The Bureau of Meteorology

Aviation services

Wind shear

Hazardous phenomena

Wind shear is a common phenomenon within the atmosphere, occurring at any level where adjacent layers or columns of air have different velocities. It can produce sudden changes in aircraft altitude and speed.

Introduction

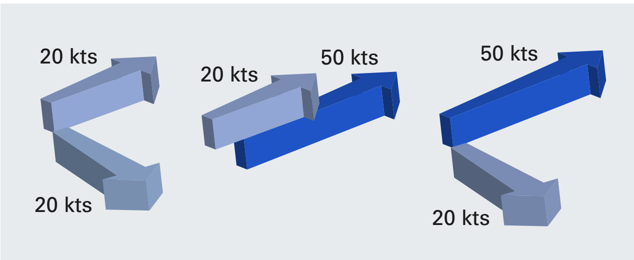
Wind shear is defined as a sudden change of wind velocity (speed and direction) in either the horizontal or vertical planes of the atmosphere or a mixture of both. It is significant when it causes changes to an aircraft's headwind or tailwind such that the aircraft is abruptly displaced from its intended flight path and substantial control action is required to correct it.

Wind shear is always present in turbulent air, but wind shear can occur without turbulence being present.

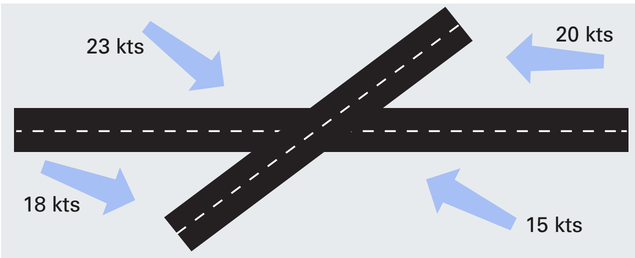
Types of wind shear

Vertical wind shear is the change of horizontal wind direction and/or speed with height.

Horizontal wind shear is the change in wind speed and/or direction at the same level.

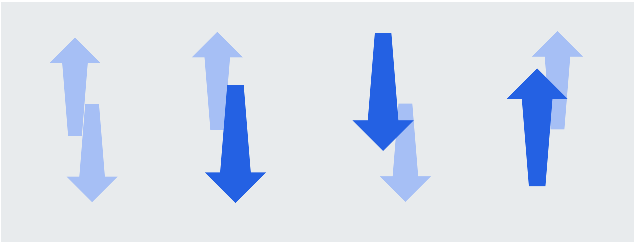


Vertical wind shear configurations



Horizontal wind shear configurations

Updraft and downdraft wind shear is the change in vertical wind velocity across adjacent columns of air. This type of shear is often encountered with convective activity.



Updraft and downdraft wind shear

Wind shear may be **transitory** (e.g. associated with moving features such as a cold front or thunderstorms) or **non-transitory** (e.g. associated with permanent obstructions such as a mountain).

Effects on aviation

For aircraft landing, a decrease in the headwind component (**undershoot shear**) may cause it to drop below the target descent path and to land short of the runway threshold. An increase in the headwind component (**overshoot shear**) may cause it to fly above the target descent path leading to a late touchdown and possible overrun.

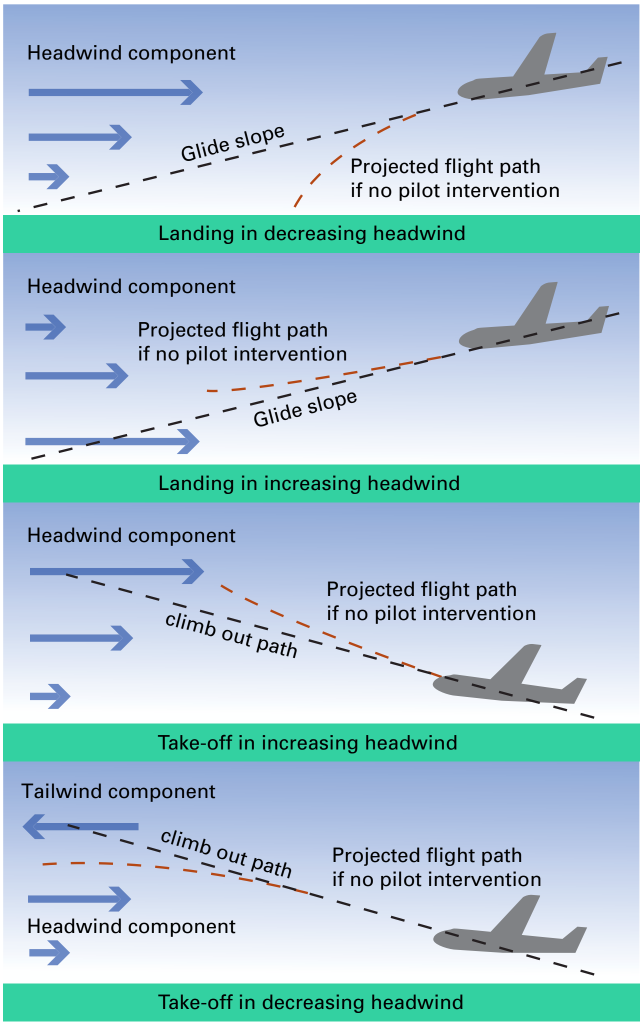
Changes in headwind and tailwind components during takeoff create changes to the amount of lift experienced. A decrease in the vertical headwind component, or an increase in the tailwind component, will result in a reduction in airspeed, and in extreme cases the resulting loss of lift may be enough to cause the aircraft to stall or have a significant drop in altitude.

