DOCUMENT
GSM-AUS-CPL.024

DOCUMENT TITLE
METEOROLOGY FOR AUSTRALIA

CHAPTER 18 – TURBULENCE

Version 3.0
November 2014

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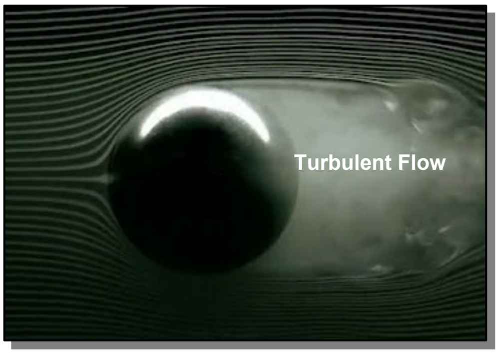
TURBULENCE

OVERVIEW

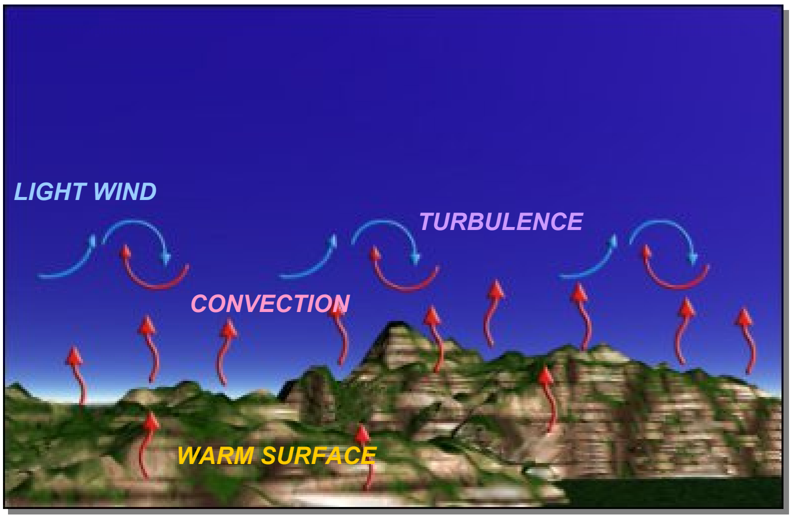


Turbulence is any variation in steady wind flow affecting aircraft flight.

CONDITIONS CAUSING TURBULENCE

Thermal Effects

Rising air, convection currents, interrupts the gradient wind flow causing a vertical acceleration to the general wind flow and to the aircraft. The wind flow is broken and turbulent.

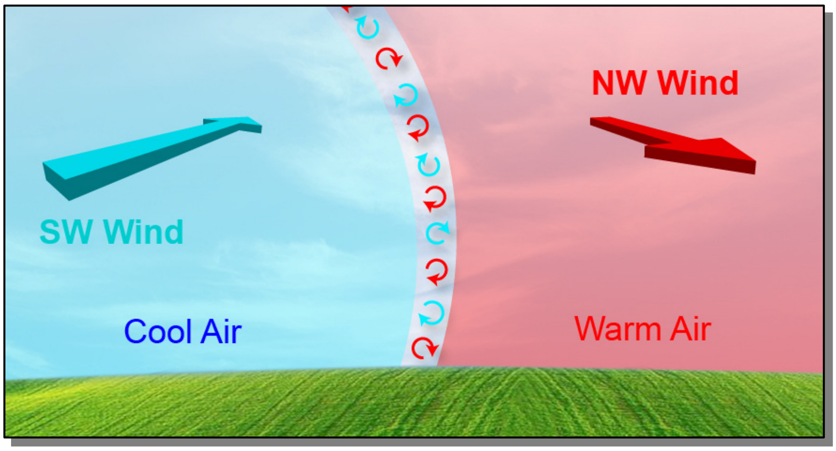


OROGRAPHIC TURBULENCE

Strong winds blowing against a mountainside are forced up and over the mountain. On the lee side, the flow may break down and become turbulent. This is called **lee turbulence**.

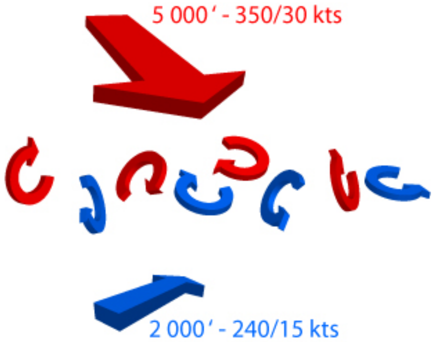
CONVERGENCE AT A FRONT

Cold air wedges under warm air and lifts it. This causes turbulence at the frontal layer. Also associated with a front is usually a large change in wind velocity for a small horizontal distance. For example, in Southern Australia the wind direction rapidly changes from NW to SW during the passage of a cold front.

