DOCUMENT
GSM-AUS-CPL.024

DOCUMENT TITLE

METEOROLOGY FOR AUSTRALIA

CHAPTER 16 – CLOUD AND WEATHER ASSOCIATED WITH FRONTS

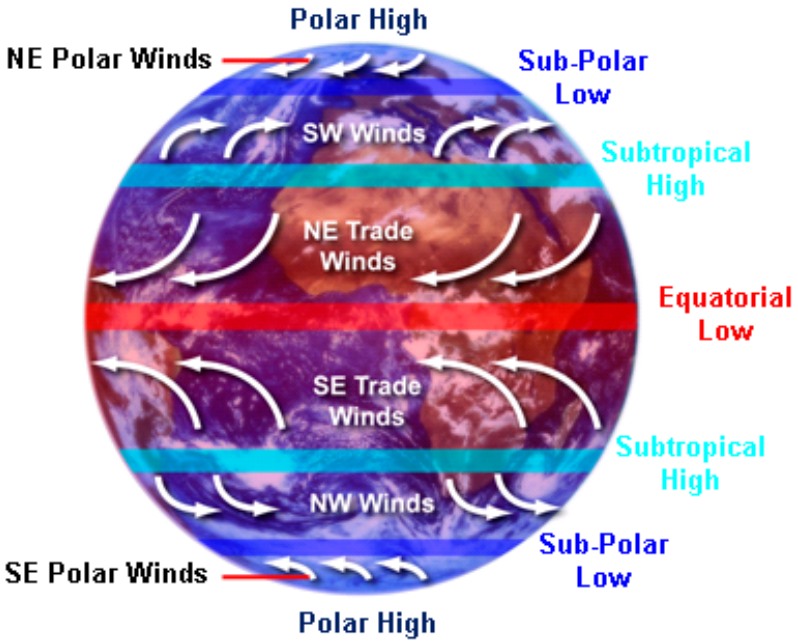
Version 3.0
November 2014

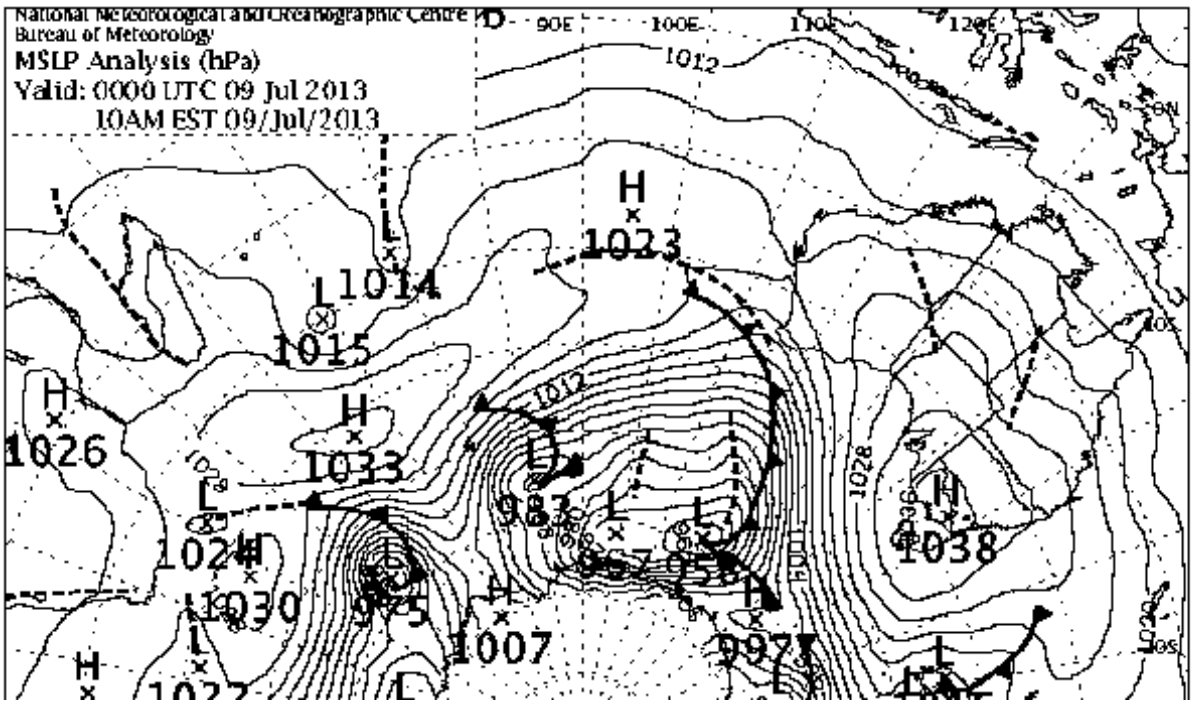
CONTENTS ..... PAGE

POLAR FRONT (MID.LAT, CIRCUMPOLAR LOW) 3
WARM-SECTOR DEPRESSIONS 4
INTRODUCTION 4
WARM FRONT WEATHER 5
Ahead of the Warm Front and at the Passage of a Warm Front 5
In the Warm Sector 6
COLD FRONT WEATHER 6
At the Cold Front Passage 6
Slow Moving Cold Front 6
Fast Moving Cold Front (normal cold front) 7
Behind the Cold Front 9
MOUNTAINS AND FRONTS 9
STATIONARY AND OCCLUDED FRONTS 11
STATIONARY FRONT 11
OCCLUDED FRONTS 11
FRONTAL ZONES 12
INTRODUCTION 12
OTHER LOW PRESSURE SYSTEMS 13
INTRODUCTION 13
MONSOON LOW 13
POLAR LOW 14
SHALLOW LOWS OVER LAND IN SUMMER 14
SHALLOW LOWS OVER INLAND WATERS IN WINTER 14
EQUATORIAL LOW PRESSURE BELT 14
OROGRAPHIC LOWS 14
TROPICAL REVOLVING STORMS AND TORNADOES 15
SECONDARY DEPRESSIONS 15
Non-frontal 15
Frontal 15
CUT-OFF LOW 16
ANTICYCLONES 17
INTRODUCTION 17
CLASSIFICATION OF ANTICYCLONES 17

POLAR FRONT (MID.LAT, CIRCUMPOLAR LOW)

This is the frontal surface between Polar and Tropical air masses. The Polar air from the high latitude sea areas meets the air moving towards these higher latitudes from the sub tropical anticyclones. A series of waves are always forming on this front which causes depressions which contain their own portions of the polar front proper.





