



# Changing Atmosphere

EARTH SCIENCE • HUMAN IMPACTS • CHANGING ATMOSPHERE

## Section 1: The Ozone Layer

### • What is the ozone layer?

Ozone is a particular form of oxygen, where three atoms of the element have bonded together. It is poisonous for us to breathe directly, and is considered a pollutant if it's found near the Earth's surface. The ozone layer is a part of the atmosphere that is rich in ozone (a naturally occurring gas); it is generally about 20km thick and sits in the stratosphere. The stratosphere is between 10 and 50km above the Earth's surface. The ozone layer absorbs 97–99% of the harmful, high frequency ultraviolet (UV) radiation known as UV-B. Although ozone represents only a small fraction of the gas present in the atmosphere, it plays a vital role by shielding humans and other life from UV-B. Exposure to UV-B radiation can cause skin cancer in humans, damage important agricultural crops and reduce the amount of phytoplankton in ocean ecosystems.

### Extension Question

#### Q1. What is ozone made from?

When an oxygen molecule is hit by UV radiation, this reaction may cause the molecule to break apart into single atoms of oxygen ( $O_2 + UV = O + O$ ). These single oxygen atoms are very reactive and they can combine with another molecule of oxygen to form ozone ( $O_2 + O = O_3$ ).

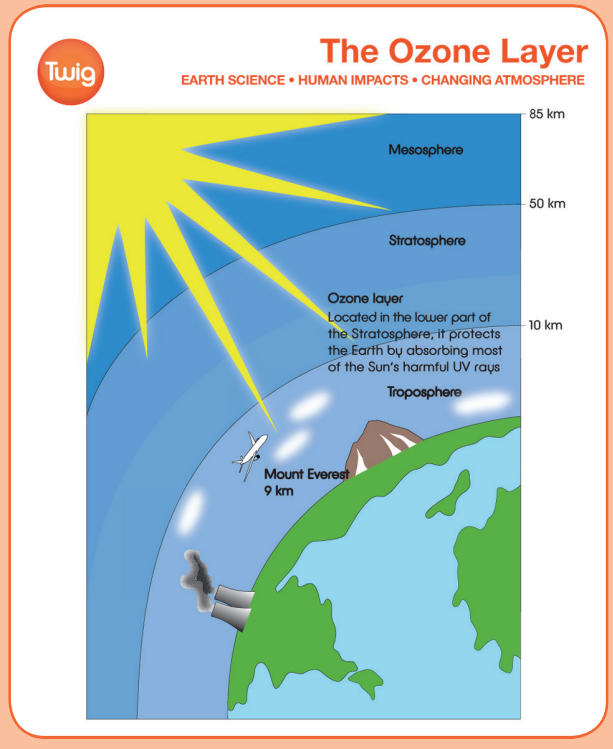
#### Q2. How does the thickness of ozone vary around the world?

Ozone is produced in the atmosphere as UV radiation reacts with oxygen. UV radiation is received in the highest quantities in the tropics. Ozone levels are relatively low in the tropics, even though it is here that most of the ozone production takes place. Scientists think ozone is moved by atmospheric circulation toward the poles. There is less ozone over the equator than over other higher latitudes, but the seasonal ozone hole above Antarctica is of great importance to humans.

#### Q3. Why does the ozone hole form over Antarctica?

The hole in the ozone layer develops because of conditions that occur in the polar winter in the stratosphere. Ozone is 'depleted' (destroyed) and reaches very low levels in winter and spring, as temperatures drop to about  $-80^{\circ}C$ . The tiny ice crystals that make up high-level clouds in the stratosphere allow chemical reactions to occur and these deplete ozone.

