CAIE Geography Pre-U

1B: The Atmospheric Environment

Detailed Notes

Definitions, classification and distribution

Start off by watching this video which explains what climate is.

What is climate classification?

The formalisation of systems that recognise, clarify and simplify climatic similarities and differences between geographical areas. (See case studies for examples of different classification systems).

Climate types

- **Equatorial** is located at 10° north/south of the equator. It experiences temperatures between 26 and 28°C and precipitation of 2000mm a year. This is due to the inter-tropical convergence zone and the fact that the sun's rays hit the equatorial region directly and so the rays are very concentrated. The high temperatures lead to high levels of evaporation leading to high humidity and cloud formation.
- **Semi-arid tropical** is located between 5 and 10° north and south of the equator. It has temperatures between 20 and 30°C with a cool season. It also has wet and dry seasons with 80% of its rain falling in 4 months. Semi-arid tropical locations experience a wet season because as the sun appears to move overhead it brings heat from the equator and also the ITCZ.
- **Arid tropical** areas are located between 15 and 30° north and south of the equator and are most extreme on western sides of the continent. Temperatures range between 30-35°C with diurnal ranges reaching up to 50°C. They experience very little rainfall, less than 250mm annually. They occur in areas of subsiding air which causes high pressure and sinking, stable air.
- **Semi-arid temperate/warm temperate west coast** areas are located on the west coast of continents 30-40° north/south of the equator. They experience temperatures between 12 and 25°C with hot summers and warm winters. With annual precipitation around 500mm. The sun's rays are intense and there is little cloud cover. They are also influenced by the trade winds which bring arid conditions and the ITCZ which brings moisture from the sea in the winter.
- **Semi-arid temperate/cool temperate continental** are found in places like North America, Russia and Austria. Temperature is around 20°C on average and they experience around 500mm of rain although this varies greatly depending on the country. As the land warms up rapidly during the summer months they experience high temperatures in the summer. However, the land also cools quickly in the winter leading to cold winters.
- **Humid temperate/warm temperate east coast** areas are located between the arctic circle and the tropic of cancer, this mainly encompasses eastern Asia. The temperature is relatively constant, between 20 and 30°C. However, they experience monsoon seasons with 600mm of annual rainfall. The causes of the monsoon will be discussed later in this topic.
- **Humid temperate/cool temperate west coast** lies in the confluence of the Ferrel and Polar cells which is at 45-60° north/south of the equator. They experience temperatures between 8 and 20°C with 2000mm of precipitation annually. The low angle of the sun in the sky, the moderating influence of the sea and the convergence of different air masses all contribute to this climate. This climate will be discussed in more detail later on.

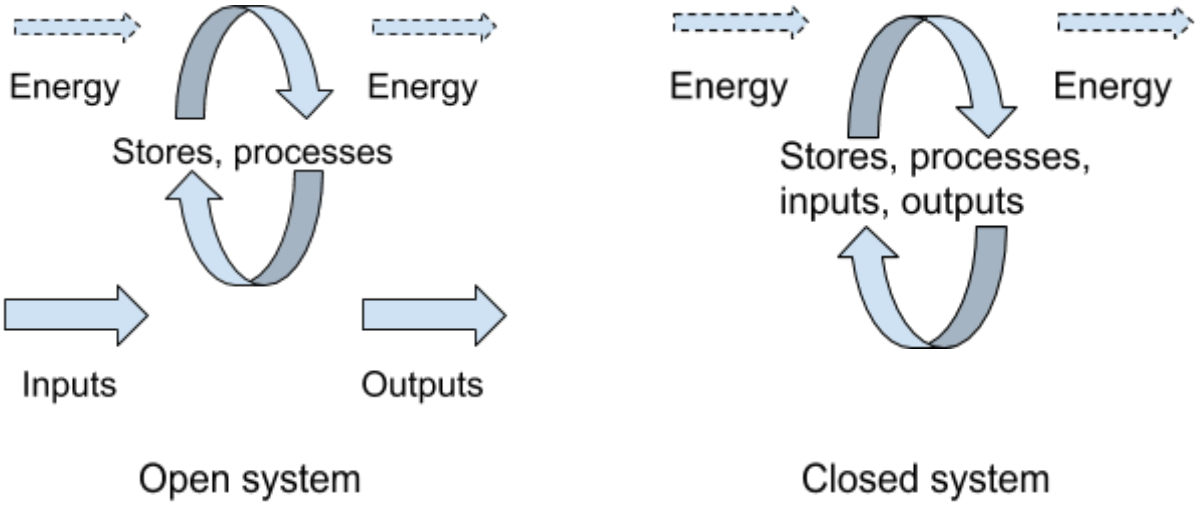
- **Boreal** climates are located at 60°N. The temperature ranges between -25 and 25°C and they experience around 300mm of rainfall. Due to the earth's tilt, this climate experiences large seasonal variations. They also have little moderating influence from the sea and strong wind chill factors. As the air is cold it can only hold limited amounts of moisture.
- **Arctic** areas are located 65° north/south of the equator. Temperature ranges from -30 to 10°C and precipitation is around 110mm annually. This is due to a low angle of the sun in the sky, high wind chill factors which can travel far due to the flat landscape. Due to the vast expanses of ice, there is an increased reflection of solar radiation so the ground does not heat up.

