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Helen Collett , Norma C. Winearls , Peter J. Holmes
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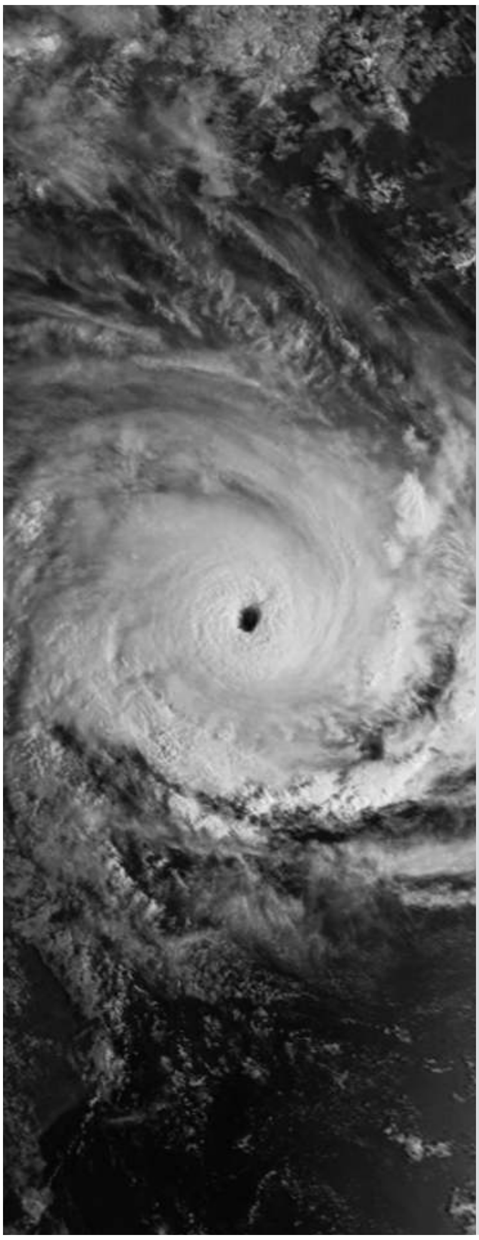
MODULE 1
GEOGRAPHICAL KNOWLEDGE

CLIMATE AND WEATHER



UNIT 1: Mid-latitude cyclones

General characteristics

Mid-latitude cyclones are spiralling low-pressure systems which bring rain to the temperate parts of the world (see Figure 1.1). In South Africa, we commonly refer to them as cold fronts. Mid-latitude cyclones:

- consist of a pair of **fronts** – a **warm front** and a **cold front** – which are linked to a central area of low pressure
- carry lots of moisture
- spiral clockwise in the southern hemisphere and anticlockwise in the northern hemisphere
- travel eastwards with the **jet stream** (or upper westerly winds)
- are very large systems – up to about 2 000 km across
- move at about 30 km.hr^{-1}, travelling a distance of about 1 200 km in one day. It takes about 48 hours for a mid-latitude weather system to pass over
- occur in families of 3–5 cyclones, which follow one after the other, 2–8 days apart.

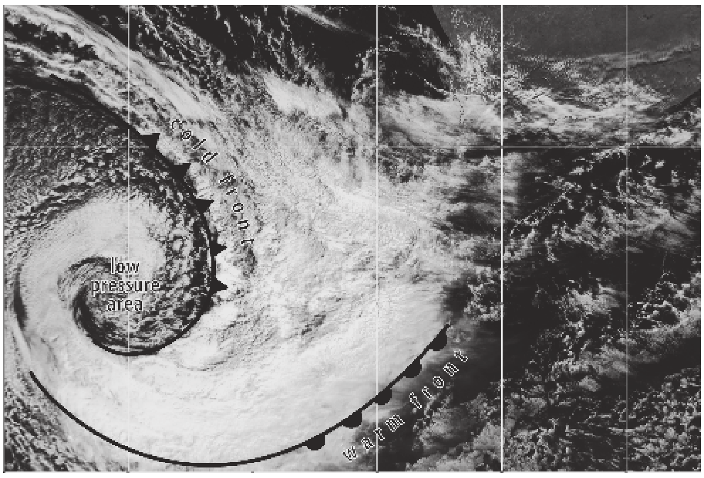


Figure 1.1 Satellite image of a mid-latitude cyclone. The centre of the cyclone's low is marked by a comma-shaped swirl of cloud.

Question
Where do mid-latitude cyclones form?

Areas where mid-latitude cyclones form

Mid-latitude cyclones form in the mid-latitudes, about 30°–75° north and south of the Equator (see Figure 1.2). They develop at the **polar front**, usually over the sea. The polar front is where the cold polar easterlies meet the warmer westerlies of the subtropics.

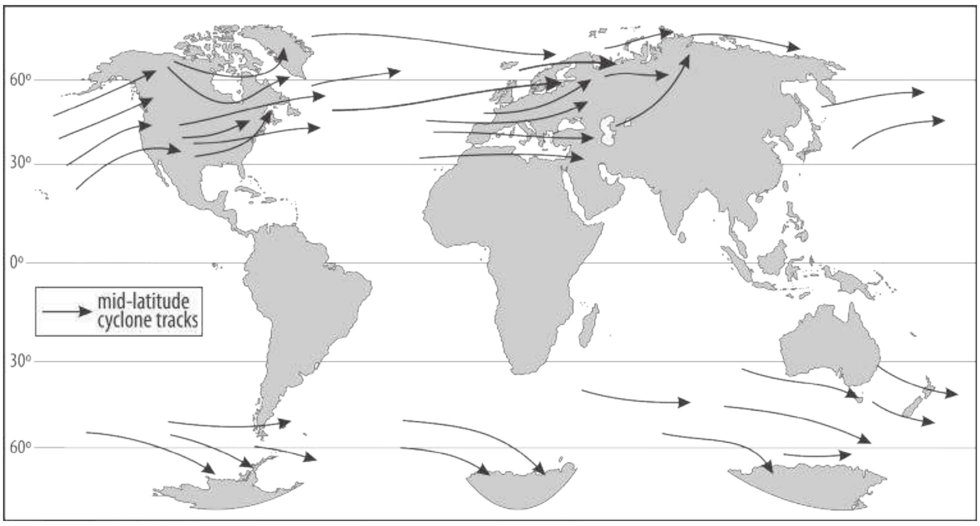


Figure 1.2 Where mid-latitude cyclones occur

(*Source*: Adapted from www.physicalgeography.net/fundamentals/7s.html)

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Questions
- How do mid-latitude cyclones form?
- What weather do mid-latitude cyclones bring?

