CPL Theory Meteorology (CMET)

CAE Oxford Aviation Academy

CMET 3 - Wind

Document Identification	
Document Category	Training Material
Document Revision Number	
Document Issue Date	
Document Status	Draft
Document Title	
Document Identification	MBWTRG-TRM-XXX

2. Related Documents

Related Documents	Document Identification

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAAM's document management procedure.

Slide	Changes

WIND

Wind

- Wind is air in motion over the earth's surface

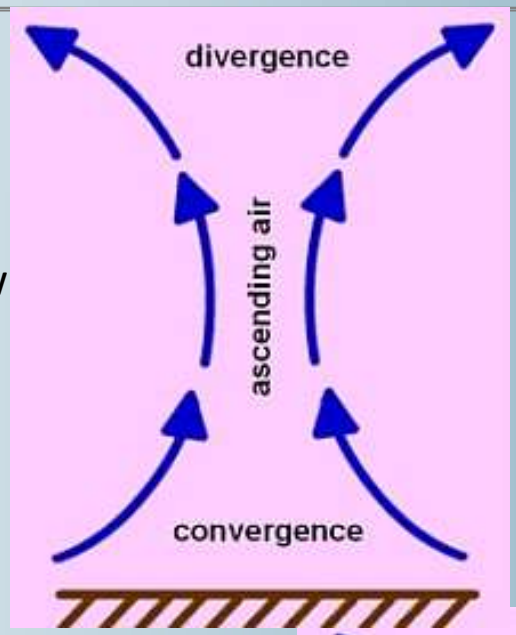
- Another term for wind is **advection** – the horizontal movement of air

MOVEMENT OF WIND

Movement of Wind

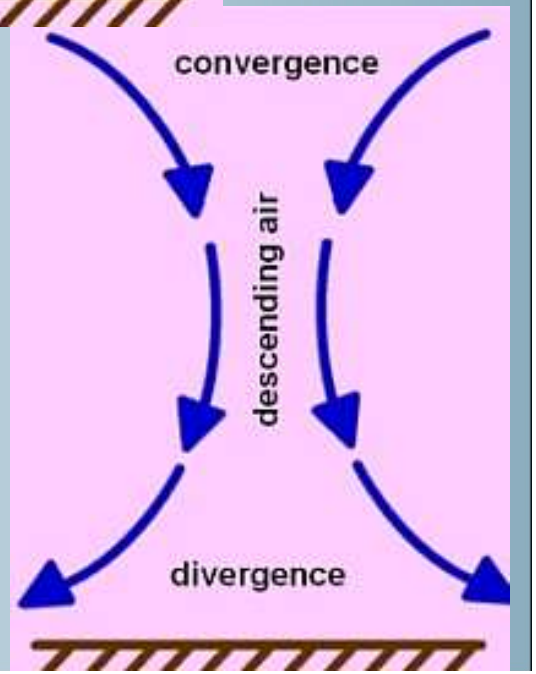
Convergence

- A horizontal inflow of air into a surface region
- When air ascends e.g. due to convection, a low pressure system is created
- Air will flow into that **low pressure** system as a result



Divergence

- A horizontal outflow of air at the surface
- When air **subsides**, a **high pressure** system is created
- Air will flow out of that high pressure system as a result



