

# Weather and Climate Change

## Climate Change

See accompanying 'climate change' videos in Glow:  
<http://tinyurl.com/z58jz7g>



## Climate change

Climate change offers an ideal context for learning within Curriculum for Excellence, providing many opportunities to develop children and young people as global citizens and deliver experiences and outcomes across many curriculum areas.

Since the start of the Industrial Revolution in the late 1800s, enormous quantities of manmade greenhouse gases have been pumped into the atmosphere. Experts believe that the carbon dioxide released when fossil fuels burn has caused our world to heat up and has caused our climate to change.

### Impact

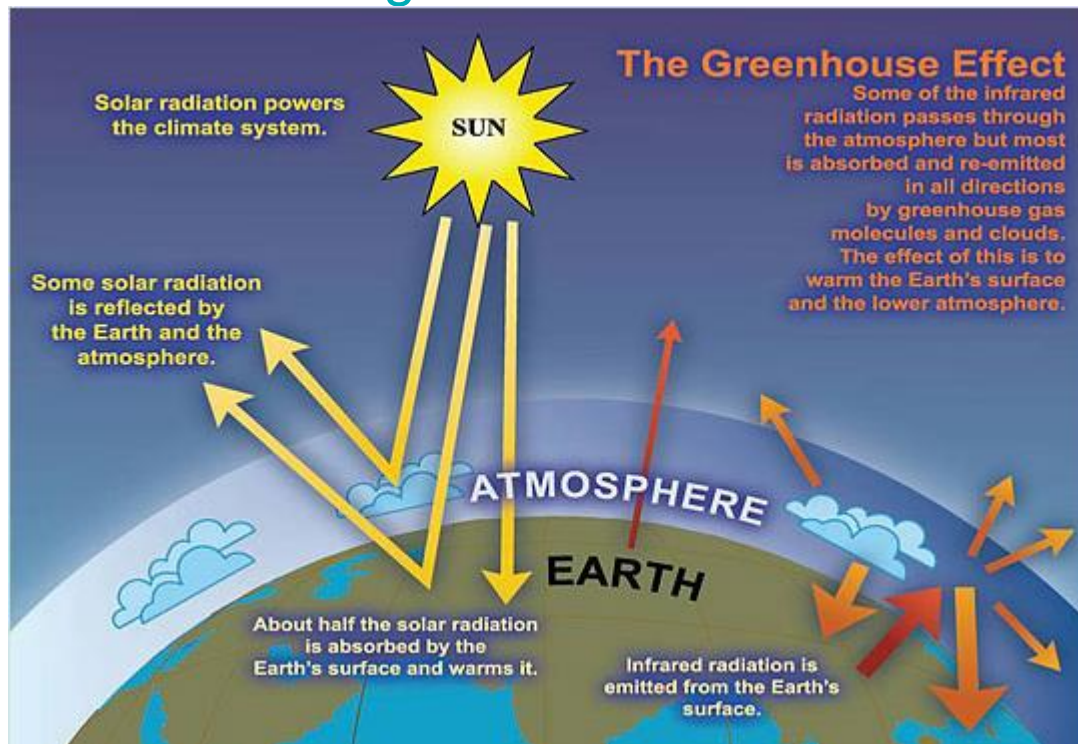
Now, in the 21st century, many believe that climate change is one of the biggest challenges facing the global community. In some parts of the world, we can already see changes taking place. Glaciers and polar ice are melting rapidly and experts say there will be more flooding in low-lying areas as sea levels rise. Other parts of the world are being hit by droughts and heat waves which may also be linked to changes in the climate. Experts believe that the things that are happening are just a sign of bigger changes to come should the Earth's average temperature rise further.

### Reflective questions

- How can we build upon the existing knowledge and awareness of learners relating to climate change?
- How can we use climate change to develop in learners a curiosity about and an understanding of the environment and their place in the living, material and physical world?
- How can we use climate change to embed global citizenship and sustainable development education themes within learning and teaching?