Conditions necessary for their formation

For mid-latitude cyclones to form:

- There must be a large temperature contrast between the subtropical westerly and polar easterly air masses, so that the polar front develops.
- There must be disturbances in the jet stream that make the cold air push into the warm air. The warm air mass then rises over the cold air mass, creating a low-pressure cell into which the wind spirals.

Stages of development and related weather conditions

There are five stages in the life of a mid-latitude cyclone (see Figure 1.3). Each stage has its own weather conditions.

1 Initial stage: A stationary polar front forms, with wind shear in two opposing directions across the front.

2 Wave stage: A kink, or wave, forms in the polar front as warm air lifts up over cold air. Air pressure starts to drop and the warm and cold air masses begin to swirl.

3 Mature stage: The polar front bends and divides into a cold front and a **warm front**. The cold front leads the cold sector of air, which pushes in the direction of the Equator. The warm front leads a warm sector of air, which pushes in the direction of the pole. Low pressure intensifies at the apex of the two fronts. The stormiest weather begins.

4 Occlusions stage: Because the cold air travels faster than the warm air, the cold front begins to overtake the warm front. At the apex, the two fronts begin to form a single, rainy front, called an **occluded front**. The lifting of the warm air off the ground is called **occlusion**. The occluded front develops. The occlusions stage is associated with nimbostratus cloud and rain.

5 Dissipating stage: Eventually, all the warm air is lifted off the ground. The pressure gradient weakens and the cyclone dies out. The air is cold and gusty as the skies clear.

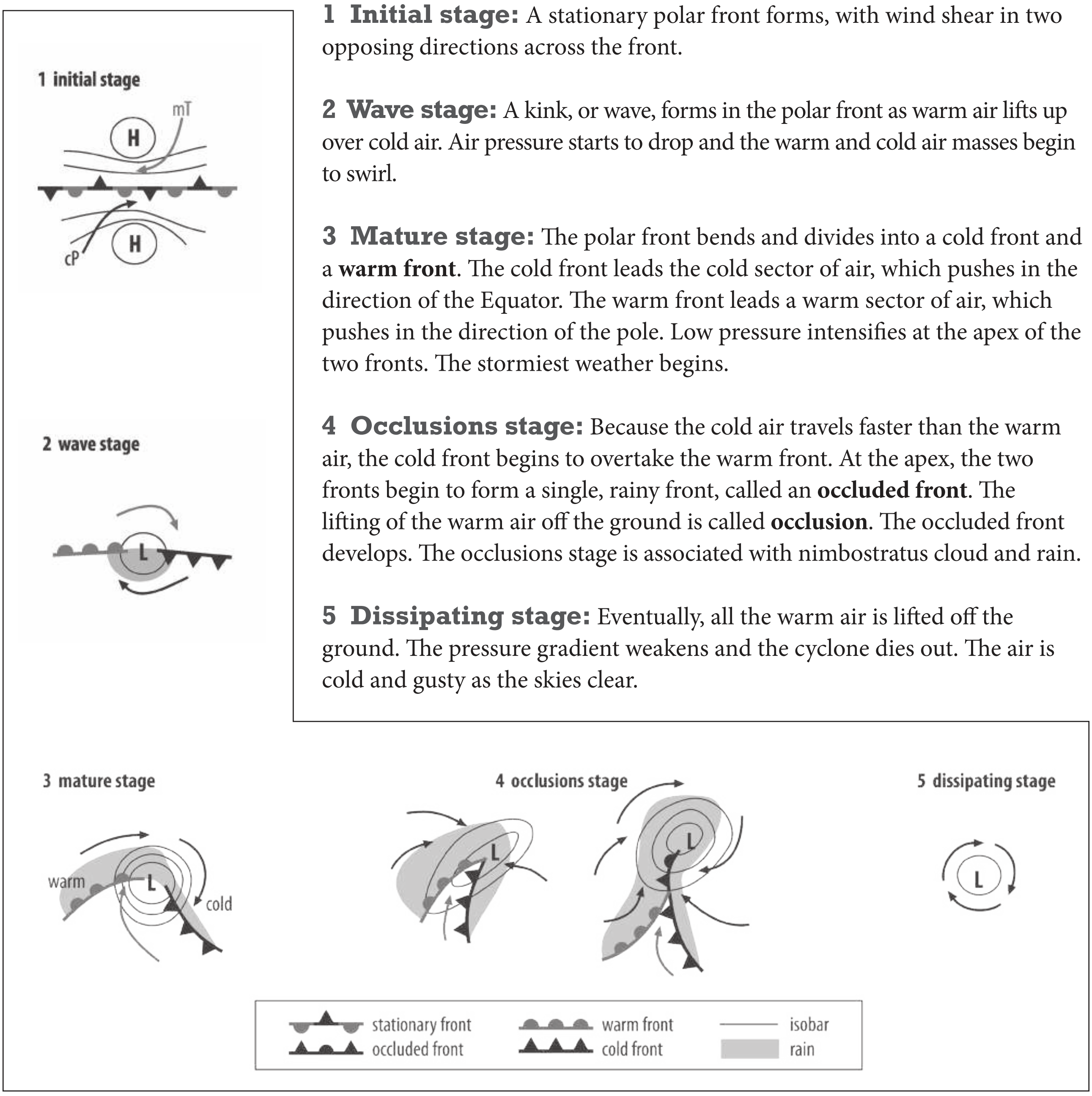

Figure 1.3 The five stages in the development of a mid-latitude cyclone

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Weather patterns associated with fronts

Figure 1.4 shows a side view of a mid-latitude cyclone as it moves from west to east.

