

## Feedbacks and forcing

### Introduction

This activity is based on a series of slides in a PowerPoint presentation. The aim is to develop your students' understanding of the greenhouse effect and the carbon cycle. The presentation will help them to appreciate the challenges involved in modelling a complex climate system.

Some of the diagrams on the slides are more complex than is required by the specification but they repay careful study and will give your students practice at interpreting unfamiliar data and ideas in diagrammatic or graphical formats.

### The activity

The notes for each slide in the PowerPoint presentation provide further background information to complement the textbook. You can use the presentation to introduce key terms and ideas, then ask students to study the related section of the textbook and answer the questions.

Answers to the questions in the textbook are provided in the textbook part of the A2 section of the Nuffield 'Science in Society' web site.

#### Science explanations

**Ma** There is a continuing cycling of elements between the atmosphere, hydrosphere, lithosphere and biosphere; and elements such as carbon exist in different chemical forms in the four spheres.

**Mb** Processes which add carbon dioxide and other chemicals to the atmosphere include: burning fossil fuels, agriculture, deforestation and industrial processes.

**Mc** Natural processes which remove carbon dioxide from the atmosphere include: solution in water and photosynthesis by sea and land plants.

**Md** The level of carbon dioxide in the atmosphere is determined by the balance between the natural processes and human activities which add and remove the gas from the air.

**Na** Visible light is part of a whole spectrum of electromagnetic radiation. Other types of electromagnetic radiation are:

radio - microwaves - infrared - visible light - ultraviolet - X-rays – gamma

**Nb** These are all similar in type (electromagnetic waves). They can all travel through empty space (a vacuum). The differences between them are due to their different wavelengths. In the list above, they are placed in order, from longest to shortest wavelength. The names of the types are a convenience only; each merges into the next.

**Nc** All objects emit radiation; the hotter they are the more radiation they emit and the shorter the wavelength at which they emit most radiation.

**Nd** When radiation strikes another object it can be reflected, transmitted or absorbed (or a combination of these). Reflected or transmitted radiation is similar to the original radiation.

**Ne** When radiation is absorbed, however, it ceases to exist as radiation, instead causing heating and perhaps also changes to molecules or other effects.

**Nf** Some gases, such as carbon dioxide, methane, nitrogen oxides and water vapour absorb infrared radiation; other gases such as nitrogen, oxygen do not.

**Ob** The temperature of an object changes if the energy it absorbs and the energy it radiates from its surface are not in balance.

**Slide 2: Three main factors affecting the greenhouse effect**

This diagram also appears in the presentation called 'Climate change science' and will reappear in this presentation. Here it provides a reminder of the earlier work, as well as a lead in to consideration of two important aspects of the climate system: feedbacks and forcing.

**Slide 3: Ice, snow and the albedo effect**

Feedbacks are covered on pages 102-3 in the A2 textbook. Ask students to explain why this simple diagram illustrates an example of positive feedback.

*When the white and gray snow and ice disappears, less sun rays are reflected out and instead the energy is absorbed by land and sea - which causes further increase in the warming.*

**Slide 4: Feedbacks in the climate system**

This slide can usefully be considered alongside figure 4.5 on page 100 of the A2 textbook which also illustrates how the atmosphere interacts with the land and with the sea.

You might divide your class into groups and ask each group to come up with an explanation of a distinct area of the slide: terrestrial coupling, marine coupling, the two negative feedbacks and the global coupling.

You could then ask students to answer questions 12 and 13 on page 103 of the A2 textbook with the help of examples found in this slide.

**Slide 5: Three main factors affecting the greenhouse effect**

This is a repeat of slide 2. Now explain what is meant by 'climate forcing'. This term is defined on page 103 of the A2 textbook.

The term 'climate forcing' refers to any factor that leads to a change in the overall balance of the energy entering or leaving the lower atmosphere (the troposphere). Positive forcing tends to warm the atmosphere. Negative forcing tends to cool the atmosphere.

