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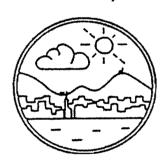
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Editorial

This issue of the Bulletin combines two issues in one volume and contains three papers.

The first paper by Edwin S.T. Lai of Hong Kong Observatory provides yet another view concerning the heavy rainstorms in early July 1997. It examines the atmospheric instability which appears to have been maintained and enhanced by the strong confluence of competing weather systems from east and west and which provided the principal mechanisms at play in the rainstorm episodes.

In the second paper, Norman K.W. Cheung of the School of Geography, University of Oxford, UK, and Bill Kyle of the Department of Geography, The University of Hong Kong, use tropical cyclone data for the western North Pacific Ocean over the past 30 years along with the associated synoptic patterns to provide a reliable working definition of the time periods of the Typhoon season and Active Typhoon Season in Hong Kong.

The third paper continues the annual review of tropical cyclone activity in the western North Pacific Ocean by Bill Kyle of the Department of Geography, The University of Hong Kong, which documents all storms occurring in the region and provides information about tracks, weather conditions, and the resulting impacts on areas affected during the 1998 season.

The remainder of the issue contains the regular feature, Hong Kong Weather Reviews.

The Editorial Board, as always, look forward to receiving any opinions, suggestions or contributions sent in by readers.

Bill Kyle, Editor-in-Chief

Hong Kong Observatory Nathan Road, Kowloon, Hong Kong Email: stlai@hko.gcn.gov.hk

East and West - The Weather Version

Abstract

The historic handover of sovereignty of Hong Kong on 1 July 1997 will be indelibly linked with one of the worst rainstorm episodes to hit the territory in recent years. The outbreak of heavy rain was unseasonal and yet tenaciously persistent. Excessive rainfall led to widespread flooding and landslips, creating havoc for the week-long festive celebrations that followed the handover ceremonies. Atmospheric instability appeared to be maintained and enhanced by strong confluence generated by competing weather systems from east and west. Through analysis of synoptic data, satellite and radar images, as well as observations from local monitoring networks, this paper highlights the various mechanisms at play on different spatial scales that combined to produce the infamous "Handover Rain".

Introduction

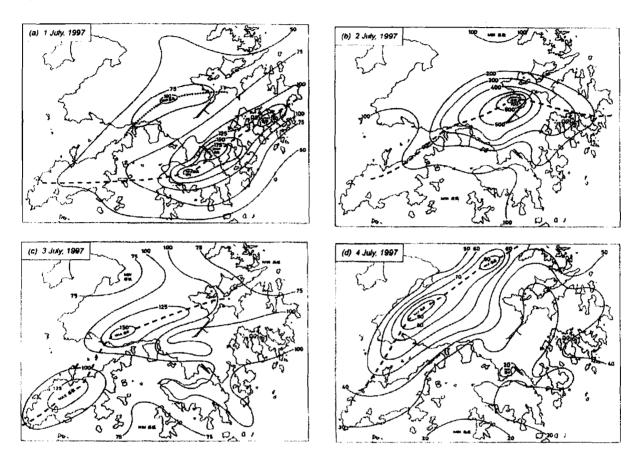
Persistent heavy rain affected Hong Kong from 30 June to 4 July in 1997. Rainfall at the Hong Kong Observatory during the period amounted to 372.4 mm. Elsewhere, Shatin had more than 700 mm with a day on 2 July (Figure 1). Black rainstorm warning was issued on the morning of 1 July, with two red warnings following on successive days. Landslip and flood warnings were also in effect at the time. A summary of the main meteorological elements during the period, as well as conditions before and after for comparison purposes, is given in Table 1.

Climatologically, the wet spell was unusual in the sense that it occurred outside the perennial June flood period in southern China. The monsoon trough should have migrated northwards to central China by then, leaving the southern parts under the dominance of the sub-tropical high. Such unseasonal happenings were set against the

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background of a momentous occasion in the history of Hong Kong - the handover of sovereignty from the British administration to the Chinese government. Numerical simulation of the rain episode was discussed in Li and Ma (1998). Presenting the observational findings from climatic and synoptic analyses, satellite and radar images, as well as local wind and rainfall data, this paper highlights the events on different atmospheric scales that combine to trigger and sustain the now notorious "Handover Rain".

Figure 1. Daily Rainfall Distribution Maps over Hong Kong (rainfall unit mm)



General Circulation and Synoptic Anomalies

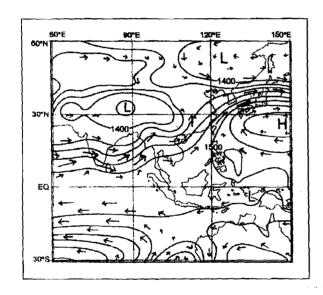
Data from the "Annual Report on Climate System" for 1997 compiled by Japan Meteorological Agency (JMA, 1998) were extracted to depict the significant synoptic evolution affecting the general circulation and weather patterns in Asia and the western Pacific. Mean fields and anomalies at 850-hPa level in Figures 2 and 3 respectively showed an unusually prominent ridge extending towards southern India during the Handover pentad (HOP) of 30 June - 4 July in 1997. Cross equatorial flow was very active over the Indian Ocean. But instead of spreading out towards the Indian subcontinent, the airstream swung around the southern India anticyclone and formed a southwesterly jet along the north flank of the extended ridge, bringing a continuous supply of moisture influx towards southern China and sustaining convective development downstream.

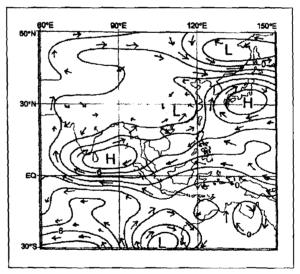
Table 1. Extract of Meteorological Observations (at Hong Kong Observatory headquarters except for winds which were recorded at Waglan Island)

Data	Mean Pressure	Total Rainfall	Wind Direction	Mean Wind
Date	(hPa)	(mm)	(deg/bearing)	Speed (km/h)
luna 2E	1002.1	14.9	160/SSE	7.4
June 25				
June 26	1002.6	57.5	070/ENE	6.3
June 27	1001.9		230/SW	8.5
June 28	1001.5	1.1	080/NofE	8.5
June 29	1001.9	4.8	150/SSE_	9.5
June 30	1002.7	27.6	190/WofS	16.9
July 1	1004.7	122.6	140/SE	19.0
July 2	1005.4	115.5	240/WSW	28.5
July 3	1006.5	83.3	909/E	15.6
July 4	1006.4	23.4	180/S	29.7
July 5	1006.6	Trace	200/SSW	27.3
July 6	1005.3	15.1	190/WofS	21.1
July 7	1004.6	Trace	200/SSW	25.0
July 8	1004.3	13.3	210/SSW	33.8
July 9	1003.9	3.4	200/SSW	30.8

Figure 2. 850 hPa mean winds and height fields during HOP

Figure 3. 850 hPa streamfunction and wind anomalies during HOP

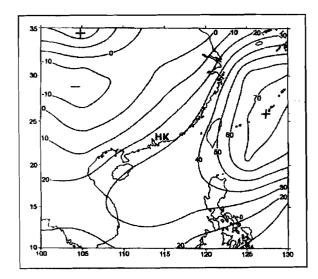


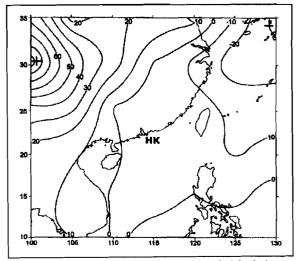


Defining "pre-HOP" to be the pentad of 25 - 29 June and "post-HOP" for 5 - 9 July, mean height differences at 850-hPa level before HOP (i.e. HOP - pre-HOP) and after HOP (i.e. post-HOP - HOP) are shown in Figure 4 and 5 respectively. The main feature was the re-intensification of the Pacific anticyclone following the passage and recurvature of Severe Tropical Storm Peter over the Ryukyus and Japan in late June. The height gradient between 120°E and 125°E suggested that the intensifying Pacific ridge was on the verge of the South China Sea but not quite able to establish a foothold inside. As a result, cyclonic curvature increased within a broad band of southwesterlies that were being swept along towards the south China coast. In streamline analyses, a region of strong confluence between the southeasterlies and the southwesterlies persisted over the coastal waters of Guangdong.

Figure 4. 850 hPa geopotential height differences(in m): HOP – pre-HOP

Figure 5. 850 hPa geopotential height differences(in m): HOP – post-HOP

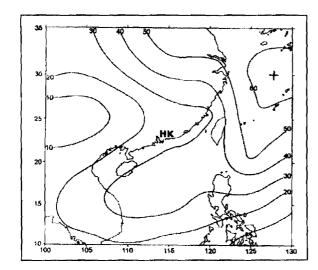


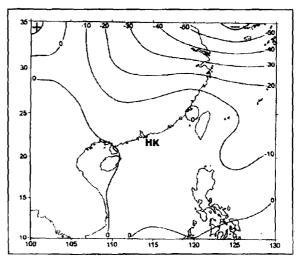


On the daily rainfall distribution maps in Figure 1, if the major axis of isohyet maxima (heavy dashed line) could be interpreted as an area of enhanced convection generated by strong confluence effect, then this line of confluence was found to move ever so slowly across Hong Kong. It covered a mere distance of about 25 kilometres in 4 days (a speed of only about 0.2 - 0.3 km per hour) and was effectively almost stationary along the longitude of 114°E. Despite the lack of speed, a consistent movement towards the northwest in response to the encroaching Pacific ridge from the east was quite unmistakable on a day-to-day basis.

Figure 6. 500 hPa geopotential height differences(in m): HOP – pre-HOP

Figure 7. 500 hPa geopotential height differences(in m): HOP – post-HOP



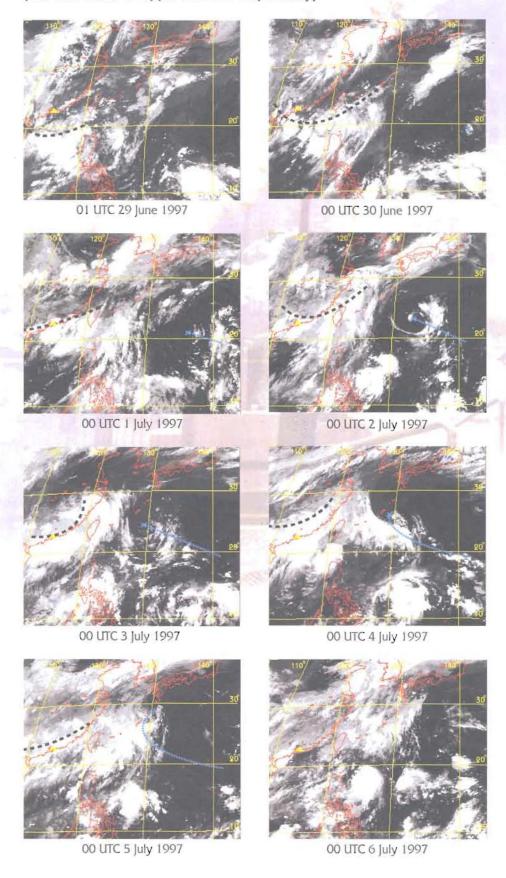


Intriguing changes also took place at the 500-hPa level (Figures 6 and 7). Here, the pre-HOP height increases were very prominent over central China. Combined with the extended ridge over the South China Sea in connection with the evolving tropical circulation, the net effect was the emergence of weak troughing over southern China against a background of general height increases. From a separate study in Chan and Lee (2000), the 500-hPa streamline analyses at 00 UTC and 12 UTC on 30 June revealed similar development. Significantly, this was also the time marking the onset of the spell of heavy rain that lasted into early July.

Mesoscale Complications

In response to weak troughing at the mid levels over southern China, there was a significant northward shift in the position of the convective cloud band over the South China Sea between 29 June and 1 July (Figure 8). Based on the position of the cloud band, a surface trough was analyzed on the surface charts from 1 July onwards. Convective activity along the trough was quite extensive, stretching from Hainan Island all the way to Taiwan. Along a length of over 1,000 km, there could be up to 5 or 6 active MCSs (mesoscale convective systems) at any one time. Development tended to be explosive and intensity was maintained in the order of several hours, typical of MCS lifespan. Movement was in general slow with no preferential direction. Fresh convection appeared to favour the sectors west of existing MCSs, suggesting a back-propagation mechanism at play.

Figure 8. GMS5 IR1 satellite images (yellow triangle – Hong Kong; black dashed line – northern edge of intense convection; blue cross and dotted line – location and past movement of upper cold low respectively)



In time, active convection became concentrated along the coast of Guangdong as development near Taiwan became more subdued. By the latter part of 4 July, convection over the eastern sector of the Guangdong coast was also suppressed and intense development was by then confined to the coastal region west of Hong Kong. Although there were signs of mesoscale cyclogenesis from time to time during the period, the vortices appeared to be transient in nature and not strongly linked with travelling westerly perturbations often seen with the classical monsoon trough earlier in the rain season. In fact, westerly waves were mostly confined to the mid-latitudes where a band of convection could also be found over central China along 30°N on 1 July. However, with rising geopotential heights and increasing subsidence, convection over central China decreased in the following days.

Meanwhile, a well-defined upper cold low over the western North Pacific tracked steadily to the west-northwest towards the Ryukyus before decelerating and weakening at a longitude just west of 130°E. The clear area associated with this upper low, however, never quite reached Taiwan throughout the episode. improvement in the weather over the southeastern part of China in terms of reduced convective activity after 4 July seemed to coincide with the weakening of the upper low and its subsequent recurvature to the northeast. The intensifying Pacific anticyclone that produced the enhanced confluence effect mentioned earlier could possibly be a lowlevel response to the westward push of the upper cold low. Once the upper low weakened and retreated eastwards, the low-level confluence effect over the south China coast also relaxed, leaving only remnant convection within a broad band of prevailing The proposed hypothesis offered a plausible explanation to reconcile southwesterlies. the observed paradoxes in the Handover Rain: (a) a consistent rise in surface pressure against a lingering trough; and (b) despite rising surface pressure, it was never a case of cloud clearance from the east normally associated with a westward extending subtropical high from the Pacific.

Owing to power failure, radar sequence for the Handover Rain was incomplete. Radar information for an in-depth study of the horrendous rain that hit Shatin during the climax on 2 July was sorely missed. A general impression from the available images (Figure 9) was that the really intense storm cells were not particularly extensive, occasionally lining up in small bands along a SW-NE orientation within a broad area of lesser rain and tracking to the east or northeast in the monsoonal flow. Organization on a larger scale such as the E-W convective band seen at 1200H on 3 July was the exception rather than the norm. Very often, the convective clusters were rather disjointed with no strong tendency to merge or to develop into supercells and squall lines. The overall picture confirmed the absence of a dominant weather system as the prime controller of events and reinforced the notion of sustained convection over a broad region of unstable flow aggravated by enhanced confluence as the southwest monsoon came up against a strengthening Pacific anticyclone.

Figure 9. Selected radar images for the Handover Rain with dates and times as indicated (in 24-hour clock, i.e. 1742H means 5:42 pm local time). Maps of radar echoes at 3-km level with echo intensity increasing from green to yellow to red. Radar site located at Tate's Cairn (centre of the image), with outer perimeter extending to a radius of 256 km.

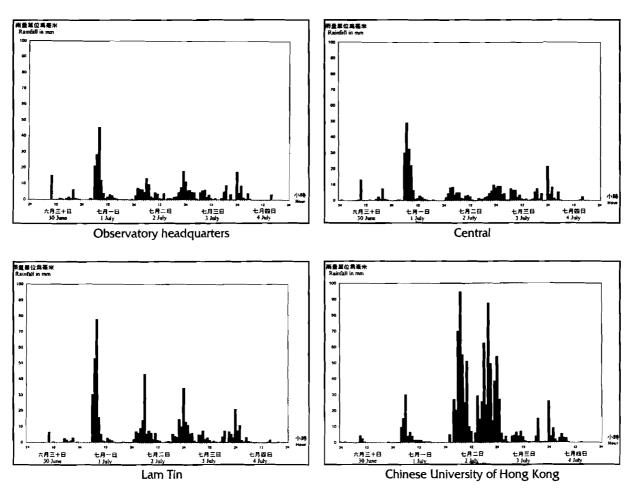


Diurnal Fluctuations

Radar images in Figure 9 were arranged in rows of days and columns reflecting roughly the diurnal cycle. Generally speaking, while convection tended to be more active over inland areas during daytime, development along the coast and over the sea areas did not seem to have strong diurnal dependency. Echo intensity was on the whole stronger in the early part of the day and weaker going into the evening, consistent with the well documented trend observed in summer monsoon rain (Peacock, 1952).

Lacking a focus in the form of a well-defined weather system, diurnal tendencies would be more difficult to tie down on the radar maps. The impression given by the rainfall time series from selected stations in Figure 10 was, however, much more striking. Disregarding the less intense showers on 30 June, there were altogether four major rainfall peaks from 1 to 4 July with periods ranging from 18 to 24 hours. Typically, each outbreak of rain lasted for 6 to 12 hours with lulls in between. Even though rain intensity and other details did vary from station to station, the diurnal signature amongst the chaos was still quite unmistakable.

Figure 10. Time series of hourly rainfall from 30 June to 4 July 1997.



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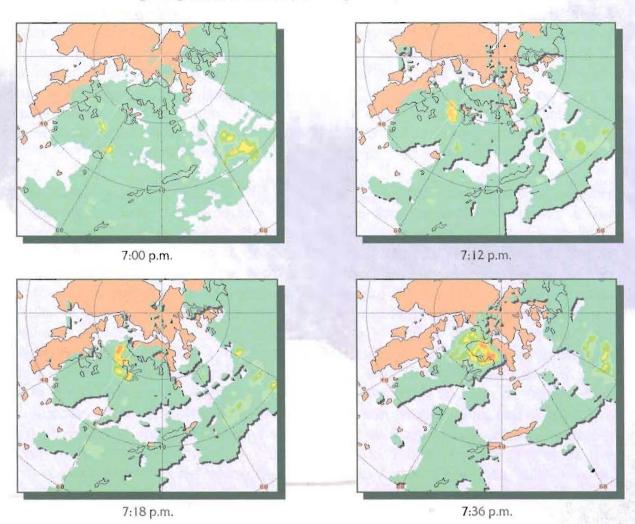
Ideally, one could look at the local winds reported by the Observatory's network of automatic weather stations (AWS) to see if such diurnal patterns were consistent with the observed changes in local convergence or confluence effects. However, as the reported winds could well be convection-driven and modulated by terrain, a direct interpretation would be impractical. On a day-to-day basis (Table 1), winds offshore at Waglan Island had been quite changeable for several days prior to 30 June. However, wind speeds then were on average less than 10 km per hour. Under such light to moderate winds, large variations in wind directions were inconsequential and not unusual. But as winds increased to 15 - 30 km per hour after 30 June, a constant switch in wind direction between the southeast and southwest quadrants became quite significant, suggesting the setting up of some kind of confluence effect on the synoptic scale. It was interesting to note that once winds at Waglan settled down to a direction of 190 - 210 degree bearing in the post-HOP, rain also became less frequent and not Over a diurnal cycle, the AWS winds revealed a tendency to back from as intense. southwesterly in the early part of the day to southeasterly in the evening. As such, on top of the synoptic confluence effect, there could also be some tidal oscillations between the protagonists involved that led to the ebb and flow of airstreams across Hong Kong.

Localized Pockets of Heavy Rain

Against a generally unsettled synoptic background, two cases of localized outbreak of rain stood out in memory: the downpour at Tamar in the early evening on 30 June and the torrential rain at Shatin for most of the day on 2 July.

The British Farewell Ceremony at Tamar in the early evening on 30 June was gatecrashed by a small cluster of wandering rain clouds that tripped over Lamma Island and landed on top of Hong Kong Island at the wrong place and at the wrong time. A stroke of bad luck it may be (Lai 1998). If not for the occasion, the 8 mm of rain in less than half an hour could just be passed off as a case of isolated summer shower and would never make the headlines. Within an extensive area of weaker echoes on the radarscope, the culprit storm cells started off innocuously enough over the waters off Cheung Chau at 7:00 p.m. (Figure 11). Moving northeastwards and feeling the effect of Lamma Island, they intensified and merged into a cluster. Against a southwesterly background flow, winds at this time turned southeasterly inside the Victoria Harbour. Doppler analyses revealed a lifting of the low-level southwesterly jet under very unstable conditions with K-index as high as 37 (Chan and Lee 1998). Convection became enhanced and the storm cluster reached peak intensity as it moved across Hong Kong Island between 7:30 and 8:00 p.m. While the mechanism for the transient intensification of the storm cluster could be understood in terms of orographic uplifting of an unstable jet, and possibly some local convergence as well as due to southeasterly winds coming back into the harbour, there were probably no better explanations for the inopportune timing other than blaming it on the stochastic nature of atmospheric process (and, some would say, the sarcastic nature of fate).

Figure 11. Convective development (in yellow and orange colours) over Lamma Island and Hong Kong Island in the early evening of 30 June 1997.



Events on 2 July, however, were much more catastrophic. Although radar images were not available for most of the day, the daily rainfall distribution maps (Figure 1) did provide some clues as to the underlying mechanisms. The Tamar shower on 30 June already suggested that the unstable southwesterly jet was extremely sensitive to orographic influence. On 1 July, a secondary rainfall maximum (short dashed line in Figure 1 (a)) could be found straddling across Tsuen Wan and Shatin. isohyet axis, meanwhile, was still over the southeastern part of Hong Kong. The southwesterlies, on the unstable side of the major axis, were lifted over the Kowloon peaks and funnelled down valley towards the Tolo Harbour (this contrasted with the absence of secondary maximum in Figure 1 (c) and (d) for 3 and 4 July respectively when Tsuen Wan and Shatin were on the stable side of the major axis). In other words, while the major axis was synoptically forced, the secondary maximum was orographically anchored. The two mechanisms reinforced one another on 2 July as the major axis edged northwestwards across the territory in response to the in-pushing ridge from the Pacific and lined up along the orographic maximum. Convection was enhanced and prolonged on account of the slow movement of the major axis, giving rise to persistent heavy rain within a confined location (Figure 1 (b)).

Concluding Remarks

For the numerous Handover ceremonies and celebrations that went awry because of the inclement weather, the inevitable question in any respectable inquest was: "How did it all happen?" The simplistic answer for the laymen's consumption would be to blame it either on "an unusually active southwest monsoon" (which, to be fair, would be true for a large part of the summer) or "a slow-moving trough". But probably a more fundamental reason was the impasse caused by the southeasterly vs. southwesterly confluence. Borrowing the title of the book written by the last Governor of Hong Kong, it would be very much a case of "East and West - The Weather Version".

However, the underlying confluence theme could be likened to a broad canvas upon which events on different atmospheric scales conspired to weave a pattern of widespread instability. In major aviation incidents, the famous last words were the oftquoted "unfortunate combination of circumstances or factors". The same could also be said for the occurrence of severe weather. On the general circulation scale, the pentad anomaly fields for 30 June - 4 July revealed the presence of an extended ridge at the lower levels from the western North Pacific to South China Sea, Indo-China and all the way towards southern India. On the northern flank of the ridge, a low-level southwesterly jet served as an efficient conveyor belt of moisture flux. Synoptically, there was also a tendency for the Pacific ridge to recoil westwards towards Taiwan following the passage and recurvature of Severe Tropical Storm Peter over the Ryukyus and Japan in late June. Sandwiched between the in-pushing ridge from the east and the moisture-laden southwesterlies from the west, the Guangdong region in southern China was subject to an enhanced confluence effect. Against this background of tussle between east and west, with local winds flip-flopping between southeasterly and southwesterly, factors on the smaller scales also came into play. The rainy scenario was modulated by diurnal variations, with rainfall locally enhanced due to orographic effects. The rainfall time series suggested a pseudo-diumal control with a recurrence period between 18 and 24 hours. The fact that rainfall was locally enhanced, such as the farewell downpour at Tamar on 30 June and the deluge at Shatin on 2 July also strongly pointed to orography and local convergence being contributory factors.

Yet despite the inherent irregularities and complications, the axis of isohyet maxima on the daily rainfall distribution maps showed a consistent march from southeast to northwest across Hong Kong from 1 to 4 July (Figure 1). Contrary to the "approaching or lingering trough" theory, a constant rise in daily mean pressure (Table 1) suggested instead an increasing influence of the ridge from the east, culminating in a break from the spell of heavy rain after 4 July. But for those who prefer to steer away from political overtones, maybe it would be best to sum up the whole rain episode as "just an unfortunate combination of factors".

