrees lower than at the Hong Kong Observatory. Unlike other stations, the class with the largest percentage of days for Lau Fau Shan is of deviations between two to four degrees instead of zero to two degrees.

As to the Ta Kwu Ling station, the percentage with deviations between zero and four degrees is around 60 per cent. Difference of more than four degrees is not uncommon. There are 16 occasions that the deviations were greater than 8 degrees. Among these, three of them were even greater than 10 degrees.

3.4 Meteorological conditions for large deviations of daily minimum temperatures from the Hong Kong Observatory

It is interesting to investigate the meteorological conditions in cases of large deviations in daily minimum temperatures from the Hong Kong Observatory. Deviations of greater than 8 degrees at Ta Kwu Ling were chosen for this purpose. These 16 cases are listed in Table 3.8.

In all the 16 cases, no rainfall was recorded and the prevailing winds were northeasterlies. The cloud amount in 13 cases were below 10 per cent. There were 14 cases having wind speed below 30 km/h (i.e. light to moderate) and among these, 10 cases were smaller than 20 km/h. For the 3 cases with deviations greater than 10 degrees, the cloud amount was either 0 or 1 per cent and the wind speed was all below 20 km/h.

The above phenomena may be explained by the urban heat island effect. The temperature differences that develop between an urbanizing area and the rural landscape greatly depend on the synoptic conditions. They are in essence a result of dissimilarity in radiative fluxes and turbulent exchange. These contrasts are largest in clear and calm conditions. Ta Kwu Ling is an inland and rural station and sometimes radiation cooling can cause sharp fall of temperatures especially at clear night. The light wind conditions can enhance the process of cooling in the layer of air immediately above the ground and thus in effect lower the minimum temperatures.

3.5 Regression analysis of daily minimum temperatures recorded at various stations against the Hong Kong Observatory under northerly surges

In winter, Hong Kong is often affected by surges of cold continental air from the north. The arrival of these cold surges can cause a sudden drop in temperatures over the territory. The definition of northerly surge used in this report is similar to that in Royal Observatory Technical Note No. 83. It is taken as four consecutive 3-hourly Waglan wind observations from 340 to 030 degrees and with mean speed of 5 m/s or above. Since winds at Cheung Chau are included operationally for consideration of strong monsoon signal and the exposure of Cheung Chau also renders it more susceptible to northerly onset, the above definition is extended to cover wind analyses at Cheung Chau. A northerly surge is considered to have arrived in Hong Kong if the set criterion is met at either Waglan or Cheung Chau. After objective selection, the surge cases are subjectively screened to reject cases due to probable influence from tropical cyclones and when synoptic analyses clearly indicated the absence of any push from the north. The surge arrival time is taken as the time of the first of four consecutive 3-hourly wind observations as defined above. If surge arrival times of Waglan and Cheung Chau are different, the earlier of the two will be adopted.

In this note, the day of surge arrival is regarded as day 0, the next three consecutive days are taken as day 1, day 2 and day 3 respectively. In order to isolate cases with more significant surges, only those surges with temperature drop of greater than 2 degrees between day 0 and day 1 are taken into the analysis. Linear regression analyses of daily minimum temperature at each station against the Observatory are conducted and the results are shown in Table 3.9.

The correlation coefficients on days 1, 2 and 3 for all the stations are generally over 0.8. Except Ta Kwu Ling, the correlation coefficients on day 1 are all above 0.96 indicating good straight lines fit. The standard errors for day 1 are in general less than one degree. For day 3 at stations like Wong Chuk Hang, Tai Po Kau and Sha Tin, the standard errors are between one to two degrees. In general, the standard error increases as the day number increases. Ta Kwu Ling exhibits the largest standard error among the stations for all the days 1, 2 and 3.

Figures 3.4 to 3.6 show the scatter diagrams, the regression lines and the 95 % confident limits for some chosen stations, Wong Chuk Hang, Sha Tin and Ta Kwu Ling.

4. CONCLUSION

Climatologically, the Hong Kong Observatory and Ta Kwu Ling recorded the highest and lowest daily minimum temperatures respectively. This clearly indicates the effect of urbanization and topography. In general, owing to the topography of Hong Kong, the stations situated in the north is colder than that of the south.

The average difference in minimum temperature variation among the stations are only one or two degrees. The greatest average difference of around three degrees is recorded between Ta Kwu Ling and the Hong Kong Observatory. However, daily deviation in minimum temperature between stations can be quite large. It is thus worthwhile to study synoptic weather conditions attributing to this.

The spatial temperature distribution pattern would be better represented if longer record period is taken. The accuracy of the forecast equations is also limited by the length of the stations' records. The forecast equations should be re-derived and tested for validity when future data are available.

ACKNOWLEDGMENTS

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TABLE 2.1

SELECTED AUTOMATIC WEATHER STATIONS IN HONG KONG

Station	Position		Elevation of ground above mean sea-level (metres)	Date of first operation
	Latitude N	Longitude E		
Hong Kong Observatory	22°18'	114°10'	32	10 July 1984
Sha Tin	22°24'	114°12'	7	1 Oct 1984
Lau Fau Shan	22°28'	113°59'	34	16 Sep 1985
Ta Kwu Ling	22°32'	114°09'	12	14 Oct 1985
Tuen Mun	22°24'	113°58'	63	23 Oct 1987
Wong Chuk Hang	22°15'	114°10'	5	1 Aug 1989
Waglan Island	22°11'	114°18'	56	22 Aug 1989
Tai Po Kau	22°27'	114°11'	4	22 Aug 1990
Sai Kung *	22°23'	114°16'	30	17 Dec 1990
Sai Kung *	22°23'	114°16'	4	3 Mar 1993

* The Sai Kung Station was relocated on 3 March 1993.

