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The Application of Lightning Density Map in the Analysis of a
Severe Rainstorm Case in Hong Kong

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THE APPLICATION OF LIGHTNING DENSITY MAP IN THE ANALYSIS OF A SEVERE RAINSTORM CASE IN HONG KONG

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1. INTRODUCTION

On 22 July 2010, Typhoon Chanthu skirted across the South China Sea and made landfall over the coast of western Guangdong. The outer rainbands of Chanthu brought intense rainstorms to Hong Kong where more than 150 millimetres of rainfall were registered, together with more than 40 reports of flooding and 10 reports of landslides. Four people were killed by the flash flood and many people were injured. A waterspout was also observed over offshore waters. This paper will present a short review of the event as well as a discussion on the application of lightning data and lightning density map in monitoring thunderstorm development in this episode.

2. BACKGROUND OF THE RAINSTORM EVENT

Tropical cyclone Chanthu formed over the central part of the South China Sea on 19 July. It moved generally northwestwards and intensified into a typhoon to the east of Hainan Island in the early hours of 22 July. Chanthu was closest to Hong Kong at about 330 km to its southwest that morning. It finally made landfall over the coast of western Guangdong that afternoon (Figure 1).

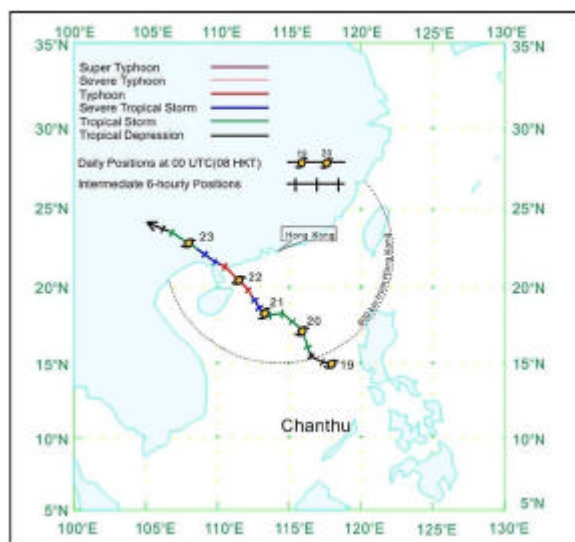


Figure 1 The track of Typhoon Chanthu over the South China Sea

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Outer rainbands of Chanthu began to affect Hong Kong in the morning of 22 July. Less than 10 millimetres of rainfall were recorded in most parts of the territory before noon. From the radar images in Figure 2, the rain echoes once weakened in the early afternoon at around 1400HKT, but they developed again after 1500HKT. The northwest-southeast oriented rainbands further intensified and, by virtue of its northwesterly movement, continuously affected almost the same region in Hong Kong during the following few hours. Over 200 millimetres of rainfall were recorded in parts of Hong Kong during the period. There were also frequent lightning strikes associated with the rainstorms.

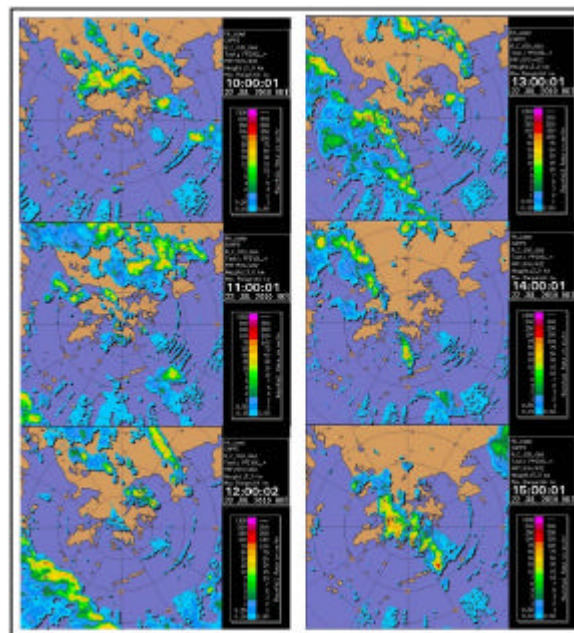


Figure 2 Radar images for Hong Kong from 1000 to 1500HKT on 22 July 2010. Isolated rain echoes swept across the territory in the morning and near noon time. The echoes once weakened at around 1400HKT but they developed again after 1500HKT.

