1 Natural hazards

1.1 What are natural hazards?

On this spread you will find out about the risks from natural hazards

What is a natural hazard?

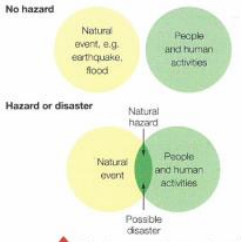
In March 2015 landslides struck Bujumbura in Western Burundi, Central Africa, killing several people and leaving thousands homeless. Following a period of heavy rain, mud and rocks plunged down hillsides destroying houses and damaging roads (photo **A**).

This event is an example of a natural hazard. It is a natural event that has had a huge **social impact**. If the landslide had occurred in a remote area where it did not pose any threat to people it would not be considered a hazard.

Landslides are not major killers. The most deadly natural hazards are floods, storms, earthquakes and droughts. Between 2002 and 2012, an average of 100 000 people worldwide were killed each year by natural hazards. In most years, flooding caused the greatest number of deaths.

Diagram **B** is called a Venn diagram. Notice that a natural hazard occurs when a natural event overlaps with human activities.

A *Landslides affecting Bujumbura, Burundi, 2015*



B *When is a natural event a hazard?*

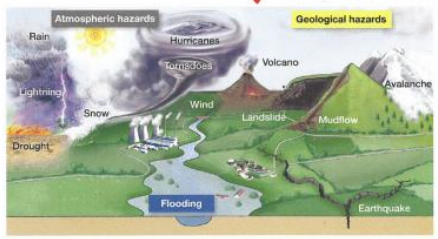
What are the different types of natural hazard?

There is a huge range of natural hazards. These include:

- volcanic eruptions
- earthquakes
- storms
- tsunami (huge waves caused by earthquakes)
- landslides
- floods.

Diagram **C** shows how natural hazards can be sorted into three main groups.

Did you know?
Hurricane Patricia (2015) was the most powerful tropical storm ever recorded, with winds reaching 320 km/h (200 mph).



C *Different types of natural hazard*

What is 'hazard risk'?

Hazard risk is the chance or probability of being affected by a natural event. People who choose to live close to a river may be at risk from flooding. Those who live close to the sea may be at risk from tropical cyclones or tsunami.

So why do people put themselves at risk by living in such places? They weigh up the advantages and disadvantages and, because such events don't happen very often, they may decide to accept the risk. Some people may have little choice of where to live or knowledge that where they are living is dangerous.

Think about it
*Are natural hazards occurring more frequently today than 100 years ago? Use diagram **B** to help you.*

What factors affect risk?

There are several factors that have led to an increase in the number of people at risk from natural events.

Factors increasing the risk from natural hazards

Poverty
In poorer parts of the world poverty may force people to live in areas at risk. This is especially true in cities such as Lima in Peru or Caracas in Venezuela. Here, a shortage of housing has led to people building on unstable slopes prone to floods and landslides.

Urbanisation
Over 50 per cent of the world's population now live in cities. Some of the world's largest cities (for example, Tokyo, Istanbul and Los Angeles) are at risk from earthquakes. Densely populated urban areas are at great risk from natural events such as earthquakes and tropical cyclones. The 2010 Haiti earthquake destroyed much of the capital Port-au-Prince killing some 230 000 people.

Farming
When a river floods it deposits fertile silt on its floodplain, which is excellent for farming. But when people choose to live there they are putting themselves at risk. In low-lying countries many people may live on floodplains, like that of the River Ganges in Bangladesh.

Climate change
In a warmer world the atmosphere will have more energy leading to more intense storms and hurricanes. Climate change may cause some parts of the world to become wetter with an increased risk of flooding. Other areas may become drier and prone to droughts and famines.

ACTIVITIES

1 Describe what has happened in photo **A**.
2 a Make a copy of diagram **B**.
  b Explain in your own words how a 'natural event' becomes a 'natural hazard'.
3 a What are the three main groups of hazard shown in diagram **C**?
  b Why do you think more people are likely to be affected by river flooding than by landslides and mudflows?
4 In the future, why is it likely that increasing numbers of people will be at risk from natural hazards?

Stretch yourself

Find out about natural hazards in Bangladesh. What are the natural events that threaten the country? Why are so many people at risk from these events?

Maths skills

Use a divided bar chart or a pie chart to present the following information.

Percentage of fatalities (2014)

Hydrological events (e.g. floods)	66%
Meteorological events (e.g. storms)	17%
Geophysical events (e.g. earthquakes)	11%
Climatological events (e.g. drought)	6%

Practice question

Explain two human developments that would increase the risk of people being affected by natural hazards. *(4 marks)*

2 Tectonic hazards

2.1 Distribution of earthquakes and volcanoes

On this spread you will find out where earthquakes and volcanoes happen and link their location to plate tectonics

Why is there a pattern of earthquakes?

An **earthquake** is a sudden and violent period of ground shaking. It is most commonly caused by a sudden movement of rocks within the Earth's crust. This occurs mainly at the margins of *tectonic plates* (map **B**) where plates are moving and enormous pressures build up and are released.

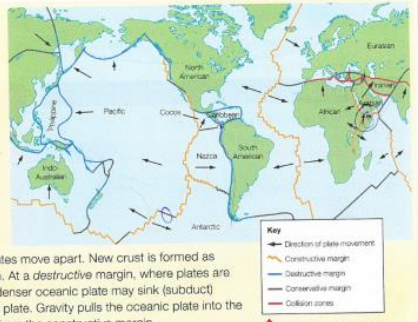
Compare map **B** to map **A**. Notice the pattern of earthquakes along **plate margins**, for example along the western coast of North and South America. The occurrence of earthquakes around the edge of the Pacific Ocean follows the plate margins.

Some earthquakes do not occur at plate margins. These may be caused by human activity such as underground mining or oil extraction.

A *Earthquakes recorded during March 2015*

Tectonic plates

- The Earth's crust is split into a number of plates about 100 km thick.
- There are two types of crust – dense, thin oceanic crust and less dense, thick continental crust.
- Plates move in relation to each other due to convection (heat) currents from deep within the Earth. Gravitational pull may play a part.
- At a *constructive* plate margin plates move apart. New crust is formed as magma rises towards the surface. At a *destructive* margin, where plates are moving towards each other, the denser oceanic plate may sink (subduct) beneath a less dense continental plate. Gravity pulls the oceanic plate into the mantle, dragging the plate away from the constructive margin.
- Tectonic activity at plate margins causes earthquakes and volcanoes.



B *The Earth's tectonic plates*

C *The distribution of volcanoes*

Think about it

Think about any major earthquakes or volcanoes that have been in the news recently. How does their location link to plate tectonics?

Where do volcanoes happen?

Look at map **C** which shows the distribution of volcanoes. A **volcano** is a large and often conical-shaped landform usually formed over a long period of time by a series of eruptions. Like earthquakes, the majority of volcanoes occur in long belts that follow the plate margins, for example around the edge of the Pacific Ocean. This is known as the 'Pacific Ring of Fire'. There is also a belt of volcanoes through the middle of the Atlantic Ocean. This is the Mid-Atlantic Ridge which includes the Azores and Iceland which are volcanic islands.

Did you know?

The biggest volcanic eruption ever recorded was Mount Tambora, in Indonesia, in 1815. Volcanic ash from the eruption blocked the sun!

Why is there a pattern of volcanoes?

Volcanoes are fed by hot molten rock (magma) from deep within the Earth. This rises to the surface at *constructive* and *destructive* plate margins. Volcanoes also form at **hot spots**, where the crust is thin and magma is able to break through to the surface. The Hawaiian Islands in the Pacific Ocean are a good example of a hot spot.

ACTIVITIES

1. Use map **A** to describe the pattern of earthquakes.
2. Use map **B** to answer the following questions.
   - **a** Which plate is the UK on?
   - **b** Name a country which is being split by two plates.
   - **c** Describe the movement of the plates at the margin of the Nazca and South American plates.
3. Describe the pattern of volcanoes (map **C**). Refer to names of oceans, continents and countries in your answer.
4. Why do the majority of earthquakes and volcanoes occur at plate margins?

Maths skills

A total of 1482 earthquakes occurred in a 7-day period at the end of April 2016. Work out the average number of earthquakes per day and per hour. Can you calculate the frequency of the earthquakes?

Practice question

Explain why the majority of earthquakes and volcanoes occur at plate margins. *(4 marks)*

Stretch yourself

Use the United States Geological Survey (USGS) website to find a map of recent earthquakes. You could look at a single day or a whole week. Copy and paste the map and write a few sentences (or use text boxes) to describe the pattern of earthquakes. Use map **B** to relate this to named plate margins.

2.2 Physical processes at plate margins

On this spread you will find out about the physical processes at plate margins

What happens at plate margins?

Iceland is a country in the North Atlantic Ocean. It is situated on the Mid-Atlantic Ridge, a plate margin where two plates are moving away from each other. There are several active volcanoes in Iceland including Eyjafjallajökull which erupted in 2010 (photo **A**). It is possible to identify three main types of plate margin:

- **Constructive** – where two plates are moving apart.
- **Destructive** – where two plates are moving towards one another.
- **Conservative (transform)** – where two plates are sliding alongside each other.

A Eruption of Eyjafjallajökull, 2010

Maths skills

At a constructive plate margin, each plate moves at an average of 2 cm a year. Calculate the increase in the width of Iceland over a period of one million years.

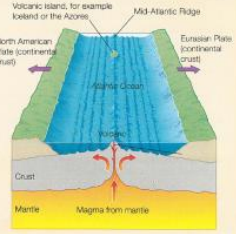
Did you know?

Volcanic eruptions over millions of years mean that Iceland is growing outwards from the middle!

Constructive margin

At a constructive margin two plates are moving apart. Diagram **B** shows what is happening at the constructive margin in the mid-Atlantic. Magma is forcing its way to the surface along the Mid-Atlantic Ridge. As it breaks through the overlying crust it causes earthquakes. On reaching the surface it forms volcanoes such as Eyjafjallajökull in Iceland.

The magma at constructive margins is very hot and fluid. Lava erupting from a volcano will flow a long way before cooling. This results in typically broad and flat *shield volcanoes*.



B Constructive plate margin

Destructive margin

At a destructive plate margin two plates are moving towards one another. Diagram **C** shows what is happening on the west coast of South America.

Where the two plates meet a deep ocean trench has formed. The oceanic Nazca Plate, which is relatively dense, is subducted beneath the less dense South American Plate. Friction between the two plates causes strong earthquakes. As the oceanic plate moves downwards it melts. This creates magma which is less fluid than at a constructive margin. It breaks through to the surface to form steep-sided *composite volcanoes*. Eruptions are often very violent and explosive.

Where two continental plates meet, there is no subduction. Instead, the two plates collide and the crust becomes crumpled and uplifted. This collision forms fold mountains such as the Himalayas. These mountain-building processes cause earthquakes. There are no volcanoes at these collision margins because there is no magma.

C Destructive plate margin

Conservative margin

At conservative plate margins, two plates are moving past each other. Friction between the plates then causes earthquakes. Map **D** shows the San Andreas Fault in California, a well-known example of a conservative margin. The faster-moving Pacific Plate is sliding in the same direction next to the slower-moving North American Plate.

Earthquakes happen along conservative margins as stresses gradually build up over many years. They can be destructive as they are close to the Earth's surface. These are released suddenly when the plates slip and shift.

There are no volcanoes because there is no magma.

D Conservative plate margin

ACTIVITIES

1 a What type of plate margin runs through the middle of Iceland?
  b Why do earthquakes occur in Iceland?
  c Explain why there are volcanoes like Eyjafjallajökull in Iceland.
2 Explain the formation of earthquakes and volcanoes at a destructive margin (diagram **C**).
3 Make a copy of map **D**
  a Use crosses to show where you would expect earthquakes to happen.
  b Why are there no volcanoes at a conservative plate margin?

Stretch yourself

Find out about the North Anatolian Fault, one of the world's most active plate margins.

- Where is it?
- What type of plate margin is it?
- What are the hazards associated with the North Anatolian Fault?
- Which major city near this fault is at greatest risk from a natural disaster?

