## 1. Introduction

According to the World Meteorological Organization (WMO), the climatological normal of a meteorological element is defined as the average computed for a uniform and relatively long period comprising at least three consecutive ten-year periods (WMO, 1983 & 1989). Following the recommendation by WMO, the Hong Kong Observatory compiled the 1961-1990 climatological standard normals in the early 1990s. These "standard normals" have since been used as the reference in all publications and summaries issued by the HKO.

A recent study of climate change in Hong Kong revealed that there were significant trends in some meteorological observations, which may be attributed to global warming and urban development in and around Hong Kong (Leung et al, 2004a). Such changes in local climate, particularly in the last few decades, suggested that a new set of climatological normals based on observations taken from the period of 1971-2000 would serve as a more useful reference for certain applications.

Observations taken from 4 stations, namely, the Hong Kong Observatory Headquarters (HKO), King's Park Meteorological Station (KP), North Point Fire Station (NP) and Waglan Island (WGL) were used to compile the 1971-2000 climatological normals. The instruments and methods of observation used in these stations are briefly described in Section 2. The methods used to compute the 1971-2000 climatological normals are discussed in Section 3. In Section 4, the results of the new 30-year climatological normals are presented and compared with the normals for 1961-1990. A summary of the findings of this study is given in Section 5.

## 2. Instruments and methods of observation

Hourly meteorological observations used in the compilation of the 1971-2000 climatological normals were all made at HKO except for the followings :

(i) global solar radiation;
(ii) total bright sunshine;
(iii) total evaporation and potential evapo-transpiration;
(iv) wind speed and direction; and
(v) sea surface temperature.

Items (i) to (iii) were recorded at KP. Item (iv) was recorded at WGL because of its relatively good exposure and being not affected by urban development. The wind recorded there is therefore more representative of the ambient wind flow over Hong Kong. Sea surface temperature measurements were manually made at the fire boat pier of NP and at WGL twice daily. Since August 1989, sea surface temperature at WGL was recorded automatically. Figure 1 shows the locations of HKO, KP, NP and WGL.

Information on the instruments used at the four locations and the elevation of the instruments above mean sea level as at 31 December 2000 are given in Table 1. Details of measurement practices and instrumental changes from 1971 to 2000 are documented in the following HKO annual publications :

(i) Meteorological Results Part I – Surface Observations (1971-1986);
(ii) Surface Observations in Hong Kong (1987-1992); and
(iii) Summary of Meteorological Observations in Hong Kong (1993-2000).

For easy reference, major instrument/site changes for some of the meteorological measurements at HKO, KP and WGL from 1947 to 2005 are summarized in Appendix I.

## 3. Methods of analysis

### 3.1 Daily, monthly, annual mean and climatological normal

The daily mean value for any particular meteorological element is computed by averaging all hourly readings of that element available in the day. Monthly means are computed from the average of all the hourly data in the month. Annual means are the averages of the 12 monthly means for that year. The 30-year climatological normals are the average of the corresponding monthly and annual mean values within the period between 1971 and 2000. Where an element is only measured at a specific hour of a day, the monthly mean of this element is calculated from the average of all the data recorded at the corresponding time of observation in the month.

### 3.2 Prevailing wind direction

The principles for the computation of 30-year climatological normals mentioned in Section 3.1 apply to all elements except for prevailing wind directions. Since computing a 30-year normal prevailing wind direction using 30 monthly values can produce erratic results, the monthly normal and annual normal of the prevailing wind directions are produced by weighting all hourly wind directions available according to the '1-4-6-4-1' scheme (Yeung et al, 1986).

### 3.3 Other statistics

The definitions of the other statistics included in this publication are as follows :

(a) Fog Days

A fog day is a day with fog (visibility below 1000 metres due to suspension of water droplets in the air) reported anytime during the day.

(b) Thunderstorm Days and Lightning Days

A thunderstorm (lightning) day is a day with thunderstorm (lightning) reported anytime during the day.

(c) Very Hot Days, Cold Days and Hot Nights

A very hot day is a day with a maximum temperature ≥ 33.0°C. A cold day is a day with a minimum temperature ≤ 12.0°C. A hot night refers to a day with a minimum temperature ≥ 28.0°C.

## 4. Results

### 4.1 1971-2000 climatological normals

4.1.1 Tables 2 and 3 summarize respectively the monthly normals of the main meteorological elements and monthly means of selected meteorological parameters in Hong Kong for 1971 – 2000.

4.1.2 Table 4 lists the annual and monthly means of number of very hot days, cold days and hot nights for 1971-2000.

4.1.3 Monthly means of number of days with daily total rainfall ≥ 0.1 mm, 10mm, 30mm, 50mm, 70mm and 100 mm for 1971-2000 are tabulated in Table 5.

4.1.4 The annual and monthly wind rose diagrams of Waglan Island from 1971 to 2000 are shown in Figures 2, 3(a) and 3(b).

4.1.5 The annual mean/total values of selected meteorological elements from 1961 to 2000 as well as the 30-year means and standard deviations are tabulated in Appendix II.

### 4.2 Comparison between climatological normals for 1961-1990 and 1971-2000

4.2.1 Table 6 summarizes the difference between the normals for 1961-1990 and 1971-2000 for selected meteorological elements.

4.2.2 A two tailed t-test was applied to test the statistical significance of the difference between the two normals at 5% significance level (Hann, 1977). Here, the test statistics $T$ for the null hypothesis $H_0$ : *difference* = 0 against the alternative hypothesis $H_1$ : *difference* ≠ 0, is given by :

$$T = (\overline{X_1} - \overline{X_2}) \Big/ \sqrt{\sigma_1^{\,2}/n_1 + \sigma_2^{\,2}/n_2}$$
$$= (\overline{X_1} - \overline{X_2}) \Big/ \sqrt{\sigma_1^{\,2}/30 + \sigma_2^{\,2}/30}$$

where $\overline{X_1}$ is the average of 30 annual data for 1971-2000
$\overline{X_2}$ is the average of 30 annual data for 1961-1990
$\sigma_1$ is the standard deviation of 30 annual data for 1971-2000
$\sigma_2$ is the standard deviation of 30 annual data for 1961-1990
$n_1$ and $n_2$ are the respective number of sample (equal to 30)

The degree of freedom is 58 ($n_1 + n_2 - 2$) and critical values for two-tailed t-test at 5% significance level are ±2.002. The population means are significantly different if $|T| > 2.002$.

4.2.3 Amongst the 18 meteorological elements listed in Table 6, the differences between the two normals for six of the elements are statistically significant at 5% level. They are :

(i) daily minimum temperature;
(ii) annual total bright sunshine duration;
(iii) daily global solar radiation;
(iv) annual total evaporation;
(v) annual number of cold days; and
(vi) annual number of hot nights.

4.2.4 The mean daily minimum temperature in 1971-2000 was 0.2 degrees higher than that in 1961-1990. An analysis of the variation of the difference in the monthly normals of mean daily minimum temperature between the two 30-year periods (Figure 4) revealed that the difference in mean daily minimum temperature was more prominent from October to April. The mean annual number of cold days in 1971-2000 was lower than that in 1961-1990 (18.6 days compared to 23.3 days). The mean annual number of hot nights in 1971-2000 was higher than that in 1961-1990 (13.1 days compared to 8.7 days). Figures 5, 6 and 7 illustrate respectively the increasing trend of the annual mean of daily minimum temperature (about 0.3 degrees per decade), the decreasing trend of the annual number of cold days (about 3.7 days per decade) and the increasing trend of the annual number of hot nights (about 4.7 days per decade) from 1961 to 2005. Recent studies on climate change in Hong Kong suggest that, besides global warming, rapid urban development around HKO in the last few decades also contributed significantly to these changes (Leung et al, 2004a).

4.2.5 The mean annual total bright sunshine duration in 1971-2000 was 5.4% lower than that in 1961-1990 (1842.9 hours compared to 1948.1 hours).

Moreover, the mean daily global solar radiation in 1971-2000 was 8.5% lower than that in 1961-1990 (13.2 MJ/$m^2$ compared to 14.5 MJ/$m^2$). The differences in the normals of the annual total bright sunshine duration and daily global solar radiation between these two periods are likely to be attributable to the increase in the concentration of the suspended particulates associated with urban development. Such increase in suspended particulates favours the formation of clouds (by increasing the concentration of condensation nuclei) and increases scattering and absorption of incoming solar radiation (Leung et al, 2004a; Leung et al, 2004b). In parallel with the decrease in the mean daily global solar radiation, the mean annual total evaporation in 1971-2000 was also 12.1% lower than that in 1961-1990 (1343.4 mm compared to 1528.8 mm). The decreasing trend of the annual total bright sunshine duration (about 68.7 hours per decade), annual mean of daily global solar radiation (about 1.0 MJ/$m^2$ per decade) and annual total evaporation (about 159.7 mm per decade) from 1961 to 2005 are illustrated in Figures 8, 9 and 10 respectively.

## 5 Conclusions

The 1971-2000 climatological normals of meteorological elements were computed and presented in this report. When compared with the 1961-1990 climatological normals, there were less sunshine (a decrease of 5.4% in sunshine duration and 8.5% in solar radiation) and significantly more hot nights (by more than 50%) during 1971-2000. All these changes are inline with global warming and the increasing extent of urban development in Hong Kong.

## 6. References

Chen, T.Y. (1976), Evaporation and evapotranspiration in Hong Kong, Hong Kong Observatory Technical Note No. 42.

Lau. S.Y. (1989), Global solar radiation in Hong Kong, Hong Kong Observatory Technical Note No. 81.

Leung, Y.K., Yeung, K.H., Ginn, E.W.L. and Leung, W.M. (2004a), Climate Change in Hong Kong, Hong Kong Observatory Technical Note No. 107..

Leung, Y.K., Lee, T.C., Leung, W.M. and Ginn, E.W.L. (2004b), Long-term Trend Analyses of Regional Rainfall in Hong Kong, The 18th Guangdong-Hong Kong-Macau Seminar on Meteorological Science and Technology, 16-18 February 2004, Hong Kong (in Chinese only).

Li, T.S. (1964), Sea surface temperatures for Hong Kong, Hong Kong Observatory Technical Note (Local) No. 5.

Hann, C.T. (1977), Statistical methods in hydrology, The Iowa State University Press. pp: 172 – 173.

Yeung, K.H., Ng, K.K. and Yau, L.K. (1986), A Solar-Powered Automatic Weather Station, Hong Kong Observatory Technical Note No. 75.