Ask students to decide whether the following give rise to a positive or a negative forcing:

- increased intensity of radiation from the Sun (*positive*)
- increased concentration of carbon dioxide in the atmosphere (*positive*)
- increased cloud cover on the earth (*depends on the type of cloud – see A2 textbook p 102*)
- increased aerosols (such as dust from a volcanic eruption) – (*negative*)
- soot from burning fuels falling on snow (*positive*)

**Slide 6: Factors contributing to climate forcing**

This type of diagram is relatively common in the literature of climate change. Students will need help to interpret the detail, but it repays careful study. The first point is that the data plotted compares climate forcing now with what it was in preindustrial times. Hence the labelling of the vertical axis as: 'relative forcing'.

Students can use the diagram to see if they correctly identified the positive and negative forcings from the list of examples given with slide 2.

Some questions to discuss:

- Why do greenhouse gases give rise to a positive value for the radiative forcing?  
*Greenhouse gases absorb IR radiated from the surface of the Earth and so decrease the energy radiated from the planet into space. This changes the balance of energy entering the troposphere and tends to warm the planet.*

- Why does ozone in the troposphere give rise to positive forcing while ozone in the stratosphere gives rise to negative forcing?  
*Ozone is formed in the troposphere where there is pollution from unburnt hydrocarbons and oxides of nitrogen. Ozone is a greenhouse gas and contributes to the absorption of IR and warming of the lower atmosphere. Ozone in the stratosphere absorbs UV from the Sun and prevents some of the energy from the Sun entering the troposphere.*
- Why should aerosols affect the albedo of clouds?  
*Anthropogenic aerosols can change the properties of clouds. An increase in aerosol concentration going into the cloud can result in the formation of a larger number of smaller droplets as compared to an unperturbed cloud. The end result is in an increase in cloud albedo*
- Why is the uncertainty associated with the cloud albedo effect so large.  
*Correctly predicting the indirect radiative effect of aerosols requires an understanding of the interactions between aerosols and clouds that determine cloud properties. This is complex and a field of active research. The process that ultimately drives the indirect radiative effect of aerosols — that of cloud droplet (or crystal) formation—happens on time scales of seconds and spatial scales of micrometers. Yet the end result of this process — the clouds themselves — is a global scale phenomenon. One of the largest challenges in understanding and predicting the indirect radiative effect of aerosols is bridging the gap between these spatial and temporal scales in terms of both our understanding of the processes involved, and in our descriptions of the processes in global-scale models.*
- How has the energy radiated from the Sun changed since preindustrial times?  
*The positive value for the relative forcing by the solar irradiance indicates that the Sun is now radiating more energy than in preindustrial times. Solar activity has been measured via satellites during recent decades and through 'proxy' variables for earlier times. It is estimated that there has been a 0.2% increase in solar irradiance just since the 17th century.*

### **Slide 7: The carbon cycle**

This diagram is similar to that on page 105 of the A2 textbook. Draw attention to the huge importance of the oceans in the carbon cycle. Diagrammatic carbon-cycles in GCSE textbooks often omit the oceans. It is also useful to distinguish between reservoirs of carbon, fluxes of carbon and the main carbon sinks that remove carbon dioxide from the atmosphere.

After exploring the diagram, students can answer questions 15-18 on page 105 of the A2 textbook.

### **Slide 8: Atmospheric carbon dioxide (Mauna Loa)**

There are two photographs on this web page that show what the Mauna Loa instrumentation is like: <http://www.drroyspencer.com/global-warming-background-articles/carbon-dioxide-growth-rate-at-mauna-loa/>

The web page also offers an alternative presentation of the data.

The Mauna Loa data are being obtained at an altitude of 3400 m in the northern subtropics. It is worthwhile discussing the annual cycle shown inset in this slide. The annual fluctuation in carbon dioxide is caused by seasonal variations in carbon dioxide uptake by land plants. Since many more forests are concentrated in the northern hemisphere, more carbon dioxide is removed from the atmosphere during northern hemisphere summer than during the southern hemisphere summer.

See page 106 in the A2 textbook and questions 19 – 20.

**Slide 9: Trends in carbon dioxide concentrations and temperatures**

This presents data from a variety of sources, as explored in the activity 'Clues from the past'.

See pages 106-7 in the A2 textbook and questions 21 – 22.

**Slide 10: Global influences and effects**

The main point of including this slide is to illustrate the complexity of all the interactions affecting the climate system, and hence the scale of the challenge faced by climate modellers.

The section of the diagram that illustrates threats provides a useful lead into the final sessions covering this topic which deal with responses to climate change.

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