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A COMPARISON OF GEOPOTENTIAL HEIGHTS MEASURED BY RADIOSONDES USED IN HONG KONG AND IN CHINA

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SUMMARY

The geopotential heights measured by radiosondes used in Hong Kong and China were examined using synoptic data available from the Global Telecommunication System. Three years of data (1976-78) were analysed.

The systematic difference between radiosondes used in Hong Kong and Guangzhou was determined. Geostrophic balance was used to estimate the true geopotential difference between the two stations. The magnitude of possible errors due to geostrophic departure was estimated. On the average, Hong Kong reports are 4 geopotential metres (gpm) higher at 850 mbar and 500 mbar, 3 gpm lower at 200 mbar for 00 GMT ascents and 7 gpm lower at 200 mbar for 12 GMT ascents. There are also seasonal variations in the systematic differences at different levels.

The single station analysis approach was used to estimate the random error associated with reported geopotential heights. Conservative estimates of the random errors for Hong Kong and Guangzhou ascents are:

	200 mbar	500 mbar	850 mbar
Hong Kong	36 gpm	17 gpm	5.8 gpm
Guangzhou	21 gpm	9 gpm	4.8 gpm

The mean night-day differences at 850 mbar and 200 mbar have opposite signs while those at 500 mbar are relatively small in magnitude. The thickness of the 850 - 200 mbar layer is greater at 12 GMT than that at 00 GMT. In general, night-day differences are less positive when the solar elevation at 00 GMT is higher. However, other factors probably also affect the night-day difference.

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1. INTRODUCTION

As part of the World Weather Watch programme, regular radiosonde ascents are made daily from a network of stations all over the world. Several types of radiosondes are in use by various meteorological services. Owing to differences in the design and fabrication of these radiosondes and differences in the conditions under which these radionsondes are operated, the data obtained from radiosondes of neighbouring areas might not be compatible. It is of considerable interest to operational meteorologists that something should be known about the differences in the characteristics of radiosondes released from various stations. This information is necessary in order that upper-air charts could be analysed in a meaningful way.

A knowledge of the compatibility of data obtained using different radiosondes is important to research workers also. In studies such as those reported in Frank (1977) which involve the technique of compositing data from a diversity of sources, the need to adjust the data to a common reference radiosonde is fairly obvious. Bell and Tsui (1973), for example, took great care to adjust the ascent data to form a homogeneous set of data before computing the mean soundings in typhoons.

The importance of studies on the compatibility of upper-air data is recognised by the Commission for Instruments and Methods of Observation (Resolution 7, CIMO-VI, see: World Meteorological Organisation, 1977). Special experiments have been organised under the auspices of the World Meteorological Organisation to compare radiosondes used by several Members.

Hong Kong is situated on the southern coast of China (see Figure 1). Twice daily ascents have been made using Vaisala type RS-18 radiosondes since 18 November 1974. The type of radiosondes used by Chinese upper-air stations is not known. It is therefore necessary to study how the data provided by Chinese stations may be compared with those of Hong Kong. This comparison may be of interest to other users of Vaisala sondes who may wish to relate their soundings to those made in China. Some of the techniques to compare radiosondes are briefly reviewed in the following section. The results of a comparison of geopotential heights measured by radiosondes used in China and in Hong Kong are then reported.

2. METHODS OF RADIOSONDE COMPARISON

(a) Definition of errors

On comparing different radiosondes, we are interested in several parameters. Hooper (1975) provided several definitions:

(i) systematic error: the departure from truth of the data mean of a population of radiosondes made to a common design;

(ii) systematic difference: the difference between the systematic errors of two radiosonde designs or populations;

(iii) sonde error: the scatter of the averaged data of individual sondes about their population mean;

(iv) random error: the scatter of individual values from a single radiosonde about their own averages.

The systematic error of a radiosonde design cannot be determined because there is currently no technique which can measure "truth" to a greater precision than radiosondes. However, it is possible to determine the difference in systematic errors of two radiosonde design because no knowledge of "truth" is required.

Sonde errors arise from variability in the radiosondes from the manufacturing process. It is thought that this is the dominant variability in radiosonde ascent data (Hooper, 1975). Sonde errors tend to vary in a regular manner with altitude. Ramdom errors are related to other factors e.g. operational conditions and tend to be unrelated to altitude. From the practical point of view, both errors contribute to variability in radiosonde ascent data and could not be easily distinguished from each other in synoptic data. In the following sections, "random error" will be used to represent the total effects of sonde and random errors defined above.

There is another source of error arising from the use of the TEMP code (World Meteorological Organization, 1974) when radiosonde ascent data are transmitted through the Global Telecommunication System (GTS). The geopotential is reported in whole geopotential metres up to, but not including, 500 mbar and in tens of geopotential metres at 500 mbar and above. The maximum errors are therefore $\pm$ 0.5 and $\pm$ 5 geopotential metres for levels below and above 500 mbar respectively. Assuming a rectangular probability distribution, the standard deviations of this truncation error are 0.29 and 2.9 geopotential metres for low and high levels respectively. This error is always present whenever data received via the GTS are used for any computation.

(b) Special flights

An obvious way of comparing radiosondes is to fly them together in an ascent. This was carried out by Apps (1971) when Hong Kong switched over from the Kew Mark IIB to the Vaisala RS13. Special flights of this nature were also organised by the World Meteorological Organization in 1968, 1969, 1972 and 1973. The results are summarised in Hooper (1975). While simple in principle, this way of direct comparison by "twin flights" is not free from technical difficulties e.g. radio-frequency interaction. An alternative of releasing radiosondes successively close together in time has also been tried e.g. during the Bracknell comparison tests in 1972. This method avoids the problem of radio-frequency interaction but has the disadvantage that the two radiosondes do not sample the same air.

Because of the great efforts required to organise special twin flights, this kind of comparison tests could only be carried out for a small number of cases covering periods of a few days each time. Because of large variability of the data and small sample size, only fairly large mean differences between radiosondes could be detected by such twin-flight exercises. When commenting on the comparison tests that had taken place, Hooper (1975) expressed the view that "the variability of the data is such that a repeat of the comparisons could well give substantially different results". In order to improve the resolution of the comparison, a large number of flights are required. However, this is very expensive to implement.

(c) Methods using routine synoptic data

Hawson and Caton (1961) devised a synoptic method for the international comparison of geopotential observations. The geostrophic balance is used to construct "relative contour charts" from wind observations for selected cases when geopotential gradient is fairly slack. By adopting the mean of eight radiosonde stations in the United Kingdom as a standard, geopotential heights at other stations could then be deduced and compared with observed ones. Systematic differences among radiosondes could therefore be deduced. Hooper (1975) described the use of automated analysis produced by computer to replace the manual analysis used by Hawson and Caton. This approach was later adopted by Spackman (1978) in analysing the compatibility and performance of radiosonde measurements of geopotential heights at 100 mbar for 1975-76. These methods based on chart analysis have the advantage that they could be carried out using conventional synoptic data which are readily available through the Global Telecommunication System (GTS) on a routine basis.

As mentioned earlier, twin-flight exercises gave some idea of the variability of radiosonde data. However, the results pertained to only very small samples. Routine radiosonde soundings could also be used to infer the variability of the data. Hooper (1975) described the use of the statistics of day-night differences (or 00 GMT - 12 GMT differences) to assess radiosonde variability. No absolute determination of the variability could be achieved because non-linearity of atmospheric changes also contributed to the results.

3. SYSTEMATIC DIFFERENCE

(a) Method of analysis

The method of Hawson and Caton (1961) requires the manual analysis of geopotential fields. However, since Hong Kong (45004) is situated only about 130 kilometres southeast of Guangzhou (Canton, 59287), a simpler procedure was therefore adopted to take advantage of this. In the following analysis, the mean differences of geopotential heights reported by Hong Kong and Guangzhou computed for selected periods were compared with those deduced from mean winds observed at Hong Kong. Let δ stand for the systematic difference between the radiosondes used in Hong Kong and Guangzhou, then:

$$\begin{aligned}\delta &= (\text{systematic error})_{HK} - (\text{systematic error})_{GZ} \\ &= \overline{Z_{HK}(\text{obs}) - Z_{HK}(\text{true})} - \overline{Z_{GZ}(\text{obs}) - Z_{GZ}(\text{true})} \\ &= \overline{Z_{HK}(\text{obs}) - Z_{GZ}(\text{obs})} - \overline{Z_{HK}(\text{true}) - Z_{GZ}(\text{true})} \\ &= D_o - D_t\end{aligned}$$

The suffices HK and GZ refer to Hong Kong and Guangzhou respectively while (obs) and (true) refer to observed and true values respectively. The overbar indicates an average value for some selected period.

The ratio of the acceleration to the Coriolis force in the horizontal equation of motion typically has a magnitude of about 0.1 (Haltiner, 1971) in the mid-latitudes. It is probably slightly larger at low latitudes. However, because we are taking averages over periods of months, the resultant contribution of the acceleration term to the equation of motion should be substantially reduced. The geostrophic balance equation was therefore used to estimate the true difference (D_t). The equation used is given below:

$$\overline{u} = \left(\frac{g}{f}\right)\left(\frac{D_t}{\Delta s}\right)$$

where $\overline{u}$ = mean wind component observed at Hong Kong perpendicular to the line joing Hong Kong and Guangzhou (positive towards bearing 044^o),

g = acceleration due to gravity (= 9.8 m s^{-2}),

f = Coriolis parameter (= $5.52 \times 10^{-5} \text{ s}^{-1}$ at 22.3^oN),

Δs = distance between Hong Kong and Guangzhou (132 km).

Monthly mean values of $\overline{u}$ were derived from data given in the series Meteorological Results Part II published by the Royal Observatory.

The observed difference (D_o) was computed from data obtained from the GTS. Only data satisfying the following criteria were included in the sample:

(i) Both height values were within a specified range. The range was fixed to include all reasonable values after manually examining a listing of the reported heights.

(ii) The computed difference was within a specified range. The upper and lower bounds of the range are:

$$\text{upper bound} = \left(\frac{f.\Delta s}{g}\right)\bar{u}_{max} + 2\sqrt{\sigma_D(GZ)^2 + \sigma_D(HK)^2}$$

$$\text{lower bound} = \left(\frac{f.\Delta s}{g}\right)\bar{u}_{min} - 2\sqrt{\sigma_D(GZ)^2 + \sigma_D(HK)^2}$$

$\bar{u}_{max}$ and $\bar{u}_{min}$ are respectively the maximum and minimum climatological monthly mean values of $\bar{u}$ at Hong Kong. These values are obtained from Chin and Lai (1974). The first terms on the right-hand side of the equations are the differences in heights corresponding to geostrophic winds of $\bar{u}_{max}$ and $\bar{u}_{min}$. The meaning and value of $\sigma_D(GZ)$ and $\sigma_D(HK)$ are given in section 4.

