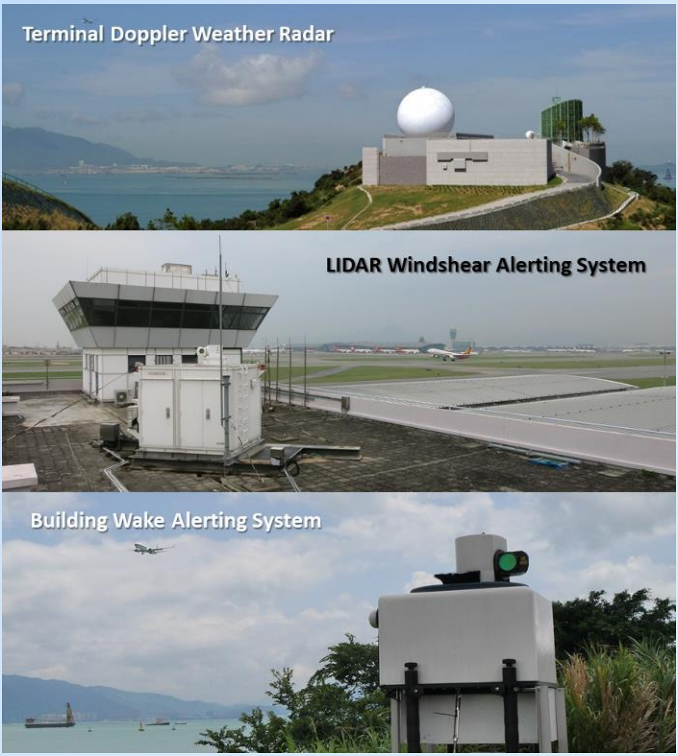
Windshear and Turbulence in Hong Kong

- information for pilots



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Foreword

The Hong Kong Observatory (HKO) provides windshear and turbulence alerting service for aircraft using the Hong Kong International Airport (HKIA) to assure flight safety.

We are pleased to partner with the International Federation of Air Line Pilots' Associations (IFALPA) and The Honourable Company of Air Pilots to prepare this booklet.

This booklet aims at providing pilots and air navigators with the basic information on windshear and turbulence, their causes, and the windshear and turbulence alerting service in Hong Kong.

Since the first publication of this booklet in 2002, windshear and turbulence alerting technology has advanced a long way. The LIDAR (LIght Detection And Ranging), first applied in aviation weather alerting by HKO, is now accepted worldwide as the standard solution for detecting clear-air windshear and turbulence. This latest edition also contains new information on the "low-level wind effects" and the alerting of building-induced turbulence.

This booklet is provided for reference and education only and is in no way intended to replace individual airline company's Standard Operating Procedures.

CM Shun
Director of the Hong Kong Observatory
August 2019

Use of Symbols

denotes important notes for pilots

denotes examples

Keep reporting windshear and turbulence!

Pilot reports (PIREPs) remain a key component of the windshear and turbulence warning service. Moreover, the HKO is continuously refining the Windshear and Turbulence Warning System (WTWS) to enhance its accuracy using PIREPS as an established method to verify the alerts. Your support is indispensable to the windshear and turbulence alerting service. If you encounter windshear or turbulence, please **report the event to ATC or email/fax a pilot report to HKO**. The windshear/turbulence reporting form can be downloaded from:

https://www.weather.gov.hk/aviat/amt_e/report_form.pdf.

If you don't encounter it and it is being forecast and/or alerted, the HKO still needs to know, so tell ATC and HKO. Your reports will continue to be used to enhance the system. Thanks to all of you for the feedback!

Introduction

This booklet is in the form of questions and answers. It starts by explaining what windshear and turbulence are and then explains how the windshear and turbulence alerting service in Hong Kong works. It goes on to explain what causes windshear and turbulence in and around HKIA, and points out some important points that pilots should understand.

Most of you reading this booklet are experienced aviators and are already familiar with windshear and turbulence and how they are caused. You may, therefore, wish to treat it as a refresher. For others, this should elucidate what windshear and turbulence are and how they can affect an aircraft.

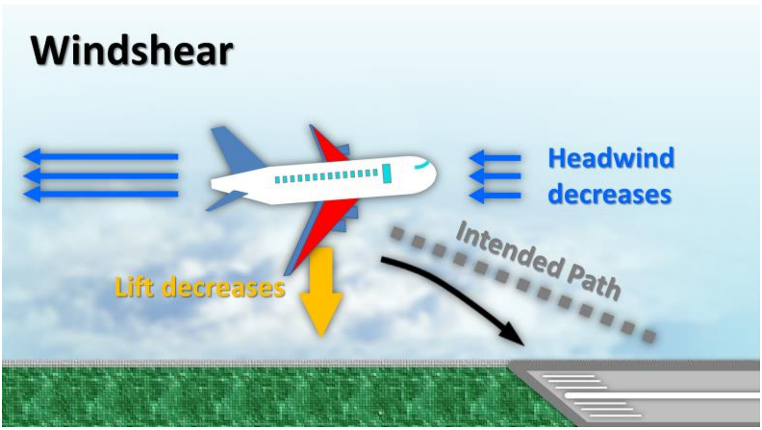
By the end of this booklet, you should understand, among others, the following:

1. How windshear and turbulence alerts are generated;
2. The local phraseology, e.g. what the terms “Microburst Alert (MBA)” and “MOD TURB 1MF” mean in Hong Kong;
3. The reason why some aircraft encounters windshear while others do not;
4. If windshear and turbulence alerts are issued, what you might experience; and
5. The effects of the local winds near the runways, including building-induced turbulence.

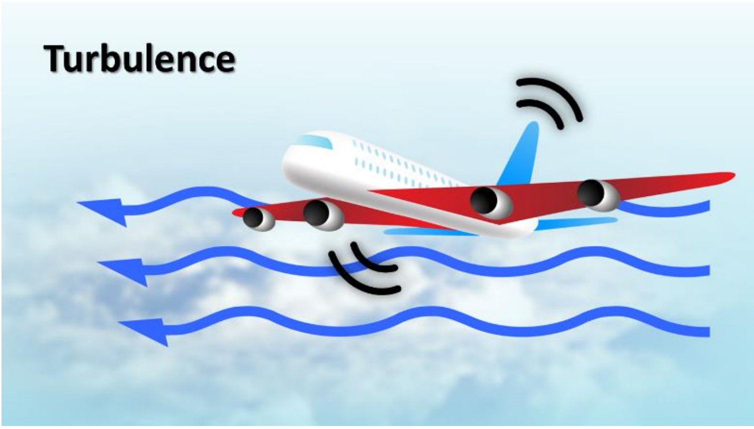
What is windshear and turbulence ?

Windshear refers to a sustained change (i.e. lasting more than a few seconds as experienced by the aircraft) in the wind direction and/or speed, resulting in a change in the headwind or tailwind (i.e. the runway-oriented wind component) encountered by an aircraft. A decreased lift will cause the aircraft to go below the intended flight path (see figure below). Conversely an increased lift will cause the aircraft to fly above the intended flight path.

Pilots should be aware that significant windshear at low levels on approach and departure zones may cause difficulty in control, thus requiring timely and appropriate corrective actions to ensure aircraft safety.

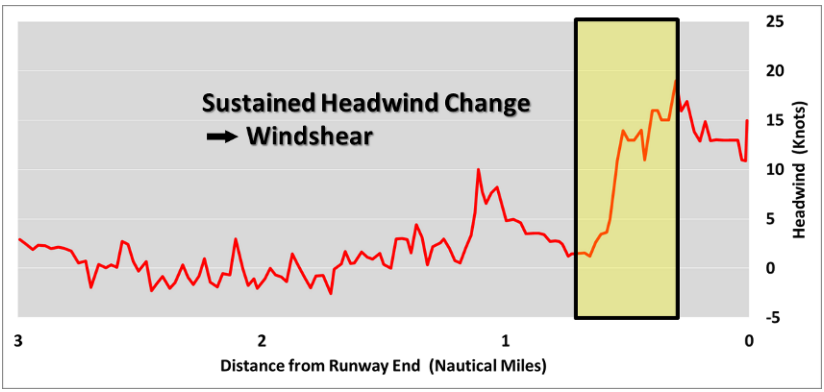


Turbulence is caused by rapid irregular motion of air. It brings about rapid bumps or jolts but does not normally influence the intended flight path of an aircraft significantly. However, in severe turbulence cases, abrupt changes in the altitude and attitude of the aircraft may occur and the pilot may suffer a momentary loss of control.

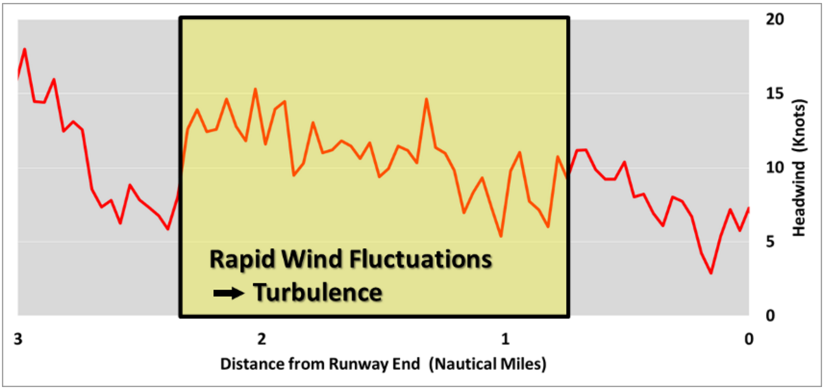


In general, **rapid fluctuations** in the wind speed and direction encountered by the aircraft are perceived as turbulence, whereas a **sustained change** of the headwind or tailwind of 15 knots or more for more than a few seconds is significant windshear.