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Norman K.W. Cheung and William J. (Bill) Kyle2

¹ School of Geography, University of Oxford, United Kingdom Email: kin-wai.cheung@geography.oxford.ac.uk ² Department of Geography, The University of Hong Kong Email: billkyle@hkucc.hku.hk

Hong Kong's Active Typhoon Season

Abstract

Climatologically, July-October is often regarded as the "Typhoon Season" (TS) while this paper defines the period from July 20th-October 12th as the "Active Typhoon Season" (ATS) for Hong Kong. It is demonstrated that comparatively more tropical cyclones, under favourable synoptic environmental flow fields, form in or enter the Western North Pacific Ocean and South China Sea in the ATS while a dry spell or a cold air surge can reduce the number of tropical cyclones considerably in the first half of July and the second half of October respectively. The physical mechanisms for these observed variations are investigated since the greatest threat and destruction brought to Hong Kong by typhoons is mainly in the ATS rather than in the TS as a whole. These new definitions of TS and ATS provide the general public and relevant government departments with more specific time periods such as TS and ATS and their duration so that they may be better prepared in advance to minimize the degree of losses brought by these atmospheric phenomena.

Introduction

A typhoon is a devastating atmospheric hazard, which can cause great loss of life and destruction of property particularly when a community is ill-prepared. For example, in Hong Kong a total of 110 persons died, and 303 small craft were sunk or wrecked by Typhoon Rose in 1971. Typhoon Ellen in 1983 led to 333 persons being injured and 44 ocean-going vessels in trouble. Arguably, these disasters were partly a consequence of an inadequate response by those who did not have a clear understanding of the concepts of "Typhoon Season" and "Active Typhoon Season" and the implications for the safety of theit lives and property. These concepts are, in contrast, well defined in the other ocean basins of the world which are subject to tropical cyclones. For example, the Hurricane Season in the Atlantic, Caribbean, and Gulf of Mexico is defined as the period from June 1 to November 30 while the Hurricane Season in the Eastern

Pacific and Central Pacific Basin occurs during the time periods from May 15 to November 30 and June 1 to November 30 respectively. Compared to these well-established concepts comparatively little research has been done on this climatological aspect of typhoons in the Western North Pacific Ocean and, in particular, with special reference to Hong Kong.

Heywood (1950) has described different aspects of tropical cyclones affecting Hong Kong while Pun (1966) provided the most comprehensive account of the climatological aspects of Hong Kong typhoons to date although the information now needs to be updated. Apart from providing detailed and updated data for the tropical cyclone climatology over the Western Pacific and the China Seas area from 1884 to 1970 in Royal Observatory Technical Memoirs No.1 & 11 (Chin, 1958, 1972), and in a statistical survey (Starbuck, 1951), Hong Kong Observatory has also published two general books on Hong Kong Typhoons for laymen in 1977 and 1992. In addition, a brief listing of tropical cyclones making landfall at Hong Kong has been given by Wang (1991).

Many climatologists in mainland China regard July-September as the typhoon season for China when they count all tropical cyclones affecting its long coastline (Bao, 1987; Niu, 1992; Yu et al., 1986). Domrös and Peng (1988) defined the typhoon season as the period from May to November while Wang and Xu (1983) set it from June to September. Japan and the Philippines regard June-November and July-September as the typhoon season respectively for their own countries in different parts of the Western North Pacific Ocean basin (Arakawa, 1969; Almario et al., 1992). Clearly, there is too much uncertainty in specifying July-September as the Typhoon Season for Hong Kong. Heywood (1950) suggested July-October as the Typhoon Season but Brand (1978) extended this period from June to October. Indeed, in reality, Hong Kong has no "official" Typhoon Season. Many citizens, from experience, merely know that tropical cyclones occur in summer in Hong Kong but generally have no idea in which months during the summer time the hazard is most significant. In truth, they are often ambiguous about the impacts of tropical cyclones and heavy rainstorms which are probably the two most severe weather hazards affecting Hong Kong.

Hence, the primary purpose of this paper is to use tropical cyclone data for the Western North Pacific Ocean for the past 30 years and the associated synoptic weather patterns to provide a reliable working definition of the time periods of the Typhoon Season and Active Typhoon Season in Hong Kong. Theoretical explanations for the observed seasonal variations of tropical cyclone activity are also offered and an attempt is made to confirm why the severity of typhoon disasters is greatest in the Active Typhoon Season. As a consequence engineers, contractors, relevant governmental departments and the general public should be better informed concerning the start of the Typhoon Season and Active Typhoon Season on the designated dates. Hence, they should be forewarned of the potential for increased tropical cyclone activity in our ocean basin. This will allow them enough time to take precautionary actions to avoid or reduce the damage caused by typhoons.

Methodology

Although tropical cyclones (TCs) in the Western North Pacific Ocean can be categorized into four different ranks according to their maximum sustained surface wind speed (Table 1), the term "typhoon" is commonly used by the public in Hong Kong to refer to all tropical cyclones occurring in this ocean basin. The best-tracks of all tropical cyclones which have occurred within the area bounded by the Equator, 45°N, 100°E and 180° from 1967 to 1996 (Figure 1) as counted by Hong Kong Observatory (HKO) are utilized for this observational analysis (Table 2). The second data set used is from the Economic and Social Commission for Asia and the Pacific / World Meteorological Organization (ESCAP/WMO). A tropical cyclone is included in the analysis when it begins to move and so initiates a track. The tracks of all tropical cyclones were constructed from 6-hour best-track positions derived from the data.

Table 1. Classification of tropical cyclones in the Western North Pacific Ocean. (Source: Hong Kong Observatory, 1992)

Classification	Maximum Sustained Wind Near Centre			
	(km/h)	(Beaufort scale)		
Tropical Depression (TD)	41-62	6-7		
Tropical Storm (TS)	63-87	8-9		
Severe Tropical Storm (STS)	88-117	10-11		
Typhoon (T)	118 or above	12		

The most recent 30-year data of tropical cyclones (a climatological mean) are used because the number and intensity of tropical cyclones might be underestimated or overestimated respectively with insufficient weather stations in land and over the sea due to absence of satellite and aircraft reconnaissance before the mid-1960s. The data before that time was rather rare, particularly over the sea, as few, if any, voluntary commercial ships would be foolhardy enough to stay in close proximity to a typhoon. Typhoon Dot (1973) was, in fact, the first time that a special reconnaissance flight by a Hong Kong based aircraft located the centre of a tropical cyclone (Dyson, 1983). However, not every tropical cyclone in the Western North Pacific Ocean was under surveillance by aircraft reconnaissance. The situation was made worse with the termination of this indispensable observational tool in August 1987 though its role in locating the centre and estimating the intensity of tropical cyclones was undeniably important up to that time (Chan and Holland, 1989; Gray et al., 1991; McBride and Holland, 1987). Furthermore, the satellite pictures from the Japanese Geostationary Meteorological Satellite (GMS) have only been used by HKO since January 1980 to help locate the centre and estimate the maximum winds of tropical cyclones. Indeed short-lived tropical cyclones might still go undetected even in the post-satellite age (Landsea, 1993).

Figure 1. The coverage area wherein all tropical cyclones are recorded and the tropical cyclone warning responsibility area of the Hong Kong Observatory

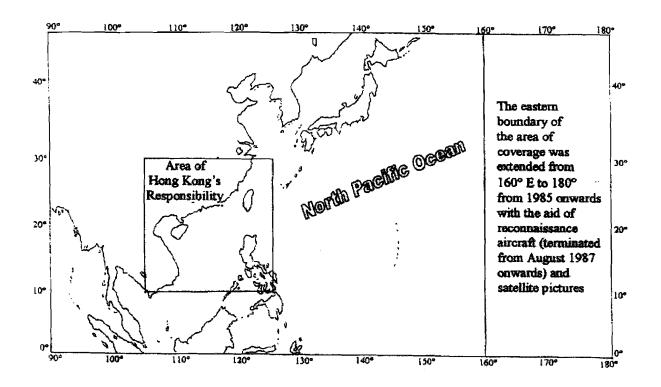


Table 2. Sources of recorded Hong Kong typhoons for analysis.

CONTRACTOR OF THE PROPERTY OF	Sources of Recorded Hong Kong Typhoons
1883	Hong Kong Observatory was founded.
1884 -1939	Reports of some destructive typhoons as Appendices in the Meteorological Results.
1940 -1946	Interruption of records due to war.
1947 -1967	Reports of all tropical cyclones which caused gales in Hong Kong in the Director's Annual Departmental Reports.*
1968 -1986	Reports of all tropical cyclones which necessitated the hoisting of tropical cyclone warning signals in Meteorological Results Part III - Tropical Cyclones Summaries.
1987 onwards	Tropical cyclones in 19XX.

(*Provisional reports on individual tropical cyclones affecting Hong Kong have been prepared since 1960.)

Note that the extension of the coverage area from 1985 onwards does not affect the analysis too much since most of the TCs over the Western North Pacific Ocean form west of 160° (Xue and Neumann, 1984). A few inconsistencies between the data sets have been collated and corrected.

In addition to the observational study, two statistical methods, namely, the Interquartile Range (IQR) and the Poisson Distribution, were adopted for further analysis of the data. The IQR is the difference between the upper and lower quartiles of a distribution:

$$IQR = q0.75 - q0.25 \tag{1}$$

The IQR is used because it ignores the upper and lower 25% of the data and hence makes it quite resistant to outliers. As such it is a useful tool for providing summarized data. The probability distribution function for the Poisson distribution is

$$\Pr\{X=x\} = \frac{\mu^x e^{-\mu}}{x!},$$
 (2)

where X is the number of occurrences; e=2.718... is the base of the natural logarithms; μ is the specific value for the parameter which can be estimated by the method of moments. It is useful in describing the number of discrete events occurring in a series, or a sequence, so it is very suitable for understanding the distribution of tropical cyclones during a typhoon season.

Hong Kong's Typhoon Season and Active Typhoon Season

There were 884 recorded tropical cyclones in the Western North Pacific Ocean for the period from 1967-1996 (Table 3). The data set exhibits quite large interannual variability with as few as 21 tropical cyclones in a quiet year (1977) but as many as 41 in an active year (1994). Tropical cyclones attaining typhoon intensity also fluctuated considerably, ranging from a peak of 21 typhoons in both 1971 and 1989 to only 8 in 1983. The number of tropical cyclones occurring within the area of Hong Kong's responsibility is also quite variable from year to year. For example, there was double the number of tropical cyclones in Hong Kong's area of responsibility in 1978 when compared to those in 1977.

Based on the Poisson model, Figures 2 to 4 show that there are on average 29 Tropical Cyclones with maximum sustained winds of at least 63 km/h, 15 Typhoons of 118 km/h or more over Western North Pacific Ocean, and 15 Tropical Cyclones occurring within Hong Kong's area of responsibility each year. These represent exactly the pattern of occurrence of tropical cyclones over the Western North Pacific Ocean for the past 30 years. However, the differences between the probabilities of the occurrence of 24, 25, 26, 27, 28, 29, 30, 31, 32 ...TCs are quite small. This fact means that the expected frequency of TC occurrence each year is difficult to predict. We can only expect there is a 56% probability we will have above average numbers of TCs over the Western North Pacific Ocean and a 59% probability that there would be above average TC occurrence within the area of Hong Kong's responsibility.

Table 3. Summary of Western North Pacific tropical cyclone statistics for 1967-1996. The numbered columns show monthly distribution of tropical cyclones for 30 years and yearly incidence of tropical cyclones and typhoons, and tropical cyclones occurring within the area of Hong Kong's responsibility. The total and mean values are shown for each column for the period 1967-1996.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total TCs	Typhoon	AoR
1967	1	-	2		-1	1	6	9	<u></u>	5	3	1	38	19	17
1968	0	1 1	0	1	-	1	3	7	3	6	4	0	27	19	12
1969	1	o	1	1	0	0	4	4	6	4	2	1	24	13	11
1970	0	1	0	0	0	3	2	7	5	6	4	0	28	12	20
1971	1	0	1	3	4	2	7	5	6	5	2	0	36	21	20
1972	1	0	0	0	1	4	7	3	5	5	2	2	30	18	15
1973	0	0	0	0	0	0	6	7	2	4	3	0	22	11	17
1974	1	0	1	1	1	4	4	7	5	4	4	2	34	14	21
1975	1	0	0	0	0	1	2	5	4	5	3	1	22	11	12
1976	2	2	0	2	2	2	4	4	5	1	1	2	27	14	10
1977	0	0	1	0	1	1	5	1	5	4	2	1	21	11	10
1978	0	0	0	1	0	3	4	8	7	6	4	0	33	13	20
1979	1	0	1	1	2	1	4	5	5	4	2	3	29	13	18
1980	0	٥	1	0	4	1	6	3	7	4	1	1	28	15	17
1981	0	Ō	0	2	0	3	5	7	3	2	4	2	28	12	15
1982	0	0	3	0	1	3	4	5	6	4	1	1	28	18	16
1983	0	0	0	0	0	1	3	6	2	6	6	2	26	8	15
1984	0	0	0	0	0	2	5	7	- 3	7	3	1	28	13	14
1985	2	0	0	1	1	3	2	8	5	4	1	2	29	16	15
1986	0	1	0	_1	2	2	3	5	3	5	_ 5	3	30	_19	16
1987	1	0	0	_1	0	2	_ 4	5	7	2	3	1	26	17_	12
1988	1	0	0	_0	1	3	2	5	9	5	2	_1_	29	15	_ 17
1989	1	0	_ 0	1	2	2	6	7	6	4	3	2	34	21	17
1990	1	0	0	1	1	4	_ 4	_6	5	- 5	4	_1_	32	19	_ 18
1991	0	_0	2	1	1	_1	4	_6	6	4	5	_0	_ 30	18	14
1992	1	_1	0	0	0	3	4	9	4	7	3	_0	32	18	11
1993	0	0	1	0	1	1	5	7	6	5	2	3	31	15	14
1994	1	0	1	0	2	2	9	9	9	6	0	2	41	19	20
1995	1	0	0	1	0	2	2	6	6	_6	2	3	29	10	17
1996	0	1	0	1	2	0	7	8_	6	2	3	_ 2	32	16	15
Total	18	7	15	_21	31	_58	133	181	159	137	84	40	884	_458	466
Average	0.60	0.23	0.50	0.70	1.03	1.93	4.43	6.03	5.30	4.57	2.80	1.33	29.47	15.27	15.53

Figure 2. Probability distribution of number of tropical cyclones in the Western North Pacific Ocean

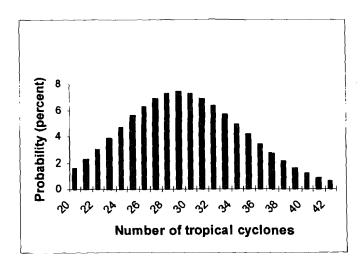


Figure 3. Probability distribution of number of typhoons in the Western North Pacific Ocean

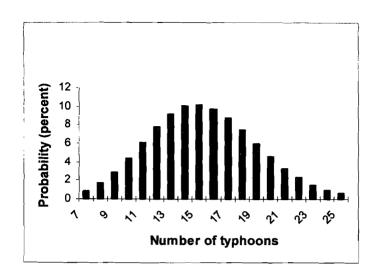
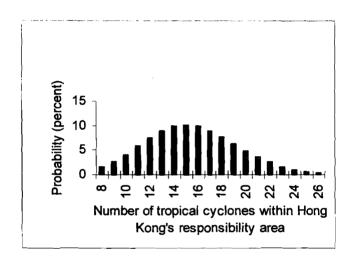


Figure 4. Probability distribution of number of tropical cyclones occurring within Hong Kong's area of responsibility



The Western North Pacific Ocean is the only ocean basin in which TCs occur in every month of a year. January-March is the quiet phase as only 40 TCs have been recorded for these 30 years and the minimum is in February. During the period from April-June, TCs are increasing but at a low frequency rate (a low-frequency increasing phase) while the high frequency increasing stage occurs in the mid-summer (July to October) with the maximum in August. The last 2 months of the year are again a declining stage with only 14 percent of the total TCs.

Unquestionably, the fact that about 70 percent of TCs occur over the Western North Pacific Ocean in the period from July - October would logically and generally mean that that period would be reckoned as "Typhoon Season" as proposed by Heywood

(1950). Indeed, over 82 percent of TCs which have necessitated the hoisting of typhoon warning signals in Hong Kong have occurred within this period (Table 4). Only 1 out of the 10 wettest TCs affecting Hong Kong was not recorded in these months (Table 5).

Table 4. The monthly distribution of tropical cyclones that necessitated the hoisting of typhoon warning signals in Hong Kong (data derived from Hong Kong Observatory, 1968-1997)

		Yeş	//////		100	\$\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\		Prigrie !
Typhoons	2	4	11	24	16	24	24	3
Severe Tropical Storms	†	1	7	16	11	11	4	
Tropical Storms	 		4	4	1 1	6	1	
Tropical Depressions			3	2	6	1	1	
Total	2	5	25	46	44	42	30	3

Table 5. The 10 wettest tropical cyclones in Hong Kong (1884-1939; 1947-1996) Source: Hong Kong Observatory, 1997)

	pj(csls.€y@folit		
HEYGATHE E	Alonilin	i i ja	ika kamalladako da
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1926	Jul		597.0
1916	Jun	•	562.0
1965	Sep	Agnes	530.7
1978	Jul	Agnes	519.0
1976	Aug	Ellen	516.1
1993	Sep	Dot	497.5
1982	Aug	Dot	491.7
1995	Aug	Helen	480.9
1904	Aug	-	473.2
1974	Oct	Carmen	469.7

However, the dominance of a sub-tropical high pressure belt in the Western North Pacific Ocean in the first half of July and the increasing frequency of strong cold surges from the north in the second half of October may restrict the development of TCs. So it is also necessary to define an Active Typhoon Season for the Western North Pacific Ocean. The frequency of occurrence of TCs over the Western North Pacific Ocean for 30 years is shown in each five-day pentad (Appendix 1). With the application of IQR for the 884 cases in the 30-year tropical cyclone study period, it is seen that TCs categorized within this range occur in the period from July 20th to October 12th which can be regarded as the "Active Typhoon Season" (ATS). The Ante-Active Typhoon Season (AATS), from July 1st - 19th, is a short dry spell period while the Post-Active Typhoon Season (PATS), from October $13^{th} - 30^{th}$ is the period under the increasing influence of winter monsoon from the north. Table 6 shows that a total of 472 TCs, or over 77 percent, and 242 typhoons, or nearly 74 percent, occurring in TS are concentrated in the ATS. More significantly, 238 TCs occurring within the area of Hong Kong's responsibility (AoR) were in the ATS compared to 51 and 35 TCs in the first half of July and the second half of October respectively (Table 7). Although there is only about a 50 percent probability that TCs would move sufficiently close to Hong Kong to necessitate the hoisting of typhoon warning signals (TWS) when they have either entered or formed within Hong Kong's area of responsibility in TS, it is notable that over 72 percent of these were in ATS (Table 8).

Table 6. The distribution of tropical storms and typhoons in Typhoon Season (AATS+ATS+PATS) and Active Typhoon Season (ATS). The ratio of tropical cyclones occurring in the ATS to those for the whole TS is also shown

		umber of TC S(July 1-Oct		Total No. of TCs in TS	% of TCs in ATS
	AATS	ATS	PATS		
Typhoon Severe	37	242	50	329	73.6%
Tropical Storm Tropical	18	79	9	106	74.5%
Storm Tropical	9	90	7	106	84.9%
Depression	5	61	3	69	88.4%
Total	69	472	69	610	77.4%

When the proportional lengths of these 3 sub-seasons are taken into account, there are still over 8 percent more TCs forming over the Western North Pacific Ocean in the ATS as here defined. More importantly, the 16 percent and 19 percent increases of

Table 7. The distribution of tropical storms and typhoons occurring within the Area of Hong Kong's responsibility (AoR) in Typhoon Season (AATS+ATS+PATS) and Active Typhoon Season (ATS). The ratio of tropical cyclones within the AoR in the ATS to those within the AoR for the whole TS is also shown

		of TCs withi July 1-Oct 3		Total No. of TCs within	% of TCs within AoR
	AATS	ATS	PATS	AoR in TS	in ATS
Typhoon Severe	25	109	23	157	69.4%
Tropical Storm Tropical	14	52	4	70	74.3%
Storm Tropical	8	44	6	58	75.9%
Depression	4	33	2	39	84.6%
Total	51	238	35	324	73.5%

Table 8. The distribution of tropical storms and typhoons leading to the hoisting of a Typhoon Warning Signal (TWS) in Typhoon Season (AATS+ATS+PATS) and Active Typhoon Season (ATS). The ratio of tropical cyclones leading to the hoisting of a TWS in the ATS to those leading to the hoisting of a TWS for the whole TS is also shown

		f TCs leading July 1-Oct	•	Total No. of TCs leading to	% of TCs leading to TWS
	AATS	ATS	PATS	TWS in TS	in ATS
Typhoon Severe	16	61	11	88	69.3%
Tropical Storm Tropical	8	32	2	42	76.2%
Storm Tropical	4	17	1	22	77.3%
Depression	2	8	0	10	80.0%
Total	30	118	14	324	72.8%

the occurrence of tropical storms and tropical depressions over the Western North Pacific Ocean reflect the fact that the ATS is clearly a more favourable time period for tropical cyclogenesis. The frequencies of tropical depressions and tropical storms (but not typhoons) occurring in the AoR and leading to the hoisting of TWS are also proportionally higher in the ATS than those in the AATS and PATS.

Mechanisms for Variations in Tropical Cyclone Activity during Typhoon Season

Tropical cyclones affecting Hong Kong either originate or come from the Western North Pacific Ocean or the South China Sea. The occurrence of a substantial number of TCs in these two areas within the TS is directly attributable to favourable weather patterns for tropical cyclogenesis and their movements which are governed by the environmental circulation field.

a. Synoptic weather patterns affecting tropical cyclogenesis in the Western North Pacific Ocean and South China Sea.

The climatological requirements for tropical cyclogenesis documented by Gray (1968, 1975, 1978) and Anthes (1982) include dynamic conditions: the presence of low-level relative vorticity $(\zeta \gamma)$, sufficient Coriolis parameter (f), vertical shear of the horizontal wind, and upper-level ventilation; and thermodynamic conditions: sufficient ocean thermal energy or sea surface temperature above 26.5°C to a depth of 60m (E), a degree of convective instability $(\frac{\partial \theta_e}{\partial p})$, and adequate middle tropospheric relative

humidity (\overline{RH}). These are all suitable for tropical cyclogenesis in the TS in the Western North Pacific Ocean basin. However, the non-stationary dynamic field of the environment or the actual surrounding atmospheric circulation still determines if a warm core tropical storm can intensify from a cold core incipient disturbance (Tuleya, 1988).

Ante-Active Typhoon Season - Dry Spell Period (1 July-19 July)

July 1st is the start of the Typhoon Season. The sea surface temperature of the Western North Pacific Ocean and the South China Sea in July is on average at about 28°C or 29°C (China Meteorological Bureau National Meteorological Centre, 1995). Theoretically, there should be many tropical cyclones generated in this month, but the dynamical atmospheric circulation restricts the tropical cyclogenesis. In the upper atmosphere as the Tibetan high develops, the polar jet shifts northward over China. With the Okhotsk high weakening, the polar front also weakens and shifts north, the Yangtze Valley Mei-yū ends and southern China experiences a dry spell (Ramage, 1971) in the first half of July. Indeed the downward flow associated with the subtropical high (STHP) retards cumulus convection and the optimum latitude for a tropical depression to intensify to typhoon strength never lies to the north of the ridge line of the STHP (Zhang and Lin, 1992). The mean position of the subtropical high is

still at low latitudes in early July, explaining why only 10 percent of TCs in the TS are recorded during this period. When it arrives at the northernmost position (27.8°N) in East Asia (110°-125°E) in August (Bao, 1987) it provides favourable conditions for typhoon formation such as a broad easterly belt with fair weather, high sea level and air temperatures and high water vapour content in the air. The general relationship between the occurrence of TCs and the strength and position of STHP is that more TCs occur if the ridge axis is weak and at more northerly latitudes while fewer TCs are recorded with a stronger STHP ridge axis dominating the lower latitudes.

Active Typhoon Season (20 July-12 October)

Tropical cyclogenesis is most active in this period under favourable environmental conditions. The initial disturbances most frequently (about 80 percent) form in the monsoon trough, and the remainder form from easterly waves (about 10 percent), in conjunction with upper cold lows, or in the baroclinic zones of intruding midlatitude troughs (Elsberry, 1995).

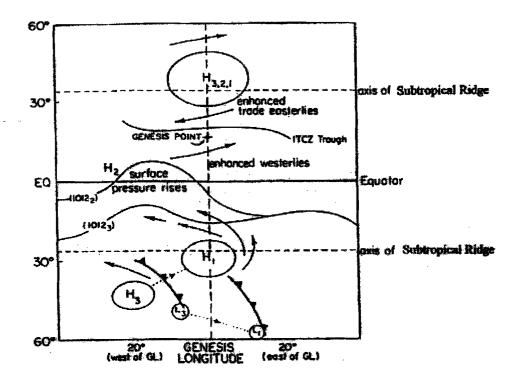
(i) Intertropical Convergence Zone (ITCZ)

Tropical storms form in close proximity to the ITCZ. Love (1982) explains that the cold high of the winter hemisphere baroclinic system initiates an equatorward surge of cold air, and so pressure rises from the midlatitude subtropical ridge to the equatorial regions. If the monsoon westerly flow is accelerated while the upper easterly flow is also intensified in the summer hemisphere, favourable conditions occur for tropical cyclogenesis in the Western North Pacific Ocean (Figure 5).