Practice question

Explain the physical processes that happen at constructive plate margins. *(4 marks)*

2.3 The effects of earthquakes

On this spread you will find out about the effects of two earthquakes in contrasting countries – Chile and Nepal

The earthquakes in Chile and Nepal

Earthquakes can have devastating effects on peoples' lives and activities. **Primary effects** are caused by ground shaking

Chile

Primary effects (caused by ground shaking)

- Around 500 people killed and 12 000 injured – 800 000 people affected.
- 220 000 homes, 4500 schools, 53 ports, 56 hospitals and other

D The effects of the Chile earthquake

Secondary effects (tsunamis, fires and landslides)

- 1500 km of roads damaged

2.3 The effects of earthquakes

On this spread you will find out about the effects of two earthquakes in contrasting countries – Chile and Nepal

Example

The earthquakes in Chile and Nepal

Earthquakes can have devastating effects on peoples' lives and activities. **Primary effects** are caused by ground shaking and can include deaths and injuries, and damage to roads and buildings. **Secondary effects** are the result of primary effects (ground shaking) and include tsunami, fires and landslides. Responses to earthquakes include emergency care and support and help with longer-term reconstruction.

Indicator	Chile	Nepal	UK
Gross Domestic Product (GDP) – a measure of wealth	38th out of 193 countries	109th out of 193 countries	6th out of 193 countries
Human Development Index (HDI) – a measure of the level of development	41st out of 187 countries	145th out of 187 countries	14th out of 187 countries

A Contrasting Chile and Nepal

Chile

Imagine what it would be like if the ground shook underneath you for three minutes! This is what happened on 27 February 2010 when a very powerful earthquake measuring 8.8 on the Richter scale struck just off the coast of central Chile (map **B**). The earthquake occurred at a destructive plate margin where the Nazca Plate is moving beneath the South American Plate.

It was followed by a series of smaller aftershocks.

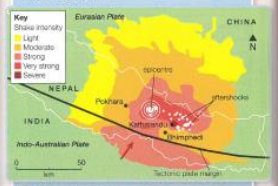
Because the earthquake occurred out to sea, tsunami warnings were issued as waves raced across the Pacific Ocean at speeds of up to 800 km per hour.

B The Chile earthquake

Nepal

On 25 April 2015 Nepal was struck by an earthquake measuring 7.9 on the Richter scale. The epicentre was about 80 km (50 miles) to the north-west of Nepal's capital Kathmandu in the foothills of the Himalayas (map **C**). This is a destructive plate margin where the Indo-Australian Plate is colliding with the Eurasian Plate at a rate of 45 mm per year. The collision and pressure at this margin are responsible for the formation of the Himalayas.

The earthquake was very shallow, just 15 km below the surface. This resulted in very severe ground shaking and widespread landslides and avalanches. The earthquake caused damage hundreds of kilometres away in India, Tibet and Pakistan.

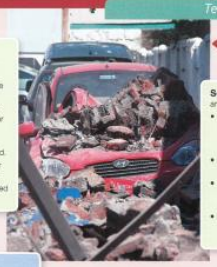


C The Nepal earthquake

Chile

Primary effects (caused by ground shaking)

- Around 500 people killed and 12 000 injured – 800 000 people affected.
- 220 000 homes, 4500 schools, 53 ports, 56 hospitals and other public buildings destroyed.
- Port of Talcahuanao and Santiago airport badly damaged.
- Much of Chile lost power, water supplies and communications.
- Cost of the earthquake estimated at US$30 billion.



D The effects of the Chile earthquake

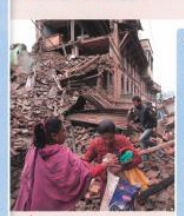
Secondary effects (tsunamis, fires and landslides)

- 1500 km of roads damaged, mainly by landslides – remote communities cut off for many days.
- Several coastal towns devastated by tsunami waves.
- Several Pacific countries struck by tsunami – warnings prevented loss of life.
- A fire at a chemical plant near Santiago – the area had to be evacuated.

Nepal

Primary effects

- 9000 people died and 20 000 injured – over 8 million people (a third of Nepal's population) affected.
- 3 million people left homeless when homes were destroyed.
- Electricity and water supplies, sanitation and communications affected.
- 1.4 million people needed food, water and shelter in the days and weeks after the earthquake.
- 7000 schools destroyed and hospitals overwhelmed.
- International airport became congested as aid arrived.
- 50% of shops destroyed, affecting food supplies and people's livelihoods.
- Cost of damage estimated at over US$5 billion.



E The effects of the Nepal earthquake

Secondary effects

- Ground shaking triggered landslides and avalanches, blocking roads and hampering relief efforts.
- Avalanches on Mount Everest killed at least 19 people – the greatest loss of life on the mountain in a single incident.
- An avalanche in the Langtang region left 250 people missing.
- A landslide blocked the Kali Gandaki River, 140 km (90 miles) north west of the capital, Kathmandu – many people evacuated in case of flooding.
- The earthquake occurred on land so did not cause a tsunami.

ACTIVITIES

1 a What is the evidence that Nepal is poorer and less developed than Chile?
b Why did the Nepal earthquake affect such a vast area?
c Why did the Chile earthquake trigger a tsunami?
2 Describe the primary effects of the Nepal earthquake shown in figure **E**.
3 To what extent did the levels of wealth and development of the two countries affect the impacts of the earthquakes?
4 What were the effects of the tsunami waves caused by the Chilean earthquake?

Stretch yourself

A second powerful earthquake struck Nepal on 12 May 2015. How might this have affected the country's recovery?

Practice question

Explain how different levels of wealth and development affected the impact of the earthquakes in Chile and Nepal. (6 marks)

2.4 Responses to earthquakes

On this spread you will find out about responses to earthquakes in Chile and Nepal

Responding to earthquakes

There are two different types of response to natural disasters such as earthquakes:

- **Immediate responses** – search and rescue and keeping survivors alive by providing medical care, food, water and shelter.

Did you know?
The last earthquake

Nepal: immediate responses

- Search and rescue teams (photo **C**), water and medical support arrived quickly from countries such as UK, India and China.
- Helicopters rescued many people caught in avalanches on Mount Everest and delivered

2.4 Responses to earthquakes

On this spread you will find out about responses to earthquakes in Chile and Nepal

Example

Responding to earthquakes

There are two different types of response to natural disasters such as earthquakes:

- **Immediate responses** – search and rescue and keeping survivors alive by providing medical care, food, water and shelter.
- **Long-term responses** – re-building and reconstruction, with the aim of returning people's lives back to normal and reducing future risk.

Did you know?
The last earthquake to hit Kathmandu was in 1934 when over 10 000 people were killed.

Comparing responses in Chile and Nepal

Earthquakes in Chile are quite common. Local communities and the government were prepared and knew how to respond quickly and effectively to the earthquake. Chile had the money to support people and to rebuild.

Earthquakes in Nepal are not uncommon. Scientists have identified a pattern of large earthquakes in this region every 80 years or so. Despite these warnings and new building regulations, little had been done to prepare the city and its people for when the earthquake struck.

Chile: immediate responses

- Emergency services acted swiftly. International help needed to supply field hospitals, satellite phones and floating bridges.
- Temporary repairs made to the important Route 5 north-south highway within 24 hours, enabling aid to be transported from Santiago to affected areas.
- Power and water restored to 90% of homes within 10 days.
- A national appeal raised US$60 million – enough to build 30 000 small emergency shelters (photo **A**).

A *Temporary wooden shelters for those made homeless by the earthquake*

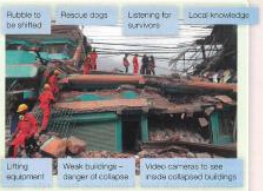
Chile: long-term responses

- A month after the earthquake Chile's government launched a housing reconstruction plan to help nearly 200 000 households affected by the earthquake.
- Chile's strong economy, based on copper exports, could be rebuilt without the need for much foreign aid.
- The President announced it could take four years for Chile to recover fully from the damage to buildings and ports (photo **B**).

B *Buildings destroyed by the Chile earthquake*

Nepal: immediate responses

- Search and rescue teams (photo **C**), water and medical support arrived quickly from countries such as UK, India and China.
- Helicopters rescued many people caught in avalanches on Mount Everest and delivered supplies to villages cut off by landslides.
- Half a million tents needed to provide shelter for the homeless.
- Financial aid pledged from many countries.
- Field hospitals set up to support overcrowded main hospitals.
- 300 000 people migrated from Kathmandu to seek shelter and support with family and friends.
- Social media widely used in search and rescue operations and satellites mapped damaged areas.



C *Searching a building for survivors in Kathmandu*

Nepal: long-term responses

- Roads repaired and landslides cleared. Lakes, formed by landslides damming river valleys, need to be emptied to avoid flooding.
- Thousands of homeless people to be re-housed, and damaged homes repaired. Over 7000 schools to be re-built or repaired.
- Stricter controls on building codes.
- In June 2015 Nepal hosted an international conference to discuss reconstruction and seek technical and financial support from other countries.
- Tourism, a major source of income, to be boosted – by July 2015 some heritage sites re-opened and tourists were starting to return.
- Repairs to Everest base camp (photo **D**) and trekking routes – by August 2015 new routes had been established and the mountain re-opened for climbers.
- In late 2015 a blockade at the Indian border badly affected supplies of fuels, medicines and construction materials.

D *Everest base camp*

ACTIVITIES

1 a Why did the Chilean government focus on repairing the main north–south highway?
b Why was the Chilean government able to respond quickly and effectively to the earthquake?
2 Describe how search and rescue teams locate and rescue people from collapsed buildings (photo **C**).
3 What were the immediate needs of the survivors of the Nepal earthquake?
4 What needs to be done to support Nepal's recovery following the earthquake?

Stretch yourself

Investigate the latest information about recovery in Chile and Nepal.
What has been done to reduce the impacts of future earthquakes in the two countries?

Practice question

Choose either the earthquake in Chile or Nepal.
Describe the immediate and long-term responses to the disaster. *(6 marks)*

2.5 Living with the risk from tectonic hazards

On this spread you will find out why people continue to live in areas at risk from earthquakes and volcanoes

Living in the shadow of a volcano

In AD79 Mount Vesuvius in southern Italy erupted, burying the nearby cities of Pompeii and Herculaneum in volcanic ash and killing thousands of people. Today over one million people live in the

Life on a plate margin in Iceland

Iceland lies on the Mid-Atlantic Ridge, a constructive plate margin that stretches through the middle of the Atlantic Ocean. There are several active volcanoes – an eruption occurs on average every five years. Earthquakes are common. Over 320 000 people live in Iceland and close to one million people visit the country each year.

- Chile's strong economy, based on copper exports, could be rebuilt without the need for much foreign aid.
- The President announced it could take four years for Chile to recover fully from the damage to buildings and ports (photo **B**).

B *Buildings destroyed by the Chile earthquake*

ACTIVITIES

1 a Why did the Chilean government focus on repairing the main north–south highway?
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Stretch yourself

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Practice question

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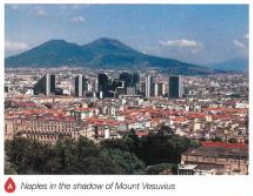
2.5 Living with the risk from tectonic hazards

On this spread you will find out why people continue to live in areas at risk from earthquakes and volcanoes

Living in the shadow of a volcano

In AD79 Mount Vesuvius in southern Italy erupted, burying the nearby cities of Pompeii and Herculaneum in volcanic ash and killing thousands of people. Today over one million people live in the shadow of the volcano, most of them in the city of Naples (photo **A**). Vesuvius last erupted in 1944. In the 300 years before then it erupted nearly every 20 years. Many people think that the next eruption is long overdue!



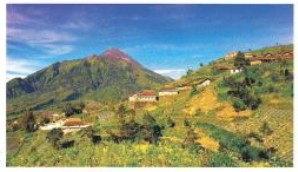
A *Naples in the shadow of Mount Vesuvius*

Living at risk from tectonic hazards

You have seen from the examples of Chile and Nepal how destructive earthquakes can be. So why do people choose to live in such dangerous places?

The majority of tectonic hazards occur at plate margins which criss-cross the Earth's surface. Some margins run through densely populated regions such as Japan, parts of China, and southern Europe (map **C**).

There are several reasons why people live in areas at risk from tectonic hazards, as shown below.