The figure below shows the headwind profile retrieved from the flight data recorder (FDR) on an aircraft approaching HKIA under a sea breeze condition. The shaded area represents the location of the sea breeze front where the aircraft experienced significant windshear of headwind increase.



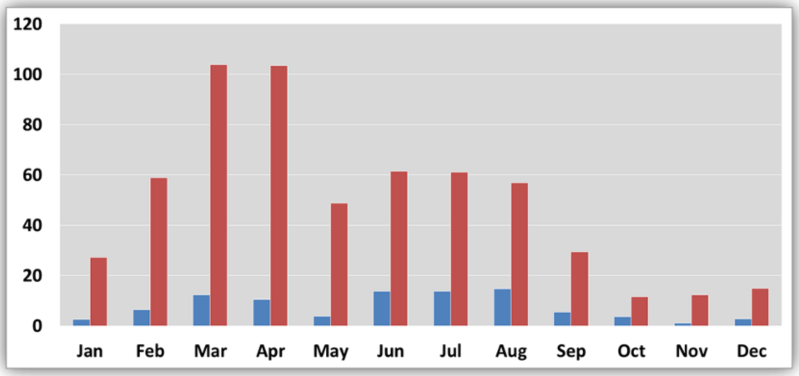
The next figure shows the headwind profile retrieved from the FDR on an aircraft approaching HKIA under a disturbed strong southwesterly wind condition. The shaded area represents the region where the aircraft experienced significant turbulence. The pilot reported moderate to severe turbulence along the glide path in this case.



Windshear events can be very small scale, sporadic and transient in nature and may affect successive aircraft differently. Therefore, windshear or turbulence as experienced by an aircraft may at times differ from the conditions reported by the preceding aircraft and from the alerts provided.

How often are windshear and turbulence experienced at HKIA ?

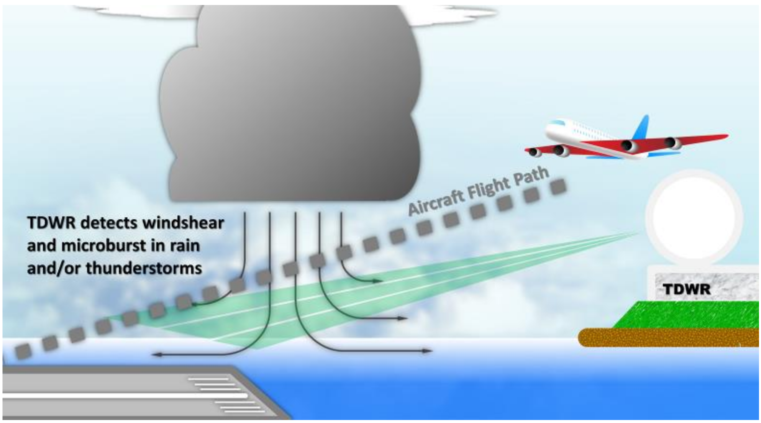
Since the opening of HKIA in July 1998, about 1 in 500 arriving and departing flights have reported significant windshear while on average around 1 in 3,500 flights have reported significant turbulence. As shown in the chart next page, a majority of these events were reported in the spring months of March and April. Statistically, a second "peak" could also be observed around the summer months of June to August, usually under the influence of tropical cyclones.



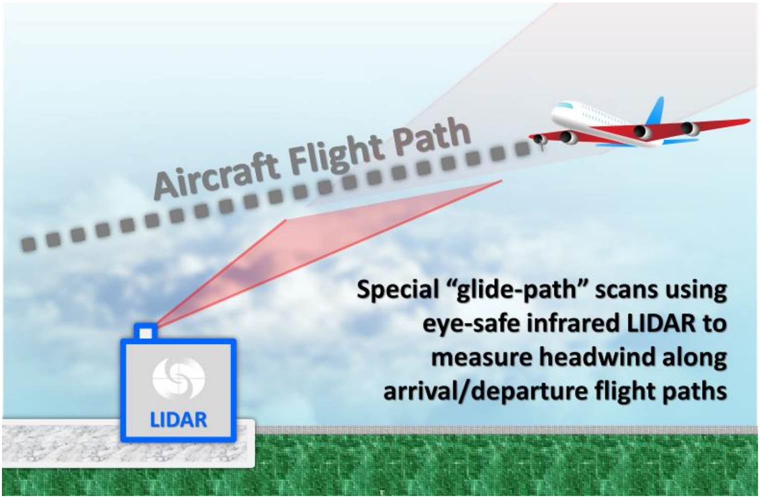
Average monthly numbers of pilot reports of significant windshear (red) and turbulence (blue) at HKIA between 2001 and 2018.

How does HKO alert aircraft to windshear and turbulence ?

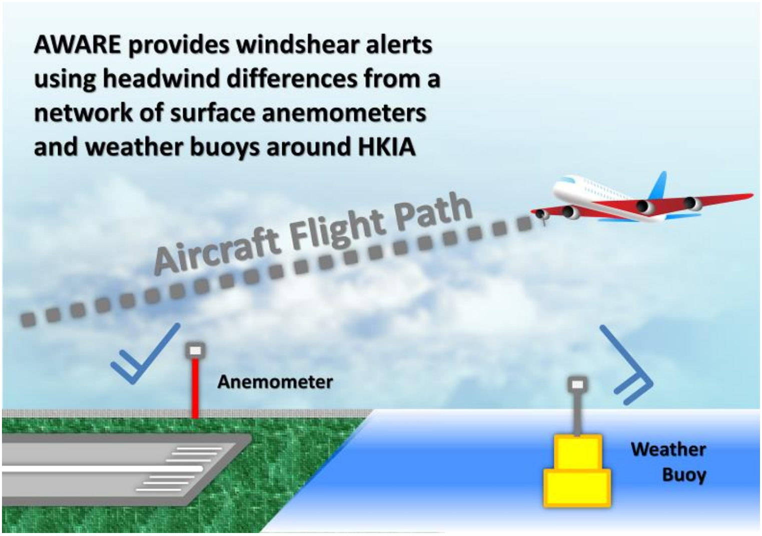
A Terminal Doppler Weather Radar (TDWR) continuously scans the runway corridors to detect windshear and microburst. This works when there is rain and/or thunderstorms around.



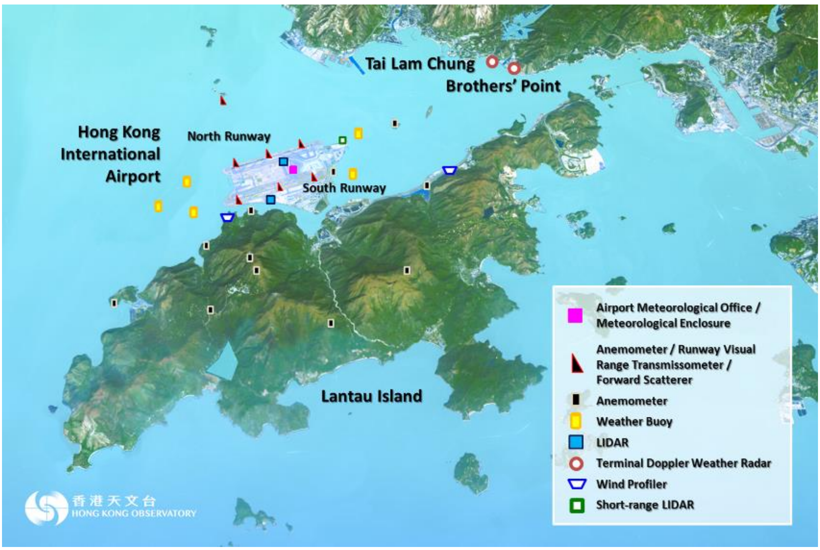
When there is no rain, the LIght Detection And Ranging (LIDAR) systems are used to measure the headwind profiles along the glide paths. The LIDAR Windshear Alerting System (LIWAS) detects significant changes in the headwind from the measured headwind profiles and issues windshear alerts. LIWAS is equipped with two LIDARs, one located near the North Runway and the other located near the South Runway, so that each runway is served by a dedicated LIDAR.



In addition, a dense network of surface wind sensors, deployed at and around the airport, monitors low-level wind changes. Besides eight anemometers on the airport and on Tai Mo To, an island east of HKIA, it also includes a number of weather buoys over the waters on both sides of HKIA. The wind sensor data are analyzed by the Anemometer-based Windshear Alerting Rules – Enhanced (AWARE) system to issue windshear alerts.



All these data are fed in real time to the Windshear and Turbulence Warning System (WTWS), which is used to automatically integrate and generate "up-to-the-minute" **alerts**, when windshear and/or turbulence are detected.