Processes in the atmospheric environment

Watch this video on how climate systems work.

Atmospheric systems

The atmospheric system consists of **inputs, stores, processes and outputs.** Ecosystems are examples of **open systems** with matter and energy flowing in and out. The Earth is a **closed system** with energy entering and exiting the system.



Atmospheric systems also undergo two types of feedback:

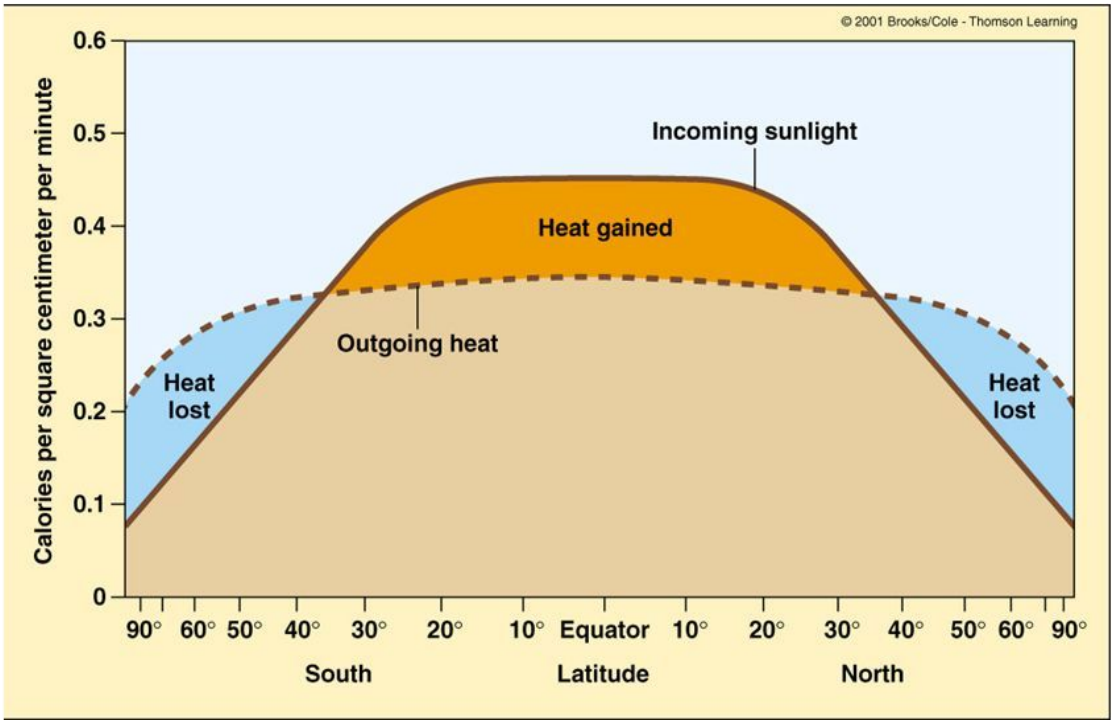
- **Positive feedback** is where the primary effect of the loop starts a process which in turn increases the primary effect. This continues in a loop and continues to enhance the stimulus.
- **Negative feedback** is where the primary effect starts a process which then decreases the stimulus and the loop breaks down.

