ROYAL OBSERVATORY, HONG KONG

Technical Note (Local) No. 69

# VISIBILITY TRENDS

# IN HONG KONG

by

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# Visibility Trends in Hong Kong

## I. Introduction

Forecasters at the Observatory noticed in the last few years that during the onset of surges of the northeast monsoon, visibility inside Victoria Harbour apparently deteriorated to a greater extent than in the past. As visibility is often treated as an indicator of visual air quality (Sloane, 1982), the trend of reduction in visibility, if genuine, would be of much interest.

Bell *et al* (1970) were among the first to study the atmospheric aspects of air pollution and the effect of pollution to visibility in Hong Kong. Chang and Koo (1986) investigated the variation in visibility in Hong Kong from 1968 to 1982. In their investigation, occurrences of visibility reduction not due to meteorological phenomena such as fog, mist, precipitation and high humidity (95 % or above) had a statistically significant upward trend during the period 1975 to 1980.

The aim of the present study is to investigate the annual and seasonal variation in reduced visibility in Hong Kong from 1968 to 1995 with a view to finding out whether there were trends in visibility. A few cases of visibility degradation will also be analyzed to help forecasters appreciate the relationship between meteorological conditions and degraded visibility.

## II. Data Base

Visibility observations at four stations in Hong Kong were analyzed. The locations of the four stations, namely the Royal Observatory (RO), Hong Kong International Airport (HKIA), Cheung Chau (CC) and Waglan Island (WI), are shown in Figure 1. RO and HKIA are located in the urban area by the side of the Victoria Harbour. CC and WI are outlying islands situated over the southwestern and southeastern side of the territory respectively. Table 1 lists the period and frequency of visibility observations at these stations.

**Table 1 Base data of visibility observations**

| | *RO* | *HKIA* | *CC* | *WI* |
|---|---|---|---|---|
| *Time period* | 1968-1995 | 1968-1995 | 1968-1991* | 1975-1988* |
| *Frequency of data* | hourly data | hourly data | hourly data | 3 hourly data |

* manual observations of visibility are not available at CC and WI after these dates

In order to examine the change in visual air quality, it is necessary to screen out meteorological influence from the visibility data. To do this, the present investigation has adopted Chang and Koo's (1986) practice of excluding cases of visibility impairment that were concurrent with reports of fog, mist, precipitation, or relative humidity of 95% or above from the visibility data. In general, visibility is said to have been reduced when it falls below 8 km. Hence, "reduced visibility" here refers to visibility below 8 km when there are no fog, mist, precipitation or relative humidity of 95% or above being reported.

The number of hours of reduced visibility at each station was counted. To facilitate comparison among the stations, the annual or monthly number of hours of reduced visibility at each station were expressed as a percentage of the total number of hours that observations were made at that station in that year or month. These percentages were analyzed to see if any trend exists.

## III. Year-to-year Variations in Reduced Visibility

Figure 2 illustrates the year-to-year variations of reduced visibility at the four stations. To minimize inter-annual variations so as to reveal the long term trend, smoothing of the curves was done by computing the running 3-yearly means of the annual frequency of reduced visibility and the results are also plotted in the same figure.

These curves suggest that the two urban stations, RO and HKIA, generally suffered from higher frequency of reduced visibility than the two outlying island stations. From Figure 2, it can be seen that the running means of RO and HKIA showed a decreasing trend before 1975 while CC experienced a weak increasing trend during that time. However, all four stations had a noticeable increasing trend from 1975 to 1979. This is similar to the findings of Chang and Koo (1986).

From 1979 onwards, the variation in the running means of CC was small and if anything showed a very weak decreasing trend. In WI, however, the percentage figure fell to a minimum in 1984. It then increased again till the late 1980s when manual observation ceased. At RO, the curve showed that the percentage of reduced visibility experienced a decreasing trend from 1979 to 1987. This period with decreasing trend was much shorter at HKIA, lasting only from 1979 to 1982. The variation from 1982 to 1987 was relatively small at HKIA. From 1987 onwards, both RO and HKIA showed a significant increasing trend. The trends of reduced visibility at the four stations are summarized in the following table:

**Table 2. Year-to-year variations in percentage of reduced visibility at the 4 stations.**

| **Period** | **Before 1975** | **1975-1979** | **1979-1983** | **1983-1987** | **1987 onwards** |
|---|---|---|---|---|---|
| **RO** | decreasing | increasing | decreasing | decreasing | increasing |
| **HKIA** | decreasing | increasing | decreasing | small | increasing |
| **CC** | increasing | increasing | small | small | small |
| **WI** | - | increasing | decreasing | increasing | - |

From the discussion above, rising and falling trends of reduced visibility at a time frame of roughly 5 years were observed at each station even from curves of running 3-yearly means. It is therefore difficult to determine from these curves long term trends for the entire period under study. To establish this long term trend, two methods were employed. Firstly, fluctuations were removed by applying a 11-year Gaussian filter to the reduced visibility data as they exhibit fluctuations with cycle of about 11 years (Fig. 2). The long term trend was then assessed from the filtered data. While this method is mathematically rigorous, it suffers from the fact that trends for the first 5 years as well as the last 5 years of the period under study cannot be determined. The second method employed fitting of straight lines to the reduced visibility data for each station by least square. The long term trend could then be inferred from the slopes of these straight lines.

After applying the 11-year Gaussian filter, the resultant reduced visibility data are plotted in Figure 3. The curve for WI is too short to infer any meaningful trend. It is, however, rather obvious that frequency of reduced visibility at RO was rising steadily. The variation of reduced visibility at HKIA was small in the long term but the rising trend after 1987 mentioned above managed to manifest itself in the filtered data. The long term trend for CC was also rising but it seemed to level off after 1981.

Results obtained using the second method are showed in Figure 4. Table 3a presents the results of the least square fitting. Among the four stations, reduced visibility at WI experienced a large fluctuation and no statistically significant trend could be inferred for it. Reduced visibility at the RO and CC both exhibited a statistically significant rising trend with overall significance (by F test) at the 1% level. The rate of rise were 0.11% and 0.09% per year at RO and CC respectively. For HKIA, although the slope of the best fitted straight line is positive, indicating a rising trend of 0.07% per year, this trend is not significant at the 1% level (by F test).

Thus the results of both methods indicate that for the period 1968 to 1995 as a whole, reduced visibility at RO and CC had a significant long term rising trend. For HKIA, while there was no statistically significant long term trend, the results hint at an increasing trend in recent years.

**Table 3 (a) Linear fit of annual percentage of reduced visibility at the four stations**

| *Station* | *Intercept a* | *Slope b* | *y = a + bt* | *y is moving average centred on* | *95% confidence limits for b* | *Coefficient of determination $r^2$* | *Overall significance by F test* |
|---|---|---|---|---|---|---|---|
| RO (1968-1995) | 1.92 | +0.11 | y = 1.92 + 0.11 t | 1967 + t, t=1,2, ..., 28 | +0.07 to +0.15 | 0.54 | 1% |
| HKIA (1968-1995) | 2.69 | +0.07 | y = 2.69 + 0.07 t | 1967 + t, t=1,2, ..., 28 | +0.01 to +0.12 | 0.18 | Insignificant at 1% |
| CC (1968-1991) | 1.13 | +0.09 | y = 1.03 + 0.09 t | 1967 + t, t=1,2, ..., 24 | +0.05 to +0.13 | 0.50 | 1% |
| WI (1968-1988) | 1.50 | -0.02 | y = 1.50 - 0.02 t | 1974 + t, t=1,2,..., 14 | -0.18 to +0.14 | 0.00 | Insignificant at 1% |

**Table 3 (b) same as Table 3(a) except for the period 1987 to 1995 at RO and HKIA**

| *Station* | *Intercept a* | *Slope b* | *y = a + bt* | *y is moving average centred on* | *95% confidence limits for b* | *Coefficient of determination $r^2$* | *Overall significance by F test* |
|---|---|---|---|---|---|---|---|
| RO | 2.78 | +0.36 | y = 2.78 + 0.36 t | 1986 + t, t=1,2, ..., 9 | +0.13 to +0.59 | 0.66 | 1% |
| HKIA | 1.47 | +0.58 | y = 1.47 + 0.58 t | 1986 + t, t=1,2,..., 9 | +0.34 to +0.83 | 0.82 | 1% |

As mentioned earlier, reduced visibility at RO and HKIA showed a noticeable rising trend since 1987. To compare the rate of increase since 1987 with the long term rate, straight lines are also fitted by linear regression to the reduced visibility data from 1987 to 1995 for RO and HKIA (Table 3b). The rate of increase at RO during this period was 0.36 % per year, more than 3 times higher than the long term rate. The increase in rate was even more pronounced at HKIA, which showed a rate of 0.58% per year. Visual inspection of the RO curve in Figure 4a suggests that the rapid increase might be the result of a combination of the long-term increasing trend and the rising segment of a quasi-periodic fluctuation with a decadal time scale. The HKIA curve in Figure 4a shows similar characteristics also.

## IV. Year-to-year Variations in Reduced Visibility in Winter

To test the notion of degradation of visibility during onset of surges of the northeast monsoon, it is worthwhile to study also the trends for reduced visibility in winter. For the purpose of the present study, "winter" is taken as the period from 16 September to the end of February of the following year. This is the period when surges of the northeast monsoon come to affect Hong Kong from time to time. Reduced visibility data for "winter" were analyzed with the same methods that were applied to the data for the whole year.

Figure 5 shows the percentage reduced visibility in winter and its 3-year running means for the 4 stations. It can be seen that curves of 3-year running means for winter follow closely the curves for the whole year. Thus, trends in the time frame of roughly 5 years described in Table 2 are basically observed in reduced visibility for winter.

Reduced visibility for winter after being treated by the 11-year Gaussian filter is plotted in Figure 6. The filtered data for winter reveals trends that resemble closely those for annual reduced visibility. Firstly, no meaningful trend for WI can be concluded. Secondly, the frequency of reduced visibility in winter was increasing at RO and CC during the entire period under study. Thirdly, the variation in reduced visibility in winter at HKIA was small but had an upward trend after 1987.

From best fitted straight lines for the reduced visibility in "winter" (Figure 7), again no statistically significant trend could be inferred for WI. From Table 4, RO, HKIA and CC exhibited an increasing trend with overall significance (by F test) at the 1% level. The rate of rise were 0.17%, 0.10% and 0.14% per year at RO, HKIA and CC respectively, all slightly higher than the rates for the whole year. Note the significant trend at HKIA in contrast to the insignificant trend in annual figures.

The above results therefore indicate that trends for reduced visibility in winter and trends for annual reduced visibility resemble each other rather closely.

**Table 4 Linear fit of percentage of reduced visibility in "winter" at the four stations**

| *Station* | *Intercept a* | *Slope b* | *y = a + bt* | *y is moving average centred on* | *95% confidence limits for b* | *Coefficient of determination $r^2$* | *Overall significance by F test* |
|---|---|---|---|---|---|---|---|
| *RO* | 1.02 | +0.17 | y = 1.02 + 0.17 t | 1967 + t, t=1,2, ..., 28 | +0.12 to +0.21 | 0.70 | 1% |
| *HKIA* | 1.86 | +0.10 | y = 1.86 + 0.10 t | 1967 + t, t=1,2, ..., 28 | +0.03 to +0.17 | 0.26 | 1% |
| *CC* | 0.71 | +0.14 | y = 0.71 + 0.14 t | 1967 + t, t=1,2, ..., 24 | +0.09 to +0.19 | 0.63 | 1% |
| *WI* | 0.72 | 0.02 | y = 0.72 + 0.02 t | 1974 + t, t=1,2,..., 14 | -0.07 to +0.11 | 0.02 | Insignificant at 1% |

## V. Month-to-month Variations in Reduced Visibility

Figure 8 depicts the mean monthly frequency of reduced visibility from 1968 to 1995. In general, the percentage of reduced visibility in the months from December to April is much higher than those of the other months. Figure 8 also shows the mean monthly lapse rate between the surface and 950 hPa level (about 600 m above mean sea level). It may be seen that the variation in the monthly frequency of reduced visibility mirrors closely that of the mean lapse rate. The lapse rate is the smallest in March when the highest instances of reduced visibility occur. The lapse rate is highest in July while the frequency of reduced visibility is the lowest. These observations indicate that a stable atmosphere is generally conducive to the occurrence of reduced visibility.