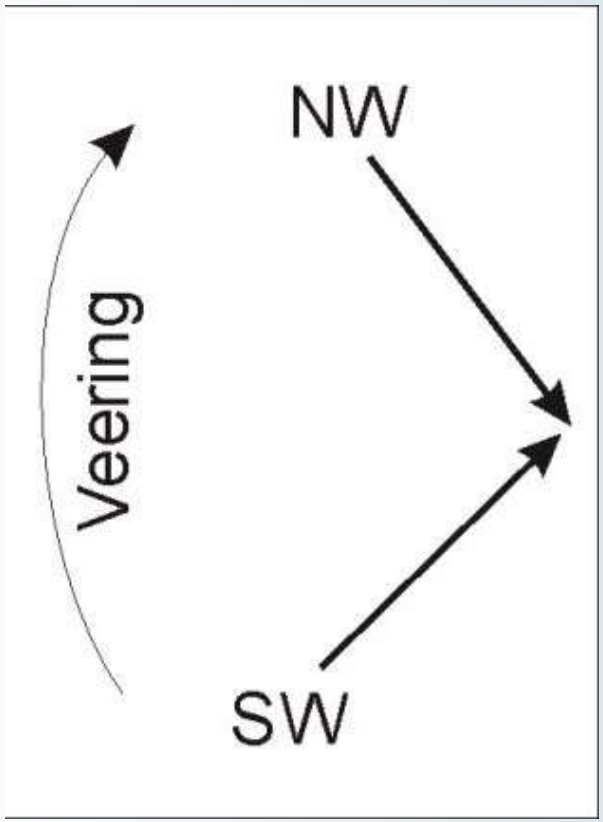
Movement of Wind

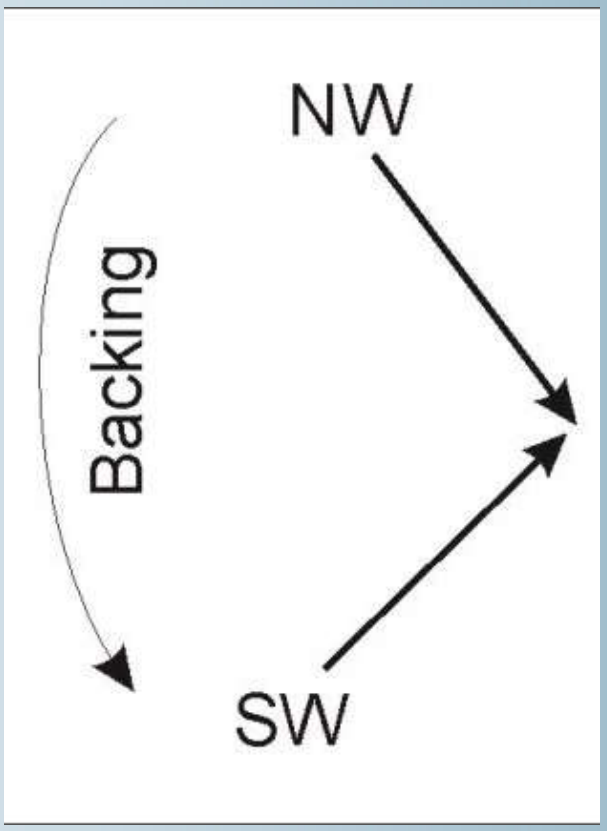
Veering

- When wind direction changes in a **clockwise direction**

Backing

- When wind direction changes in an **anticlockwise direction**



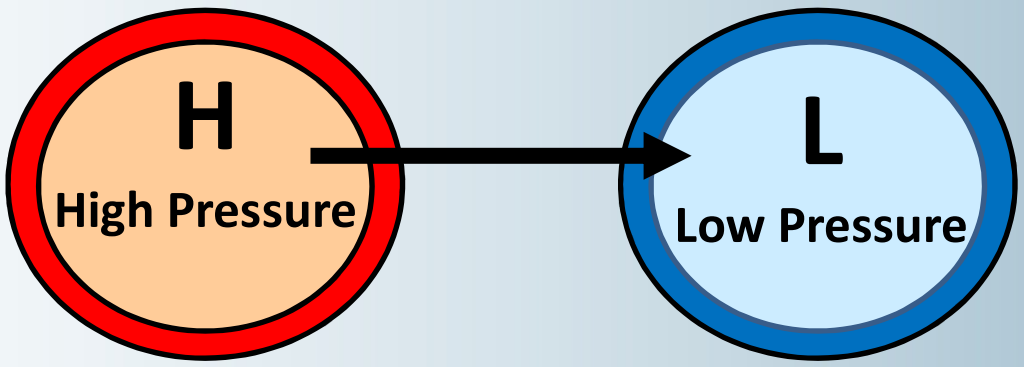


FORCES AFFECTING WIND DIRECTION

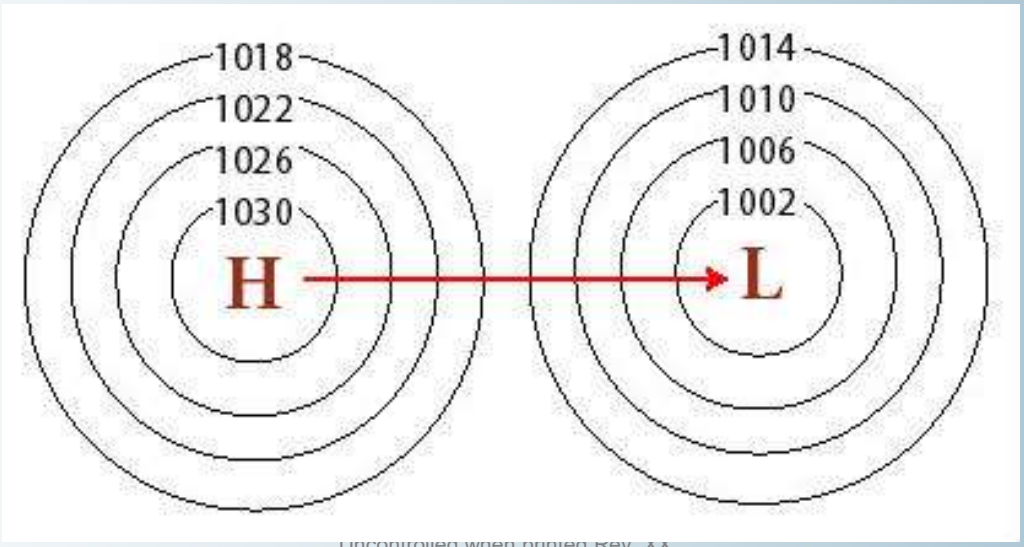
Forces Affecting Wind Direction

Pressure Gradient Force

- As we know, air will generally move from a High Pressure to a Low Pressure



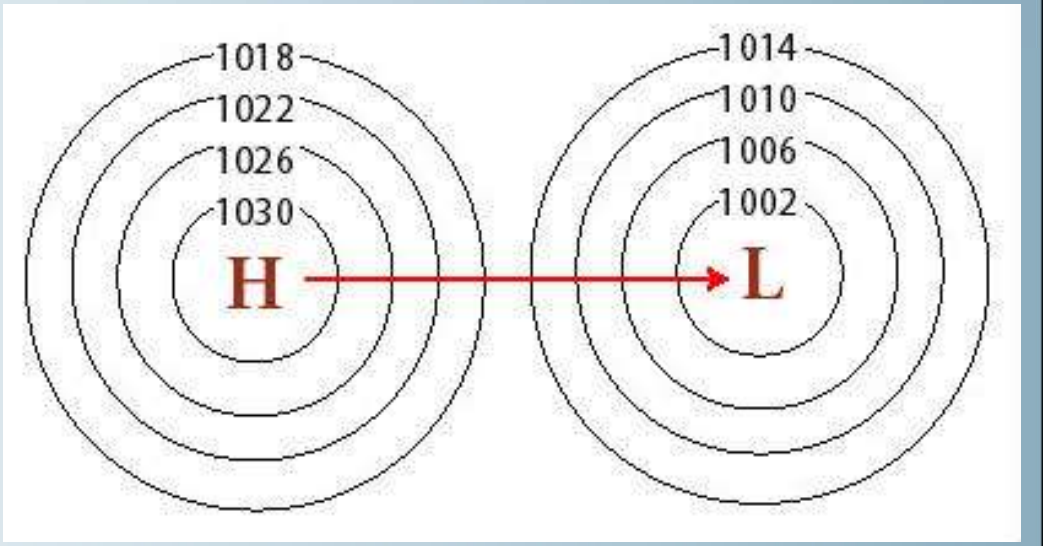
- To explore this concept further, let's consider actual high and low pressure systems…



Forces Affecting Wind Direction

Pressure Gradient Force

- At the centre of a High will be the highest pressure in that system
- At the centre of a Low will be the lowest pressure in that system
- As we move away from a High, the pressure reduces and as we more away from a Low, the pressure increases



- **Isobars are lines joining places of equal pressure**
- **Pressure Gradient Force** flows **across the isobars at right angles** from **High to Low**
- However, this is not how wind flows. There are also other forces at play…

Forces Affecting Wind Direction

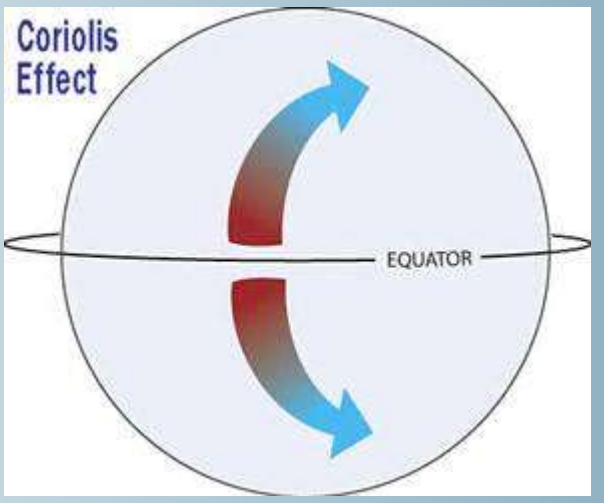
Coriolis Force

- Due to the rotation of the earth and curvature of the earth, different latitudes are moving at different rates.