TABLE 3.1

MEAN DAILY MINIMUM TEMPERATURE AVERAGED OVER 1991-95

Station	December (°C)	January (°C)	February (°C)
Hong Kong Observatory	16.5	14.3	15.0
Waglan Island	15.7	13.5	14.0
Wong Chuk Hang	15.6	13.2	14.4
Sai Kung	15.0	12.5	13.5
Tai Po Kau	14.7	12.4	13.7
Tuen Mun	14.7	12.4	14.0
Sha Tin	14.4	12.0	13.4
Lau Fau Shan	14.0	11.8	13.4
Ta Kwu Ling	13.1	11.0	13.3

TABLE 3.2

PERCENTAGE OF DAYS IN DECEMBER WITH DAILY MINIMUM TEMPERATURE BELOW SPECIFIED VALUES (1991 - 1995)

Station	Percentage of days with daily minimum temperature less than or equal to						
	12 °C	10 °C	8 °C	6 °C	4 °C	2 °C	0 °C
Hong Kong Observatory	8.7	2.7	1.3	1.3	0	0	0
Waglan Island	11.8	3.9	1.6	1.6	0	0	0
Wong Chuk Hang	15.9	7.9	2.6	1.3	0	0	0
Sai Kung	18.8	5.8	1.9	1.3	1.3	0	0
Tai Po Kau	26.0	12.3	6.8	2.1	1.4	0	0
Tuen Mun	25.0	11.2	3.9	2.0	1.3	0	0
Sha Tin	27.0	13.2	7.9	3.3	1.3	0	0
Lau Fau Shan	30.7	17.0	5.9	2.0	1.3	0	0
Ta Kwu Ling	40.1	27.6	15.1	8.6	3.3	0.7	0

TABLE 3.3

PERCENTAGE OF DAYS IN JANUARY WITH DAILY MINIMUM TEMPERATURE BELOW SPECIFIED VALUES (1991 - 1995)

Station	Percentage of days with daily minimum temperature less than or equal to						
	12 °C	10 °C	8 °C	6 °C	4 °C	2 °C	0 °C
Hong Kong Observatory	24.5	11.6	5.8	0.6	0	0	0
Waglan Island	29.5	14.4	4.1	0	0	0	0
Wong Chuk Hang	31.0	18.7	10.3	2.6	0	0	0
Sai Kung	42.2	22.7	11.0	3.2	0	0	0
Tai Po Kau	42.6	23.9	14.2	7.1	1.9	0	0
Tuen Mun	45.2	27.1	14.2	6.5	1.9	0	0
Sha Tin	44.5	27.7	17.4	8.4	1.3	0	0
Lau Fau Shan	51.6	29.7	18.1	8.4	1.9	0	0
Ta Kwu Ling	58.2	39.9	22.2	15.7	9.8	1.3	0.7

TABLE 3.4

PERCENTAGE OF DAYS IN FEBRUARY WITH DAILY MINIMUM TEMPERATURE BELOW SPECIFIED VALUES (1991 - 1995)

Station	Percentage of days with daily minimum temperature less than or equal to						
	12 °C	10 °C	8 °C	6 °C	4 °C	2 °C	0 °C
Hong Kong Observatory	8.5	0	0	0	0	0	0
Waglan Island	22.3	2.2	0	0	0	0	0
Wong Chuk Hang	14.7	4.4	0.7	0	0	0	0
Sai Kung	32.1	3.6	0	0	0	0	0
Tai Po Kau	28.4	6.4	0	0	0	0	0
Tuen Mun	28.6	10.5	0	0	0	0	0
Sha Tin	34.3	12.1	1.4	0.7	0	0	0
Lau Fau Shan	36.2	12.8	0.7	0	0	0	0
Ta Kwu Ling	41.5	16.3	5.2	2.2	1.5	0	0

TABLE 3.5

LOWEST DAILY MINIMUM TEMPERATURE RECORDED
BY VARIOUS STATIONS IN DECEMBER, JANUARY AND FEBRUARY
DURING THE PERIOD 1991 TO 1995

Station	December (°C)	January (°C)	February (°C)
Hong Kong Observatory	4.7	5.4	10.4
Waglan Island	4.4	6.4	9.4
Wong Chuk Hang	4.7	5.4	7.2
Sai Kung	3.6	4.5	8.7
Tai Po Kau	3.4	3.6	8.1
Tuen Mun	2.1	3.0	8.3
Sha Tin	3.2	2.7	6.0
Lau Fau Shan	2.6	3.2	7.2
Ta Kwu Ling	1.3	-0.4	2.7

TABLE 3.6

MAXIMUM, MEAN AND STANDARD DEVIATION OF THE DIFFERENCE (DAILY MINIMUM TEMPERATURE RECORDED BY THE HONG KONG OBSERVATORY MINUS THAT OF THE VARIOUS STATIONS) DURING THE WINTER PERIODS OF 1991 TO 1995

