WORLD METEOROLOGICAL ORGANIZATION

TECAM/PAPER 31

WMO TECHNICAL CONFERENCE ON
AVIATION METEOROLOGY (TECAM)

GENEVA, 5 TO 9 NOVEMBER 1979

LOW-LEVEL WIND SHEAR DETECTION SYSTEM AT HONG KONG INTERNATIONAL AIRPORT

K. S. Tsui

1. Introduction

During the years 1973-76, no less than 8 aircraft accidents occurred round the world as a result of low-level wind shear on final approach (Whitmore and Cokeley 1976). Over 200 people lost their lives and more were injured.

In Hong Kong, a Wind Shear Detection and Prediction Committee was formed in June 1976, consisting of representatives from the Civil Aviation Department, Royal Observatory, IFALPA, Hong Kong Aircrew Officers' Association (HKAOA) and Cathay Pacific Airways. The objectives of the Committee include the design of a system to detect low-level wind shear at Hong Kong International Airport, the standardisation of phraseology to be used by air traffic controllers when passing these wind shear warnings to pilots, and research into the various causes of significant low-level wind shear conditions with a view to establishing prediction techniques for use by the Airport Meteorological Office of the Royal Observatory.

In 1977, funds were obtained from the Hong Kong Government to purchase three additional anemometers, interfacing electronic components and a microprocessor unit including ancillary video display terminals, a cartridge recorder and a printer. During 1978-79, the anemometers were installed and the software development for the microprocessor was completed. The experimental system was finally commissioned on 10 September 1979.

2. Low-level Wind Shear Detection System

The system consists of five cup-anemometers, one at each end (Southeast SE and Northwest NW) of the runway and three additional ones at Yau Yat Chuen (YYC), Kowloon Tsai (KLT) and Lye Yue Mun (LYM), as shown in Figure 1, covering the two approaches to the airport. Aircraft landing from the southeast can make an ILS-approach onto Runway 31 but those landing from the northwest must make a curved IGS-approach onto Runway 13 (AIP Hong Kong). Table 1 shows the heights of the anemometer heads above mean sea level and the bearings of the glidepath adjacent to these anemometers. (Note: Feet is used in this paper because it is still the common unit used by aviators to measure heights and altitude.)

Table 1. Heights of anemometer heads above m.s.l. and bearings of glidepath adjacent to the anemometers.

	YYC	KLT	NW	SE	LYM
Height (feet)	210	346	47	54	239
Bearing (deg)	087	107	134	134	134

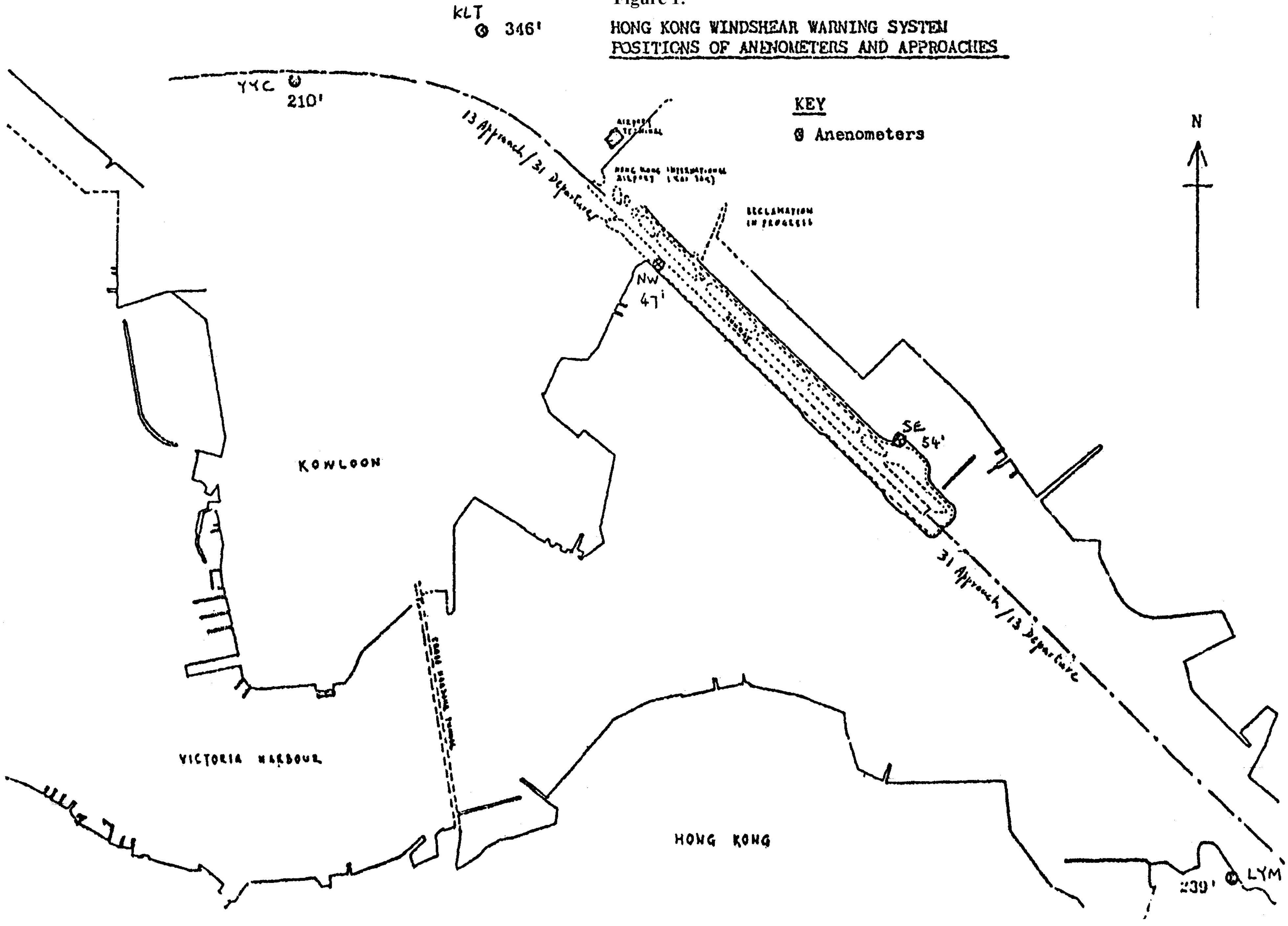
LYM guards the approach to Runway 31. For a standard approach along a 3° glidepath, LYM is about 56 seconds from touchdown and the height of the aircraft there should be around 740 feet. YYC and KLT are on the curved approach to Runway 13. YYC is about 41 seconds from touchdown and the height of the aircraft above that point should be around 540 feet.

