HONG KONG OBSERVATORY

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A CASE STUDY OF A RAINSTORM IN HONG KONG ON 30 APRIL 1996

by

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SUMMARY

A severe rainstorm occurred in Hong Kong on 30 April 1996. Rainfall distributed unevenly over Hong Kong. While a total of 89 millimetres of rainfall were recorded at the Hong Kong Observatory on that day, more than 110 millimetres fell over the northwestern part of Hong Kong Island. This heavy downpour resulted in a number of flooding cases over the territory. This study attempts to elicit the mechanism for the development of this rainstorm. Furthermore, its development and movement are examined using radar imageries as well as rainfall data from the Hong Kong raingauge network and wind data from the anemometer network.

The atmosphere over Hong Kong became very unstable as a southwesterly jetstream moved to the coast of Guangdong on 30 April. The K-index at Hong Kong increased to 39 at 0800 Hong Kong Time (HKT) that morning. A weak convergence at 850hPa level provided the necessary trigger for the development of the rainstorm.

Radar and satellite imageries on the morning of 30 April indicated explosive development of convective activities to the west of the Pearl River Estuary. They moved eastward to affect Hong Kong from 1300 to 1500HKT. Surface winds reported by automatic weather stations over the territory showed a convergence line moving across the territory ahead of the heavy rain area. By following the movement of this convergence line, the forecaster could have a rough estimation of the movement of the rain area.

On the other hand, numerical weather forecast products were not as helpful this time in view of the small scale and short-lived nature of this rainstorm.

CONTENTS

FIGURES

FIGURES (cont.)

1. INTRODUCTION

A severe rainstorm affected Hong Kong on 30 April 1996 with a daily total rainfall of 89 millimetres at the Hong Kong Observatory. The heaviest downpour was recorded from 1300 to 1500HKT, during which more than 50 millimetres of rain fell. The maximum instantaneous rainfall rate reached 164 millimetres per hour around 1415HKT. The rain became less intense afterwards but remained more or less continuous till late evening (Figure 1).

On that day, the Thunderstorm Warning was in force from 1230 to 2030HKT and the Flood Warning from 1325 to 1930HKT. The Red Rainstorm Warning was issued for the first time in 1996 at 1445HKT. A total of 14 reports of flooding were received from Kowloon and the New Territories (Royal Observatory, Hong Kong 1996).

This study aims to find out the mechanism for the development of this heavy rainstorm and to examine its development and movement by information from the radar, the satellite, the raingauge network and automatic weather stations (AWS).

In the following sections, an account of the rainfall distribution over Hong Kong and southern China will be presented. The synoptic background of the rainstorm and the mechanism giving rise to it will be discussed. Radar, rainfall and wind data observations will be described in detail. A brief review of numerical weather prediction (NWP) products will also be presented.

2. RAINFALL

The rainstorm on 30 April was severe with unevenly distributed rainfall over Hong Kong. Daily rainfall amount at various places differed by a factor of two to three (Figure 2). The northwestern part of Hong Kong Island recorded more than 110 millimetres while the northern part of the New Territories had about 40 millimetres only. The rain was heaviest over Hong Kong Island where the area of daily rainfall exceeding 100 millimetres was only about 2 kilometres by 1 kilometre.

A dense raingauge network over Hong Kong (not shown) recorded the movement of the rainstorm. Only one or two millimetres of rainfall were recorded at various places up to noon on 30 April before the rainstorm hit Hong Kong. The movement of the heavy rain areas over Hong Kong from noon to 1600HKT as reported by the raingauge network is summarized below:

1200 - 1300HKT	Heavy rain was first registered over the northwestern and southwestern parts of Hong Kong.
1300 - 1400HKT	Maximum rainfall centred over Tai Mo Shan and the central part of Lantau Island. More than 40 millimetres were recorded at these two places within an hour.
1400 - 1500HKT	Maximum rainfall centred over Victoria Harbour. More than 40 millimetres were recorded at places over Hong Kong Island.
1500 - 1600HKT	Heavy rain areas moved to the east of the territory and only several millimetres of rainfall were recorded generally over Hong Kong.

The rain then weakened but persisted until 2200HKT in the evening.

Looking further afield, significant rainfall on that day was confined to a small area around the Pearl River Estuary. The rainstorm developed over western Guangdong north of Yangjiang in the morning with more than 80 millimetres of rain recorded in 6 hours ending at 1400HKT. The rainstorm then moved eastward to hit Hong Kong in the early afternoon.

3. SYNOPTIC SITUATION

On 29 April, the coast of Guangdong was basically under the influence of an anticyclonic flow at the low levels of the troposphere. At 0800HKT, a cyclonic vortex at the lower troposphere was analyzed over Shandong Bandao with a trough extending southwestward over central China. The 700hPa flow pattern is shown on Figure 3a as an example and the trough was marked by "A" (850hPa and 500hPa flow patterns are similar and are not shown). A southwesterly jetstream just south of the trough was seen feeding into the vortex. As the vortex moved east on 30 April, the trough swung across southern China but was confined to areas north of 25°N. Hong Kong was still under anticyclonic flow (Figure 3b and 3c). No divergence was observed at 200hPa at that time (chart not shown).

The flow pattern suggested a weakening low level trough swinging across southern China but failing to reach the coastal areas of Guangdong. However, the jetstreams south of the troughs, with the associated areas of high equivalent potential temperatures, at 850, 700 and 500hPa, moved to the coastal areas of Guangdong on the morning of 30 April. With moist and warm air advected to the coast of Guangdong, the K-index at Hong Kong increased from 25 (0800HKT on 29 April) to 39 (0800HKT on 30 April). Figure 3d shows the changes in equivalent potential temperatures and K-index. This provided favourable conditions for intense convective development as suggested by Lee (1995) and 廣東科技出版社 (1986). A weak convergence at 850hPa produced forced convective uplifting necessary to trigger off the rainstorm (Figure 3e). The equivalent potential temperatures at low levels over Hong Kong all decreased at 2000HKT in the evening. This indicated that the atmosphere became less unstable and the rain in the territory subsided.

4. SATELLITE, RADAR AND WIND OBSERVATIONS

4.1 Satellite and Radar Observations

The low level jetstreams mentioned in the previous section could also be identified on satellite pictures. A band of clouds associated with the jetstreams moved southeast over southern China and reached Hong Kong at 2000HKT on 29 April. No significant rain was associated with the band at that time. This band stayed over the coastal areas of Guangdong during the night. Intense convective activity started to develop within the band north of Yangjiang in western Guangdong around 0800HKT on 30 April (Figure 4a). The development area then drifted east to cover the Pearl River Estuary at 1400HKT (Figure 4b) when the rainstorm hit Hong Kong.

On the radar, a band of relatively weak echoes moved southeastwards and reached the coastal areas of Guangdong in the early hours on 30 April. While individual echoes of this band showed signs of weakening over the Pearl River Estuary in the morning, an area of intense echoes developed over western Guangdong about 200 kilometres west of Hong Kong (Figure 4c). This area of intense echoes hit Hong Kong just before 1300HKT and traversed the territory in the following 2 hours (Figure 4d to 4f). Although the most intense echoes moved to the east of the territory, the rain band as a whole lingered over the coast of Guangdong until late that evening.

4.2 Surface wind flow pattern

A network of AWSs over the territory provided information on the wind flow in Hong Kong during the rainstorm on 30 April. The winds in Hong Kong were weak and variable on the morning of 30 April except at Tai Mo Shan and Tate's Cairn, where the winds were moderate southerly.

During the two hours from 1300 to 1500HKT when the rainstorm moved across the territory, the rainfall distribution maps and AWS wind reports indicated that a convergence line moved across the territory ahead of the heavy rainstorm. As a rough estimation, the position of the convergence line at a certain moment coincided very well with positions of heavy rain areas 15 minutes later.

At 1300HKT, when the area of heavy rain started to affect the western-most part of Lantau Island, the winds at Sha Lo Wan turned to westerlies and a convergence line could be seen extending northeastward from western Lantau Island to Yuen Long areas (Figure 4g and 4h). The rainfall distribution map 15 minutes later at 1315HKT (Figure 4i) showed that the heavy rain area moved to western Lantau Island. The convergence line then moved to the central part of the territory at 1330HKT (Figure 4j). The maps at 1400 and 1415HKT (Figure 4k and 4l) also indicated that the position of the convergence line coincided well with heavy rain areas 15 minutes later.

A vortex on the convergence line remained almost stationary over Hong Kong Island from 1415 to 1430HKT (Figures 4m and 4n). More than 40 millimetres of rain fell at places near the vortex over the northern part of Hong Kong Island during this half an hour (figure not shown). At 1445HKT, winds at Star Ferry (Central) started to drop and those at Hong Kong South picked up, which might be a clue that the vortex started to move south. The winds at 1500HKT confirmed that the convergence line left the territory (Figure 4o) and thus the rain weakened (Figure 4p).

A similar relationship between a convergence line and heavy rain areas had been discussed by Lam (1993). More effort can be put in this direction in future studies as this relationship might be possible to serve as a tool in nowcasting the start, the movement and the cessation of heavy rain over Hong Kong.

5. NUMERICAL FORECASTS

Based on data at 2000HKT on 28 April, NWP model outputs from European Centre of Medium Range Weather Forecasting (ECMWF), UK Meteorological Office (EGRR), Hong Kong Observatory Limited Area Model (OLAM) and Japan Meteorological Agency (JMA) generally predicted a situation without significant rain on 30 April. A weakening low level trough was forecast to swing across southern China without reaching Hong Kong and the flow over the territory would be anticyclonic. Equivalent potential temperatures at 850 and 700hPa were not particularly high. The K-indexes forecast by JMA for 0800 and 2000HKT on 30 April was only 34 and 30 respectively. 24-hour rainfall was forecast by OLAM and JMA to be minimal over the region around Hong Kong (Figure 5a and 5b). However, OLAM and JMA did forecast jetstreams of the southwesterlies at 700hPa and 500hPa over the coast of Guangdong at 0800HKT on 30 April. This was a sign of the atmosphere becoming unstable with increasing possibility of intense convective development.