Station	Maximum Difference (°C)	Mean Difference* (°C)	Standard Deviation of Difference* (°C)
Waglan Island	3.6	0.8	0.9
Wong Chuk Hang	6.0	0.8	1.3
Sai Kung	7.0	1.6	1.1
Tai Po Kau	5.9	1.7	1.2
Tuen Mun	4.6	1.6	1.1
Sha Tin	8.0	2.0	1.5
Lau Fau Shan	6.5	2.2	1.1
Ta Kwu Ling	11.2	2.8	2.4

* Denote the difference by d, then the mean and standard deviation of the difference are calculated by the formulae $\bar{d} = \frac{1}{n}(\sum d)$ and $\sigma = \sqrt{\frac{\sum (d - \bar{d})^2}{n}}$ respectively.

TABLE 3.7

PERCENTAGE OF DAYS IN WINTER MONTHS WITH DEVIATION (DAILY MINIMUM TEMPERATURE RECORDED BY THE HONG KONG OBSERVATORY MINUS THAT OF THE VARIOUS STATIONS) WITHIN SPECIFIED VALUES (1991 - 1995)

Station	Percentage of days with deviation (D) in daily minimum temperature in degree Celsius within the values							
	$D < 0$	$0 \leq D < 2$	$2 \leq D < 4$	$4 \leq D < 6$	$6 \leq D < 8$	$8 \leq D < 10$	$10 \leq D < 12$	$12 \leq D$
Waglan Island	19.7	73.0	7.3	0	0	0	0	0
Wong Chuk Hang	24.0	56.9	16.4	2.5	0.2	0	0	0
Sai Kung	4.2	62.1	31.2	2.2	0.2	0	0	0
Tai Po Kau	4.9	55.7	35.7	3.6	0	0	0	0
Tuen Mun	8.4	51.5	38.5	1.6	0	0	0	0
Sha Tin	2.7	58.6	26.5	9.8	2.0	0.4	0	0
Lau Fau Shan	2.5	34.8	57.4	5.1	0.2	0	0	0
Ta Kwu Ling	8.8	31.9	32.4	16.7	6.6	2.9	0.7	0

TABLE 3.8

METEOROLOGICAL CONDITIONS IN CASES OF TA KWU LING WITH DAILY MINIMUM TEMPERATURE DEVIATIONS GREATER THAN EIGHT DEGREES FROM THE HONG KONG OBSERVATORY

Date	Temperature deviation (°C)	Cloud amount (%)	Rainfall (mm)	Bright sunshine (hour)	Prevailing wind direction	Wind speed (km/h)
17.1.92	8.9	9	Nil	9.6	020	18.3
26.1.93	8.1	49	Nil	4.1	060	17.5
29.1.93	9.3	2	Nil	9.8	080	16.0
30.1.93	9.0	0	Nil	9.9	040	19.4
31.1.93	10.3	0	Nil	9.7	090	19.7
1.2.93	9.2	3	Nil	9.7	100	33.2
4.2.93	8.2	6	Nil	10.2	080	11.0
5.2.93	8.0	14	Nil	10.3	040	11.3
17.2.93	8.3	40	Nil	8.3	090	24.7
24.12.93	8.1	2	Nil	9.4	020	28.7
25.12.93	8.2	1	Nil	9.1	010	19.5
26.12.93	10.9	0	Nil	9.4	030	10.3
27.12.93	9.6	4	Nil	9.1	090	28.4
7.1.95	8.5	7	Nil	9.9	080	22.0
9.12.95	8.4	4	Nil	9.8	070	33.3
31.12.95	11.2	1	Nil	9.6	030	10.9

TABLE 3.9

REGRESSION ANALYSES OF DAILY MINIMUM TEMPERATURES RECORDED BY VARIOUS STATIONS AGAINST THE HONG KONG OBSERVATORY UNDER NORTHERLY SURGES

Station	Day	Correlation Coefficient	Standard error	Regression equation
Waglan Island	1	0.96	0.79	$T = 1.33 + 0.82\theta$
	2	0.96	0.77	$T = 1.00 + 0.86\theta$
	3	0.94	0.97	$T = 1.63 + 0.84\theta$
Wong Chuk Hang	1	0.98	0.64	$T = 0.22 + 1.01\theta$
	2	0.96	0.85	$T = 1.30 + 0.92\theta$
	3	0.90	1.34	$T = 3.09 + 0.80\theta$
Sai Kung	1	0.98	0.59	$T = -0.23 + 0.90\theta$
	2	0.98	0.59	$T = -0.39 + 0.91\theta$
	3	0.97	0.78	$T = -1.31 + 0.99\theta$
Tai Po Kau	1	0.97	0.88	$T = -1.43 + 0.97\theta$
	2	0.94	1.28	$T = -2.83 + 1.09\theta$
	3	0.95	1.16	$T = -3.95 + 1.16\theta$
Tuen Mun	1	0.96	0.82	$T = -2.13 + 1.00\theta$
	2	0.97	0.75	$T = -2.68 + 1.02\theta$
	3	0.97	0.94	$T = -4.23 + 1.19\theta$
Sha Tin	1	0.97	0.79	$T = -1.68 + 1.01\theta$
	2	0.95	1.04	$T = -2.76 + 1.10\theta$
	3	0.88	1.76	$T = -3.15 + 1.10\theta$
Lau Fau Shan	1	0.96	0.80	$T = -1.90 + 0.97\theta$
	2	0.96	0.81	$T = -2.46 + 0.99\theta$
	3	0.97	0.83	$T = -4.51 + 1.18\theta$
Ta Kwu Ling	1	0.87	1.53	$T = -1.56 + 0.90\theta$
	2	0.78	2.19	$T = -2.63 + 0.94\theta$
	3	0.82	2.50	$T = -6.00 + 1.21\theta$

Note : T represents the temperature at the station and θ the temperature at the Observatory.