WMO (1983), Guide to Climatological Practices

WMO (1989), Calculation of Monthly and Annual 30-year Standard Normals

Table 1 Instrument and elevation at the Hong Kong Observatory Headquarters (HKOHq), King's Park Meteorological Station (KP), North Point Fire Station (NP) and Waglan Island (WGL) as at 31 December 2000

| Location | Meteorological Element | Instrument | Elevation above mean sea level (metres) |
|---|---|---|---|
| HKO | Pressure | Kew-pattern barometer (F. Darton Co. Ltd) | 62 |
| | Dry and Wet bulb Temperatures | Platinum resistance thermometer (inside an open shed, back up by conventional mercury-in-glass maximum/minimum thermometers | 33 |
| | Rainfall | Ordinary 203-mm raingauge | 32 |
| | Grass and Soil Temperatures (soil temperature 50, 100 and 150 cm below soil depth) | Platinum resistance thermometer (back up by conventional mercury-in-glass thermometers) | 32 |
| KP | Sunshine Duration | Campbell-Stokes recorder | 71 |
| | Global Solar Radiation (Lau, 1989) | Thermo-electric pyranometer (Kipp & Zonen Holland) | 71 |
| | Evaporation (Chen, 1976) | Evaporation Pans (US Weather Bureau Class "A") | 65 |
| | Potential Evapotranspiration (Chen, 1976) | Lysimeters | 65 |
| WGL | Winds | R.W. Munro Mk. 4 cup-generator anemometer | 82 |
| | Sea Surface Temperature (Li, 1964) | Rosemont T-200 platinum thermometer | -1 |
| NP | Sea Surface Temperature | Conventional mercury-in-glass thermometer | --- |

# Table 2 Monthly normals of meteorological elements for Hong Kong, 1971-2000

| Month | ATMOSPHERIC PRESSURE | | AIR TEMPERATURE | | | WET-BULB TEMPERATURE | DEW POINT | VAPOUR PRESSURE | RELATIVE HUMIDITY | | | AMOUNT OF CLOUD | RAINFALL | | | | | BRIGHT SUNSHINE | | WIND | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Numbers of Days with | | | | | | |
| | Mean | Mean Diurnal Range | Mean Daily Maximum | Mean | Mean Daily Minimum | | | | Mean | Mean at 0200 hours | Mean at 1400 hours | | Total | Duration | 0.1 mm or more | 25.0 mm or more | 50.0 mm or more | Duration | Percentage of Possible | Prevailing Direction | Mean Speed |
| | hPa | hPa | °C | °C | °C | °C | °C | hPa | % | % | % | % | mm | hours | | | | hours | % | degree | km/h |
| JAN | 1020.1 | 4.1 | 18.6 | 16.1 | 14.1 | 13.5 | 11.0 | 13.7 | 73 | 78 | 65 | 60 | 24.9 | 43 | 5.60 | 0.20 | 0.00 | 141.7 | 42 | 070 | 25.4 |
| FEB | 1018.6 | 4.2 | 18.6 | 16.3 | 14.4 | 14.1 | 12.2 | 14.8 | 78 | 82 | 71 | 73 | 52.3 | 76 | 9.47 | 0.53 | 0.07 | 93.8 | 29 | 070 | 25.1 |
| MAR | 1016.1 | 4.2 | 21.5 | 18.9 | 16.9 | 17.0 | 15.5 | 18.2 | 82 | 86 | 75 | 79 | 71.4 | 91 | 10.47 | 0.67 | 0.30 | 89.6 | 24 | 070 | 23.5 |
| APR | 1012.8 | 3.9 | 25.1 | 22.5 | 20.6 | 20.5 | 19.4 | 22.9 | 83 | 88 | 76 | 80 | 188.5 | 87 | 11.67 | 2.57 | 1.23 | 101.8 | 27 | 070 | 21.2 |
| MAY | 1009.4 | 3.4 | 28.4 | 25.8 | 23.9 | 23.7 | 22.7 | 27.8 | 84 | 88 | 77 | 77 | 329.5 | 101 | 15.47 | 3.77 | 2.00 | 138.6 | 34 | 080 | 20.2 |
| JUN | 1006.2 | 3.2 | 30.4 | 27.9 | 26.1 | 25.6 | 24.6 | 30.9 | 82 | 86 | 76 | 76 | 388.1 | 95 | 18.77 | 4.17 | 2.13 | 158.3 | 39 | 230 | 23.3 |
| JUL | 1005.5 | 3.4 | 31.3 | 28.7 | 26.7 | 26.1 | 25.0 | 31.7 | 81 | 85 | 74 | 68 | 374.4 | 80 | 17.77 | 4.67 | 2.40 | 214.9 | 52 | 230 | 21.9 |
| AUG | 1005.1 | 3.5 | 31.1 | 28.4 | 26.4 | 25.9 | 24.9 | 31.5 | 82 | 86 | 75 | 69 | 444.6 | 87 | 17.43 | 5.40 | 2.40 | 189.7 | 48 | 240 | 20.0 |
| SEP | 1009.2 | 3.5 | 30.2 | 27.6 | 25.6 | 24.7 | 23.4 | 28.9 | 79 | 83 | 72 | 65 | 287.5 | 68 | 14.80 | 3.47 | 1.60 | 171.8 | 47 | 090 | 22.8 |
| OCT | 1014.0 | 3.6 | 27.7 | 25.3 | 23.4 | 21.9 | 19.9 | 23.8 | 74 | 78 | 66 | 57 | 151.9 | 50 | 8.10 | 1.57 | 1.00 | 191.1 | 53 | 080 | 28.7 |
| NOV | 1018.0 | 3.8 | 24.0 | 21.4 | 19.4 | 17.9 | 15.3 | 18.1 | 70 | 75 | 61 | 53 | 35.1 | 36 | 5.67 | 0.37 | 0.10 | 178.2 | 54 | 080 | 27.9 |
| DEC | 1020.5 | 4.0 | 20.3 | 17.8 | 15.7 | 14.5 | 11.6 | 14.4 | 69 | 74 | 60 | 51 | 34.5 | 36 | 4.27 | 0.30 | 0.13 | 173.3 | 52 | 070 | 26.5 |
| YEAR | 1013.0 | 3.7 | 25.6 | 23.1 | 21.1 | 20.5 | 18.8 | 23.1 | 78 | 82 | 71 | 67 | 2382.7 | 850 | 139.49 | 27.69 | 13.36 | 1842.9 | 41 | 070 | 23.9 |
| Observed at | Hong Kong Observatory | | | | | | | | | | | | | | | | | King's Park | | Waglan Island | |

# Table 3 Monthly means of selected meteorological parameters for Hong Kong, 1971-2000

| Month | THUNDERSTORM ACTIVITY | | NUMBER OF DAYS WITH FOG (Visibility < 1000 m) | SOIL TEMPERATURE | | | | | | MEAN DAILY GLOBAL SOLAR RADIATION | TOTAL EVAPORATION | TOTAL POTENTIAL EVAPOTRANSPIRATION | SEA SURFACE TEMPERATURE | | | | NUMBER OF DAYS WITH TROPICAL CYCLONE WARNING SIGNAL | | | | NUMBER OF DAYS WITH STRONG MONSOON SIGNAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.5 M | | 1.0 M | | 1.5 M | | | | | TIME OF OBSERVATION (HKT) | | | | | | | | |
| | | | | TIME OF OBSERVATION (HKT) | | | | | | | | | 0700 | 1400 | 0700 or 1100 | 1400 or 1700 | No. 1 and Higher | No. 3 and Higher | No. 8 and Higher | No. 9 and No. 10 | |
| | Number of Days with Lightning | Number of Days with Thunderstorm | | 0700 | 1900 | 0700 | 1900 | 0700 | 1900 | | | | | | | | | | | | |
| | | | | °C | °C | °C | °C | °C | °C | MJ/m$^2$ | mm | mm | °C | °C | °C | °C | | | | | |
| JAN | 0.13 | 0.10 | 0.23 | 18.8 | 18.8 | 20.3 | 20.4 | 21.6 | 21.6 | 10.55 | 80.7 | 57.9 | 17.5 | 17.7 | 17.5 | 17.7 | - | - | - | - | 4.33 |
| FEB | 1.00 | 0.97 | 1.23 | 18.9 | 18.9 | 19.8 | 19.9 | 20.8 | 20.8 | 9.61 | 67.6 | 53.0 | 16.7 | 17.0 | 16.6 | 16.7 | - | - | - | - | 4.33 |
| MAR | 1.77 | 1.63 | 2.30 | 20.6 | 20.7 | 20.8 | 20.8 | 21.1 | 21.1 | 10.18 | 78.1 | 63.5 | 17.9 | 18.2 | 17.6 | 17.8 | - | - | - | - | 3.83 |
| APR | 4.77 | 4.20 | 1.13 | 23.4 | 23.5 | 22.8 | 22.8 | 22.5 | 22.5 | 11.83 | 93.2 | 80.0 | 20.9 | 21.3 | 20.7 | 20.9 | 0.17 | 0.03 | - | - | 3.00 |
| MAY | 6.67 | 5.27 | 0.17 | 26.5 | 26.6 | 25.5 | 25.6 | 24.8 | 24.8 | 14.35 | 118.4 | 98.3 | 24.5 | 25.0 | 24.5 | 24.7 | 0.43 | 0.27 | 0.07 | - | 1.60 |
| JUN | 7.70 | 5.60 | - | 28.5 | 28.5 | 27.5 | 27.5 | 26.7 | 26.8 | 15.31 | 129.0 | 112.7 | 26.5 | 26.9 | 26.6 | 26.9 | 2.23 | 1.23 | 0.20 | 0.03 | 1.17 |
| JUL | 8.47 | 5.90 | - | 29.8 | 29.9 | 29.0 | 29.0 | 28.2 | 28.2 | 17.52 | 155.5 | 131.6 | 26.6 | 27.1 | 27.2 | 27.5 | 4.43 | 2.57 | 0.57 | 0.07 | 0.50 |
| AUG | 11.00 | 8.10 | - | 30.0 | 30.0 | 29.4 | 29.4 | 29.0 | 29.0 | 16.07 | 143.2 | 120.9 | 26.5 | 27.0 | 27.1 | 27.4 | 3.93 | 1.67 | 0.60 | 0.13 | 0.17 |
| SEP | 6.93 | 4.30 | - | 29.6 | 29.6 | 29.3 | 29.4 | 29.1 | 29.1 | 15.14 | 134.2 | 99.0 | 27.1 | 27.5 | 27.5 | 27.7 | 4.53 | 2.23 | 0.40 | 0.07 | 1.77 |
| OCT | 1.13 | 0.80 | - | 27.7 | 27.7 | 28.1 | 28.1 | 28.2 | 28.2 | 14.46 | 136.4 | 92.8 | 26.3 | 26.6 | 26.4 | 26.6 | 3.17 | 2.03 | 0.20 | 0.07 | 5.30 |
| NOV | 0.23 | 0.23 | - | 24.4 | 24.3 | 25.6 | 25.5 | 26.3 | 26.3 | 12.64 | 112.5 | 74.0 | 23.4 | 23.6 | 23.3 | 23.5 | 0.50 | 0.17 | 0.07 | - | 4.83 |
| DEC | - | - | 0.03 | 20.5 | 20.5 | 22.4 | 22.4 | 23.6 | 23.6 | 11.13 | 94.5 | 60.8 | 19.8 | 20.0 | 19.7 | 19.9 | 0.07 | 0.07 | - | - | 5.23 |
| YEAR | 49.80 | 37.10 | 5.09 | 24.9 | 25.0 | 24.9 | 25.0 | 25.0 | 25.1 | 13.23 | 1343.4 | 1044.5 | 22.8 | 23.2 | 22.9 | 23.1 | 19.46 | 10.27 | 2.11 | 0.37 | 36.06 |
| Period of record | 1971 - 2000 | | | 1971 - 2000 | | | | | | 1971 - 2000 | | | 1975 – 2004* | | 1971 - 2000 | | | | | | |
| Observed at | Hong Kong Observatory | | | | | | | | | King's Park | | | North Point | | Waglan Island | | | | | | |

* The 30-year mean between 1975 and 2004 is used as sea surface temperature measurement at North Point commenced since 18 June 1974.

