Chapter 1: Mid-latitude cyclones
Chapter 2: Tropical cyclones
Chapter 3: Subtropical anticyclones and associated weather conditions
Chapter 4: Valley climates
Chapter 5: Urban climates
All cyclones are systems of pressure and wind that form around a low-pressure centre. There are two main kinds of cyclones: mid-latitude cyclones and tropical cyclones. In this chapter, you will learn how mid-latitude cyclones form and how they affect South Africa’s weather and climate.

Unit 1: Characteristics, area of formation, conditions needed for formation

1. General characteristics of mid-latitude cyclones

Mid-latitude cyclones have similar patterns of pressure and wind to those associated with all cyclones. Look at Figures 2.1a and 2.1b, which show that, in a cyclone:

- the isobars are closed around a low-pressure centre
- wind blows from high pressure toward low pressure from all directions. As the wind moves toward the centre of low pressure it is deflected by Coriolis Force. This deflection is to the left in the southern hemisphere and to the right in the northern hemisphere. As a result, cyclonic airflow is clockwise in the southern hemisphere, and anticlockwise in the northern hemisphere.
- air converges and rises at the surface of Earth, and diverges in the upper air. You can see these patterns of convergence, ascent and divergence in Figure 2.1c, which is a section view, and applies to both hemispheres.
Mid-latitude cyclones also have characteristics that distinguish them from other cyclones:
- They are systems where cold polar and warm subtropical air masses meet. The boundary between these air masses is called a front. Mid-latitude cyclones have two fronts: a warm front and a cold front. Other types of cyclones do not have fronts.
- The pressure at their centre is about 996 hPa.
- Their diameters are between 1 500 and 3 000 km.
- They usually occur in families. This means that a few of them form one after the other and travel closely together.
- They travel at about 50 – 60 km per hour, covering about 1 200 km in a day.
- They last for between 4 and 14 days.

2. Areas where mid-latitude cyclones form

Mid-latitude cyclones form between about 40° and 60° north and south, where warm moist air from the tropics meets colder drier air from the polar regions. These two differing air masses meet along the polar front. The mid-latitude westerly winds of the global circulation of the atmosphere blow in these latitudes. Mid-latitude cyclones travel in these westerly winds, from west to east. In winter, mid-latitude cyclones move north as the pressure belts and wind systems move north following the apparent migration of the sun. Cold fronts pass over the Southern Cape and may extend into the interior. In summer, when the pressure belts and wind systems move south, the mid-latitude cyclones do too, and cold fronts usually pass to the south of South Africa.

Cold fronts are associated with cold weather and rain. Thus, the seasonal movement of the mid-latitude cyclones explains why:
- the south-western part of South Africa has wet winters and dry summers
- there are sometimes very cold snaps in winter in the interior of the country.

Figure 2.2 World map showing where mid-latitude cyclones form

About our world

The winds that meet along the polar front are the planetary winds of the general circulation of the atmosphere, blowing out of the subtropical and polar high-pressure cells.

Key words

air mass – a huge amount of air with similar temperature or humidity
warm front – the boundary between a mass of cold air and a mass of warm air along which the warm air rises up above the cold air ahead of it
cold front – the boundary between a mass of cold air and a mass of warm air along which the cold air pushes in under the warm air ahead of it
global circulation – the world scale pattern of pressure and winds developed in response to unequal latitudinal heating of Earth
planetary winds – winds that blow all year over large areas of Earth
cold snap – a relatively short period of unusually cold weather
3. Conditions necessary for the formation of mid-latitude cyclones

Mid-latitude cyclones need the following conditions to form:
- a mass of warm moist air meeting a mass of colder drier air
- upper air divergence, shown in Figure 2.1c. This is required to remove air that is ascending from below, and to make continued ascent possible.
- something to trigger the development of a low-pressure centre. (You will find out more about this in the next unit.)

ACTIVITY 1  THE CHARACTERISTICS AND DISTRIBUTION OF MID-LATITUDE CYCLONES

Geographical skills and techniques: using maps and other geographical representations

1. State three characteristics that mid-latitude cyclones have in common with all cyclones. (3 x 2 = 6)
2. State one characteristic of mid-latitude cyclones that other types of cyclones do not have. (1 x 2 = 2)
3. Give the main difference between mid-latitude cyclones in the northern and southern hemispheres. (2 x 2 = 4)
4. Why is upper air divergence important in the formation of a cyclone? (2)
5. Refer to Figure 2.2:
   5.1 Which side of the continents, western or eastern, is more likely to be affected by mid-latitude cyclones? Explain why. (2 x 2 = 4)
   5.2 Does South Africa lie within the latitudes where mid-latitude cyclones form? (2)
   5.3 Which province in South Africa is most likely to be affected by the northward movement of mid-latitude cyclones in winter? (2)
Unit 2: Stages of development and related weather conditions

Mid-latitude cyclones go through four stages from their initial formation to their degeneration. The first two stages make up the process of cyclogenesis, which is the development and strengthening of a cyclone. In stages three and four, the cyclone weakens and finally disappears.

**Stage 1: The initial stage**

In the initial or first stage of a mid-latitude cyclone, warm tropical air meets cold polar air along the polar front. There is a big difference in temperature across this front, and the winds on either side of the front blow in opposite directions. The front itself does not move, and is known as a stationary front.

**Stage 2: The developing stage**

Look at Figure 2.3 as you read the following information about the developing stage of a mid-latitude cyclone:
- In the developing stage a kink, or wave, develops in the polar front.
- The wave develops because disturbances in the fast moving upper air winds, known as jet streams, affect the movement of air at the surface or because a mountain range disturbs the motion of the air flowing over it.
- A small mass of warm air extends into the cold air, and rises over it.
- The rising air causes the pressure to decrease, establishing a centre of low pressure.

The related weather conditions are cloudy weather and some rain, which occur because the rising warm air cools and condenses.

**Stage 3: The mature stage**

About 24 hours after its initial formation, the mid-latitude cyclone develops to its mature stage. Figure 2.4 shows a plan view of this stage. Look at this figure as you read the information below.
- The wave increases as warm air moves further into the mass of cold air. A warm and a cold sector are established.
- Two fronts develop, marking the boundaries between the cold air and warm air masses. Each front takes its name from the temperature of the air mass that moves behind it:
  - The warm front is at the leading (eastern) edge of the warm sector. It is ahead of the warm air.
  - The cold front is at the leading edge of the cold air behind the warm sector. It is ahead of the cold air.
- The whole system moves from west to east.
Notice the different symbols used along the lines of the two fronts. The symbols indicate the temperature of the air behind the front. On a synoptic weather map, the cold and warm fronts are identified by these symbols.

Figure 2.6 on page 70 shows a vertical section along the line AB of the mature stage of a mid-latitude cyclone. It shows what the system looks like from ground level into the air above. Remember that the system is moving from west to east. Refer to this diagram as you read the points below.

- Air rises along the warm front: the warm air of the warm sector rises above the colder air ahead of the warm front.
- Air rises along the cold front as the heavier colder air behind the cold front wedges in under the warm air ahead of it.

There are specific weather conditions associated with the mature stage:
- The rising air along the fronts leads to condensation, cloud formation and rain.
- The rising air causes the pressure in the centre of the mid-latitude cyclone to drop further. Thus pressure is lower than it was in the initial stage.
- Airflow around the centre is cyclonic, which is clockwise in the southern hemisphere. This results in wind directions that vary in different parts of the system. In Figure 2.4, the winds are from the north-west in the warm sector, and from the north-east ahead of the warm front and south-west in the cold sector behind the cold front.

Stage 4: The occluded stage

Look at Figure 2.5 as you read the following information about the occluded stage.

- The cold air behind the cold front travels faster than the air in the warm sector. As a result, the cold front catches up with the warm front along most of its length.
- The warm air is forced to rise, leaving only a very small warm sector on the ground.
- The cold and warm fronts are joined. Notice that the symbol for an occluded front is a combination of the symbols for a cold and warm front.
- Widespread rain occurs as the warm air rises along the occluded front, cools and condenses.
Stage 5: The dissipated stage

This is the final stage of the mid-latitude cyclone:

- Remember, in the occluded stage, the cold front caught up with the warm front along most of its length, pushing the warm air of the warm sector upward. In this final stage, the entire warm sector is above the ground, and there is no more warm air at the surface.
- No cold or warm fronts are present. This is because there are no longer two distinctly different masses of air. There are thus no boundaries, marked by fronts, between the two air masses.
- The isobars no longer have the pattern of a mid-latitude cyclone and resume a regular pattern. This is because the mid-latitude cyclone is no longer present; it has dissipated.
- There are light gusts of cold air on the ground.

ACTIVITY 2 DRAW AND LABEL A DIAGRAM SHOWING THE MATURE STAGE OF A MID-LATITUDE CYCLONE

1. Copy the diagram below into your book. Use it to answer the following questions.

   ![Diagram showing the mature stage of a mid-latitude cyclone]

1.1 Which stage of a mid-latitude cyclone's development does it show? mature stage

1.2 Label these features of this weather system on your diagram:
   1.2.1 the cold front
   1.2.2 the warm front
   1.2.3 the warm sector
   1.2.4 the cold sector

1.3 Draw in the winds around this system.

1.4 Label the isobars with the following hectopascal values:
   1004   1006   996   1000.

(4 x 1 = 4)

2. Which stage will follow the one illustrated in your diagram? occluded stage
Unit 3: Weather patterns associated with cold, warm and occluded fronts

As you saw in Unit 2, the warm, cold and occluded fronts of a mid-latitude cyclone are associated with certain weather patterns.

1. Weather patterns associated with cold and warm fronts

Figure 2.6 shows a detailed cross-section through a mature mid-latitude cyclone. The mid-latitude cyclone travels from west to east. This is indicated as being from left to right in this diagram.

Imagine that an observer is at place X. Read the information below to see how the weather changes as the warm and cold fronts move past the observer. The two fronts do not always move past the same place. For example, places in South Africa are only affected by the cold front as the warm front always passes to the south of the country.