Wang and Leftwich (1984) have also discovered that more TCs can form when there is an intense low-level cross - equatorial current at 110°E (*i.e.* South China Sea near Hong Kong) during the northern summer while the formation of fewer TCs is related to a less intense current. The peak strength of this southern monsoon current occurs in August. This finding is supported by Cheng (1989 a,b) whose analysis confirmed that a strong, large-scale trade wind surge or a strong southwest cross-equatorial monsoon surge can be the catalyst for the increase and concentration of cyclonic circulation in the vicinity of the pre-cyclone cloud cluster. This stronger mid- to low-level cyclonic circulation distinguishes potential genesis cloud clusters from non-genesis cloud clusters as McBride (1981 a,b) McBride and Zehr (1981), and Cheng (1989 a,b) observed that there are no obvious differences in vertical motion, cumulus convection, and moisture and energy budgets for developing and non-developing systems.

The large inward eddy vorticity flux allows a tropical disturbance to increase its mean vorticity without increasing its transverse circulation and hence the cloud cluster becomes better organized. It is well known that typhoons are not formed by the small and disorganized clouds from trade winds of an inactive ITCZ while large cloud clusters in the active ITCZ can much more easily be transformed into a tropical storm (Xu and Gu, 1978). Typhoon Ora (7504) is a good example of how a typhoon is generated from a disturbance in the ITCZ (see Dong and Zhang, 1979; Zheng et al., 1981).

Figure 5. Idealized diagram showing the positions of important synoptic features 3 days and 1 day before Northern Hemisphere tropical cyclogenesis (Source: Love, 1982)



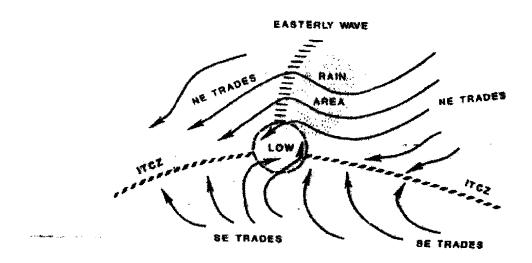
(ii) Easterly Waves

The thermal structure of easterly waves is documented by Cho and Jenkins (1987). These can be an initial disturbance or can act as a mechanism to trigger the development of another disturbance for tropical cyclogenesis (Figure 6). When an easterly wave moves over a tropical depression, the enhanced upper level divergence increases the lower level convergence and then more latent heat is released to cover the loss of sensible heat on upward movement, so that a cold core disturbance becomes a warm core tropical cyclone (Riehl, 1945). Kurihara and Kawase (1985) through the time integration of a simple numerical model found Conditional Instability of the Second Kind (CISK) type heating effect is extremely important in the formation of a tropical depression in the trough region of an easterly wave.

(iii) Cut-off Lows/ Upper Cold Vortexes

A strong cold vortex in the upper troposphere stretching to lower layers in the central Pacific Ocean in summer facilitates the development of easterly waves and depressions that may later intensify into a tropical storm. An example of the role of the Southwest China vortex in typhoon formation (74814) over the South China Sea under the effect of a specially favourable environmental flow field, in addition to strengthening of upper level anticyclone, on August 14 was given by Bao (1981). (The typhoon was called 74814, as it was never named either by China or United States Weather Bureau) This is a good example showing that the circulation conditions of the development process are sometimes more important than the thermal conditions in tropical cyclogenesis.

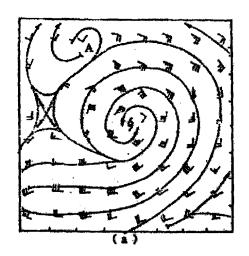
Figure 6. A combination of an easterly wave distribution and the ITCZ may lead to the formation of a tropical depression (modified from Kotsch, 1983)

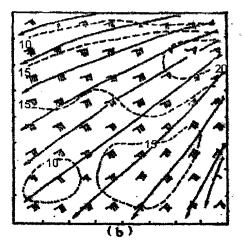


(iv) Baroclinic Disturbance

About 5 percent of all tropical storms form in a baroclinic environment. Extra-tropical wave cyclogenesis along a decaying frontal zone can culminate in tropical cyclogenesis. Bao (1987) states that a strong baroclinic frontal zone can promote typhoon regeneration. Most of these instances happen when a typhoon lands and moves northward, or recurves over the sea. After regeneration, it usually transforms into an extratropical cyclone.

Figure 7. (a) Lower level (~850 hPa) and (b) upper level (~200 hPa) streamlines and isotachs for typhoons in the South China Sea (Source: Liang, 1991)





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The environmental conditions for tropical cyclogenesis in the South China Sea are basically analogous to those in the Western North Pacific Ocean. However the dynamic field of TCs in the former area is different in its characteristic of easterly divergent flow at upper levels, rather than the anticyclonic circulation of those in the Western North Pacific Ocean (Figure 7). With low level convergence from the southwest monsoon, much water vapour is brought upward and latent heat released through its northeasterly jet stream. This unique characteristic of TCs in the South China Sea facilitates the development of a low pressure but its strong vertical wind shear can explain why there are so few severe tropical storms formed in this area (Liang, 1991).

Post-Active Typhoon Season (13-30 October)

Generally the presence of weak cold air favours tropical cyclogenesis. The cold air flowing to the South China Sea is mainly brought by a frontal trough, by anticyclonic flow from mainland China, or as cold northerly air from the western flank of TCs recurving to the east of Taiwan. This cold air not only makes moist unstable air release latent heat which accelerates tropical storm upward movement, but also provides a baroclinic environment and brings convective cloud bands which in turn will enhance low level convergence and increase geopotential buoyancy. Based on the results of hydrodynamic model experiments in the laboratory, weak cold air is regarded to be a "trigger mechanism" but never enhances the intensity of a TC; while moderate cold air can create a so-called "no-eye typhoon"; and strong cold air weakens or even dissipates a typhoon (Yao and Wei, 1985).

Wei and others (1965) have investigated the influence of cold air upon tropical cyclogenesis in the South China Sea. The upper tropospheric easterlies prevailing south of the Tibetan Plateau rapidly retreat southward in mid-October as strong subtropical westerlies penetrate there with a jet stream over the Plateau. At the same time the subtropical high also retreats southward out of the Chinese mainland. Since the polar anticyclone over Siberia is intensifying cool surges of the northeast monsoon reach northern Indochina and southern China by mid-October and are cooling the surface of the central South China Sea by the end of the month (Ramage, 1971). This is the so-called "sudden change in October" (Bao, 1987) and explains why the ATS usually ends abruptly in the middle of October.

b. Environmental Circulation Governing Tropical Cyclone Movement

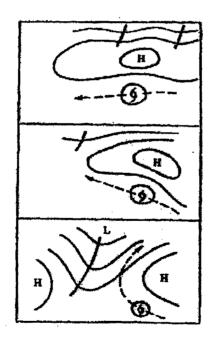
While short-lived TCs tend to dissipate over the ocean after their formation, some developing TCs recurve in the Central Pacific Ocean and make landfall over Korea or Japan or finally become extratropical cyclones in middle latitudes. Other TCs take on a westerly direction and make landfall over Vietnam. Finally, yet others pass through the Philippines and move west or west-northwesterly across the South China Sea. These often cause great damage in Guanxi, Guangdong, Taiwan and Hong Kong. Hence, the tropical cyclone activity affecting Hong Kong not only depends on how many TCs are formed over the Western North Pacific and the South China Sea but also on the environmental flow patterns governing the tropical cyclone movement.

The movements of TCs depend on the combined effect of the β -effect and the environmental steering flow with the latter force, generally, explaining more than 80 percent of the motion. They are chiefly steered by the upper flow between 500hPa and 200hPa, which is dependent on the synoptic pressure fields (Domrös and Peng, 1988; Zhang and Lin, 1992) although Chan and Gray (1982) consider that wind data at the mid-tropsphere (700, 600 and 500 hPa) correlates best with both the direction and speed of cyclone movement. When the external force is strong and steady, the typhoon track is normal and stable. Otherwise, the track tends to be more complex and anomalous. The subtropical anticyclone, westerly troughs, blocking highs & cut-off lows, and the circulation of another tropical cyclone nearby are believed to be the factors that most affect the atmospheric flow patterns that influence tropical cyclone motion.

(i) Subtropical High Pressure (STHP)

Tropical Cyclones at the southern flank of an elongated and strong 500hPa STHP belt tend to move quite stably in a westerly direction. When the STHP ridge is to the east of a TC and stretching southward, TCs may take on a more northwesterly direction. When the STHP weakens and retreats eastward, TCs to the southwest of the STHP tend to recurve across the STHP ridge over the water in Central Pacific Ocean or make landfall at Southern China and move out again to East China Sea and then to Korea and Japan (Yu et al., 1986) (Figure 8). If a typhoon is further from the anticyclone or between two anticyclones, it will stagnate, loop, or move more erratically (Bao, 1987).

Figure 8. Generalized relationships between the subtropical anticyclone and the movement of typhoons (Source: Yu et al., 1986)



(ii) Westerly Waves

When the westerly trough weakens and the STHP intensifies, tropical cyclones maintain a west-northwesterly direction along with the enhanced easterly flow at the southern flank of the STHP belt. However, when the westerly trough develops eastward and stretches down to low latitudes, this forces the Pacific STHP to retreat eastward, so that TCs to the east of the westerly trough tend to recurve northward.

(iii) ITCZ and Easterly Waves

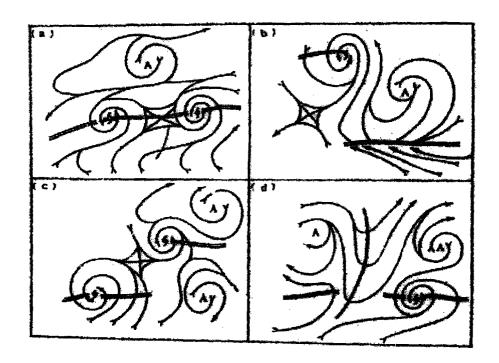
The role of the ITCZ and easterly waves appears to be more important in tropical cyclogenesis, rather than in influencing the tracks of TCs. Even if the existence of these two tropical weather systems really does affect the movement of TCs, it is more attributable to the influence of the STHP belt and the westerly wave. For example, Chen (1965) tried to explain the tracks of typhoons in terms of different circulation settings of the ITCZ. He found that westerly-moving TCs are more closely linked to a zonal ITCZ while northerly- or northwesterly-moving TCs are related to the collapse of the ITCZ (Figure 9). Yu and others (1986) have pointed out that the direction in which a TC moves is to a certain extent dependent on its location relative to the easterly wave (Figure 10). However, whether the ITCZ is a continuous or a collapsing type is more or less dependent on the strength and the changes of the STHP and the westerly wave. Easterly waves, on the other hand, are only perturbations in the northeast trades on the south flank of the Subtropical High Pressure belt. Moreover under a steady westerly wave and a strong and westward expanding STHP, easterly waves only vibrate the TC a little but basically do not materially affect the typhoon environment. However, that vibration may start changing the direction of the movement of the TC which has an impact for the rest of its life (Yu et al., 1986).

(iv) Blocking Highs and Cut-off Lows

When there is a blocking high in East Asia between 50-70°N, 110-150°E and an eastward moving cut-off low in middle latitudes, cold air moving from high latitudes tends to fill up and so weaken the STHP. TCs can then move northerly and turn to a northeasterly direction after crossing the ridge in a weak environmental flow. However, in most cases, a blocking high in East Asia at middle and high latitudes collapses along Japan Sea and moves into juxtaposition to the Pacific STHP, which is then intensified and stretched westward. TCs at the southern flank of STHP would then move in a westerly or west- northwesterly direction assisted by the enhanced easterly flow.

An upper level cold vortex cut-off from the westerly trough in middle latitudes will affect the direction and speed of TC movement. When cold air moves towards South China and the northern part of the South China Sea in autumn, it generates a low level east-northeasterly wind field so that TCs tend to move westward.

Figure 9. Models of ITCZ circulation settings affecting the track of typhoons (a) persistent type; (b) south-downward collapsing type; (c) north-upward collapsing type; east-west collapsing type (Source: Chen, 1965)

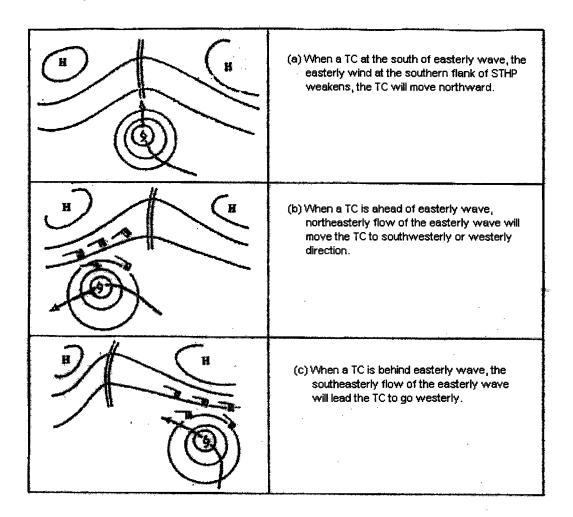


(v) Binary Typhoons

When two tropical cyclones co-exist together near each other, their flows will interact to make them stagnate, loop, rotate, recurve abruptly or even mix together. The distance between the two vortices largely determines whether they are under this so-called Fujiwhara effect. Brand (1970) pointed that the angular velocity of rotation increases rapidly with decreasing distance. No mutual attraction has been found between barotropic vortices in any experiments when initial separation distances are equal to or greater than 300km (Chang 1983).

Figure 11 shows the general directions of tropical storms and typhoons in different seasons over the Western North Pacific. Most of the tropical cyclones tend to move into the South China Sea and make landfall at Vietnam or dissipate over the water (A) at the quiet stage of the year. The characteristics of TC movement are low latitude recurving points, normally not exceeding 25°N, and distant turning points (to the east of 120°E) (B). Thus, there is little impact on the South China coast. More TCs adopt a northwesterly track to affect the south of China and the north of Vietnam (C) for the next 3 months. After entering the South China Sea, some tropical storms recurve and pass along with the westerlies to reach the East China Sea (D) while some recurve to the east of the Philippines (E). It is usually the former of these two groups which affect Hong Kong.

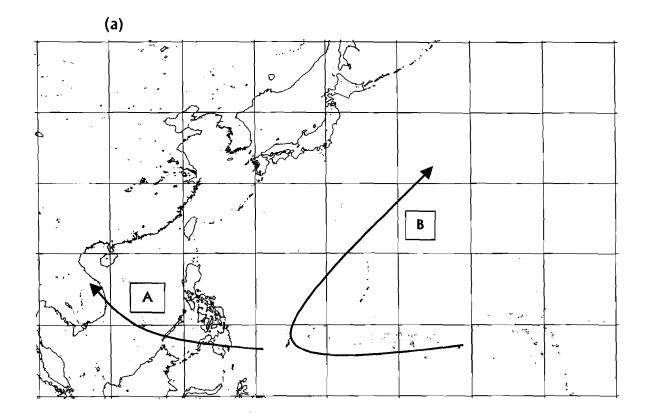
Figure 10. Easterly wave effects on the movement of typhoons (Source: Yu et al., 1986)

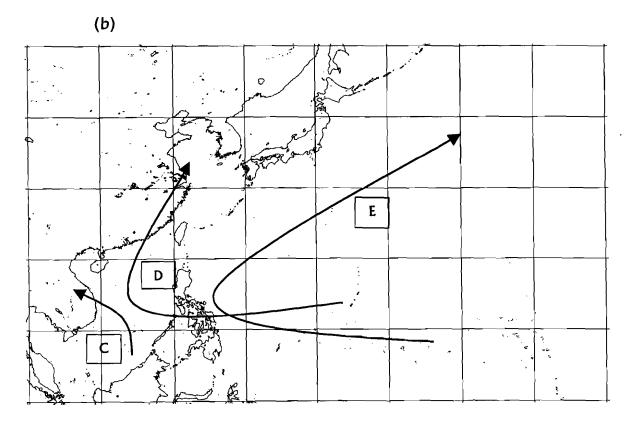


Three major tracks are discerned in the Typhoon Season. Westerly-moving TCs at about 15°-20° N enter the South China Sea and make landfall in northern Vietnam, Guangxi, Guangdong and Hainan Island or dissipate over the north part of the South China Sea (F). Northwesterly- or west northwesterly- moving TCs passing through the Philippines make landfall at Taiwan, Hong Kong, Fuzhou, Shanghai or even Korea (G). These occur most frequently in the ATS and pose the greatest risk to Hong Kong. Ramage (1971) pointed out that the upper-tropospheric easterlies "steer" many typhoons toward Southern China, so typhoon frequency and rainfall sharply increase after 10th July. Finally, some northerly-moving TCs recurve at quite high latitudes (about 25°N-30°N) to the east of 125°E (H).

In the post-active season, some TCs move westerly at about 10°N and make landfall over Guangxi, Hainan, Vietnam or dissipate over the South China Sea (I) while others to the east of the Philippines (J) recurve and take a northeasterly direction at about south of 20°N crossing the Ryukyu Islands, moving into the waters of the Japan Sea and finally dissipate or become extratropical cyclones in middle latitudes. The former group can pose a hazard to Hong Kong in the PATS.

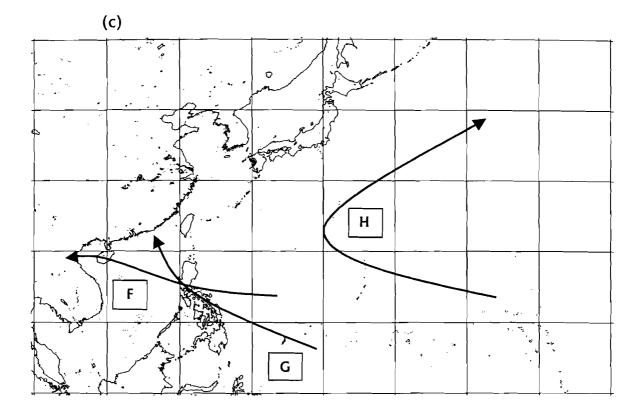
Figure 11a. General directions of tropical cyclones in different seasons over the Western North Pacific Ocean (a) January to March; (b) April to June





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Figure 11b. General directions of tropical cyclones in different seasons over the Western North Pacific Ocean (c) July to October; (b) November to December



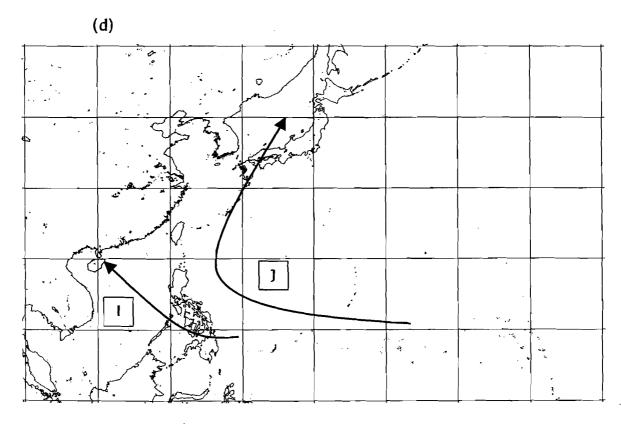


Table 9. Casualties and damage caused by tropical cyclones in Hong Kong: 1967-1996 (Source: Hong Kong Observatory, 1997)

Year	Date	Name of tropical cyclone	Ocean- going vessels in trouble	Small craft sunk or wrecked	Small craft damaged	Persons dead	Persons missing	Persons injured
4007		0 7 0 1/2						
1967	19 –22 Aug	S.T.S. Kate	3	1	0	0	_0	3
1968 1969	17 - 22 Aug 22 - 29 Jul	T. Shirley T. Viola	0	3	<u>3</u>	0	0	4
1970	1 - 3 Aug	T.D.	0	0		0 2 ⁺	0	0
1970	8 - 14 Sep	T. Georgia	2	0		0	0	0
1971	15 - 18 Jun	T. Freda	8	- 0	Ō	2	0	30
	**************************************	- I Rose	734	en 2303		110	- 5	286
1972	4 - 9 Nov	T. Pamela	3	0	0	1	0	8
1973	14 - 20 Jul	T. Dot	14			1	0	38
1974	7 - 14 Jun	T. Dinah	1	-	•	0	0	0
	18 - 22 Jul	T. Ivy	2	•	*	0	0	Ō
	15 - 19 Oct	T. Carmen	5	•	•	1	0	0
	21 - 27 Oct	T. Della	2	•	*	_0	0	0
1975	10 - 14 Aug	T.D	3	1	•	_2	1	0
	9 - 14 Oct	T. Elsie	7	2	11	0	0	46
	16 - 23 Oct	S.T.S. Flossie	11	•	•	0	0	0
1976	22 Jun - 4 Jul	T. Ruby	0	0	0	3	2	2
	21 - 26 Jul	S.T.S. Violet	_0	0	0	_2	1	1
	5 - 6 Aug	S.T.S. Clara	0	0	0	0	0	4
	21 - 24 Aug	T.S. Ellen	0	4	7	27	3	65
	15 - 21 Sep	T. Iris	6	0	1	0	0	27
1977	4 - 6 Jul	T.D.	0	_0		0	0	2
	3 - 5 Sep	T.S. Carla	1	0	0	0	0	1
4070	22 - 25 Sep	S.T.S. Freda	2	0	0	1	0	37
1978	24 - 30 Jul	S.T.S. Agnes	0	25	42	3	0	134
	9 - 12 Aug 23 - 28 Aug	T.S. Bonnie S.T.S. Elaine	8	5	8	0	0	51
	_23 - 26 Aug _22 - 26 Sep	S.T.S. Kit	0	1	0	0	7	0
	7 - 16 Oct	S.T.S. Nina	0	0	0	0	- ′	2
<u> </u>	17 - 29 Oct	T. Rita	f j	5	0		0	3
1979	1 - 6 Jul	T. Ellis	i o	2	Ö	0	0	ō
1075	26 - 30 Jul	T.S. Gordon	0	2	0	0	0	0
	Self in the Article	se allehicoes e	2/50 (6)	1.67/	C 46/207 C			2(5)
	6 - 9 Aug	T.D.	0	3	0	0	О	0
	16 - 24 Sep	S.T.S. Mac	2	12	0	1	0	67
1980	5 - 12 Jul	S.T.S. Ida	1	0	Ō	0	0	0
	18 - 23 Jul	T. Joe	4	0	1	2	1	59
	20 - 28 Jul	T. Kim	0	2	1	0	0	0
	29 Oct - 2 Nov	T.S. Cary	0	0	2	0	_ 0	0
1981	3 – 7 <u>Jul</u>	S.T.S. Lynn	0	0	3	0	0	32
1982	27 Jun - 2 Jul	T.S. Tess	0	1	0	0	0	16
	22 - 30 Jul	T. Andy	0	0	1	0	0	0
	5 - 16 sep	T. Irving	0	0	2	0	0	0
1983	12 - 19 Jul	T. Vera	0	1	0	0	0	0
	29 Aug 29 Sep	** *I*Elen* *			225+ 4			60
	10 - 14 Oct	T. Joe	2	0	3	0	0	58
1004	20 - 26 Oct	S.T.S. Lex	0	0	1 1			0
1984	27 Aug - 7 Sep	T. ike T. Hal	0	4	0 2	0	0	13
1985	19 - 25 Jun			1 1	3	2		12
1	1 7 500	T Toes				, 4	, ,	
	1 - 7 Sep	T. Tess	6		n	O	0	1
1986	13 - 22 Oct	T. Dot	0	0	0	0	0	26
1986	13 - 22 Oct 3 - 12 Jul	T. Dot T. Peggy	3		3	0 1	0	26
1986	13 - 22 Oct 3 - 12 Jul 9 - 12 Aug	T. Dot T. Peggy T.D.	0 3 0	0 0 1	0 3 5	1 0		26 3
1986	13 - 22 Oct 3 - 12 Jul 9 - 12 Aug 18 Aug - 6 Sep	T. Dot T. Peggy	3	0 0 1 3	3	0 1	0	26
	13 - 22 Oct 3 - 12 Jul 9 - 12 Aug 18 Aug - 6 Sep 11 - 19 Oct	T. Dot T. Peggy T.D. T. Wayne T.Ellen	0 3 0 0	0 0 1	0 3 5 0	0 1 0 3	0 0 1	26 3 15 ⁺
1986 1987 1988	13 - 22 Oct 3 - 12 Jul 9 - 12 Aug 18 Aug - 6 Sep 11 - 19 Oct 16 - 27 Oct	T. Dot T. Peggy T.D. T. Wayne T.Ellen T. Lynn	0 3 0 0	0 0 1 3 2	0 3 5 0	0 1 0 3 0	0 0 1 0	26 3 15 [†] 4
1987	13 - 22 Oct 3 - 12 Jul 9 - 12 Aug 18 Aug - 6 Sep 11 - 19 Oct 16 - 27 Oct 14 - 20 Jul	T. Dot T. Peggy T.D. T. Wayne T.Ellen	0 3 0 0 1 0 1	0 0 1 3 2 0 2	0 3 5 0 1	0 1 0 3 0	0 0 1 0 0 1	26 3 15 [†] 4
1987	13 - 22 Oct 3 - 12 Jul 9 - 12 Aug 18 Aug - 6 Sep 11 - 19 Oct 16 - 27 Oct	T. Dot T. Peggy T.D. T. Wayne T.Ellen T. Lynn T. Warren	0 3 0 0 1 0	0 0 1 3 2 0	0 3 5 0 1	0 1 0 3 0 0	0 0 1 0 0	26 3 15 [†] 4 1

continued Table 9. (Source: Hong Kong Observatory, 1997)

