香港天文台
HONG KONG OBSERVATORY

Reprint 416

Tropical Cyclone Warning System in Hong Kong

C.Y. Lam

Regional Technical Conference

on Tropical Cyclones and Storm Surges,

Chiang Mai, Thailand, 13-17 November 2000

Reprint 416

Tropical Cyclone Warning System in Hong Kong

C Y Lam
Hong Kong Observatory

1. Introduction

1.1 A tropical cyclone warning system is more than just a set of definitions of different "warning status" or warning criteria. It includes the means to communicate essential information to its intended audience, enabling them to take appropriate corrective actions to avoid danger or to minimize loss and damage. The form a warning system takes depends on the state of the meteorological science, the means of communication available, the physical environment including dwellings and transport infrastructure and most importantly on the expectations of the society (fig. 1).

1.2 While meteorologists would evaluate their own performance by how accurate the movement of tropical cyclones is predicted, the ultimate measure of the success of a tropical cyclone warning system is whether it meets the needs of the community it serves. This is more a matter of perception. Meteorologists as a service provider could not afford to ignore this aspect when operating a warning system.

1.3 The tropical cyclone warning system in Hong Kong has been in existence since 1884. It has evolved with time, adjusting itself to changing needs and availing itself to emerging technologies. This evolution is sketched below to illustrate how various factors have interplayed to determine the form of the warning system at the time. Hopefully this would provide food for thought for fellow meteorologists when reflecting on how their warning systems fit with the circumstances in their own country.

2. The Early Years up to 1950's

2.1 The Hong Kong Observatory (HKO) established its first tropical cyclone warning system in 1884, which was aimed at giving information to the mariners in port. A system of visual signals viz. drum, ball and cone gave indications of the existence and approximate location of a tropical cyclone. It was modified into a numbered signal system in 1917, to give warnings to the local public of wind conditions in Hong Kong. Various changes were made from time to time. By 1973, it settled down into the pattern still in use today (Table 1).

Table 1 Numbered tropical cyclone warning signal system in Hong Kong

No.	Meaning
1	A tropical cyclone is centred within about 800 km of Hong Kong and may later affect Hong Kong
3	Strong wind (force 6 or above) is expected
8	Gales (force 8 or above) are expected
9	Gales increasing significantly
10	Hurricane force wind (force 12) expected

2.2 Up to the 1950's, the operation of the tropical cyclone warning system was dependent on the analysis of synoptic reports, very few of which were transmitted by ships on the high seas. There was much uncertainty in locating and forecasting the track of tropical cyclones. Thus, there was a natural limit on the amount of information that could be supplied to the local public. In any case, no means existed to communicate much information quickly to the public beyond the hoisting of visual signals at various locations in the territory. The emphasis of the warning system was therefore **simplicity**.

2.3 Much of the population then lived in flimsy structures and there was also a significant floating population. Collapsed dwellings and sunk boats were the major cause of casualties. Thus the focus of attention in the warning system was **wind** strength.

2.4 It was also an era where the pace of life was much slower than modern days. So the signals could be hoisted say 12 hours before the expected winds arrived because little social or economic cost was involved. If the winds never materialised, there would be little complaint. Indeed, some casualties during a tropical cyclone hit was generally taken for granted by the community. The meteorological service did not perceive as much pressure on its operations as nowadays. The state of affair during the early years might be summarised in fig. 2.

3. 1960's to 1980's

3.1 HKO installed its first 3cm radar in 1959, followed by a 10cm "storm finding" radar in 1966 (Wong *et al*, 1994). It also started receiving cloud pictures from polar orbiting satellites in 1963, and later from geostationary satellites since 1977 (Bell, 1981). The tropical cyclone warning service therefore benefitted from better observational data from the 1960's onwards, especially after the GMS hourly pictures came into existence.

3.2 Fig. 3 shows a plot of the annual fraction of time with a tropical cyclone within 800 km of Hong Kong during which a local signal number 3 was hoisted in the last half century. It is quite evident that the better observational data input brought about a more consistent service after around 1960, in the sense that the wide fluctuations in the previous decade or so disappeared. Generally speaking, a better determination of the past track and the present position of a tropical cyclone gives operational forecasters greater confidence in predicting the future track and in presenting a "story" to the public.

