AQA Geography GCSE

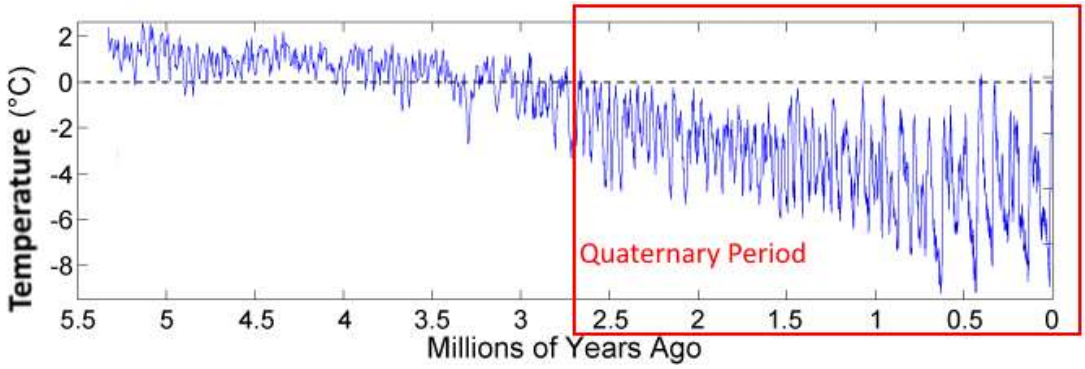
3.1.1.4: Climate Change

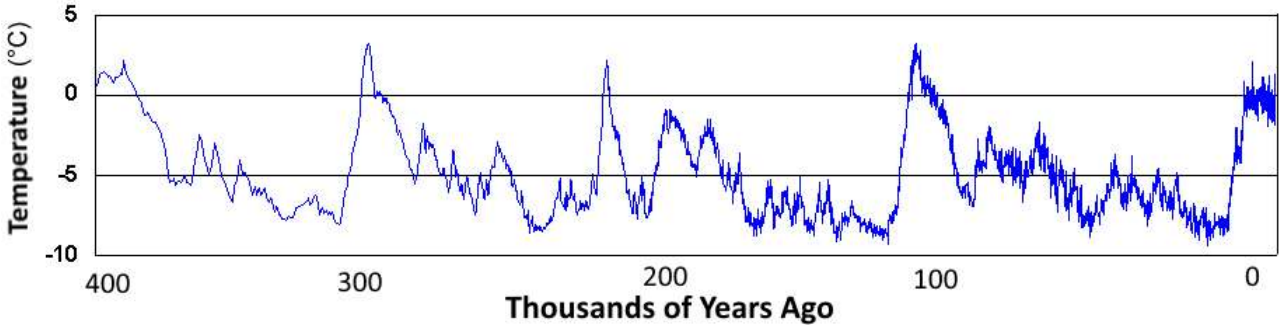
Detailed Notes

Climate Change During Earth's History

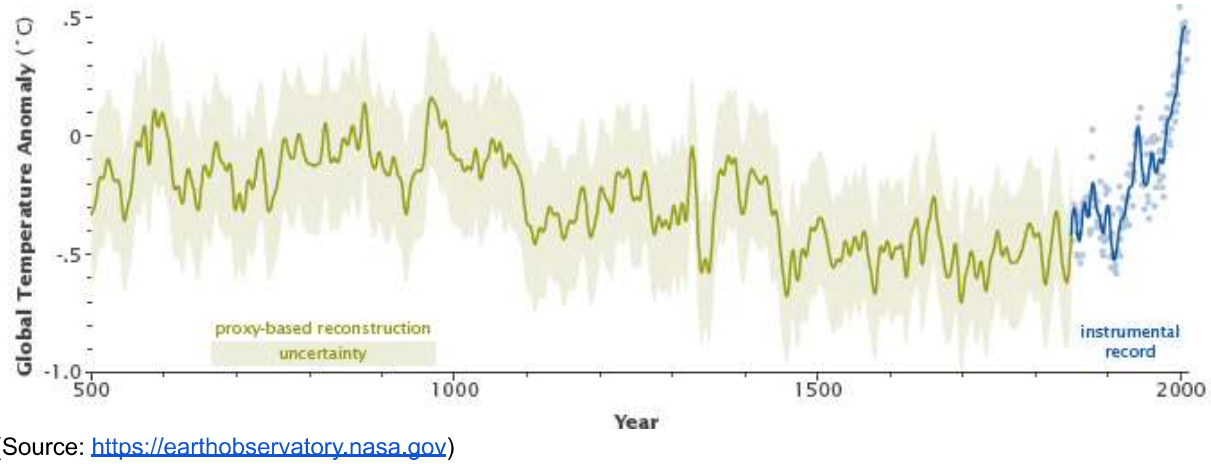
When we hear the phrase '**climate change**', we might think about the changes in our climate **over the last few decades**: rising **temperatures** in the **air** and the **sea**, more **intense tropical storms**, severe **droughts** etc. However, the climate of the Earth has gone through **dramatic changes** throughout its **history**. Some **major fluctuations in temperature** have occurred in the ***Quaternary Period***.

The **Quaternary Period** is the **geological time period** that started **2.6 million years ago**, and extends into the **present**. During the Quaternary period, there have been many fluctuations between the colder **glacial periods** and warmer **interglacial periods**. We can see these fluctuations on the graphs below, which show the temperature relative to our current average temperature (which is displayed as 0°C on the graphs).