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# Global warming



## Natural greenhouse effect

The Earth's atmosphere acts like a blanket, keeping the surface of our world much warmer than it would otherwise be. This is called the natural greenhouse effect. This is how it works:

- The sun's rays contain a broad spectrum of light. This passes through the Earth's atmosphere but some is reflected back into space by clouds and the surface of the Earth.
- The amount of the sun's radiation reflected back into space largely depends on the nature of the surface and cloud cover - for example, a snow-covered surface will reflect back much more of the energy from the sun. This reflectivity is called the Earth's albedo.
- Some of the sun's energy is absorbed by the Earth. This warms the surface of the Earth and consequently the atmosphere.
- The Earth's surface then emits infrared radiation which radiates back towards space. A portion of these infrared rays are trapped by the greenhouse gases - heating up our atmosphere and warming Planet Earth.

In equilibrium, the natural greenhouse effect maintains the average temperature of the Earth at about 14°C. It is worth noting that without the natural greenhouse gases the Earth's surface would be a very cold -18°C!

## Reflective question

- How can we enable learners to recognise the impact the sciences make on their life, the lives of others, the environment and society?

## Enhanced greenhouse effect

About 1% of the Earth's atmosphere is made up of naturally occurring greenhouse gases. Before the Industrial Revolution started 200 years ago the mix of gases in the atmosphere remained fairly constant.

However, since the Industrial Revolution we have pumped out enormous quantities of greenhouse gases into the atmosphere, disturbing the natural balance and creating what is called the enhanced greenhouse effect. These greenhouse gases include: carbon dioxide, methane, nitrous oxide, chloroflourocarbons (CFCs) and water vapour.



Many scientists believe that the enhanced greenhouse effect is causing the average temperature of the Earth to rise dramatically. It is hard to predict how much temperatures will rise by as this depends on many factors - including how quickly the global community takes action. However, estimates from mathematical modelling techniques indicate that we can expect between a 1°C and 6°C rise in the average temperature of the Earth by 2100.

### Reflective questions

- How can the study of the enhanced greenhouse effect be used to develop in learners an understanding of the Earth's resources and the need to use them responsibly?
- How can we use climate change as a theme to develop learners as scientifically literate citizens with a lifelong interest in the sciences?



# Atmosphere

Scientists working in Greenland and the Antarctic are able to investigate and measure past concentrations of carbon dioxide and other greenhouse gases in the Earth's atmosphere by drilling down hundreds of metres into the ice.

These ice cores contain tiny bubbles of air which were trapped when the ice was formed. The age of these samples is determined by the depth at which they were found. In Greenland the bubbles date to 125,000 years ago. In Antarctica the air samples go back 650,000 years.

The data from the ice cores tells us that:

- The Earth has warmed up and cooled down in the past but these changes in temperature have happened very slowly over many thousands of years
- The Earth's temperature is linked to the amount of greenhouse gases in the atmosphere - more greenhouse gas means higher temperatures and vice versa
- Greenhouse gas levels in the atmosphere are far higher now than they have ever been in the last 650,000 years.



## Measuring carbon dioxide in the atmosphere at the Mauna Loa Observatory

Scientists at an atmospheric research facility on Mauna Loa volcano in Hawaii have been continuously monitoring levels of carbon dioxide in the atmosphere. The air sampled at Mauna Loa shows that the average amount of carbon dioxide in the atmosphere over the northern hemisphere has been increasing since 1957.

### Reflective question

- How can we develop in learners the skills of scientific enquiry and investigation using practical techniques?

# Natural or man-made?

Much of the controversy surrounding climate change centres on the debate about whether or not our climate is changing because of natural processes or due to human activity (known as anthropogenic global warming).

## Causes of natural changes to climate

Many of the natural causes of climate change are well understood by the scientific community already. These include:

- The energy from the sun varies slightly in a roughly 11 year cycle (sunspots).
- The Earth has an axial tilt with the axis tilted in the same direction throughout a year. As the Earth orbits the sun, the hemisphere which is tilted away from the sun will gradually become the one oriented most closely to it. This effect is the main cause of the seasons. There is also a wobble called nutation which slowly changes the tilt of the Earth relative to the sun over 26,000 years. This causes seasons to be more or less extreme over long periods of time. For more information, visit: <http://www.schoolobservatory.org.uk/astro/esm/season2>
- The Earth's orbit around the sun varies slowly over time. These are known as Milankovitch Cycles and occur roughly every 100,000 years.