As a whole, the models, working on a large space scale and time frame, was not able to pinpoint this rainstorm episode.

6. CONCLUSIONS

The rainstorm on 30 April 1996 was intense. The atmosphere was very unstable that morning with K-index at Hong Kong rising to 39. A weak convergence at 850hPa level provided the necessary trigger for the development of intense convection. Heavy rain developed west of the Pearl River Estuary and swept across Hong Kong from 1300 to 1500HKT.

This rainstorm episode suggests that forecasters should beware of the possibility of heavy rain whenever jetstreams are in the vicinity of Hong Kong. Useful indications are:

a. K-index over Hong Kong rising sharply to above 35;

b. intense development seen upstream on radar and satellite; and

c. local wind convergence as an indicator of movement of rainstorms.

ACKNOWLEDGMENT

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4. Royal Observatory, Hong Kong* 1996 Monthly Weather Summary – April 1996, pp. 2.

Note: * -- Hong Kong Observatory was formerly known as Royal Observatory, Hong Kong before 1 July 1997.

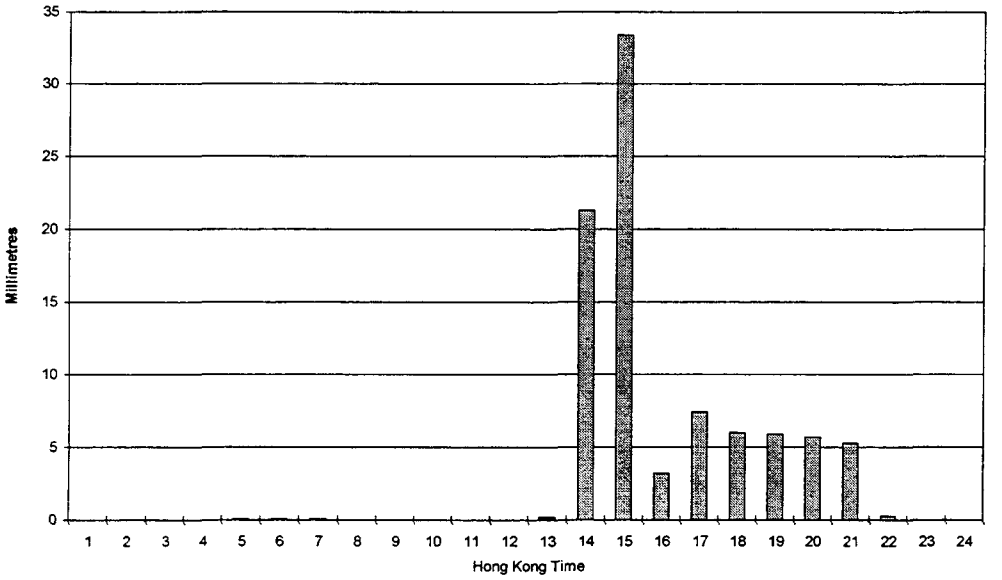

Figure 1. Hourly rainfall recorded at the Hong Kong Observatory on 30 April 1996.

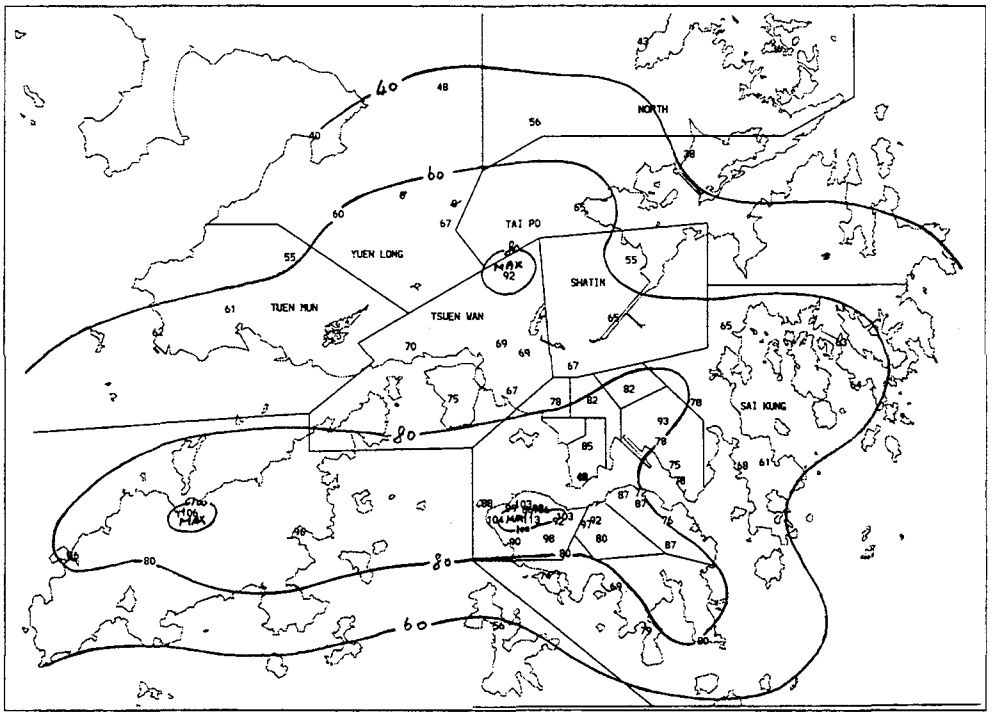

Figure 2. Daily rainfall distribution in Hong Kong on 30 April 1996.

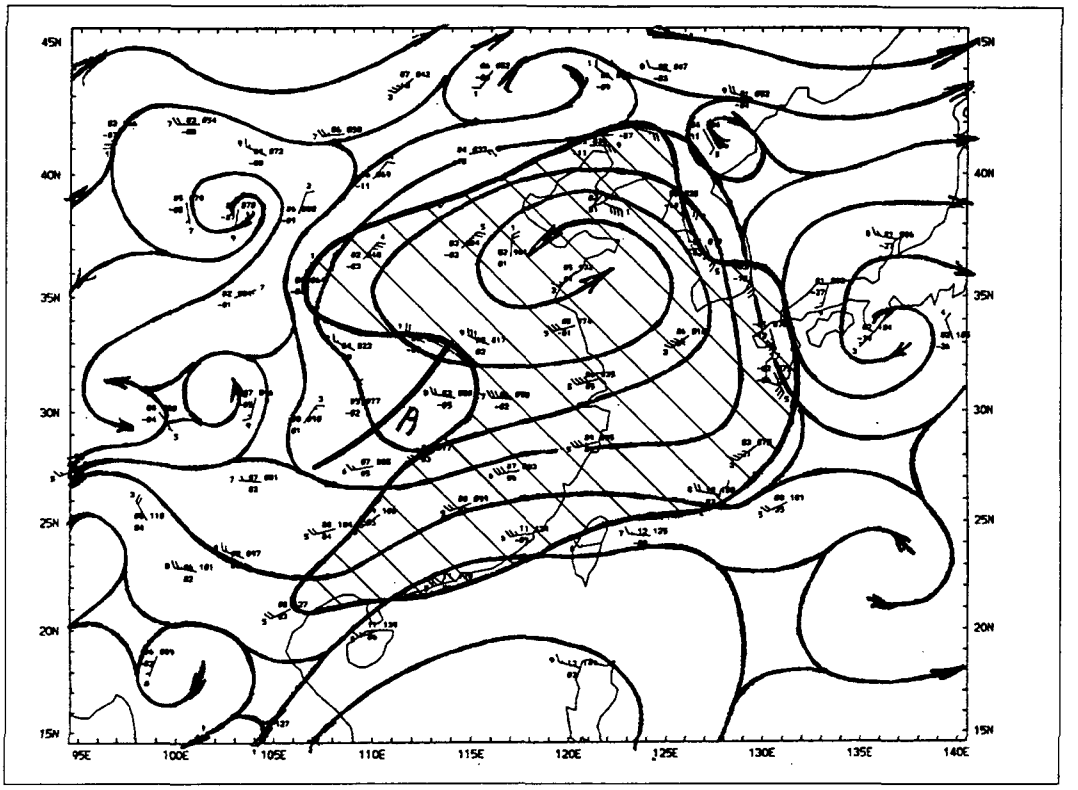

Figure 3a. 700 hPa upper-air flow at 0800HKT on 29 April 1996. Shaded area indicates wind speed greater than or equal to 10 m/s with reference to OLAM analysis.

