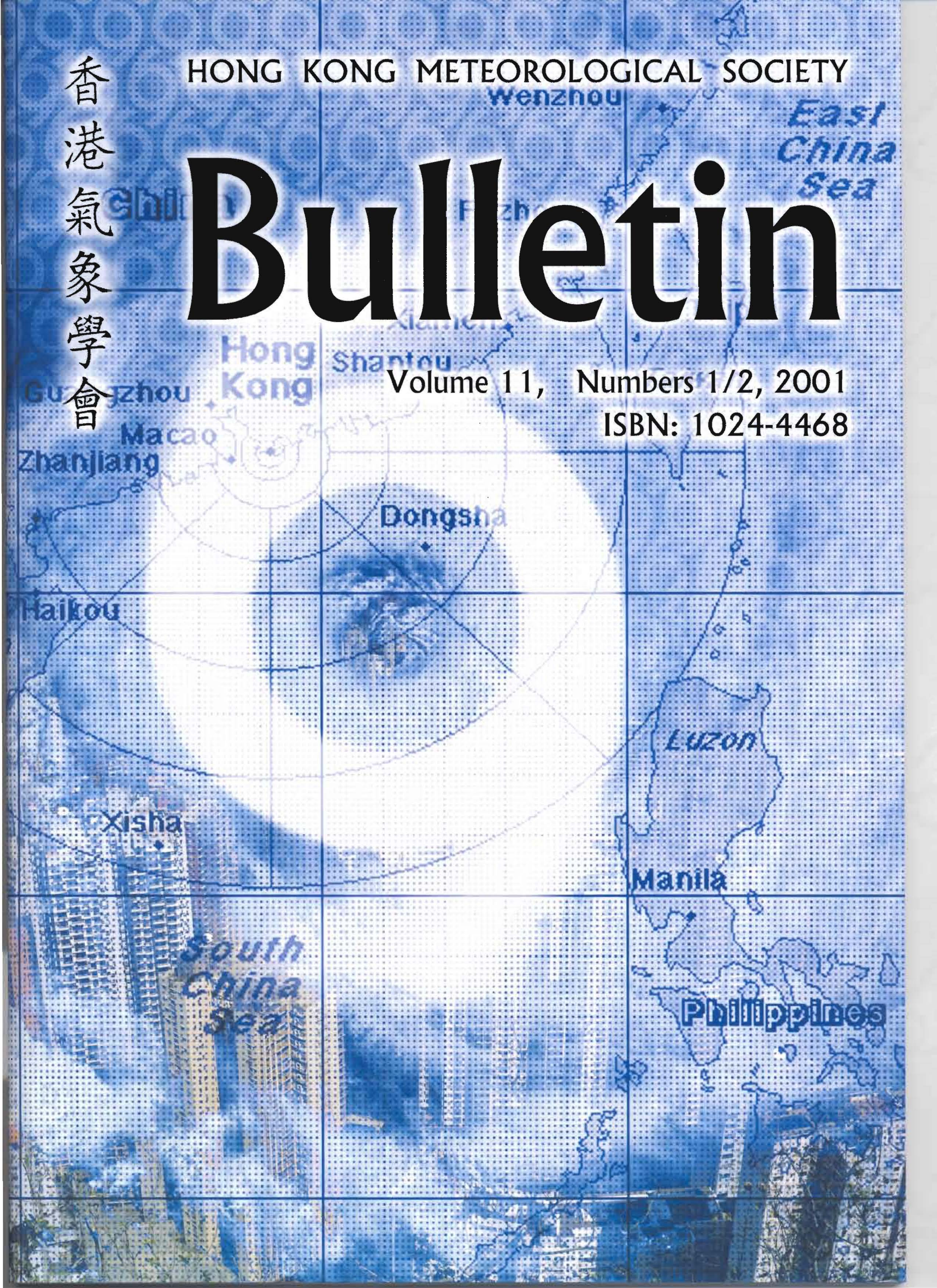
香港氣象學會

HONG KONG METEOROLOGICAL SOCIETY

Bulletin

Volume 11, Numbers 1/2, 2001

ISBN: 1024-4468



ISSN 1024-4468

The Hong Kong Meteorological Society Bulletin is the official organ of the Society, devoted to articles, editorials, news and views, activities and announcements of the Society.

Members are encouraged to send any articles, media items or information for publication in the Bulletin. For guidance see the "information for contributors" in the inside back cover.

Advertisements for products and/or services of interest to members of the Society are accepted for publication in the BULLETIN.

For information on formats and rates please contact the Society secretary at the address opposite.

The BULLETIN is copyright material.

Views and opinions expressed in the articles or any correspondence are those of the author(s) alone and do not necessarily represent the views and opinions of the Society.

Permission to use figures, tables, and brief extracts from this publication in any scientific or educational work is hereby granted provided that the source is properly acknowledged. Any other use of the material requires the prior written permission of the Hong Kong Meteorological Society.

The mention of specific products and/or companies does not imply there is any endorsement by the Society or its office bearers in preference to others which are not so mentioned.

EDITOR-in-CHIEF	EDITORIAL BOARD
Bill Kyle	*Y.K. Chan* *W.L. Chang* *Edwin S.T. Lai* *W.L. Siu*

SUBSCRIPTION RATES	(Two issues per volume)
Institutional rate:	HK$ 300 per volume
Individual rate:	HK$ 150 per volume

Published by

The Hong Kong Meteorological Society

c/o Hong Kong Observatory
134A Nathan Road
Kowloon, Hong Kong

香港氣象學會

HONG KONG METEOROLOGICAL SOCIETY

Bulletin

Volume 11, Numbers 1/2, 2001

CONTENTS

Editorial

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

The first paper by Kin-Sang Chim, P.A. Hitchcock and K.C.S. Kwok of the CLP Power Wind/Wave Tunnel Facility, Hong Kong University of Science and Technology provides a demonstration of a multi-technique for the study of the topographic effect of Waglan Island using an inter-comparison between numerical simulation using CFX software, and physical modelling using a scale model of the island in a wind tunnel.

In the second paper, C.Y. Lam of Hong Kong Observatory, describes the tropical cyclone warning system in Hong Kong which has been in existence since 1884. He examines how it has evolved with time, adjusting itself to changing needs and availing itself to emerging technologies to illustrate how various factors have interplayed to determine the form of the warning system at the time.

The third paper by Mickey M.K. Wai of Plum Rain Solutions, Tallahassee, Florida, USA also focuses on the use of warning signals in the current tropical cyclone warning system in Hong Kong. He concludes that under the current demographic condition and the diverse economic bases and land uses, the use of signals in the current tropical cyclone warning system is not suitable and proposes an alternative tropical cyclone warning system in which signals are not used. Instead a system involving tropical cyclone watch and tropical cyclone warning involving wind watch, flood watch, wind warning and flood warning within a framework of management of closure and evacuation is advocated. These are issued to targeted localities depending on the intensity of a tropical cyclone and the distance of approach.

The fourth paper, also by Mickey M.K. Wai of Plum Rain Solutions, Tallahassee, Florida, USA, use Typhoon Maggie as an example to illustrate how and when the alerts and warnings of his proposed new tropical cyclone warning system can be used. Since the warning signals are not used, an educational program is also described in order to help citizens to become familiar with the proposed new warning system.

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

Bill Kyle, Editor-in-Chief

Kin-Sang Chim, P.A. Hitchcock., K.C.S Kwok

CLP Power Wind/Wave Tunnel Facility, Hong Kong University of Science and Technology,
Clear Water Bay, Kowloon, Hong Kong

Flow over Waglan Island by Wind Tunnel and Numerical Simulation

Abstract

A demonstration of a multi-technique for the study of the topographic effect of Waglan Island using an inter-comparison between numerical simulation using CFX software, and physical modelling using a scale model of the island in a wind tunnel is presented. The inter-comparison between the numerical and physical modelling methods enhanced the reliability of the results and provided a deeper insight into the problem. The numerical simulation has an advantage for presenting the steady state flow field while the time series in particular locations can be extracted from the wind tunnel experiment. This approach can be implemented at different location without difficulty and is a useful tool for studying the topographic effect on wind flow for planned sites of major construction work.

Introduction

Waglan Island is located in the southeastern extreme of Hong Kong. To the east and south of the Waglan Island is an open sea area. It is the most remote site in Hong Kong. The total area of Waglan Island is about 0.1 km^2. Waglan Island consists of two small islands with the North Island being unmanned while all observational instruments are mounted on the South Island. There are some buildings on the South Island which include a 9.2m height lighthouse, staff quarters and a heliport (Figure 2 in Ng, 1997). Data collected from the meteorological instruments mounted on the South Island give the best representation of the undisturbed background flow in Hong Kong. Past published wind studies for Waglan Island include Chen (1975), Melbourne (1984), Davenport *et al.* (1984) and Ng (1997).

The history of the Hong Kong Observatory's anemometer is presented in Table1. The anemometer mounted on the South Island has gone through four relocations (5 sites) since its first exposure on 19600101.

For convenience in this paper, the site locations are named with their height, *i.e* the site in use from 19640101 to 19660711 with a height of 67.4m above mean sea level is referred to as Site 67.4. According to Davenport *et al.* (1984) it is believed that the anemometer site in use from 19640101 to 19660711 (Site 67.4) was under the influence of the wake of the lighthouse. The data from this site is thus not included in the present study. Anemometer measurements are also affected by the topographic effect of Waglan itself. In order to study the topographic effect of the Waglan Island, a wind tunnel experiment with 1:400 scale physical model was performed. In addition, a numerical simulation result using CFX was compared to the wind tunnel experiment. The numerical result is then used to construct a fractional speed-up chart for each anemometer site.

Table 1 **Summary of Anemometer height**

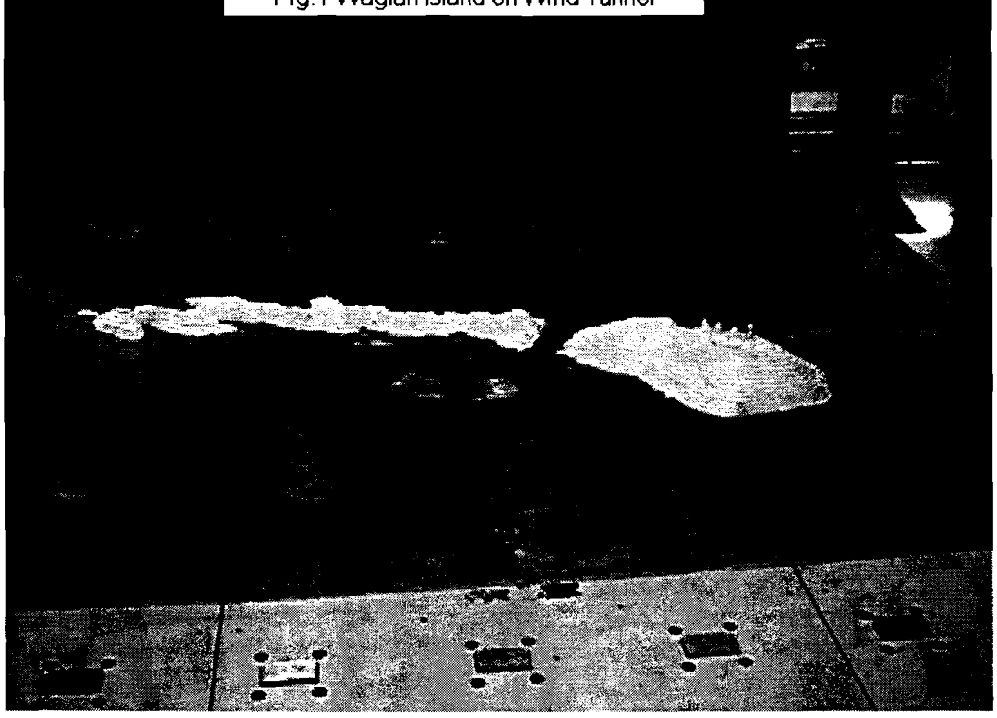
Date mounted	Height above mean sea level
1-Jan-1960	70.1m
1-Jan-1964	67.4m
12-July-1966	74.6m
19-Dec-1971	74.8m
26-Apr-1993	82.1m

This paper consists of six sections. The first describes the physical Waglan Island model and introduces the wind tunnel facilities used for the experiment. The second section discusses the wind tunnel testing procedure and the experimental results. The numerical simulation of the flow over Waglan Island using the software CFX is introduced in the third section. A comparison between the wind tunnel and numerical results is presented in section four. Section five describes the fractional speed-up charts which were constructed from the numerical results and a summary of the paper is given in section six.

The Physical Model of Waglan Island

The high-speed test section of the CLP Power Wind/Wave Tunnel Facility of the Hong Kong University of Science and Technology is 3m by 2m in size (Figure 1). The approach flow is calibrated so that it follows the definition of flow over general terrain of the Code of Practice on Wind Effects Hong Kong (Building Authority, Hong Kong, 1993) at 1:400 scale. Figure 2 and Figure 3, respectively, show the wind speed and the turbulent intensity measured on the centerline of the wind tunnel at a distance of 1.31m upstream of the turntable. The vertical wind profile matches the wind code with wind speed within 5 percent and turbulence intensity within percent. Note that the y-axis is the height normalized to gradient height (200m full scale). The wind speed at gradient height is equal to 18.9 ms^{-1} and turbulence intensity is equal to 0.072 at the same height. The gradient height is equal to 200m for general terrain of Hong Kong Wind Code.

Fig.1 Waglan Island on Wind Tunnel



Above the gradient height, wind speed and turbulence intensity are assumed to be constant. The Power Law $U/U_g = (z/z_g)^{\alpha}$, where the subscript g stands for gradient height level, is used to approximate the mean wind speed and the turbulent intensity in the Wind Code. For general terrain, the power exponent for mean wind velocity and turbulence intensity are 0.19 and -0.26 respectively. Moreover, the reference turbulence intensity at height 75m (full scale) is 0.1. The Waglan Island foam model is built in the scale of 1:400. At this scale, the gradient height of 200m above mean sea level is equal to 500mm above the tunnel floor.

Fig.2 Wind Speed v.s. Height

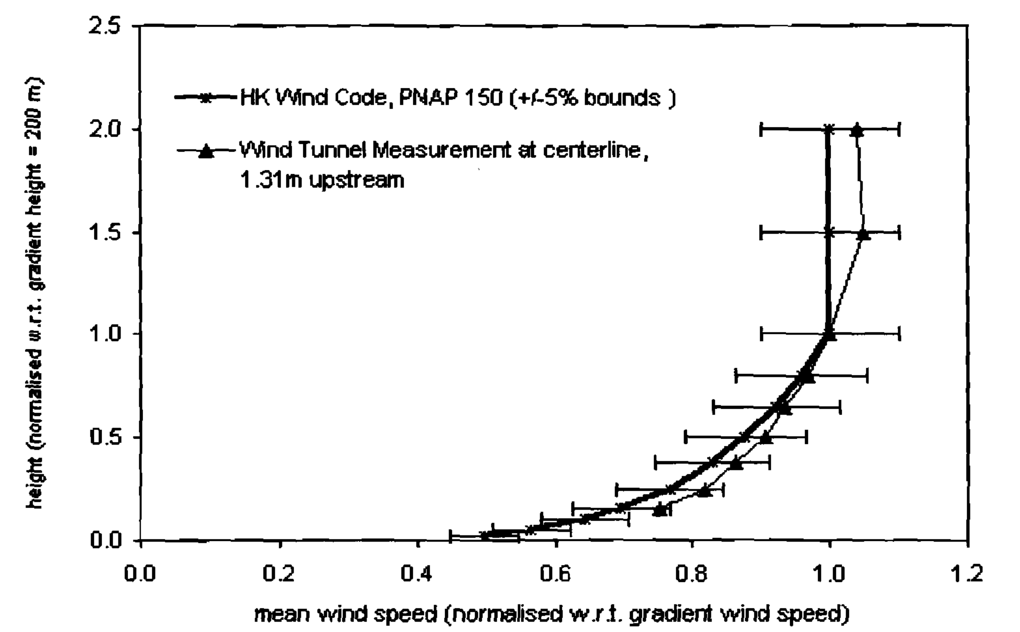
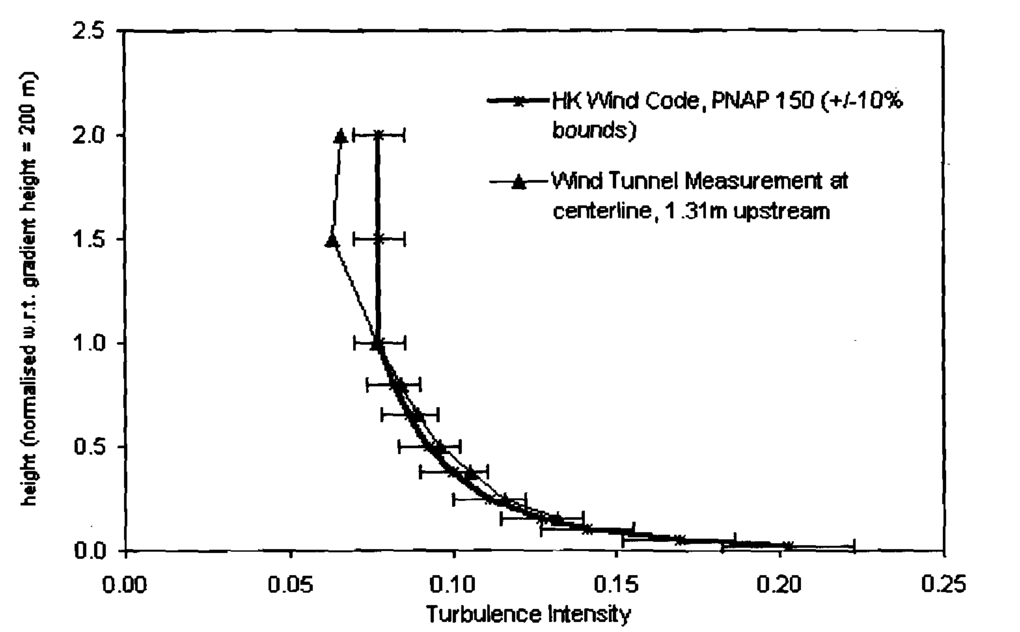


Fig.3 Turbulent intensity v.s Height



The buildings on the South Island are neglected in the foam model if they are less than 4m height full-scale. Hong Kong Observatory has mounted weather stations at different locations on the South Island. Marks were put onto the foam model to identify those observational sites. A step jump exists on the foam model for every 4m contour interval at full scale. The 4m height contour in full scale is represented by a single layer of foam with a thickness of 10mm.

Wind Tunnel Experimental Procedure and Results

The foam model was located at the center of the turntable during the experiment (Figure 1). In total 16 wind directions, starting from 0 degrees with a 22.5 degree interval through to 337.5 degrees, were tested in the study. A constant temperature single hot-wire anemometer (TSI IFA300) was used to measure the wind speed and turbulence. A T-type thermocouple is also mounted onto the IFA300 in order to provide temperature compensation for wind data measurement.

For a particular wind direction, the calibrated hot-wire anemometer was mounted on the upstream location of the model at the gradient height. The measurement taken from this location is used as the reference flow value. For all the experiments, a 2000Hz sampling frequency and a 32s sampling time were used. After the reference point measurement, the same hot-wire anemometer was relocated to the exact location of the anemometer site. The same process was repeated for all the different locations and directions.

The data collected from the wind tunnel tests was then analyzed to calculate the adjustment factor for different the locations and directions. The adjustment factor (A) is defined as the ratio of the mean wind speed at anemometer site to the mean wind speed at the reference height upstream.

$$A = \frac{U_{anemometer}}{U_{reference}}$$

The values of the adjustment factor for each of the different anemometer sites is shown in Figures 4 through 7.