## VI. Factors Contributing to Reduced Visibility

In order to find out whether other favourable factors exist, the meteorological conditions during the occurrence of reduced visibility were analyzed. Data at RO were used in the analysis as RO is the primary location of weather observations in Hong Kong.

Figure 9 shows the frequency distribution of reduced visibility at different wind speeds at RO. It indicates that around 56% of reduced visibility occurred when winds were light (force 2 or below in the Beaufort scale). On the other hand, only less than 1% occurred under fresh or stronger winds (Beaufort force 5 to 7) conditions.

To study the effect of wind direction, a wind rose was constructed for all cases of reduced visibility at RO from 1968 to 1995. This wind rose is shown in Figure 10 together with the climatological mean wind rose. Thus reduced visibility occurs predominantly in easterly and westerly winds. Let R be the frequency of a wind direction in the wind rose for reduced visibility and C be the corresponding climatological value. Table 5 lists out the values of R and C for different wind directions. For cases of reduced visibility, the proportion of winds from the west, i.e. R, is 16%. The climatological frequency of westerly winds, i.e.

C, is however a low 8%. The ratio R/C amounts to 2 and is significantly higher than the ratios for other wind directions. It therefore follows that westerly winds at RO imply a higher probability of reduced visibility than other wind directions.

**Table 5 Differences between the climatological wind rose and the wind rose for reduced visibility at RO**

| | *Climatological wind rose (C) (1961-1990)* | *wind rose for reduced visibility (R) (1968-1995)* | *R/C* |
|---|---|---|---|
| *Frequency of easterly winds* | 39% | 51% | 1.3 |
| *Frequency of westerly winds* | 8% | 16% | 2 |
| *Frequency of winds from other directions* | 53% | 33% | 0.6 |

It is well known to meteorologists in Hong Kong that because of the local terrain, when the prevailing wind is light northerly, RO very often records westerly winds. The above statistics suggest that the chance of reduced visibility at RO is higher under a northerly airstream. In this connection, it is noted that the Gobi Dessert and other arid areas of China are sources of fine particles to Hong Kong (Bell, 1970).

## VII. Cases of Reduced Visibility

In order to look more closely how the various factors discussed above affect visibility, the meteorological conditions of a few cases of reduced visibility were analyzed and the results are given below :

*(a) Weak northerly surges on 20 December 1990:*

On 19 December 1990, a ridge of high pressure lied along southeast China, bringing an easterly airstream to the coast of Guangdong (Figure 11). This ridge of high pressure weakened the next day while another ridge built up over western China. A weak northerly surge associated with the latter ridge arrived at the coast of Guangdong that day and replaced the prevailing easterly airflow. Figure 12 illustrates the changes in wind field in Hong Kong on 20 and 21 December 1990 as recorded by a network of automatic weather stations (AWS). At 10 a.m. on 20 December (Figure 12a), winds in Hong Kong were mostly light. Northerly winds associated with the weak surge had already reached the northern part of the territory. An east-west line of wind convergence between northerlies in the north and southerlies and southeasterlies to the south was clearly discernible. Visibility at both RO and HKIA was more than 8 km at this time. At 2 p.m. (Figure 12b), the northerly winds penetrated further south while the line of wind convergence drifted southeast to the Victoria Harbour. Winds over the western part of Hong Kong turned into northwesterlies. Westerly winds of 4 m/s reached RO while visibility fell slightly to 7 km. Visibility was still good at HKIA. At 6 p.m. (Figure 12c), winds over the northwestern part of the territory strengthened but wind convergence was still observable between RO and HKIA. At this time, RO recorded a low visibility of 3200 m while the value at HKIA was 3500 m. Visibility at these stations remained low for the next few hours until at 2 a.m. on 21 December 1990 (Figure 12d). By this time, convergence of winds within Hong Kong ceased to exist and visibility at RO and HKIA improved to 7 km and 9 km respectively. During the entire episode, the relative humidity remained below 80% at both RO and HKIA.

From the analysis of AWS data, the arrival of the weak northerly surge was accompanied by a line of wind convergence. Accumulation of suspended particles was favoured in the vicinity of this line of convergence. As it swept across the territory, reduced visibility was recorded first at RO and then later at HKIA. Soon after its passage and the subsequent strengthening of winds, visibility improved generally.

*(b) Lull in winter monsoon on 8 January 1994*

Figure 13 depicts the synoptic situation for 7 and 8 January 1994. A ridge of high pressure along the coast of southeast China brought an easterly airstream to Hong Kong on 7 January 1994. With the weakening of this ridge, winds in Hong Kong subsided the next day. The wind flow in Hong Kong on 8 January is shown in Figure 14. Early on 8 January 1994 (Figure 14a), moderate easterly winds prevailed inside the Victoria Harbour. Visibility at RO and HKIA was 7 km and 8 km respectively. At 10 a.m. (Figure 14b), winds inside the Victoria Harbour dropped while weak northeasterly winds invaded the northern part of the territory. On checking the synoptic conditions, it was found that the air pressure was generally falling at that time in the territory while the dew point was hardly changing at all. It was concluded that these northeasterly winds were not due to the arrival of a surge of the northeast monsoon. Instead, they probably resulted from the backing of winds following the weakening of the ridge over southeast China. At this time, a line of convergence between the northeast and easterly winds could be seen lying across the territory. Winds at both RO and HKIA had abated to 3 m/s and 1 m/s respectively. Visibility at RO dropped to 4500 m. By 1 p.m. (Figure 14c), the prevailing easterly winds retreated further east. The wind flow over the territory was weak and two lines of wind convergence could be analyzed. One of them was located in the western part of the territory while the other one lied right between RO and HKIA. Winds at RO turned to westerlies of 2 m/s while those at HKIA were southeasterlies of 3 m/s. The relative humidity at the two stations were 67 and 66% respectively. Visibility at this time was down to 4500 m at RO and 4200 m at HKIA, and remained low occasionally for the next 31 hours. By 8 p.m. on 9 January 1994 (Figure 14d), easterly winds re-established themselves again over the territory and visibility at RO and HKIA improved to 6 km and 8 km respectively. This case indicates that weakening of winds during lulls in monsoon also favoured visibility degradation.

*(c) Pre-tropical cyclone situation on 17 August 1990*

At 2 a.m. on 16 August 1990, Severe Tropical Storm Yancy was located about 700 km southeast of Taiwan (Figure 15). While Yancy travelled northwestward towards Taiwan, its outer circulation started to affect Guangdong the next day. From AWS winds (Figure 16), it was observed that winds were rather irregular in Hong Kong at 8 p.m. on 16 August (Figure 16a) because of some thundery activity around. Winds at Tai Mo Shan were moderate from the northeast. Visibility at both RO and HKIA was 10 km or above. By 6 a.m. the next morning (Figure 16b), Hong Kong came under the influence of the outer circulation of

Yancy. Winds at Tai Mo Shan turned to the northwest and organized west to northwesterly winds dominated the territory. Visibility at RO and HKIA was still good at this time. As the west to northwesterly winds continued to prevail, visibility gradually decreased. At 4 p.m. on 17 August 1990 (Figure 16c), visibility at RO and HKIA was down to 3000 m and 4000 m respectively while winds at both stations were 4 m/s. Then visibility at both stations varied between 4000 m and 7 km. At midnight late on 17 August (Figure 16d), winds turned northerly generally. Winds at HKIA increased to 7 m/s and its visibility rose to 10 km. Since RO is sheltered from the north by mountain, winds at RO was calm at this time. Its visibility, nevertheless, soared to 7 km and further improved in the next few hours.

Because of the subsidence of air on the outer periphery of Yancy, the atmosphere was rather stable as revealed by the tephigram for 8 a.m. that morning (Figure 17) and was conducive to the occurrence of reduced visibility. The subsidence also dried the atmosphere. The relative humidity at RO from 4 p.m. to midnight on 17 August ranged between 69 and 77% while the corresponding range at HKIA was 48 to 75%. In this case, no apparent line of wind convergence could be observed. Yet, drop in visibility was accompanied by the setting in of northwesterly winds.

## VIII. Conclusion

Visibility data for two urban stations (28 years) and two outlying island stations (over 10 years) were studied. Results indicate that trends for annual and winter reduced visibility resemble each other closely. Reduced visibility had statistically significant upward trends at RO and CC. While no statistically significant trend could be inferred for annual percentage of reduced visibility at HKIA, reduced visibility in winter there did show a statistically significant increasing trend. Moreover, both RO and HKIA exhibited a high rate of increase in the frequency of reduced visibility between 1987 and 1995. This may be related to the superposition of a quasi-periodic fluctuation with a decadal time scale on top of a long-term increasing trend.

It has been shown that the favourable meteorological conditions for the occurrence of reduced visibility at RO are :

(a) stable lower atmosphere,
(b) light winds, and
(c) wind direction from the west.

It was found in the case studies that the above favourable conditions might occur during the onset of a weak northerly surge and a lull in the northeast monsoon. Lines of wind convergence could be observed in Hong Kong during such occasions. Winds were light on either side of the convergence line where high concentration of suspended particles could accumulate. These lines of convergence, while sweeping across Hong Kong, brought reduced visibility to the territory. Impairment in visibility was also observed during the approach of tropical cyclones from the east, probably related to the northwesterly winds brought to Hong Kong by their outer circulations and the stable atmosphere rendered by subsidence of air typically occurring ahead of tropical cyclones. In all cases, visibility dropped when winds abated but improved as winds strengthened.