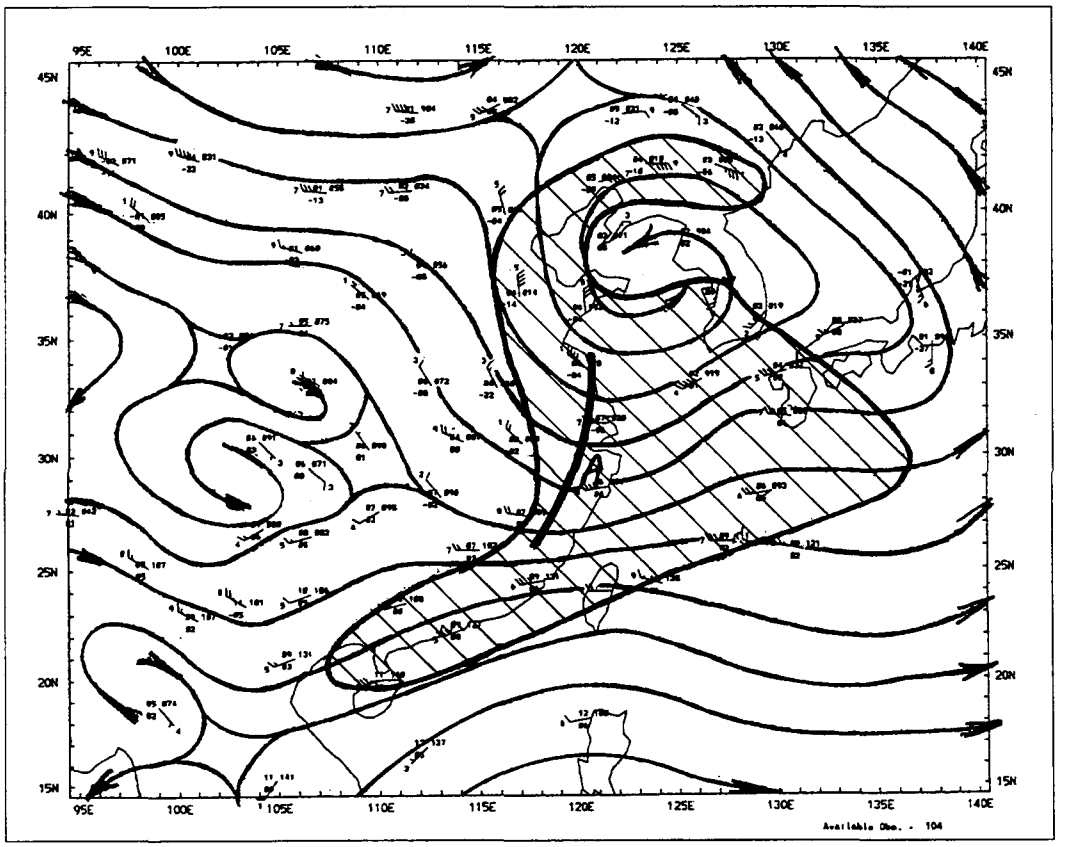

Figure 3b. 700 hPa upper-air flow at 0800HKT on 30 April 1996. Shaded area indicates wind speed greater than or equal to 10 m/s with reference to OLAM analysis.

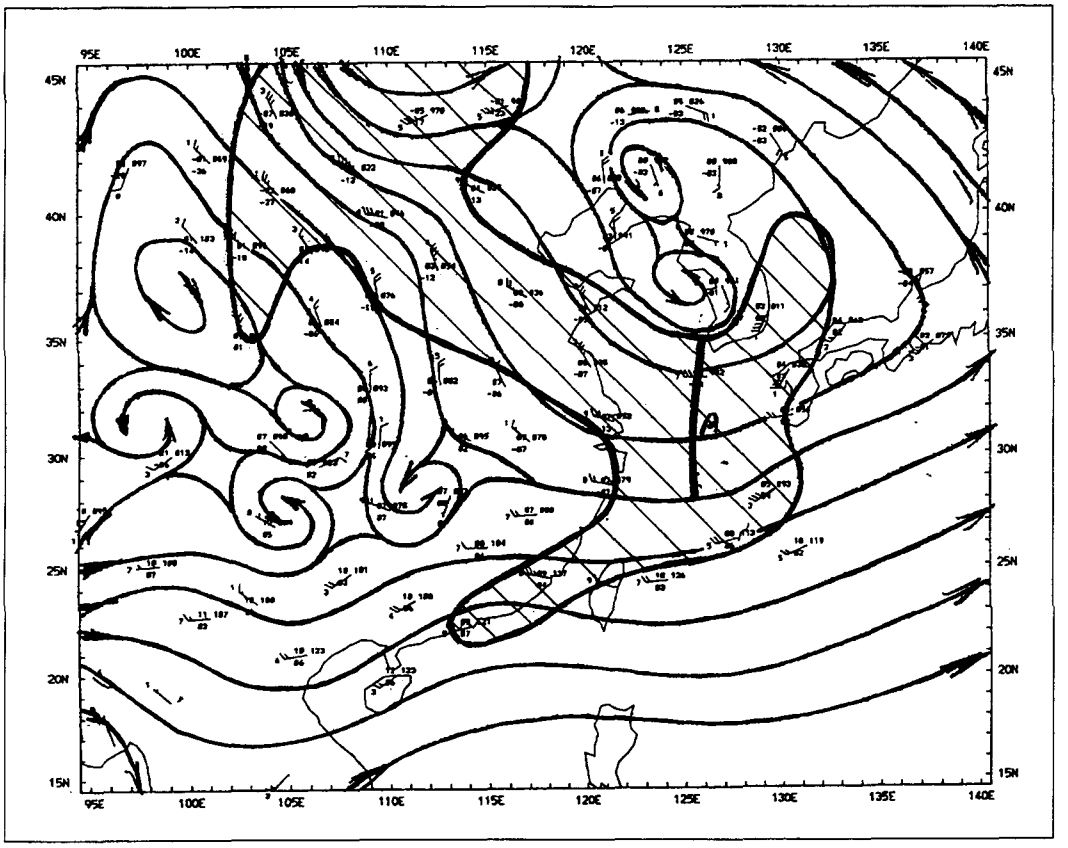

Figure 3c. 700 hPa upper-air flow at 2000HKT on 30 April 1996. Shaded area indicates wind speed greater than or equal to 10 m/s with reference to OLAM analysis.

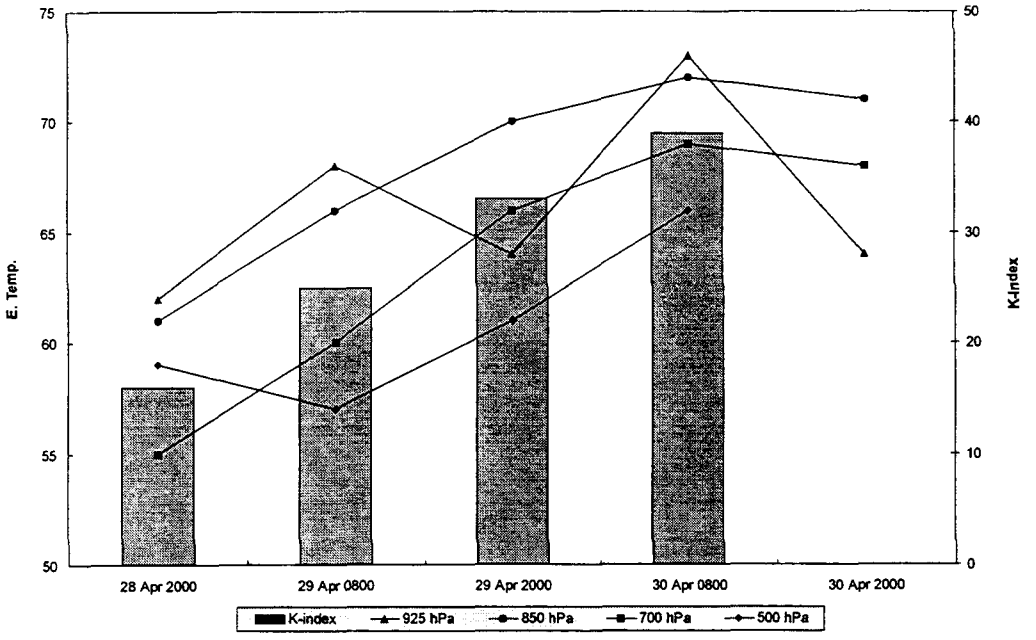

Figure 3d. Equivalent Potential Temperatures and K-indexes over Hong Kong.

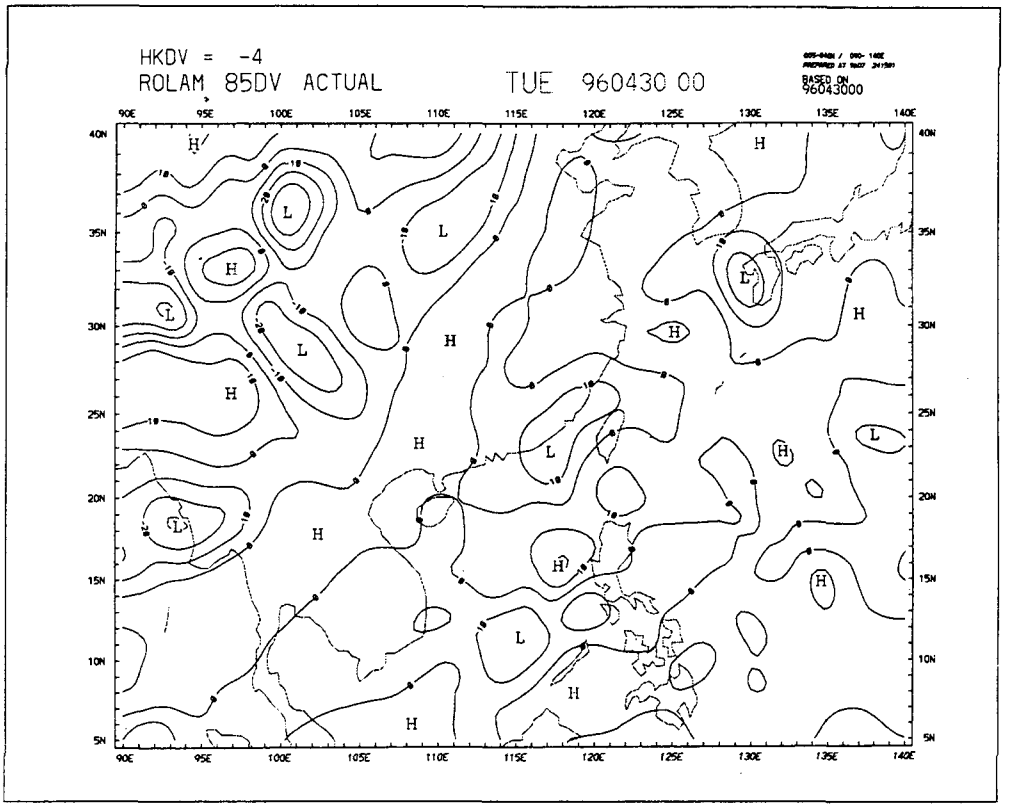

Figure 3e. OLAM's 850hPa divergence field at 0800HKT on 30 April 1996.

