ROYAL OBSERVATOY, HONG KONG

TECHNICAL NOTE NO. 40

THE AUGUST RAINSTORMS OF 1969 AND 1972 IN HONG KONG

BY

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C O N T E N T S

FIGURES

TABLE

SUMMARY

This is a comparative case study of two rainstorms in August 1969 and August 1972. Both rainstorms were associated with decaying typhoons moving on similar tracks and brought similar amounts of rainfall to Hong Kong. It is found that southwest monsoon activated by the decaying typhoon was the cause of both rainstorms. The intensity and duration of each rainstorm were closely associated with the intensity and the movement of an isotach maximum in the southwest monsoon between surface and 500 mbar.

Some synoptic differences were also found between the two occasions but they do not seem to have any marked effects in the final outcome.

1. INTRODUCTION

On 17 August 1972, typhoon Betty moving on a northwest track passed the northern tip of Taiwan. Two days later, rain occurred over Hong Kong and was almost continuous for the next three days, bringing a total of 288.4 mm of rainfall. The amount of rainfall and the synoptic situation were very similar to the rainstorm occurring in the period 9-12 August 1969 which was associated with a typhoon of the same name, Betty, moving on a similar track. A total of 295.0 mm of rainfall was recorded in a 3-day period. The latter situation was in fact used as an analogue to forecast successfully the time of the onset of rain and its amount in Hong Kong in 1972.

Chen (1969) made a detailed case study of a severe rainstorm occurring in June 1966. The rainstorms of August 1969 and August 1972 were basically of a different nature. At the same time, a search through past records looking for tropical cyclones following similar tracks (Chin 1972) revealed that these were the first two instances in which typhoons were involved having complete synoptic charts and other rainfall records available. Hence this paper is written to identify the synoptic pattern caused by decaying typhoons moving on such tracks and at the same time to list the similarities and differences of both situations.

For simplicity, the period 8-12 August 1969 will be referred to as period 1 and 17-21 August 1972 as period 2. The days in each period will be numbered from 1 to 5. The rainstorm in period 1 began at 1300 GMT on day 2 and ended at 0200 GMT on day 5. The rainstorm in period 2 began at 1700 GMT on day 2 and ended at 2200 GMT on day 5. (Fig. 1)

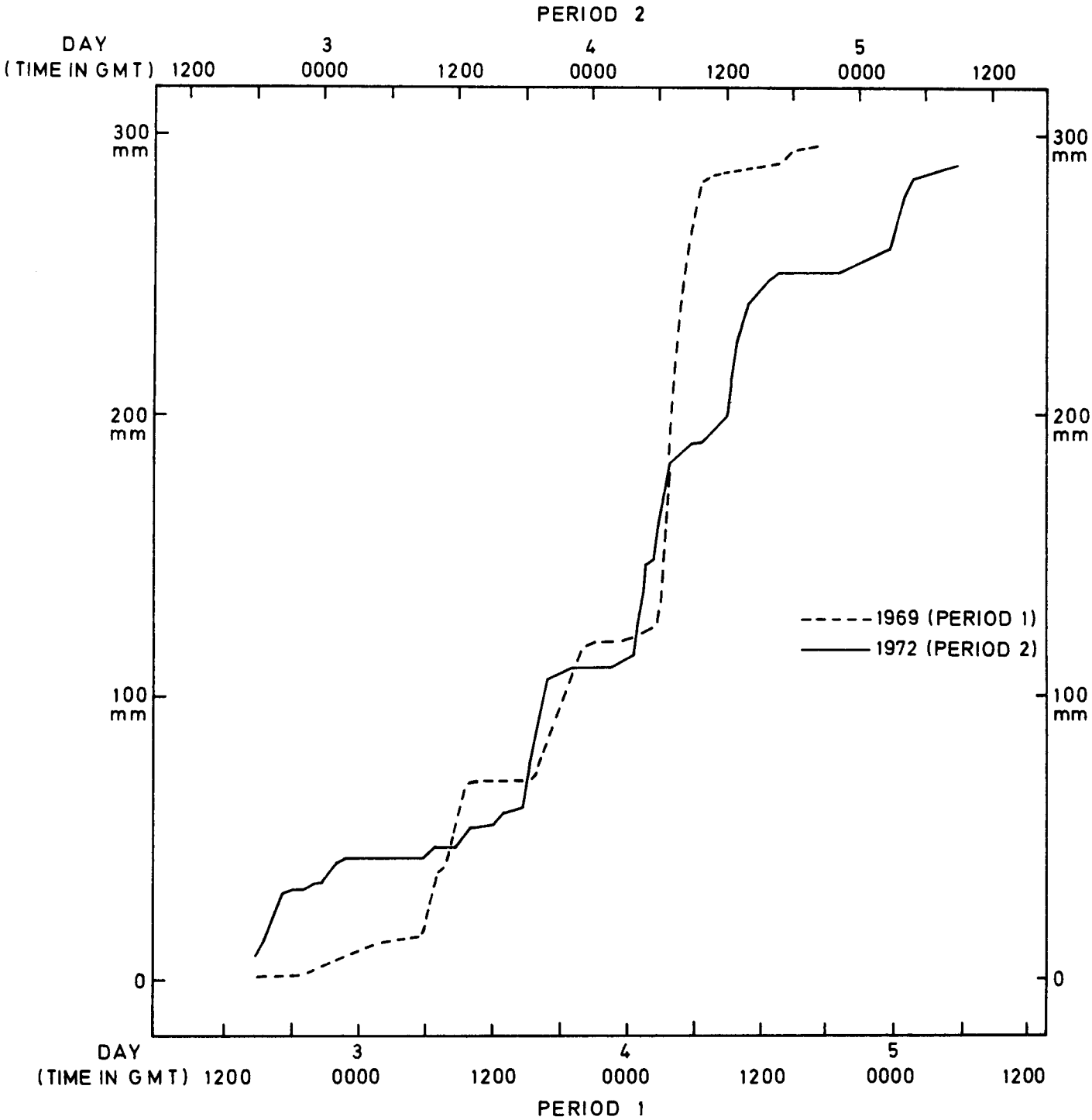


Figure 1. Cumulative rainfall at the Royal Observatory Hong Kong during period 1 and period 2.

2. THE SYNOPTIC SITUATION

The tracks of both typhoons were shown in Fig. 2. They passed the northern tip of Taiwan on day 1 and dissipated to an area of low pressure soon after landfall. Because of the positions of the centres of the remnants, southwest winds had already set in over south China on day 1, although rain began in Hong Kong towards the end of day 2 when both remnants were near the 115°E longitude. The remnant in period 1 moved at a speed of 11.3 knots while that of period 2 moved at 8.3 knots. This discrepancy in speed resulted in the different time spans from its passage across the northern tip of Taiwan to the beginning of rain in Hong Kong (36 hours in period 1 and 48 hours in period 2).

In both cases, the first shower was reported at Royal Observatory soon after the mean sea level pressure reached the minimum, indicating that the remnant had passed the point of closest approach. The southwest monsoon then increased in strength, reaching a maximum mean hourly wind speed of 32 knots in period 1 and 22 knots in period 2. Since the remnant dissipated entirely soon after its closest point of approach and was at all times more than 300 miles away from Hong Kong, the rain occurring in Hong Kong cannot be classified as tropical cyclone rainfall (Kwong 1974). In both cases, they were solely due to the strengthened southwest monsoon.

The most prominent feature in the upper air in both occasions was the isotach maximum in the surface-to-500 mbar layer in the southwest winds feeding into the upper air vortices associated with the remnants of the typhoons. The vertical structure of each maximum was shown as a time cross-section of the upper winds over Hong Kong for each period. (Fig. 3 & 4) in both cases the southwest winds extended from surface to at least 500 mbar during the period of rain and reached 200 mbar at the peak of the rainstorm with the heaviest downpour. The axis of each isotach maximum could be located by isotach analysis on the 850 mbar and 700 mbar charts. Throughout both periods of events these axes moved steadily and predictably westwards in spite of the dissipation of the surface and upper air vortices and the presence of other synoptic influences. (Fig. 5 & 6).

In both cases, rain in Hong Kong began when the axes of the isotach maxima at both levels were just off the east coast of Taiwan on day 2. The heaviest downpour, in terms of the hourly recorded rainfall amounts, occurred on day 4 when the westward-moving isotach maxima were directly overhead Hong Kong. The speeds of movement of the maxima in both periods were the same as those of the remnants. The difference in the speeds of movement of the maxima resulted in the extension of the rainstorm in period 2 until the end of day 5.

After the passage of the isotach maxima, there was a marked decrease in the amount of rain. In fact for period 1, the Pacific ridge at lower levels moved in soon after and there was a rapid clearance on day 5. Clearance was more gradual in period 2 which began at the end of day 5. Both isotach maxima finally dissipated over west China.

