THE GREENHOUSE EFFECT

Science content

Greenhouse effect, greenhouse gases, global warming, climate, biosphere.

Science curriculum links
AT 1 Exploration of science
AT 5 Human influences on the Earth
AT 9 Earth and atmosphere
AT17 The nature of science

Syllabus links
- GCSE Science, Biology, Chemistry, Physics,
- Geography
- Sixth-form General Studies

Cross-curricular themes
- Environment

Lesson time
1–3 hours
(homework possible)

Links with other SATIS materials
301 Air Pollution - where does it come from?

SATIS 16–19
69 Living in a greenhouse

NERIS
Search on
GREENHOUSE EFFECT

SUMMARY

The unit explains the factors that contribute to the greenhouse effect and its potential for global warming. Students are invited to draw their own conclusions.

STUDENT ACTIVITIES

☐ Parts A and B Reading information, interpreting data in the form of graphs, tables, maps and diagrams.

☐ Part C Considering evidence.

☐ Quiz to accompany the information.

☐ Small group discussion (or questions for written answers).

☐ Role-play simulation involving the whole class.

AIMS

☐ To link with work on the environment, harnessing energy and weather systems

☐ To develop skills in evaluating evidence

☐ To develop communication skills through role-play

☐ To heighten awareness of the impact of human activities on global warming and the life-threatening changes that may result

USING AND ADAPTING THE UNIT

☐ Activities (quiz, small group discussion and role-play) are provided for students of different abilities.

☐ Parts A, B and C used with the quiz are suitable for independent work or homework.

☐ The quiz may be used to revise prior work on the greenhouse effect before reading the unit.

☐ The role-play simulation may be used separately.

Authors **Paul Adams**
John Coulton
John Murphy
Anabel Curry

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Teaching notes

The unit provides a range of activities to accompany the text.

Parts A, B and C consist of data and reading material which may be used with the quiz or the discussion questions. Alternatively, they may be used to support students preparing for the role-play.

The quiz and questions may be used as discussion activities.

The interactions between various global cycles and the probable effects of global warming are not well understood at the moment. Students and teachers may wish to follow the development of ideas over a period of time, keeping a file or scrapbook of information from the media. The *New Scientist* and the quality press give frequent updates on research into this area.

A useful book for teachers on the greenhouse effect is *Hothouse Earth* by John Gribbin, Bantam Press 1990, (ISBN 0593 017951).

Simulated TV programme

Does it matter? is a role-play which may be used separately or to follow-up the main part of this unit. The scenario, a TV discussion programme, is about the impact on individuals of measures to limit global warming.

Role-play cards are provided to help students get into role. However, students may prefer to invent their own names and roles. Simple props like a hat are very effective. There is an optional page with 26 named roles for the audience.

Time needed

preparation	1/2 hour of lesson time plus homework
role-play	1/2 hour for TV show
debriefing and discussion	1/4–1/2 hour

Requirements

The following number of copies are needed.

page 10 (and page 14, if used)	class set
page 11 host and researcher(s)	2 to 5 copies
pages 12 and 13	1 copy of each

Allocating the roles

- The role of 'programme host' is demanding. She/he will need to prepare a set of questions or a script for the programme. This may be done as a group activity with the researchers. (Spare copies of the host's role card will be useful for the researcher(s).)
- The role of 'researcher(s)' is optional. The researcher's task is to provide support for the host in planning the programme.
- The four guests.
- Audience roles.

Suggested procedure

The SATIS General Guide for Teachers and the preliminary pages of Update 91 contain suggestions for running role-plays. The BBC Radio programme, 'The Coal Mine Project', from SATIS Topics 14–16, also provides a useful insight into preparation for a similar role-play.

- Allow time at the beginning of the lesson for students to finalise their roles. Check that members of the audience each have a question to put to the panel.
- Arrange the 'studio' seating.
- Ensure that all understand the format of the programme and that those in the audience may be invited to speak after the four guests.
- After the role-play, encourage students who have had to support a viewpoint which they do not hold to 'come out of role' and explain their own ideas on the issue.

Teachers may wish students to write a report of the 'programme' afterwards.

Acknowledgements

Figure 1,3 adapted from the IPCC's report summary 1990

Table 1 adapted from *The Independent* 17 April 1990

Figure 4 Based on data from William C. Clark, *Scientific American*, September 1989

Figure 5 reproduced by permission of R. F. Saunders Meteorological Office Photo Library

Figure 6 Based on data from U S National Academy of Sciences

Figure 7 and 11 Based on data from John Mitchell, 'Greenhouse Physics', *Physics World* June 1990

Figure 10 Based on data from British Antarctic Survey

Figure 12 Based on data from James Hansen/GISS

Figure 13 Based on data from Vostok core

Figure 14 Based on data from Charles Keeling/Carbon Dioxide Information Analysis Center

Ross Reynolds and Dr Keith Shine of the Department of Meteorology, University of Reading, read and commented on the original draft.

Answers to the quiz

The quiz is designed to provoke thought and discussion rather than lead to 'correct' answers. Opinions may vary and the answers below are for guidance only.

1 A

2 D/B

3 C

4 B/A

5 A

6 C

7 B/C Farmers may change to crops now grown in warmer climates. Crops may grow better in the north of the country.

8 A

9 D Methane, CFCs, N_2O, water vapour are also greenhouse gases.

10 B/A

11 D

12 A Methane

13 D They have a very high global warming potential.

14 B Cloud cover is thought likely to increase over the colder parts of the globe.

15 A

16 D Abandoning internal combustion engines would not reduce the emission of CO_2 sufficiently to halt global warming. As most electricity is generated from fossil fuel, using electric cars would not in fact help.

17 B More true to say that hurricanes may be more common as a result of global warming.

18 D Air trapped in polar ice 150 000 years ago is being analysed by scientists today.

19 B The impact of such feedback is thought to be slight.

20 A

Answers to the questions

A1 *Carbon dioxide, methane, water vapour and dinitrogen oxide.*

A2 *Ice sheet reflects the Sun's energy into space. Forests remove CO_2 from the atmosphere.*

Q1 *(a) Remains at the same temperature.*

(b) Temperature rises.