Year	Date	Name of tropical cyclone	Ocean- going vessels in trouble	Small craft sunk or wrecked	Small craft damaged	Persons dead	Persons missing	Persons injured
1989	16 - 21 May	T. Brenda	0	3	5	6	1	119
1303	11 - 19 Jul	T. Gordon	1	 	8	2	-	31
	8 - 14 Oct	T. Dan	1	ŏ	1 -	ō	0	0
1990	15 - 19 May	T. Marian	Ö	o -	1	0	0	0
1988	14 - 20 Jul	T. Warren	1	2	<u>i</u>	o -	1	12
1555	15 - 19 Jun	S.T.S. Nathan	1	- 5 -	2	5	1	1
	21 - 30 Jun	T. Percy	Ö	Ö	- 0	1	<u> </u>	0
	27 - 31 Jul	S.T.S. Tasha	0	1	0	ó	0	1
	25 - 30 Aug	T. Becky	0	Ö	o o	0	1 -	<u> </u>
	10 - 20 Sep	T. Ed	0	ō	0	Ö	Ö	1
1991	15 - 20 Jul	T. Amy	1	0 -	2	0	0	1
	20 - 24 Jul	S.T.S. Brenda	1	1	13	0	0	17
	13 - 18 Aug	T. Fred	0	1	ō	ō	0	0
1992	9 - 14 Jul	T. Eli	0	Ó	1	0	Ö	23
	17 - 18 Jul	T.S. Faye	1	0	3	2	0	24
	19 - 23 Jul	S.T.S. Gary	2	0	0	0	0	18
1993	21 - 28 Jun	T. Koryn	0	ō	2	0	0	183
	16 - 21 Aug	T. Tasha	0	0	7	0	0	35
	9 - 14 Sep	T. Abe	0	0	0	1	0	0
	15 - 17 Sep	S.T.S. Becky	0	0	10	1	0	130
	23 - 27 Sep	T. Dot	0	1	0	0	1	48
	28 Oct - 5 Nov	T. Ira	0	1	0	2	0	30
1994	23 - 25 Jun	T.S. Sharon	0	1	1	0	0	5
	25 - 29 Aug	S.T.S. Harry	0	0	2	1	0	2
1995	7 - 12 Aug	S.T.S. Helen	0	0	0	3	0	35
	25 Aug - 1 Sep	T. Kent	0	0	0	0	0	5
	28 Sep - 4 Oct	T.Sibyl	0	0	0	0	0	14
1996	5 - 10 Sep	T. Sally	0	0	0	2	0	4
	18 - 23 Sep	S.T.S. Willie	0	0	0	0	1	0

N.B. Based on information supplied by relevant government Departments and public utility companies. Damage reports in the local press were also examined and collated. Data unavailable

Struck by lightning

Table 10. Comparison of the intensity of three major typhoons which affected Hong Kong (data derived from Hong Kong Observatory, 1983, 1997)

Name of typhoon	Date	Nearest approach to HK Observatory (km)		Minimum mean sea- level pressure (hPa)		Maximum 60-min mean wind in points and km/h (HKO)		Maximum gust peak speed in km/h with direction in points (HKO)		Rainfall in mm (HKO)		Storm surge in metres	
_												1.0	
Rose	17-Aug-71	wsw	20_	984.5	982.8	SE	103_	ESE	<u> 224</u>	340.9	(16-17 Aug)	1.2	
		1										3.2	
Hope	2-Aug-79	NNW	10	961.8	961.6	w	75	w	175	287.4	(2-4 Aug)	1.5	
												1.7	
Ellen	9-Sep-83	sw	45	983.9	983.1	E	92	<u>E</u>	185	231.8	(8-10 Sep)	1.8	

All in all, the movement of TCs can be grouped into 4 categories: westerly, northwesterly, recurving and unusual tracks. The movement of TCs in the South China Sea is more or less analogous to those in the Western North Pacific except TCs in the South China Sea are more capricious and short-lived. The sudden change in direction of South China Sea typhoons to the west or to the east is also related to the approaches of cold air surges in the post-active typhoon season (Jiao, 1987).

Typhoon Disasters in the ActiveTyphoon Season

Gusty winds, heavy rainfall and severe storm surge, the concomitants of typhoons cause fatal disasters - flooding and landslides -to the people living in its path. It should be noted that specification of the active typhoon season (20th July - 12th October) is especially important in evaluating typhoon hazard. This is because the higher the frequency of TCs occurring in the Western North Pacific Ocean and the South China Sea area and the higher probability of more TCs moving closer to Hong Kong, the higher the risk of damage being caused in Hong Kong by such encounters. From the meteorological records, it is clear that most typhoons with high intensity (e.g. T. Rose, 10-17 August 1971; T. Hope, 28 July-3 August 1979; and T. Ellen, 29 August-9 September 1983) which caused the greatest hazards in Hong Kong all happened in the Active Typhoon Season (Table 9). Table 10 shows a comparison of the intensity of these three typhoons and their close passages over Hong Kong. Great destruction resulted after each incident.

The typhoon warning signal No. 10 is usually hoisted when a typhoon reaches the maximum wind speed of 118 km/h or above and it is in close proximity to Hong Kong. There have been 5 typhoons requiring the hoisting of the typhoon signal No.10 during the 30 year period from 1967 to 1996 and 4 of them (Shirley, 1968; Rose, 1971; Hope, 1979; and Ellen, 1983) occurred within the ATS. The eye of Typhoon Shirley passed directly over Hong Kong between 7.00 p.m. and 9.00 p.m. on 21 August 1968. This is not common as there have been only three other occasions, when this has happened, 23 November 1939, 19 May 1961, and 2 August 1997. The fifth storm, Elsie, also became a typhoon in the ATS (on 11 October 1975) although it did not finally reach Hong Kong until the 14th October, just outside the ATS.

Concluding Remarks

The Typhoon Season in Hong Kong is confirmed to be July-October while the period from 20th July - 12th October has been identified as the Active Typhoon Season for Hong Kong. This new definition is based upon the observation of the frequency of tropical storms and typhoons and can be justified by the impacts of different weather patterns on the environmental flows affecting tropical cyclones during the AATS, ATS, and PATS.

This definition of Hong Kong's Active Typhoon Season is believed to be important because:

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- 1) the knowledge of the time of the TS and ATS by the general populace will enhance their awareness of increased risk and of the precautionary measures which need to be taken to minimize it;
- 2) since the catastrophic potential of typhoons in Hong Kong may be expected to be highest in the ATS, more planning and action can be undertaken by the relevant governmental departments during this period to mitigate the hazards posed.

For the above reasons the author's suggest that an official Typhoon Season and Active Typhoon Season should be adopted, using the dates determined herein.

It should be noted, however, that these definitions of TS and ATS in the Western North Pacific Ocean are based on a statistical climatological approach and so only act as a guideline. It does not mean, for example, that no typhoons will threaten Hong Kong before or after the Typhoon Season. For example, Typhoon Koryn (9302), (21 - 28 June 1993), damaged 2 small craft and injured a total of 183 persons. Typhoon Pamela, (4 - 9 November 1972) killed one woman, injured 8 persons and made 3 ocean-going vessels run aground. We should also not underestimate the impacts on Hong Kong brought by some severe typhoons which have occurred in the AATS & PATS defined herein. For instance, Tropical Storm Gordon (8908), (11-19 July 1989) and Typhoon Ira (9323), (28 Oct. - 5 Nov. 1993) caused great productivity loss (personal injury, economic activity, public services) and property loss (buildings and civil engineering works; utilities and infrastructure) in Hong Kong (see Table 11). Even when no tropical cyclone warning signals are hoisted the interaction between the passage of a typhoon such as Nina (28 November 1987) and an unusually intense outbreak of cold polar air across the land mass of eastern Asia can generate gales which pose a hazard to Hong Kong.

An especially serious situation can occur when TCs from the South China Sea affect Hong Kong without much warning of their arrival due to the close proximity of their formation and intensification. For example, a tropical disturbance that drifted westwards across the northern part of the South China Sea without significant intensification on 16 July 1992, rapidly became Tropical Storm Faye about 110 km south-southwest of Hong Kong on the evening of 17 July. It made landfall on 18 July about 50 km northwest of the Hong Kong Observatory and then dissipated over eastern Guangdong. As a result, two people were killed, 24 injured; 152 cases of flooding were reported, and 40 cases of landslide caused in the AATS.

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Appendix 1. The frequency of occurrence of tropical cyclones over the Western North Pacific Ocean for the period from 1967-1996 in each pentad

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Department of Geography, The University of Hong Kong, Pokfulam Road, Hong Kong (email: billkyle@hkucc.hku.hk)

1998 Tropical Cyclone Summary for the Western North Pacific Ocean (west of 180 degrees)

Information employed in the compilation of this section is derived from warnings and other published materials issued by: U.S. National Hurricane Center, Mlami; U.S. Central Pacific Hurricane Center, Hawaii; U.S. Naval Western Oceanography Center, Hawaii; U.S. Joint Typhoon Warning Center, Guam; Japanese Meteorological Agency, Tokyo; Philippine Meteorological Service, Manila; and Hong Kong Observatory.

The symbols *, **, ***, ****, and ***** next to a storm show the highest Tropical Cyclone Signal (#1, #3, #8, #9, and #10 respectively) to be hoisted in Hong Kong.

Keywords: Tropical Cyclone, Tropical Depression, Tropical Storm, Hurricane, Typhoon

The year 1998 was notable for having the latest "start" to the Northwest Pacific Ocean tropical cyclone season since 1959 acording to records maintained by Guam JTWC. Only one tropical cyclone formed during July and was the first Northwest Pacific storm since Super Typhoon Paka in December 1997. The average occurrences of tropical cyclones for July are 4.3 in the Northwest Pacific. By the end of July no typhoons had been recorded in the region, the first typhoon of the 1998 season for this region not occurring until August. According to informal reports from Guam JTWC, this is the latest occurrence on record of the first typhoon. The long-term mean figures for occurrence of tropical cyclones by the end of August are 5.6 (3.4 at typhoon strength) in the Northwest Pacific. Only four systems reached tropical cyclone intensity by the end of August compared to the long-term mean of 14.6. This late season start appears to have been directly related to the "La Niña" event of 1998.

Tropical Depression 01W (9801)

Convection was persistently active over much of Southeast Asia early in July. A trough developed which extended eastwards from Taiwan to about 140° E by 7th. The first 1998 Northwest Pacific Ocean tropical depression, 9801, developed in the Philippine Sea approximately 1100 km east of Luzon that day. It intensified to reach a maximum intensity of 56 km h⁻¹ the following day. The system moved very slowly for the initial

48 hours, but began to accelerate northwestward to about 20 km h⁻¹ on the 9th July. At this time vertical wind shear resulted in the cyclone becoming an exposed low level circulation just before it struck the northern tip of Taiwan around OOZ on 10th July. After landfall, the storm dissipated quickly.

Tropical Storm Nichole (9802)

Tropical Storm Nichole (9802), was the second tropical cyclone and the first named storm to occur in 1998. On the 8th July a broad area of convection stretched from the northern part of the South China Sea and extended eastward over Taiwan to about 140° E. Several lows developed within the trough and one developed into a 46 km h⁻¹ tropical depression early that day. A surge in the southwesterly flow south of the strengthening system south of the Taiwan Strait was followed by its intensification to tropical cyclone intensity the following day as it moved steadily north-northeastward at 11 to 15 km h⁻¹. Due to constricted upper-level outflow to the north, caused by midlevel shear and its proximity to land TS Nichole could only intensify slowly to reach a maximum intensity of 93 km h⁻¹ when in the Taiwan Strait just offshore of the southwest coast of Taiwan. Interaction with land and associated dry air entrainment, together with increasing vertical shear, weakened the system rapidly and Nichole became an exposed low level circulation which moved westward and dissipated over southeastern China near Xiamen on the 12th July.

Tropical Depression 03W (9803)

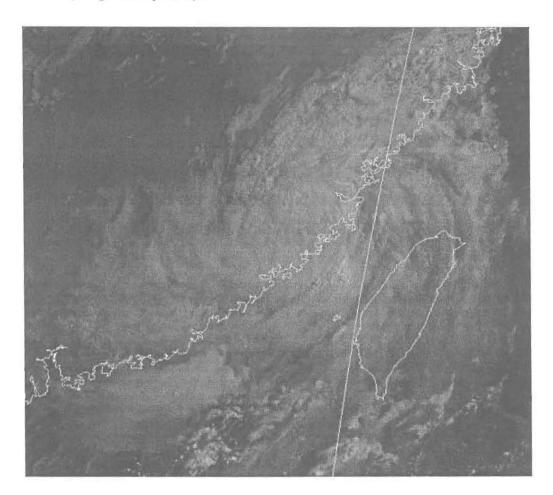
Tropical Depression O3W developed on the eastern periphery of a monsoon gyre about 800 km east-northeast of Iwo Jima on 25th July. The system moved cyclonically around the monsoon gyre and intensified for the first 24 hours. However, as it accelerated to the north under the steering influence of the subtropical ridge to the southeast, it weakened as it encountered increased vertical windshear associated with the mid-latitude westerlies which exposed the low-level circulation centre resulting in dissipation over water.

Typhoon Otto (9804)

On 2nd August a tropical low developed in the Philippine Sea east of Luzon from a persistent mesoscale convective complex to the west of a TUTT system which provided favourable upper divergence over extremely warm sea surface temperatures in excess of 30°C. Since it was south of the mid-level ridge the system began to accelerate and move northwestward toward Taiwan in response to steering flow from the mid-tropospheric subtropical ridge. Intensification to a tropical storm named Otto occurred twelve hours later and minimal typhoon intensity was reached at 1200Z on 3rd August. Otto reached a maximum intensity of 185 km h⁻¹ at 0000Z on 4th August just prior to making landfall on the southeastern coast of Taiwan. The rugged, mountainous terrain of the island temporarily lowered the cyclone's maximum sustained winds to 110 km h⁻¹. The passage of Otto caused four deaths in Taiwan and damage was estimated at NT\$ 25 million. Otto re-intensified to minimal typhoon intensity over the Taiwan

Strait and continued to move northwestward towards the coast of southeastern China. A second landfall occurred near the city of Fuzhou in Fujian at around 2000Z that day. Figure 1 shows a GMS-5 visible image taken 3 hours later. The associated heavy rainfall contributed to widespread flooding in Fujian Province. The system dissipated over land the following day.

Figure 1 GMS-5 Visible Image of Typhoon Otto (9804) taken at 0500Z on 5 August, 1998 shortly after the typhoon made landfall near Fuzhou. (Image from JTWC).

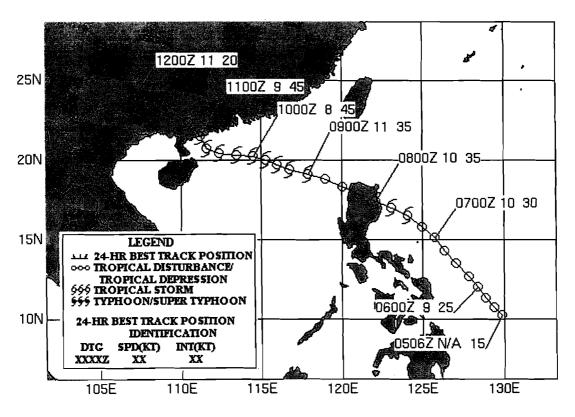


** Tropical Storm Penny (9805)

As Otto crossed the Chinese coast another low formed from a persistent mesoscale convective complex over the very warm Philippine Sea in the same manner as the disturbance which developed into Otto. As the deep convection persisted the disturbance developed into a tropical depression on 6th August near 10° N 130° E. Also, as with Otto, the midtropospheric subtropical ridge was the primary steering influence for the northwestward movement of the system towards Luzon, although the steering had more of an easterly component. During this time the system developed slowly taking some 36 hours to attain tropical storm intensity as Penny around 1200Z on 8th August. Penny adopted a west-northwestward course some 12 hours prior to making landfall over northern Luzon where interaction with the mountainous terrain

temporarily weakened it to a tropical depression again. After 18 hours Penny entered the South China Sea and re-intensified gradually as it headed towards the coast of western Guangdong. In Hong Kong the Tropical Cyclone Standby Signal No. 1 was hoisted at 0635 HKT on 9th August when Penny was about 600 km to the southeast. As Penny came nearer to Hong Kong, easterly winds strengthened gradually and the Strong Wind Signal No. 3 was hoisted at 2245 HKT that night. Maximum hourly winds of over 45 km h⁻¹ were recorded at Cheung Chau and Waglan Island the next morning. The outer rainbands associated with Penny also brought frequent and heavy squally showers. Penny was closest around noon HKT on 10th August when it was about 240 km to the south-southwest and had begun to move on a westerly track towards Hainan Dao. The storm also reached its peak intensity of around 110 km h⁻¹ at this time. With Penny moving away and headed towards western Guangdong all tropical cyclone warning signals were lowered at 1945 HKT on the evening of 10th August. At the Hong Kong Observatory the lowest hourly sea-level pressure of 105.1 kPa was recorded at 1500 HKT on 10th August. Locally, squally showers associated with Penny caused two road accidents in which one old man was killed and another man was injured. Penny made a second landfall in southern China near Zhangjiang at approximately OOZ on 11th August and weakened into a tropical depression. Moving further inland, it degenerated into an area of low pressure that night. The associated heavy rainfall contributed to widespread flooding in southwestern Guangdong. Figure 2 shows a track map of Tropical Storm Penny.

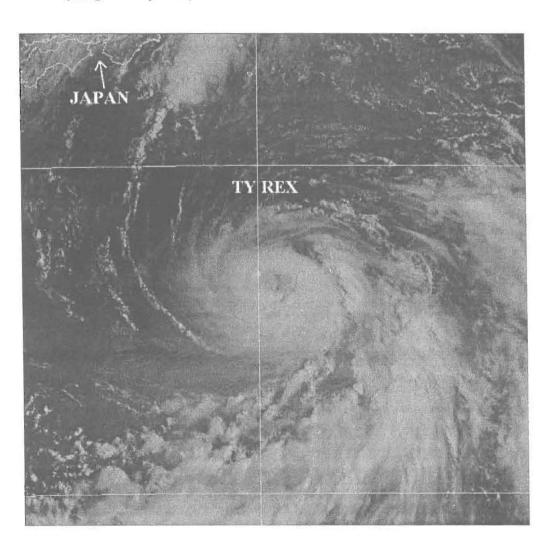




Typhoon Rex (9806)

Rex was a long-lived storm which existed at tropical cyclone intensity or above for two weeks as it meandered across the ocean under the influence of synoptic features present in the mid and upper troposphere. It developed as a low pressure system in a weak monsoon trough which extended from China over the northern Philippine Sea on 22nd August. At first the system drifted slowly but an anticyclone in the mid-level ridge to its southeast soon steered it to the northeast at 15 km h⁻¹ as it steadily intensified over SSTs exceeding 30° C. Rex reached tropical storm strength at 0600Z on 23rd August. The Tropical Upper Tropospheric Trough (TUTT) was very active in August and disturbances within this trough affected the track and intensity of Rex. The first TUTT cell weakened the subtropical ridge to the east, allowing the storm to track eastward from 1200Z on 25th to 0000Z on 27th August. It was during this eastward track that Rex was designated a typhoon with an intensity of 130 km h⁻¹ at 0000Z on 26th August.

Figure 3 GMS-5 Visible Image of Typhoon Rex (9806) taken at 0000Z on 28 August, 1998 shortly before it reached its peak intensity of 210 km h⁻¹. (Image from JTWC).



As the influence of the TUTT cell waned, and with the redevelopment of the mid-level anticyclone to its southeast, Typhoon Rex resumed a more northward course and reached its peak intensity of 210 km h⁻¹ at 0600Z on 28th August. At this time it had a 55 km diameter eye. Figure 3 shows Rex some six hours prior to this time. As Rex moved northward towards the Japanese island of Honshu a second, much deeper TUTT cell began to weaken the subtropical ridge to the east. In response to this, Rex took on a more east-southeastward track around 0600Z on 31st August and weakened to an intensity of 165 km h⁻¹ although it later intensified to 185 km h⁻¹ by 0000Z on 1st September. Rex resumed its northeastward track around 0600Z the next day after the second TUTT cell started to drift westwards. Rex began to weaken due to cooler surface temperatures and increasing vertical windshear as it passed north of 30°N on 3rd September. Around 1200Z that day a third TUTT cell began to interact with Rex causing an eastward track shift for approximately 18 hours before the rapid collapse of the weakest of the three TUTT cells. This allowed Rex to resume its northwestward movement around 1200Z on 4th September. For the next 3 days Rex continued to track northeastward before turning eastward at around 50°N 170°E on 8th September. During this time the TUTT cell persisted within 5 degrees of 25°N 170°E so providing the energy for Rex to persist as a vigorous tropical storm although it had passed north of 40°N. Rex finally transitioned to an extratropical cyclone over the North Pacific Ocean to the southeast of the Kamchatka Peninsula on 9th September. Although Rex never made landfall, its proximity to Honshu, Japan caused heavy flooding and 575 mudslides. The media reported 13 deaths, 30 injuries, and 8,000 homes destroyed.

Tropical Depression 07W (9807)

Tropical Depression 07W developed east of Taiwan on 31st August along the trailing edge of a stationary front. The system tracked rapidly northeastward under the steering influence of the 700 hPa subtropical ridge to the south. By the next day it began to accelerate and turned more east-northeastward as moderate vertical shear began to displace the cyclone's convection away from the low-level circulation centre. The depression slowed on 4th September and as the outflow of nearby Typhoon Rex caused the vertical wind shear to increase the system began to dissipate as it turned to the southeast.

Typhoon Stella (9808)

A sub-tropical ridge was evident in the northwest Pacific between 10-15°N latitude early in the month of September as Typhoon Rex moved well to the north. This slowly weakened and slipped south before a weak low formed near 20°S 165°E on the 7th September. The circulation around this system developed characteristics of the monsoon trough as it extended to the Philippine Islands on the 8th September and linked with the Southeast Asian monsoon by the 10th September. Typhoon Stella began from this weak tropical disturbance just east of the northern Marianas Islands with a Tropical Cyclone Formation Alert issued at 0000Z on 12th September. Stella developed in the

eastern portion of the monsoon trough, south of the mid-level subtropical ridge and consequently moved slowly to the north-northwest. As it did this, upper outflow improved at first and the depression reached tropical storm intensity on the 13th September when it was near 22°N 142°E. Stella continued to track northwestward towards Japan for two days before reaching typhoon intensity near 26°N 137°E as it moved into a weakness in the ridge. The cyclone was soon north of the upper level sub-tropical ridge, so further intensification became unlikely and it began transitioning into a poleward-oriented, steering pattern at 1200Z on 15th September. It gradually recurved northeastward and continued to accelerate as it began to be influenced by the mid-latitude westerlies. Stella made landfall about 1800Z on 15th September near Numazu, Japan when it was at minimum typhoon intensity. The storm then passed over Tokyo, before moving north along the eastern Honshu coast as it accelerated and became extratropical at 1200Z on 16th September. Media reports indicated at least four deaths and 25 injuries, with 7metre waves on the coast. Rainfall was also heavy with some 350 mm falling in 24 hours, resulting in many landslides.

