Air: The stories and science

Introduction

Understanding what is in our atmosphere is vital in looking after our health, economy and the environment. Environmental science and NERC research helps us to understand what's in the air that we breathe, and help solve the challenges associated with poor air quality. The National Centre for Atmospheric Science has a key role in monitoring and helping us understand how our atmosphere and quality of air is changing.

What is air?

When we talk about 'air', we're mostly talking about a collection of gases (about 78% nitrogen, 21% oxygen and 1% argon and other gases) that we find in our atmosphere. Along with these gases, air also contains tiny particles called particulate matter (PM). We breathe in everything that is in the air that surrounds us, whether it is useful to us, harmless or harmful.

What is air pollution?

Understanding air pollution is about investigating what is in the air that we breathe that can be harmful to life. Air pollution can come in the form of harmful gases and particulate matter (PM), which includes smoke, soot, dust and liquid droplets. There are many sources of both the harmful gases and particulate matter, but the main contributors to poor air quality are the burning of fossil fuels and biomass (such as coal, oil, wood, or other organic matter), emissions from industrial manufacturing plants and the use of household and farming chemicals.

As air pollution can travel all over the world from its original source, it is a global issue that can transcend national borders and requires international efforts to manage, monitor and control.

How can we monitor air pollutants?

Every hour of every day, the air we breathe is constantly being monitored through a UK-wide network of air quality monitoring equipment. There are more than 300 air quality monitoring sites throughout the UK, which gather data on particular aspects of

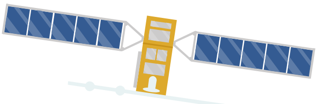
air pollution. You can view air quality data from different parts of the UK online.

Monitoring stations are capable of sensing different air pollutants using a range of equipment.

Particulate matter

Particulate matter (PM) refers to tiny particles that we find in the air. It is made up of hundreds of chemicals, most of which are the result of chemical reactions from transport, industry and energy production. These particles include soot, smoke, dirt and liquid droplets and are further categorized by the size of the particles being considered. For example PM10 refers to particles with a diameter of 10 microns or smaller (one micron is one millionth of a metre). Microscopically small PM can cause harmful effects on human health as they can get deep into our bodies and cause problems with our hearts and lungs.

Particulate matter is most commonly measured automatically using an analyser called a Tapered Element Oscillating Microbalance (TEOM). This sensor is capable of sucking air in through a sampling head onto a filter that sits on a vibrating quartz rod. As the number of fine particles captured increases, the vibration of the rod decreases. This is how the device measures the quantity of particulate matter in the air.



Nitrogen oxides

Nitrogen oxides are a group of gases formed of nitrogen and oxygen, with the most common varieties being nitric oxide and nitrogen dioxide. Nitrogen oxides are released into the air from vehicle exhausts and through the burning of fossil fuels. Exposure to high levels of nitrogen oxides can cause serious health conditions, and long term exposure can trigger serious respiratory conditions.

Nitrogen dioxide can be measured through chemiluminescence, which involves looking at the light produced during a chemical reaction between nitrogen oxides and ozone. Nitrogen oxide can also be measured using diffusion tubes, where a plastic tube containing a metal gauze coated in a substance that absorbs nitrogen dioxide is placed outside, with the results later collected and analysed in a lab.

Sulphur dioxide

Sulphur dioxide is a gas formed when fuel containing sulphur is burned. Coal and oil both contain sulphur and some forms of transport, including trains and ships, burn high sulphur fuel releasing large quantities of sulphur dioxide into the air. Long term exposure to low level sulphur dioxide can cause heart and lung conditions and short term exposure to high levels can be life threatening.

Sulphur dioxide can be measured automatically by an ultra-violet (UV) fluorescence analyser. UV radiation is a form

of electromagnetic energy, and can cause many substances to glow. Levels of sulphur dioxide pollution are measured using the fluorescent energy produced.

