CPL Theory
Meteorology (CMET)

CAE Oxford
Aviation Academy

CMET 7 – Climatology & Synoptic Meteorology

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2. Related Documents

Related Documents	Document Identification

CMET 7 – Climatology & Synoptic Meteorology

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

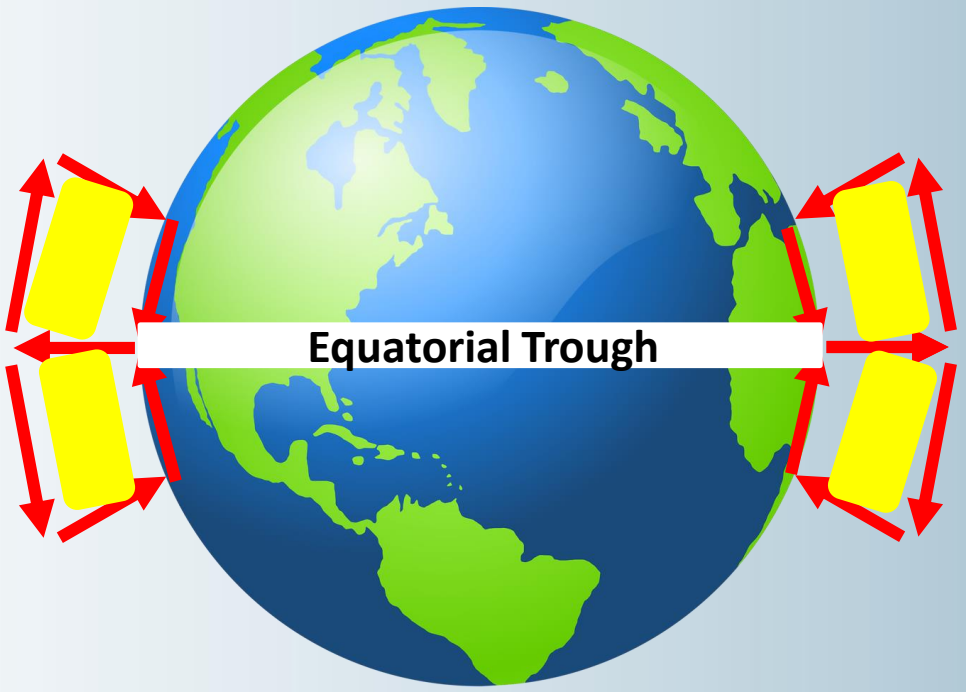
GLOBAL CIRCULATION

Global Circulation

- The sun's rays heat the earth most intensely at the equator causing air there to rise
- This creates an area of low pressure around the equator – **the Equatorial Trough**
- It then stops rising and moves horizontally towards the poles

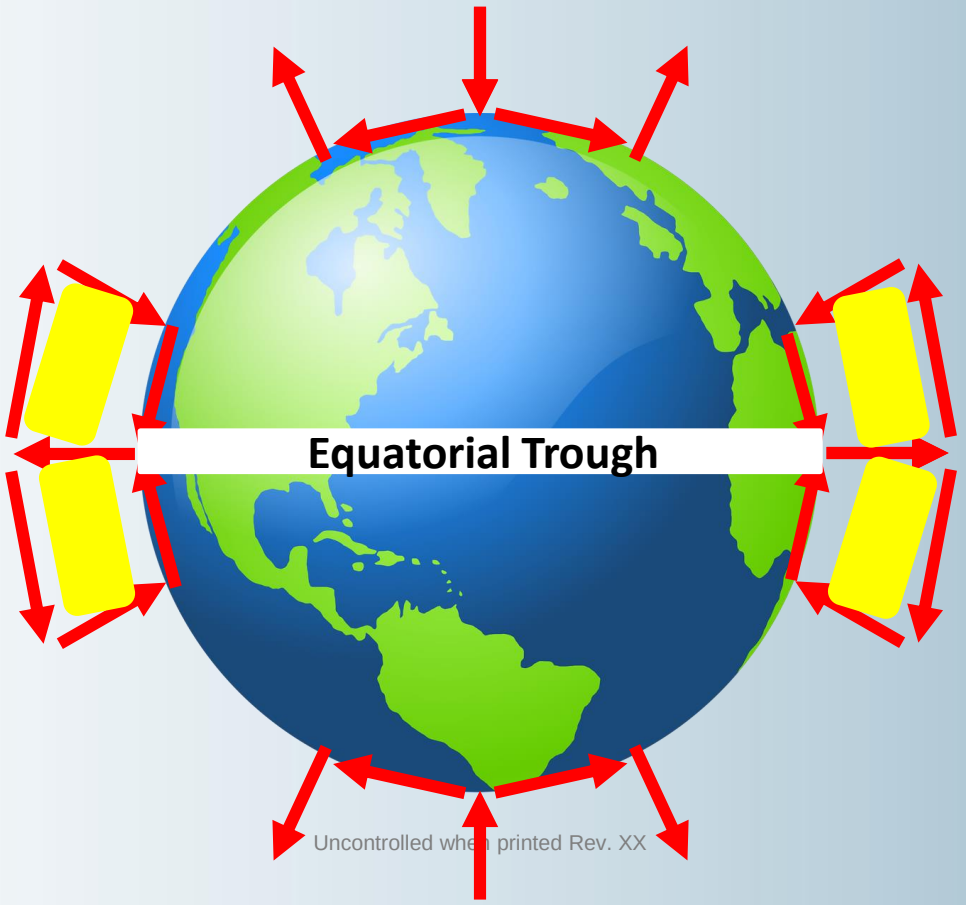
Global Circulation

- As it moves away from the equator, it cools and begins to sink
- The air then diverges back towards the equator and the process is repeated
- This circulation cell is known as a **Hadley Cell**



Global Circulation

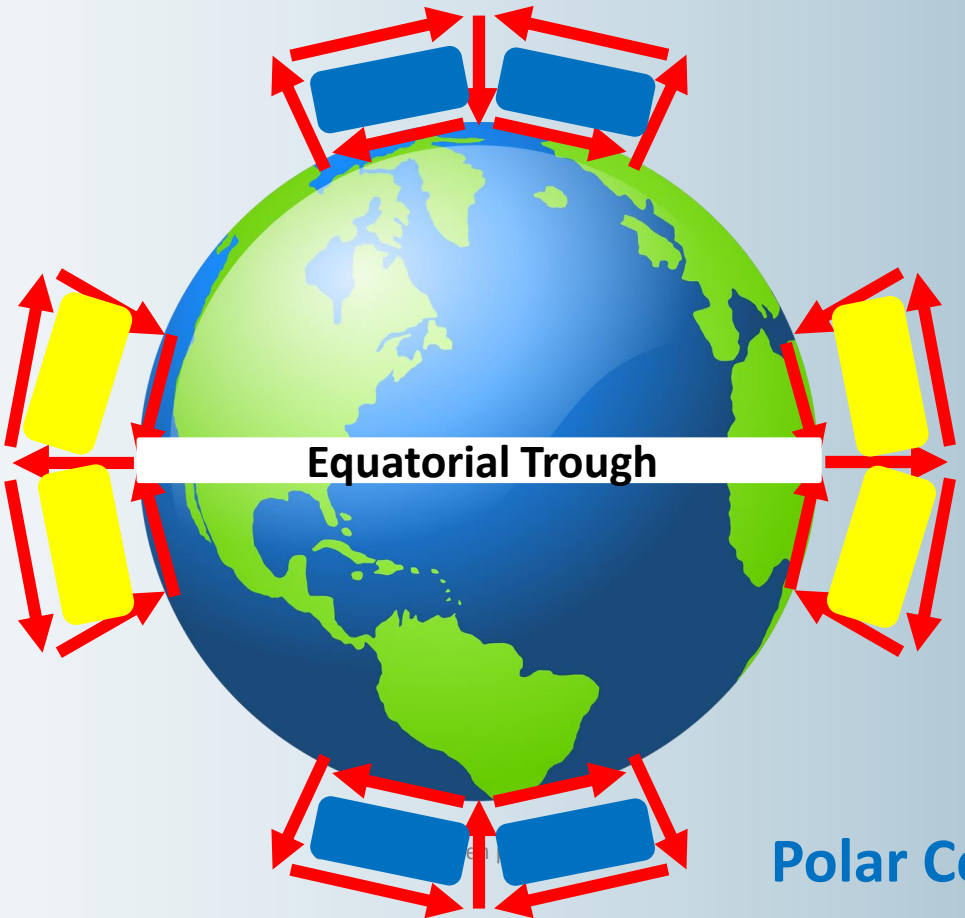
- Meanwhile at the poles, the air is very cold and will sink – forming the **Polar High**
- At the surface, this air diverges away from the poles and will begin to warm
- Eventually, it will rise once it is warm enough



Global Circulation

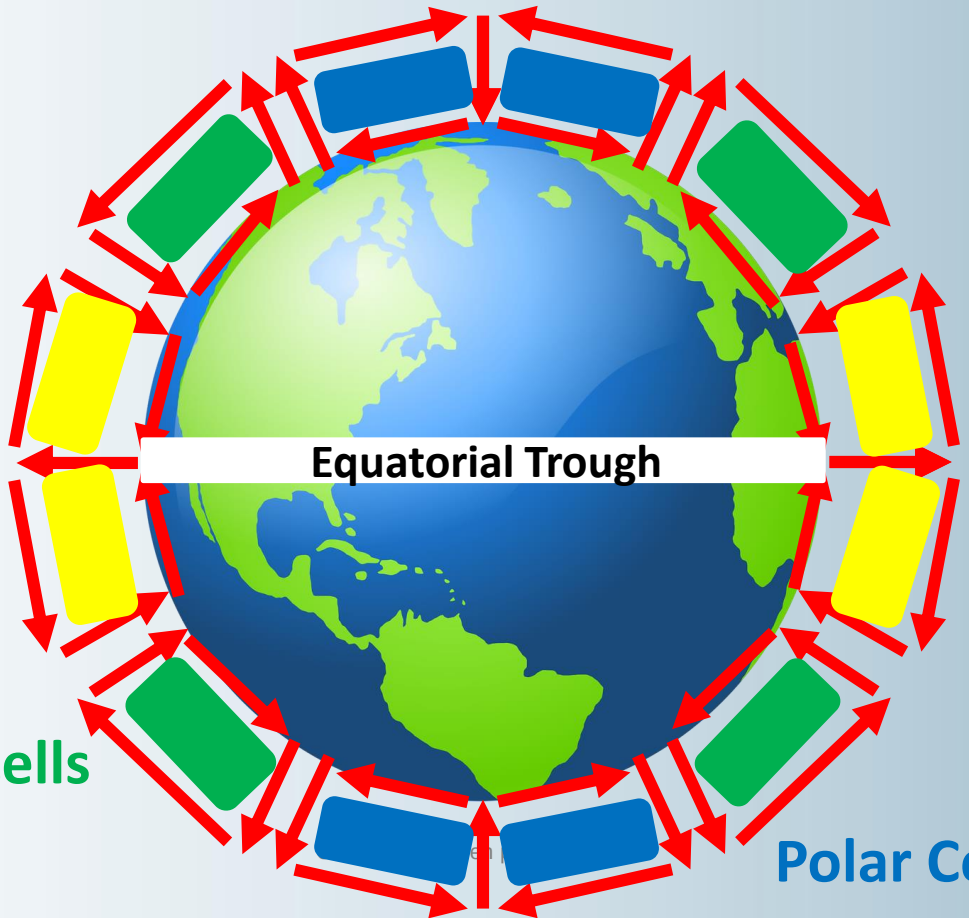
- Once the rising air reaches the tropopause, it will move horizontally back towards the poles and begin to cool and sink again

- This circulation cell is known as the **Polar Cell**



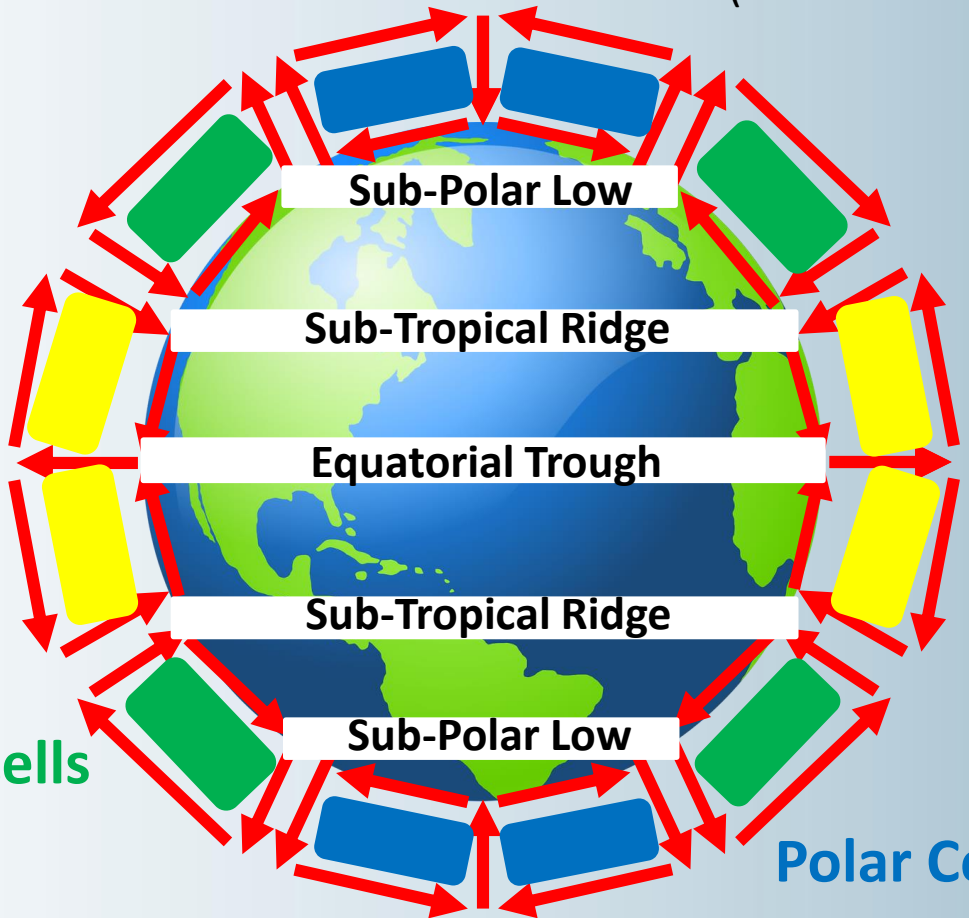
Global Circulation

- There is also a Mid-Latitude Cell
- The three cells of global circulation also give us belts of high and low pressure across the earth