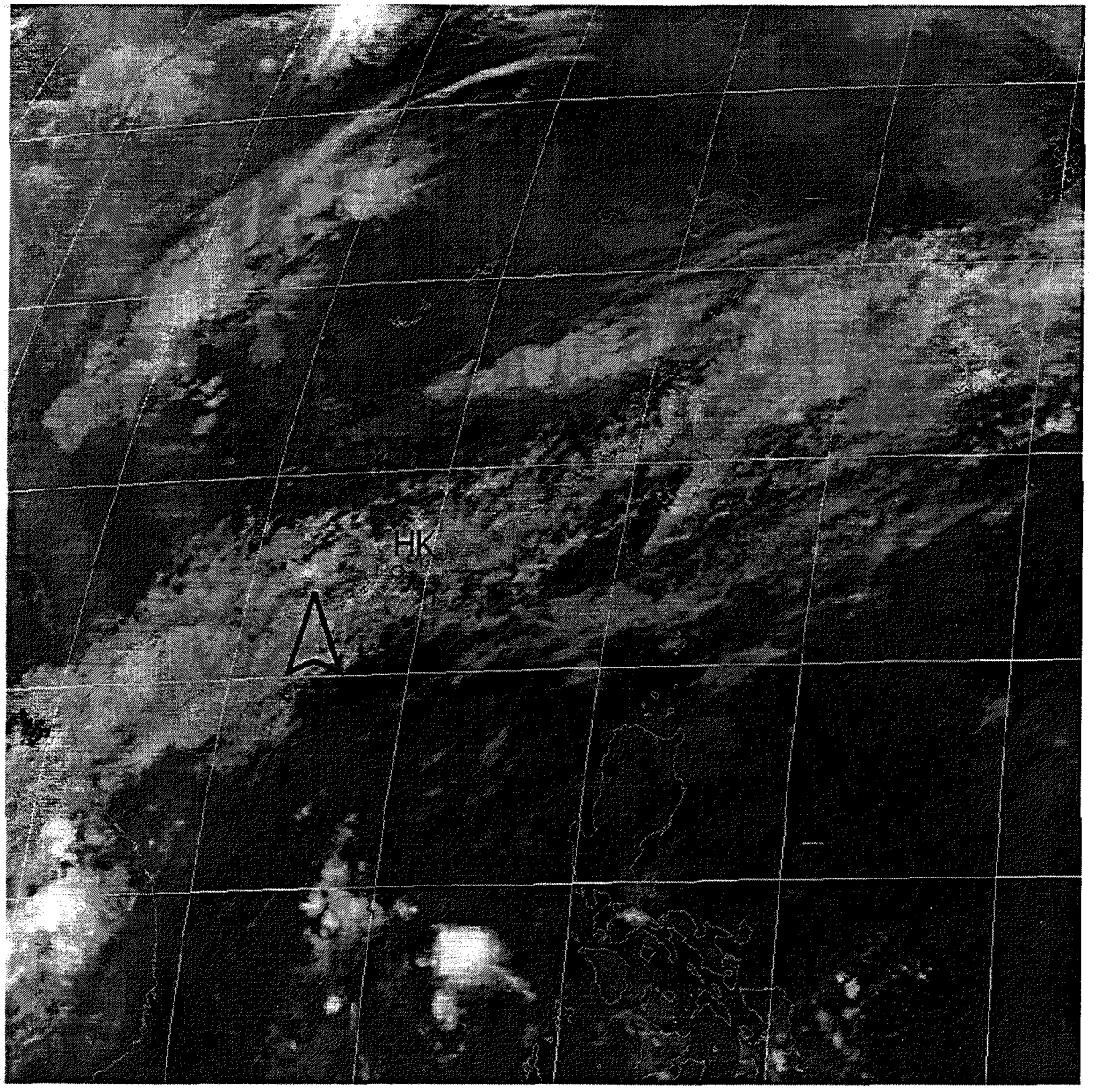

Figure 4a. Infrared image at 0800HKT on 30 April 1996 from the Japan Geostationary Meteorological Satellite.
The arrow points to the intense convective activity north of Yanjiang.

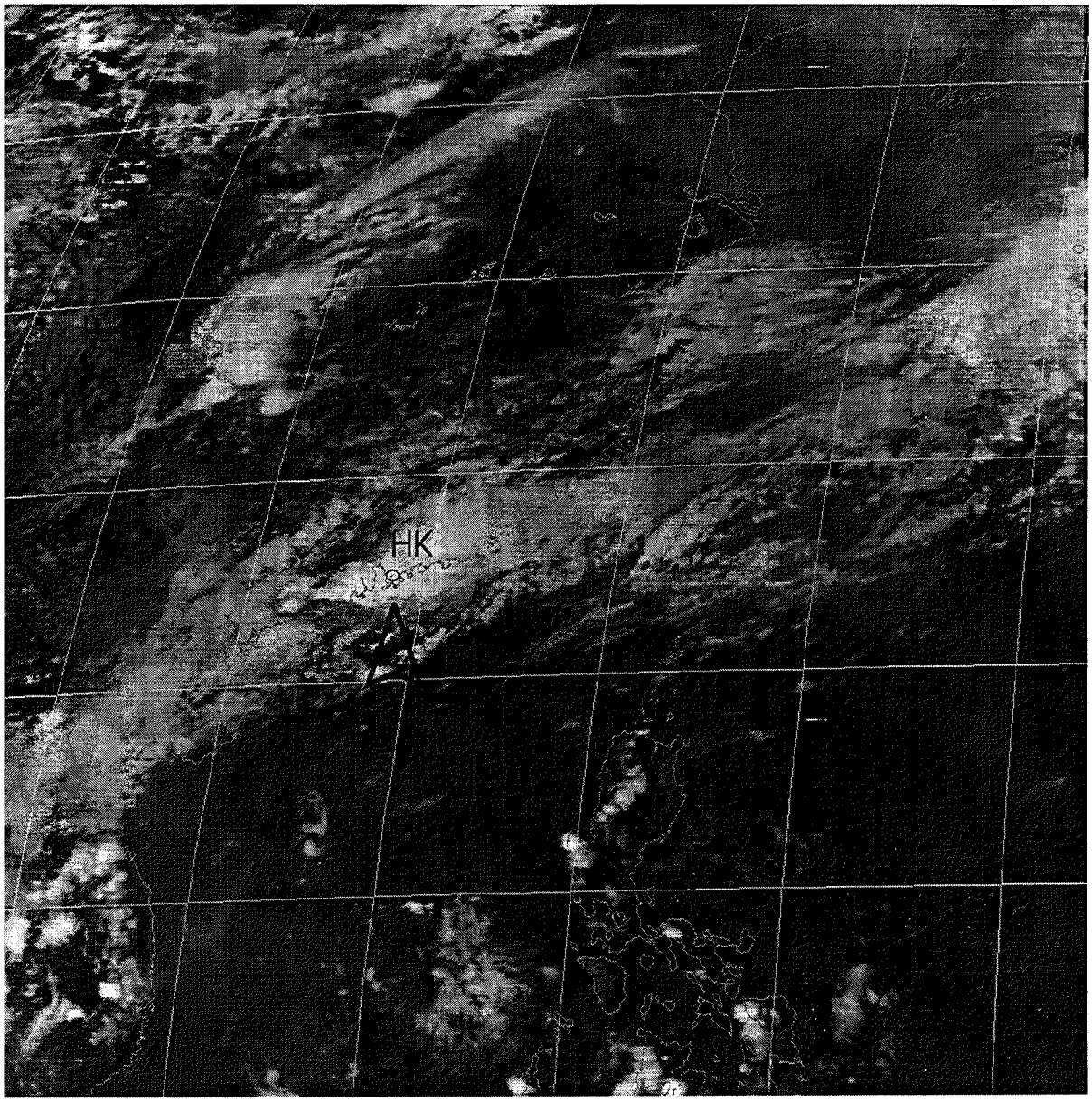

Figure 4b. Infrared image at 1400HKT on 30 April 1996 from the Japan Geostationary Meteorological Satellite.
The arrow points to the intense convective activity near Hong Kong.