## DIAGRAM 01:



### • Suggested Film

- The Ozone Layer

### • What caused the hole in the ozone layer?

The ozone layer is naturally quite thin over the polar regions, particularly the Antarctic, and this 'hole' grows bigger in winter. Man-made gases, such as chlorofluorocarbons (CFCs), are responsible for the depletion of the ozone layer as they attack and destroy ozone molecules. This has made the ozone hole much bigger. CFCs were produced in huge quantities in the 20th century, and they are very useful. They can be used as propellants in aerosol sprays, in running fridges and air conditioners, in the manufacture of foam plastic packaging, and in some solvent cleaning fluids. The Antarctic ozone hole was discovered in 1985 by British scientists Joseph Farman, Brian Gardiner and Jonathan Shanklin. Countries such as Australia have had to take measures to protect their population from the increase in UV-B radiation.



We used to use CFCs to make aerosols like hairspray and deodorant

#### Extension Questions

**Q4. Why else are CFCs a threat when released into the atmosphere?**

CFCs are powerful greenhouse gases and, though there are far smaller quantities of CFCs in the atmosphere compared to carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>), they have more 'warming' potential per molecule.

**Q5. What can people do to protect themselves against UV-B radiation?**

Wearing sun cream, avoiding strong sun in summer, and wearing hats and good sunglasses in the sun, can all help people to protect themselves against UV-B. Some governments have run public education programmes to inform citizens of the risks posed by the UV-B radiation.

**Q6. Why is some UV radiation 'harmful'?**

Radiation can be damaging to living organisms if received in too high a dose. Life on Earth evolved with the ozone layer in the atmosphere, which means bacteria, plant life and animals don't have natural protection against the UV wavelengths that have been blocked by the ozone layer during evolution.

**Q7. What are phytoplankton?**

Phytoplankton are tiny plants that live in the ocean. They are microscopic and can't be seen with the naked eye. They use sunlight to photosynthesise and so are the 'producers' of ocean ecosystems, meaning they form the crucial beginning of marine food webs.

#### • Suggested Film

- The Ozone Layer

### • Can the ozone layer ever recover?

In 2006 the largest ozone hole ever was recorded. In September 1987, in Montreal, an agreement was reached, known as the Montreal Protocol that paved the way to protect the ozone layer. Many rounds of negotiations have since been held to gain the participation of countries such as China, Brazil and the USA. Many countries have phased out the production and use of CFCs and other gases that deplete stratospheric ozone; replacement gases, such as HCFCs and HFCs, are being used instead. Real progress is being made and it is believed that by 2050 the ozone layer may have recovered if international cooperation and national efforts continue to reduce the release of harmful gases into the atmosphere.

#### • Suggested Film

- The Ozone Layer

**Extension Question**

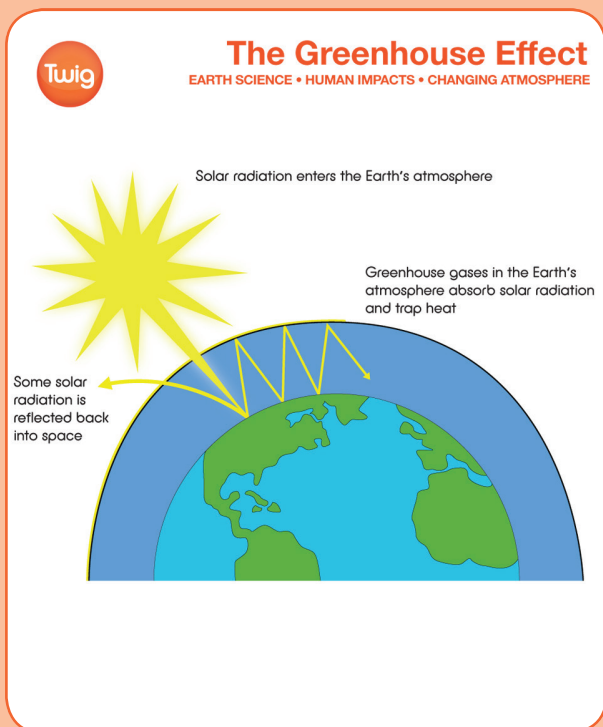
Q8. How can I tell if I'm releasing CFCs?