Over the last few hundred years, our climate has been warming **rapidly**. Average global air temperatures have risen by **0.85°C since 1880**, and the majority of this warming has occurred since the 1970s. This warming is projected to continue throughout the century.



(Source: https://earthobservatory.nasa.gov)

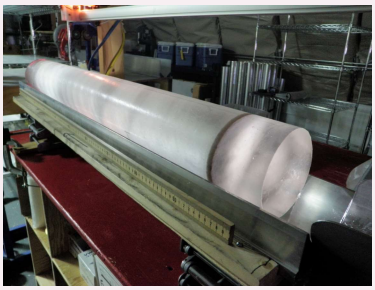
Evidence for Climate Change

In the present day, we measure **air** and **sea** temperatures using **thermometers**. Scientists started taking these measurements around 100 or so years ago, meaning we have a **reliable record** of global temperatures starting around the late 1800s (which is known as the **instrumental temperature record**). The instrumental temperature record is shown by the **blue line** on the **graph above**.

However, this means there is **no instrumental data** of global temperatures **before people started taking these readings**. Scientists have therefore had to discover other ways to **indirectly** calculate global temperatures **in the distant past**. One way scientists have done this is by using **deep marine sediment cores** and **ice cores**. By studying **air bubbles** and **the composition of water**, these cores can indicate **what the climate was like** when the ice or sediment was formed.

Thinking Further: Marine Sediment and Ice Cores

The Antarctic ice sheet and the Greenland ice sheet are the largest **and the oldest** ice sheets in the world. They contain ice crystals that were formed **hundreds of thousands** of years ago.



When snow falls on top of these ice sheets, it buries and **traps older snow** below. Over thousands of years, this snow builds up and compacts into **thick ice**.

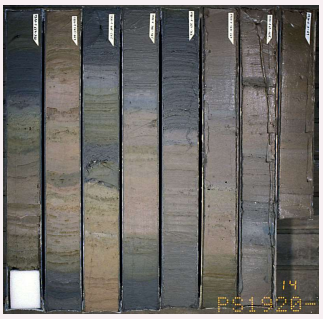
(Source: icecores.org/about-ice-cores)

Scientists have been able to **drill down** inside the ice sheets and extract **large cylinders** of ice called **ice cores** (see the image above). Scientists use these ice cores to calculate **gradual changes in temperature** over thousands of years. Right at the top of the ice core is the **youngest ice**, and as the scientists work down the ice gradually becomes **older**.

The **composition of water** can be analysed to calculate (with extreme accuracy) what the **temperature of the atmosphere** was when that water fell as snow. Air bubbles **trapped in the ice** can also be analysed; levels of CO_2 and other gases can tell us more information about the climate at that time.

Ice cores provide evidence of the climate stretching back **hundreds of thousands of years**. The furthest back in time an ice core has been able to go was 400,000 years!

Marine sediment cores are used in a similar way (image on the right). Scientists extract cores **from the deep ocean** and analyse **carbonates** and **the composition of water** to calculate past temperatures. Marine cores usually show **a greater length of time**, but are generally **less accurate** than ice cores.



(Source: By Hannes Grobe (talk) - Own work, CC BY 3.0, commons.wikimedia.org/w/index.php?curid=6829604)

Current Evidence of Climate Change

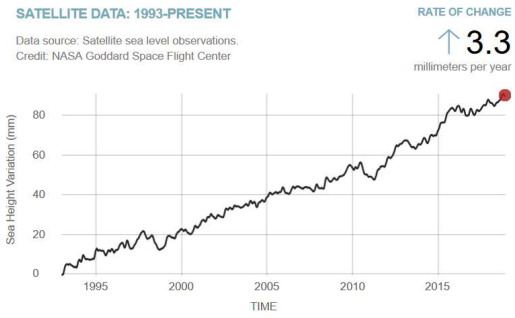
We know that our climate **has been warming** in recent years due to our temperature records, but we can also see **more evidence** of our changing climate in different parts of the world.

Sea Level Rise

The average **global sea level** has risen by **21-24cm** since the 1800s, and **a third** of this rise has occurred within the **last 25 years**.

Sea level rise has been occurring because **higher temperatures** have caused glaciers and ice sheets to melt, and this **freshwater** then flows into the sea.

Furthermore, water **expands** when it gets warmer (known as **thermal expansion**) so as the Earth warms, the whole sea is expanding and **rising**.



Decay of glaciers and ice

Glaciers and ice sheets are **melting** all around the world, which is evidence that **the climate is warming**. Some glaciers are projected to **completely melt** by 2035. The majority of glaciers are shrinking and thinning.

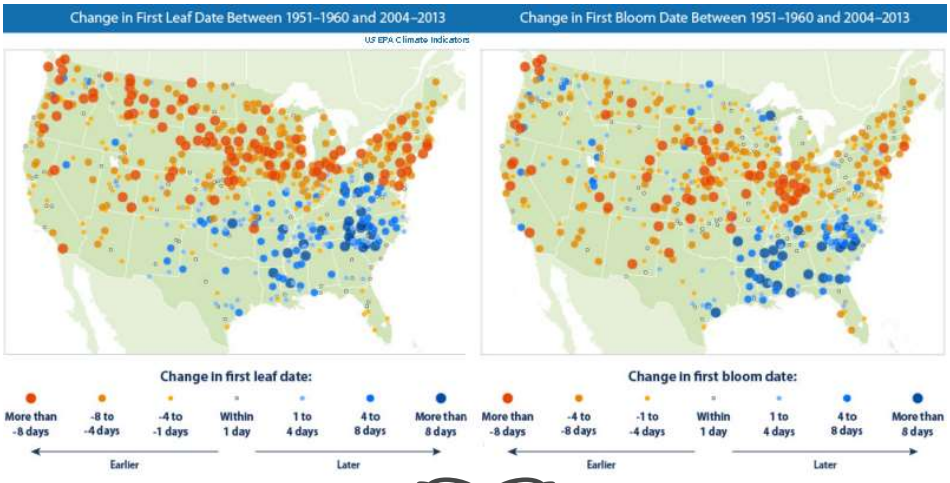
Sea ice is also **thinning** and not **extending as far**, especially in the Arctic Ocean. Sea ice has thinned by up to 65% since 1975 in the Arctic Ocean.

