

Windshear and Turbulence in Hong Kong

- information for pilots



Published by the Hong Kong Observatory, Hong Kong Special Administrative Region Government.

1st edition ©2002

2nd edition ©2005

3rd edition ©2010

Copyright reserved 2010. No part of this publication may be reproduced without the permission of the Director of the Hong Kong Observatory.

Disclaimer

The Government of the Hong Kong Special Administrative Region (including its servants and agents), the International Federation of Air Line Pilots' Associations and The Guild of Air Pilots and Air Navigators make no warranty, statement or representation, express or implied, with respect to the accuracy, availability, completeness or usefulness of the information, contained herein, and in so far as permitted by law, shall not have any legal liability or responsibility (including liability for negligence) for any loss or damage, which may result, whether directly or indirectly, from the supply or use of such information or in reliance thereon.

Foreword

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

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.

Compared with the last edition, the present edition has incorporated in particular the latest knowledge and experience with the operation of LIDAR (Light Detection And Ranging), a powerful tool in warning windshear and turbulence under clear-air conditions. Other updated items include: aircraft flight data and some analyses in connection with “gentle windshear”.

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

The booklet has been prepared in cooperation with the International Federation of Air Line Pilots’ Associations (IFALPA) and The Guild of Air Pilots and Air Navigators (GAPAN).

B.Y. Lee
Director of the Hong Kong Observatory
January 2010

Use of Symbols



denotes important notes for pilots



denotes examples

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 will be experienced aviators and will already be 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.

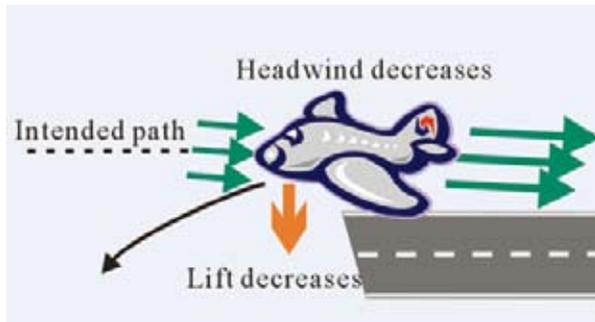
By the end of this booklet, you should understand, among others, the following:

1. How windshear and turbulence alerts are generated;
2. What the term “Microburst Alert (MBA)” means;
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 nearby HKIA.

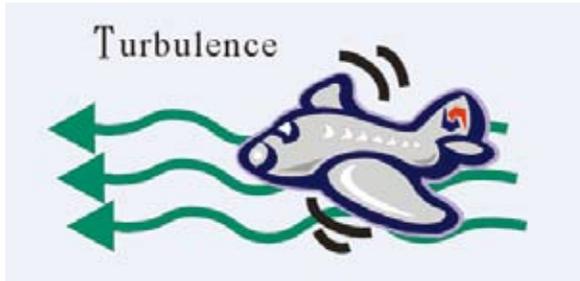
What is windshear and turbulence ?

Windshear refers to a sustained change (i.e. lasting more than a few seconds as experienced by aircraft) in the wind direction and/or speed, resulting in a change in the headwind or tailwind 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.

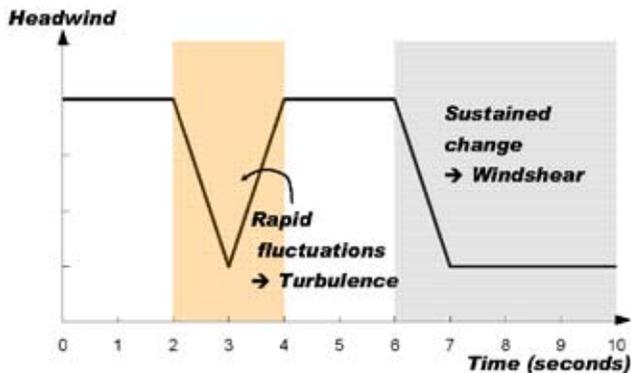
Pilots should be aware that significant windshear at low levels on approach and departure zones may cause difficulty in control, thus requiring timely and appropriate corrective actions to ensure aircraft safety.