FIGURE 2.1

A HONG KONG MAP SHOWING LOCATIONS OF SELECTED AUTOMATIC WEATHER STATIONS

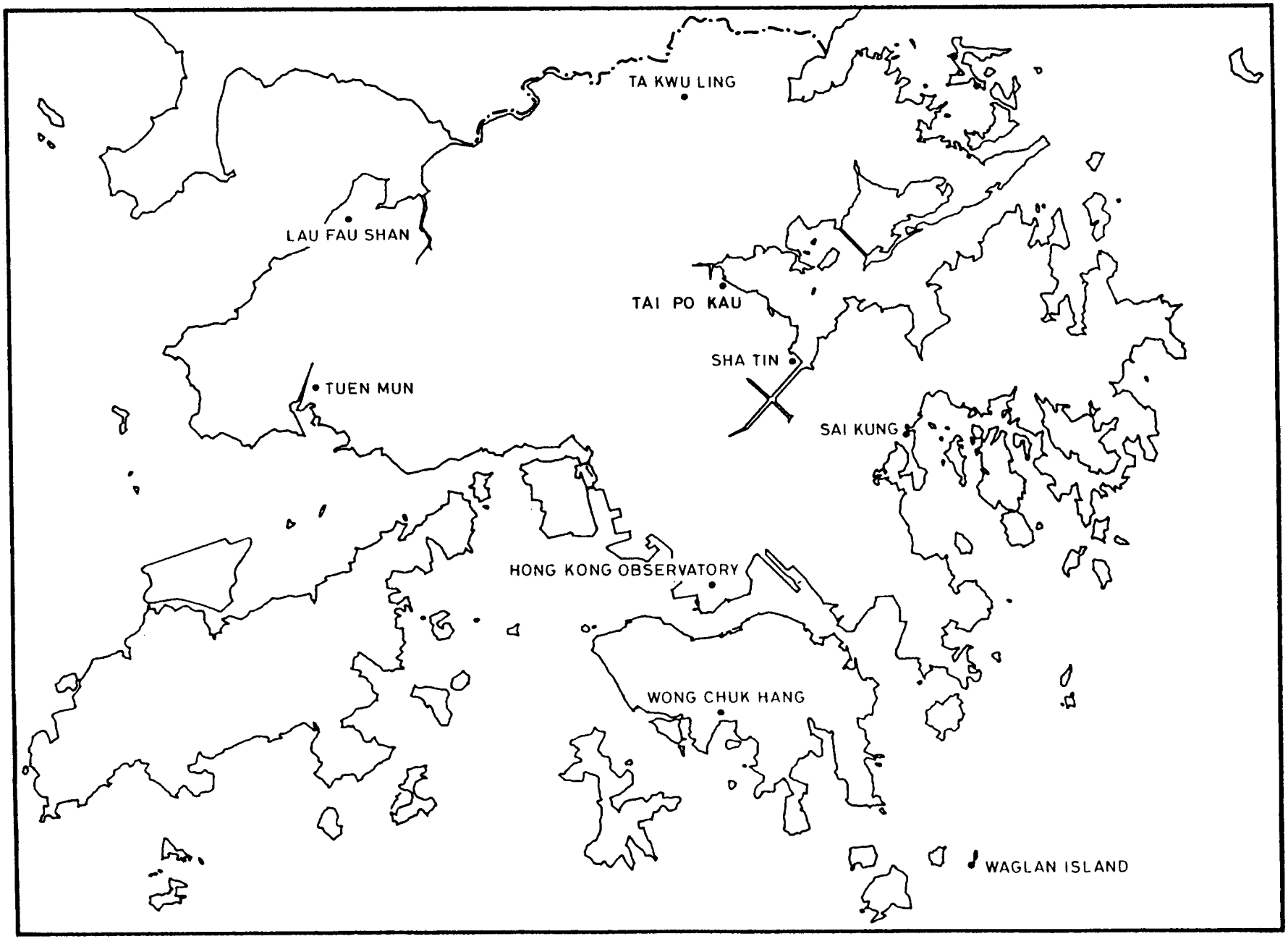


FIGURE 3.1

DISTRIBUTION OF MEAN DAILY MINIMUM TEMPERATURE AVERAGED OVER 1991-95 IN DEGREE CELSIUS FOR DECEMBER

