SESSION 1: WINDS AND GLOBAL CIRCULATION

KEY CONCEPTS:

In this session we will look at:

- Primary, secondary and tertiary circulation. We will also look at some of the types of primary, secondary and tertiary circulation.
- Understanding how temperature affects air pressure and how these factors causes movement of air then your understanding of Climate and weather is made much easier.

X-PLANATION

GENERAL INTRODUCTION TO CLIMATE AND WEATHER:

In the three presentations of climate and weather there are many overlaps regarding the different sections e.g. we will make reference to mountain and valley breezes in tertiary circulation and microclimatology. Learning these sections in this manner is very important as the answer to questions could incorporate three or more different sections.

PRIMARY, SECONDARY AND TERTIARY CIRCULATION:

**Primary circulation** is the major way in which heat energy is transferred to different parts of the earth’s surface on a global scale. It includes both horizontal and vertical movements e.g. the tri-cellular arrangement.

**Secondary circulations** are circulations that occur within primary circulations. They occur on a smaller scale, covering smaller areas and lasting from a few days to a few weeks e.g. monsoons and cyclones.

**Tertiary circulations** are more localised circulations than secondary circulations and sometimes could last for only a few hours e.g. land and sea breezes and berg winds.
HIGH PRESSURE AND LOW PRESSURE SYSTEMS:

**High pressure**
- Air subsides
- Clear skies and no cloud formation
- Temperature inversion can develop where the subsiding air becomes warmer than the air on the surface

**Low pressure**
- Air ascends (rises)
- Condensation takes place
- Latent heat is released during condensation
- Clouds form and precipitation occur

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Examples of High Pressure Systems:

- South Atlantic HP, South Indian HP and Kalahari HP.

Examples of Low Pressure Systems:

Coastal low  Mid-latitude cyclone / depression

Coastal low - coastally trapped low pressure circulation between the sea and escarpment; usually starts on the west coast and propagates along the SA coast to dissipate near Mozambique. Warm, often strong offshore berg winds in front of the low; cool onshore flow behind it often with fog. Usually indicates an approaching cold front. Usually occurs in winter but can cause very dry and hot days during summer or transition seasons.

Heat low is an inland LP that occurs as a result of the heating of the earth surface especially during summer.

Cut-off low is a low pressure that is detached to the jet stream, and becomes detached and sits over an area for a very long time just spinning.
Mid-latitude cyclone - distinctive change in weather occurs with passage of cold front. Sharp temperature drop, rain, and wind; if it extends over the interior can cause cold snaps. Heavy rainfall / floods over South Western Cape.

Tropical Cyclones

- As opposed to mid-latitude cyclones!
- Closed low pressure circulations that begin in the Indian Ocean, cross or round Madagascar and follow the Mozambique current.
- If they reach South Africa they may affect regions of KwaZulu and Mpumalanga; occur in summer months.
- Cause severe flooding and damage to regions they affect.
- Also known as hurricanes and typhoons and are named alphabetically e.g. Eline.

Surface Circulation Associated with High and Low Pressure Systems:
- Air moves away from high pressure and towards low pressure
- Northern hemisphere – anticlockwise (low pressure) – clockwise (high pressure).
- Southern hemisphere – anticlockwise (high pressure) – clockwise (low pressure).

**WIND BANDS AND PRESSURE BELTS:**
Forces that Affect the Movement of Air:

- **Pressure Gradient Force** - sets air in motion, from high to low pressure
- **Coriolis Effect** - deflects flow to the right in northern hemisphere and left in the southern hemisphere. Balances P.G.F. in absence of friction
- **Friction** - slows speed and tempers deflection
Pressure Gradient Force:

The net force directed from higher to lower pressure is called the PRESSURE GRADIENT FORCE.

The influence of the Pressure Gradient Force:

- High Pressure (H)
- Low Pressure (L)

Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign
Coriolis Force:

Coriolis Force

Caused by the earth's rotation

Objects deflect to the right in the Northern hemisphere

Objects deflect to the left in the Southern hemisphere

The apparent deflection of moving objects relative to an observer on the earth

Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign
Geostrophic Flow /Wind:

Is the wind which occurs when the pressure gradient and coriolis force are in balance and air flows straight with the isobars.