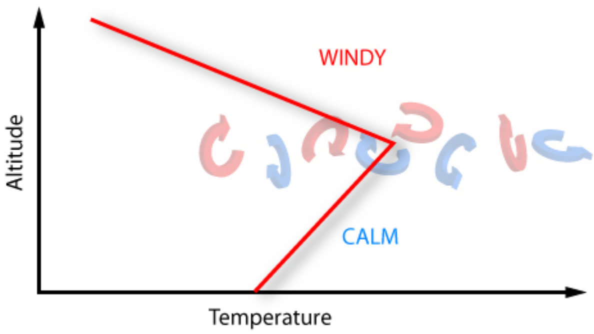


DIFFERING WIND VELOCITIES AND WIND SHEAR

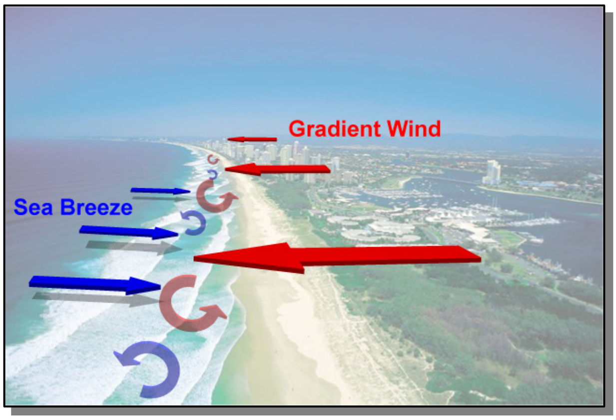
Different wind velocities occurring with a change in height is called vertical wind shear, different wind velocities on the same horizontal plane is called horizontal wind shear.



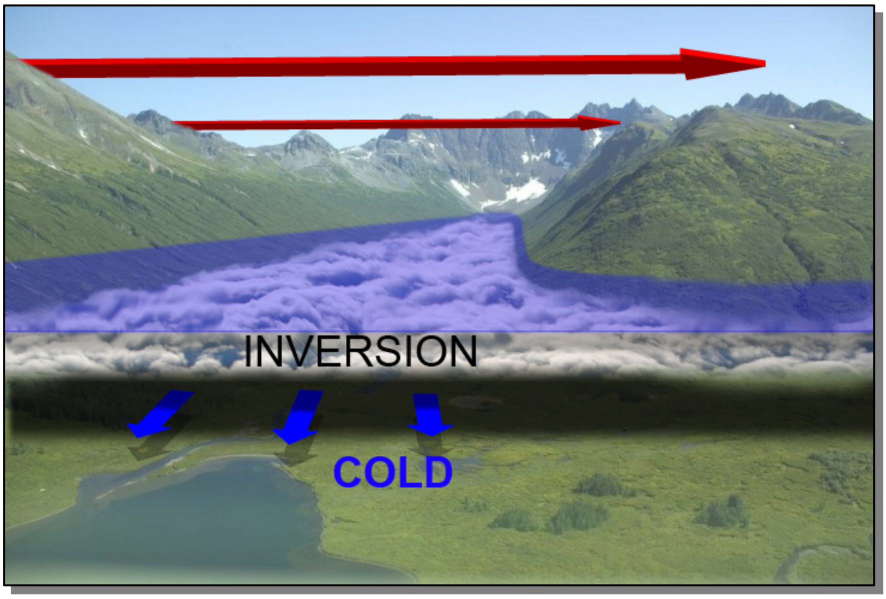
Wind Shear Turbulence



Inversions: At the inversion surface, wind shear and turbulence can occur. Usually conditions are calm below a surface inversion with stronger winds above.

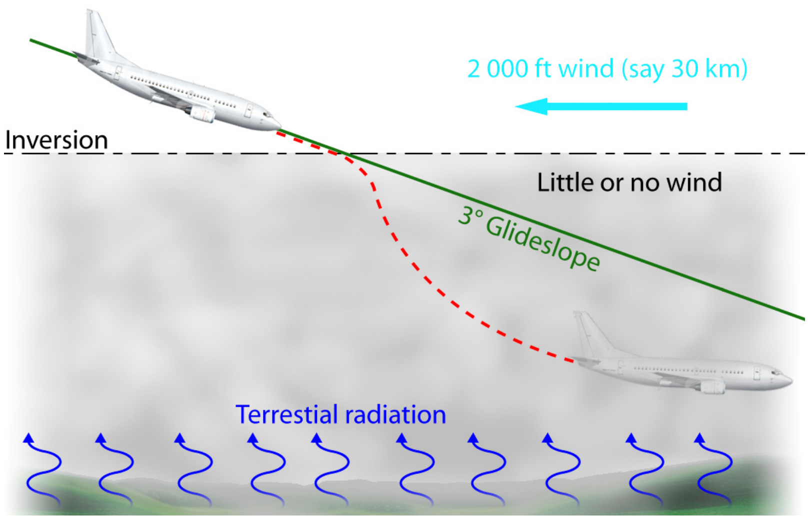


Local winds vs. gradient winds: Sea breezes, land breezes, katabatic and anabatic winds may blow with a different velocity to that of the gradient wind. Turbulence will occur where the two winds interact, e.g. sea breeze.