Table 4 Mean number of very hot days, cold days and hot nights, 1971-2000 (based on Hong Kong Observatory Headquarters data)

| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Annual Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Very Hot Days | **-** | **-** | **-** | **-** | **0.37** | **1.40** | **4.00** | **2.83** | **1.23** | **-** | **-** | **-** | **9.83** |
| Cold Days | **6.97** | **5.53** | **1.77** | **0.13** | **-** | **-** | **-** | **-** | **-** | **-** | **0.40** | **3.83** | **18.63** |
| Hot Nights | **-** | **-** | **-** | **-** | **0.37** | **3.50** | **5.43** | **3.23** | **0.57** | **-** | **-** | **-** | **13.10** |

Table 5 Mean number of days with daily total rainfall ≥ 0.1 mm, 10 mm, 30 mm, 50 mm, 70 mm and 100 mm, 1971-2000 (based on Hong Kong Observatory Headquarters data)

| Number of days | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Daily rainfall ≥ 0.1 mm | **5.60** | **9.47** | **10.47** | **11.67** | **15.47** | **18.77** | **17.77** | **17.43** | **14.80** | **8.10** | **5.67** | **4.27** | **139.49** |
| Daily rainfall ≥ 10 mm | **0.70** | **1.57** | **1.80** | **4.17** | **6.60** | **7.63** | **8.40** | **9.03** | **6.20** | **2.60** | **0.93** | **0.73** | **50.37** |
| Daily rainfall ≥ 30 mm | **0.20** | **0.30** | **0.57** | **2.17** | **3.30** | **3.53** | **3.93** | **4.47** | **2.80** | **1.37** | **0.27** | **0.20** | **23.10** |
| Daily rainfall ≥ 50 mm | **-** | **0.07** | **0.30** | **1.23** | **2.00** | **2.13** | **2.40** | **2.40** | **1.60** | **1.00** | **0.10** | **0.13** | **13.36** |
| Daily rainfall ≥ 70 mm | - | - | **0.17** | **0.47** | **1.20** | **1.43** | **1.30** | **1.40** | **1.03** | **0.73** | **0.03** | **0.07** | **7.83** |
| Daily rainfall ≥ 100 mm | - | - | **0.07** | **0.20** | **0.50** | **0.77** | **0.60** | **0.73** | **0.37** | **0.43** | **-** | **0.03** | **3.70** |

Table 6 Comparison between the normals of selected meteorological elements for 1961-1990 and 1971-2000

| | **1961-1990 Normal** | **1971-2000 Normal** | **Difference Normal(71-00)- Normal(61-90)** | | **Statistical Significance at 5 % level** |
|---|---|---|---|---|---|
| | | | Difference | Percentage | |
| Pressure (hPa) | 1012.9 | 1013.0 | 0.1 | +0.01 % | No |
| Air temperature (Deg C) | 23.0 | 23.1 | 0.1 | +0.4% | No |
| Daily maximum temperature (Deg C) | 25.7 | 25.6 | -0.1 | -0.4% | No |
| Daily minimum temperature (Deg C) | 20.9 | 21.1 | 0.2 | +1.0% | Yes |
| Daily relative humidity (%) | 77 | 78 | 1 | +1.3% | No |
| Daily cloud amount (%) | 65 | 67 | 2 | +3.1% | No |
| Annual total rainfall (mm) | 2214.3 | 2382.7 | 168.4 | +7.6% | No |
| Annual total bright sunshine duration (hour) | 1948.1 | 1842.9 | -105.2 | -5.4% | Yes |
| Daily global solar radiation ($MJ/m^2$) | 14.46 | 13.23 | -1.23 | -8.5% | Yes |
| Annual total evaporation (mm) | 1528.8 | 1343.4 | -185.4 | -12.1% | Yes |
| Annual number of thunderstorm days | 33.47 | 37.10 | 3.63 | +10.9% | No |
| Annual number of lightning days | 46.03 | 49.80 | 3.77 | +8.2% | No |
| Annual number of fog days | 5.90 | 5.09 | -0.81 | -13.7% | No |
| Annual number of very hot days | 13.37 | 9.83 | -3.54 | -26.5% | No |
| Annual number of cold days | 23.33 | 18.63 | -4.7 | -20.2% | Yes |
| Annual number of hot nights | 8.73 | 13.10 | 4.37 | +50.1% | Yes |
| Annual number of days with daily rainfall ≥ 0.1 mm | 137.40 | 139.49 | 2.09 | +1.5% | No |
| Annual number of days with daily rainfall ≥ 30 mm | 21.23 | 23.10 | 1.87 | +8.8% | No |

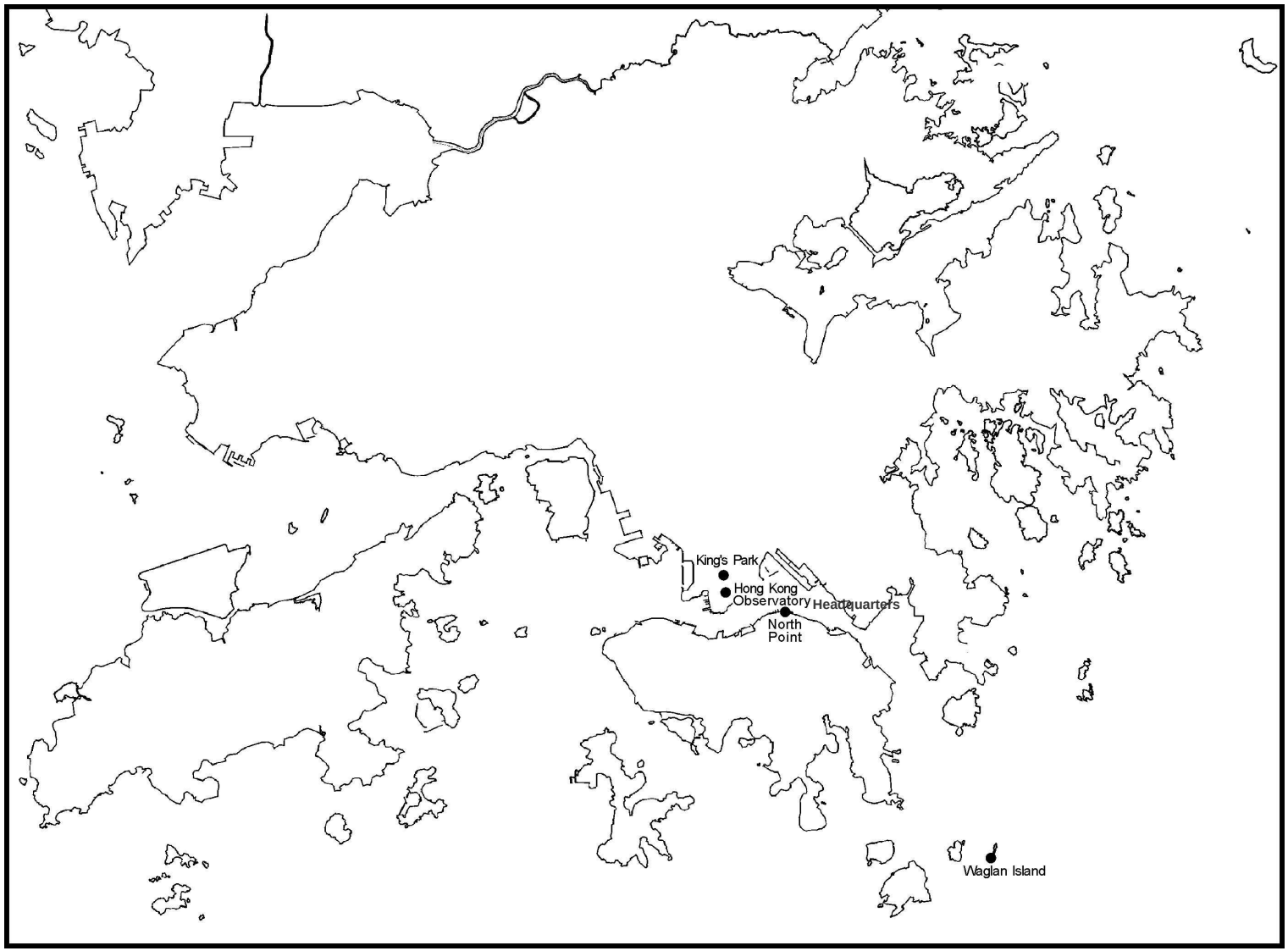
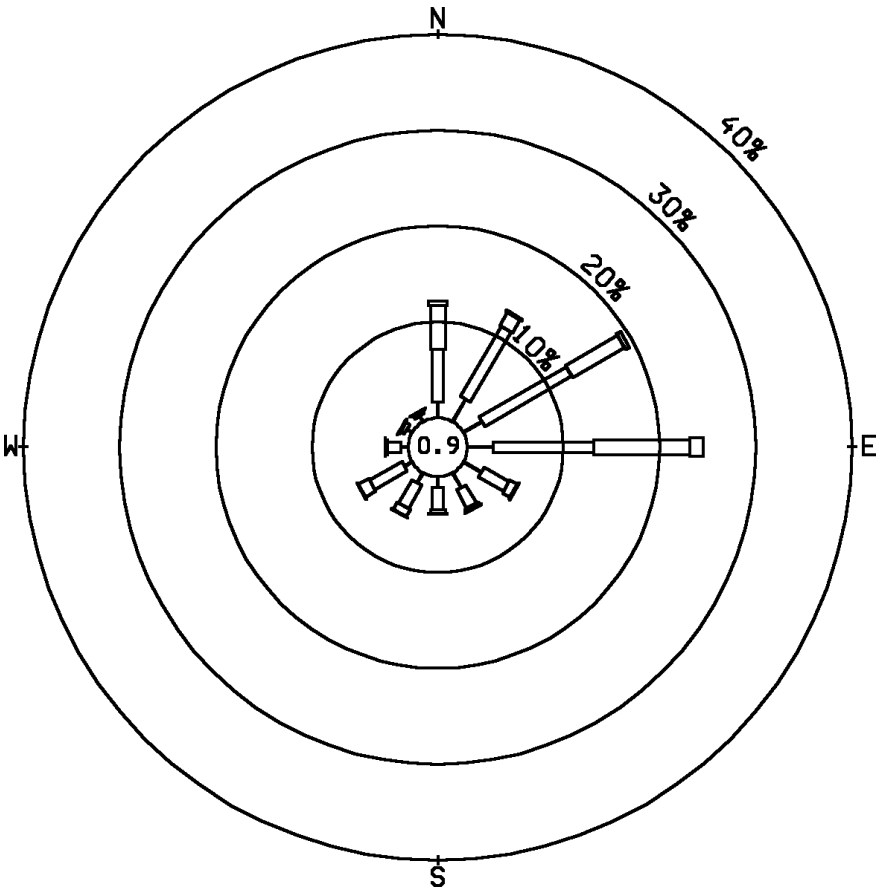



Figure 1 Locations of the Hong Kong Observatory Headquarters, King's Park, North Point and Waglan Island




**Legend :**

| 0.1 - 3.2 | 3.3 - 8.2 | 8.3 - 14.2 | > 14.2 | m/s |
|---|---|---|---|---|
| 1 - 2 | 3 - 4 | 5 - 6 | > 6 | Beaufort force |