Monthly mean values of the systematic difference δ were computed for the 200, 500 and 850 mbar levels for the years 1976-1978. The standard error of each monthly δ was estimated from:

$$\begin{array}{l}\text{standard error of}\\ \text{monthly mean } \delta\end{array} = \frac{\text{standard deviation of } \delta \text{ values}}{\sqrt{\text{number of data in sample}}}$$

The annual mean δ values were also computed. The standard error of each annual mean δ value was estimated from:

$$\begin{array}{l}\text{standard error of}\\ \text{yearly mean } \delta\end{array} = \frac{\sqrt{\sum_{\text{month}} (\text{monthly standard error})^2}}{12}$$

(b) Yearly mean systematic difference

The annual values of systematic difference between Hong Kong and Guangzhou at 200, 500 and 850 mbar levels are presented in Tables 1 to 3.

At the 200 mbar level, the 3-year mean systematic differences are -3.1 gpm and -6.7 gpm for 00Z and 12Z ascents respectively. These figures could be shown to be significantly different from zero as follows. A pessimistic estimate of the root mean square vector error of individual 200 mbar radar wind reports is 7 knots (Bannon, 1948). The standard error of an annual mean wind is therefore of the order $7/\sqrt{365} \sim 0.4$ knots.

Oort and Rasmusson (1971) provide some data on mean geostrophic departure of the mean zonal wind at different latitudes. Their values for the yearly mean departure at 200, 500 and 850 mbar levels at $22\frac{1}{2}^{\circ}$N are -1.3 m/s, -1.1 m/s and -0.3 m/s respectively. There is no data on the geostrophic departure of the meridional wind component since Oort and Rasmusson considered only zonal means. If we take the geostrophic departure of the zonal wind as a rough estimate of mean $\overline{U} - \overline{U}_g$, then the corresponding Δ values are -1.0 gpm, -0.8 gpm and -0.2 gpm. There is no straightforward way to adjust the results given in Tables 1 to 3 to account for geostrophic departure because only information on the zonal wind component is available. We only note that the estimated Δ values above are rather small compared with the computed δ values, especially at the lower levels.

Bearing in mind that geostrophic departure to some extent affects the absolute values of the computed systematic differences, the results of this comparison suggest that, when compared with Chinese radiosondes, the following systematic differences exist:

Level	Hong Kong tends to report
200 mbar	low by about 3 gpm at 00 GMT, 7 gpm at 12 GMT
500	high by about 4 gpm at 00 GMT and 12 GMT
850	high by about 4 gpm at 00 GMT and 12 GMT

All the numbers are statistically significant. However, because geopotential heights are reported in tens of gpm for 500 mbar and above, there is probably not much point in applying correction factors which are less than 5 gpm to synoptic data at these levels.

(c) Monthly mean systematic differences

Table 4 shows the annual variation of the systematic difference at the 200 mbar level for 00 GMT and 12 GMT ascents based the data of 1976-78. The geostrophic departure values given in Oort and Rasmusson (1971) are used to indicate roughly the possible difference between the true systematic difference and the computed value of δ as explained in the last section and is denoted by Δ in the table. The table indicates that during the winter months (November to February), δ was positive and was of the order of 5 gpm. In the summer months (April to October), δ was negative and its magnitude was of the order of 10-15 gpm. March is a transition month and there appears to be a substantial difference between 00 GMT and 12 GMT ascents. However, it must be noted that the uncertainty in these estimates as measured by the values of Δ is rather large for the winter months.

Table 5 shows the annual variation of the systematic differences at the 500 mbar and 850 mbar levels based on the data of 1976-78. Only 00 GMT data are presented since there is no significant difference between 00 GMT and 12 GMT ascents. At both levels, the uncertainty arising from geostrophic departure is small compared with the range of variation of the monthly systematic differences. The table indicates that at both levels, δ was larger in the winter half-year (October - March) and its magnitude was around 5 - 10 gpm. δ was small in the summer half-year.

(d) Possible dependence on solar elevation

It has been noted earlier that there is a significant difference between the annual mean systematic differences at 200 mbar for 00 GMT and 12 GMT ascents. Since 00 GMT ascents take place in daylight while 12 GMT ascents take place after sunset, it is likely that the differences between monthly systematic differences for 00 GMT and 12 GMT ascents might show some dependence on the solar elevation angle. The data given in Table 4 are plotted in Figure 2. Although there are a few large differences associated with high solar elevation angles, the points in the figure are very scattered. Furthermore, the magnitude of the differences is similar to that of Δ in some of the months so that uncertainty in the values of the differences is fairly large. There is therefore no conclusive evidence that the difference between 00 GMT and 12 GMT ascents depend on the solar elevation angle.

4. Ramdom errors from single station analysis

(a) Method of analysis

The method given in Hooper (1975) was adopted. For each day i, a quantity D_i is defined by:

$$D_i = \tfrac{1}{2}(Z_{12,\,i-1} + Z_{12,\,i}) - Z_{00,\,i}$$

That is, D_i is the difference between the 00 GMT geopotential height and the average of the heights observed 12 hours before and after. If the atmosphere always changes linearly, then D is identically equal to zero, provided no error is involved in measuring the Zs. If the standard deviation of random errors associated with the observation of Z is E, then it can be readily shown that the standard deviation of D is given by:

$$\sigma_D^{\,2} = \frac{3}{2} E^2$$

In reality, the value of σ_D will always contain a contribution from the non-linear variability of the atmosphere. If K^2 stands for the variance of D in the absence of random error, then

$$\sigma_D^{\,2} = K^2 + \frac{3}{2} E^2$$

It is thought that K varies smoothly in space. Differences in the value of E among stations could be detected in the form of abrupt changes in the spatial variation of σ_D. In the present analysis, monthly values of σ_D are calculated for the 200, 500 and 850 mbar levels for the years 1976-1978. An estimate of the standard error of σ_D is calculated from:

$$S_\sigma = \sqrt{\frac{1}{2n}}\,\sigma_D\ ,$$

where n = sample size (Davies and Goldsmith, 1972). Each annual value was calculated as the mean of the monthly values. The standard error of this mean is estimated from:

$$S_\sigma\,(\text{year}) = \frac{1}{12}\sqrt{\sum_{\text{month}} S_\sigma^{\,2}\,(\text{month})}$$

In the computation of σ_D, only data satisfying the following criteria were accepted:

(i) All three heights were within the specified range.

(ii) The absolute value of D was within four times a preliminary estimate of σ_D based on calculations which did not impose bounds on the value of D in the sample.

The latter condition is intended to be a condition on the time continuity of height reports.

(b) Results

The computed values of σ_D and the corresponding estimated standard error for Hong Kong Kong and six nearly Chinese stations are given in Tables 6 to 12. Only the results for 1978 are presented for illustration purposes. Similar tables have also been computed for 1976 and 1977.

In order to determine whether an annual variation of σ_D occurs, the standard deviation of the monthly σ_D values about the annual mean each year is computed at each level for each station. This is compared with the root mean square of the standard error of the monthly σ_D values, which is a measure of the uncertainty of the individual σ_D values. Results for 1978 are given in Tables 13(a) - (c). In all three tables, the ratios are quite small, none of them being greater than 2.0. The accuracy of the σ_D values is therefore not adequate to resolve any annual variation that may exist. This conclusion has been confirmed by visual examination of the σ_D tables for all three levels for 1976-1978. No obvious pattern of annual variation of σ_D could be found. Therefore, only the annual mean σ_D values for the seven stations are compared.

Annual mean σ_D values and their corresponding standard errors are given in Tables 14(a) - (c). According to Table 14(a), the mean σ_D values for Hong Kong at 200 mbar are consistently higher than those for the Chinese stations throughout 1976 to 1978. The difference is significantly different from zero. For example, the 3-year mean σ_D value for Hong Kong is 15.5 gpm higher than that of station 57972 Chenxian (which has the highest σ_D value among the Chinese stations) while the standard error of the difference is of the order $\sqrt{1.0^2 + 0.7^2} \sim 1.2$ gpm. The σ_D values for the Chinese stations are similar to one another, all in the range of 25-30 gpm.

At the 500 mbar level (Table 14(b)), it is also observed that the mean σ_D values for Hong Kong are consistently higher than those for the Chinese stations. The difference is statistically significant. The 3-year mean σ_D value for Hong Kong is higher than that of 57972 Chenxian (which has the highest σ_D value among the Chinese stations) by 17.3 gpm while the standard error of the difference is of the order $\sqrt{0.5^2 + 0.3^2} \sim 0.6$ gpm. The σ_D values for the Chinese stations are similar to one another in magnitude. All of them lie in the range of 11-14 gpm.

The situation is slightly different at the 850 mbar level. Table 14(c) shows that the mean σ_D value for Hong Kong tends to lie within the range of values for the Chinese stations although it is always on the high side. The station 57972 Chenxian is again the Chinese station with the highest σ_D values which are similar in magnitude to those for Hong Kong. The σ_D values are all within the range of 5-8 gpm.

The spatial variability of σ_D has not been considered in the above comparisons. As mentioned earlier, part of this variability is related to that associated with the K^2 term. In order to take account of this, the spatial distributions of the three-year σ_D values for the three selected level are presented in Figures 3 to 5. Isopleths have been constructed, ignoring the values for Hong Kong. Reasonable patterns can be analysed for all three levels. The stations farthest inland (57972 Chenxian and 57993 Gangzhou) consistently have higher σ_D values while stations closer to the coast (59287 Guangzhou, 59758 Haikou, 59316 Shantou) tend to have lower σ_D values. It therefore seems more appropriate to compare Hong Kong with stations such as Guangzhou.

Figures 3 and 4 show that there are significant differences between the value of σ_D observed at Hong Kong and that which may be extrapolated from the analysed pattern for the 200 and 500 mbar. Although it was mentioned earlier that the σ_D value for Hong Kong at 850 mbar lies in the range covered by Chinese stations, it is clear from Figure 5 that the observed value is significantly higher than that which may be deduced by extrapolation from the analysed pattern. It may be noted that the standard errors of Hong Kong and Chinese σ_D values are of the order 0.15 gpm. The standard error of the difference of any pair of σ_D values (one for Hong Kong and one for Chinese station) is therefore about 0.2 gpm. Figure 5 shows that the observed σ_D value for Hong Kong is at least 1 gpm above that deduced from extrapolation. This is five times the standard error and so is statistically significant.

