Briefing 1

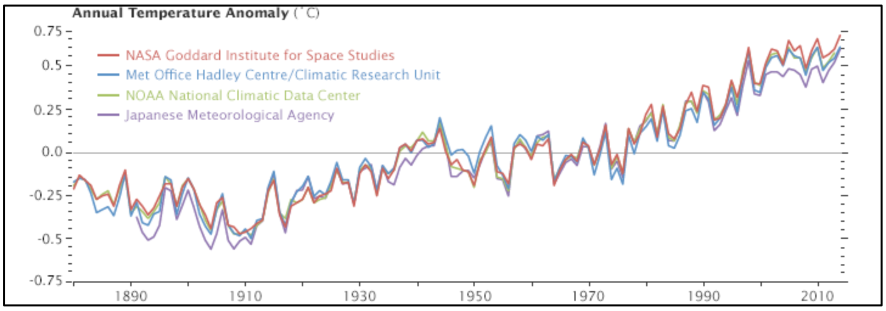
<u>What is the evidence for climate change?</u>

Climate change is perhaps the greatest environmental challenge facing humanity.

- Since 1880 the average global temperature has risen by 0.85°C (Figure 1)
- About 2/3rd of this increase has occurred since the mid-1970s at a rate of about 0.15-0.20°C per decade
- 17 of the world's 18 hottest years have occurred in the 21st century with 2016 being the hottest yet (+ 0.94°C anomaly). July 2019 was the hottest month on record.

Figure 1

Pattern of global temperature anomalies



https://earthobservatory.nasa.gov/world-of-change/DecadalTemp

Scientists believe that this rise in temperature will have huge impacts on natural environments and people's lives. Recent extreme weather events, such as floods, droughts and wildfires (Australia 2019) are consistent with changes in climatic systems associated with a warming world. Changes occurring within the world's biomes, such as melting permafrost and coral bleaching are further evidence of climate change. Global sea level rise (23cm since 1880s, increasing to a current rate of about 30cm per century), poses a serious threat to ecosystems and settlement in low lying coastal regions.

Map animations showing global temperature trends

https://earthobservatory.nasa.gov/world-of-change/DecadalTemp

http://berkeleyearth.org/2018-temperatures/

Climate change is nothing new

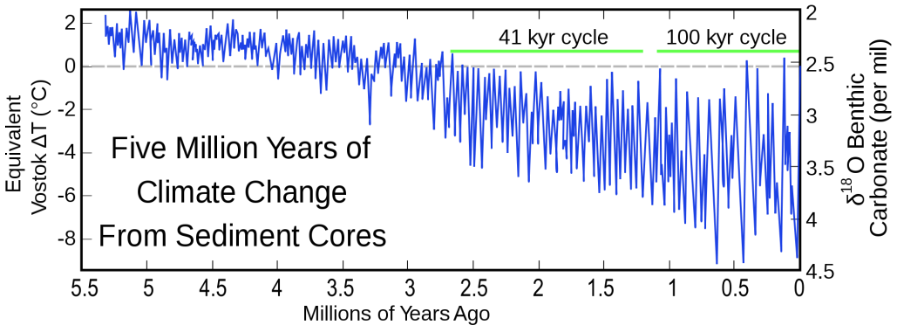
Over geological time, measured in hundreds of millions of years, climate has constantly changed, affecting the distribution and development of life on Earth.

Figure 2 shows the pattern of global temperatures for the last 5.5 million years using evidence from deep ocean sediments. The graph shows how temperature has changed over time (blue line) compared to today's average temperature (shown by the dashed line at 0°C).

The last 2.6 million years is known as the Quaternary geological period. During this period of time, temperatures fluctuated wildly, although there has been a gradual overall cooling. The cold 'spikes' in the graph are glacial periods when ice advanced over parts of Europe and North America. In between are warmer, inter-glacial periods. It is interesting to note that today's global average temperature is higher than almost all of the Quaternary period.

Figure 2

Average global temperatures for the last 5.5 million years



http://cnx.org/contents/1741effd-9cda-4b2b-a91e-003e6f587263@43.1:16/Sustainability:_A_Comprehensiv

Figure 3 shows temperature changes during the last 400,000. The temperature values on the graph are in comparison to today's global average temperature placed at 0°C. The graph shows clearly how cold glacial periods have alternated with warm inter-glacial periods when temperatures were even warmer than they are today!