## Gradual and rapid changes

These natural effects do change the Earth's climate but these changes in climate trends happen very slowly, often over many thousands of years. This explains why we have had ice ages and warmer periods in the past.

However, the majority of the global scientific community believe that the Earth's temperature is rising rapidly and that this is mostly caused by human activity. Scientists are worried that many species of animals and plants won't be able to adapt quickly enough to these rising temperatures and will become extinct.

## Reflective questions

- How can we help children and young people learn how to locate, explore and link periods, people and events in time and place?
- How can we use climate change as a context to develop learners as scientifically literate citizens who can make decisions and express opinions on social, moral, ethical and environmental issues based on sound understanding?
- How can we use the controversy and public debate about climate change to teach learners to think critically and detect bias in the media?

# Climate change in Scotland

Observational weather data collected since 1961 clearly shows that the climate in Scotland has changed significantly over the last 40 years with average temperatures in Scotland increasing by 0.5°C since 1914.

Most areas have experienced a significant rise in precipitation. This is most pronounced in winter months with the East of Scotland experiencing a 36.5% increase and the North and West of Scotland both receiving a 67%-69% increase in precipitation over 1961 levels. These changes clearly have an impact and explain why major flooding and landslides have become more frequent in some parts of Scotland.



The only notable exception is the North of Scotland which has seen a decrease in precipitation levels during the summer with some parts of the North West being up to 45% drier during the summer months.

	% Change in average precipitation since 1961			
	North Scotland	East Scotland	West Scotland	Scotland
SPRING	16.2	9.4	17.3	14.8
SUMMER	-7	0.2	7.3	-0.6
AUTUMN	5.3	22.2	5.9	9.1
WINTER	68.9	36.5	67.3	58.3
AVERAGE	21	18.4	23.3	21.1

Climate scientists predict that climate change will lead to more unusual and severe weather in Scotland. The Handbook of Climate Trends Across Scotland is a good source of information and contains other useful climate data and predictions about future trends.

[http://www.environment.scotland.gov.uk/climate\\_trends\\_handbook/index.html](http://www.environment.scotland.gov.uk/climate_trends_handbook/index.html)

## Reflective questions

- How can we adopt active learning approaches with regards to weather and climate change?
- How can we develop the skills of scientific inquiry and investigation using practical techniques?
- How can predictions about climate trends be used to stimulate thinking about life in the future?



# Impact on biodiversity

Many scientists and ecologists believe that Scotland's biodiversity is being affected by our changing climate and the Scottish Government has worked with key partners to develop a climate change adaptation framework to protect biodiversity and promote eco-system resilience.

<http://www.gov.scot/Publications/2009/12/08130729/1>

Biodiversity can be affected in a number of ways by changing climate:

- Species adapt at different rates thus favouring some populations over others, for example caterpillars emerging before birds' eggs hatch could lead to a lack of food for bird chicks.
- Plant species, for example the Diapensia, Norwegian mugwort and cloudberry that live on the high tops of Scottish mountains, may not survive as Scotland gets warmer. Birds such as the Snow Bunting may also disappear.
- Species of butterflies which prefer warmer climates, such as the orange-tip and peacock butterflies, are already being found farther north in Scotland than before.
- There will be new risks from diseases carried by pests such as ticks, midges and mosquitoes including Bluetongue Disease and Lyme Disease.
- Invasive non-native species cause enormous environmental damage and cost the Scottish economy an estimated £500 million each year.
- Bees play a crucial role in pollinating much of our food - the bee populations are already in serious decline and could be further affected by our changing climate.

Species will also be further under threat due to loss of habitat as a result of climate change whether this is loss of saltmarsh and machair to coastal erosion or loss of salmon spawning beds due to flash floods. Soils are also extremely important to biodiversity and may be affected by changing climate too.

## Reflective questions

- How can we use active and outdoor learning approaches to give learners an appreciation of biodiversity and nature?
- How can we support learning and teaching by creating opportunities for young people to engage as active citizens?



# Ocean life

The seas cover 71% of the globe and are critically important for biological diversity and commercial activities such as fishing and tourism. They also play an important role in regulating the climate.

