RECENT DEVELOPMENTS IN AVIATION METEOROLOGY

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INTRODUCTION

"It is a small world after all." This saying has never been a closer description of our world as of late. Since the Second World War, two major technological advances have brought our world together to form a global village: the rapid development in telecommunication and the expanded use of aircraft for civil aviation purposes. There were substantial increase in the number of aircraft and encounters with hazardous weather events increased proportionally. With civil aviation looks set to flourish in the booming Asia Pacific region in the years ahead, it is crucial to keep the number of aircraft accidents in this part of the world low.

2. A high standard of aviation meteorological services is central to the safety, regularity and efficiency of international air navigation. Several recent developments are contributing to the improvement in standard. The most notable ones are the use of numerical weather products in aviation, the use of satellite pictures, the use of weather and terminal doppler radar to deal with terminal weather hazards and the improvement in telecommunication. Because of the limited time, only two major developments will be discussed here: the World Area Forecast System (WAFS) and wind shear detection.

WORLD AREA FORECAST SYSTEM (WAFS)

3. The main objective of the WAFS is to supply meteorological authorities and other users with forecasts of en-route meteorological conditions in pictorial, alphanumeric and digital form. The objective is to be achieved in a cost-effective manner through a comprehensive, integrated, world-wide and, as far as practicable, uniform system.

4. At present, the WAFS is based on a three-tiered system comprising of

(a) two World Area Forecast Centres (WAFCs), London and Washington - these centres produce global forecasts of upper air winds and temperatures

(b) a number of Regional Area Forecast Centres (RAFCs) - these centres prepare significant weather (SIGWX) forecasts for selected "areas of coverage". They are also responsible for the transmission of those SIGWX forecasts, as well as upper-air forecasts to users within their "service areas", and

(c) the "users" consisting essentially of meteorological services, operators and other aeronautical users. The users receive WAFS data from the WAFCs and/or RAFCs concerned [1].

5. All these information are presently broadcast by radio. The existing system has a number of inherent short-comings, such as the system was not designed to cater for long-haul operations and consequently States have difficulties in obtaining WAFS data from one RAFC and the signal from the radio-broadcast is far from satisfactory.

6. The new WAFS using satellite broadcast offers an unprecedented opportunity to fulfill the objectives of WAFS at affordable price. With the new WAFS, large quantities of meteorological data crucial to the safe and economical operation of civil aviation will be made available to the States.

7. WAFC Washington will launch the "interim phase" of the WAFS satellite broadcast in the Asia-Pacific region in late 1994 to 1995. Figure 1 shows the footprint of its satellite broadcast. Its footprint will cover most parts of Regional Association II and V. States within this region will only need to acquire a VSAT (Very Small Aperture) terminal for receiving the satellite broadcast and a computer workstation to process the data.

8. The VSAT terminal will consist of an antenna and amplifier to receive the satellite broadcast and a microprocessor based controller for demodulation, decoding and protocol conversion etc. The VSAT terminal will be connected to the computer workstation which will then process the data. Software for processing these data may be acquired through WMO.

9. The amount of data to be broadcast will be huge. They can be divided into three main categories, namely, GRIB code data, alphanumeric OPMET data and graphical data. [2]

10. GRIB code data - these are model wind and temperature forecasts for flight planning purposes. The resolution of the data will be 1.25 by 1.25 degree latitude/longitude at the equator (about 140 km globally). These data will be available twice a day at around 0400 and 1600 UTC. The data will consists of 4 forecast valid times (12-, 18-, 24- and 30-hour), 12 levels each which include maximum wind and tropopause. Other meteorological elements such as geopotential heights, humidity, vertical velocity and precipitation etc. will also be made available initially to assist States to prepare significant weather charts.

11. Alphanumeric OPMET data - these will include METAR/SPECI, TAF, AIREP, SIGMET, NOTAM and administrative messages.

12. Graphical data - these will include significant weather charts prepared by RAFCs, volcanic ash trajectory chart as well as wind and temperature charts. In the "interim phase", these charts will be broadcast in WMO T4 digital facsimile format.

13. Work is proceeding in a few States aimed at complete automatic production of significant weather forecasts. After the WAFCs acquired the capability of producing significant weather forecasts on a global basis by objective methods, the requirements for the RAFCs will disappear. In this "final phase" of the WAFS, the two WAFCs will be responsible for preparing all the required significant weather and upper-air forecasts, and disseminating these to all users through satellite broadcasts (see Figure 2).