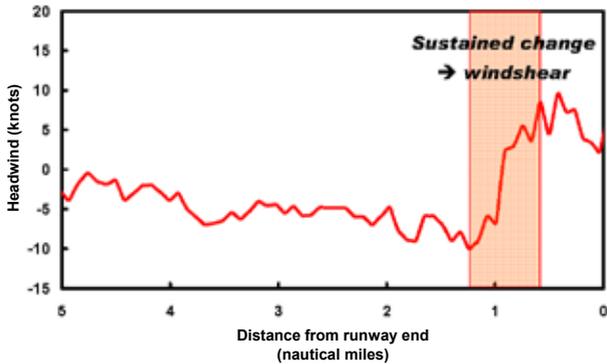
Turbulence is caused by rapid irregular motion of air. It brings about rapid bumps or jolts but does not normally influence the intended flight path of an aircraft significantly. However, in severe turbulence cases, abrupt changes in the altitude and attitude of the aircraft may occur and the pilot may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



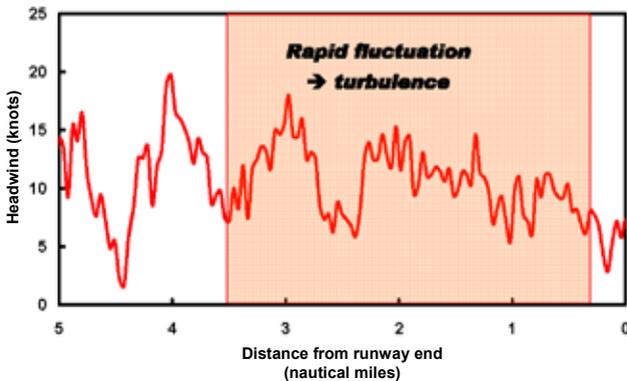
In general, **rapid fluctuations** in the wind speed and direction encountered by the aircraft for less than a few seconds are turbulence whereas a **sustained change** of the headwind or tailwind of 15 kt or more for more than a few seconds is significant windshear.



The figure on the next page 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 figure below 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 and turbulence 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 (July 1998 to December 2009), about 1 in 500 arriving and departing flights have reported significant windshear. Over the same period, around 1 in 2,500 flights have reported significant turbulence. A majority of these events were reported in the spring months of March and April.

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 Northern Runway and the other located near the Southern 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 five 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 generate “up-to-the-minute” **alerts**, when windshear and/or turbulence are detected.

In addition, HKO forecasters 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):

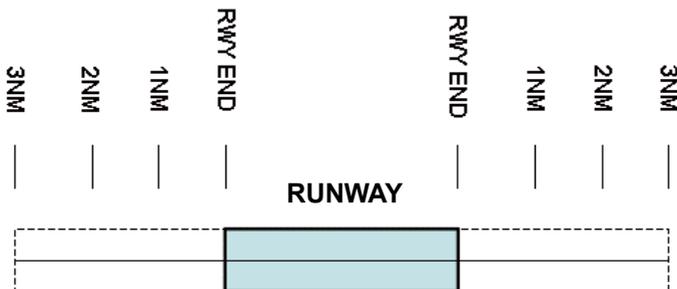
Alerts of windshear and turbulence induced by terrain or caused by convection within 3 NM of the runway thresholds, which are generated automatically by the WTWS, are passed to aircraft via ATC.

(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 issues alerts for possible windshear occurring within 3 NM of the runway thresholds:



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 runway-orientated (i.e. the headwind/tailwind component) wind speed **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 runway-orientated (i.e. the headwind/tailwind component) wind speed **loss or gain of 15 knots or greater** (except microburst). Note that a windshear gain of 30 knots or greater is issued as a WSA, not an MBA.

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 runway-orientated wind speed 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 issues alerts for possible turbulence occurring within 3 NM of the runway thresholds based on observations made by the weather sensors.

Alerts for turbulence are issued with reference to heavy category aircraft e.g. 747-400. Turbulence alerts 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 Moderate Turbulence:

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

Alert of Severe Turbulence:

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

EXAMPLE

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

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 15 and 16).

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

EXAMPLE

Caution. Moderate turbulence on departure.

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.

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'.

EXAMPLE

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

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.

EXAMPLE

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

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

EXAMPLE

*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. Whenever a turbulence warning is in force, it will always be applicable to all 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 8).

EXAMPLE

*Significant windshear forecast 07L and 07R.
(when windshear is forecast by Aviation Meteorological Forecaster for both RWY 07L and RWY07R)*

*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)*

A warning triggered by the TDWR will not be given as “forecast” or “forecast and reported” (see example on page 13).