Valley inversions: Radiation cooling at night causes a pocket of cool air to form near the ground with light winds. In the morning the stronger winds in the over-riding warm air aloft will cause a shear. Radiation cooling in a valley with rather steep sides provides a tunnel for the warm air winds and this may produce significant shear.

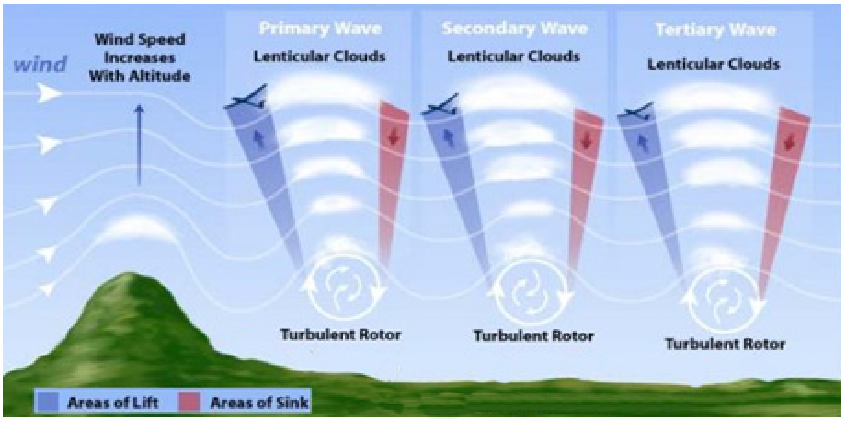
A typical example of this type of shear occurs at Zurich Airport where quite sharp vertical windshear is experienced at the top of ground fog, and at the top of the pool of stationary cold air associated with this fog over the airport.



MOUNTAIN WAVES

Under certain meteorological circumstances, mountain waves may be set up.

Mountain Waves (note the lenticular clouds downwind of the mountain)



Mountain Waves can continue several miles down wind

NECESSARY CONDITIONS

- A wind speed of at least 25 kts blowing at about 90° to the mountain range.
- The wind speed remaining at 25 kts, or increasing with height.
- An upper air inversion, (stable layer) at the height of the mountain top, with unstable air below.

CHARACTERISTICS OF THE MOUNTAIN WAVE

i. A standing wave with a wavelength of between 3 to 16 nm, depending on wind speed, stability and the shape of the mountain. The average is approximately 6 nm.
ii. Vertical speeds can be 5,000'/min. Speeds of up to 14,000'/min have been recorded.

iii. Lenticular (lens) clouds may form **if enough moisture is present**. However a mountain wave may exist without any visual indication.

iv. The slightest breakdown in smooth flow near the surface will result in rotors. Forming near the surface below the mountain wave crests, the rotors may be indicated by rotor cloud. These long clouds may have a rounded top but a ragged base. Rotors may also form above wave troughs.

Crash inquiry will study local weather

Investigators who have failed to pin down the cause of the Boeing 737 crash at Colorado Springs are calling for a meteorological study of the area in the fourth quarter of 1992.

On 3 March, 1991, in clear conditions, the United Airlines 737-200 was on final approach to runway 35 when it was seen to roll and dive into the ground. All 25 occupants were killed.

There have been no indications of crew or mechanical failure and the investigation has centred on studies of the local weather conditions.

The airport is some 6,000ft (1,800m) above sea level, close to the Rocky Mountains.

The US National Transportation Safety Board says that, on the accident date "...highly dynamic weather conditions existed along this front range. Strong mountain waves were occurring, accompanied by severe turbulence, updrafts and downdrafts. Reports of horizontal axis vortices [rotors] were noted in the area north of the airport."

The day after the accident, the crew of a Safety Board data-gathering aircraft observed a region of decreased wind speeds over the accident site, east of a mountain. The area featured a wind-direction reversal with vortices along the interface, resulting in vertical velocities of 800ft/min (4m/s) to 1,000ft/min.

The Board is recommending that the US Federal Aviation Administration "...develop and implement a meteorological programme to observe, document and analyse potential meteorological aircraft hazards in the area" to be operational by the end of 1992.

It is also recommending the development of a similar but broader programme to include other airports near mountains.

18.h. Accident possibly caused by Mountain Waves and Rotors.