* Tropical Depression 09W (9809)

Tropical Depression O9W developed in the northern part of the South China Sea within the monsoon trough about 450 km east of Hainan Dao on 12th September. In Hong Kong the Standby Signal No. 1 was hoisted at O615 HKT that day. Due to the combined effect of the tropical depression and the northeast monsoon, local winds freshened from the northeast and were occasionally strong offshore and on high ground. The weather was unsettled with occasional squally heavy showers and seas were rather rough over the coastal waters. The tropical depression was closest to Hong Kong at around 2000 HKT on 12th September when it was about 210 km to the south. At the Hong Kong Observatory headquarters, the lowest hourly sea-level pressure of 100.28 kPa was recorded at 1800 HKT that day. This system was a short-lived, minimum intensity tropical depression which remained south of the subtropical ridge, tracking westward at 18-28 km h⁻¹ with the low-level steering flow. As the tropical depression moved away from Hong Kong, signals were lowered at 1630 HKT on 13th September. Locally, squally showers associated with the tropical depression caused several road accidents, injuring around 10 people. The system reached a maximum intensity of 45 km h⁻¹ as it moved through the Hainan Strait into Beibu Wan. It made landfall and dissipated over Vietnam at 1800Z on 14th September. Figure 4 shows a track map of Tropical Depression O9W.

Typhoon Todd (9710)

On 11th September a strong high pressure system developed in the southern Indian Ocean and persisted for nearly a week, reaching a pressure of about 1040 hPa. This anticyclone enhanced cross-equatorial flow which assisted a monsoon surge around the middle of the month. The tropical system which was to become Super Typhoon Todd formed in the Philippine Sea near 19°N 126°E within a reverse oriented monsoon trough. JTWC issued a Tropical Cyclone Formation Alert at 0900Z on 15thSeptember.

Figure 4 Track Map of Tropical Depression 09W (9809), (after JTWC).

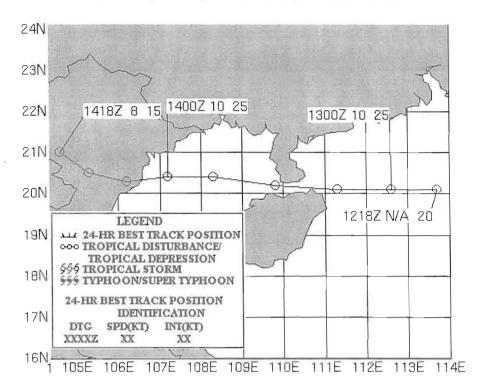
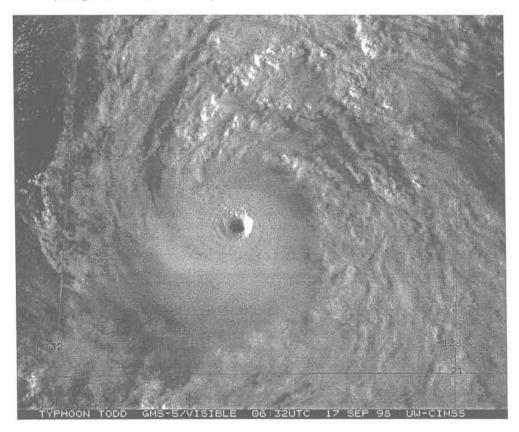


Figure 5 GMS-5 Visible Image of Super Typhoon Todd (9810) acquired at 0632 UTC on 17 September, 1998 when it was near its peak intensity. (Image from UW-CIMSS).

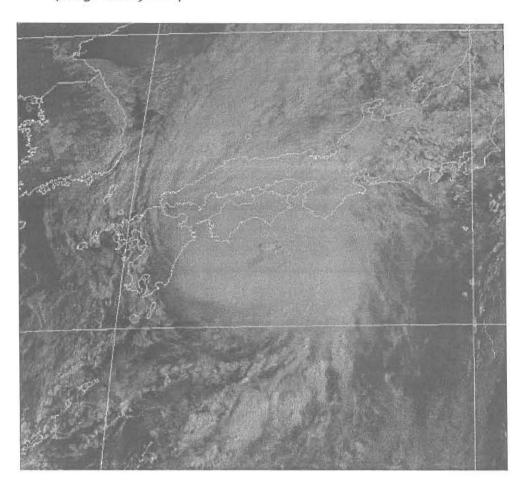


The disturbance was embedded in a large area of deep convection, which h masked its initial rapid intensification. With a strong surge of south-westerlies to its south Todd intensified quickly in response to mid-tropospheric steering flow and the influence of a monsoon gyre located in the South China Sea. JTWC issued the first warning with a maximum intensity of 83 km h⁻¹ at 0300Z on 16th September when it was near 21°N 132°E and moving on an east northeasterly track. Todd reached its maximum intensity of 240 km h⁻¹ around 0600Z on 17th September near 23°N 135°E. At that time it was moving northeastward at 20 km h⁻¹ and a 22 km diameter cloud-filled eye was clearly observed. Figure 5 provides a spectacular visible image capturing this eye. Between 0000Z on 17th and 0000Z on 18th September Todd was in the process of changing direction and accelerating in response to the steering flow of a developing anticyclone over Kyushu and a monsoon gyre in the South China Sea. As it moved north of the upper sub-tropical ridge outflow became less favourable. September a low to mid-level ridge developed to the north of the system and accelerated its movement to the west and created a strong vertically sheared environment which weakened the system. By the time Todd made landfall on the east coast of China, around 160 km south of Shanghai, it had weakened to a 102 km h⁻¹ system which continued to weaken as it moved westward over land. After 0000Z on 20th September the remnants reversed course and the exposed low-level circulation turned eastward and tracked into the East China Sea where they became quasistationary and dissipated around 1800Z that day. Although the southern Japanese island of Kyushu did not experience passage of the cyclone center, heavy rains associated with Todd caused seven fatalities from flooding and mudslides. No reports of fatalities or damage in China were reported.

Typhoon Vicki (9811)

Vicki was the only cyclone to form south of 20°N latitude in September. A Tropical Cyclone Formation Alert was issued by JTWC at 0530Z on 16th September for an area of persistent convection with an associated low-level circulation centre located in the active monsoon trough over the south China Sea west of Luzon. The first warning was issued at 0300Z on 17th September as a 56 km h⁻¹ tropical depression located near 16°N 119°E. Vicki tracked slowly toward the east-southeast under the steering influence of the 700 hPa subtropical ridge to the south and intensified while approaching the west coast of Luzon. Vicki reached tropical storm strength at 1200Z on 17th September, and typhoon strength by 0600Z on 18th September. Vicki made its first landfall over western Luzon around six hours later as an 158 km h⁻¹ typhoon and began tracking to the east northeast under the steering influence of the building midlevel subtropical ridge to the east. During the passage over Luzon it weakened to a 74 km h⁻¹ system due to interaction with land. However heavy rain led to severe flooding and landslides. Reports indicate 9 people were killed and more than 300,000 affected by Vicki's transit of Luzon. One landslide forced hundreds of people from their homes in several villages near Manila. Also on 18th September, dozens lost their lives as the ferry "Princess of the Orient" sank near the mouth of Manila Bay with 430 people onboard as it was heading for the city of Cebu. After crossing Luzon Vicki entered the

Figure 6 GMS-5 Visible Image of Typhoon Vicki (9811) taken at 0000Z on 22 September, 1998 a few hours prior to making landfall in Japan. (Image from JTWC).



Philippine Sea. The presence of a slow-moving mid-latitude trough to the northwest of Vicki combined with a high in the mid-level sub-tropical ridge to its east to result in a northeastward track, with increasing speed as the system gained latitude. Initially favourable upper outflow overcame the mid-level shear and Vicki developed to typhoon strength by 0000Z on 21st September while it was east of Okinawa near 24°N 130°E. Strong steering flow caused by the subtropical ridge to the east of the system and an approaching mid-latitude trough to the northwest combined to provide a favorable environment for Vicki to maintain its north northeasterly track at 30 to 50 km h⁻¹ toward the islands of Shikoku and Honshu in southwestern Japan. Vicki made its second landfall as a 167 km h⁻¹ system between 0000Zand 0600Z on 22nd September south of Osaka. Figure 6 shows a visible image acquired at this time. It crossed the Honshu coast soon after Waldo, which developed later, crossed in almost the same location, disrupting train and passenger service and canceling over 60 domestic flights in Japan. The system began weakening over land as it continued to accelerate within the strong westerly flow over central Japan. The storm also began to undergo extratropical transition as the mid-latitude interaction increased, becoming fully extratropical around 0300Z on 23rd September over the North Pacific Ocean to the south of the Kurile islands.

Tropical Depression 12W (9812)

Tropical Depression 12W formed in the South China Sea at 0900Z on 18th September from a monsoon trough disturbance located off the Vietnam coast. The system remained south of the mid-tropospheric subtropical ridge throughout its existence and as a result, tracked persistently northwestward. Throughout its short life it remained a poorly organized system, reaching a maximum intensity of 56 km h⁻¹ while 60 km off the Vietnamese coast. Tropical Depression 12W made landfall near Cua Ho, Vietnam around 1800Z 19th September and rapidly dissipated over land.

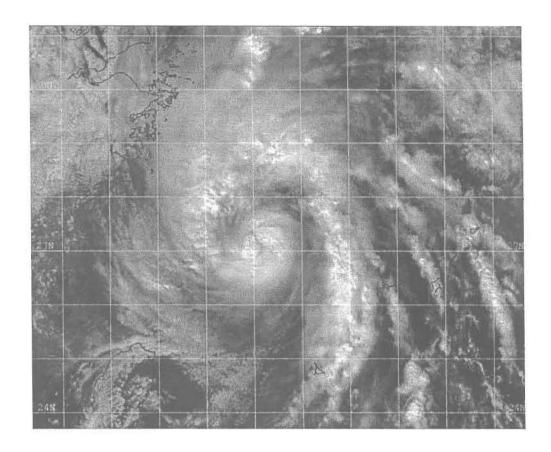
Tropical Storm Waldo (9813)

Tropical Storm Waldo, a small-sized tropical cyclone, developed from another low in the monsoon trough to the northeast of Vicki on the 20th September and was subject to similar steering flow to Vicki, although strong upper level shear over the system restricted its development. A Tropical Cyclone Formation Alert was issued at 0900Z on 19th September and the first warning at 0300Z on 20th September. Waldo developed and moved rapidly, reaching tropical storm intensity at 0600Z on 20th September while moving north at 37 km h⁻¹. The rapid northward acceleration was due to the proximity of TY Vicki to the southwest which caused an increase in the synoptic scale southerly wind flow Vicki and the mid-tropospheric subtropical ridge located to the northeast of Waldo. The upper-level outflow from Vicki also suppressed the outflow from Waldo, restricting the latter system to a maximum intensity of 83 km h⁻¹. Landfall occurred near Owase, Japan on Honshu Island around 0800Z on 21st September at marginal tropical storm intensity. Waldo crossed Japan and dissipated over the Sea of Japan around 1800Z on 21st September.

Typhoon Yanni (9814)

The northwest Pacific Ocean became relatively quiet for a few days after Waldo and Vicki passed over Japan. The depression which was to develop into Yanni formed under a TUTT system in the Philippine Sea near 13°N 134°E on 24th September. JTWC issued the first warning at 0300Z on 25th September when Yanni was a 46 km h system moving northwestward. Over the following three days the cyclone moved steadily northwestward and intensified slowly reaching tropical storm intensity at 1200Z on 27th September as it approached Taiwan. At this time there was a northeasterly surge in the South China and the monsoon trough then became more active as the subtropical ridge developed over the top. Yanni then slowed and began to move northward while continuing to slowly intensify reaching typhoon intensity at 0600Z on 28th September while tracking north along the east coast of Taiwan. Yanni attained a maximum intensity of 148 km h⁻¹ at 0000Z on 29th September before accelerating to the northeast as it was steered away from the upper ridge. Figure 7 shows a visible image of Yanni to the northeast of Taiwan around this time. The storm continued to maintain marginal typhoon strength on the 29th September as it moved northeastward toward Cheju Island, Korea at 15 km h⁻¹. Yanni began to weaken as it moved along the

Figure 7 GMS-5 Visible Image of Typhoon Yanni (9814) northeast of Taiwan acquired at 0425 UTC on 29 September, 1998 when near peak intensity (Image from Taiwan Weather Bureau).



eastern periphery of the mid-tropospheric subtropical ridge and encountered more vertical wind shear. It weakened to 102 km h⁻¹ as it passed over Cheju Island at 0000Z on 30th September. Yanni made landfall near Yeosu, South Korea as a 93 km h⁻¹ system at 0700Z on 30th September. After making landfall, the storm became an exposed low level circulation which tracked south southeastward before dissipating near the Ryukyu Islands in the East China Sea around 0900Z on 1st October. Yanni killed 50 people and forced thousands to flee their homes in Korea.

Tropical Depression 15W (9815)

Tropical Depression 15W developed near 12°N 113°E in a broad surface trough in the South China Sea on 2nd October. It drifted northeast initially and by 0900Z on 3rd October it had become a 56 km h⁻¹ tropical depression. The system failed to develop due to vertical windshear and was steered steadily northwestward at 13 to 18 km h⁻¹ toward Vietnam by southeasterly low level synoptic flow. The storm skirted Hainan Dao and made landfall near Vinh, Vietnam at 1200Z on 5th October with a maximum intensity of 56 km h⁻¹. It then dissipated quickly after moving over northern Vietnam.

Tropical Depression 16W (9816)

This system began as an area of persistent convection which developed in a surface trough located over Taiwan and the Ryukyu Islands on 3rd October. Tropical Depression 16W formed east of Taiwan as a 46 km h⁻¹ system at 0900Z on 5th October. It then remained quasi-stationary in an area of weak steering flow for 36 hours reaching a peak intensity of 56 km h⁻¹ at 1200Z on 6th October. A passing frontal boundary then caused the storm to move east northeastward. As vertical shear increased the system

Tropical Depression 17W (9817)

Tropical Depression 17W was a short-lived cyclone that formed in the reverse orientated monsoon trough in the East China Sea during early October. It was initially detected by visual satellite data as an exposed low level circulation in a high vertical wind shear environment. The first warning was issued at 0300Z on 6th October and within 12 hours the system had weakened to a 37 km h⁻¹ system, dissipating 12 hours later near 30°N 126°E.

* Super Typhoon Zeb (9818)

Super Typhoon Zeb developed from a low in the weak monsoon trough southeast of Guam in the northwest Pacific Ocean on 7th October. The disturbance originated near 11°N 151°E south of the mid-level subtropical ridge and initially moved to the west. The system was near the upper level ridge, which produced favourable upper outflow, allowing it to develop rapidly. The first warning was issued at 2100Z on 9th October when the depression was southwest of Guam. Intensification continued as the storm continued its westerly track and tropical storm strength was reached as it moved north of Yap Island. During this time another storm developed, embedded in the inflow of the intensifying Zeb. This was to become Tropical Storm Alex (9819). Zeb was upgraded to a typhoon at 1800Z on 11th October when it was near 11°N 133°E. About this time it took on a northwesterly track across the Philippine Sea in the direction of the Luzon Strait. Zeb attained super typhoon intensity at 0000Z on 13th October and reached a peak intensity of 287 km h⁻¹ prior to landfall in the Philippines just south of Palanan Bay on the northeast coast of Luzon some 24 hours later. Figure 8 shows a visible image taken just prior to landfall. During passage over northern Luzon, Zeb began to weaken and took on a northerly track moving across the strait toward Taiwan. Zeb was the first of two super typhoons to strike Luzon within a period of seven days and caused at least 83 deaths. In Hong Kong the Standby Signal No. 1 was hoisted at 0545 HKT on 15th October when Zeb was about 800 km to the eastsoutheast. Under the combined effect of Zeb's extensive circulation and the northeast monsoon, winds were moderate to fresh northerlies, occasionally strong offshore and on high ground. At the Hong Kong Observatory headquarters, the lowest hourly sealevel pressure of 100.15 kPa was recorded at 1500 and 1600 HKT that afternoon. Zeb was closest to Hong Kong at around 2000 HKT in the evening when it was about 730 km to the east. As Zeb moved away from Hong Kong and winds subsided, all

Figure 8 GMS-5 Visible Image of Super Typhoon Zeb (9818) acquired at 0032 UTC on 14 October, 1998 just prior to landfall on Luzon (Image from UW-CIMMS)

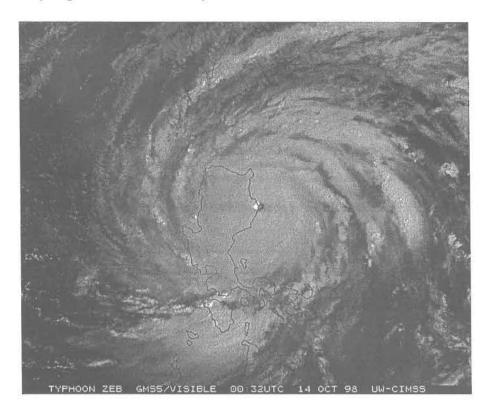
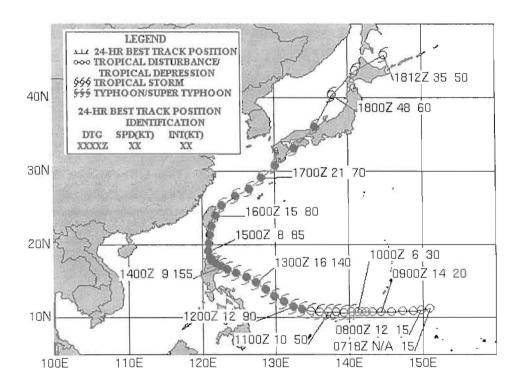


Figure 9 Track Map of Super Typhoon Zeb (9818), (after JTWC).



tropical cyclone warning signals were lowered at 0550 HKT on 16th. During the passage of Zeb, no rainfall was recorded in Hong Kong and no significant damage was reported. After tracking northward just 25 km east of Taiwan where 25 fatalities were reported Zeb recurved through a weakness in the subtropical ridge as a high amplitude mid-latitude trough approached from the west. It then accelerated toward the northeast making landfall over Kyushu shortly after 0600Z on 17th October when it was at marginal typhoon intensity. Its forward motion reached 89 km h⁻¹ as it underwent extratropical transition over southern Japan and the Sea of Japan. Media reports indicate that 12 people died in Japan during the passage. Figure 9 shows the track of Zeb.

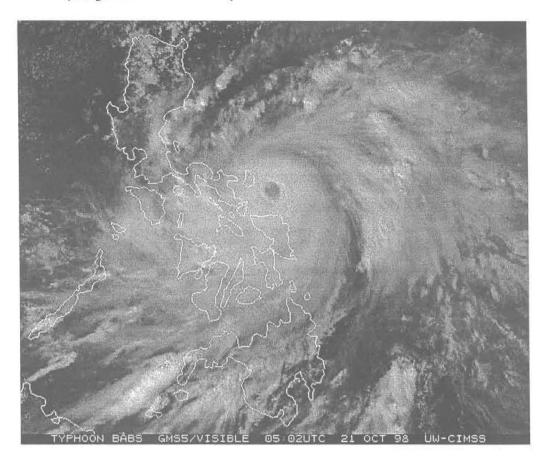
Tropical Storm Alex (9819)

Soon after Zeb began to intensify, a second centre was identified to its northeast, and this reached tropical storm intensity at 1800Z on 10th October as Tropical Storm Alex. Alex was a very small tropical cyclone that formed in the northern inflow of Zeb when the latter was an intensifying tropical storm and was first detected as Zeb was passing north of Ulithi Island. It existed for only 60 hours and attained a maximum intensity of 83 km h⁻¹ before becoming absorbed by the larger system. It was steered toward the west-northwest by Zeb's much more dominant circulation and maintained westward movement north of Zeb until 0600Z on 12th October. Alex had attained tropical storm intensity for less than 24 hours before it turned southwestward and underwent shearing in the vertical and the low level circulation was absorbed by the larger cyclone by 2100Z on 12th October.

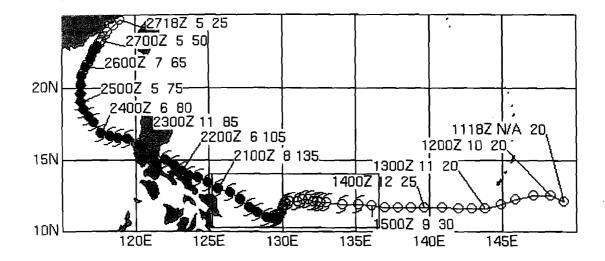
*** Super Typhoon Babs (9820)

Following the demise of Alex a low pressure centre existed in the northwest Pacific Ocean just north of 10°N for several days, early in the life of Zeb. Super Typhoon Babs, the second super typhoon within a 7-day period to strike the Philippines, was initially detected as a tropical disturbance southeast of Guam near 12°N 149°E around 1800Z on 11th October. The uniform northeasterly flow in the upper levels produced sufficient vertical windshear to slow development for several days, and continued as the system reached minimal tropical storm Intensity. The first warning was issued at O900Z on 14th October. The system was upgraded to a tropical storm when it was near 12°N 135°E at 0600Z on 15th October. At that time it was moving westward to the south of the mid-level ridge toward the Philippines at 18 km h⁻¹. At approximately 1200Z on 17th October, while moving west, interaction with a Tropical Upper Tropospheric Trough (TUTT) located to the northeast, caused the cyclone to slow, weaken and move southward for a 36-hour period in the Philippine Sea. The TUTT weakened the sub-tropical ridge thus slowing the forward motion and pushing the system south, and restricted the upper level outflow leading to the short period of weakening. After the TUTT filled, Babs began to re-intensify as upper outflow improved and moved toward the Philippines, reaching super typhoon intensity at 1200Z on 20th October while moving northwestward off the coast of Mindanao. Babs continued to move

Figure 10 GMS-5 Visible Image of Super Typhoon Babs (9819) acquired at 0502 UTC on 22 October, 1998 prior to landfall on Luzon (Image from UW-CIMMS)



northwestward across Cantanduanes and Polillo Islands before making landfall over central Luzon on the 22nd October as an intense typhoon. Figure 10 shows a visible image of Babns during this period. Media reports indicate at least 163 deaths in the Philippines as Babs maintained typhoon intensity across Luzon and passed near Manila. During passage over Luzon, the cyclone weakened to 158 km h⁻¹. Nonetheless disastrous mudslides killed 156 people and displaced nearly 400,000 from their homes. Babs entered the South China Sea on 23rd October. Once in the South China Sea it began to re-intensify until upper shear from a mid-latitude trough further weakened it and steered it northward. This more northerly track initially posed a threat to Hong Kong where the Standby Signal No. 1 was hoisted at 2215 HKT that evening when Babs was about 770 km to the southeast. Winds became strong the next day as Babs came closer and Strong Wind Signal No. 3 Was hoisted at 2340 HKT on the evening of 24th. Under the combined effect of Babs and the northeast monsoon, northerlies strengthened and winds offshore occasionally reached gale force. Maximum hourly wind of 81 km h⁻¹ and maximum gust of 113 km h⁻¹ were recorded at Wagian Island. At 0300 and 0400 HKT on 26th October, the lowest hourly sea-level pressure of 100.14 kPa was recorded at the Hong Kong Observatory headquarters. Babs passed about 240 km to the east-southeast of Hong Kong at around 0800 HKT and then



moved away gradually north-north-eastwards towards the Taiwan Strait. All tropical cyclone warning signals were lowered at 2130 HKT on 26th. Strong winds and rainbands associated with Babs affected Hong Kong on both 25th and 26th October. There were some storm-related accidents and a total of 14 people was injured. A subsequent increase in vertical shear after Babs passed through a weakness in the midlevel subtropical ridge and proximity to land led to rapid weakening and dissipation in the Taiwan Strait near the coast of China at 2100Z on 27th October due to strong vertical wind shear and the frictional effects of land. In Taiwan, over 500 mm of rain fell in 24 hours, inundating many eastern towns and villages with waist-high flooding. Landslides also wreaked havoc throughout the island. Figure 11 presents a track map for Super Typhoon Babs.

Tropical Storm Chip (9821)

Tropical Storm Chip developed in mid-November as a shearline-enhanced circulation in an active monsoon trough in the South China Sea following a northeasterly monsoon surge associated with the subtropical ridge over China. Around 1200Z on 11th November a broad cyclonic circulation became more organized as a shearline moved into the northern part of the South China Sea. Chip reached tropical storm status at 0600Z on 12th November as it tracked toward the west-northwest in a steering current associated with an upper subtropical high over the Philippines. Significant vertical shear, however, inhibited development and Chip reached a maximum intensity of 93 km h⁻¹ at 1200Z on 13th November just off the Vietnam coast near 11°N 110°E. As Chip moved closer to southern Vietnam the effects of the land interaction and vertical wind shear began to weaken it and it then turned south and moved along the coast of southern Vietnam continuing to weaken. Although not of severe intensity, Chip caused at least seventeen deaths and widespread flooding and wind damage after it

crossed the coast of southeastern Vietnam. Although weakened the disturbance successively crossed southern Indo-China, the Gulf of Thailand and the Thai peninsula.