WIND SHEAR DETECTION

14. The term "wind shear", the difference in winds between two points in space, may be relatively new to the pilots and air traffic controllers. The term, however, is not new to meteorologists. It is a property of the atmosphere that is almost always present. Wind shear and turbulence may be associated with orographic effect, thunderstorms, frontal systems, strong monsoon, tropical cyclone, land/sea breeze and other weather events. The scale may range from micro (of the order to a few metres) to large (of the order hundreds of kilometres).

15. Although wind shear may be present at all levels of the atmosphere, aircraft accidents associated with wind shear are mostly caused by low level wind shear during take off and final approaches. Although wind shear magnitudes are generally inversely proportional to the shear scale, aircraft do not respond fully to the small-scale shear. They do respond fully to middle-scale shear (of the order of a few kilometres), and for this reason, their detection is most important.

16. The pilots are most interested in the effect of wind shear on their aircraft. Since the effect depends, among other things, the type of aircraft and the time of exposure to the shear, a simple unit for wind shear is impossible without involving the computation of the expected aerodynamic response on the individual aircraft types. Thus at the Fifth Air Navigation Conference (Montreal, 1967), it was decided that wind shear will be classified into different severity based on the empirically derived wind vector difference between two winds at different points in space in units of speed per given distance. Table 1 gives the different classifications.

Table I
Criteria for wind shear intensity recommended by the
Fifth Air Navigation Conference (Montreal, 1967) [3]

Light	-	0 to 4 kt inclusive per 30 m (100 ft)
Moderate	-	5 to 8 kt inclusive per 30 m (100 ft)
Strong	-	9 to 12 kt inclusive per 30 m (100 ft)
Severe	-	above 12 kt per 30 m (100 ft)

17. Microburst, one of the more severe type of wind shear, has now become the household name within the aviation community. A microburst is a strong short-lived outflow produced by strong thunderstorms when the divergence beneath the downdraft reaches 10m/s over a distance of less than 4 km. The shape, size and strength of the microburst shear region often evolve rapidly, particularly during the early growth of the outflow. When a strong downdraft first impacts the surface, it can change from a weak surface outflow to a strong outburst within 1 to 2 minutes. Most outbursts reach peak intensity and then decay in 10 to 20 minutes.

18. Figure 3 illustrates the effect of a microburst on an aircraft on final approach. Upon entering the microburst, an aircraft first experiences an increase in head wind. This increase causes the aircraft to fly above the glide slope. The pilot may attempt to return to the glide slope by reducing air speed and angle of attack. As the airplane continues through the microburst, it encounters a strong downdraft and then a tail wind, which results in a loss of lift. The airplane falls beneath the glide slope and the pilot must now increase power and angle of attack to bring the plane back to the glide slope. The aircraft, which requires a finite amount of time to respond to the controls, crashes if it is too close to the ground to recover.

19. Other sudden windshifts can also seriously affect the operation of the airport. For example in Hong Kong, a change in wind direction may require the direction of takeoffs and landing to be reversed. This reversal would necessitate re-routing approaching aircraft and force departing aircraft to the other end of the runway. Without advance warnings, this may cause extensive delays.

20. Because of the relatively small scale, in terms of both time and space, of the shear compared with the other meteorological systems, operational forecasting of wind shear remains a challenge today. At present, forecast is basically done by predicting the occurrence of meteorological phenomena which are known to produce wind shear. Generally alerts are issued to pilots and air traffic controllers when they are actually observed or detected. In fact, real-time operational detection and observation of low level wind shear is still considered to be

among the more intractable problems facing aviation meteorology.

21. The detection of wind shear hazards presents challenges in three basic areas :

(a) the reliable measurement of horizontal winds, especially in low-signal and high-clutter environments;

(b) the automatic identification and classification of the hazardous weather signatures in the wind field measurement; and

(c) the assessment of the hazard level posed to aircraft, along with the effective communication of the hazard level to air traffic controllers and pilots, in a manner easily understood by these non-meteorologist users.[4]

The situation has improved in the past ten years with the development of remote-sensing equipment such as the terminal doppler radar.

22. Terminal doppler radar is doppler weather radar especially designed for detection wind shear hazards associated with thunderstorms. Since its surveillance area is limited to a small area around the airport terminal and thus its name. The radar measures reflectivity from rain and utilizes doppler effect to measure the radial velocity of rain or airborne micro-particulate. It uses automatic computer algorithms to identify hazardous weather signatures to provide timely warnings to the air traffic controllers.