Q2 *The large amount of carbon dioxide emitted makes it the major cause for concern. An indication of the global warming effect from emissions of each gas can be found by multiplying the first and final columns of table 1 together.*

Carbon dioxide 26 000, methane 6300, CFCs 6000, dinitrogen oxide 1740.

Q3 *Increased temperature of sea water will cause its volume to increase (like the expansion of liquid in a thermometer). If the polar icecaps melt, the sea level will rise further.*

Q4 *If the emission of greenhouse gases is severely reduced, the model predicts that global warming will continue more slowly. The reason is that the onset of global warming will trigger many positive feedback loops. For example, water vapour is a greenhouse gas. More water vapour in the air may cause the temperature to rise further. Melting of the icecaps will make more of the Earth's surface dark and therefore more of the Sun's energy will be absorbed.*

Q5 *This is very much a matter of opinion.*
(a) Figures 6 (9) and 10
(b) Figures (9), 11 and 12 may be interpreted by some as showing a slight rise.

Q6 *(a) (i) CO_2. Prevent destruction of the forests, plant new forests, restrict the burning of fossil fuels (possibly by a tax).*
(ii) Methane. Reduce number of livestock (cattle, sheep etc.). Reduce refuse tipping.
(iii) Reduce the use of foam containers (e.g. for fast foods) find substitute chemicals for CFCs in fridges, foams, solvents etc.
(iv) Reduce the combustion of wood and fossil fuels, use of fertilisers.

THE GREENHOUSE EFFECT

Many scientists predict that the world will become warmer. They say this is due to more carbon dioxide in the atmosphere and the **greenhouse effect**.

Part A and B: information, interpreting data

Part C: evidence

Quiz: for use before or after reading the unit.

Questions: for discussion or individual answers.

Role-play (optional): involving the whole class in a discussion programme.

Part A – What is the greenhouse effect?

Life on Earth depends on energy. Energy from the Sun reaches the atmosphere and warms it up. Some of the Sun's energy warms the land and the oceans too. And some of the energy the Earth receives, it reflects and radiates back into space.

The Earth's atmosphere traps the Sun's energy and keeps the surface about 35 °C warmer than it otherwise would be. This is due to its greenhouse effect. Without it, life as we know it would be impossible.

Absorption and emission of infrared energy

You can feel this happen on a sunny day in summer. The tarmac surfaces of playgrounds and roads get much hotter because, being dark, they are good absorbers of the Sun's radiant energy.

If you hold your hand above them, you can feel that they also radiate heat away.

The atmosphere contains very little **carbon dioxide,** but the amount is rising rapidly, as figure 1 shows. Carbon dioxide captures some of the Sun's energy, in the same way that a greenhouse becomes warm on a sunny day. That is why carbon dioxide is called a **greenhouse gas**. With *more* carbon dioxide in the atmosphere, the Earth traps more energy than it radiates back into space.

It is easy to see that if the Earth takes in more energy than it loses, it will gradually get hotter. Most scientists forecast **global warming**.

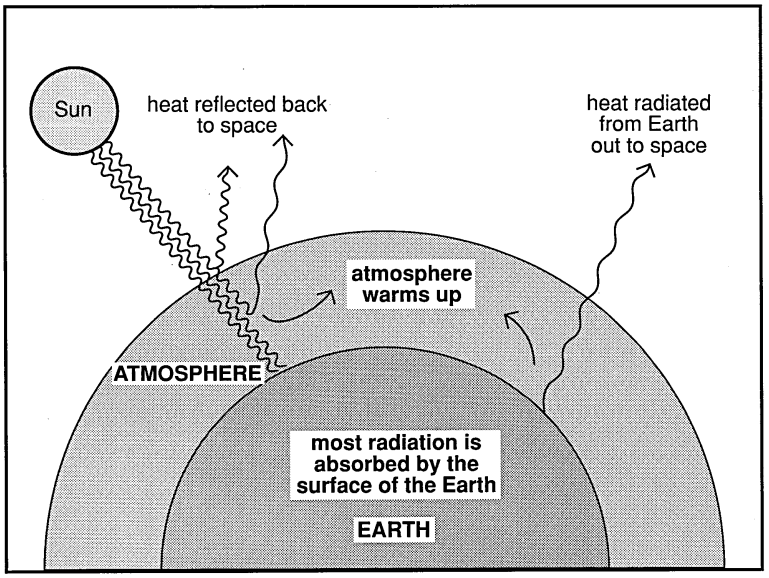


Figure 2 How the greenhouse effect works – how the Earth's atmosphere traps energy from the Sun

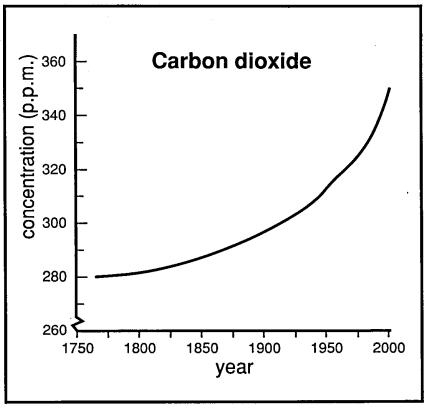


Figure 1 The concentration of carbon dioxide in the atmosphere since 1750

Carbon dioxide is not the only greenhouse gas. Water vapour is too, and it has a greater effect. Methane, chlorofluorcarbons (CFCs) used in aerosols and refrigerators, dinitrogen oxide* and ozone also trap the Sun's radiation and can lead to global warming.

Like carbon dioxide, the levels of these gases in the atmosphere are rising. The increases are due to human activities such as harnessing energy, felling forests, growing crops and keeping cattle.