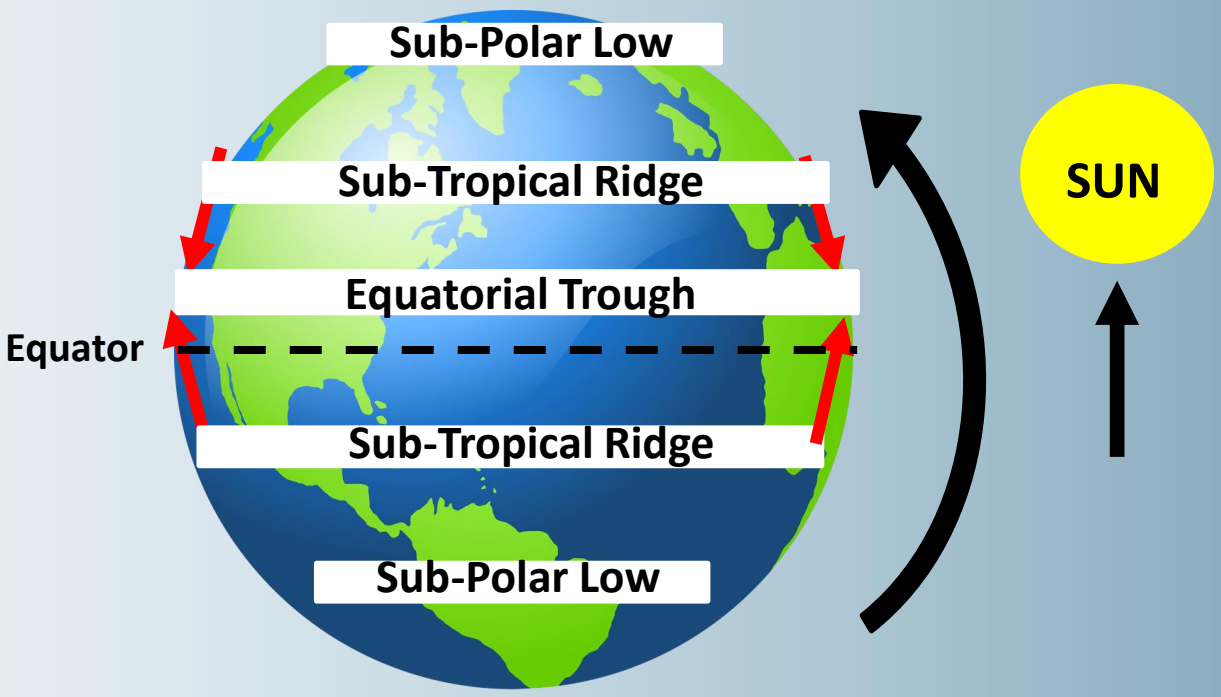
Global Circulation

- At the Equator: **Equatorial Trough** (belt of Low Pressure Systems)
- Between Hadley & Mid-Latitude Cells: **Sub-Tropical Ridge** (Anticyclones)
- Between Mid-Latitude & Polar Cells: **Sub-Polar Low** (belt of Low Pressure Systems)



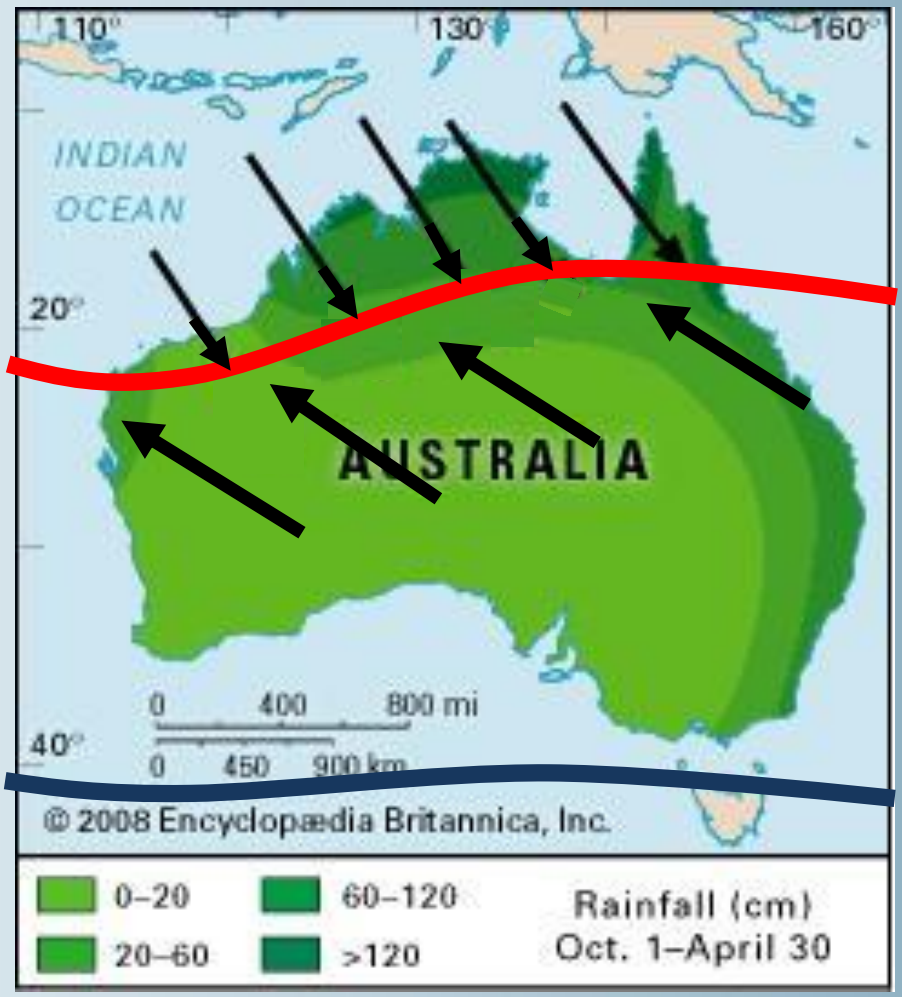
Global Circulation – Movement of cells

- Cells and associated systems will tend to 'follow the sun'
- Moves north during our winter
- Moves south during our summer
- The mean position of the equatorial trough is 5 degrees north



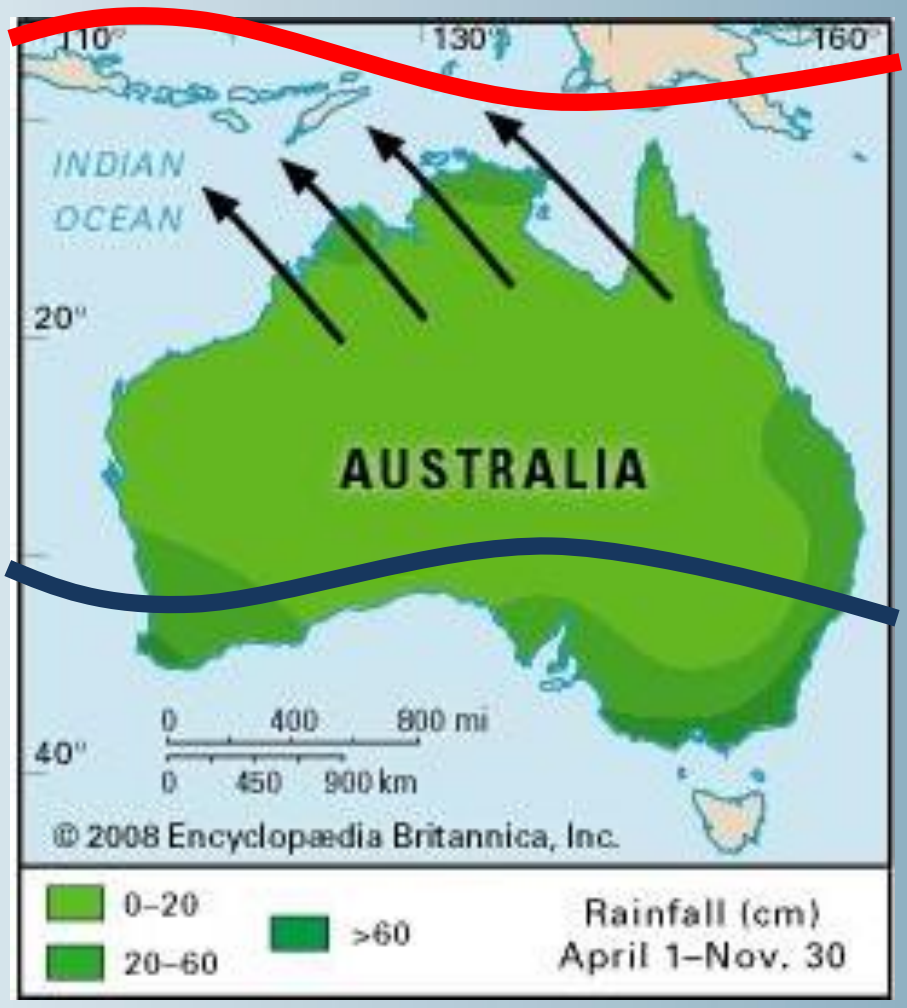
Global Circulation – North-West Monsoon

- Summer in the southern hemisphere
- The equatorial trough moves south over continental Australia
- Behind it a warm/moist north-westerly winds
- Tends to bring Cloud and heavy rainfall to northern regions (wet season) and good weather to south of the continent



Global Circulation – South-East Trade Winds

- Winter in the southern hemisphere
- The equatorial trough moves north above the equator
- Sub tropical ridge resides over the continent, bringing south easterly winds
- Tends to bring Cloud and rainfall to southern regions and dry conditions to northern Australia (dry season)



Global Circulation – Major air streams

- **Maritime**: Air flowing from a body of water
- **Continental**: Air flowing from a body of land
- **Tropical**: Air of tropical origin (low to mid latitudes)
- **Polar**: Air of polar origin (high latitudes)

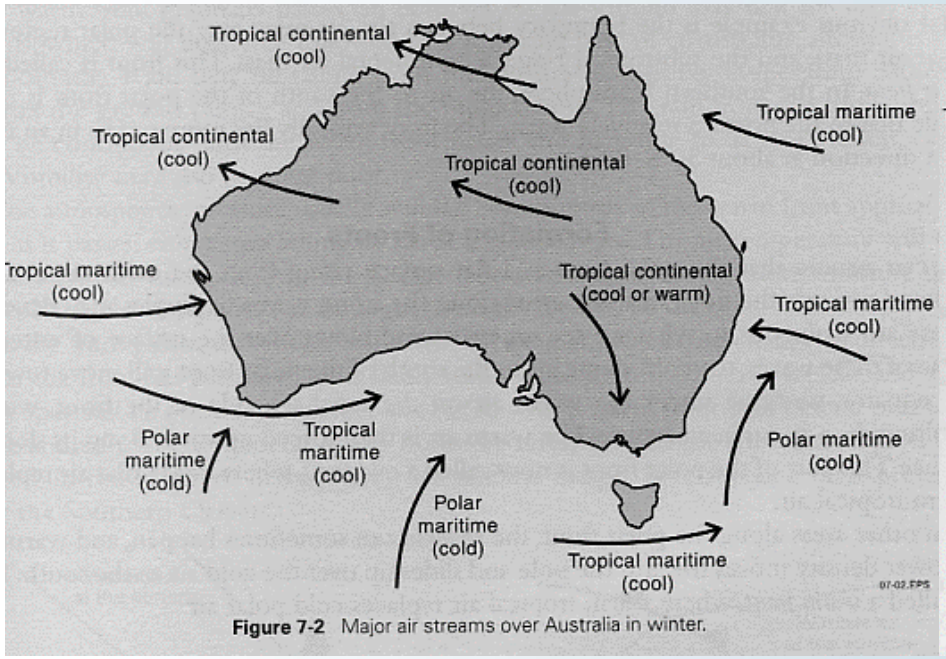


Figure 7-2 Major air streams over Australia in winter.