Crosswind shear refers to when the shear vector is perpendicular or across an aircraft's flight path and is particularly important during landing and takeoff. This type of shear can cause the airplane to roll and/or yaw unexpectedly requiring rapid control inputs. Crosswind shear may be masked by runway wind observations that seem normal and give no cause for concern.

The response of aircraft to wind shear is extremely complex and depends on many factors, including:

- type of aircraft
- phase of flight
- the scale on which the wind shear operates relative to the size of the aircraft
- the intensity and duration of the wind shear encountered.

Updated 15 July 2025



Wind shear on aircraft without intervention by the pilot

Causes of wind shear

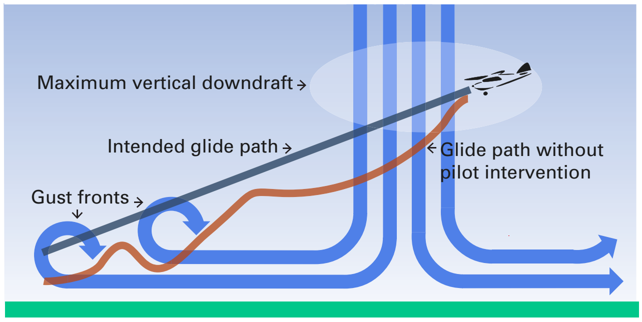
Thunderstorms

The airflow structure within, over and around thunderstorms and large cumulus clouds can pose wind shear hazards to aircraft. Wind shear between adjacent **updrafts** and **downdrafts** may cause:

- severe loadings to be imposed on the aircraft structure
- violent changes in aircraft attitude, and induce stall or other conditions where recovery may exceed the design limitations of the aircraft.

The outflow from the cloud's downdraft can produce damaging winds on and near the ground. A **microburst**, a downburst which causes damage over a horizontal diameter of less than 4 km, is the most violent form of wind shear produced by thunderstorms. If it occurs over an airport, aircraft landing or taking off may encounter strong headwinds, then strong downdrafts followed by strong tailwinds; as microbursts can be symmetric or asymmetric, the pilot experience can vary. Microbursts can be wet (i.e. occurring with precipitation) or dry.

A **gust front** is the leading edge of the cold air outflow from a thunderstorm after a downdraft reaches the ground and spreads out in all directions,

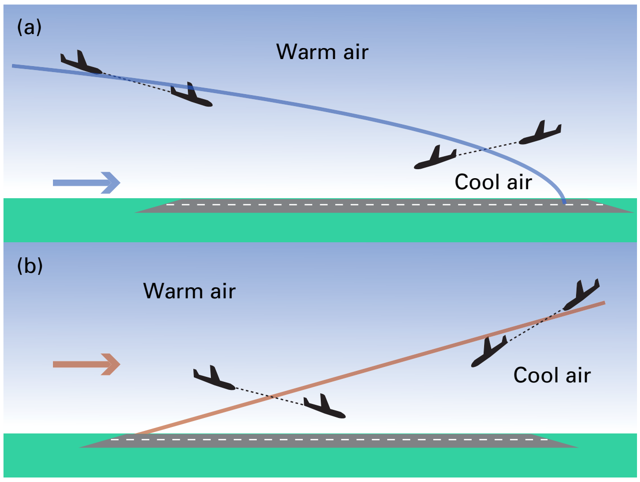


Microburst effect on landing aircraft

undercutting the surrounding warmer air. They can move tens to hundreds of kilometres outward from the thunderstorm. The gust front travels along the ground, with the direction depending on the terrain. If the thunderstorm itself is moving, the gust front advances furthest and fastest ahead of the thunderstorm. There is marked horizontal wind shear at ground level following the passage of the leading edge of the gust front, often as much as 180 degrees with wind gusts exceeding 50 knots. The gust front ahead of squall line thunderstorms can be tens of kilometres wide, i.e. spanning the length of the multicell storm.