- Objects moving large distances across the latitudes will experience an apparent force which will change its direction relative to the earth's surface, this is the Coriolis force

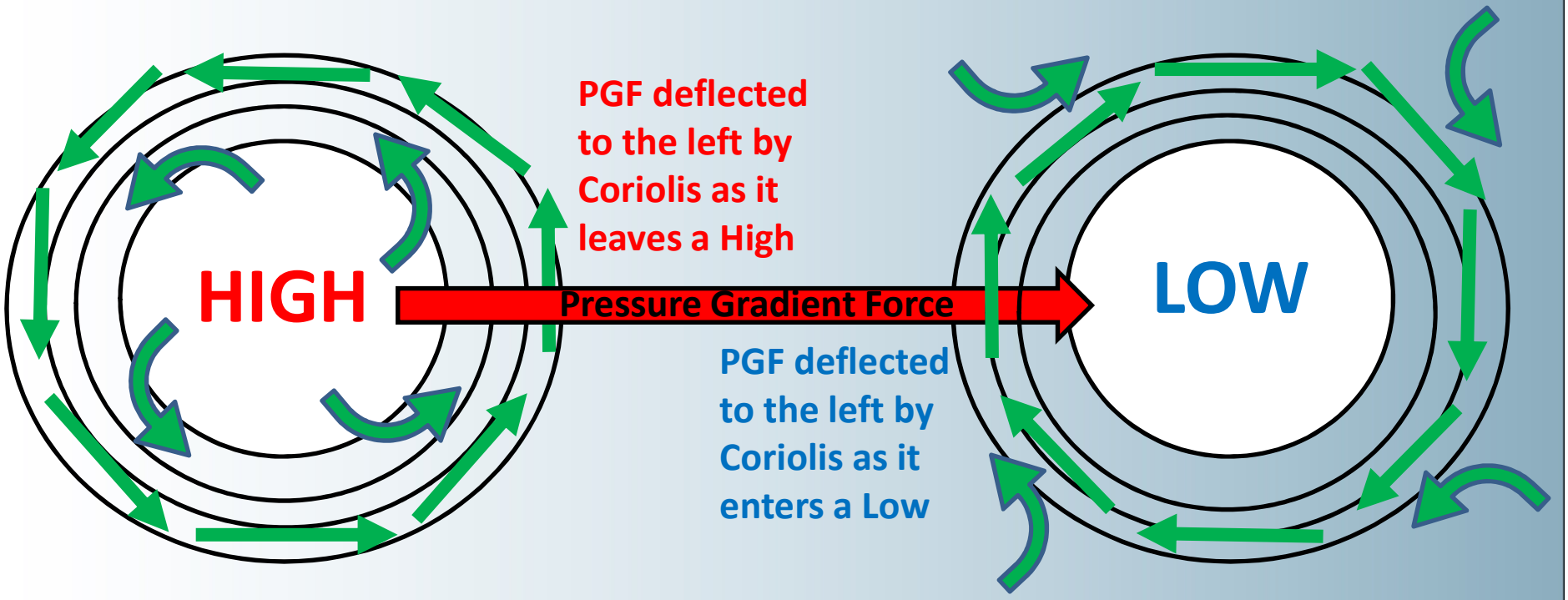
- In the Southern Hemisphere, Coriolis Force deflects the wind **to the left**

- Due to the Coriolis force, the **wind will actually flow along the isobars (Geostrophic wind)** instead of across them at right angles



Forces Affecting Wind Direction

In the *Southern Hemisphere*, wind flow is **clockwise around a Low Pressure** System and **anticlockwise around a High Pressure** System, this is known as **gradient wind**