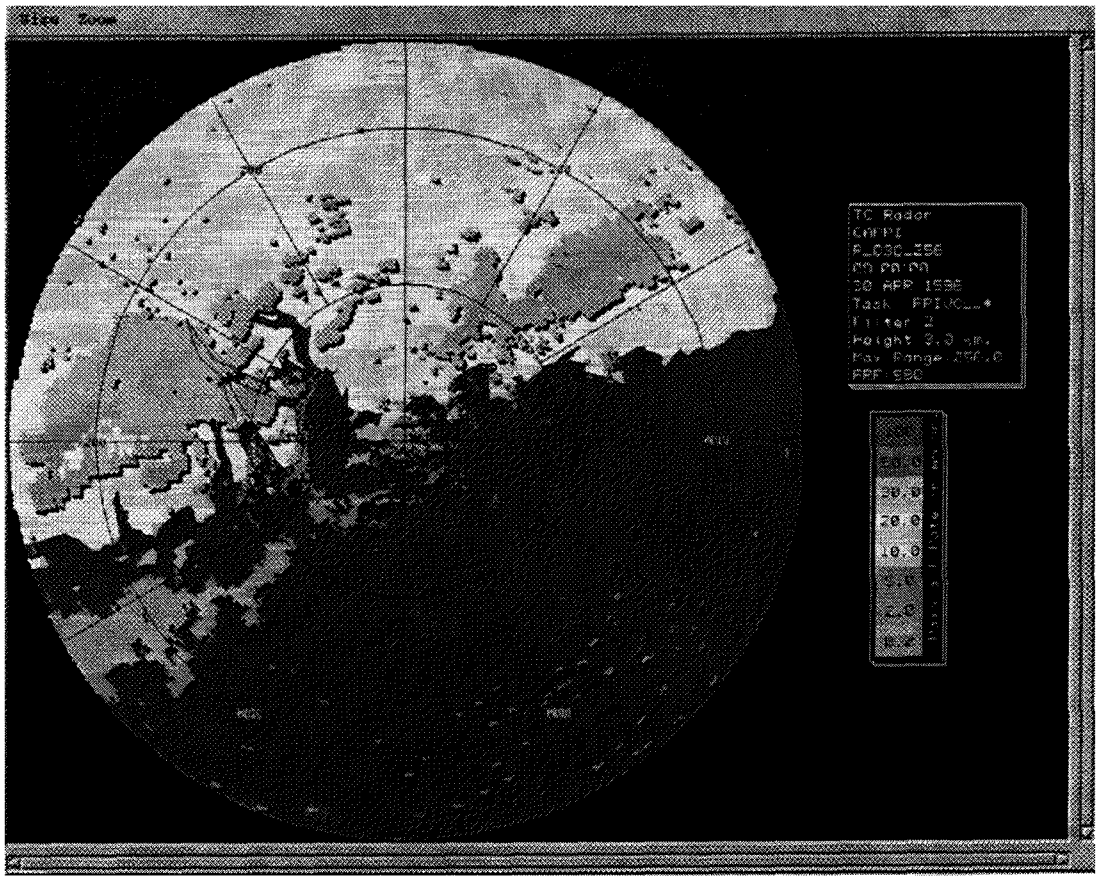

Figure 4c. 3-km CAPPI radar image at 0900HKT on 30 April 1996.

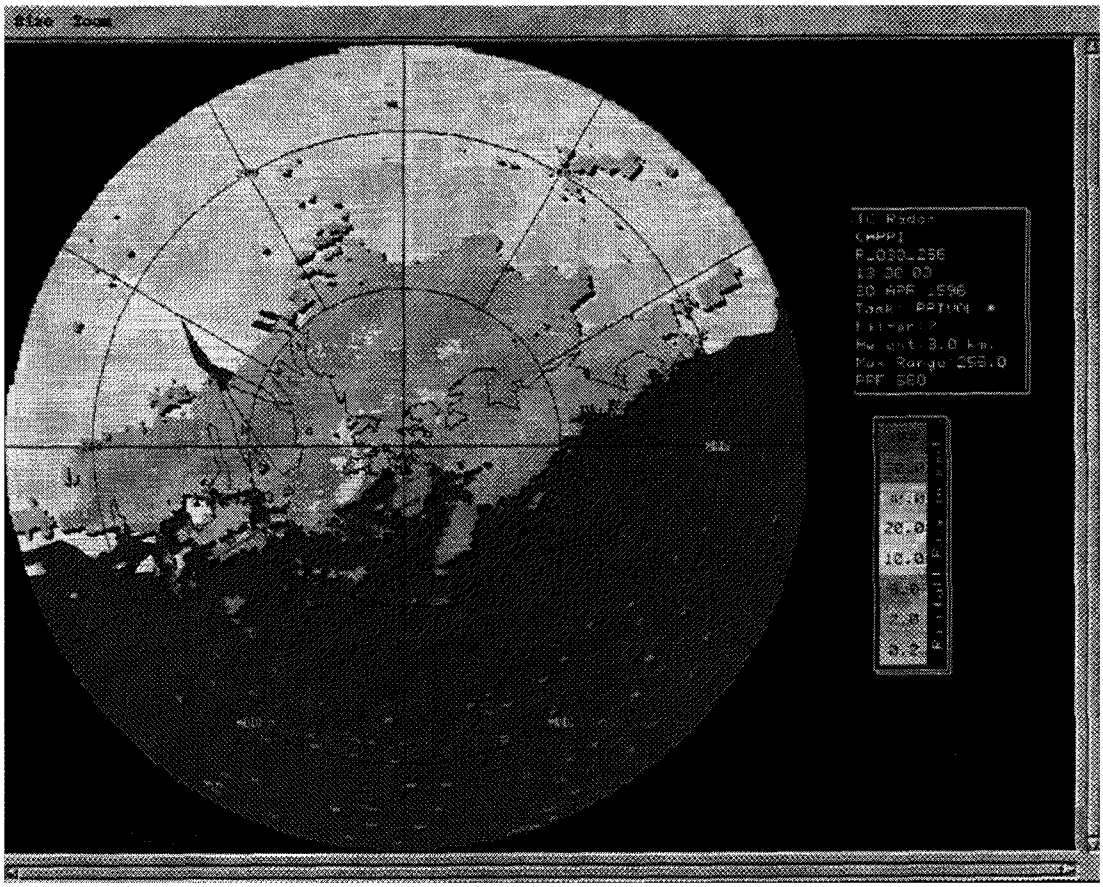

Figure 4d. 3-km CAPPI radar image at 1300HKT on 30 April 1996.

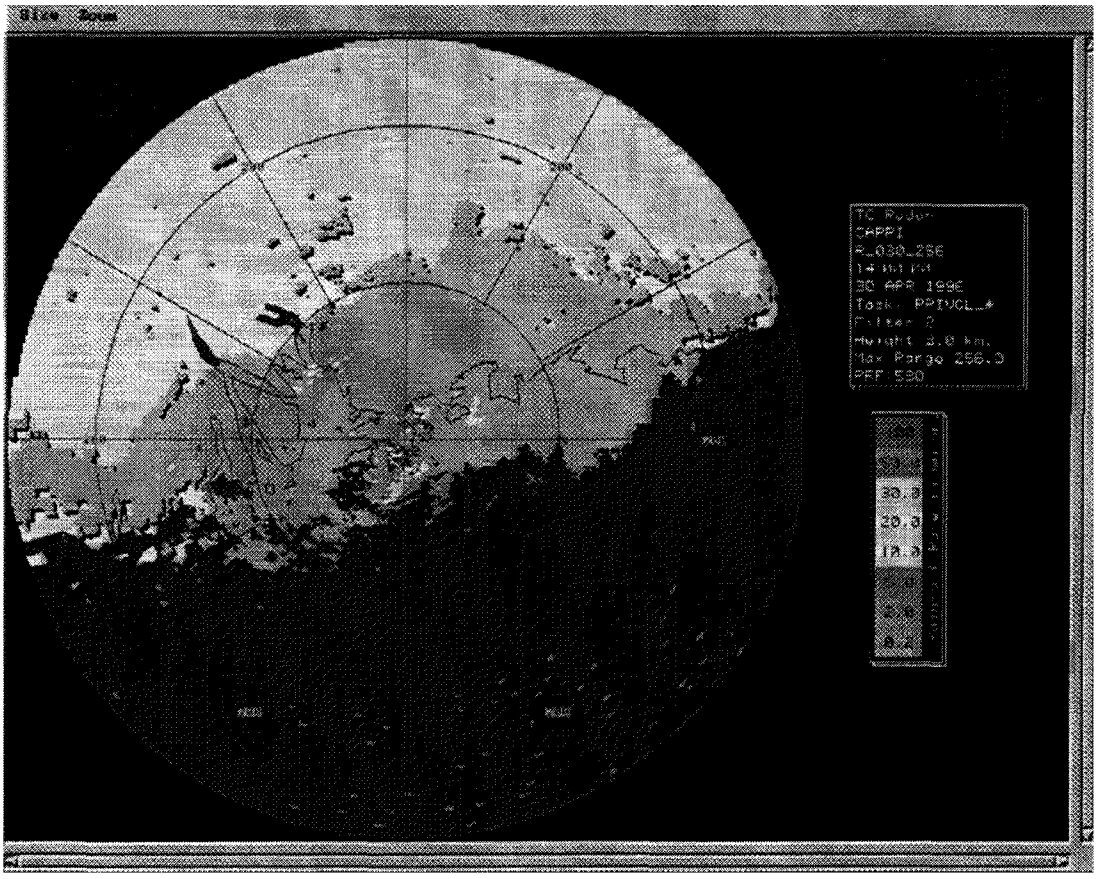

Figure 4e. 3-km CAPPI radar image at 1400HKT on 30 April 1996.

