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Climate change

Introduction

Climate change is a very complex subject. Scientists from many countries around the world strive to understand how climate works and the try to prepare for the changes that may lie ahead. There is a wealth of information available at numerous websites offering a number of different opinions, often with a bias towards the interests of those who produced the resources. Students should be encouraged to look at information from a variety of sources and then try to make their own minds up based upon what they find out.

In the first section the students will investigate climate change, paying particular attention to data analysis and evaluation. The activities are designed to challenge some of the views possibly already held by the students and should provoke some interesting group discussions.

The ozone activity looks at the history of chlorofluorocarbons (CFCs) and the ozone hole and shows how scientists like Mario Molino can influence the behaviour of governments, the chemical industry and the general public. In both activities students are encouraged to use the Internet to find out further information.

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Global warming Teacher's notes

Objectives

- To understand the greenhouse effect.
- To understand that global warming is a complex issue full of uncertainties and controversies. Science is not clear cut and it does have its limitations.
- To collect data from different sources, to consider the evidence and evaluate the evidence. To understand that data collected from different sources does not always lead to the same results.
- An introduction to computer simulated models.

Outline

This resource includes a number of different types of activities and worksheets, which can be used to promote group discussion.

- Introducing global warming and understanding the greenhouse effect.
- **A global warning** – using data from the past to predict the climate of the future.
- Methods of collecting climatic data.
- The work and lifestyle of scientists collecting climatic information and data in Antarctica.
- The Earth is getting warmer, or is it?
- Addressing the ethical issues arising from global warming. What should we do about it?

Teaching topics

This material is suitable for students in the 11–16 year old age range. With modifications it could form the basis of a post-16 environmental science unit. The activities can be included when teaching about changes to the Earth and atmosphere and the effect of burning fossil fuels on the environment. It is an excellent context for teaching about the nature of scientific data and how to handle it.

Background information

Global warming is a very large area of scientific uncertainty. There are literally thousands of scientists working around the world, trying to understand and formulating models that will predict the consequences of global warming. It is an extremely complex procedure and there are hundreds of variables that come into the model. No one knows if the models being used are even correct. What will the climate will be like in 50 or 100 years time? No one really knows. However, there are real fears that rapid climate change will have a dramatic impact on life on Earth. Over the last 10,000 years the Earth has experienced a very stable climate and life has adapted to it. Recently, however, the Earth has seen an increase in temperature change and many scientists now believe that there is a direct link between this warming and emissions of

greenhouse gases such as carbon dioxide (CO_2) and nitrogen oxides (NO_x) caused by human activities. In the past the greenhouse gases were in balance. It is feared that, at the present rate of increase of greenhouse gases, the natural balance will be upset. It takes millions of years for fossil fuels to form but only a few minutes for them to burn, releasing large quantities of CO_2 in to the air. In the past fluctuations in CO_2 levels have been explained by natural causes such as volcanic eruptions and the number of phytoplankton in the sea. There are currently several other theories about global warming such as positive and negative feedback systems of ocean currents and the position of the Earth in space.

As a result of the warming, global sea levels are expected to rise by a further 15 to 95 cm by the year 2100 because seawater expands when heated and some glacial ice will melt. Extreme events such as heavy rains and droughts are expected. There may be more hurricanes, typhoons and cyclones. Most of the predictions are based on rather slow changes in temperature, but when you look back through history there has been very sudden temperature changes which have had dramatic effects to life. The Atlantic Ocean conveyor belt system is one of the present theories that is under investigation that could explain these rapid changes in temperature. At the moment the conveyor belt (commonly known as the Gulf Stream) is switched on, thus keeping Britain and Northern Europe warm. If the conveyor was to be switched off, the story would be very different and without the Gulf Stream, there would be rapid cooling and we would be plunged into the next ice age. Some scientists believe that the conveyor belt could be switched off if large amounts of fresh water were to enter the Atlantic Ocean at the critical point. This fresh water could come from continuous rainfall as a result of a warmer, wetter climate and/or rapid melting of polar ice. Detailed data collected from ice cores have shown that in the past some temperature changes have occurred very quickly (within a hundred years). The main worry of some scientists is that the ever-increasing emissions of greenhouse gases that are causing a rapid increase in global temperature may result in the Atlantic Ocean conveyer system being switched off.