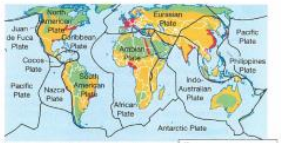


B *Fertile farmland on the slopes of Mount Merapi, Indonesia*

Life on a plate margin in Iceland

Iceland lies on the Mid-Atlantic Ridge, a constructive plate margin that stretches through the middle of the Atlantic Ocean. There are several active volcanoes – an eruption occurs on average every five years. Earthquakes are common. Over 320000 people live in Iceland and close to one million people visit the country each year.

Whilst the tectonic activity does pose a threat, the people in Iceland consider it to be a low risk. This is mainly due to effective scientific monitoring and awareness of the potential dangers. In fact, tectonic activity brings huge benefits to the country (figure **D**).



C *Tectonic plates and population density*

D *Geothermal power plant near Krafla volcano, Iceland*

ACTIVITIES

1 Why do you think one million people choose to live so close to one of Europe's most dangerous volcanoes (photo **A**)?
2 a Which areas of the world are most densely populated (map **C**)?
b Which of these areas lie on active plate margins? Name some of these margins.
c Why do you think so many people live in areas at risk from earthquakes and volcanic eruptions?
3 What evidence is there in photo **B** that people are making use of the land close to Mount Merapi?
4 How do the people of Iceland benefit from living on a plate margin (figure **D**)?

Stretch yourself

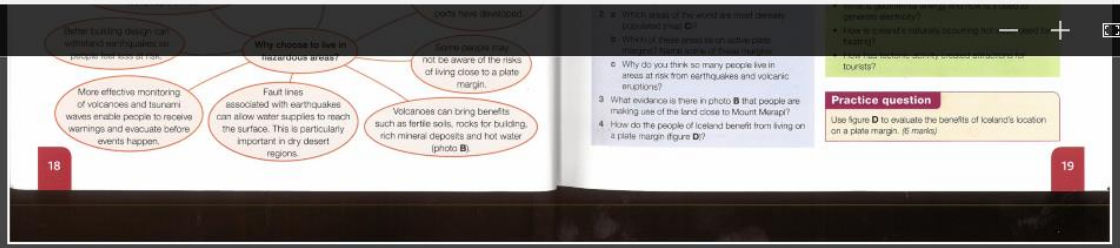
Carry out some research to find out how people in Iceland benefit from living in an area at risk from tectonic activity.

- What is geothermal energy and how is it used to generate electricity?
- How is Iceland's naturally occurring hot water used for heating?
- How has tectonic activity created attractions for tourists?

Practice question

Use figure **D** to evaluate the benefits of Iceland's location on a plate margin. *(6 marks)*

2.6 Reducing the risk from tectonic hazards



c Why do you think so many people live in areas at risk from earthquakes and volcanic eruptions?

3 What evidence is there in photo **B** that people are making use of the land close to Mount Merapi?

4 How do the people of Iceland benefit from living on a plate margin (figure **D**)?

tourists?

Practice question

Use figure **D** to evaluate the benefits of Iceland's location on a plate margin. *(6 marks)*

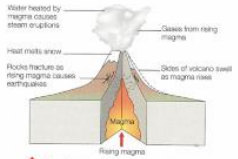
2.6 Reducing the risk from tectonic hazards

On this spread you will find out how the risks from tectonic hazards can be reduced

How can the risks from tectonic hazards be reduced?

There are four main **management strategies** for reducing the risk from tectonic hazards:

- **Monitoring** – using scientific equipment to detect warning signs of events such as a volcanic eruption.
- **Prediction** – using historical evidence and monitoring, scientists can make predictions about when and where a tectonic hazard may happen.
- **Protection** – designing buildings that will withstand tectonic hazards.
- **Planning** – identifying and avoiding places most at risk.



A *Warning signs of a volcanic eruption*

Monitoring

Volcanoes

As magma rises through a volcano it gives a number of warning signs that an eruption is likely to occur (diagram **A**).

All of the world's active volcanoes are closely monitored by scientists. If an eruption seems likely, warnings can be issued and action taken to evacuate surrounding areas. Modern hi-tech equipment is used, some of which is located on the volcano itself. Scientists monitor volcanoes in the following ways:

- *Remote sensing* – satellites detect heat and changes to the volcano's shape.
- *Seismicity* – seismographs record earthquakes.
- *Ground deformation* – changes to the shape of the volcano are measured using laser beams.
- *Geophysical measurements* – detect changes in gravity as magma rises to the surface.
- *Gas* – instruments detect gases released as magma rises.
- *Hydrology* – measurements of gases dissolved in water.

Earthquakes

Earthquakes generally occur without warning. Whilst there is some evidence of changes in water pressure, ground deformation and minor tremors prior to an earthquake, scientists have yet to discover reliable ways to monitor and predict earthquakes.

Prediction

Volcanoes

The prediction of a volcanic eruption is based on scientific monitoring. In 2010 an increase in earthquake activity beneath the Eyjafjallajökull ice cap in Iceland enabled scientists to make an accurate prediction about the eruptions that took place in March and April that year.

Earthquakes

It is impossible to make accurate predictions about earthquakes due to the lack of clear warning signs. However, scientists studying historical records of earthquakes at plate margins have identified locations that they believe are at greatest risk. Map **B** shows why scientists believe the city of Istanbul in Turkey is at risk from an earthquake ... soon!

B *Migration of earthquakes along the North Anatolian Fault, Turkey*

Protection

Volcanoes

The sheer power of a volcanic eruption means that there is often little that can be done to protect people and property. However, it is possible to use earth embankments or explosives to divert lava flows away from property. This has been done on the slopes of Mount Etna in Italy.

Earthquakes

Earthquake protection is the main way to reduce risk. It is possible to construct buildings and bridges to resist the ground shaking associated with an earthquake (diagram **C**). In Chile, new buildings have reinforced concrete columns strengthened by a steel frame. Regular earthquake drills help people keep alert and be prepared.

It is possible to construct tsunami walls at the coast to protect people and important buildings like nuclear power stations.

C *Features of an earthquake-resistant building*

Planning

Volcanoes

Hazard maps have been produced for many of the world's most dangerous volcanoes, showing the likely areas to be affected. They can be used in planning to restrict certain land uses or to identify which areas need to be evacuated when an eruption is about to happen.

Earthquakes

Maps can be produced to show the effects of an earthquake or identify those areas most at risk from damage. High-value land uses such as hospitals, reservoirs and office blocks can then be protected in these vulnerable areas.

ACTIVITIES

1 Why does rising magma cause earthquakes to occur?

2 a How can scientists monitor the changing shape of a volcano?

b What are the other warning signs of an eruption?

3 Use map **B** to explain why Istanbul is at risk from a future earthquake.

4 How can buildings be made safer to withstand earthquakes (diagram **C**)?

Stretch yourself

What methods are used to monitor *either* Mount Vesuvius or Mount Etna?

Practice question

'Earthquakes don't kill people, buildings do.'
Use evidence to support this statement. *(4 marks)*

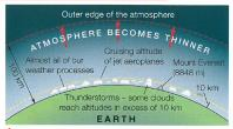
3 Weather hazards

3.1 Global atmospheric circulation

On this spread you will find out how global atmospheric circulation affects global weather and climate

What is global atmospheric circulation?

The cruising altitude (height) of an aeroplane is about 10 km above the ground surface. At this altitude the vast majority of the atmosphere's mass is below you (diagram **A**). The atmosphere – the air above our heads – is a highly complex swirling mass of gases, liquids and solids. These include water droplets, water vapour, ash, carbon dioxide and oxygen – just to mention a few!

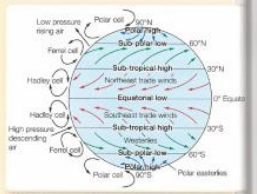


A The atmosphere

How does global atmospheric circulation work?

Diagram **B** shows global atmospheric circulation. This involves a number of circular air movements called cells. These cells all join together to form the overall circulation of the Earth's atmosphere.

- Air that is *sinking* towards the ground surface forms areas of *high pressure* (for example, at the North Pole). Winds on the ground move outwards from these areas.
- Air that is *rising* from the ground surface forms areas of *low pressure* on the ground, for example at the Equator. Winds on the ground move towards these areas of low pressure.
- Winds on the ground are distorted by the Earth's rotation. They curve as they move from areas of high pressure to areas of low pressure.
- Surface winds are very important in transferring heat and moisture from one place to another.
- The patterns of pressure belts and winds are affected by seasonal changes. The tilt and rotation of the Earth causes relative changes in the position of the overhead Sun. These seasonal changes cause pressure belts and winds to move north during our summer and then south during our winter.



B Global atmospheric circulation

Did you know?
The prevailing wind for the UK comes from the south-west over the Atlantic Ocean. This is why we have a moist and mild climate.

How does global circulation affect the world's weather?

Global atmospheric circulation is what drives the world's weather. The circulation cells, pressure belts and surface winds (diagram **B**) affect the weather around the world. For example, the trade winds in the tropics are responsible for driving tropical storms (hurricanes) across these regions bringing chaos and destruction to coastal regions in their path.

Cloudy and wet in the UK

The UK is located at about 55° North just below the 60° N line of latitude. This puts the UK close to the boundary of cold polar air moving down from the north and warm sub-tropical air moving up from the south.

The boundary between these two air masses is unstable. Here there is rising air and low-pressure belts (the *sub-polar low*) on the ground. Rising air cools, condenses and forms cloud and rain. This is why it is often cloudy and wet in the UK.

Surface winds in these mid-latitudes come from the south-west. These winds bring warm and wet conditions to the UK. But sometimes the cold polar air from the north moves down over the UK bringing snow and very cold winter weather.

G Wet weather in the UK

Hot and dry in the desert

Most of the world's hot deserts are found at about 30° north and south of the Equator. Here the air is sinking (diagram **B**), making a belt of high pressure (the sub-tropical high). Air isn't rising here, so there are few clouds forming and little rainfall. The lack of cloud makes it very hot during the day very cold at night, as heat is quickly lost from the ground.

D Hot, dry weather in the desert

Hot and sweaty at the Equator

At the Equator the air is rising (diagram **B**) and there is another low pressure belt (the *equatorial low*). This part of the world is very much hotter than the UK, with the sun directly overhead. Equatorial regions, such as central Africa and south-east Asia, experience hot, humid conditions. It is often cloudy with high rainfall. This is the region where tropical rainforests are found.

E Hot, humid weather at the Equator

ACTIVITIES

1. Copy diagram **B**. Draw the lines of latitude and label the Equator. Add the winds and circulation cells to your diagram. Use different colours to show the high and low pressure belts.
2. What do you notice about patterns of surface winds in relation to high and low pressure belts?
3. Explain why the patterns of pressure belts and surface winds move north and south during the year.
4. How does the atmospheric circulation system explain the UK's mild, cloudy and wet weather?
5. Draw a sketch to show how atmospheric circulation accounts for the high rainfall at the Equator.

Stretch yourself

Find a map to show the tracks followed by tropical storms. Use diagram **B** to add the Equator and the tropics. Draw on the trade winds to show how they are responsible for the east-west movement of the storms.

Practice question

Explain how the global atmospheric system affects the weather and climate of the tropics. *(6 marks)*

3.2 Where and how are tropical storms formed?

On this spread you will find out about the distribution and formation of tropical storms

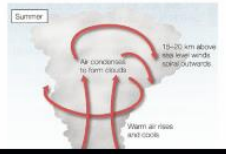
What is a tropical storm?

A tropical storm is a huge storm that develops in the Tropics (image **A**). In the USA and the Caribbean these are called **hurricanes**. In south-east Asia and Australia they are called **cyclones**, but in Japan and the Philippines they are called **typhoons**.

How do tropical storms form?

Scientists are not certain what causes the formation of a hurricane, but it involves the sequence of events shown below.

On reaching land the storm's energy supply (evaporated water) is cut off. Friction with the land slows it down and it begins to weaken. If the storm reaches warm seas after crossing the land, it may pick up strength again.



How does global circulation affect the world's weather?

Global atmospheric circulation is what drives the world's weather. The circulation cells, pressure belts and surface winds (diagram **B**) affect the weather around the world. For example, the trade winds in the tropics are responsible for driving tropical storms (hurricanes) across these regions bringing chaos and destruction to coastal regions in their path.

winds move north and south during the year.