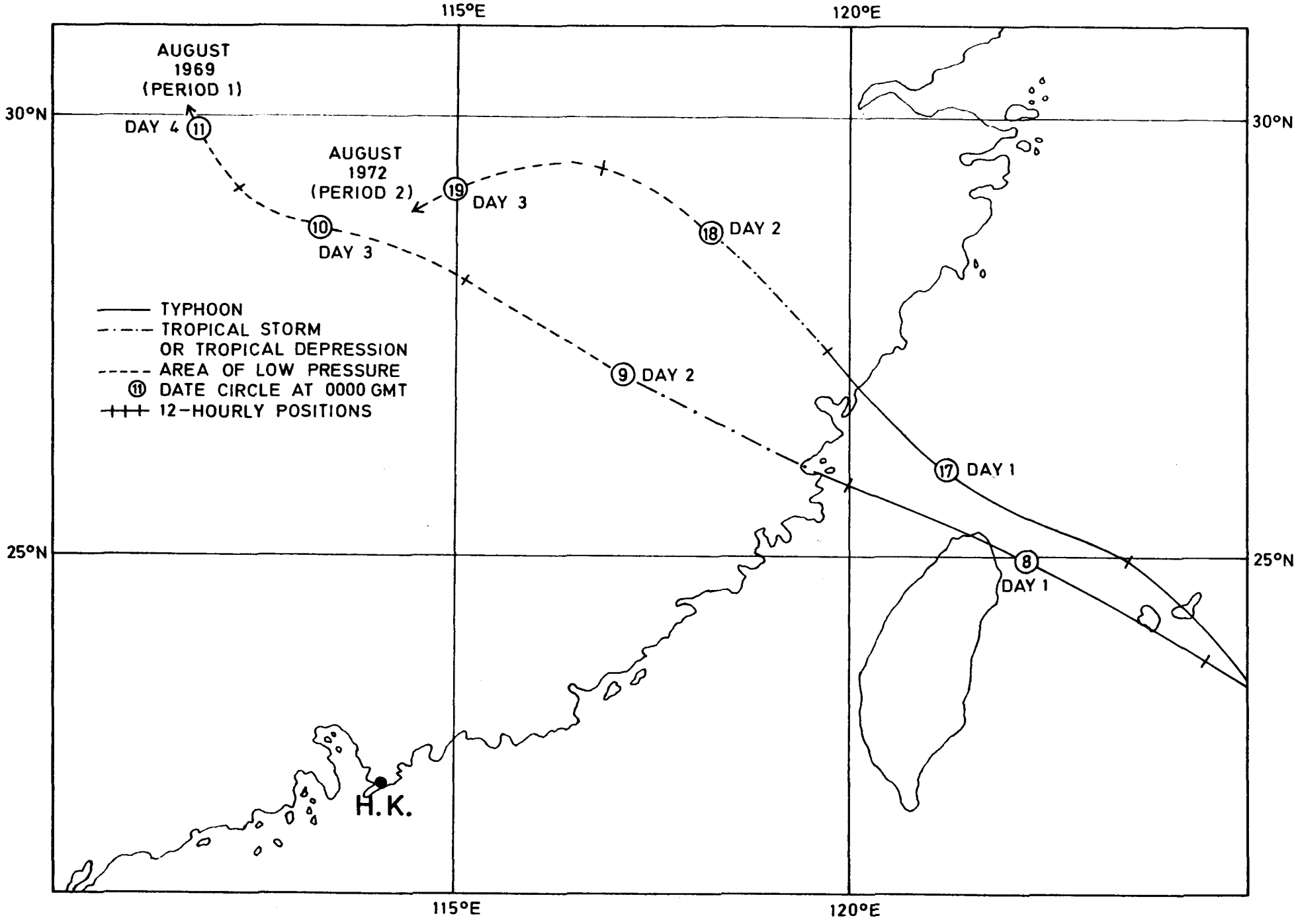
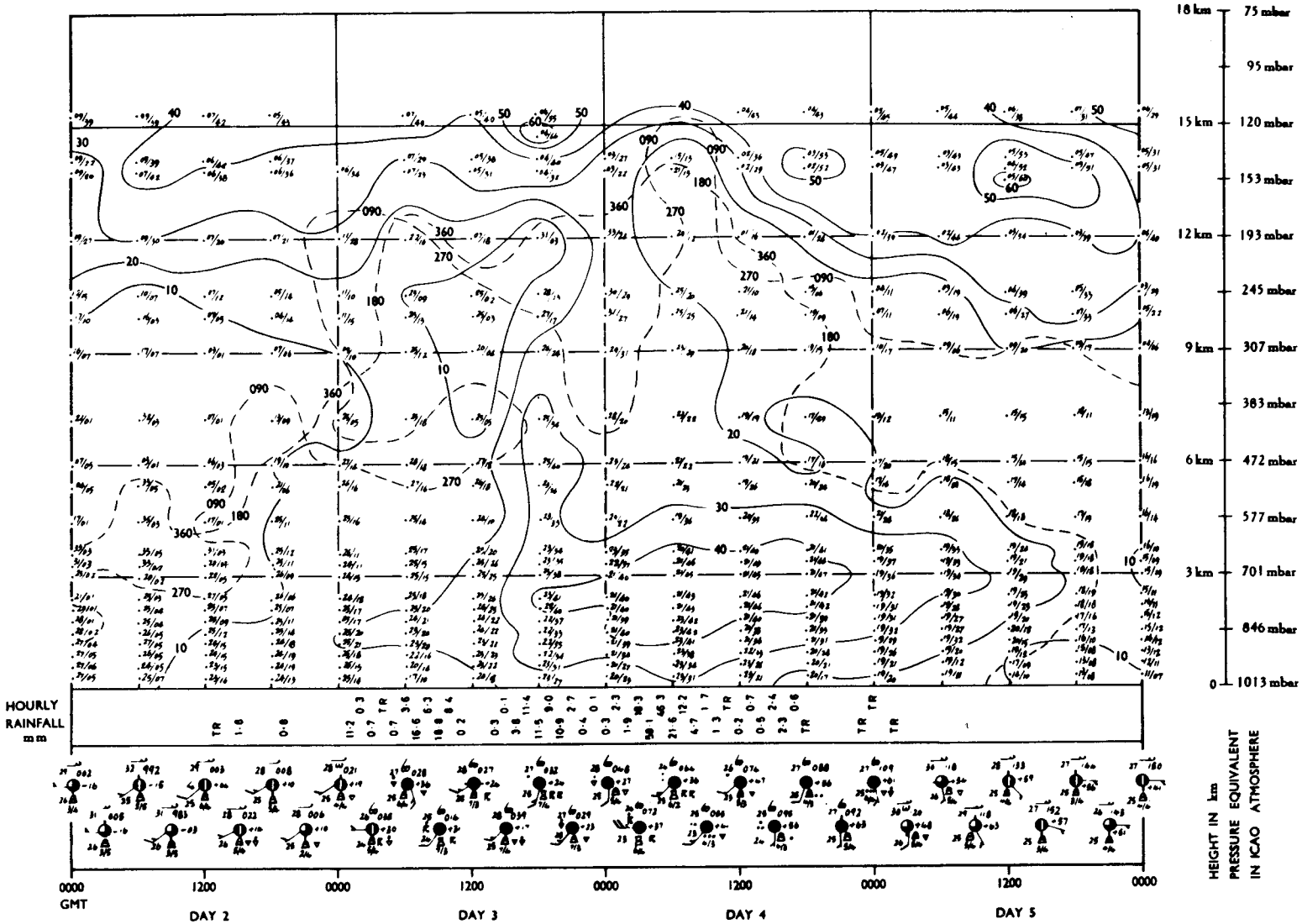


Figure 2. Tracks of Betty in August 1969 and August 1972.



PERIOD 1

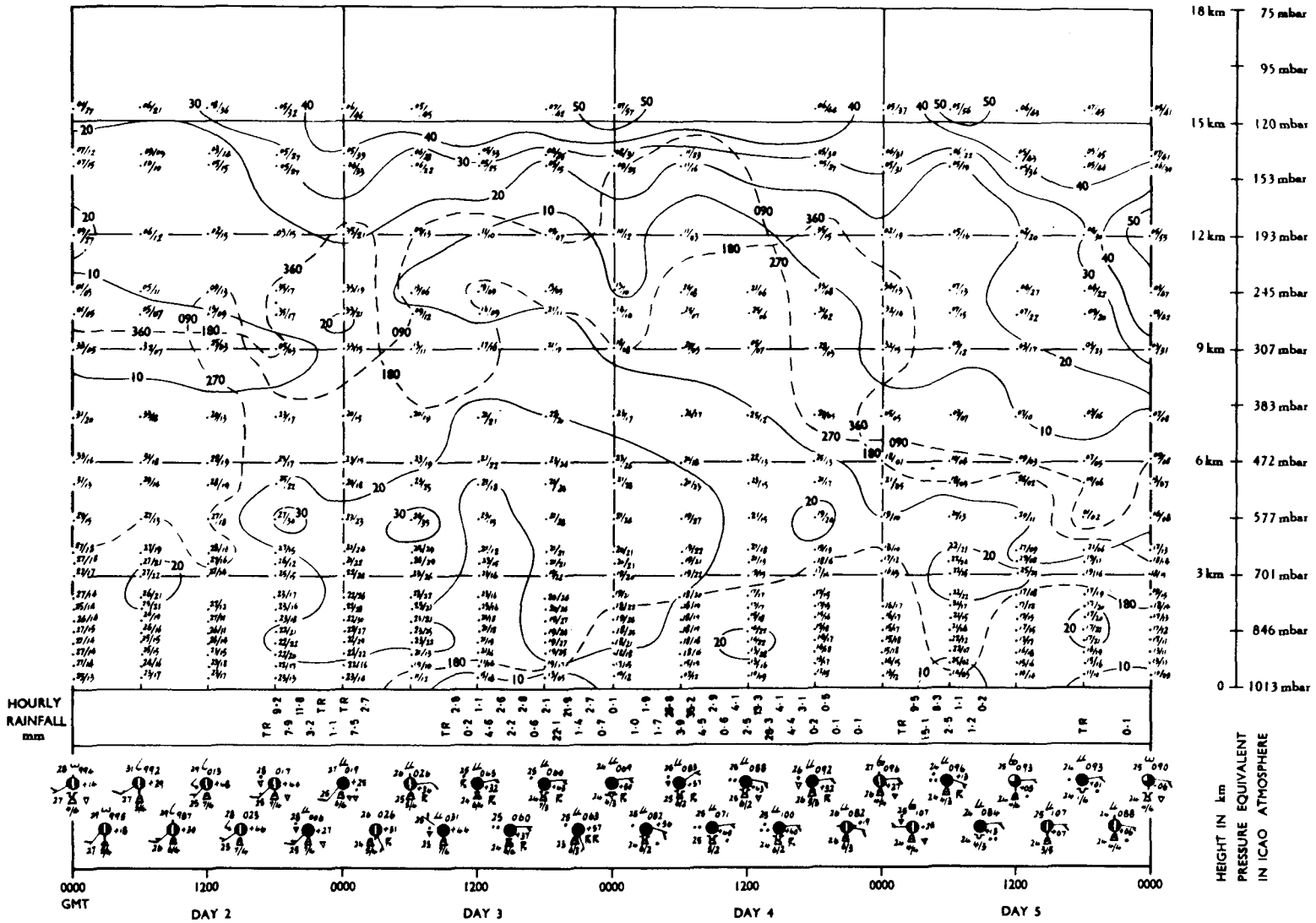
STATION: ROYAL OBSERVATORY HONG KONG

– – – ISOGON (090°, 180°, 270°, 360°)