Figure 1.

HONG KONG WINDSHEAR WARNING SYSTEM
POSITIONS OF ANEMOMETERS AND APPROACHES

KEY

⊗ Anenometers



Readings from the five anemometers are telemetered back to a central microprocessor unit at the Airport Meteorological Office via private telephone lines. This microprocessor is an ALTAIR MITS-8800B and can be programmed to compute 2-minute mean winds for the five locations and the 31 Approach/13 Departure and 13 Approach/31 Departure wind shear in knots per 100 feet of altitude change. Here, wind shear is calculated using only the longitudinal wind components because our aim is to determine the "lifting" or "sinking" effect of the wind variation which would be caused, for example, by an increasing headwind (same as decreasing tailwind) or a decreasing headwind (same as increasing tailwind). For the 31 Approach/13 Departure, the wind shear is calculated using the 2-minute mean longitudinal winds at LYM and SE and for the 13 Approach/31 Departure those at NW and YYC. The height factor used in the computation is the difference between the heights of the respective anemometer heads (see Table 1).

The value of the longitudinal wind shear for each end of the runway is displayed on video terminal together with an appropriate description selected from "lifting", "sinking" or "no shear". When the magnitude of the wind shear equals or exceeds a pre-determined value which indicates a significant level, the description reads "significant lifting" or "significant sinking", as appropriate, and blinks on the video terminal to alert the duty air traffic controller who then passes a warning of lifting or sinking wind shear, as the case might be, to aircraft landing or taking off at the time.

Readings of the KLT anemometer have not been utilised for the calculation of the longitudinal wind shear data, but the microprocessor computes the 2-minute mean lateral wind component and the maximum 1-second gust for that location in order to provide information on the severity of lateral winds on the curved portion of the IGS-approach. KLT wind read-outs are also useful for tracking the movement of gust-fronts as shown by Chen and Lee (1978).

The anemometers do not measure the vertical component of the wind. Hence, the system does not monitor vertical air motions like downdrafts or updrafts in the vicinity of squally showers or thunderstorms. There is only limited quality control in the system. When there is no anemometer signal received, the microprocessor displays "Data Not Available" on the video terminal, but the system will continue to operate as long as transmissions are present even though they could be erroneous as a result of anemometer sensor deficiencies or interference in the telemetry process.

3. Warning Criterion

To enhance flight safety during landings and take-offs, pilots must be warned of significant low-level wind shear conditions so that the appropriate corrective action can be taken in time.