Development of a front

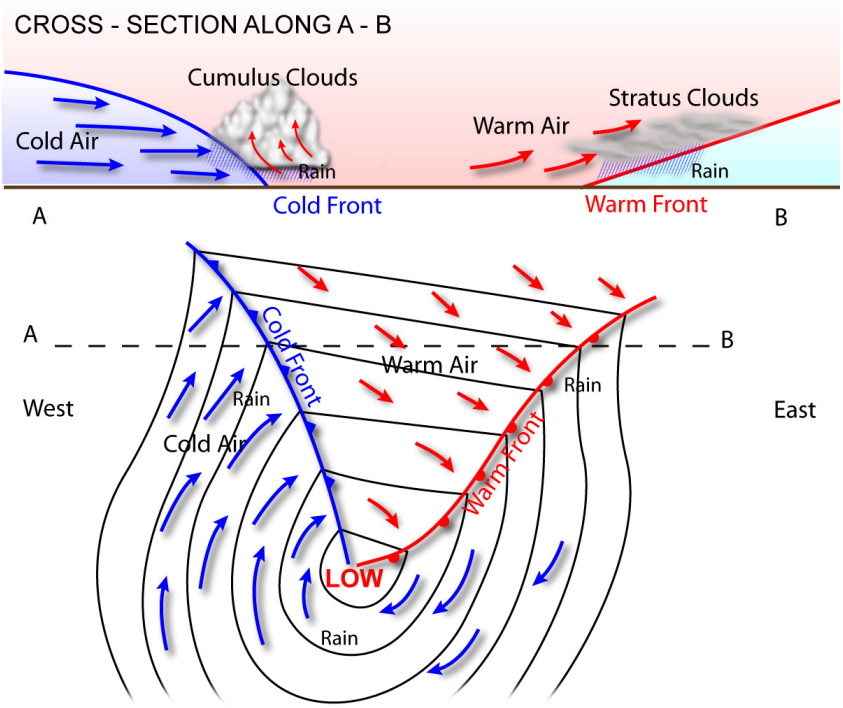
Depressions which form on the polar front produce very active weather from the surface and throughout the flying atmosphere. These are the most common depressions and they form in the temperate latitudes.

When one depression develops, moves along the front and finally becomes occluded, the cold front trails back from the point of the occlusion. Conditions may be favourable for a new development passing through the same stages and in this way there forms a series, train or family of depressions. As each occludes in turn the cold air spreads round it and penetrates to lower latitudes so that successive depressions usually follow a more northerly track (south hemisphere) until at last the cold air sweeps through and goes to feed the trade winds of lower latitudes. Eventually the polar front has been displaced far to the north (SH) of its normal position and a large anti-cyclone builds up in the polar air breaking the sequence of formation.

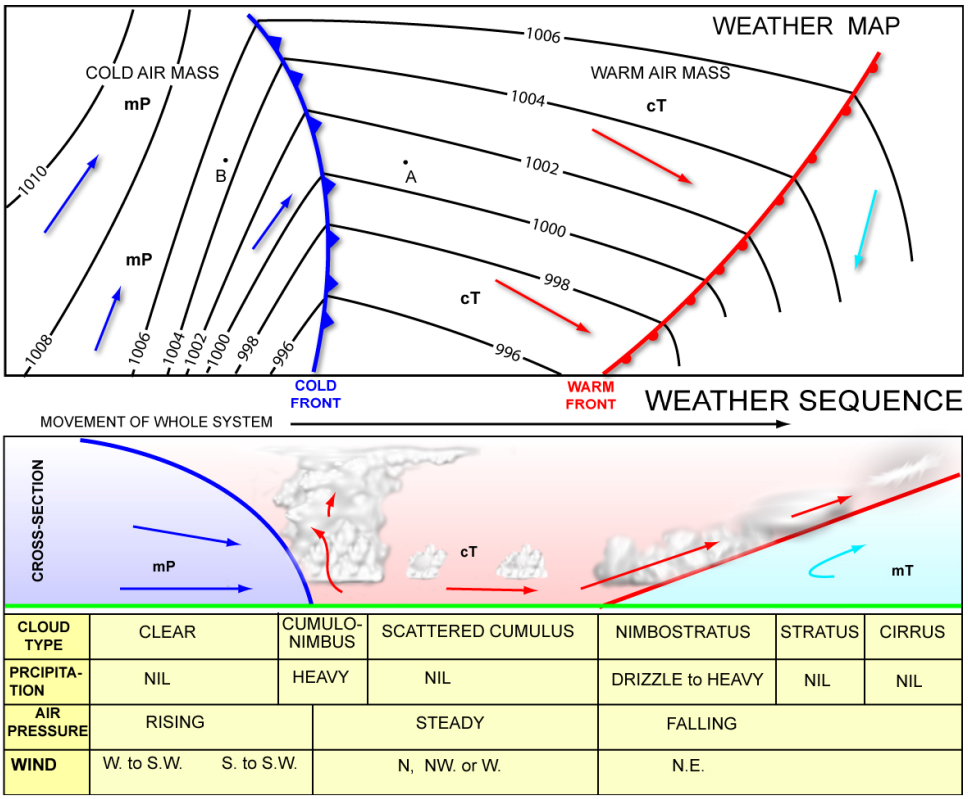
WARM-SECTOR DEPRESSIONS

INTRODUCTION

The following diagram and table detail the weather and cloud associated with a warm-sector depression. This will be broken down into each of the areas of weather or cloud change. (Keep in mind that the mature warm sector depression occurs to the south of Australia although Tasmania may be affected by a warm front once or twice per year.)



Typical Cyclone of the Southern Hemisphere

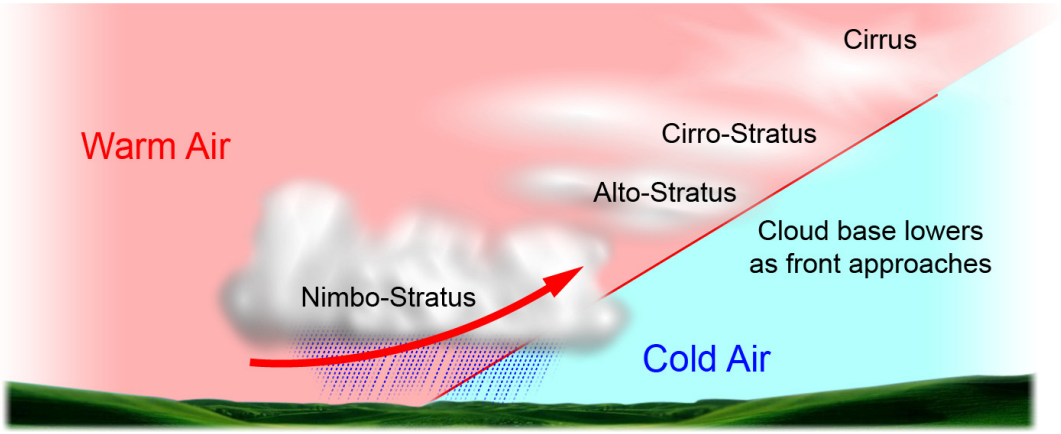


CLOUD TYPE	CLEAR	CUMULO-NIMBUS	SCATTERED CUMULUS	NIMBOSTRATUS	STRATUS	CIRRUS
PRCIPITA-TION	NIL	HEAVY	NIL	DRIZZLE to HEAVY	NIL	NIL
AIR PRESSURE	RISING		STEADY	FALLING		
WIND	W. to S.W. S. to S.W.		N, NW. or W.	N.E.		