(Source: www.flickr.com/photos/wasifmalik)

Changes in ecological patterns

Many ecological studies have shown that **seasonal patterns** of wildlife have been changing. This is evidence that the **climate** must be influencing the seasons.

Bird migration, plant flowering patterns and breeding seasons have been **shifting** throughout the world. Below is a map showing how the dates of first leafing and first blooming has changed in recent years in the USA.



Natural Causes of Climate Change

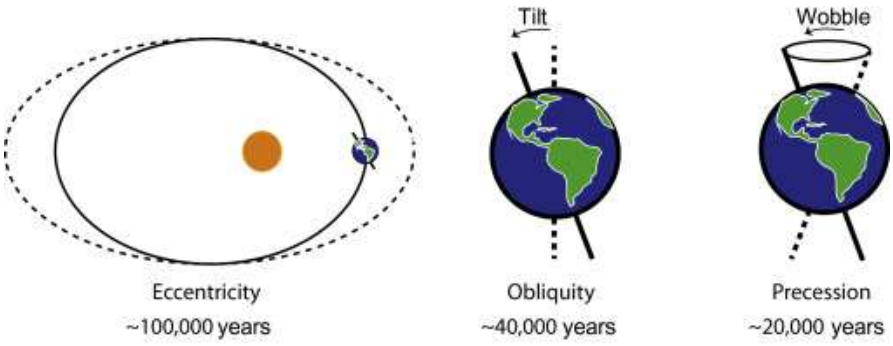
There are several **natural factors** that have caused **changes in Earth's climate** for millions of years. The main natural influences on climate change are:

- Variations in the **Earth's orbit** around the Sun
- The effects of **volcanic eruptions**
- Changes in the **solar output** (amount of heat energy) of our Sun

Orbital Changes

The way in which the **Earth orbits around the Sun** changes over **thousands of years**. These orbital changes affect **where the Sun hits the Earth**, and how **intense** the Sun is, which in turn controls the seasons and affects the climate. Orbital changes follow **very similar patterns** to **glacial** and **interglacial** periods, and scientists theorise that orbital changes caused these **temperature fluctuations**.

The influence of Earth's orbit on the climate is known as '**orbital forcing**' and the cycles are commonly referred to as **Milankovitch cycles** after the Serbian geophysicist Milutin Milankovitch who discovered them. There are **3 distinguishable orbital changes** that the Earth goes through:

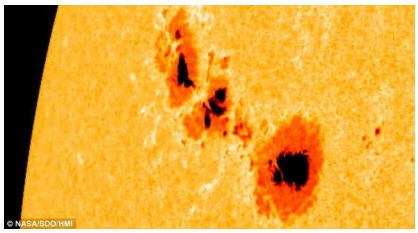


(Source: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/orbital-forcing)

1. **Eccentricity:**
   - The orbit of the Earth around the Sun changes from a **near-perfect circle** to an **ellipse** (squashed circle/oval).
   - This affects how **intense** the Sun's rays are on Earth. If the Earth is orbiting in an **elliptical shape**, it will be **further away from the Sun** at certain points than if it was orbiting in a **circle**.
   - 1 cycle takes around **100,000 years**.
2. **Obliquity (tilt):**
   - The **tilt** of the Earth's **axis**, which changes from **21.5° and 24.5°** (currently 23.5°).
   - Affects the contrast between summer and winter **seasons**.
   - To change between 21.5° and 24.5° takes around **41,000 years**.
3. **Precession:**
   - Describes the **wobble** of the Earth's axis (imagine the movement of a **spinning top** when it starts to slow down - the Earth wobbles on its axis in a similar way).
   - Affects the **length of days**, especially in the poles.
   - A full cycle takes just over **20,000 years**.

Solar Output

There are **variations** in the amount of **solar energy** that the Sun **emits** which are thought to have an effect on the **Earth's climate**.



One example of a variation in solar output is the **sunspot cycle**. The **sunspot cycle** is an **11-year cycle** where the amount of **sunspots** on the Sun's surface (darker spots with reduced temperatures) varies from a **minimum** to a **maximum**, and then back to a **minimum**.

At the sunspot cycle's **minimum**, there is **reduced solar output**. At the sunspot cycle's **maximum**, there is an **enhanced solar output**.