4 How does the atmospheric circulation system explain the UK's mild, cloudy and wet weather?

5 Draw a sketch to show how atmospheric circulation accounts for the high rainfall at the Equator.

Practice question

Explain how the global atmospheric system affects the weather and climate of the tropics. *(6 marks)*

3.2 Where and how are tropical storms formed?

On this spread you will find out about the distribution and formation of tropical storms

What is a tropical storm?

A tropical storm is a huge storm that develops in the Tropics (image **A**). In the USA and the Caribbean these are called **hurricanes**. In south-east Asia and Australia they are called **cyclones**, but in Japan and the Philippines they are called **typhoons**.

Tropical storms are incredibly powerful and can cause devastation to small islands and coastal regions. Photo **B** shows some of the damage caused by Hurricane Sandy on the east coast of the USA in 2012. It was the costliest and most deadly Atlantic storm of the year, killing 285 people.

A Satellite image of Hurricane Sandy off the coast of Florida, USA, 2012

Where do tropical storms form?

Map **C** shows the distribution of tropical storms. It also provides some useful clues about the formation of tropical storms.

- Tropical storms form over warm oceans (above 27 °C), which explains why they are found in the Tropics.
- They form in the summer and autumn when sea temperatures are at their highest.
- Most tropical storms form 5–15° north and south of the Equator. This is because at the Equator there is not enough 'spin' from the rotation of the Earth. The effect of the Earth's rotation is called the *Coriolis effect*. A tropical storm is a spinning mass of clouds (photo **A**).
- In tropical regions the intense heat makes the air unstable causing it to rise rapidly. These unstable conditions are important in the formation of hurricanes.

B The impact of Hurricane Sandy in Queens, New York

C The distribution of tropical storms

How do tropical storms form?

Scientists are not certain what causes the formation of a hurricane, but it involves the sequence of events shown below.

On reaching land the storm's energy supply (evaporated water) is cut off. Friction with the land slows it down and it begins to weaken. If the storm reaches warm seas after crossing the land, it may pick up strength again.

As the storm is carried across the ocean by the prevailing winds, it continues to gather strength.

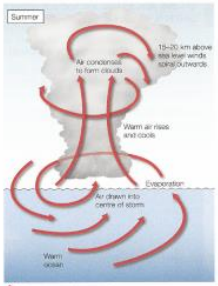
The storm now develops an eye at its centre where air descends rapidly. The outer edge of the eye is the eyewall where the most intense weather conditions (strong winds and heavy rain) are felt.

Several smaller thunderstorms join together to form a giant spinning storm. When surface winds reach an average of 120km per hour (75 miles per hour) the storm officially becomes a tropical storm.

As the air condenses it releases heat which powers the storm and draws up more and more water from the ocean.

This evaporated air cools as it rises and condenses to form towering thunderstorm clouds.

A strong upward movement of air draws water vapour up from the warm ocean surface.



D Formation of a tropical storm

ACTIVITIES

1 a In which part of the world are tropical storms called cyclones?
b During which months are hurricanes most likely to affect the east coast of the USA?
c On average how many cyclones affect Australia each year?
d Which countries are most likely to experience tropical storms during the year?
2 Why do tropical storms not form at the Equator?

Stretch yourself

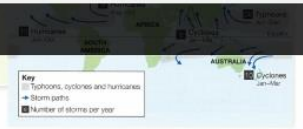
Make a copy of diagram **D** showing how a tropical storm forms. Add detailed labels in the form of a sequence (1, 2, 3, etc.). Describe the formation of a tropical storm.

Practice question

Using map **C** and your own knowledge, describe the global distribution of tropical storms. *(4 marks)*

3.3 The structure and features of tropical storms

conditions are important in the formation of hurricanes.



A strong upward movement of air draws water vapour up from the warm ocean surface.

Practice question

Using map **C** and your own knowledge, describe the global distribution of tropical storms. *(4 marks)*

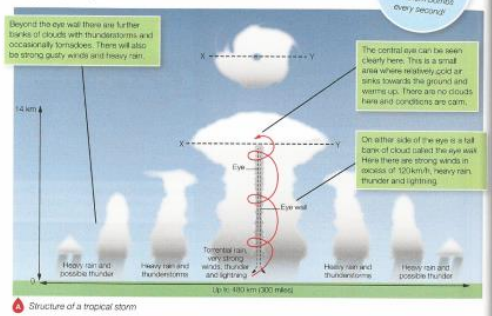
3.3 The structure and features of tropical storms

On this spread you will find out about the structure and features of tropical storms, and how climate change might affect tropical storms in the future.

What is the structure of a tropical storm?

Tropical storms can be huge, up to 480km (300 miles) across. A tropical storm has a roughly symmetrical shape. Diagram **A** shows an imaginary cross-section (X–Y) through a tropical cyclone.

Did you know?
A tropical storm can release the energy of 10 atom bombs every second!



A Structure of a tropical storm

Will climate change affect tropical storms?

There is strong scientific evidence that global temperatures have risen over the last few decades. These rises may be impacting on the world's natural systems. But what impact will they have on tropical storms?

Tropical storm facts

- Tropical storms are the most destructive storms on Earth.
- They are given names for identification. Hurricanes, for example, are given alternating male and female names each 'season'. The first hurricane starts with 'A', the second 'B', and so on. In 2016, the first hurricane will be Alex, then Bonnie, then Colin...
- Hurricane Camille in 1969 had the highest recorded wind speed, estimated at 304 km/h (190mph).

How strong is a hurricane?

Hurricanes are measured using the Saffir-Simpson scale.

Category	Wind speeds
5	> 252 km/h
4	209–251 km/h
3	178–208 km/h
2	154–177 km/h
1	119–153 km/h

Distribution

Over the last few decades sea surface temperatures in the Tropics have increased by 0.25–0.5°C. As patterns of sea surface temperatures change, they may affect the distribution of tropical storms.

In the future, tropical storms may affect areas outside the current hazard zone, such as the South Atlantic and parts of the sub-tropics. Hurricanes may also become more powerful.

Hurricane Catarina (2004)

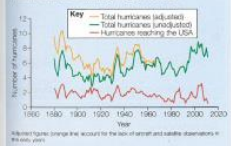
In March 2004, the south-east coast of Brazil was struck by a Category 2 hurricane, the first ever recorded here. Coastal communities were taken by surprise and extensive damage was done. Some people died, 40000 homes were damaged and 85 per cent of the region's banana plants were destroyed.

Hurricanes do not usually form in the South Atlantic (see map **C** on page 24). Cold ocean currents keep waters below the minimum temperature required for hurricane formation. Strong winds 'shear' rising air preventing storms from forming.

In March 2004, sea surface temperatures were unusually high. Conditions were right for a hurricane to form. Such events might become more common as sea surface temperatures change.

Frequency

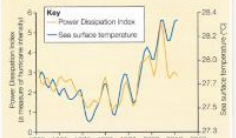
Graph **B** shows the number of hurricanes recorded in the North Atlantic since 1878. Six of the ten most active years since 1950 have happened since the mid-1990s. Some computer models indicate that the frequency of tropical storms may decrease in the future – but, their *intensity* might increase.



B Hurricanes in the North Atlantic, 1878–2013

Intensity

Graph **C** shows hurricane intensity in the North Atlantic has risen in the last 20 years. This appears to be linked to increases in sea surface temperatures. But comparisons with the past may not be completely reliable. More data will be needed over a longer period of time.



C Hurricane intensity in the North Atlantic, 1951–2011

ACTIVITIES

1. Make a copy of diagram **A**. Add labels to describe the main features of a tropical storm.
2. **a** What is the orange line on graph **B** and why is it important?
   b Describe the pattern of hurricanes reaching the USA since 1980.
   c Is there evidence of an overall trend since 1878?
3. Describe and explain the pattern of the Power Dissipation Index between 1950 and 2011 (graph **C**).

Stretch yourself

Carry out some research on Hurricane Catarina. Why did the formation of the storm make it so unusual?

Practice question

Study graph **C**. Has there been an increase in hurricane intensity in recent decades? Support your answer with evidence. *(4 marks)*

3.4 Typhoon Haiyan – a tropical storm

On this spread you will find out about the effects of and responses

What were the responses to Typhoon Haiyan?

- Hurricane Camille in 1969 had the highest recorded wind speed, estimated at 304 km/h (190 mph).

c Is there evidence of an overall trend since 1878?

3 Describe and explain the pattern of the Power Dissipation Index between 1950 and 2011 (graph **C**).

Practice question

Study graphs **C** and **D**. How far does the data support the claim that hurricanes have increased in intensity in recent decades? Support your answer with evidence. *(4 marks)*

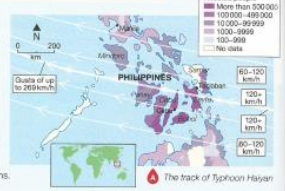
3.4 Typhoon Haiyan – a tropical storm

On this spread you will find out about the effects of and responses to Typhoon Haiyan

Example

Tropical storms can have devastating effects on people and property. The strong winds can tear off roofs, overturn cars and make large objects fly. Torrential rain can lead to flooding. Strong winds and low atmospheric pressure may cause the sea level to rise by several metres to form a destructive storm surge. These storm surges cause the most loss of life.

Tropical storms can be tracked and warnings given for people to evacuate coastal areas. In the aftermath, people need emergency support. Reconstruction may take many months.



A The track of Typhoon Haiyan

What happened?

In November 2013 'Super' Typhoon Haiyan – a category 5 storm on the Saffir-Simpson scale – hit the Philippines (map **A**). Huge areas of coastline and several towns were devastated by winds of up to 275 km/h (170 mph) and waves as high as 15 m (45 ft). It was one of the strongest storms ever recorded.

What were the effects of Typhoon Haiyan?

The province of Leyte took the full force of the storm. The city of Tacloban was one of the worst affected places, with most of the 220 000 inhabitants left homeless.

Most of the destruction in Tacloban was caused by a 5-metre high storm surge. This is a wall of water similar to a tsunami. The very low atmospheric pressure associated with the typhoon caused the level of the sea to rise. As the strong winds swept this water onshore, it formed a wall of water several metres high.

B The destruction at Tacloban

Primary effects (impacts of strong winds, heavy rain and storm surge)

- About 6300 people killed – most drowned by the storm surge.
- Over 600 000 people displaced and 40 000 homes damaged or flattened – 90% of Tacloban city destroyed.
- Tacloban airport terminal badly damaged.
- The typhoon destroyed 30 000 fishing boats.
- Strong winds damaged buildings and power lines and destroyed crops.
- Over 400 mm of rain caused widespread **flooding**.

Secondary effects (longer-term impacts resulting from primary effects)

- 14 million people affected, many left homeless and 6 million people lost their source of income.
- Flooding caused landslides and blocked roads, cutting off aid to remote communities.
- Power supplies in some areas cut off for a month.
- Ferry services and airline flights disrupted for weeks, slowing down aid efforts.
- Shortages of water, food and shelter affected many people, leading to outbreaks of disease.
- Many jobs lost, hospitals were damaged, shops and schools were destroyed, affecting people's livelihoods and education.
- Looting and violence broke out in Tacloban.

What were the responses to Typhoon Haiyan?

Immediate responses

- International government and aid agencies responded quickly with food aid, water and temporary shelters.
- US aircraft carrier *George Washington* and helicopters assisted with search and rescue and delivery of aid.
- Over 1200 evacuation centres were set up to help the homeless.
- UK government sent shelter kits (photo **D**), each one able to provide emergency shelter for a family.
- French, Belgian and Israeli field hospitals set up to help the injured.
- The Philippines Red Cross delivered basic food aid, which included rice, canned food, sugar, salt and cooking oil.

A survivor in Tacloban

Long-term responses

- The UN and countries including the UK, Australia, Japan and the US donated financial aid, supplies and medical support.
- Rebuilding of roads, bridges and airport facilities.
- 'Cash for work' programmes – people paid to help clear debris and rebuild the city.
- Foreign donors, including the US, Australia and the EU, supported new livelihood opportunities.
- Rice farming and fishing quickly re-established. Coconut production – where trees may take five years to bear fruit – will take longer.
- Aid agencies such as Oxfam supported the replacement of fishing boats – a vital source of income.
- Thousands of homes have been built away from areas at risk from flooding.
- More cyclone shelters built to accommodate people evacuated from coastal areas.

D The contents of a Shelter Box

ACTIVITIES

1 Describe the track of the typhoon (map **A**).

2 **a** Why do you think so many buildings were destroyed (photo **B**)?

b What are the challenges facing the authorities in rebuilding this area?