WARM FRONT WEATHER

Ahead of the Warm Front and at the Passage of a Warm Front

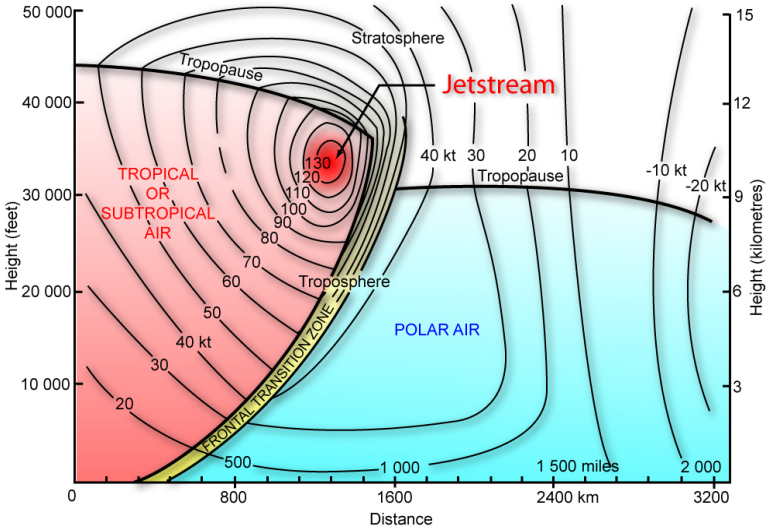
The first indication of an approaching warm front is the thickening and increase of the cirri form cloud cover. In evening light this can be quite a bright red colour, hence the phrase “red sky at night, shepherd’s delight”. The bad weather should occur overnight and the next day is fine.



Warm Front

Ahead of the warm front altostratus thickens and lowers. Soon the base of the altostratus becomes low. At about the same time, the rain falling from the cloud has increased to become more than just slight intermittent, and the altostratus becomes nimbostratus, meaning rain producing. The change from altostratus to nimbostratus is a natural progression, with no obvious interruption or gap between two different cloud types.

There is often a jet stream associated with the temperature contrast, which exists across the warm front. The warm front jet is positioned 400 to 500 nm ahead of the surface position of the warm front, but, because of the height at which the jet blows, and the 1:125 slope of the front, it is actually located in the warm air, ie. Behind the front at the level of the jet.



The jet core lies above the polar tropopause, but below the higher and colder tropopause in the tropical air, at a level at which both air masses have almost identical temperatures.

Clear air turbulence (CAT), associated with fronts will be found most commonly **below** the jet core towards the **cold** air.

In the Warm Sector

The warm sector is usually a mixture of Tc and Tm air. The warm sector cloud is commonly (overcast) 8/8 St/Sc, and poor visibility in light intermittent rain and/or drizzle is normal, especially in winter. Summer usually sees clear skies with scattered cumulus.

Warm sector isobars are usually straight and parallel.

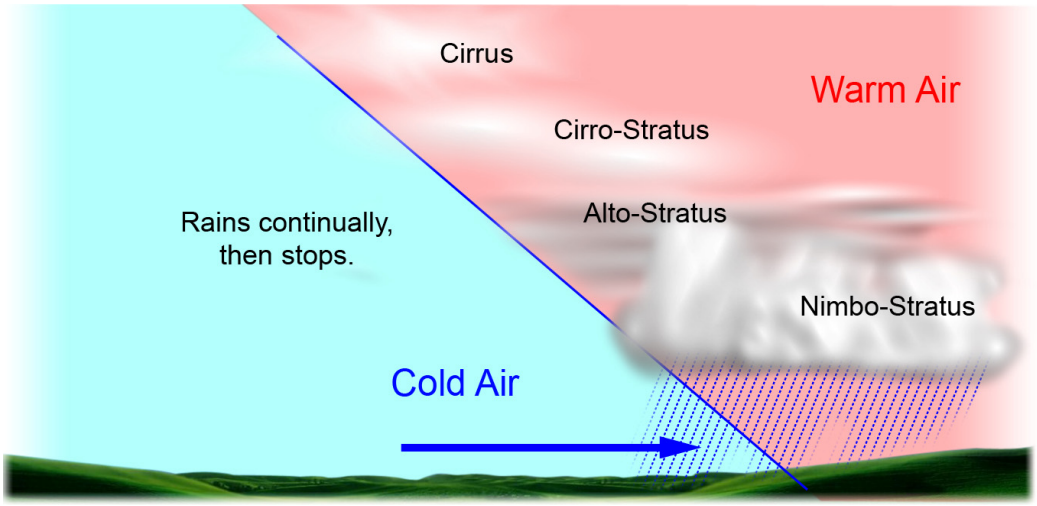
The depression centre moves with the speed and direction of the warm sector isobars, but slows down as the depression occludes

COLD FRONT WEATHER

At the Cold Front Passage

<u>Slow Moving Cold Front</u>

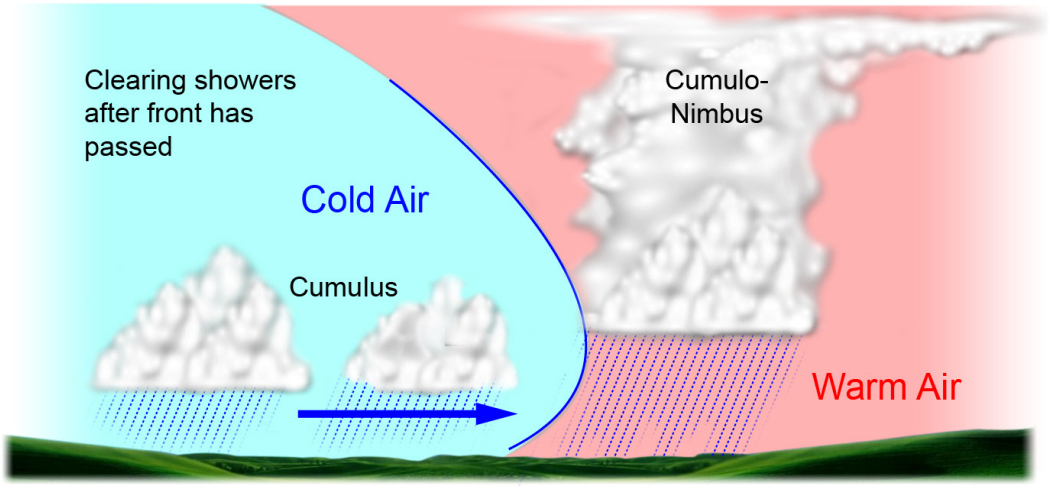
The typical cloud is Ns and As giving a uniform overcast sky. Light rain occurs ahead of the front, which becomes heavier as the front passes. There is no sharp clearance of cloud.