There is an identifiable **relationship** between **the Earth's climate** and the **amount of sunspot activity present** on the Sun. There have been incidences of **temperature change** on Earth that are linked to these **cycles**, so it appears that **solar output variations** do affect the temperature on Earth, although this is only a **theory**. It has been hypothesised that temperatures during a cold period called the '**Little Ice Age**' plummeted further during sunspot minimums (1450 to 1534, and 1654 to 1715)

Volcanic Activity

Very large **volcanic eruptions** have had an effect on the **Earth's climate** in the past. The **ash** and **gas** that is **erupted** into the atmosphere when there is a huge eruption can cause a **cooling effect** on the Earth's climate. This reduction in surface temperatures caused by an eruption is known as a **volcanic winter**. Volcanic eruptions do this in two ways:

- Large amounts of **volcanic ash** can stay in the atmosphere and **block out the sun**. This is usually a **short term cooling**.
- Volcanic eruptions can emit **sulfurous gases** which react to form aerosols which **reflect solar radiation**. This effect can last several years.

Thinking Further: Volcanic Winters

There have been many examples of large volcanic eruptions causing **volcanic winters**.

- **1783 - Laki, Iceland**. The year after the eruption, Northern Hemisphere temperatures fell by about **1°C**, resulting in severe weather. 8,000 additional deaths in the UK were recorded in the winter of 1783-1784. **Severe weather** continued for several years in Europe.
- **1815 - Mount Tambora, Indonesia.** The eruption caused global temperatures to fall by **0.4-0.7°C**, resulting in crop failures and famines. 1816 was commonly referred to **'The Year Without a Summer'**.

Artistic representation of the 1815 eruption.
(Source: Greg Harlin/Wood Ronsaville Harlin)

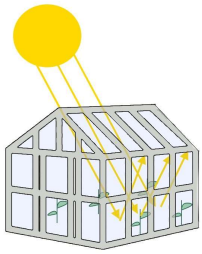
Human Causes of Climate Change

There is **overwhelming evidence** to suggest that **humans** have been a major cause of **climate change**, especially the **rapid warming** since the 1970s. This is due to **human activities** that influence how much **energy is in the Earth's atmosphere**. The main ways that humans are thought to have caused global warming are:

- The **burning of fossil fuels**, which has released **greenhouse gases**
- **Different farming methods**, which release **methane** (a powerful **greenhouse gas**)
- **Deforestation**, which has **reduced the CO_2** taken up by trees, contributing to higher levels of **greenhouse gases in the atmosphere**.

The Greenhouse Effect

Human activities have contributed to global warming through the release of **greenhouse gases**, but **how has this caused recent climate change**?

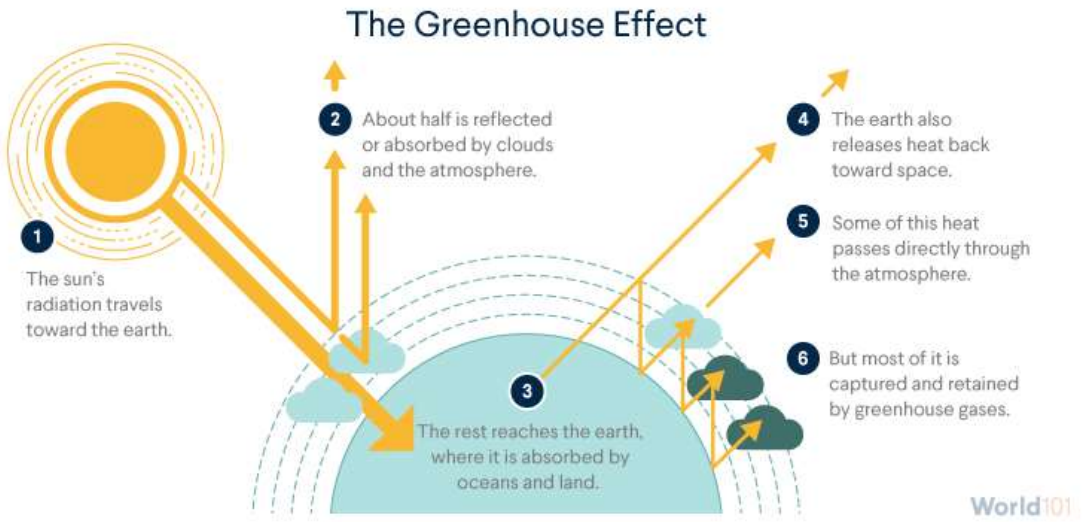


The Greenhouse Effect is a natural process where **greenhouse gases** (mainly carbon dioxide, methane, water vapour, and nitrous oxides) trap the energy from the Sun inside the Earth's atmosphere, which heats the Earth.

This effect is similar to what happens in a **greenhouse**. In a greenhouse, the **Sun** shines through the glass, which **heats up the air** inside. This heat cannot escape as it is **trapped** by the glass, which keeps it **warm** inside.

A similar effect happens when the **Sun** shines on our **Earth**:

- **Solar radiation** from the Sun (short-wave radiation) travels to our Earth and **heats up the Earth's surface.**
- The Earth **gives off heat** (long-wave radiation) when it cools.
- Some of this heat **leaves our atmosphere and goes into space.**
- Some of this heat is **trapped by greenhouse gases**, which keeps our Earth warm.



The Greenhouse Effect is the reason the Earth is **warm enough** to live on. Without it, Earth would be far too cold for life as we know it.

The Enhanced Greenhouse Effect

Human activities release **greenhouse gases** into the atmosphere at a **higher rate than natural processes**, which has resulted in an **enhanced greenhouse effect**.

As there are higher amounts of **greenhouse gases** in the atmosphere, more heat is **trapped** and cannot escape into space. This heat is **reradiated around the Earth** and causes the air to heat up more and more. This process has led to **increased warming** in recent years.