**Dinitrogen oxide is commonly known as nitrous oxide*

Figure 3 The changing concentration of methane, CFCs and dinitrogen oxide in the atmosphere since 1750

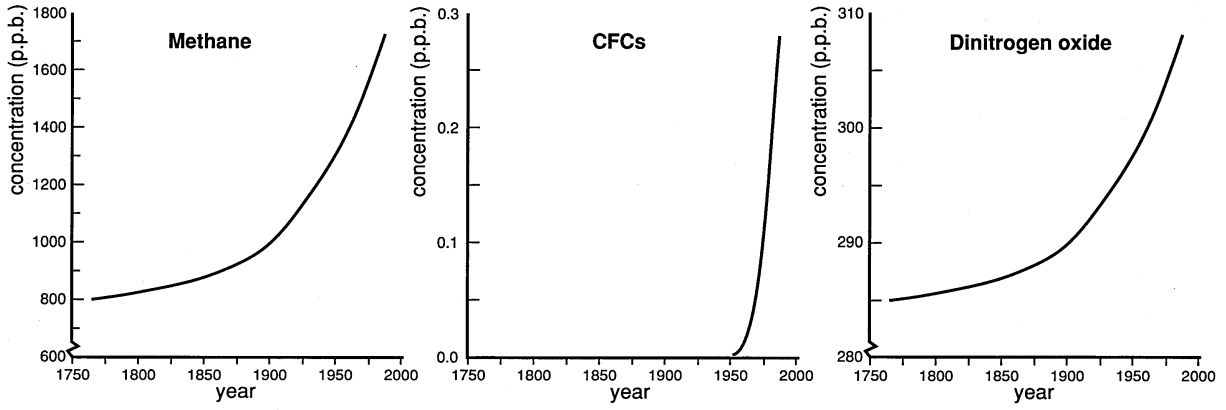


Table 1 The increase in greenhouse gases. The global warming effect shows how much warming one tonne of the gas causes in a century, compared with the warming produced by one tonne of carbon dioxide

Gas and sources	**Emissions in 1990** (10^6 tonnes)	**Concentration** (parts per million in atmosphere)	**Yearly increase** %	**Global warming effect**
carbon dioxide burning fossil fuels and forests	26 000	354	0.5	1
methane swamps, bogs, paddy fields, animal dung, natural gas leakage, rubbish tips	300	1.72	0.9	21
CFCs fridges, foams, solvents aerosol sprays	1	0.001	4	6 000
dinitrogen oxide burning forests and fossil fuels	6	0.31	0.25	290

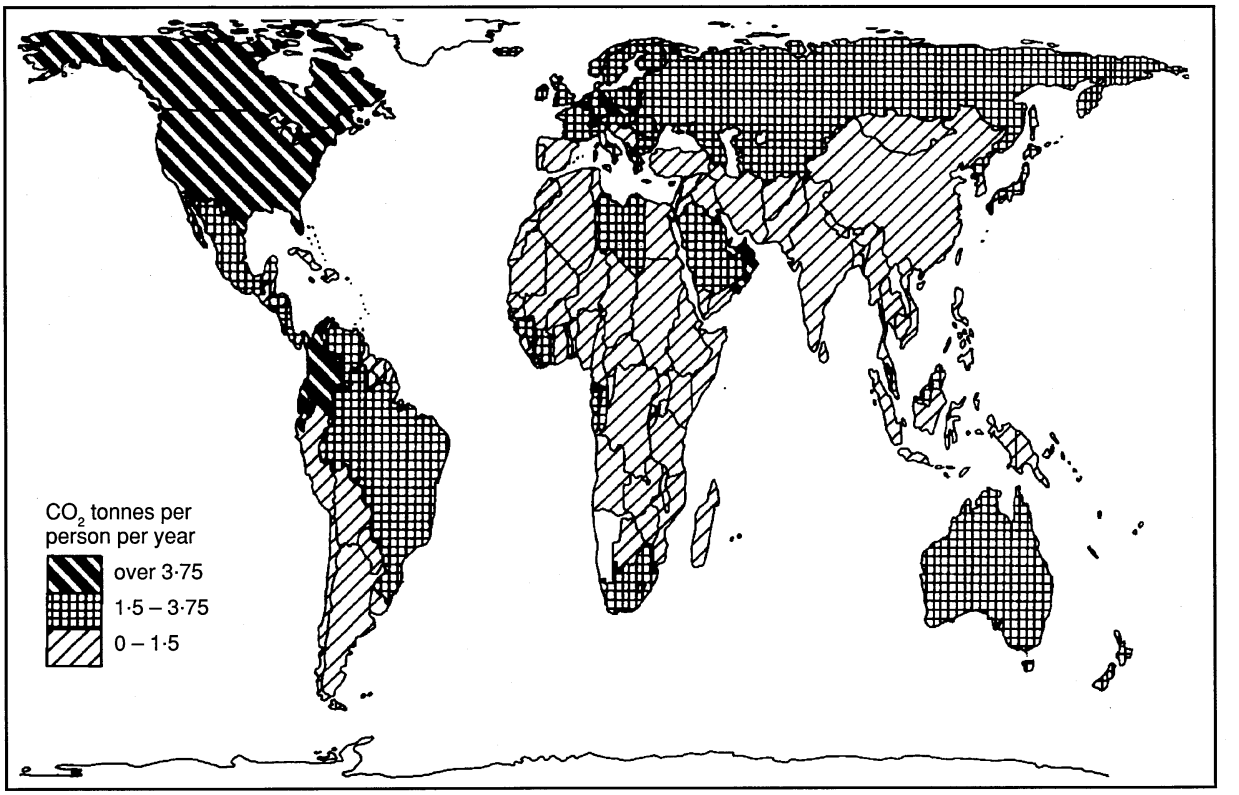


Figure 4 Carbon dioxide emissions from using energy. The map shows the number of tonnes per person per year

Part B – Global warming

What would global warming mean in practice?

The atmosphere, the Earth's surface and the oceans would become hotter. Sea levels would rise – mainly because water in the oceans expands as its temperature rises.

A warmer atmosphere would evaporate more water from the oceans. Certainly the climate would be different.

Scientists who study climate are modelling weather patterns with computers. They predict that global warming would not affect all parts of the Earth equally. There would be more rain and snow near the poles and droughts elsewhere.

Global warming may force people to flee from drought and famine to more temperate lands further north. Rising sea levels would threaten the homes and livelihood of millions of people, for example, in parts of Bangladesh, Britain and Holland.