——— ISOTACH IN 10-KNOT INTERVAL

FIGURES GIVE THE DIRECTION IN TENS OF DEGREES AND SPEED IN KNOTS OF THE WIND

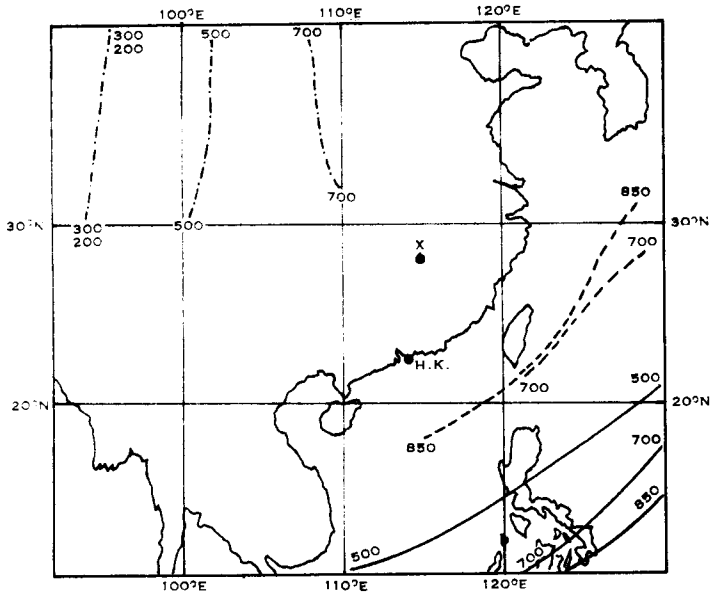
Figure 3. Time cross-section of wind in period 1.



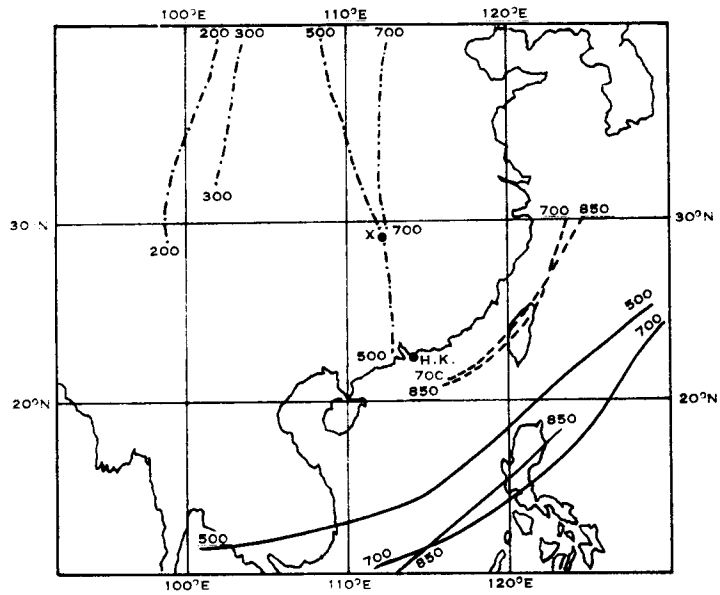
PERIOD 2
STATION: ROYAL OBSERVATORY
HONG KONG

— — — ISOGON (090°, 180°, 270°, 360°)
——— ISOTACH IN 10-KNOT INTERVAL
FIGURES GIVE THE DIRECTION IN TENS OF DEGREES AND SPEED IN KNOTS OF THE WIND

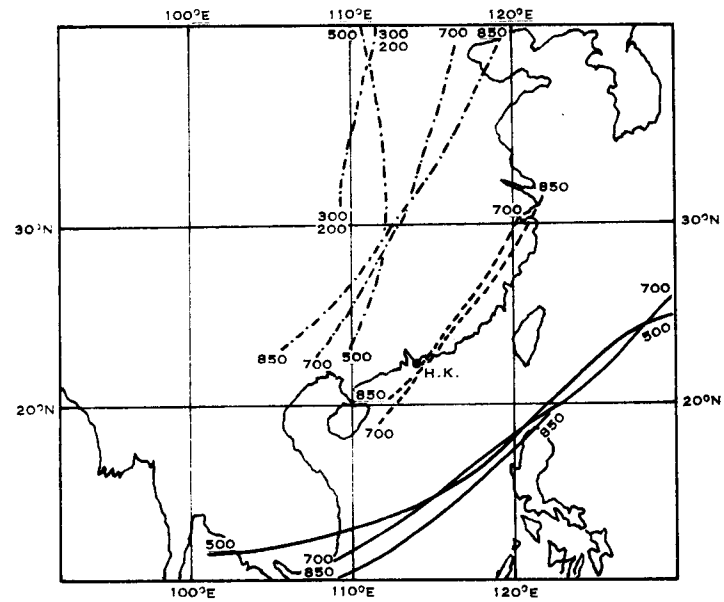
Figure 4. Time cross-section of wind in period 2.



1200 GMT DAY 2



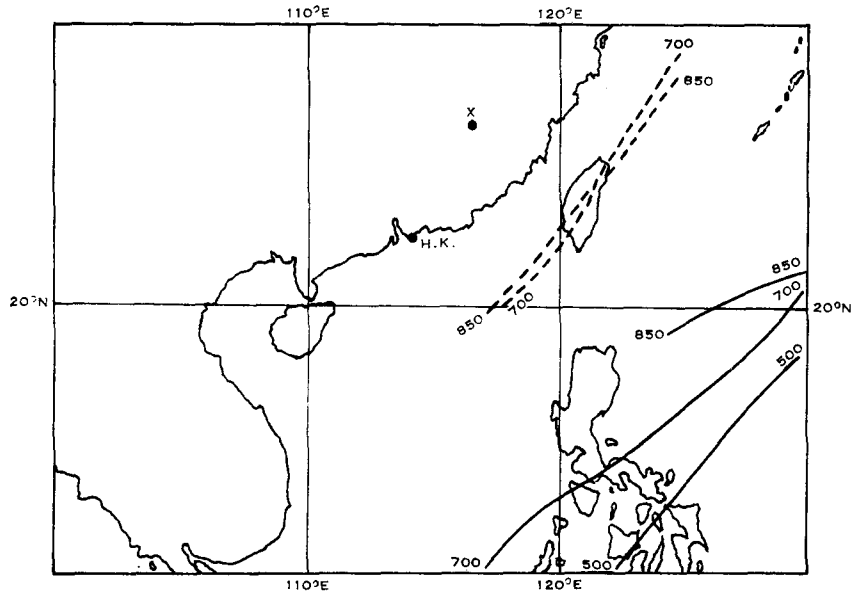
1200 GMT DAY 3



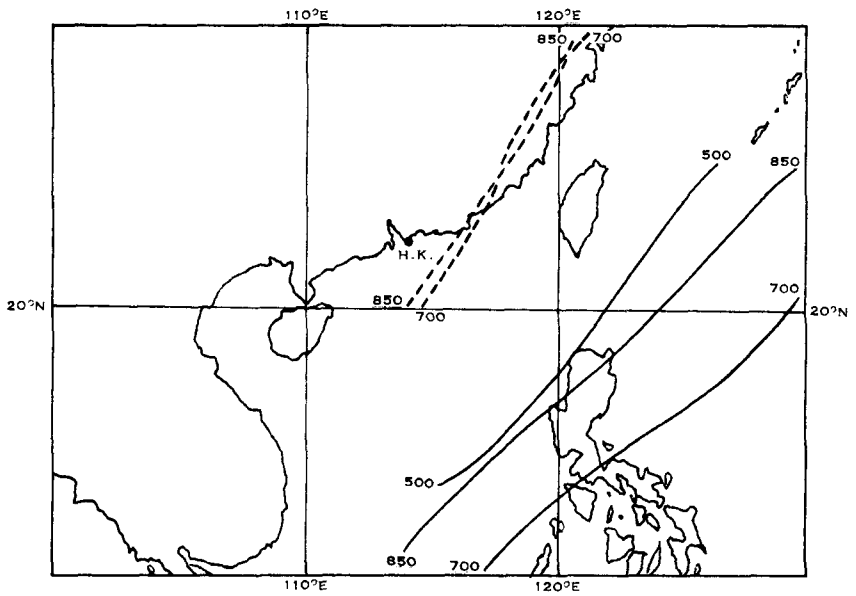
1200 GMT DAY 4

-----AXIS OF ISOTACH MAXIMUM
——— AXIS OF PACIFIC RIDGE
-·-·-·- AXIS OF WESTERLY TROUGH
X POSITION OF CYCLONIC VORTEX
ALL AXES ARE LABELLED BY PRESSURE LEVELS IN MBAR

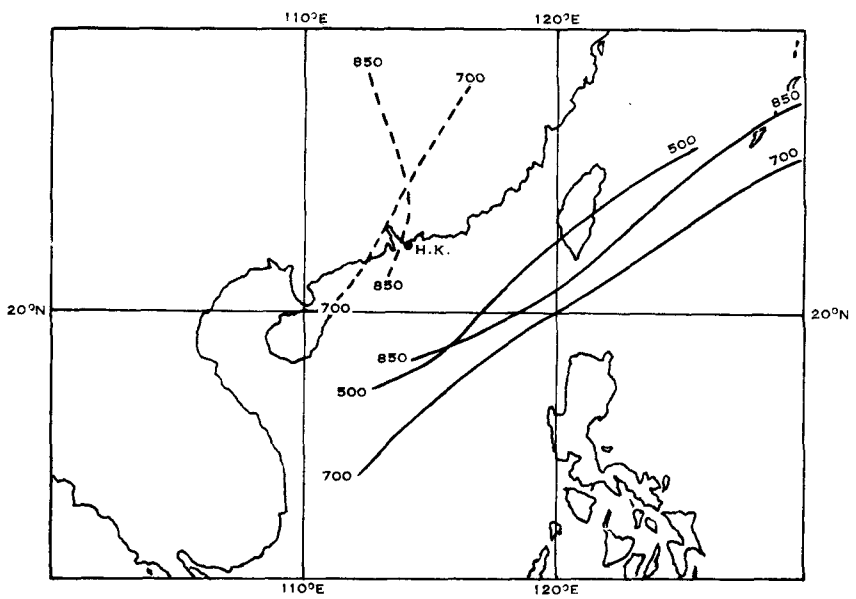
Figure 5. Upper air conditions: days 2-4 period 1.