THE TRI-CELLULAR ARRANGEMENT / GLOBAL CIRCULATIONS CELLS AND WINDS:
The Hadley or Tropical Cell:
Air rises at the Inter Tropical Convergence Zone (ITCZ) due to the high temperatures at the equator. This is an area where very little wind occurs as there is lots of convection but little advection (horizontal movement of air). The air cools down to reach and condensation takes place. Clouds form and tropical rain occurs from these clouds. The upper air diverges and sinks at 30º North and South. Owing to the rising air, a low pressure area develops at the equator and owing to the subsidence at 30º North and South, the sub-tropical high pressure cells develop there. Wind blows from the sub-tropical high pressure cells to the tropical low pressure cells. These winds are deflected by Coriolis force and develop as south easterly winds and north easterly winds in the respective hemispheres. Refer back to the table that describes weather at high pressure and low pressure areas.

Ferrel Cells:
Air is forced up at the polar fronts (60º north and south) and forms the sub-polar low pressure cells. Air circulates and sinks at the 30º North and South at the sub-tropical high pressure cells. The westerly winds form between the sub tropical high pressure...
cells and the sub-polar low pressure cells. The Westerlies are also deflected by Coriolis force.

The Polar Cells:
An intense high pressure develops at the poles due to the very cold conditions. The air moves away from the high pressure as Polar Easterly winds (deflected by Coriolis winds) to the sub-polar low pressure areas. Upper air is drawn to the Polar High pressure.

Inter Tropical Convergence Zone (ITCZ):
A zone where the easterly trade winds meet. It occurs around the equator. Its exact geographical position depends on seasonal changes in air circulation. Here air rises to create a low pressure. The direct sunlight moves between the tropics as the seasons change. The ITCZ follows the warmest area – Heat Equator. All of the global circulation cells move with the direct sunlight and the equator.
The Map Illustrates the Shifting Heat Equator caused by the Shifting Direct Sunlight:

Monsoons:

It is a name for seasonal winds. Monsoons are a name for seasonal winds system of winds that influences the climate of a large area and that reverses direction with the
seasons. Monsoons are caused primarily by the much greater annual variation in temperature over large areas of land than over large areas of adjacent ocean water. This variation causes an excess of atmospheric pressure over the continents in the winter and a deficit in the summer. The disparity causes strong winds to blow between the ocean and the land, bringing heavy seasonal rainfall. In southern Asia, a wind that is part of such a system and that blows from the southwest in the summer and usually brings heavy rains.

**Mountain and Valley Winds:**

*Valley winds / Anabatic Winds - Day:*

Anabatic winds: during the day, the slopes warm due to insolation. The air above the slopes warms, becomes lighter and rises up the slopes.
Mountain breeze / Katabatic winds – Night:

Katabatic winds: at night, the slopes cool due to terrestrial radiation. The air above the slopes becomes cold and dense and blows down the valley sides.

Land and Sea Breezes:

Land Breeze:

Rising air helps form clouds

Cooler air sinks

Sinking air spreads along surface

Land cools down (heat sink)

Ocean is warmer compared to land (heat source)
Sea Breeze:

Land and sea breezes occur in areas where a large body of water is located next to land. During the day the land becomes warmer than the water. As warm air rises over the land (LP), cold air from over the water moves in to fill the space (HP), thus causing a sea breeze. However, during the night, because water holds heat longer than land, the air over the water is warmer than the air over the land. As the warm air over the water rises (LP), the cold air over the land moves in to take its place (HP), thus causing a land breeze.

An easy way to remember the difference between a land breeze and a sea breeze is that a land breeze comes off the land and over the water and a sea breeze comes from over the water to over the land.

Tornado:

Can be described as a rotating column of air ranging in width from a few yards to more than a mile whirling at destructively high speeds, usually accompanied by a funnel-shaped downward extension of a cumulonimbus cloud. It is associated with extremely low pressure. (600mb). When over water it is called a water spout.
Föhn wind:

A Föhn wind is a type of dry down-slope wind that occurs in the leeward side (downwind side) of a mountain range. It is a rain shadow wind that results from the subsequent adiabatic warming of air that has dropped most of its moisture on windward slopes. As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes. Föhn winds can raise temperatures by as much as 30 °C in just a matter of hours. Central Europe enjoys a warmer climate due to the Föhn, as moist winds off the Mediterranean Sea blow over the Alps.
Berg Winds:

It occurs during winter when there is a well developed high pressure system over the interior and a coastal low pressure system. Air moves from the high pressure to the low pressure. As it moves down the escarpment it warms up adiabatically to become a warm dry wind. It causes veld fires and creates uncomfortable conditions for humans.

**X-AMPLE QUESTIONS**

**Question 1:**
(Source: DoE March 2009 Supplementary Paper)

Refer to the figure 1.1. Indicate whether the following statements are TRUE or FALSE. Choose the answer and write only 'true' or 'false' next to the question

1.1 The diagram illustrates conditions that exist during daytime.
1.2 The graph illustrates a temperature inversion.
1.3 The downward flow of air illustrated in FIGURE 1.1 is known as anabatic air flow.
1.4 The zone marked X is the warm thermal belt.
1.5 The heat loss is as a result of terrestrial radiation. (5 x 2) [10]
XERCISE QUESTIONS

Question 1:  
(Source: Sunday Times Practice Paper November 2009)

Refer to the figure and answer the following questions. The figure shows a cross section of the ITCZ.