- The cyclone has a warm front and a cold front. There is cold air ahead of the warm front, and cold air behind the cold front. There is warm air in the middle.
- Clouds form along the fronts, where the warm air is pushed up. There are cirrus and stratus clouds at the warm front and cumulonimbus and cumulus clouds at the cold front.
- As the cyclone passes over, the weather conditions change.

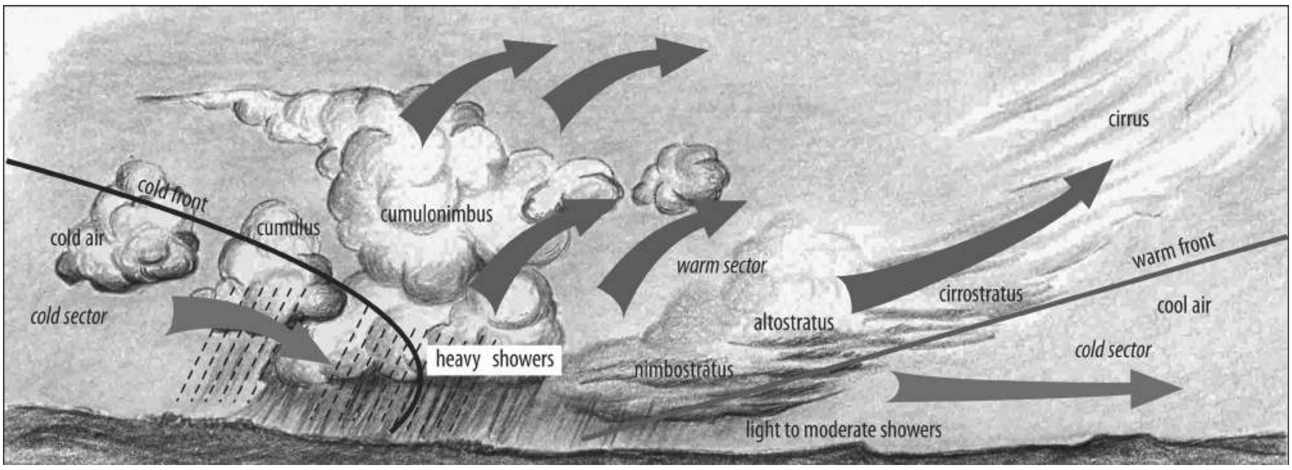

Figure 1.4 Side view of weather produced by a mid-latitude cyclone

Cold front conditions

- Air pressure drops to its lowest, and then increases with the arrival of the cold, dense air.
- Temperature decreases and humidity (dew point) decreases.
- Cumulus and cumulonimbus clouds form.
- Heavy rain falls; sometimes there is snow.
- Surface wind direction changes (backs), and wind speed increases.

In the Cape, the wind direction changes from north-west to west to south-west to south. This anticlockwise change in wind direction behind a cold front is called **backing** (see Figure 1.5).

Warm front conditions

- Air pressure drops.
- Temperature increases and humidity (dew point) increases.
- Wispy cirrus clouds form, followed by stratus clouds.
- Gentle rain falls from nimbostratus clouds.
- As the front moves on, the weather becomes mild, calm and warm.

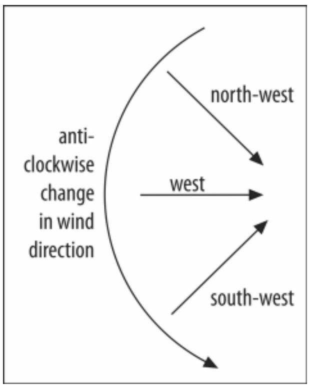

Figure 1.5 Backing

Occluded fronts

An occluded front brings a combination of a cold front's tight band of stormy weather and a warm front's wide area of cloudiness.

- A **cold occlusion** forms when the overtaking cold front lifts the warm front, plus the air mass ahead of the warm front, off the ground (see Figure 1.6 on page 5). Cold occlusion weather is similar to cold front weather. Cold occlusions are much more common than warm occlusions.
- A **warm occlusion** forms when the overtaking cold front is lifted by the colder retreating air ahead of the warm front (see Figure 1.7 on page 5). Warm front occlusion weather is similar to warm front weather.

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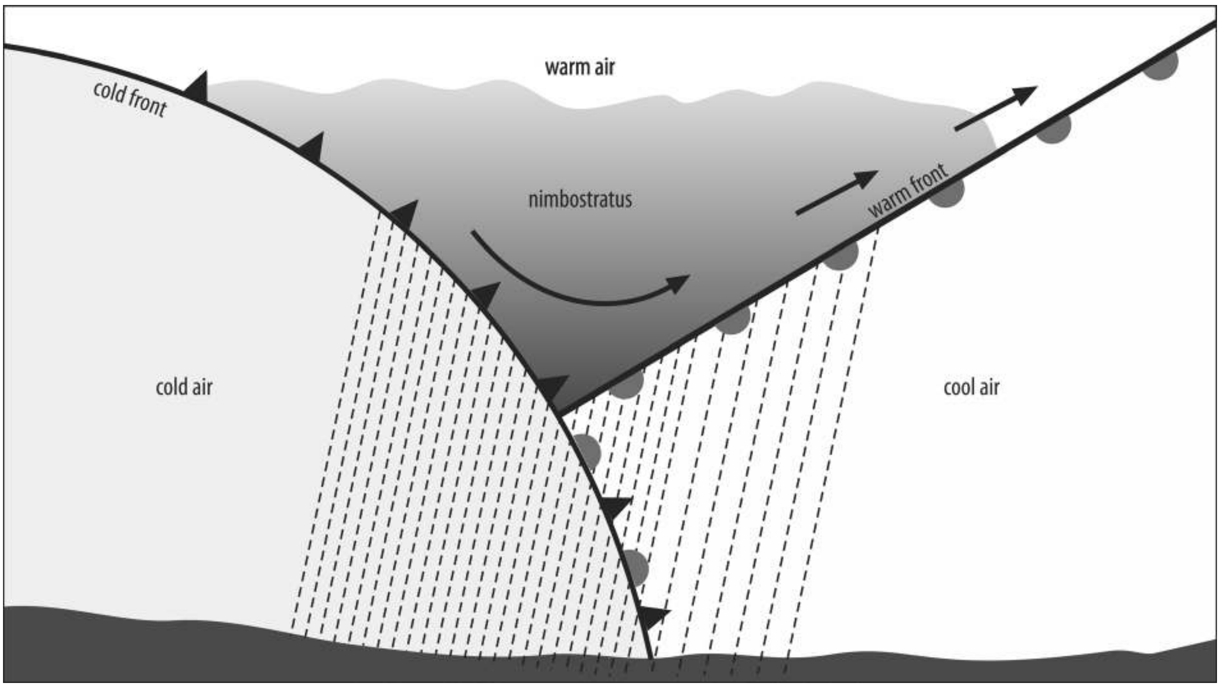