1200 GMT DAY 2



1200 GMT DAY 3



1200 GMT DAY 4

----- AXIS OF ISOTACH MAXIMUM
——— AXIS OF PACIFIC RIDGE
X POSITION OF CYCLONIC VORTEX
ALL AXES ARE LABELLED BY PRESSURE LEVELS IN MBAR

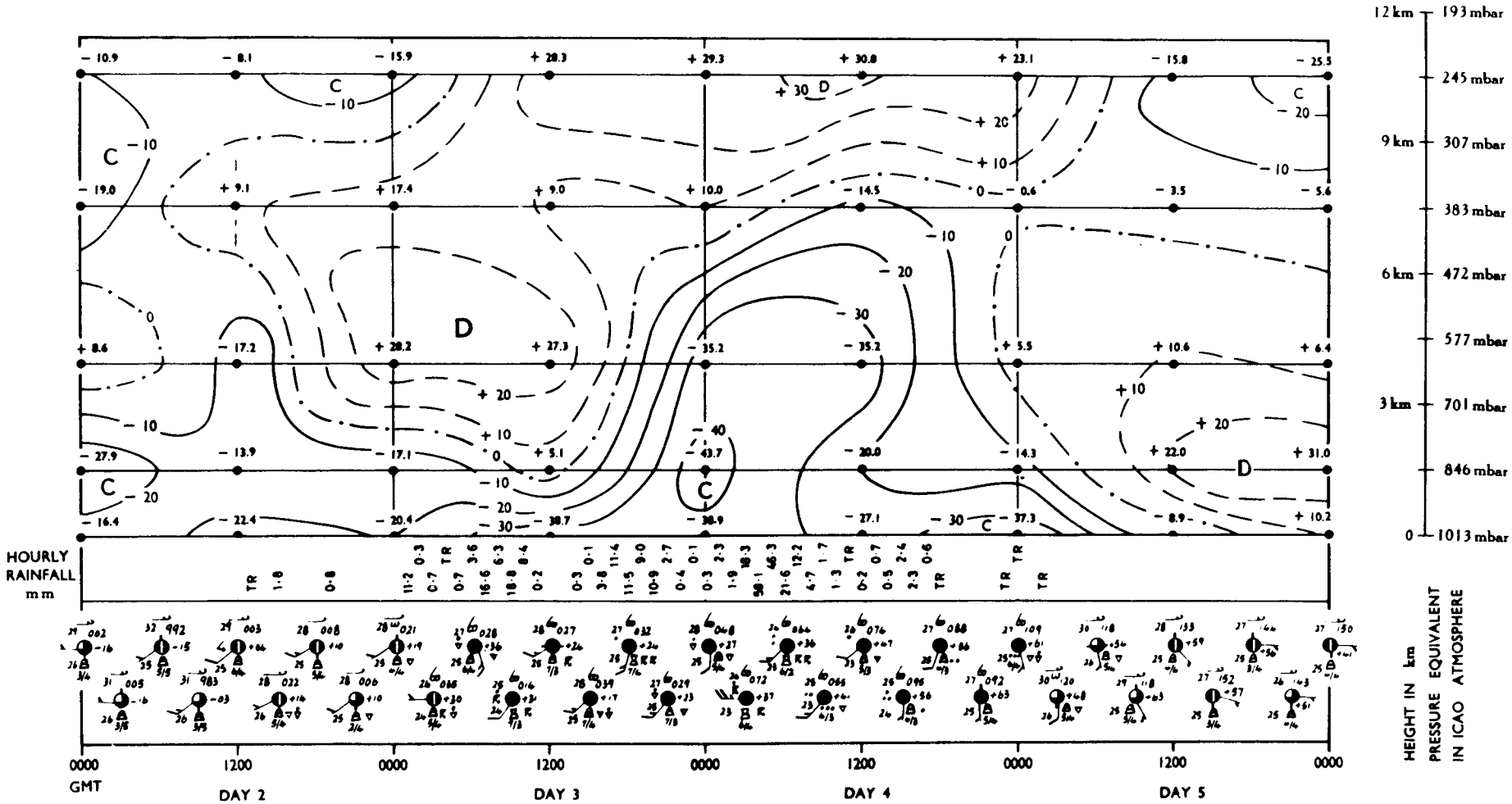
Figure 6. Upper air conditions: days 2–4 period 2.

Another feature in the upper air which was prominent in period 1 but was absent in period 2 was a trough in the westerlies. This trough was first located at 500 mbar and higher levels on day 1 over the Tibetan Plateau moving eastwards at a steady speed of 20 knots. On day 3, when they began to slow down, a trough at 700 mbar was formed. On day 4, a 850 mbar trough was also formed. At the same time the 500 mbar and higher level troughs became stationary just east of 110°E longitude. The vortices associated with the remnant of the typhoon on the lower three levels became part of the westerly troughs. This resulted in an extension of the trough axes to south China to the west of Hong Kong. Meanwhile, the isotach maximum continued to move west with unchanged speed and intensity. The combined effect of being ahead a westerly trough and a eastward moving isotach maximum was the marked rise in the height of the level of non-divergence to 300 mbar on day 4 with convergence below (Fig. 7). This resulted in the large amount of rainfall (126.0 mm in the 3 hours of heaviest rainfall) during the peak of the rainstorm in period 1 when the isotach maximum was directly overhead Hong Kong.

No influence from the higher latitude westerlies occurred in period 2. The subtropical ridge above 500 mbar was strong throughout the entire period with its axis near 30°N. The height of the level of non-divergence changed gradually (Fig. 8) and there were only 65.9 mm of rainfall recorded during the 3 hour-peak of the rainstorm on day 4.

Satellite photographs taken around noon by the meteorological satellite ESSA 9 on day 2 to day 4 of each period were shown in Fig. 9 and 10 for reference. There were three areas of cloudiness of interest on day 2 of period 1: the area near Taiwan Strait was associated with the isotach maximum, the area over central China was associated with the decaying typhoon and the band further west was associated with the approaching westerly trough. On day 3, the last two areas merged into one and extended south to 25°N while the first area moved west. These two areas finally became one as the latter continued to move west on day 4.

The photograph on day 2 of period 2 was similar to that of period 1 minus the cloud band associated with the westerly trough. There were only two areas of cloudiness of interest: one associated with the remnant of the typhoon and the other with the isotach maximum near Taiwan Strait. The former dissipated on day 3 while the latter moved progressively westwards through successive pictures.



PERIOD 1

STATION : ROYAL OBSERVATORY HONG KONG

— — — ISOPLETH OF POSITIVE DIVERGENCE

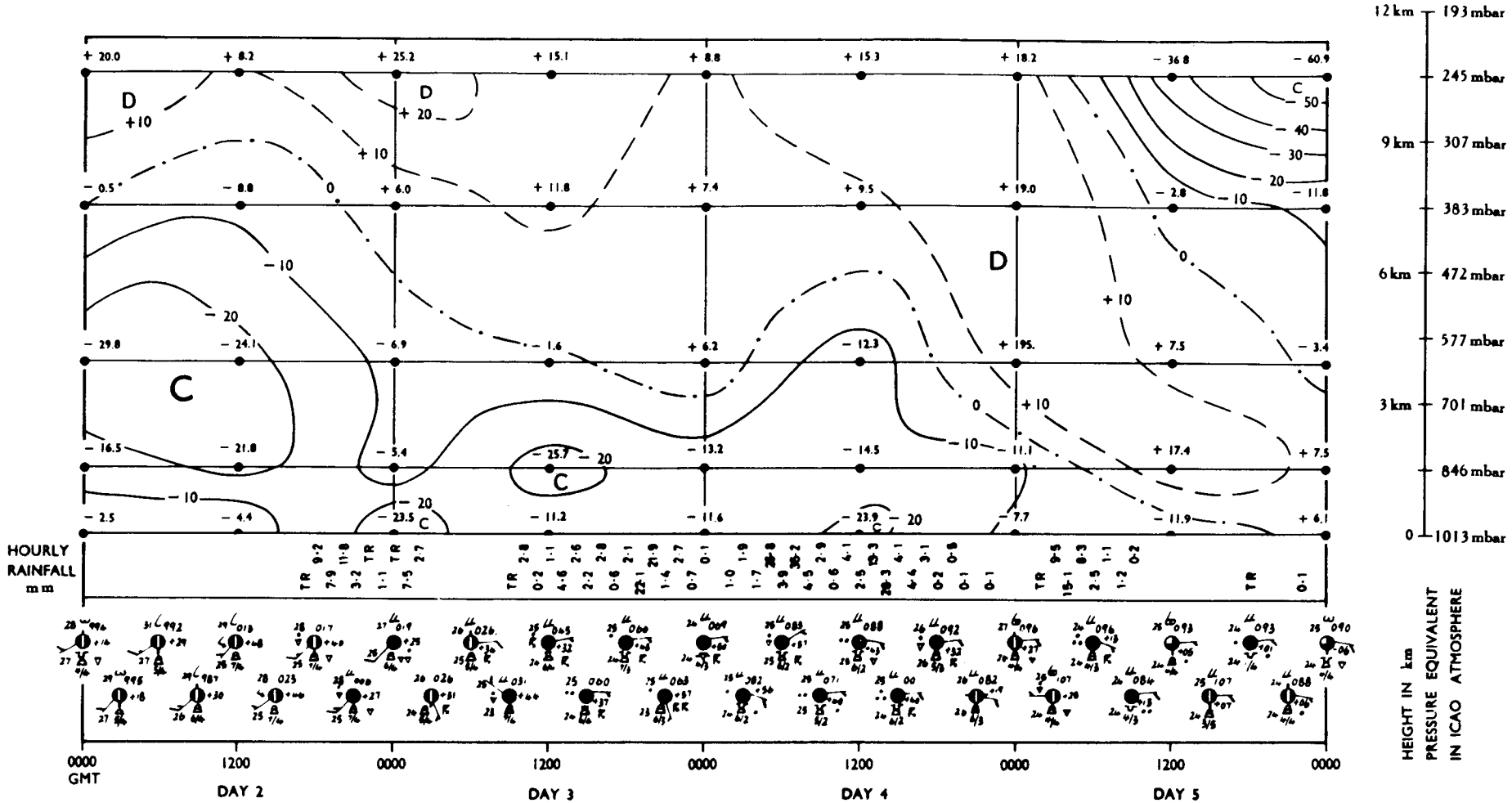
——— ISOPLETH OF NEGATIVE DIVERGENCE (CONVERGENCE)

—·—·— LEVEL OF NON-DIVERGENCE

ISOPLETHS ARE LABELLED IN 10^{-6} s^{-1}

D (C) LOCAL MAXIMUM OF POSITIVE (NEGATIVE) DIVERGENCE

Figure 7. Time cross-section of divergence in period 1.