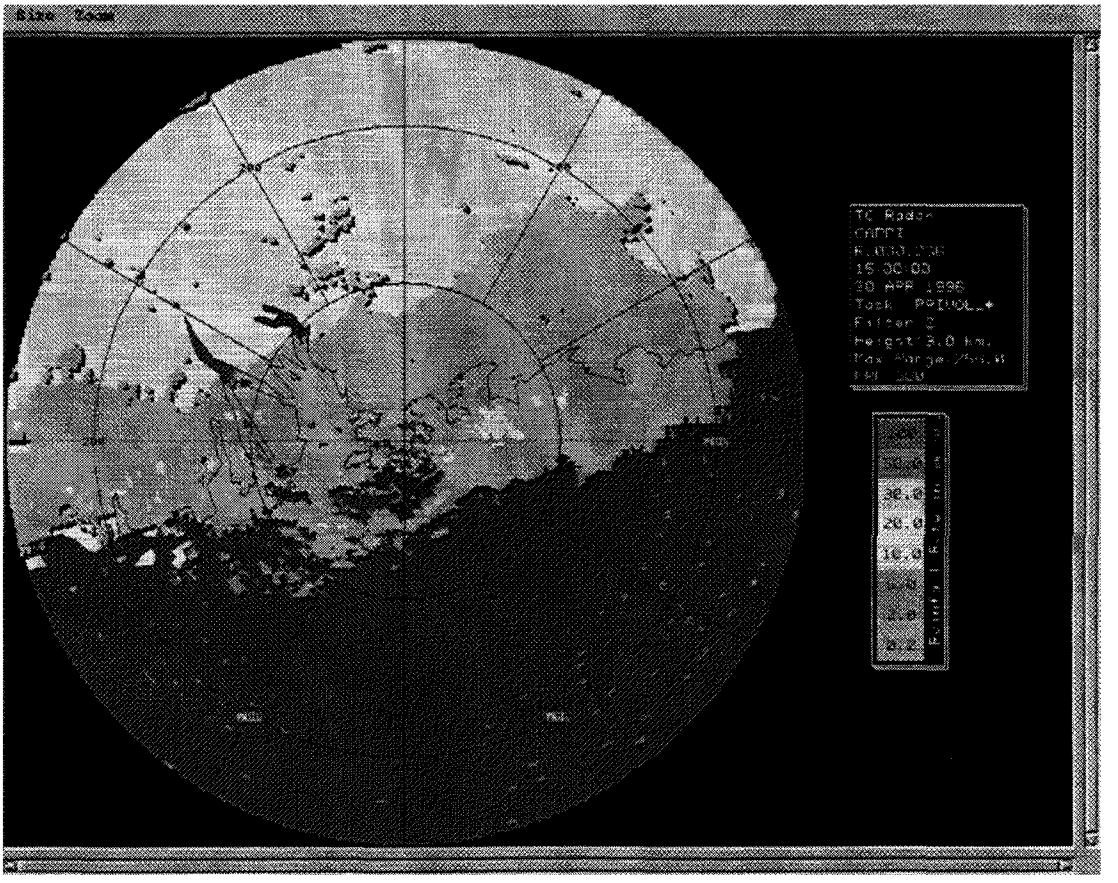

Figure 4f. 3-km CAPPI radar image at 1500HKT on 30 April 1996.

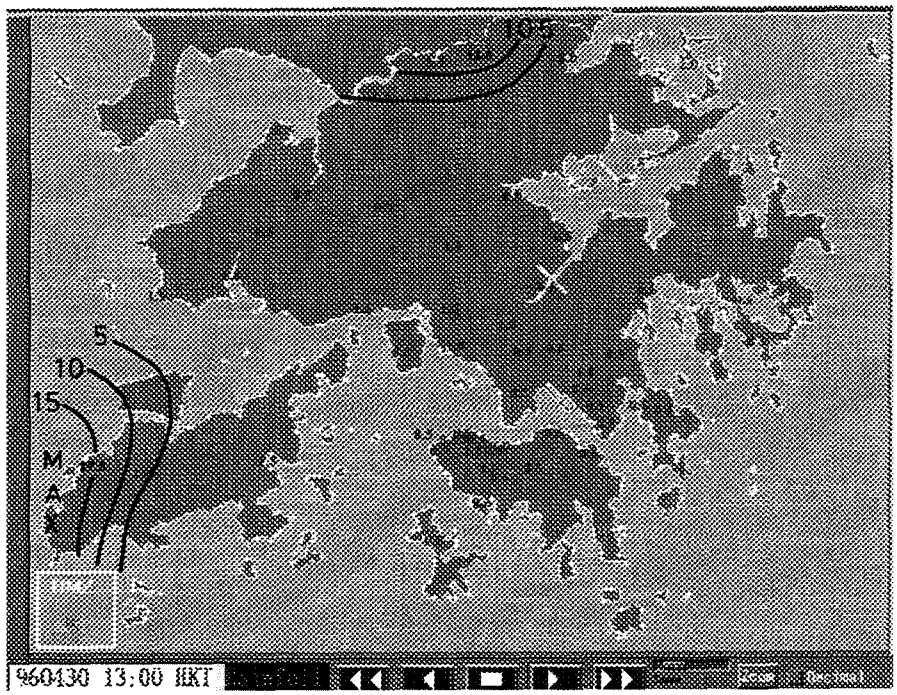

Figure 4g. 15-minute rainfall distribution map ending at 1300HKT on 30 April 1996.

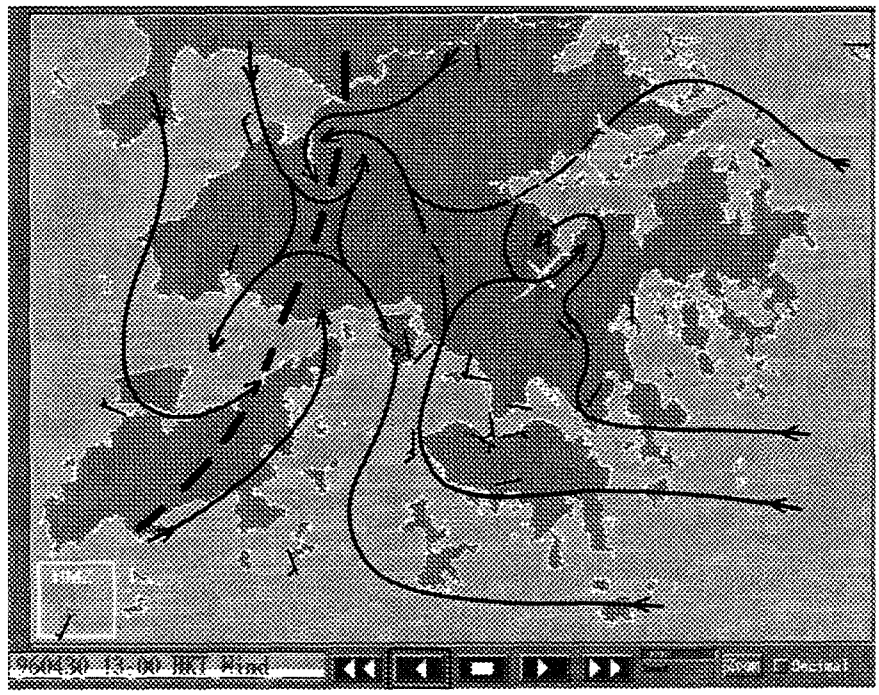

Figure 4h. Surface streamline over Hong Kong at 1300HKT on 30 April 1996. The dotted line depicts the convergence line of local winds.

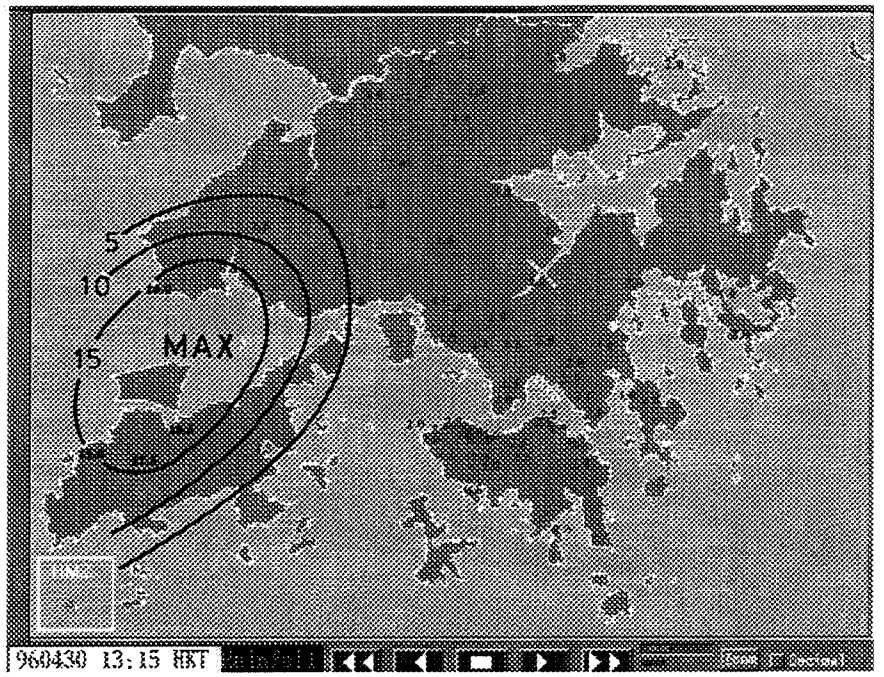

Figure 4i. 15-minute rainfall distribution map ending at 1315HKT on 30 April 1996.