An analysis of the rainstorm will be discussed in Section 3, while an analysis of the lightning data related to the rainstorm event will be given in Section 4.

3. CAUSE OF THE RAINSTORM

A detailed review of the synoptic and mesoscale situations of the rainstorm case on 22 July 2010 was given by Hon and Tong (2011). A brief summary of the cause of the rainstorm event as reviewed in the study of Hon and Tong is given below.

3.1 Conditions favourable for heavy rain

In Figure 3, the water vapour channel satellite image at 0800HKT on 22 July showed that there was abundant moisture associated with Typhoon Chanthu over the northern part of the South China Sea. From the upper air analyses at 850hPa and 700hPa levels at 0800HKT, a low level jet towards the south China coastal region was formed under the convergence of the outer circulation of Chanthu and the subtropical ridge over the northwestern Pacific (Figure 4). Strong southeasterly winds at the low level maintained abundant supply of moisture to the coastal region.

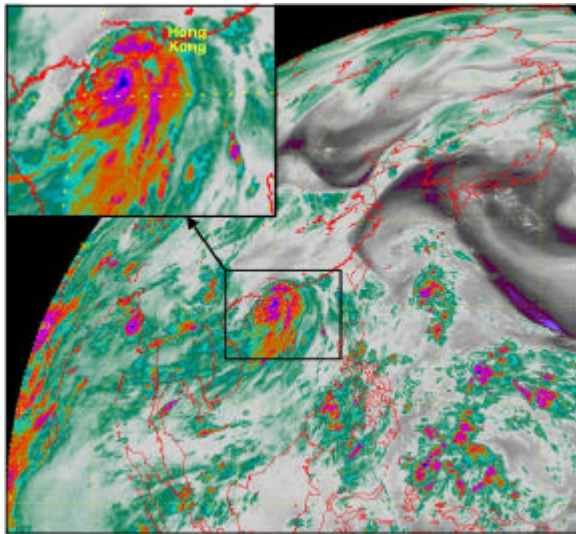


Figure 3 Water vapour channel satellite image at 0800HKT on 22 July 2010 from the Multi-functional Transport Satellite (MTSAT) of Japan Meteorological Agency.

The upper air sounding in Hong Kong at 0800HKT on 22 July showed that the atmosphere was moist and unstable at the lower level (Figure 5). The K-index and CAPE were 37 and 3140 J/kg respectively.

Meanwhile, from the 200hPa streamline analysis at 0800HKT on 22 July (Figure 6), there was an area of strong upper level divergence over the northern part of the South China Sea and the coast of Guangdong.

With abundant moisture supply in an unstable atmosphere, coupled with divergence aloft, it was favourable for the formation of heavy rain over the south China coastal area on 22 July.