Weather patterns associated with warm fronts

- The warm front has a relatively gentle angle. As a result, it covers a wide area.
- Warm moist air from the warm sector rises over the cold air ahead of the warm front causing clouds to form. Three cloud types are associated with a warm front: high-level cirrus, altostratus, and nimbostratus.
- Soft rain falls because of the relatively gentle uplift of air along the front. This rain covers a large area, most of which lies ahead of the front.
- The changing cloud types will indicate to an observer at X that the warm front is approaching. They will first see the cirrus, then the altostratus, and then the nimbostratus clouds.
- As the warm front passes over an observer:
  - temperature increases as the warm sector arrives behind the front, replacing the cold air ahead of the front
  - pressure decreases because of the warmer, rising air in the warm sector. Remember, higher temperatures are associated with lower pressure.
  - humidity increases as the warm air behind the front can hold more water vapour than the cold air ahead of it
  - the wind direction backs as the front arrives. This means that it changes direction in an anticlockwise direction. If you look at Figure 2.4, you will see that the wind is north-easterly ahead of the front, but backs to become north-westerly behind the front.

Keyword

Backs - a change in wind direction in an anticlockwise direction
Weather patterns associated with cold fronts

The cold front is much steeper than the warm front, so uplift of air is rapid. Tall cumulonimbus clouds form. These clouds are associated with heavy rain and thunderstorms both ahead of and behind the front. The area over which rain falls is usually smaller than that of the rainfall area associated with the warm front. Most rain falls in the area behind the front.

As the cold front passes over an observer:
- temperature decreases as the cold air behind the front arrives. Snow often falls on high ground in winter.
- pressure increases in the colder air.
- humidity decreases; colder air holds less water vapour than warm air.
- the wind backs. In Figure 2.4, you can see that the wind backs from northwesterly ahead of the cold front to southwesterly behind it.

ACTIVITY 3 RECORD INFORMATION IN A TABLE AND DRAW A CROSS-SECTION

1. Read the information about weather associated with cold and warm fronts.
2. Copy the table below into your workbook, and fill in the missing information.

(6 x 2 = 12)

<table>
<thead>
<tr>
<th>Weather conditions associated with the passing of cold and warm fronts</th>
<th>Warm front</th>
<th>Cold front</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud type/s</td>
<td>cirrus</td>
<td>stratus</td>
</tr>
<tr>
<td>Rainfall</td>
<td></td>
<td>heavy</td>
</tr>
<tr>
<td>Pressure</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in wind direction</td>
<td>westerly</td>
<td>southerly</td>
</tr>
</tbody>
</table>

3. Draw a cross-section of the mature mid-latitude cyclone shown in Figure 2.4 on page 67 along line AB. Name the cloud types and annotate the diagram to show what happens at this stage.

(1 x 10 = 10)

2. Weather associated with occluded fronts

As you learnt in Unit 2, an occlusion occurs when the cold front catches up with the warm front, pushing the air in the warm sector upwards. When this happens, the cold air behind the cold front meets the cold air ahead of the warm front. The two cold air masses are not always the same temperature. These differences in temperature cause the formation of two different types of occlusion:

- A cold front occlusion is formed when the cold air behind the cold front is colder than the cold air ahead of the warm front.
- A warm front occlusion is formed when the cold air ahead of the warm front is colder than the cold air behind the cold front.

Read the information that follows and look at Figures 2.7a and 2.7b to find out about the weather associated with each type of occlusion.
Weather associated with a cold front occlusion

- The cold front has caught up with the warm front, causing the air in the warm sector to rise above the ground.
- The cold front touches the ground, while the warm front is lifted off the surface.
- The colder air behind the cold front undercuts the cold air ahead of the warm front, forcing it to rise. Cold, wet conditions, similar to those at a cold front, are experienced on the ground.

Weather associated with a warm front occlusion

Look at Figure 2.7b as you read the information.

- The cold front has caught up with the warm front, causing the air in the warm sector to rise above the ground.
- The warm front touches the ground, while the cold front is lifted off the surface.
- The less cold air behind the cold front is lighter than the colder ahead of the warm front, and so rises above this colder air.
- Cool, wet conditions, similar to those at a warm front, are experienced on the ground.

ACTIVITY 4  INTERPRET A DIAGRAM

Look at Figures 2.7a and 2.7b.

1. How will temperature change as:
   1.1 the cold occluded front moves past an observer?
   1.2 the warm occluded front moves past an observer?
Case study

Read the news report below and answer the questions that follow:

Stormy weather blasts Southern Africa: five dead after two days of severe weather

Snow coats the ground after a cold front brings heavy snow and cold weather to many parts of southern Africa.

Five people are reported to have died after torrential rain and cold weather battered South Africa and Lesotho.

The temperatures dropped so low that two people froze to death in the icy conditions. Their bodies were discovered early Sunday morning, lying by the side of two separate roads in the south of the Eastern Cape. According to the South African Weather Service, temperatures as low as -9 °C were recorded. As the cold weather raged, snow blocked several major highways, stranding dozens of car and truck drivers. The snow, which is unusual in Southern Africa, trapped 41 drivers who were travelling along Lesotho's Butha Buthe pass. All were later rescued, but many of them were suffering from slight hypothermia and dehydration.

As well as heavy snow, record rainfall was also reported in some districts. In Port Elizabeth, three people drowned and 2,000 people were evacuated as torrential rain lashed the city. Two people had to be rescued as they ignored a ban and rowed across a flooded river. In just two days, 118 mm of rain was reported and some residents are still waiting for their power to be restored.

The weather has now improved across the majority of South Africa, but cold weather is persisting across the Eastern Cape.

Source: Stormy weather blasts Southern Africa, Steff Gaulter, Al Jazeera, 17 July 2012

ACTIVITY 5  ANSWER QUESTIONS ON THE NEWS REPORT

1. With what kind of weather system is the front that caused the severe weather associated? (2)

2. Explain why this system affects South Africa in winter. (2 x 2 = 4)

3. Where did the cold air in the system originate? (2)

4. 4.1 Is the severe weather likely to have occurred ahead of or behind the cold front? (2)

4.2 Explain your answer in 4.1. (2)

5. Lesotho experienced heavy snow. Why would snow be expected here? (2)

6. Explain why cold weather is persisting in the Eastern Cape when it has cleared elsewhere. (2)

7. The cold front reported in the article had a negative impact on people. Cold fronts do, however, also bring some benefits. Write a paragraph of no more than twelve lines in which you describe at least four of the negative impacts of the passage of this cold front, and also suggest at least two possible benefits. (6 x 2 = 12)
Unit 4: Reading and interpreting satellite images and synoptic weather maps

1. Mid-latitude cyclone in satellite images
Mid-latitude cyclones are clearly visible on satellite images of Southern Africa because of the distinctive band of cloud associated with the cold front. You can see two cold fronts in the satellite image in Figure 2.8. They form a family of mid-latitude cyclones. The older cyclone is located east of the younger cyclone. The comma shape of the cyclone to the west indicates cold associated with the front and leads to the centre of the mid-latitude cyclone, which is in the bottom left in the satellite image.

2. Mid-latitude cyclones on synoptic maps
Cold fronts are always clearly marked on a synoptic map by a solid line with triangles pointing in the direction in which the front is moving. The cold air is always located behind this line.

Use your knowledge of the weather conditions associated with the passage of a front to help you to predict what will happen as the front moves from west to east. Revise what you learnt in Grade 11 about station models and their associated symbols.

- Temperature will be higher ahead of the front (to the east of the front) as the cold air behind the front has not yet arrived. As the front moves eastwards, temperatures can be expected to drop in the cold air behind the front.
- The wind backs as the front passes. Thus, a north-easterly wind will become north-westerly, and a north-westerly wind will become south-westerly. This will help you to predict changes in wind direction as the front passes.
- There is likely to be more cloud cover and rain behind the front, though these conditions are also sometimes found just ahead of the front. Again, these conditions change as the front moves eastwards. Use this information to predict what will happen.
- Sometimes cold fronts are associated with thunderstorms and snow on high land. Always look carefully at the precipitation symbols on the synoptic map.
- Cold fronts usually pass to the south of South Africa in summer. This is a clue to the season of the synoptic map if the date is not provided.
1. Name the weather system centred at about 42°5'S; 20°E. (2)

2. What is the pressure at the centre of this weather system? (2)

3. Name the type of front extending to the:
   3.1 north-east of the low-pressure centre (2)
   3.2 south-east of the low-pressure centre (2)

4. The station model in Figure 2.9c shows the weather at Cape Town on 22 June 2011.

   4.1 Draw a table to compare the weather at Cape Town on 22 June with the Cape Town weather shown on the map for 23 June. Use Figure 2.9d to help you. (1 × 15 = 15)

<table>
<thead>
<tr>
<th></th>
<th>22 June 2011</th>
<th>23 June 2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud cover</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2 Explain why the temperature has changed in the way you describe. (2 × 2 = 4)

5. Write a short paragraph in which you describe how the weather might be expected to change in Durban in the next 24 hours. (1 × 6 = 6)

6. If this synoptic chart were created in a GIS, several layers of data would have been used to create it.

   6.1 Name at least four layers that are needed to show all the information on this map. (4 × 1 = 4)

   6.2 Which two of the following kinds of data are used: raster, vector or attribute? (2 × 1 = 2)

   6.3 Suggest one benefit of having the layers used for this map in a GIS. (1 × 2 = 2)
Tropical cyclones are storm systems that can be extremely destructive. In this unit, you will find out how and where they form, how they affect people and the environment, and what can be done to protect people from these destructive storms.

Unit 1: General characteristics, areas where they form and factors necessary for their formation

1. General characteristics of tropical cyclones

Tropical cyclones are systems of wind blowing round a low-pressure centre. Airflow around the centre is therefore clockwise in the southern hemisphere and anticlockwise in the northern hemisphere. (Remember, this is due to the Coriolis Force, which deflects winds moving in toward the low-pressure centre.) Tropical cyclones share this characteristic with mid-latitude cyclones, but in other ways are very different. These differences are evident in this list of general characteristics:

- The isobars around the central low-pressure area are usually almost circular.
- Pressure at the centre is very low, usually about 960 hPa. Central pressures as low as 870 hPa have been recorded.
- They have a diameter of 600 km to 1000 km. They are thus smaller than mid-latitude cyclones.
- They develop in a warm moist air mass and are not associated with fronts.
- In the Tropical Easterlies, tropical cyclones travel westward at speeds of about 10 to 20 km per hour and on average cover about 200 km a day.
- Once a mature cyclone has developed, it lasts about a week. It will last less than this if it reaches land.
- They form in late summer and early autumn, when the water surface is warmest. In the southern hemisphere, they are most common in February and March.