The balance of nature would alter as climate zones change. Britain in the 21st century may be too warm for many of its native trees or for the conifers planted by foresters. Insect pests normally killed by cold winters could thrive. Plants and trees may flower early and remain unpollinated through lack of insects.

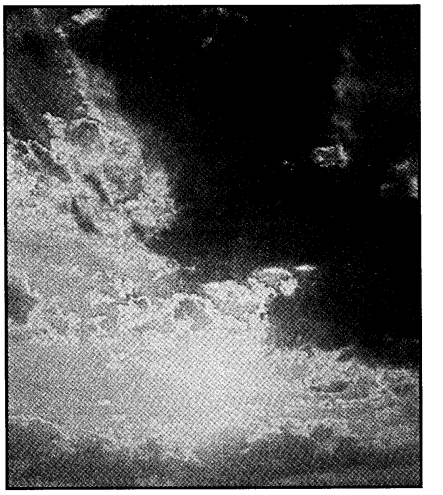
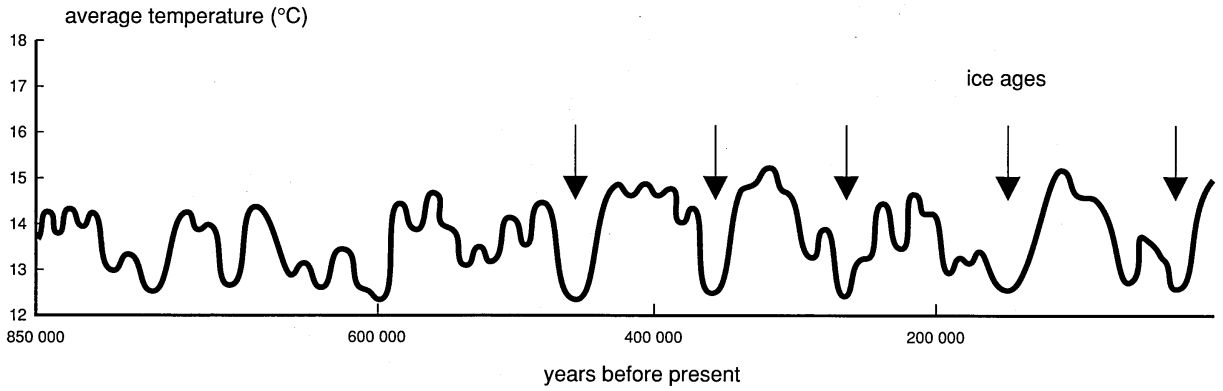


Figure 5 Clouds form part of the water cycle. Global warming predictions suggest that cloud cover may increase in some areas

Will global warming happen?

The climate has changed many times since the Earth was formed 4500 million years ago. So has the mixture of gases in the atmosphere. We live in a warm period, but ice ages have been common in the Earth's past. The cold winters of the 1960s and 70s caused some people to predict the beginning of a new ice age.

Figure 6 Changes in the average temperature of the Earth over the past 850 000 years. The peaks represent warm periods, the troughs are ice ages



The computer models of the Earth's climate system predict that once global warming starts it will continue at an ever increasing rate. By 2030, the climate could be warming over 50 times faster than it did after the last ice age.

The curves in figure 7 below predict the temperature of the Earth. Curve (a) shows what would happen if the amount of carbon dioxide in the atmosphere continues to rise as it has done in the past. Curve (b) shows what would happen if there were strict measures to reduce the rise in greenhouse gases.

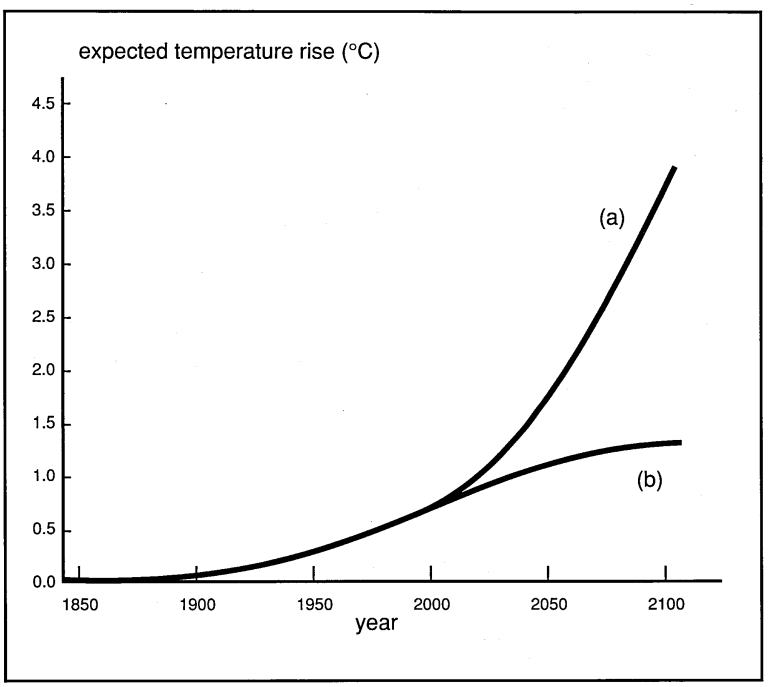


Figure 7 The temperature of the Earth if CO_2 levels (a) continue to rise and (b) are cut back as much as possible.

Most scientists agree that global warming will occur. But they are unsure about how soon or what the effects will be. They say we understand too little of the systems that regulate our planet.

The links between animals, atmosphere, plants, oceans and rocks are not fully understood. There are too many factors that affect the climate to be sure of any predictions.

Look at figure 8.