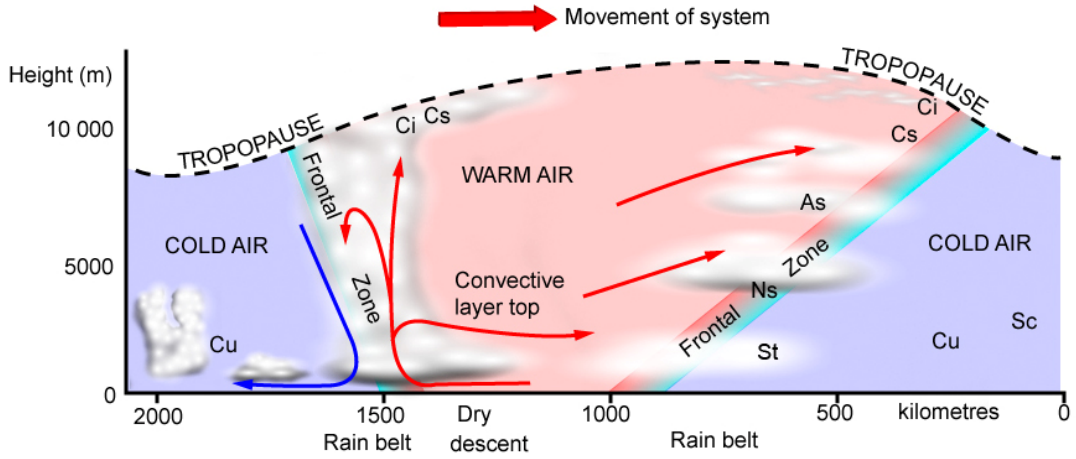
Fast Moving Cold Front (normal cold front)

The typical clouds are Cu, TCu and Cb. Showers predominate before and after the passage of the front. These showers may be heavy and be of hail and/or rain. Thunderstorms may result from the Cbs. After the front passes, bright periods occur between the clearing showers.

The cold front often overhangs near the ground, due to surface friction.

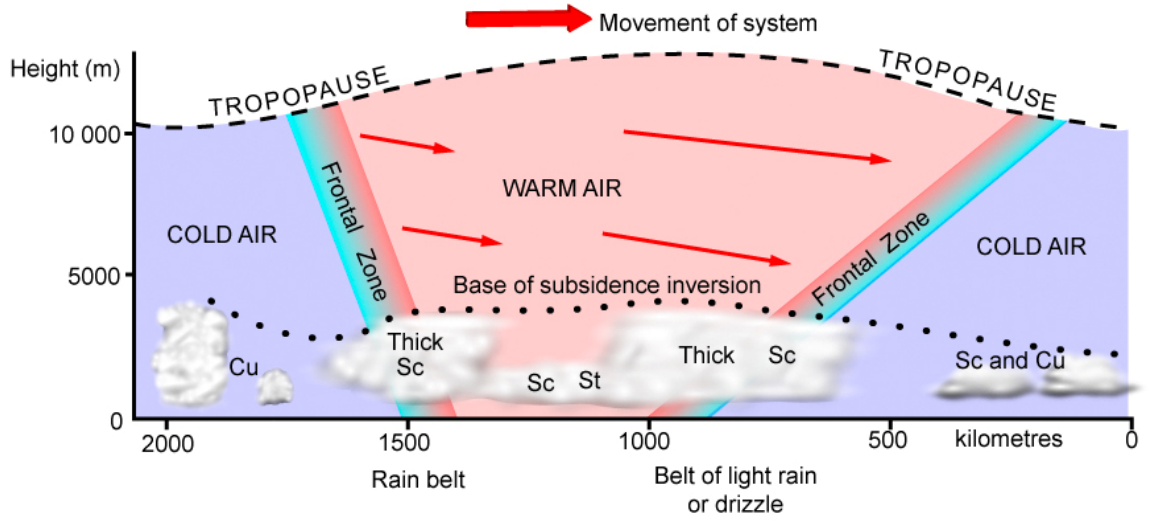


While most warm fronts look much the same, cold fronts are often varied. The cross-section shows Cu/Cb as the major frontal cloud, and this will be the case where the front is of the 'ana' type, i.e. where the warm air motion is upwards at the cold front. This tends to be the case when the advancing cold air is pushing the warm air out of its way. A cold ana-front is a serious weather phenomenon.



Ana-front

The alternative to a cold ana-front is a cold kata-front, which is the name given to a cold front at which there is a significant downward component of motion in the warm air. The cold kata-front is therefore perhaps best thought of as arising when the warm air is leaving an area, and the cold air is passively coming in behind it to occupy the space which would otherwise be left. Obviously, with a downward motion, large convective cloud is not a problem and instead we have some Ns or perhaps only a little St/Sc in the extreme case. Most Australian cold fronts are somewhere between these two extremes, i.e. with Ns and the possibility of embedded Cu/Cb. The very violent cold fronts often experienced in central USA are of the cold ana-front type.



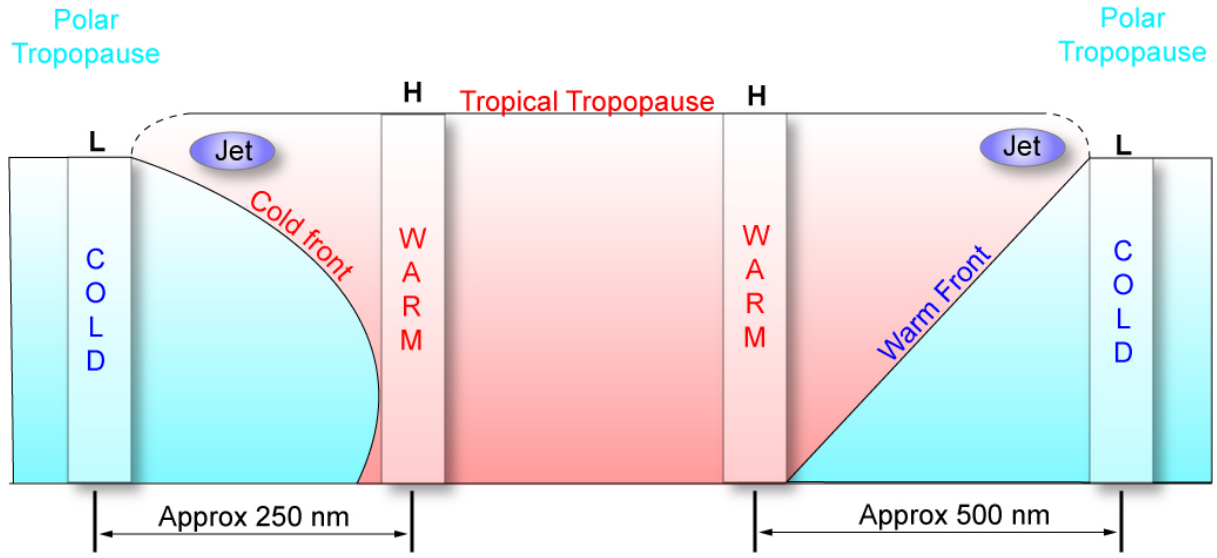
Kata-front

Behind the Cold Front

Dew points usually fall sharply at the front, with a further fall as the cold air becomes established.

The cold air mass has a lower and warmer tropopause.

The cold front jet is located in the warm air mass, but, because of the steep frontal slope, only some 200 nm behind the surface position of the cold front.