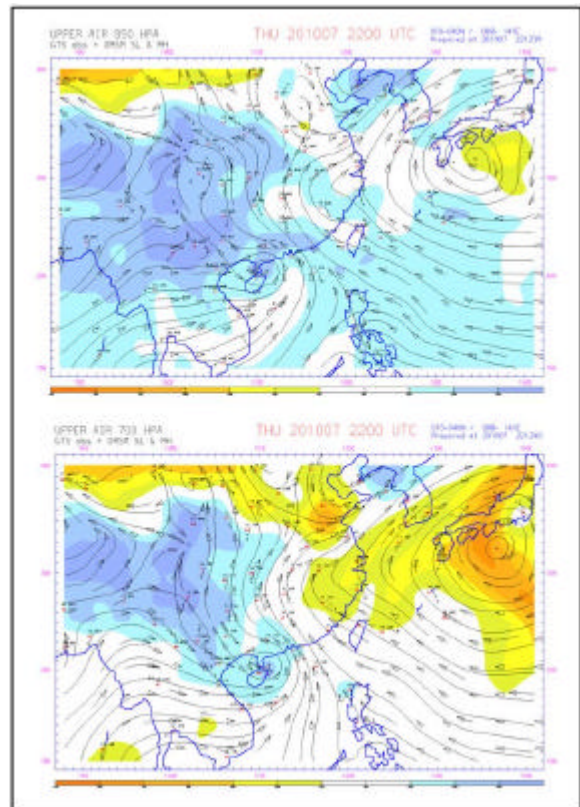


Figure 4 Upper air analyses at 850hPa and 700hPa levels at 00UTC (i.e. 08HKT) on 22 July 2010. A low level jet towards the south China coastal region was formed under the convergence of the outer circulation of Chanthu and the subtropical ridge over the northwestern Pacific.

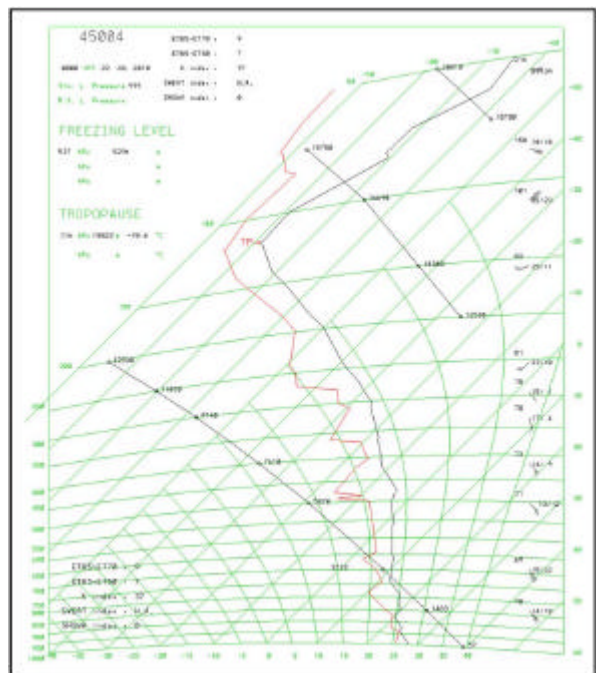


Figure 5 The upper air sounding in Hong Kong at 00UTC (i.e. 08HKT) on 22 July 2010 showed that the atmosphere was moist and unstable at the lower level.

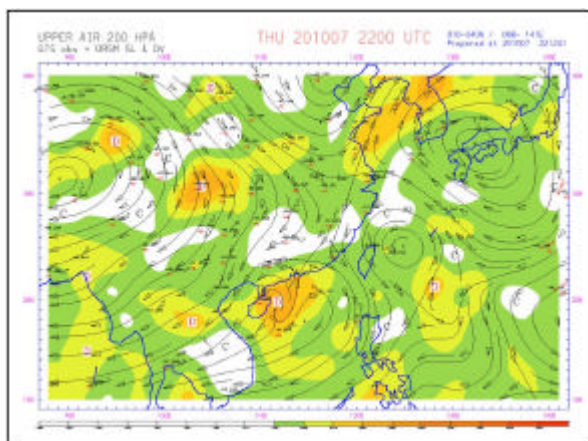


Figure 6 Streamline analysis at the 200hPa level at 00UTC (i.e. 08HKT) on 22 July 2010 showed that there was an area of strong upper level divergence over the northern part of the South China Sea and the coast of Guangdong.

3.2 Intensification of the rainband

On 22 July 2010, under the influence of the outermost circulation of Typhoon Chanthu, winds over Hong Kong were generally southeasterly at around 1400HKT. However, over the eastern part of Hong Kong, winds changed to easterly near 1500HKT, and southeasterly continued to prevail over the western part of Hong Kong (Figure 7). This resulted in an enhanced low level convergence which was conducive to further development of the convective activities near the convergence zone in the following few hours after 1500HKT.

