Briefing 2

What are the causes and processes of climate change?

Climate change is nothing new - the world's climate has changed throughout geological time. However, in recent decades, scientists believe that the rapid changes in climate have resulted largely from human activities and that the unprecedented rate of change threatens global ecosystems.

Natural causes of climate change

1. *Sun spot activity*

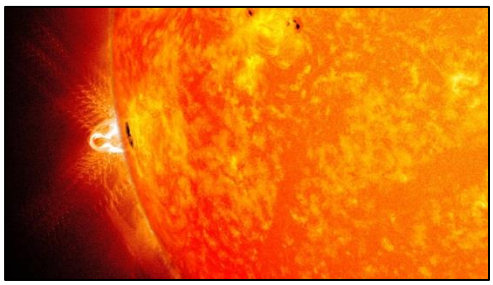
A **sunspot** is a spot or dark patch that appears from time to time on the surface of the sun. The number of sunspots increases from a minimum to a maximum and then back to a minimum over a period of about 11 years known as the **sunspot cycle**. Sunspots are associated with strong magnetic fields and often give rise to large explosions on the sun's surface causing solar flares (Figure 1).

Whilst the origin of sunspots is not fully understood, scientists have suggested connections between sunspot activity and climate change. For example, very few sunspots were observed between 1645 and 1715 – a period known as the Maunder Minimum. This coincides with the coldest period during the European Little Ice Age. So, despite the fact that sunspots are dark areas on the sun, it seems that the more sunspots there are the more effective the sun is at giving off heat.

Whilst scientists think that the natural sunspot cycles may have some impact on the Earth's climate, their influence is probably not as significant as the impacts of human activities such as the burning of fossil fuels.

Figure 1

Sunspot and solar flare on the surface of the sun (2014)



http://www.nasa.gov/sites/default/files/feb_25_x_5_pre-flare-sunspot_crop1.jpg

2. *Volcanic eruptions*

Violent volcanic eruptions blast huge quantities of ash, gases and liquids into the atmosphere. Fine particles of ash can block out the sun leading to a reduction in surface temperatures called a 'volcanic winter'.

Ash does not usually stay in the atmosphere for more than a few weeks so is unlikely to have a long-term impact on climate. Sulphur dioxide, however, can lead to longer-term cooling. The fine aerosols

that result from the conversion of sulphur dioxide to sulphuric acid act like tiny mirrors reflecting radiation from the sun. This results in the cooling of the lower atmosphere.

Case Study

Mount Pinatubo, 1991

The eruption of Mount Pinatubo in the Philippines on 15 June 1991 was one of the largest eruptions of the twentieth century. An enormous cloud of ash and gases, including sulphur dioxide, was ejected more than 20 miles into the stratosphere (Figure 2). Satellites recorded the highest concentration of sulphur dioxide since observations began in 1978. The aerosols cooled the world's climate for a period of three years by up to 1.3°C.

Figure 2

The eruption of Mount Pinatubo, Philippines (1991)

http://volcanoes.usgs.gov/hazards/gas/pinatubo.jpg

> *The USGS has published an excellent summary of the impacts of volcanic activity on climate*
>
> https://volcanoes.usgs.gov/vhp/gas_climate.html

3. *Milankovitch cycles*

The Milankovitch cycles are cyclical time periods that relate to the Earth's orbit around the sun (Figure 3). There are three cycles:

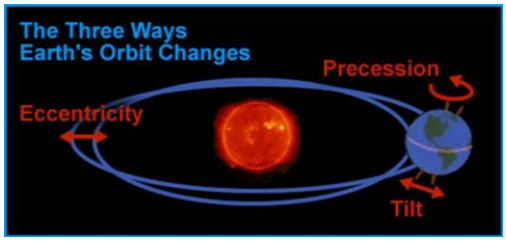
- **Eccentricity** – this describes the path of the Earth as it orbits the sun. The Earth's orbit is not fixed – it changes over time from being almost circular to being mildly elliptical (Figure 3). A complete cycle – from circular to elliptical and back to circular again occurs about every 100,000 years.
- **Axial tilt** – the Earth spins on its axis, causing night and day. The Earth's axis is currently tilted at an angle of 23.5 degrees. However, over a period of about 41,000 years, the axial tilt of the Earth moves back and forth between two extremes - 21.5 degrees and 24.5 degrees.