The cold front jet is usually stronger than the warm front jet, by 20 kts or more. This is a further consequence of the steeper cold front slope. A steeper front means that the temperature gradient will also be steeper. At height, therefore, the thermal contrast will be greater giving a larger thermal wind component.

CAT in association with the cold front jet is again associated with regions of **maximum windshear**, on the cold air mass side of the jet, and also both **above and below** the cold jet.

Both warm and cold jets are virtually parallel to their respective fronts.

Cold air mass cumulus and cumulonimbus are quite different from the cold front cumulus and cumulonimbus in that they arise from different trigger actions in different air masses.

MOUNTAINS AND FRONTS

If a cold front with its unstable polar maritime air following the front is taken over a mountain and lifted again by an orographic low pressure, the additional uplift may result in widespread Cb with heavy showers and thunderstorms.

	Ahead of Warm Front at Passage	In Warm Sector	Cold Front Passage	Behind Cold Front
CLOUD	Ci, Cs, As, Ns with broken St at passage. Cu and St in cold air	St and/or Sc	Cu/Cb with broken St below, or very low Ns. Possible Ac, As and Ci.	Rapid clearance then Cu and Cb which often clear at night.
PRESSURE	Falls; then steadies at passage.	Steady	Rises, sometime rapidly	Further rise
SURFACE WIND	Backs at passage.	Steadies	Backs, (NW-SW) sometimes with a squall	May back slowly
TEMPERATURE	Slow rise, then further steep rise at frontal passage.	Steady	Fall	Further fall
VISIBILITY	Deteriorates as rain falls. Worst at frontal passage.	Poor, with fog at times	Becomes good as soon as precipitation stops	Good except in showers
WEATHER	Intermittent slight rain or snow may begin 200–250 miles ahead, and become moderate continuous nearer the front.	Slight intermittent rain or drizzle with hill fog (winter)	A narrower belt of heavier precipitation–moderate intermittent rain	Showery
DEW POINT	Rise, then steep rise	Steady	Fall	Further fall

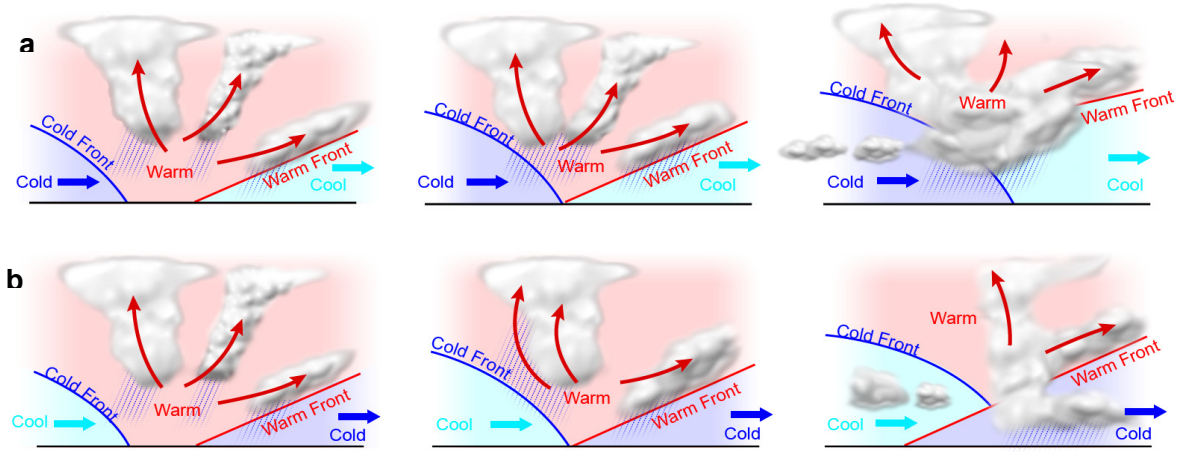
STATIONARY AND OCCLUDED FRONTS

STATIONARY FRONT

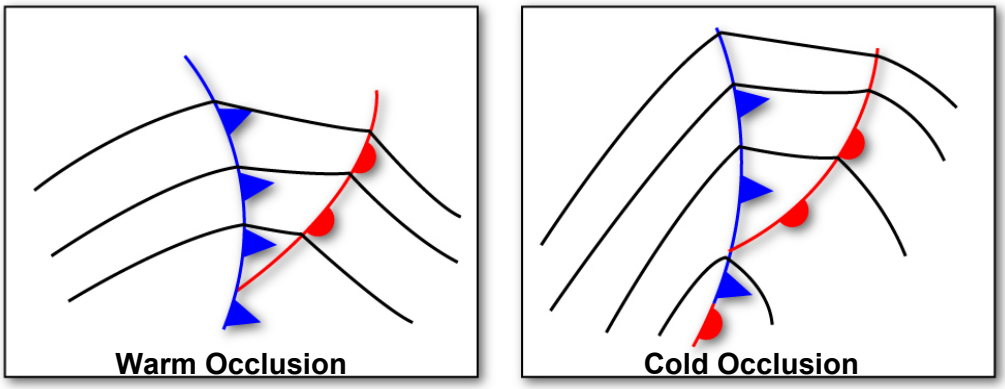
A Stationary Front is one where, as the name suggests, the two air masses are side by side and are not interacting. The result will be little or no weather.

OCCLUDED FRONTS

Warm is forced upwards and there is also an interaction between the cold air and the cool air. The cool air also rises. The result will be cloud and precipitation which may produce violent weather such as Cbs embedded in Ns. **Warm occlusions tend to give the most violent weather.**



The three stages of (a) a cold occlusion, and (b) a warm occlusion
The main difference is the temperature of the invading air



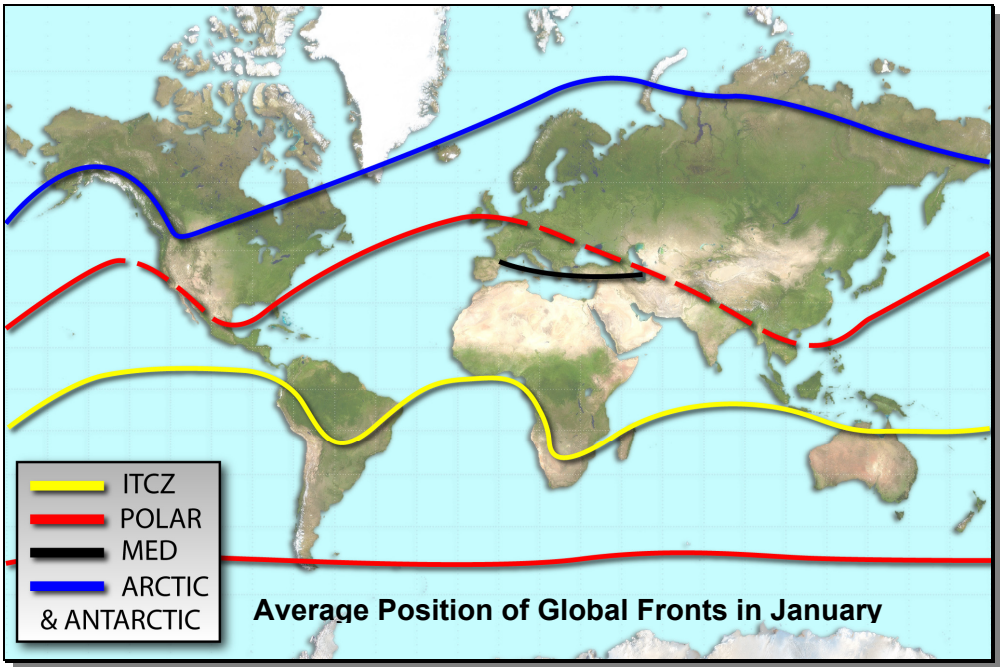
Note that in the cold occlusion, the air behind the cold front has a greater south to north track than the air behind the cold front in the warm occlusion. In the later stages of its life, the cold occlusion resembles a cold front.