2. Areas where tropical cyclones form

The map in Figure 2.10 shows the areas where tropical cyclones occur. Look at the map while you read the information that follows:

- They form in tropical latitudes and are driven by the Tropical Easterly winds.
- Tropical cyclones form over warm oceans between 5° and 20° north and south.
- Tropical cyclones are very rare in the southern Atlantic Ocean because the water there is not warm enough.
- They tend to form on the eastern side of continents, where there is a warm current.
- They move from east to west, but later tend to curve north or south toward the poles, often steered by the position of the subtropical high-pressure cells. Their tracks are irregular and difficult to predict.
by different names in the areas where they form. You can see these names on the map in Figure 2.10.

- Tropical cyclones are named once wind speeds reach 65 km per hour. They are named in alphabetical order, using male and female names alternately. The list restarts each season. Each area of formation has a separate list. For example, the first tropical cyclone in the Indian Ocean might be Anna, and the next one Bobby.

3. Factors necessary for formation of tropical cyclones

Tropical cyclones need the following conditions to form:
- a warm sea surface, with a temperature of at least 27 °C. At this temperature, water evaporates, and rises rapidly. This helps to initiate the low-pressure centre. Energy used for evaporation is released as latent heat when the water vapour condenses. This latent heat provides the energy needed for the tropical cyclone to continue developing. It warms the air, causing it to rise further, and reduce the central low pressure. This leads to further surface convergence and uplift of air.
- Coriolis Force is necessary for the rotation of air around the low-pressure centre. Coriolis Force is zero at the equator, and weak close to it. Thus, tropical cyclones do not form between 5° North and South.
- upper air divergence to remove the rapidly rising air in the centre of the cyclone and thus encourage continued rising.

ABOUT OUR WORLD
Tropical cyclones sometimes have local names. In Eastern Australia, for example, they are known as willy-willies.

KEY WORD
Latent heat – 'hidden' heat energy absorbed and stored in water vapour during the process of evaporation. It is released during condensation.

ACTIVITY 1: NAME AND LOCATE TROPICAL CYCLONES

(Geographical skills and techniques: using maps and other graphical representations)

1. Look at the map in Figure 2.10. What name is used for tropical cyclones that affect:
   1.1 Japan and China? (1)
   1.2 the Gulf of Mexico? (1)
   1.3 Mauritius, Madagascar and South Africa? (1)
   1.4 the state of Queensland in Australia? (1)
   1.5 Southern India? (1)

2. In March 2010, a tropical cyclone formed off the coast of Brazil. Explain why this made headline news as a rare event. (2 × 2 = 4)

3. In June 2012, cyclone Debbie hit the coast of Florida. How many tropical cyclones had developed in the north Atlantic in 2012 before this one? (2)
Unit 2: Stages of development of tropical cyclones

There are four stages in the development and decline of a tropical cyclone: formative, immature, mature, and decaying or degenerative stages. Each of the first two stages has a specific name. Only the third, the mature stage, is referred to as a tropical cyclone.

Stage 1: The formative stage (tropical depression)

- Atmospheric pressure begins to decrease in a wave in the easterly winds, but is still above 1 000 hPa.
- Winds bend around the developing low-pressure centre in cyclonic motion (clockwise in the southern hemisphere; anti-clockwise in the northern).
- Winds reach speeds of up to 64 km per hour.
- Spirals of tall cumulonimbus clouds surround the centre.

Stage 2: The immature stage (tropical storm)

In this stage of its development, the cyclone is given a name.

- The air pressure in the centre falls to below 1 000 hPa.
- The isobars become almost circular.
- A wall of cumulonimbus cloud develops around the centre, called the eye. The wall of tall clouds around the eye is known as the eyewall.
- Wind speeds are between 65 km per hour and 117 km per hour. Speeds are highest within 30 to 50 km of the developing eye, but are still high up to 500 km away.
- Wind speed and rainfall are greatest in the active quadrant.

KEY WORDS

spirals – three-dimensional curves
eye – central cloudless and calm area of a tropical cyclone
eyewall – the tall cumulonimbus clouds that surround the eye of a tropical cyclone
quadrant – a quarter of a circle
Stage 3: Mature stage (tropical cyclone)

Wind and weather is the worst and most widespread in the left-hand quadrant

Figure 2.11c Mature stage (tropical cyclone)

- The pressure in the eye is very low (less than 980 hPa), but no longer decreasing.
- The extent of the tropical cyclone has increased. Wind speeds are now at least 118 km per hour.
- There is a tight band of tall cumulonimbus clouds around the centre, the eyewall, and the eye is clearly visible.

Stage 4: Degenerating (decaying or dissipating) stage

- Pressure begins to increase.
- The area covered by the cyclone decreases.
- Wind speeds begin to decrease.
- Heavy rain still falls, but the tight wall of cloud begins to break up.

Not all tropical cyclones develop to Stage 3. A tropical cyclone can dissipate at any stage if its supply of warm moist air is reduced. This happens when:

- it moves into higher latitudes, where it is cooler and there is thus less evaporation from the sea surface
- it reaches land where it is dry. There will then be no evaporation and subsequent release of latent heat. Friction with the land also slows down the tropical cyclone.

A tropical cyclone that is dissipating can regenerate if it moves back over a warm ocean. As a result, the same system can change from a tropical cyclone to a tropical storm and then regain tropical cyclone status.
ACTIVITY 2  IDENTIFY THE STAGES OF DEVELOPMENT OF CYCLONES

(Geographical skills and techniques: applying map skills, map interpretation)

1. Look at the figures of the tropical cyclone at different stages of development (Figures 2.11a to d). How does the pattern of the isobars indicate that the wind speeds are greater closest to the eye? (2)

2. Copy the diagram of the mature cyclone stage shown in Figure 2.11c without the labels. Draw in the wind flow around this cyclone for the southern hemisphere. (2)

3. Refer to Figure 2.12 to answer these questions:

![Diagram of a tropical cyclone](image)

**Figure 2.12** Simplified weather map of a tropical cyclone

3.1 What is the pressure in the eye of the tropical cyclone? (2)

3.2 What is the diameter of this storm from the 1000 hPa isobar on the east through the centre to the same isobar in the west? (2)

3.3 In which stage is this weather system? Give two pieces of evidence to support your answer. (2 x 3 = 6)

3.4 Which place will receive the worst weather, the Florida or the Yucatan Peninsula? Give a reason for your answer. (1)

3.5 What is a tropical cyclone called in this part of the world? (2)
Unit 3: Weather patterns associated with tropical cyclones

A tropical cyclone is always associated with low pressure, heavy rain, and high wind speeds. The cross section of a mature cyclone in Figure 2.13 gives more detail about the weather associated with a tropical cyclone. Refer to it as you read the points below:

![Cross-section of a mature tropical cyclone](image)

**Figure 2.13 Cross-section of a mature tropical cyclone**

- The ‘eye’ has a diameter of about 25 km, but this does vary. It is associated with gently subsiding air. This air warms as it subsides. Thus, no clouds form in the region of the eye. The sky is clear, and the air is still and calm. No rain falls.
- On either side of the eye, the air rises and cools, forming high walls of cumulonimbus clouds. The clouds of the eyewall can extend vertically as high as 15 km.
- Rain is heaviest in the eyewall. There will also be heavy rain some distance from it.
- Cirrus and altostratus clouds extend away from the eyewall, sometimes as far as 500 km.
- Winds have high speeds. The wind speed is highest near the eyewall. The eyewall is also known as the **vortex** of the tropical cyclone because of the spinning air found there.

The graph in Figure 2.14 shows how pressure, wind speed and temperature change across a mature tropical cyclone. It clearly shows that pressure is lowest, conditions are calm, and temperature is highest in the eye.

![Graph showing how pressure, wind speed and temperature change across the mature tropical cyclone](image)

**Figure 2.14 Graph showing how pressure, wind speed and temperature change across the mature tropical cyclone**

**KEY WORD**

**vortex** – a mass of spinning fluid or air
ACTIVITY 3 IDENTIFY WEATHER ASSOCIATED WITH THE PASSAGE OF A MATURE CYCLONE

1. A mature tropical cyclone approaches an observer in the southern hemisphere. Copy and complete the table below to show how weather conditions change as the tropical cyclone passes over the observer. Refer to Figures 2.13 and 2.14 and the text to help you.

<table>
<thead>
<tr>
<th></th>
<th>In first eyewall</th>
<th>In eye</th>
<th>In second eyewall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air pressure</td>
<td>decreases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td></td>
<td>increases</td>
<td></td>
</tr>
<tr>
<td>Wind direction</td>
<td>south/south-westerly</td>
<td>no wind</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clouds</td>
<td>tall cumulonimbus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainfall</td>
<td>very heavy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. What kind of clouds would the observer see first as the tropical cyclone approached?

3. How far away from the eye could rain fall?

4. Give a brief explanation of why:
   4.1 it is warmest in the eye
   4.2 the wind direction is opposite on each side of the eye.
   4.3 Use a simple sketch to support each explanation.

5. Read the descriptions of weather given in the newspaper headlines below and then answer the questions that follow.

- Cold front brings bitterly cold weather to the Western Cape
- The weather system is moving westward, bringing gale force winds and very heavy rain
- Cold snap experienced on the Highveld
- After battering the East Coast, the weather system moved over land and dissipated.

5.1 Write down the number of each headline that describes weather that could be associated with a tropical cyclone.

5.2 What kind of weather system could be associated with the other headlines?
Unit 4: Reading and interpreting satellite images and synoptic weather maps

1. Satellite images of tropical cyclones

On satellite images of tropical cyclones:

- the pattern of the clouds shows the circular cloud pattern associated with a tropical cyclone quite clearly.
- the pattern of clouds usually indicates the direction of winds around the tropical cyclone; this indicates whether the system is in the northern or southern hemisphere. Follow the lines of cloud as they swirl in toward the centre of the tropical cyclone in Figure 2.15. Can you see that they show a clockwise direction? Therefore this cyclone is in the southern hemisphere.
- the eye of a mature cyclone is visible in the centre of the system. You can see it clearly as the dark central part of Figure 2.15.
- the active quadrant is shown by the thickest and whitest clouds. In Figure 2.15, this is in the south-west quadrant of the cyclone.

![Satellite image of a tropical cyclone](image)

- Figure 2.15 Satellite image of a tropical cyclone

2. Tropical cyclones on synoptic weather maps

Tropical cyclones only appear on synoptic maps in the summer months. They are only found between 5° and 30° north and south. They are identifiable on synoptic maps by several features:

- There is a distinctive circular pattern of isobars around a centre of low pressure.
- In a mature tropical cyclone, the symbol $\bigcirc$ is placed in the centre of the system. The other stages have an L for the low pressure in the centre.
- Closely spaced, very small, circular isobars mark the eye.
- The name of the tropical cyclone is printed near the eye.
- If there are weather stations in the vicinity of the cyclone, their symbols will show:
  - overcast conditions and, often, rain or thunderstorms
  - cyclonic airflow.