PERIOD 2

STATION : ROYAL OBSERVATORY HONG KONG

— — — *ISOPLETH OF POSITIVE DIVERGENCE*

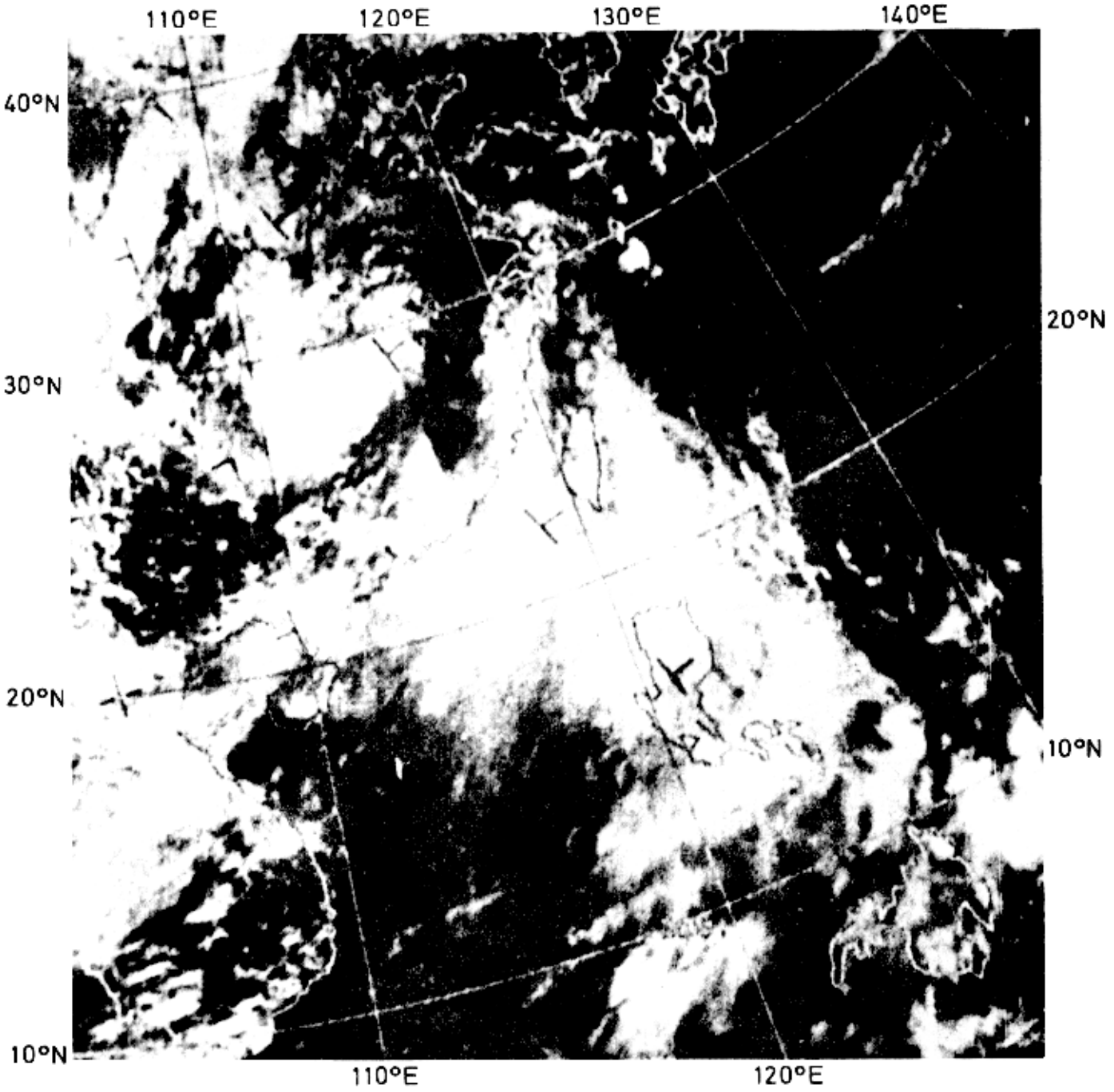
——— *ISOPLETH OF NEGATIVE DIVERGENCE (CONVERGENCE)*

—·—·— *LEVEL OF NON-DIVERGENCE*

ISOPLETHS ARE LABELLED IN $10^{-6}\ s^{-1}$

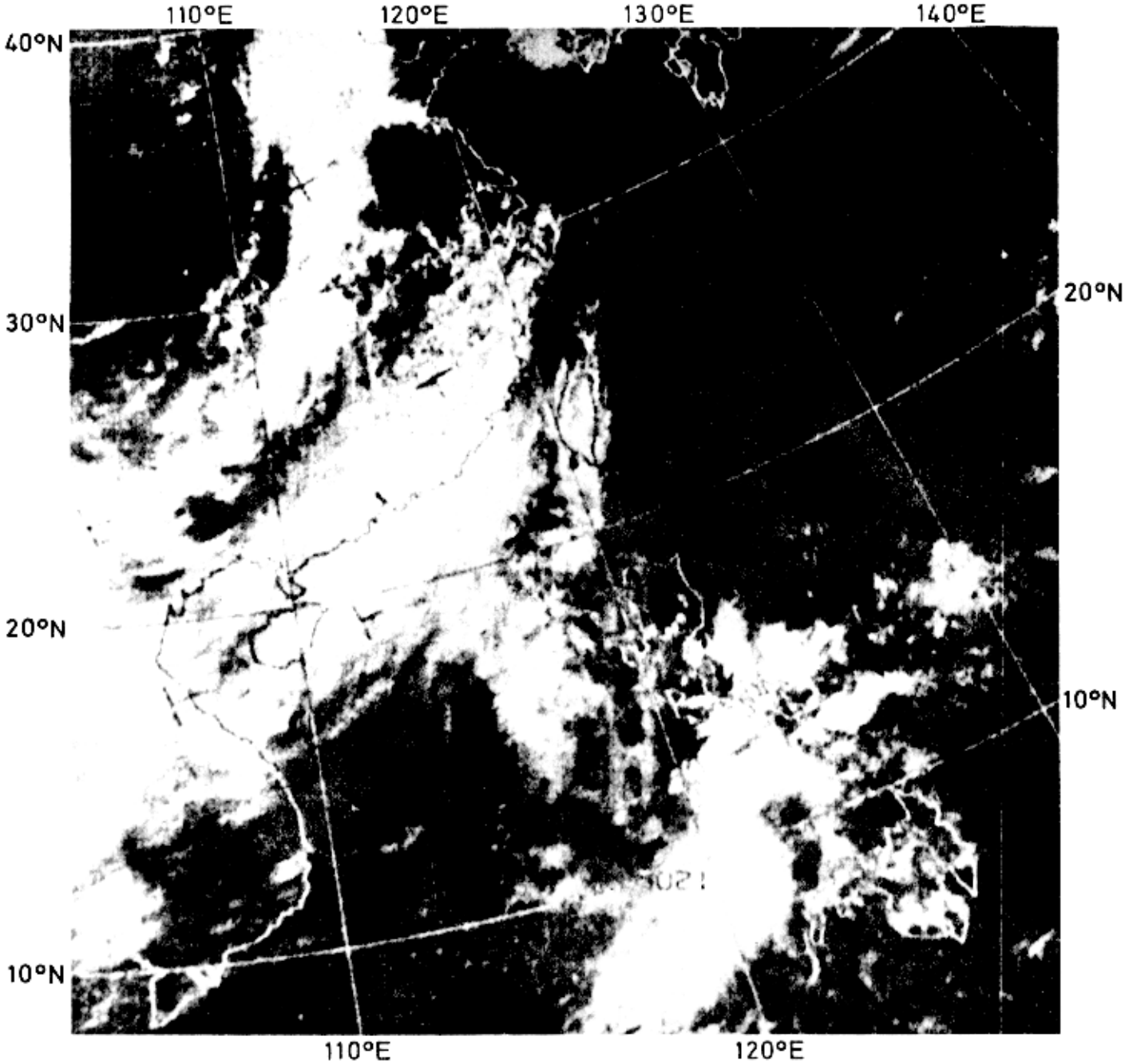
D (C) LOCAL MAXIMUM OF POSITIVE (NEGATIVE) DIVERGENCE

Figure 8. Time cross-section of divergence in period 2.