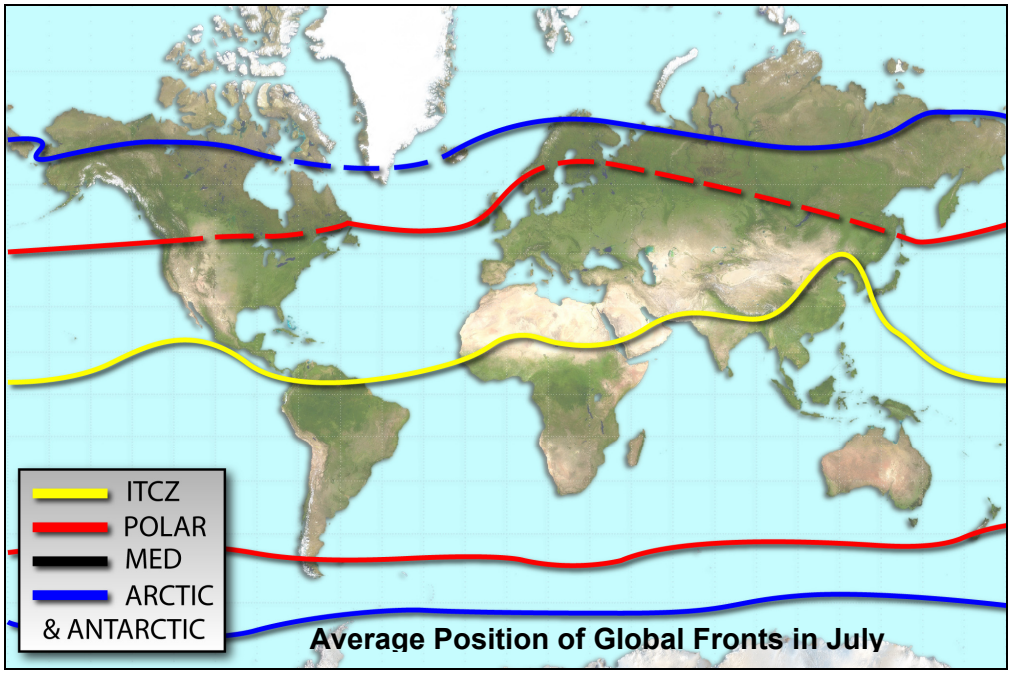
FRONTAL ZONES

INTRODUCTION

The main front affecting southern Australia is the polar front being the boundary between polar and sub-tropical air. The polar front varies in position but patterns emerge:

- Winter: 35°-45°S. Perth, Adelaide, Melbourne, Sydney
- Summer: 45°-60°S. Although not as common as in winter, fronts affecting Australia in summer tend to be more violent.

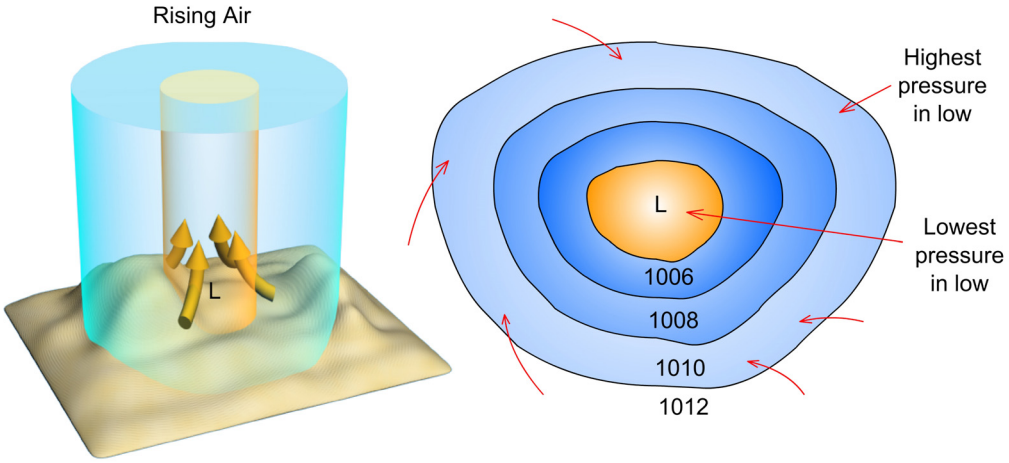




OTHER LOW PRESSURE SYSTEMS

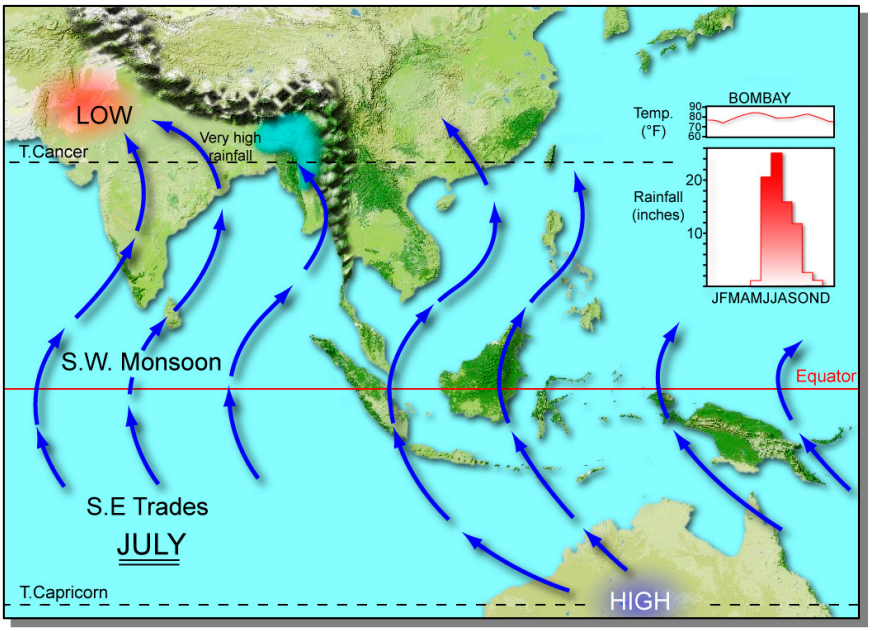
INTRODUCTION

Most other non-frontal L.P. systems are thermal in origin and form due to thermal heating and/or from the release of latent heat. Besides the lee depression, all lows are regions of ascending air. The airflow is turned by geostrophic force and a cyclonic circulation exists at the surface. Because of anticyclonic flow above a surface low, thermal lows tend to be very shallow.