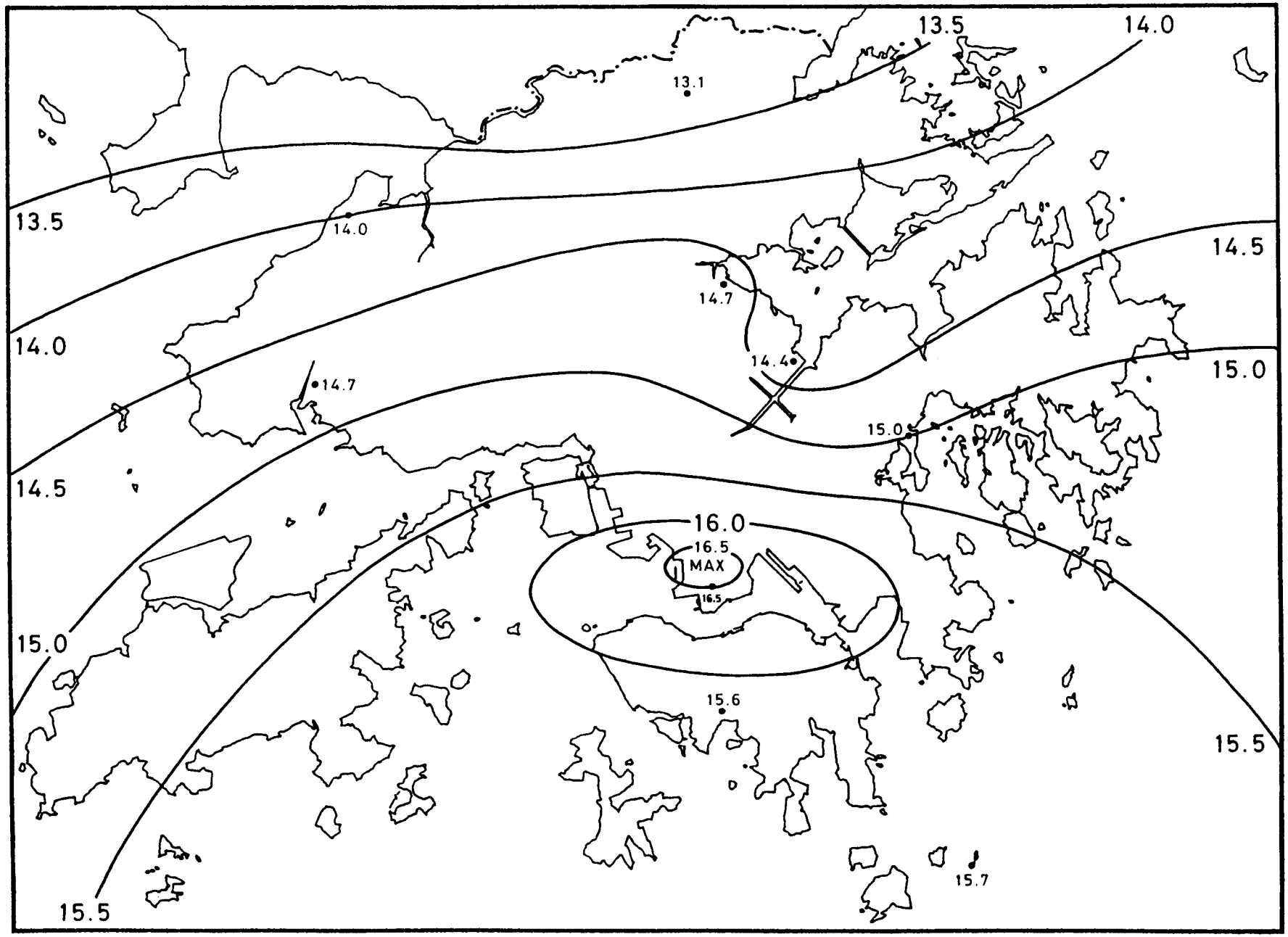


FIGURE 3.2

DISTRIBUTION OF MEAN DAILY MINIMUM TEMPERATURE AVERAGED OVER 1991-95 IN DEGREE CELSIUS FOR JANUARY

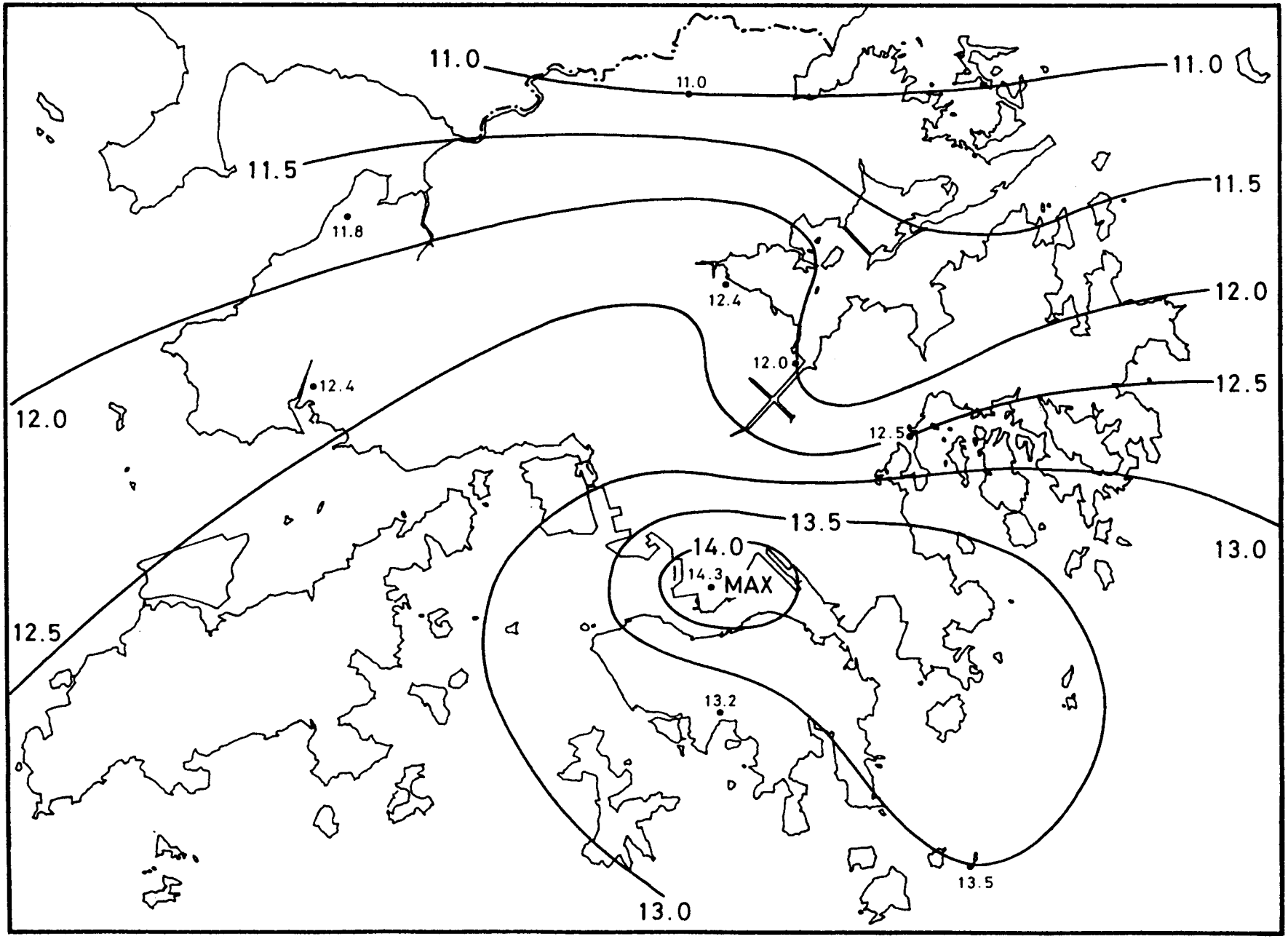