The Earth's atmospheric system consists of four layers:

- The **troposphere** is the lowest atmospheric layer, contains our weather and decreases in temperature as altitude increases.
- The **stratosphere** extends up from the troposphere, increases in temperature and contains the ozone layer.

- The **mesosphere** extends up from the stratosphere, it decreases in temperature and reaches the coldest of all atmospheric layers.
- The **thermosphere** is the last atmospheric layer and it is the hottest layer that increases in temperature.

The vertical energy budget



http://slideplayer.com/slide/10011173/

Watch this video on differential heating.

Inputs to the vertical energy budget are in the form of **short-wave solar radiation**, commonly known as **insolation**. There are four factors that affect the level of insolation that enters our atmospheric system:

- The **solar constant** varies according to the activity of spots on the sun. This affects the long-term climate of the earth.
- Due to the **eccentric orbit** of the earth, there is a **6% difference** in the level of insolation from the sun due to the different **distances from the sun**.
- Due to the curved nature of the earth, each radiation bundle has twice the area to heat up at 60°N compared with the equator. And so the **altitude of the sun in the sky** affects the level of energy a place receives.
- Due to the tilt of the earth, the length of night and day can vary. In places poleward of 66.5° N/S they receive no insolation for several months.

Vertical heat **transfers** occur when the energy is entering or exiting the system. There are three types of vertical energy transfers:

- **Absorption** by the ozone layer, water vapour, CO_2 and dust.
- **Reflection** by clouds and the earth's surface

- **Scattering** where insolation is diverted by particles of dust or molecules of gas. Ozone, gases and buildings can also store heat energy.

Outputs are in the form of long-wave radiation. They can occur in four ways:

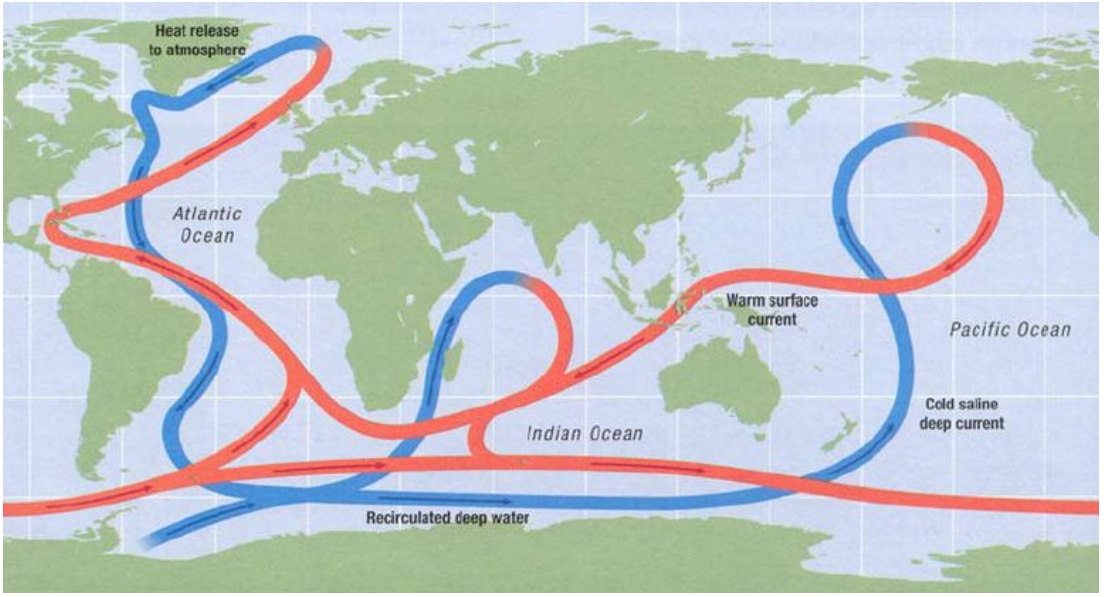
- **Radiation**
- **Conduction**
- **Convection**
- **Latent heat** which is the amount of heat energy needed to change the temperature of a substance.

The ratio between incoming radiation and the amount reflected is known as the **albedo** and varies according to the surface.