Figure 1.6 Cold front occlusion

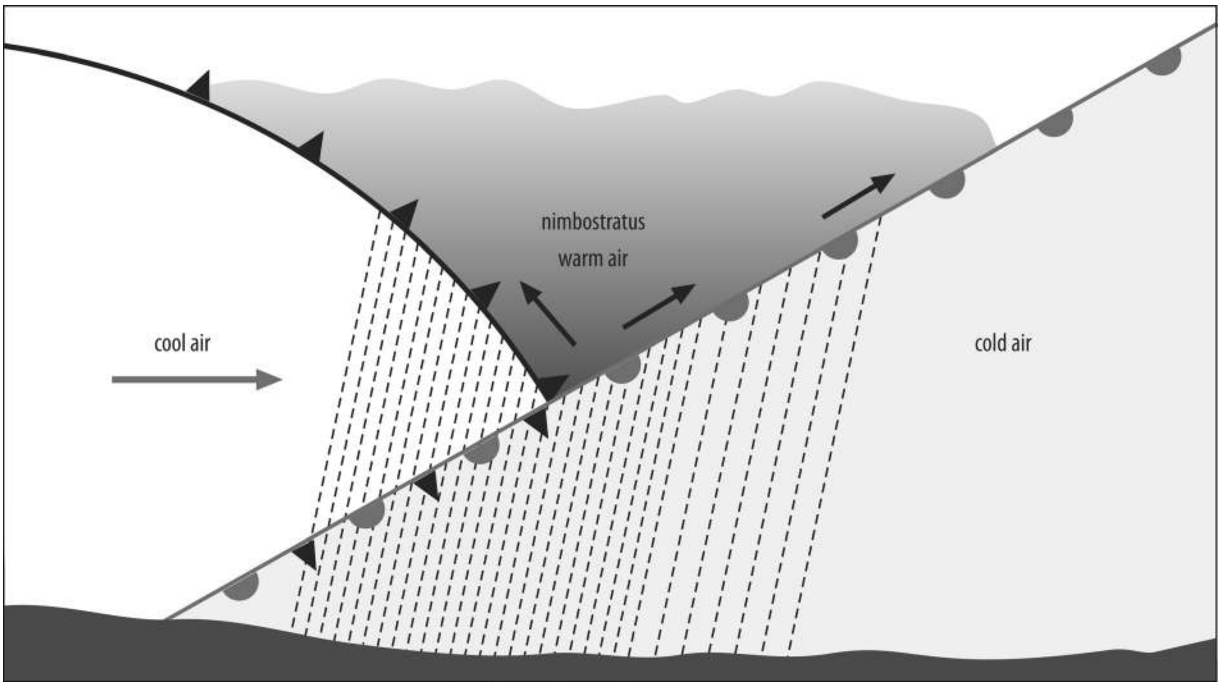


Figure 1.7 Warm front occlusion

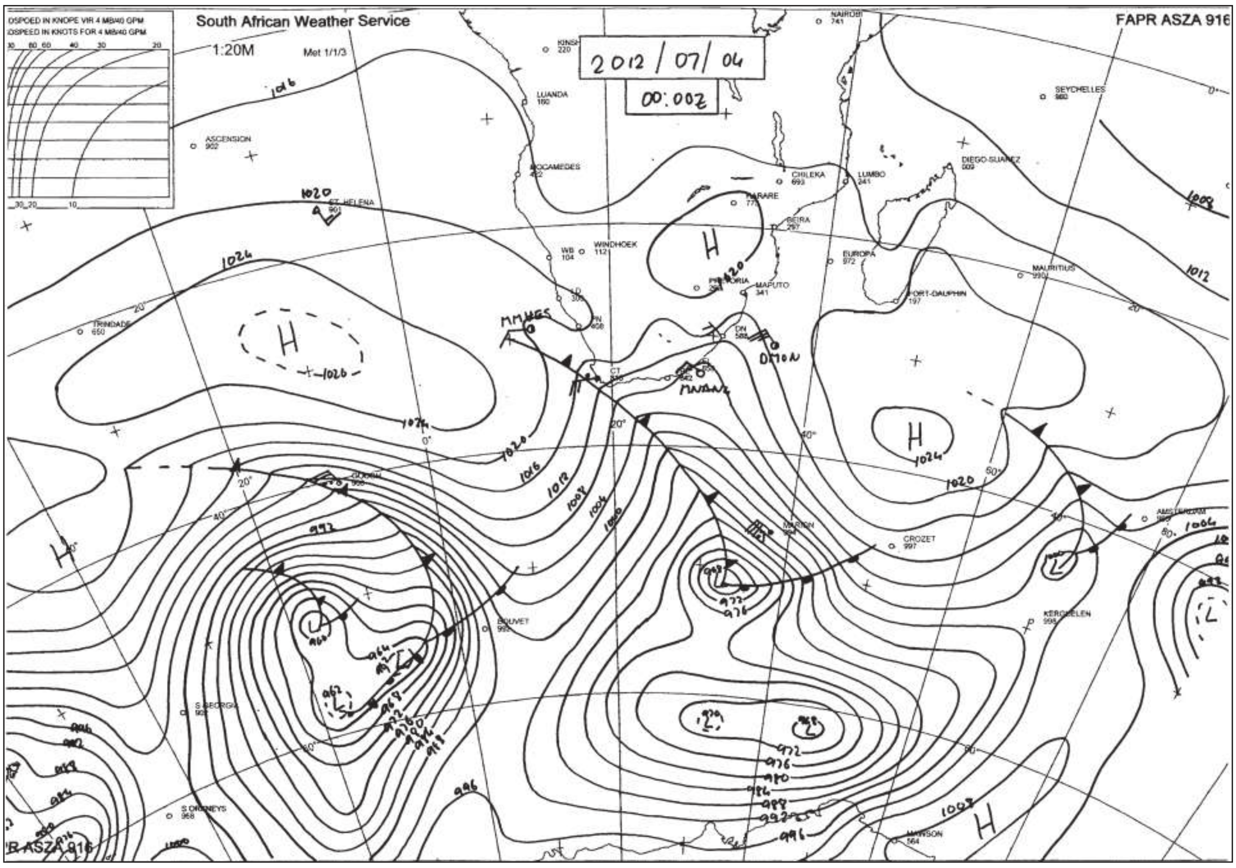
Synoptic chart (rather than map) is the correct term for the visual presentation of weather conditions. These charts are used to summarise present weather conditions, and to forecast future conditions.