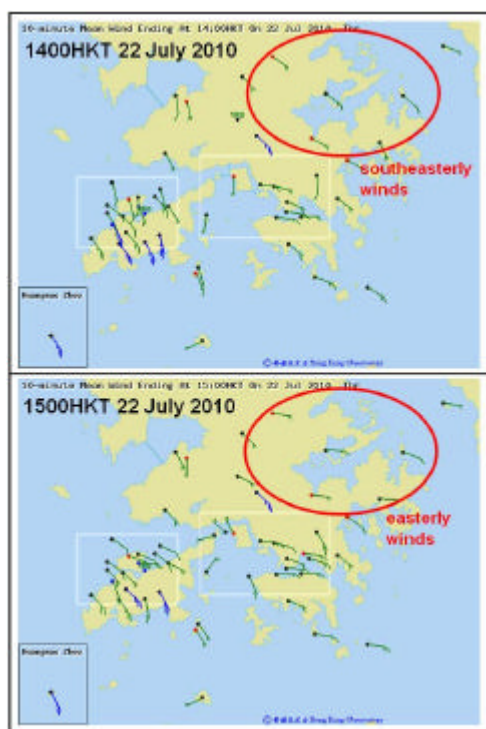


Figure 7 Surface winds over the eastern part of Hong Kong changed from southeasterly to easterly near 1500HKT on 22 July 2010.

From an analysis of the mesoscale situation in the vicinity of Hong Kong, the occurrence of easterlies over the eastern part of the territory may be related to the change in wind direction over inland Guangdong to the northeast of Hong Kong. The surface observations in Figure 8 show that the winds over inland Guangdong to the northeast of Hong Kong gained more northeastward component from 1400HKT to 1700HKT and there was also a pressure rise over the region. It is believed that this pressure rise was associated with the downdraught and cooling effect of the rain affecting the inland Guangdong area that afternoon.

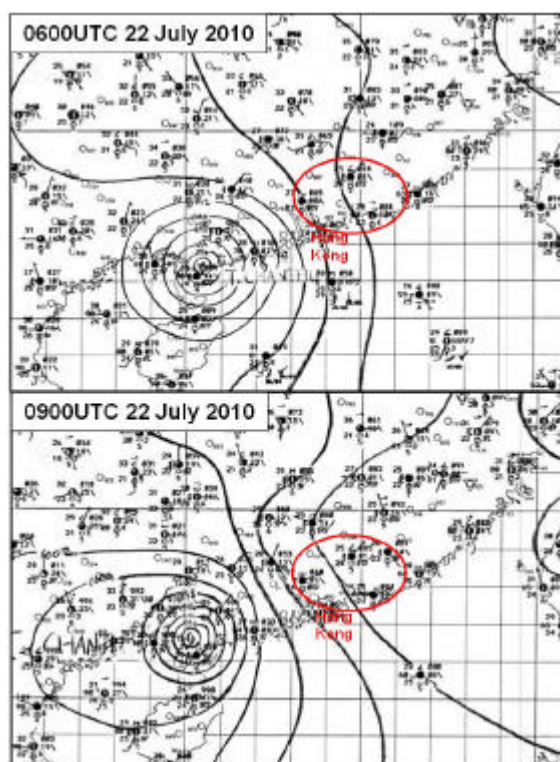


Figure 8 Surface observations showed that the winds over inland Guangdong to the northeast of Hong Kong gained more northeastward component from 06UTC (14HKT) to 09UTC (17HKT) associated with a pressure rise over the region.

4. ANALYSIS OF LIGHTNING DATA

4.1 Lightning Location Network

The Hong Kong Observatory set up a lightning location network in 2005 to monitor lightning activities over Hong Kong and its neighbouring regions round-the-clock. The network comprises six lightning sensors of the IMPACT ESP model (Vaisala, 2004), which are located at Chung Hom Kok, Tsim Bei Tsui and Sha Tau Kok in Hong Kong; Taipa in Macao; Sanshui and Huidong in Guangdong (Figure 9). A good spatial coverage provides sufficient redundancy for detecting cloud-to-ground lightning with more than 90% efficiency within the network. Since the lightning

sensors are designed to detect mainly cloud-to-ground lightning, the efficiency of cloud lightning detection is not high and is estimated to range from 10% to 50%. Lightning information, including lightning stroke timing, location (latitude and longitude), stroke type (cloud or cloud-to-ground lightning), polarity and peak current, are updated every minute for the reference of the weather forecasters in Hong Kong.