3 **a** Why do you think the man in photo **C** appears happy despite all the destruction around him?

b What are his immediate needs and what are the challenges facing him in the future?

4 Describe the purpose of each of the items in the Shelter Box (photo **D**).

Stretch yourself

How has the city of Tacloban been rebuilt since the disaster struck? What is the situation like now? Is the city in a better position to cope with a future typhoon?

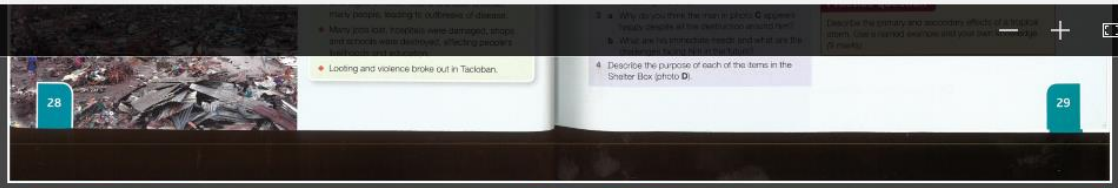
Practice question

Describe the primary and secondary effects of a tropical storm. Use a named example and your own knowledge. *(9 marks)*

3.5 Reducing the effects of tropical storms

On this spread you will find out how the effects of tropical

Planning



28

- Looting and violence broke out in Tacloban.

4 Describe the purpose of each of the items in the Shelter Box (photo **D**).

29

3.5 Reducing the effects of tropical storms

On this spread you will find out how the effects of tropical storms can be reduced

Monitoring and prediction

4 *The predicted track of Typhoon Haiyan*

Map **A** shows the location of Typhoon Haiyan at 11 pm local time on Thursday 7 November 2013. This was just 9 hours before it struck Leyte and flattened most of the city of Tacloban. The map shows the predicted course (track) of the tropical storm across the Philippines. Notice that the area showing the predicted track becomes wider with time. This is because the future track of the tropical storm is uncertain.

Developments in technology have made it possible to predict and monitor tropical storms more accurately and effectively.

In the North Atlantic, there are two levels of warning issued by the National Hurricane Center in Miami:

- Hurricane Watch – advises that hurricane conditions are possible.
- Hurricane Warning – advises that hurricane conditions are expected and that people should take immediate action (e.g. evacuate to high ground or take shelter).

Think about it

Storm surges are often the greatest threat to life and property from a tropical storm. Why do you think this is?

Protection

There are a number of options available to protect people from the hazards associated with tropical storms.

- Windows, doors and roofs reinforced to strengthen buildings to withstand strong winds.
- Storm drains constructed in urban areas to take away excessive amounts of rainfall and prevent flooding.
- Sea walls built to protect key properties from storm surges.
- Houses close to the coast constructed on stilts so that a storm surge will pass beneath.
- In Bangladesh nearly 2000 cyclone shelters have been built (photo **B**).

B *Cyclone shelter in Bangladesh*

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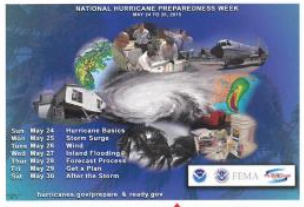
Planning

It is unrealistic to stop the tens of millions of people living and working in coastal areas that are at risk from tropical storms. Many people rely upon fishing or tourism to make a living. Even in rich countries like the USA, vast urban developments have been allowed to take place on vulnerable barrier islands off the coast of Florida, for example Miami Beach. South Miami was hit by a powerful hurricane in 1992. However, building developments have still taken place on land at risk from flooding. It's only a matter of time before Miami gets hit again.



C *National Hurricane Preparedness Week (USA)*

D *Bikes carry cyclone warnings to rural communities in Bangladesh*

Planning to reduce the tropical storm hazard is mostly about raising individual and community awareness. People need to understand the potential dangers and be able to respond. In the USA there is a National Hurricane Preparedness Week (image **C**) which focuses on educating people about potential dangers ahead of the next hurricane season. Families are encouraged to devise their own plan of action should a warning be issued.

Bangladesh – a success story

Early warning systems, cyclone shelters (photo **B**) and greater awareness have helped reduce the death toll from tropical cyclones in Bangladesh. The number of deaths has decreased 100-fold over the past 40 years from 500 000 deaths in 1970 to 4234 in 2007.

Tropical cyclones are tracked by the Bangladesh Meteorological Department. Warnings are issued in several languages by radio, television and via social media. In rural areas, even the most remote communities are reached – sometimes by bike (photo **D**)!

ACTIVITIES

1 a Use map **A** to describe the characteristics of Typhoon Haiyan at 11 pm on Thursday 7 November.

b Describe the direction of the predicted track of the typhoon.

c How many hours was the typhoon expected to take to cross the Philippines?

d Where was the typhoon expected to make landfall after the Philippines?

2 What are the special design features of the cyclone shelter in photo **B** to reduce the impacts of a storm surge?

Stretch yourself

Do some further research about the work of the National Hurricane Center in Miami.

- How are hurricanes forecast and predictions made?
- What advice is given to people who live in vulnerable areas to help them prepare?

Practice question

Explain why planning and being prepared is the best option for reducing the effects of tropical storms. *(4 marks)*

31

3.6 Weather hazards in the UK

On this spread you will find out how the UK is affected by a variety of weather hazards

Strong winds

The UK does occasionally get battered by strong winds. Sometimes the remnants of hurricanes travel over the Atlantic from the USA

- In Bangladesh nearly 2000 cyclone shelters have been built (photo **B**).

B Cyclone shelter in Bangladesh

Built on raised ground

Shelter can be used as a community centre, school or medical centre for most of the year

Practice question

of a storm surge?

3.6 Weather hazards in the UK

On this spread you will find out how the UK is affected by a variety of weather hazards

What are the UK's weather hazards?

The weather is a description of the day-to-day conditions of the atmosphere. We might talk about the temperature, amount of cloud, the strength and direction of the wind or whether it is raining. When we talk about climate, this is the average weather over a long period of time. Data are used over a 30-year period to describe the climate of a place.

Weather hazards are extreme weather events. Even though the UK has a moderate climate, it experiences its share of **extreme weather**. Weather is driven towards the UK by south-westerly prevailing winds. Fuelled by the warm and moist conditions of the Atlantic Ocean, strong winds and heavy rain batter the exposed western areas.

Did you know?
Between 30 and 60 people are struck by lightning in the UK each year. Most people survive!

Thunderstorms

In July 2014 dramatic electrical storms resulted in 3000 lightning strikes across southern Britain following a period of hot weather (photo **A**). Torrential rainfall associated with thunderstorms can result in sudden 'flash' flooding as happened in Boscastle in Cornwall in 2004 (photo **B**).

A *Lightning above Canary Wharf, London, July 2014*

Prolonged rainfall

Persistent rainfall over a long period can lead to river floods. This is common in the UK especially during the late winter and early spring when snowmelt makes the problem worse. During the very wet winter of 2014 flooding was widespread across much of southern England.

Drought and extreme heat

The UK has experienced long spells of dry, hot weather resulting in drought. Rivers can dry up and reservoirs become dangerously low, which affects water supplies and wildlife. Very high temperatures – heatwaves – can be dangerous to frail and elderly people. In 2003 much of Europe suffered the most extreme heatwave for 500 years (photo **C**). Over 20 000 people died, and several countries, including the UK, recorded their highest ever temperatures.

B *Boscastle flash flood, 2004*

Heavy snow and extreme cold

Long periods of severe winter weather have become less common in recent years, but there are occasions when heavy snow and severe cold can cause great hardship to people particularly in the north of the UK.

Strong winds

The UK does occasionally get battered by strong winds. Sometimes the remnants of hurricanes travel over the Atlantic from the USA and Caribbean. These can cause disruption to power supplies and damage from fallen trees. Read about the strong winds that hit the UK in February 2014 (extract **D**).

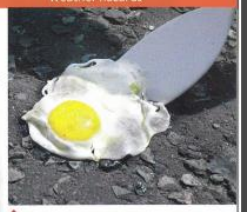
Strong winds bring chaos to UK

There was widespread disruption to road and rail networks, leaving 21 000 people without power, as strong winds continued to batter the UK this week.

Electricity supplies were affected in South Wales, the south-west and the West Midlands. Wind speeds of up to 105 mph were recorded in Aberdaron in north-west Wales, with gusts of 92 mph recorded on the Gower Peninsula, south-west Wales.

The Met Office has warned that coastal areas of the UK could be battered by large waves. Clifton suspension bridge in Bristol was closed briefly for the first time ever because of high winds, and storms have brought down many trees.

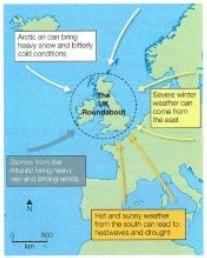
D *News report, February 2014*



C *'Hot enough to fry an egg' – heatwave in 2003*

Why does extreme weather occur in the UK?

The UK is rather like a roundabout (map **E**) because it is at the meeting point of several different types of weather from different directions. This explains why we experience such varied weather from week to week and how occasionally we can be affected by extreme weather events.



E *The UK's weather roundabout*

ACTIVITIES

1. What is the difference between weather and climate?
2. What are the hazards associated with thunderstorms?
3. Use evidence from photo **B** to describe the impacts of the flash flood on the lives of local residents in Boscastle.
4. What is a drought and what impact does it have on the natural world?
5. Read extract **D**. What were the effects of the strong winds in February 2014?

Stretch yourself

The European heatwave of 2003 was a truly extreme weather event.

- How long did the heatwave last and what was the highest temperature?
- What were the impacts of the heatwave on people and the natural world?

Practice question

Describe two types of weather hazard that could affect the UK. *(4 marks)*

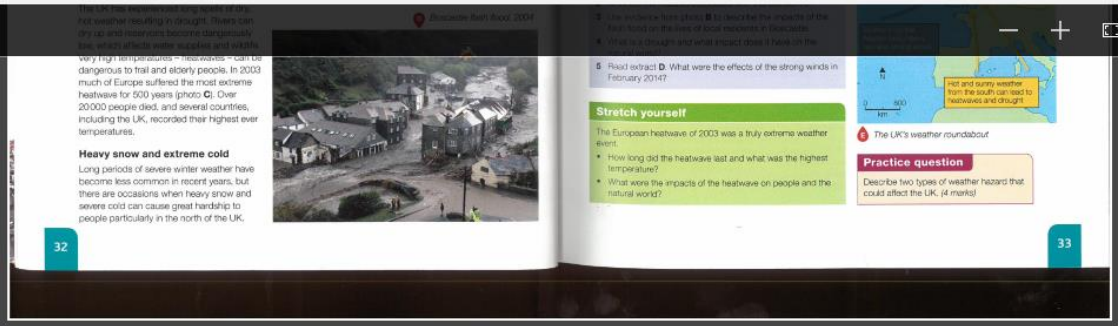
3.7 The Somerset Levels floods, 2014 (1)

On this spread you will find out about flooding on the Somerset Levels in 2014

Where are the Somerset Levels?

Managing the floods

Immediate responses



The UK has experienced long spells of dry, hot weather resulting in drought. Rivers can dry up and reservoirs become dangerously low, affecting water supplies and wildlife. Very high temperatures – heatwaves – can be dangerous to frail and elderly people. In 2003 much of Europe suffered the most extreme heatwave for 500 years (photo **C**). Over 20 000 people died, and several countries, including the UK, recorded their highest ever temperatures.

Heavy snow and extreme cold

Long periods of severe winter weather have become less common in recent years, but there are occasions when heavy snow and severe cold can cause great hardship to people particularly in the north of the UK.

5 Read extract **D**. What were the effects of the strong winds in February 2014?

Stretch yourself

The European heatwave of 2003 was a truly extreme weather event.

- How long did the heatwave last and what was the highest temperature?
- What were the impacts of the heatwave on people and the natural world?

The UK's weather roundabout

Practice question

Describe two types of weather hazard that could affect the UK. *(4 marks)*

Example

3.7 The Somerset Levels floods, 2014 (1)

On this spread you will find out about flooding on the Somerset Levels in 2014

Where are the Somerset Levels?