Volatile organic compounds (VOCs)

Volatile organic compounds are chemicals that contain carbon that can be easily transformed into vapours or gases. Along with carbon, they contain other elements, which can include sulphur and nitrogen. Most VOCs are released from burning fuel, but they can also be released through other means, such as paints, adhesives, cleaning products or solvents. VOCs can combine with nitrogen oxides to form ozone at ground level.

Monitoring of VOCs is conducted using absorption tubes that absorb VOCs into a material. The VOCs are then removed from the tubes before being analysed by processes such as gas chromatography.

Ozone

Ozone is a gas formed of three atoms of oxygen found both in the stratosphere of Earth's atmosphere and at ground level (tropospheric ozone).

Tropospheric ozone is formed when sunlight interacts with other forms of pollution from cars, industry, power and chemical plants. Repeated exposure to ozone can cause irreversible lung damage, aggravate other health conditions and damage plants.

Ozone pollution is monitored by taking a sample of air into an analyser, which shines specially produced light through the sample inside a tube. A measurement of how much light is absorbed is proportional to the concentration of ozone in the air.

What are the main causes of air pollution?

Vehicles such as cars and buses, industrial processes including manufacturing, energy production, farming, our homes and our waste all contribute to air pollution in our towns and cities.

Emissions of major air pollutants across Europe have declined in recent decades, resulting in heavily improved air quality across the continent. However, certain sectors haven't reduced their emissions enough to meet air quality standards or have increased emissions of some pollutants. In urban areas, traffic remains one of the biggest causes of air pollution. Exhaust fumes from vehicles are hazardous and emit particles that are harmful to us. The particulate matter emitted in car exhaust fumes can be smaller than 2.5 microns. The width of a human hair is about 70 microns, so these particles are about 30 times smaller than that. Because of their size, if these tiny toxic particles enter our bodies, they can damage our heart and lungs and enter our bloodstream. It's not just exhaust fumes that can contribute to air pollution, brake wear and tyre pollution have also been shown to be a big part of the problem too.

How NERC research is helping

The National Centre for Atmospheric Science (NCAS) is a world leader in atmospheric science. They carry out research programmes on:

- The science of climate change, including modelling and predictions.
- Atmospheric composition, including air quality.
- Weather, including hazardous weather.
- Technologies for observing and modelling the atmosphere.

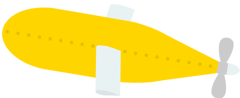
NCAS provides the UK academic community and the Natural Environment Research Council with valuable research data.

NERC research has included:

- Identifying the hole in the ozone layer above Antarctica, leading to the Montreal Protocol being signed in 1987. All nations that signed this international treaty agreed to phase out the production of ozone depleting substances such as choloflurocarbons (CFCs), hydrochlorofluorocarbons (HCGCs), and hydroflurocarbons (HFCs). The ozone layer is now recovering slowly.
- Analysing gas and ash clouds ejected into the atmosphere by volcanoes to establish risks to aircraft, human health or impacts on the atmosphere.
- Monitoring the increase in levels of atmospheric methane emitted by intense livestock farming and other industries as well as natural events and how this will affect global temperatures.
- Monitoring air quality to provide air quality forecasting and advance warning to people with health conditions and impact on populations with low air quality.

Climate change

Our climate is changing at the fastest rate in human history. Why is this happening, what do we know and what can be done?



Overview

Scientists and environmental researchers across the globe provide us with evidence that climate change is a significant challenge to the health of our planet and all life on Earth. The evidence collected by environmental scientists from across the globe provides a compelling account of environmental change at an unprecedented pace, leading many to argue that climate change is the biggest environmental challenge of our time. The challenges of climate change however, are not only reserved to the physical environment of Earth, as they connect all areas of science with society and our everyday lives.

Links with NERC science

Although the evidence that our climate is warming is unequivocal, approaches to how individuals, societies, nations and the international community manage and mitigate its effects, are not as clear-cut. Conflicting viewpoints and tensions surround climate change in media, political and corporate spheres. These tensions give rise to confusing or mixed messages surrounding both the science of climate change, and how it should – or perhaps should not – be dealt with.