ABOUT OUR WORLD

Wind speed is shown in knots on a synoptic map. One knot is about 1.8km/hr.
Refer to the satellite weather map in Figure 21.2.4 

1. Look at the satellite image in Figure 21.4.6 

(a) Describe the weather system in the tropical oceans. 

(b) Explain why this weather system is a tropical cyclone. 

(c) Describe the wind direction around the region. 

(d) Draw a sketch to show the pattern of isobars. 

(e) Give one piece of evidence that supports your answer. 

(f) Write the date of the weather system as shown in the picture. 

(g) Describe the location of the storm. 

(h) Give two pieces of evidence for your answer.
Unit 5: Case study of a tropical cyclone

Tropical cyclone Irina was a tropical storm that affected Southern Africa in late February and early March of 2012. Read the information provided about its life history, and then answer the questions that follow.

Case study: Tropical cyclone Irina

Irina began life in the Indian Ocean as a tropical depression named System 92S and followed the track you can see in Figure 2.18. Refer to this as you read about some key events in its development.

- Between 27 February and 1 March, the system was centred over the ocean close to the west coast of Madagascar. High rates of evaporation from the warm water (29 °C) led to strengthening of the system. When wind speeds reached 65 km/hour and pressure dropped sufficiently, the system was reclassified as a tropical storm and named Irina.
- Irina then moved westward, and by 3 March was only 280 km from the coast of Mozambique, but did not make landfall. Parts of Mozambique experienced strong winds (up to 92 km per hour), high rainfall and a drop in temperature.
- As Irina moved south on 3 and 4 March, heavy rains were experienced over Swaziland and parts of KwaZulu-Natal.
- From 5 March, Irina moved towards the open ocean, and by 6 March was no longer affecting weather over land. As Irina moved into cooler water, she began to lose strength.
- On 9 March, Irina's winds dropped below 64.8 km per hour and the dissipating storm was reclassified as a tropical depression.

Figure 2.18 Track of tropical cyclone Irina

ACTIVITY 5 CASE STUDY OF TROPICAL CYCLONE IRINA

(Geographical skills and techniques: Mapwork techniques)

1. Refer to the information about the life cycle of tropical storm Irina.
   1.1 How did Irina’s status change from 28 to 29 February?  
   1.2 What made this change possible?  
   1.3 What change occurred around 9 March?  
   1.4 What caused this change?  

2. Look at the satellite image in Figure 2.19.
   2.1 On which date was this satellite image taken?  
   Give a reason for your answer.  
   2.2 Has the storm in this image made landfall?  
   2.3 What information is there in the satellite image to support your answer?
2.4 In which quadrant is there most rain and thickest cloud?
2.5 Is this the quadrant you would expect to have the most rain and cloud?
2.6 Explain your answer to Question 2.5.

3. Refer to the synoptic weather map in Figure 2.20b.
3.1 Copy the table below into your book and record the weather at Maputo. Refer to Figure 2.20a to help you.

<table>
<thead>
<tr>
<th>Wind direction</th>
<th>Wind speed</th>
<th>Temperature</th>
<th>Dew point temperature</th>
<th>Cloud cover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2 Are wind speeds higher to the north or south of the storm?
3.3 Give one piece of evidence from the map to support your answer to Question 3.2.
3.4 Give one piece of information that is:
   3.4.1 available on the satellite image, but not on the synoptic chart
   3.4.2 available on the synoptic chart but not on the satellite image

4. Describe and explain what would happen to this tropical storm if it continued to move westward.
1. Impact of tropical cyclones on human activities and the environment

Tropical cyclones are associated with very strong winds, and with large amounts of rain that fall in a short space of time, known as torrential rainfall. The pressure towards the centre of the system is low. These factors affect the environment in the following ways:

- Floods occur if the large amount of rain cannot naturally drain away quickly enough.
- Forceful winds may uproot trees and blow roofs off buildings. Loose objects can be blown about, which may batter buildings and cars, and harm people and animals.
- High wind speeds give rise to stormy waters, which can be dangerous for shipping and for people on the beach or in the water.
- A cyclone can lead to a storm surge, which is an abnormal rise in sea level. This may flood a wide area of coastal land. The surge is caused by:
  - the exceptionally low pressure, which allows the water to rise higher than usual
  - forceful winds between the tropical cyclone and a coast. The winds drive the water toward the shore, and it slows down and piles up as it approaches land.
- As well as other flood related damage, a storm surge can result in widespread flooding of salt water, which may pollute the soil.
- Tornadoes can develop in the cumulonimbus clouds of tropical cyclones. A tornado is a violently rotating column of winds extending from a thunderstorm to the ground. Tornadoes can reach speeds of 400 km per hour, and can thus be very destructive. Water spouts, such as the one illustrated in Figure 2.21b, are weak tornadoes that form over water in association with a tropical cyclone.

The effects of tropical cyclones on the environment in turn affect people and their activities:

- People may be killed and injured by the flood water and high winds.
- People may lose their homes and their livelihood, as fields of crops and businesses are flooded or damaged by strong winds.
- Daily living may be disrupted if water, sanitation, transport, and communication links are damaged and destroyed.
- Disruption in water and sanitation services can lead to the outbreak of waterborne diseases such as cholera.
- Essential services, such as hospitals and schools, may be disrupted.
- Ships and fishing related resources may be damaged or destroyed.
- Where flooding is not excessive, an area may benefit from the rain filling rivers and lakes.
2. Strategies that help prepare for and manage the effects of tropical cyclones

There are a number of measures that can be taken to decrease the risks to the people living in areas with a high incidence of tropical cyclones:

- Monitor the path of the cyclone and its development using remote sensors on satellites. This enables weather to be forecast and a warning given to people likely to be in the path of a cyclone. Unfortunately, paths are not always predictable, but at least warning can be given.
- Prepare evacuation plans so that people may leave an area in time once they have been warned of the arrival of a forceful tropical cyclone.
- Do not build on low lying ground that can easily be flooded.
- Build structures in ways that can withstand floods and strong winds, for example building on stilts, using brick, and ensuring roofs are attached firmly to the structure.
- Build strong shelters where people can gather before a storm arrives. These shelters should be stocked with food, water, medical supplies, and a generator for electricity.
- Ensure that there is a disaster management plan. The plan should include emergency medical supplies and food, and a source of skilled people to assist. If a powerful tropical cyclone causes much damage, international government and aid agencies such as the Red Cross and the Red Crescent need to assist.

**Tropical cyclone Irina causing havoc in KZN**

Saturday, 3 March 2012

Senior Forecaster at the South African Weather Service, Mkhuluswa Msimanga, says the weather service has issued a flood warning to areas where heavy rain is likely to fall as a result of tropical cyclone Irina. Msimanga says that by ten o'clock tonight the storm will be at its worst, with waves along the coast reaching up to seven metres in height.

KwaZulu-Natal Cooperative Governance and Traditional Affairs MEC, Nomusa Dube, says all emergency centres have been placed on alert for tropical cyclone Irina, which is due to hit northern parts of the province this weekend. Dube has urged the public to remain indoors until the cyclone has passed.

Adapted from: Tropical cyclone Irina causing havoc in KZN, SABC, 3 March 2012

**Activity 6**

**THE IMPACT OF TROPICAL CYCLONE IRINA IN KZN**

Read the extract provided and answer the questions below:

1. Which agency issued a warning about the impact of the tropical cyclone?
2. What impacts of tropical storm Irina are reported in the extract?
3. Could any impacts be beneficial? Explain your answer.
4. What future conditions are forecast?
5. What are people advised to do to protect themselves from the effects of Irina?
6. Which agencies are mentioned as being responsible in some way for preparing for the impact of the storm and managing its effects?
7. The use of GIS can assist people to prepare for and manage the effects of tropical storms. Write a paragraph suggesting at least four ways in which GIS would be of assistance.
Unit 1: Location and general characteristics of high-pressure cells that affect South Africa

1. Location of the high-pressure cells that affect South Africa

Three high-pressure cells affect South Africa. You can see them in Figure 2.22. They are:
- the South Atlantic high-pressure cell to the west of South Africa (SAHP). This is also known as the South Atlantic anticyclone. (SAAC)
- the South Indian high-pressure cell to the east of South Africa (SIHP). This is also known as the South Indian anticyclone. (SIAC)
- the Kalahari high-pressure cell over the interior of South Africa. This is also known as the Kalahari anticyclone.
2. General characteristics of these high-pressure cells

The three high-pressure cells have several key characteristics:
- They are large systems (about 3,000 to 4,000 km in diameter)
- These three cells, unlike the mid-latitude and tropical cyclones, are always present. Their positions shift slightly, but they never move away completely.
- There is anticyclonic airflow around the high-pressure centre. This is anti-clockwise in the southern hemisphere, as illustrated in Figure 2.23. Notice that winds blow onshore from both the SAAC and the SIAC, but over ocean currents with different temperatures.

![Plan view of a high-pressure cell](image)

Figure 2.23 Plan view of a high-pressure cell
- Air subsides at the centre of the anticyclone, and then diverges. You can see this in Figure 2.24. **Subsiding** air warms and as a result, its relative humidity decreases. Anticyclones are thus associated with dry air.

![Cross section view of a high-pressure cell](image)

Figure 2.24 Cross section view of a high-pressure cell
- There is a **temperature inversion** above the surface of Earth. Normally, the temperature of the atmosphere decreases with altitude. In a temperature inversion, this relationship is turned upside down, or inverted, and temperature increases with height. When air rises at the normal temperature lapse rate, the higher you go the colder it gets. A temperature inversion
occurs when it gets warmer as you go higher. The graph in Figure 2.25 shows
temperature decreasing with altitude from A to B, and from C to D. The graph
also shows that temperature increases from B to C, indicating a temperature
inversion. In sub-tropical anticyclones, the temperature inversion is the
result of the adiabatic warming as the air subsides.

![Diagram of temperature and altitude with an inversion layer]

**Figure 2.25 An inversion layer**

- The air is stable. This is because of the presence of the temperature inversion.
  Warm air at the surface of Earth rises and adiabatic cooling until it reaches
  the same temperature as the surrounding air. While it is warmer than the
  surrounding air, and thus rising, it is said to be unstable. Once it has reached
  the same temperature as the surrounding air it no longer rises, and is said to
  be stable. If there is a warmer layer in the atmosphere, the rising air will no
  longer continue to rise and will be stable. A temperature inversion is a warmer
  layer and is thus associated with stable air. It effectively blocks the continued
  rising of air, and thus inhibits the formation of rain.