In addition, Aviation Meteorological Forecasters of HKO issue **warnings** for imminent windshear and turbulence based on the broad prevailing meteorological conditions, the real time data from the above detection systems, and the aircraft reports provided by pilots through air traffic controller and by the Aircraft Meteorological Data Relay (AMDAR) data received automatically from air-ground data link.

Aircraft operating at HKIA are alerted of low-level windshear and turbulence in two ways:

(a) Windshear and turbulence alerts passed by air traffic controllers (ATC):

Alerts of windshear and turbulence induced by terrain, buildings or caused by convection which are generated automatically by the WTWS, are passed to aircraft via ATC.

(b) Windshear and turbulence warnings provided on Automatic Terminal Information Service (ATIS):

Warnings of windshear and turbulence, which are issued by the Aviation Meteorological Forecaster, are provided to aircraft on Voice-ATIS and Digital-ATIS (D-ATIS). In addition, microburst and windshear detected by the TDWR will also trigger a warning.

What levels of windshear alerts are issued ?

The WTWS continuously monitors possible occurrence of windshear within 3 NM of the runway thresholds and issues alerts.

Alerts for windshear are classified into two levels: '**Microburst Alert**' and '**Windshear Alert**'. This follows the same terminology adopted by the US Federal Aviation Administration (FAA) in classifying windshear alerts issued by the TDWR installed at major aerodromes throughout the US.

Microburst Alert (MBA):

Alerts for windshear with headwind **loss of 30 knots or greater** and when **precipitation is present**. This can only be generated by the TDWR.

Windshear Alert (WSA):

Alerts for windshear with headwind **loss or gain of 15 knots or greater** (except microburst). Note that the following will be issued as a WSA, not MBA: (i) a headwind gain of 30 knots or greater; and (ii) a headwind loss of 30 knots or greater but with NO precipitation present.

The way in which an aircraft is affected by windshear is dependent on a number of important factors. These include the rate of change of wind speed, the total magnitude of the headwind/tailwind change, the airspeed of the aircraft, the distance over which the windshear operates, the aircraft type, and the aircraft response.

'**MBA**' is only a terminology to denote an alert generated by TDWR, when the headwind loss is 30 knots or greater and accompanied by precipitation. It may be caused by phenomena other than a 'conventional' microburst. For instance, strong southerly flow across Lantau Island, coupled with rain, may also trigger an MBA on TDWR. As such, you **should not expect the typical sequence of events in traversing a 'conventional' microburst** (i.e. headwind gain and lift preceding a downdraft, followed by headwind loss and sink) **to always occur when an MBA is in effect**.

What levels of turbulence alerts are issued?

The WTWS continuously monitors possible occurrence of turbulence within 3 NM of the runway thresholds and issues alerts based on observations made by weather sensors.

Alerts for turbulence are issued with reference to heavy category aircraft e.g. A330 and B777. Turbulence alerts, other than those associated with building wakes, are classified into two levels based on a quantity called the cube root of the eddy dissipation rate (EDR), viz **$EDR^{1/3}$**:

Alert of Severe Turbulence:

A severe turbulence alert is generated for turbulence with $EDR^{1/3}$ of 0.5 or above.

Alert of Moderate Turbulence:

A moderate turbulence alert is generated when $EDR^{1/3}$ falls between 0.3 and 0.5.

For building-induced turbulence over arrival corridor 25R, the corresponding moderate turbulence alert is generated when the "coherent integrated differential velocity" is 0.4 or above.

Remember that this classification refers to the effect of turbulence on **heavy category aircraft**. The effect may be more intense on a medium or light category aircraft.

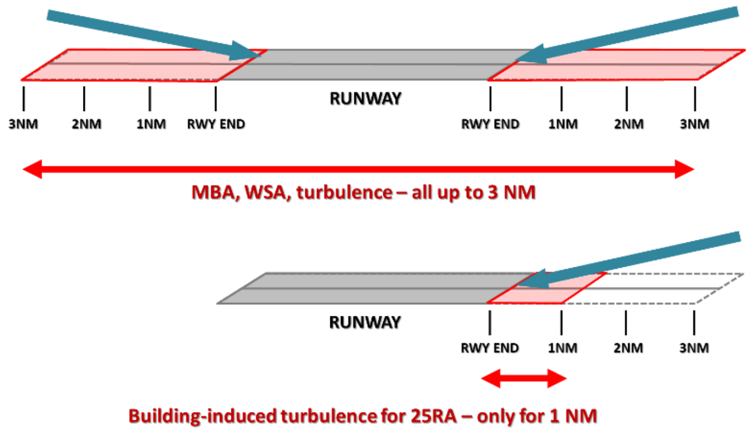
What is the coverage of the alerts?

Arrival corridors: Microburst, windshear and turbulence (not building-induced) events out to a distance of 3 NM will be alerted. Moreover, for corridor 25R, building-induced turbulence within the final 1 NM will be alerted when no other turbulence alerts are concurrently in force.

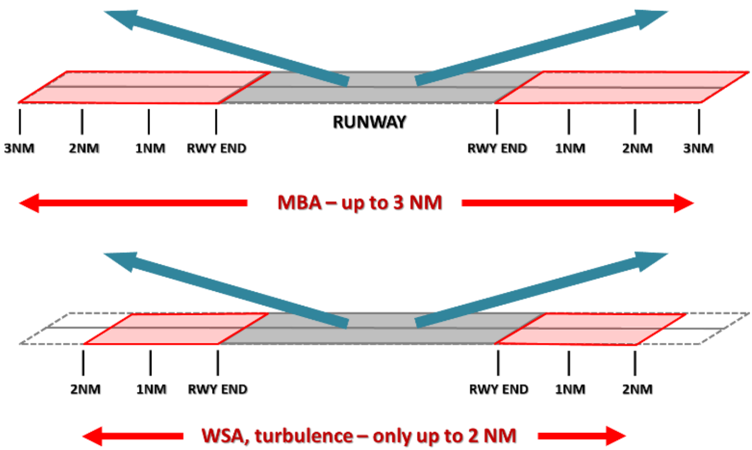
Departure corridors: Alerts of microburst will be issued for events up to 3 NM. For windshear and turbulence, only events out to a distance of 2 NM (or an altitude of around 1000 feet) will be alerted.

The spatial coverage of alerts of windshear and turbulence is summarised in the following diagrams:

Arrival:



Departure:



What is the phraseology of windshear and turbulence alerts passed by ATC ?

The **Microburst Alert** or **Windshear Alert** passed by ATC includes the **type of alert** (i.e. microburst or windshear), the **magnitude of the runway orientated wind speed difference** and the **location** (i.e. final approach, departure or runway area as appropriate).

The **Turbulence Alert** passed by ATC includes the **intensity of alert** (i.e. moderate or severe turbulence) and the **location** (i.e. final approach, one mile final or departure area as appropriate).

In order to provide concise alerting information for each runway corridor, only a single Microburst Alert or a single Windshear Alert will be passed by ATC, irrespective of whether one or more occurrences of windshear is detected for that particular corridor. The same applies to the dissemination of Turbulence Alerts.

This is different from the phraseology being used in TDWR at major US airports, which is based on the "First Encounter-Maximum Intensity" principle, where the location of the expected encounter with the first significant windshear event is reported along with the intensity of the maximum windshear event that is expected to be encountered. The phraseology adopted at HKIA is simpler and is intended to avoid possible misinterpretation of the alert message. The alert, issued at HKIA, means that aircraft may encounter the windshear event with the maximum intensity **anywhere** along the corridor and there may be more than one event (see examples on pages 17 and 18).

EXAMPLE *Caution. Microburst minus 30 knots on final approach.*
Caution. Windshear plus 15 knots on departure.

EXAMPLE *Caution. Moderate turbulence on departure.*

When a ‘Microburst Alert’ or a ‘Windshear Alert’ is given for a particular runway corridor and turbulence is also detected for that particular corridor, a ‘Turbulence Alert’ will be passed by ATC together with the ‘Microburst Alert’ or ‘Windshear Alert’.

Caution. Windshear minus 20 knots and moderate turbulence on departure.

For building-induced turbulence at arrival corridor 25R, the ‘Turbulence Alert’ will cover specifically the final nautical mile (see page 13).

Caution. Moderate turbulence 1 mile final.

What is the phraseology of windshear and turbulence warnings provided on ATIS ?

A windshear warning provided on the “Arrival ATIS” and/or “Departure ATIS”, as appropriate, includes the type of warning (significant windshear) and the specific runway corridor(s) to which the warning is applicable.

Significant windshear forecast 07R.
Significant windshear forecast 25L and 25R.

Microburst and windshear detected by the TDWR will also trigger a warning.

A warning triggered by the TDWR will not be given as “forecast” or “forecast and reported”.

Microburst and significant windshear 07L and 07R.
Significant windshear 25L and 25R.

A turbulence warning provided on ATIS includes the intensity and type of warning (i.e. moderate or severe turbulence), and the relevant runway corridors.

EXAMPLE

Moderate turbulence forecast 07L and 07R.
Severe turbulence forecast 25L and 25R.

A warning will be given as "forecast" when the information is forecast by the Aviation Meteorological Forecaster of HKO, or "forecast and reported" when the information has also been confirmed by a pilot or AMDAR aircraft report (see page 10).