**Wind Speed**

0 10 20 30 40 50

**The number in the inner circle is the percentage frequency of occurrence of calm and variable winds.**

**Percentage Frequency**

Figure 2 Annual wind rose for Waglan Island from 1971 to 2000

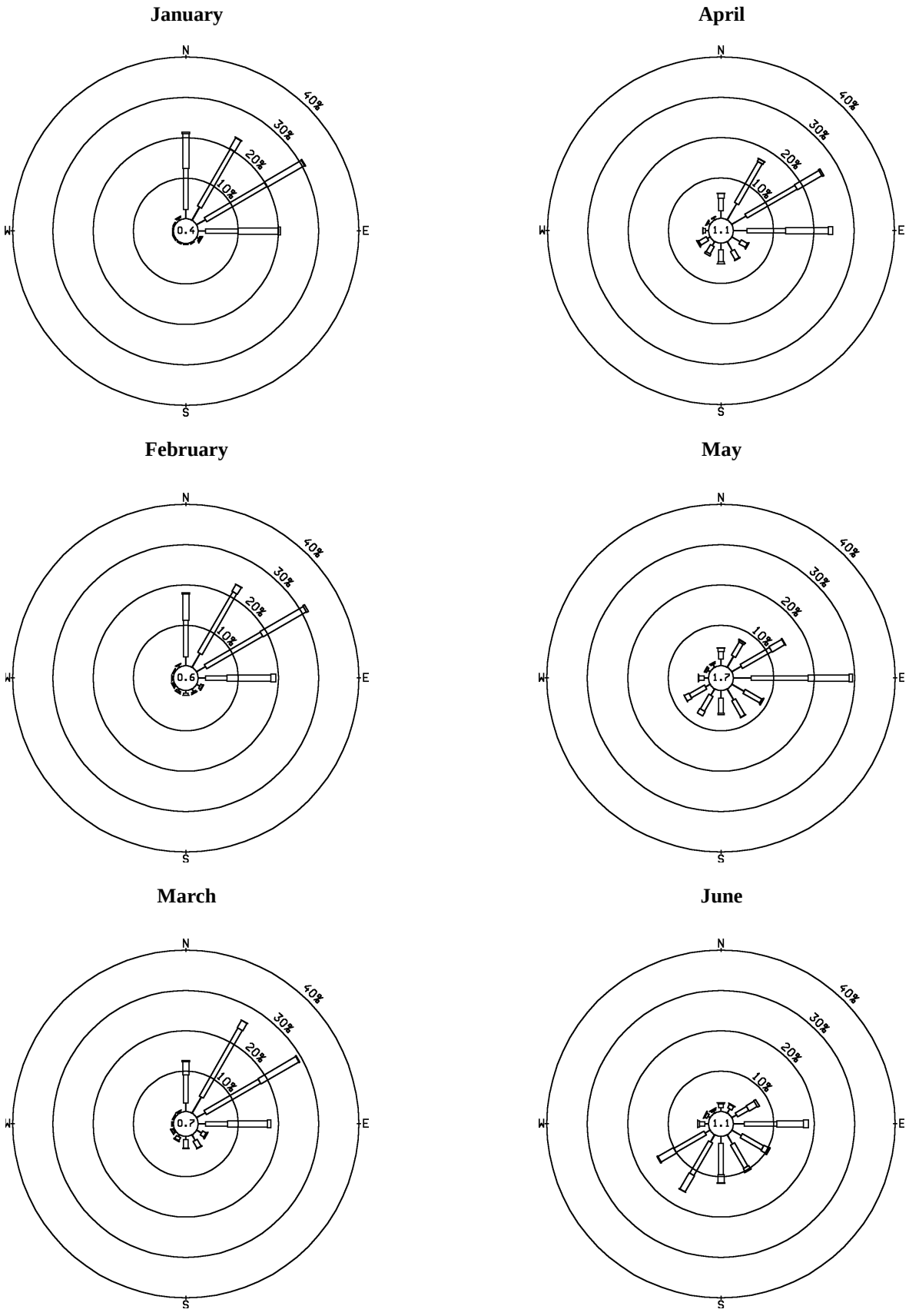



Figure 3(a) Monthly wind roses for Waglan Island from 1971 to 2000 (January to June)

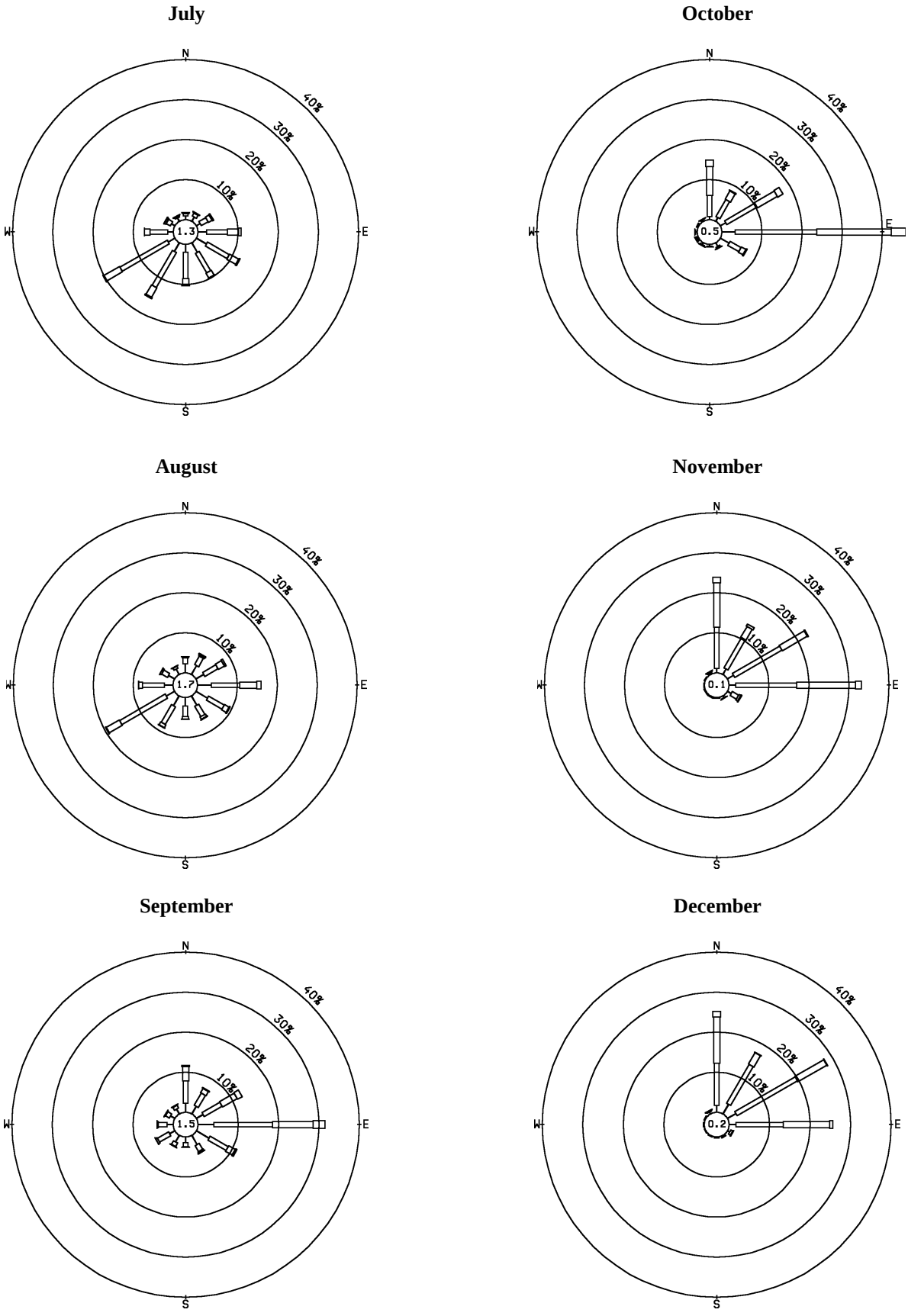



Figure 3(b) Monthly wind roses for Waglan Island from 1971 to 2000 (July to December)

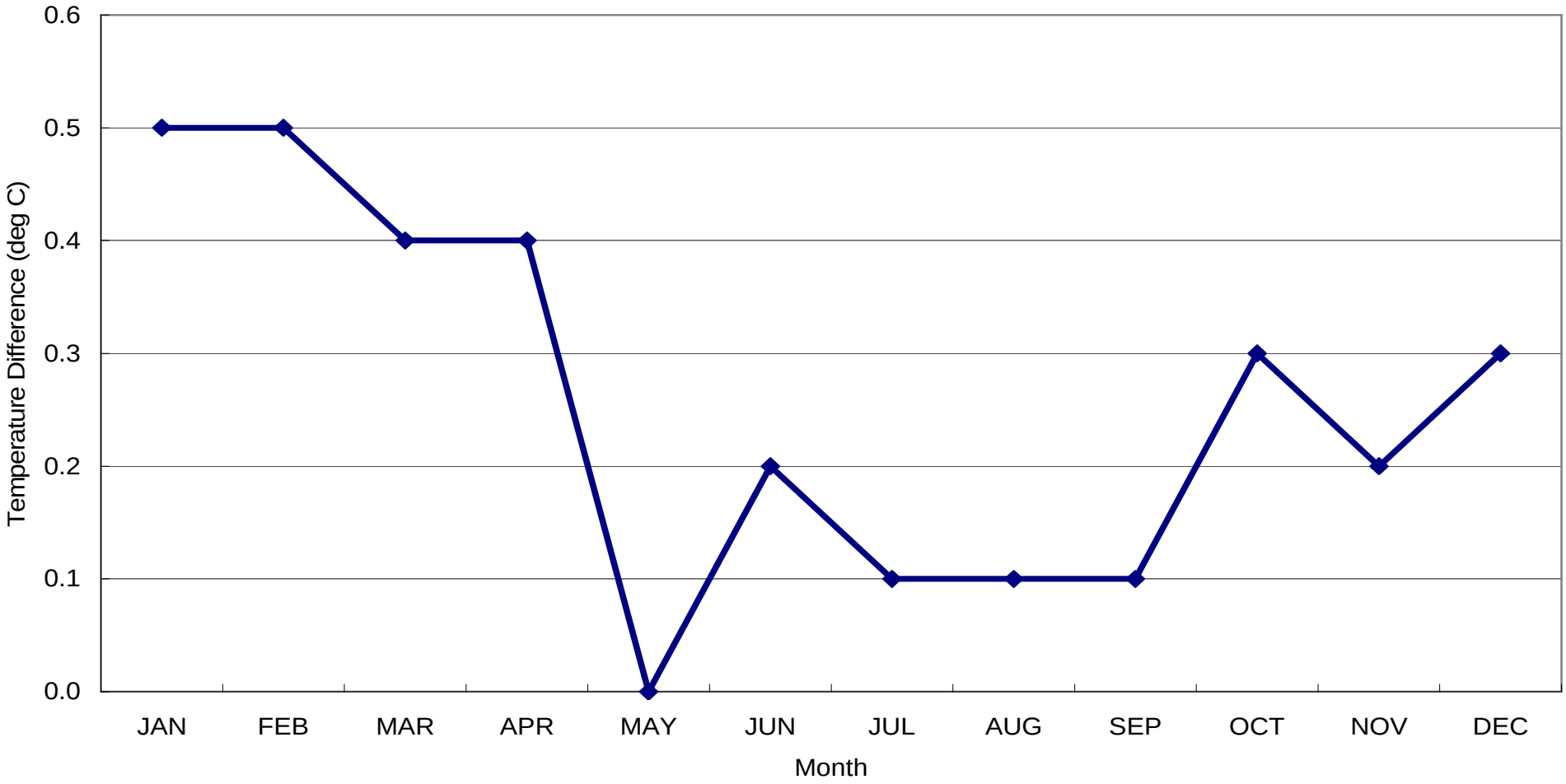



Figure 4 Deviation of the 1971-2000 monthly normals of mean daily minimum temperature from those of 1961-1990