What constitutes a suitable warning criterion has been discussed in detail during and following the ICAO 8th Air Navigation Conference in 1974. ICAO (1974a, 1974b) has recommended that wind variations exceeding the limits specified for the certification of automatic landing systems (such as autopilots) should be measured and reported to pilots. (In the U.K. and U.S.A., wind models used for the certification of automatic landing systems are based on the boundary layer shears and the maximum acceptable wind shear specified has been about 8 knots per 100 feet.) Until this objective is fully met, ICAO (1974a, 1974b) has further recommended that data on vertical wind shear equivalent to vector differences of 10 knots or more per 100 feet should be passed to aircraft for all Category I operations.

Noting the recommendations given by ICAO, the Hong Kong Wind Shear Detection and Prediction Committee agreed that initially in the experimental system, the warning criterion to be used should be 8 knots per 100 feet. Such a criterion for significant low-level wind shear could be revised if necessary in the light of experience gained.

The anemometer heads at LYM and YYC are not exactly on the glidepath because they would otherwise pose obstructions to aviation. The wind shear calculated based on the anemometer readings therefore may not be the same as that experienced by the aircraft. In order to assess how realistic the computed value is as a measure of the wind shear along the glidepath, aircraft wind read-outs at 600 feet in the vicinity of the YYC anemometer during significant wind shear conditions in 1978-79 have been collected. Although there were only six occasions, computations showed that on the average, the longitudinal wind shear as measured by the system (using 2-minute mean winds) exceeded the actual value (using instantaneous aircraft winds) by just 0.2 knots per 100 feet. This result is indeed very encouraging.

In another independent study utilising AIDS (Aircraft Integrated Data System)-data supplied by SWISSAIR DC-10s landing in Hong Kong during August 1978 to March 1979, it was found that the longitudinal component of wind measured at YYC (denoted by x in knots) is related to that experienced by the aircraft on the glidepath over YYC (denoted by y in knots) according to the following formula:

$$y = 1.01x + 3.97 \qquad (1)$$

(Correlation coefficient 0.75, number of cases 136) Equation (1) shows that y is approximately equal to x. Thus, as the height of the anemometer head is less than that of the glidepath, the wind shear as calculated by the system in knots per 100 feet should therefore tend to over-read under normal conditions, but fortunately it is on the safe side.

4. Causes for Low-level Wind Shear

In Hong Kong Aeronautical Information Circular (AIC) 7/75, pilots were requested to provide verbal reports of low-level wind shear and/or turbulence of any intensity to Air Traffic Control whenever these conditions were encountered. In AIC 13/76, pilots of aircraft equipped with INS or R Navigational Equipment were further asked to give after each approach Computer Display Unit wind read-outs at 1000, 800, 600 and 400 feet levels. As a result, during the period from September 1976 to March 1979, a total of 160 aircraft reports were received which indicated the existence of low-level wind shear and/or turbulence over Hong Kong Airport. About half of these occasions were covered with detailed low-level aircraft wind data.

Based on these pilots' reports, it is found that wind shear (irrespective of intensities) can occur in any month of the year. On the average, the frequency of occurrence is about 5 days per month. However, if one considers only significant wind shear of 3 knots or more per 100 feet as detected by the anemometer system, for the 13 Approach/31 Departure, there were actually just 5 days in the 12 months of 1978.

Causes for low-level wind shear have been discussed in detail by Greene et al. (1977). Table 2 shows the various conditions under which wind shear was generated over Hong Kong Airport in 1977-78 together with their percentage frequencies.

Table 2. Various causes for low-level wind shear at Hong Kong Airport during 1977-78 and their percentage frequencies.

	13 Approach/31 Departure	31 Approach/13 Departure
Cold fronts	7 %	12 %
Troughs of low pressure	9	31
Tropical cyclones	29	20
Monsoons	40	21
Others	17	16

It can be seen from Table 2 that for 13 Approach/31 Departure, there is a very high frequency of wind shear caused by Northeast or Southwest Monsoon. This situation is, more often than not, the result of the sharp turn in the IGS-approach/climb-out phase. Thus, noting that the bearing of the glidepath over YYC is 087° and that over NW 134° (see Table 1), for a uniform wind (assuming no vertical or horizontal wind shear over the area) of speed I in knots and azimuth Θ in degrees, a longitudinal wind difference would be created across the NW and YYC anemometers equal to $I\cos(134-\Theta) - I\cos(87-\Theta)$. As we have set 8 knots per 100 feet as the warning criterion, the system would therefore call for alert as soon as the following condition is met:

$$I\cos(134-\Theta) - I\cos(87-\Theta) = 8 \times 1.63 = 13.04 \qquad (2)$$

(1.63 being the height difference in units of 100 feet) In Table 3 where the relation between I and Θ is tabulated, it is obvious that a uniform North-northeasterly flow (030°) or South-southwesterly (210°) of only 17 knots would already be strong enough to trigger off an alarm of significant longitudinal wind shear for 31 Departure and 13 Approach respectively.