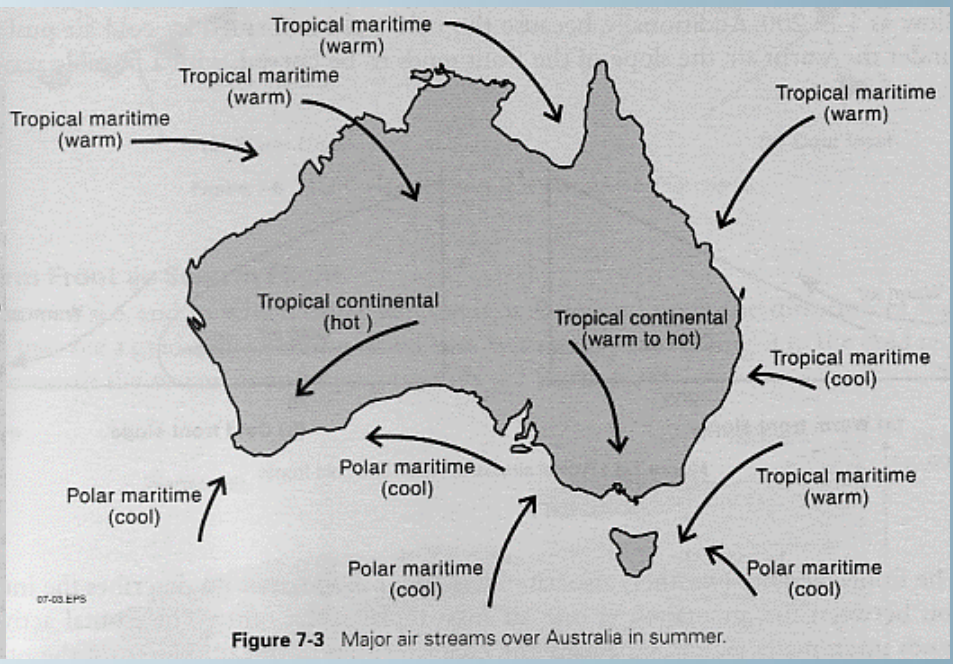
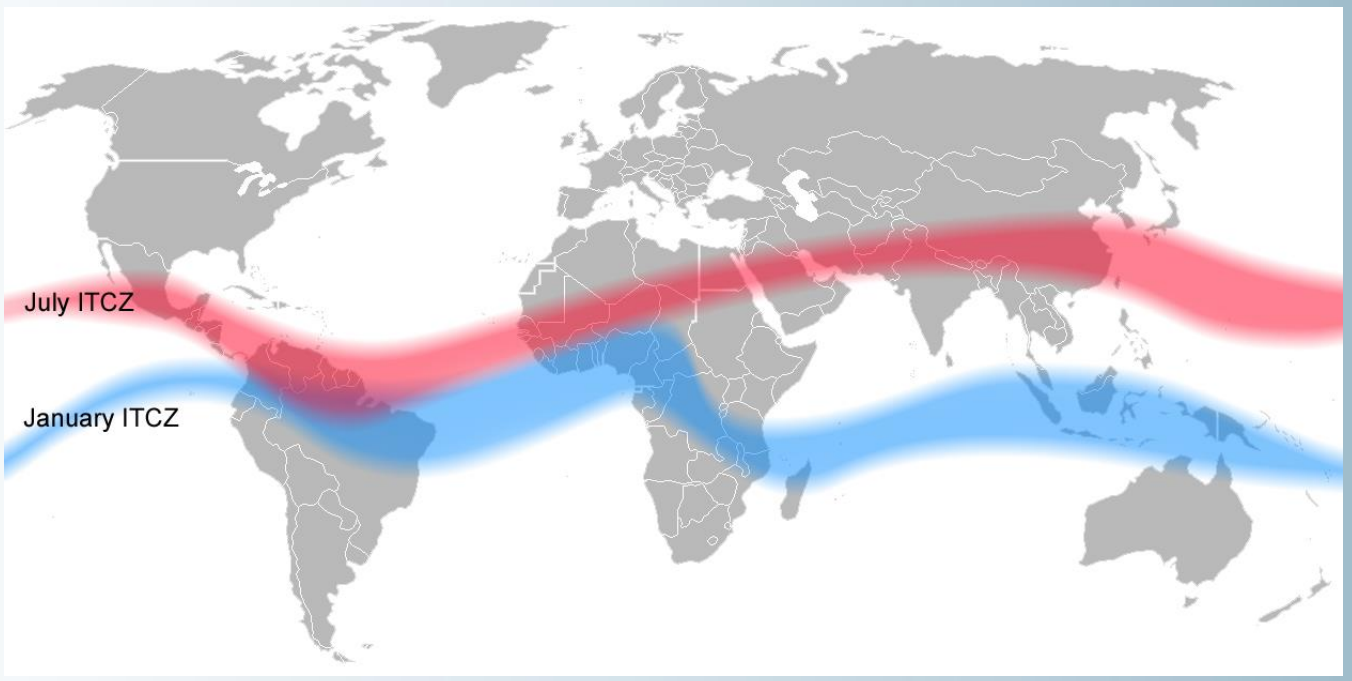


Figure 7-3 Major air streams over Australia in summer.

Global Circulation – ITCZ

Inter-tropical convergence zone (ITCZ):

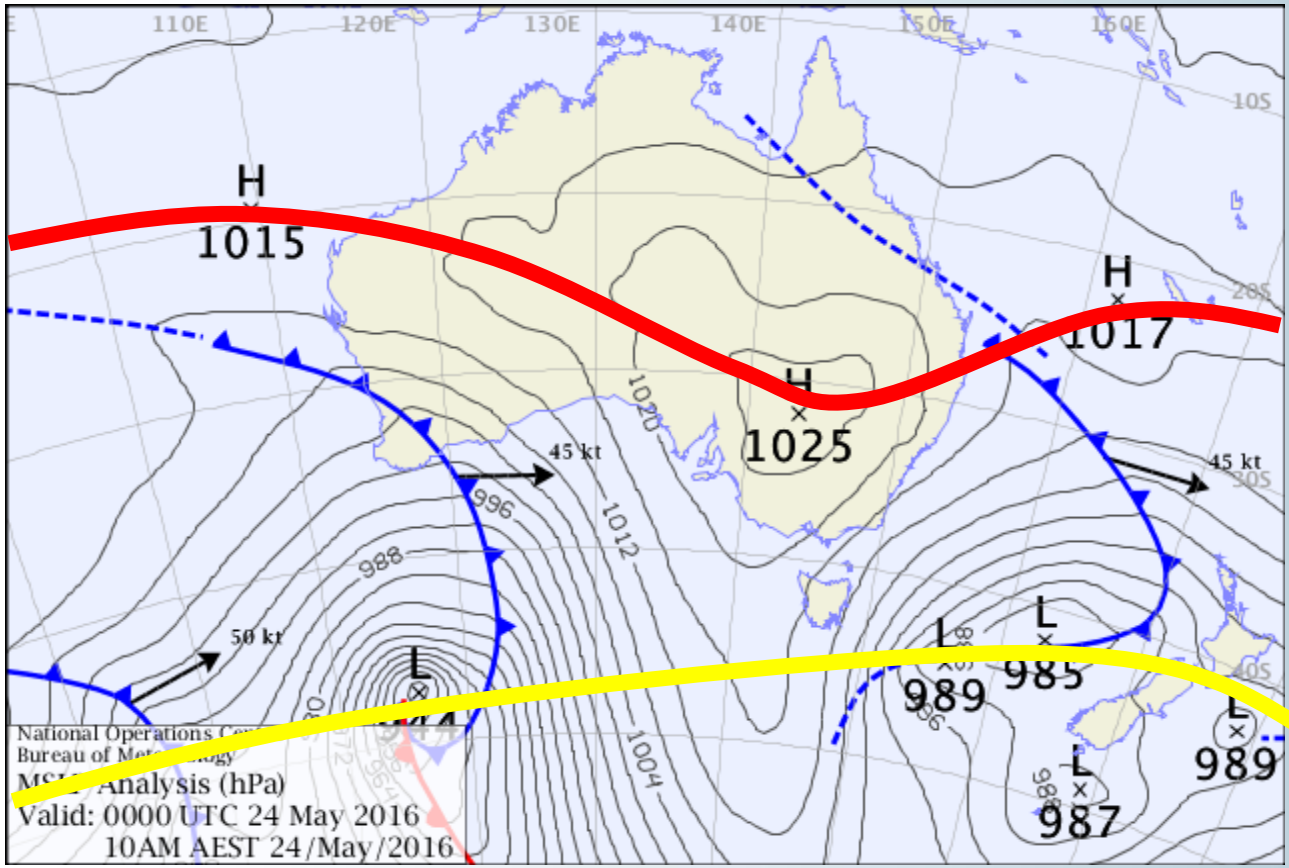
- The point where North-East trade winds and South-East trade winds **converge** together
- Also known as the **Doldrums**
- Brings **widespread convective activity** and frequent thunderstorms



SYNOPTIC CHARTS

Synoptic Charts

- Synoptic Charts, also known as MSL Analysis Charts, depict pressure systems



Sub-Tropical Ridge

Sub-Polar Low

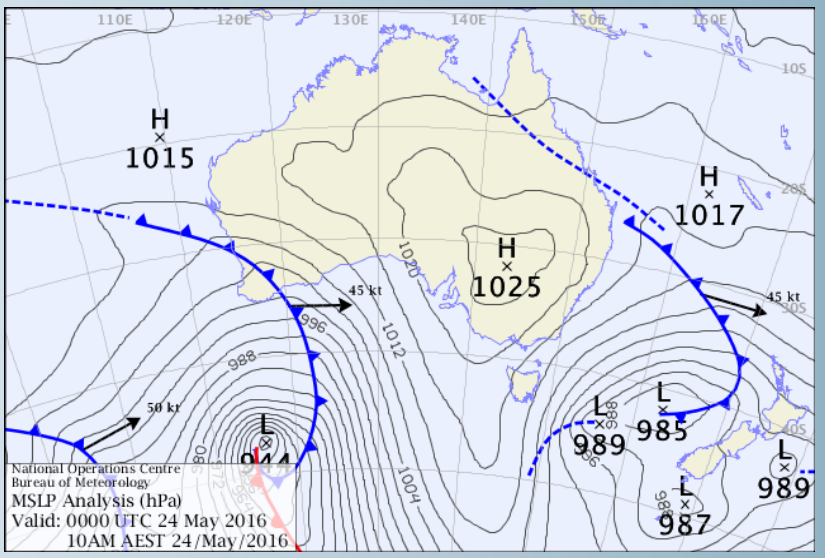
- Note that this Synoptic Chart is from the winter season
- In Summer, the Sub-Tropical Ridge would move further south, keeping the ugly weather associated with Low Pressure Systems/Cold Fronts well south of the country

Synoptic Charts

- Also sometimes called a Mean Sea Level prognosis/chart (MSLP)

Important notes:

- Isobar spacing is generally 2 or 4 hPa (4hPa is more common)
- Fronts extend from low pressure systems
- Troughs and ridges are marked by either broken or solid lines



PRESSURE SYSTEMS

Pressure Systems – Low (Depression)

- The centre of a Low Pressure System is surrounded on all sides by higher pressure
- They are usually caused by surface heating to commence the ascension of air
- Flow is clockwise in the Southern Hemisphere and the Pressure System itself will move from West to East across the country
- Winds are generally strong and the weather is usually ugly:

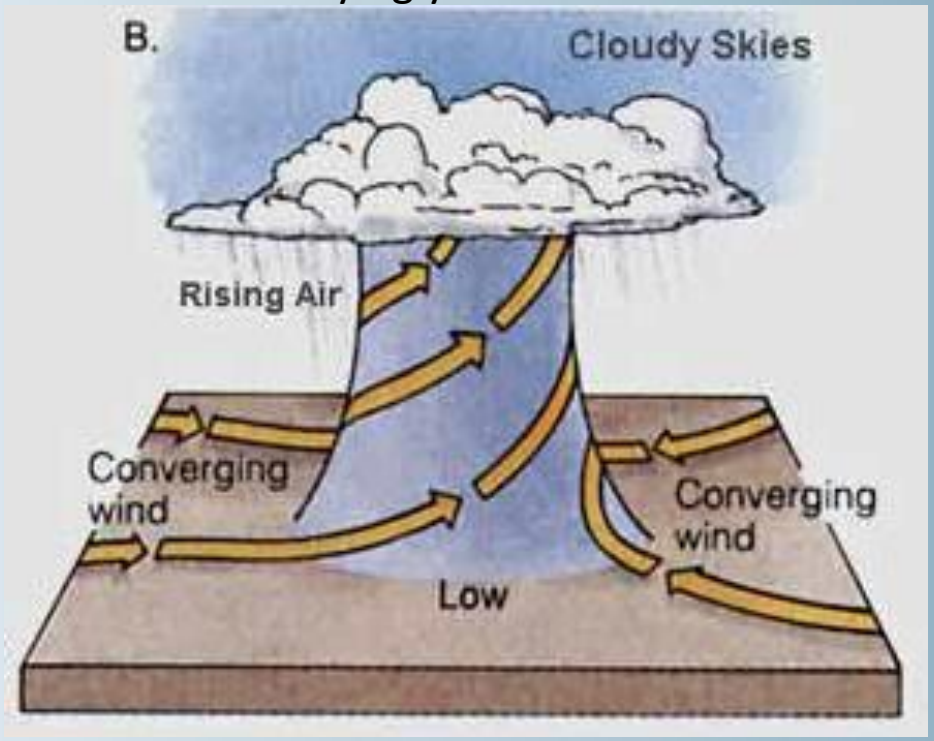
1. Low cloud

2. Poor visibility

3. Rain/snow/fog

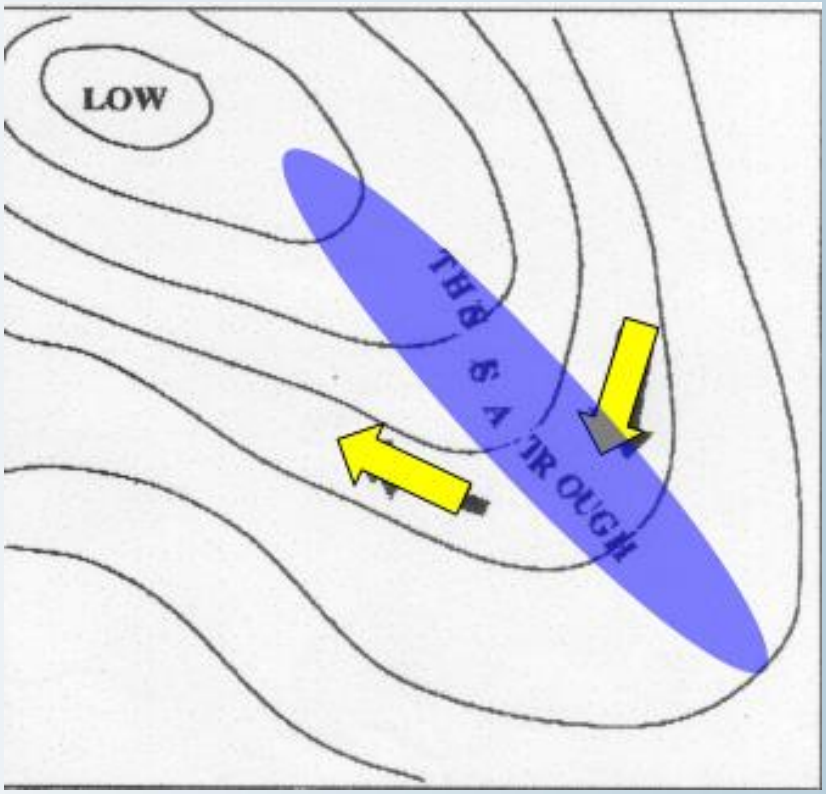
4. Strong, gusty winds

5. Turbulence



Pressure Systems – Trough

- An elongated area of relatively low pressure
- Usually extended outwards from a Low Pressure System
- Weather is frequently violent along a trough