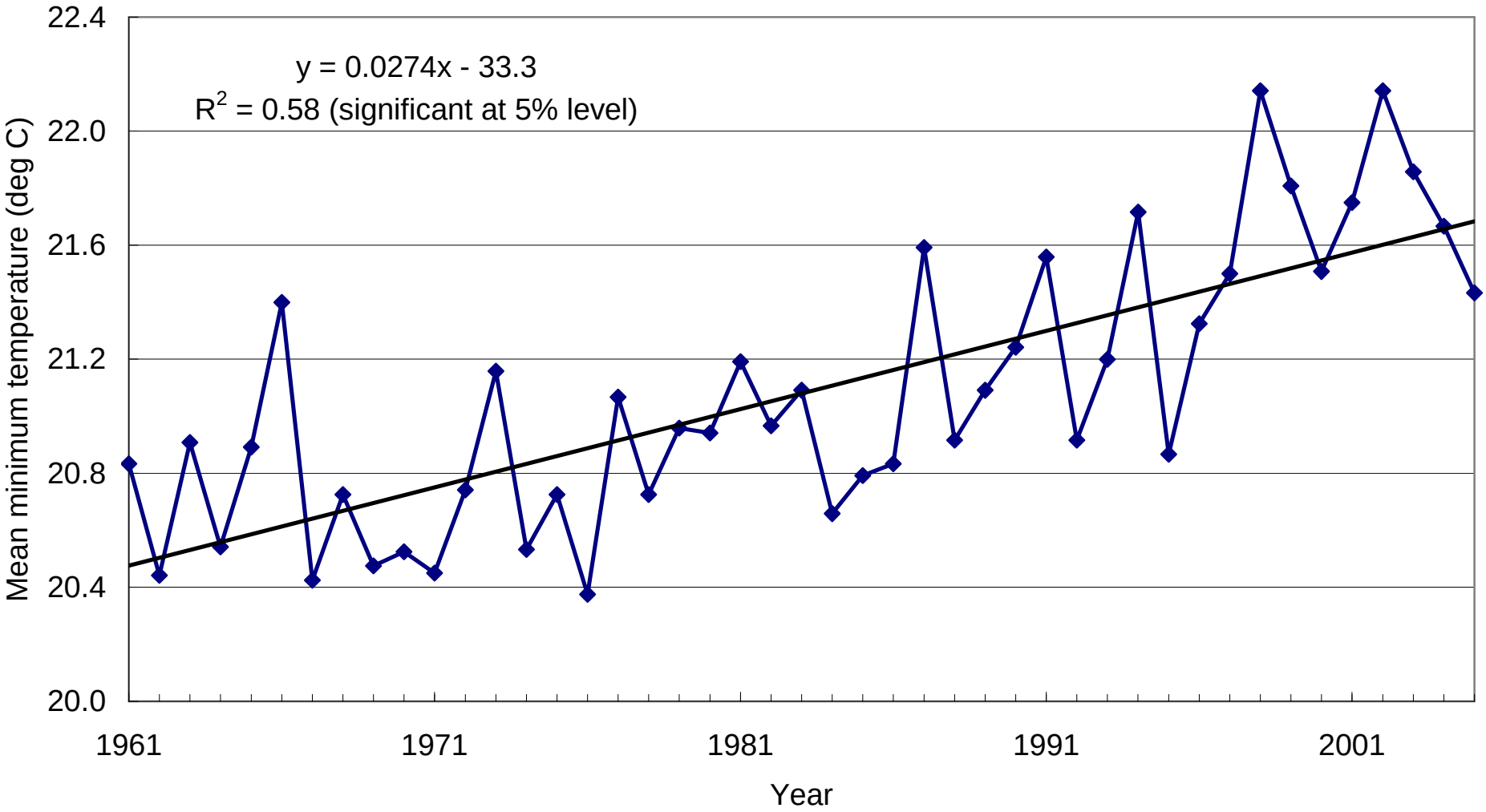



Figure 5 Long-term trend in the annual mean of the daily minimum temperature, 1961-2005