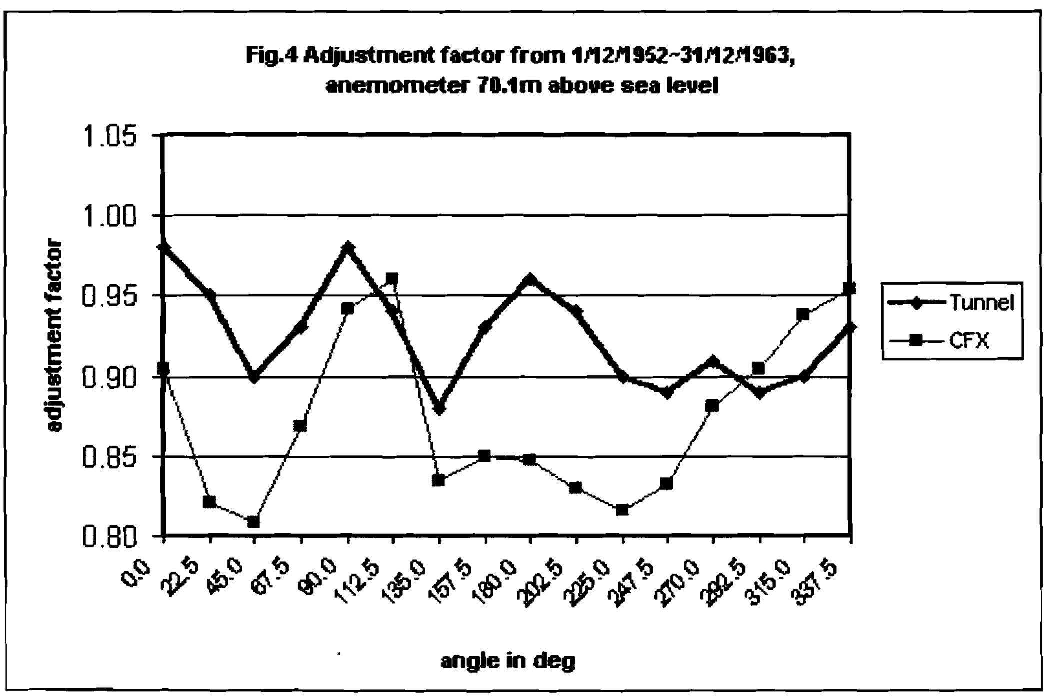


Fig.5 Adjustment factor from 12/7/1966~18/12/1971, anemometer 74.6m above sea level

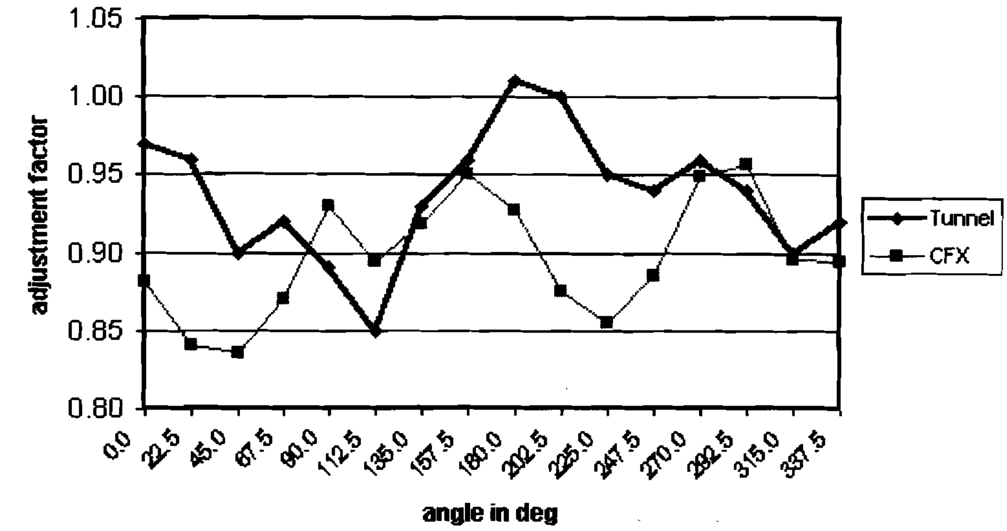
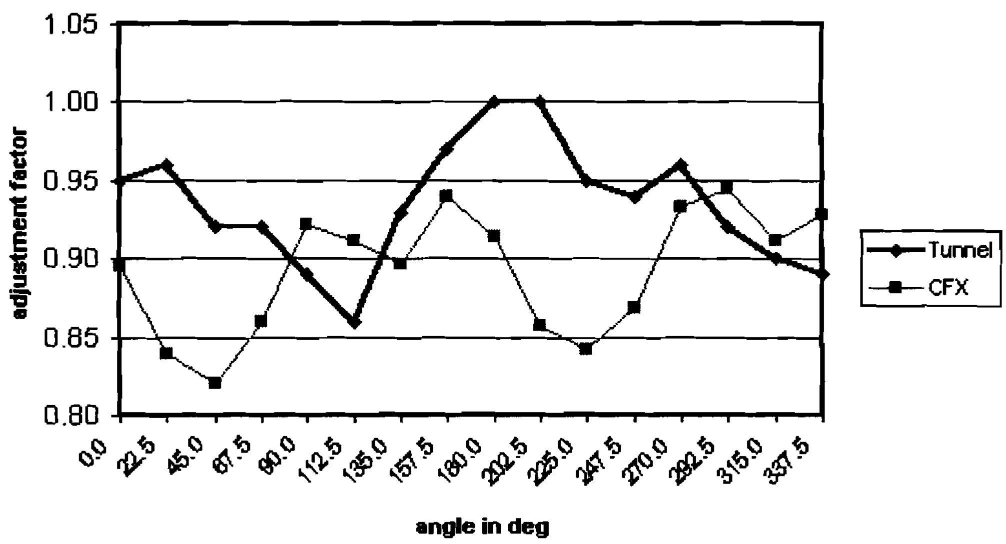


Fig.6 Adjustment factor from 19/12/1971~25/4/1993, anemometer 74.8m above sea level



These figures also present the adjustment factor calculated by the CFX simulation to be presented in the next section. Physically, an adjustment factor greater than 1 indicates that the measured velocity at the anemometer site has a higher value than that measured at the reference the reference location.

Table 2 presents a summary of the adjustment factor for all four sites. The max ΔA for a particular site is defined as the maximum A minus the minimum A measured. A higher value of max ΔA suggests larger variation of A among different wind direction and consequently higher directional topographic influence on the flow. On this basis it can be seen that Site 74.6 exhibits most directional topographic influence when compared to the other three anemometer sites.

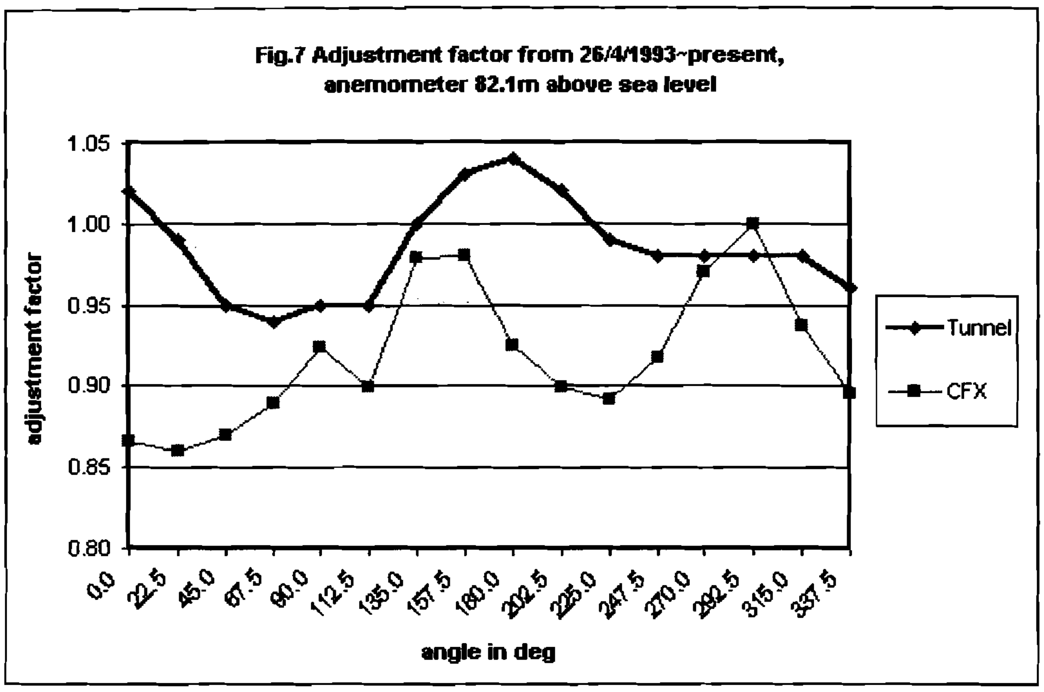


Table 2 **Summary of adjustment factor for different sites**

	Site 70.1	Site 74.6	Site 74.8	Site 82.1
Max ΔA	0.1	0.16	0.14	0.1
Max A direction	0 degrees	180 degrees	180 degrees	180 degrees
Min A direction	135 degrees	112.5 degrees	112.5 degrees	67.5 degrees

Computational Domain and Boundary Condition

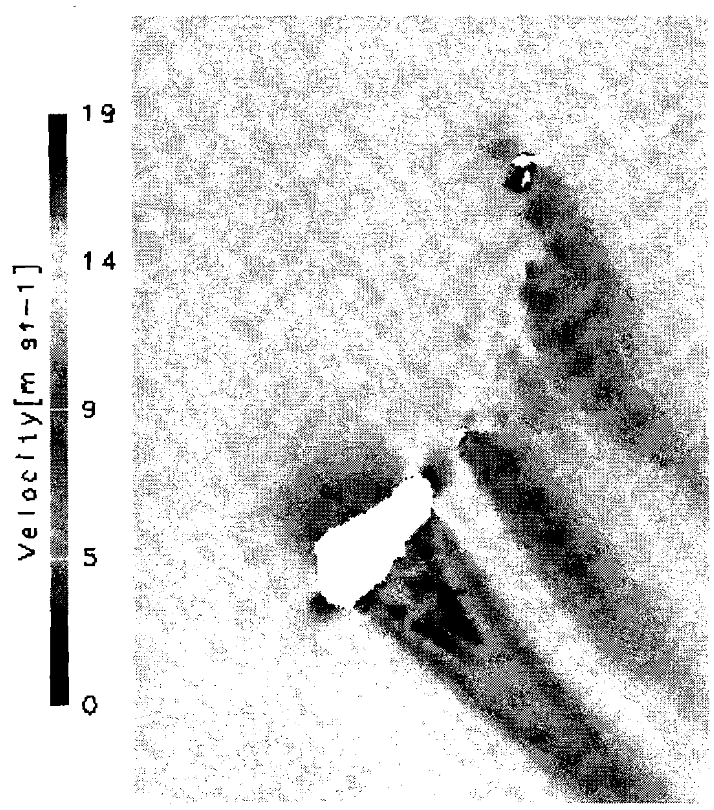
CFX is a commercial computational fluid dynamic package based on finite volume formulations (CFX Online Manual). It can handle highly distorted surface calculations.

The computational domain is setup such that both North and South Island of Waglan are included. Figure 8 shows the computational domain with wind field at 25m above mean sea level. The topographic data is at 10m resolution and was interpolated from the digital map provided by the Hong Kong Map Office. The domain is spanned by 97 X 134 surface data points. The size of the computational domain is 970m X 1340m X 250m. The lower surface of the computational domain did not necessarily pass through all of those 10m resolution terrain height data a curve fitting process on the surface boundary was involved. The computational domain consists of 116824 tetrahedrons, 100716 prisms and 436 pyramids. The maximum edge length among all the elements is 49.28m and the minimum edge length is 1.02m. Moreover, nodes are specially constructed at the four anemometer sites to reduce the interpolation error during the data extraction process.

The fluid and flow properties of the computational domain were defined as $\rho = 1.284\,\mathrm{kgm}^{-3}$, $\mu = 1.725E5\,\mathrm{kgms}^{-1}$, $P_0 = 101.3\,\mathrm{kPa}$ and $R_d = 287.04\,\mathrm{Jkg}^{-1}\mathrm{K}^{-1}$. An isothermal approximation with $T_{av} = 300K$ was used where ρ, μ, P_0, R_d and T_{av} are air density, dynamic viscosity, reference pressure, gas constant of dry air and fluid averaged temperature respectively. In addition to the fluid properties, the physical options that were used for the present study include the differential Reynold's stress type turbulence scheme (CFX Online Manual) which provides superior results for flows with streamline curvature and in rotating systems.

The initial field of the computational domain was set to uniform flow, not power law flow, and the initial velocity was defined as U=19 ms^{-1}. The settings enhance the convergence rate of the simulation. Note that U refers to the upstream velocity, not the x-component of the mean wind. The upstream boundary condition is defined by the Hong Kong Wind Code. Note that the initial condition is defined by uniform flow while the upstream flow boundary is not. Other boundaries including the side-wall, downstream and top boundaries are specified as open boundaries which permitted disturbance to propagate in and out freely. The lower boundary consists of different kinds of land use (sea, ground) and consequently different surface momentum fluxes.

Fig.8 Waglan computational domain under wind from 315deg, horizontal cross section at 25m above mean sea level.



The ground surface is defined as a no-slip boundary, with an assumed $z_0 = 0.001m$, which is defined based on the category of off-sea wind in coastal areas in Figure 9.6 of Stull (1993). The sea surface is simulated by a free-slip boundary in order not to alter the upstream wind profiles. Moreover, all boundaries assume no heat fluxes for the simulation.

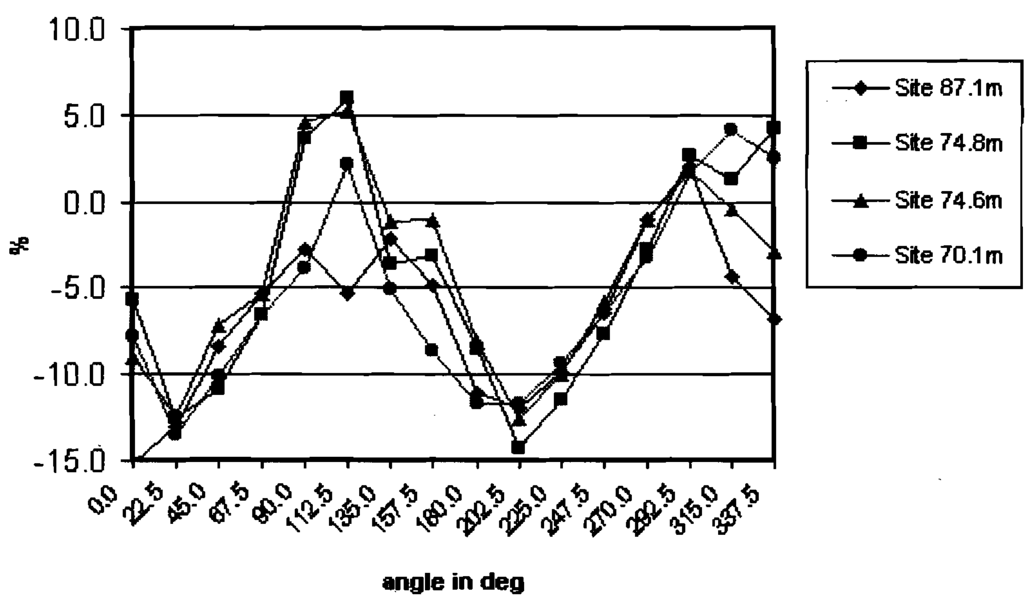
The CFX is performing a steady state simulation and the total integration time varies with wind direction. The convergence criteria are defined as the RMS residual of all dependent variables less than 0.001 and the physical time step is equal to 10s.

Comparison Between Wind Tunnel Result and Numeric Simulation

The CFX simulated adjustment factor for all four sites with different wind direction has already been presented in Figures 4 through 7. The percentage difference of the numerical result with respect to the wind tunnel measurement is show in Figure 9.

The maximum percentage difference (15 percent) occurs at wind direction 0 degrees for Site 87.1. The numerical simulated adjustment factor has the value less or equal to 1 for all wind directions and sites while the wind tunnel experiment indicated that the adjustment factor attains values both greater than and lesser than 1.

Fig. 9 % difference between Tunnel and CFX for adjustment factor



The CFX simulation shows a major drop of adjustment factor at 225 degrees and around 22.5 to 45 degrees, although the wind tunnel testing did not show a similar trend. The authors postulate that this is caused by the difference of the ground surface characteristic between the physical foam model and the numerical model. The physical foam model consists of step jumps while the numerical model uses curve fitting to smooth out the topography.

It is also important to understand that the physical model depends very much on the calibration of the wind tunnel and instruments. On the other hand, the numerical model is constrained by its formulation and the design of the computational domain, especially the surface characteristic and the grid resolution. The variability of the results from these two approaches provides a sense of the range of predicted values so explaining why it is beneficial to perform both numerical and wind tunnel testing for the same project.

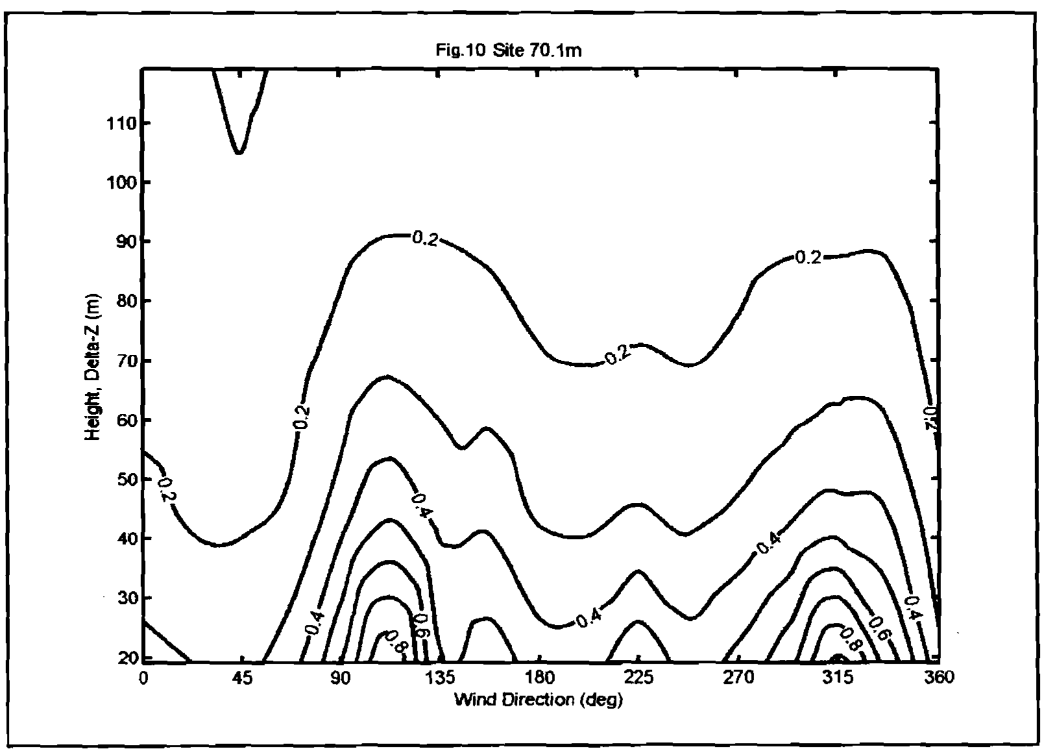
Fractional Speed Up

The fractional speed up is defined according to Teunissen (1983), that is

$$\Delta S_{SF}(z) = \frac{U(z) - U_U(z-h)}{U_U(z-h)}$$

where $z - h$ is the height above local ground level where h is the local terrain height and z is the height above mean sea level. Based on this definition, if $\Delta S_{SF} > 1$ it means that the wind speed at the anemometer site increased with respect to the upstream flow at the same height above mean sea level. On the other hand, when $\Delta S_{SF} < 1$ it means that the wind speed decreases with respect to the upstream flow.

Figures 10 through 13 show the fractional speed up for different sites based on the CFX simulation. Two regions of relatively high fractional speed up are identified at the surface. At 315 degrees predicted $\Delta S_{SF} > 1$ were found at Site 70.1, Site 74.6 and Site 74.8. Physically, what this means is that, at this particular wind direction, wind speed in the surface layer increased. This suggests that the overall shape of Waglan Island would tend to increase the surface wind speed for a 315 degree wind. A second local maximum of fractional speed is evident at 112.5 degrees to 135 degrees. This phenomenon is very obviously found at Site 70.1 but not at the other three sites. Site 70.1 is located near the heliport and is isolated with respect to the other three sites. The simulated result shows the northern part of South Island received a different degree of topographic influence when compared to the southern part of the South Island. The authors postulate that this is caused by the flow over a valley located at 120 degrees from the Site 70.1. The study of the flow over this valley is not within the scope of the present study. At the range 0 degrees to 45 degrees, and especially at 22.5 degrees, the values of fractional speed up are found to be lowest at surface. This suggests that the incoming flow first pass through the North Island before reaching the anemometer site. The frictional effect of the North Island decreases the surface wind speed and hence decreases the value of fractional speed up.