Somerset is a county in south-west England. The Somerset Levels and the Somerset Moors form an extensive area of low-lying farmland and wetlands bordered by the Bristol Channel and Quantock Hills to the west and the Mendip Hills to the north (map **A**).

The area is drained by several rivers, most notably the Tone and the Parrett, which flow to the Severn Estuary via Bridgwater. Flooding has occurred naturally here for centuries. As the area has been developed for farming and settlement, many people are now at risk from extreme flood events.

The Somerset Levels

What caused the floods in 2014?

There were several factors that led to extensive flooding of the Somerset Levels.

- It was the wettest January since records began in 1910. A succession of depressions (areas of low pressure) driven across the Atlantic Ocean brought a period of wet weather lasting several weeks. About 350 mm of rain fell in January and February, about 100 mm above average.
- High tides and storm surges swept water up the rivers from the Bristol Channel. This prevented fresh water reaching the sea and it spilled over the river banks.
- Rivers had not been dredged for at least 20 years, and had become clogged with sediment.

Rescuing a resident from Moorland

What were the impacts of the flood?

Between December 2013 and February 2014, the Somerset Levels hit the national headlines as the area suffered extensive flooding. It was the most severe flooding ever known in the area.

Social	Economic	Environmental
• Over 600 houses flooded • 16 farms evacuated • Residents evacuated to temporary accommodation for several months • Villages such as Moorland and Muchelney cut off. This affected people's daily lives, e.g. attending school, shopping, etc. • Many people had power supplies cut off	• Somerset County Council estimated the cost of flood damage to be more than £10 million • Over 14 000 ha of agricultural land under water for 3–4 weeks • Over 1000 livestock evacuated • Local roads cut off by floods • Bristol to Taunton railway line closed at Bridgwater	• Floodwaters were heavily contaminated with sewage and other pollutants including oil and chemicals • A huge amount of debris had to be cleared • Stagnant water that had collected for months had to be reorganised before being pumped back into the rivers

The impacts of the Somerset Levels floods

Managing the floods

Immediate responses

As the floodwaters spread out over the Somerset Levels, homeowners coped as best they could. Villagers cut off by the floods used boats to go shopping or attend school. Local community groups and volunteers gave invaluable support.

The village of Burrowbridge almost cut off by the floods

Longer-term responses

A £20 million Flood Action Plan has been launched by Somerset County Council who will work together with agencies such as the Environment Agency to reduce the risk of future flooding.

- In March 2014, 8 km of the Rivers Tone and Parrett were dredged to increase the capacity of the river channel (diagram **E**).
- Road levels have been raised in places to maintain communications and enable businesses to continue during future flood events.
- Vulnerable communities will have flood defences.
- River banks are being raised and strengthened and more pumping stations will be built.
- In the longer term – by 2024 – consideration will be given to a tidal barrage at Bridgwater.

How dredging works

ACTIVITIES

1 Why do you think the Somerset Levels are prone to flooding (map **A**)?

2 What were the factors contributing to the floods in 2014?

3 a Describe the extent of the flooding (photo **D**).

b Several roads were flooded. What impact did this have on local people?

c Suggest the impact of the flooding on farmers in the area.

4 Make a copy of diagram **E**. Add labels to describe how dredging can help reduce the flood risk.

Stretch yourself

Imagine you are a local councillor in Somerset. Analyse research plans to construct a tidal barrage at Bridgwater (they can be found on the internet).

What would this scheme involve and how would it reduce the risk of flooding?

Practice question

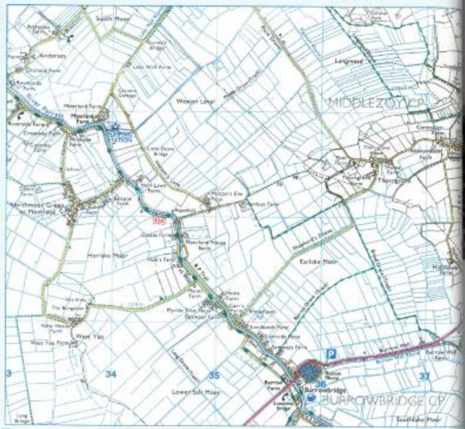
Using table **C**, evaluate the main impacts of the flooding of the Somerset Levels. *(6 marks)*

3.8 The Somerset Levels Floods, 2014 (2)

On this spread you will use a 1:25 000 map to find out about flooding on the Somerset Levels in 2014

Example

Map **A** is a 1:25 000 map extract of the Somerset Levels a few kilometres south-east of the town of Bridgwater. Photo **B** shows flooding in the village of Moorland (also called Northmoor Green: grid reference 3332). The key for OS maps can be found on page 352.



A 1:25 000 map extract of the Somerset Levels

© Crown copyright

B Flooding in Moorland, Somerset (2014)

Practice question

Suggest the likely social, economic and environmental impacts of the flooding. Use evidence from photo **B** to support your answer. *(4 marks)*

Think about it

How can maps help you to interpret aerial photographs?

ACTIVITIES

1 Use map **A** to answer the following questions.
  a What is the evidence from the map that this area is very flat and low-lying?
  b What is the name of the main river?
  c Why do you think the area has hundreds of drainage ditches?
  d What is the six-figure grid reference of the pumping station?
  e Why do you think there is a pumping station at this location?
  f In what direction is Burrowbridge from the pumping station?
  g To the nearest 100 m, what is the straight line distance from the pumping station to the bridge over the river at Burrowbridge (grid reference 357304)?
  h What is the evidence that most of this area is farmland?
  i Use evidence from the map to suggest why Moorland is at risk from flooding.

2 Photo **B** shows part of the flooded village of Moorland. Locate the church at the bottom left of the photo. Now locate the church on map **A**. It is at the road junction in the centre of the village.
  a What is the six-figure grid reference of the church?
  b In what direction is the photo looking?
  c What is the name of the farm at the top left of the photo?
  d What has been done to try to stop this property from flooding?
  e Describe the extent of flooding in the photo.

3.9 Extreme weather in the UK

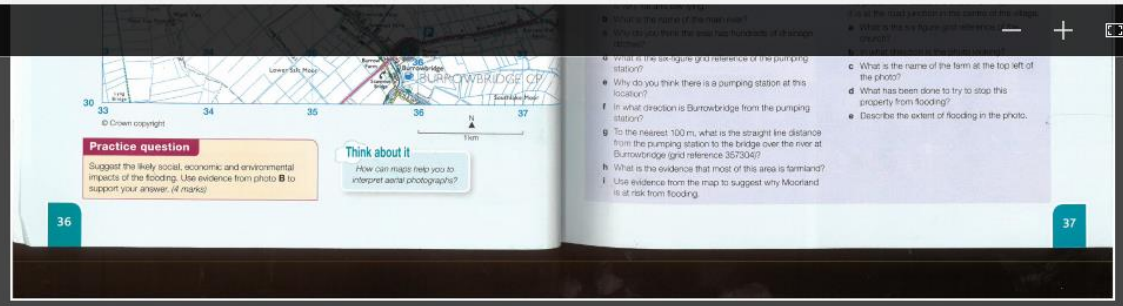
On this spread you will find out if the UK's weather is becoming more extreme

What is the evidence?

2009 Floods

Why might extreme weather events be on the increase?

Recent extreme weather events have also occurred elsewhere in the world. There have been devastating floods in Pakistan (2010), intense heatwaves in Russia (2010) and severe



Practice question

Suggest the likely social, economic and environmental impacts of the flooding. Use evidence from photo **B** to support your answer. *(4 marks)*

Think about it

How can maps help you to interpret aerial photographs?

- What is the name of the main river?
- Why do you think the area has hundreds of shingle pits?
- What is the six-figure grid reference of the pumping station?
- Why do you think there is a pumping station at this location?
- In what direction is Burrowbridge from the pumping station?
- To the nearest 100 m, what is the straight line distance from the pumping station to the bridge over the river at Burrowbridge (grid reference 3573040)?
- What is the evidence that most of this area is farmland?
- Use evidence from the map to suggest why Moorland is at risk from flooding.
- What is the name of the farm at the top left of the photo?
- What has been done to try to stop this property from flooding?
- Describe the extent of flooding in the photo.

3.9 Extreme weather in the UK

On this spread you will find out if the UK's weather is becoming more extreme

What is the evidence?

There have been many extreme weather events in the UK throughout history. However, scientists have noticed that these events seem to be occurring more frequently than in the past. Look at the diagram below to read about extreme weather events in the UK since 2000.

2003 Heatwave
The UK recorded its highest ever temperature of 38.5°C in Kent. Over 2000 people died due to the heat, railway tracks buckled and in places the roads melted!

2009 Heavy snow
Parts of south-west and south-east England were affected by heavy snow with 20cm falling in the capital.

2009 Floods
The town of Cockermouth in Cumbria was devastated by floods. Record rainfall amounts fell in November in the Lake District.

2010 Heavy snow
Much of the UK was hit by heavy snowfalls in December. Northern Ireland recorded a record low temperature of –18.7°C at Castlederg.

2007 Floods
Several people died and many were left homeless by summer floods affecting Hull, Sheffield and Gloucestershire.

2008 Floods
Severe flooding occurred in south-west and north-east England with Somerset, Worcestershire and Northumberland badly hit.

2013/14 Floods
Severe flooding occurred across southern England causing the River Thames to burst its banks and vast areas of the Somerset Levels to become inundated. It was England's wettest winter in 250 years.

2015/16 Floods
Severe storms and exceptionally heavy rainfall caused devastating floods to many areas, especially the north of England. Yorkshire and Cumbria (photo **C**) were badly affected. December 2015 was the wettest and warmest month ever recorded in the UK.

Trafalgar Square during the heatwave of 2003

Snow causes traffic chaos in 2010

Why might extreme weather events be on the increase?

Recent extreme weather events have also occurred elsewhere in the world. There have been devastating floods in Pakistan (2010), intense heatwaves in Russia (2010) and severe droughts in western USA (2014).

No single extreme weather event can be blamed on climate change. However, scientists believe that a trend over many years could be linked to a warming world.

- More energy in the atmosphere could lead to more intense storms.
- The atmospheric circulation (see page 22) may be affected, bringing floods to normally dry regions and heatwaves to normally cooler areas.

In 2011 the Intergovernmental Panel on Climate Change concluded that extreme weather would become more common as global warming heats the planet.

Floods in Carlisle, 2015

Could our weather patterns be getting 'stuck'?

Weather systems cross the UK mainly from west to east, driven by winds from the *jet stream*. The jet stream moves north and south but can 'stick' in one position, resulting in a long period of the same type of weather, such as heavy rain or drought. A large area of high pressure over Northern Europe can block the easterly movement of weather systems and have a similar effect on UK weather.

In 2014 scientists in Germany published a report. It suggested that in recent years weather patterns have become 'stuck' for long periods of time. This has resulted in prolonged periods of high temperatures (heatwaves and droughts) and heavy rain (floods).

These periods seem to have become more frequent in recent years and this could be due to climate change. A warming Arctic, for example, may slow down the atmospheric circulation in the northern hemisphere mid-latitudes resulting in the weather 'sticking' for long periods of time. This could explain the recent heatwaves and floods.

The Intergovernmental Panel on Climate Change, 2014

Stretch yourself

Imagine you're a journalist writing an article about extreme weather in the UK since January 2014.

- What happened and what were the impacts?
- How have these events – along with the others since 2000 – been linked with climate change?

ACTIVITIES

1. Draw a timeline to describe the extreme weather events in the UK since 2000. Use text boxes to describe the impacts of the events and illustrate your timeline using photos. Add any recent events.
2. What UK weather records have been broken by extreme weather events since 2000?
3. Newspapers sometimes blame an individual extreme weather event on climate change. Why is this misleading?

Practice question

Suggest why the UK's weather might be becoming more extreme. *(4 marks)*

4 Climate change

4.1 What is the evidence for climate change?

On this spread you will consider the evidence for climate change from the beginning of the Quaternary period to the present day

It's not as cold as it used to be!

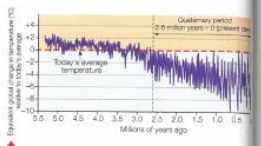
Graph **A** shows the pattern of global temperatures for the last 5.5 million years. This may sound like a long time but remember that the Earth was formed 4600 million years ago!