23. Figure 4 shows the stages of evolution of a microburst. The computer first identifies regions of surface divergence. An area with outflow exceeding 10 m/s will be declared a microburst. The detection of storm features aloft relaxes the strength and temporal requirements for alarm generation. The computer also uses algorithms to detect microburst pre-cursor signatures, such as descending reflectivity core coupled with convergence aloft, to warn air traffic controllers of imminent microbursts. Past experience in U.S.A. indicates that TDWR can detect around 90 percent of the microbursts with around 5% false alarms [5].

24. At airport terminals without TDWR, wind shear can be observed by using a dense anemometer network coupled with visual observation. The anemometer network provides an immediate depiction of horizontal wind shear. The most well known one is of course the low-level wind shear alert system (LLWSAS) developed in U.S.A. LLWSAS is made up of a network of 12 to 16 anemometers located roughly symmetrically at a distance of around 3000 ft from the threshold of the runway. Whenever a vector difference of 15 knots is detected, it will generate an audio and visual alarm to warn the pilots of possible microbursts.

25. In Hong Kong, a similar network with anemometers installed on hills situated near the approach path has employed since the early 1980's to provide information for wind shear warning (Figure 5). Such a network, however, could only detect wind shear but would

not be able to give an advance warning like TDWR. Therefore at the new Chek Lap Kok airport to be opened in 1997, a TDWR will be installed to detect wind shears associated with thunderstorms.

References

[1] ICAO Doc. 8896-AN/893/4, 1993: Manual of Aeronautical Meteorological Practice. ICAO.

[2] U.S.A. 1993: WAFS Satellite Data Broadcast from WAFC Washington. Third Asia/Pacific Regional Air Navigation Meeting.

[3] Turnbull, D., McCarthy, J., Evans, J. and Zrnic D., 1989: The FAA Terminal Doppler Weather Radar (TDWR) Program. Third International Conference on the Aviation Weather System, Anaheim, CA, American Meteorological Society, Boston, MA.

[4] M.W. Merritt, D. Klingle-Wilson, and S.D. Campbell, 1989: Wind Shear Detection with Pencil-Beam Radars. The Lincoln Laboratory Journal, Vol. 2, No. 3.

[5] ICAO Circular 186-AN/122, 1987: Wind Shear. ICAO.