Since 1870 the sea surface temperatures of the UK waters have risen by 0.5°C - 1°C. If sea temperatures continue to rise throughout the 21st century as predicted then marine life will be directly impacted by the warmer waters and indirectly affected by secondary effects such as changes to ocean currents and the chemical composition of sea water.



## Impact on biodiversity

The changing climate is likely to affect marine biodiversity in a number of ways:

- Plankton and other microscopic creatures at the bottom of the food chain could be affected by the changing climate - affecting populations of many different species which depend on them for food either directly or indirectly.
- There is likely to be an increase in the number of southern species entering our waters. For example, in 2009 more than 650 short-beaked common dolphins were spotted in the Moray Firth.
- Species such as the sea-pen, green sea urchin and possibly the cod may disappear from our waters altogether due to rising sea temperatures.
- Birds such as the Scottish crossbill, the snow bunting and the great and arctic skuas may also be lost whilst populations of puffins, guillemots and kittiwakes may be affected too.

Climate change is likely to have a significant impact on marine habitats which sustain a diverse range of life. Many coastal habitats will be affected by sea level rises and rising sea temperatures may bleach and kill coral reefs which are home to many species.

## Reflective question

- How can we create opportunities for learners to develop curiosity, wonder and understanding of the environment and their place in the living, physical and material world?

# Flooding

Research by the UK Climate Impacts Programme has predicted that in the coming decades the number and severity of storm events across Scotland could increase, leading to increased risk of flooding. Data collected from rivers already shows a significant increase in river flows over the last 80 years.

We have 50,000 km of rivers in Scotland and 3,425 km<sup>2</sup> of fluvial flood zone – that's 4.3% of the land area of Scotland. The Scottish Environment Protection Agency (SEPA) has produced a flood map to show the areas at risk of flooding from rivers or the sea. It is estimated that almost 100,000 properties lie in those areas at risk of flooding – approximately 73,300 from rivers and 26,200 from the sea. A total of 3.6% of properties in Scotland are deemed to be at risk from flooding.

<http://map.sepa.org.uk/floodmap/map.htm>



## Impact

Flooding affects our lives in many ways. It can have serious effects on our health and wellbeing, our homes and businesses and the environment. It isolates communities and causes major disruption to transport networks and to vital services. The economic cost of flooding in Scotland is estimated to average £31.5 million per year from inland flooding and £19.1 million from coastal flooding.

In July 1997, a severe flood in Elgin affected 600 residential properties and 170 commercial properties causing £100 million of damage. Over 1200 people were evacuated. Further flooding occurred in 2009. Other examples of severe flooding include: Hawick (2005), Huntly, Dumfries and Stonehaven (2009).

Flooding also carries with it increased risk of landslides. In 2007, Scotland experienced its wettest June since 1938. In the autumn of that year, landslides caused by heavy rain brought hundreds of tonnes of mud down on the small coastal village of Pennan in Aberdeenshire.

## Reflective question

- How has our community been affected by flooding and what impact did this have on people's lives and livelihoods?

# Drought and heatwaves

Data observations show that the climate in Scotland has changed significantly over the last 40 years. Since 1961, some parts of Scotland have become up to 45% drier in summer.

The first six months of 2010 were the second driest recorded in the UK in 96 years. Across Britain, this caused some river levels to drop to 50% of their normal levels and some canals had to be closed to boats because levels were so low. Parts of western Scotland were described as 'exceptionally water-stressed'. The drop in river levels led to hundreds of fish deaths.



## Heatwaves

Over the last 25 years, the average global temperature has risen by 0.6°C. The predictions for Scotland's climate indicate that droughts and heatwaves will be more common, and more prolonged, in future. Heatwaves can cause serious health problems for many – particularly the elderly, the young and those with chronic health problems. This is because extreme heat can force the body into overdrive as it tries to stay cool through perspiration and evaporation. Increased exposure to sun and ultraviolet rays can also cause sunburn and skin cancer.