The graph shows how temperature has changed over time (purple line) compared to today's average temperature (shown by the dashed line at 0). The last 2.6 million years is called the *Quaternary period*. During this geological period temperatures have fluctuated a great deal. Despite these fluctuations the graph shows there has been a gradual cooling during this period.

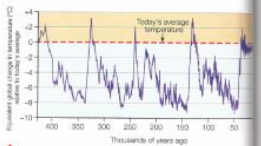
In Graph **B** the downward cold 'spikes' are *glacial periods* when ice covered parts of Europe and North America. The warmer periods in between are called *inter-glacial periods*. Notice that today's average temperature is higher than during almost all of the last 400 000 years.

Graph **C** shows that in the last few decades the average global temperature has increased relative to the 1901–2000 average. This has become known as 'global warming', the most recent indication of climate change.

Since 1880 the average global temperature has risen by 0.85 °C. Most of this increase has occurred since the mid-1970s.



A *Average global temperatures for the last 5.5 million years using information from sediment cores*

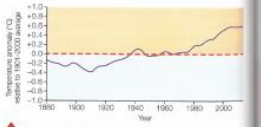


B *Alternating cold (glacial) and warm (interglacial) periods experienced over the last 400 000 years*

Global effects of climate change

Climate change has already had significant effects on global ecosystems and on people's lives.

- Many of the world's glaciers and ice caps are shrinking.
- Arctic sea ice is less extensive than in the past, affecting wildlife such as polar bears (pages 78–9). However, this may provide opportunities for ships to use the North West Passage in the future.
- Low-lying islands such as the Maldives and Tuvalu are under threat from sea-level rise.
- Sea levels may rise by 1 m by 2100 flooding agricultural land in Bangladesh, Vietnam, India and China.



C *Average global temperature (1880–2013) based on recorded temperature records*

Key
Warmer than today
Cooler than today

What is the evidence for climate change?

Temperature is measured directly using an instrument called a thermometer. Reliable measurements using thermometers go back only about a hundred years. In the UK, for example, reliable weather records began in 1910. So, how do we know what temperatures were in the distant past?

Without the use of thermometers, scientists use indirect data stored as a fossil record. These are found in deep ocean sediments and frozen ice cores.

When layers of sediment or fresh falls of snow become buried they trap and preserve evidence of the global temperature at that time. Scientists can study the oxygen in ocean sediments or water molecules in ice to calculate temperature. They can be accurately dated and this information used to plot graphs such as graphs **A** and **B**. Ice cores have been used to reconstruct temperature patterns from as long as 400 000 years ago (photo **D**).

D *Extracting ice cores from the Antarctic ice sheet*

Things are heating up!

Direct measurements of temperature using thermometers have indicated a clear warming trend (graph **C**). There is other evidence that climate change is taking place.

Shrinking glaciers and melting ice

Glaciers throughout the world are shrinking and retreating. It is estimated that some may disappear completely by 2035. Arctic sea ice has thinned by 65 per cent since 1975 and in 2014 its extent was at an all-time low (photo **E**).

What is the recent evidence for climate change?

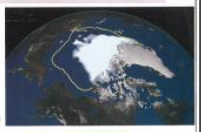
Rising sea level

According to the Intergovernmental Panel on Climate Change (IPCC), the average global sea level has risen between 10 and 20 cm 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.

Seasonal changes

Studies have suggested that the timing of natural seasonal activities such as tree flowering and bird migration is advancing. A study of bird nesting in the mid-1990s discovered that 65 species nested an average of 9 days earlier than in the 1970s. Could this be evidence of a warming world?



E *Shrinkage of Arctic sea ice, 1979–2012 (yellow line indicates extent in 1979)*

ACTIVITIES

1 Describe the pattern of temperatures during the Quaternary period (graphs **A** and **B**).
2 a Describe the trend of the average temperature between 1880 and 1940 (graph **C**).
b Describe the trend in average temperature since 2000.
c Do you think this graph provides strong evidence for global warming?
3 Briefly describe how ice cores provide scientists with data about past temperatures.

Stretch yourself

Research the shrinking of the world's glaciers and how this is providing evidence of climate change. Find images to show the changes that have taken place in the last few decades. What impact might the melting of glaciers have on people's lives?

Practice question

Study photo **E**. Explain how the shrinkage of Arctic sea ice could be evidence of climate change. (4 marks)

4.2 What are the natural causes of climate change?

On this spread you will find out about the natural causes of climate change

Natural causes of climate change

Scientists believe that there are several natural causes for climate change. These include:

- changes in the Earth's orbit

- When sunspot activity is at a *maximum*, the Sun gives off more heat. Large explosions occur on the surface of the sun resulting in solar flares.
- When sunspot activity is at a *minimum* the solar output is reduced. This can lead to lower temperatures

4.2 What are the natural causes of climate change?

On this spread you will find out about the natural causes of climate change

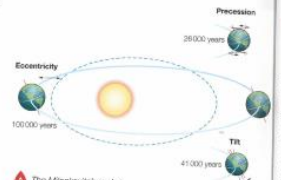
Natural causes of climate change

Scientists believe that there are several natural causes for climate change. These include:

- changes in the Earth's orbit
- variations in heat output from the Sun
- volcanic activity.

Orbital changes

Milutin Milankovitch was a Serbian geophysicist and astronomer. Whilst he was imprisoned during the First World War (1914–18) he studied the Earth's orbit and identified three distinct cycles that he believed affected the world's climate. These are known as *Milankovitch cycles* (diagram **A**).



A *The Milankovitch cycles*

Scientists believe that these cycles affect the timings and seasons of the Earth's climate. In particular, the 100 000-year eccentricity cycle coincides closely with the alternating cold (glacial) and warm (inter-glacial) periods in the Quaternary period.

Eccentricity
This describes the path of the Earth as it orbits the Sun. The Earth's orbit is not fixed – it changes from being almost circular to being mildly elliptical. A complete cycle – from circular to elliptical and back to circular again – occurs about every 100 000 years.

Axial tilt
The Earth spins on its axis, causing night and day. The Earth's axis is currently tilted at an angle of 23.5 degrees. However, over a period of about 41 000 years, the tilt of the Earth's axis moves back and forth between two extremes – 21.5 degrees and 24.5 degrees. You can see this on diagram **A**.

The Milankovitch cycles

Precession
This describes a natural 'wobble' rather like a spinning top. A complete wobble cycle takes about 26 000 years. The Earth's wobble accounts for certain regions of the world – such as northern Norway – experiencing very long days and very long nights at certain times of the year.

Solar activity

Scientists have identified cyclical changes in solar energy output linked to the presence of *sunspots*. A sunspot is a dark patch that appears from time to time on the surface of the Sun (photo **B**). The number of sunspots increases from a minimum to a maximum and then back to a minimum over a period of about 11 years. This 11-year period is called the *sunspot cycle*.

B *Sunspot and solar flare on the surface of the Sun, 2014*

- When sunspot activity is at a *maximum*, the Sun gives off more heat. Large explosions occur on the surface of the sun resulting in solar flares.
- When sunspot activity is at a *minimum* the solar output is reduced. This can lead to lower temperatures on Earth.

For example, very few sunspots were observed between the years 1645 and 1715. This coincided with the coldest period during the so-called 'Little Ice Age', when Europe experienced a much colder climate with severe winters (image **C**).

C *A 'Frost Fair' on the River Thames during the 'Little Ice Age'*

Volcanic activity

Violent volcanic eruptions blast huge quantities of ash, gases and liquids into the atmosphere.

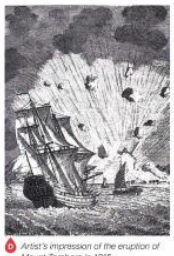
- Volcanic ash can block out the Sun, reducing temperatures on the Earth. This tends to be a short-term impact.
- The fine droplets that result from the conversion of sulphur dioxide to sulphuric acid act like tiny mirrors reflecting radiation from the Sun. This can last a lot longer and can affect the climate for many years.

The cooling of the lower atmosphere and reduction of surface temperatures is called a *volcanic winter*.

Eruption of Mount Tambora, 1815

In 1815 there was a massive volcanic eruption of Mount Tambora in Indonesia (image **D**). It was the most powerful eruption in the world for 1600 years! Ash and sulphuric acid caused average global temperatures to fall by 0.4 °C–0.7 °C and 1816 became known as 'The year without a summer'.

Across the world harvests failed. There were major food shortages throughout North America and Western Europe, including the UK. Food prices rose sharply and there were riots and looting in European cities. It was the worst famine in Europe in the nineteenth century, resulting in an estimated 200 000 deaths.



D *Artist's impression of the eruption of Mount Tambora in 1815*

ACTIVITIES

1 Use diagram **A** to answer the following questions.
   - **a** Which of the Milankovich cycles takes 41 000 years to complete?
   - **b** Explain the eccentricity cycle.
   - **c** What is the evidence that the eccentricity cycle has affected global climates?
   - **d** Describe the precession cycle.

2 Describe how sunspot activity can have an effect on global climates.

Stretch yourself

Carry out some research about 1816, 'The year without a summer'. Find more information about the impacts of the eruption of Mount Tambora. Could this happen again in the future?

Practice question

Use the example of Mount Tambora to explain how and why volcanic activity can affect global climate. (4 marks)

4.3 What are the human causes of climate change?

On this spread you will find out about the human causes of climate change

Human causes of climate change

Many scientists believe that human activities are at least partly to blame for the rapid rise in temperatures – known as global warming – since the 1970s. To understand how this is possible you need to understand a bit of the science of the atmosphere.

Think about it

Think about your own **carbon footprint**. How do you as an individual contribute to the production of greenhouse gases in your everyday life?

The human impact

In recent years, the amounts of greenhouse gases in the atmosphere have increased. Scientists believe that this is due to human activities (diagram **C**).

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Mr E Stevenson

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Solar activity

Scientists have identified cycles of change in solar energy output linked to the presence of *sunspots*. A sunspot is a dark patch that appears from time to time on the surface of the Sun (photo **B**). The number of sunspots increases from a minimum to a maximum and then back to a minimum over a period of about 11 years. This 11-year period is called the *sunspot cycle*.

ACTIVITIES

1 Use diagram **A** to answer the following questions.
- **a** Which of the Milankovich cycles takes 41 000 years to complete?
- **b** Explain the eccentricity cycle.
- **c** What is the evidence that the eccentricity cycle has affected global climates?
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of the eruption of Mount Tambora. Could this happen again in the future?

Practice question

Use the example of Mount Tambora to explain how and why volcanic activity can affect global climate. *(4 marks)*

4.3 What are the human causes of climate change?

On this spread you will find out about the human causes of climate change

Human causes of climate change

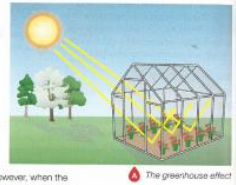
Many scientists believe that human activities are at least partly to blame for the rapid rise in temperatures – known as global warming – since the 1970s. To understand how this is possible you need to understand a natural feature of the atmosphere called the *greenhouse effect*.

Think about it

Think about your own ***carbon footprint****. How do you as an individual contribute to the production of greenhouse gases in your everyday life?*

What is the greenhouse effect?

You probably know that a greenhouse is a small building entirely made of glass and used by gardeners to create warm conditions to grow plants. So how does it work?

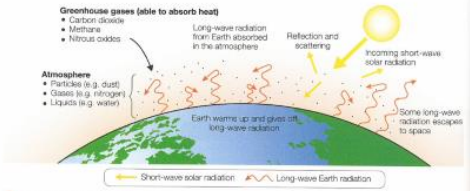


The greenhouse effect

Glass allows radiation (heat) from the Sun to enter the greenhouse (diagram **A**). However, this heat cannot escape through the glass. As a result, the greenhouse becomes warmer than the air outside and is ideal for growing tomatoes and vegetables which need constant warm conditions.

Like a greenhouse, the atmosphere allows most of the heat from the Sun (short-wave radiation) to pass straight through it to warm up the Earth's surface (diagram **B**). However, when the Earth gives off heat in the form of long-wave radiation, some gases such as carbon dioxide (CO_2) and methane are able to absorb it. These gases are called *greenhouse gases*.