Older fridges and air conditioning systems (at home or in cars) may use CFCs, but it won't be obvious, as it will have no label to indicate this. Older spray cans, cleaning solvents and packaging probably won't be labelled either, and you won't be able to tell if CFCs were used in their manufacture. However, by law, many countries require this kind of labelling now and, in many countries, if you look at a spray can of deodorant or hair spray it will say if it is CFC free.

**Section 2: The Greenhouse Effect**

• What is the greenhouse effect?

**DIAGRAM 02:**



Life on Earth depends on the natural process known as the greenhouse effect. Some gases in the Earth's atmosphere act a bit like a 'greenhouse' or 'blanket' and keep the planet about 33°C warmer than it would otherwise be. However, it's not quite that simple, the Sun's energy is absorbed by the Earth's surface, and when it is radiated back into the atmosphere its wavelength has changed so that gases in the atmosphere can more easily absorb it (compared to on the way in). So, greenhouse gases act like filter, letting energy in, but trapping it once it's been changed and is trying to get back out to space.

• **Suggested Films**

- The Greenhouse Effect
- Global Dimming

**Extension Question**

Q9. Why does the Sun's energy get trapped more on the way out of the atmosphere than on the way in?

The Sun is very hot (about 5500°C) and the wavelength of energy coming from it is much shorter than the longer wavelength radiation given off from a warmed surface of the Earth (say at 15°C). This longer wavelength is more easily absorbed by the greenhouse gases, and is infrared radiation.

• What are the greenhouse gases?

Nitrogen and oxygen make up about 99% of the atmosphere; they have nothing to do with the greenhouse effect. The greenhouse effect is caused mostly by the presence of water vapour, but also other naturally occurring gases like carbon dioxide and methane. Ozone, nitrous oxide and man-made gases such as CFCs are also greenhouse gases, but their effects are complicated and not fully understood. The level of carbon dioxide in the atmosphere is linked to historical climate change (during ice ages the atmospheric carbon dioxide level was low, in warmer inter-glacial periods it is higher).

• **Suggested Films**

- The Greenhouse Effect
- Clathrate Gun Hypothesis
- Climate Cycles

### Extension Questions

**Q10. What is the composition of the Earth's atmosphere?**

78% nitrogen, 21% oxygen, 1% other gases (including argon 0.9% and carbon dioxide 0.03%).

**Q11. What is an interglacial?**

Earth has experienced many alternating warmer and cooler periods. Each period can last thousands, even hundreds of thousands, of years. The cold periods, during which ice sheets accumulate and glaciers advance, are known as ice ages. The warmer periods between, as we are in right now, are known as 'interglacials' (between ice ages).

### • How may humans be making the greenhouse effect stronger?

Many human activities are releasing greenhouse gases. Carbon dioxide is produced by burning fossil fuels, and we do this to power our homes, transport and industry. We also release carbon dioxide when we burn forest; this occurs across the tropics during deforestation of rainforests. Methane is produced by cattle farming, landfill sites and rice agriculture. The release of other greenhouse gases, such as nitrous oxide, ozone and CFCs, occurs as a result of pollution by transport and manufacturing. Taken together, human activity has enhanced the atmosphere's ability to trap outgoing infrared energy.



Human activities, including industry, produce greenhouse gases

### • Suggested Films

- The Greenhouse Effect
- Water Cube

## Section 3: Global Warming

### • What is global warming?



Global warming is causing the polar icecaps to melt

Global warming is the increase in temperatures of Earth's oceans and atmosphere. World temperatures have risen by about 0.8°C in the last 140 years; 10 of the warmest recorded years have occurred in the last 12 years. Global warming has occurred throughout geological history, as ice ages give way to warmer interglacials. Most scientists believe that some of the global warming that has occurred in the previous century is due to human activity. This is known as anthropogenic global warming (warming due to humans rather than nature). Global warming is not occurring evenly over the planet; some areas such as the Arctic are warming much more quickly. Once Arctic ice melts, the darker ocean or land surface absorbs more solar insolation and this encourages further ice melt. This is an example of positive feedback.