## Acknowledgment

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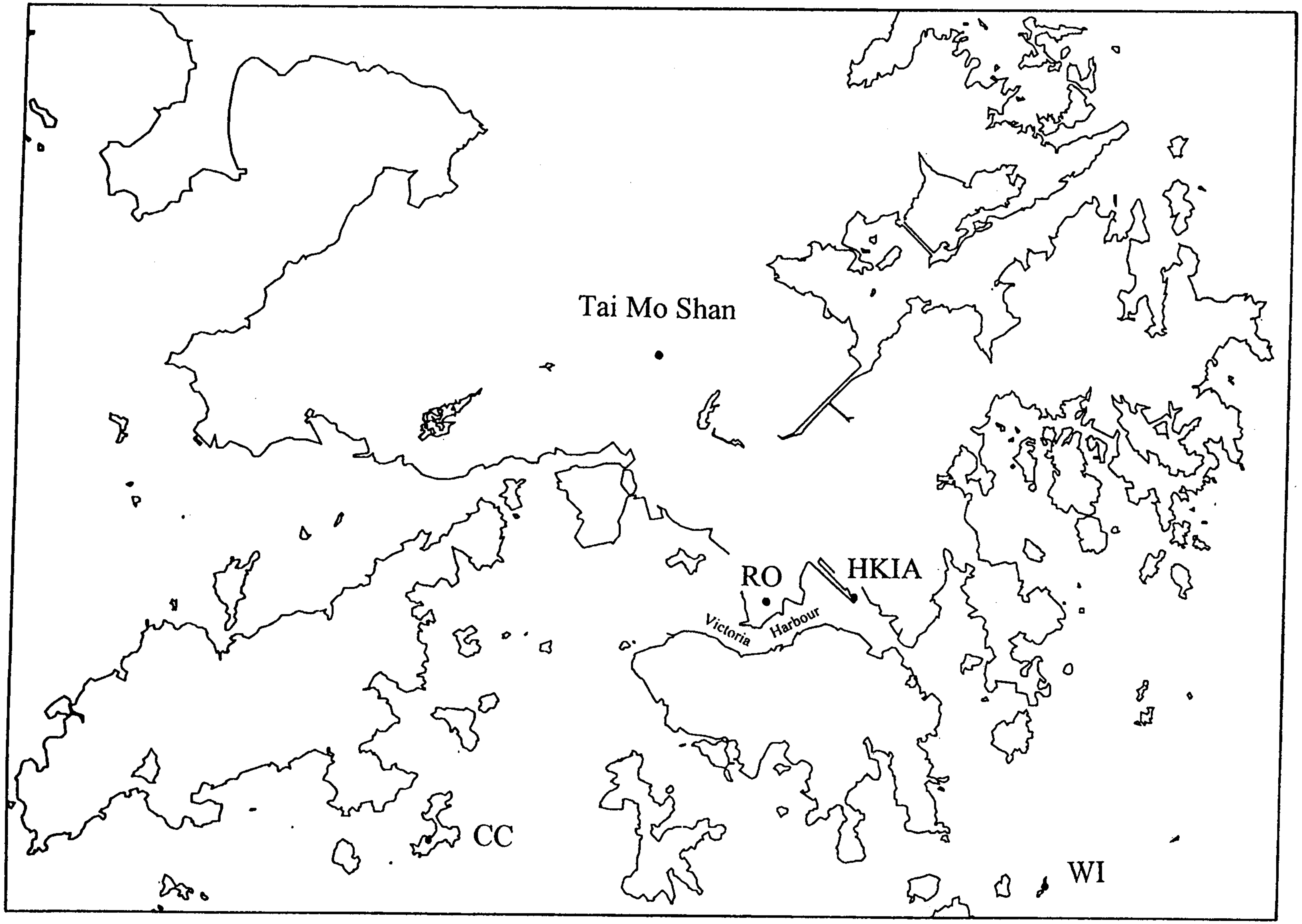



Figure 1    Location of four stations in Hong Kong.

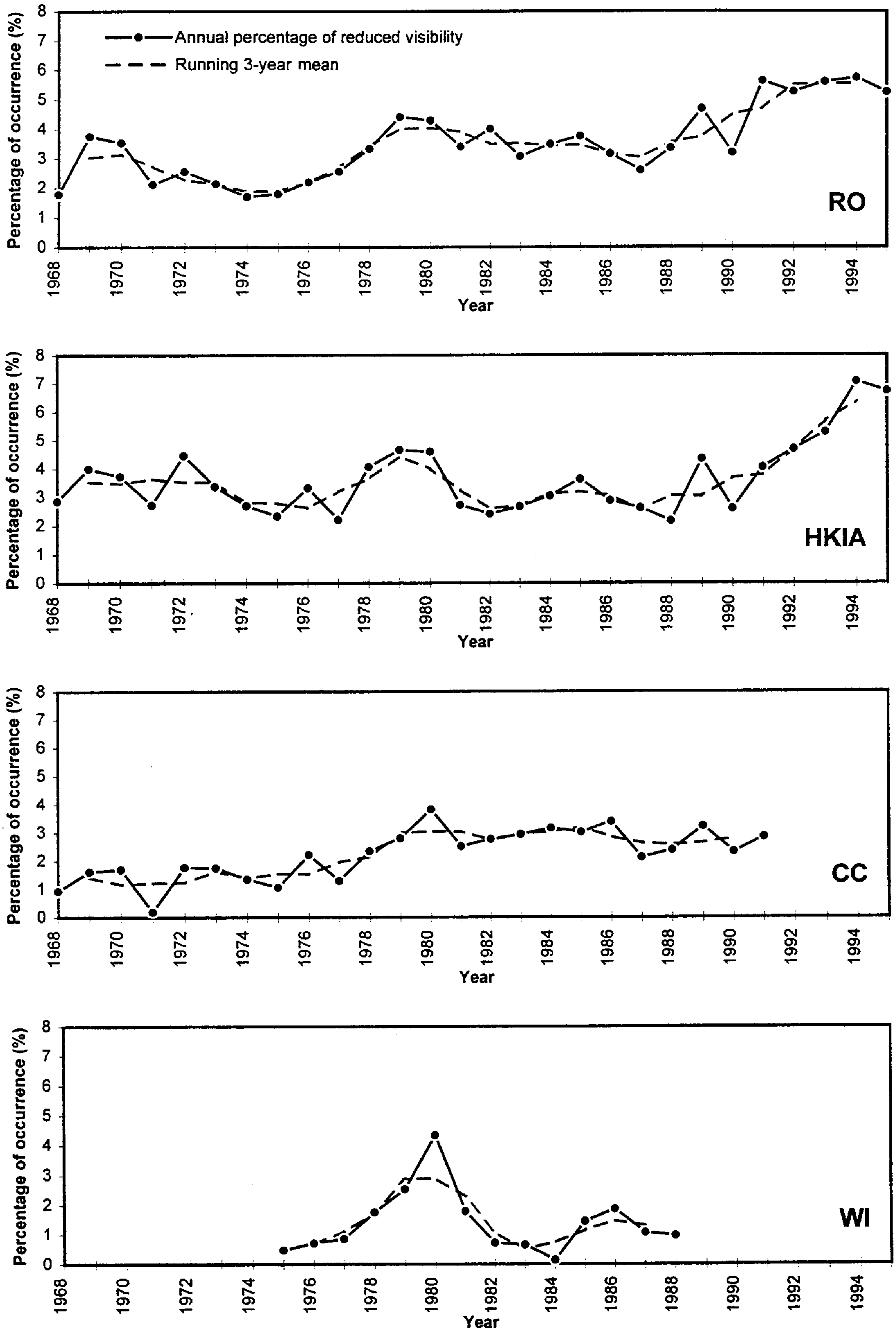



Figure 2 Annual percentage of reduced visibility (solid line) and their running 3-year mean (dashed line).

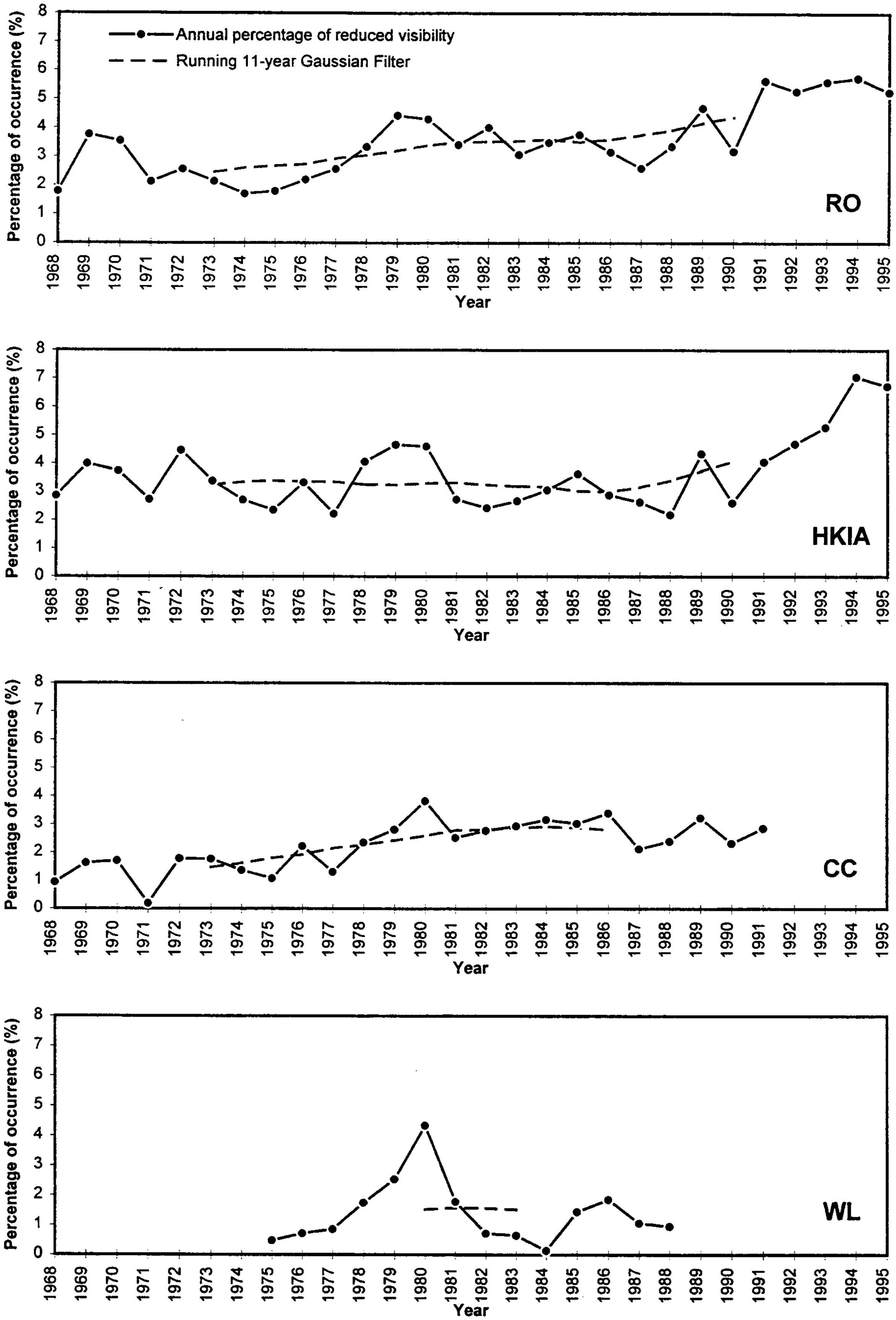



Figure 3 Annual percentage of reduced visibility (solid line) and the running 11-year Gaussian filtered annual percentage of reduced visibility (dashed line).