Warnings given on D-ATIS are coded in ICAO abbreviations, e.g. “SIG WS FCST 07L AND 07R” or “MOD TURB FCST AND REP 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 of multiple windshear occurrences on the same runway corridor, what alert is issued ?

Both the WTWS and the TDWR generate alerts of windshear for specific locations along the runway corridors. When more than one occurrence of windshear is detected by the TDWR and by the WTWS for a particular runway corridor, alerts will be generated by each system based on the **highest priority** and the **maximum intensity**. The order of priority is such that when both loss and gain events impact the same area, **loss events will have higher priority over gain events**.

When a Microburst Alert and a Windshear Alert are generated by the TDWR or the WTWS for a particular runway corridor, the alerts are consolidated to form an integrated alert based on the following priority system which takes into account the severity of the alerts 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 Windshear of minus or plus 15 knots or greater except Microburst
4. (lowest) WTWS Windshear of minus or plus 15 knots or greater except (2)

Note: WTWS windshear alerts include those issued by LIWAS and AWARE (see page 7).

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.

EXAMPLE

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, particularly in terrain-induced windshear events (see page 18). 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.

EXAMPLE

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 five 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. 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 (see map on page 8), including winds associated with the passage of tropical cyclones and a strong monsoon. They account for about 70% of all the pilot windshear reports. Sea breeze is the cause of windshear for about 20% of the pilot reports. The remaining 10% of windshear occurrences based on pilot reports are due to gust front, microburst and low level jet. 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 caused by microburst and gust front could be higher.

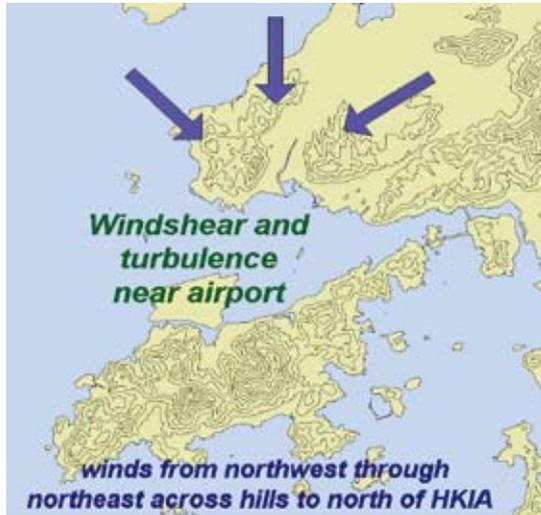
The major causes of windshear and turbulence in HKIA are elaborated in the following pages.

What is 'terrain-induced windshear' ?

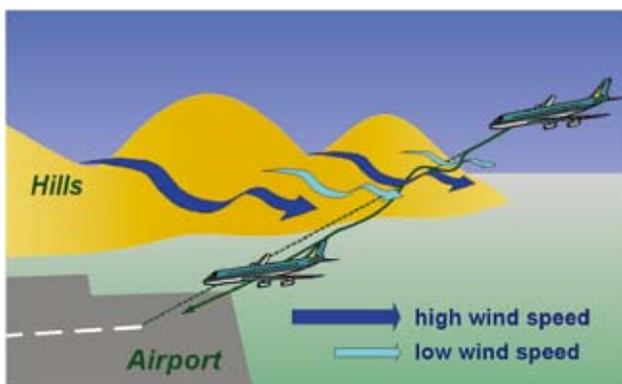
Hills disrupt the flow of air across them and hence may induce windshear and turbulence. HKIA is located to the north of the mountainous Lantau Island, the highest peak on which is above 900 m (3,000 feet). Windshear and turbulence may occur near the airport, when winds of **15 knots or higher blow across 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.