### Extension Questions

#### Q12. What is positive feedback?

Any change to a system that results in further change is 'positive feedback'. Negative feedback is when a change to a system brings conditions back to original balance or equilibrium.

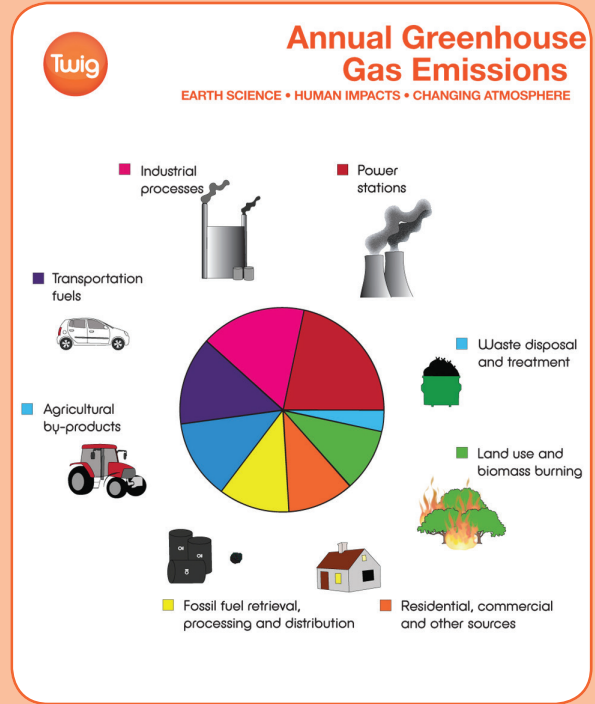
#### Q13. When did global warming start?

It is difficult to give a definitive date, but many would argue that it coincided with the Industrial Revolution, as fossil fuels were burnt and the developed world became industrialised. There are records as far back as 1850 that support this theory.

#### • Suggested Films

- Natural Climate Change
- Global Warming
- State of the Greenland Ice Sheet
- The Big Chill
- Beetles
- Ocean Conveyor

### DIAGRAM 03:



### • Why do we worry about global warming?

We worry about global warming for several reasons. We worry that rising ocean temperatures is causing more violent hurricanes and that other weather events, such as drought and flooding, are becoming more extreme. Secondly, sea levels are rising due to both melting ice sheets and thermal expansion of the oceans. A rise of 15 to 20cm occurred in the 20th century. Rising sea levels threaten low-lying areas of Earth such as river deltas, estuaries and some islands. We also worry that global warming may be occurring too fast for our agricultural systems and the world's ecosystems to adapt effectively. Scientists are also concerned that 'tipping points' may be reached that represent the sudden and dramatic change in the way the oceans and the atmosphere circulates. For example, the Gulf Stream current that warms north-west Europe may be 'cut-off' like a switch, rather than gradually.



Global warming could lead to increased flooding

#### • Suggested Activity

- Discuss: the relationship between rising sea temperatures and hurricanes. 2005 was the most active hurricane year (Katrina), this is because sea temperatures were higher than average

#### • Suggested Films

- Global Warming
- State of the Greenland Ice Sheet
- The Big Chill

### Extension Questions

#### Q14. What is the Gulf Stream?

The Gulf Stream is a powerful ocean current that is hundreds of metres deep and a hundred or so kilometres wide. It is generated by surface winds and differences in water density. Ocean water in the Atlantic is cooled by winds from the Arctic. It also becomes saltier, as winds evaporate water at the surface, and denser, meaning it sinks to the ocean floor. (The cold water then moves along the ocean bed and begins a journey around the globe before rising and warming again). Like a large convection cell driven by winds, the Gulf Stream moves as warm water from the Gulf of Mexico moves north-east through the Atlantic. Further north it is known as the North Atlantic Drift.