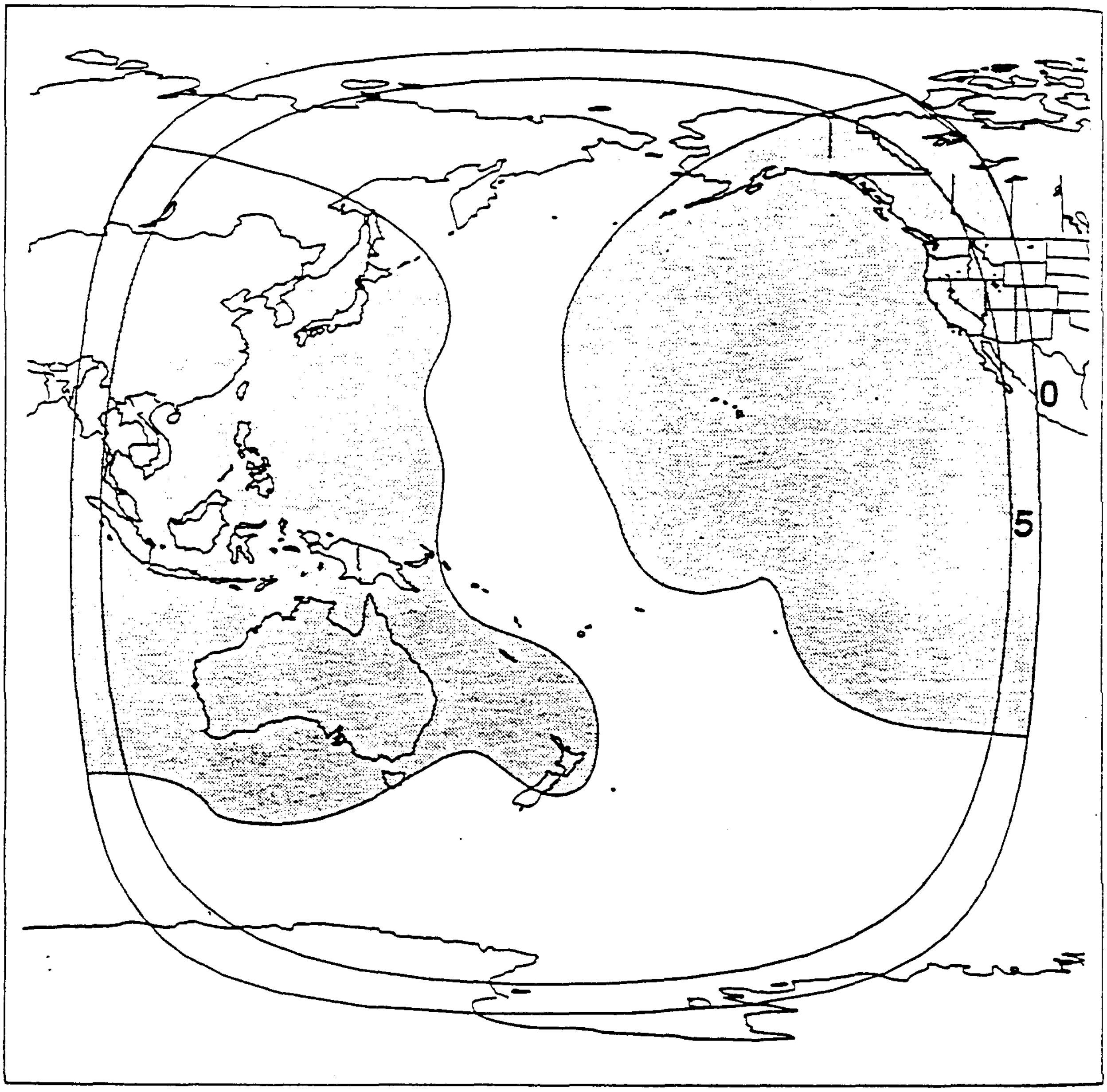

Figure 1 - Tentative WAFS Asia-Pacific Region Footprint

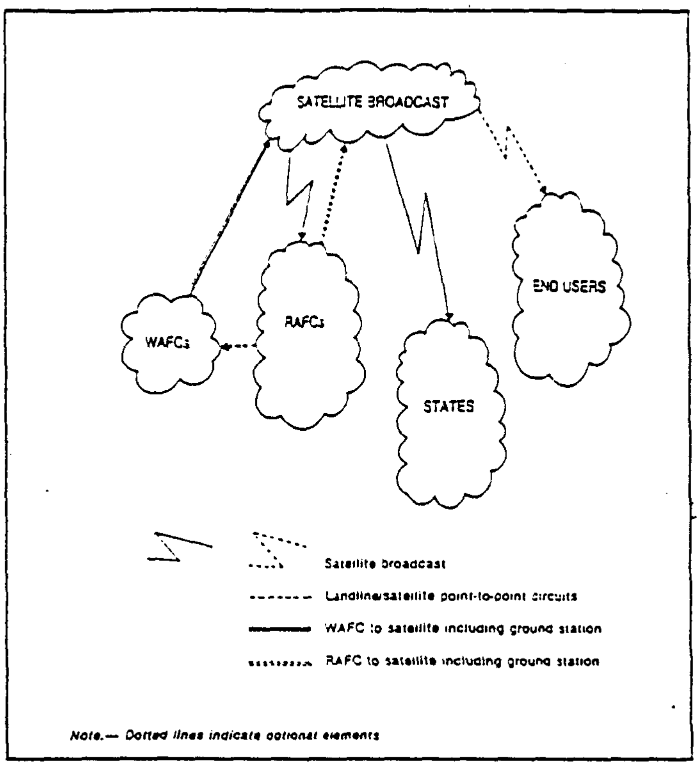

Figure 2a - Concept for satellite