Pressure Systems – High (Anticyclone)

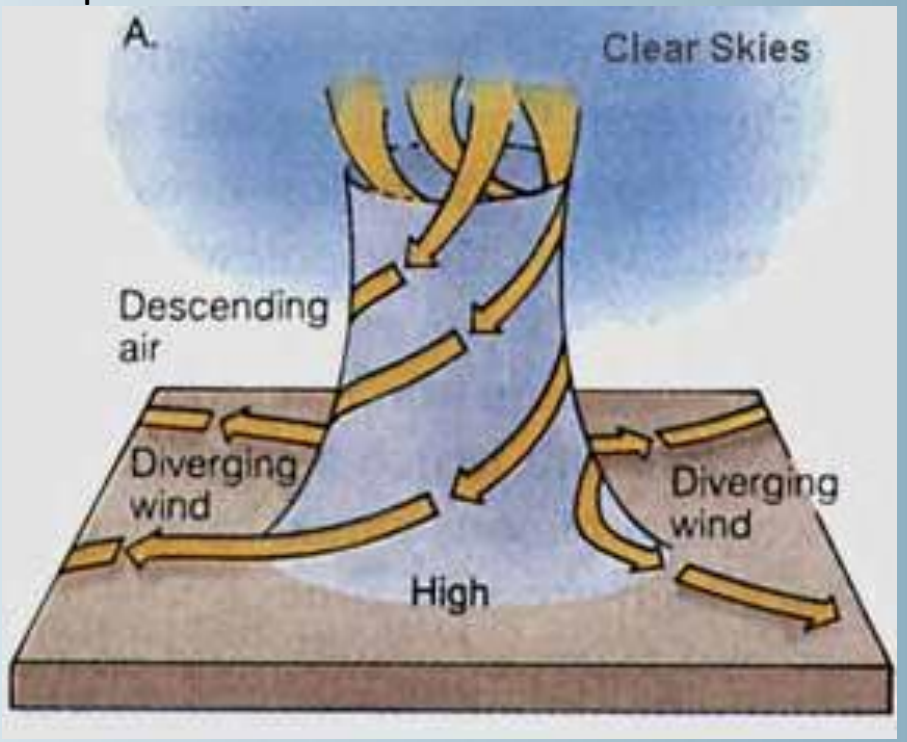
- The centre of a High Pressure System is surrounded on all sides by lower pressure
- They are usually caused by cold air subsiding
- Flow is anti-clockwise in the Southern Hemisphere and the Pressure System itself will move from West to East across the country
- Highs are actually the dominant system and predominate over cold surfaces
- Associated weather includes:

1. Light and variable winds

2. Cloudless weather

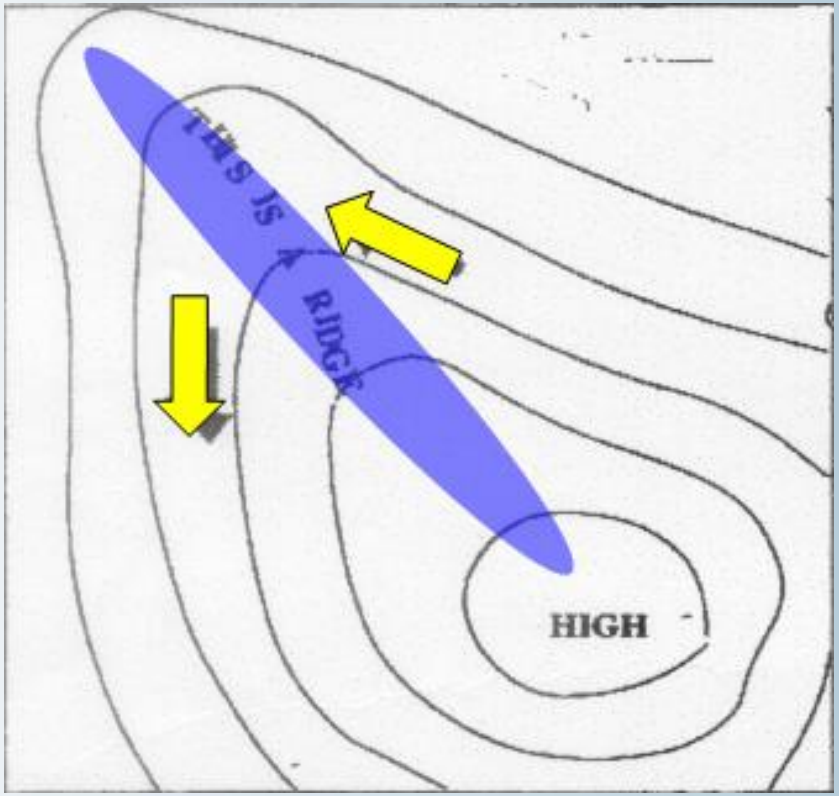
3. High temperatures

4. Visibility may be reduced by haze and fog



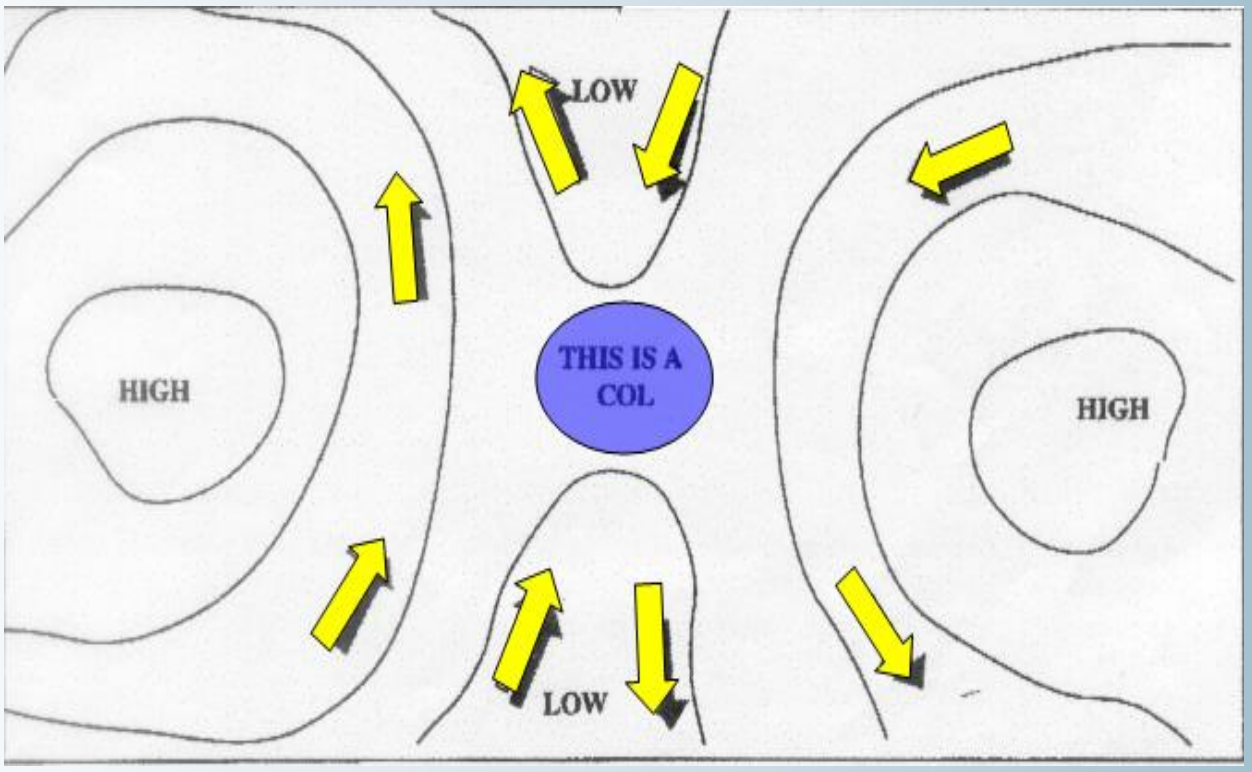
Pressure Systems – Ridge

- An elongated area of relatively high pressure
- Usually extends outwards from a High Pressure System
- Generally favourable flying weather will prevail



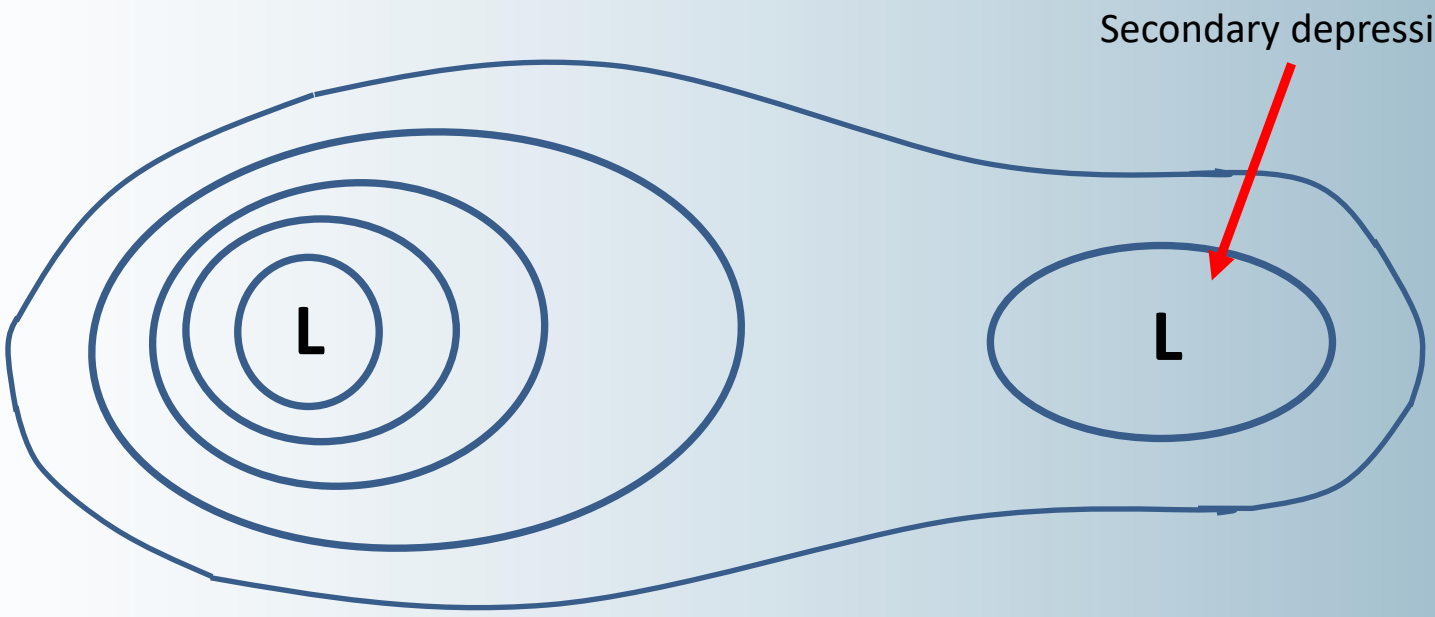
Pressure Systems – Col

- A neutral area that exists between two highs and two lows
- The wind is light and variable
- Easily displaced by other pressure systems – the weather is likely to change quickly!