Interpret satellite images and synoptic charts

Figure 1.8 on page 6 shows a mid-latitude cyclone on a **synoptic chart** (A), and the corresponding satellite image (B). Notice on the synoptic chart and in Figures 1.6 and 1.7 above how the different types of fronts are depicted:

- Cold fronts (▲): the triangles point towards the warmer air and the direction that the front moves in. The cold air is behind the cold front.
- Warm fronts (◓): the semicircles point towards the colder air and the direction that the front moves in. The warm air is behind the warm front.
- Occluded fronts (◓▲): there are alternating semicircles and triangles.

A



B

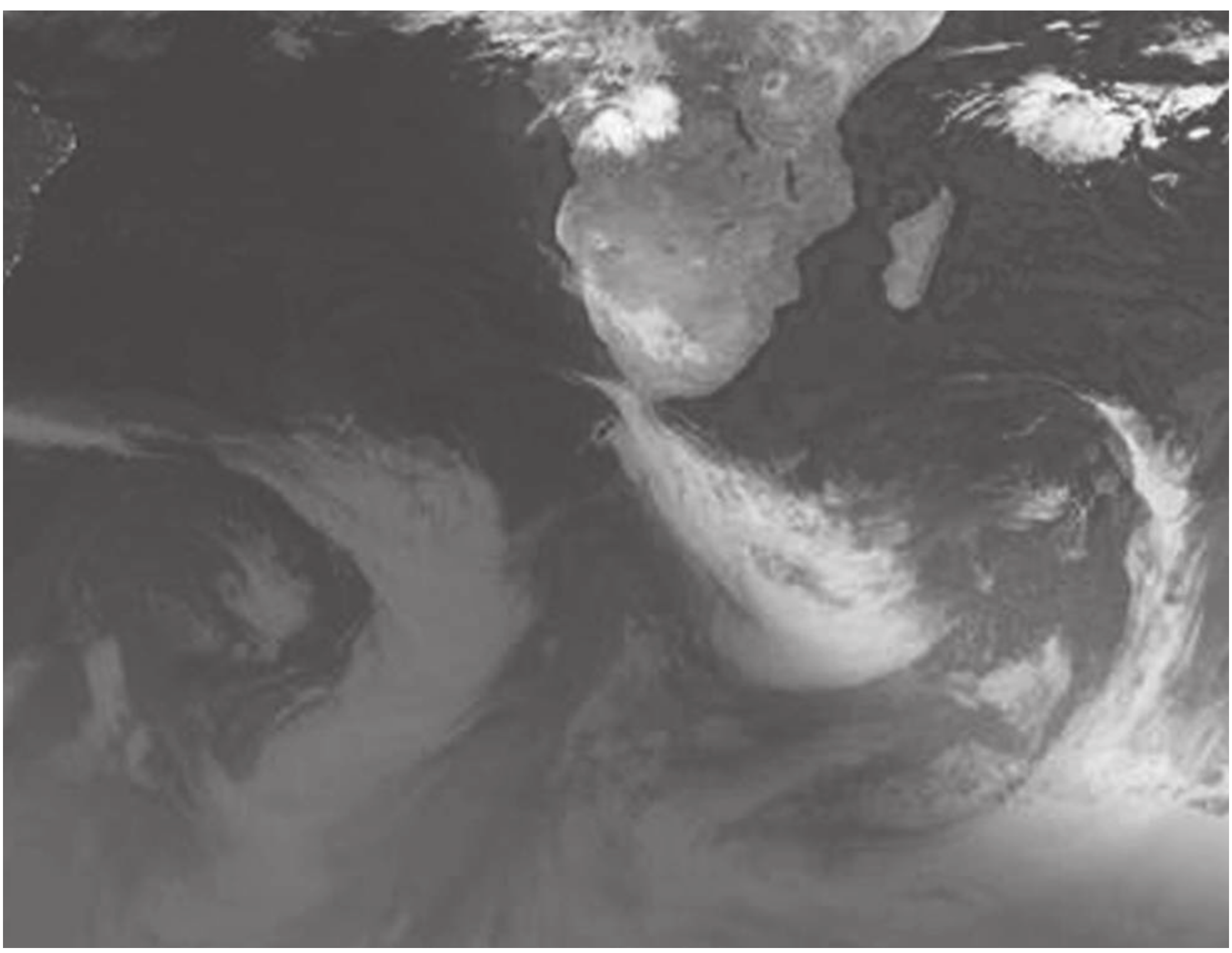


Figure 1.8 The arrival of a mid-latitude cyclone on 4 July 2012, shown on a synoptic chart (A) and a satellite image (B)

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Activity 1.1 Interpret satellite images and synoptic charts

Refer to the 4 July 2012 synoptic chart in Figure 1.8 on page 6.