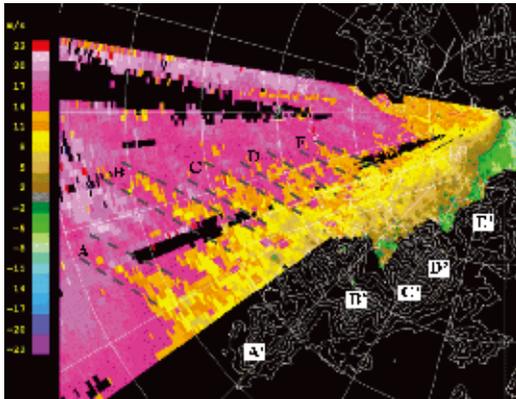


On windy occasions, such as the approach of a tropical cyclone, air streams of high wind speed may emerge from mountain gaps. Lying between these high-speed air streams are air streams of lower wind speed. Aircraft, traversing through alternating high-speed and low-speed air streams, may encounter headwind losses and gains at different locations along the approach and departure corridors (refer to the second example on page 16).



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. The wind speeds are lower (at locations A, B, C, D and E) downstream of the higher terrain on Lantau Island (at locations A', B', C', D' and E').



TDWR image on 11 Sep 2002 during the passage of Severe Tropical Storm Hagupit. The cool/warm colours represent winds towards/away from the TDWR (see scale on the left).

Apart from windy situations, windshear may also occur over the airport in lighter wind conditions, when the atmosphere is stable (e.g. presence of a low-level temperature inversion). In fact, windshear has been known to occur even 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 Southern Runway, because of the closeness to the hills of Lantau Island.



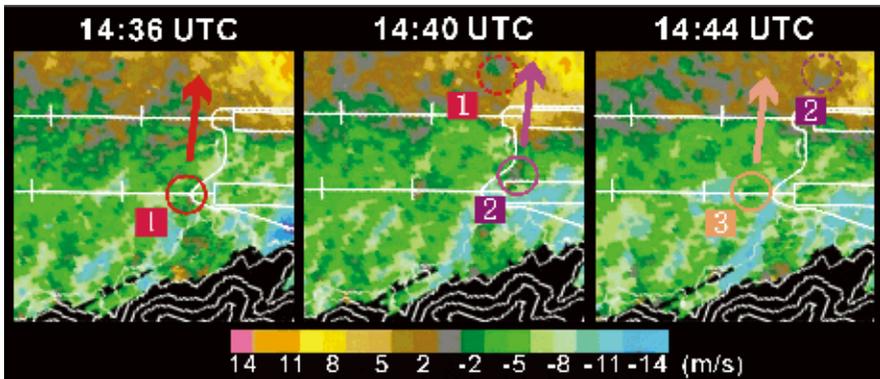
Terrain-induced windshear does not necessarily occur in rain. In fact, a majority of the terrain-induced windshear reports received from aircraft flying into or out of HKIA are not associated with precipitation.



While terrain-induced windshear is not caused by a 'conventional microburst' (see page 10 and 25), the headwind loss and the sink that it brings to an aircraft may be comparable to that of a 'conventional' microburst.

How changeable is the windshear in Hong Kong ?

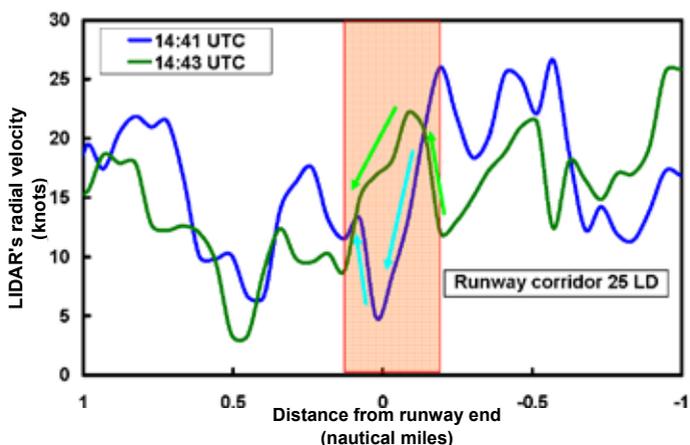
The following three LIDAR images, taken 4 minutes apart on 30 August 2004, reveal small-scale windshear and turbulence features (circled regions) moving over the western approach/departure corridors, under strong southerly winds disrupted by the terrain of Lantau Island.