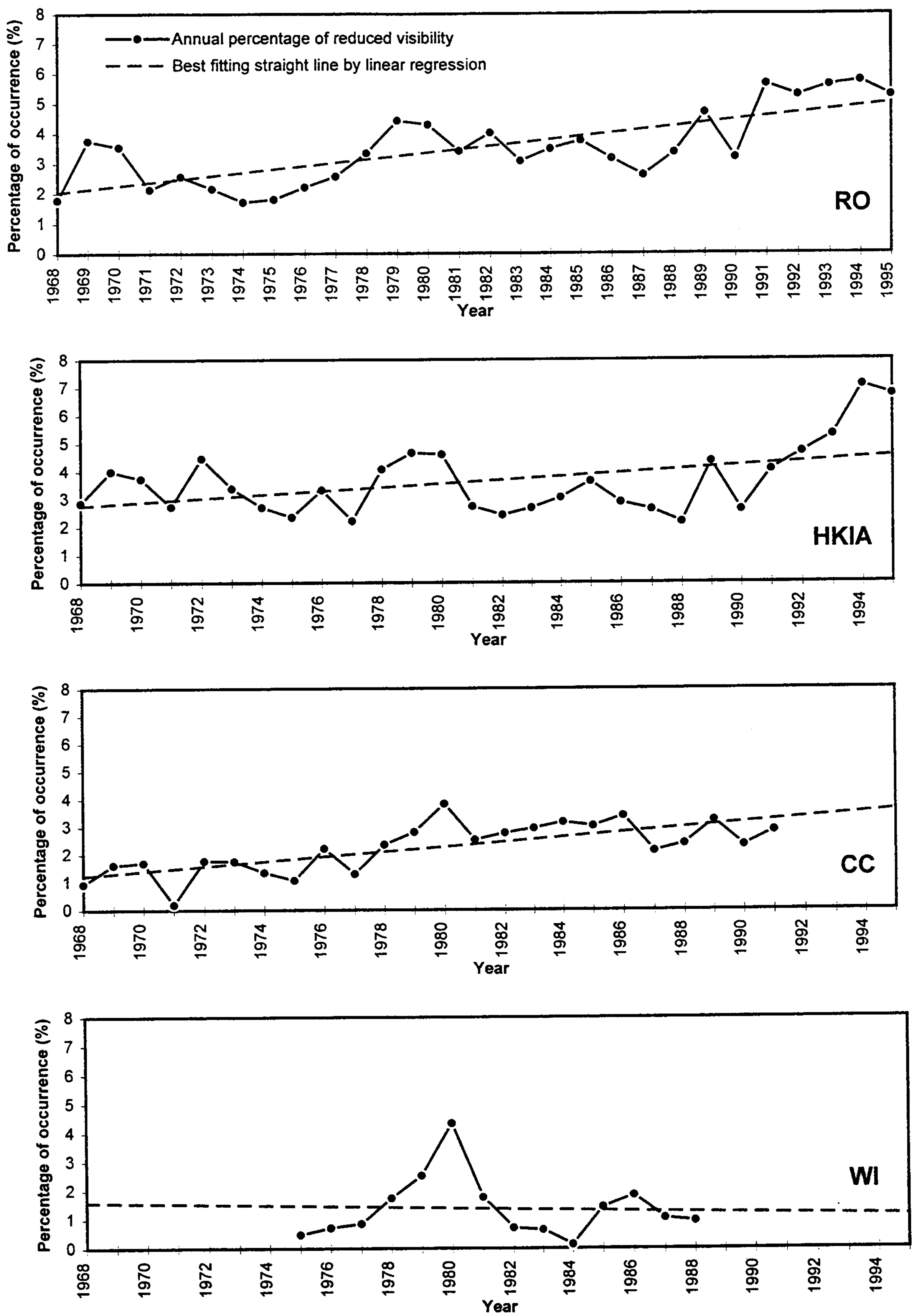



Figure 4(a) Annual percentage of reduced visibility (solid line) and the best fitting straight line by linear regression (dashed line).

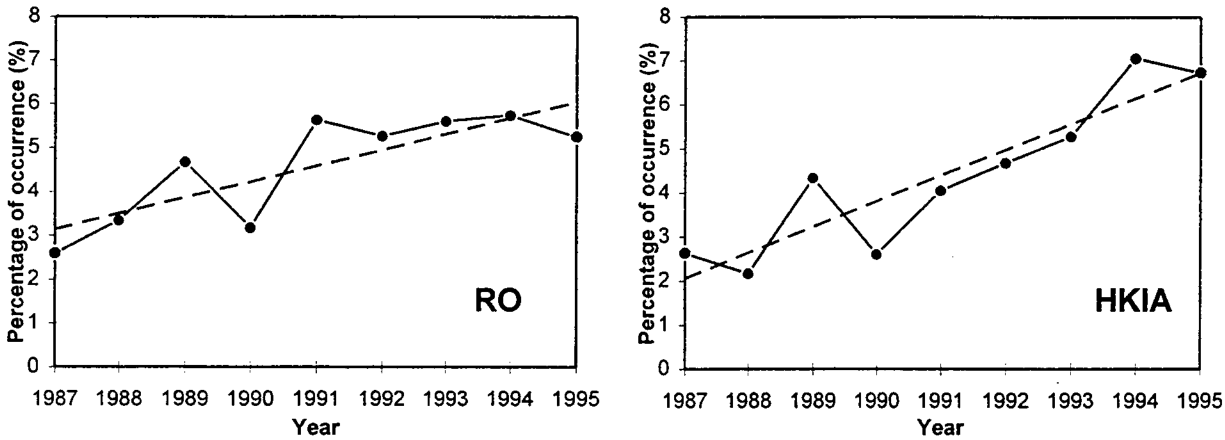



Figure 4 (b)  same as Figure 4(a) except for the period 1987 to 1995 at RO and HKIA.

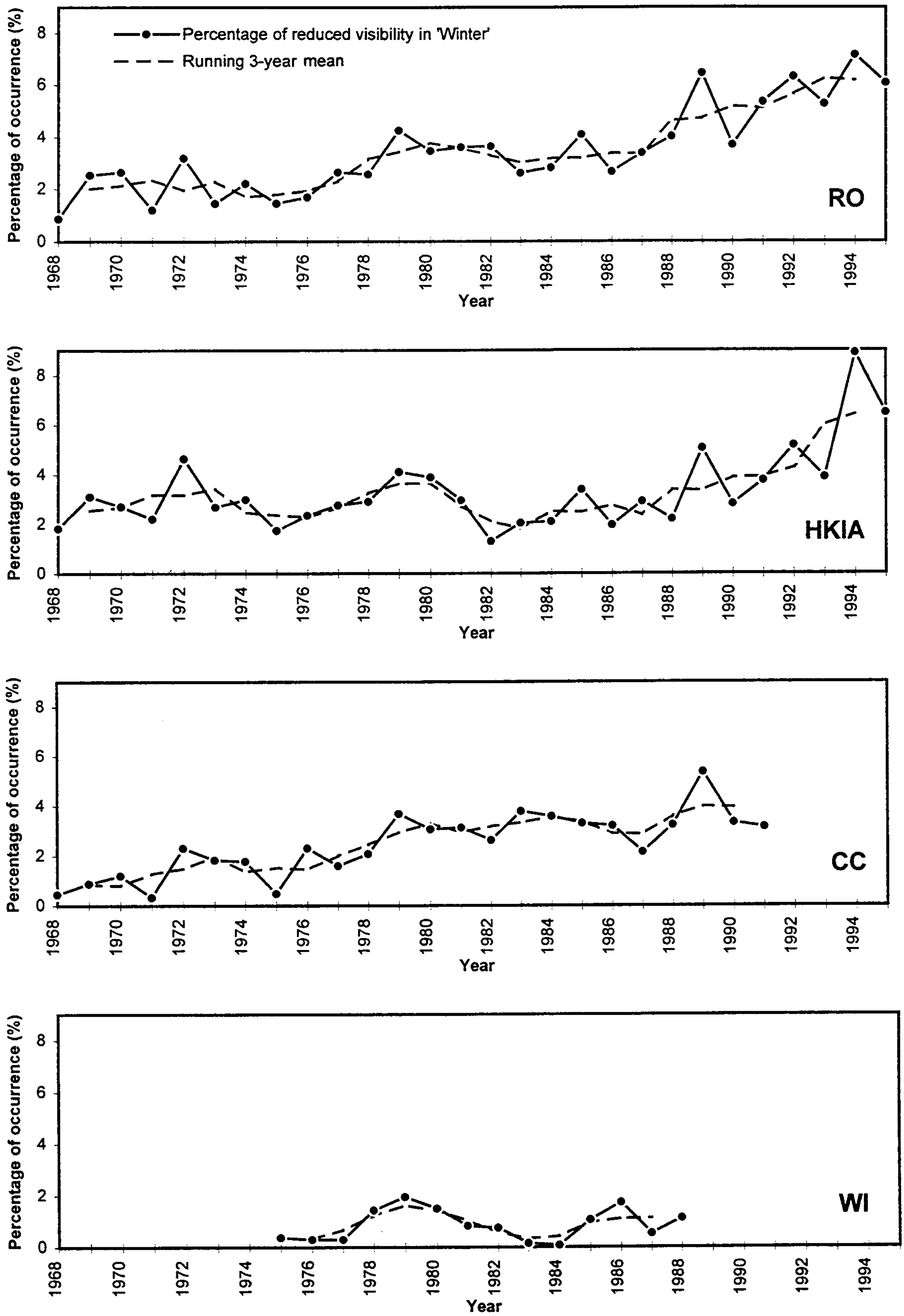



Figure 5 Percentage of reduced visibility in "winter" (solid line) and their running 3-year mean (dashed line).

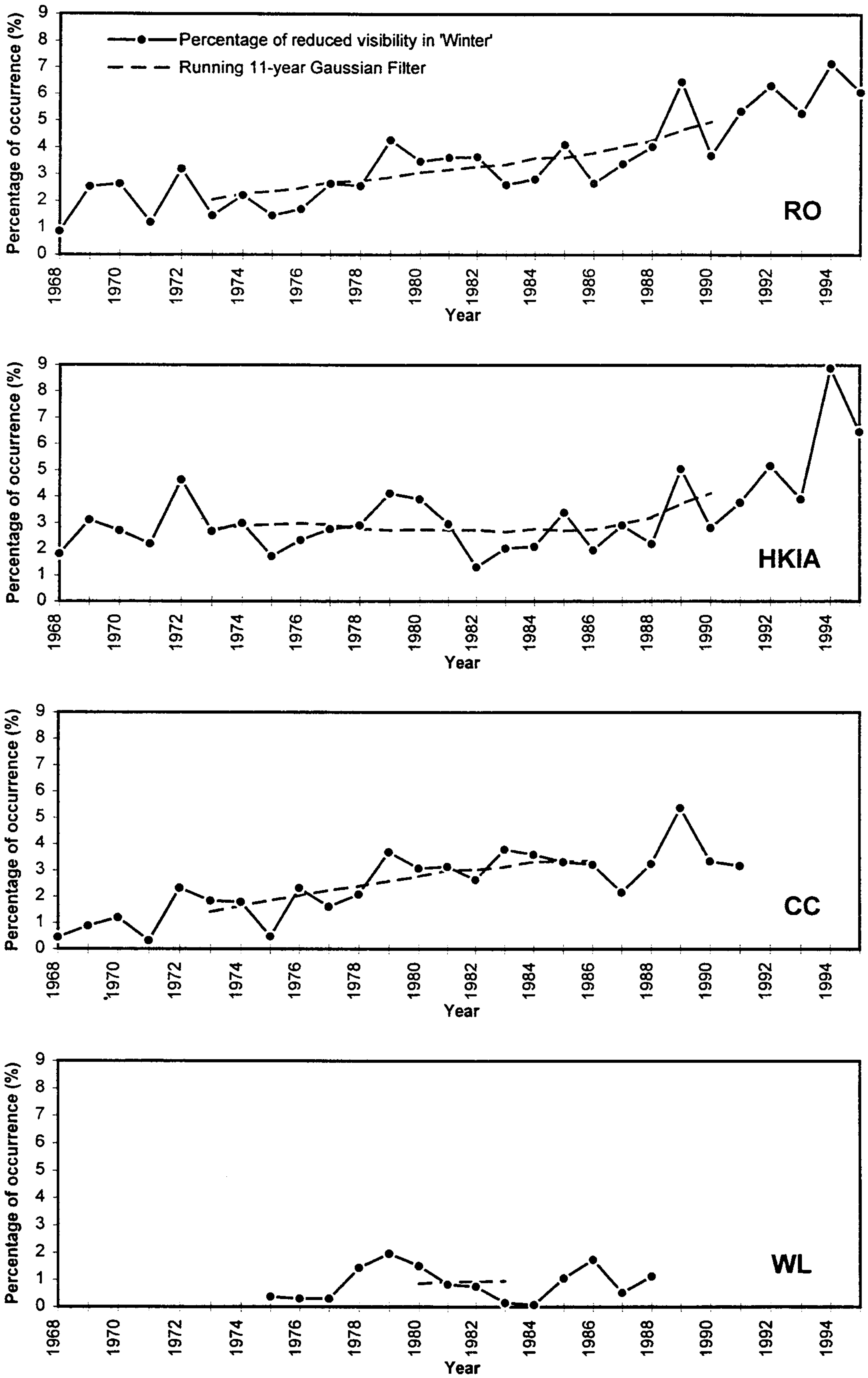



Figure 6 Percentage of reduced visibility in "winter" (solid line) and their running 11-year Gaussian filtered values (dashed line).