A1 *Which greenhouse gases are being added to the atmosphere?*

A2 *Which features in the landscape help to prevent global warming?*

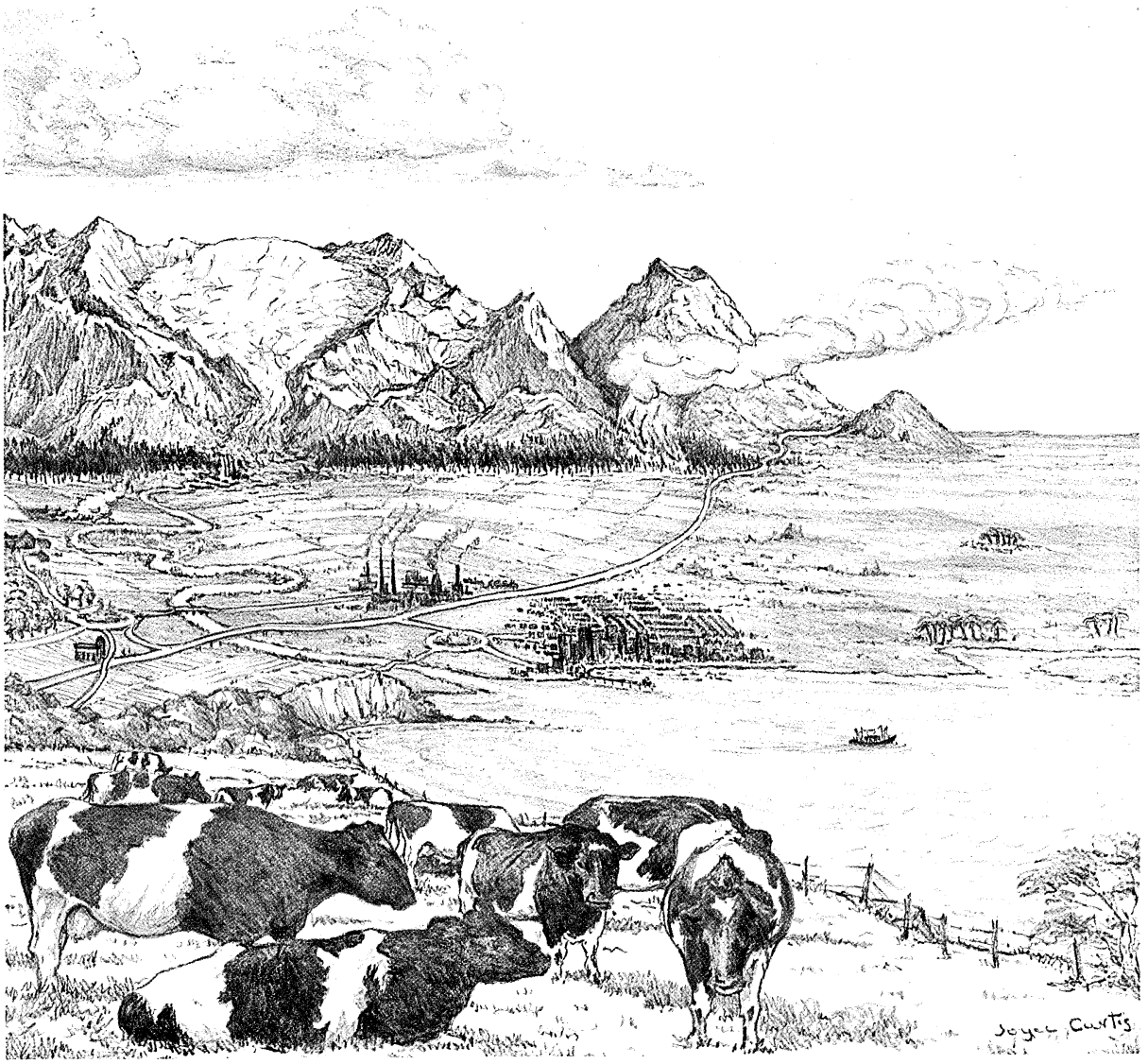


Figure 8 Human activity and the biosphere

Part C – Is the world getting warmer?

Detecting global warming is not easy. Some say the evidence is already here and that global warming has begun.

The next two pages contain data for you to consider the evidence for yourself.

Figure 9 The extremes of Britain's weather through the ages

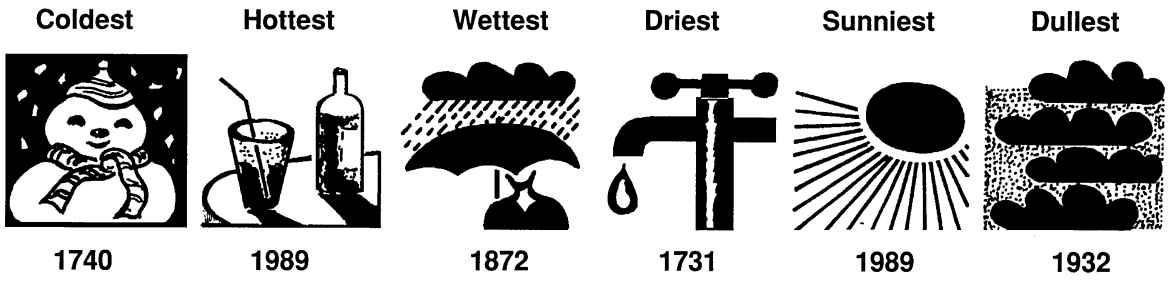


Figure 10 The changes in the annual average temperature of the Antarctic

The Antarctic is far from where people live. If the Earth's temperature is rising it should show up as a rise in the average temperature of the Antarctic. Some people think the graph shows an increase, but it is not 'statistically significant'.