MONSOON LOW

In summer intense surface heating of Asia and the Indian sub-continent causes an outflow of air aloft. A subsequent fall of pressure at the surface draws in air from the south-west (the Indian Ocean). This SW Monsoon flow is shallow (5,000 to 7,000 ft) and the growth of cumulus cloud is inhibited by the air above being very much drier, and usually blowing in a very different direction. When within 100 to 200 miles of the coastline, the monsoon flow thickens (11,000 to 13,000 ft), allowing cumulus cloud to grow appreciably. Further lifting over the coast and hills causes growth of cloud and high rainfall. The SW Monsoon is covered in more detail in Global Climatology.



POLAR LOW

Cold Polar air (-20°C → +4°C) moving northwards over warmer oceans become more unstable on this northerly track due to heating from below.

SHALLOW LOWS OVER LAND IN SUMMER

Surface heating over land often gives rise to localized shallow depressions. Associated with instability, they can cause squally thunderstorm weather, particularly over inland Australia. They can also occur in stable conditions, as within a high pressure system. In this case they have little or no associated weather other than localized Cu and Cb but are often masked in the overall pressure distribution. Where they are caused by surface heating, they appear by day and disappear by night.

SHALLOW LOWS OVER INLAND WATERS IN WINTER

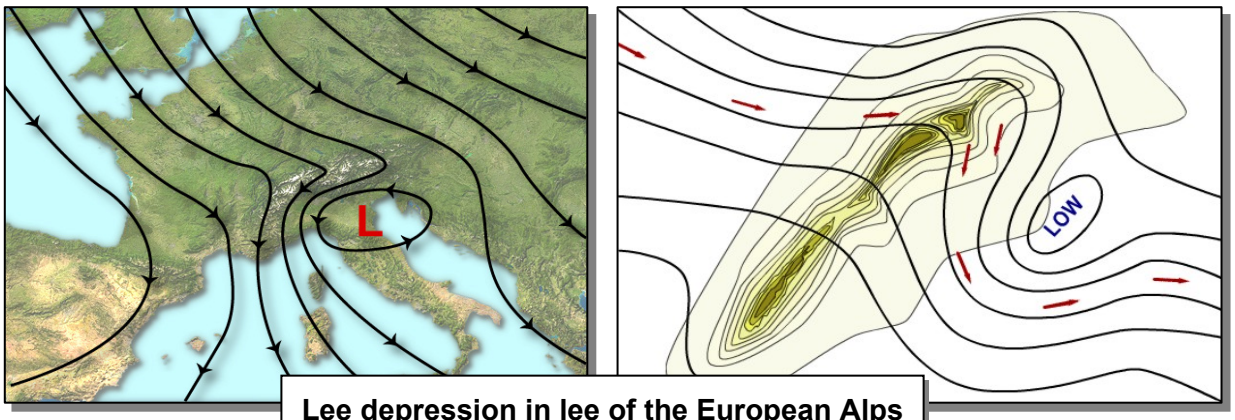
The Mediterranean, Black Sea and Great Lakes are examples of areas where the winter water temperature is high enough in contrast with the surrounding land mass to cause instability in invading polar air. Being warmer than the surrounding land, these waters are normally areas of lower pressure in winter, and the heating from below continues by day and by night.

EQUATORIAL LOW PRESSURE BELT

The equatorial trough is a permanent series of heat lows in a more or less continuous belt around the earth. This is covered in more detail in Chapter 28.

OROGRAPHIC LOWS

Air taking the easiest path often flows around an obstacle, e.g. a mountain, rather than over it. An eddy can form in the lee of the mountain range often being large enough for geostrophic force to induce circulation. However the weather is mainly fine due to the Fohn effect, but the arrival of a cold front may result in bad weather

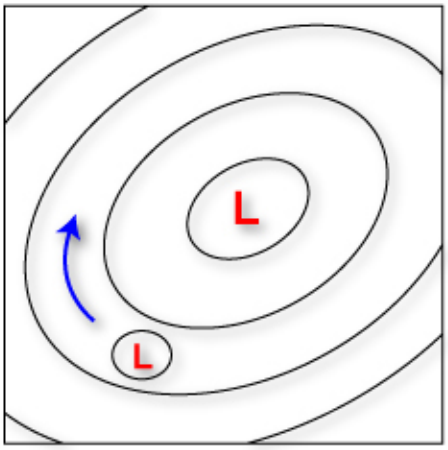


Lee depression in lee of the European Alps

TROPICAL REVOLVING STORMS AND TORNADOES

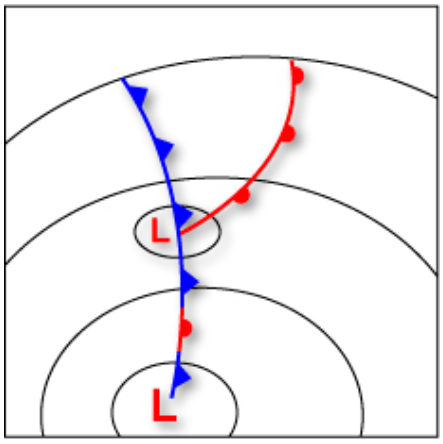
These are cases of extreme L.P. systems, but are also covered in more detail in Chapters 18, 26 and 27.

SECONDARY DEPRESSIONS



Non-frontal

These may form in a trough behind a cold front; it may be an old occluded depression. They move slowly, clockwise around the primary low and results in generally showery weather or short periods of rain and/or snow