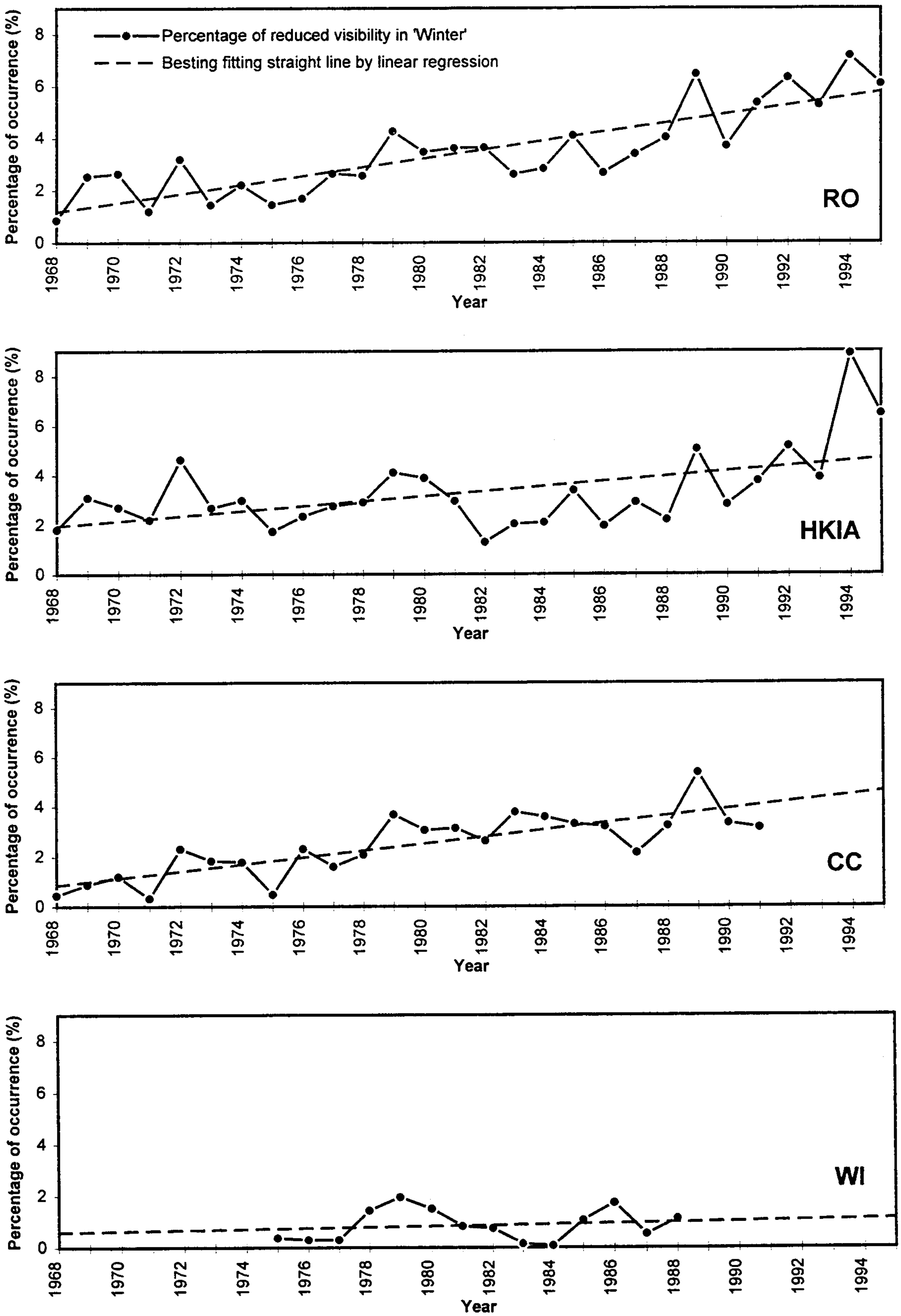



Figure 7 Percentage of reduced visibility in "winter" (solid line) and the best fitting straight line by linear regression (dashed line).

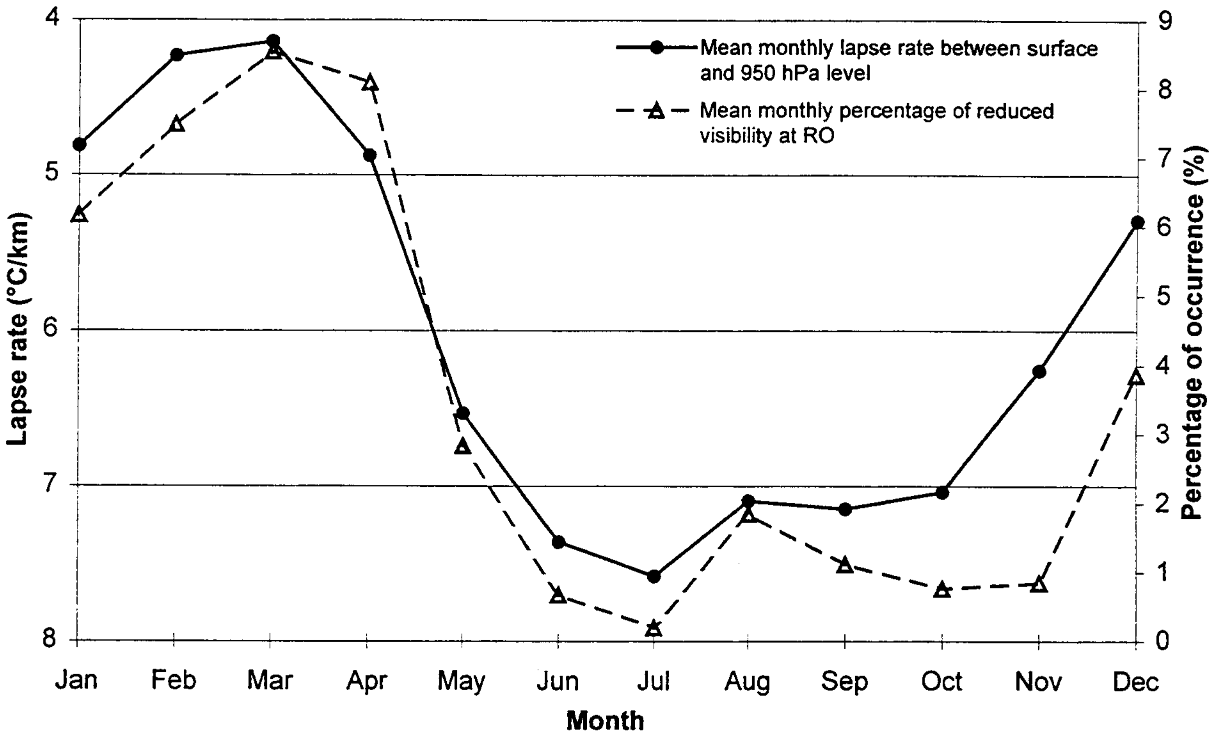



Figure 8 Variation in monthly percentage of reduced visibility at RO and mean monthly lapse rate between surface and 950 hPa level.

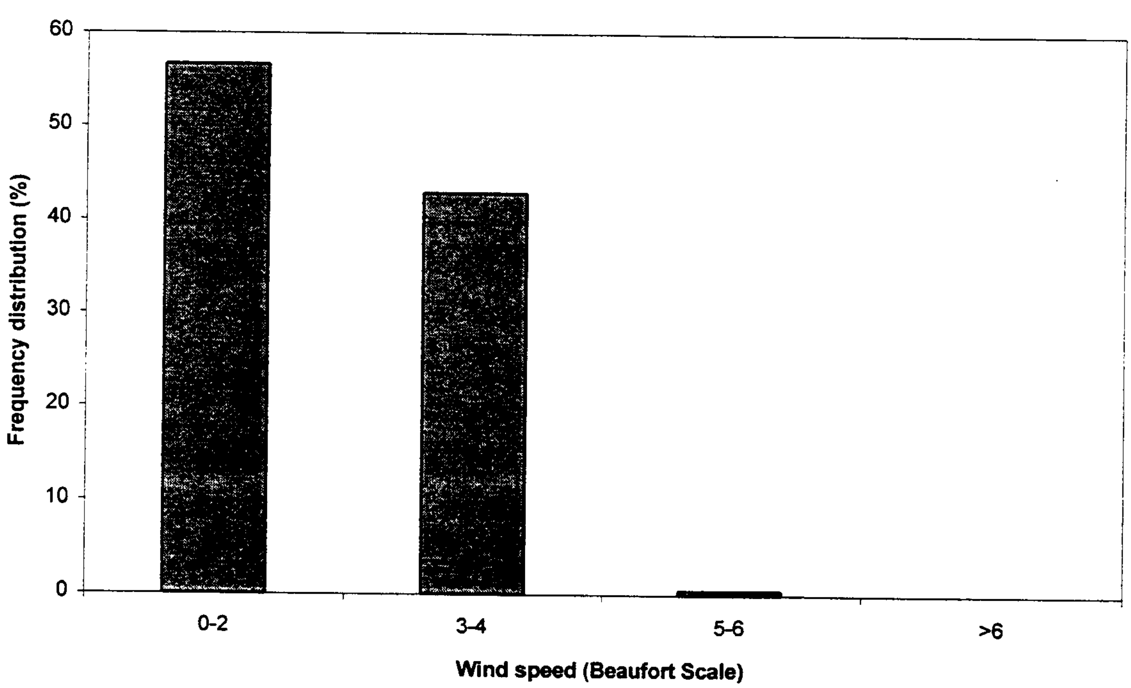



Figure 9 Frequency distribution of reduced visibility at different wind speeds at RO.