Horizontal energy budget

Due to the vertical energy budget, the equator receives more energy than the poles, this means that in order to stop the equator from continuing to warm and the poles continuing to cool, transfers need to take place. These are known as **horizontal heat transfers.**

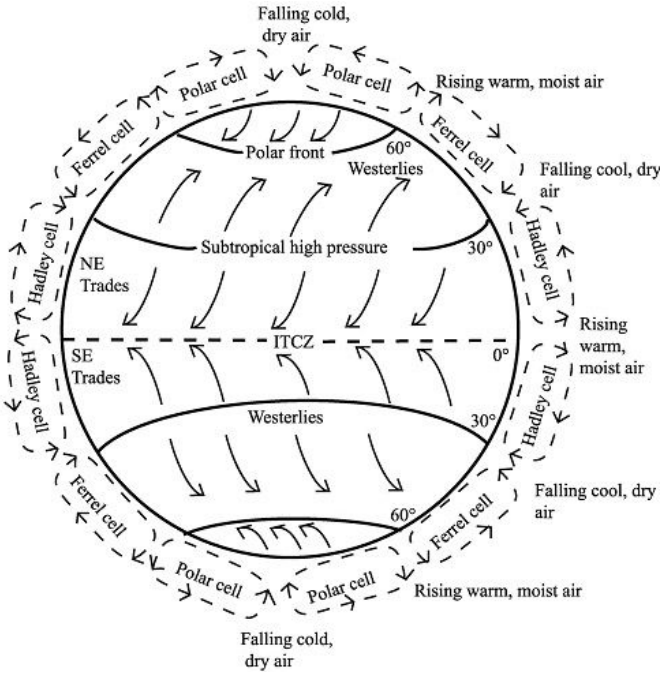
Oceanic energy transfers are responsible for **20%** of the total horizontal heat transfers. Due to the uneven heating of the surface of the oceans, convection currents between high and low latitudes are formed. Intense sun at the equator warms the water up. This water becomes less dense so travels along the surface towards the poles. As there is less insolation at the poles the water is colder and denser. It, therefore, travels along the sea bed towards the equator. These convection currents are started by the wind that moves over the surface and starts to drag the water.



Source: www.researchgate.net

In the northern hemisphere, ocean currents travel clockwise. In the southern hemisphere, ocean currents travel anticlockwise. Watch this video on the ocean conveyor belt and the Gulf stream.

Atmospheric energy transfers are responsible for **80%** of the total horizontal energy transfers. The main way this occurs is shown by **the tri-cellular model** shown below which also shows the movement of winds from high pressure to low pressure zones. Watch this video about the three cells:



https://physics.stackexchange.com/questions/73450/why-does-the-wind-direction-vary-locally

As you can see in the diagram above, there are areas where air is rising and areas where the air is falling. Where the air is rising, **low pressure** is created on the surface. Where the air is falling, **high pressure** is formed on the surface. You can also see that air moves from areas of high pressure to areas of low pressure and is deflected right in the northern hemisphere and left in the southern hemisphere.

The ITCZ is the **inter-tropical convergence zone** which is the meeting of the trade winds in the equatorial region. This can move north and south depending on the position of the sun and is involved in the monsoon of the Indian subcontinent.

The tri-cellular model is formed due to the influence of the **Coriolis force** which means that more than one cell is created. Because the earth rotates on its axis, the wind that is blowing over the earth's surface appears to deflect either right in the northern hemisphere or left in the southern hemisphere. This creates multiple cells on the earth's surface. Watch this video about the Coriolis force.

Determinants of climate

- Areas of higher **latitudes** have lower temperatures, and those at lower latitudes have higher temperatures. This is because, as was discussed earlier, the amount of land heated by the suns rays increases at higher latitudes and so the intensity decreases.