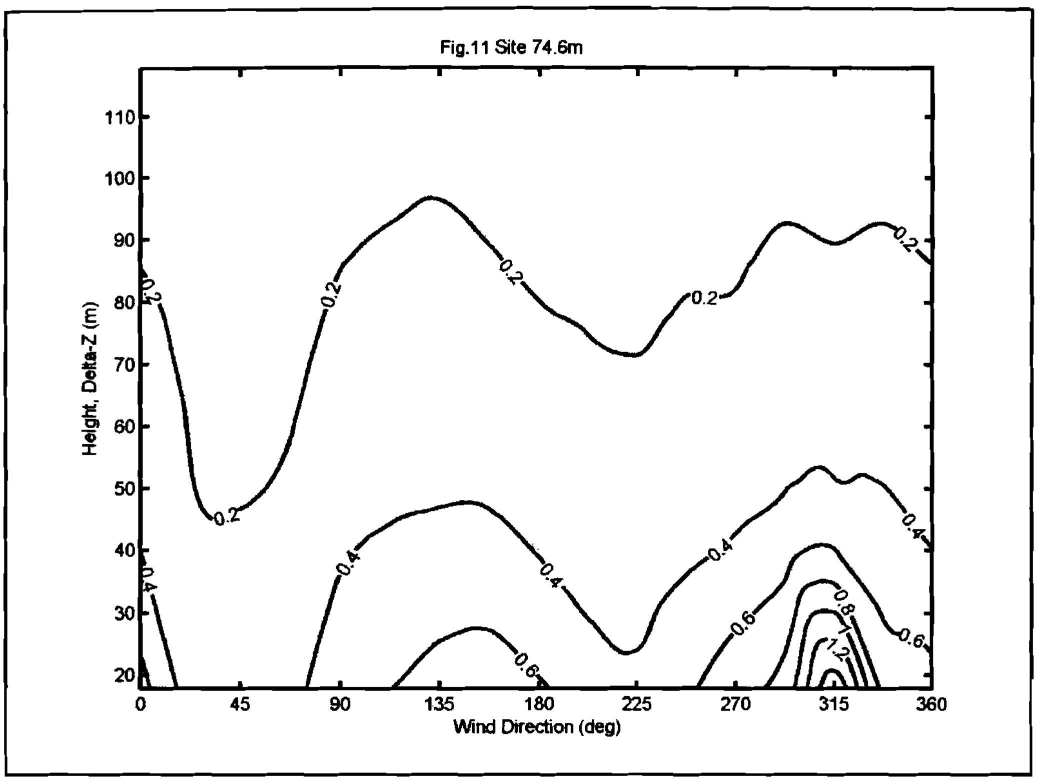


Fig.11 Site 74.6m
Height, Delta-Z (m)
Wind Direction (deg)

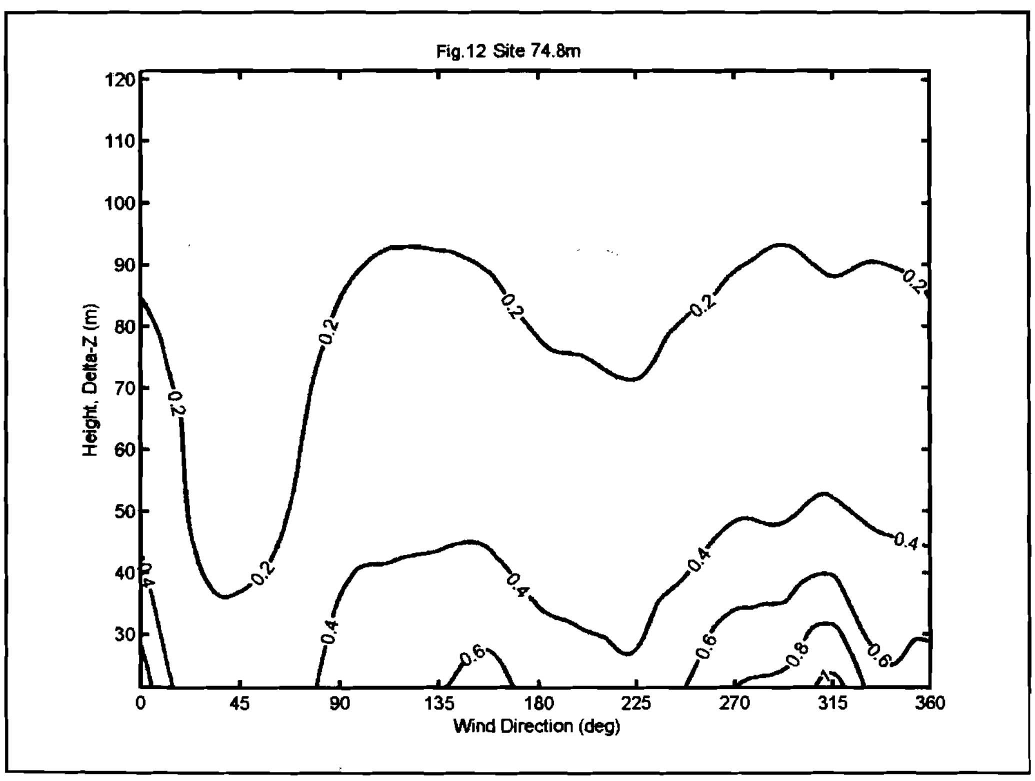


Fig.12 Site 74.8m
Height, Delta-Z (m)
Wind Direction (deg)

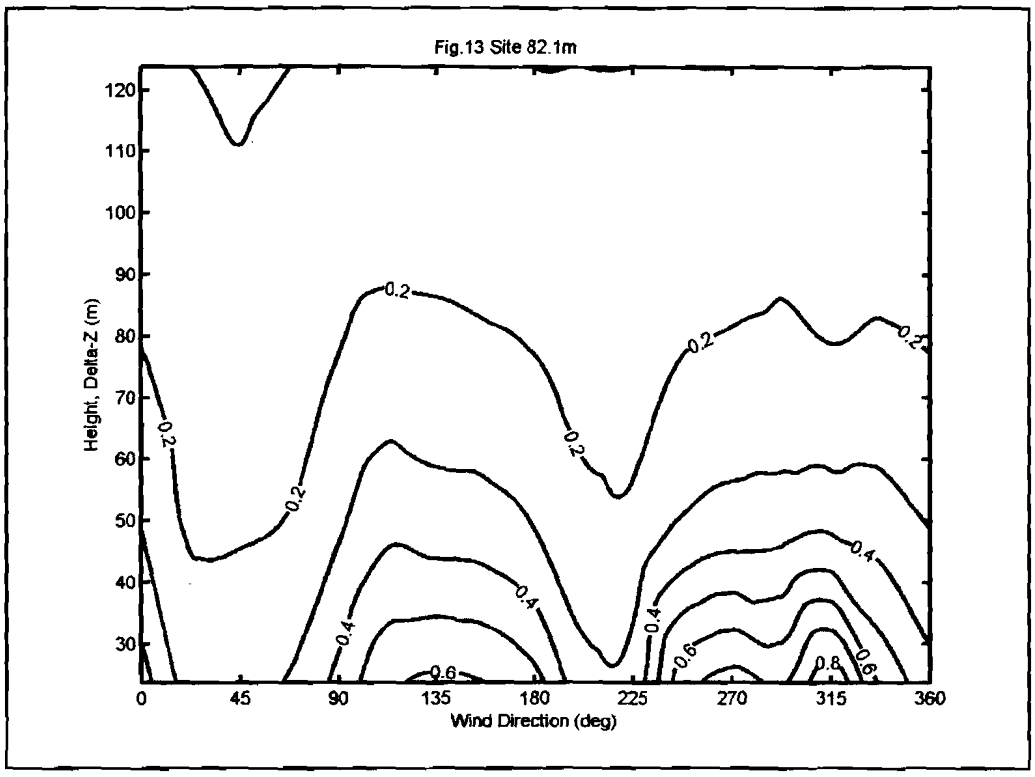


Fig.13 Site 82.1m

Summary

A 1:400 scale Waglan Island foam model was tested in the wind tunnel the flow in which was calibrated so that it follows the general terrain specification of the Hong Kong Wind Code. Wind speed and turbulent intensity were measured at the four anemometer locations and the values normalized by the values measured at the upstream gradient height. The adjustment factor of all 16 wind directions and 4 different sites were calculated. The maximum difference of adjustment factor was calculated for every site among all 16 wind directions. The value attained its maximum (0.16) at Site 74.6. Based on this value, Site 74.6 exhibits the most directional topographic influence.

A numerical simulation was also performed using the software CFX and adjustment factors were determined based on the simulated values. A comparison was then made between the wind tunnel experimental result and the numerical simulated result. This indicated that the maximum percentage difference between the two approaches is 15 percent for the northerly wind case. Fractional speed up charts were also constructed for all four sites. These suggested that the overall effect of Waglan Island on the wind flow is to enhance the wind speed from a direction of 315 degrees and to decrease it from a direction of 22.5 degrees with respect to the upstream flow.

The present study demonstrates the application of a multi-technique for the investigation of the topographic effect of Waglan Island. The inter-comparison between the numerical and physical modeling enhances the reliability of the result. Moreover, the comparison of the results from these two methods provides a deeper insight into the problem. In this case, the numerical simulation has an advantage for presenting the steady state flow field while the time series in particular locations are best extracted from the wind tunnel experiment. This approach can be implemented at different locations without difficulty so making it a useful tool to study the topographic effect on wind flow for planned sites of major construction work.

References

CFX Online Manual: Mathematical Models and Solution Algorithms.

Chen.T.Y. (1975) *Comparison of Surface Winds in Hong Kong.* Technical Note No.41, Royal Observatory, Hong Kong, 12-14.

Davenport.A.G., Georgiou.P.N., Surry.D., Mikitiuk.M., Lythe.G. (1984) *Design Wind Data for Hong Kong and Surrounding Coastline.* Third International Conference on Tall Buildings, Hong Kong and Guangzhou.

Hong Kong Government Printer (1993) *Code of Practice on Wind Effects Hong Kong : 1983*, Building Development Department, Hong Kong Government, Hong Kong, 14p.

Melbourne.W.H. (1984) *Design Wind Data for Hong Kong and Surrounding Coastline.* Third International Conference on Tall Buildings, Hong Kong and Guangzhou.

Ng, M.C. (1997) *Climatology of Waglan Island 1968-1988.* Technical Note No.91, Hong Kong Observatory, Hong Kong.

Stull, R.B. (1993) *An Introduction to Boundary Layer Meteorology.* Kluwer Academic Publishers, Dordrecht, 670p.

Teunissen H.W. (1983) Wind-tunnel and full-scale comparisons of mean wind flow over an isolated low hill. *Journal of Wind Engineering and Industrial Aerodynamics*, **15**, 271-286.

C. Y. Lam

Hong Kong Observatory, 132A Nathan Road, Kowloon, Hong Kong

Tropical Cyclone Warning System in Hong Kong

Introduction

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 (Figure 1).

Figure 1 Factors determining the form of a warning system

<table>
<tr><td>The Built Environment</td><td>Expectations of Society</td></tr>
<tr><td colspan="2">Warning System</td></tr>
<tr><td>Meteorological Science</td><td>Communication</td></tr>
</table>

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 can not afford to ignore this aspect when operating a warning system.

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 in the following sections to illustrate how various factors have interplayed to determine the form of the warning system at the time. Hopefully this will provide food for thought for fellow meteorologists when reflecting on how their warning systems fit with the circumstances in their own country.

The Early Years up to 1950's

The Royal Observatory, Hong Kong (ROHK), the predecessor of the present 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 had settled down into the pattern still in use today (Table 1).

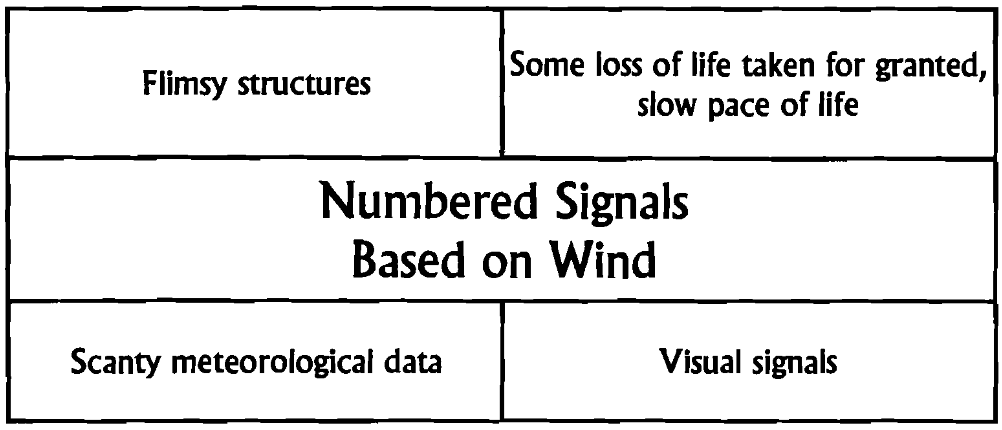
Table 1 **Numbered tropical cyclone warning signal system in Hong Kong**

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

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.

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. 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 materialized, 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 affairs during the early years might be summarized in Figure 2.

Figure 2 **Tropical cyclone warning system in the early years**

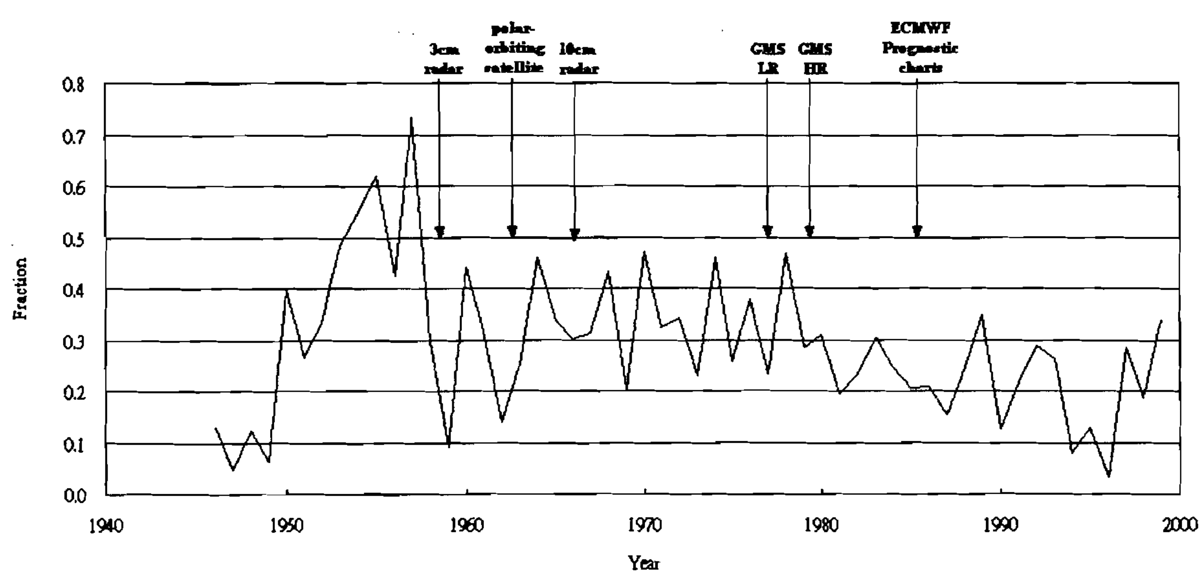


The 1960's to 1980's

ROHK installed its first 3 cm 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.

Figure 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.

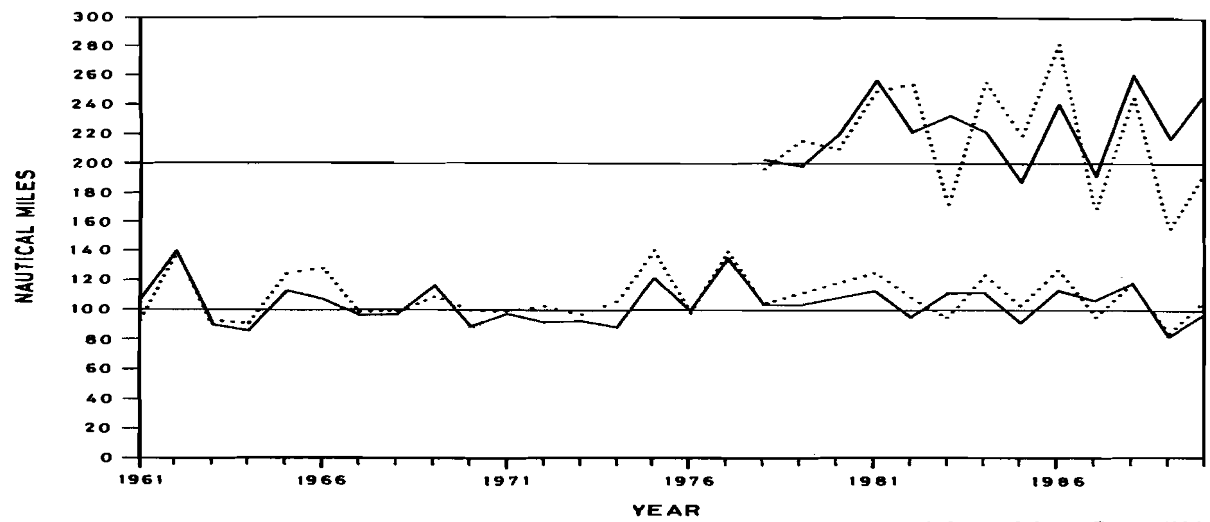
Figure 3 **Fraction of time with a tropical cyclone within 800km of Hong Kong during which a local signal number 3 was hoisted.**



An interesting aspect of this period is that the accuracy in 24-hour forecast positions showed no significant improvement (Lam, 1993, Figure 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.

Figure 4 **Annual mean errors in operational forecasting positions by the ROHK/HKO.**

The dotted line refers to results from an objective method combining persistence and climatology.



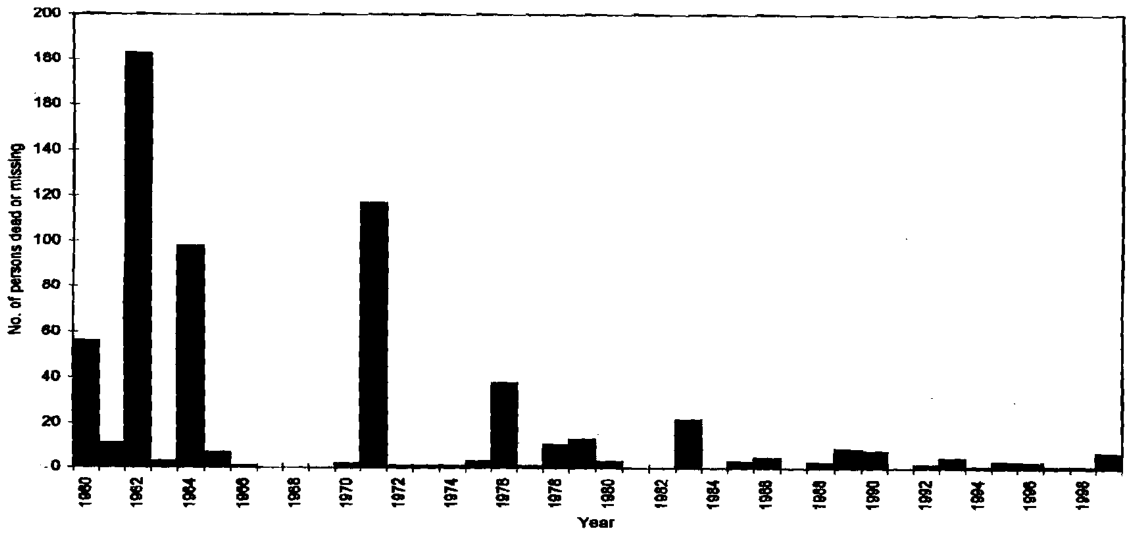
Adapted from Lam (1992).

Radar and satellite enabled the Observatory 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".

Another factor bearing on the operation of the 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 hours 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 Figure 5.

However, this translated into another demand from the public – the Observatory would be flooded by enquiries on whether the hoisting of the number 8 was imminent. To this demonstrated information need, the response after much reluctance and trepidation was an endeavouring to give a 2-hour advance alert to government departments, transport operators and the public whenever it seemed likely 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.

Figure 5 **Casualties caused by tropical cyclones in Hong Kong**



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 Observatory 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 Observatory people directly. This sense of direct contact was instrumental in nurturing rapport between the Observatory and the public.

Figure 6 **Tropical cyclone warning system, 1960's to 1980's**

<table>
<tr><td>Better houses</td><td>Increasing value placed on life
faster pace</td></tr>
<tr><td colspan="2">Textual Information, Broadcasts
Wind & Track</td></tr>
<tr><td>Satellite, radar</td><td>Radio, TV announcements</td></tr>
</table>

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, ROHK gradually operated the signals in a way that allowed less false alarms, that is, less lead time before the expected wind strength was reached. Thus, one finds in Figure 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 Figure 6.

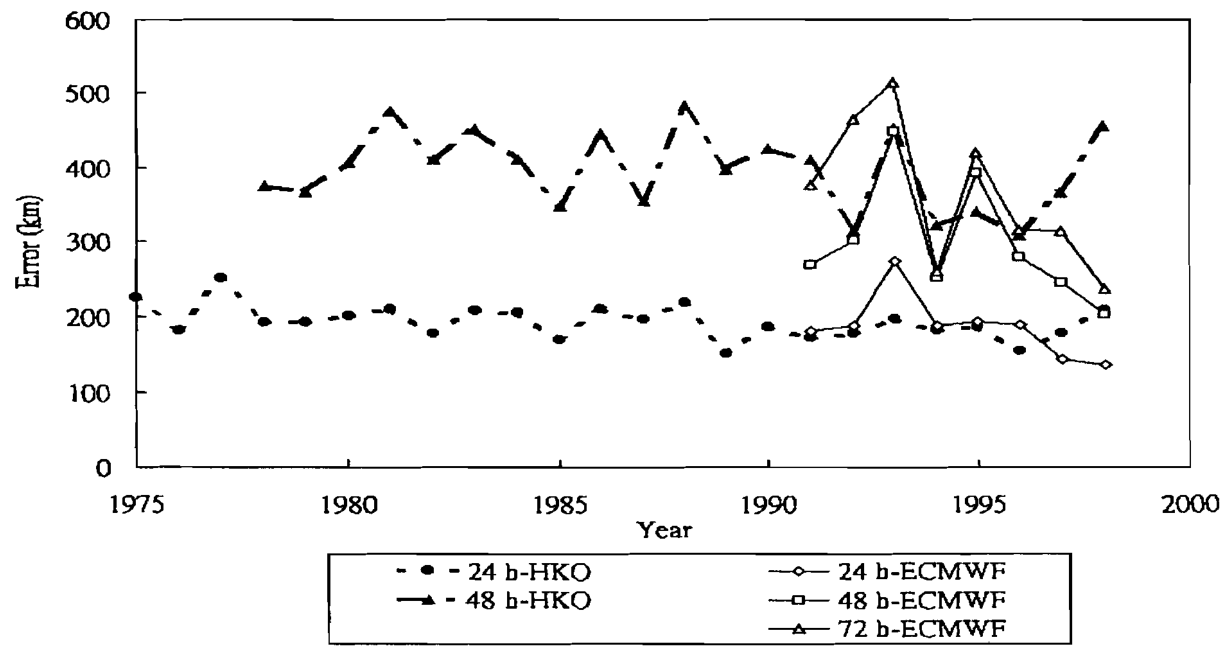
The 1990's

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.

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 enormous pressure on HKO.

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, Figure 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.

Figure 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 (2001).**

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).

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 indoors in black signal situations.

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 individualized alerting was practiced.

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.