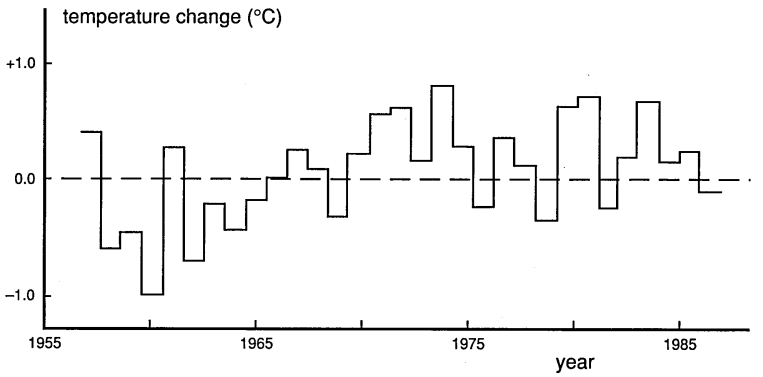


Figure 11 Are the oceans getting warmer? The map compares the average sea temperatures between 1903 and 1912 with those between 1978 and 1987

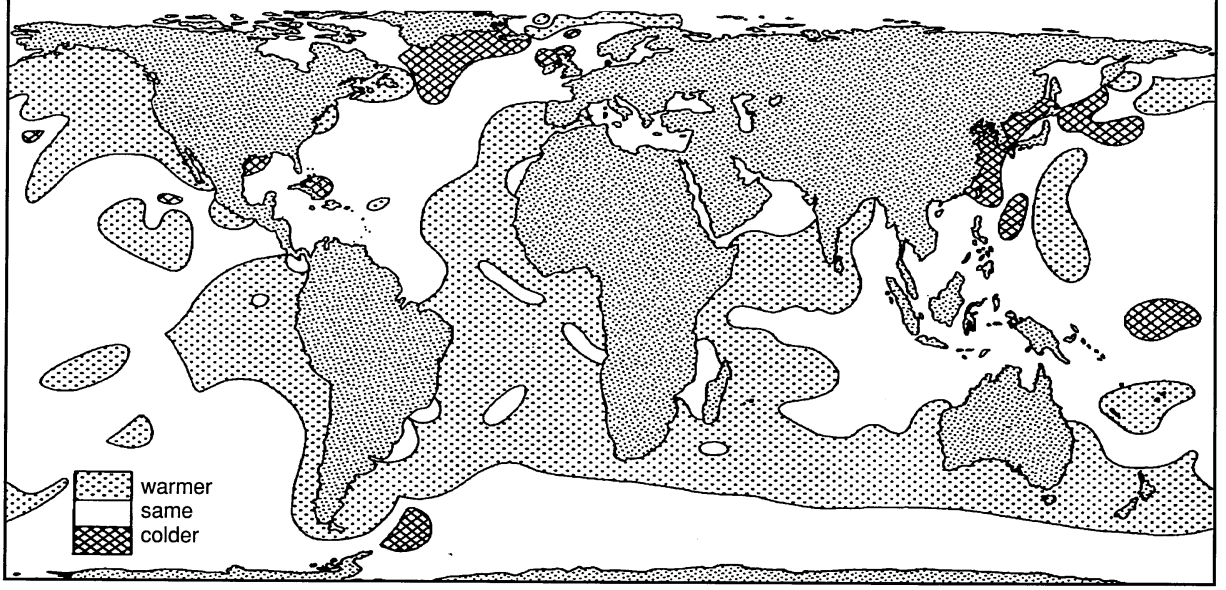


Figure 12 How average sea level has changed over recent years

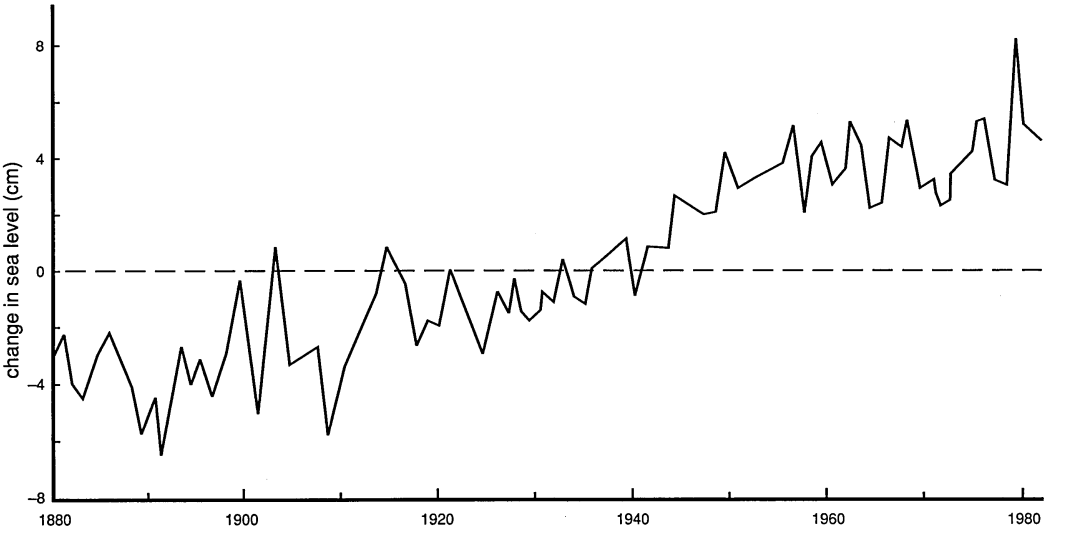
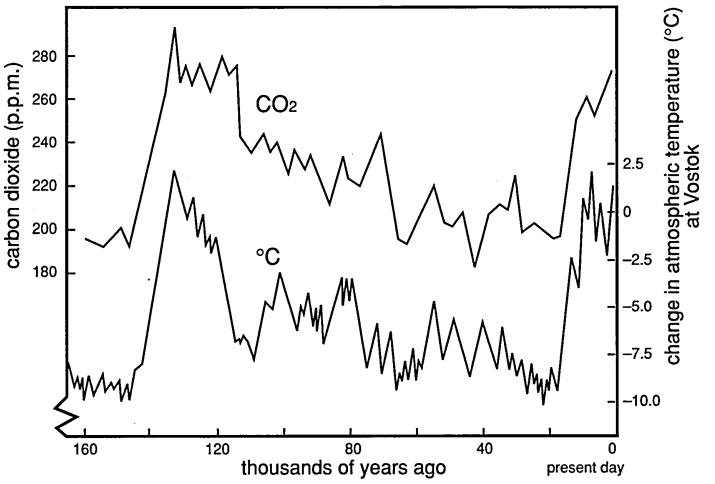
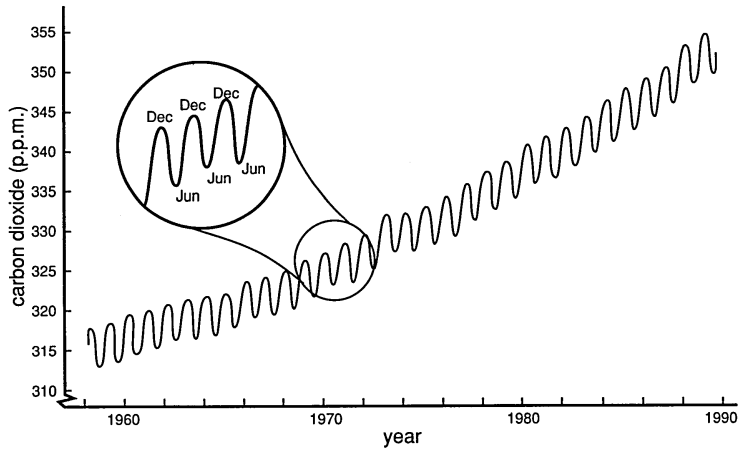