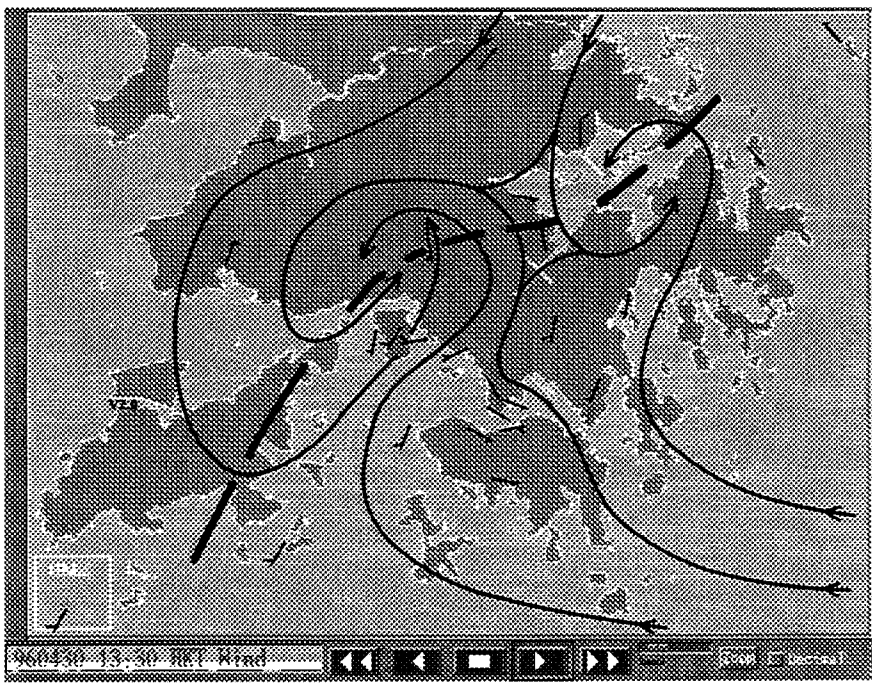

Figure 4j. Surface streamline over Hong Kong at 1330HKT on 30 April 1996. The dotted line depicts the convergence line of local winds.

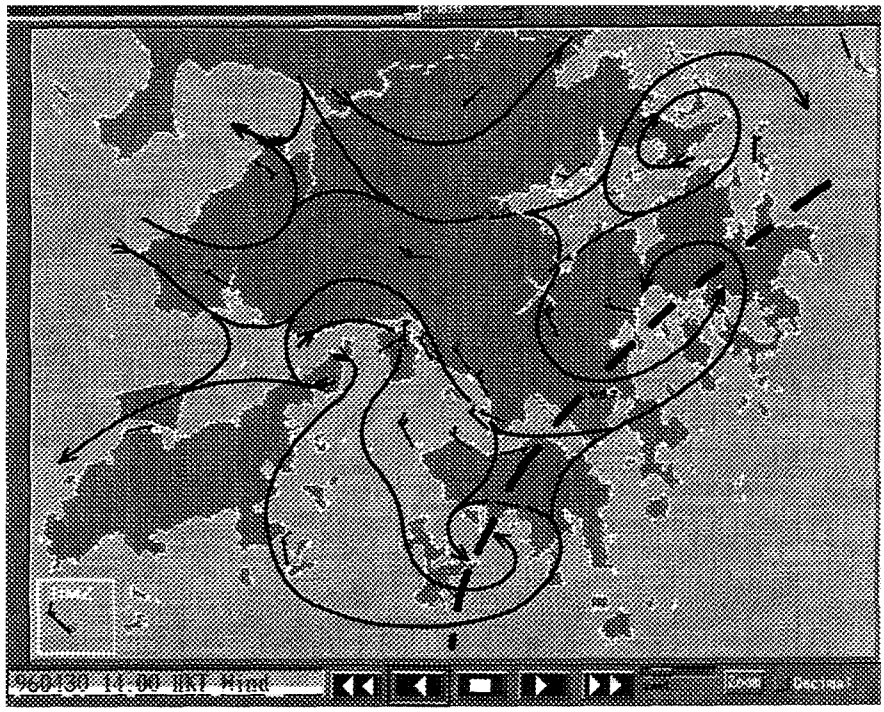

Figure 4k. Surface streamline over Hong Kong at 1400HKT on 30 April 1996. The dotted line depicts the convergence line of local winds.

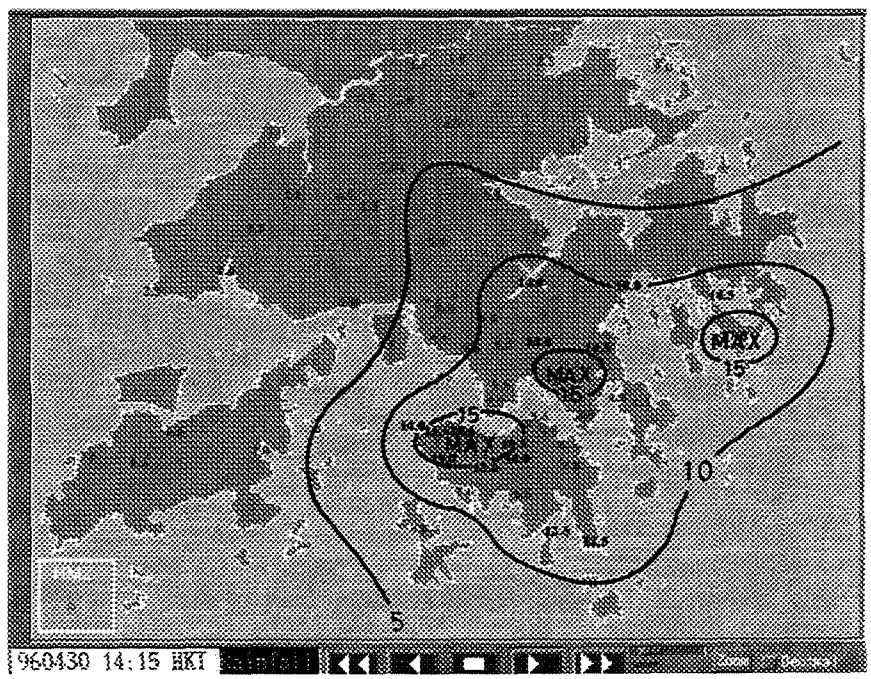

Figure 4l. 15-minute rainfall distribution map ending at 1415HKT on 30 April 1996.

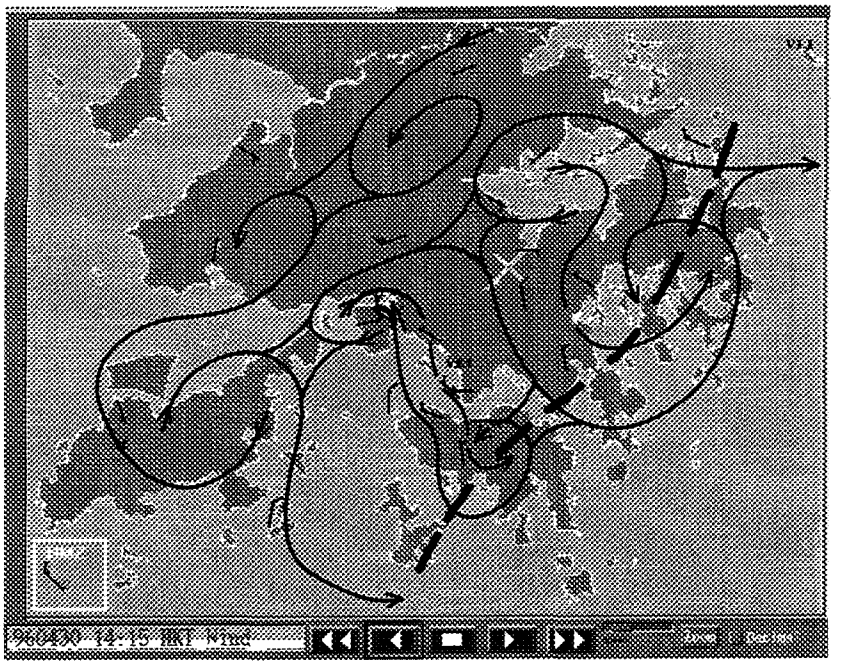

Figure 4m. Surface streamline over Hong Kong
at 1415HKT on 30 April 1996.
The dotted line depicts the convergence
line of local winds.

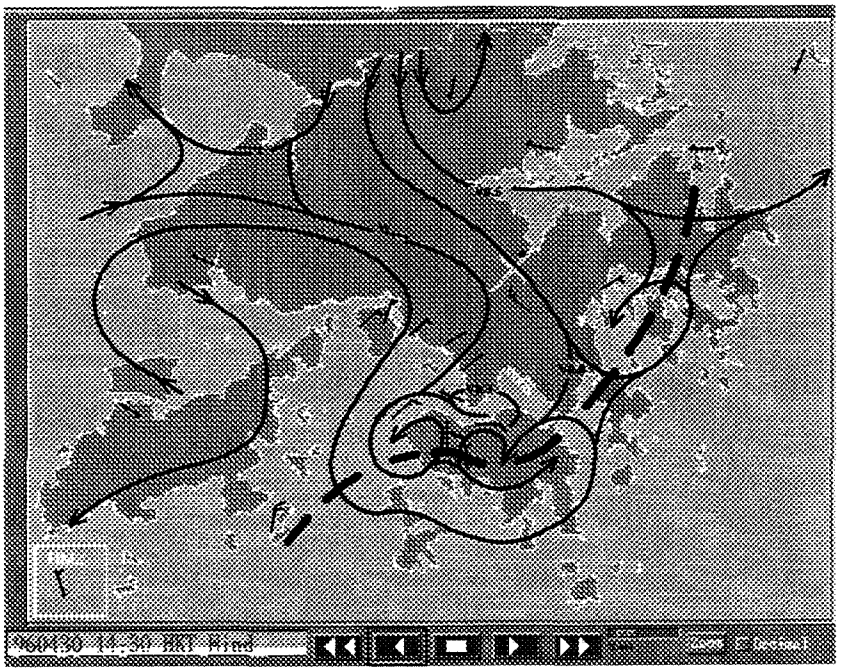

Figure 4n. Surface streamline over Hong Kong
at 1430HKT on 30 April 1996.
The dotted line depicts the convergence
line of local winds.