Figure 3

Trends in average global temperatures (400,000 years – present day)

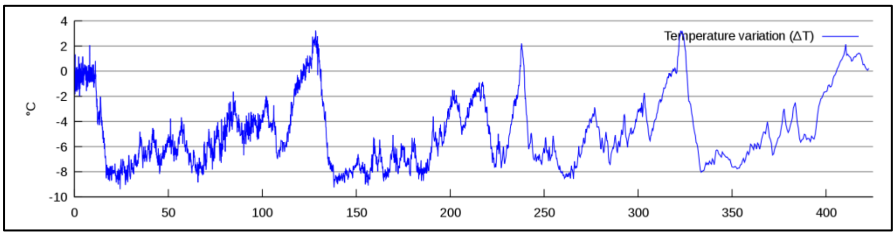


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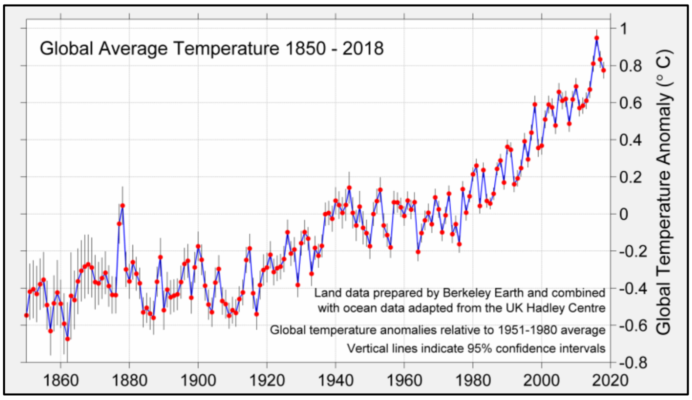
Figure 4 shows the most recent changes in average global temperatures from 1850 to 2018. It shows clearly the increased rate of temperature change (global warming) since 1980.

Figure 4

Average global temperature (1850-2018)



http://berkeleyearth.org/wp-content/uploads/2019/01/GlobalAverage_2018.png

Evidence of climate change

The reliable measurement of temperature using thermometers goes back about a hundred years. In the UK, for example, reliable weather records began in 1910.

Past evidence of climate change

Informed judgements about ancient climates can be made using fossil evidence. Scientists can also use data that has accumulated over long time periods and been stored, trapped within ice or deep sea sediments.

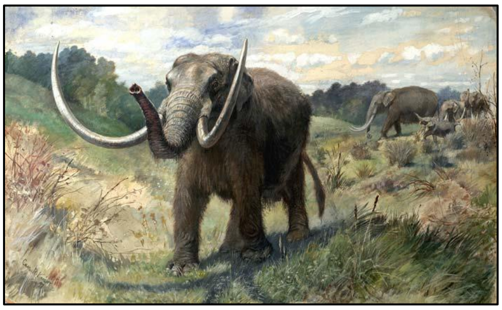
1. Geological fossil evidence

Plants and animals are good indicators of the environment as different species tend to favour particular climatic conditions. Evidence of past climates can be suggested by the presence of living organisms preserved as fossils. For example, 60-million-year-old crocodiles found in North Dakota, USA, suggest that the climate of the past was much warmer than it is today.

Elephant-like mammals called Mastodons (Figure 5) were widespread across the USA during cold, glacial periods. Their thick woolly coats enabled them to survive the very cold conditions. Fossil mastodons have been found from Alaska to Florida indicating that these cold periods extended across the whole of the USA.

Figure 5

Masodons were widespread across the USA during cold glacial periods



Source: [Charles R. Knight](#)

http://cnx.org/contents/1741effd-9cda-4b2b-a91e-003e6f587263@43.1:16/Sustainability:_A_Comprehensiv

2. Ice cores

An important source of past global temperatures has come from studying ice cores extracted from the Antarctic and Greenland ice sheets. When snow falls in cold polar environments it gradually builds up layer upon layer, year upon year. The buried layers of snow are compressed and gradually turn to ice. The Antarctic ice sheet is some nearly 5km thick in places and the oldest ice – at its base – is thought to be 800,000 years old!

Scientists are able to drill deep into the ice to extract cylindrical cores (Figure 5) from ice that is many thousands of years old. The layers of ice within a core can be accurately dated. By analysing the trapped water molecules, scientists can calculate the temperature of the atmosphere when the snow fell. Gas trapped within the ice can also be analysed to measure concentration of atmospheric gases such as carbon dioxide.