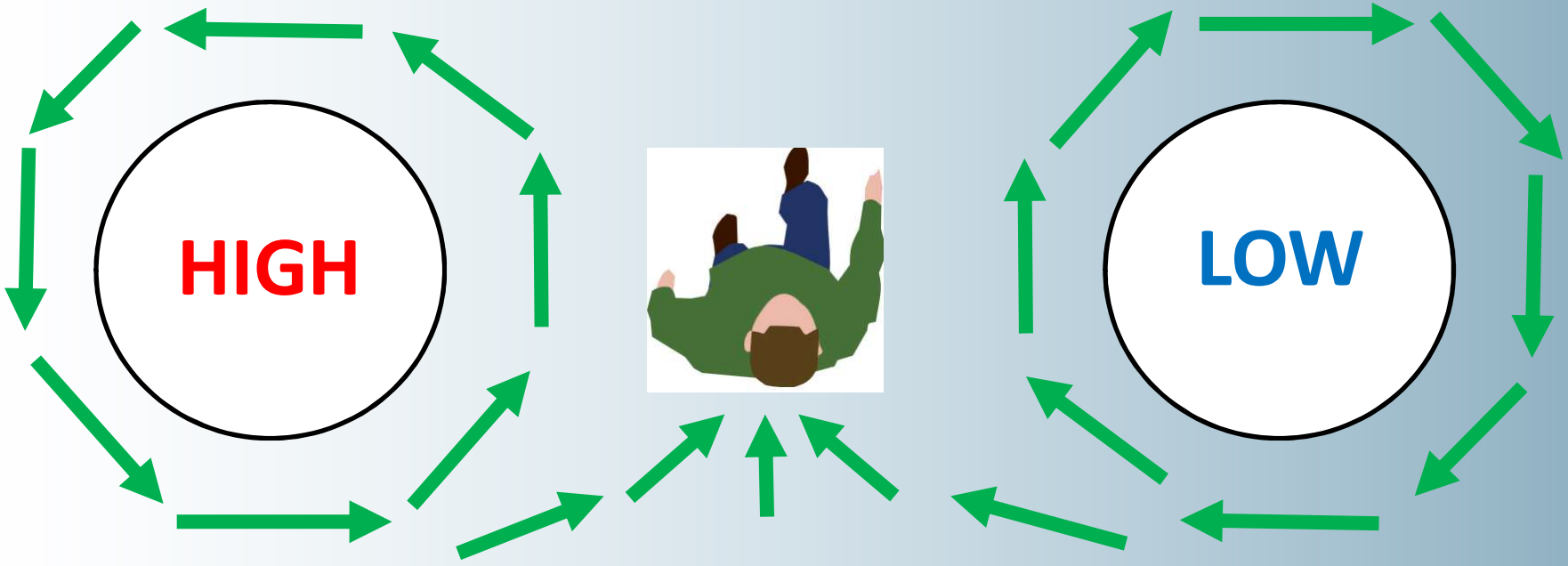


BUYS BALLOT'S LAW

Buys Ballot's Law

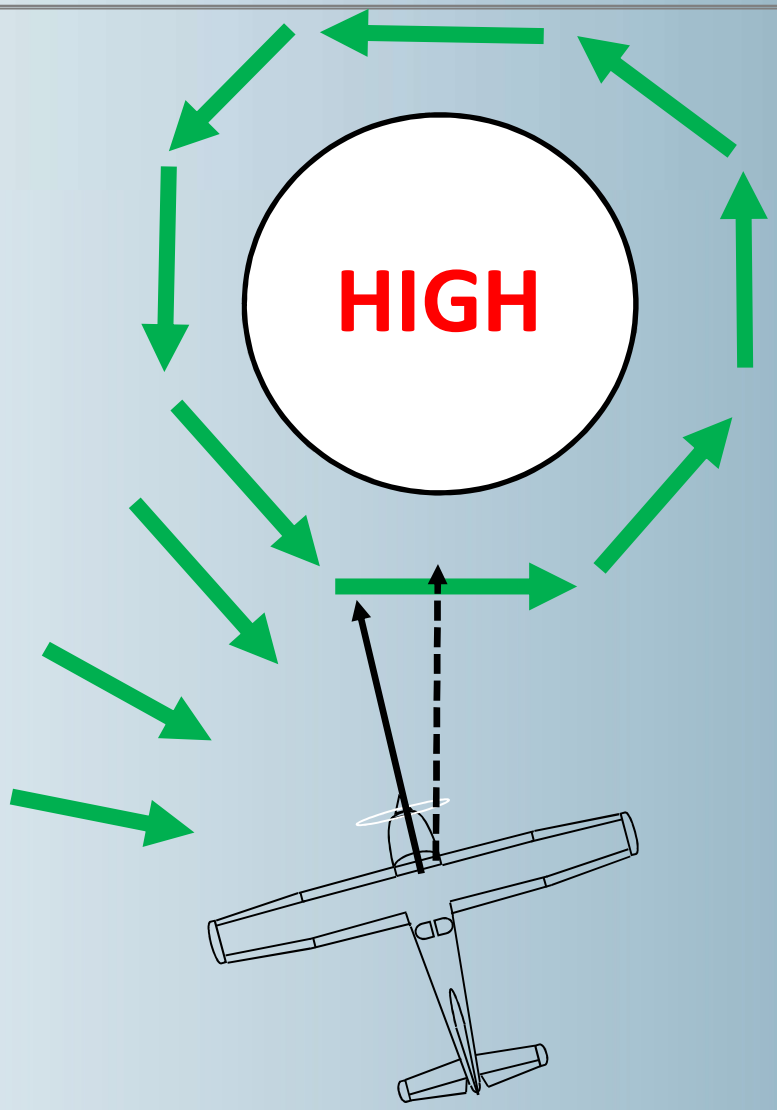
- Buys Ballot's Law is used to determine the location of a Low Pressure System using the local wind direction

"If an observer stands with his back to the wind, the lower pressure is on his right in the Southern Hemisphere"



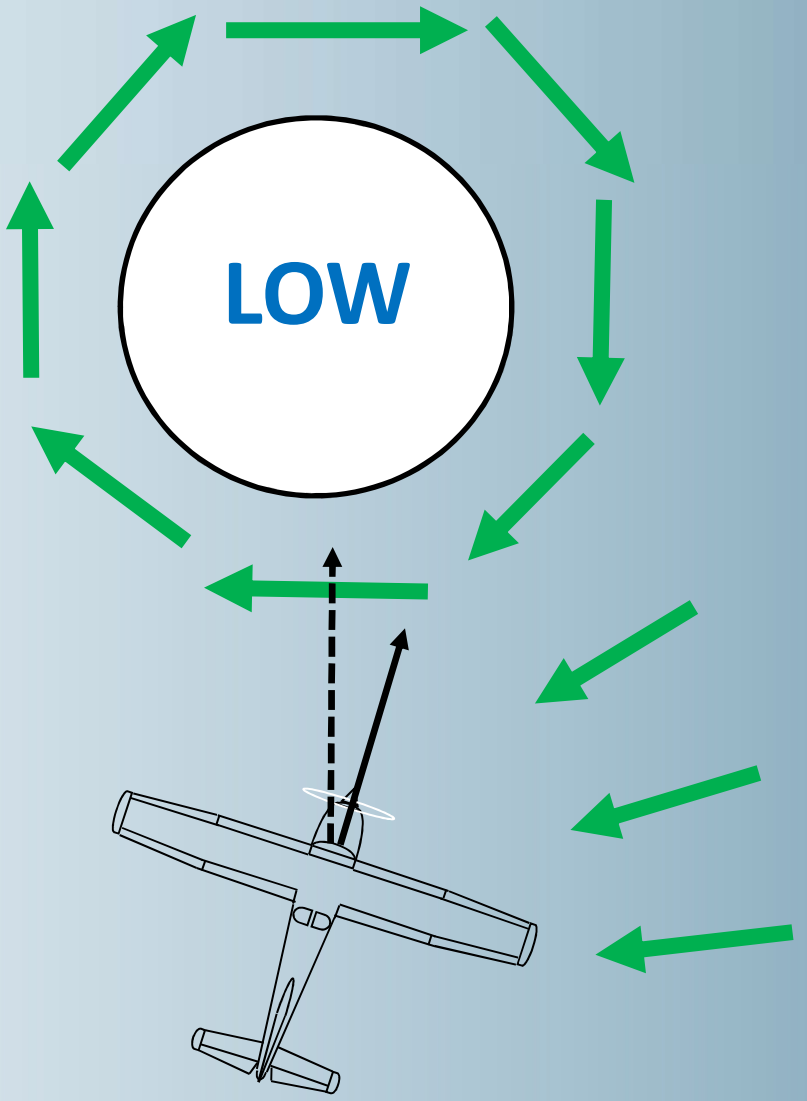
Flying towards a high

- Right drift means a crosswind component from the left
- flying towards a high



Flying towards a Low

- Left drift means a crosswind component from the right
- Therefore flying towards a low



EFFECT OF SURFACE FRICTION ON WIND

Effect of Surface Friction on Wind

- The **lower 3000ft** of the atmosphere is known as the **friction layer**
- Here, the **wind speed is reduced due to friction** with the earth's **surface**
- This results in a difference between the **surface wind** and the **gradient wind**
- Compared to the gradient wind (above 3000ft), the surface wind is:

  1. Reduced by 2/3rd over land

  2. Reduced by 1/3rd over sea (less friction)

- The reduction in wind speed also reduces Coriolis Force. This causes the surface wind to veer when compared to the gradient wind:

  1. 30° Veer over land

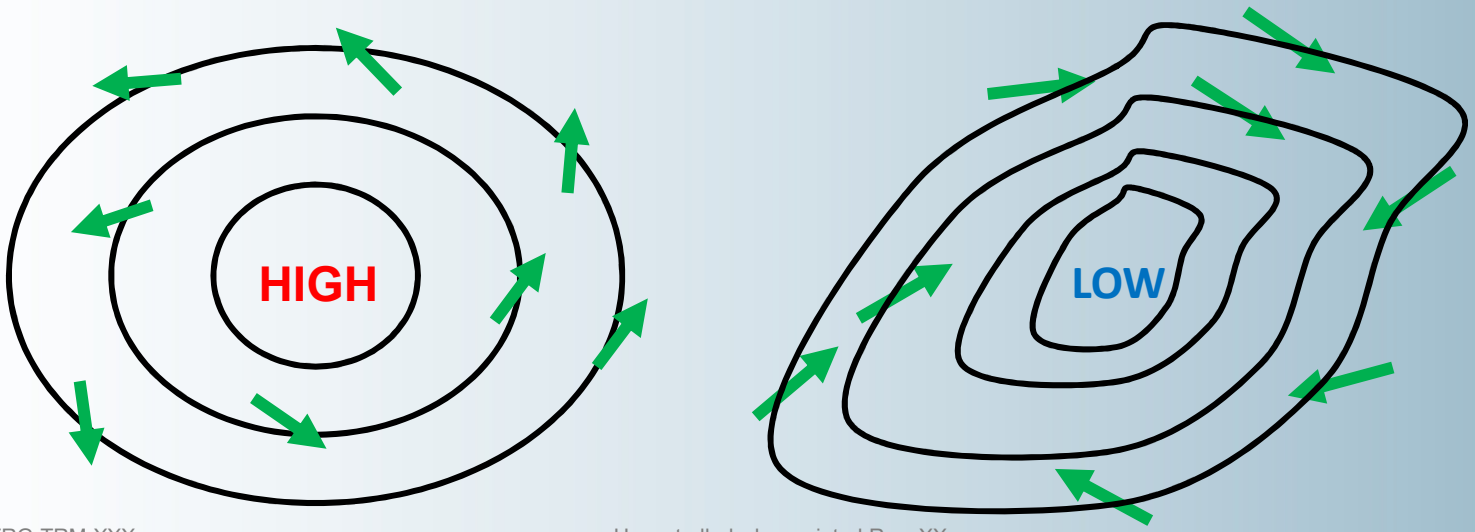
  2. 10° Veer over sea (less friction)

Effect of Surface Friction on Wind

- The wind direction follows the isobars most closely above 3000ft (gradient wind)
- Near the surface, the decrease in Coriolis Effect means that the Pressure Gradient Force is the dominating force
- This means that:

1. In a LOW → Air flows Clockwise and Inwards

2. In a HIGH → Air flows Anticlockwise and Outwards



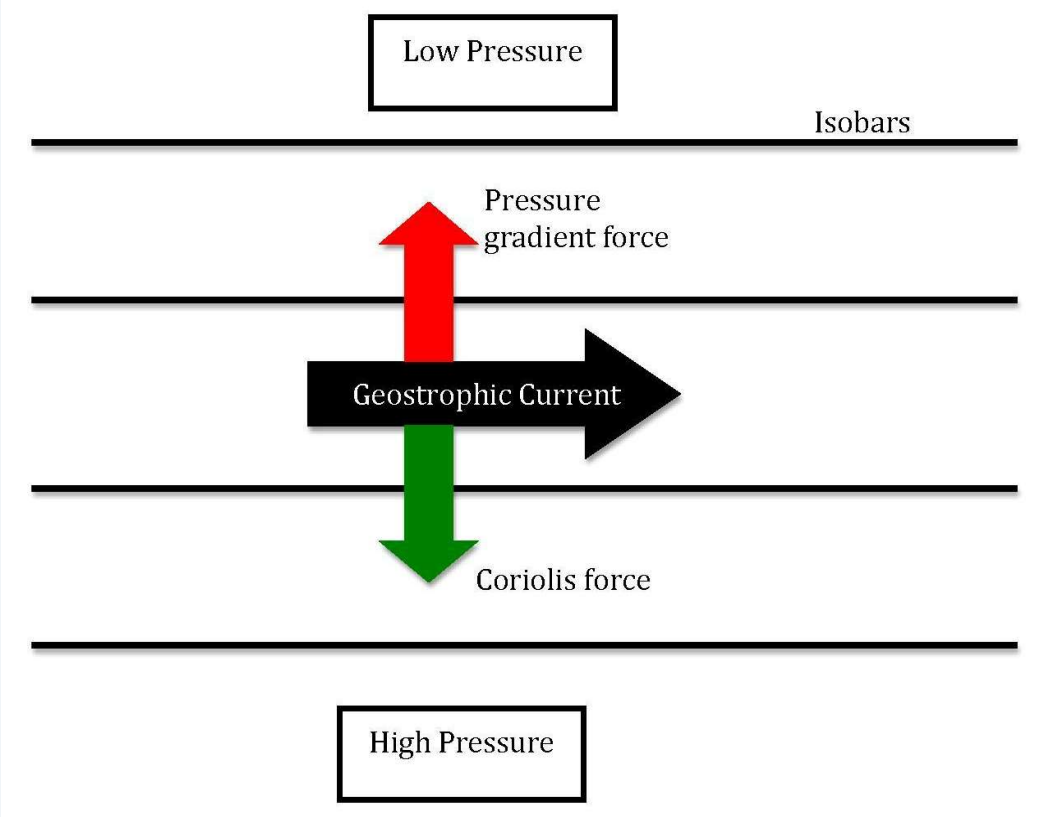
TYPES OF WIND

Types of Wind

Geostrophic Wind

- Wind flow that is parallel to **straight isobars**

- Occurs when the **Pressure Gradient Force matches the Coriolis Force**

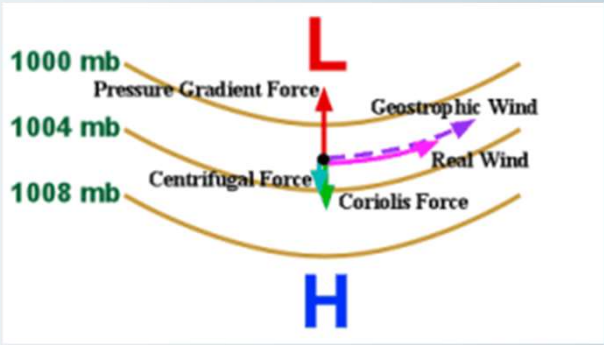


Types of Wind

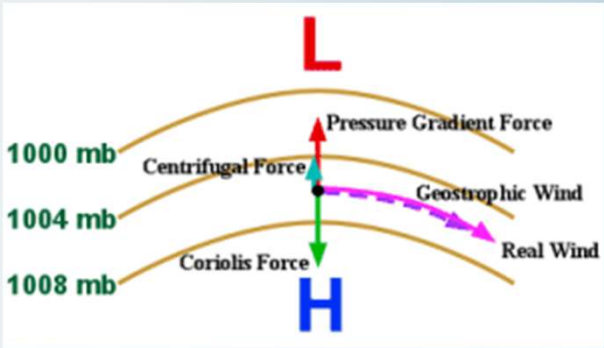
Gradient Wind

- Wind flow that is tangential to **curved isobars**

- Occurs when the **Pressure Gradient Force exceeds the Coriolis Force around a low**



- when the **Coriolis Force exceeds the Pressure Gradient Force around a high**



Types of Wind

Gust

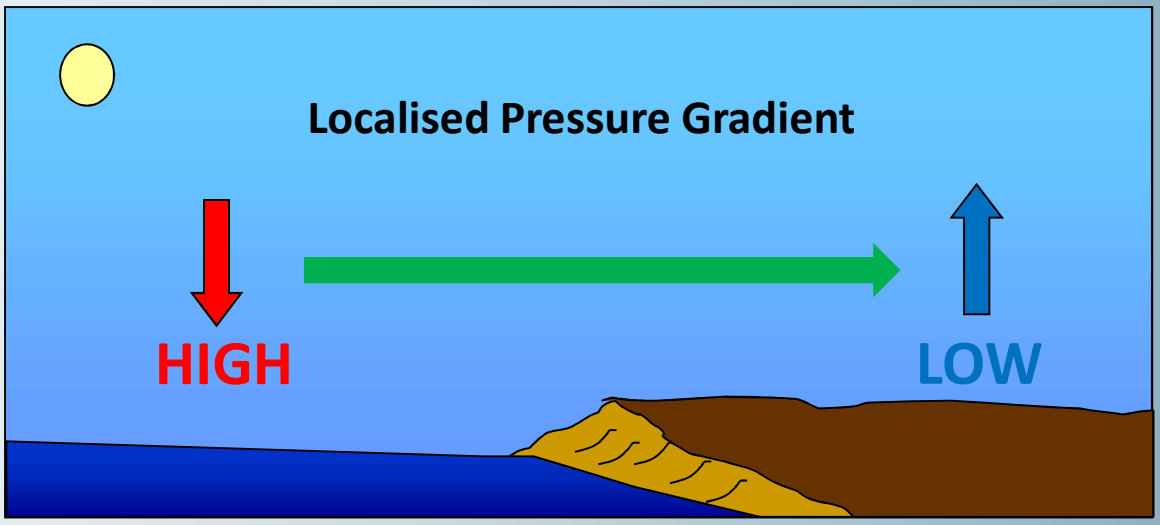
- A increase in wind speed lasting for just a few seconds
- Indicative of instability and turbulence
- Typically 30-40% greater strength than that of the mean wind

Squall

- An increase in wind speed lasting **at least one minute**
- Technically speaking, it is only a squall if the wind strength is at least **16 knots greater than the mean wind**
- It must also be **at least 22 knots**

Types of Wind

Sea Breeze

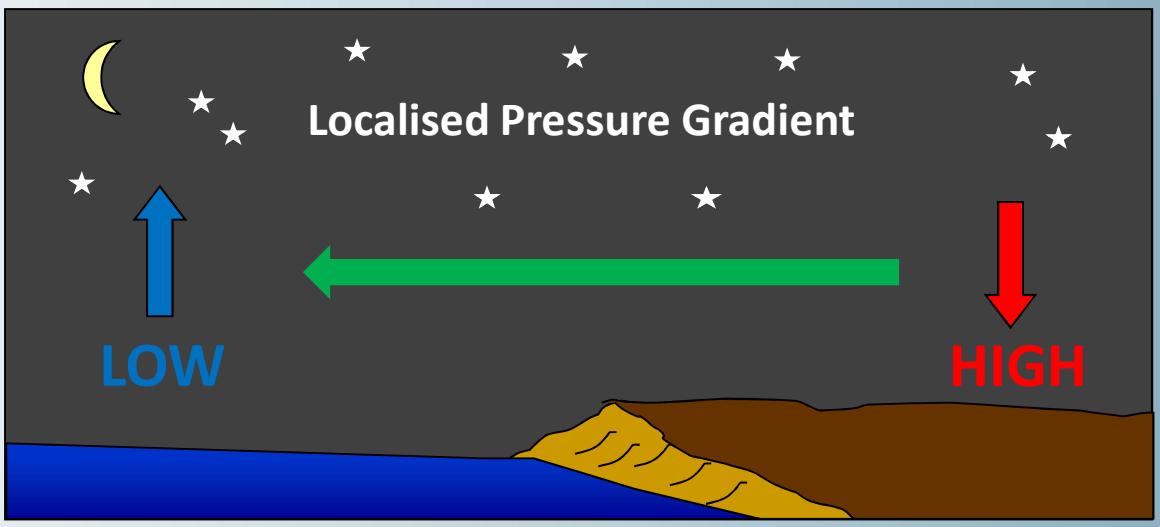


- **During the day**, insolation heats up the surface
- Land will heat faster than the sea, which is more resistant to temperature change
- Air over the warm land will begin to rise due to convection
- This creates an area of **Low Pressure over land** and an area of **High Pressure over sea**
- The wind will now follow the **localised Pressure Gradient** and **flows from sea to land**
- Also known as an **On-Shore Breeze**, sea breezes are strongest **mid-afternoon**

Types of Wind

Land Breeze

- **At night**, the sea will be warmer due to its specific heat – it is more efficient at retaining heat from the day