Based on the above considerations, it may be concluded that the values of σ_D for Hong Kong are significantly larger than those for nearby Chinese stations at the 200, 500 and 850 mbar levels. In the absence of further information about the value of K^2, a conservative estimate of the random errors E associated with the reported geopotential heights may be derived from:

$$\sigma_D^2 = \frac{3}{2}\hat{E}^2$$

that is, assuming K^2 equal to zero in the equation for σ_D. Since K^2 is in reality greater than zero, $\hat{E}$ is always greater than the standard deviation of the radiosonde random error E. The values of $\hat{E}$ for Hong Kong and Guangzhou calculated from the 3-year mean σ_D values are given below.

Level	200 mbar	500 mbar	850 mbar
$\hat{E}$ (Guangzhou)	21 gpm	9 gpm	4.8 gpm
$\hat{E}$ (Hong Kong)	36 gpm	17 gpm	5.8 gpm

5. NIGHT-DAY DIFFERENCE

(a) Method of analysis

In the course of calculating of σ_D (section 4), the mean values of D_i at each station were also calculated. The standard error of each monthly mean S_D was estimated from the usual formula:

$$S_{\bar{D}} = \frac{\sigma_D}{\sqrt{\text{sample size}}}$$

The yearly mean was computed as the average of the twelve monthly means and its standard error was estimated from:

$$S_{\bar{D}}\ (\text{year}) = \frac{1}{12}\sqrt{\sum_{\text{month}} S_{\bar{D}}^{2}}$$

Three years of data (1976-78) were examined as in the case of the random error study.

(b) Results

The results of computations for 1978 data are presented in Tables 6 to 12. Data are also available for 1976 and 1977 but are not presented. A summary table (Table 15) giving the mean difference for the whole period (1976-78) is quite interesting. It shows that there are significant mean night-day differences at the 200 and 850 mbar levels while the magnitude of 500 mbar mean differences is quite small. The mean differences at high and low levels are also opposite in sign. On subtracting the mean differences at 200 and 850 mbar levels, it is observed that the thickness of the 200-850 mbar layer is greater at 12 GMT. This is consistent with the idea that the atmosphere as a whole is warmer at 12 GMT after a day of heating by the sun. The mean difference at 500 mbar is small because the negative mean difference at 850 mbar is to a large extent compensated by the increased thickness between the two levels. An attempt was made to relate the change in 200-850 mbar thickness to the latitude of the station (which should serve as an indicator of the amount of solar heating). There was too much scatter so that no pattern could be discerned.

Before examining the annual variation of the monthly mean differences, it is necessary to check whether the accuracy of the data is sufficient to resolve any annual variation that may exist. Using 1978 data, Table 16 has been prepared to show the ratios between the standard deviations of the monthly mean night-day differences and the corresponding root mean squares of the monthly standard deviations. The latter term is a measure of the uncertainty of the individual monthly mean differences. If the ratio is large, then the accuracy is adequate to resolve the annual variation. Table 16 shows that the annual variation at 200 mbar could not be adequately resolved. The 500 mbar level is a marginal case. The highest ratios are found at the 850 mbar level where several ratios are close to two. At all levels, the ratio for Hong Kong is smallest. This arises because of the greater random errors associated with Hong Kong ascent data (see section 4).

The monthly mean night-day differences averaged over 1976-78 at Hong Kong and Guangzhou are given in Figures 6 and 7. At both stations, the mean differences at 200 mbar show no significant annual variation. At the 500 mbar level, the graph for Guangzhou suggests a minimum in summer (June to August) and a maximum in winter (December to February). No pattern could be found for Hong Kong data. The curves at the 850 mbar level for both stations are fairly similar, showing minima in March and maxima in December. Minor "dips" in May, July and November are also found in the graphs for both stations. Although the magnitude of these dips is rather small compared with the typical standard error of the monthly values, the fact that they occur in two curves which are independent of each other suggests that they might be genuine.

Spackman (1978) presented diagrams relating day-night difference to solar elevation at the time of the ascent in daylight. The monthly mean night-day difference at Hong Kong and Guangzhou (1976-78) is plotted againt the solar elevation at 00 GMT on the 15th day of each month in Figure 8. The points for each station are joined together in monthly sequence.

At the 200 mbar level, there is no clear-cut pattern. However, apart from an odd point for Hong Kong, there is apparently a tendency for the difference to become smaller with higher solar elevation. This is similar to the pattern given by Spackman (1978) in his Figure 1(a). Note that the sign used by Spackman is opposite to that used in this report.

At the lower levels (500 and 850 mbar), the two stations exhibit similar "signature" in the graphs. The differences generally become more negative with higher solar elevation. However, there are also some seasonal variations. For example, there tend to be "dips" around March and November and "peaks" around April and September.

From the above discussions, it would appear that the annual variation of night-day differences depends on more than one factor and certainly not on the solar elevation at 00 GMT alone. Indeed, it is likely that the variation depends on the phase and amplitude of the diurnal and semi-diurnal tides of the atmosphere. Since we are sampling only twice per day, the night-day difference might vary a lot if the tidal curve is shifted by an hour or so. It is therefore likely to be a futile exercise to relate night-day difference to solar elevation at the time of the ascent in daylight. In this sense, tables given by McInturff and co-workers (1979) are very difficult to interpret because data obtained at different local times (hence different phases in the tidal curve) are combined together. This probably also explains why the mean night-day differences derived from the present study are at variance with theirs.

6. CONCLUSIONS

Synoptic data received via the GTS have been used to compare the performance of the radiosondes released in China and in Hong Kong for the period 1976-78.

Systematic differences between Hong Kong and Guangzhou have been determined using the geostrophic balance to estimate the real geopotential difference between the two stations. On the average, Hong Kong reports are 4 gpm higher than those reported by Chinese radiosondes at 850 and 500 mbar. At the 200 mbar level, Hong Kong reports are lower by 3 gpm for 00 GMT ascents and 7 gpm for 12 GMT ascents. Significant seasonal variations of the systematic differences exist. The range of variation is around 20 - 25 gpm at 200 mbar and around 5 - 10 gpm at 500 and 850 mbar.

Uncertainty in the computed systematic differences arises from departure from geostrophic balance. The magnitude of this uncertainty is comparable with the computed values of the systematic differences at the 200 mbar level. However, it is probably small compared with those at the 850 mbar and 500 mbar levels.

The single station analysis shows that random errors of geopotential height reports from Hong Kong is larger than Chinese ones at all three levels.

At all stations, the mean night-day differences at 200 and 850 mbar mbar are opposite in sign, implying a thicker layer between the two levels at 12 GMT than at 00 GMT. At all stations and levels, the monthly mean night-day differences are less positive when the solar elevation at 00 GMT is smaller. However, the relation is quite complicated and other factors are thought to be present that affect the night-day difference.

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Table 1 . 200 mbar systematic difference between
Hong Kong and Guangzhou

(a) 00 GMT ascents

year	D_o	standard error of D_o	$\bar{U}$	D_t	systematic difference
1976	1.7 gpm	2.4 gpm	23.0 knots	8.9 gpm	-7.2 gpm
1977	17.7	2.3	28.0	10.7	7.0
1978	1.5	2.4	27.9	10.7	-9.1
1976-78	7.0	1.4	26.3	10.1	-3.1

(b) 12 GMT ascents

year	D_o	standard error of D_o	$\bar{U}$	D_t	systematic difference
1976	3.2 gpm	2.5 gpm	22.9 knots	8.8 gpm	-5.6 gpm
1977	8.8	2.2	26.5	10.2	-1.4
1978	-2.8	2.3	27.0	10.1	-12.9
1976-78	3.1	1.3	25.5	9.7	-6.6

Table 2 . 500 mbar systematic difference between
Hong Kong and Guangzhou

(a) 00 GMT ascents

year	D_o	standard error of D_o	$\bar{U}$	D_t	systematic difference
1976	9.1 gpm	0.9 gpm	15.2 knots	5.8 gpm	3.3 gpm
1977	12.7	1.0	15.8 .	6.1	6.6
1978	7.2	1.0	15.4	5.9	1.3
1976-78	9.7	0.6	15.5	5.9	3.7

(b) 12 GMT ascents

year	D_o	standard error of D_o	$\bar{U}$	D_t	systematic difference
1976	11.3 gpm	1.0 gpm	16.2 knots	6.2 gpm	5.1 gpm
1977	11.7	0.9	17.4	6.7	5.0
1978	9.5	1.0	15.8	6.1	3.4
1976-78	10.8	0.6	16.5	6.3	4.5

Table 3 . 850 mbar systematic difference between Hong Kong and Guangzhou

(a) 00 GMT ascents

year	D_o	standard error of D_o	$\bar{\bar{U}}$	D_t	systematic difference
1976	4.6 gpm	0.4 gpm	2.87 knots	1.1 gpm	3.5 gpm
1977	5.9	0.3	3.02	1.2	4.7
1978	4.6	0.4	0.90	0.3	4.1
1976-78	5.0	0.2	2.26	0.9	4.1

(b) 12 GMT ascents

year	D_o	standard error of D_o	$\bar{\bar{U}}$	D_t	systematic difference
1976	4.1 gpm	0.4 gpm	2.52 knots	1.0 gpm	3.1 gpm
1977	5.1	0.3	1.51	0.6	4.5
1978	4.6	0.4	-0.57	-0.2	4.8
1976-78	4.6	0.2	1.15	0.4	4.2

Table 4 . Monthly mean systematic difference between Hong Kong and Guanzhou ascents at 200 mbar (1976-78)

Month	δ		Δ^*	difference between 00GMT & 12GMT	solar elevation at 00GMT on 15th day of the month
	00 GMT	12 GMT			
January	9.7 gpm	7.6 gpm	-4.7 gpm	2.1 gpm	11°
February	8.2	8.3	-4.6	-0.1	13
March	11.1	-6.1	-4.2	17.2	19
April	-12.1	-10.8	-0.6	-1.3	26
May	-9.6	-15.5	0.4	5.9	30
June	-7.5	-8.8	1.5	1.3	30
July	-10.6	-10.4	1.8	-0.2	28
August	-12.8	-19.7	1.3	6.9	26
September	-12.1	-22.5	2.0	10.4	25
October	-9.3	-13.2	1.2	3.9	22
November	1.2	4.4	-1.5	3.2	17
December	6.2	8.5	-3.4	2.3	12

* estimate of error due to geostrophic departure based on data given in Oort and Rasmusson (1971). See text for details.