The main human activities that have caused an **increase in greenhouse gas levels** in the Earth's atmosphere are outlined below:

Fossil Fuels

Fossil fuels - such as coal, oil and gas - are fuels that are made up of **the remains of organic material**. We burn fossil fuels for **energy**, which produces our **electricity**, fuels our **cars**, and heats our **homes**.

When fossil fuels are burnt, **greenhouse gases** are released, such as carbon dioxide, nitrous oxides and methane. These greenhouse gases concentrate within the atmosphere, contributing to the **enhanced greenhouse effect**.

The vast majority of **CO_2** comes from the burning of fossil fuels.

Agriculture

Another source of **greenhouse gases** is due to **farming** activity.

Agricultural activities produce a lot of **methane**. **Methane** is a **more effective greenhouse gas** than CO_2, so it is **better at trapping heat**. About **25%** of global warming is thought to be caused by methane emissions, despite there being **much** less methane in the atmosphere than CO_2.

Rice Farming

In a paddy field (a flooded field where they grow rice) there are the right conditions to release a **lot of methane**. As rice is **heavily cultivated** across the world, rice farming is a **large contributor** to the levels of methane in the atmosphere.

Livestock

Some **farm animals**, such as cows and sheep, **produce methane** when they digest food. One of these animals on average produces 250-500 litres of methane a day!

Animals are kept all over the world **as livestock** to meet the population's demand for **meat and animal products**, which contributes to **huge methane emissions**.

(Source: https://www.nationalgeographic.org/encyclopedia/ranching/)

Agricultural fertilisers also produce **nitrous oxides**, which can be up to **300 times** more effective in capturing heat than carbon dioxide.

Deforestation

Deforestation is the process of **cutting down trees**. Deforestation occurs all over the world, mainly to **make space** for **agriculture**, or to **collect wood** to use for other means or to **burn** as fuel.

Trees take in **CO_2** from the atmosphere and store it inside them as **carbon**. Deforestation removes **large amounts of trees**, which in turn **reduces** the amount of **CO_2** that is being taken in and stored, resulting in higher levels in the atmosphere.

Also, forested areas are often **burnt** to make space quickly, and chopped wood is also burnt for fuel. The burning of wood **releases CO_2** that was originally stored in the trees and puts it in the atmosphere.

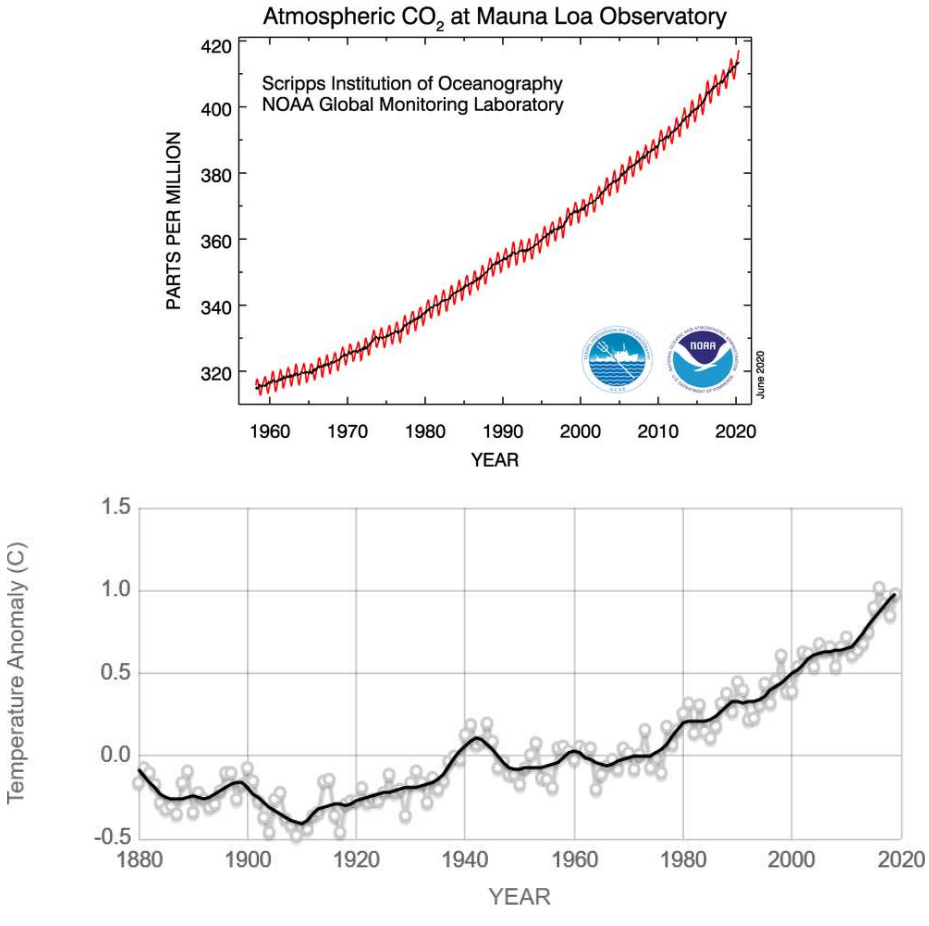
(Source: AFP via Getty Images)

Greenhouse Gas Levels and Climate Change

Emissions of greenhouse gases due to human activities is thought to be a **bigger influence** on **current global warming** than **natural causes of climate change**.

Average global **temperatures** are projected to increase by as much as **4°C** by the end of the century (projected between 1.8°-4°C) due to human activities.