EXAMPLE

Significant windshear forecast 07L and 07R.
(when windshear is forecast by Aviation Meteorological Forecaster for both RWY 07L and RWY 07R)

Significant windshear forecast and reported 07L and 07R.
(when the warning has been confirmed by a pilot or automatic aircraft report over either of the corridors)

Warnings given on D-ATIS are coded in ICAO abbreviations, e.g. "SIG WS FCST AND REP 07L AND 07R" or "MOD TURB FCST 25L AND 25R".

To assist pilots in evaluating the possible wind changes that may be experienced during the final phase of the approach under strong wind conditions, an estimated 2,500 feet wind based on 2-minute mean winds measured by a hilltop anemometer to the south of HKIA is given at the end of the "Arrival ATIS" when the wind speed exceeds 35 knots.

EXAMPLE

2,500 feet estimated wind 160 degree 40 knots.

This wind is for guidance only! Due to spatial variability of the wind and different geographical environment of the hilltop stations, the hilltop wind readings may be different from the wind actually experienced at 2,500 feet on the approach path.

In case more than one of the sub-systems detect windshear on the same runway corridor, what alert is issued?

The WTWS integrates real-time information from a number of sub-systems, including TDWR, LIWAS and AWARE to generate automatic windshear alerts. Within each sub-system, when more than one event is detected within a particular runway corridor, a loss event will have higher priority over gain event.

When more than one sub-systems detect possible occurrence of windshear over a particular runway corridor, the alerts are consolidated to form an integrated alert based on the following priority scheme which takes into account the severity of the alerts (**microburst over windshear; loss over gain**) and the confidence level of the different data sources which generate the alerts:

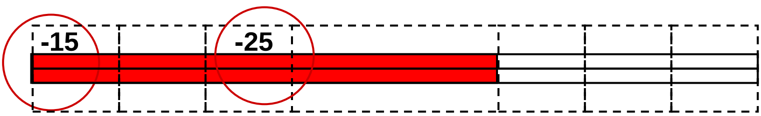
1.	**(highest)**	**TDWR Microburst**
2.		**WTWS Windshear of minus 30 knots or greater**
3.		**TDWR/WTWS Windshear of minus 15 knots or greater**
4.	**(lowest)**	**TDWR/WTWS Windshear of plus 15 knots or greater**

Note: WTWS windshear alerts include those issued by LIWAS and AWARE (see pages 8 and 9).

The alert with a higher priority is issued and passed to aircraft by ATC.

EXAMPLE

If a windshear of minus 15 knots at 3 mile final and another windshear of minus 25 knots at 1 mile final are detected by TDWR, the alert provided is "Caution. Windshear minus 25 knots on final approach".



It should be noted that the alert refers to the maximum intensity of windshear events within 3 NM from the runway threshold. The reported intensity is the maximum loss or gain that may be encountered **anywhere** along the 3 NM corridor on approach or departure to the runway.

If a windshear of plus 20 knots at 2 mile final and another windshear of minus 20 knots at 1 mile final are detected by WTWS algorithms, the alert provided is "Caution. Windshear minus 20 knots on final approach".

Cases like the above example can happen, whether in terrain-induced windshear (see pages 20-26) or microburst-like events (see page 27). Pilots should note that gain and loss events can co-exist on the same arrival or departure corridor. This means that while a windshear alert of wind loss is given to the aircraft, you may also encounter a wind gain event.

If an MBA of minus 30 knots at 1 mile final is generated by TDWR and a WSA of plus 15 knots at 3 mile final is generated by WTWS, only the MBA will be issued.

What are the typical causes of windshear and turbulence at HKIA ?

Windshear and turbulence can be caused by a wide variety of phenomena. The six typical causes of windshear and turbulence in Hong Kong, based on pilot report statistics, are listed below in decreasing frequency of occurrence:

1. Winds blowing across terrain (terrain-induced);
2. Sea breeze;
3. Gust front (thunderstorm-related);
4. Microburst (thunderstorm-related);
5. Building-induced turbulence;
6. Low level jet.

Most windshear and turbulence at HKIA are caused by strong winds blowing across the hills over Lantau Island to the south of the airport, including winds associated with the passage of tropical cyclones and a strong monsoon. They account for about 75% of all the pilot windshear reports. Sea breeze is the cause of windshear for about 15% of the pilot reports. The remaining 10% of events based on pilot reports could be attributed to other meteorological factors such as gust front, microburst, low level jet and building-induced turbulence, etc.

Since the above figures are based on pilot reports statistics, the actual percentage of windshear **occurrence** could be different. For instance, pilots would generally avoid flying the aircraft into thunderstorm and thus the actual percentage of occurrence of windshear phenomena caused by microburst and gust front could be higher.

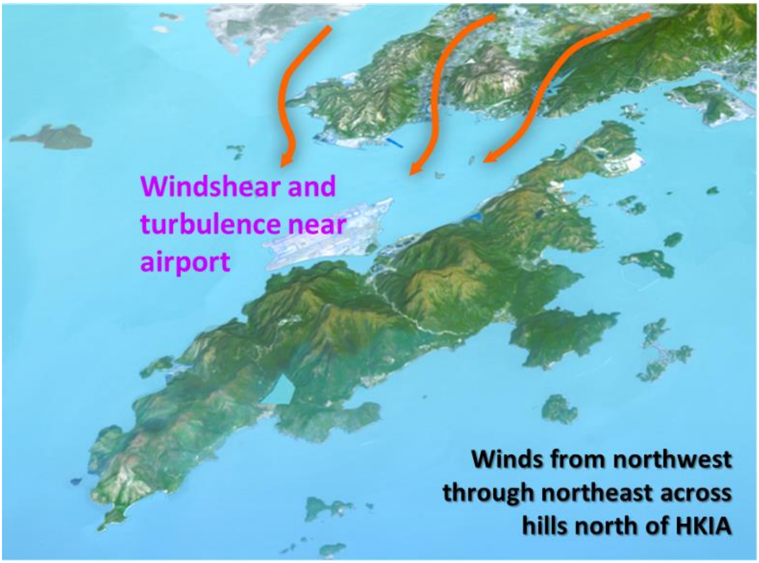
Apart from terrain, buildings and man-made structures can also lead to turbulence at HKIA under favourable wind speeds and/or directions. Moreover, under certain atmospheric condition, wake turbulence, a disturbance caused by an aircraft in flight, might dissipate slower than the norm leading to significant turbulence encountered by the following aircraft.

These factors are elaborated in the following pages.

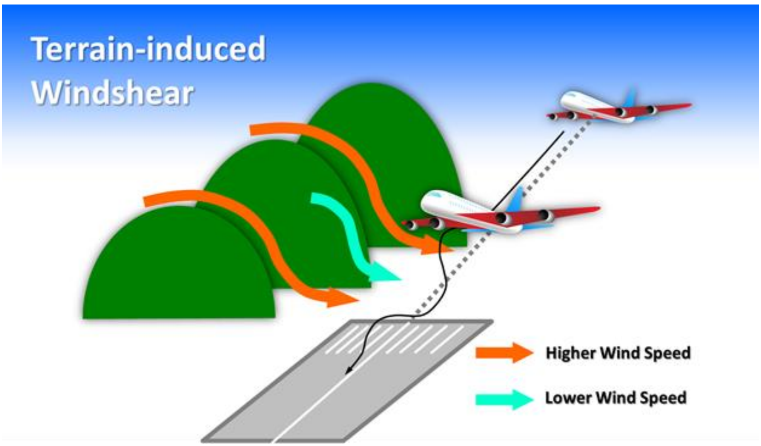
What is 'terrain-induced windshear' ?

Hills disrupt the flow of air across them and hence may induce windshear and turbulence. HKIA is located to the north of the mountainous Lantau Island, the highest peak on which is above 900 m (3,000 feet). Windshear and turbulence may occur near the airport, when winds of **15 knots or higher blow across the hills on Lantau from the east, southeast, south and southwest**. Larger magnitude of windshear and turbulence is possible, when the wind speed is over 30 knots.

Windshear and turbulence may also occur near the airport, when winds of **20 knots or higher come from the northwest through northeast sectors across the hills to the north of HKIA**, though much less frequently.

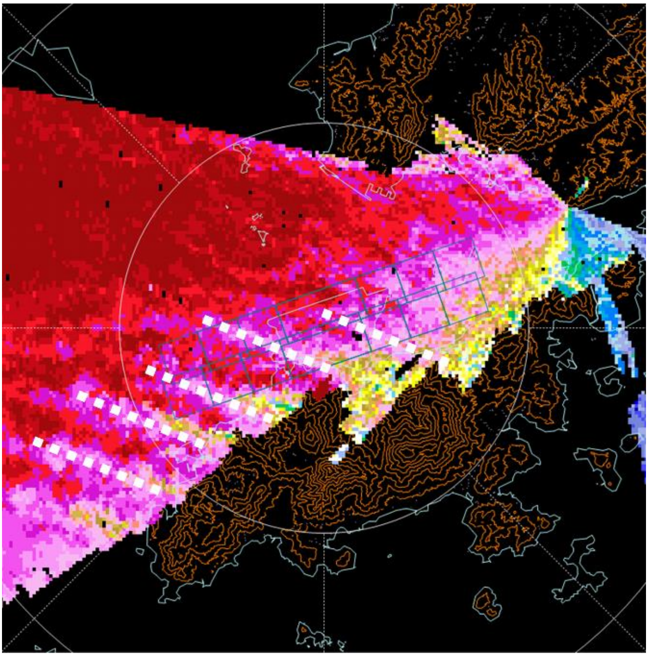


On windy occasions, such as the approach of a tropical cyclone, air streams of high wind speed may emerge from mountain gaps. Lying between these high-speed air streams are air streams of lower wind speed. Aircraft, traversing through alternating high-speed and low-speed air streams, may encounter headwind gains and losses at different locations along the approach and departure corridors.