This information – accurate dates and temperatures - has enabled scientists to graph temperature changes over the last 400,000 years. The results of this research show the fluctuating temperatures that indicate past glacial and inter-glacial periods (Figure 2).

Figure 5

Ice core extracted from the Antarctic ice sheet

https://nsidc.org/sites/nsidc.org/files/images//icecore_drill.jpg

Ice cores published by the British Antarctic Survey

https://www.bas.ac.uk/data/our-data/publication/ice-cores-and-climate-change/

3. Ocean sediments

In the same way that layers of snow build up over thousands of years in a cold environment, layers of sediment do much the same thing in deep ocean basins. Scientists have been able to drill into sediments that are over 5 million years old. By studying oxygen isotopes trapped within these sediments, it has been possible to calculate past atmospheric temperatures (Figure 2).

4. Historical records

Historical records can provide additional evidence of climate change.

- Ancient cave paintings of animals in France and Spain depict nature as it was 40,000 – 11,000 years ago, a period of time when the climate changed significantly. The problem with cave paintings is accurately dating when they were drawn.
- Records of extreme weather events such as floods and droughts have been used to suggest that in recent decades extreme weather events have become more frequent.
- Some studies have suggested that the timing of natural seasonal activities (called phenology), such as tree flowering and bird migration is advancing. A study of bird nesting conducted by the British Trust for Ornithology in the mid-1990s discovered that 65 species nested an average of 9 days earlier than in the 1970s. Swallows are arriving in the UK some 20 days earlier than they did in the 1970s.
- Diaries and written observations can also provide evidence of climate change, although personal accounts can lack objective accuracy.

Recent studies of bird migrations

https://www.massaudubon.org/our-conservation-work/climate-change/effects-of-climate-change/on-birds

https://royalsocietypublishing.org/doi/full/10.1098/rspb.2017.2329

Case Study

The Little Ice Age (1300 – 1870)

The Little Ice Age was a period of time when parts of Europe and North America experienced much colder winters than today. The coldest periods were in the 15th and 17th centuries. Much of the evidence of the Little Ice Age comes from diaries and written observations made at the time. Accounts speak of bitterly cold winters, crop failures and famines.

- The price of grain increased and vineyards in much of Europe became unproductive
- Travellers to Scotland recorded permanent snow on the Cairngorm Mountains
- Tax records in Scandinavia show how farms were destroyed by advancing glaciers

- Sea ice engulfed Iceland preventing ships from landing. As crops failed many people decided to emigrate. Iceland lost half its population during the Little Ice Age.
- In the Alps, the treeline and snowline lowered in altitude
- The sea froze around parts of the UK and regular winter 'Frost Fairs' were held on the frozen River Thames
- Throughout Northern Europe, rivers froze and people suffered from intensely cold winters when food supplies were limited. Several painters of the time captured this winter landscape (Figure 6).

Figure 6

Winterlandschaft mit Vogelfalle ('Winter Landscape with Skaters and Bird Trap') by Pieter Brueghel the Elder (1601)

http://upload.wikimedia.org/wikipedia/commons/3/34/Pieter_Bruegel_d._%C3%84._107.jpg

Despite these harsh climatic conditions and the suffering caused, European culture and technology flourished. Huge innovations occurred in agriculture, land was reclaimed in the Netherlands and the UK and sea trading expanded. Did the Little Ice Age perhaps trigger these human responses in the face of the harsh climatic conditions?

Recent evidence of climate change

Recent evidence of climate change, particularly the recent warming trend comes from a number of sources.

1. Global temperature data

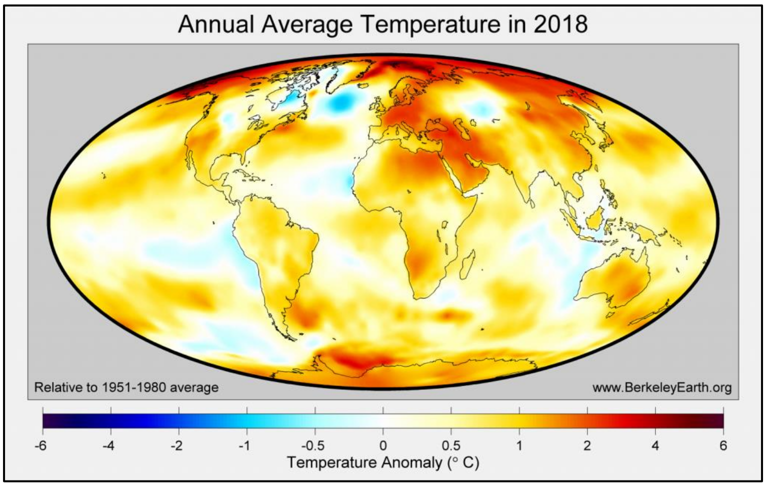
Figure 7 shows global temperature anomalies (variations from the long-term average) for 2018, the fourth warmest year on record. This map was produced using data collected from over 1,000 ground weather stations together with satellite information. The map clearly shows a warming trend across much of the world, although there are considerable regional variations.