The heatwave in 2003 caused an estimated 2,000 deaths in the UK and more than 35,000 deaths across Europe. This period of extreme heat is thought to have been the warmest in 500 years with many European countries experiencing record high temperatures. The World Meteorological Organisation estimates that the number of heat-related deaths could double in less than 20 years.

<http://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena/case-studies/heatwave>

## Benefits

The changing climate in Scotland can bring benefits to some. The incidence of air and ground frost has decreased by 25% since 1961, which may have been a factor in reducing the number of cold-related deaths. The length of the growing season each year has increased on average by 33 days which has benefited gardeners and farmers.

## Reflective question

- How can we use topical news stories relating to weather and climate to engage learners in deeper learning about the global impact of climate change?

# Climate change in Greenland

Rising global temperatures have caused ice to melt across the polar regions. This is particularly evident on the west coast of Greenland where melt water from the Russell Glacier and ice sheet flows through the settlement of Kangerlussuaq and into the sea.

In the summer of 2014, a team of school leavers from Scotland organised an expedition to Greenland. The aim of the expedition was to study the changing landscape in Greenland and the impact this has on the people who live there.

Two team members had previously been on expeditions with the British Exploring Society to the Indian Himalayas and Arctic Norway. It was through these trips that they gained the experience that allowed them to organise their own trip.

They documented their studies and experiences in Greenland to produce this online mini-series. These resources can be used by learners and teachers to communicate messages about climate change and its impact on the landscape and people of Greenland. The expedition team hopes the videos and resources inspire the next generation to take on their own challenges to combat climate change.

Education Scotland would like to thank Cameron Mackay, Emily Macduff, Craig Mushet and James Wylie for their generosity in sharing these materials with schools in Scotland.

Find out more about the British Exploring Society:  
<http://www.britishexploring.org/>





# Glaciers and ice sheets

If you want to learn about how ice can flow and form huge structures such as glaciers, Greenland is one of the best places to visit!

The surface of Greenland is covered by 656,000 square miles (1.7 million square kilometres) of ice. That's just over 20 times the size of Scotland! This ice flows very slowly towards the coast, forming some of the world's largest glaciers as it does so.

## Glaciers

The four-person expedition team travelled to the western edge of the Greenland Ice Sheet where the Russell Glacier is situated. The glacier has been receding due to climate change. The team observed water draining from the ice sheet and captured 'calving' events on film. This is when ice breaks off from the glacier.



## Ice sheets

The team also travelled onto the Greenland Ice Sheet itself to see for themselves the features that can form there. They saw the huge cracks in the ice called 'crevasses' that form as the ice twists around mountains and rocky outcrops. The team observed how the crevasses are reacting to the harsh Arctic conditions.

## Reflective questions

- How have glaciers shaped our own landscape here in Scotland?
- How do our actions in Scotland affect the ice sheet in Greenland?
- What changes have we observed in relation to the Scottish climate?

# Melt water rivers

As temperatures have risen in recent years, the landscape in Greenland has been transformed. The warmer temperatures have caused a large volume of ice to melt. This has turned the once gentle streams into torrential rivers, carrying melt water from the glaciers and ice sheet into the sea.

## Melt water rivers

When exploring West Greenland, the expedition team was in constant awe of the melt-water rivers that flowed from the ice cap, past their basecamp and into the sea near the settlement of Kangerlussuaq. As these rivers flow they erode the glacier and deposit huge quantities of rock and ice. This turns the river beaches into scatterings of fragmented ice and stones.

## Summer temperatures

In the summer of 2014 the team found themselves subjected to the highest recorded temperatures in Kangerlussuaq, of up to 23°C. When speaking to local people, they were told of a recent disaster that left the town without water. In 2012 the bridge that the locals use to cross the river and access fresh water was washed away by the melt water river as it flooded.

## Reflective questions

- How do the causes and effects of flooding differ between Scotland and Greenland?
- How do we feel about climate change? Do we recognise the impact it is having on our lives or that of others?
- To what extent are the people of Greenland responsible for rising global temperatures and the melting of the ice sheet?



# Time lapse

Melting ice sheets can sometimes be a difficult concept to get our heads around. Although we know it is happening, the process is too slow for us to see with the naked eye. The 2014 Greenland expedition team took several time-lapse cameras to the Arctic to capture what was happening and help people visualize the impact.