**ACTIVITY 1  HIGH-PRESSURE CELLS**

1. Draw a well-labelled sketch to show the positions of the three
   sub-tropical high-pressure cells that influence South Africa's weather and
   climate.  
   \(3 \times 2 = 6\)

2. Copy the paragraph below into your books, choosing the correct alternative
   from the underlined words.
   Anticyclones are centres of high/low pressure, and circulation around them in
   the southern hemisphere is clockwise/anticlockwise. They are associated with
   rising/subsiding air and stable/unstable conditions. The subsiding air results
   in a temperature inversion in which temperature decreases/increases with
   height.  
   \(5 \times 1 = 5\)
Unit 2: Anticyclonic air circulation around South Africa and its influence on weather and climate

In this unit, we will consider how anticyclonic circulation associated with the three subtropical high-pressure cells influences South Africa's weather and climate.

In the previous unit, you saw that anticyclonic circulation around high-pressure cells is associated with stable air, which does not rise. In order for rain to form, air needs to rise and cool until it is cold enough for condensation to occur and clouds to form. The stable air associated with anticyclonic circulation of the SAAC, SPC, and the Kalahari anticyclones thus reduces the chance of rain over South Africa, resulting in a generally low rainfall.

1. Influence of the Kalahari high-pressure cell

Wet summers, dry winters in the interior

Winters are dry and summers are wetter over the interior of South Africa because the height of the base of the temperature inversion over the country changes with the seasons.

Look at Figure 2.26. It shows that, in winter, subsiding air sinks down to the level of the plateau. The base of the inversion layer is below the escarpment. The inversion acts a bit like a lid, preventing moist sea air from rising above the escarpment and reaching the plateau. As a result, the interior of the country is dry. Winters characterised by clear, sunny skies, stable air and very little rain. Days are warm, and nights are cold as the cloudless sky means that much of the heat received during the day is reradiated back to space at night.

In summer, the land surface is heated, causing warm air to rise and a surface low to form. As a result, air subsiding from the Kalahari high-pressure cell does not reach the surface and the inversion layer is above the level of the escarpment. Moist air is therefore able to reach the plateau and rise, leading to a greater possibility of rain.

Figure 2.26 Seasonal differences in the height of the temperature inversion
2. The influence of the South Atlantic and South Indian high-pressure cells

A wetter eastern and drier western part of the country

In Figure 2.22, you saw that onshore winds from the SAAC move across the Benguela current. They do not pick up much moisture, as the Benguela current is cold. In addition, this anticyclone remains fairly close to the coast in both winter and summer. This means that winds blowing onshore do not have much distance in which to pick up moisture. For these two reasons, the winds from the South Atlantic anticyclone do not bring much moisture to the western part of the country, contributing to the western region being dry.

In Figure 2.22, you also saw that winds from the SIAC blow over a warm ocean current called the Agulhas current. The SIAC moves further away from the coast in summer, and onshore winds thus have a greater distance over which they can pick up moisture. These two factors contribute to the eastern parts of the country receiving more rain than the western parts, especially in summer.

Intense cold snaps in winter

In winter, the South Atlantic anticyclone sometimes extends to the east, behind a cold front. This ‘ridging in’ of the anticyclone, as illustrated in Figure 2.27, strengthens the flow of cold air from the south-west behind a front, leading to very low temperatures and snow in the interior, especially in the high-lying parts of the country.

The south-easter ‘Cape Doctor’ in summer

In summer, the South Atlantic anticyclone moves further south. When it ridges in to the east, (see Figure 2.28) it causes a strong south-easterly wind to blow in Cape Town, and other parts of the Cape Peninsula and the southern Cape. As the south-easter rises over Table Mountain, the moisture it contains condenses and forms the cloud cover known as the tablecloth.

ACTIVITY 2 CLIMATE AND WEATHER PATTERNS ASSOCIATED WITH SUBTROPICAL ANTICYCLONES

1. Write a paragraph explaining why the plateau of South Africa has dry winters and wet summers. Use sketches to support your answer. (10 x 1 = 10)

2. Snow fell in Gauteng on 7 August 2012. Temperatures at night were as low as -2 °C. Offer a possible explanation for this unusually cold weather. Use a sketch to help you to explain why temperatures were so low. (8 x 1 = 8)

KEY WORD

ridging – the development of a long narrow extension of a high-pressure cell

ABOUT OUR WORLD

In the past, people believed that the forceful South-Easter blew disease out of Cape Town, and so it became known as the Cape Doctor. Nowadays it blows pollution out of the city, clearing the air.
Unit 3: Travelling disturbances associated with anticyclonic circulation

1. Moisture front and line thunderstorms

Fronts are the boundaries between air masses with different characteristics. A moisture front is a front that separates air masses of different humidity. A moisture front develops over South Africa in summer. Refer to Figure 2.29 as you read the information about the moisture front and its associated thunderstorms.

- The Kalahari high-pressure cell over the interior is lifted, and warm moist air from the South Indian anticyclone flows into the interior from the north-east.
- Colder drier air flowing around the South Atlantic high-pressure cell blows into the interior from the south-west.
- The more moist north-easterly winds and the drier south-westerly winds converge, forming a moisture front that extends from south-east to north-west across South Africa.

At the front, the warm moist air rises, mainly because of convergence. The rising air is unstable, and thus rises to great heights. As it rises, it cools adiabatically. Condensation occurs and tall cumulonimbus clouds form. These are associated with thunderstorms, heavy rain, and possible hail in a series of storms along the line of the front. Line thunderstorms are not caused mainly by heating of the surface, as is the case in convectional thunderstorms, and can thus also occur at night.

- The rising air along the front results in lower pressure. The lower pressure area is called a trough of low pressure.

2. Coastal low-pressure systems

A coastal low is a small low pressure system that develops on the west coast, and moves along the coast towards the east. A coastal low is not associated with fronts. Wind circulates in a clockwise direction around the coastal low, resulting in onshore winds on its western side, and offshore winds on its eastern side (refer to Figure 2.30). The onshore winds bring rain or fog, while the offshore winds are associated with warm dry conditions.

3. South African berg winds

Berg winds are hot dry winds that blow from the plateau to the coast. Look at Figures 2.31a and 2.31b as you read the information about their formation and effects.

- Berg winds blow in response to a pressure gradient that exists when there is high pressure over the land and lower pressure along the coast. The low pressure is associated with an approaching cold front, and often also with a coastal low.
As the wind descends from the plateau, it warms adiabatically at a rate of 1 °C/100 m and temperatures increase, usually by at least 10 °C.

When the cold front arrives, the temperature drops sharply in the cold air behind the front. The pressure rises in the colder air. The difference in pressure between the plateau and the coast no longer exists and so the berg wind ceases.

On the west coast, berg winds blow from the north-east, while on the east coast they blow from the north-west.

The hot, dry windy conditions associated with a berg wind are unpleasant, and sometimes cause fires to break out. Berg winds are most frequent between April and September, the winter months. They can blow during the day or at night. As a result, some places experience their highest annual temperature in winter or at night.

Figure 2.31a Map showing conditions for a berg wind

Figure 2.31b Cross-section showing the movement of the berg wind from plateau to coast.

**ACTIVITY 3  BERG WINDS**

(Geographical skills and techniques: using maps and other graphical representation)

1. Look at Figure 2.29 (a moisture front) and answer these questions:
   1.1 On which side of the moisture front does most rain fall? (2)
   1.2 Which winds converge along the moisture front? (2)
   1.3 Explain why these winds are not equally humid. (2 x 2)
   1.4 Explain why thunderstorms form along the moisture front. (1 x 8 = 8)

2. Look at Figure 2.30 (a coastal low) and then describe how the wind direction and the chance of rain will change as the coastal low moves past an observer to the east of its present position. (2 x 2 = 4)

3. The onset (start) of a berg wind is marked by a sudden increase in temperature. Its cessation (end) is marked by a sharp drop in temperature.

   3.1 Explain why the onset of a berg wind is associated with a sudden increase in temperature. (2 x 2 = 4)

   3.2 What environmental problem can a berg wind cause? (1)

   3.3 Why does the temperature drop sharply when a berg wind stops blowing? (2)
Unit 4: Reading and interpreting satellite images and synoptic weather maps

Many of the weather and climate features associated with anticyclonic circulation can be seen on satellite images and synoptic maps. The information below will help you to read and interpret these sources.

1. Reading and interpreting satellite images
   - The large high-pressure systems that affect South Africa are associated with fair weather. They can be seen on satellite images as large cloudless areas.
   - A berg wind off the west coast is sometimes marked by a plume of dust going out to sea.
   - Line thunderstorms, and the low-pressure trough associated with them, appear as a band of cloud across the country from south-east to north-west.
   - A coastal low appears as a patch of cloud on the coast.

2. Reading and interpreting synoptic charts
   - The subtropical anticyclones appear as large systems of isobars, with a high in the centre.
   - A berg wind is marked by offshore winds and raised temperatures at coastal weather stations ahead of an approaching cold front.
   - Ridging anticyclones are indicated by an elongated pattern of isobars extending away from the centre of high pressure.
   - The South-Eastern/Cape Doctor is indicated by south-easterly winds blowing parallel to isobars of the SAAC, which has ridged to the east of its centre and lies south of the Western Cape.
   - South-westerly winds ridging in behind a cold front indicate an intense cold

**KEY WORD**

dew point temperature – the temperature at which water vapour in the air starts to condense

<table>
<thead>
<tr>
<th>Winter conditions are indicated by:</th>
<th>Summer conditions are indicated by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low temperatures over the interior (20 °C)</td>
<td>High temperatures over the interior (30 °C)</td>
</tr>
<tr>
<td>Cloudless conditions over the interior</td>
<td>The possible presence of a moisture front</td>
</tr>
<tr>
<td>Dry conditions in the interior indicated by a large difference between temperature and dew point temperature (low relative humidity)</td>
<td>The possible presence of a tropical cyclone to the east of the country</td>
</tr>
<tr>
<td>The Kalahari high-pressure cell present over the land</td>
<td>The absence of the Kalahari high-pressure cell over the interior</td>
</tr>
<tr>
<td>The presence of the SAAC and the SIAC to the north</td>
<td>The SAAC and the SIAC are present, but located further south</td>
</tr>
<tr>
<td>Cold fronts close to and extending over the country</td>
<td>Cold fronts passing to the south of the country</td>
</tr>
</tbody>
</table>

- The moisture front and line thunderstorms can be identified by the overcast, rain and thunderstorm symbols at stations along the usual position of the front. This front extends from south-east to north-west across the country. Wind direction at stations to the east of the front will be north-easterly.
- A coastal low is seen as a small low-pressure system on the coast that has no fronts. A weather station ahead of a coastal low will indicate offshore winds and clear skies, while a station behind it will indicate onshore winds and cloudy skies (and sometimes rain or fog).