- **Precession** – this describes a natural 'wobble' that occurs with the Earth rather like a spinning top. A complete wobble cycle takes about 26,000 years. The Earth's wobble accounts for certain regions of the world such as the northern Norway experiencing very long days and very long nights at certain times of the year.

Scientists believe that these cycles affect the timings and seasonality of the Earth's climate. In particular, the 100,000 year eccentricity cycle coincides closely with the alternating cold (glacial) and warm (inter-glacial periods) in the Quaternary period.

Figure 3

The Milankovitch cycles: changes in the Earth's orbit



https://www.windows2universe.org/earth/climate/cli_sun.html&edu=high

Human activities and climate change

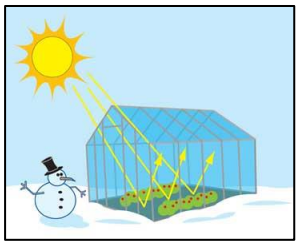
Most scientists believe that human activities are responsible for the rapid rise in temperatures (global warming) since the 1970s.

The greenhouse effect

A greenhouse is a house made of glass. If you have been inside a greenhouse you will know that it is warm even during the night and also during the winter. This is why people often grow vegetables and fruit such as tomatoes in greenhouses. The reason why a greenhouse is warm is because it retains the heat from the sun. Look at Figure 4. Notice that heat from the sun passes through the glass but does not escape.

Figure 4

The greenhouse effect . . . in a greenhouse



http://climatekids.nasa.gov/greenhouse-effect/

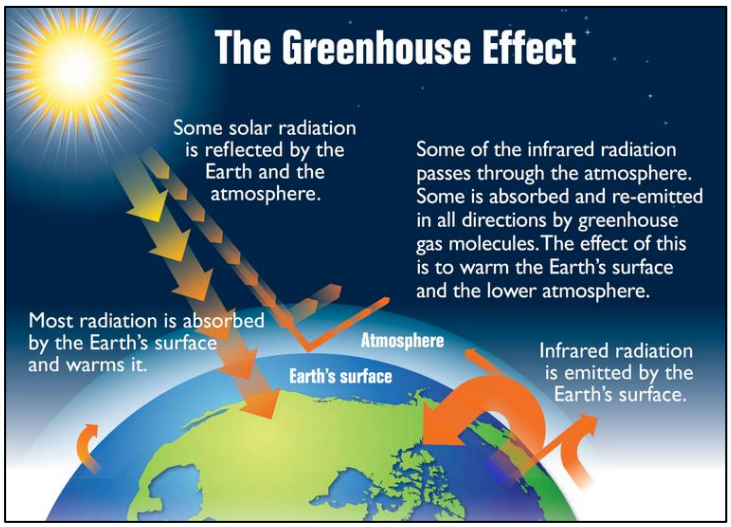
The Earth's atmosphere behaves in a similar way (Figure 5).

- Heat in the form of short-wave solar radiation travels some 93 million miles to reach the earth's outer atmosphere
- Some radiation is reflected in the atmosphere but most passes through to warm the Earth's surface
- This warmth is then released in the form of long-wave infrared radiation (like heat given off by a radiator).
- The heat is easily absorbed by liquids and so-called 'greenhouse gases' in the atmosphere, particularly carbon dioxide, methane and nitrous oxides (Figure 6).
- Some heat escapes to space

The warm atmosphere acts like a blanket over the Earth keeping us warm. Without the greenhouse effect, it would be too cold for life to exist on Earth.

Figure 5

The Natural Greenhouse Effect



https://energyeducation.ca/encyclopedia/Greenhouse_effect

The enhanced greenhouse effect

Many scientists believe that in recent decades the natural greenhouse effect has become more effective at retaining infrared heat given off from the Earth. The 'blanket' around the Earth has in effect become warmer! This is the enhanced greenhouse effect.