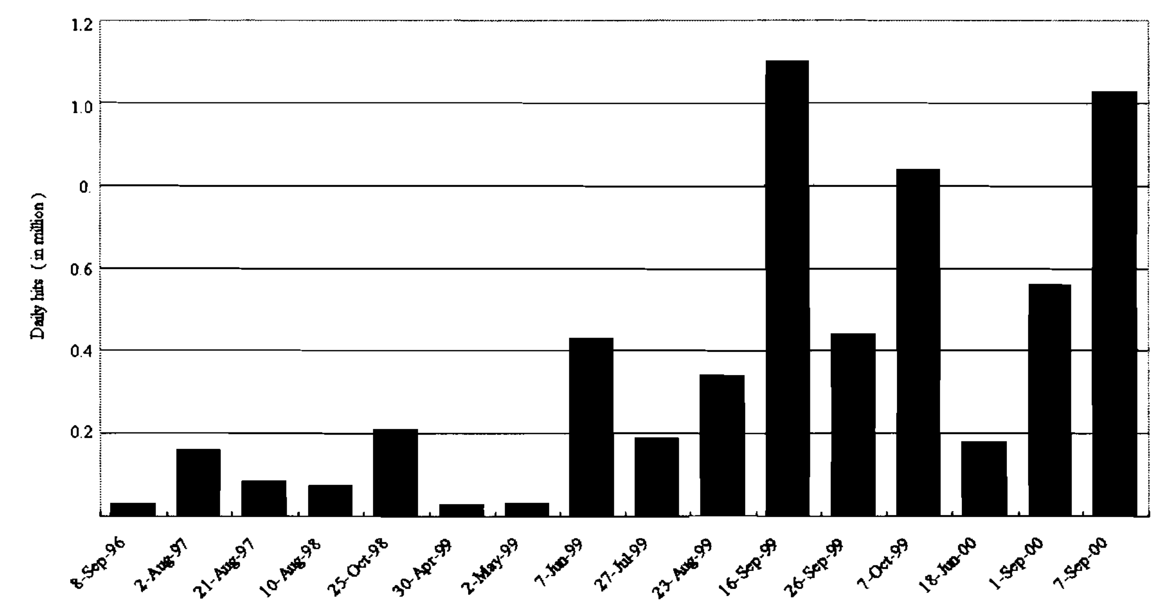
Figure 8 **Tropical cyclone warning system, 1990's**

<table>
<tr><td>Complex
transport
infrastructure</td><td>"no loss of life"
Minimum disruption to
economic activities</td></tr>
<tr><td colspan="2">Textual and Graphic Information on
Tropical Cyclone and Local Weather
Individualised Alerting, Homepage
Wind, Rain, Track</td></tr>
<tr><td>NWP
automatic weather stations</td><td>Telephone, pager
mobile phone
internet</td></tr>
</table>

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 Figure 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 (Figure 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.

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



Looking Ahead

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 organized 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.

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.

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. (2001) Performance of the ECMWF model in forecasting the tracks of tropical cyclone in the South China Sea and parts of the western North Pacific. *Meteorol. Appl.*, Vol. 8, 339-344.

Mickey Man-Kui Wai

Plum Rain Solutions, 2019 Skyland Drive, Tallahassee, FL 32303, USA

Is There Any Hope for the Use of Signals in the Tropical Cyclone Warning System in Hong Kong?

Abstract

Under the current demographic condition, the use of signals in the current tropical cyclone warning system is not suitable for Hong Kong. It is because no one surface station can be used to issue a signal appropriate for the entire territory of Hong Kong. The effects of terrain and urban development in various manners make the local winds at numerous localities weaker than the intensity of the tropical cyclone. Therefore, the surface wind signified by the signal does not always represent the surface wind speeds and directions over the territory. The closing of Hong Kong under the warning signal No. 8 is an emergency response to a potential natural disaster under the current Hong Kong three-tier emergency response system, which focuses mainly on rescue, recovery, and restoration. Considering the spatial and temporal aspects, the emergency response to a major accident differs from the emergency management of a typhoon closure or evacuation. An alternate tropical cyclone warning system is outlined in the study. In this system, the signals are not used; instead the tropical cyclone watch and the tropical cyclone warning are used. Wind watch, flood watch, wind warning and flood warning are issued to targeted localities. Associated with the proposed tropical cyclone warning system, a framework of the typhoon management of closure and evacuation is illustrated and highlighted.

Introduction

When a tropical cyclone approaches Hong Kong, three important forecasting problems emerge. The first forecasting problem is the changes in the intensity and directions of movement of tropical cyclones when the tropical cyclones penetrate into the South China Sea. A recent study (Wai, 2000) has focused on the changes in the intensity of the tropical cyclones in the South China Sea. The second forecasting problem is the timing to issue the warning signals to the Hong Kong public and the mandatory closure of the territory. Because of the complex terrain of Hong Kong, the third forecasting problem is to understand how the local wind and rainfall patterns vary as a tropical cyclone passes by or crosses over Hong Kong from various directions. The latter two problems are important topics in the typhoon forecasting over Hong Kong. A study of the third forecasting problem will be presented in another paper. In this paper, we shall focus on the use of warning signals in the current tropical cyclone warning system in Hong Kong.

The use of warning signals to warn the public about the local winds as a result of the arrival of a typhoon or a tropical storm in Hong Kong dates back to 1884 (Anonymous, 1930; Anonymous, 1938). Although the warning system has been revised numerous times in the past century, the objectives of the warning system to provide adequate meteorological information to mariners in the territory and in the open oceans are fundamentally unchanged for two reasons. First, the prosperity of Hong Kong owes much to its role as a trading post through her successful seaport in Victoria Harbor. It thus is necessary to provide mariners with accurate meteorological and oceanographic information so that they can steer the vessels or small crafts so as to enter and depart the harbor safely. Second, it has been documented that the Victoria Harbor is not considered as a safe typhoon haven (Mautner and Brand, 1973; Brand 1996). Therefore, it is of utmost importance for the forecasting office to provide accurate and prompt meteorological and oceanographic information associated with a typhoon to mariners such that they have enough time to make a safe evasion. Such warnings are also critical to those who have business or valuable properties along the waterfront within the harbor.

The current warning system (see Appendix I) has not been studied quantitatively in the past 25 years even though Hong Kong has undergone rapid changes. Therefore, in view of the recent demographic condition and the diverse economical bases and land uses, there are several reasons to justify the need for such a study.

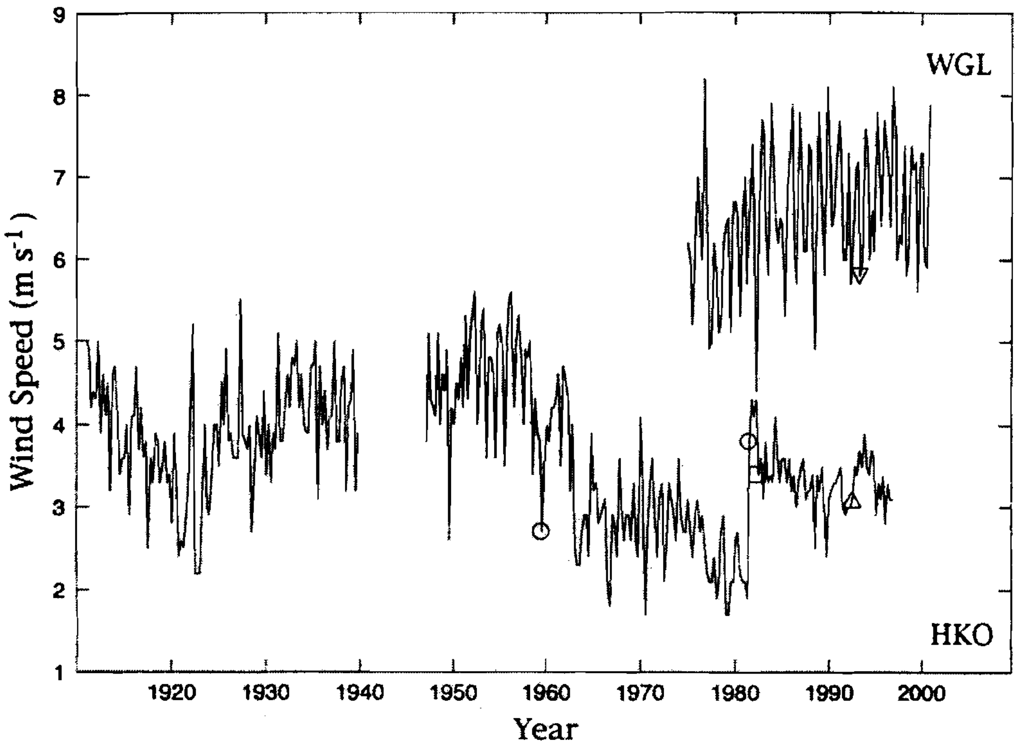
First, the current warning system involves two procedures. The first is the typhoon forecast, and the second is the issuance of the warning signals. The second part requires keen judgment, which can be hamstrung by poor understanding of the approaching tropical cyclone. Since the uncertainty of the track of a tropical cyclone over open oceans is quite large and the erratic behavior of the tropical cyclones can be beyond human's comprehension and the ability of the numerical weather predication model, making judgment when to issue the signal will make the task not only difficult but also make the signal less credible. Therefore, it is unclear if the use of signal in the current warning system is the most suitable for Hong Kong.

Second, being the headquarter of the Hong Kong Weather Service, the surface observations at the Hong Kong Observatory (HKO) are often used to denote the official surface observations in the territory. In the post war years, the rapid commercial development surrounding HKO has a significant local effect on the wind flow. As shown in Figure 1, the wind speeds recorded at HKO in the prewar years and at Waglan Island (WGL) suggest that the surface wind differential between these two surface stations is probably 2 ms^{-1}. However, in the post war years, the differential between these surface stations widened gradually to about 5 ms^{-1} in 1980. After the mast at the HKO was raised even higher in 1990s, the differential was reduced to about 4 ms^{-1}. The downward trend of weaker surface wind persists at HKO. Therefore, it is uncertain if there is a reference surface station the winds at which can be used to issue a warning signal.

Third, over the years, the public has learnt to become accustomed to the 'stay at home' or 'go home' signal No 8. To keep the vibrant city going, increasing pressure is to use the blanket 'go home' signal in the late afternoon hours in order to make the 'go home' signal coincide roughly with the end of a workday. Similarly, the 'stay at home' signal is preferably used prior to the beginning of a workday in order to avoid the traffic chaos. While the practice is simple, however, it could be very costly in terms of the loss of productivity or possibly the loss of life. It is also unclear if one signal can represent the wind conditions over the whole Hong Kong territory.

Fourth, numerous New Towns have been developed in various remote parts of the territory since 1970s in order to redistribute the overcrowded population along the narrow coastal stripes within the Victoria Harbor and in the inner cities on the Kowloon Peninsula. Therefore, the commercial and industrial activities, social services, and educational activities are also decentralized from along the waterfront and in the inner cities on the Kowloon Peninsula. Consequently, the focal point in the current warning system solely on the Victoria Harbor does not serve the public at large well.

Figure 1 **Surface wind speeds at Waglan Island (top) and the Hong Kong Observatory (bottom) in ms^{-1}. The symbols mark the dates when the center of the anemometer was raised to a higher altitude.**



Fifth, because of the development of New Towns, many private, public, and commercial organizations have also moved into these New Towns in order to for provide better services without requiring the local residents to travel long distances. Moreover, to meet the re-distribution of the population and relocation of large infrastructures, a network of roadways connects the downtown district with various remote townships, the airport, industrial complexes, and private or public service organizations throughout the territory. The network of roadways has provided the expedient transportation to reach many remote localities in the territories where they were once beyond the reach by public transportation years ago. Therefore, the blanket 'stay at home' or 'go home' signal no. 8 becomes less mandatory simultaneously for every public or private sectors.

Objectives

The objectives of this study are centered on four questions. The first question is whether the use of signals is suitable for Hong Kong. Is there a station where the surface winds can be used to issue a warning signal? Also, can one signal represent the wind condition over the Hong Kong territory? The assertion of 12-hour advanced warning of a gale from signal No.3 to signal No. 8 requires substantiation. One can investigate these questions by analyzing the actual wind observations at various surface stations during the passages of tropical cyclones. If the results of the analyses do not support the objectives of the current warning system, then what will be the alternate solution to the present warning system?

The remaining paper is organized in the following manner. The next section gives a description of the data used. Then there follows an analysis of the data and a description of the results. The discussion and conclusions are presented in the remaining sections.

Data

The surface wind velocities, surface pressure, and rainfall for a group of 37 tropical cyclones between 1960 and 1999 (Table 1) were obtained from Hong Kong Observatory (HKO). In this study, the wind observations are used. The wind data are the 10-minute mean at the top of the hour except at Waglan Island (WGL), where the wind speeds are 60-minute means and the directions are given by the prevailing mean direction. Between 1960 and 1971, the daily wind observations at WGL were incomplete. The unavailable observations at the time, when the typhoon signals are issued, are considered as missing data.

Table 1 Names of tropical cyclones used in study (1960 to 1999)

Year	Date	Name	Highest Signal Number	Number of Stations
1960	8 – 9 Jun	Mary	10	2
1961	19 May	Alice	10	2
1962	31 Aug – 1 Sep	Wanda	10	2
1964	5 – 6 Sep	Ruby	10	2
1964	12 – 13 Oct	Dot	10	2
1966	13 – 14 Jul	Lola	8	2
1968	21 – 22 Aug	Shirley	10	4
1971	16 – 17 Aug	Rose	10	4
1973	16 – 17 Jul	Dot	9	4
1975	13 – 14 Oct	Elsie	10	2
1979	2 – 3 Aug	Hope	10	5
1980	11 – 12 Jul	Ida	-	5
1980	26 – 28 Jul	Kim	3	5
1981	6 – 7 Jul	Lynn	8	3
1983	8 – 9 Sep	Ellen	10	5
1983	13 – 15 Oct	Joe	8	5
1984	24 – 25 Jun	Wynne	8	5
1985	24 – 25 Jun	Hal	8	5
1986	11 – 12 Jul	Peggy	8	5
1987	27 – 28 Oct	Lynn	3	5
1987	17 – 18 Nov	Nina	-	5
1988	19 – 20 Jul	Warren	3	5
1989	19 – 20 May	Brenda	8	11
1989	17 – 18 Jul	Gordon	8	11
1990	30 – 31 Jul	Tasha	3	12
1991	23 – 24 Jul	Brendan	8	12
1993	27 – 28 Jun	Koryn	8	11
1993	19 – 20 Aug	Tasha	8	11
1993	16 – 17 Sep	Becky	8	11
1993	25 – 26 Sep	Dot	8	11
1994	11 –12 Sep	Luke	3	11
1995	10 –11 Aug	Helen	8	11
1995	30 – 31 Aug	Kent	8	11
1995	2 – 3 Oct	Sibyl	8	11
1999	6 – 7 Jun	Maggie	9	30
1999	22 –23 Aug	Sam	8	30
1999	15 – 16 Sep	York	10	30

At HKO, the 10-minute mean wind velocities of 5 tropical cyclones prior to 1966 were not available. To replace these missing data, the 10-min velocities of several tropical cyclones in more recent years, such as 1988, are compared with their 60-minute mean velocities that are listed in the *Surface Observations in Hong Kong*. The differential in the wind direction is only plus or minus 5 degrees, and the differential in the wind speed is less than 5 knots. The wind direction is basically coming from the same quadrant; the magnitude of the wind speed lies in the range of the wind speed signified by the signal. Therefore, to complete the length of the data, the missing 10-minute wind observations at HKO between 1960 and 1966 are replaced by the hourly mean listed in the *Surface Observations in Hong Kong*.

During this period, the number of available stations ranges from two stations in 1960 to thirty three stations in 1999. To gain some insights into the use of signals in the current warning system within the Victoria Harbor, HKO, WGL, Cheung Chau (CCH), Green Island (GI), Tamar (TAM), Star Ferry, Kowloon (SF), and Central, Hong Kong Island (CEN) are selected. When the changes in the wind speed are studied during a tropical cyclone, all of the stations are used in that tropical cyclone (see Table 2).

Waglan Island and Cheung Chau are marine stations located in southern Hong Kong, which are relatively well exposed to the winds. Hong Kong Observatory can be considered as an urban station even though it is approximately 1 km from Victoria Harbor. Star Ferry, Kowloon, Central, Hong Kong Island, and Tamar are stations along the waterfront inside Victoria Harbor. Green Island is a small, unhabited island located at the western end of Victoria Harbor. The observations at these stations within Victoria Harbor would provide some insight of the wind condition when the typhoons pass by or cross over Hong Kong.

Table 2 **Names and codes of surface stations used in study.**

Station Name	Code
Central	CEN
Chek Lap Kok	HKA
Cheung Chau	CCH
Cheung Sha Wan	CSW
Green Island	GI
Hong Kong Observatory	HKO
Kai Tak Airport	AMO
King's Park	KPS
Lau Fau Shan	LFS
Sai Kung	SKG
Sha Lo Wan	SLW
Shatin	SHA
Shek Kong	SEK
Shell Tsing Yi	HUD
Star Ferry, Kowloon	SF
Ta Kwu Ling	TKL
Tai Mei Tuk	PLC
Tai Mo Shan	TMS
Tate's Cairn	TC
Tsak Yue Wu	TYW
Tuen Mun	TUN
Waglan Island	WGL
Wong Chuk Hang	HKS

Data Analysis

For each tropical cyclone, the wind speed and wind direction are grouped under the warning signals No.3, No.8 (NE, SE, SW and NW), and No. 10 for HKO, CEN, WGL, CCH, SF, GI and TAM when the warning signals are issued. The warning signal No. 9 is not included in the analyses because the signal No. 9 does not signify the wind speed or wind direction. Several simple statistics are also calculated.

When the signal is issued, the time does not necessarily correspond to the wind observation at the top of the hour in the dataset. Therefore, additional tasks are required to select the appropriate wind velocity. If the signal is issued within 10 minutes to the top of the hour, the wind observation at that top of the hour is selected to represent the wind velocity corresponding to the signal. If the signal is issued outside the 10 minutes to the top of the hour, the wind velocity at the top of the hour, which either immediately comes before or after the signal, is selected when the wind speed agrees with the progression of the signals. The absolute magnitude of the wind velocity is of secondary importance because each warning signal signifies a given range of wind speeds and wind directions.

Results

Duration of 12-hour from signal No. 3 to No. 8

To verify the assertion of 12-hour advanced warning of a gale from signal No.3 to signal No 8, the duration of warning signals are tabulated from the HKO warnings and signal database from 1946 to August 1999. There were sixty-nine incidences when signal No. 3 was replaced by signal No. 8.

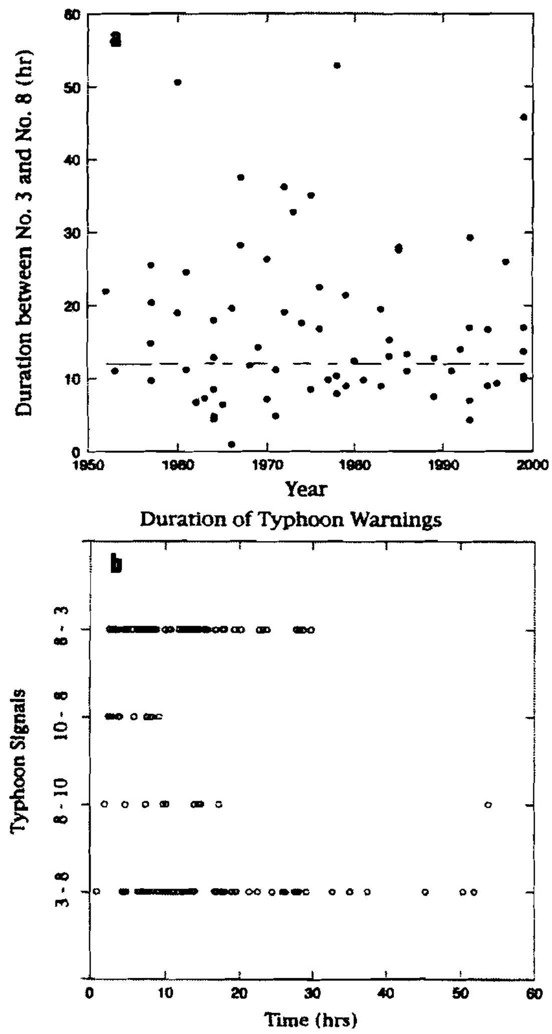
Figure 2a shows a scatter plot of these sixty-nine incidences based on the yearly consideration. The horizontal line marks the duration of 12 hours. About 43% of the total incidences are below 12 hours. The randomness of the data in the diagram does not show a trend that the signal No 8 will replace the signal No.3 within 12 hours, indicating that the assertion of 12-hour advanced warming has no basis.

To examine the variability in the duration, the change of signal is plotted against duration. For comparison, Figure 2b also shows the plots of duration from signal No. 8 to signal No. 10, from signal No. 10 to signal No. 8, and from signal No. 8 to signal No. 3.

The variability in the duration from No. 3 to No. 8 is large ranging from 1 hour to 51 hours, which has a mean of 16.6 hours with a standard deviation of 10.5 hours. About 72 percent of the 69 incidences fall below 20 hours. If the calculation is based on this sample, it has a mean of 11.3 hours with a standard deviation of 5.6 hours. However, the mean becomes 8.2 hours if the sample is taken between 1 and 10 hours (31.8 percent of the incidences). Similarly, the mean increases to 14.4 hours if the sample is taken between 10 to 20 hours (40.5 percent of the incidences). Moreover, if the tabulation is centered on 12 hours with plus or minus one hour, only 11 percent of the incidences lie between 11 to 13 hours. Clearly, the intention to provide 12 hours in advance warning is difficult to achieve.

Comparing to others, the variability in the duration from signal No. 8 to No. 10, and from signal No. 10 to signal No. 8 are both small and more consistent than the duration from signal No. 3 to No. 8 and also from No. 8 to signal No. 3. When the signal No. 8 is replaced by the signal No. 10, it is the indication that a storm is making landfall in the vicinity of Hong Kong. Therefore, the duration that Hong Kong is exposed to a storm under the landfall situation is relative short. More frequently, the synoptic situations prevent the storms from reaching close enough to Hong Kong or the intensity does not warrant a higher signal after the signal No 8 is issued. Then, the storms either recur away from Hong Kong or wander in the South China Sea. Therefore, the duration of typhoon warnings on the wings are longer and more variable.