Synoptic weather maps for summer and winter have certain differences. Many, though not all, relate to the position of the subtropical high-pressure cells and their associated weather patterns. The positions of mid-latitude cyclones and tropical cyclones, (which you will learn more about in Topic 3), also vary from season to season. The table shows some of the key indicators that will help you recognise the season in which a synoptic map was compiled.
ACTIVITY 4  READ AND INTERPRET A SATELLITE IMAGE AND SYNOPTIC CHART

(Geographical skills and techniques: Mapwork techniques)

1. Look at the satellite image. It shows smoke from fires in the Drakensberg being blown towards the coast.
   1.1 Suggest why the wind is blowing toward the coast. \(2 \times 2 = 4\)
   1.2 What do you call a wind that blows from the plateau to the coast? \(1\)

2. Refer to the synoptic chart provided and answer these questions.
   2.1 Name the pressure systems labelled A, B and C. \(1 \times 3 = 3\)
   2.2 Name the low-pressure systems marked D and E. \(1 \times 2 = 2\)
   2.3 What kind of fronts are F and G? \(2 \times 1 = 2\)
   2.4 Give a full description of weather conditions at Upington. The station model is shown in Figure 2.33a \(1 \times 7 = 7\)
   2.5 Are conditions moist or dry over the interior? \(2\)
   2.6 Give three pieces of evidence from the map for your answer. \(3 \times 2 = 6\)
   2.7 State whether this map shows summer or winter conditions? Motivate your answer by giving at least five pieces of evidence from the map. \(6 \times 2 = 12\)

Figure 2.32 Satellite image of Drakensberg

Figure 2.33a Station model for Upington on 7 July 2002

Figure 2.33b Synoptic weather chart, 7 July 2002, 12:00 UT
Valley climates

The weather systems you have learnt about in previous chapters affect the climate of large regions of Earth. Smaller scale variations in the heating of the atmosphere and in pressure and winds can affect the climate of much smaller, more local areas. Valley climates are one example of such local climates.

Unit 1: The micro-climate of valleys (the effect of the slope aspect)

The sun's rays strike the surface of Earth at an angle, known as the angle of incidence. The angle of incidence varies. For instance, it changes during the day: it is low at sunrise and sunset, and high at noon. It also varies with the season: it is higher in summer than in winter. In Figure 2.34, you can see the sun's rays striking Earth at three different angles at three different places. At A, they strike Earth at an angle of 90°. We say that they strike Earth directly. The angle of incidence at A is large. At places B and C, the sun's rays strike Earth more obliquely and the angle of incidence is smaller. The size of the angle of incidence affects the heating of the surface, and the temperature of the air above it.

Figure 2.34 illustrates how, where the angle of incidence is large (at A), the sun's rays spread out over a smaller area than where it is smaller (at B and C). The same amount of energy has to heat a smaller surface area at A than at B and C. Temperatures will be higher at A and lower at B and C.

The direction that a slope faces affects the angle at which the sun's rays strike it. The direction in which a slope faces is called its aspect.

In the southern hemisphere, the sun's rays strike north-facing slopes more directly than south-facing slopes. This is because the sun's rays come from the north, the direction of the equator. In the northern hemisphere, the rays strike the southern slopes more directly because here the sun's rays come from the south. Figures 2.35a and 2.35b show a southern hemisphere situation in winter and in summer. In summer, the sun's rays strike the north-facing slope more directly than the south-facing slope. Thus, the north-facing slope will be warmer than the south-facing slope. The same applies in winter: the north-facing slope will be warmer than the south-facing slope. However, in winter, both slopes will be cooler than they are in summer because the sun's rays on both slopes are at a lower angle than in summer. This lower angle in winter means that the lower parts of south-facing slopes and the bottom of the valley sometime get no sun at all. They are in a shadow zone.

There will be more evaporation on warmer than colder slopes. As a result, soils on hotter north-facing slopes are drier than soils on south-facing slopes.
Unit 2: Development of anabatic and katabatic winds, inversions, frost pockets and radiation fog

1. The development of anabatic and katabatic winds

Differences in heating and cooling in different parts of a valley during the day and at night lead to differences in temperature. This leads to pressure differences, which cause winds. Different winds develop during the day in a valley from those that develop at night. Read the information below and look at Figures 2.36a and 2.36b to find out about these winds.

Winds that develop in a valley during the day

Anabatic winds blow in response to differences in temperature and pressure between the top and bottom of the slopes of the valley sides. During the day, the upper slopes of a valley receive more energy than the lower slopes, as the sun’s rays strike them more directly, and for a longer time, especially if part of the valley floor is in a shadow zone. The air close to the upper slopes therefore gets hotter than air close to the lower slopes. As a result, the pressure is lower on the upper slopes. The wind blows upslope in response to this difference in pressure. This upslope wind, which blows during the day, is called an anabatic wind.

Valley winds are winds that blow along the length of the valley. As the slopes warm during the day, the smaller amount of air in the narrow head of the valley heats up faster than the greater amount of air lower down, where the valley is broader and less of the air is in contact with the warm sides. The difference in temperature results in the pressure being lower in the upper part of the valley than it is further down the valley. As a result, a wind develops and blows up the valley toward the mountains, in the opposite direction to the flow of water. This wind that blows up the valley during the day is known as a valley wind.

Winds that develop in a valley at night

Katabatic winds are winds that blow in response to differences in temperature and pressure between the top and bottom of the slopes along the side of a valley at night. At night the air on the valley slopes loses energy through terrestrial radiation and becomes cold and dense. This cold, dense air flows down the valley sides. The cold winds that drain downslope at night are called katabatic winds. They contribute to the development of a pool of cold air on the valley floor.

Mountain winds are winds that blow in response to differences in temperature, and thus pressure between air at the head of the valley, near the mountains, and air further down the valley at night. At night, the smaller volume of air at the head of the valley loses heat faster than the greater volume of air at the foot of the valley. It is thus colder at the head of the valley, resulting in a higher pressure here than further down the valley. As a result, a wind develops, which blows down the valley away from the mountains, in the same direction that water flows. This cold wind that blows down the valley at night is known as the mountain wind.
2. Inversions

Temperature usually decreases with height. If the temperature increases with height, the layer in which it increases instead of decreases is called an inversion layer.

In winter, a temperature inversion often develops in a valley at night. Ideal conditions for the formation of a valley inversion are cold, clear and windless nights, which are common in winter. Cloudless conditions mean that terrestrial radiation from the upper slopes of the valley is not retained, and so the temperature on the upper slopes drops. The windless conditions mean that the cold air is not mixed with the warmer air below it. Instead, it moves down the valley sides, replacing the warm air.

The warmer air forms a layer in the middle of the valley, creating a layer known as the thermal belt. This warm air in the middle level of the valley lies above the pool of cold air on the valley floor, forming an inversion. Figure 2.37 illustrates this situation.

![Figure 2.37 A temperature inversion in a valley at night](image)

3. Frost pockets

If water vapour cools to its dew point temperature, it condenses. If dew point temperature is less than 0 °C, the water will freeze. When water close to the ground freezes, it forms frost. Cold air collecting on the bottom of a valley can cause temperature to drop sufficiently for frost to form. The frost forms a ‘frost pocket’ on the valley floor.

![Figure 2.38 Radiation fog in a valley near Piketburg, Western Cape](image)

4. Radiation fog

Fog is made of tiny drops of water that condense when air reaches dew point temperature. Cold air sinking in a valley on a clear winter’s night can cause temperature to drop enough to reach dew point temperature, resulting in the formation of fog. Fog forms when dew point temperature is above 0 °C. This kind of fog is called radiation fog as the air was cooled through loss of long wave radiation from Earth at night. As the temperature rises during the morning, the fog evaporates.
Unit 3: The influence of local climates on human activities such as settlement and farming

1. The influence of aspect

People in the southern hemisphere prefer to build on a north-facing slope. This slope is warmer and lighter than south-facing slopes. The sun does not shine much into buildings facing north in summer, as it is so high in the sky. This keeps them cool. In winter, however, the lower angle of the sun means that it does shine into north-facing buildings, warming them. These differences moderate the temperature, making the building more comfortable to be in during both winter and summer.

North-facing slopes are hotter and drier than south-facing slopes. Some crops do better in the conditions on north-facing slopes than in the cooler, moister conditions on south-facing slopes.

2. The influence of the temperature inversion

The cold air in the bottom of a valley makes it unpleasant to live there. People tend to build their settlements above the cold air, in the warm thermal belt.

The warmer air layer above the colder air in an inversion creates stable conditions. The air does not rise as it is trapped below the base of the inversion. This means that in a valley, air pollution from industry, veld fires, motor vehicles and fires in people’s homes does not easily rise up and move out of the valley. On foggy days, smog forms. Smog is a mixture of fog and smoke. The pollution forms a layer over the area as the pollution plume from the smoke stacks is prevented from rising by the inversion. Instead, the plume spreads out horizontally beneath the inversion layer. You can see the effect of the temperature inversion on pollution in a valley in Figure 2.39.

A temperature inversion results in a high concentration of pollutants in a valley because it prevents a pollution plume from dispersing. The high concentration of air pollutants harms people’s health. It can also lead to the formation of acid rain. Acid rain forms when the by-products from the combustion of fossil fuel, particularly sulphur dioxide and nitrogen oxides, mix with rainwater to form weak solutions of nitric and sulphuric acid. Acid rain can corrode buildings and damage crops.

Pollution in valleys is a particular problem when heavy industry is located on the flat land close to a river to make use of the water it supplies.
3. The influence of the frost pocket

A frost pocket affects farming. Most crops grow better if they are planted above a frost pocket. Farmers farming in a frost prone valley need to grow frost resistant crops, such as cabbages and beetroot, and to use methods that protect plants from frost. In the Western Cape, apple and pear trees are planted lower down a slope than peach trees, which are more sensitive to frost. In some places, such as California in the USA, farmers heat their orchards at night to protect their citrus crops from frost.