Frontal systems

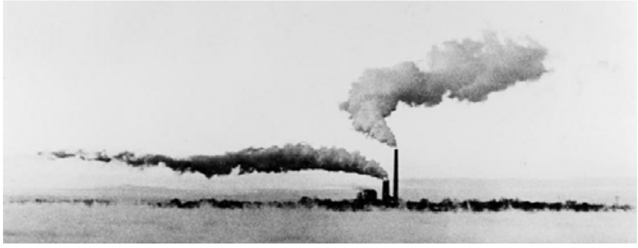
Frontal systems consist of air masses of different temperature separated by a narrow zone called the frontal zone, which is the region where wind shear significant to aviation is most likely to occur.



Aircraft may experience wind shear prior to (a) cold fronts and (b) behind warm fronts

Sea breezes

A sea breeze is essentially a shallow cold front, as cooler air is replacing warmer air. Wind shear occurs predominantly at the surface along the leading edge as the front penetrates inland, although wind shear of lower magnitude exists at higher levels. The extent of a sea breeze at any particular location is influenced considerably by the surrounding topography and therefore may be of a localised nature. If the prevailing wind is offshore, the sea breeze front may be marked



Wind shear across a sea breeze front. Credit: Ralph Turncote, (Haupt et al, 2019)

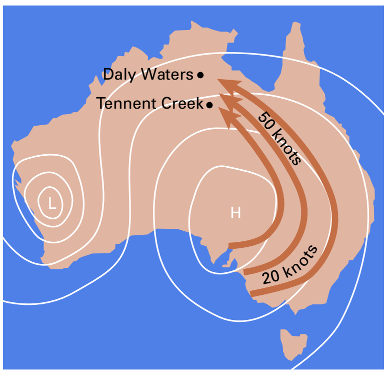
by a line of convergence and vigorous convection that, in favourable circumstances, gives rise to lines of showers or even thunderstorms.

Frictional shearing of surface winds

Frictional wind shear is an outcome of the drag exerted by the surface on the wind flowing above it and can result in both speed and directional vertical wind shear. This can result in significant differences between the surface wind speed and that at higher levels. The resultant shear intensity can be greater over flat and open land than over rougher terrain because the rougher elements generate turbulence to a greater depth, having the effect of mixing out layered velocity fluctuations.

Strong temperature inversions

Temperature inversions at any altitude are likely regions of wind shear. Shear is enhanced when low-level winds are decoupled from upper-level winds due to overnight radiation inversions. Such inversions can almost completely cut off the downward transfer of the horizontal wind momentum to the boundary layer, resulting in large differences between surface flow (which may be light or even calm due to frictional effects) and the flow above the inversion. An aircraft descending through an inversion would pass through a zone of turbulence before experiencing a dramatic loss or gain of lift and airspeed. Temperature inversions are more pronounced in clear skies and wind shear is strongest around the inversion height.



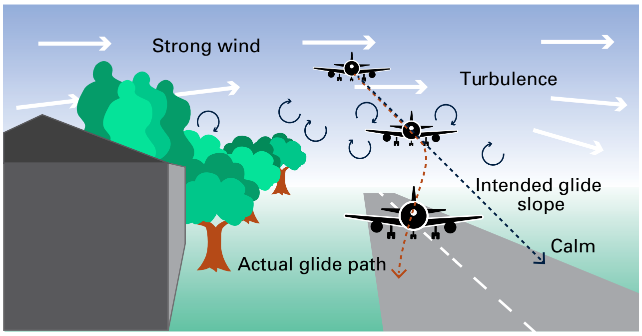
Nocturnal low-level jet

When the inversions are very strong, **low-level jets** may form overnight, possibly just a few hundred feet above a calm surface wind. The jet speed can be enhanced ahead of an approaching cold front, and also windward of barriers such as hills and escarpments. The inversion is effective in shielding the flow above from surface frictional effects, allowing the wind speed to increase in a narrow band near the top of the inversion, with surface winds being very light or calm.

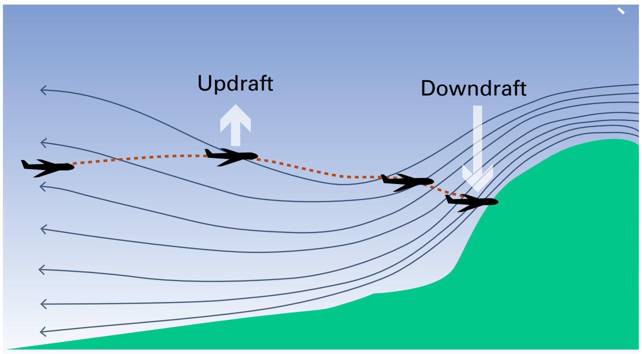
Obstacles

Strong surface winds flowing over and around obstacles (such as large buildings, low hills or close-planted tall trees) upwind of an aerodrome can create localised areas of wind shear, often accompanied by clear air turbulence (CAT). The intensity of wind shear induced by obstacles is largely dependent on:

- stability of the atmosphere
- shape and size of the obstacle(s)
- the speed of the oncoming wind
- the angle at which the wind encounters the obstacle(s).