Pressure Systems – Secondary depression

- A secondary low/depression may sometimes form when a trough extends from a deep depression



FRONTS

Fronts

- Simply defined as **"the boundary between two air masses"**

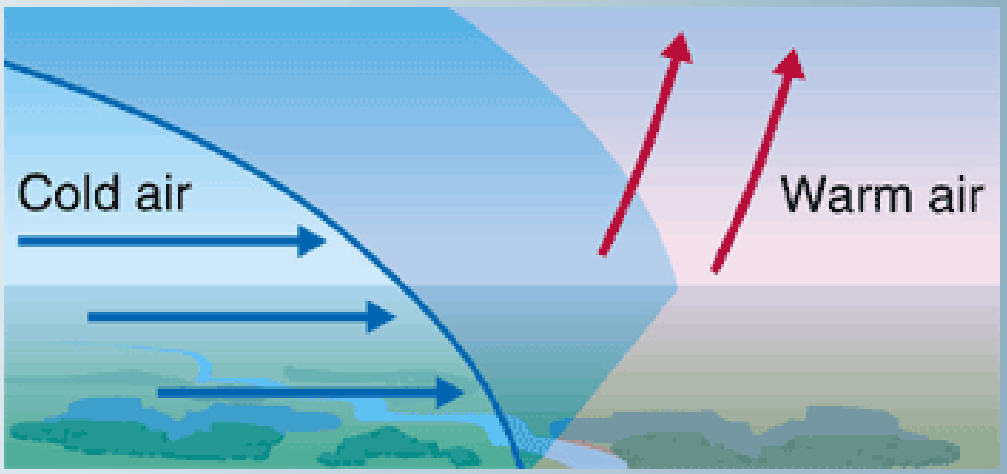
- With the passage of a front, cold or warm, you will notice:

1. A change in temperature

2. A change in pressure

3. A change in wind

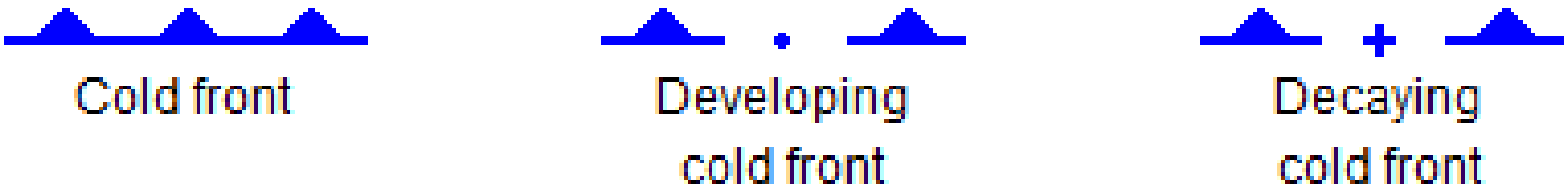
4. A change in weather



e.g. When a cold air mass moves into an area of relatively warm air, the boundary between the two air masses is known as a "Cold Front"

Cold Front

- Cold Fronts occur when a cold air mass slides underneath a warmer air mass
- They originate from a **Low Pressure System**
- They are usually orientated NW/SE and move East or South East
- They can be classified as either **slow moving or fast moving**:
    1. Fast fronts can move up to 50 knots
    2. Normal speed is around 25-35 knots
- **Fast-moving Cold Fronts are more violent**, often carrying turbulence and thunderstorms which may appear as **Squall Lines** 50-300nm ahead of the front



Cold Front

- With the **approach** of a cold front, the following will occur as the front nears:

  1. Cirrus cloud forming

  2. Wind north-westerly and backing and strengthening

  3. Temperature increasing

  4. Barometric pressure falling

  5. Cu and possible Cb forming

- With the **passage** of a cold front, the following will occur:

  1. A fall in temperature

  2. A backing of the wind to south-west

  3. A rise in pressure

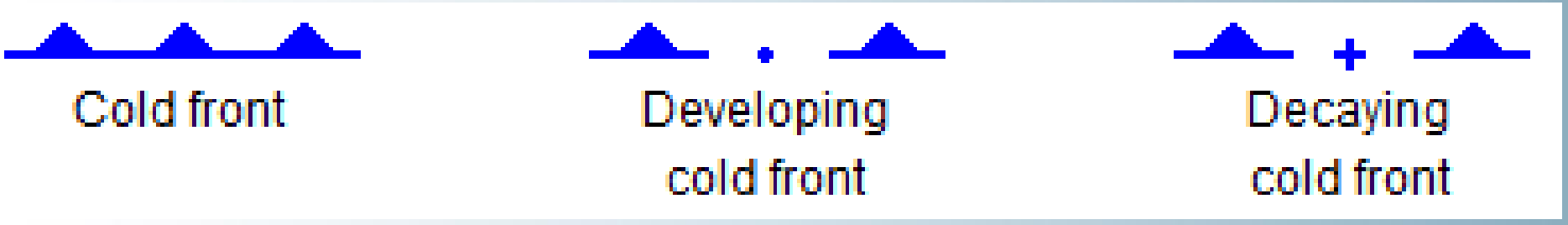
  4. Possible TS and squalls

  5. Low cloud

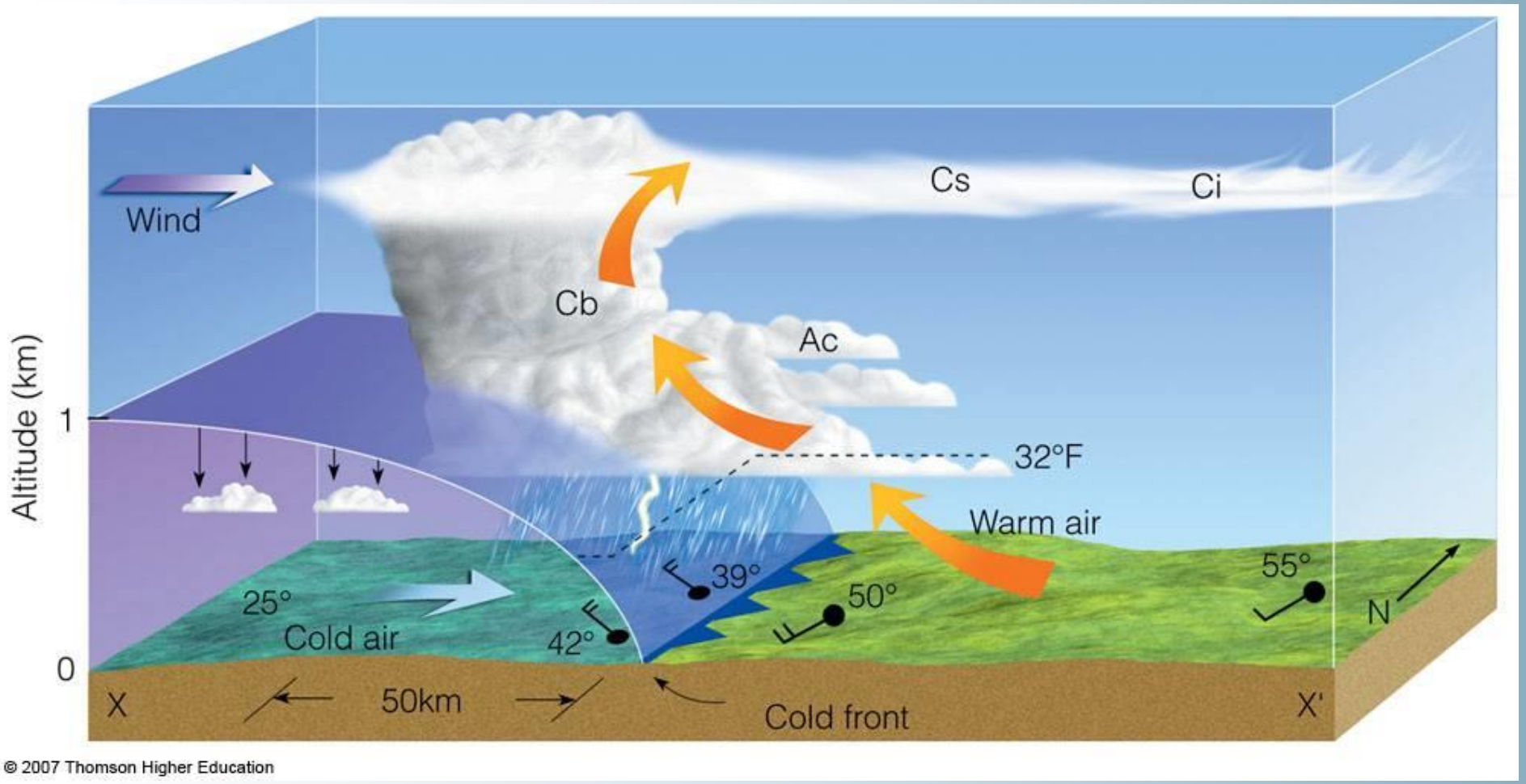
Cold Front

- Clouds normally associated with a cold front include:

1. **Cirrostratus**
2. **Altostratus**
3. **Altocumulus**
4. **Cumulus (behind the front)**
5. **Cumulonimbus**

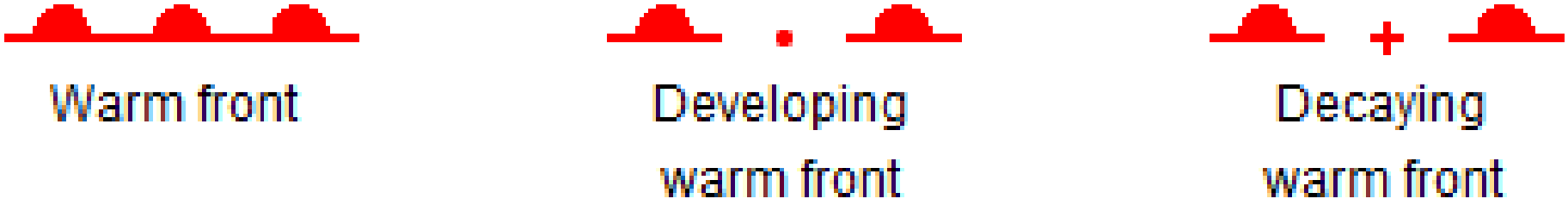


Cold Front



Warm Front

- Warm Fronts occur when a warm air mass slides up and over a cooler air mass
- They also originate from a **Low Pressure System**
- The speed of warm fronts are about half that of cold fronts (15 knots or less)
- Rarely seen in Australia – often seen to the south of the continent on a synoptic chart



Warm Front

- With the **approach** of a warm front, the following will occur:

  1. Cloud developing well ahead, thickening and lowering

  2. wind from north-east

  3. barometric pressure falling

  4. Rain beginning 150nm ahead of surface position

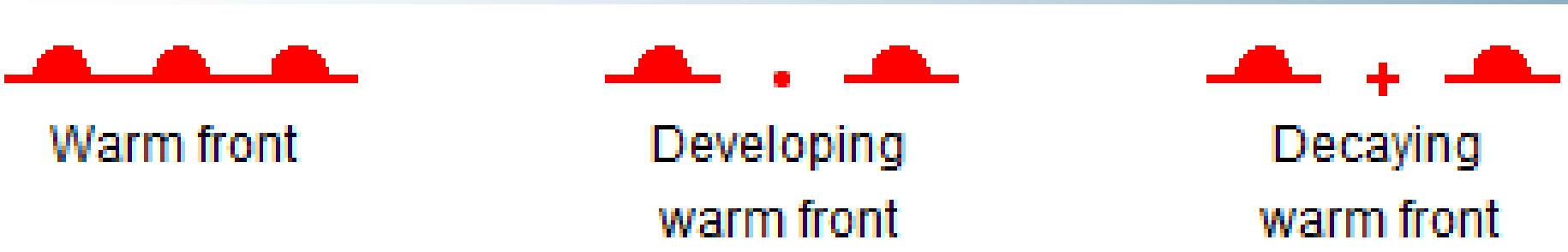
- With the **passage** of a Warm Front, the following will occur:

  1. A rise in temperature

  2. A backing of the wind

  3. The fall in pressure will decrease

- Clouds normally associated with a warm front include:
  1. **Cirrus and Cirrostratus at the beginning of the front (high altitude)**
  2. **Altostratus as the front approaches**
  3. **Nimbostratus as the surface front passes through (heavy continuous rain)**
  4. **May clear rapidly into nil significant weather**