ACTIVITY 1  APPLY AND EXPLAIN KNOWLEDGE OF VALLEY CLIMATES

1. Read the questions sent in by two farmers to a farming magazine. Write a reply to each question, giving a full explanation for your answer.

Question A: I have recently bought a farm with a valley trending west-east. I am deciding where to locate my farmhouse. My farm manager advises me to locate the house on the valley floor, but I think a slope with a view would be better. Please advise me. Should I build on the valley floor, or on one of the slopes?

(b 10 x 1 = 10)

Question B: I planted sunflowers on both a south-facing slope and a north-facing slope on my farm, but did not get as good a crop from the south-facing slope as from the north-facing slope. What could be the reason for this?

(5 x 1 = 5)

2. Write a paragraph to describe and explain how the winds that blow on valley slopes during the day differ from those that blow at night.
Urban climates

Cities have small-scale, local climates created by changes made to the natural environment in these settlements. The urban climate is therefore sometimes called an "artificial climate".

Unit 1: Reasons for differences between rural and urban climates

Climate conditions in a city differ from those in the surrounding rural area. The table below lists some of the main differences, and the reasons for the differences.

Table 2 Differences between rural and urban climates and reasons for them

<table>
<thead>
<tr>
<th>Element</th>
<th>Urban versus rural climate</th>
<th>Reasons for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Cities are warmer, especially at night</td>
<td>• Most surfaces in urban areas are artificial, with few areas of vegetation and water. Concrete, tar, bricks and wood absorb heat very quickly during the day, while water, grass, and trees absorb heat more slowly. At night, artificial surfaces lose their heat quickly, thus raising the temperature of the air in the city at night. Natural surfaces lose heat slowly so country air is cooler. • Increased pollution levels in cities lead to increased absorption of radiation, and thus higher temperatures.</td>
</tr>
<tr>
<td>Wind speed</td>
<td>Generally lower in urban areas, but high in 'canyons' along city streets</td>
<td>• Buildings increase friction and act as windbreaks, lowering wind speeds. However, tall buildings can channel airflow through the narrow city streets between them. This creates wind tunnels along which strong winds blow.</td>
</tr>
<tr>
<td>Humidity</td>
<td>Lower in urban areas</td>
<td>• There are fewer plants in urban areas and so less water vapour is released by evapotranspiration from plants’ leaves. • There is less surface water in urban than rural areas as runoff flows into stormwater drains instead of sinking into the ground. There is thus less evaporation, and less water vapour in the air (lower humidity). • Higher temperatures lower the relative humidity. Warm air can hold more water vapour than cool air. Thus, the air in the city can hold more moisture than cooler rural air. This reduces the relative humidity of air in the city.</td>
</tr>
<tr>
<td>Clouds, fog and precipitation</td>
<td>More cloud cover, fog, smog and precipitation in urban areas</td>
<td>• Cities produce more dust and other particles due to the amount of industry and construction work. Increased dust and other particles act as condensation nuclei, encouraging the formation of clouds and fog. • The greater heat in the city encourages convection. Warm air rises, cools and condenses. Clouds form and the chance of rain increases.</td>
</tr>
<tr>
<td>Sunshine</td>
<td>Cities receive less sunshine</td>
<td>• Cities have more cloud cover than rural areas. Clouds reflect and absorb incoming radiation, reducing the amount that reaches the surface. • High-rise buildings block incoming radiation and cast shadows over Earth’s surface in cities. The amount of sunshine received at the surface is thus reduced in cities. • There is more dust to reflect and absorb sunlight, reducing the amount reaching the surface.</td>
</tr>
<tr>
<td>Air pressure</td>
<td>Lower in urban areas</td>
<td>• The higher temperatures in urban areas lead to lower pressure in cities.</td>
</tr>
</tbody>
</table>
Unit 2: Urban heat islands

Temperatures in urban areas are higher than in surrounding rural areas, usually by between 1 °C and 4 °C. They can be as much as 10 °C higher. The difference in temperature is greatest at night. The area of high temperature surrounded by areas with lower temperatures is called the ‘urban heat island’.

The graph and map in Figures 2.40a and 2.40b give two different views of the horizontal temperature changes across a city. In both figures, it is clear that temperatures are highest over the CBD and decrease outward to the rural area.

Figure 2.40a The urban heat island can be seen in a city’s temperature profile. This is a graph showing how temperature at various places along a line drawn across the city, from the rural area on one side, through the CBD, to the rural area on the other side.

The warm air of the urban heat island does not only exist at the surface. It forms a dome over the city. You can see a simplified illustration of an urban heat dome in Figure 2.41. The height of the urban heat dome above the central part of the city is usually about 300 metres.

Figure 2.41 A dome of hot air over the city. Little vegetation or evaporation causes cities to remain warmer than the surrounding countryside.

1. Causes and effects of urban heat islands

Causes of urban heat islands

The raised temperatures in urban heat islands are caused by four main differences between urban and rural areas. These are:

- Differences in the surfaces of rural and urban areas:
  - Many artificial surfaces in cities, such as tarred roads, are dark. This means that they do not reflect incoming solar radiation during the day but absorb it and thus warm up.
  - The sides of tall buildings and the many roofs increase the surface area that can absorb incoming radiation and heat up.
Greater absorption by city surfaces together with the greater area of surfaces in cities means that they become hotter during the day than do rural areas. At night, when there is no incoming radiation, the greater amount of energy available for re-radiation in urban areas means that they do not cool as much as surrounding rural areas. Urban areas are cooler at night than they are during the day, but are still warmer than rural areas.

- Differences in the amount of heat emission:
  - More heat is added to the urban than to the rural atmosphere by such things as industry, transportation, vehicle exhaust heat and air conditioning.
- Differences in air quality:
  - High levels of air pollution in cities increase the atmosphere's ability to absorb outgoing terrestrial radiation. This greater absorption of energy leads to higher temperatures.
- Differences in amounts of evaporation and evapotranspiration:
  - Evaporation from water surfaces and plant leaves (known as evapotranspiration) causes cooling. This is because both these processes use heat energy, which therefore is not available for heating. There is less evaporation and evapotranspiration, and thus less cooling in cities, for two reasons:
    - In urban areas, there is less surface water because paved surfaces lead to increased runoff and less absorption by the ground. In addition, rainwater is rapidly channelled into drains. Reduced surface water decreases the amount of evaporation in cities.
    - In urban areas, there is less vegetation cover, and thus less evapotranspiration.
  - Less evaporation and evapotranspiration in urban areas than rural means that they are cooled less by these processes, and so are warmer than rural areas.

**Effects of urban heat islands**

The urban heat island has both positive and negative effects.

Positive effects:
- Less heating is required in cold places. This saves energy.
- The amount and frequency of snowfall is reduced, and ice does not form on roads in cold climates. This makes the roads safer.
- The amount of rainfall is increased because warm air rises, cools and condenses.

Negative effects:
- The use of air conditioning increases, which increases the use of energy. This outweighs the benefits from the reduced need for heating.
- High temperatures can lead to heat stroke, especially in the elderly or young children.

2. Concept of pollution domes: causes and effects

One of the effects of an urban heat island is the creation of a pollution dome. You will recall that the warm air over a city forms a dome. When dust, soot and chemical emissions are trapped in this warm air, the dome becomes a pollution dome.
Causes of pollution domes

The pattern of air circulation over the city, together with the high levels of pollution in the city leads to the formation of the pollution dome. Refer to Figure 2.42 and read the information below to find out why this occurs.

Figure 2.42 A pollution dome

In an urban heat island, temperatures are highest in the city centre and lowest at the edges of the city. During the day, a convection cell develops over the city. The hottest air in the middle of the heat island rises and cools. Cooler air from the rural area moves in towards the lower pressure created by the rising air, and replaces it. As the air rises, it cools, diverges and spreads out toward the suburbs where it sinks.

Air circulating in the dome spreads the pollution through the dome. The dome thus becomes a pollution dome. The pollution in the dome is most dense and closest to the surface at night, when there is less surface heating and thus little vertical movement of air. As the dome warms up during the day, the rising air strengthens, extending the dome vertically. The pollution is thus dispersed (spread) through a larger area, and becomes less concentrated.

The pollution dome can be influenced by larger scale air movements. In cities that are influenced by the subtropical high-pressure cells, such as Johannesburg, the pollution dome is strengthened both in winter and at night. If prevailing winds are strong, they can blow pollutants out of the dome, and carry them downwind as a pollution plume.

Effects of pollution domes

Pollution affects people's health, increasing levels of respiratory problems such as asthma and bronchitis. This is especially noticeable in winter, when there is less dispersal of pollution and more pollution due to people burning wood and coal for heat. Pollution is usually worst in the urban heat island but where prevailing winds create a pollution plume, pollution can be carried downwind into rural areas.

3. Strategies to reduce the heat island effect

The heat island effect is caused mainly by the presence of air pollutants, the lack of urban vegetation, the dark surfaces of urban buildings, and impermeable ground surfaces.
Strategies to deal with these effects include:
- changing urban surfaces by:
  - painting roofs white or light colours and using concrete instead of tar as a road surface. This will increase the reflection from these surfaces, and decrease the absorption of heat. Reduced surface heat absorption decreases the heat island effect.
  - creating more permeable surfaces by using materials such as cobbles and grass.
  - maintaining and developing wetlands to reduce runoff and increase evaporation from city surfaces and hence increase cooling in urban areas.
- greening the city by:
  - planting more trees, developing more parks, planting grass on pavements and creating roof gardens. This will increase the amount of evapotranspiration from cities, which leads to cooling.
- reducing pollution by:
  - insulating buildings more effectively to reduce the demand for heating.
  - increasing the use of solar and other ‘clean’ energy to reduce the amount of fossil fuels burnt, thus reducing pollution.
  - encouraging the use of public transport so that more people travel in one vehicle, and promoting the use of bicycles to decrease the amount of fossil fuels used by motor vehicles.
- reducing urban density by:
  - encouraging industrial decentralisation.
  - legislating for lower density and height of buildings.

ACTIVITY 1  APPLY KNOWLEDGE TO INTERPRET INFORMATION IN PICTURES

1. Briefly explain what an urban heat island is. (2)
2. Match the pictures A and B to a strategy or strategies to reduce the heat island effect. (2 × 2 = 4)
3. For each of your answers to Question 2, explain fully why the strategy or strategies will help reduce the urban heat island. (8 × 1 = 8)
Case study of a heatwave

A. Interpret a satellite image and draw a map and a graph

1. Refer to Figure 2.44 to answer the questions that follow. Note that C is in the CBD of this city, and A and B are in the surrounding rural area.