- **Maritime** areas, those by the sea, have lower annual temperature ranges. This is because the sea has a greater specific heat capacity than land and so heats up more slowly in the summer and cools down more slowly in the winter.
- As the **altitude** increases, there is a decreasing area of land surface from which to heat the surrounding air. The density of air also decreases and so does its ability to hold heat. This means that areas with higher altitudes have lower temperatures.
- The **position in relation to the tri-cellular model** also impacts the climate. Areas of high pressure are drier and more stable compared with areas of low pressure. It also affects the direction from where the winds blow. If winds blow from lower latitudes and blow over a continent, then the area will experience dry, warm weather.
- If an area lies on a slope, then the **aspect** of the slope will play a role in the determination of the climate. For example, north-facing slopes in the northern hemisphere will be cooler as they will be in shadow for most of the year.

Short term changes and their impact

Characteristics of Cool temperate western maritime climate

Cool temperate western maritime (CTWM) climates are located between 40° and 60° within the **Ferrel cell** and on the **boundary with the polar cell**. They are **close to the ocean** which moderates the temperature. As they are located on the **west side** of the continent they are influenced by warm ocean currents which travel along the west coast.

CTWM climates experience **heavy cloud cover and prolonged periods of rain, drizzle and fog**. CTWM climates can vary greatly in the short term due to the influence of the polar front, various air masses and the influence of both high and low pressure. The UK has a CTWM climate.

Jet streams

Jet streams are narrow zones of **high-speed winds** that are found high up in the atmosphere. They are formed through significant differences in temperature. The **polar front jet stream (PFJS)** is formed through the meeting of **subtropical and subpolar air** that also form a boundary called the polar front.
The polar front jet stream meanders around the globe, these meandering waves are called **Rossby waves**. The jet stream helps to transfer energy and controls the location of air masses. Watch this video on jet streams.

Air masses

Air masses are parcels of air which have the **same temperature, humidity and lapse rate**. The UK stands on the **polar front** and so is at the boundary between different air masses. Air masses have different characteristics depending on where their source was located and the characteristics of the surface over which it travelled. Watch this video on air masses.

The UK is affected by 5 air masses:

- **Arctic maritime** which originated from the north and so brings extremely cold weather. Although it travelled over the sea, the air was too cold to pick up much water.
- **Polar continental** brings very cold weather from the northeast.
- **Tropical continental** travels from the south-east from Africa to bring hot and dry weather.
- **Tropical maritime** brings mild and wet weather in winter and cool moist weather in the summer from the south-west.
- **Polar maritime** travels from the north-west bringing cold and moist weather to the UK.

Watch this video on the air masses affecting the UK.

Polar front

The polar front is the **transition boundary** between **tropical maritime air and polar maritime air**.

- When the PFJS moves northwards, the UK experiences warm weather as the overlying air mass is tropical maritime.
- If the PFJS moves southwards the UK will experience cold, wet weather.

There are three types of front:

- A **warm front** which is where warm air is advancing and being forced to override the cold air. This causes the temperature to rise in the cold air mass and pressure gradually falls. This causes precipitation to occur in a wide belt.
- A **cold front** is where advancing cold air undercuts the body of warm air. This causes a rise in pressure and a fall in temperature.
- The final type of front is the **occluded front**. This is formed as a result of a cold front catching up with a warm front and is often marked by a belt of high clouds.

Watch this video on weather fronts.

Depressions

Depressions are areas of low pressure and mostly occur at mid-latitudes. Watch this video on depressions.

A depression cycle undergoes three stages:

- The **embryonic stage** is when warm, moist tropical maritime air meets colder drier polar maritime air. The warm air is forced to rise and so there is less air at the surface, resulting in low pressure.
- The **mature stage** is when the pressure continues to fall as more warm air is forced to rise. As there is less air in this area, winds blow into this area and as pressure continues to decrease, these winds increase in strength.
- The final stage is known as the **decaying stage.** This is where the cold front catches up with the warm front to form an occluded front. There is no longer any warm sector at ground level and pressure gradually rises to lead to decreased wind speeds.

In the summer low-pressure weather creates prolonged rainfall and flooding, although nice weather can be experienced in-between weather fronts. In the winter heavy rainfall and snowfall can occur and stormy conditions also occur. (See case studies for an example of a depression and a mid-latitude storm.)

Anticyclones

Anticyclones are areas of high pressure formed by falling air. In the summer, warm, dry weather is created and heatwaves and droughts can occur. In the winter, high-pressure zones experience cold, dry, frosty days.