Figure 9 Distribution of sensors in the HKO lightning location network. The rectangle in the inset map shows the location and coverage of the main map (from Lee, 2009).

4.2 Analysis of lightning data

Figure 10 shows the number of total lightning (i.e. cloud and cloud-to-ground lightning) counts during the past ten minutes detected within a 128-kilometre square grid covering Hong Kong from 1400 to 2100HKT. It can be seen from Figure 10 that the lightning counts increased significantly near 1500HKT (point A) and there was a further sharp increase at around 1730HKT (point B). It is believed to be associated with the development of the thunderstorm cells as seen from the radar imageries during the corresponding time intervals (Figure 11). Other studies have demonstrated that the change in total lightning rate is related to the development of thunderstorm cell and severe weather (e.g. Demetriades, 2008). During the hour from 1730 to 1830HKT, the rain was particularly heavy and over 100 millimetres of rainfall were recorded in parts of Hong Kong (Figure 12).

The total lightning density maps for the past 30 minutes from 1730 to 1805HKT are shown in Figure 13. It can be seen clearly that the lightning density increased with time which corresponds to the development of radar echoes as shown in Figure 11(b). For example, there was a significant increase in the lightning density over the northeastern part of the territory where the radar echoes continued to intensify and the rain was heaviest. This demonstrates that lightning density map is a good supplement to the radar image in monitoring thunderstorm development.

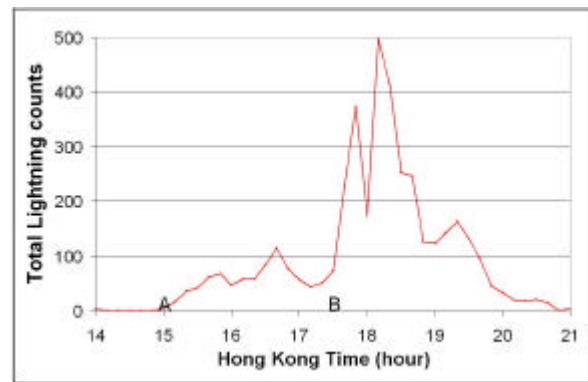


Figure 10 The number of total lightning counts detected within a 128-kilometre square grid over Hong Kong from 1400 to 2100HKT on 22 July 2010.

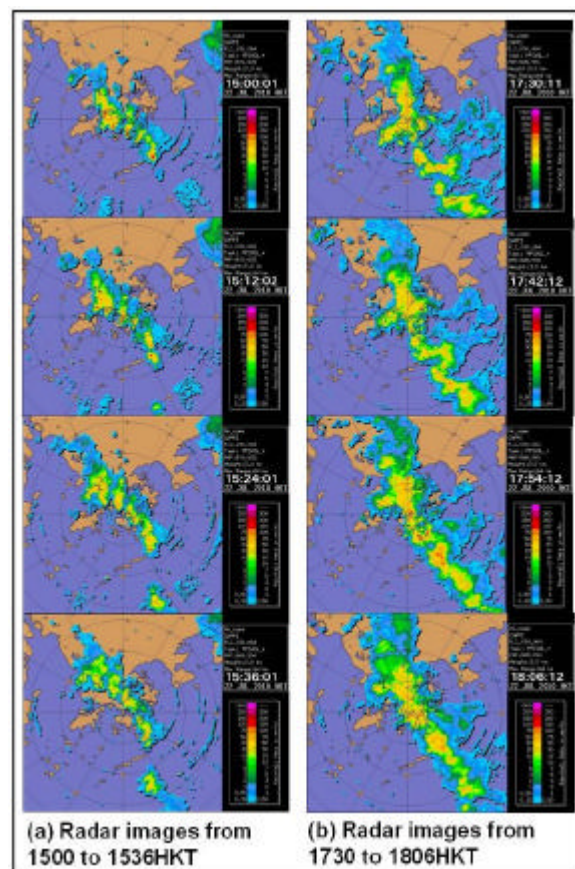


Figure 11 Radar images showing the development of echoes during two time intervals in the afternoon of 22 July 2010.