Figure 2 **Duration of warning signals. (a) Yearly changes of duration between the warning signal No. 3 and the warning signal No. 8. (b) Various duration of warning signals. The horizontal dashed line indicates the 12-hour duration.**



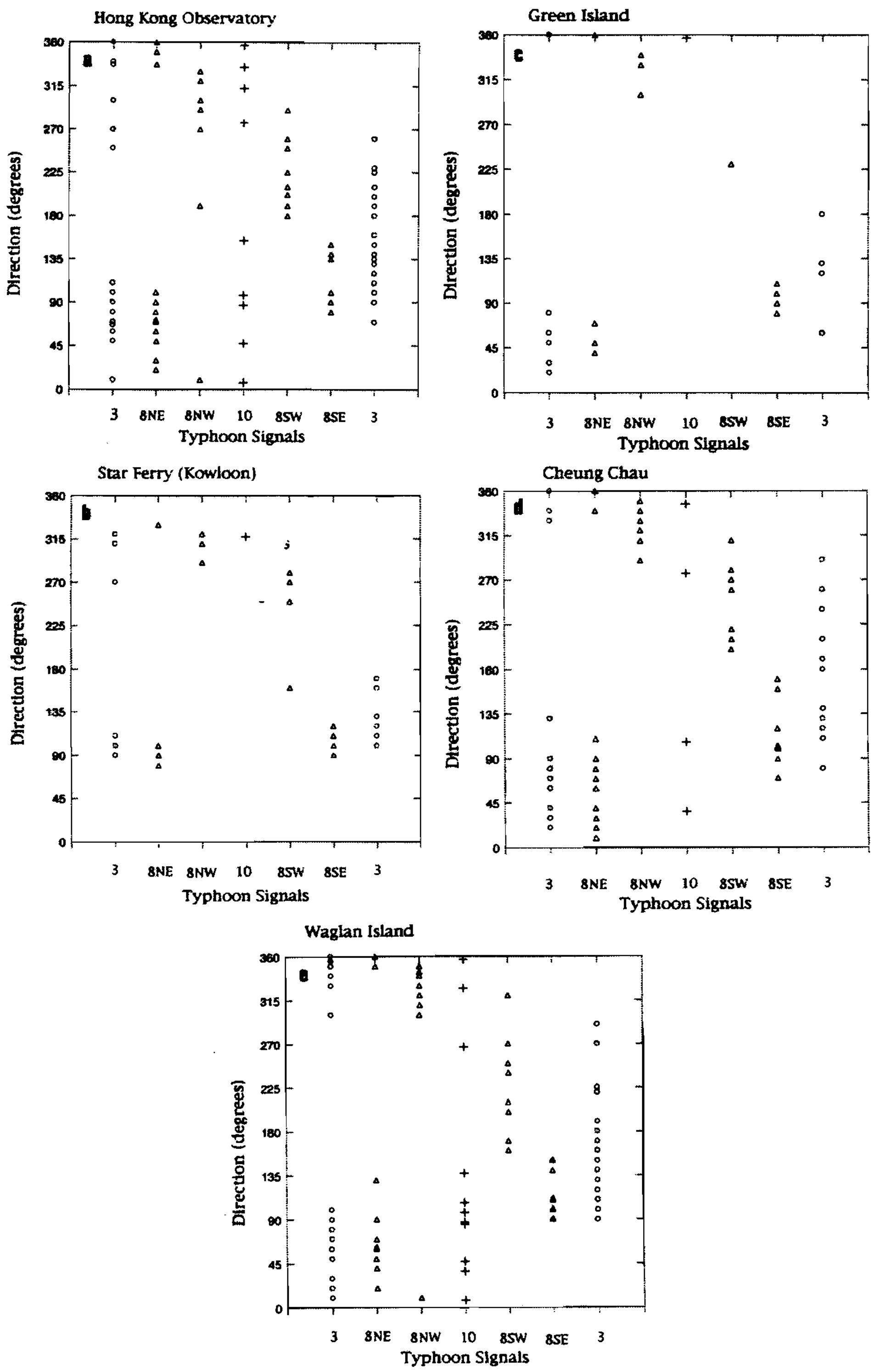
Wind direction

Figure 3 displays the observed wind directions at HKO, SF, GI, CCH, and WGL when the warning signals are issued. The results for TAM and CEN are not shown because of their short records but interesting features are included in the discussion. For brevity, the signified wind directions or wind speed by a warning signal are defined as the forecasted wind directions or wind speeds.

The timeline of the passage of a tropical cyclone is depicted by the orders of the warning signal in the diagram. For instance, from left to right, the warning signal No. 3 indicates the approach of a tropical cyclone. Similarly, the last warning signal No. 3 refers to the last signal prior to the departure of the tropical cyclone from Hong Kong. One should bear in mind that the timeline for a tropical cyclone can begin with a signal No. 3, and then followed by No.8 NE, No.8 SE, and finally No. 3.

The wind directions at the HKO, SF, GI, CCH, and WGL show a similar temporal pattern. As a tropical cyclone approaches Hong Kong, the surface winds in the Victoria Harbor and the coastal water in the southern territory come out from the north. When the tropical cyclone has passed by or crossed over Hong Kong, the surface winds come out from the south.

Figure 3 Observed wind directions in degrees under various warning signals. Symbol circles refer to the warning signal No.3. Symbol triangles represent the warning signal No. 8. (a) Hong Kong Observatory; (b) Star Ferry, Kowloon, (c) Green Island, (d) Cheung Chau, and (e) Waglan Island.



When the signal No 8 is issued, the percentages of agreement in the wind direction vary from station to station. When the signal is No. 8 NE, about 66 percent of the wind directions at HKO agree with the signal (Figure 3a). At SF, it decreases to 1 percent (Figure 3b). When the signal is No. 8 NW, 66 percent of the observed wind directions at HKO agree with the signal (Figure 3a). At SF, the agreement increases to 100 percent (Figure 3b). When the signal is No. 8 SW, only 81 percent of the observed wind directions at HKO correspond to the signal (Figure 3a). At SF, a comparable 75 percent of agreement is found (Figure 3b). However. At CEN, the agreement is only 5 percent.

The worse incidence occurred when the typhoon signal No. 8 SE is issued. For instance, 25 percent of the observed wind directions at HKO agree with the signal (Figure 3a). At TAM, it is a zero percent. When the typhoon signals No.8 SE and No. 8 NE are issued, 60 percent of the wind directions inside Victoria Harbor (as indicated by HKO, SF, CEN, and TAM)) come from a narrow angle between 80 and 100 degrees. Basically, the wind inside Victoria Harbor is easterly.

Outside Victoria Harbor, the percentages of agreement in the four wind directions range from 60 percent to 100 percent at GI (Figure 3c). Similarly, 60 to 70 percent of the observations at Cheung Chau agree with the signal (Figure 3d) while 45 to 77 percent of the wind directions at Waglan Island agree with the signal (Figure 3e).

Wind speed

In Figure 4 the observed wind speeds under various warning signals are shown. The horizontal dashed lines mark the cut off that corresponds to the warning signals. For instance, the symbol + above the horizontal dash line at 64 kt corresponds to the warning signal No. 10. If the symbol + lies below 64 kt, the signal No. 10 is issued at the time when the wind speed is below what the warning signal signifies. Since the data do not include gust data, a brief discussion on the gust factor will be given in a later section.

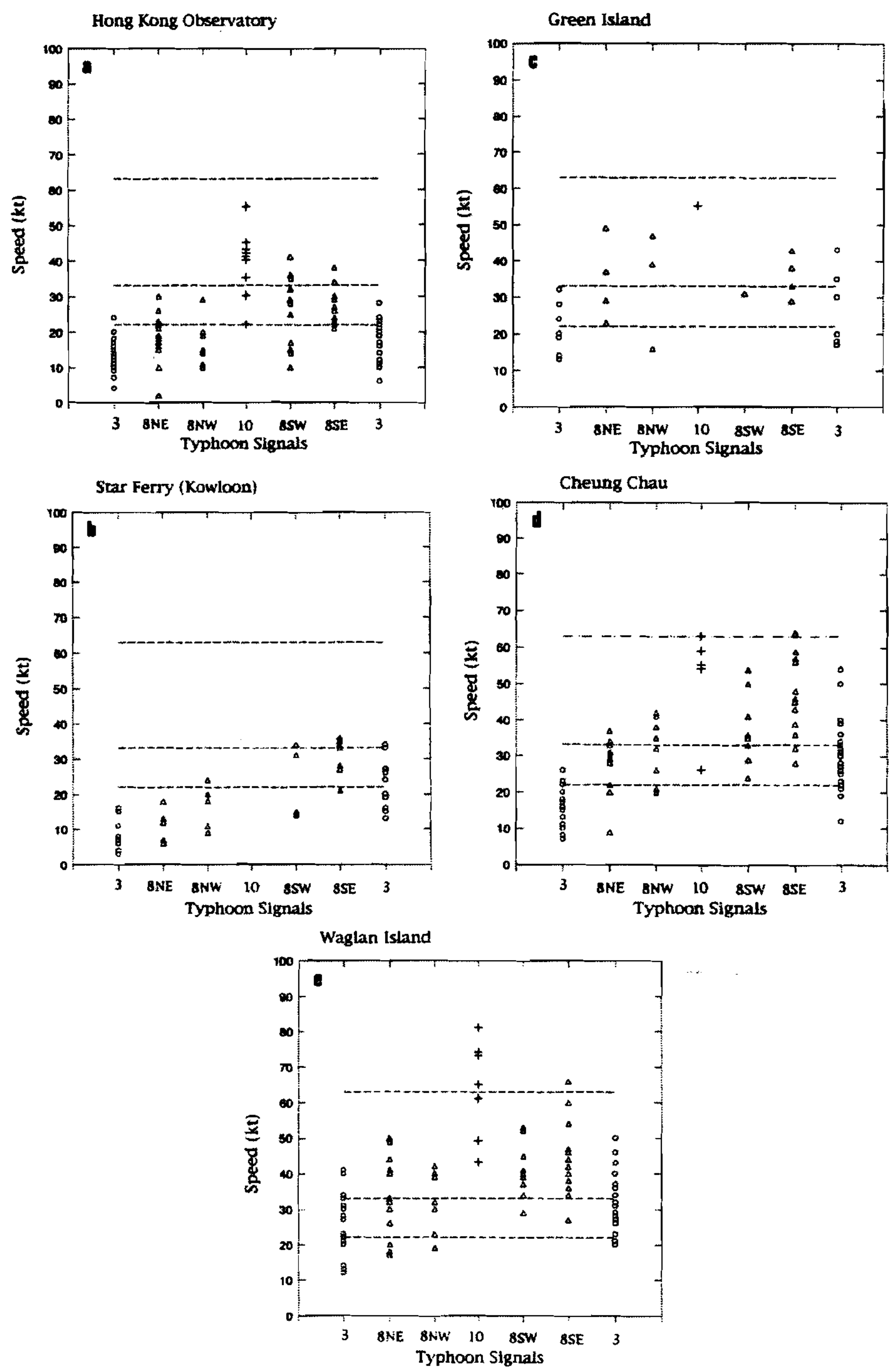
Inside Victoria Harbor, the observed wind speeds are mostly lower than what all of the warning signals indicate (Figure 4a and 4b). None of the reported winds are in the typhoon wind force when the signal No.10 is issued. When signal No. 8 SE is issued, less than 50 percent of the observed winds agree with the forecasted wind speeds. For other directional signals of No.8, less than 25 percent of the observed winds agree with the signal. However, at Green Island, which is further away from the interior harbor, the percentages of agreement are relatively better (Figure 4c). For instance, about 50 percent of the observed winds concur with the signal No. 8 SE while about 50 and 60 percent of the observed winds agree with signal No. 8 NE and No. 8 NW respectively. At CCH (Figure 4d) and WGL (Figure 4e), the percentages of agreement are between 70 and 100 percent for the four directional signals of No. 8.

In is interesting to note that the wind speeds are higher in the post-storm period than those in the pre-storm period. Note that these higher wind speeds are not associated with gusts because they do not exceed the gust that signifies a warning signal. Under signal No. 8, the wind speeds are higher when they come from the SW and SE quadrants. In one incidence under the warning signal No. 8 SE, the local wind speeds at CCH (Figure 4d) and Waglan Island (Figure 4e) are actually the typhoon wind force.

Moreover, 30 percent of the wind speeds at CCH under warning signal no. 3 can be treated as the warning signal No. 8 (Figure 4d). Similarly, 36 percent of the wind speed at WGL under the warning signal No. 3 in the post-storm period can be issued as the warning signal No.8 (Figure 4e). Even at HKO, only 25 percent of the wind speeds under the warning signal No. 3 in the post-storm period concur with the wind speed in the warning signal No. 3 (Figure 4a). However, in the pre-storm period under the warning signal No. 3, only 5 percent of the observed wind speeds at HKO agree with the signal.

In short, under a typhoon or a tropical storm, the wind speeds over various parts of Hong Kong vary significantly. In particular, the wind speeds within Victoria Harbor are substantially lower than the

Figure 4 **Observed wind speeds in knots under various warning signals. Symbol circles refer to the warning signal No.3. Symbol triangles represent the warning signal No. 8. Horizontal dash lines mark the speed in knots corresponding to the signals. (a) Hong Kong Observatory; (b) Star Ferry, Kowloon, (c) Green Island, (d) Cheung Chau, and (e) Waglan Island.**



forecasted wind speed by the signal. Therefore, using the wind speed in Victoria Harbor as the reference point does not serve the public at large well. The patterns of the wind speed and wind direction reveal the difficulty of using the signals in the current system to warn the Hong Kong public. If the winds at CCH or WGL were used to issue a signal, the signal would very well over warn those who reside in the urban areas and in the New Territory. On the contrary, if the signal is issued based on the wind speed within Victoria Harbor, the signal would under warn those who reside in those densely populated islands, such as CCH, and townships where are exposed to winds coming from the southeastern and southwestern quadrants.

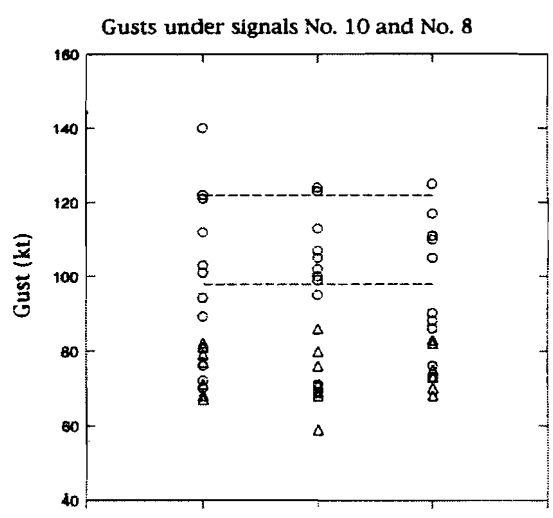
In the case of Typhoon Ellen, the wind speed at CCH is in the typhoon wind force while the signal is No. 8. Furthermore, in some cases, the actual wind speeds at some localities in the post typhoon period tend to be higher than the wind speed signified by the signal, suggesting that the lowering of warning signals is too early with respect to those localities. Therefore, one signal cannot represent the general wind conditions over the Hong Kong territory.

The gust during the tropical cyclones

In the current tropical cyclone warning system, gusts are also used to signify the warning signals. Therefore, it is appropriate to examine the relationship between the gust and the signal. The gust dataset is based on the calculation done by Poon (1982), who catalogued the peak gusts at HKO, WGL and CCH for 20 tropical storms between 1947 and 1979. Using HKO as a reference point, the warning signals were determined by using Poon's data, the HKO warnings and signals database, and the records in the *Surface Observations in Hong Kong.*

In Figure 5, symbol circles refer to signal No. 10 and symbol triangles mark the signal No. 8. The horizontal dash lines at 122 kt and 98 kt correspond to the gusts that signify the warning signal No. 10 and warning signal No. 8 respectively. There are a total of six incidences (about 20 percent) that gusts are around or above 122 kts at HKO, WGL, and CCH. The other 80 percent are below 122 kts that signify warning signal No 10. Moreover, none of the gusts at the three stations reach or exceed 98 kts that signify warning signal No. 8. Therefore, the usefulness of gusts to signify a warning signal is limited.

Figure 5 **Gust under warning signals No. 10 and No. 8 at the Hong Kong Observatory, Waglan Island and Cheung Chau. Symbol circles represent the warning signal No. 10 and symbol triangles represent the warning signal No. 8. The horizontal lines indicate the gust speed corresponding to the warning signals.**



Changes in wind speed during the typhoon

As discussed earlier, the observed wind speeds in Victoria Harbor do not always agree with the forecasted wind speed when the signal is issued. However, the expected wind speeds may eventually reach the forecasted wind speed of the corresponding signal. It is of interest to determine the length of time for the wind speeds to reach the gale wind force after the signals No.8 are issued from a group of tropical cyclones. In this case, Mary (1960), Alice (1961), Wanda (1962), Ruby (1964), Dot (1964), Shirley (1968), Rose (1971), Elsie (1975), Hope (1979), Ellen (1983), Brendan (1991), Maggie (1999), Sam (1999), and York (1999) are selected. Except for Brendan, the rest of the tropical cyclones are typhoons.

After signal No. 8 is issued, the lengths of time required to reach the gale wind force do not show any uniformity. The changes in the wind velocities in the territories during the passages of typhoons are quite complicated. To illustrate the changes in the wind velocity, the time series of wind velocities during the passages of Typhoon Mary, Typhoon Rose, and Typhoon York are given in Figures. 7, 9 and 11. The changes of the warming signals during these three storms are shown in Figures 6, 8, and 10 respectively. A detailed discussion of the changes in the wind velocity will be given in a forthcoming article on the interaction between tropical cyclones and local terrain.

Figure 6 **Warning signals for Typhoon Mary. Keys: No. 3 ⊥, No. 8 NE, No. 8 SE, No. 8 SW ∇, No. 8 NW Δ, No. 9 ⧖, No.10 +.**

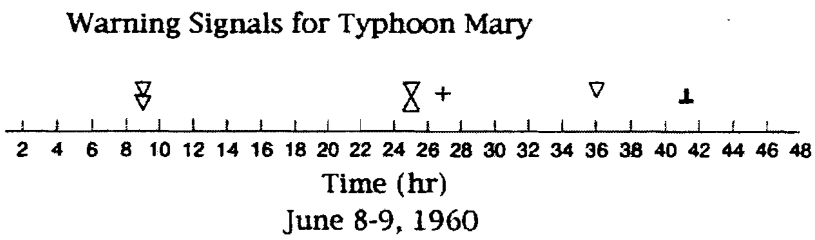


Figure 7 **Time series of surface wind velocities at (a) the Hong Kong Observatory and (b) Waglan Island during the passage of Typhoon Mary. The bottom panel shows the temporal changes of intensity, distances, and the direction of approach of the typhoon from Hong Kong. The solid circles represent direction in degrees and histograms give the wind speeds or typhoon intensity in knots.**

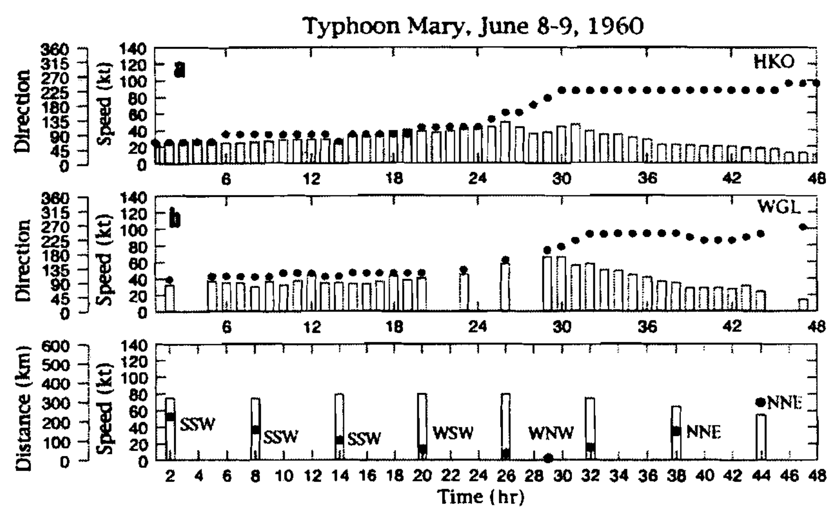


Figure 8 Warning signals for Typhoon Rose. Keys: same as in the Figure 6.