FIGURE 3.3

DISTRIBUTION OF MEAN DAILY MINIMUM TEMPERATURE AVERAGED OVER 1991-95 IN DEGREE CELSIUS FOR FEBRUARY

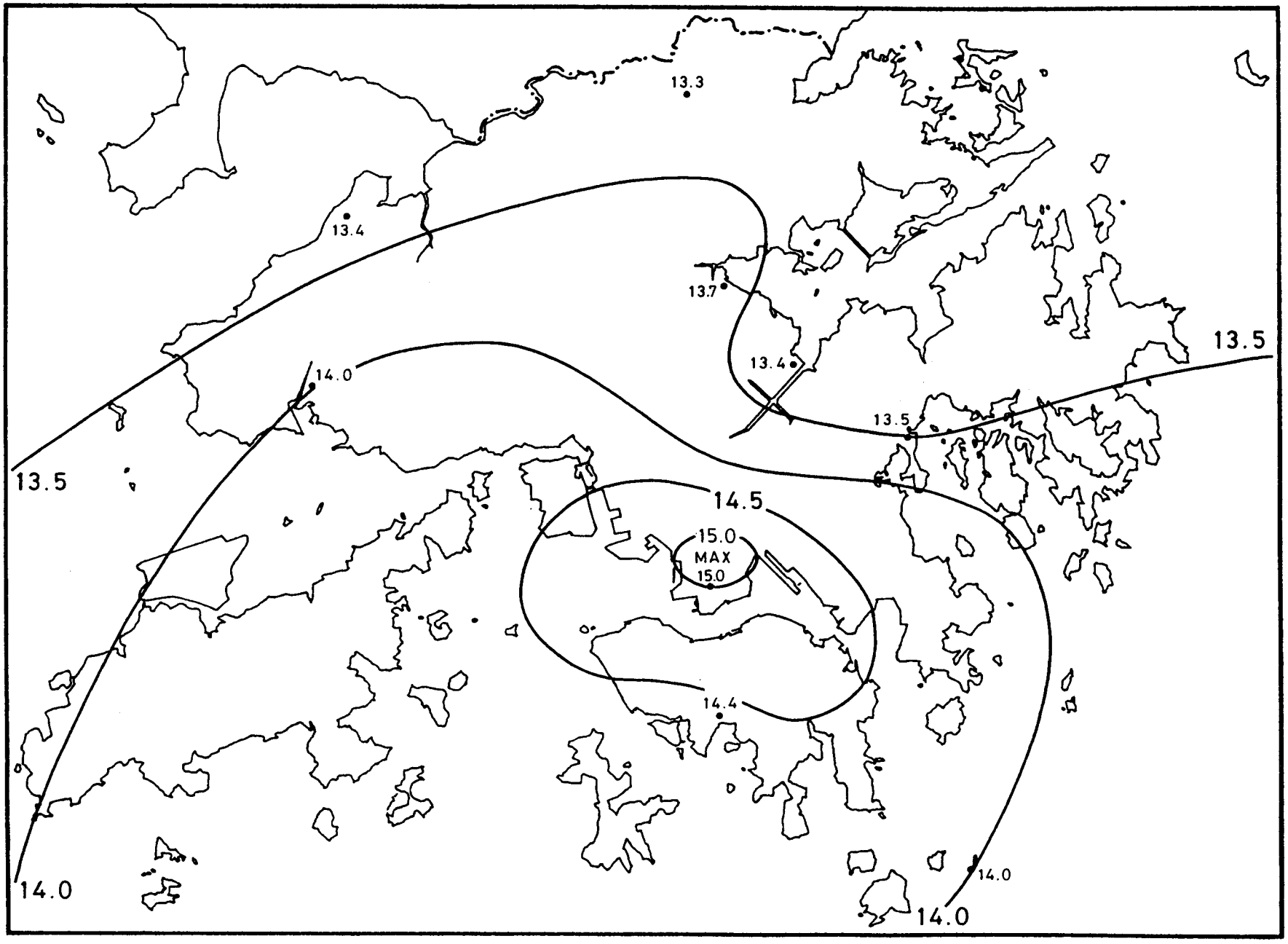


FIGURE 3.4

LINEAR REGRESSION OF DAILY MINIMUM