3.3 An interesting aspect of this period is that the accuracy in 24-hour forecast positions showed no significant improvement (Lam, 1993; fig. 4). In spite of this, the tropical cyclone warning service was perceived by the Hong Kong community as generally **improving**! The key apparently lay in the gradually increasing amount of information communicated to the public in the form of **textual bulletins** broadcast over **radio**.

3.4 Radar and satellite enabled HKO to describe the track to the public in such bulletins. Latest wind information from various manned stations gave people a good feel of the evolution of the local weather. The bulletins also contained recommended precautionary actions, advising people to respond to the approaching storm situation in a graded and orderly manner. Taken overall, the public's information need was met and this was sufficient to ensure "customer satisfaction".

3.5 Another factor bearing on the operation of warning system was the better housing available to the people of Hong Kong. Home became the safe refuge for most people. The primary objective of the warning system became: "keep people at home before high winds strike". A tradition eventually emerged in which schools would close and people would be released from work if a number 8 signal was hoisted during office hours. Or if the signal was hoisted before office started, people would stay home. This was a simple but very effective measure; the number of casualties due to tropical cyclones dropped significantly through the years, as is evident in fig. 5. However, this translated into another demand from the public - HKO would be flooded by enquiries on whether the hoisting of the number 8 was imminent. To this demonstrated information need, HKO responded

after much reluctance and trepidation by endeavouring to give a 2-hour advance alert to government departments, transport operators and the public whenever that the signal number 8 would be hoisted. To the pure scientist, this would appear to be an awkward and illogical step to take. But the public took it as an improvement, showing that the meteorological service **cares** about them.

3.6 The caring image was further strengthened by the deployment of professional meteorologists to deliver regular briefings on approaching tropical cyclones on television. Such TV appearances reassured the public that HKO professionals were in control of the situation. By the careful choice of words spoken by the meteorologists, TV viewers would feel that they received advice from HKO people directly. This sense of direct contact was instrumental in nurturing rapport between HKO and the public.

3.7 One final aspect about the period was the faster pace of life associated with the developing and booming economy. By 1980, it was becoming clear that the sophistication of the population and the better transport system generally enabled the community to respond swiftly to warning signals and to complete necessary precautions. In line with this development and without a conscious decision being made at the time, HKO gradually operated the signals allowing less false alarms, that is, less lead time before the expected wind strength was reached. Thus, one finds in fig. 3 a falling trend in the fraction of time with No. 3 signals. Of course, this was aided to a great extent by the hourly GMS pictures available since the late 1970's. We may represent the situation for the 1960's to the 1980's schematically in fig. 6.

4. The 1990's

4.1 The 1990's saw Hong Kong's transformation into an international metropolis with a complex array of economic activities running at a fast pace round the clock. The city became more vulnerable to tropical cyclones and its associated weather. It was not a question of casualties. Instead it was because there was much more commuter traffic and the transport infrastructure became very complex and susceptible to weather impacts. Also, a wide range of economic activities were affected by weather. For example, the container port would scale down or even stop operation in force 6 winds while a number 8 signal would cause courts, stock exchanges, schools and most shops to close and buses and ferries to stop running.

4.2 In general, the community became very intolerant of both over-warning and under-warning. The former was associated with high perceived economic cost. In the case of the latter, the loss of even one life would be unacceptable. The better educated population was more ready than ever to complain and knew how to do it with effectiveness. The tropical cyclone warning system was therefore under microscopic examination by different sectors of the community, each with their own interest, every time a tropical cyclone hit Hong Kong. This put economous pressure on HKO.

4.3 Fortunately, numerical weather prediction (NWP) has gradually come of age. Towards the end of the decade, operational NWP models such as that of ECMWF began showing significant skill for tropical cyclone track predicting up to 72 hours (Lam, 2000; fig. 7). It enabled forecasters to anticipate the forecast scenario in the next day or two and to communicate it to the public. The addition of this information to the weather bulletins was a great boost to the image of HKO, because it was badly needed information for those who would like to plan ahead.

4.4 A major change in the 1990's was the rising concern about the effect of heavy rain which led to floods and landslips. Wind was causing less casualties but rain was causing more chaos by disrupting transport and commuter traffic. To facilitate easy interpretation of the weather situation by the man in the street, **separate rainstorm warning signals** were introduced in the early 1990's.

Table 2 Rainstorm warning signals in Hong Kong

Signal	Meaning
Amber	30 mm in an hour generally
Red	50 mm in an hour generally
Black	70 mm in an hour generally

As in the case of tropical cyclone signals, it has been tied to certain community responses. Schools would close with a red rainstorm warning while people would be advised to stay indoor in black signal situations.