Tropical Storm Dawn (9822)

This was the second system to develop in an active monsoon trough in the South China Sea. A separate circulation first appeared on the 16th November, adjacent to the southern Philippines island of Palawan, becoming better organized following a northeasterly surge. Initially detected as a tropical disturbance on the 17th November, the first warning on Dawn was issued at 0900Z on 18th November after meteorological satellite data indicated an intensity of 46 km h⁻¹. Under the steering influence of the subtropical ridge. Dawn moved northwest, away from an area of strong vertical wind shear and reached tropical storm intensity at 1800Z on 18th November. Continuing to move northwestward, it reached a maximum intensity of 83 km h⁻¹ before making landfall near Cam Ranh, Vietnam at 1500Z on 19th November. Though not a severe storm Dawn caused widespread flash flooding after crossing the southeastern coast of Vietnam early on the 20th November, with reports of the loss of over 100 lives. Dawn dissipated over northern Cambodia on 20th November.

Tropical Storm Elvis (9823)

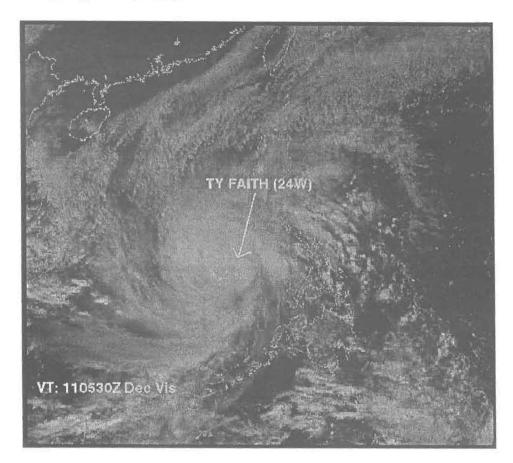
The monsoon trough remained active across the South China Sea and southern Philippines following the brief passage of Dawn. A new depression formed to the east of Mindanao on the 20th November, and tracked west-northwest across the archipelago over the next three days. By the 23rd November a well-defined monsoon depression was located in the eastern part of the South China Sea near Palawan. Based on ship reports and intensity estimates from satellite data this system reached a 46 km h⁻¹ intensity at 0300Z on 24th November, following another winter monsoon surge. It began tracking west-northwest at 15 km h⁻¹ under the influence of the upper subtropical ridge to the north and reached tropical storm intensity at 1200Z on 24th November. The system continued to move west-northwestward and attained a maximum intensity of 83 km h⁻¹ at 0000Z on 25th November. Increasing vertical shear suppressed development from the afternoon of the 26th November and Elvis remained at 83 km h⁻¹ until making landfall at 2300Z on 25th November north of Quy Nhon, Vietnam. The cyclone dissipated 12 hours after moving onshore. Although a comparatively weak storm its associated rainfall and flooding added to the already serious flooding problems in the region. 49 fatalities and some US\$30 million worth of damage in the Binh Dinh and Quang Ngai provinces of Vietnam are reported to have resulted from the passage of Elvis.

Typhoon Faith (9824)

Faith formed in the western Caroline Islands in the second week of December. A Tropical Cyclone Formation Alert was first issued at 0330Z on 8th December, when the disturbance was located south of Sorol Atoll, Federated States of Micronesia. The

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Figure 12 GMS-5 Visible Image Typhoon Faith (9824) acquired at 0530 UTC on 11 December, 1998 some 6 hours before reaching maximum intensity (Image from JTWC).



first warning was issued at 0900Z on 8th December as data and synoptic reports indicated a 46 km h⁻¹ intensity. At 0000Z on 9th December, the system headed northwestward towards the central Philippine Islands in response to a weak mid-latitude trough that passed north of the cyclone in the mid-tropospheric westerlies. It then resumed a westward track and was upgraded to Tropical Storm Faith at 1800Z on 9th December. Faith intensified fairly rapidly as it approached the Philippines. Six hours prior to the landfall over Samar Island, the cyclone took another short jog to the northwest in response to a second weak passing mid latitude trough, but again resumed a more westward heading after the trough had passed to the northeast. Faith reached typhoon status at 1200Z on 10th December over Samar Island, Philippines. The storm continued across the central Philippine Islands while maintaining minimal typhoon intensity. It was able to maintain this intensity as it crossed the islands as vertical wind shear was weak and there was good upper level divergence aloft. Reports from the Philippines indicated 29 people were killed and over 20,000 were displaced due to the passage of Faith. The Philippine Navy rescued 100 people from a disabled ferry travelling from the Philippines to Malaysia. The damage estimate for the Philippines was over US\$13 million. Faith continued to track in a generally westward direction over the South China Sea under the steering influence of the subtropical ridge to the north. Intensification continued while Faith moved west-southwestward at 26 to 33 km h⁻¹.

The cyclone attained a maximum intensity of 167 km h⁻¹ in the South China Sea at 1200Z on 11th December and maintained this intensity while slowing during the following 24 hours. Figure 12 shows a visible image during this stage of Faith's life. Vertical wind shear increased as the storm approached Vietnam and it gradually lost organisation and weakened. Continuing west it weakened further and made a second landfall near Cam Ranh, Vietnam at 0000Z on 14th December as a tropical storm. Faith dissipated rapidly in the mountainous region of central Vietnam. At least 38 people were reported killed in Vietnam with over 10,000 evacuated due to flooding in low-lying areas. Damage assessments for Vietnam reached over US\$20 million.

Tropical Storm Gil (9825)

Tropical Storm Gil began as a monsoon depression from an area of heavy convection and thunderstorm activity with numerous small cyclonic circulations in the South China Sea off the coast of north Borneo on 8th December. The first warning was issued at 1500Z on 9th December as satellite and synoptic data indicated consolidation and organization into a single cyclone. Gil initially moved west-northwest at 13 to 17 km h⁻¹ as it slowly consolidated and intensified, reaching tropical storm intensity at 1800Z on 10th December while just to the south of Vietnam. Persistent vertical wind shear caused by mid to upper tropospheric southwesterlies and low to mid tropospheric easterlies and interaction with land inhibited further development. Gil weakened to 56 km h⁻¹ at landfall over the Malay Peninsula near Songkhla, Thailand and rapidly dissipated on 13th December.

Tropical Depression 26W (9826)

Tropical Depression 26W began from numerous small circulations within as a very large area of convection over the southern Philippines on 17th December and tracked northward through the centre of the country. The first warning was issued at 1500Z 17th December when the system was in the Sibuyan Sea. Initially the system tracked west-northwestward at 22 to 30 km h⁻¹ but then turned northward, passing over central Luzon and into the South China Sea just north of Lingayen Gulf. The storm failed to consolidate and intensify due to vertical shear and inflow disruption caused by the mountainous terrain of the Philippine Islands. It rapidly weakened during its transit over Luzon and dissipated by 0300Z on 19th December.

Tropical Depression 27W (9827)

Tropical Depression 27W formed from a loosely organized cluster of convection in the central South China Sea near 13°N 113°E on 18th December. The first warning was issued at 0900Z on 19th December. Like 26W, this system experienced a slight increase in organization and then maintained a steady state with a 56 km h⁻¹ intensity for about 24 hours. During this time it drifted north to northeastward at 6 to 11 km h⁻¹. The cyclone had a poorly defined low-level circulation center with disorganized convection and subsequently failed to consolidate and organize any further. Around

0000Z on 21st December it turned more east-northeastward and weakened as it moved into a greater vertical wind shear environment associated with strong mid to upper tropospheric westerly flow, dissipating by 0300Z on 22nd December in the South China Sea just south of Pratas Island.

Acknowledgements

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Department of Geography, The University of Hong Kong Pokfulam Road, Hong Kong (Email: billkyle@hkucc.hku.hk)

Hong Kong Weather Reviews

Climatological information employed in the compilation of this section is derived mainly from published weather data of the Hong Kong Observatory and is used with the prior permission of the Director.

Review of Autumn 1998

Important Climatological Events

Autumn 1998 was rather warmer and drier than usual. The mean temperature of 25.7 °C was 1.0 °C above normal and the total rainfall of 393.69 millimetres was only 82 percent of normal. Although September was only slightly warmer than normal both October and November were considerably warmer. In October the mean temperature of 26.1 °C and the mean minimum temperature of 24.3 °C being the third and second highest respectively on record. Similarly, the mean temperature of 23.2 °C and the mean minimum temperature of 21.4 °C were the highest on record for November, while the mean maximum temperature of 25.3 °C was the seventh highest. All three months recorded lower than normal rainfall at 77, 92 and 82 percent of normal for September, October and November respectively. Tropical cyclone activity was relatively low with only seven storms occurring in the South China Sea and the western North Pacific Ocean. Three of those necessitated the hoisting of Tropical Cyclone Warning Signals in Hong Kong. The relative humidity of 21 per cent recorded early on 17th October equalled the lowest record for the month previously set in 1991.

Seasonal statistics

Extreme daily maximum temperature	32.3 ℃	(on 14 ^{sh} October)
Mean daily maximum temperature	27.9 ℃	(0.4 °C above normal)
Mean daily temperature	25.7 ℃	(1.0 °C above normal)
Mean daily minimum temperature	24.0 °C	(1.4 °C above normal)
Extreme daily minimum temperature	19.3 ℃	(on 26 th November)
Rainfall (provisional)	393.6 mm	(82 %)
Number of Days with ≥0.1 mm rain	26	(2.84 below normal)
Number of Days with ≥25.0 mm rain	8	(2.53 above normal)
Number of Days with ≥50.0 mm rain	2	(0.60 below normal)

September

September 1998 was slightly warmer than usual. The mean minimum temperature of 26.2 °C was the fourth highest on record for the month and the mean temperature of 27.8 °C was 0.2 °C above normal. The total rainfall of 230.9 millimetres was 68.8 millimetres below normal. Nevertheless, two Amber Rainstorm warnings and a total of seventeen Thunderstorm warnings were issued. The Standby Signal No. 1 was hoisted on one occasion for a Tropical Depression which formed in the South China Sea to the south of Hong Kong. The Strong Monsoon Signal was hoisted twice and two Red Fire Danger Warnings were issued in the latter part of the month.

Under the influence of a trough of low pressure over the northern part of the South China Sea, heavy thundery showers affected Hong Kong on the morning of 1st, and a Thunderstorm Warning was in effect from 0945 to 1345 HKT that day. The heavy showers also prompted an Amber Rainstorm Warning which was in effect from 1145 to 1330 HKT. The weather gradually improved and there were sunny intervals apart from isolated thundery showers in the next few days with Thunderstorm Warnings being issued briefly from 1045 to 1330 HKT on 2nd, and again from 0530 to 0730 HKT on 5th. Thunderstorms returned early on 6th as another trough of low pressure approached from the north. During that day three Thunderstorm Warnings were in effect, from 0120 to 0720 HKT, from 0845 to 1045 HKT, and from 1345 to 1745 HKT. The second Amber Rainstorm Warning of the month was in effect from 1545 to 1745 HKT during the third episode. Showers moderated over the next couple of days

although Thunderstorm Warnings were issued once on 7th, from 0510 to 0910 HKT, and twice on 8th, from 1025 to 1225 HKT and again in the evening from 2015 to 2115 HKT. The thundery conditions returned again on 9th, during which three Thunderstorm Warnings were in force, from 1030 to 1630 HKT, from 1652 to 1730 HKT and from 2315 HKT in the evening to 0600 HKT the following morning. Thundery conditions persisted the next few days with the issuance of Thunderstorm Warnings from 1530 to 1930 HKT on 11th, and twice on 12th, from 0245 to 0645 HKT and again from 2300 HKT to 0600 HKT on 13th. During this time an area of low pressure developed over the northern part of the South China Sea, forming a tropical depression about 270 km south-southeast of Hong Kong on the early morning of 12th. In Hong Kong the Standby Signal No. 1 was hoisted at 0615 HKT that day. Due to the combined effect of the tropical depression and the northeast monsoon, local winds freshened from the northeast and were occasionally strong offshore and on high ground. The weather was unsettled with occasional squally heavy showers and seas were rather rough over the coastal waters. The tropical depression was closest to Hong Kong at around 2000 HKT on 12th when it was about 210 km to the south. At the Hong Kong Observatory headquarters, the lowest hourly sea-level pressure of 100.28 kPa was recorded at 1800 HKT that day. Tracking westwards, the storm passed the north coast of Hainan Island the next day entering Beibu Wan and degenerating into an area of low pressure after making landfall over northern Vietnam on 14th. As the tropical depression moved away from Hong Kong, signals were lowered at 1630 HKT on 13th. Locally, squally showers associated with the tropical depression caused several road accidents, injuring around 10 people. With the tropical depression well to the west, fresh to strong easterlies set in on 14th, prompting the hoisting of the Strong Monsoon Signal from 0000 to 0500 The airstream also brought thundery showers in the early morning. Thunderstorm Warnings were in effect from 0245 to 0645 HKT and from 0725 to 1125 HKT that day. Showers eased off in the afternoon and there were sunny periods. Fine weather continued for the next couple of days. On the evening of 16th, winds strengthened from the east again as a ridge of high pressure extended southwards across the Taiwan Strait. The second Strong Monsoon Signal of the month was hoisted at 2145 HKT that evening and remained in effect until 0545 HKT in the morning of 17th as winds moderated and the weather became sunny apart from some isolated showers. A dry northerly airstream arrived on 19th, bringing fine weather to southern China for the next few days. Temperatures rose to 32.1 °C on 20th, the highest in the month. Haze was reported over parts of Hong Kong on 21st and 22nd. The dry conditions led to the issuing of a Red Fire Danger Warning at 1045 HKT on 20th. This warning remained in force until 1145 HKT on 22nd, when winds turned easterly bringing cloudier weather and some light showers the next morning. Fine weather returned in the afternoon of 23rd and lasted over the next few days. On 27th, another northerly airstream affected Hong Kong and haze was again observed. The weather remained fine and dry till the end of the month, resulting in a second Red Fire Danger Warning being in effect from from 0600 HKT on 28th until the end of the month. Temperatures dropped to 24.3 °C on 30th, the lowest recorded during September.

Monthly Statistics

Extreme daily maximum temperature	32. 1 ℃	(on 20 th)
Mean daily maximum temperature	30.1 ℃	(0.2 °C below normal)
Mean daily temperature	27.8 °C	(0.2 °C above normal)
Mean daily minimum temperature	26.2 °C	(0.7 °C above normal)
Extreme daily minimum temperature	24.3 °C	(on 30 th)
Total Rainfall (provisional)	230.9	mm (77 % of normal)
Number of Days with ≥0.1 mm rain	11	(3.37 below normal)
Number of Days with ≥25.0 mm rain	6	(2.43 above normal)
Number of Days with ≥50.0 mm rain	1	(0.63 below normal)

October

October 1998 was much warmer than normal, with the mean temperature of 26.1 °C and the mean minimum temperature of 24.3 °C being the third and second highest respectively on record. Three tropical cyclones occurred in the South China Sea and the western North Pacific in the month, two of which necessitated the hoisting of Tropical Cyclone Warning Signals. The total rainfall of 133.9 millimetres in the month was 10.9 millimetres below the normal figure. Some 40 percent of this total was brought by thunderstorms on 10th when the two Thunderstorm Warnings of the month were issued. Much of the rest was brought by rainbands associated with tropical cyclones. The mean pressure of 101.16 kilopascals was the eighth lowest for October. The relative humidity of 21 per cent recorded early on 17th equalled the lowest record for the month previously set in 1991. The Strong Monsoon Signal was hoisted on only two occasions early in the month when a tropical depression formed south of the SAR. The generally dry conditions led to six Red and two Yellow Fire Danger Warnings being issued.

Under the influence of a continental airstream, the fine and dry weather at the end of September continued into October. The Red Fire Danger Warning issued on 28th September was replaced by the Yellow Fire Danger Warning at 0600 HKT on 2nd. However, this was upgraded to Red again at 1015 HKT on 3rd. This warning remained in effect until 1800 HKT that evening when the weather became cloudy as a tropical depression formed over the South China Sea on 3rd and moved towards Hainan Dao.

The Strong Monsoon Signal was hoisted from 0820 to 1415 HKT as winds strengthened. A total of 25 hill fires broke out on 3rd, resulting in three huts being destroyed in Yuen Long and eight people becoming homeless. Rainbands associated with this tropical depression began to affect Hong Kong towards midnight on 3rd, with easterly winds strengthening offshore. The Strong Monsoon Signal was re-hoisted at 0005 HKT on 4th and remained up until 1945 HKT on 5th when winds moderated. Some heavy showers occurred in the urban areas and the northern part of the New Territories the next afternoon. Rain eased off on 7th and it became mainly fine apart from some mist in the morning. Sunny periods continued for another day. Cloudy weather returned on 9th and there were some isolated heavy showers which became more widespread the next day. Thunderstorm Warnings were in effect from 1015 to 1415 HKT and again from 1740 to 1940 HKT on 10th. Out in the Pacific Ocean a tropical depression named Zeb formed about 410 km southwest of Guam in the early morning of 10th. Locally rain eased off on 11th and the weather improved the next day with long sunny periods. Meanwhile Zeb intensified into a typhoon on 12th and moved northwestwards to traverse northern Luzon, causing serious flooding and landslides. Zeb then tracked north- northeastwards passing the east coast of Taiwan. During that time dry and sunny weather prevailed in Hong Kong. The weather was hazy on 14th and temperatures rose to 32.3 °C, the highest in the month, that afternoon. In Hong Kong the Standby Signal No. 1 was hoisted at O545 HKT on 15th when Zeb was about 800 km to the east-southeast. Under the combined effect of Zeb's extensive circulation and the northeast monsoon, winds were moderate to fresh northerlies, occasionally strong offshore and on high ground. The dry northerly airstream resulted in the issuing of a Red Fire Danger Warning at 0615 HKT on 15th. At the Hong Kong Observatory headquarters, the lowest hourly sea-level pressure of 100.15 kPa was recorded at 1500 and 1600 HKT that afternoon. Zeb was closest to Hong Kong at around 2000 HKT in the evening when it was about 730 km to the east. As Zeb moved away from Hong Kong and winds subsided, all tropical cyclone warning signals were lowered at 0550 HKT on 16th. During the passage of Zeb, no rainfall was recorded in Hong Kong and no significant damage was reported. Tracking northeastwards over the East China Sea, Zeb weakened into a severe tropical storm on 17th and then made landfall over Kyushu and Shikoku, finally becoming an extratropical cyclone over Japan. About the time Zeb was closest to Hong Kong a tropical depression named Babs developed about 320 km northwest of Yap on 15th. Tracking westwards, Babs intensified into a tropical storm on 18th and attained typhoon strength two days later. Meanwhile, in Hong Kong fine and dry conditions persisted apart from some light rain patches between 20th and 22nd. Twenty-four hill fires were reported on 18^{th} . The Red Fire Danger Warning was rescinded at 0545 HKT on 19th only to be re-issued six hours later at 1145 HKT that morning. This warning remained in effect until 0600 HKT on 22nd. Another Red Fire Danger Warning was issued twelve hours later at 1200 HKT that day. Babs entered the South China Sea on 23rd and took on a more northerly track initially posing a threat to Hong Kong where the Standby Signal No. 1 was hoisted at 2215 HKT that evening when Babs was about 770 km to the southeast. Winds became strong the next day as Babs came closer and Strong Wind Signal No. 3 was hoisted at 2340 HKT on the

evening of 24th. The Red Fire Danger Warning was rescinded a few hours earlier at 1800 HKT, although it was briefly in effect again from 0615 to 0845 HKT the next morning. Under the combined effect of Babs and the northeast monsoon, northerlies strengthened and winds offshore occasionally reached gale force. Maximum hourly wind of 81 km h⁻¹ and maximum gust of 113 km h⁻¹ were recorded at Wagian Island. At 0300 and 0400 HKT on 26th, the lowest hourly sea-level pressure of 100.14 kPa was recorded at the Hong Kong Observatory headquarters. Babs passed about 240 km to the east-southeast of Hong Kong at around 0800 HKT and then moved away gradually north-north-eastwards towards the Taiwan Strait where it finally dissipated on 27th. All tropical cyclone warning signals were lowered at 2130 HKT on 26th. Strong winds and rainbands associated with Babs affected Hong Kong on both 25th and 26th. There were some storm-related accidents and a total of 14 people was injured. Temperatures also dropped to 21.7 °C, the lowest in the month, on 26th. As Babs moved away the weather improved on 27th and fine and sunny weather prevailed till the end of the month. A Yellow Fire Danger Warning was in force from 0600 HKT on 27th until the same time on 29th.

Monthly Statistics

Extreme daily maximum temperature	32.3 ℃	(on 14 th)
Mean daily maximum temperature	28.3 °C	(0.4 °C above normal)
Mean daily temperature	26.1 ℃	(0.9 °C above normal)
Mean daily minimum temperature	24.3 °C	(1.2 °C above normal)
Extreme daily minimum temperature	21.7 ℃	(on 26 th)
Total Rainfall (provisional)	133.9mm	(92 % of normal)
Number of Days with ≥0.1 mm rain	9	(0.40 above normal)
Number of Days with ≥25.0 mm rain	2	(0.50 above normal)
Number of Days with ≥50.0 mm rain	1	(0.60 above normal)

November

November 1998 was much warmer than normal. The mean temperature of 23.2 °C and the mean minimum temperature of 21.4 °C were the highest on record for the month, while the mean maximum temperature of 25.3 °C was the seventh highest. On the other hand, the mean pressure of 101.56 kpascals was the fifth lowest for the

month. The total rainfall of 28.8 millimetres in the month was 6.3 millimetres below normal. Three tropical cyclones occurred in the South China Sea and the western North Pacific in the month, only one of which influenced weather in Hong Kong. The Strong Monsoon Signal was hoisted on only one occasion. Four Yellow and four Red Fire Danger Warnings were issued.

The month began with a mainly fine day and a Yellow Fire Danger Warning in effect from 0000 HKT. Cloudy conditions with a few rain patches appeared in the evening and the Yellow Fire Danger Warning was rescinded at 0600 HKT the next morning. The weather improved on 3rd and became fine and sunny the next day. Cloud amount increased again on 5th and light rain patches returned that evening. A drier airstream reached the coast of southern China on 6th, and fine and sunny weather prevailed till 13th although there was some haze on 9th. During this time three Red Fire Danger Warnings were in force, from 0000 HKT on 7th to 1800 HKT on 8th, from 1145 HKT on 9th to 0600 on 13th, and from 1100 HKT on 13th until 0600 HKT on 14th. This last warning was replace by a Yellow Fire Danger Warning as generally cloudy weather returned on the morning of 14th. It, in turn, was rescinded at 1800 HKT on 15th. Fine and sunny conditions returned again on 16th. Temperatures rose to 29.1 °C, the highest in the month, on 17th, although the weather became cloudy as a weak cold front crossed the coast of Guangdong that evening. Winds strengthened from the east but moderated the next day. The weather remained mainly cloudy for the next few days. A drier airstream from the north then began to affect the weather and the Yellow Fire Danger Warning was issued at 1200 HKT on 21st. It was replaced by the Red Fire Danger Warning at 0600 HKT on 22nd as fine and sunny weather prevailed. A total of 34 cases of hill fire was reported the following day. Due to the formation of Tropical Storm Elvis in the South China Sea and the intensification of the winter monsoon over southeast China, winds freshened from the northeast on 24th and became occasionally strong offshore that evening. The weather also turned cloudy the next day as the outer rainbands of Elvis affected the south China coast. With a return to moister conditions the Red Fire Danger Warning was rescinded at 1800 HKT on 25th. The weather became overcast with periods of rain on 26th, with temperatures dropping to 19.3 °C, the lowest in the month, that morning. Rain became more widespread on 28^{th} but turned less frequent towards the end of the month, prompting the issuance of a Yellow Fire Danger Warning from 0615 to 1800HKT on 29th.

Monthly Statistics

Extreme daily maximum temperature	29.1 ℃	(on 17 th)
Mean daily maximum temperature	25.3 °C	(1.1 °C above normal)
Mean daily temperature	23.2 °C	(1.8 °C above normal)
Mean daily minimum temperature	21.4 ℃	(2.2 °C above normal)

Extreme daily minimum temperature	19.3 ℃	(on 26 th)
Total Rainfall (provisional)	28.8 mm	(82 % of normal)
Number of Days with ≥0.1 mm rain	6	(0.13 above normal)
Number of Days with ≥25.0 mm rain	0	(0.40 below normal)
Number of Days with ≥50.0 mm rain	0	(0.10 below normal)

Review of Winter 1998-99

Important Climatological Events

Following a warmer than normal autumn, winter 1998-99 was exceptionally warm with the mean temperature of 18.4 °C for the three winter months from December 1998 to February 1999 setting a new record high surpassing the value of 18.3 °C set for the same period in 1978-1979. All three months were much warmer than normal recording mean temperatures of 2.0 °C, 1.9 °C, and 2.8 °C above normal for December, January and February respectively. The season was also exceptionally dry with a total of only 18.2 millimetres, less than one fifth of the 1961-90 normal rainfall of 98.7 mm. The dearth of rain increased as the season progressed with December receiving only about half of the normal amount, January only about one fifth, and February, only a trace, the second lowest for on record for the month. February was also particularly sunny with the mean cloud amount of 40 percent the third lowest for the month while the total sunshine duration reached 182.6 hours, more than twice the normal value of 84.9 hours. The mean relative humidity of 67 percent was also the third lowest for the month.