Table 3. Relationship between I and θ in Equation (2).

Wind direction θ	Wind speed I	Wind Shear Effect
360 degrees	17.5 knots	Sinking
030	16.6	Sinking
060	21.2	Sinking
090	46.7	Sinking
120	99.1	Lifting
150	25.7	Lifting
180	17.5	Lifting
210	16.6	Lifting
240	21.2	Lifting
270	46.7	Lifting
300	99.1	Sinking
330	25.7	Sinking

In order to understand more about the various causes for generating significant low-level wind shear at Hong Kong Airport, the available aircraft wind read-outs have been analysed and all occasions in which the wind shear between two adjacent levels was 8 knots or more per 100 feet have been taken out. Table 4 lists all the 10 situations in which significant wind shear was encountered. Figure 2 shows the associated weather patterns.

Table 4. Significant wind shear situations encountered by aircraft during September 1976 to March 1979.

Date/Time (GMT)	Flight No.	Approach	Cause for wind shear	Winds & longitudinal components at 1000'	800'	600'	400'	200'	surface	Magnitude of significant wind shear & layer
770923/1507	CX 411	31	Tropical Cyclone Dinah	06032 8.8	04028 - 2.0	06025 6.9	36028 -19.5	- -	02014 - 5.7	13.2 kt/100 ft 600'/400'
771113/0731	CX 710	31	Monsoon	34418 -15.6	34717 -14.3	34817 -14.1	34817 -14.1	35415 -11.5	05005 0.5	- 7.5 kt/100 ft 200'/surface
780109/0451	-	31	Monsoon	17016 12.9	27013 - 9.4	30015 -14.6	16011 9.9	- -	04008 - 0.6	-11.2 kt/100 ft 1000'/800' 12.3 kt/100 ft 600'/400'
780222/0356	BA 824	31	Monsoon	30011 -10.7	28013 -10.8	29012 -11.0	12006 5.8	- -	calm 0	- 8.4 kt/100 ft 600'/400'
780226/0322	CV 892	13	Monsoon	07515 14.5	08510 10.0	36012 0	12017 15.8	- -	08020 11.8	7.9 kt/100 ft 600'/400'
780915/0459	JL 731	13	Tropical Cyclone	27004 - 4.0	12015 13.0	12012 10.4	16015 7.0	- -	14012 11.9	8.5 kt/100 ft 1000'/800'
780930/1123	QF 27	13	Tropical Cyclone Lola	07036 33.8	07728 27.3	06335 31.2	05015 10.0	- -	06020 5.5	-10.6 kt/100 ft 600'/400'
781001/1252	TE 272	13	Tropical Cyclone Lola	11038 35.7	- -	09040 40.0	10020 20.0	09015 10.8	09020 14.4	-10.0 kt/100 ft 600'/400'
781016/0505	JL 731	13	Tropical Cyclone Nina	07538 36.7	06025 21.7	07025 23.5	05015 10.0	- -	09024 17.3	- 7.5 kt/100 ft 1000'/800'
781109/0604	CX 503	13	Monsoon	00324 1.3	08724 24.0	08525 24.9	08824 23.6	- -	10017 14.0	11.4 kt/100 ft 1000'/800'