Blocking anticyclones are areas of high pressure which remain stationary for long periods of time. This distorts the usual eastward progression of pressure systems and often are the cause of heatwaves. (See case studies for an example of a heatwave.)

Impacts and management of high-pressure and low-pressure systems

	Low pressure	High pressure
Summer positives	Good irrigation for plant growth. Increase in sale of waterproofs and warm clothes.	Increase flight demands. More plant growth. More vitamin D. Increase in moods. Increased tourism. Infrastructure can be built.
Summer negatives	Trees are blown down. Damage to infrastructure. Crops damaged. Flooding.	Restriction on train speeds. Forest fires. Low rivers. Drought. Hyperthermia.
Summer management	Planning, Irrigation/drainage. Flood measures. NHS strategies.	Irrigation. Hosepipe bans. Health information.
Winter positives	More public transport used. Increase in winter sports. Increased trade abroad. Increase in online shopping.	Increase in indoor leisure activities. Increased online shopping.
Winter negatives	Road travel difficult. Rural settlements isolated. Agricultural production halted. Increase in illness. People unable to get to work.	Travel and transport disrupted. Old and very young vulnerable to serious colds. Damage to water pipes.
Winter management	Contingency planning. Gritters for the roads. NHS strategies.	Warnings of weather on the internet, radio, news etc. Health information provided.

Watch this video on how the weather affects shopping habits.

Seasonal changes and their impacts

The monsoon is the seasonal reversal in winds and the subsequent change in precipitation.

Causes of the monsoon

In the summer months **land heats up rapidly** whereas the **ocean only heats up gradually**. This creates an area of **lower pressure over the land** compared with the sea. This means that air, carrying moisture, travels from the sea onto the land. The **ITCZ** also moves northwards during the summer months allowing winds to blow from the south. The **Himalayas to the north interfere with the general circulation** of the atmosphere stopping the wind from blowing north and creating **orographic rainfall**. Watch this video on what causes India's monsoon:

Summer monsoon

The sun appears to move northwards bringing with it the **ITCZ**. Heat increases over the Indian subcontinent as **insolation increases** and creates a large area of **low pressure**. As a result of this, **warm, moist air is drawn northward**. The rainfall totals are accentuated as the air is forced to rise because of the **Himalayas**, by both **orographic and convectional uplift**.

Impacts of the summer monsoon include:

- Extreme flooding
- Damage to crops
- Lots of water for irrigation
- Infrastructure and tourism damaged
- Compromise of water purification facilities

Winter monsoon

The sun and the **ITCZ** both **move southwards**. The land experiences **intense cooling** which creates a very large **high-pressure zone**. The air moving over the land is dry because it originated in a semi-desert area and they become warmer and drier as they **descend from the Himalayas**.
Impacts of the winter monsoon include:

- Allows the rice to ripen, be harvested and be planted
- Low amounts of water are available for irrigation
- Drought

Changes in the monsoon

Due to climate change and possibly other unknown factors, the monsoon is becoming more **unreliable**. The amount of rainfall each year and when it arrives varies considerably and this makes it difficult for farmers to predict when to plant their crops. The **yield of rice is down by 30%** and further global warming could increase this number.

Management

Holiyas are simple holes dug in the ground lined with plastic piping and can contain storage below. They allow excess water to be collected during the summer monsoon so flooding does not occur and then the collected water can be used during the winter.

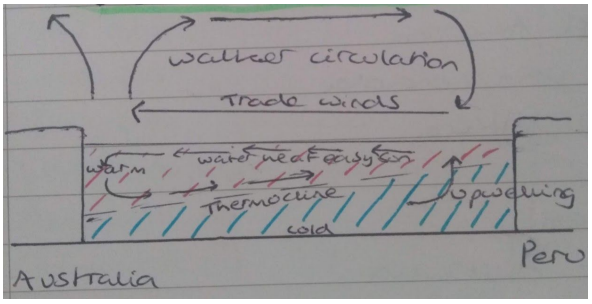
Drought and flood-resistant crops have been developed to withstand the extreme levels of water.
The government and charities are improving **forecasting and early warning systems** to alert farmers when the rains will come, although because the exact mechanisms of the monsoon are unknown this is difficult. A **30 million pound water distribution** improvement programme, as well as **seed banks**, have also been established.