Table 5. Monthly mean systematic difference at 500 mbar and 850 mbar for 00 GMT ascents (1976-78)

Month	500 mbar		850 mbar	
	δ	Δ*	δ	Δ*
January	9.6 gpm	-0.7 gpm	7.4 gpm	-0.2 gpm
February	7.9	-0.6	6.9	-0.1
March	7.6	-0.7	6.5	-0.2
April	3.8	-0.0	4.5	0.0
May	1.4	-0.3	2.6	-0.1
June	1.7	-0.4	0.4	-0.2
July	-2.7	-0.2	-0.6	-0.2
August	0.2	-0.3	1.4	-0.2
September	-0.1	-0.2	3.1	0.0
October	2.8	-0.4	5.8	-0.1
November	5.7	-0.6	5.5	-0.1
December	7.9	-0.8	6.8	-0.3

* estimate of error due to geostrophic departure based on data given in Oort and Rasmusson (1971). See text for details.

Table 6 Statistics of night-day geopotential difference for Hong Kong (station 45004) in 1978

Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a. 200 mbar (unit: 10 gpm)					
1	1.00	5.02	.90	.64	31
2	.88	5.52	1.04	.74	28
3	-.82	4.77	.90	.64	28
4	-.53	3.02	.55	.39	30
5	-.27	4.10	.75	.53	30
6	1.09	4.39	.81	.58	29
7	1.86	3.37	.67	.48	25
8	.97	3.64	.65	.46	31
9	1.27	5.87	1.07	.76	30
10	.72	4.63	.86	.61	29
11	1.80	4.36	.80	.56	30
12	1.12	4.26	.79	.56	29
YEAR	.76	4.41	.24	.17	29
b. 500 mbar (unit: 10 gpm)					
1	.59	3.28	.61	.43	29
2	.18	2.72	.51	.36	28
3	-.54	2.16	.41	.29	28
4	-.32	1.65	.30	.21	30
5	-.38	1.76	.32	.23	30
6	-.34	2.04	.38	.27	29
7	.33	1.41	.28	.20	26
8	.56	2.04	.37	.26	31
9	.43	2.25	.41	.29	30
10	.09	2.08	.39	.27	29
11	.77	1.65	.30	.21	30
12	.66	1.89	.35	.25	29
YEAR	.17	2.08	.11	.08	29
c. 850 mbar (unit: 1 gpm)					
1	-3.18	8.09	1.48	1.04	30
2	-6.52	7.86	1.49	1.05	28
3	-9.19	8.08	1.50	1.06	29
4	-6.13	7.76	1.42	1.00	30
5	-6.73	8.18	1.49	1.06	30
6	-4.81	7.47	1.39	.98	29
7	-7.63	8.53	1.67	1.18	26
8	-4.15	8.42	1.54	1.09	30
9	-2.62	9.11	1.69	1.20	29
10	-2.07	6.99	1.30	.92	29
11	-5.32	5.06	.92	.65	30
12	-1.94	8.61	1.66	1.17	27
YEAR	-5.03	7.85	.43	.30	28

Table 7 Statistics of night-day geopotential difference for Guangzhou (station 59287) in 1978

	Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a.	200 mbar (unit: 10 gpm)					
	1	1.23	2.47	.47	.33	28
	2	1.74	2.72	.52	.37	27
	3	1.24	3.00	.60	.42	25
	4	.93	2.06	.40	.28	27
	5	1.59	2.43	.46	.32	26
	6	.77	2.52	.51	.36	24
	7	-.84	2.95	.59	.42	25
	8	1.44	2.63	.54	.38	24
	9	.27	2.78	.52	.37	28
	10	1.19	2.57	.50	.35	27
	11	1.19	2.01	.39	.28	26
	12	1.40	2.73	.51	.36	29
	YEAR	1.01	2.57	.15	.10	26
b.	500 mbar (unit: 10 gpm)					
	1	.39	1.50	.28	.20	28
	2	.31	1.11	.21	.15	27
	3	-.08	1.10	.22	.15	26
	4	.21	.94	.17	.12	29
	5	-.27	1.05	.20	.14	28
	6	-.36	1.07	.20	.14	28
	7	-.98	1.15	.24	.17	23
	8	-.16	1.60	.30	.21	26
	9	-.29	1.17	.23	.16	26
	10	.04	1.15	.22	.15	28
	11	.29	1.17	.23	.16	26
	12	.36	1.73	.32	.23	29
	YEAR	-.04	1.23	.07	.05	27
c.	850 mbar (unit: 1 gpm)					
	1	-3.15	6.48	1.25	.88	27
	2	-4.63	6.48	1.25	.88	27
	3	-7.88	5.81	1.14	.81	26
	4	-4.76	6.27	1.16	.82	29
	5	-4.82	4.89	.92	.65	28
	6	-6.64	5.68	1.05	.75	29
	7	-10.02	7.01	1.40	.99	25
	8	-5.11	8.48	1.60	1.13	28
	9	-3.18	7.13	1.35	.95	28
	10	-2.79	6.05	1.14	.81	28
	11	-5.29	4.37	.86	.61	26
	12	-2.41	5.74	1.07	.75	29
	YEAR	-5.06	6.20	.35	.24	27

Table 8 Statistics of night-day geopotential difference for Shantou (station 59216) in 1978

Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a. 200 mbar (unit: 10 gpm)					
1	1.82	1.91	.35	.25	30
2	2.31	3.45	.81	.58	18
3	1.97	2.24	.41	.29	30
4	.79	2.98	.56	.40	28
5	1.40	3.19	.59	.42	29
6	.48	2.74	.54	.38	26
7	.83	2.86	.55	.39	27
8	.56	3.70	.76	.53	24
9	.09	2.26	.44	.31	27
10	.17	4.49	.94	.66	23
11	1.02	2.60	.54	.38	23
12	1.37	2.23	.43	.30	27
YEAR	1.07	2.89	.17	.12	26
b. 500 mbar (unit: 10 gpm)					
1	.32	1.18	.21	.15	31
2	.40	1.19	.23	.17	26
3	.45	1.05	.19	.14	29
4	-.02	.86	.16	.11	29
5	.02	1.20	.23	.16	28
6	-.44	1.03	.20	.14	26
7	-.35	1.27	.23	.16	31
8	.19	1.68	.32	.23	27
9	-.53	1.08	.20	.14	29
10	-.19	1.29	.25	.18	27
11	.09	1.28	.24	.17	29
12	.40	1.20	.22	.16	29
YEAR	.03	1.19	.07	.05	28
c. 850 mbar (unit: 1 gpm)					
1	-1.77	5.67	1.02	.72	31
2	-2.31	7.26	1.42	1.01	26
3	-6.52	6.94	1.29	.91	29
4	-2.27	6.83	1.29	.91	28
5	-3.50	4.48	.83	.59	29
6	-4.48	4.25	.83	.59	26
7	-7.76	5.60	1.01	.71	31
8	-4.09	7.55	1.45	1.03	27
9	-2.91	7.17	1.33	.94	29
10	.43	5.19	.96	.68	29
11	-4.24	5.07	.94	.67	29
12	-.21	6.16	1.14	.81	29
YEAR	-3.30	6.01	.33	.23	28

Table 9 Statistics of night-day geopotential difference for Chenxian (station 57972) in 1978

Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a. 200 mbar (unit: 10 gpm)					
1	1.94	2.82	.58	.41	24
2	2.02	2.73	.54	.38	26
3	1.24	3.45	.69	.49	25
4	1.19	2.66	.63	.44	18
5	1.92	2.70	.54	.38	25
6	2.77	3.12	.66	.47	22
7	1.03	3.40	.63	.45	29
8	1.30	2.95	.63	.44	22
9	.50	3.00	.67	.47	20
10	1.45	2.52	.56	.40	20
11	1.00	2.29	.47	.33	24
12	1.39	3.07	.59	.42	27
YEAR	1.48	2.89	.17	.12	23
b. 500 mbar (unit: 10 gpm)					
1	.50	1.63	.30	.21	30
2	.62	1.42	.28	.20	26
3	.30	1.57	.30	.21	28
4	-.10	1.24	.27	.19	21
5	-.09	1.11	.21	.15	28
6	.06	1.09	.22	.16	24
7	-.31	1.11	.21	.15	29
8	-.54	1.45	.28	.20	27
9	-.22	1.15	.24	.17	25
10	.13	1.11	.22	.15	26
11	-.12	1.44	.28	.20	26
12	.52	1.98	.38	.27	27
YEAR	.06	1.36	.08	.05	26
c. 850 mbar (unit: 1 gpm)					
1	-.85	9.69	1.77	1.25	30
2	-3.52	9.61	1.92	1.36	25
3	-7.03	5.87	1.05	.75	31
4	-5.43	5.47	1.14	.81	23
5	-6.38	6.43	1.19	.84	29
6	-5.54	5.40	1.10	.78	24
7	-10.93	6.50	1.21	.85	29
8	-9.37	8.31	1.63	1.15	26
9	-4.78	7.05	1.47	1.04	23
10	-4.31	8.91	1.75	1.24	26
11	-5.33	5.86	1.15	.81	26
12	-2.09	8.90	1.65	1.17	29
YEAR	-5.46	7.33	.42	.30	26

Table 10 Statistics of night-day geopotential difference for Ganzhou (station 57993) in 1978

Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a. 200 mbar (unit: 10 gpm)					
1	2.35	3.08	.64	.45	23
2	1.46	2.41	.50	.35	23
3	.91	3.55	.74	.52	23
4	-.24	3.94	.95	.68	17
5	-.93	3.26	.71	.50	21
6	.81	2.79	.57	.40	24
7	.73	2.43	.52	.37	22
8	.02	2.99	.59	.42	26
9	1.13	1.83	.37	.26	24
10	.52	2.73	.55	.39	25
11	.79	2.29	.45	.32	26
12	.28	2.20	.44	.31	25
YEAR	.65	2.79	.17	.12	23
b. 500 mbar (unit: 10 gpm)					
1	.34	1.71	.34	.24	25
2	.14	1.35	.27	.19	25
3	.10	1.41	.26	.19	29
4	-.28	1.18	.26	.19	20
5	-.71	1.09	.21	.15	26
6	-.29	.90	.17	.12	28
7	-.43	1.11	.21	.15	28
8	-.72	1.47	.27	.19	30
9	-.33	.84	.16	.11	27
10	-.29	1.18	.23	.16	26
11	-.27	1.03	.19	.14	28
12	.19	1.05	.20	.14	27
YEAR	-.21	1.19	.07	.05	26
c. 850 mbar (unit: 1 gpm)					
1	-1.10	7.68	1.54	1.09	25
2	-3.87	8.04	1.55	1.09	27
3	-5.72	6.33	1.18	.83	29
4	-3.50	6.79	1.39	.98	24
5	-5.75	5.43	1.11	.78	24
6	-5.09	5.29	1.00	.71	28
7	-9.84	4.99	.93	.66	29
8	-6.90	7.54	1.38	.97	30
9	-4.77	4.03	.76	.54	28
10	-3.13	5.49	1.06	.75	27
11	-4.50	4.18	.76	.54	30
12	-.44	7.84	1.51	1.07	27
YEAR	-4.55	6.14	.35	.25	27

Table **11** Statistics of night-day geopotential difference
for **Wuzhou** (station 59265) in 1978

Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a. 200 mbar (unit: 10 gpm)					
1	1.68	2.26	.41	.29	31
2	1.40	3.27	.65	.46	25
3	1.95	2.48	.47	.33	28
4	.39	3.11	.59	.42	28
5	-.06	2.20	.42	.30	27
6	.60	3.00	.60	.42	25
7	.93	2.91	.54	.38	29
8	.35	2.71	.49	.35	30
9	1.28	2.38	.44	.31	29
10	1.56	2.49	.51	.36	24
11	.90	2.30	.46	.33	25
12	1.66	2.33	.44	.31	28
YEAR	1.05	2.62	.15	.10	27
b. 500 mbar (unit: 10 gpm)					
1	.57	1.51	.28	.20	29
2	.13	1.65	.31	.22	28
3	.22	1.40	.26	.18	29
4	.21	1.24	.23	.16	29
5	-.61	.94	.17	.12	31
6	-.07	1.14	.21	.15	28
7	-.23	1.06	.19	.14	31
8	-.82	1.12	.20	.14	31
9	-.55	1.07	.20	.14	26
10	-.19	1.08	.20	.14	29
11	.13	1.21	.23	.16	28
12	.56	1.11	.20	.14	31
YEAR	-.06	1.21	.07	.05	29
c. 850 mbar (unit: 1 gpm)					
1	-.16	7.90	1.42	1.00	31
2	-4.05	9.20	1.74	1.23	28
3	-8.07	6.29	1.15	.81	30
4	-6.53	8.16	1.49	1.05	30
5	-7.44	6.89	1.24	.87	31
6	-7.63	5.71	1.08	.76	28
7	-10.24	7.02	1.26	.89	31
8	-8.21	4.90	.88	.62	31
9	-5.81	4.86	.90	.64	29
10	-4.38	5.75	1.09	.77	28
11	-5.00	4.03	.78	.55	27
12	-2.11	6.85	1.23	.87	31
YEAR	-5.80	6.46	.35	.25	29

Table 12 Statistics of night-day geopotential difference for Haikou (station 59758) in 1978

Month	Mean difference	Standard deviation	Standard error of mean difference	Standard error of standard deviation	Number of observations
a. 200 mbar (unit: 10 gpm)					
1	1.83	2.72	.51	.36	29
2	1.74	2.26	.43	.31	27
3	1.22	2.08	.39	.27	29
4	1.61	2.47	.47	.33	28
5	1.26	2.85	.55	.39	27
6	1.35	2.07	.40	.28	27
7	1.17	2.65	.51	.36	27
8	.21	3.02	.59	.42	26
9	1.39	2.85	.54	.38	28
10	1.67	2.50	.51	.36	24
11	1.10	2.85	.53	.37	29
12	1.46	3.22	.63	.45	26
YEAR	1.33	2.63	.15	.10	27
b. 500 mbar (unit: 10 gpm)					
1	.77	1.25	.22	.16	31
2	.36	1.33	.25	.18	28
3	.32	1.00	.18	.13	31
4	.62	1.08	.20	.14	29
5	.12	1.34	.24	.17	30
6	.30	.91	.18	.12	27
7	-.07	.98	.18	.13	29
8	-.12	1.50	.28	.20	29
9	.21	1.31	.25	.17	28
10	.07	1.14	.22	.16	27
11	.24	.99	.18	.13	29
12	.47	1.16	.21	.15	30
YEAR	.27	1.17	.06	.04	29
c. 850 mbar (unit: 1 gpm)					
1	-2.31	7.50	1.35	.95	31
2	-3.95	6.30	1.19	.84	28
3	-7.45	5.15	.92	.65	31
4	-6.29	9.45	1.75	1.24	29
5	-9.04	6.26	1.18	.84	28
6	-7.50	6.43	1.24	.87	27
7	-9.98	6.81	1.27	.89	29
8	-6.48	8.53	1.61	1.14	28
9	-3.55	4.83	.88	.62	30
10	-3.07	5.44	1.05	.74	27
11	-4.62	4.63	.84	.60	30
12	.17	7.08	1.29	.91	30
YEAR	-5.34	6.53	.36	.25	29

Table 13. Likelihood of annual variation of σ_D (1978). Unit : gpm

(a) 200 mbar

	station						
	45004	59287	59316	57972	57993	59265	59758
A. standard deviation of monthly σ_D values	8.3	3.1	7.4	3.4	6.1	3.7	3.6
B. root mean square of standard errors of monthly σ_D values	5.9	3.5	4.2	4.2	4.2	3.5	3.5
C. ratio (A/B)	1.4	0.9	1.8	0.8	1.5	1.1	1.0

(b) 500 mbar

	station						
	45004	59287	59316	57972	57993	59265	59758
A. standard deviation of monthly σ_D values	5.1	2.4	2.0	2.8	2.5	2.1	1.8
B. root mean square of standard errors of monthly σ_D values	2.8	1.7	1.7	1.7	1.7	1.7	1.4
C. ratio (A/B)	1.8	1.4	1.2	1.6	1.5	1.2	1.3

(c) 850 mbar

	station						
	45004	59287	59316	57972	57993	59265	59758
A. standard deviation of monthly σ_D values	1.0	1.1	1.1	1.6	1.4	1.5	1.5
B. root mean square of standard errors of monthly σ_D values	1.0	0.8	0.8	1.0	0.9	0.9	0.9
C. ratio (A/B)	1.0	1.4	1.4	1.6	1.6	1.7	1.7

Table 14. Annual mean of monthly σ_D values. Unit : gpm

(a) 200 mbar

station	1976		1977		1978		1976-78	
	mean σ_D	SE	mean σ_D	SE	mean σ_D	SE	mean σ_D	SE
45004	46.3	1.9	40.9	1.7	44.1	1.7	43.8	1.0
59287	25.8	1.1	24.6	1.0	25.7	1.0	25.3	0.6
59316	25.7	1.0	28.5	1.1	28.9	1.2	27.7	0.6
57972	27.5	1.2	28.6	1.2	28.9	1.2	28.3	0.7
57993	30.5	1.4	25.8	1.2	27.9	1.2	28.1	0.7
59265	27.0	1.1	28.8	1.2	26.2	1.0	27.3	0.6
59758	25.5	1.1	25.5	1.0	26.3	1.0	25.8	0.6

(b) 500 mbar

station	1976		1977		1978		1976-78	
	mean σ_D	SE	mean σ_D	SE	mean σ_D	SE	mean σ_D	SE
45004	20.2	0.8	20.1	0.8	20.8	0.8	20.4	0.5
59287	11.1	0.4	10.9	0.4	12.3	0.5	11.4	0.3
59316	12.1	0.5	12.0	0.5	11.9	0.5	12.0	0.3
57972	12.8	0.5	12.9	0.5	13.6	0.5	13.1	0.3
57993	12.1	0.5	12.7	0.6	11.9	0.5	12.2	0.3
59265	11.8	0.5	13.2	0.5	12.1	0.5	12.4	0.3
59758	11.0	0.4	11.6	0.5	11.7	0.4	11.4	0.3

(c) 850 mbar

station	1976		1977		1978		1976-78	
	mean σ_D	SE	mean σ_D	SE	mean σ_D	SE	mean σ_D	SE
45004	6.91	0.27	6.72	0.26	7.85	0.30	7.16	0.16
59287	5.79	0.23	5.83	0.23	6.20	0.24	5.94	0.13
59316	5.38	0.30	5.54	0.21	6.01	0.23	5.64	0.14
57972	7.26	0.30	7.74	0.34	7.33	0.30	7.44	0.18
57993	6.57	0.27	6.63	0.30	6.14	0.25	6.45	0.16
59265	6.35	0.25	6.37	0.25	6.46	0.25	6.39	0.14
59758	5.96	0.24	6.24	0.24	6.53	0.25	6.24	0.14

Table 15. Mean annual night-day difference (1976-78)
Unit : gpm

(a) 200 mbar

	45004	59287	59316	57972	57993	59265	59758
mean difference	5.5	9.5	9.8	14.0	6.8	3.8	11.6
standard error	1.4	0.8	0.9	1.0	1.0	0.9	0.9

(b) 500 mbar

	45004	59287	59316	57972	57993	59265	59758
mean difference	1.3	0.3	-0.7	1.6	-1.1	-0.4	2.4
standard error	0.6	0.4	0.4	0.5	0.4	0.4	0.3

(c) 850 mbar

	45004	59287	59316	57972	57993	59265	59758
mean difference	-6.0	-5.7	-4.0	-5.2	-4.6	-6.4	-6.1
standard error	0.2	0.2	0.2	0.3	0.2	0.2	0.2

Table 16. The existence of resolvable annual variation
in monthly mean night-day difference
based on 1978 data
Unit : gpm

(a) 200 mbar

	45004	59287	59316	57972	57993	59265	59758
standard deviation of monthly mean D	8.2	6.7	6.8	5.7	8.0	6.1	4.1
root mean square of standard errors of monthly mean D	8.3	5.2	5.9	5.9	5.9	5.2	5.2
ratio	1.0	1.3	1.2	1.0	1.4	1.2	0.8

(b) 500 mbar

	45004	59287	59316	57972	57993	59265	59758
standard deviation of monthly mean D	4.4	3.8	3.2	3.5	3.3	4.3	2.5
root mean square of standard errors of monthly mean D	3.8	2.4	2.4	2.8	2.4	2.4	2.1
ratio	1.2	1.6	1.3	1.3	1.4	1.8	1.2