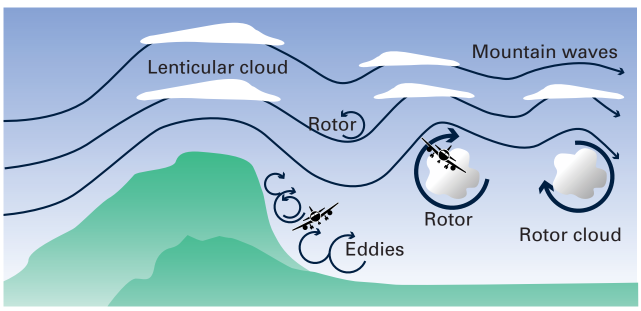
Wind shear downwind of trees and buildings



Wind shear near terrain

Mountain waves

On a larger scale, when the wind flow is forced over a mountain range, a series of standing waves may be formed in the wind flow on the lee side of the mountains. If the mountain waves that develop are of sufficient amplitude, a closed rotor eddy may be formed beneath a wave crest. In extreme conditions, rotors can penetrate to ground level and can reverse the prevailing surface wind directly below the rotor.

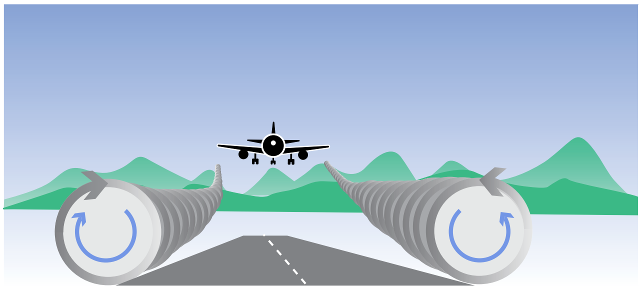


Wind shear in mountain waves, rotors and eddies

(a) Roll cloud. (b) Wet microburst. Reverse flow evidenced by rolling cloud/dust. Credit: Jimmy Deguara, sourced from Manual of Aviation Meteorology, 2003 and (c) Lenticular cloud. Credit: David Miller.

Wake vortices

Wind shear is generated behind every aircraft in flight, mainly as wake vortices forming 2 counter-rotating cylindrical vortex tubes trailing behind the wing tips. The cores of these spinning currents can reach speeds of 180 knots. The strength of the vortex is governed by the weight, speed and shape of the wing of the generating aircraft. They can pose a significant hazard to aircraft following too closely behind.



Wake vortices

Detection and monitoring

Visual clues to the possible presence of low-level wind shear include:

(a) strong, gusty surface winds, especially where an aerodrome is located near hills or large buildings

(b) virga from convective cloud, because downdrafts may still exist and reach the ground even though the precipitation itself has evaporated

(c) a roll-cloud surrounding the base of a thunderstorm and advancing ahead of the storm cell, indicating the presence of a gust front

(d) cumulonimbus clouds, which should always be assumed to have the capability of producing hazardous wind shear

(e) lenticular cloud (smooth lens-shaped altocumulus) indicating the presence of standing waves, usually downwind from a mountain

(f) areas of dust raised by wind, particularly when in the form of a ring below convective clouds, indicating the presence of a downburst

(g) wind socks or runway observations indicating winds from different directions

(h) smoke plumes, with upper and lower sections, or clouds at different heights, moving in different directions.

A pilot must report any wind shear encounters in the form of a Special AIREP.

Forecasts and warnings

Wind shear warnings are issued for a limited number of aerodromes. They are issued when wind shear (that could adversely affect aircraft on the approach or takeoff paths, or on the runway during the landing or takeoff phases, and during circling approach) is observed, reported or expected, between runway level and 1,600 feet above that level.

Wind shear alerts (as distinct from wind shear warnings) may be provided at locations where automated, ground-based, wind shear remote sensing or detection equipment is installed.

Further aviation educational resources produced by the Bureau of Meteorology can be found at www.bom.gov.au/aviation/knowledge-centre.

| A vertical line in the margin indicates a change or addition since last update.

Contact us

www.bom.gov.au

webav@bom.gov.au

Updated 15 July 2025