1.1 What do the letters ITCZ stand for?  
1.2 Over which line of latitude does the ITCZ lie?  
1.3 Which season is it in the Southern Hemisphere? Give a reason for your answer  
1.4 Name the planetary winds that are blowing towards the ITCZ.  
1.5 Explain why heavy rain is shown at the ITCZ.  

[16]
Question 2:  
(Source: 2008 Exemplar)

Refer to the figure below showing the tri-cellular circulation of the atmosphere.

2.1. Why do meteorologists refer to a tri-cellular circulation of the atmosphere?  
(1 x 2) (2)

2.2. (a) Identify the THREE cells of circulation labelled P, Q and R respectively.  
(3 x 2) (6)
(b) What does the abbreviation ITCZ stand for?  
(1 x 2) (2)
(c) Where, at X, Y or Z, would the ITCZ be found?  
(1 x 2) (2)
(d) Name any TWO weather conditions that one will experience at the ITCZ.  
(2 x 2) (4)
(e) Explain why the weather conditions mentioned in 2.2.d occur at the ITCZ.  
(2 x 2) (4)
Question 3:  
(Source: DoE November 2009)

Climatologists discovered many years ago that a reversal in wind direction occurs along the coastline from daytime to night-time. These reversed wind conditions are referred to as land and sea breezes. Land and sea breezes are localised and have a moderating influence on coastal temperatures. Use your knowledge of land and sea breezes, and also refer to the figure on the following page to answer the questions below.

3.1 Does the figure illustrate a land breeze or a sea breeze? (1 x 2) (2)
3.2 What does it mean if one says the breeze is localised? (1 x 2) (2)
3.3 Briefly describe the development of the breeze illustrated in the figure (3 x 2) (6)
3.4 The breeze illustrated in the figure will result in high-income suburbs with high land values along the coastline bordered by warm ocean currents. Give ONE reason why this is so. (1 x 2) (2) [12]
Questions 4:
(Source: DoE November 2010)

Refer to the figure below showing the development of the South African bergwind. strong subsidence over the plateau of South Africa results in a well-developed high-pressure cell over the interior, which will result in specific weather conditions there.

4.1 Name the high-pressure cell visible in the figure above that result from subsidence over the plateau. (1 x 2) (2)

4.2 How does the berg wind affect the weather along the southeast coast of South Africa? (2 x 2) (4)

4.3 Name the environmental hazard associated with the development of berg winds. (1 x 2) (2)

4.4 State ONE possible measure that can be introduced to reduce the impact of the environmental hazard named in QUESTION 4.3 (1 x 2) (2)

4.5 During which season do berg winds mainly affect the weather along the southeast coast of South Africa? (1 x 2) (2)
Question 5:

Refer to figure below showing air movement. Choose the correct answer from the alternatives provided in brackets to make all the statements TRUE. Only write down the question number and the correct term next to it.

![Air Movement Diagram]

Air moves from a 5.1 [high pressure to a low pressure/low pressure to a high pressure]. This movement of air is related to 5.2 [coriolis/pressure gradient] force. Moving air is deflected by 5.3 [coriolis /pressure gradient ]. When the air flows parallel to the isobars it is called 5.4 [parallel winds/geostrophic winds]. The air movement shown in FIGURE 1.1 is taking place in the 5.5 [southern/northern] hemisphere.

(5 x 2) (10)

Question 6:

Refer to figure below showing FÖHN WIND CONDITIONS. Indicate whether the following statements are TRUE or FALSE. Choose the correct answer and only write 'true' or 'false' next to the question number.

![Föhn Wind Conditions Diagram]

6.1 Föhn winds are moist down-slope winds.
6.2 Föhn winds result from adiabatic warming of air
6.3 Föhn winds drop temperatures by as much as 30ºc in a matter of hours.
6.4 Föhn winds are called snow eaters because of their ability to make snow sublimate.

6.5 Föhn winds occur in mountainous regions.

Question 7:

7.1 What does Monsoon winds refer to? (1 x 2) (2)
7.2 Is the monsoons an example of a secondary or tertiary circulation? (1 x 2) (2)
7.3 State the general direction of the Summer monsoons winds. (1 x 2) (2)
7.4 Summer monsoons bring rainfall to Asia and Winter monsoons don't. Give reasons for this occurrence. (2 x 2) (4)
Question 8:

Study the picture and answer the questions that follow

8.1 Identify the feature shown on the photo.  
8.2 Describe this feature.  
8.3 State two weather conditions associated with this feature.  
8.4 Is this feature an example of primary or tertiary circulation?