The real problem for the scientist is that climate change is very difficult to predict.

Using oxygen isotopes as temperature indicators

This method is commonly used to indicate temperatures using seabed sediments and ice cores. Students will need to understand the term isotopes and know the difference between oxygen-16 ($^{16}_{8}O$) and oxygen-18 ($^{18}_{8}O$).

Fossil shells are often made up of calcium carbonate. During its lifetime, the creature that inhabited the shell slowly extracted oxygen from water to build up its shell. Experiments have shown that the proportion of oxygen –16 and oxygen – 18 in the shell is sensitive to the temperature. This is the temperature of the water the creature lived in. So scientists can estimate past ocean temperatures by determining the oxygen isotope ratios in the shell. Both surface temperatures and seabed temperatures can be determined by analysing the fossils of creatures that lived near the surface and on the bottom of the sea.

At high temperatures more of the lighter isotopes escape, thus a high $^{18}O : {}^{16}O$ ratio indicates a higher temperature that a low ratio does. The idea is simple, but in practice it is quite difficult to determine the individual layers of sediment.

Atmospheric temperatures can be measured by determining the ratio of oxygen isotopes in the layers of an ice core. Each year a new distinct layer of ice is formed, so it is easy to determine the age of the ice.

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Using leaves as thermometers

Plants adapt to their environment. For example leaves which evolve in shaded, humid conditions are large and thin. If the same type of leaf is exposed to high levels of light, then it evolves to become small and thick with large cuticles. The conflicting demands of water conservation, gas exchange and light capture are governed by the laws of physics (evaporation and gas diffusion). Plants solve these dilemmas by physically adapting to meet the needs of the immediate environment. Within certain limits these adaptations are so constant that climatic comparisons can be made.

In 1915, two American botanists I.W. Bailey and E.W. Sinnott noted that leaves of modern woody 'broadleaved' flowering plants, *eg* fig and willow, tend to have smooth margins in warm climates but toothed 'jagged' ones in cooler climates. In the late 1970s, Jack Wolf, another American, by using modern species growing in drought free environments of south east Asia, was able show that there was a linear relationship between the mean annual temperature in degrees centigrade (°C) and the percentage of entire margined leaf species. The relationship breaks down if there is a limited water supply.

Today this method is used for estimating the climate millions of years ago.[1,2] Analysis of fossilised leaves indicate the temperature. This method is however subject to large sources of error and a large volume of data is required to get meaningful results.

Sources of information

- For background information on global warming, including a history of scientific discoveries since 1896, myths and facts about global warming / greenhouse effect and initiatives set up by a variety of different countries, visit the global warming website that will link you to 10 other relevant sites. **http://www.ulisse.it/~irrsaege/globaw/siti_ing.html** (accessed April 2001).
- The United Nations Environment Programme website is a place to visit if you are interested in what the politicians are thinking. **http://www.unep.ch/** (accessed April 2001)
- You may like to get involved in the Science Across the World project on the Greenhouse effect. Go to **http://www.scienceacross.org** (accessed April 2001) click on useful links and then choose global warming.
- A simulated model showing global warming on a spinning globe of the earth can be seen or downloaded from **http://www.meto.gov.uk/sec5/CR_div/Amin/ghg.html** (accessed April 2001).
- The Casino-21 experiment, a climate simulation of the 21st century. For the experiment to work millions of people are needed to run a simulation on their computer. The idea is to predict the climate in 2050. Details of the project and how to register can be found at **http://www.climate-dynamics.rl.ac.uk/~hansen/casino21.html** (accessed April 2001).
- **http://www.exxon.mobil.com** (accessed April 2001).
- **http://www.bp.com/default.asp** accessed April 2001).
- G. Best, *Environmental Pollution Studies*, Liverpool: Liverpool University Press, 1999.
- S. Lamb and D. Sington, *Earth Story, The shaping of our world*, London: BBC Worldwide Ltd., 1998.