4.5 On the delivery of service to the public, HKO was greatly helped by first the popular use of pagers, then mobile telephones and finally the internet. Collaboration with paging companies and mobile phone services cast a wide and efficient net; millions of people would know about changes in warning status virtually in terms of minutes, in a way commensurate with the fast pace of life in the modern society. Instead of customers passively waiting for information broadcast by radio or TV, it was a new age in which **individualised alerting** was practised.

4.6 The internet allowed HKO to reach out to the public directly without going through intermediaries like radio or TV. HKO set up its own homepage in 1996, at first giving out merely the internet version of the conventional tropical cyclone bulletins. Other relevant information was added gradually and increasingly in **graphic form**, including items like: 48-hour forecast track in graphic form, satellite imageries, latest rainfall distribution in Hong Kong and real-time information from a network of automatic weather stations (AWS) in Hong Kong.

4.7 With 48-hour track charts and AWS information going online lately, the intelligent members of the public could now make their own judgement about what to do as a tropical cyclone approaches. To them, the conventional warning signal system has a diminishing role in guiding their responsive actions. The situation of the tropical cyclone warning service towards the end of the 1990's is represented schematically in fig. 8.

4.8 An important development of the 1990's was the very significant growth in the frequency of **direct contacts** between HKO and its customers. The dial-a-weather service answered telephone calls from the public and delivered taped recordings of weather information including tropical cyclone position and signal status. It handled 0.1 million calls in 1985 but grew rapidly, exceeding 20 million calls by 1995. The HKO homepage started operation in 1996; the number of hits in 2000 is estimated to be close to 40 million. Increasingly high hit rates have been recorded on days with approaching tropical cyclones as the internet-connected population grew (fig. 9). Typhoon York brought more than a million hits on 16 September 1999 when it crossed Hong Kong. Another typhoon Wukong did the same on 7 September 2000 even though it only skirted past Hong Kong. We greatly value this opportunity to deliver service directly to the customers. We could now receive feedback from them and respond by adjusting our operations without going through any intermediaries. This is extremely conducive to the continual improvement of our service in a way desired by the community we serve.

5. Looking Ahead

5.1 We have now arrived at an age where "the public" has evolved into a spectrum of "**market niches**". At the one end, the simple numbered signal system serves to trigger the organised response of the government and that of the man in the street. The virtue is simplicity linked to a well-established behaviour pattern, which is conducive to an orderly response to approaching threat. At the other end, the comprehensive information provided by HKO is sufficiently detailed to enable individuals to decide for themselves on actions to take to suit their own special circumstances. Thus in commercial parlance, HKO is marketing a **diversity of products** to serve a wide spectrum of customers with different requirements and different degrees of

sophistication. The tropical cyclone warning system is becoming a generic name for a range of products.

5.2 Looking ahead, two lines of work are to be pursued. Firstly, the significant gain in NWP in track forecasting towards the end of the 1990's will have to be translated into more accurate operational track forecasts, and then in turn into more useful advisory bulletins for the public. Emerging success in mesoscale modelling should also be transformed into better forecasts of wind and rain to help people prepare for the weather impact of tropical cyclones. Secondly, with the aid of internet and other technology, meteorological services will have to refine and expand their identification of market niches and to develop tailor-made services commensurate with the requirements and degree of sophistication of these niches.

5.3 The more we recognize that people are different, the more we would serve them better. The more our customers are satisfied, the more our own survival would be guaranteed. Operating a tropical cyclone warning system is no different from running a commercial company.

References

Bell, G.J., 1981: 15 years of satellite meteorology in Hong Kong. *Weather*, Vol.36, No. 1, 9-15.

Wong, S.K., and Ho, K.L. 1994: A brief history of the Royal Observatory weather radars. *HKMetS Bulletin*, Vol, 4, No. 2, 7-11.

Lam, C.Y., 1992: Operational tropical cyclone forecasting from the perspective of a small weather service. *Tropical Cyclone Disasters: Proceedings of ICSU/WMO International Symposium, 12-16 October 1992*. Peking University Press, Beijing, China.