(1 x 2) (2)  
(1 x 2) (2)  
(2 x 2) (4)  
(1 x 2) (2)  
[10]
ANSWERS TO HOMEWORK X-ERCISES

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Question 1:

1.1 Inter-tropical convergence zone ✓✓ (1 x 2) (2)
1.2 Tropic of Capricorn/ 23½°S ✓✓ (1 x 2) (2)
1.3 Summer – sun overhead Tropic of Capricorn/ITCZ in Southern Hemisphere. ✓✓✓✓ (2 x 2) (4)
1.4 Tropical easterlies ✓✓ (1 x 2) (2)
1.5 Air is hot air therefore light and rises, ✓✓ Convergence of winds leads to air rising, ✓✓ Rising air cools and condenses. ✓✓ (3 x 2) (6)

[16]

Question 2:

2.1 (a) Because circulation occurs in three cells in each hemisphere ✓✓ (1 x 2) (2)
(b) P – Ferrell (2) ✓✓
Q – Hadley (2) ✓✓
R – Polar (2) ✓✓ (3 x 2) (6)
2.2 (a) Inter-Tropical Convergence Zone ✓✓ (1 x 2) (2)
(b) X ✓✓ (1 x 2) (2)
(c) High temperatures/Hot ✓✓
Cumulonimbus cloud/Heavy cloud cover ✓✓
Thundershowers/Heavy downpours ✓✓
[Any TWO] (2 x 2) (4)
d) (Along the equator where it is warm ✓✓
Rapidly rising air condenses and form clouds ✓✓
Large scale condensation results in heavy rain ✓✓
[Any TWO. Must refer to weather conditions mentioned above] (2 x 2) (4)

[20]

Question 3:

3.1 Sea breeze ✓✓ (1 x 2) (2)
3.2 Happens on small / local scale / in immediate surroundings ✓✓
Microclimatic condition ✓✓
Tertiary circulation ✓✓
[Concept] [Any ONE] (1 x 2) (2)
3.3 Land heats up more during daytime ✓✓
Causes low pressure to develop over land ✓✓
Air rises over land ✓✓
Sea takes longer to heat up during the day ✓✓
High pressure at sea ✓✓
Air moves from high to low pressure ✓ ✓
Breeze from sea to land ✓
[Any THREE] (3 x 2) (6)

3.4 High-income suburbs along the coastline will benefit from the cooling /
Moderating effect of the sea breeze ✓ ✓
Experiences clean, fresh air ✓ ✓
Breeze blows from sea to land ✓ ✓
[Any ONE] (1 x 2) (2)

Question 4:

4.1 Kalahari/Continental high ✓ ✓ (1 x 2) (2)
4.2 Temperatures will warm up ✓ ✓
Humidity level will be low/dry ✓ ✓
No/little cloud cover ✓ ✓
No rain ✓ ✓
[Any TWO] (2 x 2) (4)
4.3 Veldfires/Bushfires ✓ ✓ (1 x 2) (2)
4.4 Educating people on the dangers associated with veldfires –
accept example ✓ ✓
Look-out towers in bergwind season ✓ ✓
Firebreaks ✓ ✓
Warning over weather forecast ✓ ✓
[Any ONE] (1 x 2) (2)
4.5 Winter ✓ ✓ (1 x 2) (2)

Question 5:

5.1 High pressure to low pressure. (2)
5.2 Pressure gradient force. (2)
5.3 Coriolis force (2)
5.4 Geostrophic winds. (2)
5.5 Northern hemisphere. (2) (5x2) (10)

Question 6:

6.1. False (2)
6.2. True (2)
6.3. False (2)
6.4. True (2)
6.5. True (2) (5x2) (10)

Question 7:

7.1 Seasonal winds. (1 x 2) (2)
7.2 Secondary or tertiary circulation. (1 x 2) (2)
7.3 Nw to SE (1 x 2) (2)
7.4 Summer monsoons blow from the ocean bringing moisture (2)
Winter monsoons blow from the land which is associated with dry air. (2)

(2 x 2) (4)

[10]

Question 8:

8.1 Tornado.
8.2 Is described as a rotating column of air ranging in width from a few yards to more than a mile whirling at destructively high speeds (Concept).
8.3 Strong winds (2)
Heavy rainfall (2)
8.4 Tertiary circulation

(1 x 2) (2)
(1 x 2) (2)
(1 x 2) (2)

[10]