Furthermore, previous studies found that cloud lightning usually occurs before the first cloud-to-ground strike with a lead time of about ten minutes or more (e.g. Darden *et al.*, 2010). In this case, the cloud lightning strikes generally preceded those of cloud-to-ground by a couple of minutes. This might be due to the relatively low detection efficiency of cloud lightning by the network. Nevertheless, utilization of the cloud lightning data together with radar images could potentially provide longer lead time in determining whether a

thunderstorm cell has become more electrically active or not.

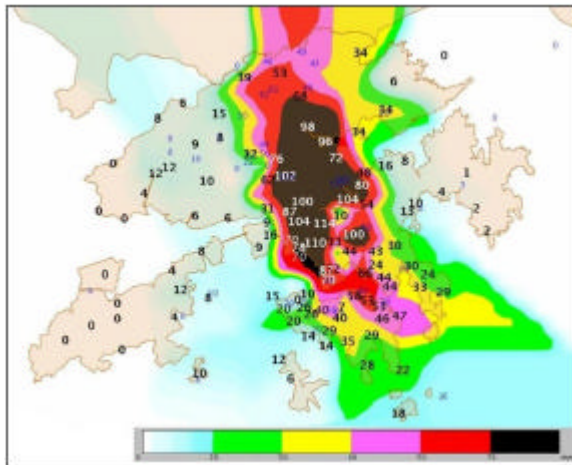


Figure 12 Rainfall distribution over Hong Kong from 1730 to 1830HKT on 22 July 2010.

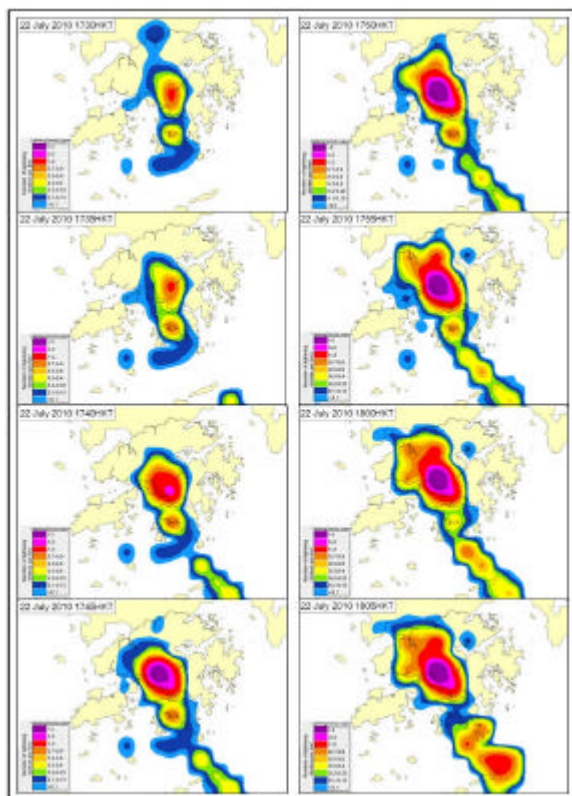


Figure 13 Lightning density maps from 1730 to 1805HKT on 22 July 2010. Increase in the lightning density corresponds to the development of radar echoes shown in Figure 11(b).

5. SUMMARY AND DISCUSSION

The heavy rain and thunderstorm event in Hong Kong on 22 July 2010 was analyzed. On that day, an unstable atmosphere with abundant moisture supply

over the south China coastal region in the vicinity of Hong Kong was observed. Furthermore, there was strong divergence at the upper level of the atmosphere, and a low level jet was formed under the convergence of the outermost circulation of Typhoon Chanthu and the subtropical ridge over the northwestern Pacific. In the afternoon, the convective activities further developed due to the convergence between the easterly airstream originating from inland Guangdong and the prevailing southeasterlies, leading to the heavy downpours which resulted in floods and landslides.

By looking at the lightning data collected during the period, the total lightning rate increased with thunderstorm development. Areas with intensifying lightning density matched well with developing radar echoes. As the lightning density maps have a higher updating frequency than that of radar images, it could provide a more timely indication to the forecaster in terms of expected thunderstorm development.

6. ACKNOWLEDGEMENT

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