1. Give the time on the synoptic chart.
2. How many mid-latitude cyclones are shown on the chart?
3. In which direction are the cyclones moving?
4. What is the air pressure at the centre of the low for the mid-latitude cyclone that is about to pass over Cape Town?
5. Describe the weather conditions shown on the map for:
   a) Cape Town **b)** Gqeberha (Port Elizabeth).
6. Now look at the 4 July 2012 seven-day forecasts for Cape Town and Gqeberha (Port Elizabeth) in Figures 1.9 and 1.10 below.
   a) **i)** Compare the wind direction for Cape Town on the synoptic chart and the Wednesday forecast. (Look at the isobars behind the cold front. Notice how the change in wind direction is predicted.)
   ii) What is the term for this change in wind direction?
   b) **i)** When does the cold front reach Gqeberha (Port Elizabeth)?
   ii) How does the wind direction change on this day?
   iii) How long does the cold front last?
   c) Describe the weather conditions for Cape Town on Thursday, once the cold front has passed by.
   d) When is the next cold front expected to arrive in Cape Town?
   e) Is this cold front likely to reach Gqeberha (Port Elizabeth)?

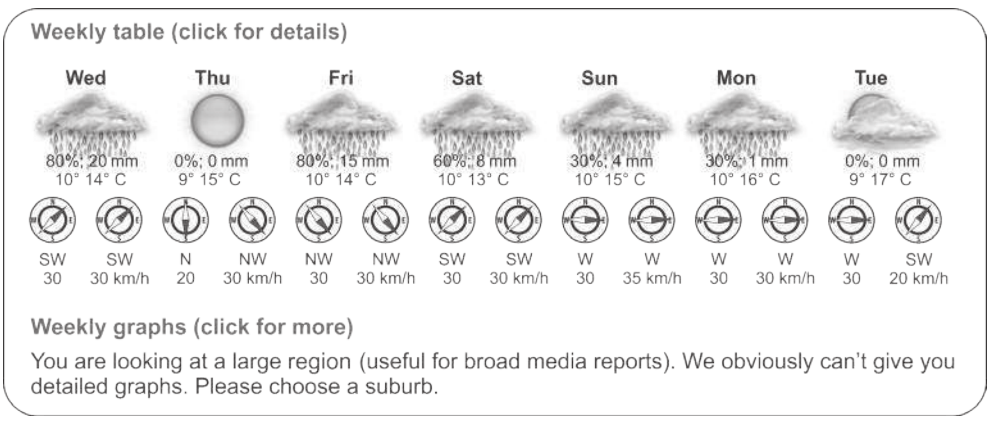

Figure 1.9 Cape Town, Wednesday, 4 July 2012

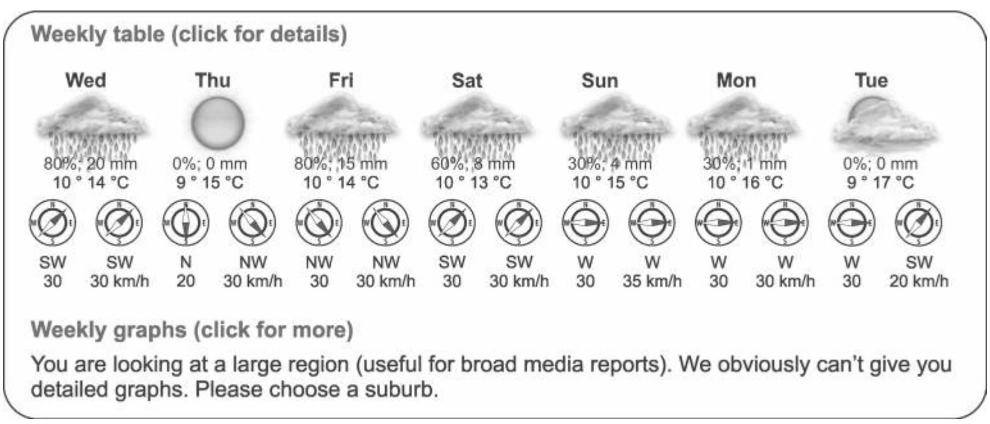

Figure 1.10 Gqeberha (Port Elizabeth), Wednesday, 4 July 2012

UNIT 2: Tropical cyclones

General characteristics

Tropical cyclones are powerful spiralling storm systems that bring heavy rain and strong winds to tropical parts of the world.

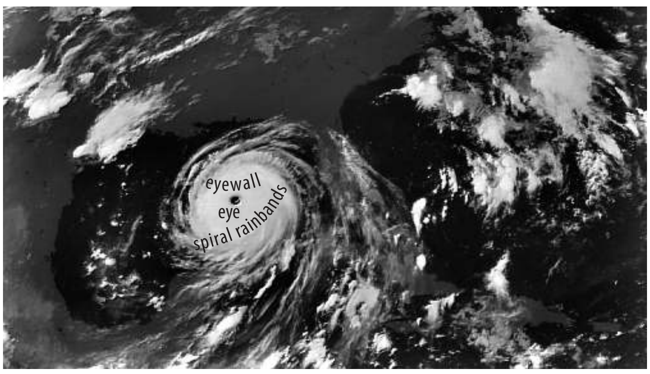

Figure 1.11 Satellite image of the deadly tropical cyclone Katrina, 2005

Tropical cyclones have the following characteristics:

- They are intense low-pressure systems.
- They consist of three parts (see Figure 1.11):
  - the **eye** – the low-pressure warm, calm, cloudless centre
  - the **eyewall** – the towering wall of cumulonimbus clouds around the eye; this is where the heaviest rain and the strongest winds occur
  - the **spiral rainbands** – swirling bands of rain-filled clouds.
- Their winds spiral clockwise in the southern hemisphere and anticlockwise in the northern hemisphere.
- They have **wind speeds** of 120–320 km.h^{-1}.
- They cover an area of 200–750 km.
- They travel westwards, at about 15–50 km.h^{-1}, with the tropical easterly winds.
- They have a lifespan about one week (4–7 days).