broadcast of WAFS products - interim phase

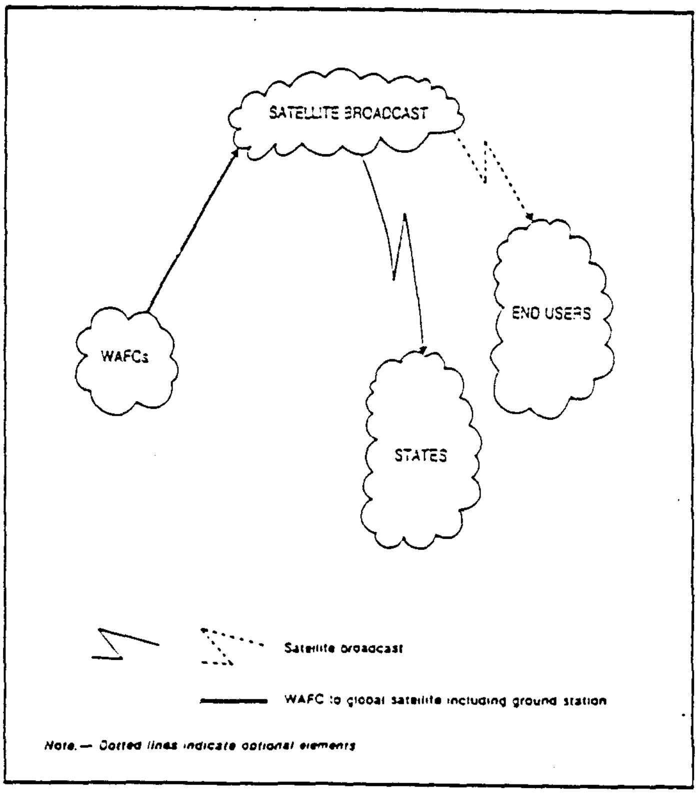

Figure 2b - Concept for satellite broadcast of WAFS products - the final phase of the WAFS