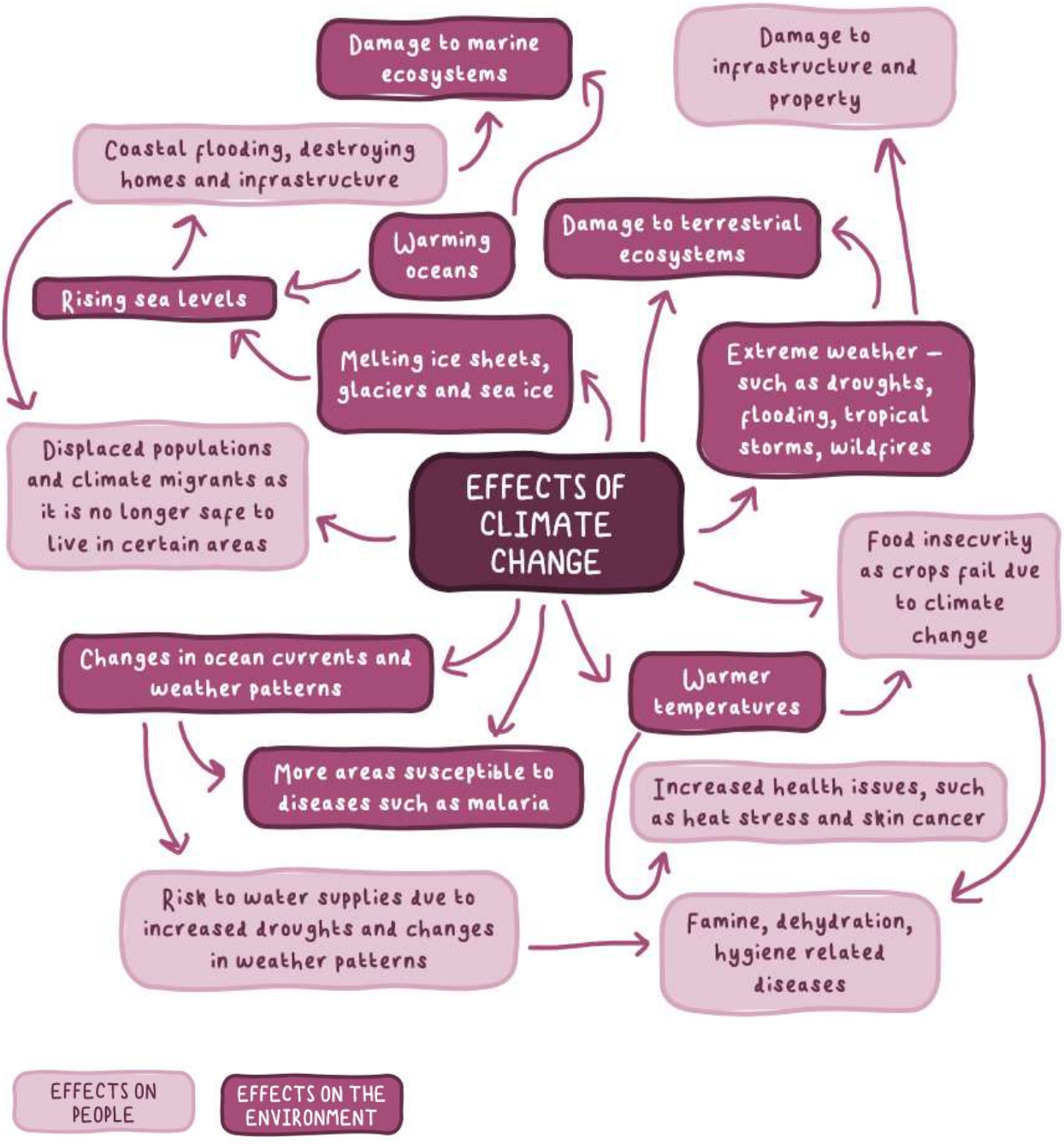
Below is a graph of the amount of **atmospheric CO_2** recorded since **1958**, and a graph of **average temperature difference** (anomaly) since **1880**. Notice how the global temperatures are rising in a similar pattern to the levels of CO_2 in the atmosphere.



Source: climate.nasa.gov

Effects of Climate Change

There are many different effects of climate change on **humans** and on **the environment**. Below are some examples of these effects. Many are **interlinked** and **related** to each other, and many **environmental effects** can cause **human effects**.



Managing Climate Change

In order to live with the **adverse effects of climate change**, society is finding new ways to **manage these effects**. In general, there are two **approaches** to managing climate change:

1. **Mitigation: reducing the causes** of climate change, so that climate change **slows** or **even stops**. This management strategy is mainly coming up with ways to **reduce greenhouse gas emissions**.

2. **Adaptation**: **responding to climate change** by coming up with ways to **live** and **cope** with the effects. This is mainly by reducing the **risks** associated with climate change, like building **flood defenses** to manage **sea level rise**.