Figure 13 How the carbon dioxide content of the atmosphere and the global temperature have changed over the last 160 000 years



Scientists obtained the data for the carbon dioxide content of the atmosphere in the past from air bubbles in the ice covering Greenland and Antarctica. The bubbles deep down contained air trapped long ago.

Figure 14 The global carbon dioxide content of the atmosphere measured at the observatory at Mauna Loa in Hawaii



Hawaii is in the middle of the Pacific Ocean more than 2500 km from the nearest mainland. The observatory is on the top of a mountain, at a height of over 3000 m.

The global level of carbon dioxide varies during the year. This is due to photosynthesis. It is highest in December and lowest in June because there is more land and therefore plants to take up carbon dioxide in the northern hemisphere.

Quiz

What do you know about the greenhouse effect and global warming?

Here are some statements. Decide if they are

A	**true**
B	**can't be sure**
C	**unlikely**
D	**false**

1 There is more carbon dioxide in the atmosphere than there was 100 years ago.

2 If summer temperatures in Britain reach record highs next year, you can be sure that the global warming has started.

3 Global warming will not happen for another 100 years.

4 The greenhouse effect will cause global warming.

5 Global warming will cause sea levels to rise.

6 All ski resorts will have to close by the year 2010 because of global warming.

7 Global warming will make crops grow better in Britain.

8 Carbon dioxide in the atmosphere helps to trap the Sun's energy.

9 Carbon dioxide is the only gas with a 'greenhouse effect'.

10 Felling the forests and burning fossil fuels leads to global warming.

11 On a warmer Earth, people will need to burn less fuel to keep themselves warm, so global warming will slow down and stop.

12 Cows release gases which add to global warming.

13 CFCs damage the ozone layer but do not contribute to the greenhouse effect.

14 If the Earth's temperature rises there will be more clouds in the sky because more water will evaporate into the atmosphere.

15 Water vapour in the atmosphere traps the Sun's heat and adds to the greenhouse effect.

16 If the global warming starts we can stop it by using electric cars instead of burning petrol.

17 Hurricane force winds are caused by global warming.

18 Scientists cannot tell how much carbon dioxide was in the atmosphere 150 000 years ago because nobody made any measurements then.

19 Global warming will increase the rate of photosynthesis in plants. This will help to lower carbon dioxide levels.

20 If the Earth's temperature rises, it will radiate more energy back into space. The temperature of the Earth will settle at a new higher level.

Questions

These questions are for discussing in a group or for answering by yourself.

Q1 The Earth loses some of the energy it receives from the Sun by radiating and reflecting it out to space.

What would happen to the temperature of the Earth if it absorbs

(a) as much energy as it loses,

(b) more energy than it loses?

Q2 Explain why carbon dioxide is the major cause of concern in global warming although other gases (see table 1 on page 2) have a greater global warming effect.

Q3 Explain how global warming could cause sea levels to rise.

Q4 What does figure 7 predict will happen to global temperatures if emissions of greenhouse gases are much reduced? Suggest why this may be so.

Q5 What information can you find in this unit that suggests:

(a) there is no clear evidence of global warming taking place

(b) global warming has already begun?

Q6 (a) What could be done to stop the increase in the following greenhouse gases in the atmosphere

(i) carbon dioxide,

(ii) methane,

(iii) CFCs,

(iv) dinitrogen oxide?

(b) Who do you think should be responsible for reducing greenhouse gases: individuals, local communities or governments?

Discussing questions in a small group

- Appoint someone to chair the group.
- Arrange your seats so that everyone in the group can hear and see each other.
- Make sure that everybody has a chance to contribute.
- Make a note of your group's answers and ideas.
- Nominate someone to report the main points of your discussion to the class, if asked to do so.

Answers to the questions are given in the *Teachers' Notes.*

THE GREENHOUSE EFFECT · *Does it matter?*

A role-play simulation of a TV discussion programme.

Does it matter?

This is about an imaginary TV programme, 'Does it matter?', in which you will take part with your class. It is a weekly programme which looks at issues involving science. Four guests, scientists and non-scientists, will air their views before a specially invited audience.

The topic of this week's programme is 'The Greenhouse Effect – does it matter?'

Everybody in the class will have a role to play as:

- a member of the specially invited audience,
- the programme's host (who may be assisted by researcher[s])
- one of the four invited guests.

To prepare for your role

- *Find out all you can about the greenhouse effect.*
- *What is the point of view of the person you will be playing?*
- *What will be the viewpoints of people in the other roles?*
- *If you are a member of the audience, what question would you like to ask the panel?*

8.30 p.m. Does it matter?

The TV chat show about science issues is hosted by Alexis Alexander.

The topic for today's guests will be *the greenhouse effect.*

As usual four people with a wide range of interests will take part in a discussion before an invited studio audience.

Ann Ellis is a scientist who has worked for the British Antarctic Survey for over thirty years and is an expert on the possible causes of changes in climate.

Juan Vaqueiro owns one of the largest cattle ranches in South America. He created it from virgin rainforest 40 years ago. The land has lost its fertility and his sons continue the task of felling trees to provide more grazing land.