Lam, C.C., 2000: Performance of the ECMWF model in forecasting the tracks of tropical cyclone in the South China Sea and parts of the western North Pacific. Accepted by *Meteorol. Appl.*

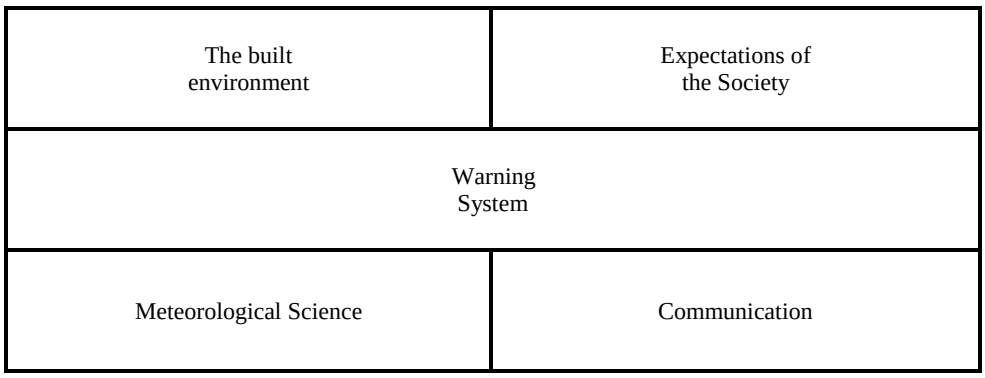

Fig. 1 Factors determining the form of a warning system

flimsy structures	some loss of life taken for granted slow pace
numbered signals focus on wind	
little data	visual signals

Fig. 2 Tropical cyclone warning system in the early years

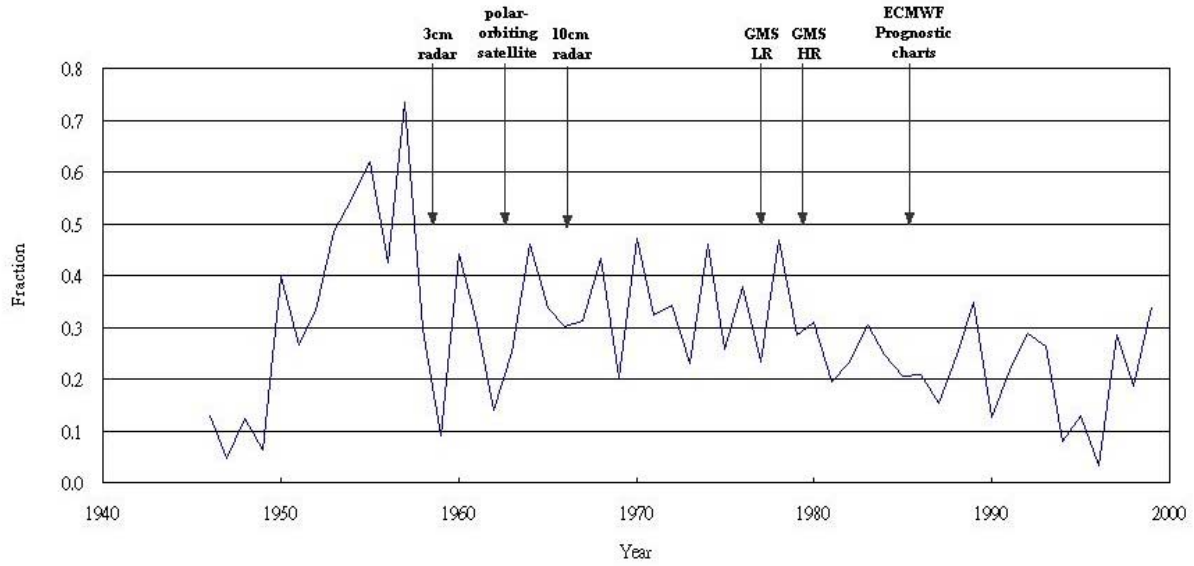

Fig.3 Fraction of time with a tropical cyclone within 800km of Hong Kong during which a local signal number 3 was hoisted.