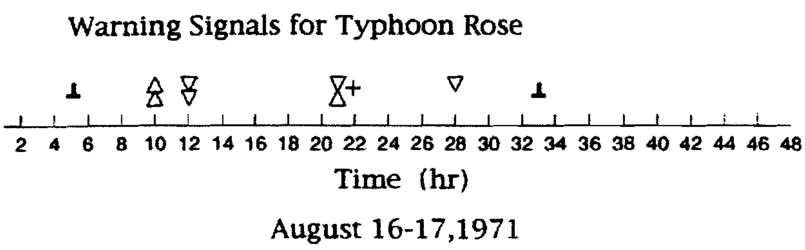
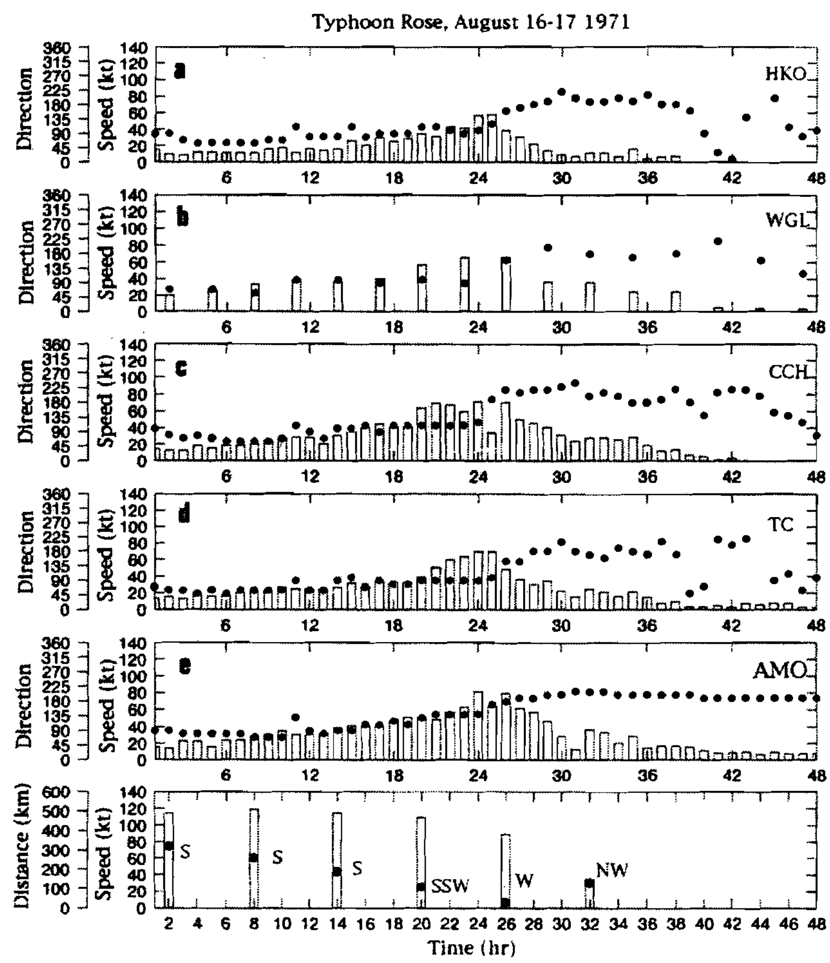


Figure 9 Time series of surface wind velocities at (a) the Hong Kong Observatory and (b) Waglan Island, (c) Cheung Chau, (d) Tate's Carin, and (e) Kai Tak during the passage of Typhoon Rose. The bottom panel shows the time changes of intensity, distances, and the direction of approach of the typhoon from Hong Kong. The solid circles represent direction in degrees and histograms give the wind speeds or typhoon intensity in knots.



On contrary, before the warning signal No. 8 is issued, the gale wind force at WGL (Figure 7) has been blowing for seven hours in the cases of Typhoon Mary and for two hours in the case of Typhoon Rose (Figure 9). In the cases of Typhoon Dot, Typhoon Shirley and Typhoon Elsie, the wind speeds at Waglan Island reach the gale wind force when the warning signal No.8 is issued. Only in Typhoon Alice, Typhoon Wanda, Typhoon Hope, and Typhoon Ellen, did the wind speed reach the gale wind force within a couple of hours after the warning signal No. 8 was issued.

In a more recent case of Typhoon York (Figure 11), the surface winds at Waglan Island and Tate's Carin had been in gale wind force for 5 to 6 hours when the signal No 8 was issued. Even at CCH, the surface wind was already in the gale wind force. During the entire passage of typhoon York, the surface winds at HKO, CEN, CSW, LFS, and TKL and HKS did not reach the gale wind force. At other stations, the surface wind reached the gale wind force from 1 to 5 hours.

Figure 10 **Warning signals for Typhoon York. Keys: same as in the Figure 6.**

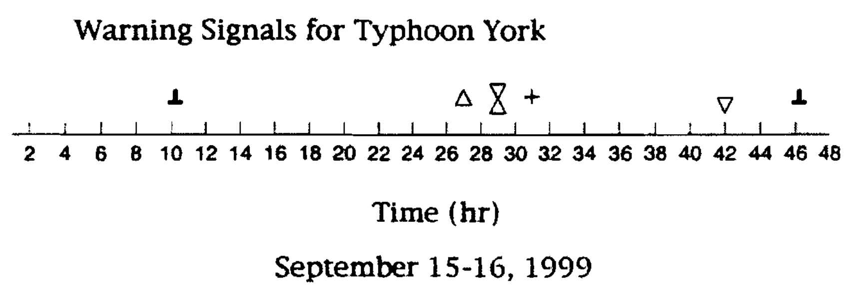
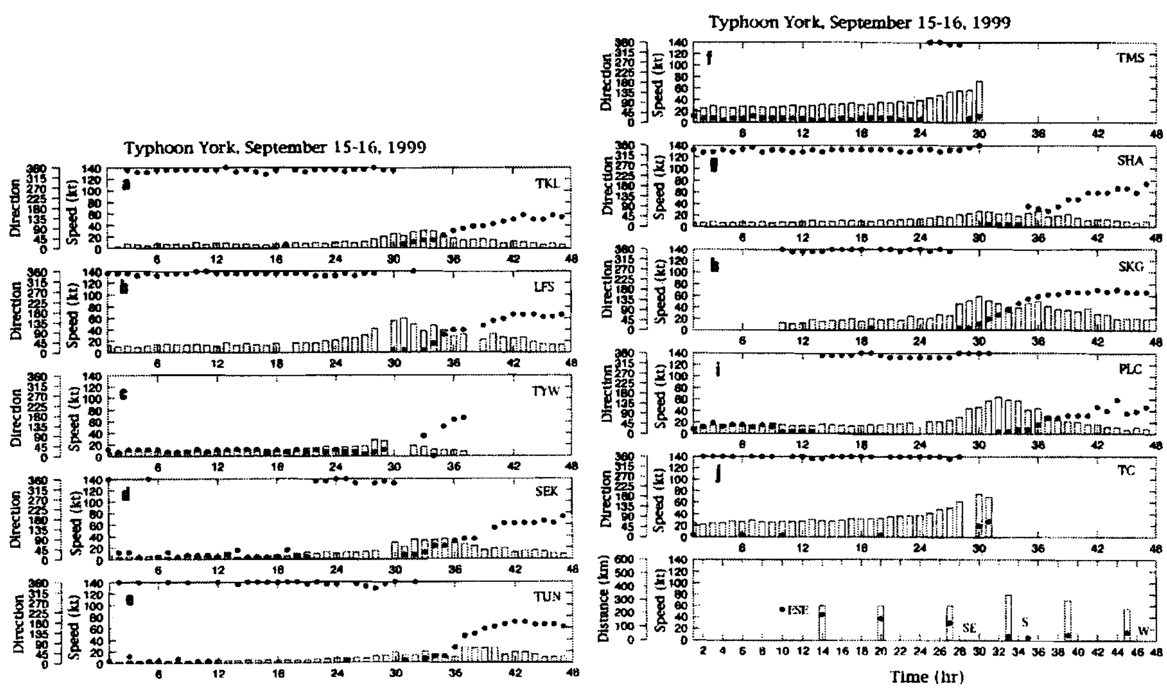
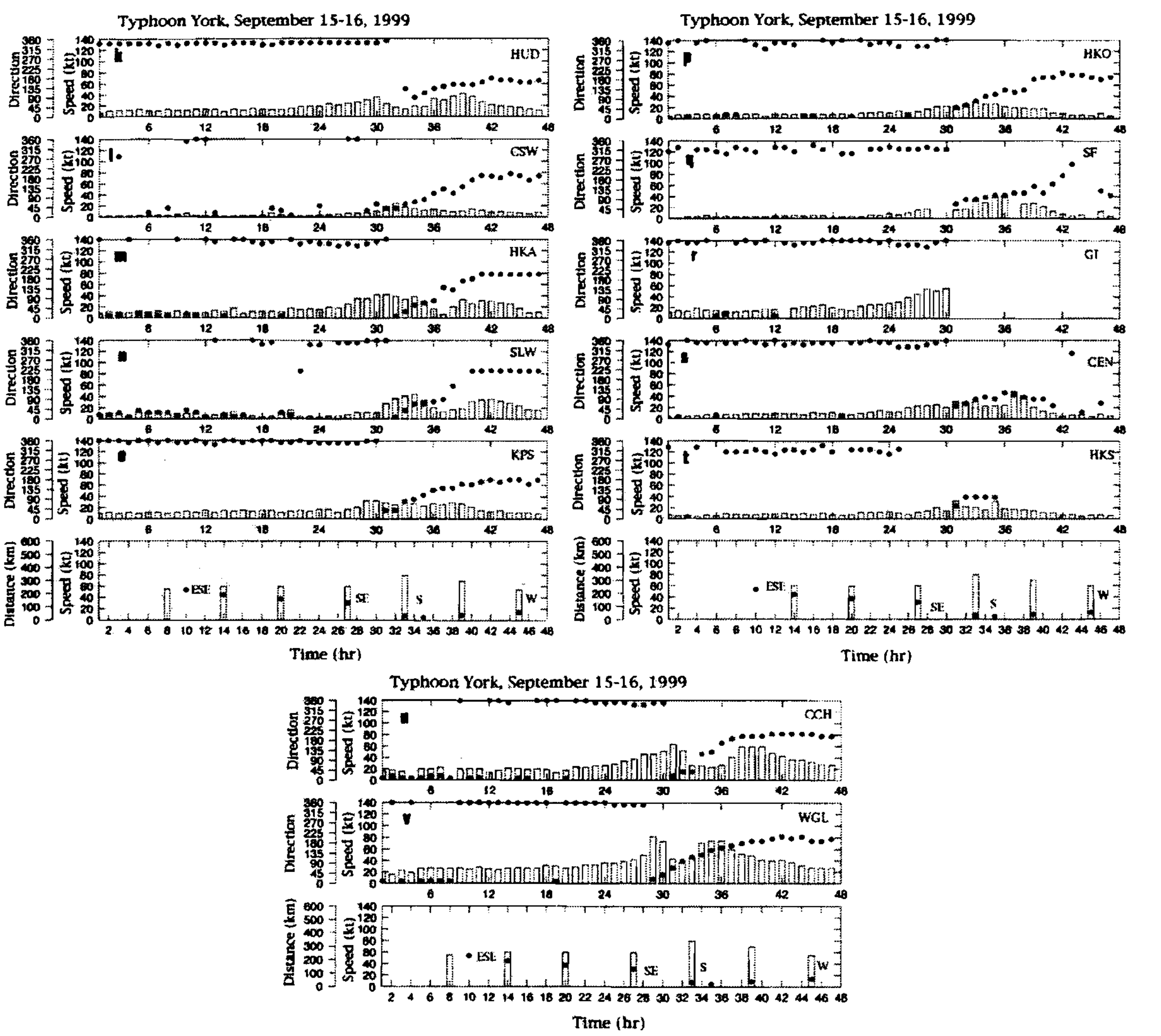


Figure 11a **Time series of surface wind velocities at (a) Ta Kwu Ling, (b) Lau Fau Shan, (c) Tsak Yue Wu, (d) Shek Kong, (e) Tuen Mun (e) Tuen Mun, (f) Tai Mo Shan, (g) Shatin, (h) Sai Kung, (i) Tai Mei Tuk and (j) Tate's Cairn during the passage of Typhoon York. The solid circles represent direction in degrees and histograms give the wind speeds or intensity in knots. The solid circles represent direction in degrees and histograms give the wind speeds or intensity in knots.**



The surface winds over many localities do not reflect the intensity of Typhoon York. Although the eye of the storm crossed over western Lantau Island, all of the stations show the wind shift. However, not every station left the signature of the eye of the storm just by examining the wind speed. The pattern of surface winds over the territories reveals the complex physics of the local effects. The discussion of the interaction between tropical cyclones and local terrain will be presented in a forthcoming paper.

Figure 11b Time series of surface wind velocities at (k) Shell Tsing Yi, (l) Cheung Sha Wan, (m) Chek Lap Kok, (n) Sha Lo Wan, (o) King's Park, (p) Hong Kong Observatory, (q) Star Ferry, Kowloon, (r) Green Island, (s) Central, Hong Kong, (t) Wong Chuk Hang, (u) Cheung Chau, and (v) Waglan Island during the passage of Typhoon York. The figure at the bottom is the temporal changes of intensity, distances, and the direction of approach of the typhoon from Hong Kong. The solid circles represent direction in degrees and histograms give the wind speeds or intensity in knots.



From the time series of the typhoon wind velocities at the surface stations, a reference station does not exist such that the wind velocity at the reference station is representative of the surface wind pattern over the territory and also agrees with what the signal predicts. Therefore, no one station can be used to issue the warning signals for Hong Kong under the current demographic conditions and the diverse economical bases and land uses.

Moreover, when the signal is issued, there is a time lapse that the observed wind speed either has already achieved the forecasted wind speed at one township or will approach the signified wind speed later in another district. In the worst situation, the wind speeds at some stations do not reach the forecasted wind speed during the passage of a typhoon. The situation will create the credibility problem of a signal. It can be hazardous to the public safety.

Discussion

Because no one station can be used to issue a signal appropriate for all of Hong Kong, the signal almost always leads to negative reactions from the public of being either over warned or under warned. In other cases, the public would find the signal is issued or cancelled either too early or too late. Moreover, the signal in the current tropical cyclone warning system does not always give the true wind conditions in the territory due to a tropical cyclone. Despite this, the death toll actually dropped rapidly from 10,000 in the 1900s to 130 in the 1960s, and finally to less than 5 in the 1990s. The decrease is not directly attributed to the use of the signal but rather it is more likely the results of other governmental policies.

First, the resettlement of boat residents in certain districts and squatter dwellers along the hillside removed the risk of facing heavy casualties when a typhoon makes landfall or passes by Hong Kong within 100 km radius. Second, numerous typhoon shelters in the exposed areas provide boats and small crafts a shelter during typhoons. Third, a strong building code and better building design have provided a safe and strong shelter for the citizens. In particular, the use of gust velocity as the basis for design helps the buildings better withstand a higher wind loading (Jeary, 1997). The occurrence of building collapse or the loss of rooftops due to typhoon wind force is rare.

While the signal system does not perform as is hoped for, does not mean that it is necessary to conclude that the tropical cyclone warning system should be abolished. On the contrary, because Hong Kong is located in the busiest typhoon basin and because Victoria Harbor is not a safe typhoon haven (Mautner and Brand, 1973; Brand, 1996), the tropical cyclone warning system is needed more than ever to inform the public and mariners of the arrival of a typhoon or a tropical storm. However, one must bear in mind that a tropical cyclone warning system can be effective without the use of signals and the use of the Victoria Harbor as a reference point.

Beside raising the signals, HKO has also become responsibile for notifying the public when to close all of Hong Kong whenever the signal No.8 is issued. The closing of Hong Kong is an emergency response to a potential natural disaster under the current Hong Kong three-tier emergency response system, which is organized in such a way that it mainly focuses on rescue, recovery, and restoration.

In many aspects, the emergency response to a major accident differs from the emergency management of a typhoon closure or evacuation. For the spatial consideration, the area of potential destruction at the ground zero in a major accident is confined to about 1 km square or less while the area of potential destruction during a typhoon passage is the entire area of Hong Kong. The chaos from a major accident is confined to a radius of 1 to 2 km surrounding the ground zero but the chaos from the typhoon closure or evacuation will spread over the entire territory. The magnitude in the potential loss of life, property, and productivity during a typhoon passage can be many orders larger than a major accident.

For the temporal consideration, the lead-time to issue a warning from a major accident ranges from zero to a few minutes. Therefore, in many cases of emergency response, the course of action begins after a major accident has occurred. Therefore, the emphases of rescue, recovery, and restoration under the situation are appropriate. On the contrary, in the cases of a typhoon, the lead-time to issue a warning of the arrival of a typhoon is at least 24 hours. Therefore, the course of action can begin before the potential disaster may occur.

Since the density of Hong Kong population is one of the highest among the cities in the industrial nations, the mandatory closure of all of the private and public sectors simultaneously will put millions of people requiring access to transportation, causing an enormous strain on the carrying capacity of the transportation providers and the major roadway and railway networks of. Moreover, the political boundary of Hong Kong and the mix of hilly terrain and water will limit the evacuation within the same district, island, or the peninsula the most. If the closure and evacuation are managed poorly, the man-made chaos will create many undesirable outcomes. Hence, if proper management of closure and evacuation are in place, loss of life can be prevented and loss of productivity and property minimized.

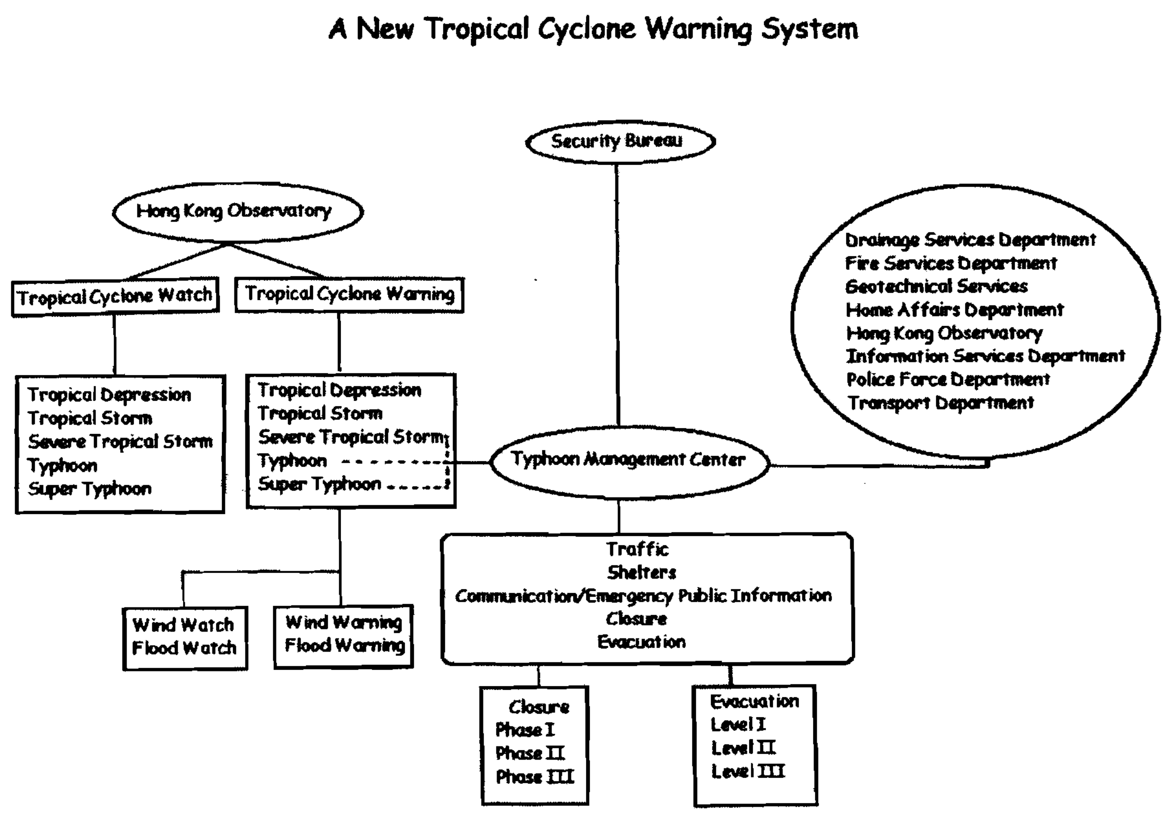
Concept of typhoon management

The management of the passage of a typhoon or a tropical storm over Hong Kong ought to start at an early stage when the magnitude of the threat was unknown and difficult to predict. Adequate preparedness would prevent the disastrous consequence of being unable to respond to a direct threat of an approaching tropical cyclone.

The management consists of two components. In the first component, HKO will be responsible for issuing the tropical cyclone watch and tropical cyclone warning to the public about the current state and the tendency of the tropical cyclones that will post potential threat to Hong Kong. In both tropical cyclone watch and the tropical cyclone warning, the signals are not used. The second component is to issue the voluntary/mandatory closure or evacuation to the public when it becomes necessary. The decision-making for closure or evacuation will be rest on an emergency management team, which is made up of the representatives of essential governmental departments and agencies.

A schematic diagram of the tropical cyclone warning system and its relation to the closure and evacuation illustrates one such a warning system in Figure 12. In the diagram, the ovals refer to the governmental departments or agencies. The rectangles represent the components of the warning system. The rectangles with rounded corners list the concept of operations.

Figure 12 A schematic diagram of a new tropical cyclone warning system.



The discussions of the logistical and organizational details in the Typhoon Management Center during a passage of a typhoon are beyond the scope of this study. A companion paper (Wai, 2001) illustrates how and when the watch and warning in the tropical cyclone warning system are applied in the Typhoon Maggie situation. Here brief discussions of the alerts, warning, closure, and evacuation in the tropical cyclone warning system are given.

Tropical cyclone warning system

The tropical cyclones in the tropical cyclone watch and tropical cyclone warning are tropical depression, tropical storm, severe tropical storm, typhoon, and super typhoon. These five types of tropical cyclones are currently used at HKO and other forecasting offices in the South China Sea basin.

Although one may further classify the typhoons into several categories based on their intensity, such classifications neither improve the skill of the typhoon forecast nor our understanding of the nature of the typhoon. As the typhoons pass by or cross over Hong Kong, the typhoons frequently lose their characteristic of intensity because the blocking effects of local terrain and the dense high-rise buildings make many local winds weaker than the true intensity of the typhoons.

Tropical cyclone watch

A tropical cyclone watch is an alert. Depending on the intensity of a tropical cyclone, the tropical cyclone watch can be a tropical depression watch, a tropical storm watch, a severe tropical storm watch, a typhoon watch, or a super typhoon watch.

A tropical cyclone watch is issued to the public under two situations The first is when a tropical cyclone enters a semi-circular zone between 800-1500 km of Hong Kong. The tropical cyclone watch is issued to the public indicating that a tropical cyclone is located just outside the 800 km threat radius from Hong Kong and its potential threat to Hong Kong. The second situation is when a tropical cyclone is observed developing within the South China Sea. If the intensity of a tropical cyclone in this 800-1500 km zone or in the South China Sea is higher than a severe tropical storm, advisory is issued to the mariners for proper action as the mariners may require at least 2 days to make preparation for a safe evasion to sea. The tropical cyclone watch includes information such as the position of a tropical cyclone, direction of movement, intensity of the tropical cyclone, speed, and distance from Hong Kong.