Mitigation

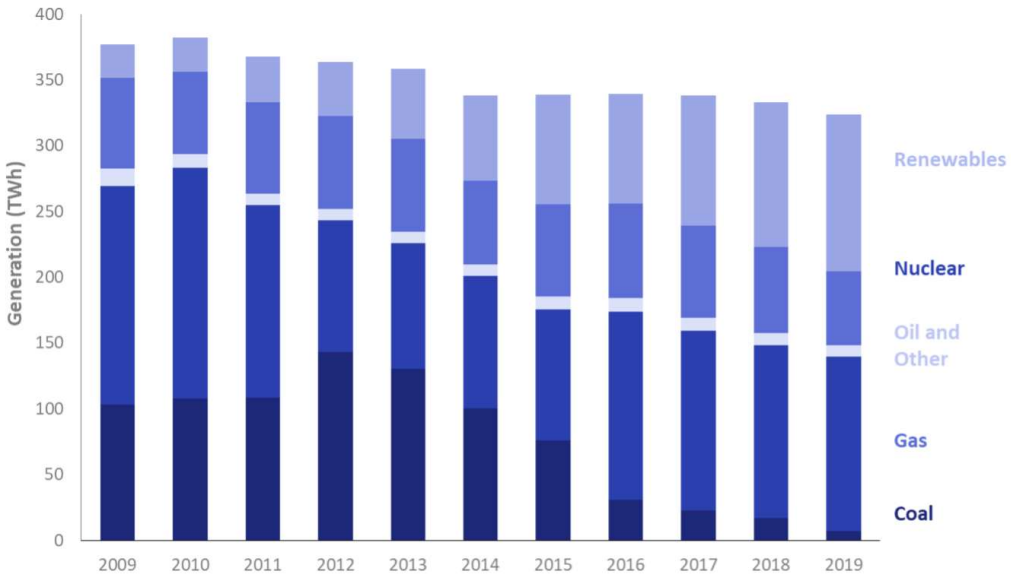
Alternative Energy Production

Burning fossil fuels is the largest contributor to **greenhouse gases** and the biggest cause of **global warming**. Therefore, new ways of **producing energy** are being developed in order to reduce society's reliance on **fossil fuels**, and therefore lower greenhouse gas emissions.

These **alternative sources of energy** produce less CO_2, and many alternative sources are also renewable (will not run out, infinite) Alternative sources of energy include:

- Nuclear power
- Biomass
- Hydro-electric power
- Geothermal
- Solar, wind and tidal power

The UK has invested a lot into renewable energy, and now over ⅓ of the UK's energy comes from renewables.

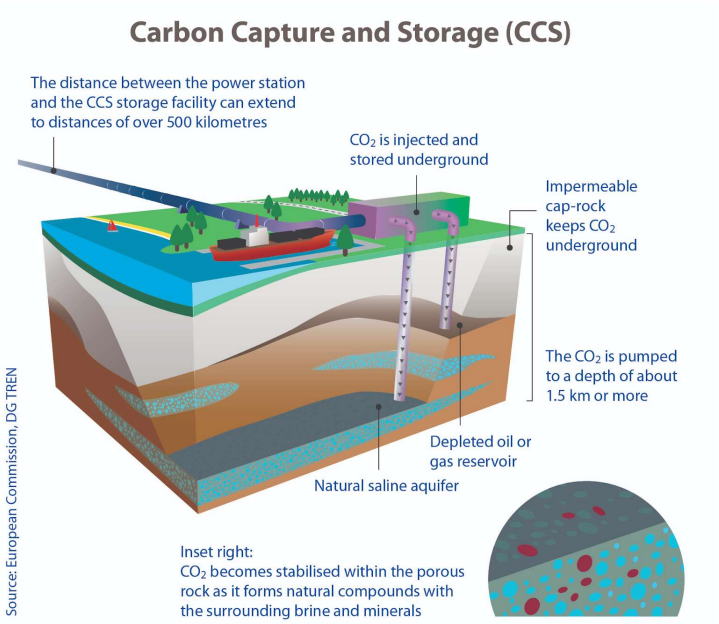


(Source: https://www.gov.uk/government/statistics/electricity-section-5-energy-trends)

Carbon Capture

Carbon capture and storage (CCS) is the process of **capturing** carbon dioxide that would usually be emitted from fossil fuel burning, and storing it **underground** in reservoirs.

CCS is a **developing technology**, but has the potential to reduce greenhouse gas emissions massively. Up to **90%** of carbon dioxide from industry and electricity generation could be stored in this way.



Tree Planting

Trees take in and store carbon dioxide via **photosynthesis**, so planting many trees can help to **take in carbon dioxide** from the atmosphere.

Furthermore, trees also **release moisture into the atmosphere**, producing **clouds** which reflect solar radiation.

However, planting trees alone would not **absorb all of the CO_2** we emit, so although it is a helpful strategy it cannot be used as the only solution to reduce greenhouse gases.

(Source: /www.greenandgrowing.org/what-is-afforestation/)

International Agreements

There are **international organisations** dedicated to **managing climate change** by providing **education**, creating **frameworks** for countries to follow, and encouraging countries to **set goals to reduce their emissions**. The **Intergovernmental Panel on Climate Change (IPCC)** is a body of the **United Nations** that creates **international agreements on climate change** which member states are expected to follow. Aspects of the agreements include **aims to reduce emissions** and create more **sustainable societies**.

Kyoto Protocol - 2005

The first **international treaty** to reduce **greenhouse gas emissions**. Countries agree to their own **emission reduction targets** ranging from **0% - 10% reductions** from their 1990 levels by **2012**. The US (a major greenhouse gas emitter) did not sign, but over 170 other countries agreed.

Paris Climate Agreement - 2015

195 countries agreed to **ensure warming is kept well below 2°C** by the end of the **century**, and strive to **limit temperature increase to 1.5°C above pre-industrial levels**. The agreement also aims to "**strengthen** the ability of countries to **deal with the impacts** of climate change".