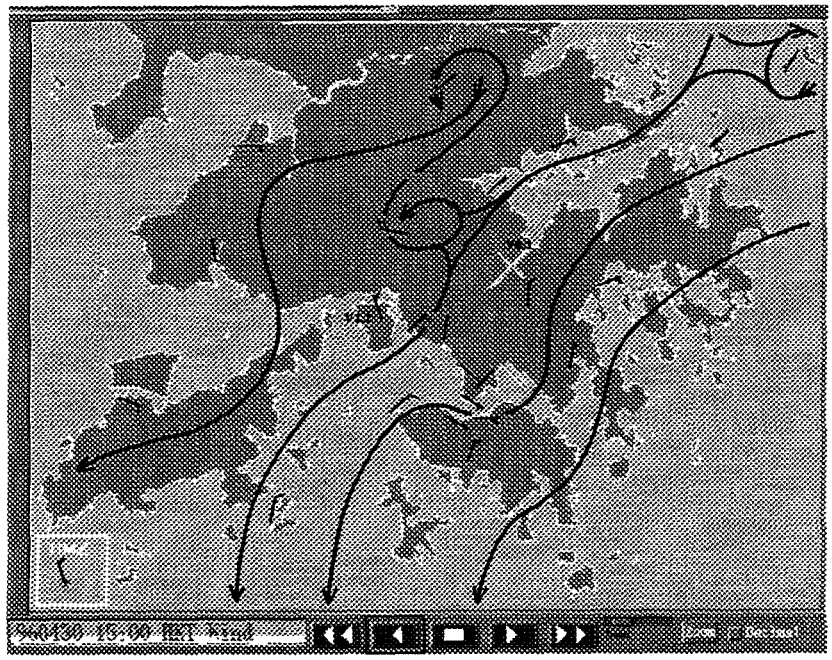

Figure 4o. Surface streamline over Hong Kong
at 1500HKT on 30 April 1996.

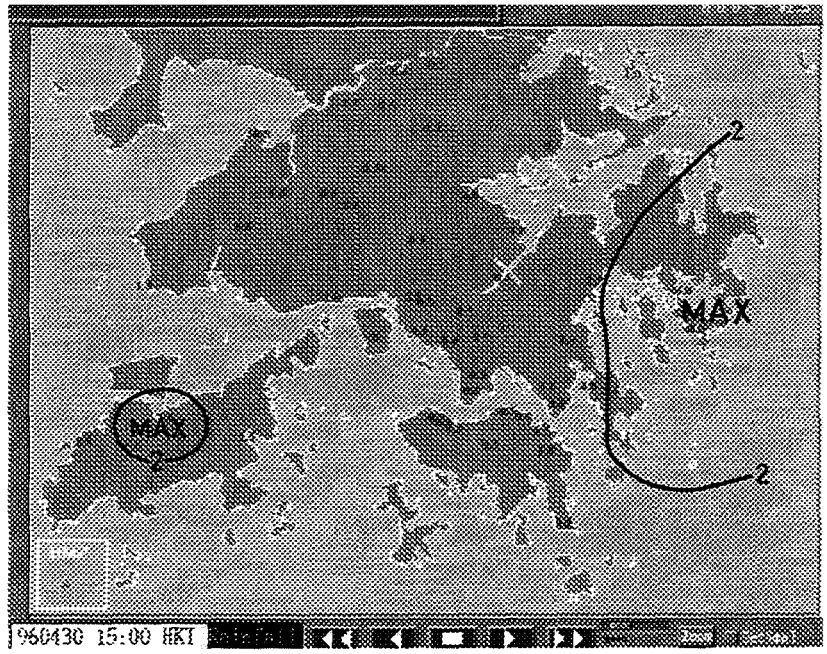

Figure 4p. 15-minute rainfall distribution map ending
at 1500HKT on 30 April 1996.

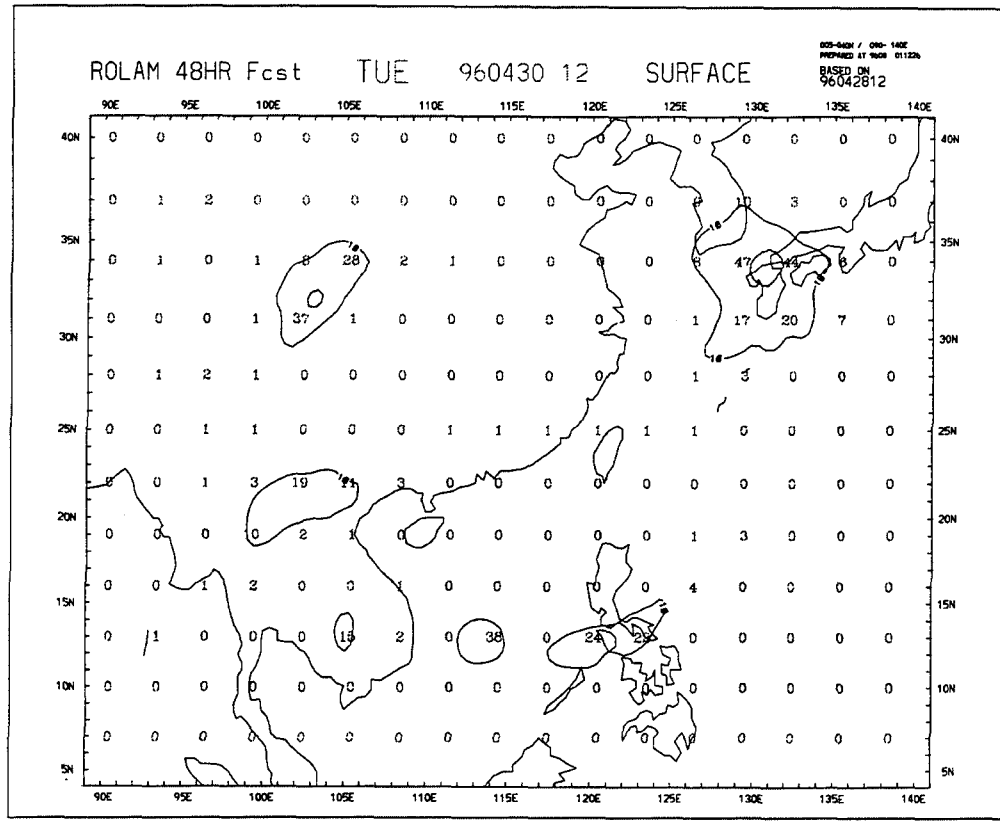

Figure 5a. 24-hour rainfall forecast (in mm) ending at 2000HKT on 30 April 1996 by OLAM.

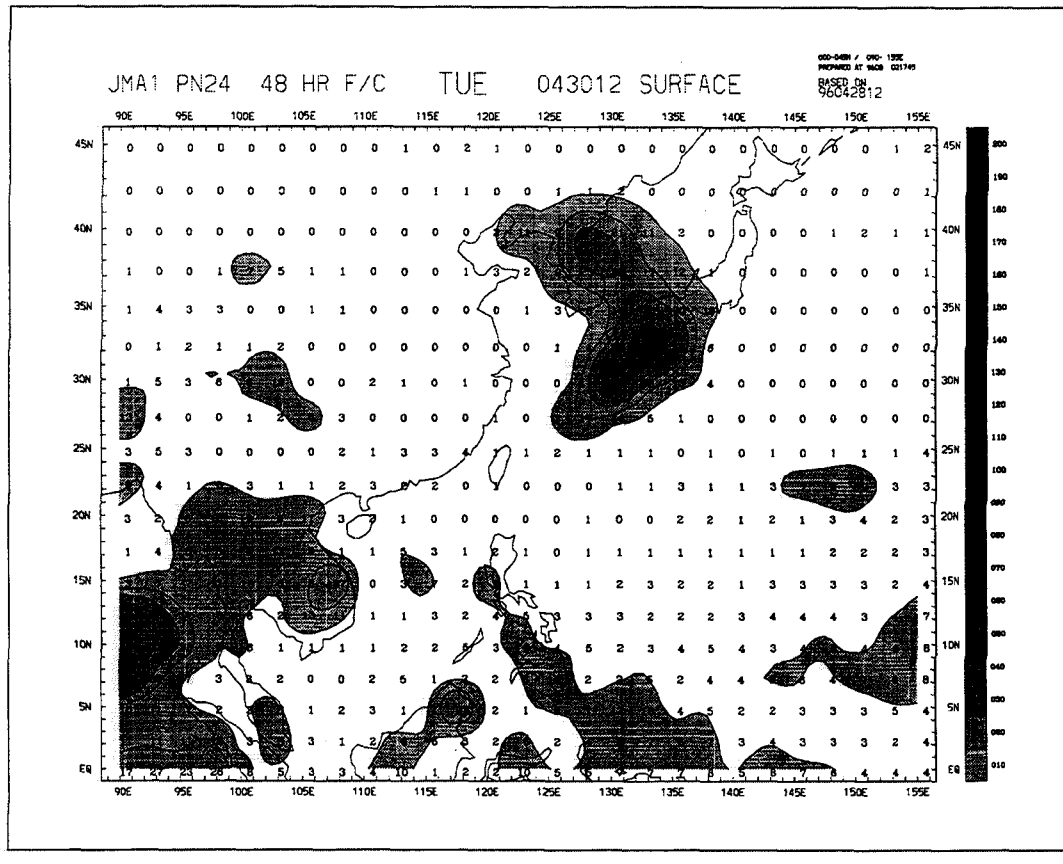

Figure 5b. 24-hour rainfall forecast (in mm) ending at 2000HKT on 30 April 1996 by JMA.