Frontal

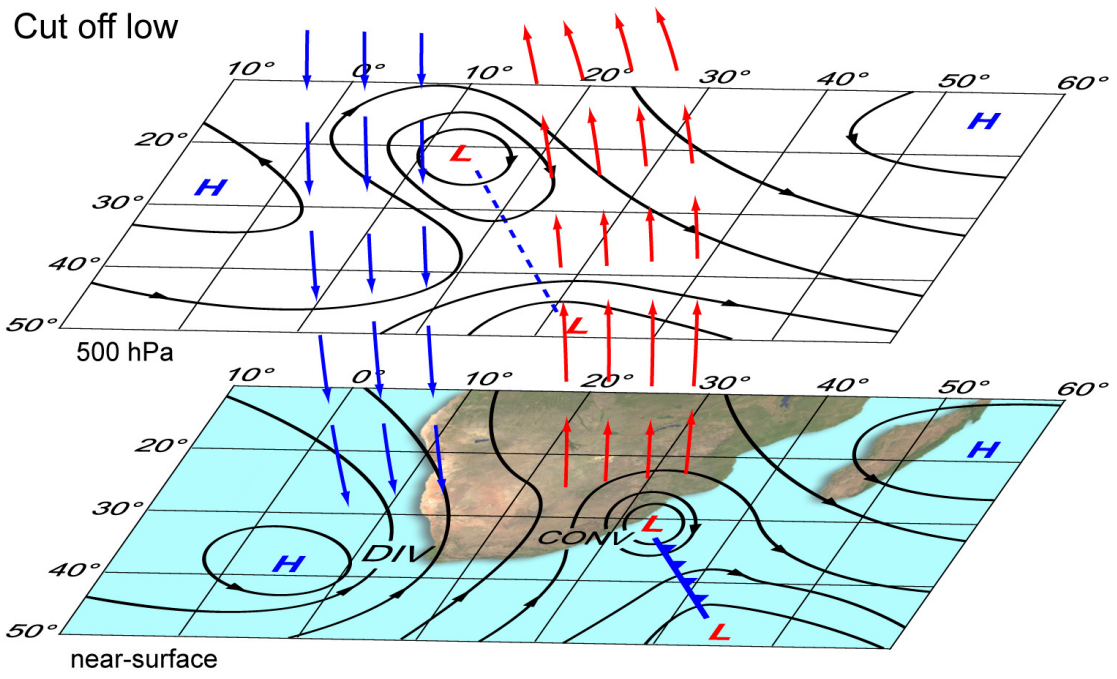
These may form:

- As a wave on a slow moving cold front
- At the tip of the occluding warm sector
- As a wave on a warm front (rare)

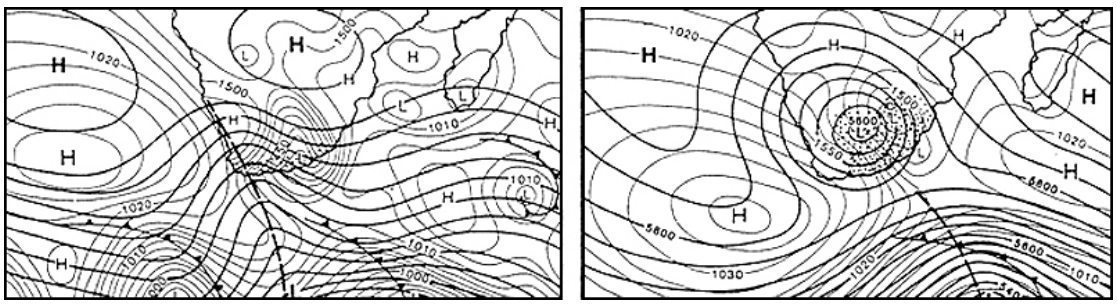
They move quickly between SW and NW and may result in heavy rain and/or snow and gales for a short period.

CUT-OFF LOW

A more intense form of westerly trough is the cut-off low, a feature that is a cold –cored depression, which starts as a trough in the upper westerlies and deepens into a closed circulation extending downward to the surface. They become displaced equator wards out of the basic westerly current. Cut-off lows are unstable, baroclinic systems which slope to the west with increasing height and are associated with strong convergence and vertical motion, particularly while they are deepening. These often occur to the east of Bass Strait off the Victorian coast.



A schematic representation of the near-surface and 500 hPa circulation associated with a cut-off low

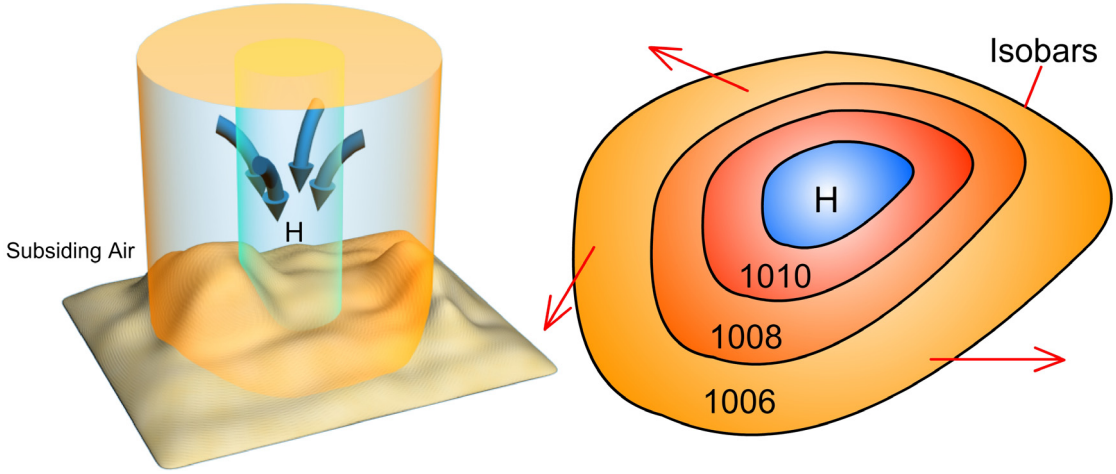


Westerly Low **Cut-Off Low**

ANTICYCLONES

INTRODUCTION

Air masses originate in areas of stable anticyclonic pressure systems. An anticyclone is a system of closed isobars with the highest pressure in the centre. Descending air causes an outflow (divergence) of air at the surface with wind blowing about 30° across the isobars.



Air that descends warms at the DALR. Since the descending air is very dry, a typical anticyclone is an area of:

- Stable conditions (possible inversions)
- No large convective clouds
- Poor visibility
- Usually light winds

CLASSIFICATION OF ANTICYCLONES

Anticyclones are classified as either “warm” or “cold” depending upon the cause of their formation. Warm or cold refers to average temperatures and not to surface temperatures.

- Warm Anticyclones: due to greater depth of air, ie the Sub-tropical High
- Cold Anticyclones: due to the greater weight of cold dense air, eg. Over Siberia, Canada and Antarctica.

		Warm Anticyclones	Cold Anticyclones
a)	Location	25-35° North and South. Sub-tropical High, strongest over the sea	North and south of Polar Fronts, e.g. Siberian High and Antarctica
b)	Movement	Normally stationary	Usually stationary, but others move with the frontal systems.
c)	Depth	Closed high pressure circulation exists to great heights.	Not extending to a great height due to rapid fall off of pressure with height in cold air.
d)	Upper Wind	Similar circulation aloft, hence similar wind at height and at the surface.	May be an area of low pressure above Surface High, hence winds may reverse direction above 10,000 ft and be largely thermal (westerly) above.
e)	Weather	(1) Extension from sub-tropical high: fine settled weather but radiation fog or turbulence cloud if air moist. Sea fog. (2) Subsiding and warming Polar air, fine settled weather, inversion, possible Sc.	Primarily bright and dry. Some Cu overland in summer (heating) and risk of fog or turbulence cloud in winter (advective cooling).

Properties of Anti-Cyclones

A cold anti-cyclone will be a shallow feature. The surface circulation will fall to calm winds at some fairly low height (10,000 ft. in the case of an intense high) and then tend to reverse direction above. A warm anticyclone, on the other hand, should be traceable well above 15,000 ft., and the sub-tropical highs exist to very great heights. (Up to the tropopause)