- Climate Change, scientific certainties and uncertainties, NERC, Polaris House, North Star Avenue, Swindon, SN1 1EU. Email requests@nerc.ac.uk (This leaflet also gives a list of climate change contacts.)
- C. O'Driscoll *Chemistry in Britain*, 2000, **36(2)**, 28. (**http://www.chemsoc.org/chembytes/ezine/2000/toolkit_feb00.htm**)
- A. Jones *Chemistry in Britain*, 2000, **36(2)**, 33. (**http://www.chemsoc.org/chembytes/ezine/2000/toolkit_feb00.htm**)

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Answers

The greenhouse effect and global warming

1. –18 °C
2. The surface temperature of the earth is slowly warming up.
3. Coal fired power stations, gas/ oil central heating, any type of fires, vehicles etc.

Looking at the data – temperature changes over the last century

1. The general trend shows an increase in temperature. In the early 80s the temperature was stable for about three years before it started to increase again.
2. The maximum temperature change is about 0.25 °C.
3. Most students will sketch a graph which shows another increase over the next 20 years. Some students will copy the exact shape of the curve *ie* showing a plateau around 2002–2005. Accept a bigger increase – as some students may already know the connection between CO_2 level and temperature.
4. In the period 1960–1980 the overall temperature change was approximately zero. There was a steady decline in temperature (approximately 0.2 °C) between 1960 and 1975, when it started to increase.

   Whereas in the period 1940–1960, the temperature fluctuated raising to a maximum of about 0.05 °C and a minimum of about –0.05 °C.
5. Some students may chose to keep their 2000–2020 graph the same (based on previous knowledge). Other students may redraw their graph showing a steady decline in temperature by about 0.2 °C or they might show the graph fluctuating.
6. 1920–1940 saw a steady temperature increase from approximately –0.35 to + 0.00 °C, whereas between 1900–20 a decline in temperature was seen in the first decade followed by a steady increase in the second decade. The overall temperature change was approximately –0.2 °C.
7. Accept any reasonable graph.
8. The overall temperature increase in the 20th century is approximately 0.5 °C.

9&10

It should be pointed out that there is no correct answer because so many variables are involved. This data alone does not give enough evidence to make an accurate prediction of what will happen, but the overall temperature trend over the century has been to increase, so this might favour a graph showing an increase in temperature.

11. Yes the overall trend is the same, but there are some differences in the smaller temperature fluctuations.
12. Approximately the same +0.5 °C.
13. Data has been collected using different instruments, at different times of the day and night, in different places *ie* a fair test has not been carried out. Different variables are taken into account at different times.

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Looking at the data – temperature changes over several centuries

1. Yes, it was cooler, the temperature change oscillated more.
2. 19th century.
3. Approximately 1699.
4. It took about 4 years to warm up by a degree.
5. Temperatures reach a similar maximum temperature and then in the late 1730s the temperature fell again.
6. Similar temperatures.
7. Again, stress that the 'correct' answer is unknown, accept any reasonable attempt.

8, 9, 10. Teachers may wish each group to report back.

Extension sheet

At this point it may be appropriate to summarise the results so far.

1. Conclusion– the evidence considered so far indicates that the surface temperature of the Earth has increased by about 0.5 °C during the 20th century, but the evidence is too limited to make firm predictions about future temperature changes.
2. In practice several different methods are used. Geologists look for fossilised / petrified plants and animals, in sediment cores from fresh water lakes and the seabed. Surface rocks can also be used to reveal clues. They use the temperatures that these animals lived in to determine the temperature. Ice cores are used to determine the temperature by looking at the ratio of oxygen isotopes. Air pockets are sampled to reveal CO_2 levels from past climates. Accept any reasonable answers.

Looking at climatic data from the past

1. There has been a small temperature decrease before stabilising out.
2. 16,000 and 50,000 years ago.
3. 12000, 22000, 36000 years ago.
4. The last time the temperature was similar to that today, it was followed by a gradual decrease over the next 10000 years. This could happen again.
5. It has not really varied but been stable.
6. Approx. 124–128000 years ago.
7. 5 °C lower than today.
8. 20–30000, 60–70000 and 140–150000 years ago.
9. 140–150000 years ago.
10. The temperature rose to reach the maximum recorded temperature (greater than today's temperature). Over the next 200 years the temperature rapidly dropped to today's temperature, where is stabilised out over the next 400 years before it continued to drop further.
11. Temperatures continued to drop until they reached a minimum.
12. It may follow the pattern of 130000–100000 years ago, plunging us into the next ice age.