Paula Watt is a director of a new electricity generating company. Her company has bought old power stations to recondition them to run on cheap imported coal.

Arthur Plank is a Midlands manufacturer of high class furniture. Most of his hardwoods come from tropical countries. His raw materials, hardwoods, are becoming scarcer and more expensive.

You need 3 to 5 copies of these role cards.

Role card

Host, Alexis Alexander

You will introduce the show, ensure that the conversation runs smoothly and, if there is time, invite people from the audience to make a point or to question the guests.

1 Welcome the viewers and audience to the show. Announce this week's topic, 'The greenhouse effect – does it matter?'. Introduce the specially invited guests (as described in the TV paper).

2 Give some background information:

The amount of carbon dioxide in the atmosphere is increasing. Nobody is sure what the effects will be but many scientists believe that the world is getting warmer.

They blame:

(i) the increase in burning of fossil fuels, such as coal, gas, oil, as well as wood,

(ii) the felling of forests, especially the tropical rainforests.

3 Ask a different question of each of your guests to invite them to express their point of view.

4 Ask members of the audience if they have a question to put to the panel or a point to make.

5 Finish the programme by:

(i) summing up the points made in the programme,

(ii) thanking the guests and the invited studio audience.

Optional role card

Researcher

Your task is to ensure that the host and guests have interesting ideas to contribute to the discussion.

Help the host to plan the interviews with the guests and check that the guests will have good answers.

You will need one copy of these role cards

Role card

The cattle rancher, Juan Vaqueiro

You and your wife Maria have a large family and live in large ranch house. The land you ranch was once forest and is now infertile. You have cleared half the land but the grazing is poor and the cattle need more land.

You need to sell more beef cattle for export. Your country is very poor and has large debts to the richer countries. This has caused a high level of inflation, the goods in shops become dearer each day.

Many of your workers have already left the countryside and moved into the slums in the cities. Here the death rate is high, especially for babies. If you clear more forest you can continue to employ a large workforce and provide them with houses and medical care. If you cannot expand your grazing area you will have to sack many workers.

Role card

Electricity company director, Paula Watt

You help to run a new electricity company formed after the privatisation of the electricity supply industry.

Your company is buying old power stations and reconditioning them. This is much cheaper than building new ones although they are less efficient to run. Your company believes it can keep the price of electricity low by using cheap imported coal.

You should be able to undercut the prices charged by other companies to the benefit of the consumer. You want people to use more electricity so that your company can grow fast.

You will need one copy of these role cards.

Role card

Furniture manufacturer, Arthur Plank

Your furniture manufacturing business has been in the family for three generations.

You make tables and chairs from hardwoods which come from the tropical rainforests. Your agent buys large areas of forest cheaply from ranchers who want to clear their land.

You could buy hardwood from a producer in Indonesia who replants the areas of forest which have been felled. This would cost more. Your profit margins are so small that using a more expensive supplier might cause your firm to become bankrupt. Families which have been employed by your firm for generations could lose their livelihood.

Role card

Scientist, Ann Ellis

You have worked for the British Antarctic Survey for 30 years. In your research you have found a strong link between carbon dioxide levels in the atmosphere and the temperature of the Antarctic.

You have been studying bubbles of air trapped in the snow over the last 160 000 years. Your figures show that in the past, the temperature of the atmosphere rose when carbon dioxide levels were high.

You have investigated the worst thing that global warming could cause. This would be the melting of the icecaps at the poles. If this happens, sea levels will rise by 5 metres, according to your calculations. The ordinary person in the street is unaware of the seriousness of the problem. Much of the world's low-lying land will be below sea level. Pacific atolls will be flooded as well as many cities and much of the world's most fertile land. You have agreed to take part in the programme to try to convince people of the possible consequences of global warming.

Audience roles (female)

A: You are **Doris Old**, pensioner.

B: You are **Gabrielle Green**, a prominent member of Friends of the Earth.

C: You are **Winifred Winney**, mother of five and member of the Women's Institute.

D: You are **Mary Mawani**, an overseas student from a coral island in the Pacific Ocean. The highest point of your homeland is only 5 metres above sea level.

E: You are **Gloria Slim**, American fashion model.

F: You are **Tessa Helps**, Mr Plank's secretary.

G: You are **Ann Word**, science editor of a national newspaper.

H: You are **Rosa Medina**, a doctor working in the slums of a South American city.

I: You are **Freda Storm**, a climatologist from the University of East Anglia. Your research involves predicting how the Earth's climate will change.

J: You are **Katy Carr**, a sales and marketing executive for the Acme Motor Company.

K: You are **Sarah Smith**, a biologist working for the World Wide Fund for Nature. You are making a special study of the animals of the tropical rainforest.

L: You are **Caroline Cooper-Jones,** city stockbroker and financial analyst.

M: You are **Samantha Storr**, the founder of a chain of furniture superstores, recently voted business woman of the year.

Audience roles (male)

N: You are **Nigel Nuke**, a worker in a nuclear power station. Nuclear power does not add to the greenhouse effect.

O: You are **Ivan Acre**. You farm low lying land near the Wash. Last year 10 hectares of your land was flooded by sea water when spring high-tides coincided with heavy storms.

P: You are **Terence Tube**, chairman of the London Underground.

Q: You are **Hans Schulz**, a German scientist. You have discovered that methane gas from decomposing cow dung is contributing to the greenhouse effect.

R: You are **Mr Lee**, a timber merchant from Indonesia.

S: You are **Nasim Khan**, from Bangladesh. Most of the land of your country is low lying and would be flooded if the sea level rose.

T: You are **Joseph Joiner**, employed in Mr Plank's furniture factory for 30 years. Your son has just joined the firm.

U: You are **Robert Rump**, owner of an American chain of steak houses called the Roasted Rib.

V: You are **Marcel Leblanc**, chef at one of London's smartest restaurants.

W: You are **Randy Gold**, multi-millionaire pop star.

X: You are **Father Patrick O'Neal**. You run a mission in the slums of a South American city.

Y: You are **Pedro Rodriguez,** a ranch hand from Brazil.

Z: You are **Sven Borg**, a Swedish ecologist.