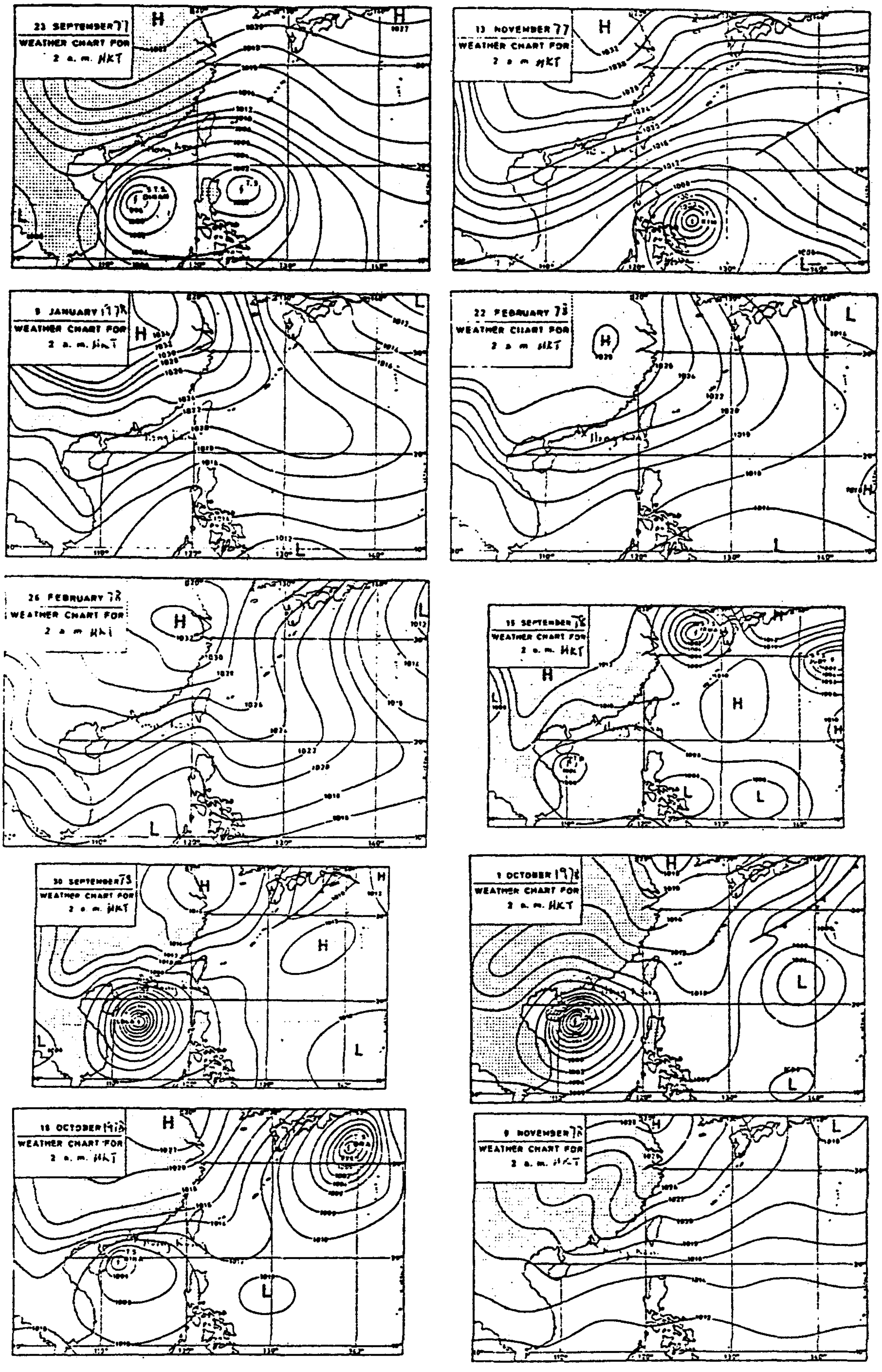


Figure 2. Weather patterns for significant low-level wind shear situations given in Table 4. (HKT = GMT + 8)

5. Future Development

Although the experimental low-level wind shear detection system at Hong Kong International Airport has been commissioned, a lot of developmental work has still to be completed. First, a verification programme based on pilots' feedback has to be initiated to examine the effectiveness of the present warning system. If necessary, the warning criterion of 8 knots per 100 feet could be revised in the light of experience gained. Secondly, the on-going research into the various causes for generating significant low-level wind shear will be continued with a view to establishing improved prediction methods for use by aviation forecasters in the future.

Acknowledgements

The author, on behalf of the Director of the Royal Observatory Hong Kong, thanks all the airlines that have provided low-level wind shear data for the Hong Kong Wind Shear Project and in particular SWISSAIR for its generous supply of AIDS-data during 1978-79.

REFERENCES

Chen T.Y. and H.N.Lee, 1978: Wind Shear at Hong Kong International Airport in Four Squally Shower Situations, Hong Kong Royal Observatory Technical Note No. 46, 35 pp.

Greene G.E., H.W. Frank, A.J.Bedard Jr., J.A.Korrell, M.M.Cairns and P.A.Mandics, 1977: Wind Shear Characterization, FAA Report No. FAA-RD-77-33, 120 pp.

ICAO, 1974a: Aeronautical Requirements for Wind Shear Data, ICAO 8th Air Navigation Conference Agenda Item 12b, 18 pp.

ICAO, 1974b: Measurement and reporting of wind shear and turbulence at low levels, Air Navigation Commission, 8 pp.

Whitmore C.A. and R.C. Cokeley, 1976: Windshears on Final Approach, 29th Annual International Air Safety Seminar and Aviation Safety Technical Exposition, Anaheim California, 40 pp.