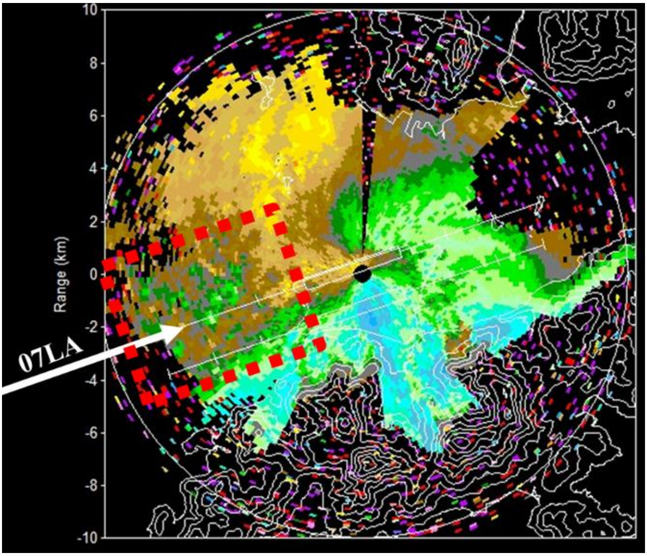
In particular, if an aircraft flies from a low-speed air stream to a high-speed air stream, it may experience a large headwind gain leading to a lift of the aircraft. On the other hand, if the aircraft moves from a high-speed air stream to a low-speed air stream, it may experience a large headwind loss resulting in a sinking motion. This sink occurs irrespective of whether there is accompanying precipitation or not.

The high-speed and low-speed airstreams are observed by TDWR in the example below, which occurred during the passage of a tropical cyclone near Hong Kong. Wind speeds are lower downstream of the higher terrain on Lantau Island in an alternating manner.



TDWR scan on 5 Sep 2015 during passage of Severe Typhoon Mujigae. Alternating red and purple stripes (highlighted in white) indicating respectively regions of higher and lower wind speeds blowing across HKIA runway corridors (rectangles) from Lantau.

The example below shows the occurrence of terrain-induced windshear in the form of a wake downstream of the mountains on Lantau Island as observed by the LIDAR. It appears in cross-mountain flow in stable atmospheric condition.



LIDAR image in the afternoon of 5 Mar 2015. Over the approach of RWY 07L (highlighted), the green/brown colour pixels represented eddies each with relatively low wind speeds but nonetheless led to record-breaking number of windshear reports on that day.

When the atmosphere is stable (e.g. presence of a low-level temperature inversion), winds will flow around the mountains leading to wakes downstream of mountains. In fact, apart from windy situation, windshear has been known to occur even at HKIA when winds of less than 15 knots blow across the hills on Lantau Island, in the spring months.

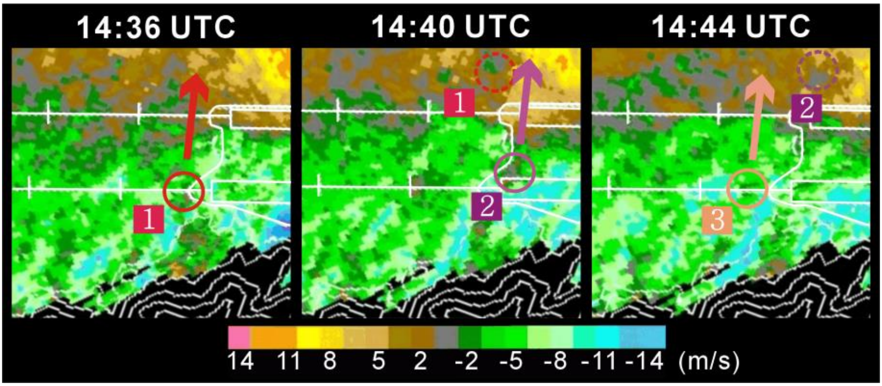
Windshear and turbulence are on average more significant on the South Runway, because of the closeness to the hills of Lantau Island.

Terrain-induced windshear does not necessarily occur in rain. In fact, a majority of the terrain-induced windshear reports received from aircraft flying into or out of HKIA are not associated with precipitation.

While terrain-induced windshear is not caused by a ‘conventional microburst’ (see pages 11 and 27), the headwind loss and the sink that it brings to an aircraft may be comparable to that of a ‘conventional’ microburst.

How changeable is windshear in Hong Kong ?

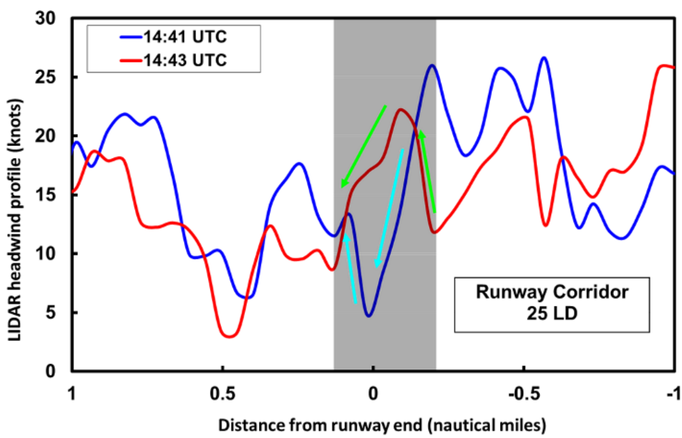
The following three LIDAR images, taken 4 minutes apart on 30 August 2004, reveal small-scale windshear and turbulence features (circled regions) moving over the western approach/departure corridors, under strong southerly winds disrupted by the terrain of Lantau Island.



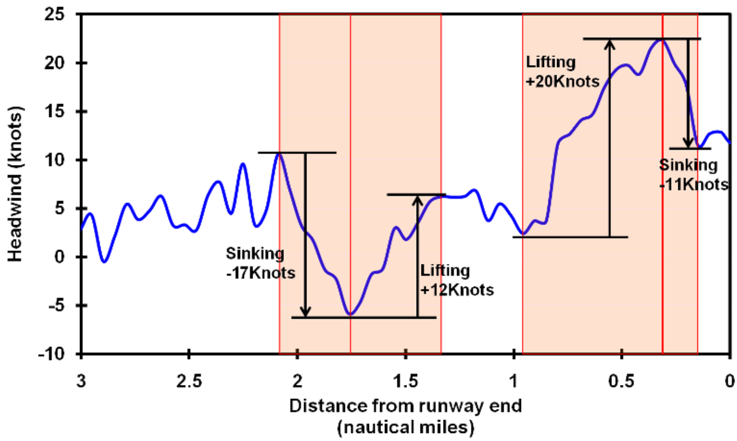
LIDAR images on 30 August 2004. The cool/warm colours represent winds towards/away from the LIDAR (see scale at the bottom). The arrows indicate the movement of the windshear features marked by circles within the subsequent 4 minutes.

The transient and sporadic nature of small-scale windshear and turbulence at HKIA is vividly revealed by the above images – in a space of a few minutes, these small-scale features emerged from the terrain of Lantau Island, moved quickly within the strong southerly airflow across the runway corridors and dissipated. Aircraft traversing these small-scale features would encounter a sequence of headwind changes. Whilst some may encounter headwind loss followed by gain, others may encounter headwind gain followed by loss. The LIDAR clearly shows that for terrain-induced windshear, the conditions experienced by successive aircraft can be "out of phase" with the alert given.

The headwind profiles measured by the LIDAR also vividly illustrate the transient and sporadic nature of terrain-induced windshear. For instance, on 30 August 2004, there was a headwind loss of 20 knots followed by a headwind gain of 10 knots around the runway end (blue arrows within the region highlighted in grey in the figure below) at 14:41 UTC on the departure corridor 25LD. However, the headwind sequence in the same region was found to reverse only 2 minutes later, with a headwind gain of 10 knots followed by a headwind loss of nearly 15 knots (green arrows). An aircraft departing at 25LD at that time reported encounter of significant windshear.



For terrain-induced windshear, headwind loss and gain may co-exist over the same runway corridor. An example on 14 February 2005 is shown on the next page, based on the headwind profile measured by the LIDAR.