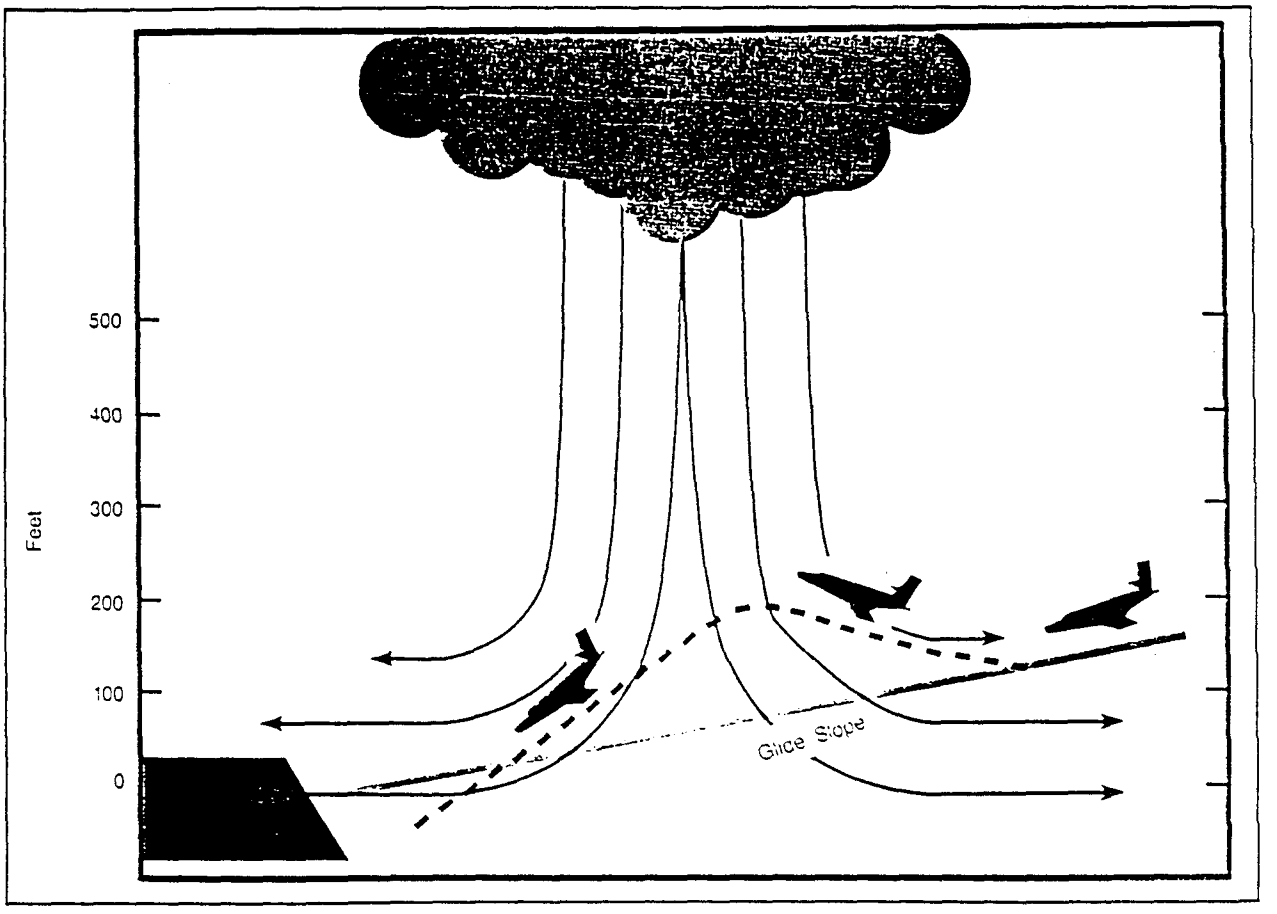

Figure 3 - Example of an aircraft encounter with a microburst. The spreading winds from a strong downdraft form the microburst outflow. A penetrating aircraft first experience an increase in head wind, followed rapidly by a downdraft, and finally a tail wind. The loss in altitude across the event may result in ground impact.

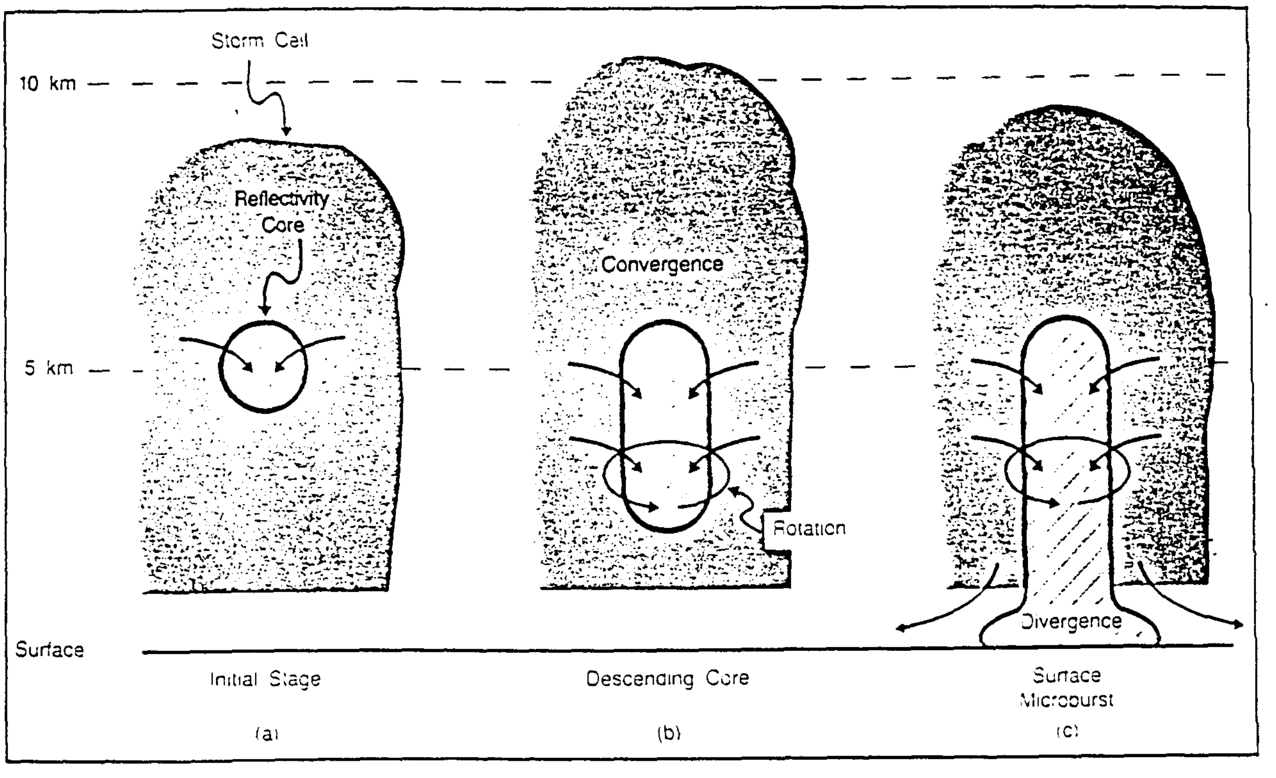

Figure 4 - Stages in the evolution of a microburst. (a) A reflectivity core initially forms aloft at 5 to 10 min prior to the onset of surface outflow. (b) As the downdraft develops, the core descends, and convergence and rotation develop. (c) Finally, the core reaches the surface and the surface outflow begins.