Tropical cyclone warning

The tropical cyclone warning will be issued in two situations. The first is when a tropical cyclone enters Hong Kong's 800 km threat radius or will affect Hong Kong within 24-48 hours at the direction of movement. The second situation is when a tropical cyclone that originates in the South China Sea has developed to a severe tropical storm. Similar to the tropical cyclone watch, the tropical cyclone warning can be a tropical depression warning, a tropical storm warning, a severe tropical storm warning, a typhoon warning, or a super typhoon warning, depending on the intensity of the tropical cyclone.

The elements in the warning include the positions of a tropical cyclone, distance from Hong Kong, direction of movement, intensity, sea state and swell, anticipated tidal surge, expected gust, storm surge, precipitation, and arrival time or closest proximity to Hong Kong at the present direction of movement. The key elements in the warnings will depend on the intensity of the tropical cyclone and the direction of movement of the tropical cyclone.

When a typhoon warning or a super typhoon warning is issued within the 800 km threat radius, or when a severe tropical cyclone that originates in the South China Sea can intensify to a typhoon or a super typhoon, the wind and flood watches begin. As the tropical cyclone comes closer to Hong Kong, separate wind warnings are issued to the targeted districts in Hong Kong instead of using one signal as the wind warning for the entire Hong Kong in the old system. As an integral part of the tropical cyclone warning, wind and flood warnings are issued to certain districts in Hong Kong for potential wind and flood damages. For completeness, the warnings are supplemented with the observations of local wind velocity and precipitation over targeted parts of the territories.

Voluntary/mandatory closures or evacuation

If Hong Kong is within the path of damage wind and rainfall upon the issue of a typhoon warning, or a severe tropical storm that could develop into a typhoon is on its way to Hong Kong, the Typhoon Management Center is activated (Figure 12). The representatives of the essential governmental departments and agencies will operate the Typhoon Management Center. Possible representatives of these governmental departments and agencies are shown in Figure 12. The staff at the Typhoon Management Center will collect emergency and management data from which the management team will manage traffic, shelters, communication/emergency public information, and make decision in closure or evacuation.

If the center of a typhoon or a severe tropical storm will make landfall or pass by within 350 km radius of Hong Kong in 24 hours, the Phase I of closure is issued. In phase I, the closure or the release of employees is strictly voluntary. The Phase II of closure is issued when the center of a typhoon or a severe tropical storm will make landfall or pass by Hong Kong within 200 km radius in 12 hrs. In Phase II, non-essential governmental employees are released. The Phase III of closure will be issued when the center of a typhoon or a severe tropical storm will make landfall or pass by Hong Kong within 100 km radius in 6 hr. The non-essential governmental departments or agencies under emergency situation will be closed. The parameters for helping the decision for closure are the intensity of the storm, direction of movement, speed of the storm, the local wind condition, and others.

The private sectors can either follow the practices of the government in closure or make their own judgment to close based on their location in the territories, the nature of the business, requirements to operate the business, the public demands of the services, among others. However, the private business is allowed to remain open only if the certain requirements are met. For instance, if the office of the stock market wishes to remain open during the passage of a typhoon, the premises must meet the typhoon building code, the office must install an emergency generator that can provide electricity up to 7 days, and it also allows their employees to have access to food, a place to rest, and other necessities within the premise in case they cannot go home and work at a longer shift.

There are three levels of evacuation as the results of a potential flood, storm surge, landslide, or typhoon wind damage. Level I of evacuation is issued when the residents are evacuated from a single building or a block of buildings from a street. Level II of evacuation is issued when the residents are evacuated from a zone. Level III of evacuation is issued when the residents are evacuated from a township.

Length of hours of operation

From a study of the changes in the typhoon intensity in the South China Sea, Wai (2000) showed roughly various lengths of time within which the tropical cyclones have affected Hong Kong after they had entered the South China Sea. If a tropical cyclone enters the South China Sea through the Bashi-Balintang Channel, the tropical cyclone will affect Hong Kong within 48 hours. Similarly, when the tropical cyclones pass over Luzon Island into the South China Sea, the tropical cyclone will affect Hong Kong within 24-72 hours. Further south, the majority of the tropical cyclone will affect Hong Kong within 48-96 hours after crossing Mid-Philippine. However, if the time begins to count at the top of the 800 km threat radius, the tropical cyclone would affect Hong Kong within 48 hours.

When the tropical cyclones originate in the South China Sea in the late typhoon season, the tracks of these tropical cyclones are usually erratic. Despite this, the tropical cyclones will roughly affect Hong Kong in 24 to 72 hours.

Considering all of the possible situations, it requires the staff to man the Typhoon Management Center normally from two days to perhaps 3 days for the passage of a typhoon or a severe tropical storm over Hong Kong. The number of staff can be adjusted with an increment or a decrement as the severe weather conditions change in particular if the tropical cyclone originates in the South China Sea.

Conclusion

Under the current demographic condition and the diverse economical bases and land uses, the use of signals in the current tropical cyclone warning system is not suitable for Hong Kong. It is largely because no one surface station can be used to issue a signal appropriate for the entire Hong Kong. The combine effects of terrain and urban development in various manners make the local winds at numerous localities weaker than the intensity of the tropical cyclone. Therefore, the surface wind signified by the signal does not always represent the surface wind speeds and directions over the territory. Because no one station can be used to issue a signal appropriate for the entire Hong Kong, the signal almost always leads to the public negative reaction of being either over warned or under warned. In some other cases, the public would find the signal is being issued or cancelled either too early or too late. There is little hope for the use of signals in the current tropical cyclone warning system in Hong Kong.

The closing of Hong Kong under the warning signal No. 8 is an emergency response to a potential natural disaster under the current Hong Kong three-tier emergency response system, which focuses mainly on rescue, recovery, and restoration. Considering the spatial and temporal aspects, the emergency response to a major accident differs from the emergency management of a typhoon closure or evacuation.

An alternate tropical cyclone warning system is outlined in the study. In this system, signals are not used; instead the tropical cyclone watch and the tropical cyclone warning are used (*see* Figure 12). In the tropical cyclone warning, wind watch, flood watch, wind warning and flood warning are also issued to targeted localities, depending on the intensity of a tropical cyclone and the distance of approach.

Associated with the proposed tropical cyclone warning system, a framework of typhoon management of closure and evacuation is illustrated (*see* Figure 12) and highlighted in the discussion. The complete logistical and organizational details are required to be worked out depending on the local technical and human resources.

In many aspects, the proposed tropical cyclone warning system is considered more effective and than the use of signals in the current tropical cyclone warning system, which has little hope to meet the current demographic conditions and the diverse economical bases and land uses. The proposed typhoon management of closure and evacuation would work better than the current emergency response system, which is organized based on rescue, recovery, and restoration, and the current system discusses little on the concept of operations beginning from the approach of a distant typhoon or a severe topical storm to the arrival of a typhoon or a severe topical storm, and finally to the departure of a typhoon or a severe tropical storm.

Acknowledgements

The author thanks the staff, especially Mr. C. H. Ng and Mr. K. P. Wong, at the Hong Kong Observatory for providing him the data of thirty-six tropical cyclones in the study. The kind help of Mr. Y. K. Chan is appreciated.

The comments of Mr. Carl Smith and Mr. Jeff Hui are helpful; in particular, Mr. Smith has provided the author insightful comments that have led to the improvement of the article as well as its usefulness.

Appendix I The current tropical cyclone warning system

The present typhoon warning system, which has been used since 1973 with minor changes, consists of five signals: No. 1, No. 3, No. 8, No. 9 and No. 10. Signal No. 1, a standby signal, means that the center of a depression or a typhoon is located within 400 nautical miles (800 km) of Hong Kong. Signal No. 3 is a strong wind signal, which is used when the strong wind of 22-33 kts (41-62 km hr^{-1}) is expected or blowing in Victoria Harbor, with gusts which may exceed 60 kts (110 km hr^{-1}). When there is reason to believe that the wind in Victoria Harbor will reach gale force of 34-63 kts (63-117 km hr^{-1}) with gusts of 98 kts or more or observations indicate that the wind in Victoria Harbor has reached gale force, gale signal No. 8 is issued. Depending on the wind direction, signal No. 8 can be No. 8 NW, No. 8 NE, No. 8 SE, and No. 8 SW. The timing to replace signal No. 3 by signal No. 8 is aimed to give about 12-hour advance warning of a gale in Victoria Harbor but the sustained wind speed may reach 34 knots within a shorter period over more exposed waters. If the gale or storm force wind is increasing or anticipated to increase, signal No. 9 is issued. Finally, typhoon signal No. 10 is used when local wind is expected or has reached typhoon force with sustained speed increasing upwards from 63 kt (118 km hr^{-1}) and with gusts possibly exceeding 122 kts (220 km hr^{-1}).

References

Anonymous (1930) *Non-local storm signal code.* Historical Paper No. 10. Royal Observatory, Hong Kong.

Anonymous (1938) *Hong Kong storm signals.* Historical Paper No. 15. Royal Observatory, Hong Kong.

Brand, S. (1996) *Typhoon havens handbook for the Western Pacific and Indian Oceans.* NRL/PU/7543-96-0025. Marine Meteorology Division, U. S. Navy.

Jeary, A. P. (1997) The wind climate of Hong Kong. *J. Wind Eng. Industr. Aerodynamics*, **73**, 433-444.

Mautner, D. A. and S. Brand (1973) *An evaluation of Hong Kong Harbor as a typhoon haven.* ENVPPERRSCHFAC Technical Paper No. 9-73. Naval Postgraduate School, Monterey, CA 93940.

Poon, W. C. (1982) *Tropical cyclones causing persistent gales at the Royal Observatory 1884 -1957 and Waglan Island 1953-1980.* Technical Note No. 66. Royal Observatory, Hong Kong.

Wai, M. M-K. (2000) Changes in the characteristics of typhoons affecting Hong Kong. Part I: Typhoon intensity in the South China Sea. *HKMetS Bulletin*, **10(1/2)**, 17-45.

Wai, M. M-K. (2001) A case study of Typhoon Maggie using the proposed new tropical cyclone warning system for Hong Kong. *HKMetS Bulletin*, **11(1/2)**, 45-55.

Mickey Man-Kui Wai

Plum Rain Solutions, 2019 Skyland Drive, Tallahassee, FL 32303, USA

A Case Study of Typhoon Maggie Using the Proposed New Tropical Cyclone Warning System for Hong Kong.

Introduction

In a companion paper, Wai (2001) presented two components of a proposed new tropical cyclone warning system for Hong Kong. This new tropical cyclone warning system does not utilize Victoria Harbor as a reference location at which the wind speed is used to issue the warnings for the entire Hong Kong Territories. Additionally, signals are not used in the warning system.

The first component is made up of alerts and warnings. The alerts are tropical depression watch, tropical storm watch, severe tropical storm watch, typhoon watch, super typhoon watch, flood watch, and wind watch. The warnings are tropical depression warning, tropical storm warning, severe tropical storm warning, typhoon warning, super typhoon warning, flood warning, and wind warning.

The second component is the typhoon emergency management, which consists of the Typhoon Management Center and concepts of emergency operations. In this component, a management team, which is made up of representatives from appropriate governmental departments and agencies, will run the Typhoon Management Center when the emergency status is warranted. During the emergency duration, the team will collect emergency and management data from which the management team will manage traffic, shelters, communication/emergency public information and make decision in closure and evacuation.

Wai (2001) illustrates a schematic diagram of these two components in the tropical cyclone warning system. The logistics and the organizational details of the Typhoon Management Center are beyond the scope of this paper and also of the companion paper (Wai, 2001). As for the alerts and warnings, one can show how to apply the alerts and warning during the passage of a tropical cyclone. Therefore, the objective of the this article is, taking Typhoon Maggie as an example, to illustrate how and when to use the tropical cyclone watches, tropical cyclone warnings, flood watch, wind watch, flood warning, and wind warning. Furthermore, an educational program is presented in order for the citizens to familiarize with the system since the warning signals are not used.

Definitions

To be precise in the warning languages, a glossary of terms is shown in Appendix I. Additionally, to be specific in the locations, it is necessary to divide the Hong Kong territory into various districts.

Several Hong Kong departments or agencies have divided the Hong Kong SAR into various regions for their own purposes related to the delivery of governmental services. For instance, the Planning Department (1995) divides the Hong Kong SAR into five regions: Southwest New Territories, Southeast New Territories, Northeast New Territories, Northwest New Territories, and the Metropolitan Area. Hong Kong Observatory (HKO) divides the Hong Kong SAR into 10 regions with straight lines, which are parallel to the longitudes and latitudes, for the purposes of reporting the rainfall distribution. In these two cases, it is not clear what rationale is used to delineate the boundaries like they are drawn. Finally, the Drainage Service Department (DSD) divides the Hong Kong SAR into 12 regions. The boundaries in this case appear to follow the watershed boundaries.

Several reasons make the use of watershed boundaries a better choice in this case. First, the watersheds seldom intercept a building block, a township or a busy street within an urban center. Therefore, confusion will be prevented. Second, certain parts of Hong Kong SAR are either flood-stricken areas or frequently exposed to strong winds when a tropical cyclone approaches Hong Kong from a certain direction. The use of watersheds hence clearly identifies certain vulnerable districts where much attention is needed during the approach of a tropical storm. Since local topography can produce noticeable climatological signals of local maximum or minimum rainfall and wind speed (Smith *et al.*, 1994, Wai & Smith, 1998), the use of watersheds can also provide helpful hints in interpreting the synoptic situation.

Figure 1 **A map of nine districts in the tropical cyclone warning system.**

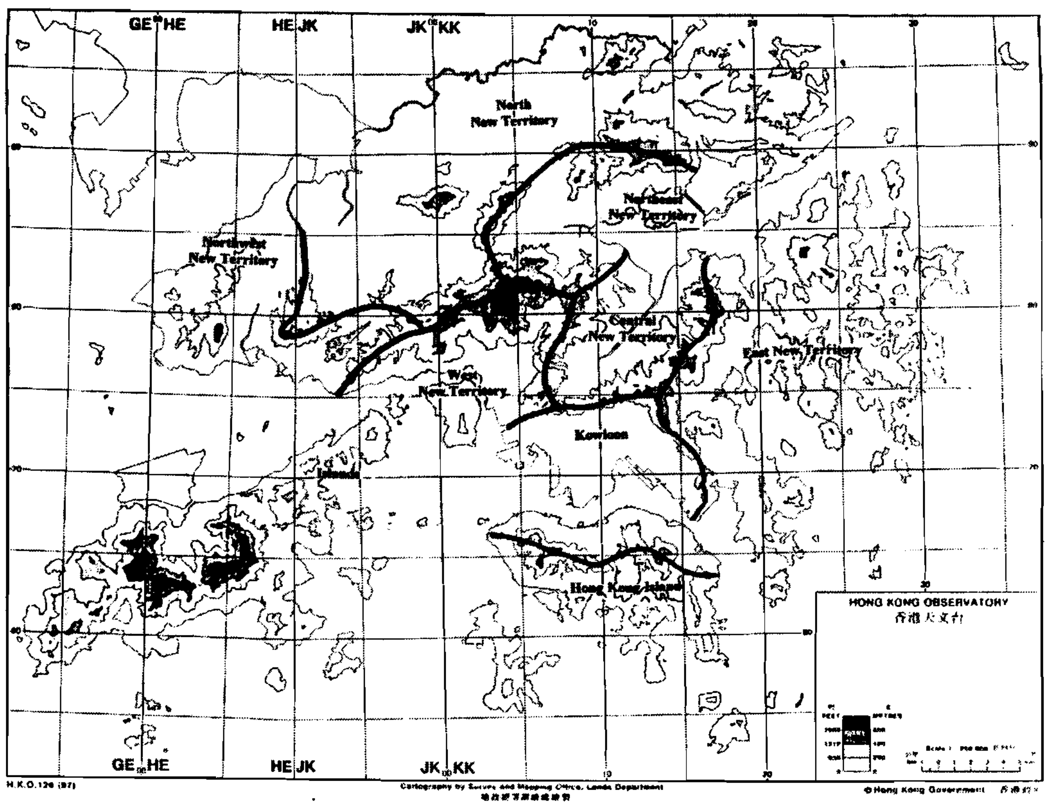


Figure 1 shows the 9 districts identified in the proposed tropical cyclone warning system. They are Northeast New Territories, North New Territories, Northwest New Territories, East New Territories, Central New Territories, West New Territories, Kowloon, Hong Kong Island, and Islands. The shapes of these nine districts are similar to those in the flood black spot map of the Drainage Service Department (DSD) except for several locations. For instance, DSD divides Kowloon and North Hong Kong Island into East and West sub-regions.

A Case Study of Typhoon Maggie

Using the passage of Typhoon Maggie over Hong Kong as an example, the uses of watch and warning in the proposed tropical cyclone warning system are illustrated. Much of the information about Typhoon Maggie is obtained from the Hong Kong Observatory and Wai (2000).

Bulletin No 1 ***HK Time : 23:45, June 5, 1999***

A typhoon watch is issued to the Hong Kong SAR at 11:45 pm. At midnight, the center of Typhoon Maggie is located roughly at 20 degrees North and 121.7 degrees East, within 800 km east-southeast of Hong Kong. Typhoon Maggie is forecast to move west-northwest at about 22 km h^{-1}. Typhoon Maggie is forecast to move closer to the South China coast. Later tomorrow, local winds over Hong Kong will strengthen. Weather will also deteriorate gradually towards tomorrow evening.

Bulletin No 2 ***HK Time : 09:52, June 6, 1999***

A typhoon warning is issued to the Hong Kong SAR at 09:52 am. At 10:00 am, Typhoon Maggie has entered the South China Sea. Its center is located near at 22.1 degrees North and 119.6 degrees East, about 560 km east of Hong Kong. Typhoon Maggie is forecast to move west-northwest at about 22 km h^{-1} towards the South China coast. Later today, local winds over Hong Kong will strengthen. Weather will deteriorate towards the evening.

Bulletin No 3 ***HKTime: 13:56, June 6, 1999***

A typhoon warning remains in effect in the Hong Kong SAR at 1:56 pm. At 1:00 pm, Typhoon Maggie is located near 22.2 degrees North and 118.4 degrees East, about 440 km east of Hong Kong. Typhoon Maggie is forecasted to moved west northwest at about 30 km h^{-1} towards the coast of Guangdong. Typhoon Maggie will continue to approach closer to Hong Kong. Overnight Maggie is expected to move closest to Hong Kong and will pose a direct threat to Hong Kong.

Typhoon Maggie maintains maximum winds of about 130 km h^{-1} near the center. Winds over Hong Kong will strengthen towards the evening and weather will deteriorate.

Bulletin No 4 ***HKTime: 15:15, June 6, 1999***

A typhoon warning is currently in effect in the Hong Kong SAR at 2:15 pm. At 3:00 pm, the center of Maggie is located near at 22.4 degrees North and 118.1 degrees East, about 410 km east of Hong Kong. Typhoon Maggie is forecast to move west-northwest at about 30 km h^{-1} towards the coast of Guangdong. On the present forecast track, Typhoon Maggie will continue to approach closer to Hong Kong and will pose a direct threat to Hong Kong. Overnight, Maggie is expected to move closest to the Hong Kong SAR.

Maggie has maintained maximum winds of about 130 km h^{-1} near the center. Wind watch is issued at 2:15 pm to the communities in the North New Territories, Northwest New Territories, Lantau Island, Cheung Chau Island, Lamma Island, and at the high elevations on Hong Kong Island. Local winds in these districts can reach up to 41-62 km h^{-1}. Weather over Hong Kong will deteriorate.

Bulletin No 5 ***HKTime: 21:03, June 6, 1999***

A typhoon warning remains in effect in the Hong Kong SAR at 9:00 pm. At 9:00 pm, the center of Maggie is located near at 22.7 degrees North and 116.4 degrees East about 230 km east of Hong Kong. Typhoon Maggie is forecast to move west or west-northwest at about 30 km h^{-1} striking the coast of Guangdong. Present indications are that Typhoon Maggie will be closest to Hong Kong in the early morning on June 7 1999 and the chance that Typhoon Maggie will enter Hong Kong territory is high.

Maggie has maintained maximum winds of about 130 km h^{-1} near the center. Wind watch remains in effect over the communities in the North New Territories, Northwest New Territories, Lantau Island, Cheung Chau Island, Lamma Island, and at the high elevations on Hong Kong Island. Local winds in these regions can reach up to 41-62 km h^{-1} towards this evening.

Bulletin No 6 ***HKTime: 00:31, June 7, 1999***

A typhoon warning is currently in effect in the Hong Kong SAR at 00:30 am. At 00:30 am, the center of Maggie is located near at 22.7 degrees North and 115.0 degrees East about 100 km east of Hong Kong. Typhoon Maggie is forecast to move west at about 30 km h^{-1} in the general direction of Hong Kong. By 4:00 am, Typhoon Maggie will pass within 50 km of the urban area.

Maggie has maintained maximum winds of about 130 km h^{-1} near the center. Wind warning is issued at 1:00 am to the communities in the North New Territories, Northwest New Territories, Lantau Island, Cheung Chau Island, Lamma Island, and at high elevations on Hong Kong Island. Local winds in these regions can exceed 62 km h^{-1}. Wind watch is issued at 1:00 am to the communities in East New Territories, Kowloon, and Hong Kong Island.

Weather over Hong Kong will deteriorate. Rain bands associated with Typhoon Maggie will come even closer to Hong Kong. Local weather will be frequent squalls and heavy rain.