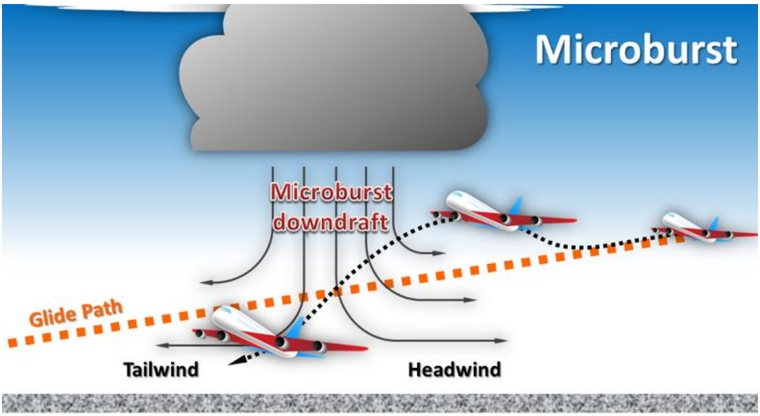


From the above example of terrain-induced windshear, it should be noted that:

- Runway gain and loss events can co-exist on the same corridor.
- While windshear alert of wind loss is given, you may also encounter a wind gain event.
- Due to the transient and sporadic characteristics of windshear, a headwind loss/gain may not necessarily be followed/preceded by a headwind gain/loss.
- The sequence of events (e.g. headwind loss followed by headwind gain, or vice versa) may be experienced differently by successive aircraft.
- Some aircraft may experience windshear and turbulence, while others do not, even though the weather conditions are broadly the same.

What is a 'microburst' ?

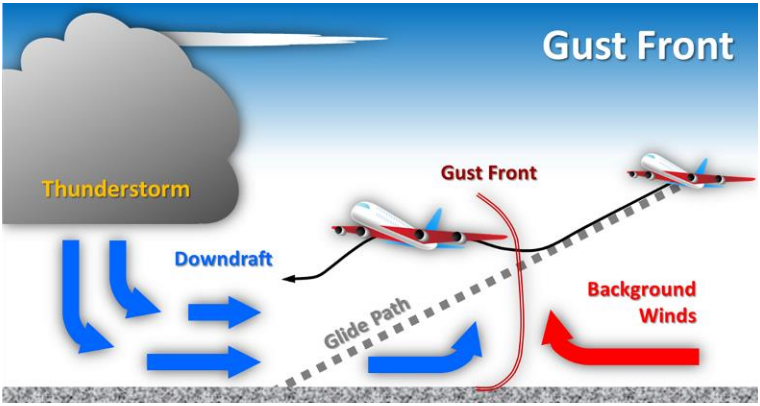
Microburst is the most violent form of downdraft from a thunderstorm. It is characterized by an intense and localized descent of cool air, causing a sudden outflow of horizontal winds above the ground with a typical horizontal extent of a few kilometres. An aircraft flying through a microburst may first encounter an increasing headwind and lift, then a downdraft from above the aircraft, followed by an increasing tailwind and sink. To overcome the adverse effect of the microburst, the pilot needs to take timely corrective action to ensure aircraft safety.



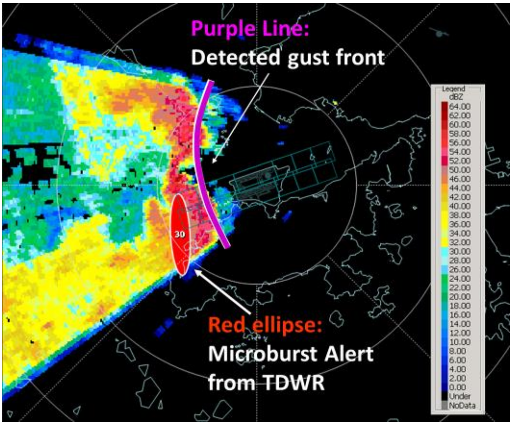
Well, that is the ideal theoretical world, though it can happen like this in practice, as some pilots have experienced. The first point, however, is that microburst can be asymmetric, having winds on one side stronger than the other side. The second point is that the column of downdraft can hit the ground at an angle, rather than vertically downward. So, if you are carrying out an approach through a microburst, you may not encounter the "classic" headwind gain and lift prior to the downdraft and headwind loss.

What is a 'Gust Front' ?

Severe thunderstorms are associated with intense convection, often resulting in violent downdraft and heavy rain. The descending air is cool and dense, and spreads out on hitting the ground. The leading edge of the cool air is called the **gust front**. Aircraft flying across a gust front may encounter increased headwind and lift.



An example of gust front captured by the TDWR is shown on the next page. The gust front occurs at the convergence between the background flow and the downdraft associated with a thunderstorm.



TDWR image from 4 Apr 2016 indicating occurrence of gust front (purple line) ahead of intense thunderstorms. A microburst alert (red ellipse) was also triggered. Coloured pixels represent intensity of precipitation (scale on the right).

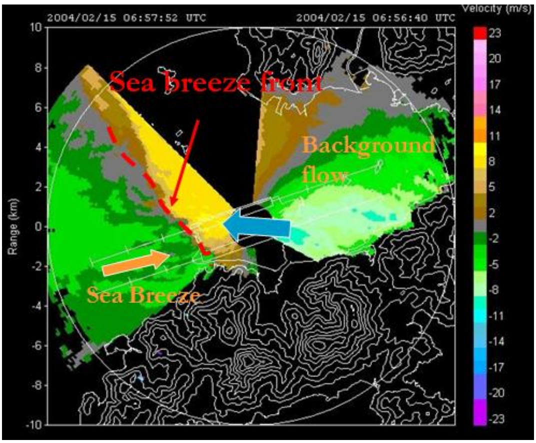
What is 'sea breeze' ?

Sea breeze usually develops under fine weather and light wind conditions when cooler and denser air over water flows towards warmer and less dense air over land due to the differential solar heating between the sea surface and the landmass (see the first headwind profile example on page 5). At HKIA, the onset of sea breeze is typically characterized by winds turning westerly over the western part of the airport. With prevailing easterly winds blowing in the background, significant windshear in the form of headwind gain to an aircraft may develop along the runways. Similarly, with prevailing west to southwesterly winds blowing in the background, sea breeze may appear as easterly over the eastern part of the airport. It should be noted that headwind loss may also occur for windshear associated with sea breeze due to the complex vertical structure of the interface between the sea breeze and the background wind.

While not frequent, windshear of 20 knots or greater associated with sea breeze may occur under background winds of 10 knots or higher.

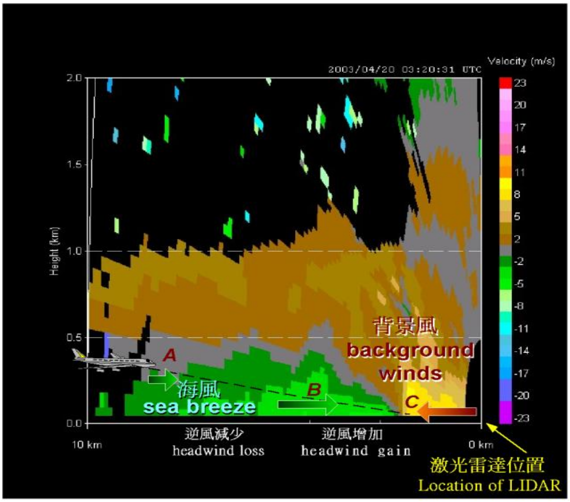
Turbulence, in addition to windshear, is also known to occur in a sea breeze.

A typical example of windshear associated with sea breeze is shown in the LIDAR scan below. LIDAR is good at capturing sea breeze front, which occurs in mainly fine weather.



LIDAR image on 15 February 2004. The cool/warm colours represent winds towards/away from the LIDAR (see scale on the right). The dashed line represents the boundary, viz. the sea breeze front, where the background easterly met the westerly brought by the sea breeze.

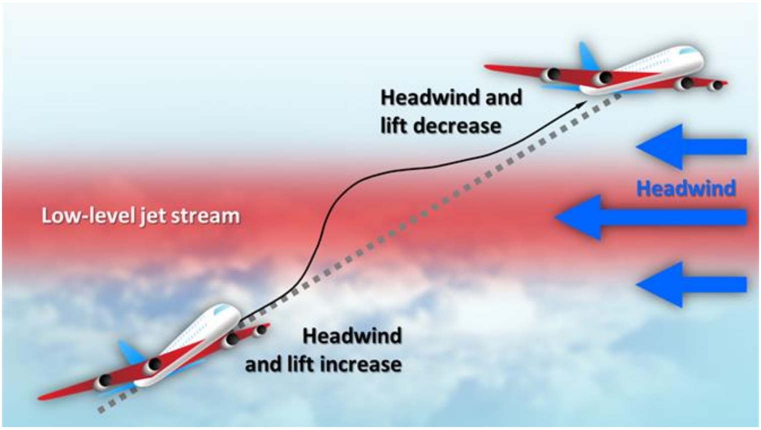
The complex structure of the sea breeze front is shown in the vertical scan of the LIDAR below. As the aircraft descents on the glide path from A to B, it would experience headwind loss with the wind changing from the background easterly to the westerly brought by the sea breeze. When the aircraft descends further from B to C, it would experience headwind gain with the wind changing from the westerly back to the background easterly.



Vertical cross section image of the LIDAR on 20 April 2003. The black dashed line indicates the descending glide path. The grey band (near zero wind speed) separates the sea breeze beneath (cool colour) and the background wind aloft (warm colour).

What is 'low-level jet' ?