#### Q15. What might happen if the Gulf Stream is 'cut off'?

In one scenario scientists have painted, the loss of the Gulf Stream may be cut by advancing cold fresh water from melting Arctic and Greenland ice. If this happens we may lose the Gulf Stream and be plunged into an ice age!

#### Q16. Where will sea level rise be a problem?

Low-lying regions throughout the world are more at risk; in particular, river deltas and estuaries, and many low-lying islands. Cities like London, Amsterdam, Tokyo and Rio de Janeiro are all at risk of increased flooding from sea level rise. Already, places such as the Maldives and Tuvalu are facing the challenges of sea level rise. They may be using 'soft' management strategies, such as moving people off the islands, or 'hard' management strategies such as building sea defences.

#### Q17. Are there any positives of global warming?

Longer growing seasons in some parts of the world will increase agricultural production. There will be fewer deaths from injuries caused by extreme icy weather. Melting ice sheets and ocean is allowing resources to be exploited in places previously inaccessible, including the Greenland coast and the Arctic seabed. However, in such cases, pollution fears remain.

### • Why is it proving hard to tackle the threat of global warming?

The Kyoto Protocol is an international agreement that sets out a path for tackling global warming. It has been difficult to address the issue of global warming because, to start with, it is not fully understood, and 'climate sceptics' argue that any warming we have experienced may be natural variation in the Earth's oceans and atmosphere. Also, reducing greenhouse gas emissions is hard to do, as there are few alternatives to fossil fuels that offer as much energy so cheaply. As more countries develop they will need to provide more energy for their increasing population and its demand for higher standards of living. Countries can't always agree on how big greenhouse gas emissions should be cut and who should pay for the necessary changes. There are many debates about whether it is more effective to try to stop change or to adapt to it.



The ozone layer prevents harmful ultraviolet rays reaching the Earth

### Extension Question

Q18. Is global warming harder to deal with than the depleting ozone layer?

Put simply, the technical fix to solve the ozone depletion was much easier. Industry has developed substitutes to CFCs and other gases that were causing the ozone hole. This has been quite easy to do relatively cheaply and quickly. However, the alternatives to burning fossil fuels and clearing land for agriculture have been much harder to develop and integrate into both national development strategies and individuals' lives.

### • Suggested Films

- Natural Climate Change
- Inventions to Save the Planet
- Climate Models
- The Great Global Warming Debate: Part 1
- The Great Global Warming Debate: Part 2
- Water Cube

### • Suggested Activity

- Discuss: Do rich countries have a responsibility to monitor and impose regulations on carbon emissions?

## • Quizzes

## The Ozone Layer

## Basic

## • The ozone layer is found in the

- A – stratosphere
- B – troposphere
- C – ionosphere
- D – none of the above

## • The ozone layer is

- A – about 1km high up in the atmosphere
- B – about 15km high up in the atmosphere
- C – 15–50km high up in the atmosphere
- D – 50km high up in the atmosphere

## • The ozone layer protects us from harmful radiation from

- A – the Earth's core
- B – ultraviolet
- C – the Sun
- D – the Moon

## • CFCs, the man-made gases that destroy the ozone layer, are

- A – used to make fridges
- B – used to make aerosol sprays
- C – used in air conditioners
- D – all of the above

## Advanced

## • The ozone layer is found

- A – 15–50km up in the troposphere
- B – 15–50km up in the stratosphere
- C – 2–10km up in the stratosphere
- D – 2–10km up in the lower atmosphere

## • Ozone is a molecule of

- A – two oxygen atoms
- B – three oxygen atoms
- C – any number of oxygen atoms
- D – chlorine, fluorine and carbon

## • Ozone can block harmful

- A – infrared radiation
- B – solar ultraviolet radiation
- C – gamma radiation
- D – solar infrared radiation

## • The ozone hole was noticed

- A – in 1982 over Antarctica
- B – in 1986 over Antarctica
- C – in 1986 over North America
- D – in 2006 over North America



## The Ozone Layer

### Basic

- CFCs can last in the atmosphere for

- A – 4 years
- B – 40 years
- C – forever
- D – 40 days

### Advanced

- Which statement is false?