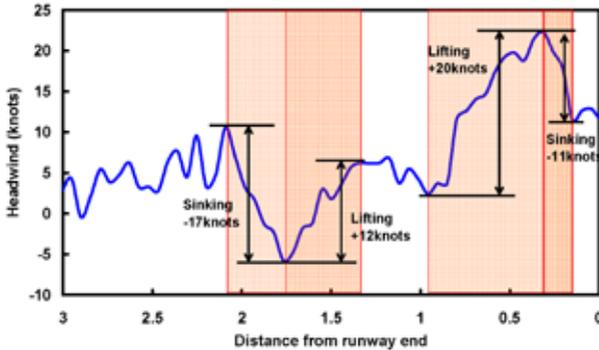
LIDAR images on 30 August 2004. The cool/warm colours represent winds towards/away from the LIDAR (see scale at the bottom). The arrows indicate the movement of the windshear features marked by circles within the subsequent 4 minutes.

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 red 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 below, based on the headwind profile measured by the LIDAR.

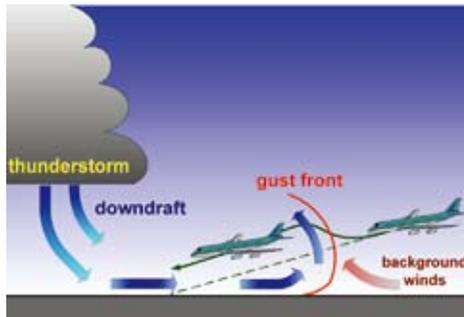


From the above example of terrain-induced windshear, it should be note that:

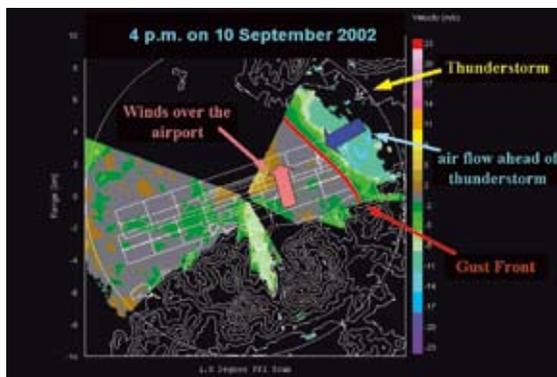
- Runway gain and loss events can co-exist on the same corridor.
- While windshear alert of wind loss is given, you may also encounter a wind gain event.
- Due to the transient and sporadic characteristics of windshear, a wind speed loss/gain may not necessarily be followed/preceded by a wind speed gain/loss.
- The sequence of events (e.g. wind speed loss followed by wind speed 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 '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.



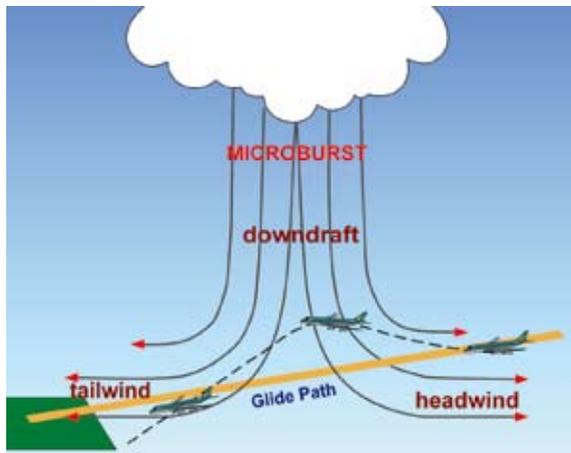
An example of gust front captured by the LIDAR is shown below. The gust front occurs at the convergence between the background southerly flow and the northeasterly downdraft associated with a thunderstorm.



LIDAR image on 10 September 2002. The blue arrow indicates the movement of the gust front originated from the thunderstorm located to the northeast. The cool/warm colours represent winds towards/away from the LIDAR (see scale on the right).

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.

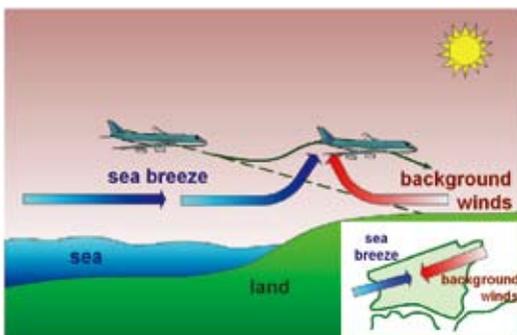


Well, that is the ideal theoretical world, though it can happen like this in practice, as some pilots have experienced. The first point, however, is that microburst can be asymmetric, having winds on one side stronger than the other side. The second point is that the column of downdraft can hit the ground 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.