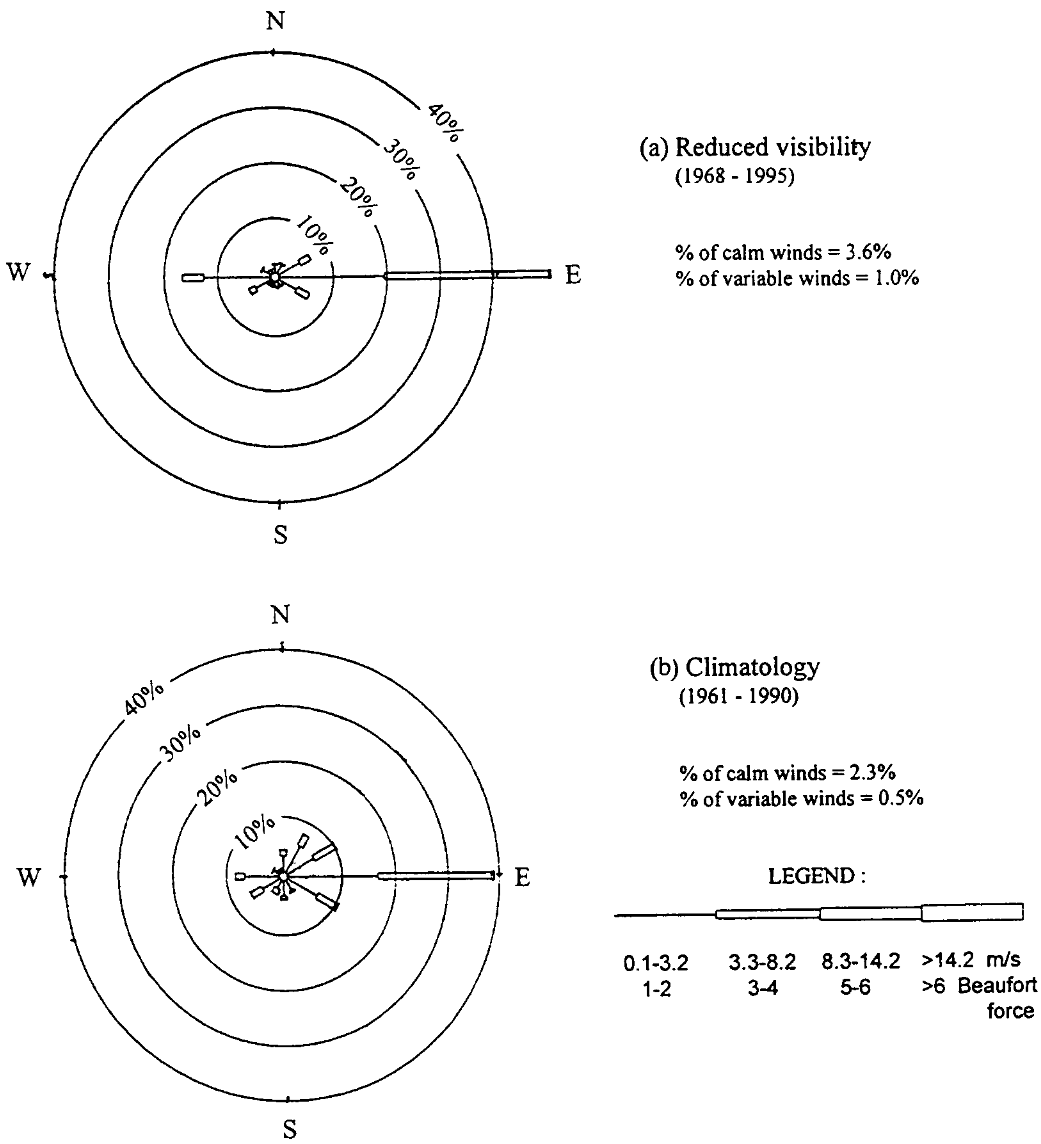



Figure 10 (a) Wind rose for reduced visibility at RO from 1968 to 1995.
(b) Climatological wind rose for RO from 1961-1990.

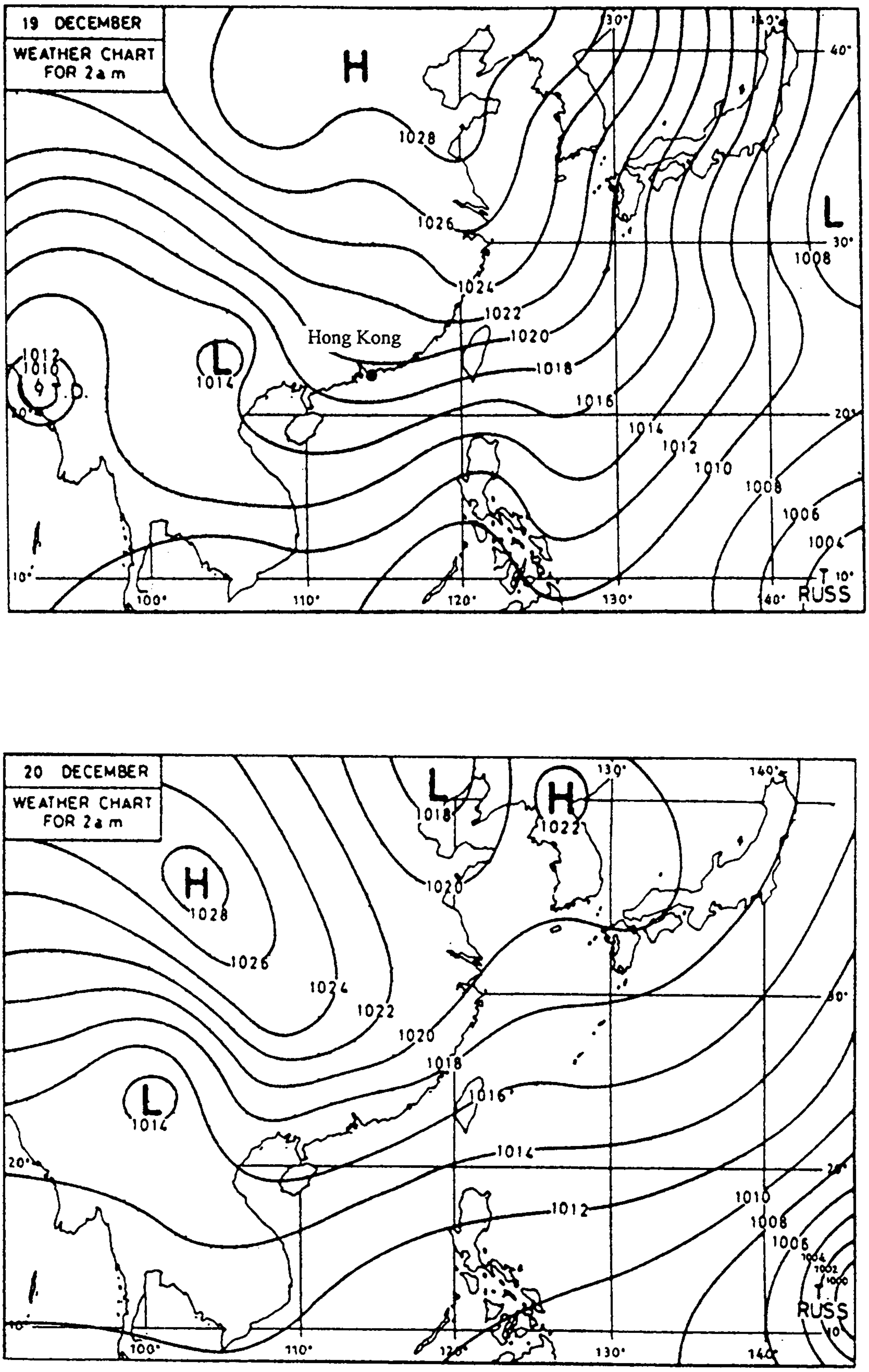
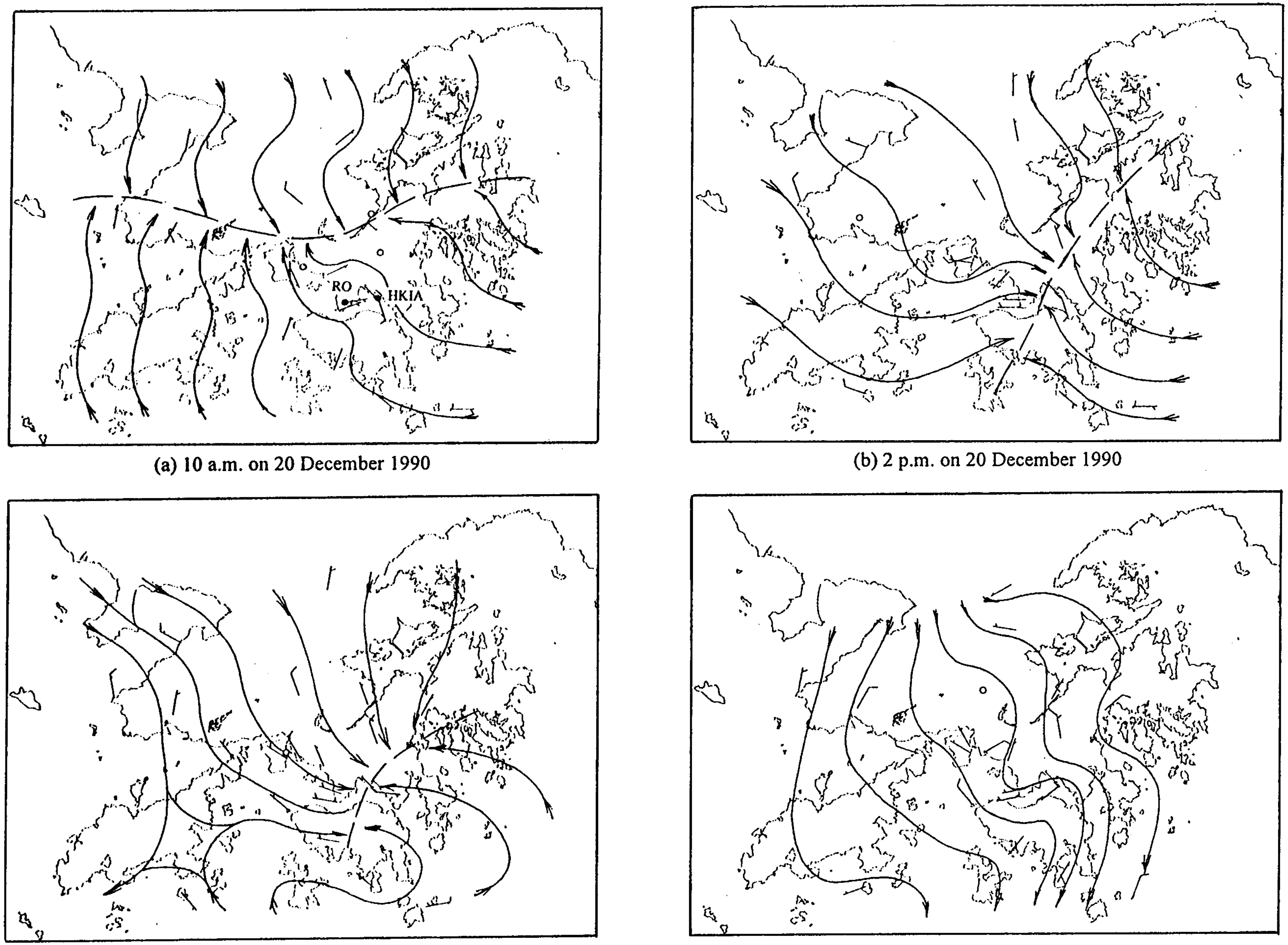



Figure 11 Synoptic weather map for 2 a.m. on 19 and 20 December 1990.