![Satellite image showing temperature pattern over a large city](image)

**Figure 2.44** Satellite image showing the temperature pattern over a large city

1.1 Identify the co-ordinates of this city given in Figure 2.44. Use these co-ordinates and your atlas to identify the city shown in the satellite image.

1.2 Draw a sketch to show this image as an isotherm map. Draw your map the same size as Figure 2.44. Mark the line AB on your map, as well as the CBD.

1.3 Draw a profile of the temperature from A through C to B. Show temperature on the y axis. Indicate the CBD on your profile.

1.4 What is the temperature difference between C and B?

1.5 What local climate feature do the satellite image and your map and graph show to be present at this city?

B. Answer questions about the 2003 European heatwave

2. Read through the text and then answer the questions that follow.

**Heatwave kills thousands**

**August 2003**

Temperatures in Europe soared this month, with maxima well above the norm. Over 15,000 people died in France alone in one of the worst heatwaves ever to affect Europe. The death toll was particularly high in Paris, where over 4,500 people died. Deaths were mainly due to heat stroke, dehydration and other conditions caused by the unusually high temperatures. The hot air was stagnant, and high pollution levels also contributed to deaths among people with respiratory problems. It appeared that high night-time temperatures were a significant factor in causing deaths.

2.1 What is a heatwave?

2.2 In which seasons did this heatwave occur?

2.3 How many people died in France?

2.4 What was the cause of their deaths?

2.5 How many people died in Paris?
3. Refer to the graph in Figure 2.45 to answer the questions that follow.
3.1 On which day were temperatures highest? (1)
3.2 How high were the temperatures on this day:
   3.2.1 during the day? (2)
   3.2.2 during the night? (2)
3.3 How many people died on this day? (1)
3.4 Research showed that 'high night-time temperatures were a significant factor in causing deaths'. Briefly explain why city temperatures are higher at night than temperatures outside cities. (4)

[Image: Graph showing number of deaths/day and temperatures]

Figure 2.45 Numbers of deaths and temperature on selected days in June, July and August 2003

4. Refer to the synoptic map in Figure 2.46 to answer the questions that follow.
4.1 What pressure system is present over Europe? (2)
4.2 Draw a sketch to show the pattern of convergence/divergence and subsiding/rising air associated with this type of system. (4)
4.3 Why would this type of system have contributed to the very high temperatures in Europe? (2)
4.4 How could this system have contributed to the stagnant air and high levels of pollution in Paris? (10)

[Image: Synoptic map showing pressure systems]

Figure 2.46 Synoptic map

Total: 50
**Question 1: Mid-latitude cyclones**

1. Draw a well-labelled cross-section through a mature mid-latitude cyclone to show:
   1.1 both fronts
   1.2 cloud types
   1.3 warm and cold air
   1.4 rainfall.
   \[(2 \times 1 = 2)\]

2. Draw up a table to show how weather conditions change as a cold front passes an observer. Include the following: wind direction, temperature, pressure, humidity, precipitation.
   \[(5 \times 2 = 10)\]

**Question 2: Subtropical high-pressure systems**

1. Draw a labelled sketch showing the position of the inversion associated with the Kalahari anticyclone in summer.
   \[(2)\]

2. Explain how the position of the inversion you described in your answer to Question 2.1 makes it possible for rain to form on the plateau of South Africa in summer. Develop the sketch you drew in Question 2.1 to illustrate your answer.
   \[(2 \times 3 = 6)\]

3. Briefly explain why the interior is dry rather than wet in winter.
   \[(2 \times 3 = 6)\]

4. Name the warm dry wind that blows from the plateau to the coast.
   \[(1)\]

5. In which season is this wind most common?
   \[(1)\]

6. Explain why it is most common in this season.
   \[(2 \times 2 = 4)\]

**Question 3: Tropical cyclones**

1. Refer to the satellite image in Figure 2.47 to answer the questions that follow.

   ![Satellite image of a mature tropical cyclone](image)

   **Figure 2.47** A satellite image of a mature tropical cyclone

   1.1 In which hemisphere is this tropical cyclone located?
   \[(1 \times 2)\]

   1.2 Describe conditions in the eye of a tropical cyclone. Refer to temperature, pressure, wind speed, precipitation, cloud cover, and vertical movement of air.
   \[(6 \times 2 = 12)\]

**Question 4: Valley climates**

1. Define the term ‘anabatic wind’.
   \[(2)\]

2. Name the two winds that blow in valleys during the day.
   \[(2 \times 1 = 2)\]

3. Describe what a ‘frost pocket’ is.
   \[(2)\]

4. Explain how a frost pocket forms. Use a labelled diagram to assist you.
   \[(2 \times 3 = 6)\]

5. Many rural dwellers in South Africa build their homes halfway up a north-facing slope. Write a short paragraph explaining why this is a good choice of site.
   \[(4 \times 1 = 4)\]
**Question 5: Urban climates**

1. Briefly describe what an urban heat island is. (2)
2. State two factors which lead to the formation of an urban heat island. Explain the role of each in its formation. (3 \times 2 = 6)
3. Suggest one way in which the heat island effect can be reduced. (2)

**Question 6: Synoptic charts**

Refer to the synoptic chart in Figure 2.48 to answer the questions that follow.

1. Give the specific name of the high-pressure systems
   1.1 to the west of the country (1)
   1.2 to the east of the country (1)
2. Which of the following statements are correct? (2 \times 2 = 4)
   2.1 There is a ridge of high pressure to the south of the country
3.2 in the north-east of the map
4. Give five pieces of evidence from this map that show it is a summer synoptic situation. (5 \times 2 = 10)
5. Explain the following conditions at Cape Town:
   5.1 clear skies and lack of rain (2 \times 2 = 4)
   5.2 high temperature, but not as high as over the interior (2 \times 2 = 4)
   5.3 SSE wind direction (2)

Total: 110 marks
Chapter 1: Mid-latitude cyclones

- Form between 40° and 60° north and south where cold polar air and warmer subtropical air meet; travel from west to east in the westerly winds.
- Have a central pressure of about 996 hPa; diameters of 1 500 – 3 000 km and travel at 50 – 60 km/hour.
- Bring rain to the Western Cape and cold to the interior in winter; less effect in summer as they have moved further south.
- Pass through four stages: initial, mature, occluded and dissipated
- Cirrus, altostratus, and nimbostratus clouds mark a warm front’s arrival. As the front passes temperature increases, pressure decreases, humidity increases, wind backs. Rain is gentle.
- A cold front’s arrival is marked by cirrus, then cumulonimbus clouds. As the front passes temperature drops, pressure increases, humidity decreases, wind backs. Rain is heavy.
- An occlusion occurs when the cold front overtakes the warm front, forcing the air in the warm sector to rise above the ground. A warm front occlusion occurs when the air behind the cold front is warmer and than the air ahead of the warm front. Conditions are cool and wet.
- In a cold front occlusion, the air behind the cold front is colder than the air ahead of the warm front. Conditions are cold and wet (similar to cold front conditions).
Chapter 2: Tropical cyclones

- Form in the tropical easterlies over warm oceans on the east side of continents between 5° and 20° north and south. To develop they require sea temperature of at least of 27 °C, Coriolis Force, and upper air divergence.
- Travel from east to west at about 10 – 20 km/hour, and cover about 200 km a day.
- Known as hurricanes, tropical cyclones and typhoons.
- Pass through four stages: formative (tropical depression), immature (tropical storm), mature (tropical cyclone), and degenerating (or decaying or dissipating) stage.
- Can dissipate at any stage if the supply of warm moist air is lost (by moving over land); and can also regenerate (by moving back over a warm ocean).
- In the eye, air subsides and conditions are warm, dry and cloudless; pressure is lowest here. Tall cumulonimbus clouds make up the eyewall; heavy rain and winds of high speed occur in the eyewall; winds blow in opposite directions on either side of the eye.
- Heavy rain and high winds cause flooding and damage to infrastructure and vegetation; storm surges and waterspouts can form.
- Strategies to reduce the impact of a tropical cyclone include early warning, good evacuation plans, building of storm shelters, a disaster management plan to provide rescue and services.
Chapter 3: Subtropical anticyclones and associated weather conditions

- The three anticyclones that affect South Africa are the South Indian anticyclone, South Atlantic anticyclone and Kalahari anticyclone; they are centred at about 30°S.
- Associated with stable air, and a temperature inversion.
- Winters are dry in the interior because the base of the inversion is below the level of the plateau, preventing moist sea air from reaching it. In summer, the base of the inversion lifts, allowing most air to flow on to the plateau, rise, and produce rain.
- The eastern part of the country is wetter than the western part, partly because onshore winds from the SIAC blow over a warm ocean current, picking up moisture, while onshore winds from the SAAC blow over a cold ocean current and so are drier.
- Line thunderstorms form in summer along a moisture front formed where warm moist north-easterly winds blowing round the SAIC meets drier SW air blowing round the SAAC.
- Onshore winds behind a coastal low bring rain or fog; offshore winds ahead of the coastal low are warm and dry.
- Berg winds are hot dry winds that blow from higher pressure on the plateau to lower pressure on the coast ahead of a cold front.
Chapter 4: Valley climates

- In the southern hemisphere, the sun’s rays shine more directly on north-facing than on south-facing slopes making them drier.
- During the day, sides of the valley heat up more than the valley floor. The differences in pressure caused by this unequal heating cause an anabatic wind to blow up valley slopes and a valley wind to blow up a valley.
- At night, the opposite happens. The valley sides cool due to terrestrial radiation, cooling the air in contact with them. A katabatic wind blows down the valley sides, and a mountain wind blows down the valley.
- Cold air draining into the valley floor at night causes a temperature inversion. Pollution is trapped below this layer.
- A frost pocket occurs in the bottom of the valley if the dew point temperature is below freezing. Frost sensitive crops are therefore grown higher up the valley sides. If the dew point temperature is above freezing, radiation fog forms.
Chapter 5: Urban climates

- Temperatures are higher, wind speed is lower, humidity is lower, there is more cloud, smog and precipitation and less sunshine in urban than rural areas.
- Differences in temperature are caused by absorption of heat by buildings and roofs, decrease in plant cover and permeable surfaces, and greater pollution in urban areas.
- A heat island forms over the city, and pollution becomes trapped in a pollution dome above it.
- The heat island effect can be reduced by making surfaces lighter and more permeable, planting more vegetation, and decreasing the amount of pollution.