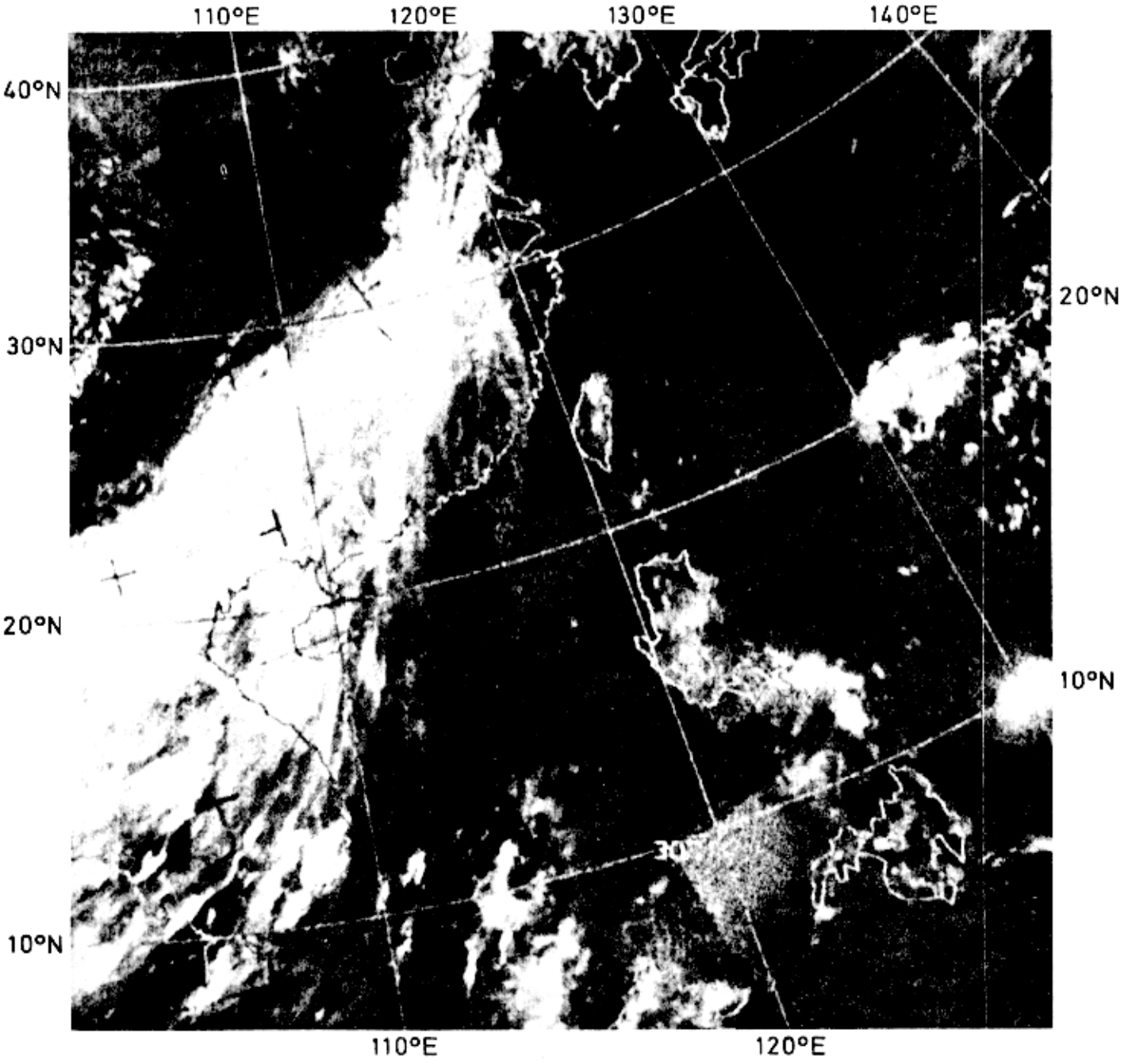
(a) DAY 2 PERIOD 1 PASSES: 2049–2061

Figure 9. Pictures taken daily by the meteorological satellite, ESSA 9, on days 2-4 period 1.



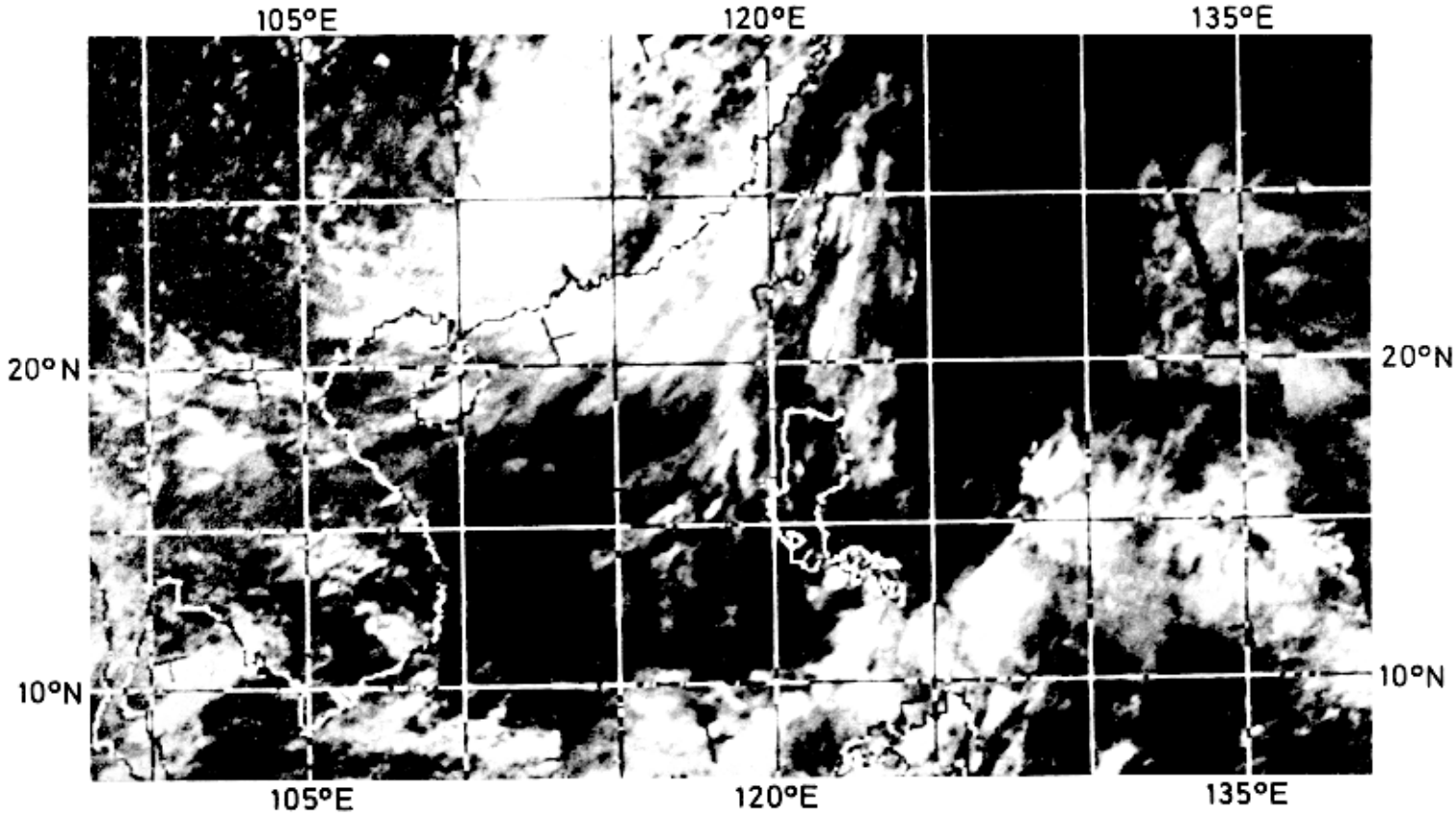
(b) DAY 3 PERIOD 1 PASSES: 2062–2074

Figure 9. (Cont'd).



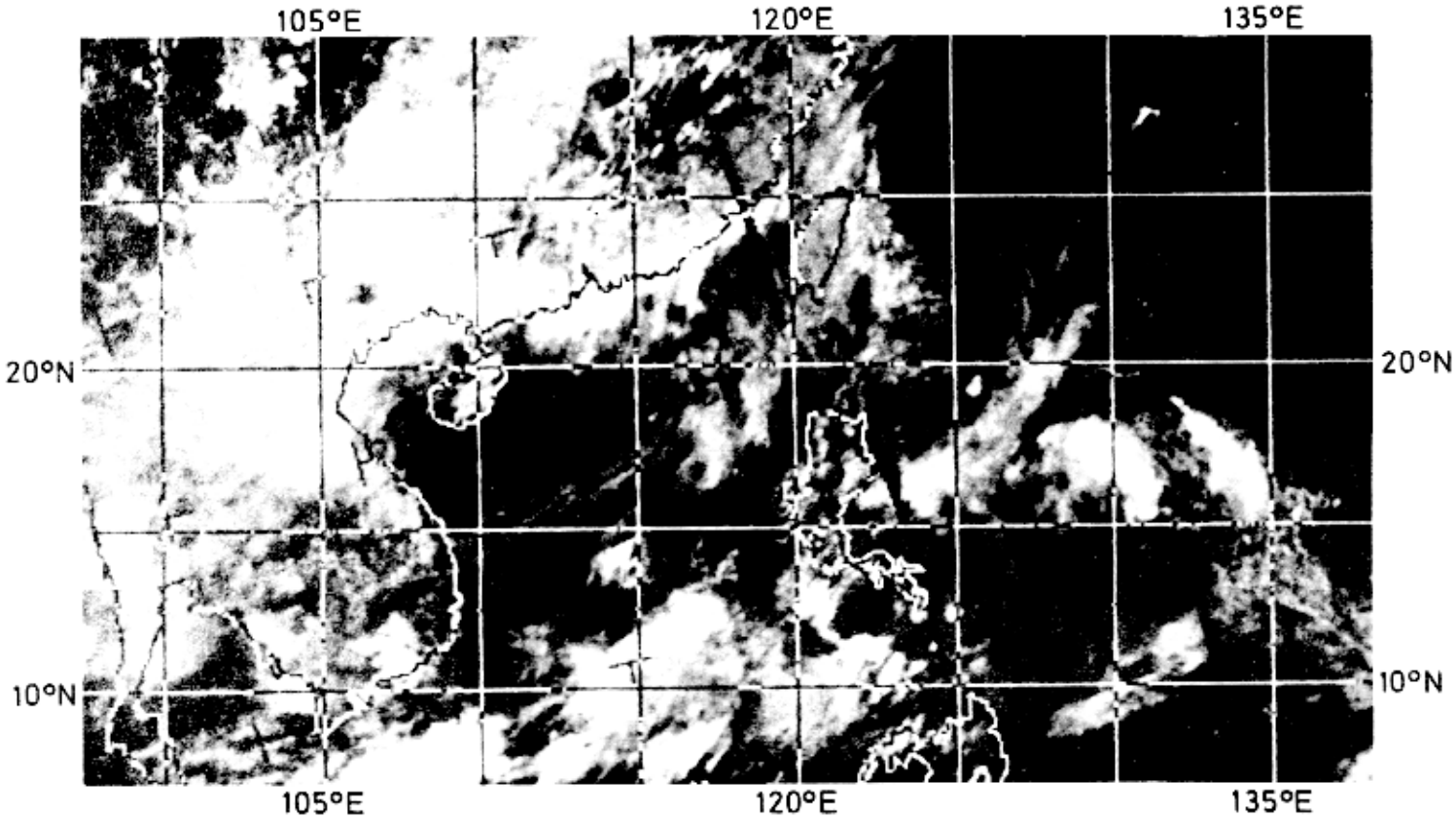
(c) DAY 4 PERIOD 1 PASSES : 2074–2086

Figure 9. (Cont'd).