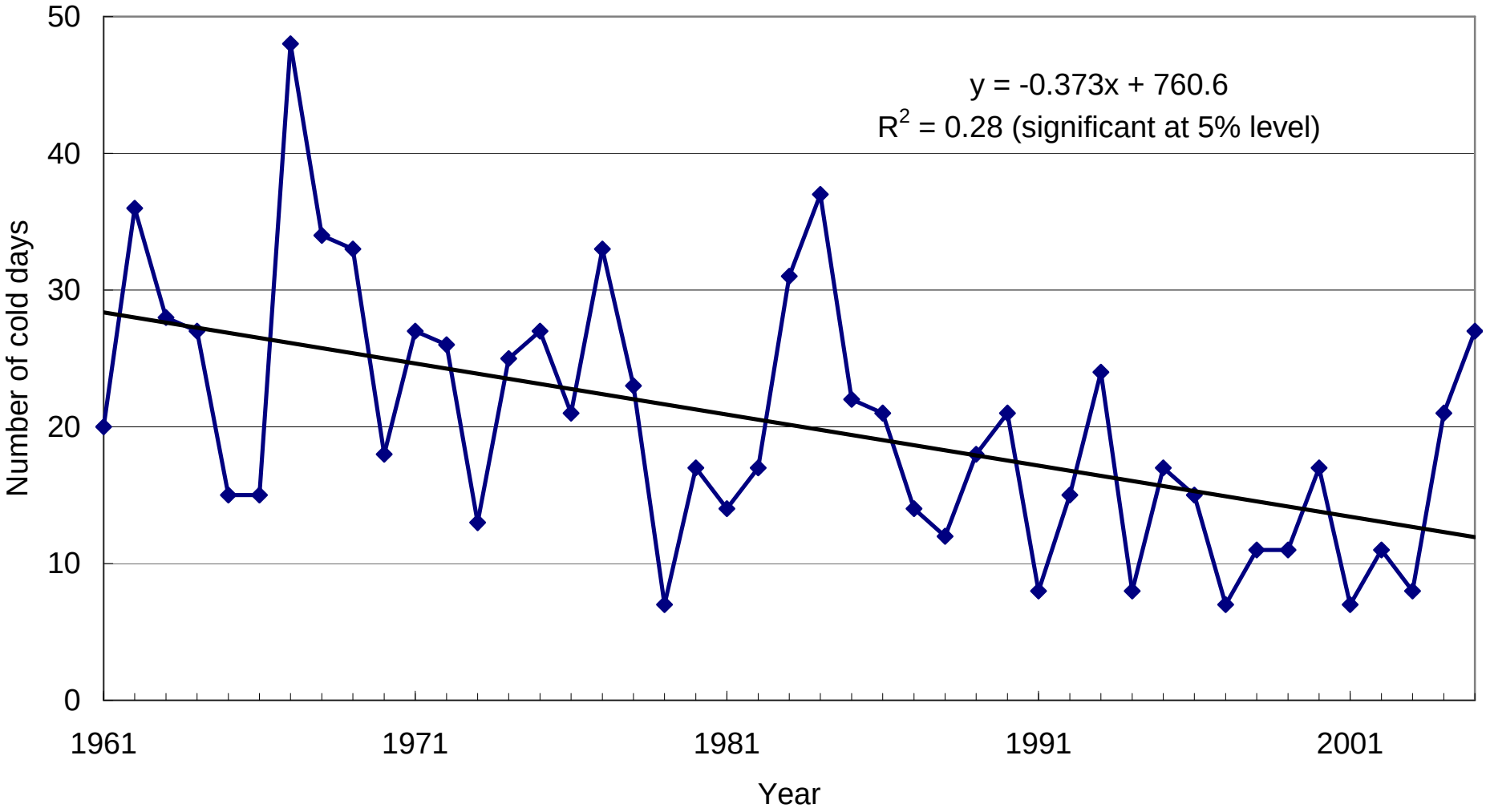



Figure 6 Long-term trend in the annual number of cold days, 1961-2005

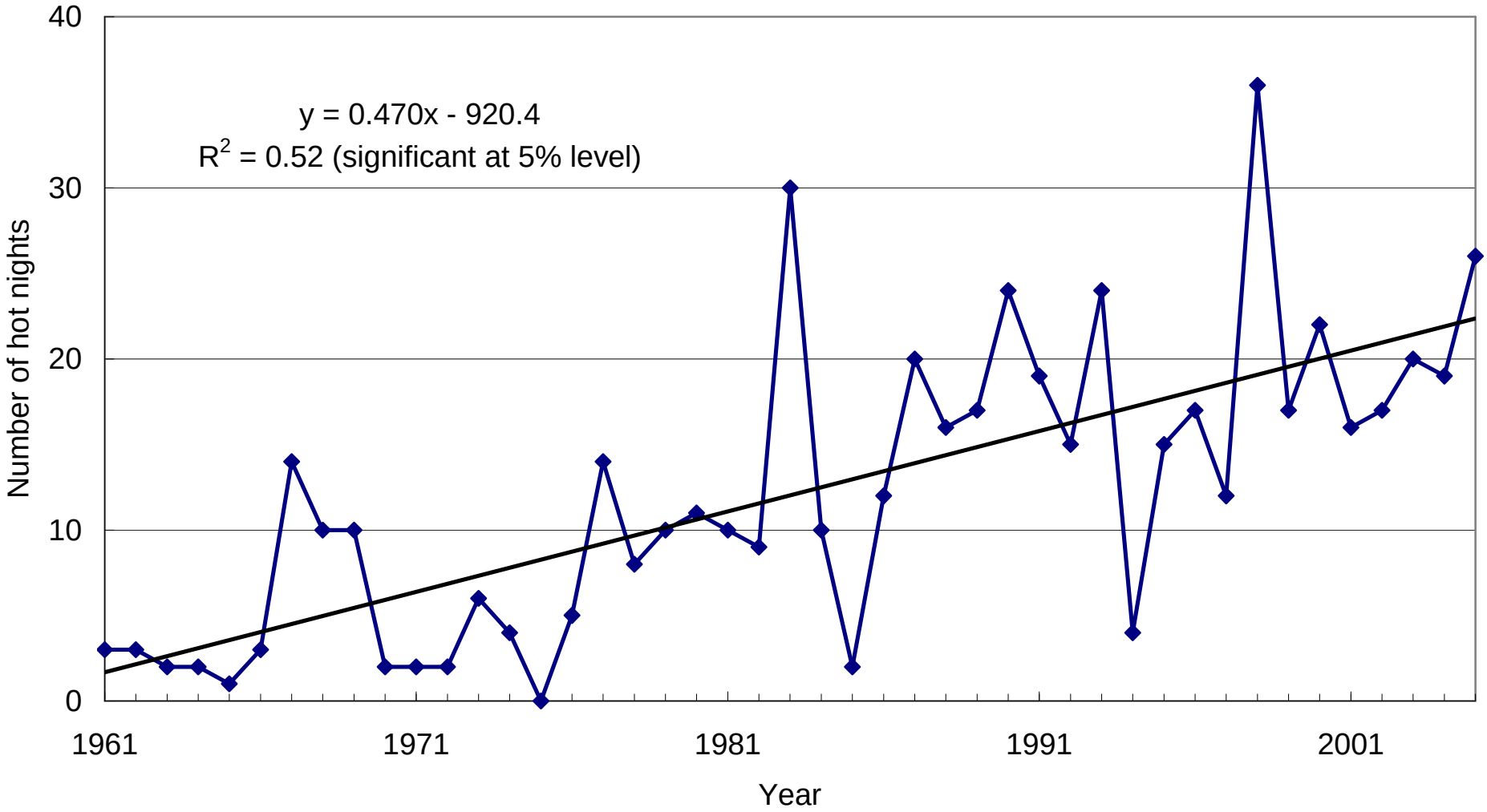



Figure 7 Long-term trend in the annual number of hot nights, 1961-2005

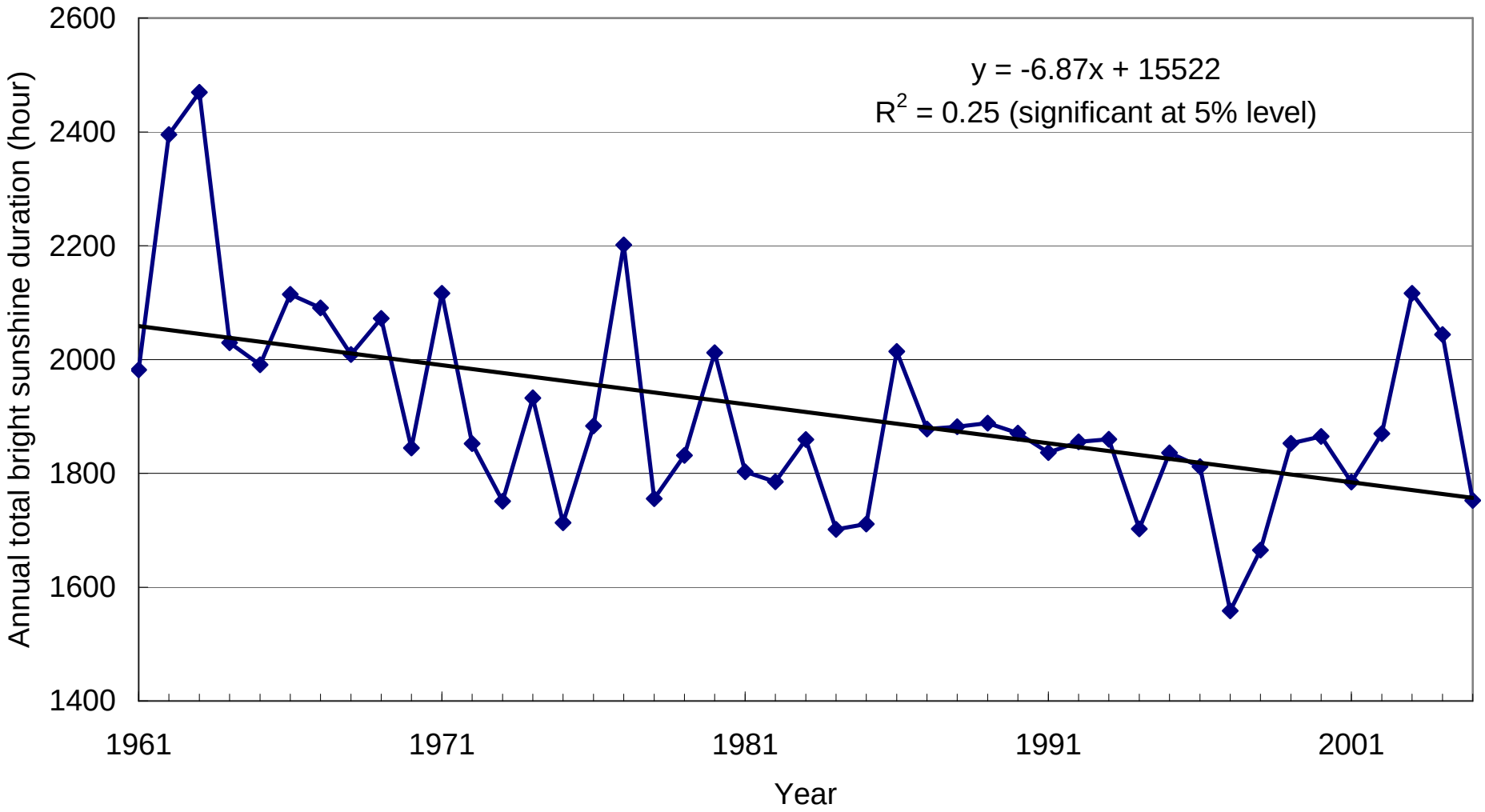



Figure 8 Long-term trend in the annual total bright sunshine duration, 1961-2005

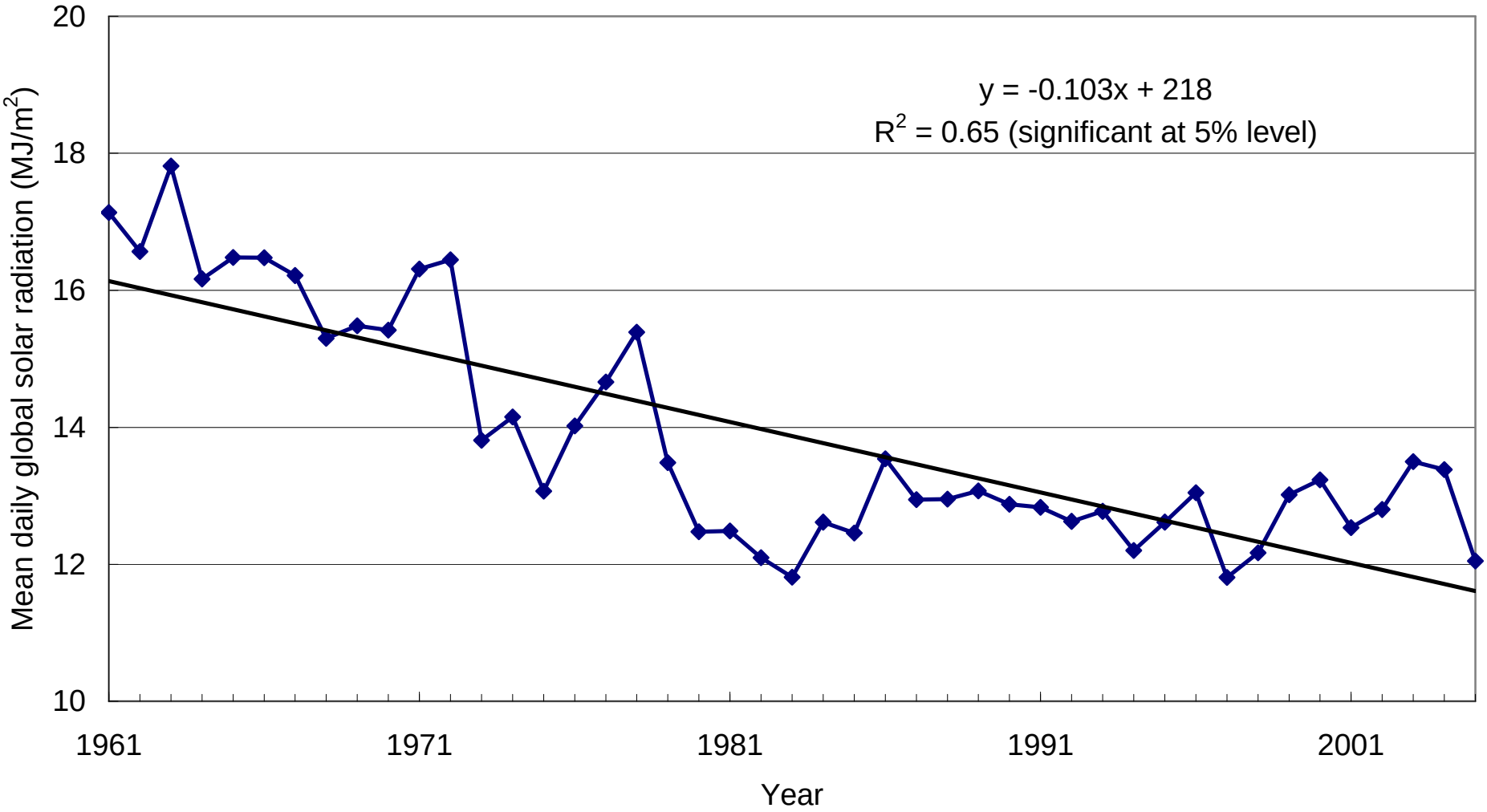



Figure 9 Long-term trend in the annual mean of the daily global solar radiation, 1961-2005

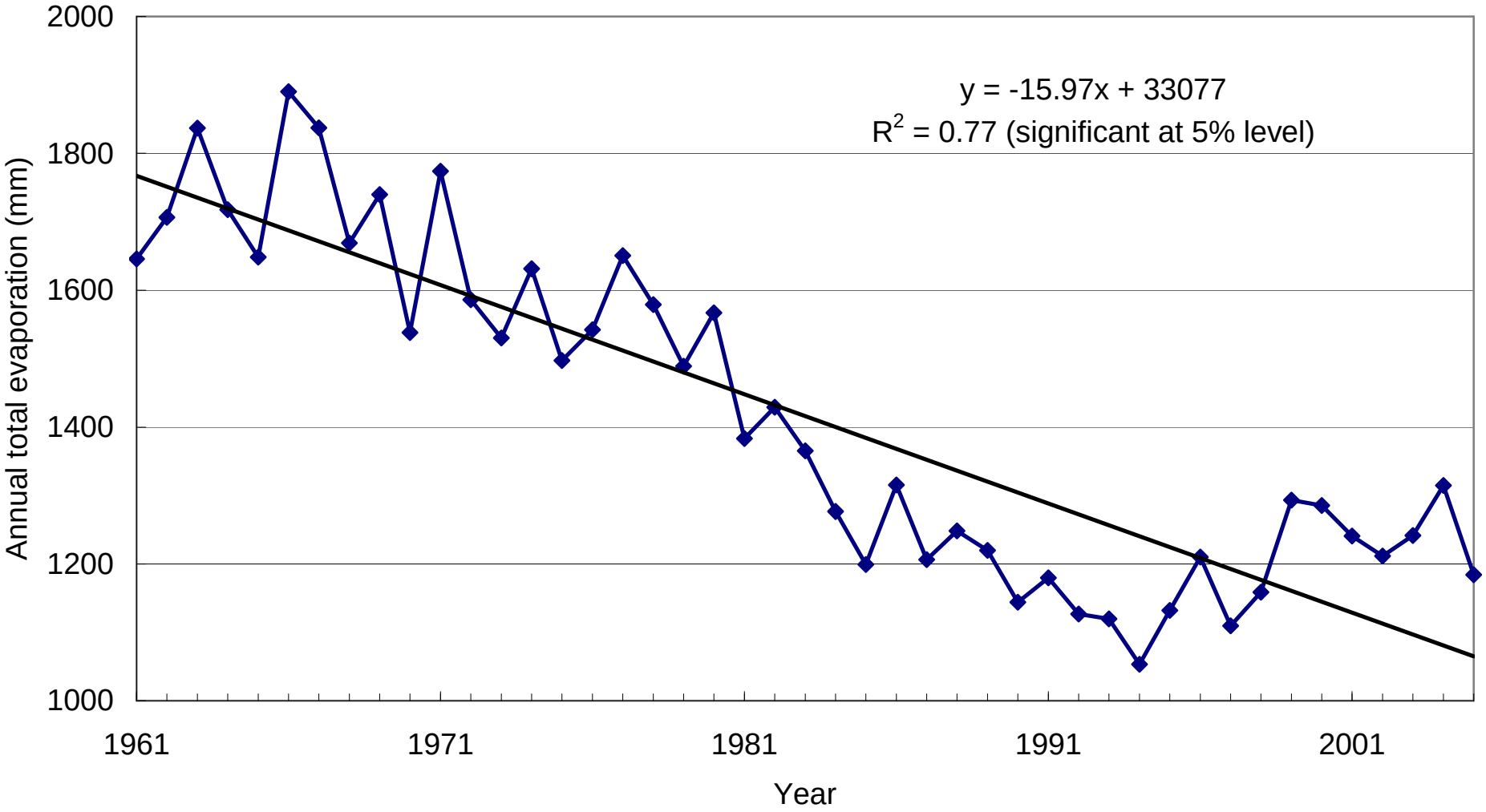



Figure 10 Long-term trend in the annual total evaporation, 1961-2005

## Appendix I

## Summary of major instrument/site changes for some of the meteorological measurements at the Hong Kong Observatory Headquarters (HKO), King's Park Meteorological Station (KP) and Waglan Island (WGL) (from 1947 to 2005)