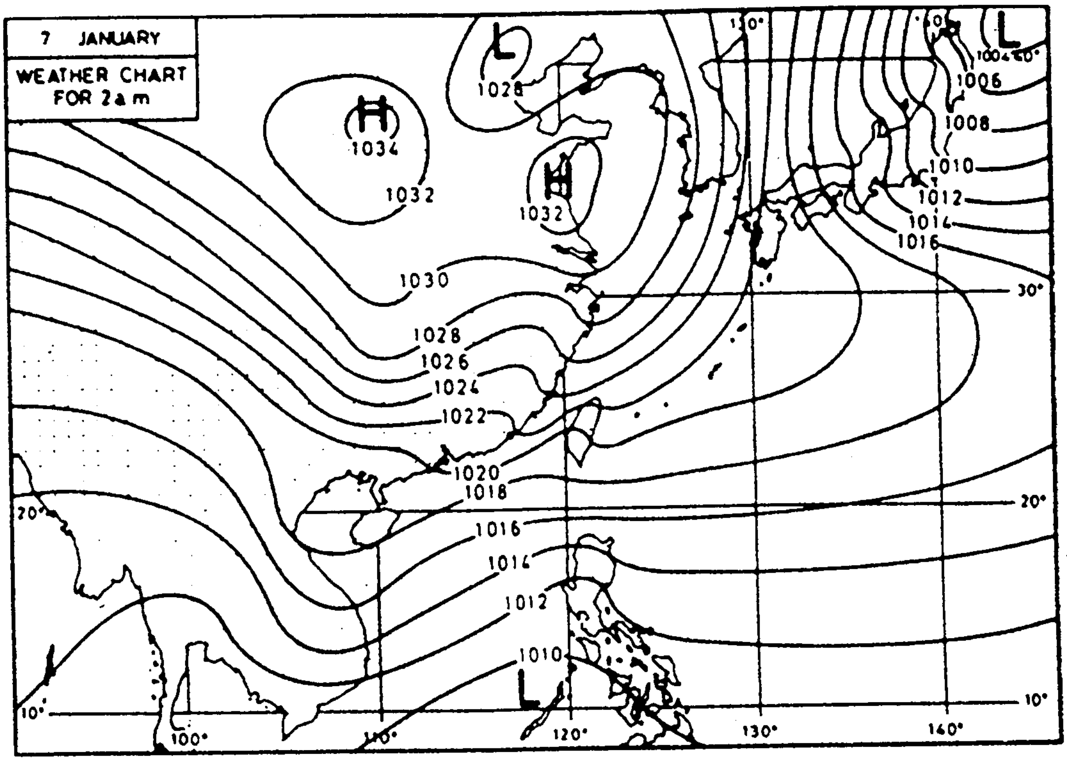

(a) 10 a.m. on 20 December 1990

(b) 2 p.m. on 20 December 1990

(c) 6 p.m. on 20 December 1990

(d) 2 a.m. on 21 December 1990

Figure 12 Wind flow over Hong Kong (a) at 10 a.m. on 20 December 1990, (b) at 2 p.m. on 20 December 1990, (c) at 6 p.m. on 20 December 1990 and (d) at 2 a.m. on 21 December 1990.



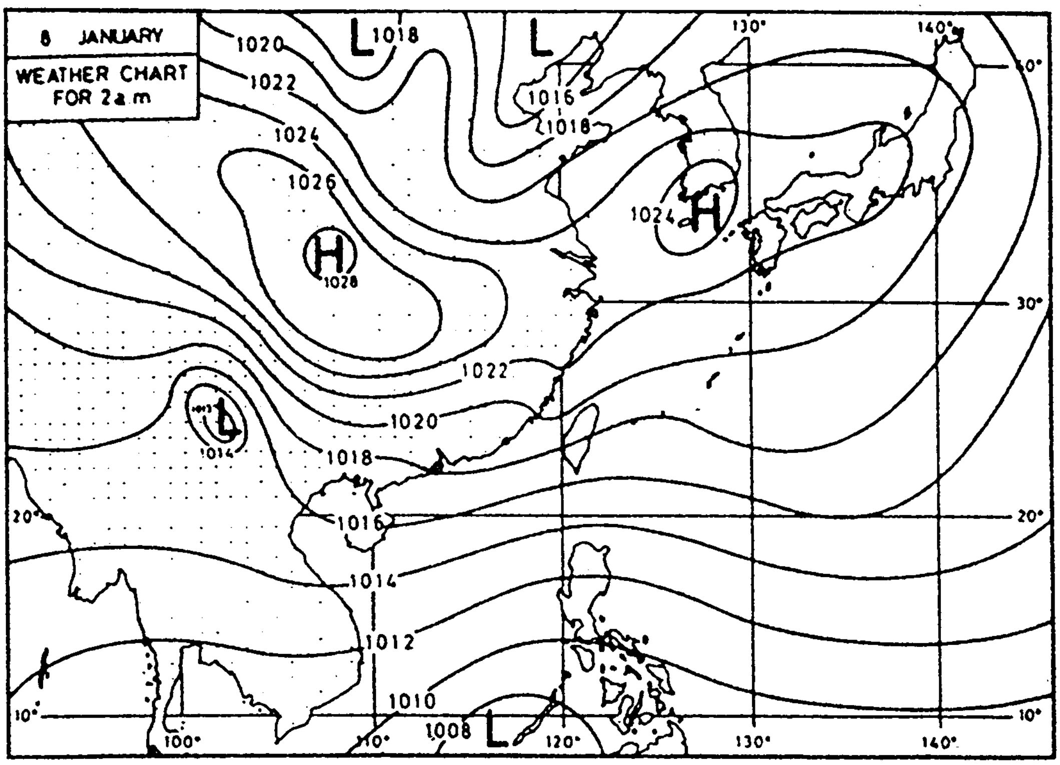
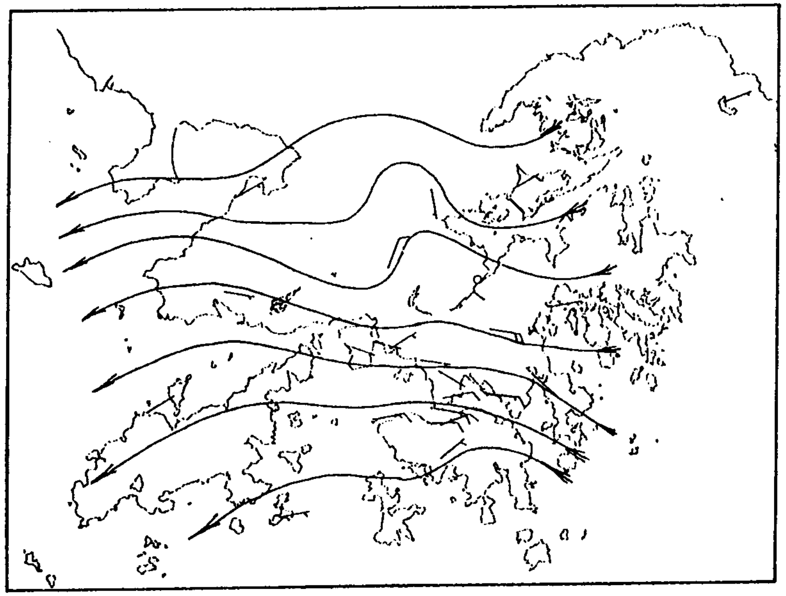
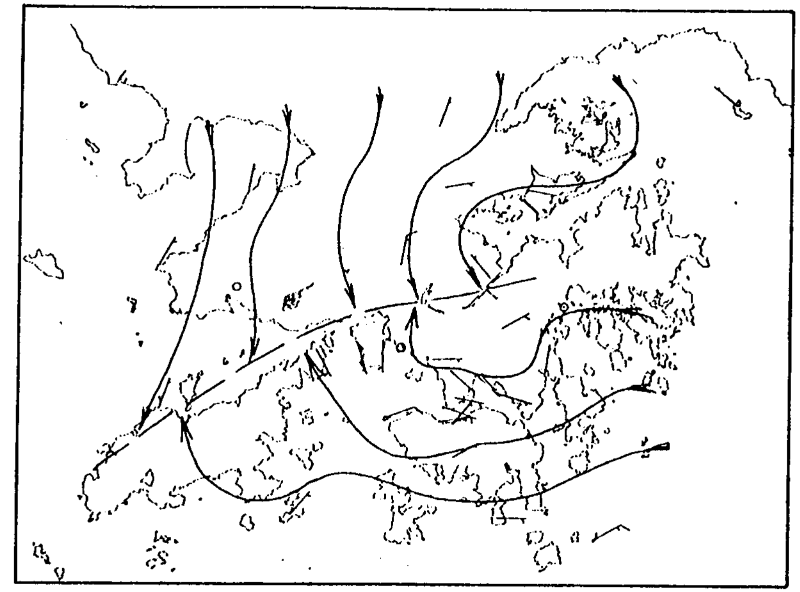



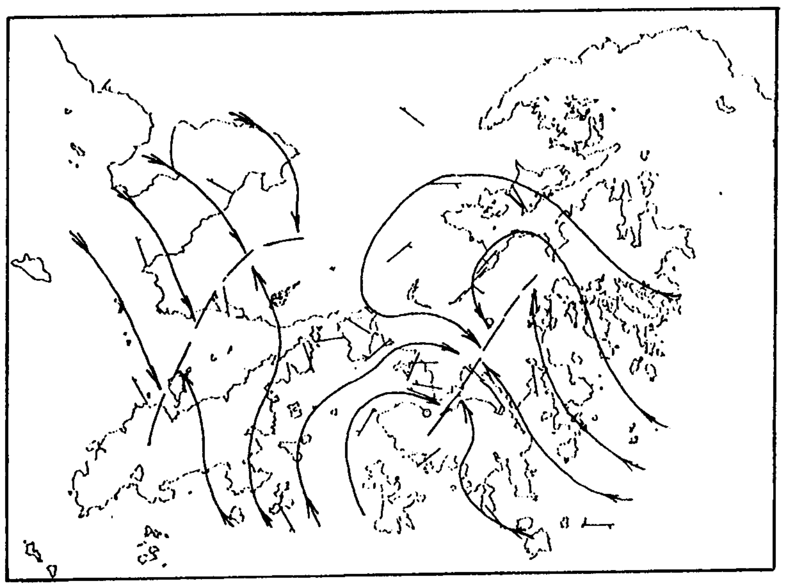

Figure 13 Synoptic weather map for 2 a.m. on 7 and 8 January 1994.



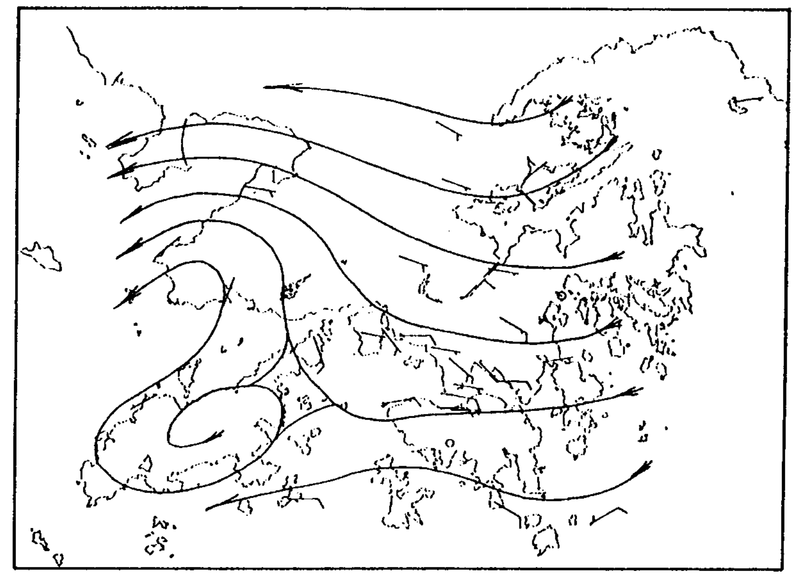
(a) midnight early on 8 January 1994



(b) 10 a.m. on 8 January 1994



(c) 1 p.m. on 8 January 1994



(d) 8 p.m. on 9 January 1994

Figure 14 Wind flow over Hong Kong (a) at midnight early on 8 January 1994, (b) at 10 a.m. on 8 January 1994, (c) at 1 p.m. on 8 January 1994 and (d) at 8 p.m. on 9 January 1994.