Cyclical changes and their impacts

The **El Nino Southern Oscillation (ENSO)** is the irregular periods of changing wind speeds and the resulting change in the ocean currents in the Pacific Ocean. Watch this video on ENSO.

There are three different periods of ENSO: El Nino, La Nina and neutral conditions.

Neutral conditions

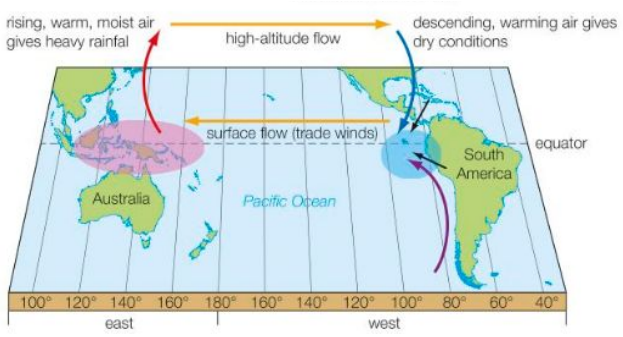


Upwelling of cold water off the coast of South America gives productive fishing due to nutrient-rich waters.

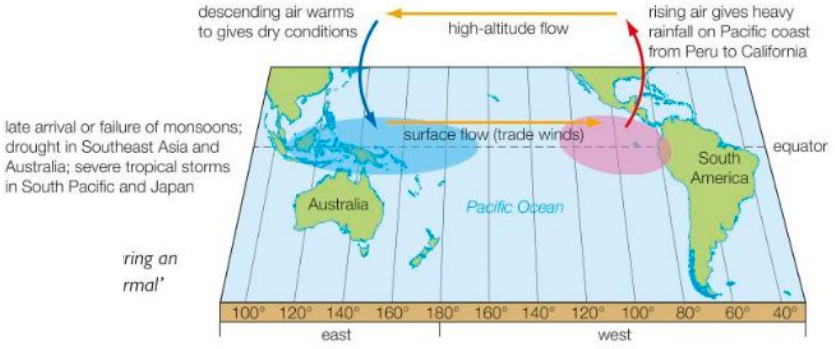
El Nino Southern Oscillation

El Nino is the **change** in water body patterns within the Southern hemisphere, leading to unusual weather conditions. The causes of El Nino aren't fully understood.

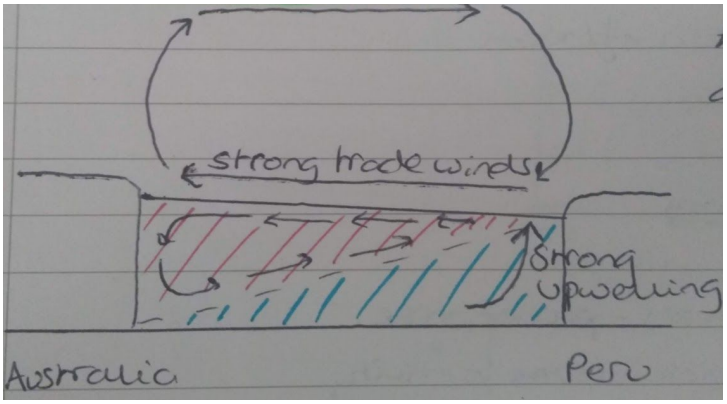
- Normally cool water is found along the Peruvian coast, and warm waters are found around Australia.
- ENSO causes this to switch (Peru gets warm waters, whereas Australia get cold water) and usually occurs every 3 to 7 years, generally lasting for 18 months.
- Peruvians can determine ENSOs occurrence based on their **anchovy** harvest - anchovies prefer cold waters, therefore as the water warms up (due to El Nino) the anchovies will migrate away, causing a reduction in Peruvian harvest.
  - ENSO can also trigger **extremely dry conditions** in areas South & South-East Asia, Eastern Australia and North-East Brazil. In South Asia, ENSO can **weaken the annual monsoon**.



The conditions before and during El Nino



La Nina



The atmospheric pressure differences are large so the trade winds are strong. This gives very productive fishing in Peru. Australia experiences increased rainfall, whereas South America experiences drier conditions.

Watch this video on the impact of El Nino on World Hunger.