Seasonal Statistics

Mean daily maximum temperature 20.7 °C (1.4 °C above normal Mean daily temperature 18.4 °C (1.9 °C above normal Mean daily minimum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily maximum temperature 16.5 °C (2.2 °C above normal mean daily max	maximum temperature 27.3 °C	(on 27th February)
	eximum temperature 20.7 °C	(1.4 °C above normal)
Mean daily minimum temperature 16.5 °C (2.2 °C above normal	mperature 18.4 °C	(1.9 °C above normal)
	nimum temperature 16.5 °C	(2.2 °C above normal)
Extreme daily minimum temperature 3.5 °C (on 15 th January)	minimum temperature 3.5 °C	(on 15 th January)

Rainfall (provisional)	18.2mm	(18 %)
Number of Days with ≥0.1 mm rain	9	(9.43 below normal)
Number of Days with ≥25.0 mm rain	0	(0.76 below normal)
Number of Days with ≥50.0 mm rain	0	(0.13 below normal)

December

December 1998 was much warmer than normal with the winter monsoon weak but dominating the weather for most of the month. The mean temperature of 19.1 °C and the mean minimum temperature of 17.4 °C were the sixth and the third highest respectively on record for the month. The total rainfall in the month was 13.7 millimetres, only about half of the normal amount. Two tropical cyclones formed in the western North Pacific and the South China Sea in the month but neither affected Hong Kong. The Strong Monsoon Signal was hoisted on four separate occasions and four Yellow and three Red Fire Danger Warnings were issued during the month.

December started misty with light rain patches, with visibility reduced to 1200 metres in the harbour on 1st. However it became sunny the next day. A cold front crossed the coast of south China early on 3rd bringing some rain and brief spells of strong northerly winds offshore. The Strong Monsoon Signal was hoisted from 0130 to 0945 HKT that morning. Winds moderated the next day and generally cloudy and cooler weather remained till 6th. A Yellow Fire Danger Warning was in effect from 0700 HKT on 5th until 1800 HKT on 6th. Under the influence of a drier airstream from the north, it became fine on 7th. The Red Fire Danger Warning was issued at 0000 HKT on 8th as dry conditions set in. Sunny weather prevailed during the next few days. Northerly winds strengthened on the morning of 11th but moderated later during the day. Cloudy weather returned with periods of light rain on 13th, prompting the rescinding of the Red Fire Danger Warning at 1800 HKT that day. Winds strengthened from the north again on 14th bringing along cooler air and light rain patches. Temperatures dropped to 13.8 °C that afternoon, the lowest in the month. Winds moderated the next day, but the dry conditions led to the issuance of another Red Fire Danger Warning at 0600 HKT on 15th. This remained in force until 2300 HKT on 17th. Apart from an interlude of sunny weather on 17th, it remained generally cloudy with rain during the following days. The rain was particularly heavy on 19th in the western part of the New Territories. Fine and sunny weather returned on 21st. Mist was reported over the western part of Hong Kong and temperatures at the Observatory rose to 25.7 °C, the highest in the month, on the winter solstice on 22nd. As dry conditions developed, a third Red Fire Danger Warning was issued at 1200 HKT and remained in effect for 24 hours. A hill fire occurred in Tseung Kwan O destroying about 400,000 square metres of trees on 23rd. Fine weather prevailed till the end of the month apart from periods of haze over the

western areas from 27th to 29th. Easterly winds strengthened briefly offshore early an 30th. During this time three Yellow Fire Danger Warnings were in force, from 0600 HKT on 25th to 0600 HKT on 28th, from 0600 to 1800 HKT on 30th, and from 1800 HKT on 31st until the end of the month.

Monthly Statistics

Extreme daily maximum temperature	25.7 ℃	(on 22 nd)
Mean daily maximum temperature	21.3 °C	(0.8 °C above normal)
Mean daily temperature	1 9. 1 ℃	(1.5 °C above normal)
Mean daily minimum temperature	17.4 ℃	(2.0 °C above normal)
Extreme daily minimum temperature	13.8 ℃	(on 14 th)
Total Rainfall (provisional)	13.7 mm	(50 % of normal)
Number of Days with ≥0.1 mm rain	6	(2.13 above normal)
Number of Days with ≥25.0 mm rain	0	(0.23 below normal)
Number of Days with ≥50.0 mm rain	0	(0.10 below normal)

January

January 1999 was warmer and much drier than normal. The mean temperature of 17.3 °C and the mean minimum temperature of 15.5 °C were the eighth and the seventh highest respectively on record for the month. The total rainfall in the month was 4.5 millimetres, only about one fifth of the normal amount. No tropical cyclone occurred over the western North Pacific and the South China Sea in January. The Strong Monsoon Signal was hoisted on only one occasion. One Gas Water Heater Safety Alert, five Yellow Fire Danger Warnings and two Red Fire Danger Warnings were issued during the month.

The year started cloudy with some light rain patches as winds freshened from the east. Winds subsided during the day and it soon became fine and sunny. Under the influence of a dry continental airstream, sunny and dry conditions prevailed until 9th. The Yellow Fire Danger Warning that had been issued at 1800 HKT on the last day of December was replaced by the Red Fire Danger Warning at 0640 HKT on 4th. It, in turn was replaced by the Yellow Fire Danger Warning at 0600 HKT on 9th when cloudy

returned. The weather remained cloudy with sunny intervals during the next couple of days. The Yellow Fire Danger Warning was rescinded at 0600 HKT on 11th. An intense surge of the winter monsoon brought cold and rainy weather to southern China on 12th with temperatures dropping to 10.3 °C, the lowest in the month. It remained generally cold with rain patches during the next few days. Temperatures in the northern part of the New Territories dropped to about 7 °C on 13th. A further replenishment of the winter monsoon reached the south China coastal areas on the afternoon of 14th, with winds strengthening from the north and bringing drier air to our region. The Strong Monsoon Signal was hoisted at 1530 HKT on 14th and remained so until 0445 HKT on 16th when winds moderated. The cold weather prompted the issuance of a Gas Water Heater Safety Alert which was in effect for six days from 1630 HKT on 11th until the same time on 17th. The dry conditions also resulted in the issuance of the Red Fire Danger Warning at 1430 HKT on 15th. This was replaced by the Yellow Fire Danger Warning, which remained in effect for 24 hours, at 0600 HKT on 17th. There were some light rain patches on 17th and 18th and haze affected local areas on 18th. Visibility was reduced to 1800 metres in the harbour and 1400 metres at Chek Lap Kok Airport the next day. Visibility improved significantly in the harbour on 20th, but low values of visibility down to 1100 metres were still experienced at the airport. There were light rain patches the following couple of days. Fog occurred in Chek Lap Kok on the morning of 23rd reducing visibility to 600 metres. Mist and haze lingered around the western part of Hong Kong during the next two days although it was fine and sunny elsewhere in the SAR. Winds freshened from the east on 26th and fine weather was generally experienced in Hong Kong. The Yellow Fire Danger Warning was in effect from 0625 to 1730 HKT on 27th. Temperatures climbed to 25.0 °C, the highest in the month, on 28th. A fresh northeast monsoon brought cloudy conditions and cooler air to local areas on 29th. As winds subsided, sunny periods developed during the last two days of the month. Another Yellow Fire Danger Warning was in effect from 0600 to 1800 HKT on 30th.

Monthly Statistics

Extreme daily maximum temperature	25.0 °C	(on 28 th)
Mean daily maximum temperature	19.6 ℃	(1.0 °C above normal)
Mean daily temperature	17.3 ℃	(1.5 °C above normal)
Mean daily minimum temperature	15.5 ℃	(1.9 °C above normal)
Extreme daily minimum temperature	3.5 ℃	(on 15 th)
Total Rainfall (provisional)	4.5 mm	(19 % of normal)

Number of Days with ≥ 0.1 mm rain 3 (2.63 below normal) Number of Days with ≥ 25.0 mm rain 0 (0.10 below normal) Number of Days with ≥ 50.0 mm rain 0 (normal)

February

February 1999 was very warm and dry with fine and sunny weather dominating the month. The mean temperature of 18.7 °C, 2.8 °C above normal, was the third highest on record for the month. The mean maximum and minimum temperatures of 21.2 °C and 16.5 °C respectively were both the fourth highest for February. Moreover, the mean temperature of 18.4 °C for the three winter months from December 1998 to February 1999 surpassed the highest record of 18.3 °C set for the same period in 1978-1979. The mean cloud amount of 40 percent was the third lowest for the month while the total sunshine duration reached 182.6 hours, more than twice the normal value of 84.9 hours, making it the seventh highest for February. The mean relative humidity of 67 percent was also the third lowest for the month. Only a trace of rainfall was recorded and this was the second lowest for February. Fire Danger Warnings were in force on 22 days of the month. There was one tropical cyclone over the western North Pacific and the South China Sea but it did not affect Hong Kong. The Strong Monsoon Signal was hoisted three times and two Gas Water Heater Safety Alerts were issued.

Apart from a cloudy start and a few light rain patches in the early hours, the weather was fine and warm on the first day of the month. A cold front passed the south China coast early on 2nd bringing a very dry northerly airstream to Hong Kong and strong winds affected coastal areas. The Strong Monsoon Signal was hoisted at 0800 HKT on 2nd and the Yellow Fire Danger Warning was issued at the same time. This was replaced by the Red Fire Danger Warning at 1430 HKT that afternoon. Two hours later a Gas Water Heater Safety Alert was also issued. Temperatures dropped to 12.2 °C, the lowest in the month, on 4th. It was much cooler in the New Territories and the minimum temperature at Ta Kwu Ling was 5.4 °C that morning. Winds moderated and turned to easterly, resulting in the lowering of the Strong Monsoon Signal at 0815 HKT on 4th. The Gas Water Heater Safety Alert was withdrawn at 1630 HKT that afternoon. Long sunny periods and dry weather persisted the next few days. The Yellow Fire Danger Warning replaced the Red at 0600 HKT on 7th and was rescinded at 1800 HKT on 8th. It was re-issued at 1400 HKT on 9th, on which day a hill fire broke out in Tseung Kwan O damaging a car. Cloud amount increased that evening as Hong Kong came under the influence of a maritime airstream. The clouds cleared again the next evening. Hazy and dry conditions retuned on 11th and visibility at the airport was reduced to 2000 metres. A hill fire broke out in the Castle Peak area that afternoon, affecting an area of 160,000 square metres and people nearby had to be

evacuated. A continental airstream reached the coast of Guangdong on the evening of 11th and winds freshened from the north. The Yellow Fire Danger Warning was changed to Red at 0600 HKT the next morning. Winds turned easterly late on 12th. Fine and sunny conditions prevailed until 17th when local areas once again came under the influence of a maritime airstream and cloud amount increased. The Red Fire Danger Warning was once again replaced by Yellow at 0600 HKT on 14th. A cold front crossed the south China coast on the evening of 18th. Winds were fresh from the north, occasionally strong off-shore. The Strong Monsoon Signal was hoisted for the second time in the month at 2245 HKT that evening and lowered at 1130 HKT on 19th as winds subsided. Although there were light rain patches on 19th, the Red Fire Danger Warning was substituted for the Yellow at 0600 HKT that morning. It was cloudy to overcast with cooler temperatures for the next two days while winds moderated gradually. A Gas Water Heater Safety Alert was issued between 2000 HKT on 20th and 1645 HKT on 21st. Sunny periods developed on 22nd and fine weather continued for the next couple of days. The Red Fire Danger Warning was rescinded at 1800 HKT on the evening of 22nd ending a continuous spell of 14 days when Fire Danger Warnings were in force. It was misty in the western areas on 24th and visibility was reduced to 1200 metres at the airport. Misty conditions affected the harbour the following day and it was mainly cloudy. The weather turned fine again later on 26th. Temperatures rose to 27.3 °C, the highest in the month, in the hazy afternoon of 27th. The Strong Monsoon Signal was hoisted at 2000 HKT as a cold front crossed the coast of Guangdong that evening and winds strengthened from the east accompanied by light rain patches. It was lowered at 0730 HKT the next morning. The weather became slightly cooler on 28th. The last Yellow Fire Danger Warning was also issued at 0600 HKT on the last day of the month and remained in force for 24 hours.

Monthly Statistics

Extreme daily maximum temperature	27.3 °C	(on 27 th)
Mean daily maximum temperature	21.2 ℃	(2.6 °C above normal)
Mean daily temperature	18.7 °C	(2.8 °C above normal)
Mean daily minimum temperature	16.5 ℃	(2.6 °C above normal)
Extreme daily minimum temperature	12.2 °C	(on 4 th)
Total Rainfall (provisional)	0.0 mm	(O % of normal)
Number of Days with ≥0.1 mm rain	0	(8.93 below normal)
Number of Days with ≥25.0 mm rain	0	(0.43 below normal)
Number of Days with ≥50.0 mm rain	0	(0.03 below normal)

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Review of Spring 1999

Important Climatological Events

The warm winter conditions of the winter continued into Spring 1999 with the seasonal mean temperature of 23.2 °C being 1.0 °C higher than the 1961-90 normal figure. Both March and April were very warm with mean temperatures of 20.4 °C and 24.3 °C being 1.9 °C and 2.1 °C higher than normal. May, however, broke the spell and was cooler than normal with a monthly mean temperature of 24.9 °C which was one degree below the 1961-90 normal value. Overall, the season recorded below normal rainfall with a total of 378.3 millimetres, some thirty percent less than usual. However, there was marked monthly variability in rainfall. The winter dearth of rain continued into March with a total of 23.6 millimetres of rainfall recorded, only 35 percent of normal rainfall. In April the monthly rainfall of 176.9 millimetres some 10 percent above normal although a trough of low pressure brought nearly half of that total on one This trough prompted the issuance of the Amber Rainstorm Warning for the first time in 1999. May was again much drier than usual with the month's total rainfall of 177.8 millimetres being only 56 percent of normal. During March, the anticyclone over China was relatively weak resulting in the recording of the lowest mean sea-level pressure in Hong Kong on record for March, 101.15 kilopascals. Two tropical cyclones occurred in the South China Sea and the western North Pacific Ocean during the season. One of these, Leo, significantly affected the weather of Hong Kong at the end of April and into May requiring the hoisting of the Strong Wind Signal No. 3 on 30th April, the first time that signal has been raised so early in the year. In early May it posed a major threat to Hong Kong and the Number 8 Northeast Gale or Storm Signal was hoisted on 2nd May, the earliest date on which a Number 8 signal has been hoisted since 1946. trough of low pressure brought heavy rain and thunderstorms on 19th May necessitating the issuance of the Amber Rainstorm Warning for the second time during the spring.

Seasonal statistics

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Rainfall (provisional)	378.3 mm	(69 %)
Extreme daily minimum temperature	12.7 °C	(on 22 nd March)
Mean daily minimum temperature	21.3 ℃	(1.1 °C above normal)
Mean daily temperature	23.2 °C	(1.0 °C above normal)
Mean daily maximum temperature	25.6 °C	(0.6 °C above normal)
Extreme daily maximum temperature	31.5 °C	(on 17 th May)

Number of Days with ≥0.1 mm rain	43	(6.87 above normal)	
Number of Days with ≥25.0 mm rain	5	(1.20 below normal)	
Number of Days with ≥50.0 mm rain	2	(1.17 below normal)	

March

March 1999 was very warm with both the mean temperature of 20.4 °C and the mean minimum temperature of 18.4 °C being the sixth highest for the month. During the month of March, the anticyclone over China was relatively weak. In Hong Kong, the mean sea-level pressure was 101.15 kilopascals, the lowest on record for March. The month was also very dry with a total of 23.6 millimetres of rainfall recorded, only 35 percent of normal rainfall. No tropical cyclone occurred over the western North Pacific and the South China Sea in the month. The Strong Monsoon Signal was hoisted on four occasions. Three Thunderstorm Warnings and two Yellow Fire Danger Warnings were issued.

Under the influence of a dry winter monsoon, it was fine and sunny during the first few days of the month. Nevertheless, the Yellow Fire Danger Warning issued on the last day of February was rescinded at 0600 HKT on 1st. A humid airstream affected the south China coastal areas on 6th and visibility deteriorated. Two cargo vessels were reported to have collided in fog, with one of them sinking, killing two crewmen. Five others were reported missing. A cold front crossed the coast of Guangdong early on 8th. The Strong Monsoon Signal was hoisted for 24 hours between 0445 HKT on 8th and the same time on 9th as winds strengthened from the east. The weather became gloomy and misty with periods of rain. These damp conditions prevailed for the next couple of days although winds gradually moderated. Another cold front reached the coastal areas on the evening of 10th and the Strong Monsoon Signals was hoisted again at 2215 HKT. The fresh to strong northerly winds brought the temperatures down as well as cleared the mist. Winds subsided the next morning and the Strong Monsoon Signal was lowered at 0950 HKT on 11th. It was misty again the following day when a 300-tonne cargo vessel sank off the Kwo Chau Islands. Six crewmen were killed and two others reported missing. Visibility remained poor in mist and rain during the next couple of days. The weather improved temporarily on 15th prompting the issuance of a Yellow Fire Danger Warning from 0600 to 1800 HKT that day although it remained mainly cloudy. A Thunderstorm Warning was issued between 1125 and 1325 HKT on 16th although only light rain occurred. Sunny intervals were reported in the next few days, although a Thunderstorm Warning was issued again from 1520 to 1830 HKT on 17th. Under the influence of a maritime airstream, fog affected the coastal areas again on the evening of 20th. Visibility improved significantly on 21st, due to the fresh northerly winds brought about by the passage of a cold front the previous evening. On the morning of 22nd, winds became occasionally strong offshore and the Strong Monsoon Signal was hoisted

for the third time at 0145 HKT. It was lowered again at 0700 HKT as winds moderated. Temperatures dropped to 12.7 °C, the lowest in the month. Misty and rainy weather returned on 23rd. Fog spread inside the harbour on 25th, reducing the visibility to 100 metres at Waglan Island that morning. Two cargo vessels collided off the East Lamma Channel that evening. Under the influence of this warm maritime airstream, temperatures rose to 29.5 °C on 27th, the highest in the month. Another cold front crossed the coast of Guangdong late on the evening of 27th. It was accompanied by rain which was heavy in Shatin. The Strong Monsoon Signal was hoisted at 2315 HKT that night as winds strengthened from the east. Strong winds persisted until the morning of 29th when the signal was lowered at 0945 HKT. A dry northerly airstream cleared the clouds on 30th and it became mainly fine and sunny during the last two days of the month.

Monthly Statistics

Extreme daily maximum temperature	29.5 °C	(on 27 th)
Mean daily maximum temperature	22.7 ℃	(1.4 °C above normal)
Mean daily temperature	20.4 °C	(1.9 °C above normal)
Mean daily minimum temperature	18.4 °C	(1.9 °C above normal)
Extreme daily minimum temperature	12.7 ℃	(on 22 nd)
Total Rainfall (provisional)	23.6 mm	(35 % of normal)
Number of Days with ≥0.1 mm rain	14	(3.93 above normal)
Number of Days with ≥25.0 mm rain	0	(0.60 below normal)
Number of Days with ≥50.0 mm rain	0	(0.27 below normal)

April

April 1999 was very warm with a mean temperature of 24.3 °C, the third highest for the month. The mean minimum and mean maximum temperatures of 22.4 and 26.9 °C were the third and sixth highest respectively for the month. It was also relatively dry with the mean relative humidity of 79 percent, the fourth lowest for the month. Although the monthly rainfall of 176.9 millimetres was only 10 percent above normal, the first Amber Rainstorm Signal of the year was issued on 12th as a trough of low pressure brought nearly half of that total. Two tropical cyclones, Kate and Leo occurred

in the South China Sea and the western North Pacific in the month. One of these, Leo, significantly affected the weather of Hong Kong at the end of the month and into May. The first Tropical Cyclone Warning Signal of the year was hoisted on 29th. The Strong Wind Signal No. 3 was hoisted on 30th the first time that signal has been raised so early in the year. The Strong Monsoon Signal was hoisted twice during the month. Four Thunderstorm Warnings and two Fire Danger Warnings were also issued.

It was mainly fine during the first two days of April though there were also a few light rain patches. The Yellow Fire Danger Warning was issued at 0600 HKT on 2nd. Winds strengthened from the east as a cold front crossed the coast of Guangdong late that evening. The Strong Monsoon Signal was hoisted at 2345 HKT and was lowered at 1600 HKT on 3rd as winds moderated gradually that day. However, the cloudy weather prevailed for a few more days until long sunny periods developed on 5th as Hong Kong came under the influence of a dry continental airstream. The Yellow Fire Danger Warning was replaced by Red at 0600 HKT on 6th as the fire risk became extreme. During the Easter Holidays and Ching Ming Festival, about 880 hectares of vegetation and 5,400 trees were burnt in hill fires. There were 475 cases of hill fire from 4th to 7th. Cloudy weather with light rain patches returned later on 8th and the Red Fire Danger Warning was rescinded at 1400 HKT that afternoon. Cloudy conditions then persisted over the next few days. It turned fine again with long sunny periods on 10th but cloudy weather with rain again returned the next day. Thunderstorms and heavy rain associated with a trough of low pressure affected Hong Kong early on 12th, and a Thunderstorm Warning was in effect from 0030 to 0830 HKT. The first Amber Rainstorm Warning of 1999 was issued at 0115 HKT and remained in force until 0800 HKT on 12th. Rain was heaviest over Hong Kong Island and eastern Lantau Island where over 80 millimetres of rainfall were recorded. A minor landslip occurred in Lai King. The weather was fine and sunny on 13th but it became cloudy with some light rain patches again that evening as an intense replenishment of the northeast monsoon reached the south China coastal areas. Winds strengthened from the east and persisted the next day prompting the hoisting of the Strong Monsoon Signal at 1530 HKT that afternoon. The weather improved on 15th and winds moderated and the signal was lowered at 0830 HKT that morning. Isolated showers developed on 17th especially over the New Territories. A trough of low pressure crossed the south China coast early on 19th bringing thunderstorms and heavy rain to Hong Kong. The Thunderstorm Warning was in effect from 2330 HKT on 18th until 1330 HKT the following afternoon. About 30 millimetres of rain were recorded in eastern areas of the SAR. Rain became widespread on the evening of 21st. The weather improved the next day with long sunny periods. Temperatures rose to 31.1 °C on 23rd, the highest recorded in the month. Under the influence of a maritime airstream, isolated heavy showers affected the northeastern part of the New Territories on 24th. Thunderstorm Warnings were in effect from 0735 to 0935 HKT and again from 1025 to 2025 HKT that day. The weather improved with long sunny periods on 25th although there was some light rain. Winds freshened from the east on the evening of 26th and it turned cloudy with some showers again. A tropical depression named Leo developed about 170 km

southwest of Xisha Dao on 28th. Tracking northeastwards over the South China Sea, Leo intensified into a tropical storm that afternoon as it moved closer to approach Hong Kong. The Standby Signal No. 1 was hoisted at 0940 HKT on 29th when Leo was about 600 km to the south-southwest and the outer rainbands began to affect the coastal areas on 29th. This was the first tropical cyclone warning signal of the year. It was cloudy to overcast with heavy rain at times and offshore winds became strong. Leo intensified into a typhoon on 30th. Under the combined effect of Leo and the northeast monsoon, winds were strong offshore and on high ground and sea conditions also became rough. The Strong Wind Signal No. 3 was hoisted at 1615 HKT on 30th, the earliest date on record for the hoisting of that signal. The weather remained cloudy to overcast with periods of rain on that day as Leo continued to pose a threat to Hong Kong. Temperatures also dropped to the lowest value recorded in the month, 18.3 °C, in the morning. Outside Hong Kong, high waves associated with Leo caused a vessel to sink about 275 km off Waglan Island on the last day of the month. One sailor drowned, 13 were reported missing and another seven were rescued in the raging sea.

Monthly Statistics

Extreme daily maximum temperature	31.1 ℃	(on 23 rd)
Mean daily maximum temperature	26.9 ℃	(2.0 °C above normal)
Mean daily temperature	24.3 °C	(2.1 °C above normal)
Mean daily minimum temperature	22.4 °C	(2.2 °C above normal)
Extreme daily minimum temperature	18.3 ℃	(on 30 th)
Total Rainfall (provisional)	176.9 mm	(110 % of normal)
Number of Days with ≥0.1 mm rain	12	(0.87 above normal)
Number of Days with ≥25.0 mm rain	2	(0.20 below normal)
Number of Days with ≥50.0 mm rain	2	(1.03 above normal)

May

May was cooler and drier than usual. The monthly mean temperature of 24.9 °C was one degree below normal while the month's total rainfall of 177.8 millimetres was only 56 percent of normal. Only one tropical cyclone, Typhoon Leo, occurred in the South China Sea and the western North Pacific in the month. It posed a major threat to Hong Kong in the early part of the month. The Number 8 Northeast Gale or Storm

Signal was hoisted for the first time in 1999 on 2nd, the earliest date on which a Number 8 signal has been hoisted since 1946. The Amber Rainstorm Warning was issued for the second time in the year on 19th as a trough of low pressure brought heavy rain and thunderstorms. All together, six Thunderstorm Warnings were issued during May.