TEMPERATURES RECORDED BY WONG CHUK HANG AGAINST THE HONG KONG OBSERVATORY UNDER NORTHERLY SURGES

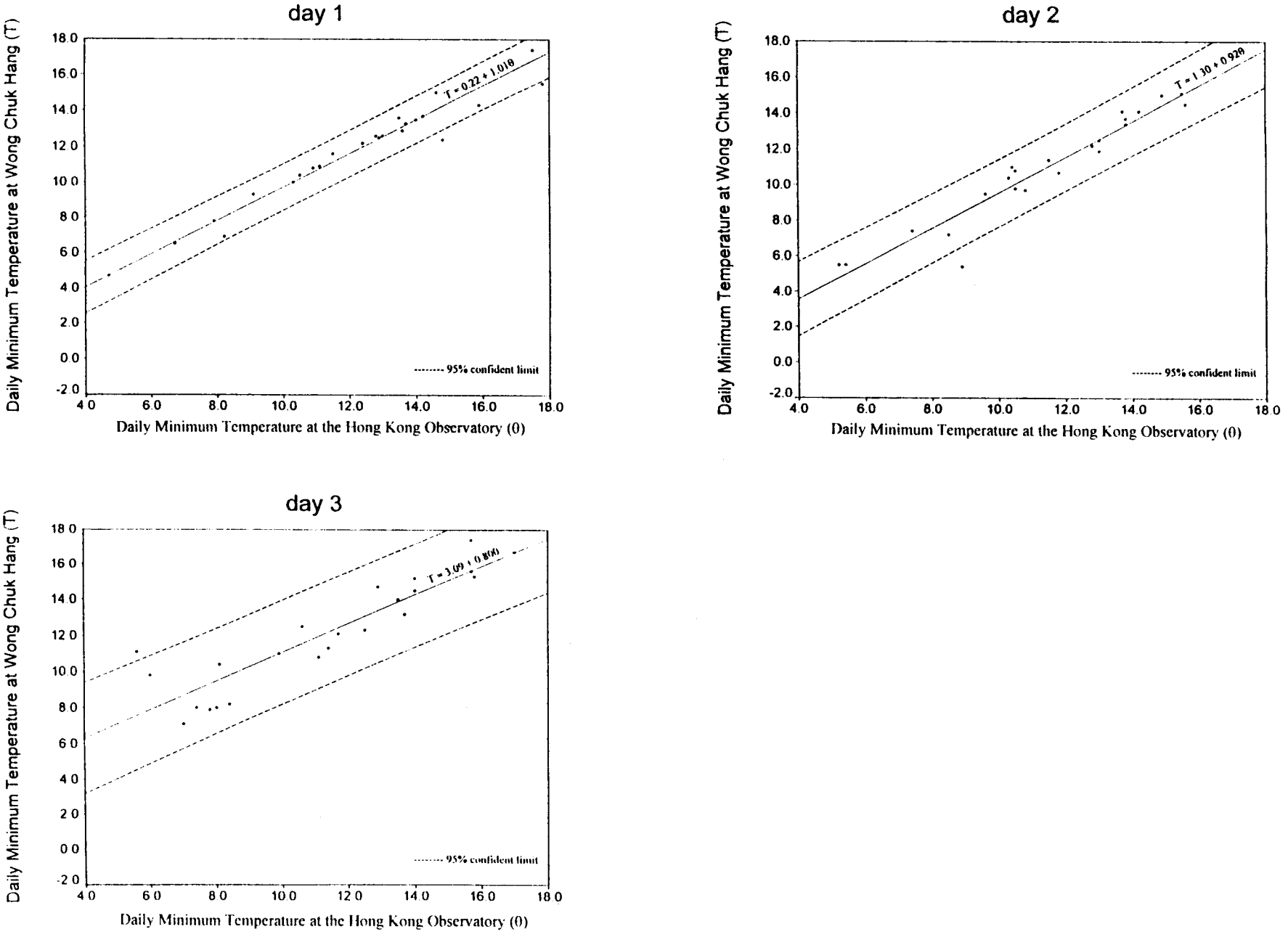
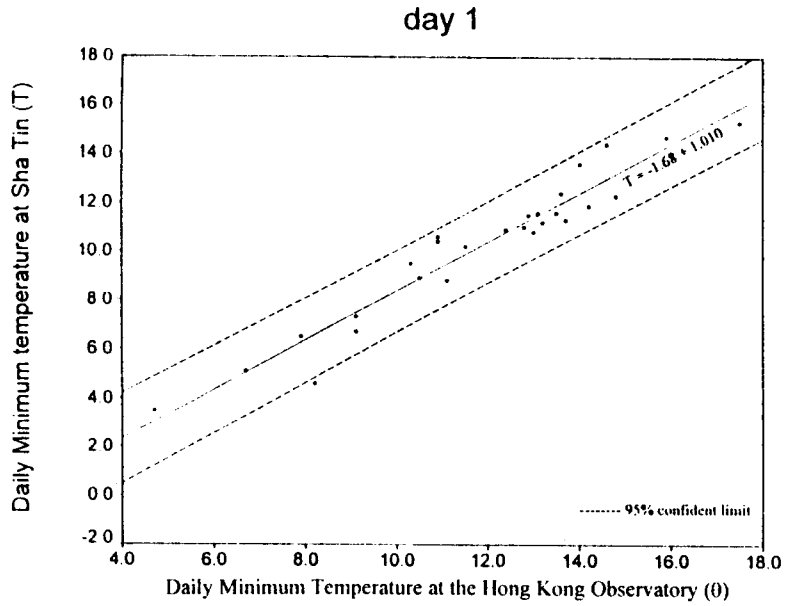
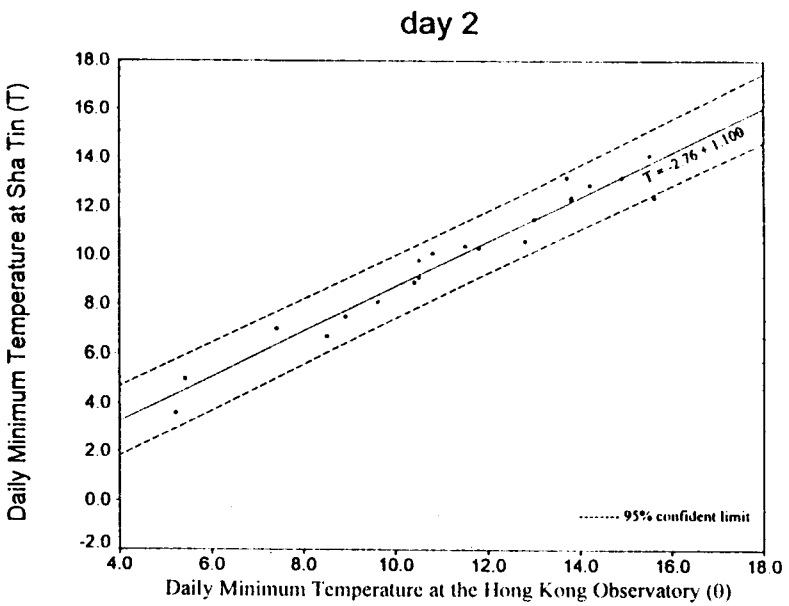