(c) 850 mbar

	45004	59287	59316	57972	57993	59265	59758
standard deviation of monthly mean D	1.6	2.1	1.8	2.5	1.8	2.1	2.5
root mean square of standard errors of monthly mean D	1.4	1.1	1.0	1.0	1.3	1.2	1.2
ratio	1.1	1.9	1.8	2.5	1.4	1.8	2.1

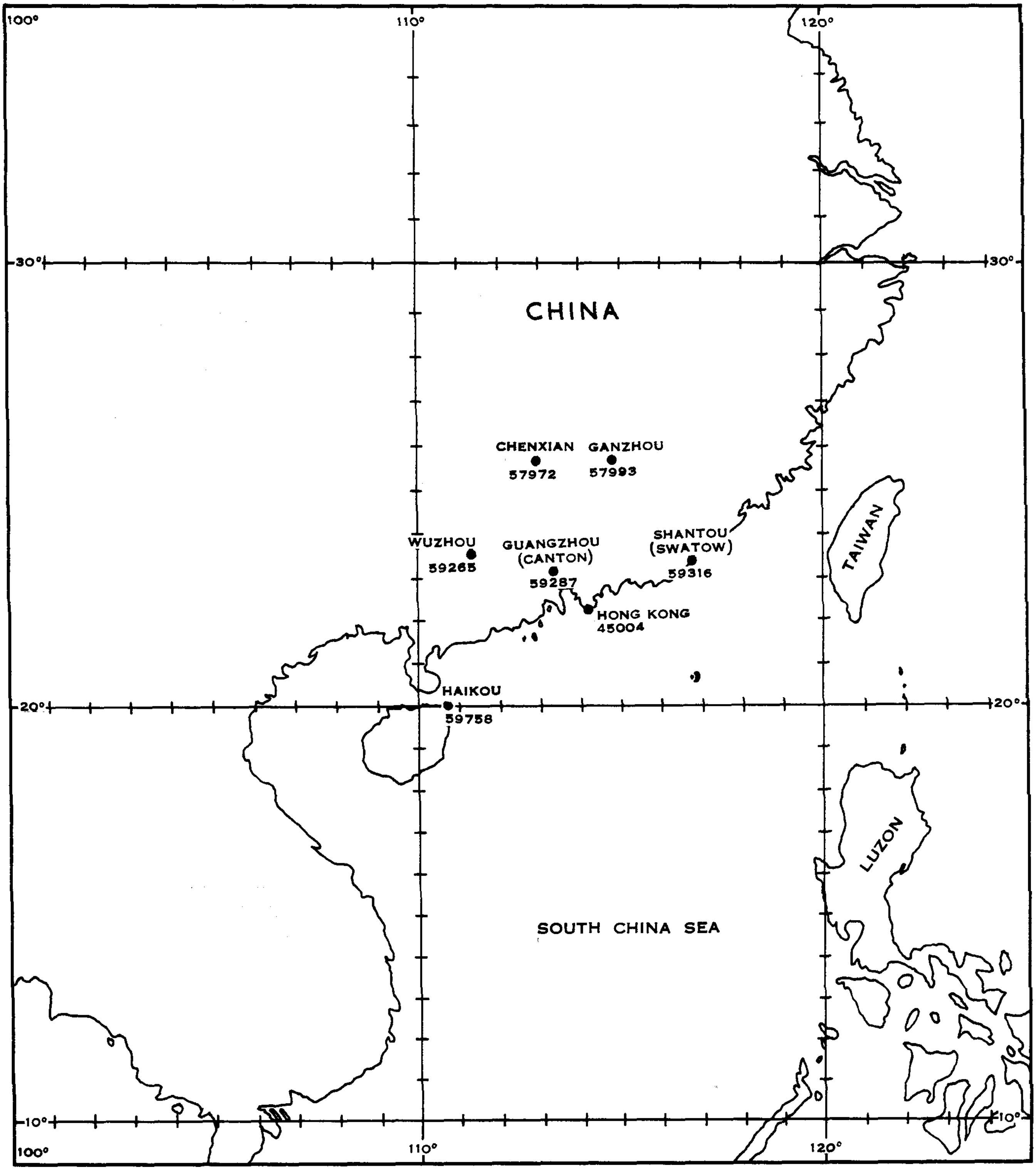

FIGURE 1. MAP TO SHOW THE LOCATIONS OF RADIOSONDE STATIONS

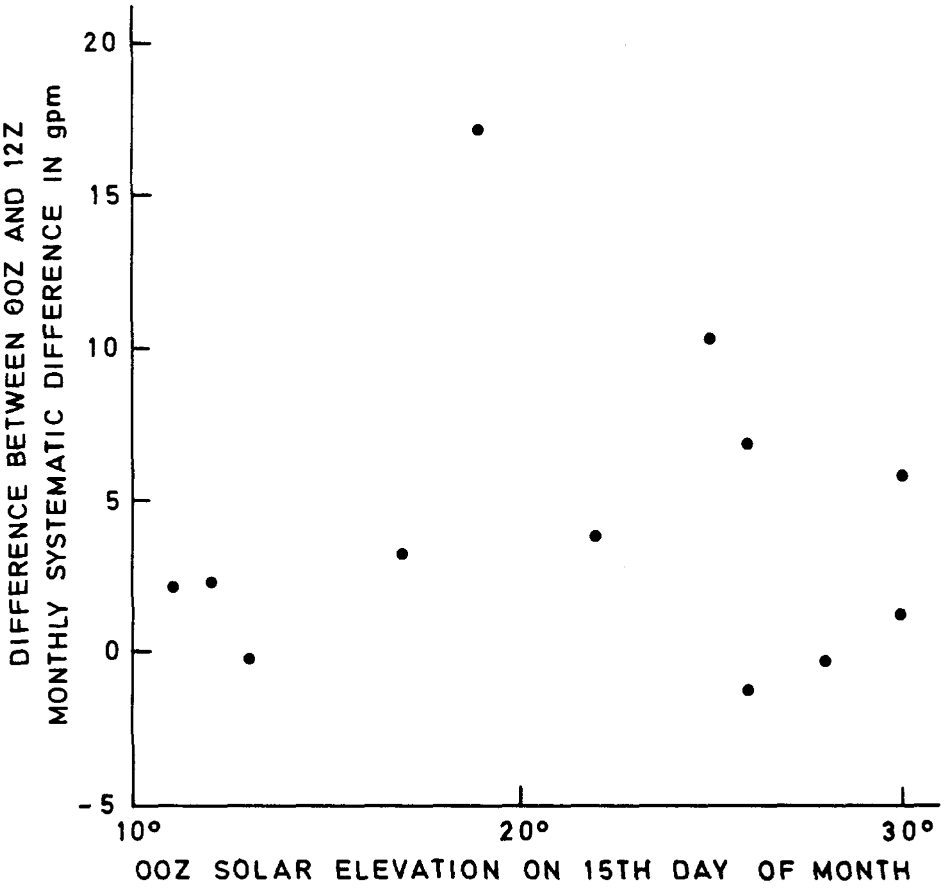

FIGURE 2. DEPENDENCE OF 200 mbar SYSTEMATIC DIFFERENCE BETWEEN HONG KONG AND CHINESE RADIOSONDES ON SOLAR ELEVATION

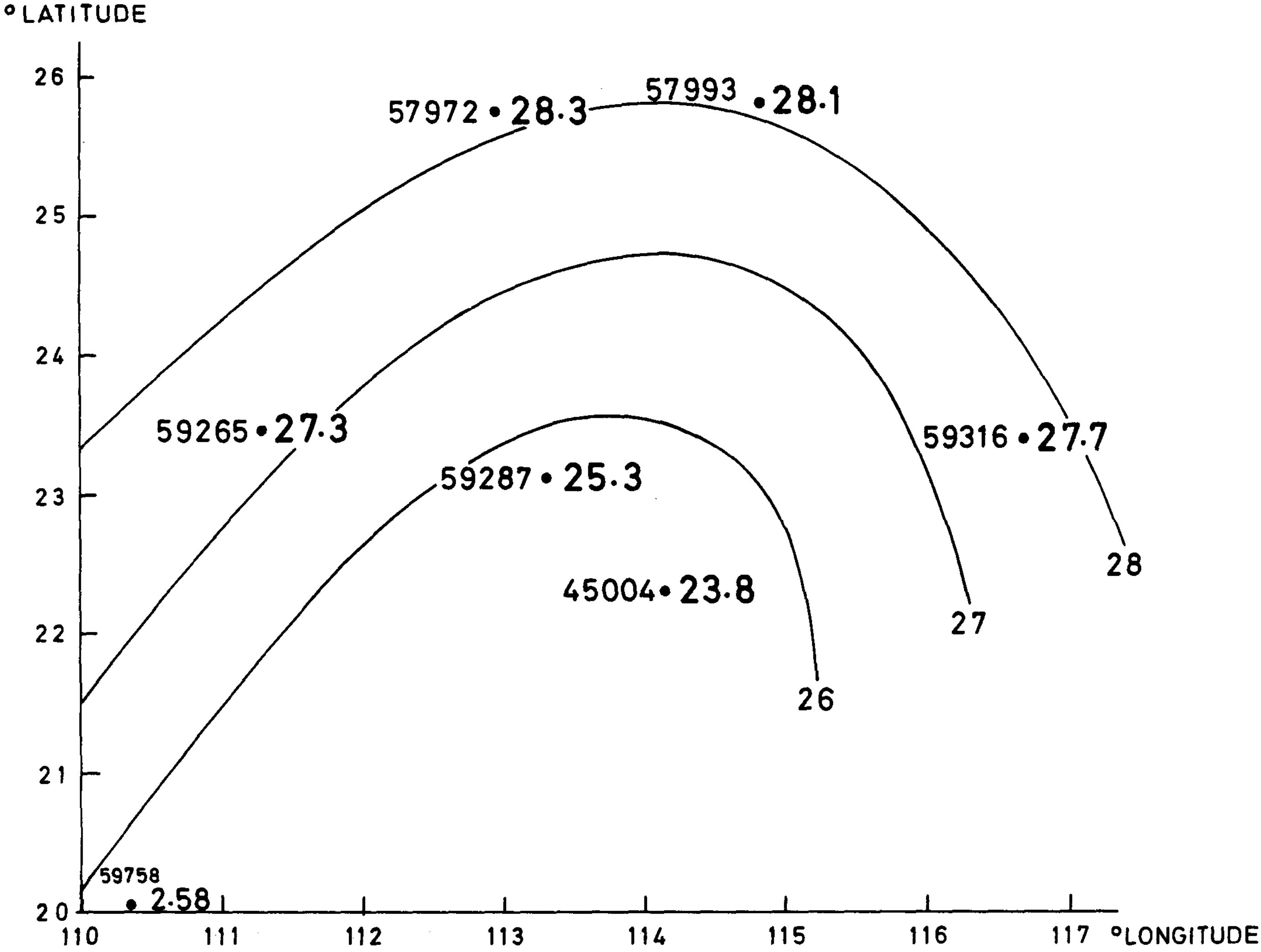

FIGURE 3. SPATIAL VARIATION OF MEAN σ_D AT 200 mbar (1976-78)