NASA suggests that average global temperatures have increased by 0.6 degrees C since 1950 and 0.85 degrees C since 1880.

Weather stations are not evenly distributed across the world and some regions, especially in Africa, have a fairly sparse network. Computer programmes have been used to produce global maps such as Figure 7 but this does not make them absolutely accurate and reliable.

Figure 7

Global temperature anomalies (2018)



http://berkeleyearth.org/2018-temperatures/

2. Shrinking ice sheets and glaciers

One of the most striking effects of the recent warming trend has been the retreat of ice sheets and glaciers. Maps and photos show that many of the world's glaciers are retreating (Figure 8).

There is plenty of evidence from around the world of melting ice:

- The snows of Kilimanjaro have melted by 80% since 1912; 26% of the ice that was there in 2000 is now gone
- Glaciers in parts of the Himalayas could disappear by 2035; the rate of melting has doubled in the last 20 years
- Arctic sea ice has declined in volume by over 10% in the last 30 years
- NASAs monitoring of the Greenland ice sheet suggests that it is shrinking
- In 1910 Glacier National Park (USA) had about 150 glaciers; there are now just 25 active glaciers
- Low level ski resorts in Europe have suffered economic hardship and some businesses have had to close due to increasingly unreliable snowfall – 2/3rd of region's ice could be gone by 2100
- The Muir Glacier (Alaska, USA) retreated by 11km between 1941 and 2004 (Figure 8)

Arctic sea ice news and analysis

http://nsidc.org/arcticseaicenews/

Figure 8

Retreat of the Muir Glacier, Alaska (1941 and 2004)

https://climate.nasa.gov/climate_resources/4/graphic-dramatic-glacier-melt/

Case Study

Retreat of the Columbia Glacier, Alaska, USA

The Columbia Glacier has its source in the Chugach Mountains in southern Alaska. It flows for some 50 km to the sea in Prince William Sound. Its maximum thickness is 550m. The glacier is known as a 'tidewater glacier' because it flows directly into the sea.

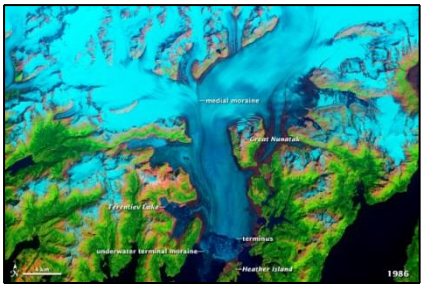
The Columbia Glacier is one of the most rapidly changing glaciers in the world. It has been retreating rapidly since the 1980s. By 2014, the snout (front) of the glacier had retreated by about 16km since 1982 and it had lost half of its thickness and volume. In the early 2000s the glacier was retreating at a staggering rate of some 30m a day producing huge icebergs as the snout broke apart.

Scientists believe that the thinning of the ice may well be due to warming global temperatures. If global warming continues, the glacier seems likely to continue to shrink. As it does so, the meltwater will contribute towards sea level rise.

The extremely fast rate of retreat at the snout is probably mostly due to mechanical factors associated with the glacier extending into the sea, although global warming may well have played a part in making the snout unstable in the 1980s.

Figure 9

Satellite photos of the Columbia Glacier (1986 and 2014)



http://earthobservatory.nasa.gov/Features/WorldOfChange/columbia_glacier.php

3. Sea level change

According to the Intergovernmental Panel on Climate Change (IPCC), the average global sea level has risen between 10 and 20cm in the past 100 years. There are two reasons why sea levels have risen:

- When temperatures rise and freshwater ice melts, more water flows to the seas from glaciers and ice caps.
- When ocean water warms it expands in volume – this is called thermal expansion

Interestingly, during the warmer interglacial periods in the Quaternary, temperatures were some 1-2°C above the current levels resulting in sea level being 15-25m higher than it is today. Imagine what would happen to coastal regions of the world if they were faced with this kind of sea level rise!