| Location | Meteorological Element | Instrument / Site Changes | |
|---|---|---|---|
| HKO | Pressure | 1 Sept 1947 | Casella No. 3623 (Fortin) used as standard barometer/ Negretti and Zambra (Kew Type) No. 3336 barometer was used for hourly readings |
| | | 1 Dec 1950 | Casella No. 3623 (Fortin) used as standard barometer / Darton (Kew type) no.3478 barometer was used for hourly readings |
| | | 21 Jul 1962 | Darton (Kew Type) No. S3423/47/56 barometer |
| | | 1 July 1979 | Darton (kew Type) No. S3495/46/54/56 barometer |
| | | 7 May 1982 | The station barometer, S3495/46/54/56, was removed to the Central Forecasting Office of the new building with the elevation of cistern 62.2 m above MSL |
| | | 1 Apr 2000 | Setra Model 361 Digital Pressure Gauge/ Mercury in glass barometer (backup) |
| | | 1 Jan 2003 | Setra Model 270 Digital Pressure Gauge/ Mercury in glass barometer (backup) |
| | | 16 Dec 2005 | Elevation of the barometer changed to 40 m above MSL |
| | Temperature | 1947 | Ordinary fixed thermometer and max. & min. thermometers |
| | | 1981 | Platinum resistance thermometer with digital display replaced the ordinary thermometer |
| | | 7 May 1982 | Platinum resistance thermometer with digital display further replaced the max. and min. thermometers |

| | | | |
|---|---|---|---|
| | Rainfall | 1947<br>Aug 1979<br>May 1982<br>1 Jan 1989 | 8-inch standard raingauge / Dines tilting siphon raingauge<br>Satellite antenna erected close to raingauges to north-northwest (Figure A)<br>Satellite antenna dismantled<br>new 203-mm raingauge replaced the 8-inch standard raingauge and installed at 8.5 m south by west of entrance to main building (Figure B) |
| KP | Sunshine Duration | 15 Jul 1957<br>1 Jan 1969<br><br>1 Jan 2005 | Campbell-Stokes recorder on the roof of the Radiosonde Operations Room<br>The recorder was moved to the roof of the Weather Satellite Workshop/Radiation Laboratory (elevation : 71 m above MSL)<br>The Kipp & Zonen CSD-1 sunshine duration sensor replaced the Campbell Stokes recorder as the sunshine duration measuring instrument |
| | Global Solar Radiation (Lau, 1989) | 28 Jan 1959<br>1 Jan 1969<br><br>17 Apr 2000 | Bimetallic actinograph installed<br>The bimetallic actinograph was moved to the roof of the Weather Satellite Workshop/Radiation Laboratory<br>Thermo-electric pyranometer (Kipp & Zonen Holland) replaced the bimetallic actinograph |
| | Evaporation (Chen, 1976) | 4 Jul 1957 | Evaporation Pans (US Weather Bureau Class “A”) |
| | Potential Evapotranspiration (Chen, 1976) | 1 Oct 1951 | Lysimeters |

| | | | |
|---|---|---|---|
| WGL | Winds | 1 Dec 1952 | Dines Head pressure-tube anemometer (elevation 70 m above MSL) |
| | | 1 Jan 1964 | Anemometer transferred to marine signal tower (elevation 67 m above MSL) |
| | | 1 Jan 1966 | Anemometer extension (elevation 74 m above MSL) |
| | | 19 Dec 1971 | Anemometer transferred to the new instrument room annexed to the signal tower (elevation 75 m above MSL) |
| | | 19 Mar 1975 | MK4 Cup anemometer (elevation 74.8 m above MSL) |
| | | 14 Aug 1989 | Teledyne Geotech WS-201 anemometer (elevation 74.8 m above MSL) |
| | | Apr 1993 | Teledyne Geotech WS-201 anemometer and R.W. Munro Mk 4 Cup-generator anemometer and vane (82.1 m above MSL) |
| | | 15 Nov 1999 | R.W. Munro Mk 4 Cup-generator anemometer and vane (82.1 m above MSL) |


Figure A A satellite antenna was erected close to raingauges from August 1979 to May 1982

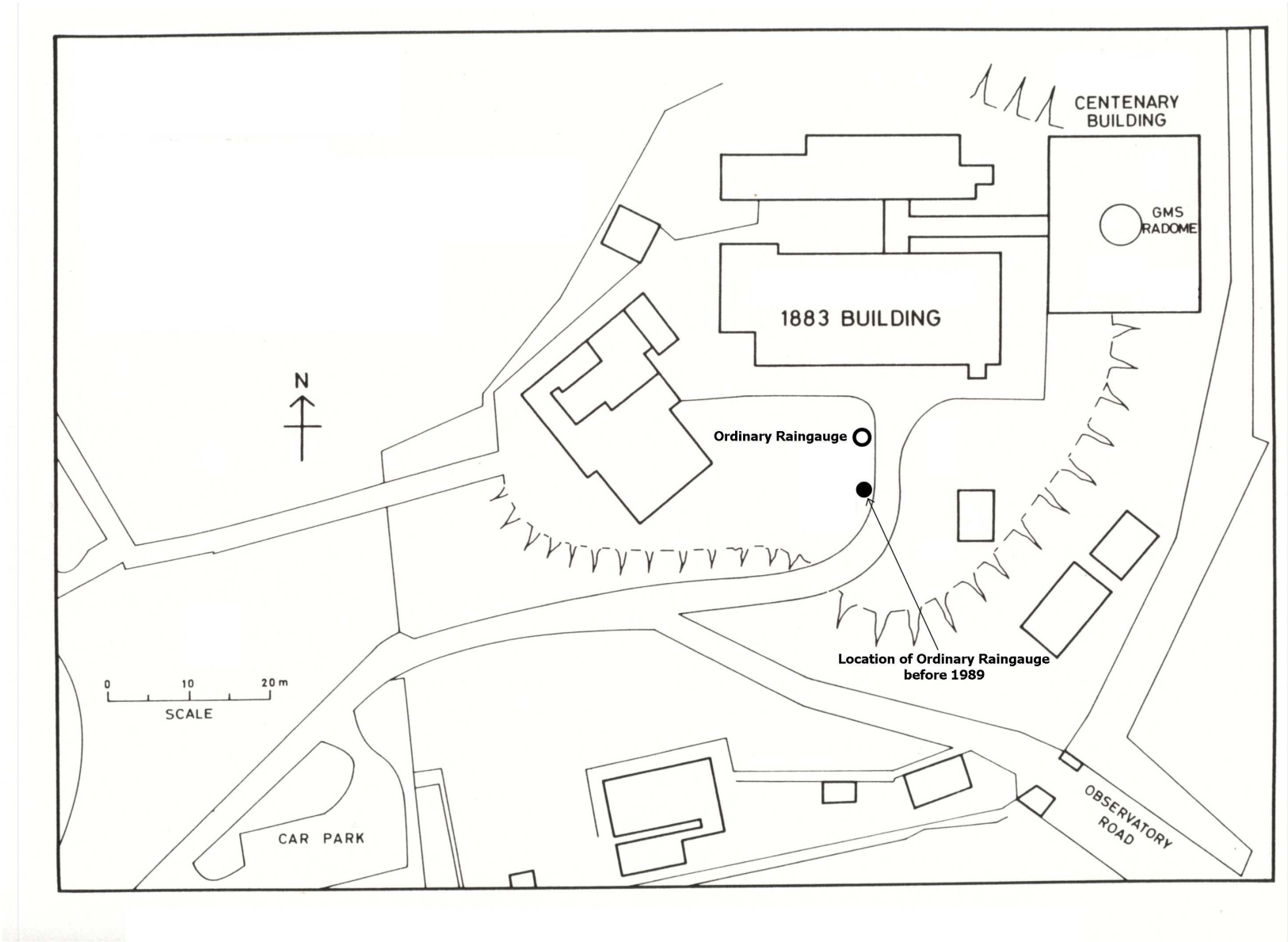



Figure B Layout plan showing the relocation of the ordinary raingauge of the Hong Kong Observatory in 1989.

**Appendix II** The annual mean/total values of selected meteorological elements from 1961 to 2000 as well as the 30-year means and standard deviations (S.D.) for 1961-1990 and 1971-2000