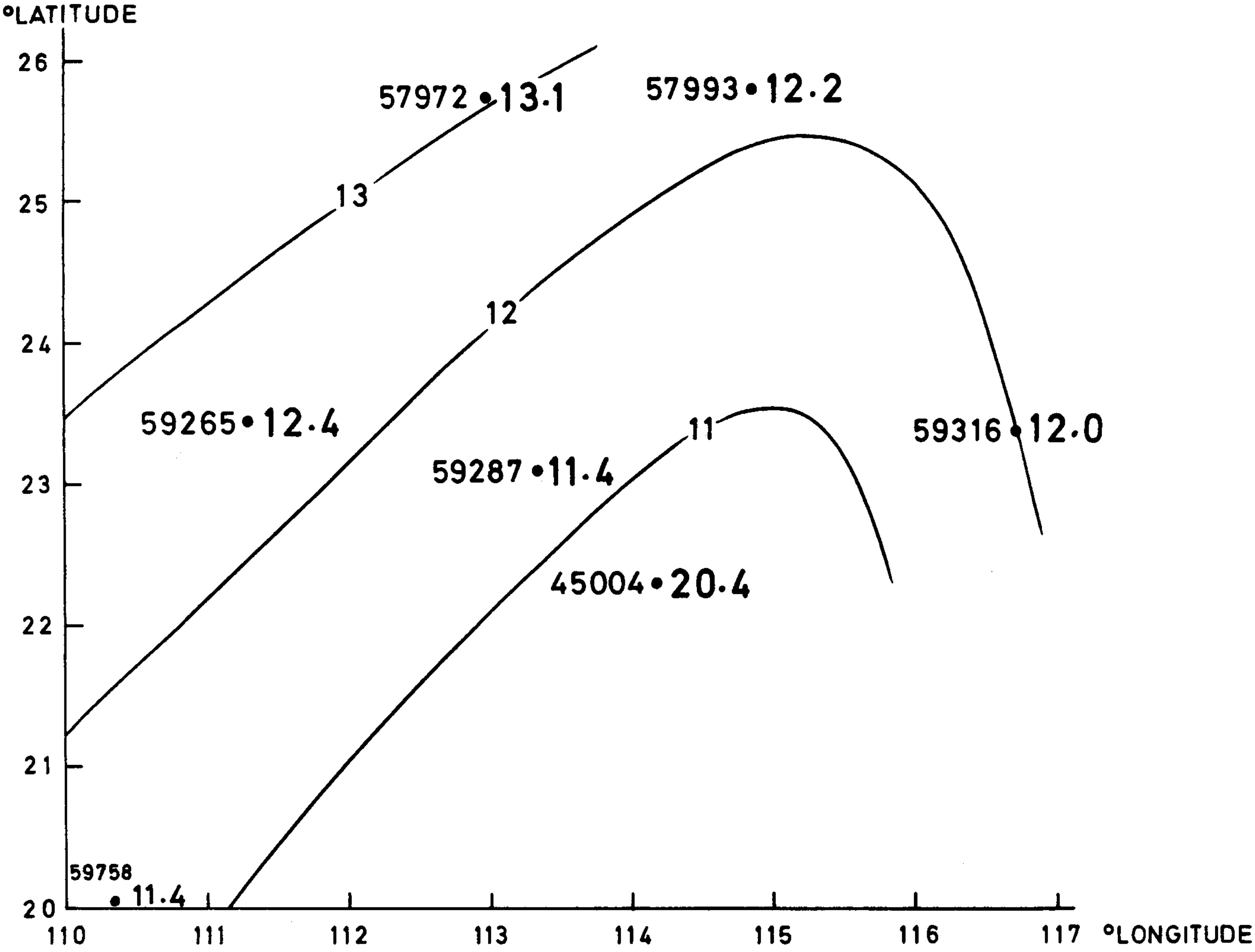

FIGURE 4. SPATIAL VARIATION OF MEAN σ_D AT 500 mbar (1976-78)

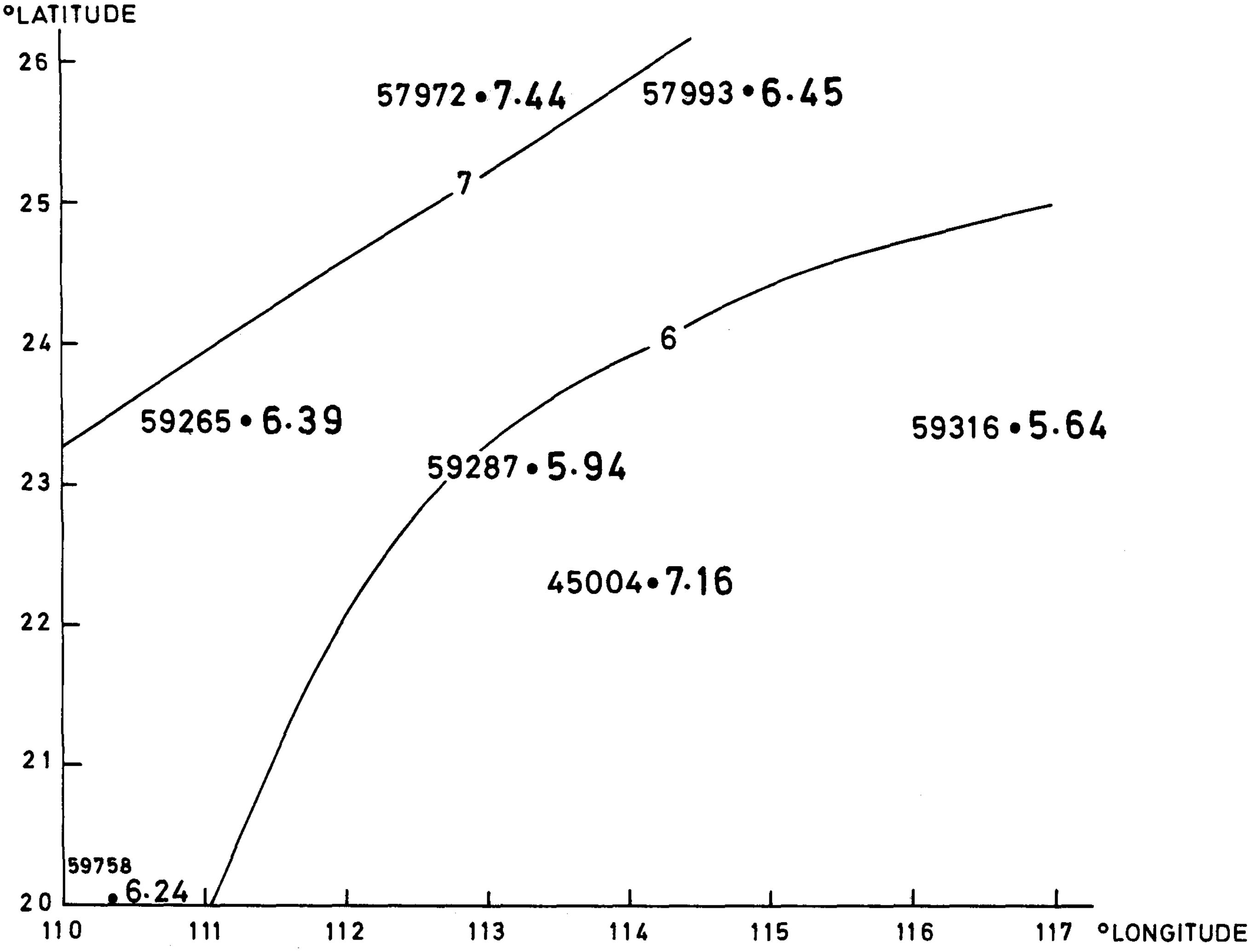

FIGURE 5. SPATIAL VARIATION OF MEAN σ_D AT 850 mbar (1976-78)