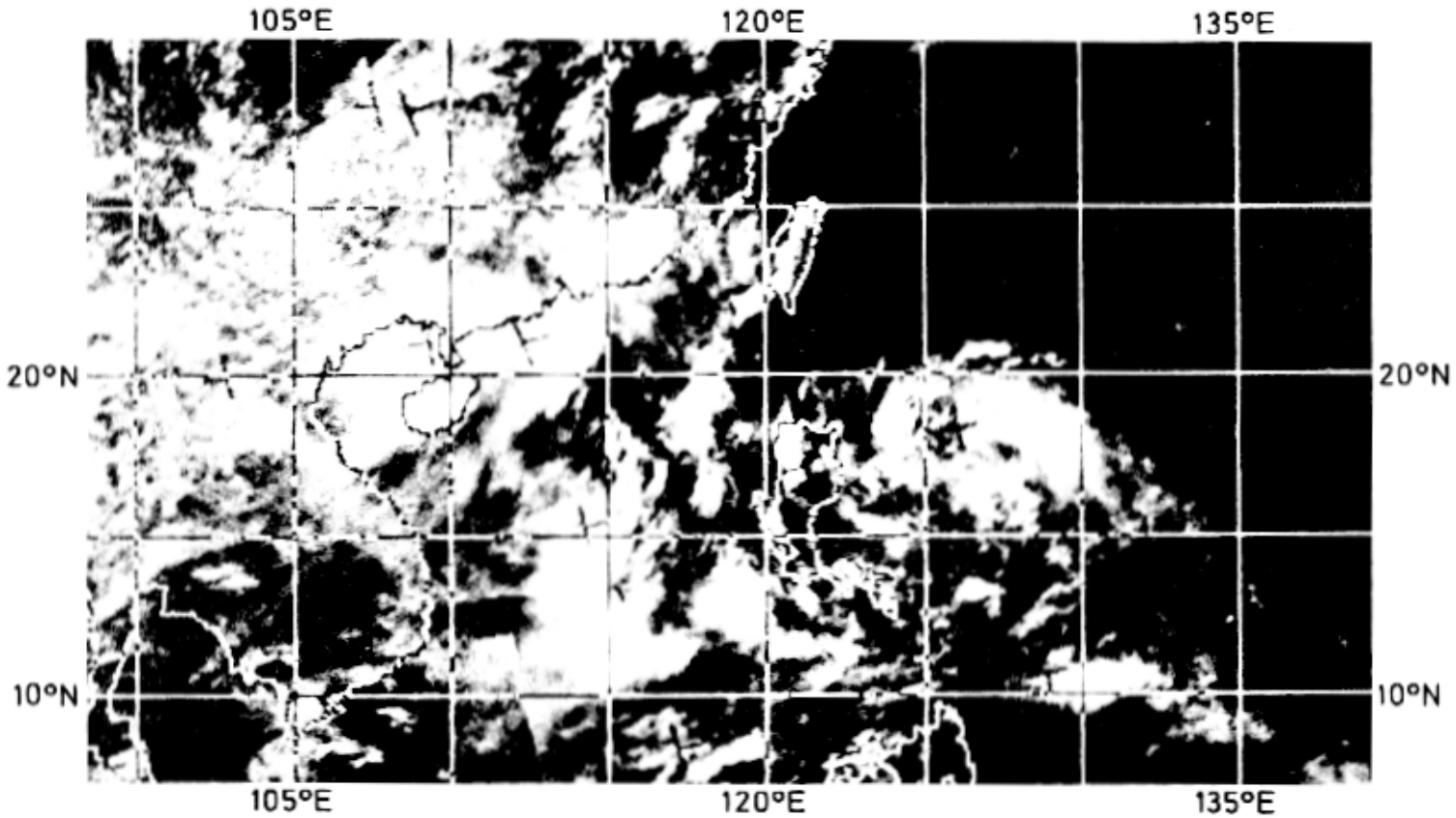
(a) DAY 2 PERIOD 2 PASSES: 5853–5864

Figure 10. Pictures taken daily by the meteorological satellite, ESSA 9, on days 2-4 period 2.



(b) DAY 3 DERIOD 2 PASSES : 5865–5876

Figure 10. (Cont'd).



(c) DAY 4 PERIOD 2 PASSES : 5878–5889

Figure 10. (Cont'd).

3. THE RAINFALL CHARACTERISTICS

The areal distributions of rainfall over south China during period 1 and period 2 were shown in Fig. 11 and 12 respectively. In both cases, a rainfall maximum was located along the south China coast near Hong Kong associated with the westward-moving isotach maximum. Another rainfall maximum located well inland was associated with the remnant of the typhoon. The two maxima in both cases were separated by a relatively dry area. This agrees with the previous observation that the rainfall over south China (hence those over Hong Kong) was not directly caused by the circulation of the remnant. Instead southwest monsoon activated by the decaying typhoon was the cause of both rainstorms.

Table 1 which shows the amount of the 3-day rainfall in 24-hour periods after rain began in Hong Kong is included for reference so that similar situations occurring in the future will be able to have a daily rainfall forecast by analogue. Over 65% of the total rainfall was recorded within the second 24-hour period in both cases.

TABLE 1 THE 3-DAY RAINFALL IN MM RECORDED AT THE ROYAL OBSERVATORY IN 24-HOUR PERIODS AFTER RAIN BEGAN AT H HOUR

	Period 1		Period 2	
	Amount	percentage of total	Amount	percentage of total
H				
	69.7	23.6	60.3	20.9
H + 24				
	220.0	74.6	189.3	65.6
H + 48				
	5.3	1.8	38.8	13.5
H + 72				
TOTAL	295.0	100.0	288.4	100.0

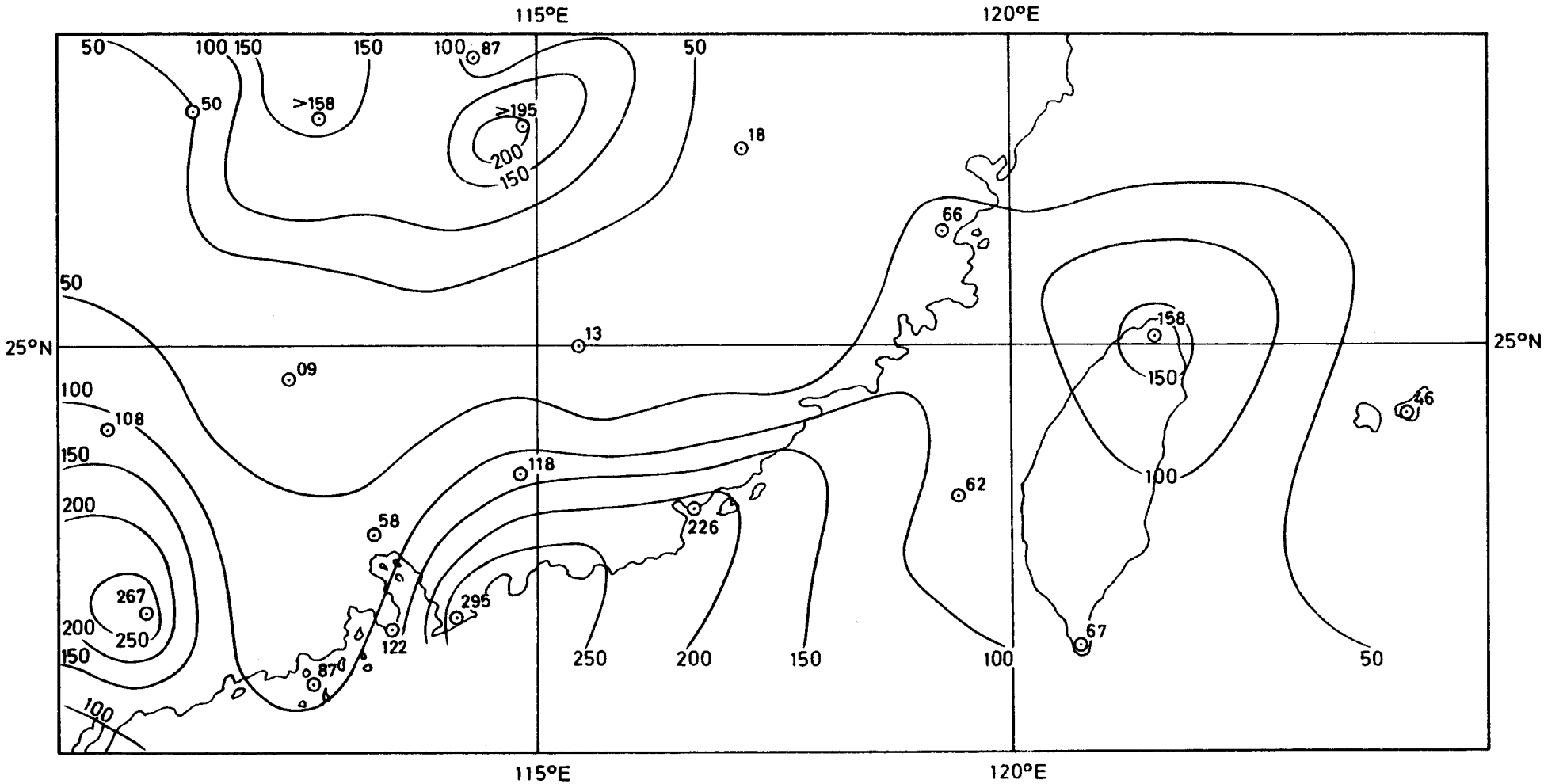


Figure 11. Total rainfall in period 1 (10-12 August 1969) (isohyets and rainfall figures in mm).