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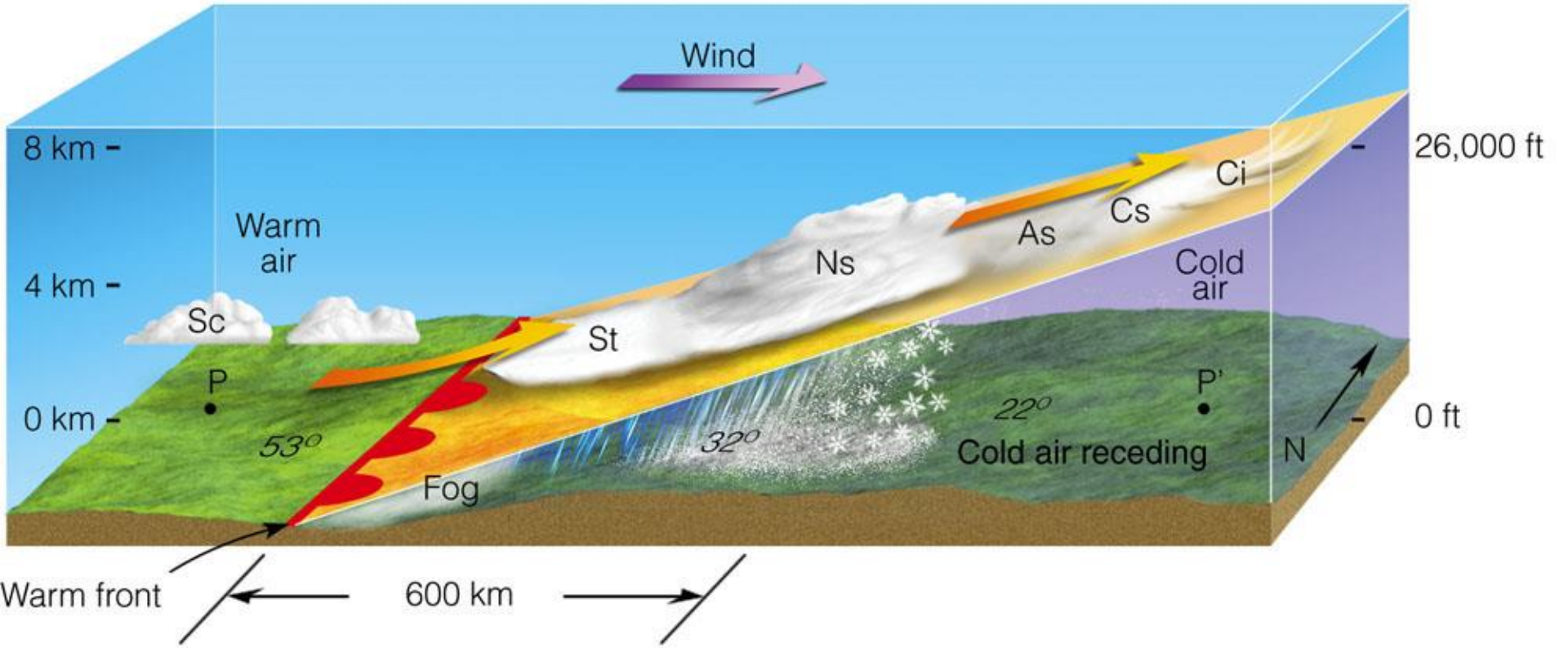
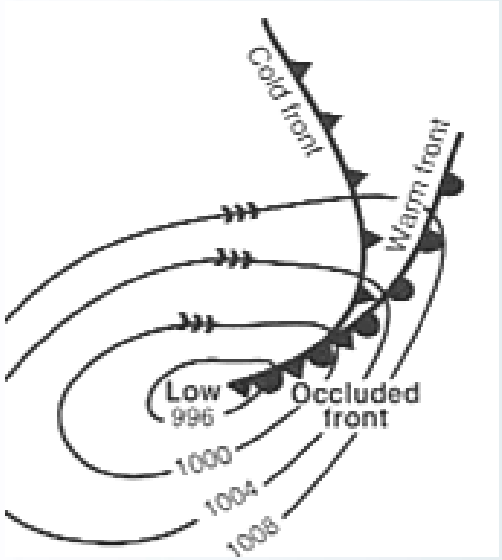
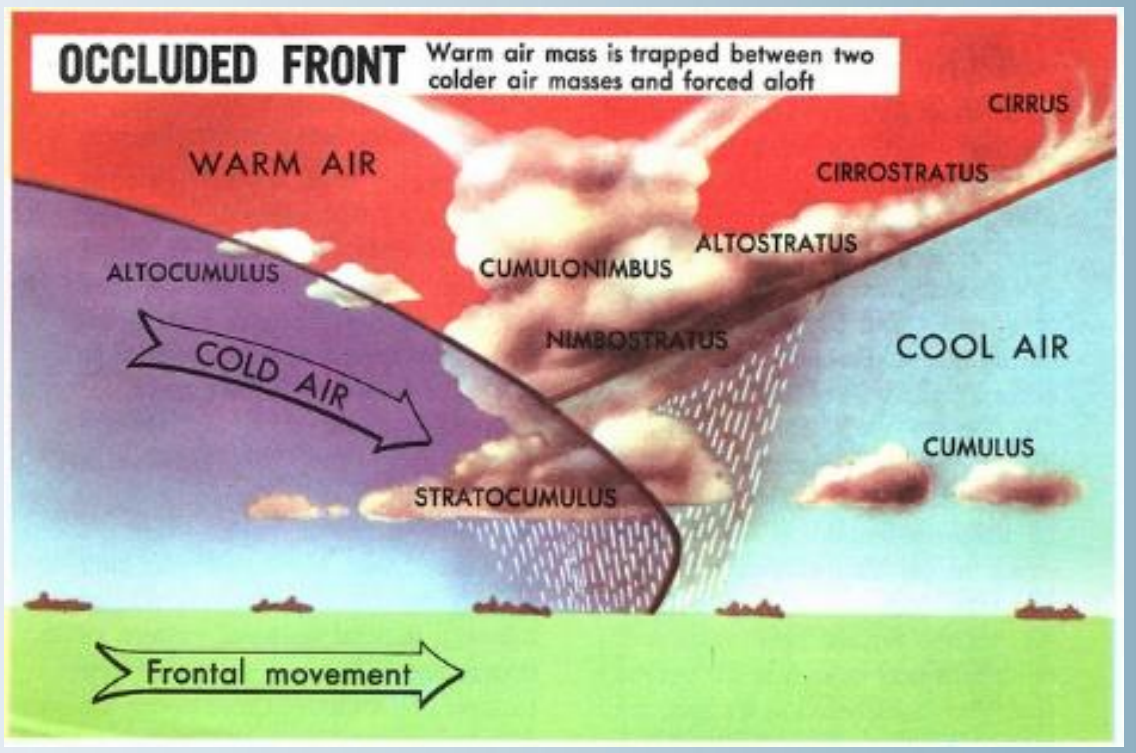


Occluded front

- When a cold front moves faster than a warm front ahead of it, the cold front will eventually overtake the warm front

- The cloud types will be dependent upon that originally associated with the cold or warm front

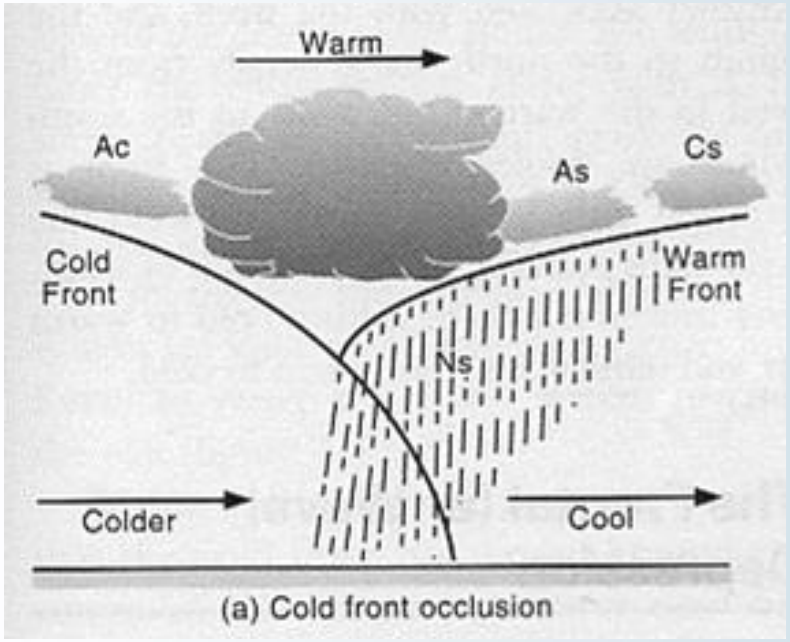




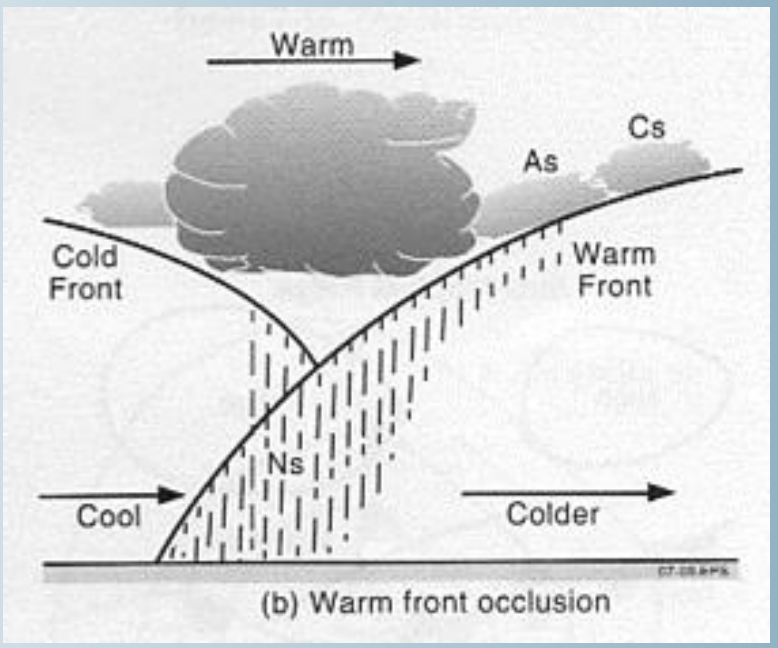
Occluded front

- **Cold front occlusion** is where the **coldest air** is undercutting the **warm front and the cool air** ahead of it

- **Warm front occlusion** is where **cool air** is undercutting a warm front, but is sliding over the **coldest air ahead of the warm front**



(a) Cold front occlusion



(b) Warm front occlusion

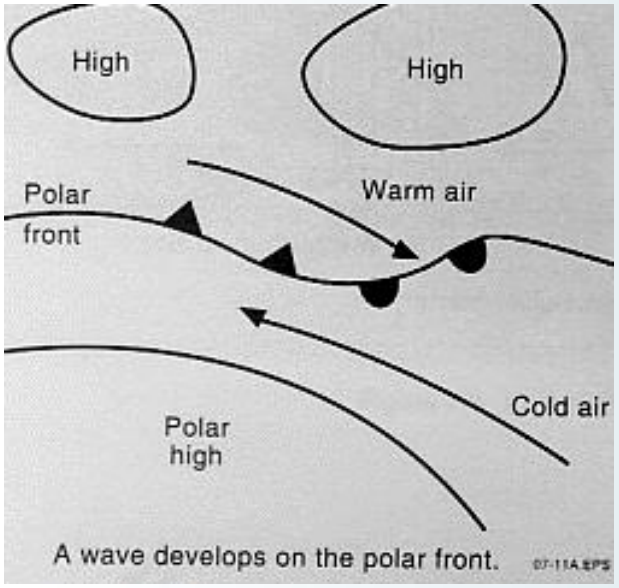
Quasi-Stationary front

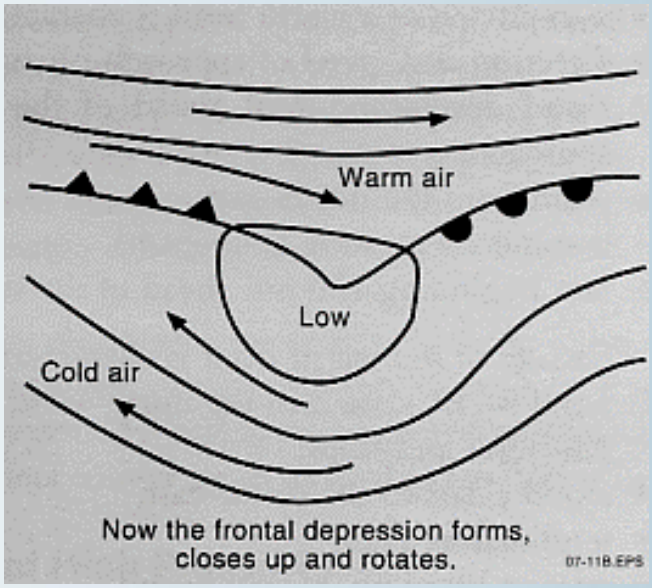
Quasi-Stationary Front:

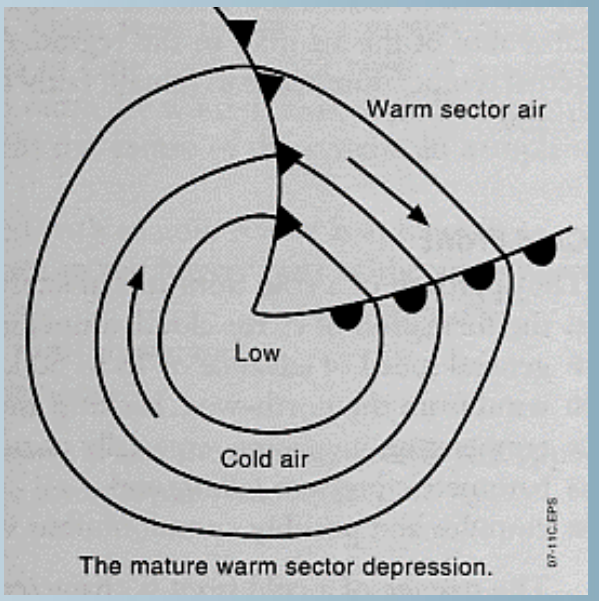
- When a front has little or no movement it is referred to as stationary or quasi-stationary
- The surface winds tend to blow parallel to the front
- Weather is comparable with that of a Warm Front, but usually less intense

Frontal (wave) depression

- Cold air pushes northwards while warm air pushes southwards
- Cold air (front) moves faster and begins to catch up to the warm from
- Cold air undercutting the warm air causes the warm air to rise, generating a low pressure at the surface
- Eventually a low (depression) develops with a warm sector







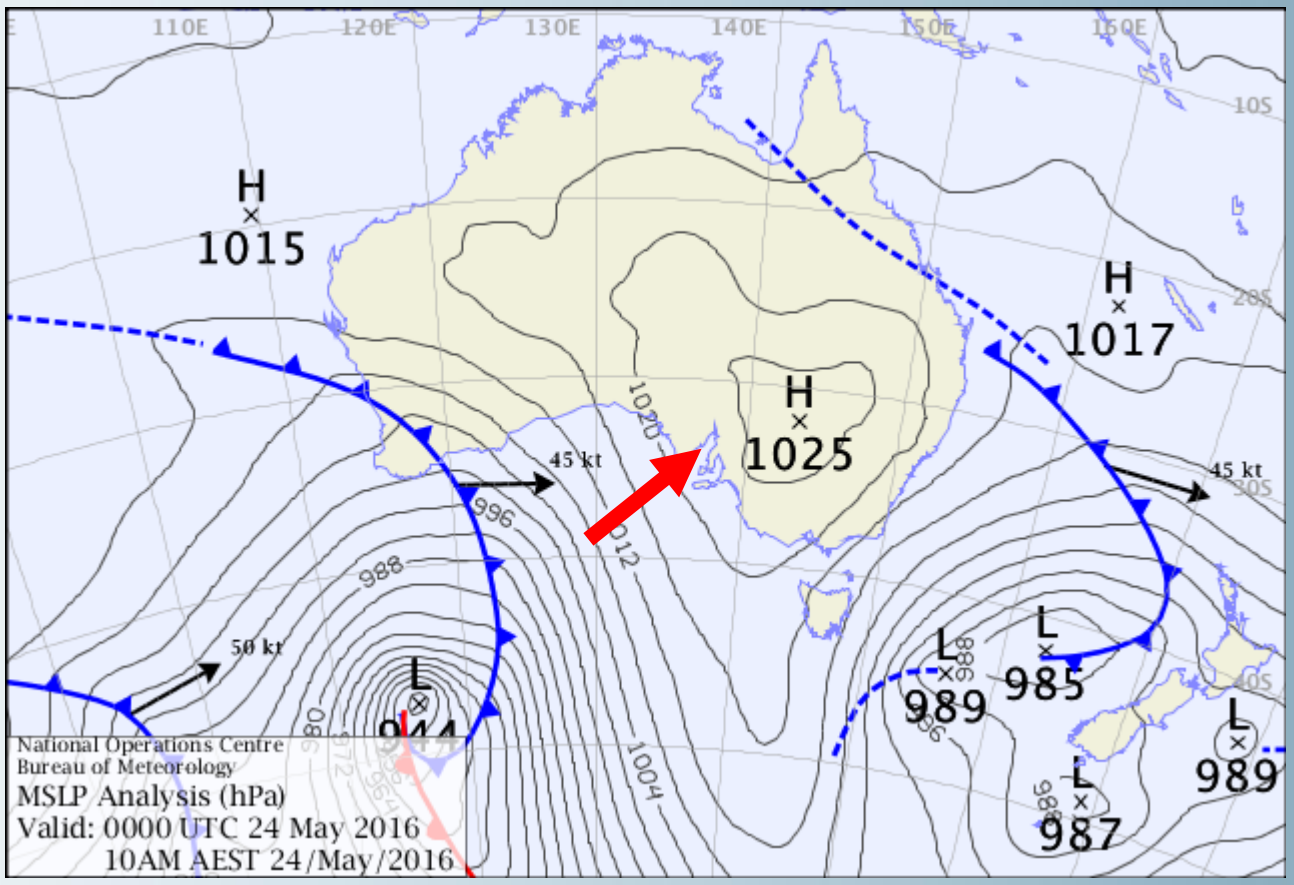
WIND DIRECTION ON A SYNOPTIC CHART

Wind Direction on a Synoptic Chart

e.g. What is the wind direction in Adelaide?