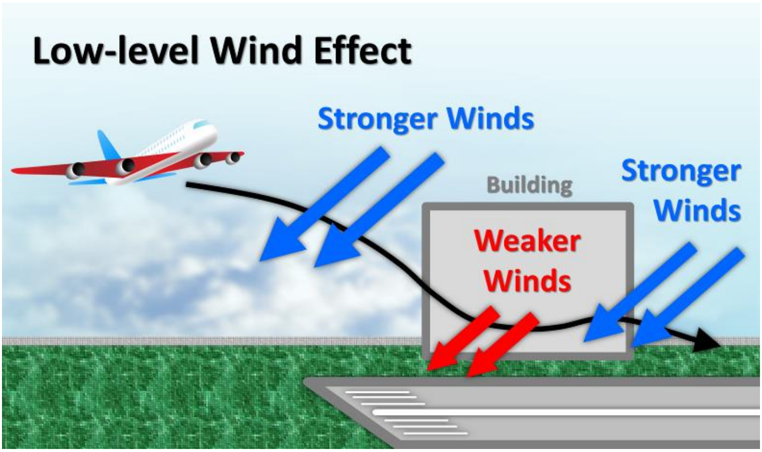
A **low-level jet** is a narrow band of strong winds in the lower atmosphere. Windshear arising from a low-level jet is relatively infrequent in HKIA. When an aircraft departing from the airport ascends and enters the jet, it experiences increasing headwind and lift. As it departs the jet, however, the headwind and lift decrease.



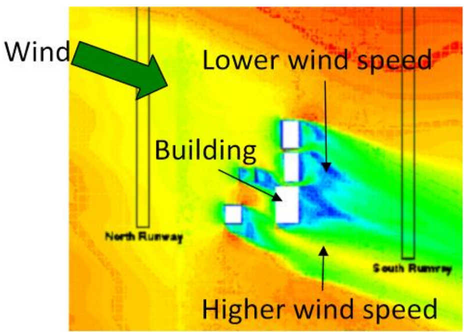
A landing aircraft passing through a jet will also encounter the same sequence of headwind changes, because it is usually flying against the prevailing wind. However, since a landing aircraft is usually descending on a 3 degrees glide path compared with the higher climb gradient of a departing aircraft, the headwind changes it would experience is generally more "gentle" than that for a departing aircraft.

What is 'low-level wind effect'?

Low-level wind effect, or building wake, refers to significant airflow disruption due to buildings and other man-made structures close to the runway, leading to turbulence, crosswind changes and possibly windshear under certain wind conditions.



As the air flows over a building, depending on the background wind speed and direction, the stability of the atmosphere and the size of the building, the air may be blocked, flow over or around the building. This is similar to the occurrence of waves and vortices downstream of a stone in a river.

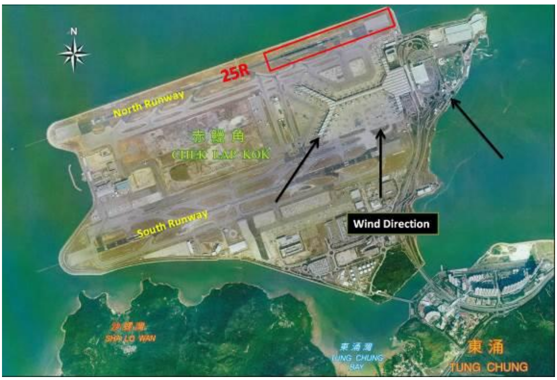


If the building is rather close to the flight path and is sufficiently large in size, it may bring about rapid fluctuations of the wind that are perceived to be wind changes (headwind/crosswind changes) and/or turbulence by the pilots.

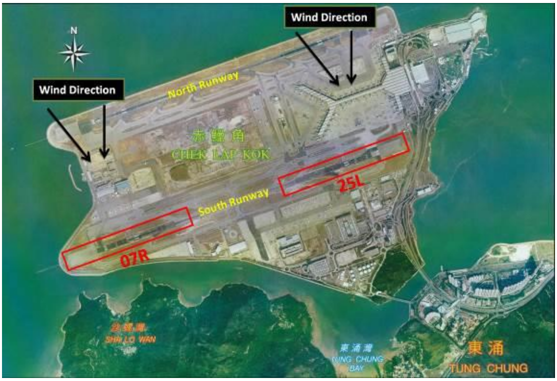
When the low level wind effect causes the crosswind component to fluctuate, pilots may experience control difficulties during take-off and landing. Under such conditions, directional control would be more challenging on a wet runway.

New buildings or structures to be constructed inside and around HKIA would be required to go through a "**low-level wind study**" to assess their potential impact on low-level wind conditions.

The hot spots of low level wind effect are downwind of major buildings. Pilots should be aware when landing on HKIA RWY 25R in strong southwesterly/southerly/southeasterly winds that there is the possibility of encountering building-induced turbulence and windshear.



Similarly, there is the possibility of encountering building-induced turbulence and windshear when: (a) landing on RWY 25L in strong northwesterly/northerly winds; or (b) landing on RWY 07R in a background northwesterly/northerly winds of about 15 knots or more.



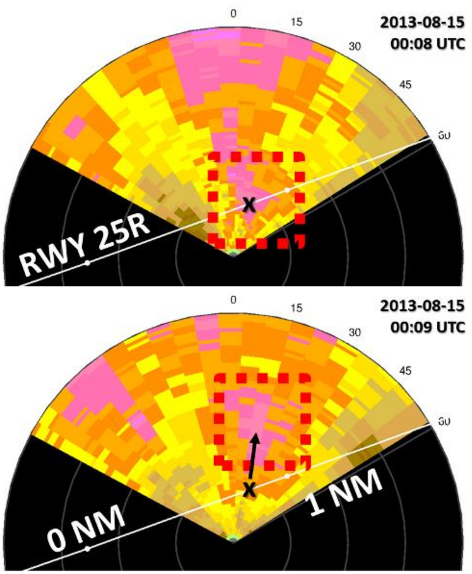
Pilot should be aware when landing on HKIA from RWY 25L in strong northwesterly/northerly winds of the possibility of building-induced turbulence and windshear. Similarly, when landing on RWY 25R in strong southwesterly/southerly/ southeasterly winds, there is the possibility of building-induced turbulence and windshear. (See AIP Hong Kong GEN 3.5, Sub-para. 17.6.1.)

Pilots should be aware when landing on Hong Kong International Airport's RWY 07R in northwesterly/northerly winds with a background speed of about 15 knots or more of the possibility of building-induced turbulence and windshear effects over the touch down zone. (See AIP Hong Kong GEN 3.5, Sub-para. 17.6.2.)

How is building-induced turbulence detected ?

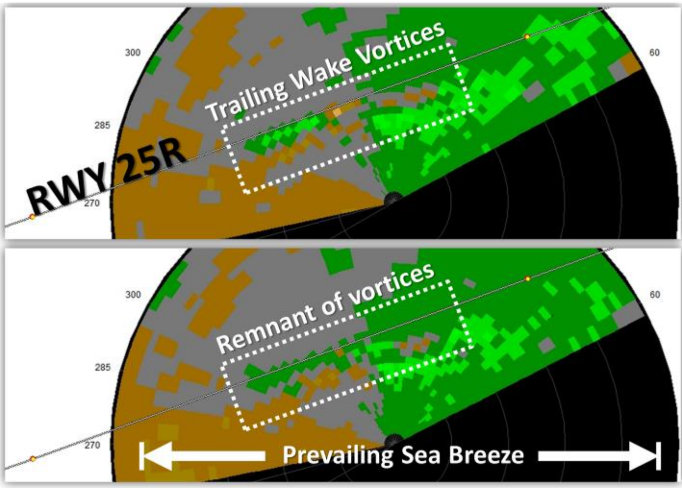
Due to their small spatial scale compared to other known windshear phenomena, building-induced wind features cannot be detected effectively by conventional wind sensor networks.

A short-range LIDAR (SRL) has been introduced to monitor and alert building-induced turbulence over the final nautical mile of approach to RWY 25R. With higher resolution and more agile scans of the laser beam, the SRL is able to capture those fast-evolving airflow disturbances associated with building wakes over the northeastern corner of HKIA.



Short-range LIDAR image over the final nautical mile of approach to RWY 25R. Here a windshear-inducing airflow disturbance could be observed to develop and traverse the landing flight path within a minute or so.

What are the other possible causes of windshear/ turbulence events ?



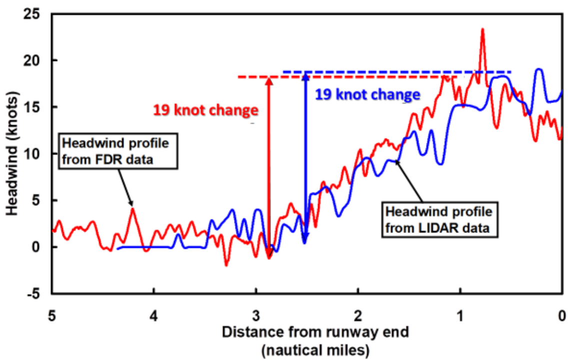
With the availability of SRL technology, HKO has also conducted the first series of aircraft wake vortex (or wake turbulence) measurements at HKIA since 2014. In addition to providing input to studies on Recategorization of ICAO wake turbulence separation minima (RECAT) for possible future enhancements of air traffic flow capacity, there are also instances observed where remnant wake turbulence airflow, coupled with weak sea breeze features, combine to create conditions conducive to actual windshear reports. HKO would conduct further scientific studies of such phenomena and bring the results to the attention of pilots as they become available.