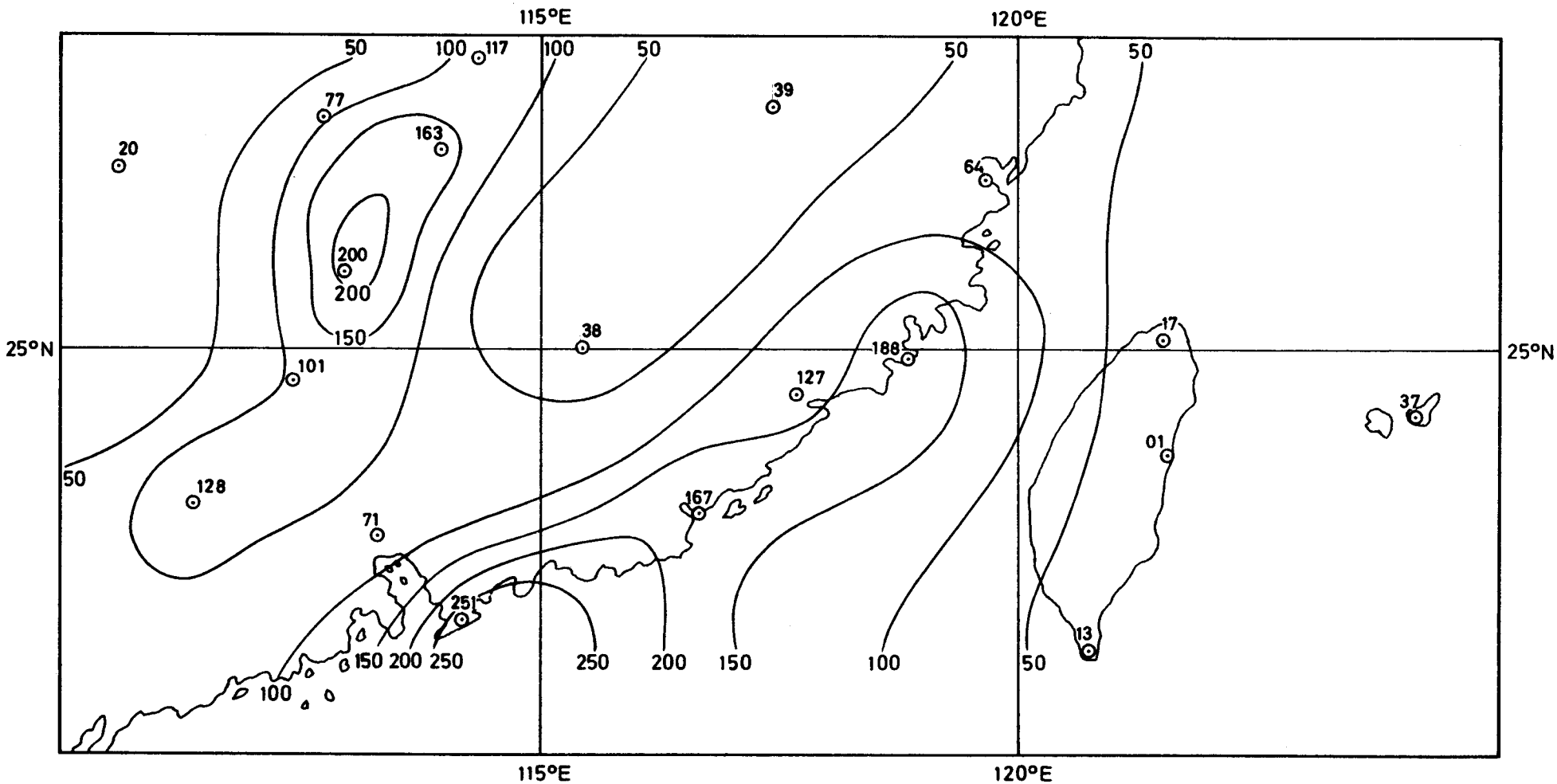


Figure 12. Total rainfall in period 2 (19-21 August 1972) (isohyets and rainfall figures in mm).

4. CONCLUSIONS

From the above discussions it is concluded that both rainstorms were caused by southwest monsoon activated by a decaying typhoon moving on tracks shown in Fig. 2. In each occasion, an isotach maximum was located in the southwest monsoon between surface and 500 mbar moving steadily and predictably from east Taiwan westwards across the south China coastal areas. The speed of movement was the same as that of the decaying typhoon and remained unchanged even after the latter had dissipated completely.

The presence of a westerly trough in close proximity to the maximum in period 1 did not appear to have any significant effect on its movement and intensity. The only difference detected between period 1 and period 2 in this respect was the marked increase in height of the level of non-divergence in period 1 and the associated larger amount of rainfall at the peak of the rainstorm.

On both occasions, rain was first reported in Hong Kong when the remnant of the typhoon was near 115°E longitude between 28°N and 30°N. At the same time, the layer of southwest winds extended from surface up to 500 mbar. The heaviest downpour which lasted a few hours occurred when the isotach maximum was directly overhead. The rain fell almost continuously for three days with over 65% of the rain recorded in the second 24-hour period. Improvement in the weather occurred after the passage of the isotach maximum while clearance depended on the immediacy of the extension of the Pacific ridge over south China following the passage of the maximum.

This comparative study of two cases of typhoon passages across the northern tip of Taiwan is considered to be useful to forecasters as analogues when similar cases occur in the future. However results of this study should not as yet be applied generally to all typhoon passages across Taiwan until more case studies are included.

REFERENCES

1. Chen, T.Y. 1969 The Severe Rainstorms in Hong Kong during June 1966, Royal Observatory, Hong Kong, Supplement to Meteorological Results 1966.

2. Chin, P.C. 1972 Tropical Cyclone Climatology for the China Seas and Western Pacific from 1884 to 1970, Volume I : Basic Data, Royal Observatory Hong Kong Technical Memoir No. 11.

3. Kwong, W.P. 1974 Tropical Cyclone Rainfall in Hong Kong, Royal Observatory Hong Kong Technical Note No. 38.

4. Riehl, H. 1954 Tropical Meteorology, Mcgraw Hill, New York

APPENDIX

COMPUTATION OF DIVERGENCE

For horizontal velocity divergence the following standard equation is used (Riehl 1954) :

$$\text{div } \bar{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

To compute the value of divergence at Hong Kong, Hong Kong was used as the origin 0 of a x-y rectangular grid having a grid length of d as shown in Fig. 13.

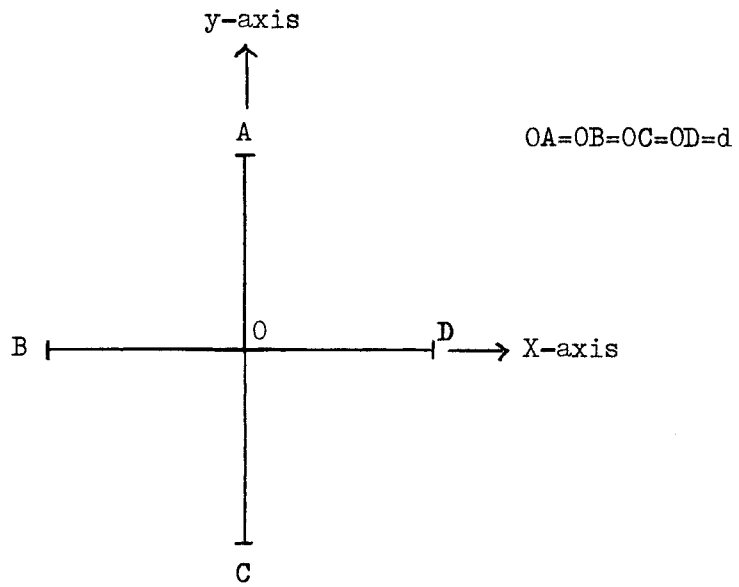


Figure 13. Rectangular grid used for the computation of divergence at Hong Kong

The rectangular grid was super imposed onto the upper air chart of the desired level, with 0 over Hong Kong. The directions and speeds of wind at the four nearest grid points A, B, C and D were obtained by interpolation of reports at nearby stations. The x- and y- coponents of the wind at these grid points were then calculated.

It is obvious that divergence at 0 will be affected by the x-components of the winds at B and D and the y-components of the winds at A and C only.

Let u (+d) = x-component of wind at D

u (-d) = x-component of wind at B

v (+d) = y-component of wind at A

v (-d) = y-component of wind at C

u (o) = x-component of wind at 0

Using the Taylor's expansion, the central difference at O of B and D is

$$u(+d) - u(-d) = u(o) + d\frac{\partial u}{\partial x} + \frac{d^2}{2}\frac{\partial^2 u}{\partial x^2}$$

$$- u(o) - d\frac{\partial u}{\partial x} + \frac{d^2}{2}\frac{\partial^2 u}{\partial x^2} + O(d^3)$$

Where all derivatives are evaluated at the origin O and the symbol $O(d^3)$ represents a term involving the third power of d or higher. Simplifying

$$u(+d) - u(-d) = 2d\frac{\partial u}{\partial x} + O(d^3)$$

Hence the speed divergence at O along the x-axis is

$$\frac{\partial u}{\partial x} = \frac{u(+d) - u(-d)}{2d} + O(d^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Provided that d is small, higher order partial derivatives of u with respect to x will get progressively smaller. $\frac{\partial u}{\partial x}$ will be accurate up to the third order partial derivative of u if the last term in (1) is neglected.

Hence $\quad \frac{\partial u}{\partial x} = \frac{u(+d) - u(-d)}{2d} \quad$ up to third order

similarly $\quad \frac{\partial v}{\partial y} = \frac{v(+d) - v(-d)}{2d} \quad$ up to third order

and the total horizontal velocity divergence at O

$$\text{div } \bar{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

or

$$\text{div } \bar{V} = \frac{u(+d) - u(-d)}{2d} + \frac{v(+d) - v(-d)}{2d} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

up to third order. This is positive if a net amount of air is moving out of the grid ABCD and negative if moving in.

In a flow where the streamlines are parallel or almost parallel, the grid is usually rotated so that the x-axis is parallel to the streamline through O. In this case, the second term in (2) is small while the first term large. Resolution of the winds into components sometimes is not necessary, thus simplifying the computation.

In the present computation, d was taken as one degree of latitude or 60 nautical miles on account of the separation of neighbouring reporting stations. Wind speeds were in knots. Divergence of one knot per two degree latitude is equal to 2.3×10^{-6} s^{-1}, correct to two significant figures.

In interpreting the values obtained from divergence computations, one must bear in mind that the degree of accuracy of the upper winds reported by stations concerned are not certain so that there is an unknown factor of error in the interpolation procedure to obtain the grid point values.