Answer:

- Nearest system is a High
- Flow around a High is Anti-Clockwise
- Follow isobars until Adelaide is reached
- Wind Direction approx. 350°



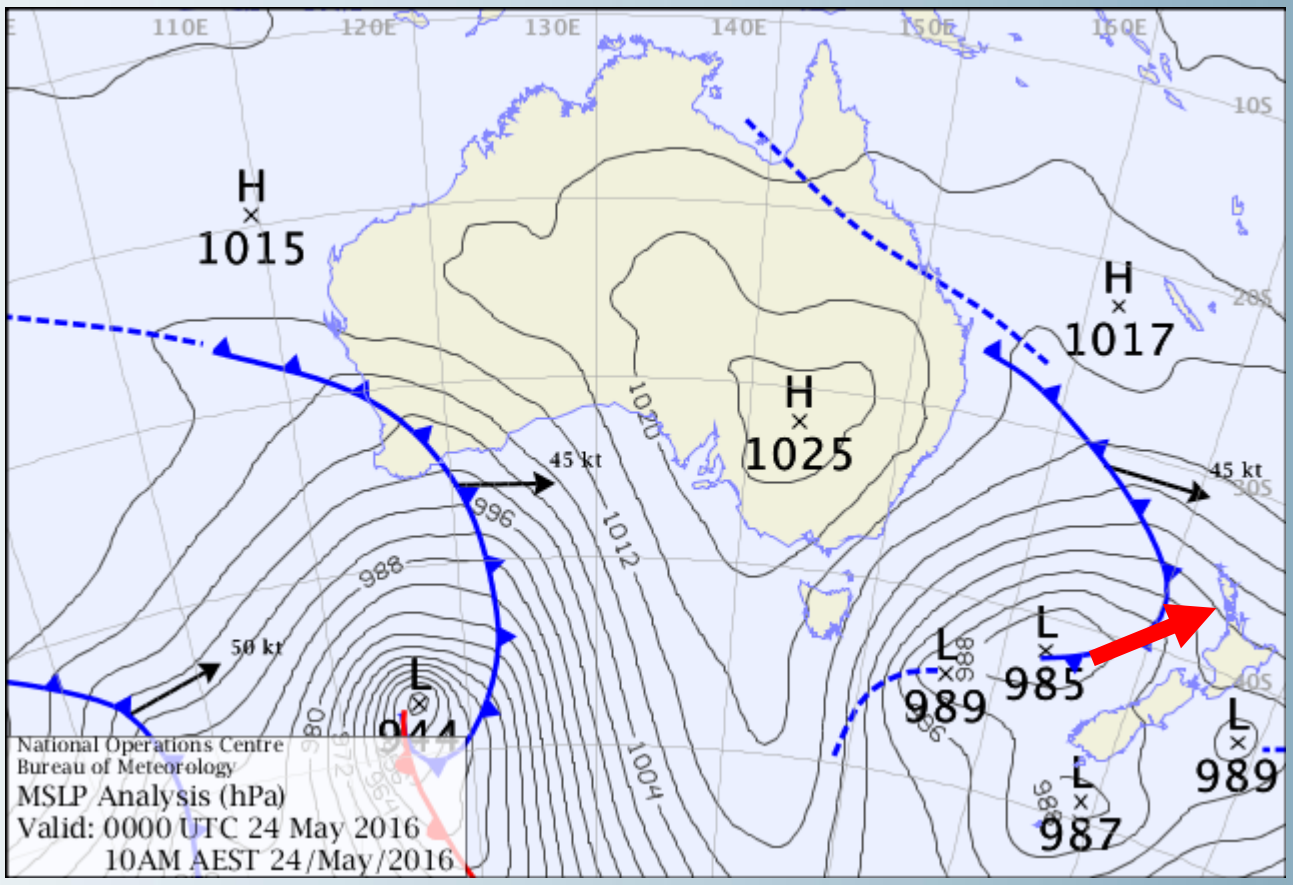
- Wind Strength can be determined from the spacing of the isobars

Wind Direction on a Synoptic Chart

e.g. What is the wind direction in Auckland?

Answer:

- Nearest system is a Low
- Flow around a Low is Clockwise
- Follow isobars until Auckland is reached
- Wind Direction approx. 300°

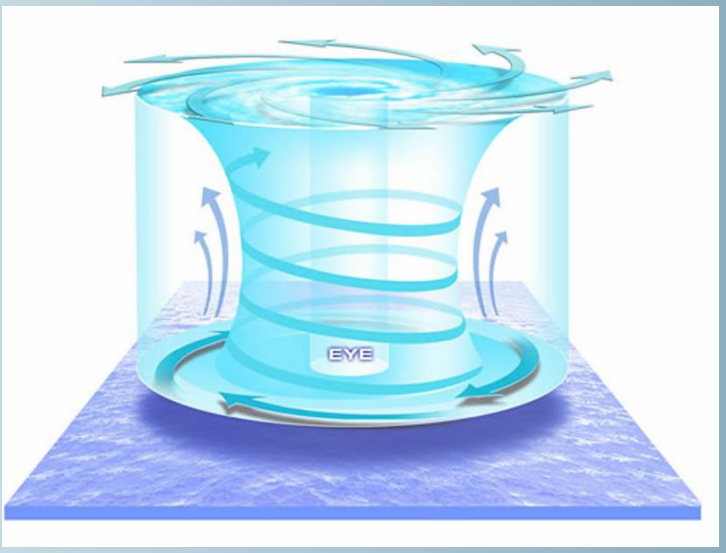


- Wind Strength can be determine from the spacing of the isobars

Tropical Cyclones

Cyclones - characteristics

- Tropical cyclones are by far the most destructive of the larger-scale storms in the world.
- They have established several records for low pressures, high winds and heavy rainfalls.
- **Where do they form?**
  - Tropical cyclones breed over the **warm tropical oceans where sea-surface temperatures are above about 28 degrees Celsius**.
  - **Typically within the 5 to 15 degrees latitude band** (within 5 degrees of the equator there Coriolis force is too weak)
- Warm waters are critical because the cyclones are powered by the release of latent heat from the condensation of water vapour in the atmosphere. **This is their power source!**

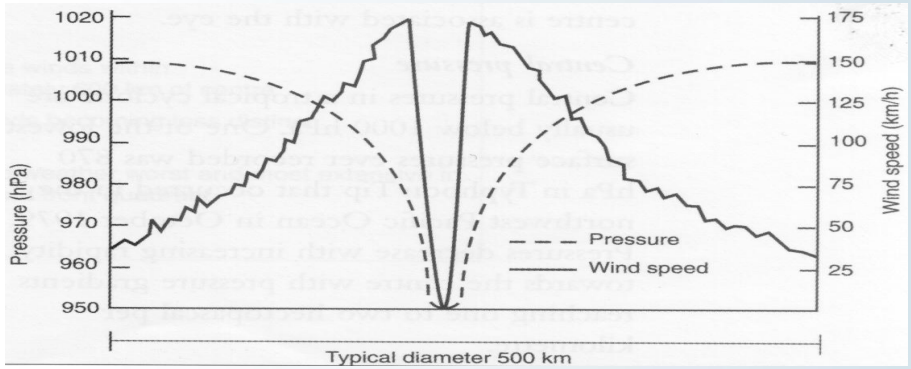


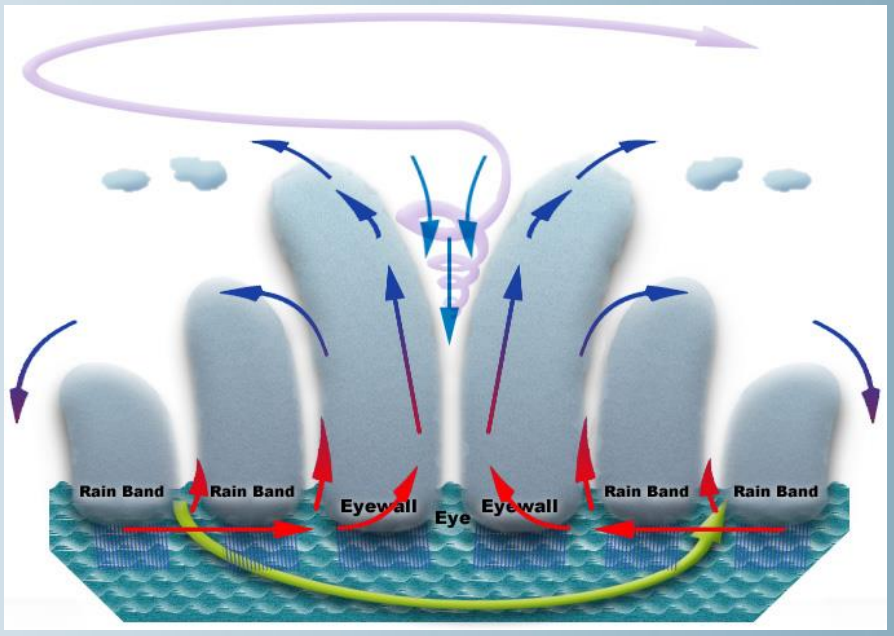
Cyclones - characteristics

- A typical well-developed tropical cyclone consists of a more or less circulation area of hurricane winds (over 63 kts), around 80km in radius.
- Outside this area the wind force decreases fairly rapidly.
- The cyclone eye develops in the middle of these spiralling winds and is surrounded by a spectacular wall of cloud extending in a steep slope to the upper rim at an altitude of 32,000ft or more.

Cyclones - characteristics

- Outside the wall cloud is the maximum speed ring, where the winds may exceed 300 km/h and towering cumulonimbus clouds produce torrential rain and thunder activity.
- The winds and associated rain are best developed in the forward quadrants of the cyclone.
- The rain areas can often be detected by radar and are known as spiral rain bands.





Cyclones - Formation

- A cyclone starts as a tropical disturbance, and requires the Coriolis force to develop the balance circulation flow.

- **Therefore where will a Tropical Cyclone form?**
- Outside 5 degrees of the equator. **Typically within the 5 to 15 degrees latitude band**.

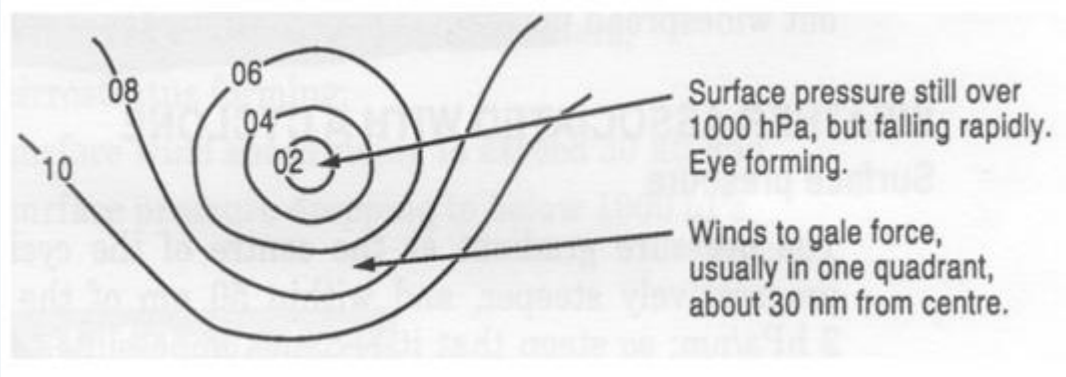
- Once the circulation starts, it results in a strong surface convergence which triggers the formation of deeply unstable cloud.

- When the cyclonic circulation is established, it will be categorised as a tropical depression.

- Tropical cyclones only last on average, about six days before they either cross inland and lose their strength, or enter sub-tropical latitudes.