Bulletin No 7 ***HKTime: 02:01, June 7, 1999***

A typhoon warning remains in effect in the Hong Kong SAR at 02:01 am. At 2:00 am, the center of Typhoon Maggie is located near at 22.6 degrees North and 114.8 degrees East about 70 km east northeast of Hong Kong. Typhoon Maggie is forecast to move west at about 30 km h^{-1} in the general direction of Hong Kong. Around 4 am, Typhoon Maggie will pass within 50 km of the urban area.

Typhoon Maggie has maintained maximum winds of about 130 km per hour near the center. Wind warning is currently in effect over the Northwest Territories, Lantau Island, Chung Chau Island, Lamma Island, and at high elevations of Hong Kong Island. Local winds in these districts can exceed 62 km h^{-1}. Wind watch remains in effect over the communities in East New Territories, Kowloon, and Hong Kong Island.

Rain bands associated with Typhoon Maggie will come even closer to Hong Kong. Local weather will continue to deteriorate with frequent squalls and heavy rain. Flood watch is issued to the lowland communities in the Northeast Territories, North Territories, Northwest Territories, and Central New Territories.

Bulletin No 8 ***HKTime: 04:29, June 7, 1999***

A severe tropical storm warning is issued to the Hong Kong SAR at 04:29 am. Typhoon Maggie has weakened into a severe tropical storm. At 4:00 am, the center of STS Maggie is located near at 22.5 degrees North and 114.2 degrees East about 20 km north of the Hong Kong Observatory. STS Maggie has made landfall over Sai Kung Peninsula. STS Maggie is forecast to move westward across the New Territories at about 30 km h^{-1}. At the present forecast track, STS Maggie will leave the Hong Kong Territories in the late morning.

Wind warning remains in effect at 1:00 am over the communities in the Northwest New Territories, Lantau Island, Cheung Chau Island, Lamma Island, and at the high elevations in the Hong Kong Island. Local winds in these regions can exceed 62 km h^{-1}. At Lau Fau San, wind has reached to 76 km h^{-1}. At Cheung Chau, wind had blown at 72 km h^{-1}, and at Green Island, wind had been recorded at 65 km h^{-1}. Wind watch is current in the East New Territories, Kowloon, and Hong Kong Island.

Rain bands associated with STS Maggie will come even closer to Hong Kong. Local weather will continue to deteriorate with frequent squalls and heavy rain. Flood warning is issued to the lowland communities in the North New Territories, Northwest New Territories, and Central New Territories. Since midnight, more than 50 mm of rainfall fell in these regions: Tai Mei Tuk - 52 mm, Tai Ku Ling – 54 mm, Sek Kong – 62 mm, Sha Tin – 52.5 mm. Flood watch is extended to North Lantau Island. More than 30 mm of rainfall fell in Hong Kong International Airport-37.2 mm, Sai Lo Wan- 32.5 mm, Tsing Yi- 43.5 mm.

Bulletin No 9 ***HKTime: 06:35, June 7, 1999***

A severe tropical storm warning is currently in effect in the Hong Kong SAR at 06:35 am. At 6:00 am, the center of STS Maggie is located near at 22.1 degrees North and 113.8 degrees East, about 40 km west southwest of the Hong Kong Observatory. During the passage of STS Maggie over Hong Kong, STS Maggie drifted from west to southwest and skirted the southern part of Lantau Island and moved to the offshore waters southwest of Hong Kong. STS Maggie is forecast to move west at about 30 km h^{-1} towards the waters of western Guangdong. At the present forecast track, STS Maggie will move west-southwest along the coast of western Guangdong.

Wind warning is issued at 6:00 am to the communities in the West Kowloon, Lantau Island, Cheung Chau Island, Lamma Island, and West and South Hong Kong Island. Local winds at these districts can exceed 62 km h^{-1}. Wind watch is extended to the East New Territories, North and East Hong Kong Island.

Rain bands associated with Typhoon Maggie will come even closer to Hong Kong. Local weather will continue to deteriorate with frequent squalls and heavy rain. Flood warning is issued to the lowland communities in the Northeast New Territories, North Territories, and Northwest New Territories. More than 50 mm of rainfall were recorded in these districts since midnight. Squalls and heavy rain are expected to continue in the next 24 hours. Flood watch is current in effect over the Lantau Island.

Bulletin No 10 ***HKTime: 10:07, June 7, 1999***

A tropical storm warning is issued to the Hong Kong SAR at 10:07 am. At 10:00 am, the center of STS Maggie has weakened into a tropical storm. TS Maggie is located near 21.8 degrees North and 113.3 degrees East, about 110 km west-southwest of the Hong Kong Observatory. TS Maggie is forecast to move west at about 30 km h^{-1} towards the waters of western Guangdong. On the present forecast track, TS Maggie will continue to move west-southwest along the coast of western Guangdong, moving away from the Hong Kong SAR.

Wind warning is issued at 10:00 am to the Lantau Island, West Kowloon, West Hong Kong Island. Local winds in these regions can exceed 62 km h^{-1}. Wind watch is currently in effect over the South Hong Kong Island, and East New Territories.

Flood warning remains in effect over the lowland communities in the Northeast New Territories, North New Territories, and Northwest New Territories. More than 50 mm of rainfall were recorded in these sectors since midnight. Squalls and heavy rain are expected to continue in the next 24 hours. Flood watch remains in effect over the Lantau Island.

Bulletin No 11 *HKTime: 11:07, June 7, 1999*

A tropical storm warning remains in effect in the Hong Kong SAR at 11:07 am. At 11:00 am. TS Maggie is located near 21.8 degrees North and 113.1 degrees East, about 120 km west-southwest of the Hong Kong Observatory. TS Maggie is forecast to move west at about 30 km h^{-1} towards the waters of western Guangdong. On the present forecast track, TS Maggie will continue to move west-southwest along the coast of western Guangdong, moving further away from the Hong Kong SAR.

Wind warning is issued at 11:00 am to the Lantau Island, West Kowloon, and West Hong Kong Island. Wind watch is current in East New Territories, East Kowloon, and East Hong Kong Island.

Flood warning and flood watch have been cancelled in the Hong Kong SAR at 10:15 am.

Bulletin No 12 *HKTime: 08:40, June 8, 1999*

A tropical storm warning remains in effect in the Hong Kong SAR at 08:40 am. At 08:00 am. TS Maggie is located near 23.0 degrees North and 112.4 degrees East, about 200 km west-northwest of the Hong Kong. TS Maggie is forecast to move west at about 12 km h^{-1} north-northwest. TS Maggie has made landfall near Shangchuan Dao early this morning and continues to move further inland.

Wind watch is issued to the Lantau Island, West Kowloon, and West Hong Kong Island at 08:00 am. Local winds in these regions can reach up to 62 km h^{-1}.

Bulletin No 13 *HKTime: 13:45, June 8, 1999*

TS warning and wind watch are cancelled in the Hong Kong SAR at 1:45 pm.

Educational programs

HKO has been very successfully making a wide range of HKO services, meteorological information and products, and educational resources available for the public to view and access over the HKO web sites.

To avoid complacency, an educational program about the tropical cyclone preparedness prior to the typhoon season is needed annually. The educational program focuses on the tropical cyclone warning system, how to prepare a personal or a family evacuation plan, how to assemble a home survival kit, what to do when a tropical cyclone watch is issued, what to do when a tropical cyclone warning is issued, what to do when a wind watch is issued, what to do when a wind warning is issued, what to do when a flood watch is issued, and what to do when a flood warning is issued. The information can be disseminated by radio, television, printed literature, or the HKO website in order to reach the Hong Kong citizens with various social backgrounds. A brief discussion for each area in the educational program is given in the following section.

Tropical cyclone warning system

A companion article (Wai, 2002) discusses the tropical cyclone warning system in some detail and readers are referred to the companion article.

Prepare a personal, family, or a business evacuation plan

If you are a home owner or a tenant

- Know which district you live in
- Know the closest shelters to your home in your district

- Know what route to take to the shelter
- Know ahead of time what personal items you need to bring to a shelter when you are told to evacuate
- Know ahead of time where you could go if you are told to evacuate. Choose several places - a relative's home, a friend's home, a shelter, or a hotel

- Know how to assemble a home survival kit
    - First aid kit and essential medication
    - At least one week supply of nonperishable/special diet food
    - Non-electrical can opener
    - Drinking water
    - Protective clothing
    - Battery-power radio, flashlight, and extra battery
    - Special items for infants, elderly, or disabled family members
    - Clean-up supplies (mop, bucket, towels, trash bag, and disinfectant)
    - Written instructions for how to turn off electricity, gas and water if authorities advise you to do so

If you must evacuate

- Let relatives or friends know where you and your family are going
- Take important papers with you including ID cards, driver's license, special medication information, insurance policy, and property inventories

If you are a business owner

- Protect your business
    - Know your risk - Is your business located where you are vulnerable to storm surge and flood? Is your workplace vulnerable to typhoon force winds?
    - Take the necessary precautions- if a tropical storm threatens, secure the premise. Cover windows with shutters, plywood or wind protection film. Cover and move equipment and furniture to a secure area. Protect your data with backup files. Make provisions for alternate communication and power. Store emergency supply at the premise in case it is difficult to get around after the storm or the typhoon
    - Review your insurance coverage
- Protect your employees
    - Employee safety comes first – prepare, distribute and exercise your business typhoon plan for warning, closure, and post-typhoon communication

Tropical cyclone

- Know what a watch or a warning means
    - Tropical Cyclone Watch: tropical cyclone conditions are possible in the specific area of the watch; usually within 48 hours.
    - Tropical cyclone Warning: tropical cyclone conditions are expected in the specific area of the warning; usually within 24 hours.

Tropical cyclone watch

- Tropical storm watch
  - Listen to radio, television stations, or visit the HKO website for up-to date storm information.
  - If you plan to visit Macau, or any of the off-shore islands, New Territories, or remote parts of Hong Kong, you are reminded that the changes in weather will affect your plan.
  - Those who live in wooden huts, hilly areas, and in low-lying areas should take necessary preparation against strong winds and flooding. Clear gutters and drains of debris.
  - Take necessary precautions against damaged winds. Check hinges, bolts, locks, shutters of windows and doors.
  - Engineers, architects and contractors should check and secure scaffoldings, hoardings and other temporary structure are secured.
  - Sea states may deteriorate soon. Those, who engage in water sports, should take precaution against changes in the weather condition.

- Tropical storm watch
  - Listen to radio, television stations, or visit the HKO website for up-to date storm information.
  - If you plan to visit Macau, or any of the off-shore islands, New Territories, or remote parts of Hong Kong, you are reminded that the changes in weather will affect your plan.
  - Those who live in wooden huts, hilly areas, and in low-lying areas should take necessary preparation against strong winds and flooding. Clear gutters and drains of debris.
  - Take necessary precautions against damaged winds. Check hinges, bolts, locks, shutters of windows and doors.
  - Bring inside any hanging clothes, hanging plants, outdoor decorations and anything that can be picked up by the wind. Make sure that all loose objects are secured.
  - Check batteries, and stock up on canned food, first aid supplies, drinking water, and medications.
  - Engineers, architects and contractors should check and secure scaffoldings, hoardings and other temporary structure is secured.
  - Sea state may deteriorate soon. Those who engage in water sports should take precaution against changes in the weather condition.
  - Owners of outdoor commercial or private items (i. e. shop signs, advertisements and aerials) should check and secure these structures.

- Severe tropical storm watch, typhoon, watch, and super typhoon watch
  - Listen to radio, television stations, or visit the HKO website for up-to date storm information.
  - If you plan to visit Macau, or any of the off-shore islands, New Territories, or remote parts of Hong Kong, you are reminded that the changes in weather will affect your plan.
  - Those who live in wooden huts, hilly areas, and in low-lying areas should take necessary preparation against strong winds and flooding. Clear gutters and drains of debris.

- Take necessary precautions against damaged winds. Check hinges, bolts, locks, shutters of windows and doors.
- Bring inside any hanging clothes, hanging plants, outdoor decorations and anything that can be picked up by the wind. Make sure that all loose objects are secured.
- Check and prepare for the home survival kit.
- Owners of outdoor commercial or private items (i. e. shop signs, advertisements and aerials) should check and secure these structures.
- Engineers, architects and contractors should check and secure scaffoldings, hoardings and other temporary structure is secured.
- Sea state may deteriorate soon. Those who engage in water sports should take precaution against changes in the weather condition.
- Owners of small craft and fishing vessels now complete arrangement for the safety of their boats. Check again that all deck fittings are firmly fastened. If heavy anchors are available, prepare to use these heavy anchors in addition to regular anchors. It is not safe for small crafts and fishing vessels to stay in open seas.

Tropical cyclone warning

- Tropical depression warning
  - Listen to radio and television stations; visit the HKO web pages, Typhoon Emergency Management Center for up-to date storm information.
  - Prepare to act when a wind warning or a flood warning is issued.

- Tropical storm warning
  - Listen to radio and television stations; visit the HKO web pages, Typhoon Emergency Management Center for up-to date storm information.
  - Prepare to act when a wind warning or a flood warning is issued

- Severe tropical storm warning, typhoon warning, and super typhoon warning
  - Those, who have definite duties during a tropical cyclone, should now remain on call or contact their control centers periodically.
  - Prepare to act when a wind warning or a flood warning is issued
  -
- Wind watch
  - Listen to radio and television stations, visit the HKO website for up-to date storm information.
  - Check and assemble the home survival kit. Obtain any needed items.
  - Prepare to act if a wind warning is issued to your district.
- Wind warning
  - Listen to radio and television stations, visit the HKO website, Typhoon Emergency Management Center for up-to date storm information. If you are told to return home or evacuate, do so as soon as possible.
  - Lock all windows and doors. Fit bars into position and insert reinforced shutters and gates if they are available. Cover windows with shutters, plywood or window protection film.
  - Move all furniture and valuables away from these areas. Put plastic bags over appliances such as TV, lamps, computer among others. If windows and doors are broken, only fix broken windows and doors when there is no danger.
  - During the storm, stay inside and away from windows and exposed doors. Find a safe area in your home - an interior or reinforced room.

- If the eye of the typhoon moves directly across Hong Kong, there may be a lull lasting from a few minutes to several hours. The lull will be followed by a sudden resumption of violent winds from a different direction. Remain in your safe area and be prepared for destructive winds and the change in wind directions.
- If you are away from home and cannot return home soon in time, find a safe place and remain there until the danger is over.
- Seas are rough. You are advised to stay away from the shoreline and do not engage in water sports.
- Owners of Neon signs are reminded to turn off the electricity supply to their signs.
- Offer your home as shelter to friends or relatives who live in vulnerable districts or in wooden home.

Flooding

- What to expect
  - Know the flood risk in your area due to poor drainage or storm surge - if you are unsure, call Drainage Service Department (DSD).
  - If it has been raining for several hours, or steady raining for several days, be alert to the possibility of a flood.
  - Listen to radio and television stations; visit the HKO web site, or Typhoon Emergency Management Center for flood information
- Flood watch
  - Move your furniture and valuables to higher floors of your home
- Flood warning
  - Listen to local radio and television stations for advice. If official tells you to evacuate, do as soon as possible.

Conclusions

This paper shows how to apply the alerts and warnings in a real typhoon situation. Because the warning signals are not used in the warning system, this paper provides some details on an educational program in order to help the citizens to be familiarizing with the new warning system. By combining the steps in this article and the author's companion article, one can establish a warning system, which is better than the current system that uses the warning signals.

Acknowledgements

The author thanks the staff of HKO for information on the life history of Typhoon Maggie.

The idea for this article largely comes from Mr. Carl Smith, who reviewed the author's companion article. In his review, Mr. Smith indicates that the usefulness of the companion article would be enhanced substantiantly by applying the first component of the proposed new tropical cyclone warning system to a real typhoon situation. Moreover, since the typhoon signals are not used in the new warning system, Mr. Smith concludes that an appropriate educational program is necessary in order to inform the citizens about the new tropical cyclone warning system.

Appendix I. Glossary of Terms

Community: town such as Lau Fau Shan, Yuen Long, and Kennedy Town.

District: An area is either an Island or bounded by the watershed. The Hong Kong SAR is divided into nine districts: Hong Kong Island, Kowloon, East New Territories, Central New Territories, West New Territories, Northeast New Territories, North New Territories, Northwest New Territories, and Islands. The Islands consists of Lantau Island, Cheung Chau, Lamma Island, and Tsing Yi Island.

Flood watch: An alert that flooding due to rainfall is to be expected in low land areas if weather patterns develop as forecast.

Flood warning: A warning that significant flooding due to rainfall is to be expected in the low lands area if weather patterns develop as forecast.

Tropical cyclone watch: An alert that a tropical cyclone, located in 800-1500 km from Hong Kong or a district, will affect Hong Kong, or a district, in 48 hours. The tropical cyclone watch can be a tropical depression watch, a tropical storm watch, a severe tropical storm watch, a typhoon watch, or a super typhoon watch.

Tropical cyclone warning: a tropical cyclone, located within 800 km from Hong Kong or a district, will affect Hong Kong or a district in 24 hours. A tropical cyclone warning can be a tropical depression warning, a tropical storm warning, a severe tropical storm warning, a typhoon warning, or a super typhoon warning.

Watershed: a ridge divides the areas drained by different river or stream systems.

Wind watch: An alert that winds with damaging magnitude is expected to affect Hong Kong, or a district, or a community within 24 hours.

Wind warning: Winds with damaging magnitude is expected to affect Hong Kong, or a district, or a community within 12 hours.

References

Planning Department (1995) *Town Planning in Hong Kong: A Quick Reference.* Planning Department, Hong Kong Government. 50 p.

Smith, E. A., M. M.-K. Wai, H. J. Cooper, and M. T. Rubes (1994) Linking boundary layer circulations and surface processes during FIFE 89. Part I. Observational analysis. *J. Atmos. Sci.*, **51**, 1497-1529.

Wai, M. M.-K., and E. A. Smith (1998) Linking boundary layer circulations and surface processes during FIFE 89. Part II. Maintenance of secondary circulation. *J. Atmos. Sci.*, **55**, 1260-1276.

Wai, M. M-K. (2000) Changes in the characteristic of typhoon affecting Hong Kong. Part I: Typhoon intensity in the South China Sea. Submitted to the *Bull. Hong Kong Meteor. Soc.*, **10(1/2)**, 17-45.

Wai, M. M-K. (2001) Is there any hope for the use of signals in the tropical cyclone warning system in Hong Kong? *Bull. Hong Kong Meteor. Soc.*, **11(1/2)**, 24-44.

This space is available for your advertisement

Contact the Society Secretary For further information

HONG KONG METEOROLOGICAL SOCIETY

Office Bearers: *(2001-2002)*

Chairman	Vice Chairman
Mr. C.Y. Lam	Prof. Bill Kyle
Hon. Secretary	Hon. Treasurer
Ms. Olivia S.M. Lee	Mr. Y.K. Chan
Executive Committee Members	
Mr. Clarence C.K. Fong	Dr. K.S. Lam
Dr. Alexis Lau	Dr. C.N. Ng
Dr. W.L. Siu	

INFORMATION FOR CONTRIBUTORS TO THE BULLETIN

Technical or research articles, as well as reviews and correspondence of a topical nature are welcome. In general contributions should be short, although exceptions may be made by prior arrangement and at the sole discretion of the Editorial Board. Copyright of material submitted for publication remains that of the author(s). However, any previous, current, or anticipated future use of such material by the author must be stated at the time of submission. All existing copyright materials to be published must be cleared by the contributor(s) prior to submission.

Manuscripts must be accurate and preferably in the form of a diskette containing an electronic version in one of the common word processing formats. WORD is preferred but others are also acceptable. Whether or not an electronic version is submitted, two complete manuscript copies of the articles should be submitted. These should be preceded by a cover page stating the title of the article, the full name(s) of the author(s), identification data for each author (position and institution or other affiliation and complete mailing address). An abstract of about 150 words should be included. Manuscripts should be double-spaced, including references, single-side only on A4 size paper with a 2.5 cm margin on all sides, and be numbered serially. All references should be arranged in alphabetical and, for the same author, chronological order. In the text they should be placed in brackets as (Author'(s) name(s), date). In the reference list at the end the Author'(s) name(s) and initials followed by the date and title of the work. If the work is a book this should be followed by the publisher's name, place of publication and number of pages; or, if a journal article, by the title of the periodical, volume and page numbers.

Submission of electronic versions of illustrations is encourage. Originals of any hardcopy illustrations submitted should be in black on tracing material or smooth white paper, with a line weight suitable for any intended reduction from the original submitted size. Monochrome photographs should be clear with good contrasts. Colour photographs are also accepted by prior arrangement with the Editorial Board. Originals of all illustrations should be numbered consecutively and should be clearly identified with the author'(s) name(s) on the back. A complete list of captions printed on a separate sheet of paper.

All submitted material is accepted for publication subject to peer review. The principal author will be sent comments from reviewers for response, if necessary, prior to final acceptance of the paper for publication. After acceptance the principal author will, in due course, be sent proofs for checking prior to publication. Only corrections and minor amendments will be accepted at this stage. The Society is unable to provide authors with free offprints of items published in the Bulletin, but may be able to obtain quotations from the printer on behalf of authors who express, at the time of submission of proofs, a desire to purchase a specified number of offprints.

Enquiries and all correspondence should be addressed to the Editor-in-Chief, Hong Kong Meteorological Society Bulletin, c/o Department of Geography, The University of Hong Kong, Pokfulam Road, Hong Kong. (*Tel. +(852) 2859-7022; Fax. +(852) 2559-8994 or 2549-9763; email: billkyle@hkucc.hku.hk.*

香港氣象學會

HONG KONG METEOROLOGICAL SOCIETY

Bulletin

Volume 11, Numbers 1/2, 2001

SINGLE COPY PRICE: HK$ 150

(for subscription rates see inside front cover)

CONTENTS