Why is the alerted windshear sometimes not experienced, and vice versa ?

The first possibility is the transient and sporadic nature of terrain-induced windshear as illustrated on pages 24-26. The windshear feature may affect a particular runway corridor for a short period of time and thus is not experienced by all aircraft operating over that corridor.

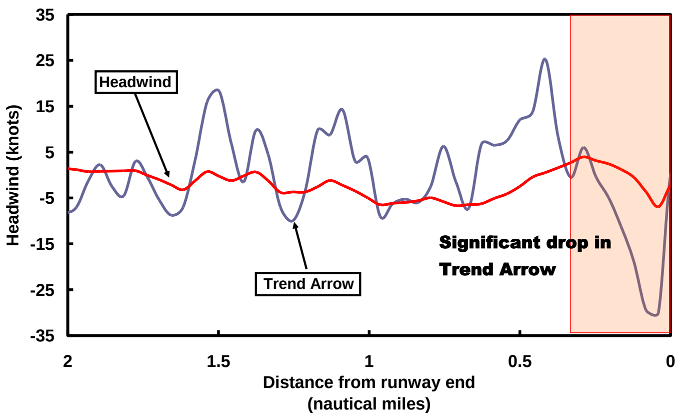
Moreover, studies of null reports from pilots together with weather data at HKIA have revealed that pilots tend not to report or report less for windshear with length-scale near the higher end of the horizontal spatial scale, i.e. between 3 and 4 km. Such "gentle windshear" events are often observed in spring-time at HKIA, when surface easterly winds prevail in the airport area. Quite often, the easterly winds gradually veer with altitude to southeasterly at hilltop and thus the headwind encountered by aircraft on approach from the west to HKIA would gradually increase. It is not practical to remove the alerting of "gentle windshear" events altogether because they are still considered to be significant in quite a number of pilot reports.

The figure below shows a case of "gentle windshear". The aircraft FDR data and the LIDAR data are consistent with each other, both indicating the occurrence of significant windshear of comparable magnitude. The pilot however reported no windshear in this case.



The "gentle windshear" may not be regarded as significant particularly for departing aircraft because the aircraft is normally in takeoff thrust and wind speed increasing with altitude is generally expected to occur. As such, LIWAS has already used different length scales for windshear detection over the arriving and departing runway corridors, with a shorter length scale being employed for the departure corridors.

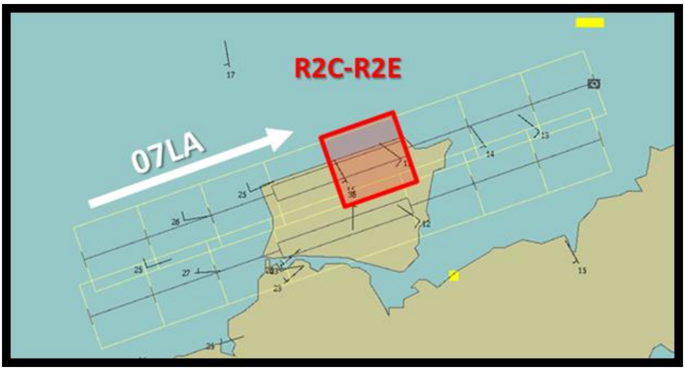
Furthermore, discussions with pilots in various occasions suggest that low-level windshear might be reported by making reference to elements in addition to the headwind changes, such as the on-board "Speed Trend Arrow" available on the Primary Flight Display. The Trend Arrow is determined based on the past wind data an aircraft has just experienced and represents the projected wind change in the next several seconds the aircraft might experience. Studies using aircraft flight data have indicated that the Trend Arrow might sometimes over-estimate the actual wind speed change that an aircraft would encounter. The figure below shows an example in which the pilot reported significant windshear possibly based on the Trend Arrow information but the actual headwind loss was less than 15 knots.



What are the recent enhancements to further improve performance of the windshear alerts ?

It has been mentioned in the previous section that some "gentle windshear" events might not be regarded as significant by pilots. To further narrow down the issuance of windshear alerts, with effect from 1 October 2015, LIWAS no longer provide alerts for such "gentle windshear" (i.e. smooth headwind changes accumulating over a longer distance, typically 3 km or more, which might nonetheless exceed 15 knots).

The AWARE algorithms provide windshear alerts by considering the wind differences measured by the dense network of surface anemometers around HKIA. Certain portions of AWARE, the so-called "go-around" rules, are based on the headwind differences at 1 NM beyond the touchdown zones of each arrival corridor (e.g. wind difference between anemometer R2C and R2E for 07LA). Following consultation with aviation users, the "go-around" rules for the North Runway (i.e. 07LA and 25RA) have been switched off with effect from 1 January 2017 to reduce false alerts.



The above two measures are expected to effectively cut down the duration of windshear alerts, contributing to increased accuracy of HKO's windshear alerting service by reducing possible false alarms.

Notes to pilots

In summary, here are a number of important points to note:

- Windshear and turbulence events can be **transient** and **sporadic**. This is especially so when winds change rapidly, for example, when winds blow across terrain during the passage of a tropical cyclone. Even though the weather conditions may remain broadly similar, some aircraft may experience the effects, while others do not.

- Windshear associated with an "MBA" may be caused by phenomena other than a microburst in the conventional sense. Pilots **should not expect the typical sequence of events in traversing a 'conventional' microburst** (i.e. headwind gain and lift preceding a downdraft, followed by headwind loss and sink) **to occur every time the MBA is in effect**.

- Terrain-induced windshear does not necessarily occur in rain. Terrain-induced windshear, coupled with rain, may generate an "MBA".

- Multiple occurrences of windshear/turbulence on the same runway corridor are consolidated to generate a single windshear/turbulence alert. Remember that **the first encounter may not be the worst encounter**. There may still be windshear/turbulence events after the first encounter.

- Gain and loss events can co-exist on the same runway corridor, particularly for terrain-induced windshear. **While a windshear alert of wind loss is given, you may encounter a wind gain event as well**.

- Most windshear and turbulence, at HKIA, are caused by strong winds blowing across the hills on Lantau Island to the south of the airport, including winds associated with the passage of tropical cyclones.

- Windshear and turbulence induced by the hills on Lantau Island are more significant on the South Runway, because of its closeness to the hills.

- To assist pilots in evaluating the possible wind changes during the final phase of the approach, a 2,500 feet “hilltop wind” is given on the “Arrival ATIS”, when the hilltop wind speed exceeds 35 knots.

- Whenever an “MBA” or “WSA” is in effect, particularly for windshear gain or loss of 30 knots or greater, you are advised to avoid entering into the microburst or windshear region.

Way forward

The Windshear and High-Impact Weather (WHIX) Panel, which consists of all relevant aviation stakeholders at the HKIA, replaced the Windshear and Turbulence Warning System Working Group (WTWS WG) starting from June 2013. The WHIX Panel reviews regularly the performance of HKO's windshear and turbulence alert service and explores ways to further enhance performance.

The HKIA is a rapidly evolving environment. HKO will continue to work closely with developers and aviation stakeholders in the conduct of low-level wind studies for assuring the safety of landing and departing aircraft.

To detect and alert possible building-induced windshear/turbulence at Runway 25 Approach, a permanent short-range LIDAR (SRL) has been set up. The alert using SRL has been integrated into the WTWS with effect from summer 2019.

The availability of high-performance computing environment together with advances in numerical prediction techniques has made possible detailed modelling of the airflow at the HKIA and its immediate surroundings on a real-time basis. In addition to more precise winds and temperature forecasts, this also offers the possibility of predicting at a couple of hours ahead the potential for low-level windshear and turbulence at the HKIA, making use of meteorological observations from the dense network of weather sensors at and near the HKIA.

Since the inception of the WTWS, pilot reports of significant windshear and turbulence have been relayed to HKO manually through ATC. Given the rapid advancement of mobile applications and social media platforms in recent years, HKO is working closely with aviation users in exploring more direct and convenient means of information transmission to and from the cockpit e.g. through HKO's electronic flight bag application "MyFlightWx".

Furthermore, with kind support from major local airlines, the Hong Kong AMDAR programme has seen continual expansion in terms of the number of AMDAR-enabled aircraft as well as the volume of meteorological reports. HKO will actively support the proposed WMO-IATA collaboration on AMDAR programme by contributing to future collaborative regional operations.

Further information

- For more information on the windshear and turbulence alerting service in Hong Kong, please visit HKO's website at:

  https://www.weather.gov.hk/en/aviat/amt/windshear_warning.htm

  You may also refer to section GEN 3.5 in the Hong Kong Aeronautical Information Publication (AIP) which is available at:

  https://www.ais.gov.hk/

- More information on windshear, particularly the effect of low-level windshear on aircraft performance, can be found in:

  ICAO Manual on Low-level Wind Shear and Turbulence (Doc 9817)

  US Federal Aviation Administration's Advisory Circular No.00-54 "Pilot Windshear Guide" (1988)

  HKO/IFALPA/WMO/ICAO Windshear Posters, available at: https://www.hko.gov.hk/en/aviat/ws_poster/ws_poster.htm

  Pamphlet on "Low Level Wind Effect At Airports", available at: https://www.hko.gov.hk/en/aviat/articles/files/llw_pamphlet_3col_v17.pdf

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