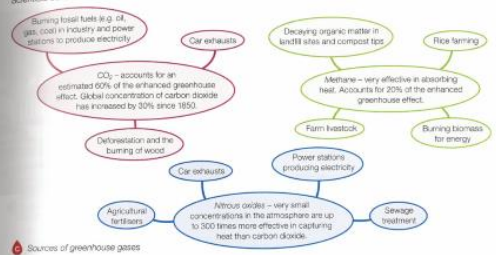
In the same way that glass traps heat inside a greenhouse, the greenhouse effect keeps the Earth warm. Without this 'blanketing' effect it would be far too cold for life to exist on Earth.



How the greenhouse effect works

The human impact

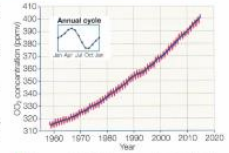
In recent years, the amounts of greenhouse gases in the atmosphere have increased. Scientists believe that this is due to human activities (diagram **C**).



Sources of greenhouse gases

Graph **D** shows the recorded changes in carbon dioxide since the 1960s. The trend of this graph is identical to that of average global temperatures. Many scientists believe that this provides clear evidence that human activities are affecting global climates.

It is the increased effectiveness of the greenhouse effect – the so-called *enhanced greenhouse effect* – that scientists believe is causing recent global warming. For the first time in history, human activities appear to be affecting the atmosphere with potentially dramatic effects on the world's climate. By the end of the century average global temperatures could rise by 1.8–4 °C. This could lead to a rise in sea level of 28–43 cm.



Increase in CO_2 obtained from direct readings at the Mauna Loa Observatory, Hawaii

ACTIVITIES

1 Make a large copy of diagram **B**. Add the main sources of greenhouse gases (diagram **C**) using simple sketches.

2
- **a** Describe the trend of CO_2 concentration in the atmosphere (graph **D**).
- **b** Can you suggest why CO_2 in the atmosphere increases in the winter but decreases in the summer? (Hint: think about plants.)
- **c** Does the graph support the suggestion that human activities may be contributing to global warming? Explain your answer.

3 Explain the enhanced greenhouse effect.

Stretch yourself

Research more information about the sources of greenhouse gases resulting from human activities. Focus your research on carbon emissions and find out which countries are the highest contributors.

Practice question

Outline two reasons why human activities effect the concentration of CO_2 in the atmosphere. *(4 marks)*

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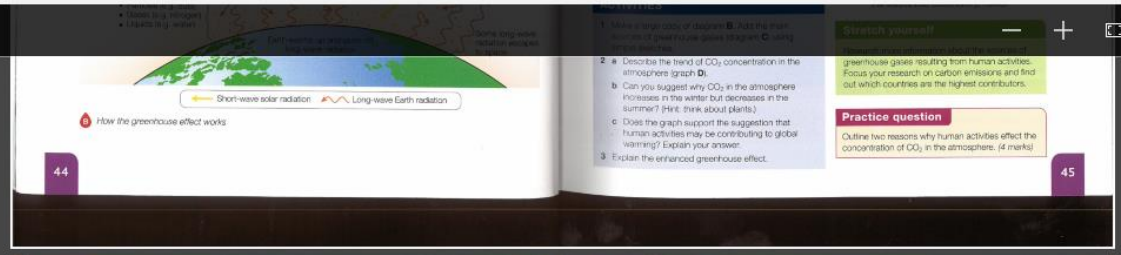

A How the greenhouse effect works

2 a Describe the trend of CO_2 concentration in the atmosphere (graph **D**).
b Can you suggest why CO_2 in the atmosphere increases in the winter but decreases in the summer? (Hint: think about plants.)
c Does the graph support the suggestion that human activities may be contributing to global warming? Explain your answer.
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Stretch yourself

Research your presentation about the sources of greenhouse gases resulting from human activities. Focus your research on carbon emissions and find out which countries are the highest contributors.

Practice question

Outline two reasons why human activities effect the concentration of CO_2 in the atmosphere. *(4 marks)*

4.4 Managing the impacts of climate change (1)

On this spread you will find out how the causes of climate change can be managed (mitigated)

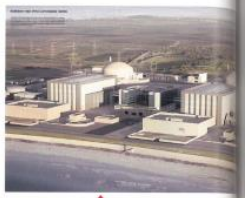
How can climate change be managed?

Alternative energy sources

The burning of **fossil fuels** (coal, oil and gas) to produce electricity, fuel vehicles and power industry contributes 87 per cent of all human-produced CO_2 emissions. The rest comes from land use changes – mostly deforestation (9 per cent) and industrial processes like making cement (4 per cent).

To help reduce carbon emissions many countries are turning to alternative sources of energy such as:

- hydro-electricity
- nuclear power
- solar, wind, and tides.



A Artist's impression of the new Hinkley Point nuclear reactor

These do not emit large amounts of CO_2. Some are also renewable and will last into the future. Nuclear power uses uranium to generate electricity but does not emit CO_2 as a by-product.

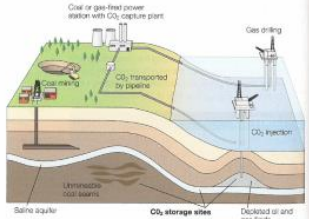
The UK aims to produce 15 per cent of its energy from renewable sources by 2020. There has been investment in renewable energy projects like wind power. Power companies are encouraged to use renewable sources. A new nuclear reactor is being built at Hinkley Point in Somerset (photo **A**).

Carbon capture

Coal is the most polluting of all fossil fuels. China gets 80 per cent of its electricity from burning coal, India 70 per cent and the USA 50 per cent. How can coal continue to be used in a less damaging way?

Carbon capture and storage (CCS) uses technology to capture CO_2 produced from the use of fossil fuels in electricity generation and industrial processes. It is possible to capture up to 90 per cent of the CO_2 that would otherwise enter the atmosphere.

Diagram **B** shows how carbon capture works. Once captured, the carbon gas is compressed and transported by pipeline to an injection well. It is injected as a liquid into the ground to be stored in suitable geological reservoirs.



B Carbon capture and storage

Planting trees

Trees act as carbon sinks, removing CO_2 from the atmosphere by the process of photosynthesis. They also release moisture into the atmosphere. This has a cooling effect by producing more cloud, reducing incoming solar radiation.

Tree planting is well established in many parts of the world. Plantation forests can absorb CO_2 at a faster rate than natural forests and can do so effectively for up to 50 years.

International agreements

Climate change is a global issue and requires global solutions. Carbon emissions spread across the world and affect everyone (figure **C**).

C Global impacts of climate change

2005 The Kyoto Protocol – the first international treaty – became law. Over 170 countries agreed to reduce carbon emissions by an average of 5.2 per cent below their 1990 levels by 2012. Of the major greenhouse gas emitters, only the USA and Australia refused to sign the treaty.

2009 World leaders met in Copenhagen to consider international agreements on tackling climate change beyond 2012. The outcome was the Copenhagen Accord. It pledged to reduce emissions with financial support for developing nations to help them cope with the impacts of climate change. But there was no legally binding agreement.

2015 Paris Agreement 2015 – 195 countries adopted the first ever universal and legally binding global climate deal.

- To peak greenhouse gas emissions as soon as possible and achieve a balance between sources and sinks of greenhouse gases in the second half of this century.
- To keep global temperature increase below 2°C and limited to 1.5°C above pre-industrial levels.
- To review progress every five years.
- US$100 billion a year to support climate change initiatives in developing countries by 2020, with further finance in the future.

There have been criticisms that many of these agreements are 'promises' or aims and not firm commitments.

ACTIVITIES

1 How can alternative sources of energy address the problem of carbon dioxide emissions?
2 Make a copy of diagram **B**. Use detailed annotations to describe how carbon capture and storage works.
3 Why are forests described as 'carbon sinks'?
4 Do you think international agreements will help to solve the problems associated with climate change? Explain your answer.

Stretch yourself

Find out more about carbon capture and storage.

- What are the benefits of this mitigation option?
- What problems and issues need to be overcome for it to be widely used in the future?

Maths skills

Draw a pie chart to show changes to human-produced CO_2 emissions burning fossil fuels, and use and industrial processes. (Don't forget to multiply the percentages by 3.6 to convert them into degrees.)

Practice question

'International agreements are critical in the challenge to reduce global carbon emissions.' Use evidence to support this statement. *(6 marks)*

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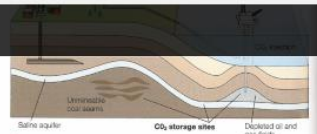


B *Carbon capture and storage*

3 Why are forests described as 'carbon sinks'?

4 Do you think international agreements will help to solve the problems associated with climate change? Explain your answer.

- What problems and issues need to be overcome for it to be widely used in the future?

Maths skills

Draw a pie chart to show changes to human-produced CO_2 emissions: burning fossil fuels, land use and industrial processes. (Don't forget to multiply the percentages by 3.6 to convert them into degrees.)

Practice question

'International agreements are critical in the challenge to reduce global carbon emissions.' Use evidence to support this statement. *(6 marks)*

4.5 Managing the impacts of climate change (2)

On this spread you will find out how climate change can be managed by adapting to changes

How can we adapt to climate change?

Scientists believe that climate change will have a huge impact on agricultural systems across the world.

- Patterns of rainfall and temperature will change.
- Extreme weather events such as heatwaves, droughts and floods will become more common.
- The distribution of pests and diseases will change.

Farmers will need to adapt to these changes.

Agricultural adaptation in low latitudes

Scientists think that the greatest changes to agriculture will occur in low latitudes. Southern Africa's maize crop could fall by 30 per cent by 2030 and the production of rice in South Asia could fall by 10 per cent.

There are several adaptations that can be made (photo **A**).

Agricultural adaptation in middle latitudes

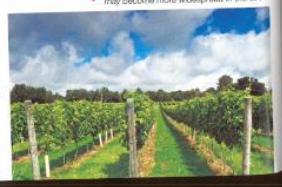
A warmer climate in Europe and North America could lead to an increase in production of certain crops such as wheat. In the UK, Mediterranean crops such as vines (photo **B**) and olives may thrive.

A *Irrigating crops in the Gambia*

B *Vineyards such as this one in West Sussex may become more widespread in the UK*

Managing water supply

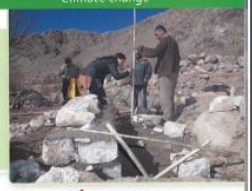
Climate change is already causing more severe and more frequent droughts and floods. Unreliable rainfall and periods of water shortage require careful management. Future climate change will affect the current patterns of water supply, impacting on the quantity and quality of our water. It is the most vulnerable, particularly in rural parts of poorer countries, who are likely to be affected the most.



Managing water supply in the Himalayas

Millions of people in Asia depend on rivers fed by snow and glacial melt for their domestic and agricultural water supply. In the Himalayas most of the 16000 glaciers are receding rapidly due to global warming. This threatens the long-term security of water supply in the region.

Photo **C** shows an artificial glacier project that will supply water to villages in Ladakh, India. Water is collected in winter through a system of diversion canals and embankments and it freezes. When the 'glacier' melts in spring it will provide water for the local villages.



C *Creating artificial glaciers to provide water for villages*

Reducing risk from rising sea levels

Did you know that average sea levels have risen by 20 cm since 1900? By 2100 sea levels are expected to rise by a further 26–82 cm. This will flood important agricultural land in countries such as Bangladesh, India and Vietnam.

As sea levels rise, rates of coastal erosion will increase. Fresh water supplies will become contaminated by saltwater and coastal areas will be prone to damage from storm surges.

Managing rising sea levels in the Maldives

The Maldives are a group of tiny islands in the Indian Ocean some 500 km south-west of India. The highest point on the islands is just 2.4 m. Some climate models suggest that the islands may be uninhabitable by 2030 and submerged by 2070.

The 380 000 inhabitants have a very uncertain future as sea levels rise.

D *How can the Maldives manage sea-level rise?*

ACTIVITIES

1 How can farmers adapt to the possible impacts of climate change?

2 a What do you think the people in photo **C** are doing?

b How does this system of water harvesting work?

c Why is it important that local communities in remote areas start taking action to secure their water supply?

3 How might rising sea levels affect coastal communities?

4 How is the Maldives managing sea-level rise?

Stretch yourself

Research more information about water harvesting techniques. Find out, for example, how water droplets in fog can be harvested from the air to support people living in the Atacama Desert in Chile.

Practice question

Choose either the risk of reduced water supply or rising sea levels. For the issue chosen, describe examples of strategies used to manage them. *(6 marks)*