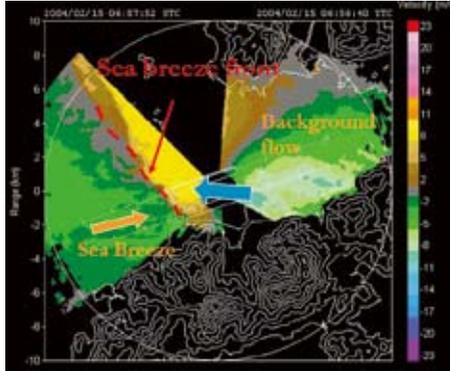
What is 'sea breeze' ?

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 6). 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.

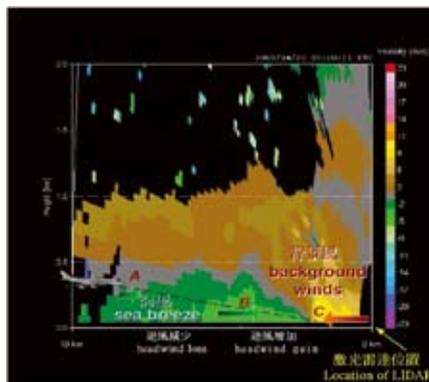


A typical example of windshear associated with sea breeze is shown in the LIDAR scan below. LIDAR is good at capturing sea breeze front, which occurs in mainly fine weather.



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.

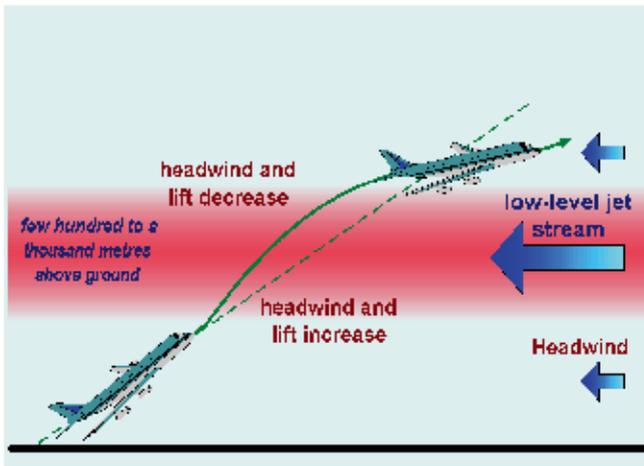
The complex structure of the sea breeze front is shown in the vertical scan of the LIDAR below. As the aircraft descends on the glide path from A to B, it would experience headwind loss with the wind changing from the background easterly to the westerly brought by the sea breeze. When the aircraft descends 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 dashed line indicates the descending glide path. The grey line (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 extent of headwind changes it would experience is generally less than that for a departing aircraft.

What is 'low-level wind effect' ?

Low-level wind effect refers to turbulence and possibly also windshear in association with winds blowing over man-made structures, such as buildings at the airport.



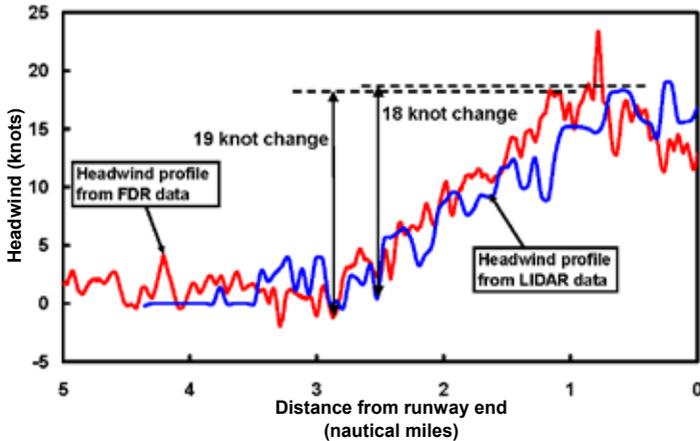
Pilot should be aware when landing on HKIA from RWY 25L in strong northwesterly/northerly winds of the possibility of building-induced turbulence and windshear. Similarly, when landing on RWY 25R in strong southwesterly/southerly/southeasterly winds, there is the possibility of building-induced turbulence and windshear.