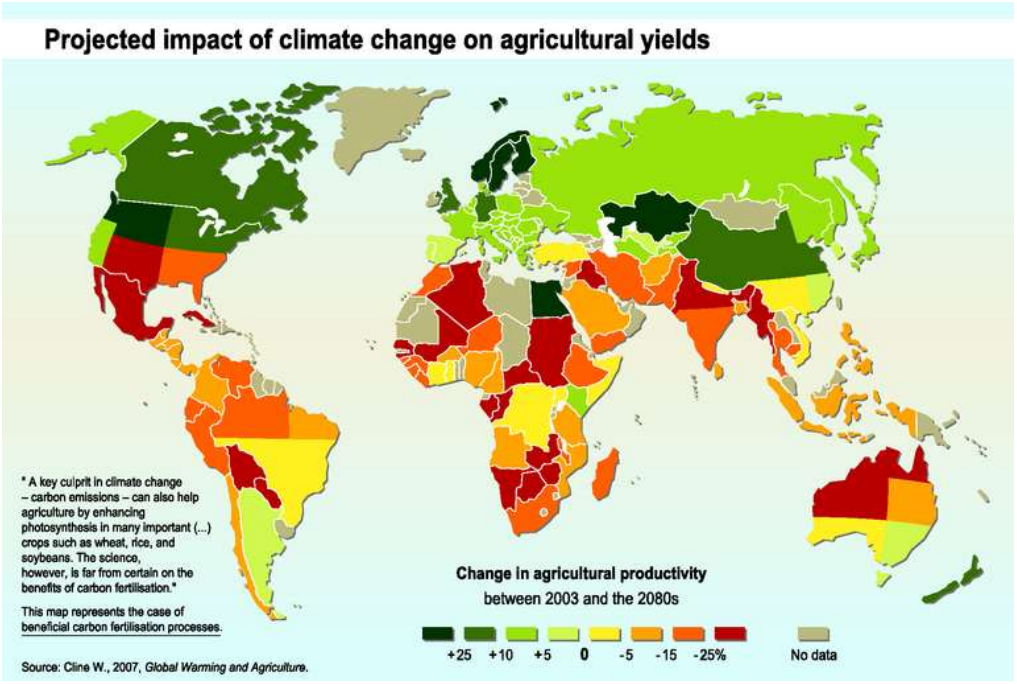
Adaptation

Changing Agricultural Systems

Climate change is predicted to **affect agricultural systems all over the world**. Even if we drastically reduce greenhouse gas emissions, it is likely that there will still be changes in the climate:

- The distribution of **pests** and **diseases**, such as locust swarms, are expected to change.
- Rainfall and temperature patterns will change, which will make some areas **more suitable for agriculture**, but others less suitable.
- **Extreme weather events**, such as droughts, floods, and heatwaves are expected to become more common. This means farmland may be destroyed and crops might fail more frequently.

The map below shows how **agricultural yields are projected to change** all over the world due to **climate change**.



Farmers will therefore need to **adapt to these changes** to make sure they can still grow crops. Some adaptation techniques include:

- Introducing **irrigation systems** (giving crops a **controlled amount of water**, usually through pipes and sprinklers etc.)
- Introducing more **resistant crops** and creating **new strains** of crops that produce **higher yields**
- **Educating** farmers on the changes so they can change their systems (e.g. sowing seeds at different times)
- Water harvesting and storage methods, such as rainwater harvesting
- Using new **technology** (e.g. in some farms in Sudan they have air-conditioned rooms for cows)

(Source: https://www.bbc.co.uk/news)

Water Supply Management

With predicted changing patterns of **rainfall** and the projected increase in **extreme weather**, water supplies are under threat in many places around the world. Countries will need to **manage their water supplies** so that enough water is available for the population. Strategies include:

- Building **dams** and **reservoirs** to **store water** for the population
- Educating the population to **not waste water**
- More efficient ways of **using water supplies** (e.g. drip irrigation, where plants are **watered in smaller amounts** directly onto their roots, which saves water)
- Using **new technologies** to redistribute water

For example, in the Himalayas, millions of people are dependent on snow and glacier meltwater, but warming temperatures mean these sources are **melting rapidly**. In the future, the region may **not have any sources of meltwater left**. Engineers have responded to this threat by creating **artificial glaciers**. Meltwater is collected from elsewhere and is **sprayed onto a structure** so it **freezes** and can be stored until it is needed.

(Source: https://www.newyorker.com/magazine/2019/05/20/the-art-of-building-artificial-glaciers)

Managing Sea Level Rise

By 2100, **sea levels are expected to rise** anywhere from 26-82cm. This sea level rise will have massive implications on **coastal areas**, and there is a **severe risk of very significant coastal flooding**. This also threatens **freshwater supplies**, as they may become **contaminated by seawater**.

Some strategies are being adopted to manage sea level rise:

- Construction of **flood defenses** such as **sea walls**, or the use of **sandbags** to physically stop sea water
- Housing built on **stilts** so they are **raised off the ground**, which will stop properties flooding
- Designating areas as **unsafe to live** and redistributing populations to other areas
- Constructing areas that are **high above sea level**
- Restoration of **mangroves** - mangroves are shrubs that can **trap sediment** and **slow water flows** with their thick roots. Many countries are deciding to **restore mangrove forests** because they are natural flood defenses. The photo to the right is a community-based mangrove restoration project in El Salvador.

(Source:www.iucn.org/content/community-based-mangrove-restoration)