- A – the ozone layer lets in more heat from the Sun
- B – the ozone layer poses a risk to human skin
- C – the ozone layer is destroyed by chlorofluorocarbons
- D – the ozone layer is slowly recovering

## The Greenhouse Effect

### Basic

- Which of these is NOT a greenhouse gas?

- A – water vapour
- B – nitrogen
- C – carbon dioxide
- D – methane

- The greenhouse effect

- A – lets more light through the atmosphere
- B – keeps the Earth warmer than it would be without it
- C – is a man-made disaster
- D – is made by the ozone layer

- Carbon dioxide is released by

- A – burning coal to make electricity
- B – burning petrol and diesel in cars
- C – burning forests
- D – all of the above

- The cattle industry produces a lot of

- A – nitrous oxides
- B – ozone
- C – carbon dioxide
- D – methane

### Advanced

- A – keeps the Earth at about 32°C
- B – keeps the Earth at about 32°C above what it would be without the greenhouse effect

- C – keeps the Earth at about 3.2°C
- D – keeps the Earth at about 3.2°C above what it would be without the greenhouse effect

- Which of these activities does NOT produce carbon dioxide?

- A – burning petrol in a car
- B – burning diesel in a car
- C – deforestation
- D – they all do

- Agriculture generates

- A – 14% of carbon dioxide emissions
- B – 14% of methane emissions
- C – 40% of all greenhouse gas emissions
- D – 14% of all greenhouse gas emissions

- Photosynthesis

- A – absorbs greenhouse gases
- B – absorbs carbon dioxide
- C – doesn't absorb carbon dioxide from fossil fuels
- D – increases when deforestation occurs

## The Greenhouse Effect

### Basic

- Scientists generally believe human activity is

- A – making the greenhouse effect stronger
- B – destroying the greenhouse effect
- C – making more photosynthesis
- D – all of the above

### Advanced

- Scientists believe the Earth is getting warmer

- A – because the greenhouse effect is becoming stronger
- B – because humans are using so much more energy
- C – because the ozone hole has grown so much bigger since 1986
- D – because the greenhouse effect is getting weaker

## Global Warming

### Basic

#### • The Earth's climate

- A – had been stable until the 1980s
- B – has often been much hotter than it is now
- C – has begun to warm quite quickly since the 1980s

#### • The change in Earth's climate

- A – is believed to be linked to the hole in the ozone layer
- B – is believed to be linked to greenhouse gas emissions
- C – is believed to be just a natural phenomenon

#### • Scientists

- A – all agree on what is happening to the Earth's climate
- B – all disagree on what is happening to the Earth's climate
- C – generally agree the planet is getting warmer because of human activity

#### • Global warming could

- A – melt the icecaps and make sea levels rise
- B – make storms stronger and cause more flooding
- C – both of the above

### Advanced

#### • Global warming is predicted to be

- A – between 1.4°C and 5.8°C in the next 100 years
- B – at least 5.8°C in the next 100 years
- C – 1.4°C each year for the next 100 years

#### • Global warming is believed to be linked to

- A – the rise in greenhouse gases emitted since the agricultural revolution
- B – the rise in greenhouse gases emitted since the industrial revolution
- C – the rise in greenhouse gases emitted since 1980

#### • Global warming is likely to

- A – cause more flooding but less drought
- B – cause more drought but less flooding
- C – cause more flooding and more drought

#### • If the Earth's icecaps melt

- A – sea levels could rise by 9m
- B – sea levels could rise by 90cm
- C – sea levels could rise by 9cm



## Global Warming

### Basic

- Global warming

A – is likely to get stronger as developing countries get richer

B – is likely to be less serious as developing countries get richer

C – is not such a threat as it was in the 1980s

### Advanced

- Global warming is difficult to stop because

A – greenhouse gases are already in the atmosphere

B – developing nations are likely to release higher levels of greenhouse gases in the future

C – developed countries are using more and more energy

## • Answers

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