A 'time-lapse' is a filming technique that stitches a series of still images together to show change of an object over time. 'Interval Timer Photography' is used to tell each camera to take pictures at set intervals for a long period of time.

The team set up four cameras facing the Russell Glacier and the footage they got at the end of their trip showed several weeks of melt and calvings in the space of a few minutes.



## Reflective questions

- How can time-lapse photography be used to allow learners to understand other processes in nature?
- What technologies can we use to creatively document our own experience with climate change?

# Human impact

Greenland is a country of extremes. The vast ice sheet and mountainous landscape have resulted in all settlements being built near the coast. Travel between settlements is difficult and is usually done by boat or plane. This means that people in Greenland depend very heavily on their local area to earn a living.

The expedition team asked the local people of Kangerlussuaq, West Greenland, a question: How is climate change affecting your life?

The answers they received were very surprising. It appeared that the local people were positive about some aspects of climate change. Their farming and tourism industries had both benefited as a result of rising temperatures. The rising temperatures meant that local people could now grow their own food. The impact of climate change on the ice-sheets had also brought many tourists and scientists to the country. Both aspects were helping to support the local economy.

## Reflective questions

- How has climate change affected the lives of people in Scotland, for better and worse?
- How has climate change affected the lives of the poorest people in the UK and in developing countries?
- What is meant by climate justice?
- How can learners help to engage their local communities in climate action?



# Expressive arts

Climate change is a complex issue and one that is not fully understood by all. The Greenland360 team, once home from their expedition to the Arctic in 2014, used expressive arts to communicate their experiences of climate change. Through artwork and music, they sought to share their experiences with different audiences and help people see the impact climate change was having on the landscape in Greenland.

## Art

Emily Macduff, the artist on the expedition, composed a series of paintings to tell a progressive story of the ongoing issue and destructive nature of climate change. Through using a range of techniques, she represents many elements of the issue in her work.



## Music

A series of music was composed and recorded to accompany other artistic and scientific outputs from the research expedition to Greenland. The pieces of music use a series of creative techniques to represent the process of climate change through a theme and its variations.

## Submit your own work

Submit your own creative interpretations of climate change – send us your photos, artwork and music files so we can share them on Education Scotland's climate change gallery.

Email: [Ian.Menzies@educationscotland.gsi.gov.uk](mailto:Ian.Menzies@educationscotland.gsi.gov.uk)

## Reflective questions

- How is climate change represented by contemporary artists?
- How have the expressive arts shaped the way we interact with nature?
- How can expressive arts be used to engage new audiences in important issues?



# Climate change around the world

Climate change will present many challenges in the 21st century. Developed nations such as the UK are already investing heavily in contingency planning and are also developing strategies to adapt to the changes that are likely to occur.



## Developing nations

However, developing nations often lack the resources and capacity to adapt sufficiently and at the same time are more vulnerable to large-scale natural disasters. It is estimated that 94% of disasters and 97% of disaster-related deaths occur in developing countries. Predictions indicate that climatic disasters such as powerful tropical storms, floods, droughts and heatwaves will occur more often as global temperatures continue to rise.

## The poorest are most vulnerable

There are many reasons why impoverished communities are particularly vulnerable in times of disaster:

- The poorest people tend to live on marginalised land that no one else wants – for instance on steep mountainsides or land prone to flooding
- Their houses are often flimsy and offer little protection in times of disaster
- They also have little in the way of savings or resources to buy essential food or supplies when disaster strikes or their crops fail
- Their countries have little in the way of boats, helicopters, communication systems or other essential services to provide emergency aid or rescue.

Many aid and development organisations are calling for climate justice for the world's poor. They claim it is unfair that the poorest countries are being so badly affected by climate change when they have done least to cause it. For example, the average person in the UK produces 48 times more carbon dioxide than the average person living in Bangladesh.

## Reflective questions

- How can we enable learners to understand that they live in an interdependent world and that our actions as global citizens affect others around the world?
- How can we effectively use topical news stories about climate events to engage learners and make learning more relevant and meaningful?
- How can we encourage learners to make a positive difference to the world by putting their beliefs and values into action?