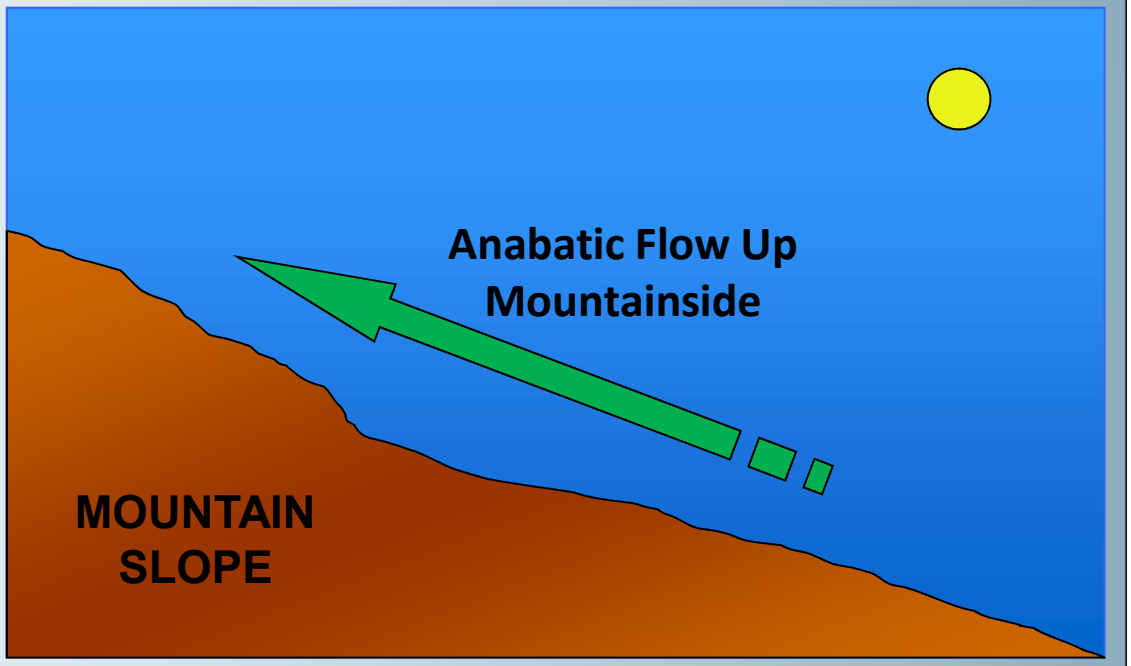


- Now, the Low Pressure will be over sea and the High Pressure over land
- This creates a localised Pressure Gradient opposite to that of a sea breeze
- The **wind will flow from land to sea** (also known as an **Off-Shore Breeze**)
- A Land Breeze will not be as strong as a Sea Breeze as the Pressure Gradient is not as steep

Types of Wind

Anabatic Wind

- **During the day**, the warm surface of a mountain side will heat the air above it via conduction
- The warmed air now has a **reduced density** and will begin to rise
- **The flow is up-slope**

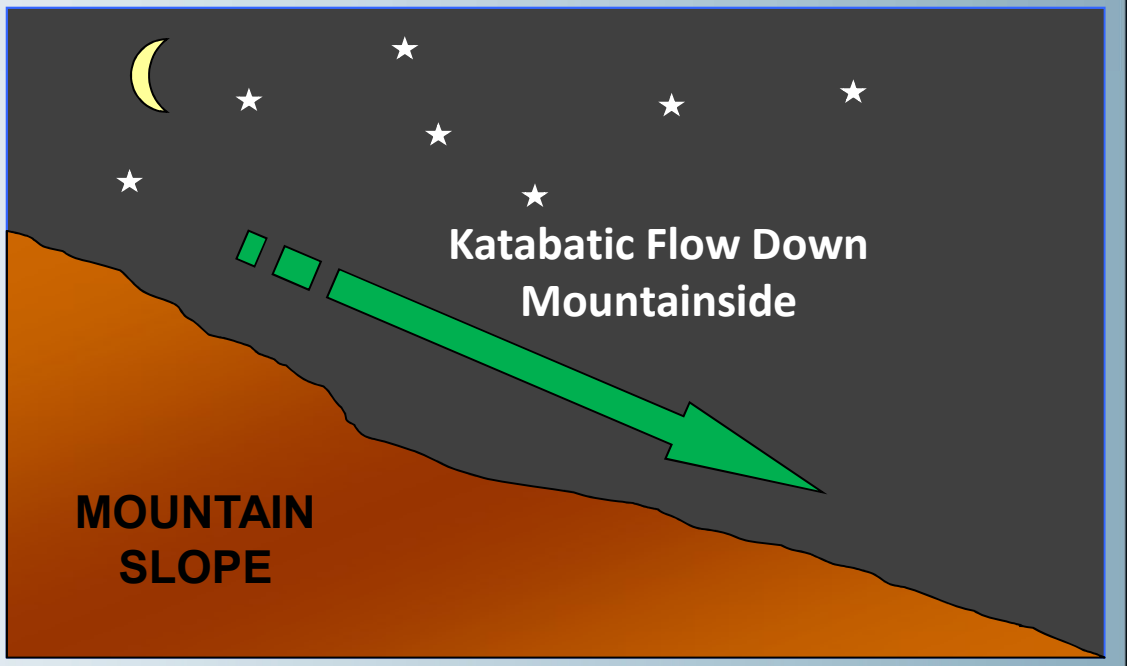


- Anabatic Winds are generally **quite weak** as they travel against gravity
- If located near a coast, **Anabatic Wind will re-inforce a Sea Breeze**

Types of Wind

Katabatic Wind

- At night, the mountain surface will lose heat in the form of **terrestrial radiation**
- This means the air above the surface will also cool via **conduction**
- The cooler air now has an **increased density and will begin to sink**



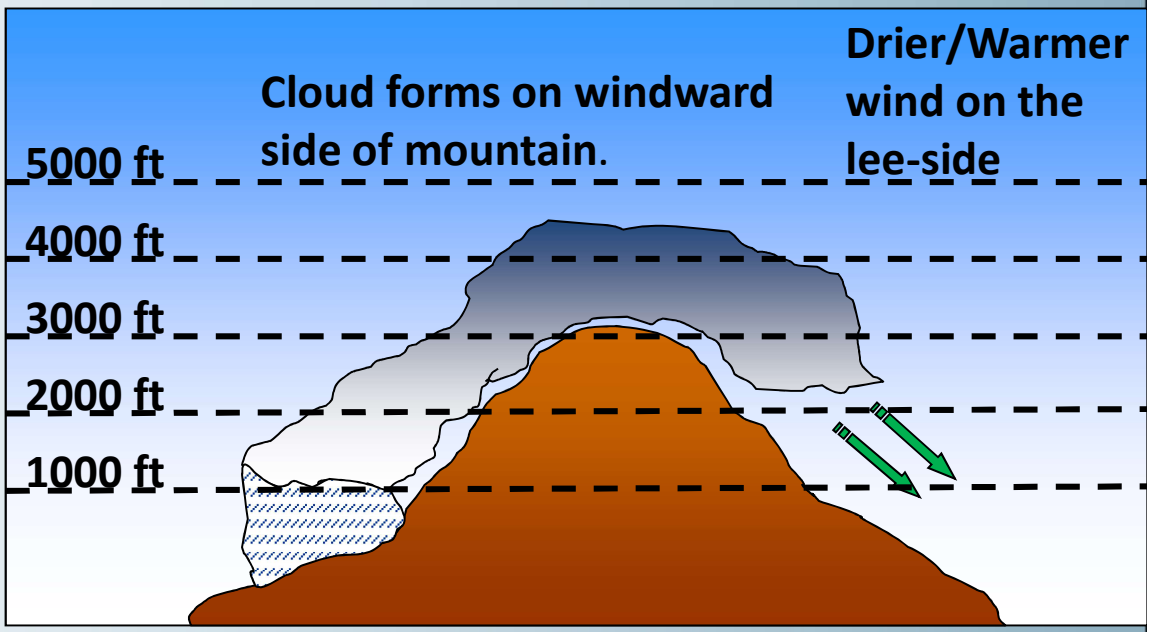
- **The flow is down-slope and will be strongest at dawn**
- Katabatic Winds are **generally quite strong** as they are assisted by gravity
- If located near a cost, **Katabatic Wind will re-inforce a Land Breeze**