During the first two days of the month Hong Kong was under the threat of Typhoon Leo, a tropical depression which developed about 170 km southwest of Xisha Dao on 28th April, and intensified into a typhoon on 30th April. Leo started to weaken on the first day of the month while moving towards the coastal waters of Guangdong. However, the storm continued to approach Hong Kong on a northwestward course and continued to pose a threat to Hong Kong during the next two days. With winds increasing and reaching gale force at Waglan Island in the morning of 2nd and with Leo being a well-organized tropical cyclone which was expected to come very close to Hong Kong, the No. 8 Northeast Gale or Storm Signal was hoisted at 1330 HKT that day. This was the earliest No. 8 signal displayed since 1946. The weather was cloudy with periods of rain. Strong northerly winds affected most parts of Hong Kong, reaching gale force offshore and on high ground. Maximum hourly wind of 90 kmh⁻¹ and maximum gust of 130 kmh⁻¹ were recorded at Waglan Island on 2nd. The lowest hourly sea-level pressure of 100.47 kPa was recorded at the Hong Kong Observatory headquarters at 1700 HKT when Leo was about 45 km to the east-southeast and at its closest to Hong Kong. However, Leo began to turn northeast and move away from Hong Kong at this time and the No. 8 Signal was thus replaced by the Strong Wind Signal No. 3 at 1730 HKT. Leo continued to weaken and move further away during the evening and became an area of low pressure that night making landfall near Daya Bay. All tropical cyclone warning signals were lowered at 2045 HKT on 2nd. During the passage of Leo, three men got into trouble in heavy seas but were all rescued. Slippery roads also caused 13 injuries in three separate traffic accidents. Most ferry services were suspended and two flights were cancelled. Shark prevention nets at five beaches in Hong Kong Island were severely damaged by rough seas. As Leo dissipated over land, winds subsided rapidly and the weather improved the next day with plenty of sunshine. A trough of low pressure crossed the south China coast on 4th, bringing rainy weather to the coastal areas during the next couple of days. It was overcast with occasional heavy rain and isolated thunderstorms on the morning of 5th. A Thunderstorm Warning was in effect for 3 hours from 1000 to 1300 HKT that day. A northeast monsoon reached the south China coastal areas on 6th. As winds freshened from the northeast, there was continual rain and temperatures fell to 17.0 °C, the lowest in the month, late in the afternoon. This was the fourth lowest daily minimum temperature recorded in May. It remained cloudy to overcast with periods of rain during the next few days. A dry continental airstream brought fine weather to southern China on 10th, and generally fine weather persisted for the next few days. It became progressively warmer as a maritime airstream began to affect the south China coastal areas on 15th and there were some isolated showers. The maximum temperature rose to 31.5 °C on 17th. A trough of low pressure crossing the south China coast on 18th brought heavy rain and

thunderstorms to Hong Kong. A Thunderstorm Warning was issued from 1530 to 1930 HKT on 18th and again the next day, from 0100 to 1500 HKT. The Amber Rainstorm Warning was also in effect from 0440 to 1345 HKT on 19th. Under the influence of the fresh easterly airstream behind the trough, the weather remained generally cloudy with some rain for the next couple of days. Temperatures varied within only a few degrees during this period. The easterly winds were replaced by a maritime southeasterly airflow on 22nd which brought patches of rain in the morning. The weather became fine with abundant sunshine the next day. It turned cloudy again on 24th with a few isolated showers. Hong Kong came under the influence of a trough of low pressure over Guangdong from 25th onwards. The weather was cloudy with showers which were heavy and thundery on the early morning of 25th. Thunderstorm Warnings were issued between 0100 and 0700 HKT that day, and again from 1955 HKT on 26th to 0730 HKT on 27th as the trough crossed the south China coast bringing more heavy showers. It remained cloudy to overcast with a few isolated showers during the next couple of days. The weather became fine and sunny on the last day of the month.

Monthly Statistics

Extreme daily maximum temperature	31.5 ℃	(on 17 th)
Mean daily maximum temperature	27.2 °C	(1.5 °C below normal)
Mean daily temperature	24.9 °C	(1.0 °C below normal)
Mean daily minimum temperature	23.1 °C	(0.8 °C below normal)
Extreme daily minimum temperature	17.0 ℃	(on 6 th)
Total Rainfall (provisional)	177.8mm	(56 % of normal)
Number of Days with ≥0.1 mm rain	17	(2.07 above normal)
Number of Days with ≥25.0 mm rain	3	(0.40 below normal)
Number of Days with ≥50.0 mm rain	0	(1.93 below normal)

Review of Summer 1999

Important Climatological Events

Summer 1999 was somewhat warmer and wetter than normal with a mean daily temperature of 28.8 °C, 0.5 °C above normal and a total seasonal rainfall of 1293.2 millimetres, 19 percent above normal. However, there was considerable variation with June recording a monthly mean temperature of 28.9 °C making it the warmest June since records began in 1884. July was also warmer than normal with a mean temperature of 29.2 °C. On the other hand, August posted near normal temperatures. Although a southerly airstream persisted over the south China coast in June the month was much drier than normal with the monthly total rainfall of 197.4 millimetres being 178.6 millimetres less than the 1961-90 normal figure. The mean relative humidity of 79 percent was the third lowest recorded for June. Cloudy conditions and showery weather dominated during July and there were only four days on which no rainfall was recorded. Nonetheless, total rainfall during the month was only 203.8 millimetres, 119.7 millimetres less than the normal figure. The mean amount of cloud reached 82 percent making it the cloudiest July on record. Consequently, the total bright sunshine duration was 73.1 hours below normal. In marked contrast to lune and luly, August 1999 was very wet with the total monthly rainfall of 892.0 millimetres being the second highest for August. Like July the month was also cloudier than normal with the mean cloud amount of 80 percent being the fourth highest for the month. The total bright sunshine duration was only 138.5 hours, the fifth lowest for August. Although 13 tropical cyclones occurred in the South China Sea and the western North Pacific Ocean during the season, only three necessitated the hoisting of Tropical Cyclone Signals in Hong Kong, one in each month. The Increasing Gale or Storm Signal Number 9 was hoisted on 7th June during the passage of Typhoon Maggie. The approach of one tropical storm required the hoisting of the Strong Wind Signal No. 3 on 26th July. Typhoon Sam crossed the northeastern part of the New Territories on 22nd August and necessitated the hoisting of Gale or Storm Signal No. 8. Heavy rain also led to the issuance of the Black Rainstorm Warning Signal on 23rd and 24th August.

Seasonal statistics

Extreme daily maximum temperature	35.1 °C	(on 21st August)
Mean daily maximum temperature	31.3 ℃	(0.3 °C above normal)
Mean daily temperature	28.8 °C	(0.5 °C above normal)
Mean daily minimum temperature	26.7 ℃	(0.4 °C above normal)
Extreme daily minimum temperature	23.7 °C	(on 23 rd August)

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Rainfall (provisional)	1293.2 mm (119 %)		
Number of Days with ≥0.1 mm rain	58	(4.00 above normal)	
Number of Days with ≥25.0 mm rain	14	(1.14 above normal)	
Number of Days with ≥50.0 mm rain	6	(0.11 below normal)	

June

June 1999, which posted a monthly mean temperature of 28.9 °C was the warmest June since records began in 1884. The mean maximum temperature of 31.5 °C and the mean minimum temperature of 26.8 °C were the third and the fifth highest respectively for the month. The month was characterized by the persistence of a southerly airstream over the south China coast. Nevertheless, the monthly total rainfall of 197.4 millimetres was 178.6 millimetres below normal. Furthermore, the mean relative humidity of 79 percent was the third lowest for the month. One tropical cyclone, Typhoon Maggie, occurred in the South China Sea and the western North Pacific in the month. The Increasing Gale or Storm Signal Number 9 was hoisted on 7th during the passage of Typhoon Maggie. The Strong Monsoon Signal was hoisted once during the month. Amber Rainstorm Warnings were issued on four occasions and there was a total of twelve Thunderstorm Warnings during the month.

The weather was fine and hot the first four days of June with only the month a few isolated showers. In the early morning of 2nd a tropical depression formed over the western North Pacific about 1,070 km east-southeast of Manila and followed a northwesterly track as it intensified rapidly attaining typhoon strength on 4th. The storm named Maggie moved across the Bashi Channel into the South China Sea on 6th and headed westward towards the south China coast. Locally, the weather turned hazy on 5th and 6th as Maggie moved closer to Hong Kong. The Standby Signal No.1 was hoisted at 2345 HKT on 5th when the typhoon was about 800 km to the eastsoutheast. As Maggie moved closer, local winds strengthened from the north and the Strong Wind Signal No. 3 was hoisted at 1415 HKT on 6th. It was very hot that afternoon with the maximum temperature reaching 33.4 °C, the highest in the month. The continued approach of Maggie led to the hoisting of the No.8 Northwest Gale or Storm Signal at 0030 on 7th. With the imminent landfall of Maggie over the eastern part of the SAR the winds continued to strengthen in the early hours and the Increasing Gale or Storm Signal No. 9 was hoisted at 0245 HKT. Typhoon Maggie made landfall over the Sai Kung Peninsula around 0315 HKT on 7th and traversed the New Territories in a northeast to southwest direction at about 30 km h⁻¹. Many areas experienced gale or storm force winds and heavy rain during this time. An Amber Rainstorm Warning was in effect from 0320 HKT to 1035 HKT during the passage of Maggie. A maximum hourly wind of 88 km h⁻¹ and a maximum gust of 142 km h⁻¹ were recorded at Tai Mo Shan while a maximum hourly wind of 77 km h⁻¹ and a

maximum gust of 137 km h⁻¹ were recorded at Sha Lo Wan. There was a temporary lull in winds and a sharp drop in pressure near the centre as the eye passed by. The lowest instantaneous mean sea-level pressure recorded at Shatin was 97.71 kPa and at the Hong Kong Observatory, 98.08 kPa. As Maggie moved westward to the coastal waters of western Guangdong local winds turned easterly to northeasterly and the No. 9 signal was replaced by the No 8 Northeast Gale or Storm Signal at 0545 HKT on 7th. The weather became overcast with continuing heavy showers and as the storm continued to move away during the morning, winds began to subside and the No. 8 signal was replaced by Strong Wind Signal No. 3 at 1015 HKT. All tropical cyclone signals were lowered at 1445 HKT. Generally there was little disruption although at least 5 people were injured. In the afternoon Maggie began a counter-clockwise loop off Shangchuan Dao. Its re-intensification and slow eastward movement in the evening brought strong south to southeast winds to Hong Kong. As a result the Standby Signal No 1 was hoisted again at 2230 HKT. As winds became stronger the Strong Wind Signal No. 3 was hoisted at 0045 HKT on 8th. Winds over Hong Kong remained strong until around midday despite Maggie having made landfall during the morning. All tropical cyclone warning signals were lowered at 1345 HKT as Maggie dissipated over inland Guangdong in the afternoon. Sunny weather returned on 9th although there were still isolated showers. A few isolated thunderstorms the next morning resulted in the issuance of a Thunderstorm Warning from 0315 to 0745 HKT on 10th. Generally fine and hot weather then persisted until 14th. It became cloudy with isolated showers for the next couple of days. Under the influence of an unstable southerly airstream, isolated thunderstorms occurred on the morning of 17th. A Thunderstorm Warning was in effect from 0545 to 1145 HKT that day. Temperatures dropped to 25.0 °C in thundery showers, the lowest in the month. There were again isolated thunderstorms the next day, resulting in three separate Thunderstorm Warnings, from 0907 to 1107 HKT, from 1410 to 1510 HKT, and again from 2300 HKT until 0900 HKT the following morning. A trough of low pressure formed over southern China and crossed the coast early on 19th bringing showers to local areas. Hong Kong came under the influence of an unstable southerly airstream over the next few days and there were occasional heavy thundery showers on 20th and 21st. Thunderstorm Warnings were issued between 0115 and 0615 HKT and between 1005 and 1500 HKT on 20th. The next day saw the issuance of two more Thunderstorm Warnings which were in effect between 0325 and 1130 HKT and between 2255 HKT and 0655 HKT on the morning of 22nd. Over 80 millimetres of rainfall were recorded over the southwestern part of Hong Kong Island on the morning of 21st. It remained cloudy with isolated thunderstorms on 22nd, and a Thunderstorm Warning was again issued from 0925 to 1025 HKT that morning. A fresh southwest monsoon brought strong winds and further isolated thunderstorms to Hong Kong the next day. The Strong Monsoon Signal was hoisted from 1030 to 2145 HKT on 23rd. Two Thunderstorm Warnings were issued on that day, from 0632 to 0832 HKT and from 1230 to 1615 HKT. monsoon moderated in the evening but cloudiness persisted with isolated showers the It turned fine and sunny on 25th and fine weather prevailed for the rest of the month apart from some isolated showers.

Monthly Statistics

Extreme daily maximum temperature	33.4 °C	(on 6 th)
Mean daily maximum temperature	31.5 ℃	(1.2 °C above normal)
Mean daily temperature	28.9 ℃	(1.1 °C above normal)
Mean daily minimum temperature	26.8 °C	(0.9 °C above normal)
Extreme daily minimum temperature	25.0 °C	(on 17 th)
Total Rainfall (provisional)	197.4mm	(53 % of normal)
Number of Days with ≥0.1 mm rain	16	(3.23 below normal)
Number of Days with ≥25.0 mm rain	2	(2.23 below normal)
Number of Days with ≥50.0 mm rain	2	(0.03 above normal)

July

July 1999 was warmer than normal. The mean temperature of 29.2 °C ranked the sixth highest for the month and the mean minimum temperature of 27.2 °C was the fifth highest for July. On the other hand, it was the cloudiest July with the mean amount of cloud reaching 82 percent. Consequently, the total bright sunshine duration of 158 hours was 73.1 hours below normal. The month was characterized by showery weather and there were only four days on which no rainfall was recorded. However, the total rainfall amounted to 203.8 millimetres only, 119.7 millimetres below the normal figure. Five tropical cyclones occurred in the South China Sea and the western North Pacific in the month. The approach of one tropical storm necessitated the hoisting of the Strong Wind Signal No. 3 on 26th. The Amber Rainstorm Warning Signal was issued on two occasions. Thunderstorm Warnings were issued on 17 occasions.

The weather was sunny apart from a few showers during the first two days of the month. It became cloudier on 3rd and showery activity persisted the next few days. It became thundery with heavy and squally showers on the morning of 8th. Temperatures dropped to 23.8 °C in heavy showers, the lowest in the month. Heavy and thundery showers persisted the next day especially in Shatin and Sai Kung but it became brighter in the afternoon. Sunny periods developed on 10th although there were still one or two isolated showers. Generally fine weather prevailed on 11th and 12th. A trough of low pressure in south China brought unsettled weather to the coast and heavy thunderstorms affected Hong Kong early on 13th. It remained cloudy with a

few showers the next few days but there were also sunny periods. Showery activities weakened on 18th and the weather turned mainly sunny the next day. The fine weather persisted the next few days until thundery showers occurred again on 22nd and 23rd. However, sunny conditions on 24th brought the temperature up to 33.7 °C in the afternoon, the highest in the month. An area of low pressure developed into a tropical depression about 500 km south-southwest of Hong Kong on 25th. It drifted slowly at first but began moving northeastwards. In Hong Kong the Standby Signal No.1 was hoisted at 1145 HKT on 25th when the tropical depression was about 470 km to the south-southwest. Winds locally freshened from the east to northeast with occasional strong winds offshore and on high ground, but the weather remained fine during the day. Squally showers began to affect Hong Kong that evening as the outer rainbands of the tropical depression affected the SAR. As the tropical depression intensified into a tropical storm over the northern part of the South China Sea on 26th, local winds strengthened and sea conditions became rough. The rain became heavier and more frequent during the day as the tropical depression moved closer to Hong Kong. The lowest hourly sea-level pressure of 99.32 kPa was recorded at the Hong Kong Observatory Headquarters at 1700 HKT on 26th. The tropical storm continued to move towards the south China coast and with winds over Hong Kong expected to strengthen generally, the Strong Wind Signal No. 3 was hoisted at 2245 HKT that evening. Locally, winds turned fresh to strong northerly. The closest approach of this tropical storm was about 120 km to the southeast of Hong Kong at around 0400 HKT on 27th. It then continued to move towards the northeast, weakened into a tropical depression in the afternoon, and made landfall near Shantou, dissipating over land. Although strong winds affected Hong Kong early on 27th, they subsided in the afternoon as the tropical storm moved away. As local winds subsided, all tropical cyclone warning signals were lowered at 1345 HKT. Locally, 18 swimmers were injured in rough seas, but no significant damage was reported. The weather remained mainly cloudy to overcast with light showers during the day. Hong Kong came under the influence of a southwesterly airstream on 28th. The weather became fine with long sunny periods the next day as winds turned to easterly. This fine weather persisted until the last day of the month when some isolated showers returned.

Monthly Statistics

Extreme daily maximum temperature	33.7 ℃	(on 24 th)
Mean daily maximum temperature	31.6 ℃	(0.1 °C above normal)
Mean daily temperature	29.2 °C	(0.4 °C above normal)
Mean daily minimum temperature	27.2 °C	(0.6 °C above normal)
Extreme daily minimum temperature	23.8 °C	(on 8 th)

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Total Rainfall (provisional)	203.8 mm	(63 % of normal)
Number of Days with ≥0.1 mm rain	22	(4.53 above normal)
Number of Days with ≥25.0 mm rain	3	(0.93 below normal)
Number of Days with ≥50.0 mm rain	0	(1.97 below normal)

August

August 1999 was very wet. The total monthly rainfall amounted to 892.0 millimetres and was the second highest for August. August was also cloudier than normal. The mean cloud amount stood at 80 percent and was the fourth highest for the month. The total bright sunshine duration was only 138.5 hours, the fifth lowest for August. Seven tropical cyclones occurred in the South China Sea and the western North Pacific in the month. Only, one, Typhoon Sam, affected Hong Kong as it crossed the northeastern part of the New Territories on 22nd and necessitated the hoisting of Gale or Storm Signal No. 8. The Black Rainstorm Warning Signal was issued on 23rd and 24th and the Landslip Warning was also issued on 22nd and 25th.

The weather was fine and sunny on the first day of the month. Under the influence of an area of low pressure over the northern part of the South China Sea, the weather turned cloudy with some isolated heavy showers on 2nd. Showers became thundery on 3rd although sunny intervals also managed to appear. Over 100 millimetres of rainfall were recorded in Tseung Kwan O and Cheung Sha Wan on 4th and 5th respectively. There were 15 reports of flooding in Kowloon and the New Territories on the latter day. It remained cloudy with isolated heavy or thundery showers for the next couple of days. The low pressure area developed into Tropical Depression Rachei on 6th and moved towards Taiwan without further affecting Hong Kong. As the southwest monsoon became established over the northern part of the South China Sea on 8th, unsettled weather continued to affect Hong Kong and there were isolated heavy showers over Lantau Island. Showers were heavy or thundery again from 9th till 14th and a minor landslip occurred in Cha Kwo Ling on 12th. Fine weather eventually prevailed on 15th when a ridge of high pressure extended westwards to cover southeastern China. It was hot on 16th. Fine and sunny weather persisted for the next few days. A tropical depression developed about 680 km east-northeast of Manila on 19th. It tracked westnorthwestwards over the Pacific Ocean and intensified into a tropical storm named Sam that night. It was hazy on 20th as Sam swept across the northern part of Luzon. In Hong Kong the Standby Signal No. 1 was hoisted at 1615 HKT that afternoon when Sam was about 800 km to the east-southeast. Upon entering the South China Sea, Sam intensified on 21st and moved northwestwards towards the coast of Guangdong. As Sam approached Hong Kong from the southeast, the weather that day was fine and very hot with haze at first. The maximum temperature of 35.1°C recorded in the afternoon was the highest since 1990, the highest for the month and the highest recorded in

1999. Showers began to set in from the late afternoon of 21st as Hong Kong came under the influence of the first of Sam's outer rainbands. Winds freshened from the north that evening and became strong early next morning. With Sam moving closer to Hong Kong and winds becoming strong offshore and on high ground, the Strong Wind Signal No. 3 was hoisted at 0230 HKT on 22nd. Sam attained typhoon strength later that morning and local winds reached gale force at Waglan Island and Cheung Chau. The No. 8 Northwest Gale or Storm Signal was hoisted at 1230 HKT. Sam was the third tropical cyclone necessitating the hoisting of No. 8 or higher signals in 1999. The last time that No. 8 or higher signals had to be hoisted on three separate occasions between January and August was in 1971. Heavy rain began to buffet the territory on the afternoon of 22nd and gale force winds from the northwest affected the western areas of Hong Kong. After weakening, Sam made landfall over the eastern part of Sai Kung at around 1800 HKT in the evening. Sam was closest to the Hong Kong Observatory Headquarters at around 1815 HKT when it was about 25 km to the northeast. Following landfall Sam traversed the northeastern part of the New Territories at a speed of about 25 km/h and crossed into Shenzhen. During the passage of Sam, a maximum hourly wind of 52 km h⁻¹ and a maximum gust of 115 km h⁻¹ were recorded at Tap Mun on 22nd. At Waglan Island, a maximum hourly wind of 96 km h⁻¹ and a maximum gust of 148 km h⁻¹ were recorded on the same day. As Sam moved into Shenzhen and entered the Zhujiang Estuary, local winds began to turn southwesterly and the No. 8 Southwest Gale or Storm Signal was hoisted at 2010 HKT on 22nd. After crossing the Zhujiang Estuary, Sam gradually weakened further into an area of low pressure over inland Guangdong early on 23rd. With Sam moving gradually away and weakening, the No. 8 Signal was replaced by the Strong Wind Signal No. 3 at 0350 HKT on 23rd and all tropical cyclone warning signals were lowered at 0900HKT that morning. Although winds moderated gusts occasionally reached gale force and the southwesterly flow trailing in the wake of Sam continued to bring heavy rain to Hong Kong. The Black Rainstorm Warning Signal was issued at O613 HKT on 23rd and was replaced by the Amber Rainstorm Warning Signal at noon. Temperatures dropped to 23.7 °C the lowest in the month, in heavy showers on 23rd. The Black Rainstorm Warning Signal was raised again on 24th and in force between 0435 and 1000 HKT. A total of 609.4 millimetres of rainfall was recorded from 22nd to 25th. The tropical cyclone rainfall, defined as the total rainfall recorded at the Hong Kong Observatory from the time when a tropical cyclone was centred within 600 km of Hong Kong to 72 hours after the tropical cyclone has dissipated or moved outside 600 km of Hong Kong, brought by Sam amounted to 616.5 mm. This exceeded the previous record of 597.0 mm brought by a tropical cyclone in 1926 and gave Sam the accolade of being the wettest tropical cyclone to affect Hong Kong since records began in 1884. Considerable damage was inflicted on Hong Kong by Sam and the rainstorms that followed in its wake. An accident occurred while an aircraft was trying to land at the airport at Chek Lap Kok airport in the evening of 22nd. Three passengers were killed and more than 200 injured in the incident. Over 360 other flights were delayed or cancelled in the following few days. More than 100 people suffered minor injuries in various storm related accidents. The heavy rain resulted in 310 cases of flooding and

200 cases of landslides in various parts of Hong Kong. The most severe flooding occurred in the northern New Territories where floodwaters two metres in depth were reported. In Sham Tseng San Tsuen, one man was buried alive and 28 others were injured in a landslide on 23 August. In Tin Wan in Aberdeen, 30 stores were swamped by mudflow. Sunny periods developed at last on 26th as a ridge of high pressure became established over southeastern China. It remained fine the next day. The weather turned cloudy with heavy showers and thunderstorms on 28th. Showers eased off on 30th and there were sunny periods. It remained cloudy with sunny periods apart from isolated thundery showers on the last day of the month.

Monthly Statistics

Extreme daily maximum temperature	35.1 ℃	(on 21 st)
Mean daily maximum temperature	30.8 °C	(0.5 °C below normal)
Mean daily temperature	28.3 ℃	(0.1 °C below normal)
Mean daily minimum temperature	26.2 ℃	(0.1 °C below normal)
Extreme daily minimum temperature	23.7 ℃	(on 23 ^{trd})
Total Rainfall (provisional)	892.0 mm	(228 % of normal)
Number of Days with ≥0.1 mm rain	20	(2.70 above normal)
Number of Days with ≥25.0 mm rain	9	(4.30 above normal)
Number of Days with ≥50.0 mm rain	4	(1.83 above normal)

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