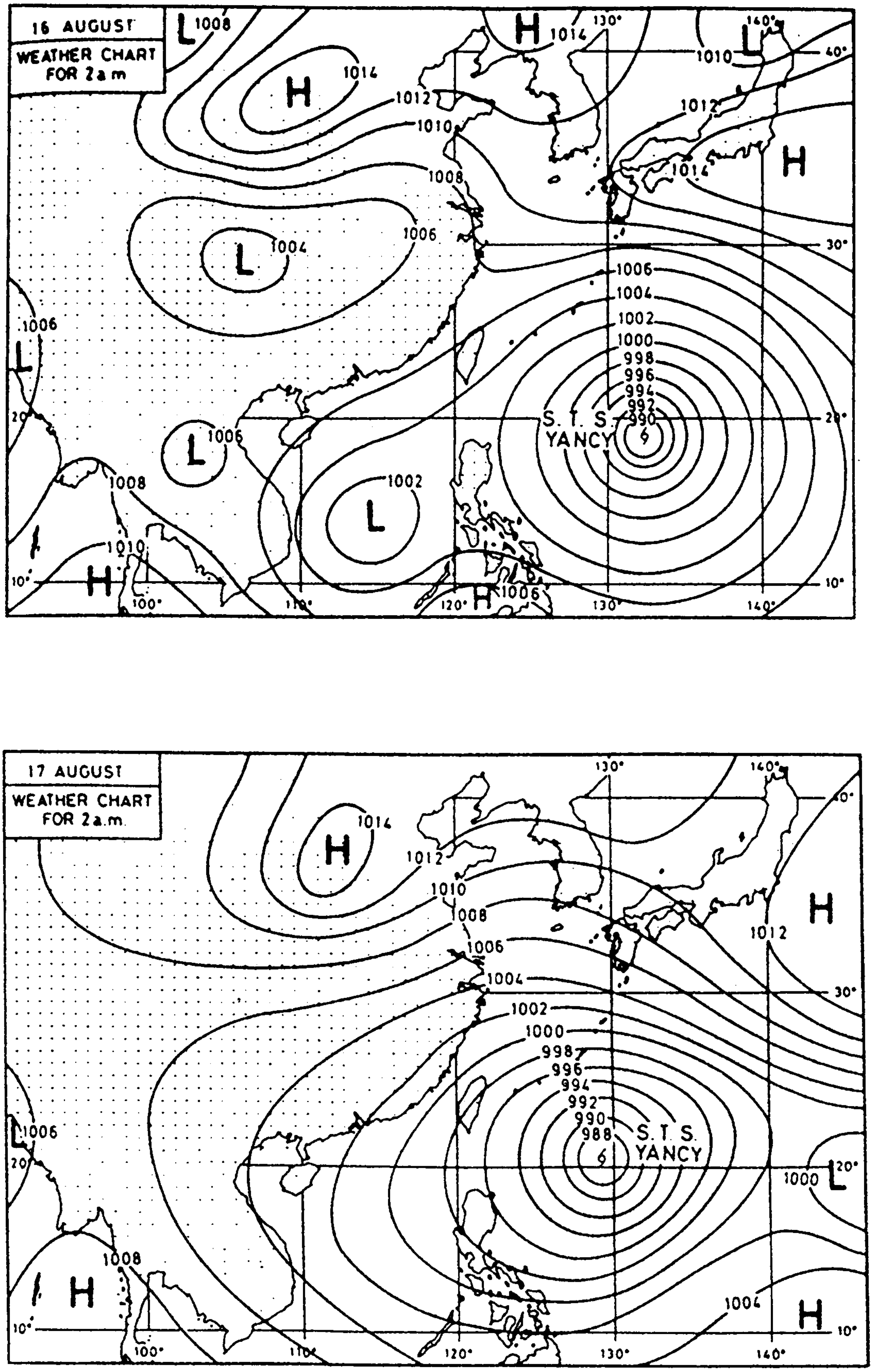
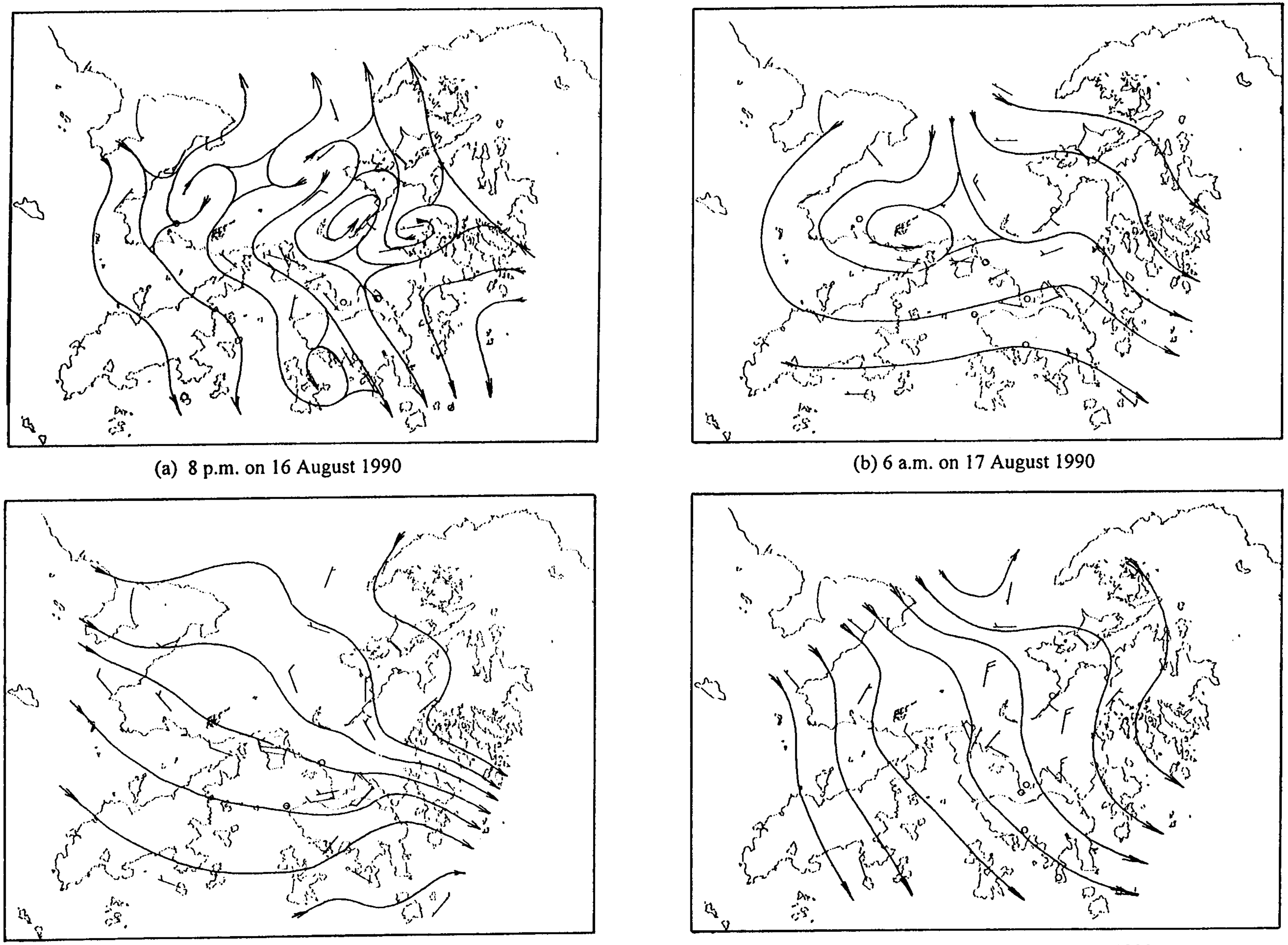



Figure 15 Synoptic weather map for 2 a.m. on 16 and 17 August 1990.



(a) 8 p.m. on 16 August 1990

(b) 6 a.m. on 17 August 1990

(c) 4 p.m. on 17 August 1990

(d) midnight late on 17 August 1990

Figure 16 Wind flow over Hong Kong (a) at 8 p.m. on 16 August 1990, (b) at 6 a.m. on 17 August 1990, (c) 4 p.m. on 17 August 1990 and (d) at midnight late on 17 August 1990.

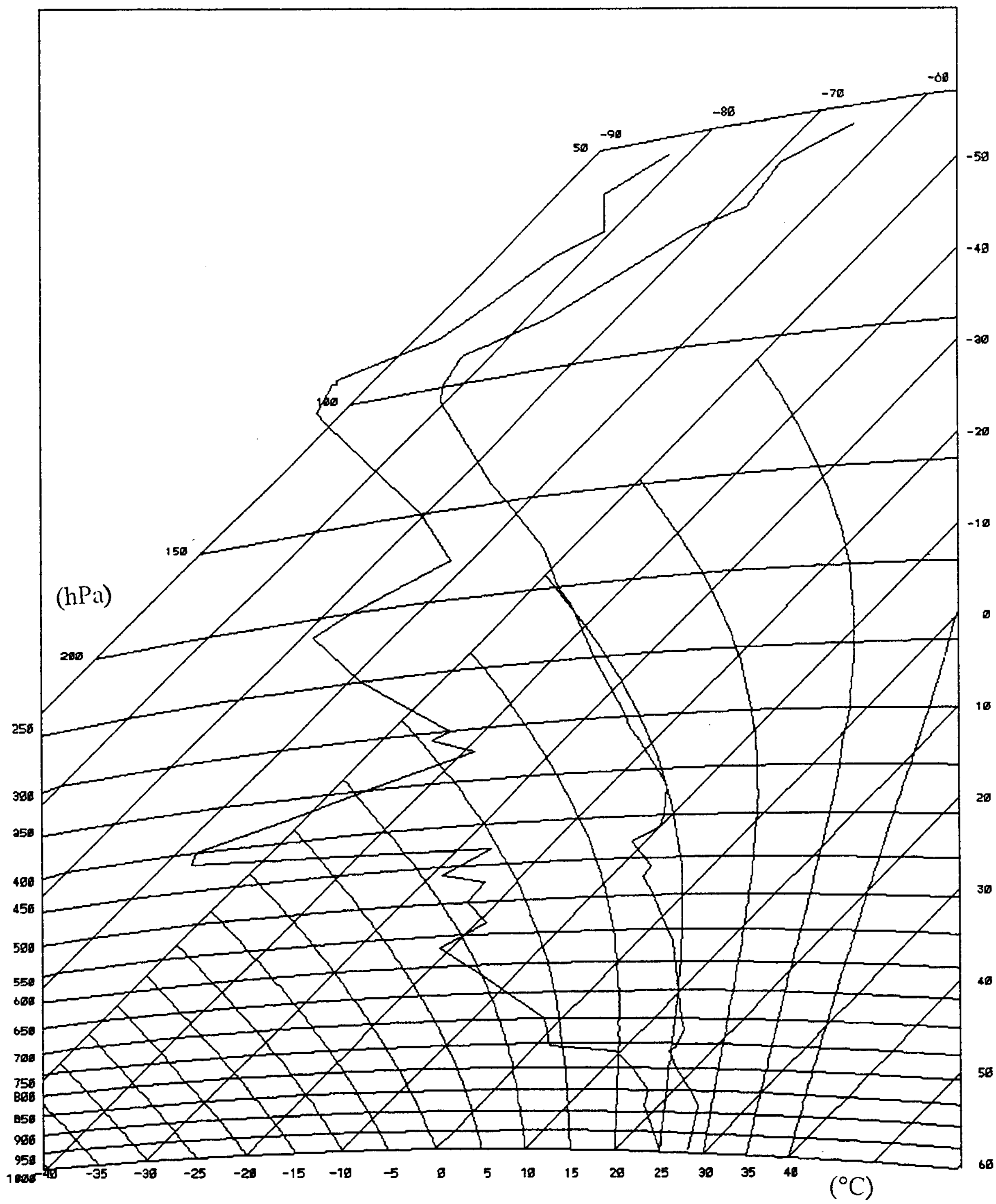



Figure 17        Tephigram for Hong Kong at 8 a.m. on 17 August 1990.