FIGURE 3.5

LINEAR REGRESSION OF DAILY MINIMUM TEMPERATURES RECORDED BY SHA TIN AGAINST THE HONG KONG OBSERVATORY UNDER NORTHERLY SURGES





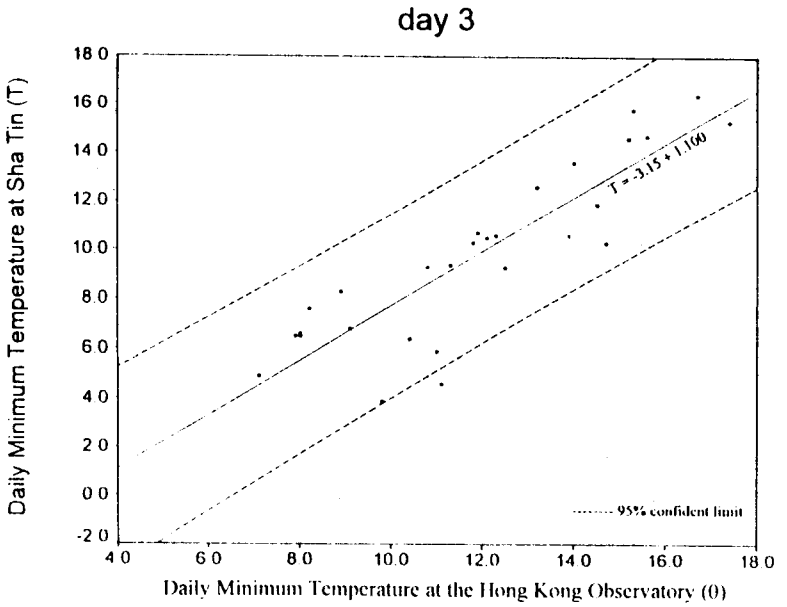


FIGURE 3.6

LINEAR REGRESSION OF DAILY MINIMUM TEMPERATURES RECORDED BY TA KWU LING AGAINST THE HONG KONG OBSERVATORY UNDER NORTHERLY SURGES