Management of ENSO

ENSO can be monitored through **buoys** in the sea that can measure temperature. Warmer sea surface temperatures could suggest an El Nino year whereas cooler temperatures could suggest a La Nina year. The **height of the ocean** can be measured by **buoys and by satellites**. Strong trade winds pull the water towards Australia making the surface of the ocean higher compared with when there are weaker trade winds.

If these monitoring systems can detect whether an El Nino year or La Nina year is about to occur then **planning** can be put in place. **Drought/flood-resistant crops** can be planted and extra **seeds stored**. The government can issue **advice** to citizens and make sure that emergency services are prepared and drills carried out.

Long term changes and their impact

Causes

The earth's climate has been changing throughout history. The earth can undergo **global warming** as a result of natural and/or human causes. Natural causes of global warming include:

- **Astronomical forcing** which is the change in the tilt and orbit of the earth and can result in the earth being slightly closer to the sun and so it will receive more insolation.
- The amount of **energy emitted by the sun can vary** due to sunspots.
- The **eruption of volcanoes** can release materials such as ash into the atmosphere which can absorb heat energy or reflect it back at the earth.
- There are also **natural greenhouse gases** which absorb heat or reflect it back to earth.

Humans have increased the levels of greenhouse gases in the atmosphere, this is known as the **enhanced greenhouse effect** and it is as a result of increased levels of pollution and carbon dioxide mainly due to **industrialisation. Deforestation** for farming land, timber, urbanisation or the creation of reservoirs have removed trees which absorb CO2. Large scale, **commercialised agriculture**, especially that of animals such as cows have released lots of greenhouse gases into the environment.

Impacts

Global warming affects both humans and animals across the world. Here are just some examples of the possible impacts:

- More storms in Britain
- Flooding by the sea in Bangladesh and India
- Many Pacific Islands being submerged by the sea
- The seas by Canada becoming too warm for salmon and trout
- In Britain there will be 30% more rain in winter and 30% less rain in summer by 2080.
- Increased coral bleaching
- Extinction of many animals
- Increased levels of malnutrition and famine
- Vectors of diseases such as the mosquito that carries malaria will be able to breed in higher latitudes and so the distribution will increase
- Cereal production in high latitudes will increase but in low latitudes will decrease

Watch this video on the impacts of climate change.

Management

Management of climate change can either be **mitigation** or **adaptation.** Mitigation is trying to stop climate change by using **renewable energy** sources such as wind and solar, setting targets to **reduce GHG emissions** and **capturing carbon emissions**. Adapting is making changes so that we can live with the effects of climate change. This will include **planting drought-resistant crops**, **managing coastline retreat** and investing in **better freshwater provision**.

Mitigation is obviously preferable to adaptation as many of the countries that have contributed the least to climate change are the ones that are likely to suffer the most from it and also the ones that

won't be able to adapt to the changes. It is also not just about the impacts on humans. The rest of the world's species also need to be considered and if we just rely on adaptation then many of these species will become extinct.

Watch this video on the good news about tackling climate change.

Views on climate change

People across the world have different outlooks on climate change. There are those who believe in climate change and say that we need to do something about it. There are those who believe in climate change but say that it won't have a great impact on our lives and that it has happened naturally before so we should not change our lifestyles and there are those who don't believe in climate change.

So here is a variety of evidence so that you can use it to argue for and against in a question or essay:

- July 2016 was the 379th consecutive month with global temperatures above the 20th-century average.
- Over the last 11 year solar cycle, solar output has been lower than it has since the mid 20th century so global warming cannot be as a result of this.
- There have been many periods hundreds of thousands of years ago where the temperature is at about the same level as today and the earth's temperature has been constantly under flux.
- In less than 100 years the levels of CO_2 have been constantly increasing and are around double the previous maximum. Although correlation between rising CO_2 and rising temperatures does not necessarily mean causation.
- The oceans are becoming more acidic due to harmful gases which have been released by humans being absorbed by the oceans.
- The glaciers and the polar ice is shrinking.
- Not enough historical data available to confirm if temperatures are increasing and some scientists say that there has been no significant increase in global temperatures since 1997.
- Models used to predict future impacts of climate change are flawed and give false predictions.