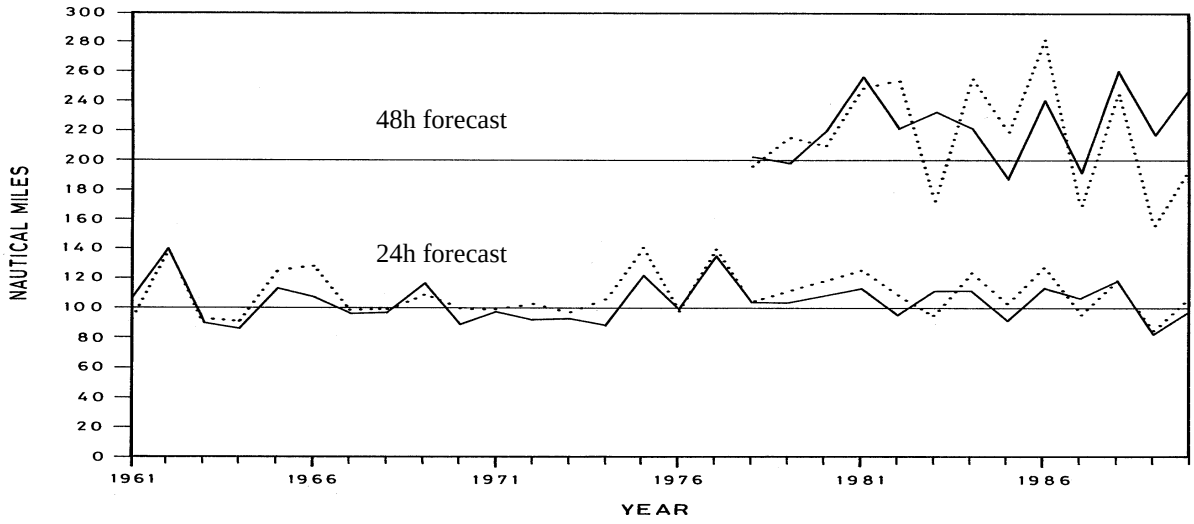

Fig. 4 Annual mean errors in operational forecasting positions by the HKO. The dotted line refers to an objective method combining persistence and climatology. Adapted from Lam (1992).

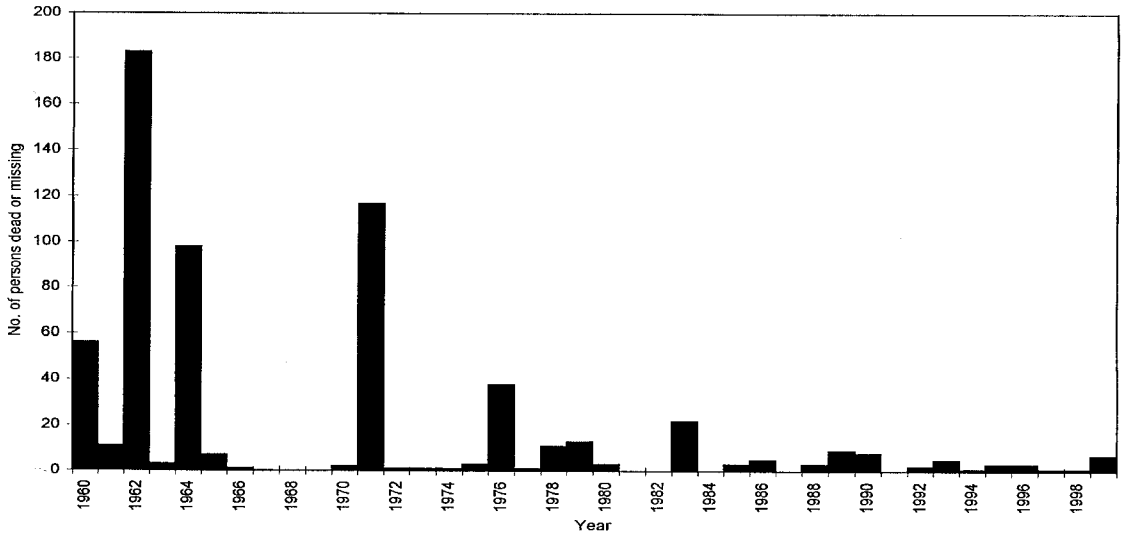

Fig.5 Casualties caused by tropical cyclones in Hong Kong

better houses	increasing value placed on life faster pace
textual information broadcasts wind & track	
satellite radar	radio TV