Types of Wind

Fohn Wind

- When moist air is lifted orographically, the air may saturate and cloud will form (usually on the wind-ward side of the mountain)

- If precipitation occurs, then by the time the airflow reaches the lee side, it may contain little or no moisture



- Consequences of this include:

1. A higher cloud base on the lee side of the mountain

2. A warmer, drier airflow on the lee side of the mountain

LOW LEVEL JETSTREAM

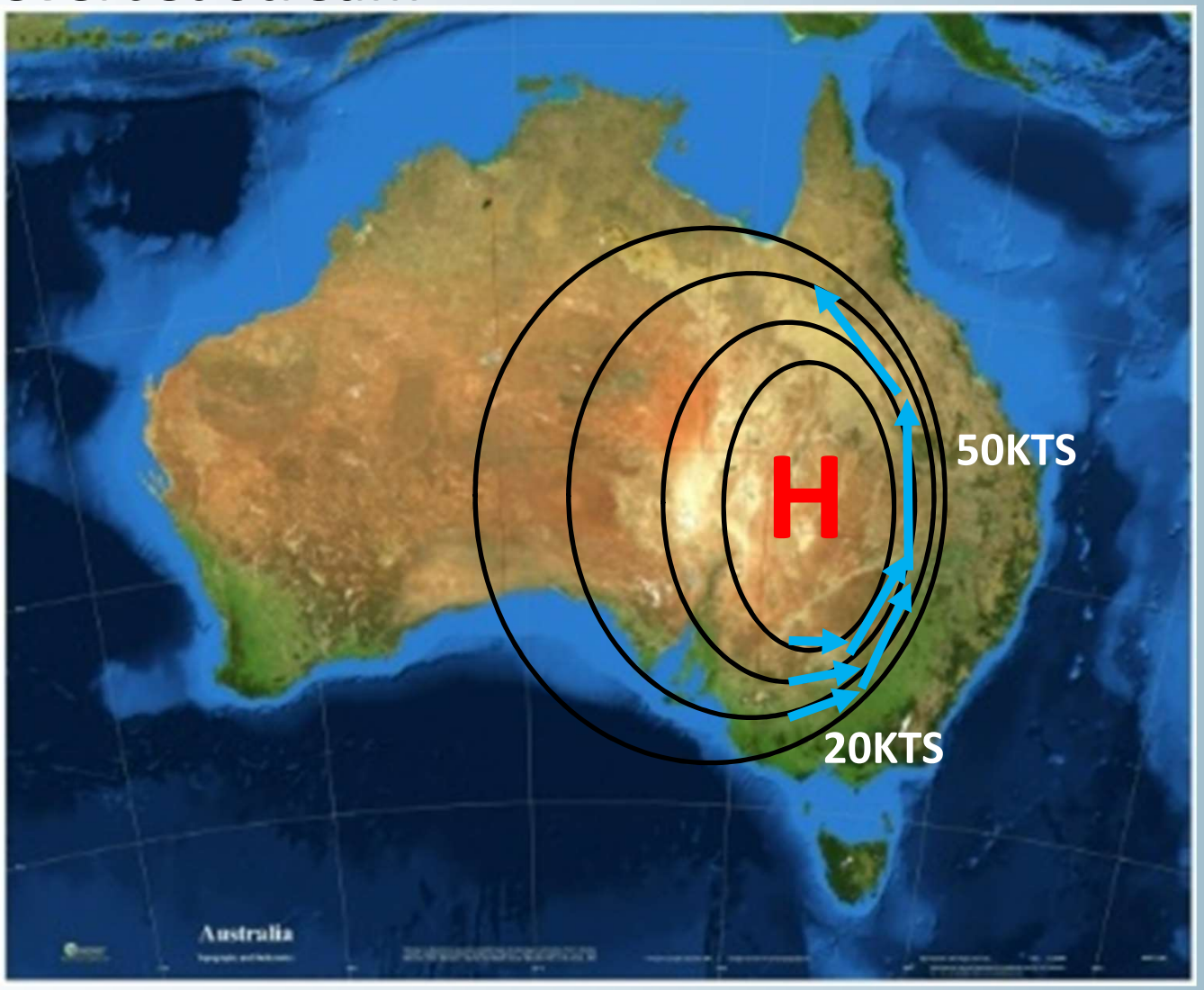
Low-level Jet Stream

- Low level jet streams are a phenomena which can affect parts of Australia under the right conditions
- They can result in strong winds of up to 50kts, at levels below 3000ft
- **Conditions required for low level jet:**
  - A source of **wind**, such as a resident high situated over continental Australia
  - A physical **obstruction** (e.g. great dividing range) to bank up the isobars
  - Surface **inversion** to minimise mixing of the low level air and associated friction

Low-level Jet Stream

- The most prominent jet stream is the nocturnal low level jet
- It forms over eastern Australia when there is a high over Australia and the great dividing range blocks eastward travel of the winds, forcing them to accelerate north into a narrow stream
- There generally also needs to be a surface inversion to ensure minimal vertical movement of the jet and mixing with the above layers
- The jet is generally strongest in the winter at around dawn (strongest surface inversion), between Daly Waters and Tennant Creek

Low-level Jet Stream



Low-level Jet Stream

NOTE: Smaller scale Jet Streams can also occur in different locations, providing the conditions are correct

- **Wind**
- **Physical barrier**
- **Surface inversion**