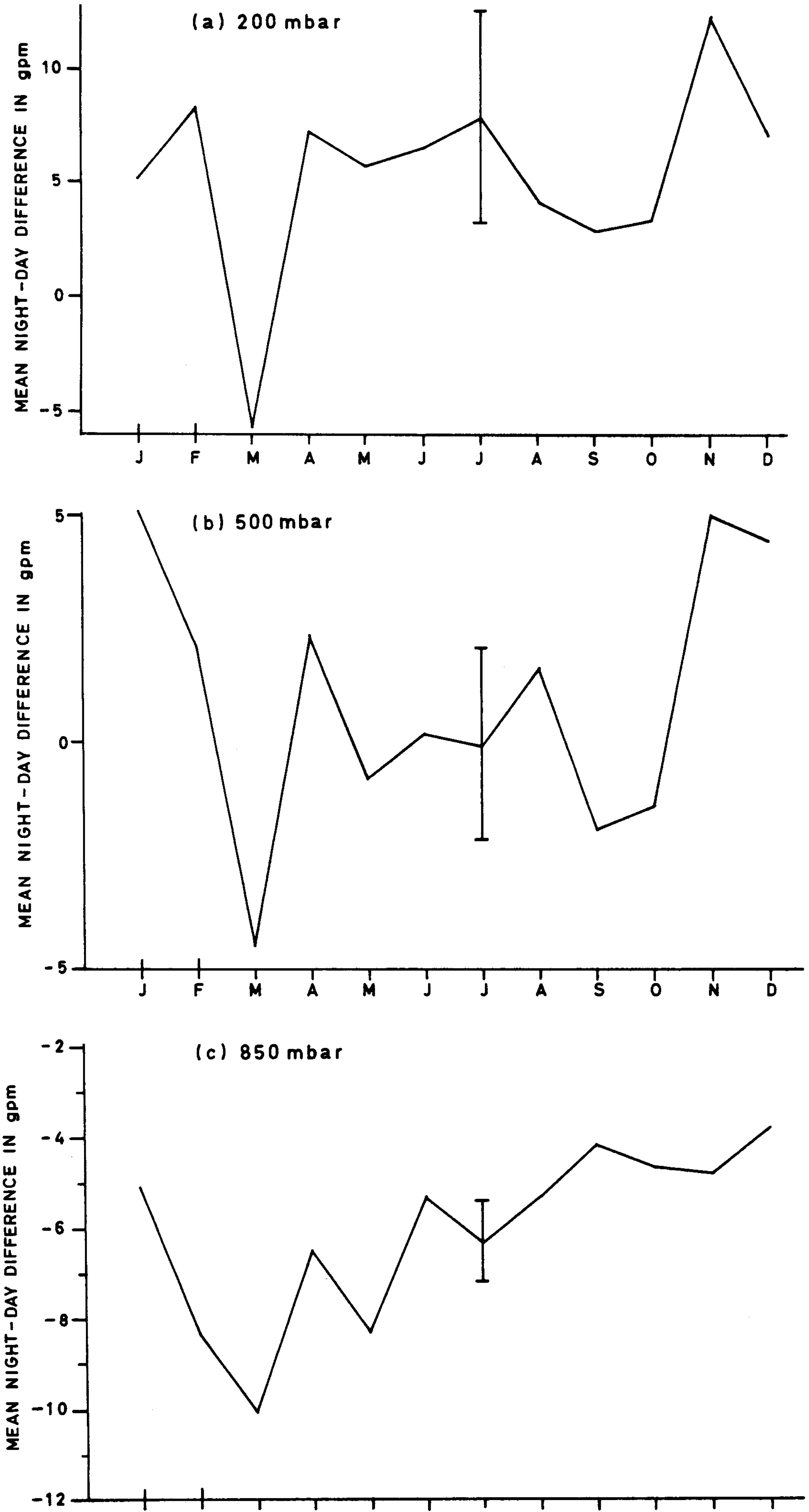

FIGURE 6. MONTHLY MEAN NIGHT–DAY DIFFERENCE AT HONG KONG (1976–78). THE VERTICAL BAR SHOWS THE TYPICAL STANDARD ERROR OF MONTHLY DIFFERENCES.

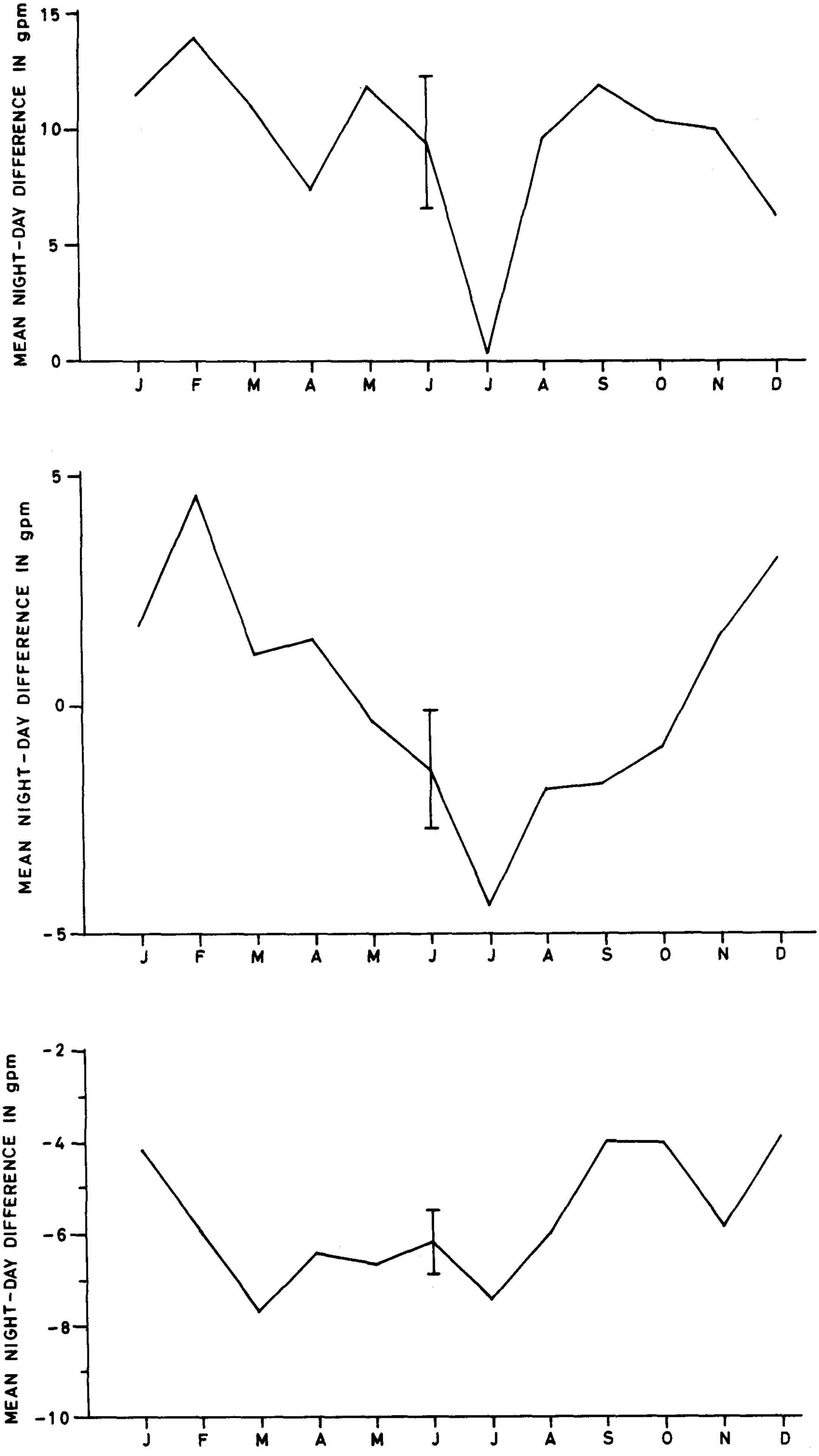

FIGURE 7. MONTHLY MEAN NIGHT-DAY DIFFERENCE AT GUANGZHOU (1976-78). THE VERTICAL BAR SHOWS THE TYPICAL STANDARD ERROR OF MONTHLY DIFFERENCES.

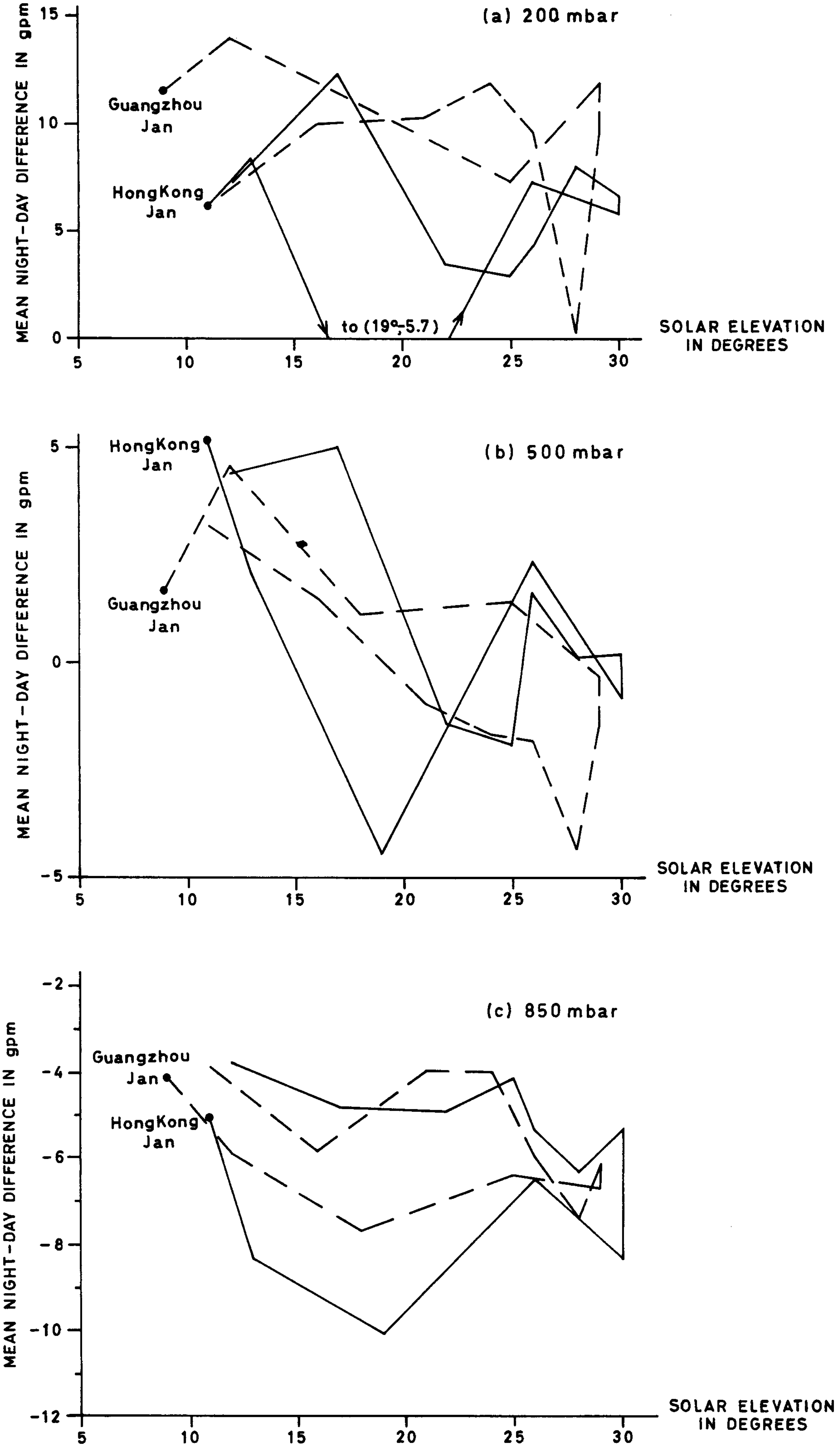

FIGURE 8. MONTHLY MEAN NIGHT-DAY DIFFRENCE AND MID-MONTH SOLAR ELEVATION AT 00 GMT.