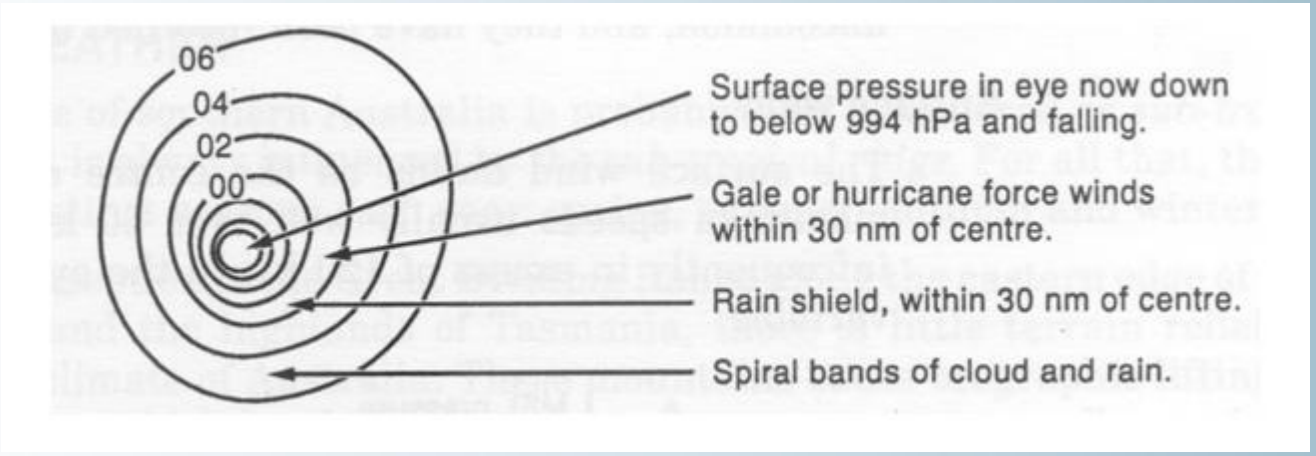
Cyclones - Formative stage

- Tropical cyclones form in pre-existing disturbances.
- Deepening to a pressure near 1000 Hpa may take days or only a few hours. Winds reach gale force, usually in one quadrant only, and the eye forms.



Cyclones - Developing stage

- This is reached when the central pressure **falls below about 1000Hpa**.
- Winds reach hurricane force (**64 kt** or more), and spiral bands are formed.
- The area affected is small and the hurricane force winds may only blow within a 30 to 50 km radius.
- The **surface pressure continues to fall**.

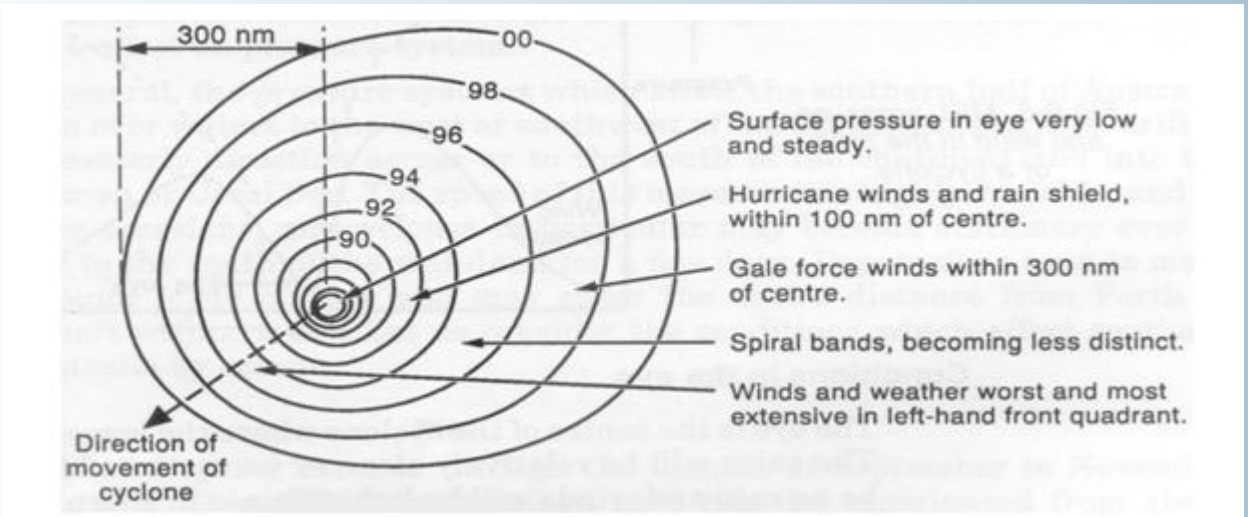


- The cyclone may sometimes die within 24 hours of this stage.

Cyclones - Mature stage

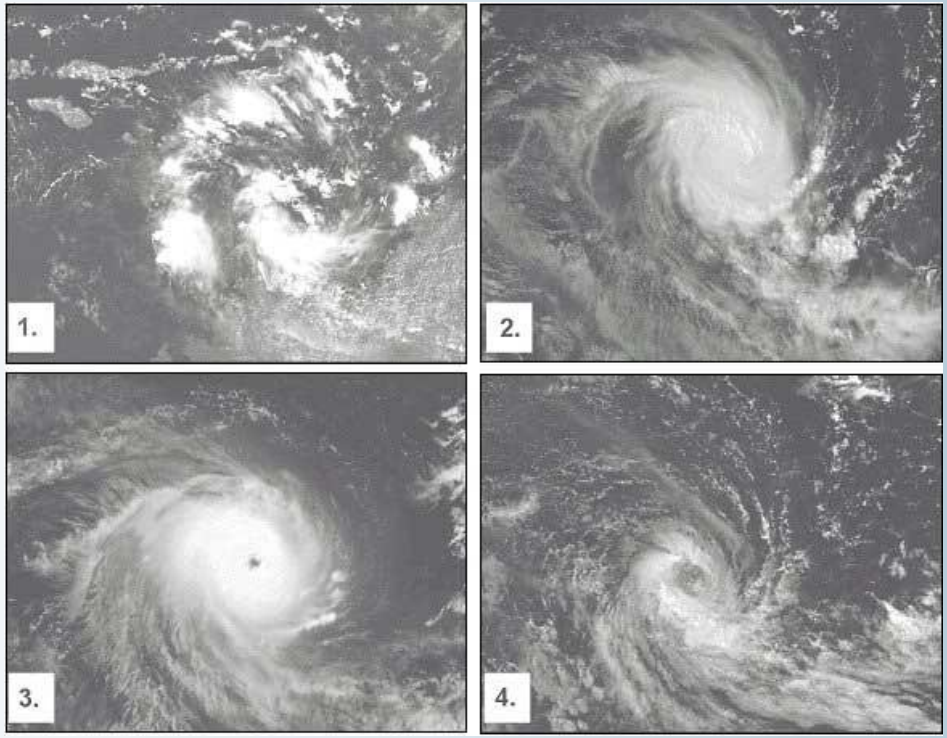
- During the mature stage, the **central pressure stops falling**, having reached a low of something like 950 hPa in the eye.

- The hurricane force winds and bad weather now extend out to some 150 nm from the centre, with the **strongest winds being in the left forward quadrant**.



Cyclones - Decaying stage

- At the decaying stage, central pressure rises, and the areas affected by the system decreases in size.
- In many cases, the cyclone dissipates over the land, or more commonly it moves to higher latitudes and becomes a sub-tropical depression of considerable intensity.
- The winds decrease in strength, but widespread flood-rains may continue for several days.

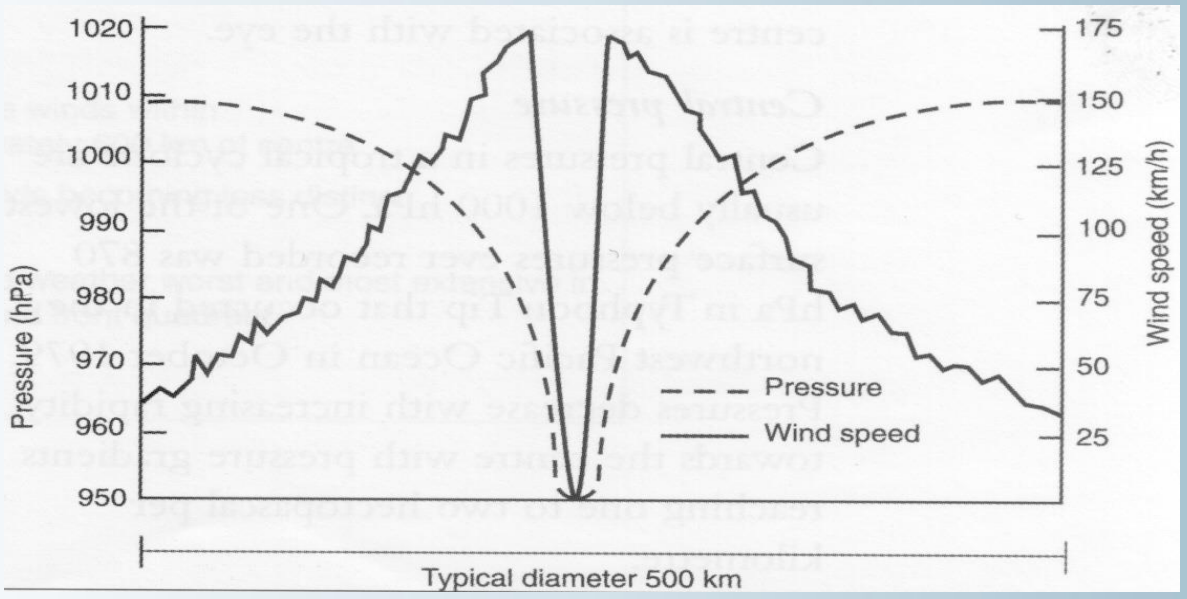


Cyclones - Associated weather

Surface Pressure

- The pressure gradient as the centre of the cyclone approaches becomes progressively steeper, and within 50 nm of the eye, can be as steep as 2 hPa/nm; so steep that is becomes impossible to plot all the isobars on a surface weather chart.

- Surface pressure in the eye of 950 hPa are not uncommon, and they have been recorded below 900 hPa.

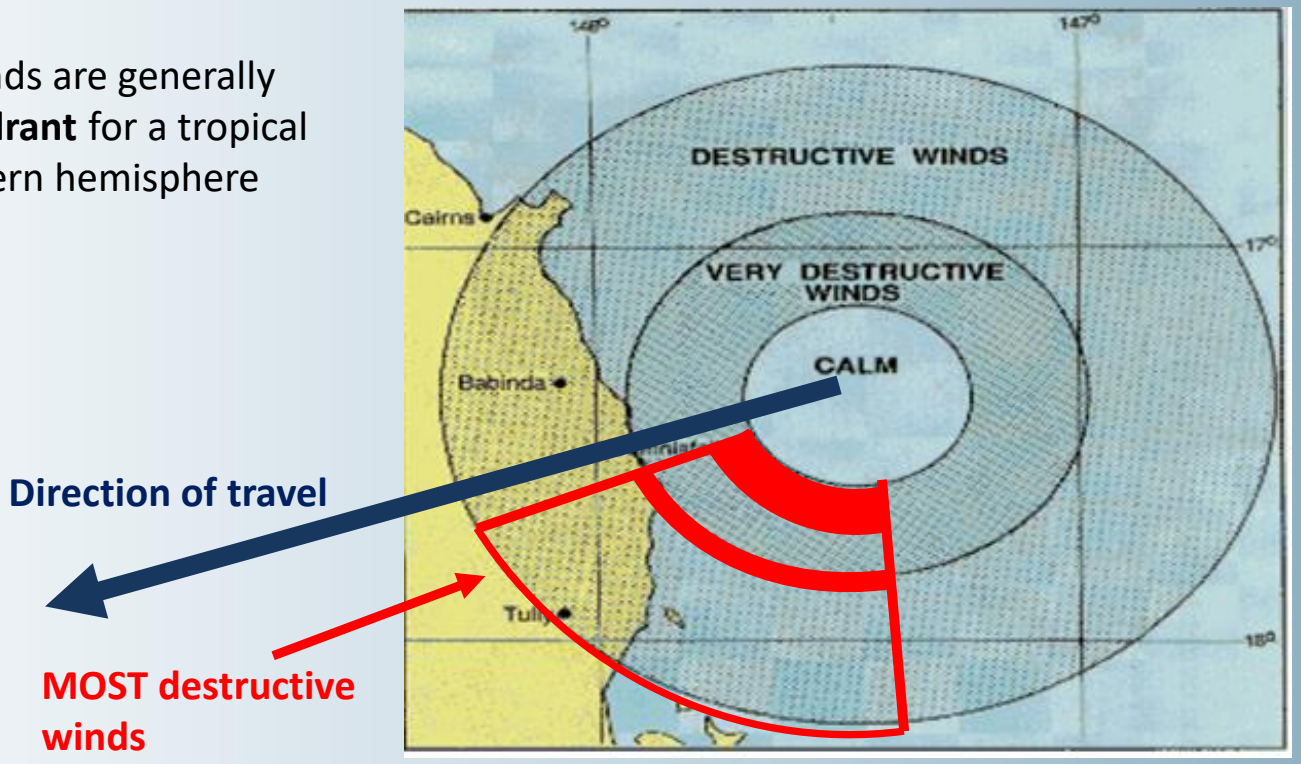


Cyclones - Associated weather

Surface Wind

- The surface wind builds as the centre of the system approaches , with maximum speeds usually well over 60 kt in the mature stage, and not infrequently in excess of 120 kts. **In the eye itself, winds become light and variable**.

- Most destructive winds are generally in the **front left quadrant** for a tropical cyclone in the southern hemisphere



Cyclones - weather in the eye

- The eye is the centre of the cyclone where the lowest surface pressure occurs.
- The skies will be relatively clear, or be scattered with low cloud, there will be **no rain and winds will be light and variable**.
- This is in sharp contrast to the surrounding strong winds, heavy rain and dense cloud.

Cyclones - Clouds

- Around the edge of the eye, there will be deep shield of heavy rain cloud being a mixture of:

- Nimbostratus
- Spiral bands of cumulus and cumulonimbus embedded in it

- Like what you see with satellite weather pictures.

- The rain shield in a mature cyclone stretches out to some 120nm from the centre.

- The clouds can extend from a base as low as 500ft, with tops reaching up to at least 40,000 ft in most storms, and sometimes as high as 60,000 ft.

Cyclones - Summary

- They form over the **ocean** between **5°S and 15°S**;
- **Surface sea temperatures** need to be about **27/28°C**;
- The **lowest surface pressure** (*about **900** hPa*) is to be **found in the eye**;
- The **strongest winds** *(>**64** kts*) **surround the eye**;
- The **maximum wind speed occurs in the left forward quadrant**; and
- They tend to **die out, or form intense rain depressions**, once they move **inland or penetrate south of 15°S**.