Fig. 6 Tropical cyclone warning system, 1960's to 1980's

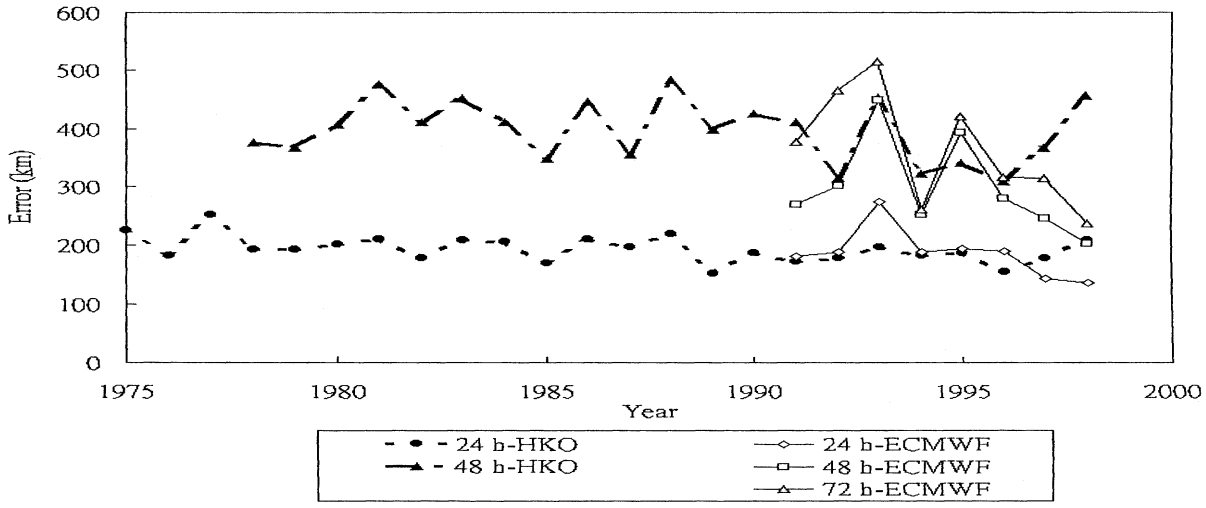

Fig. 7 Annual mean position errors of ECMWF forecasts and HKO subjective forecasts for TCs over the verification area 10-30°N, 105-125°E After Lam (2000).

complex transport infrastructure	"no loss of life" minimum disruption to economic activities
textual and graphic information on TC and local weather individualised alerting, homepage wind, rain, track	
NWP automatic weather stations	telephone pager mobile phone internet

Fig. 8 Tropical cyclone warning system, 1990's

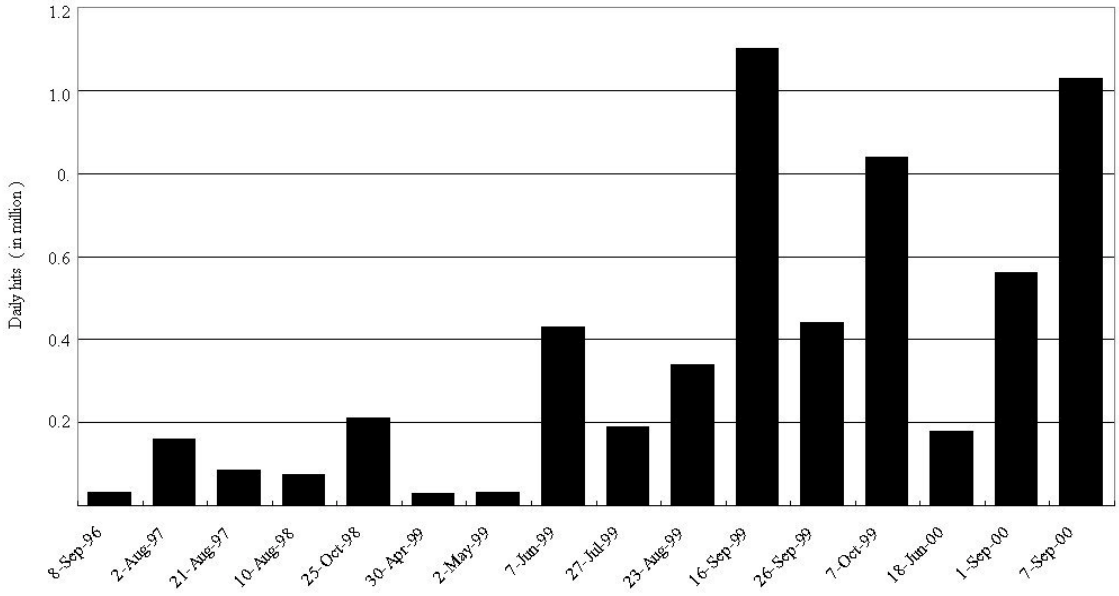

Fig. 9 Daily hit rates of Hong Kong Observatory homepage on days with tropical cyclone signal No. 3 or Higher