| Year | | Annual Mean Value | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Pressure (hPa) | Air Temperature (deg C) | Daily Max. Temperature (deg C) | Daily Min. Temperature (deg C) | Relative Humidity (%) | Cloud Amount (%) | Daily Solar Radiation ($MJ/m^2$) |
| 1961 | | 1012.6 | 22.9 | 25.6 | 20.8 | 79 | 66 | 17.14 |
| 1962 | | 1013.2 | 22.7 | 25.8 | 20.4 | 76 | 58 | 16.57 |
| 1963 | | 1013.4 | 23.3 | 26.5 | 20.9 | 73 | 52 | 17.82 |
| 1964 | | 1012.7 | 22.9 | 25.7 | 20.5 | 77 | 65 | 16.17 |
| 1965 | | 1012.8 | 23.1 | 25.9 | 20.9 | 77 | 63 | 16.48 |
| 1966 | | 1012.2 | 23.8 | 26.8 | 21.4 | 76 | 62 | 16.48 |
| 1967 | | 1012.8 | 22.9 | 25.9 | 20.4 | 74 | 66 | 16.22 |
| 1968 | | 1012.7 | 22.9 | 25.8 | 20.7 | 77 | 66 | 15.30 |
| 1969 | | 1012.8 | 22.7 | 25.7 | 20.5 | 77 | 64 | 15.48 |
| 1970 | | 1012.5 | 22.8 | 25.5 | 20.5 | 77 | 69 | 15.42 |
| 1971 | | 1013.1 | 22.7 | 25.9 | 20.5 | 74 | 59 | 16.31 |
| 1972 | | 1012.4 | 22.8 | 25.9 | 20.7 | 80 | 66 | 16.45 |
| 1973 | | 1012.6 | 23.3 | 26.3 | 21.2 | 79 | 69 | 13.81 |
| 1974 | | 1012.1 | 22.8 | 25.9 | 20.5 | 77 | 66 | 14.15 |
| 1975 | | 1012.6 | 22.8 | 25.6 | 20.7 | 79 | 71 | 13.07 |
| 1976 | | 1013.1 | 22.5 | 25.4 | 20.4 | 77 | 65 | 14.02 |
| 1977 | | 1013.5 | 23.3 | 26.4 | 21.1 | 76 | 61 | 14.66 |
| 1978 | | 1012.7 | 22.8 | 25.6 | 20.7 | 79 | 71 | 15.39 |
| 1979 | | 1013.0 | 23.1 | 25.9 | 21.0 | 78 | 66 | 13.48 |
| 1980 | | 1013.4 | 23.0 | 25.9 | 20.9 | 78 | 66 | 12.48 |
| 1981 | | 1013.1 | 23.1 | 25.5 | 21.2 | 77 | 68 | 12.49 |
| 1982 | | 1013.0 | 22.9 | 25.2 | 21.0 | 78 | 68 | 12.10 |
| 1983 | | 1013.7 | 23.0 | 25.4 | 21.1 | 78 | 69 | 11.81 |
| 1984 | | 1012.5 | 22.5 | 24.9 | 20.7 | 77 | 72 | 12.62 |
| 1985 | | 1012.3 | 22.6 | 25.0 | 20.8 | 80 | 71 | 12.46 |
| 1986 | | 1013.1 | 22.8 | 25.3 | 20.8 | 78 | 63 | 13.54 |
| 1987 | | 1013.9 | 23.4 | 25.7 | 21.6 | 79 | 68 | 12.94 |
| 1988 | | 1013.1 | 22.8 | 25.1 | 20.9 | 78 | 67 | 12.95 |
| 1989 | | 1013.1 | 23.0 | 25.3 | 21.1 | 78 | 66 | 13.07 |
| 1990 | | 1012.9 | 23.1 | 25.4 | 21.2 | 79 | 68 | 12.88 |
| 1991 | | 1013.3 | 23.5 | 25.9 | 21.6 | 78 | 66 | 12.83 |
| 1992 | | 1013.3 | 22.8 | 25.2 | 20.9 | 78 | 65 | 12.63 |
| 1993 | | 1013.6 | 23.1 | 25.5 | 21.2 | 78 | 68 | 12.77 |
| 1994 | | 1012.7 | 23.6 | 25.9 | 21.7 | 79 | 69 | 12.20 |
| 1995 | | 1013.7 | 22.8 | 25.2 | 20.9 | 77 | 69 | 12.61 |
| 1996 | | 1013.0 | 23.3 | 25.6 | 21.3 | 76 | 68 | 13.04 |
| 1997 | | 1013.3 | 23.3 | 25.5 | 21.5 | 79 | 70 | 11.81 |
| 1998 | | 1012.8 | 24.0 | 26.3 | 22.1 | 79 | 73 | 12.17 |
| 1999 | | 1011.9 | 23.8 | 26.2 | 21.8 | 75 | 67 | 13.02 |
| 2000 | | 1011.9 | 23.3 | 25.5 | 21.5 | 78 | 69 | 13.23 |
| 1961-1990 | Mean | 1012.9 | 23.0 | 25.7 | 20.9 | 77 | 65 | 14.46 |
| | S.D. | 0.44 | 0.28 | 0.43 | 0.30 | 1.70 | 4.13 | 1.75 |
| 1971-2000 | Mean | 1013.0 | 23.1 | 25.6 | 21.1 | 78 | 67 | 13.23 |
| | SD. | 0.51 | 0.36 | 0.39 | 0.42 | 1.37 | 2.94 | 1.17 |

| Year | | Annual Total Value | | | | | |
|---|---|---|---|---|---|---|---|
| | | Rainfall (mm) | Sunshine (hour) | Total Evaporation (mm) | Number of Thunderstorm days | Number of Lightning days | Number of Fog days |
| 1961 | | 2232.4 | 1981.6 | 1645.6 | 38 | 55 | 8 |
| 1962 | | 1741.0 | 2395.4 | 1706.4 | 20 | 34 | 7 |
| 1963 | | 901.1 | 2469.7 | 1837.0 | 20 | 30 | 0 |
| 1964 | | 2432.1 | 2029.6 | 1717.8 | 30 | 41 | 6 |
| 1965 | | 2352.6 | 1990.7 | 1648.1 | 30 | 42 | 4 |
| 1966 | | 2398.2 | 2114.8 | 1890.4 | 31 | 42 | 5 |
| 1967 | | 1570.6 | 2090.9 | 1837.1 | 20 | 34 | 9 |
| 1968 | | 2288.2 | 2008.7 | 1669.1 | 34 | 48 | 9 |
| 1969 | | 1895.5 | 2072.6 | 1740.1 | 35 | 49 | 19 |
| 1970 | | 2316.3 | 1844.7 | 1538.3 | 33 | 45 | 6 |
| 1971 | | 1903.8 | 2116.6 | 1774.0 | 23 | 36 | 2 |
| 1972 | | 2807.3 | 1852.3 | 1586.4 | 44 | 54 | 4 |
| 1973 | | 3100.4 | 1750.9 | 1530.4 | 43 | 51 | 3 |
| 1974 | | 2322.9 | 1932.6 | 1631.4 | 31 | 42 | 4 |
| 1975 | | 3028.7 | 1713.4 | 1497.3 | 41 | 63 | 4 |
| 1976 | | 2197.2 | 1883.5 | 1542.3 | 23 | 35 | 5 |
| 1977 | | 1680.0 | 2201.3 | 1650.5 | 43 | 61 | 2 |
| 1978 | | 2593.0 | 1755.2 | 1579.1 | 43 | 53 | 8 |
| 1979 | | 2614.7 | 1831.5 | 1489.1 | 35 | 41 | 3 |
| 1980 | | 1710.6 | 2012.0 | 1567.0 | 44 | 48 | 10 |
| 1981 | | 1659.5 | 1802.9 | 1383.4 | 28 | 36 | 1 |
| 1982 | | 3247.5 | 1785.0 | 1429.1 | 46 | 66 | 3 |
| 1983 | | 2893.8 | 1859.4 | 1365.3 | 42 | 51 | 5 |
| 1984 | | 2017.0 | 1701.9 | 1276.6 | 23 | 34 | 11 |
| 1985 | | 2191.4 | 1711.2 | 1199.0 | 29 | 49 | 7 |
| 1986 | | 2338.3 | 2014.0 | 1315.2 | 34 | 48 | 11 |
| 1987 | | 2319.3 | 1878.0 | 1206.3 | 41 | 51 | 5 |
| 1988 | | 1685.0 | 1881.9 | 1248.4 | 33 | 47 | 5 |
| 1989 | | 1944.6 | 1888.5 | 1219.8 | 25 | 38 | 7 |
| 1990 | | 2046.9 | 1871.0 | 1144.1 | 42 | 57 | 4 |
| 1991 | | 1639.1 | 1836.6 | 1179.6 | 27 | 33 | 11 |
| 1992 | | 2678.8 | 1855.5 | 1126.6 | 43 | 60 | 11 |
| 1993 | | 2343.9 | 1859.9 | 1119.4 | 47 | 59 | 3 |
| 1994 | | 2725.6 | 1702.5 | 1053.2 | 40 | 60 | 3 |
| 1995 | | 2754.4 | 1836.1 | 1131.8 | 35 | 43 | 6 |
| 1996 | | 2249.1 | 1811.7 | 1210.1 | 41 | 56 | 0 |
| 1997 | | 3343.0 | 1558.2 | 1109.3 | 53 | 66 | 1 |
| 1998 | | 2564.6 | 1665.3 | 1158.7 | 49 | 61 | 10 |
| 1999 | | 2129.1 | 1852.6 | 1293.3 | 35 | 48 | 1 |
| 2000 | | 2752.3 | 1864.9 | 1285.3 | 30 | 47 | 3 |
| 1961-1990 | Mean | 2214.3 | 1948.1 | 1528.8 | 33.47 | 46.03 | 5.90 |
| | S.D. | 512.48 | 186.64 | 209.91 | 8.24 | 9.30 | 3.75 |
| 1971-2000 | Mean | 2382.7 | 1842.9 | 1343.4 | 37.10 | 49.80 | 5.09 |
| | SD. | 491.14 | 129.53 | 197.45 | 8.36 | 9.91 | 3.38 |

| Year | | Annual Total Value | | | | |
|---|---|---|---|---|---|---|
| | | Number of Very Hot days | Number of Cold days | Number of Hot nights | Number of days with daily Rainfall ≥ 0.1mm | Number of days with daily Rainfall ≥ 30mm |
| 1961 | | 16 | 20 | 3 | 155 | 20 |
| 1962 | | 30 | 36 | 3 | 120 | 17 |
| 1963 | | 37 | 28 | 2 | 105 | 9 |
| 1964 | | 13 | 27 | 2 | 164 | 20 |
| 1965 | | 7 | 15 | 1 | 144 | 25 |
| 1966 | | 16 | 15 | 3 | 116 | 26 |
| 1967 | | 28 | 48 | 14 | 112 | 15 |
| 1968 | | 18 | 34 | 10 | 149 | 21 |
| 1969 | | 19 | 33 | 10 | 139 | 18 |
| 1970 | | 8 | 18 | 2 | 144 | 20 |
| 1971 | | 10 | 27 | 2 | 119 | 14 |
| 1972 | | 16 | 26 | 2 | 130 | 26 |
| 1973 | | 3 | 13 | 6 | 148 | 33 |
| 1974 | | 11 | 25 | 4 | 125 | 21 |
| 1975 | | 2 | 27 | 0 | 165 | 31 |
| 1976 | | 9 | 21 | 5 | 125 | 18 |
| 1977 | | 17 | 33 | 14 | 131 | 17 |
| 1978 | | 28 | 23 | 8 | 152 | 22 |
| 1979 | | 14 | 7 | 10 | 134 | 29 |
| 1980 | | 16 | 17 | 11 | 121 | 19 |
| 1981 | | 5 | 14 | 10 | 137 | 17 |
| 1982 | | 8 | 17 | 9 | 146 | 28 |
| 1983 | | 13 | 31 | 30 | 169 | 30 |
| 1984 | | 7 | 37 | 10 | 132 | 21 |
| 1985 | | 2 | 22 | 2 | 151 | 25 |
| 1986 | | 7 | 21 | 12 | 129 | 20 |
| 1987 | | 9 | 14 | 20 | 124 | 27 |
| 1988 | | 4 | 12 | 16 | 138 | 15 |
| 1989 | | 15 | 18 | 17 | 138 | 15 |
| 1990 | | 13 | 21 | 24 | 160 | 18 |
| 1991 | | 12 | 8 | 19 | 126 | 17 |
| 1992 | | 16 | 15 | 15 | 148 | 19 |
| 1993 | | 6 | 24 | 24 | 142 | 23 |
| 1994 | | 5 | 8 | 4 | 143 | 26 |
| 1995 | | 7 | 17 | 15 | 142 | 26 |
| 1996 | | 9 | 15 | 17 | 136 | 27 |
| 1997 | | 5 | 7 | 12 | 147 | 35 |
| 1998 | | 10 | 11 | 36 | 152 | 28 |
| 1999 | | 6 | 11 | 17 | 133 | 17 |
| 2000 | | 10 | 17 | 22 | 141 | 29 |
| 1961-1990 | Mean | 13.37 | 23.33 | 8.73 | 137.40 | 21.23 |
| | S.D. | 8.55 | 9.04 | 7.34 | 16.46 | 5.69 |
| 1971-2000 | Mean | 9.83 | 18.63 | 13.10 | 139.49 | 23.10 |
| | SD. | 5.57 | 7.83 | 8.66 | 12.71 | 5.86 |