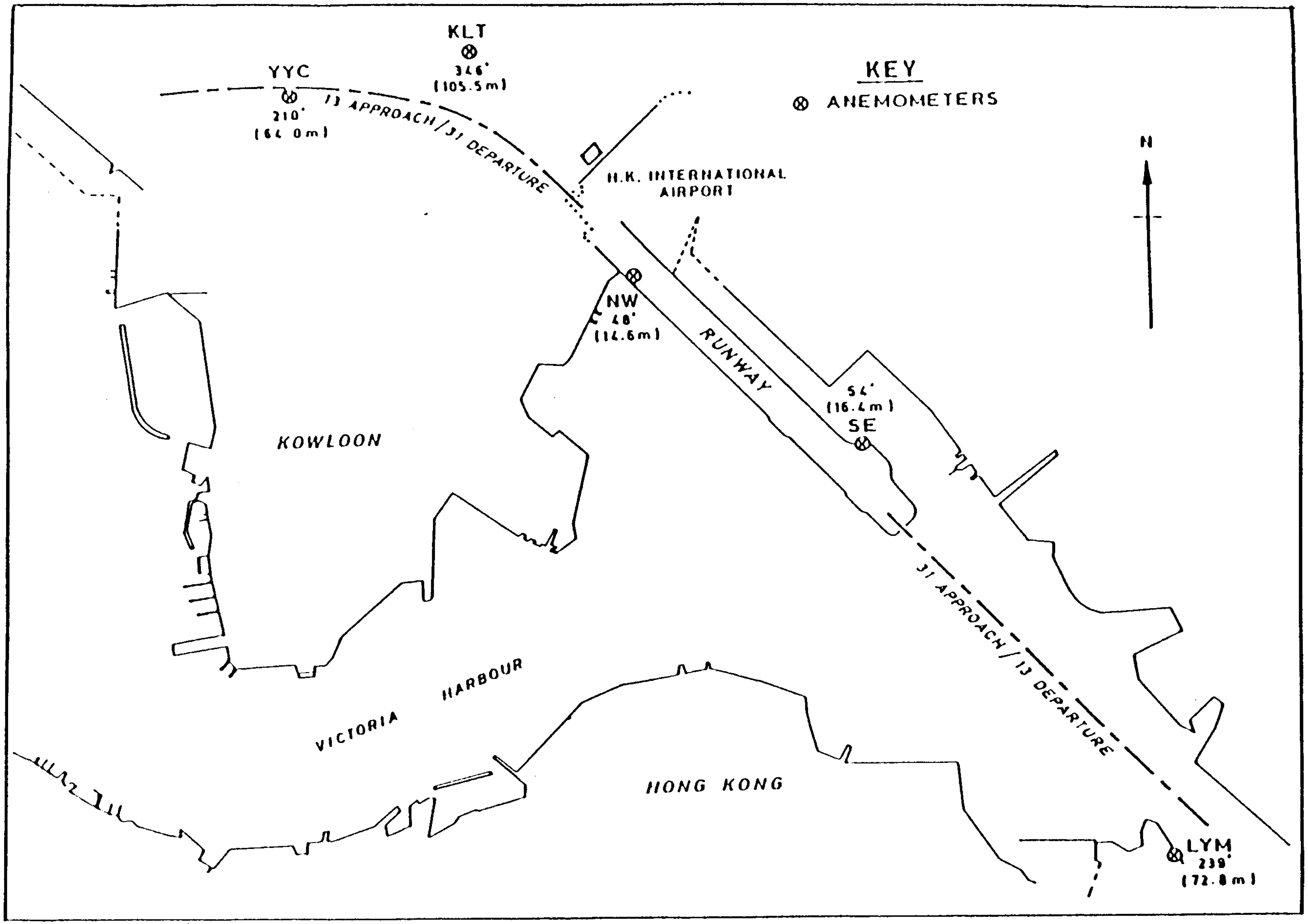

Figure 5 - Positions of anemometers and approaches around Hong Kong International Airport