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

The first possibility is the transient and sporadic nature of terrain-induced windshear. The windshear feature may affect a particular runway corridor for a short-period of time and thus is not experienced by all aircraft maneuvering 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 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.

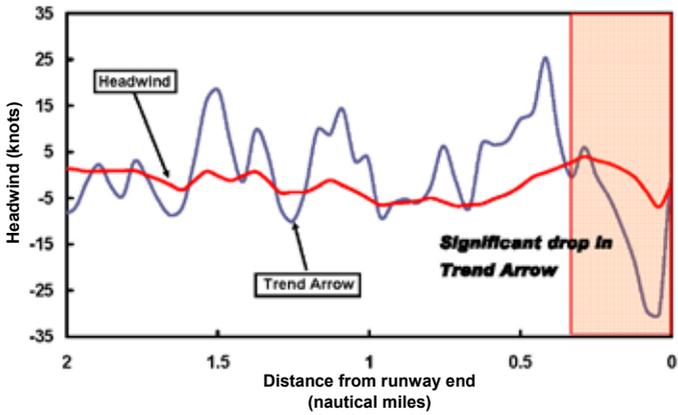
The figure below shows a case of “gentle windshear”. The aircraft FDR data and the LIDAR data are consistent with each other, both indicating the occurrence of significant windshear of comparable magnitude. The pilot however reported no windshear in this case.



The “gentle windshear” may not be regarded as significant particularly for departing aircraft because the aircraft is normally in full thrust and wind speed increase 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.





Notes to pilots

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

- Windshear and turbulence events are by nature **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”.
- Microbursts can be asymmetric, having winds on one side stronger than the other side. The column of downdraft from a microburst can hit the ground at an angle, rather than vertically downward. So, if you have to carry out **an approach through a microburst**, you **may not encounter the “classic” headwind gain and lift prior to the downdraft and headwind loss**.

- 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. Also remember that 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 Southern 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.

The HKO is continuously refining the windshear alerting system to enhance its accuracy, using pilot windshear reports (PIREPs) as one method to verify the alerts. Your support is indispensable to the on-going development of the windshear alerting service. If you encounter windshear or turbulence, please **report the event to ATC or fax/email a pilot report to HKO**. The windshear/turbulence reporting form can be downloaded from http://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 and answers to the surveys have already been used and will continue to be used to enhance the system. Thanks to all of you for the feedback. **Keep reporting windshear and turbulence!**

Way forward

The Windshear and Turbulence Warning System (WTWS) Working Group consisting of all the relevant aviation stakeholders regularly reviews the performance of WTWS and provides recommendation for enhancement.

Further research is underway to explore the use of the LIDAR data and the TDWR data in the detection of turbulence. Apart from pilot reports, EDR based turbulence intensity calculated from the FDR data of commercial aircraft and a meteorological instrumented fixed-wing aircraft of Government Flying Service in Hong Kong will form the basis in the development of the new turbulence detection algorithms.

Besides vertical wind profiles, the stability profile of the atmosphere can also be used to derive/diagnose the likelihood of terrain-induced turbulence and windshear. This could be based on temperature profiles continuously measured by the microwave radiometer at HKIA (see page 8). New windshear warning rules utilizing the radiometer data are under development.

Apart from terrain-induced disturbances, there have been pilot reports of similar phenomena, albeit smaller scales, associated with building structures at HKIA. The low-level wind effects due to these structures will continue to be studied. For instance, a short-range LIDAR with high spatial resolution will be deployed to observe the wind fluctuations downstream of the structures and calculate the turbulence intensity.

Work is also in hand to study the feasibility of uplinking real-time windshear and turbulence alerts to the flight deck for immediate attention of the pilots. Prototype windshear and turbulence products in graphical format will be developed for future uplink applications.



Further information



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

http://www.weather.gov.hk/aviat/amt_e/windshear_warning_e.htm

You may also refer to section GEN3.5 in the Hong Kong Aeronautical Information Publication (AIP) which is available at:

http://www.hkadc.gov.hk/HK_AIP/aip.htm



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:
http://www.hko.gov.hk/aviat/ws_poster/ws_poster.htm

HKO homepage: www.weather.gov.hk

HKO email address: outreach@hko.gov.hk

IFALPA homepage: www.ifalpa.org

GAPAN homepage: www.gapan.org

Published by the Hong Kong Observatory