The strength of a tropical cyclone is categorised on a scale of 1 to 5, with 1 being the lowest and 5 being the most severe (**wind speeds** over 252 km per hour).

Areas where tropical cyclones form

Tropical cyclones form in the tropics, i.e. in the 5°–30° latitudes. They are called cyclones in the Indian Ocean, **hurricanes** in the Atlantic Ocean, and **typhoons** in the Pacific Ocean (see Figure 1.12).

Question
Where do tropical cyclones form?

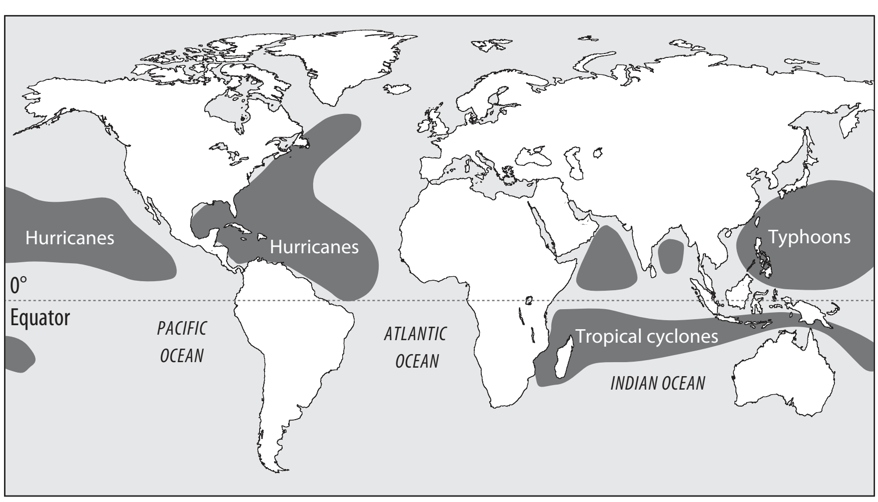

Figure 1.12 Where tropical cyclones occur

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Question
How and where do tropical cyclones form?

Tropical cyclones do not develop at the Equator because there is no Coriolis force there.

Factors necessary for their formation

Tropical cyclones usually occur in late summer. To form, they need:

- warm sea surface temperatures – about 28°C or more
- high humidity, i.e. a lot of moisture in the air
- converging winds, to create low pressure and atmospheric instability
- sufficiently strong Coriolis force.

Stages of development

Table 1.1 describes the four stages in the life of a tropical cyclone (see Figure 1.13).

1 Formative or initial stage	A tropical cyclone begins with a disturbance in the air pressure pattern and a loose cluster of convection storms. Air diverges (rises) at the top and converges (sinks) at the bottom. Air divergence draws more air into the low-pressure system.
2 Immature stage	Clouds grow taller and wind speed, evaporation and condensation increase. Air pressure at the centre drops below 1000 **hPa**. Bands of cloud spiral inwards and the eye begins to form, although it can be hidden by a cover of cirrus cloud. Winds become gale-force strength, with wind speeds up to 60 $km.h^{-1}$.
3 Mature stage	Air pressure at the centre reaches a minimum – less than 950 hPa. The pressure gradient is now at its steepest, and the cyclone forms a strong vortex system. Some air sinks into the centre of the storm, producing the clear and calm, stable conditions of the well-developed eye. Cumulonimbus clouds produce heavy rainfall. The south-west quadrant of the cyclone coincides with the tropical easterly winds, and so carries the strongest, most destructive winds. Wind speeds reach up to 120 $km.h^{-1}$.
4 Decaying, dissipating or degenerating stage	The cyclone decays when it reaches land or cooler waters. Its supply of moist air is cut off, and friction slows down the wind over land. Air pressure at the centre rises, the eye disappears and the wind drops, but heavy rain continues.