The main reason why this has happened is because human activities such as burning fossil fuels, deforestation and emissions from vehicles have increased the concentration of the greenhouse gases in the atmosphere (Figure 6).

Figure 6

The main greenhouse gases

Gas	Causes
Carbon dioxide (CO2)	• Burning of fossil fuels (coal, gas and oil) • Deforestation (burning wood) • Industrial processes (e.g. making cement)
Methane (CH4)	• Emissions from livestock and rice cultivation • Decay of organic waste in landfill sites
Nitrous oxides (NOx)	• Emissions from vehicle exhausts • Agriculture and industrial processes

Carbon dioxide is by far the most significant greenhouse gas (Figure 7). Methane is a very potent greenhouse gas, however it does not last much more than a decade in the atmosphere; carbon dioxide lasts much longer.

Figure 7

Global greenhouse gas emissions

Gas	Percentage
Carbon dioxide (burning fossil fuels)	57%
Carbon dioxide (deforestation, decay of vegetation)	17%
Carbon dioxide (other)	3%
Methane	14%
Nitrous oxide	8%
Fluorinated gases	1%
TOTAL	**100%**

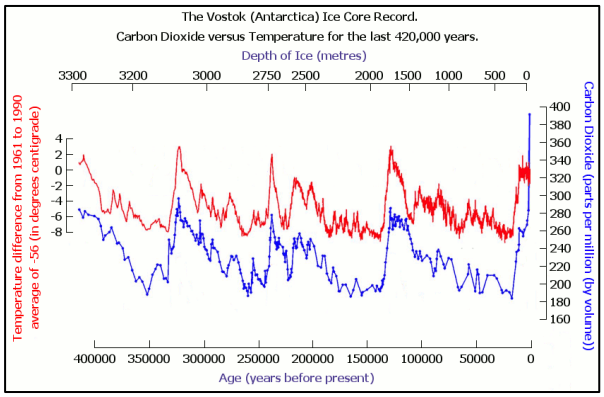
http://www.epa.gov/climatechange/ghgemissions/global.html

What is the evidence for the increased carbon dioxide concentrations in the atmosphere?

Figure 8 shows temperatures and carbon dioxide concentrations based on data extracted from ice cores. Notice that the trends mirror each other. The higher temperatures (inter-glacial periods) coincide with the high levels of carbon dioxide and vice versa. Look at far right hand side and notice the rapid rise in carbon dioxide to nearly 400 parts per million, much higher than at any time during the last 400,000 years!

Figure 8

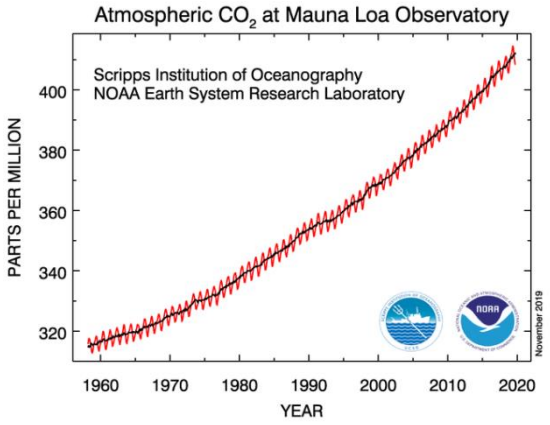
Vostok (Antarctica) ice core records of global temperatures and carbon dioxide concentrations



http://www.preearth.net/phpBB3/viewtopic.php?f=16&t=23

More recent data obtained by direct measurements at the Mauna Loa Observatory on Hawaii (Figure 9) supports this rapid rise in carbon dioxide. The mean annual concentration of carbon dioxide recorded at Mauna Loa has continued to rise to reach 408.53 parts per million in 2019. Essentially, as carbon dioxide levels continue to rise, the enhanced greenhouse effect will lead to greater atmospheric warming and higher temperatures on the Earth's surface.

Figure 9



https://www.esrl.noaa.gov/gmd/ccgg/trends/

Look up the latest data on carbon dioxide concentrations at:

https://www.esrl.noaa.gov/gmd/ccgg/trends/