Table 1.1 The four stages of a tropical cyclone

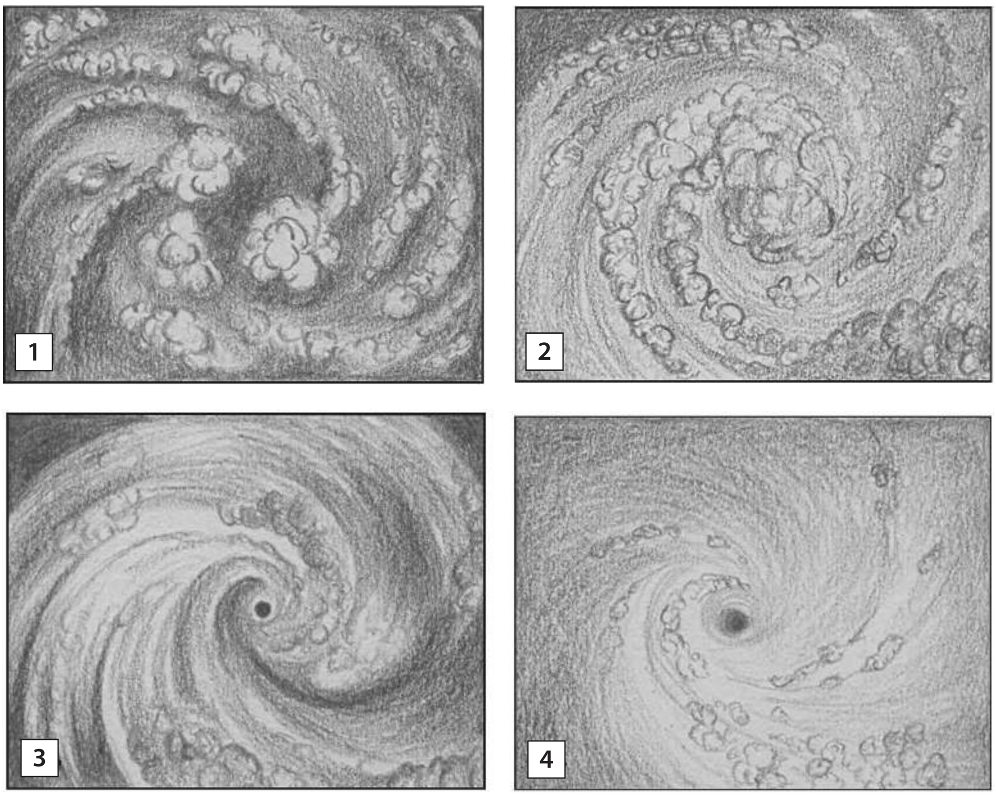

Figure 1.13 The four stages in the development of a tropical cyclone

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Question
What weather do tropical cyclones bring?

Associated weather patterns

As soon as the wind speed exceeds 120 km.h^{-1} a tropical storm becomes a tropical cyclone. Tropical cyclones are associated with extreme and, often, very dangerous weather conditions. The worst weather accompanies the mature stage. Typical weather patterns include:

- high-speed winds which blow around the eye of the storm
- towering cumulus and cumulonimbus cloud formations and very heavy rainfall
- calm conditions as the eye of the storm passes over a point or place on the ground
- a repeat of the previous severe weather, as the back ‘wall’ of the storm passes over, with winds now blowing in the opposite direction
- storm surges, associated with a tropical cyclone hitting a coastal area, which cause a temporary rise in sea level of several metres.

Interpret satellite images and synoptic charts

Figure 1.14 shows tropical cyclone Funso on a synoptic chart. Notice that:

- The date shows that the tropical cyclone occurred in late summer, when temperatures were high.
- The symbol for a tropical cyclone (🌀) and the name of the tropical cyclone are placed in the eye of the cyclone.
- The isobars are close together, so the pressure gradient for the cyclone is steep.
- The cyclone wind speeds are high and they spiral in a clockwise direction.

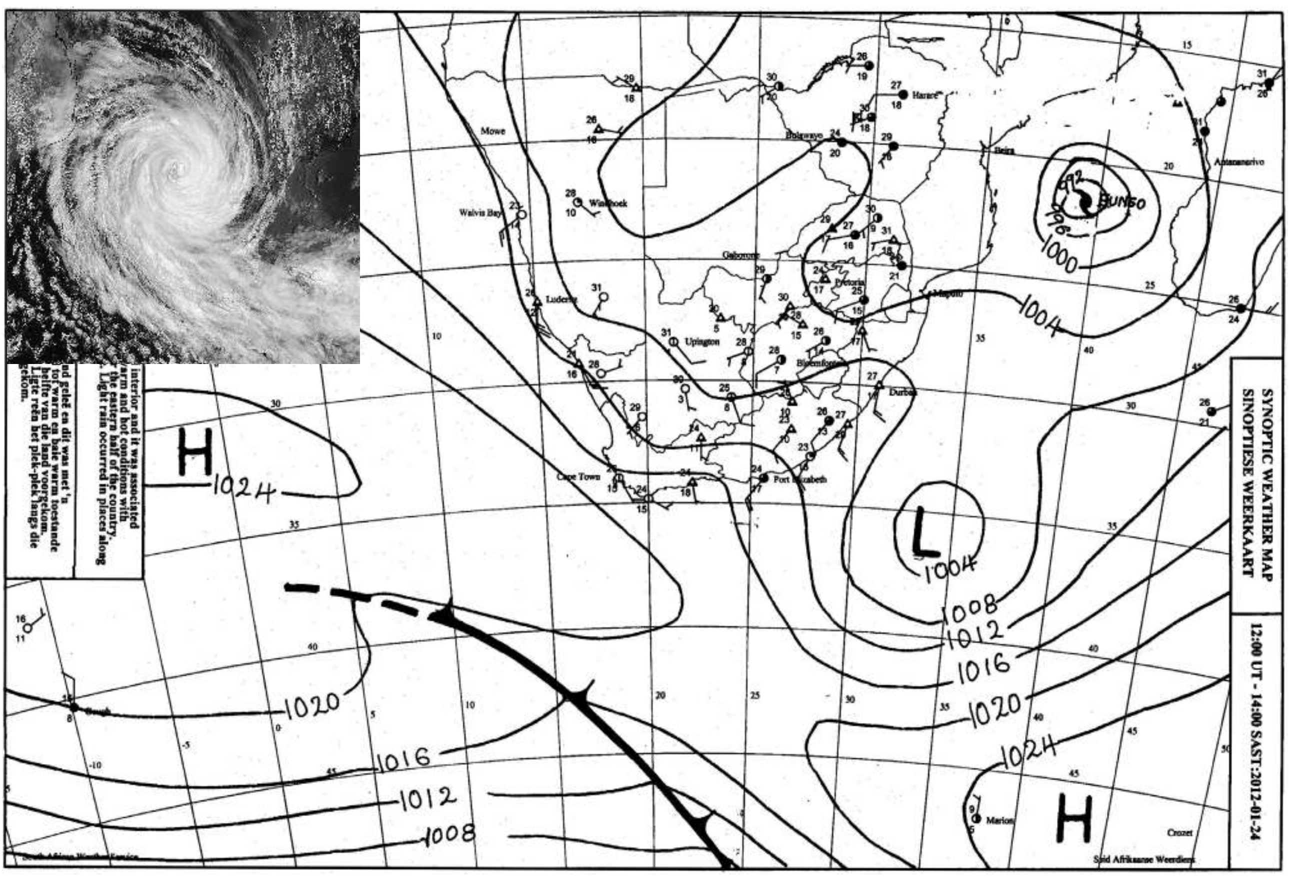

Figure 1.14 A synoptic chart showing tropical cyclone Funso, 24 January 2012. The inset shows a satellite image of the cyclone.