NERC research explores how and why the climate of our planet is changing, and provides scientific evidence on which decisions can be made on how to manage and mitigate the effects of climate change.

What is 'climate change'?

Scientists working to understand climate change are interested in finding out about long-term and large-scale shifts in Earth's weather patterns and average temperatures. This is different to thinking about changes in day-to day weather, like you would hear Meteorologists (or weather presenters) tell you about on your television or radio. Weather is the day-to-day elements we all experience in our everyday lives, such as rain, sleet, snow or glorious sunshine. Weather can change frequently, on a daily or even hourly time-scale. Climate, on the other hand, refers to weather patterns over a much longer period of time, such as decades. Our planet is split into different climate zones, or biomes, which can be thought of as different bands of climate at different geographies of Earth.

How has Earth's climate changed throughout time?

Throughout the history of Earth, the climate has varied naturally. For example, our planet goes in and out of ice ages, with the most recent one ending around 11,000 years ago. More recent warming and cooling is associated with changing patterns of

ocean temperatures on a decadal time scale. Since the end of the last ice age, the average temperature of Earth has remained fairly stable. However, over the past 100 years, scientists have witnessed a significant temperature increase of our planet. This temperature change is attributed to the actions of humankind.

What is causing the temperature increase scientists have found over the past century?

The story of Earth's climate begins with the sun, Earth's life-giving star. The sun shines down on our planet, providing the heat and light energy required for life to survive. Surrounding Earth is an atmosphere; a layer of gases held in place by the force due to gravity. This atmosphere protects life from the sun's harmful radiation, and also helps our planet stay at a habitable temperature. Most sunlight passes through the atmosphere, warming Earth, and is 'trapped' by the gases in the atmosphere called greenhouse gases. Greenhouse gases prevent our planet from cooling, and help provide a temperature on Earth which can support life. Greenhouse gases in our atmosphere occur naturally, and include carbon dioxide, methane, ozone and water vapour. Over the past 100 years – and since the industrial revolution – humankind has emitted unprecedented levels of additional greenhouse gases into the atmosphere. Evidence provided from environmental science tells us that current levels of greenhouse gases in our atmosphere are higher than at any other point in human history, and that natural drivers of climate variation could not produce the rates of change scientists have found.

Whilst the industrial revolution in the UK is an event of the past, many countries throughout the world are going through similar periods of development and industrialisation today. Ethical issues are raised surrounding whether or not limitations or restrictions on emissions should be imposed on newly-industrializing nations, as nations such as the UK have been allowed to industrialise and develop largely without restriction in the past.

More developed nations throughout the world today continue to create climate challenges. Traffic is one of the biggest emitters of greenhouse gases, as well as other harmful environmental pollutants - and can be attributed as a problem in every developed nation on Earth. Everyday consumption practices in a globalized world mean that the goods and services we consume are part of an interconnected web of production throughout different parts of the world, which all contributes to the environmental issues we associate with the climate system.

It can be argued that climate change exists at odds with the system of the global economy, and that only by tackling issues associated with our production and consumption patterns will we truly get to the root cause of climate change. When arguments such as this are presented, it's clear how climate change becomes an issue for societal, political and economic systems, and is not restricted solely to issues of the science of climate change itself.

Regardless of individual viewpoints of how best to tackle climate change, and what the role of governments, industry and individuals should be in tackling it, it's important to remember that the evidence that climate change is happening as a result of human

actions is unequivocal, and therefore debate surrounding issues of climate science should focus on how we deal with it, rather than whether is it happening or not.

What evidence is there that our climate is warming?

Our planet gives us the indicators that our climate is changing. Environmental scientists study different phenomena all over the world and have obtained reliable data which tells us our climate is warming. Climate observations mostly come from weather stations, weather balloons, radars, vessels at sea and satellites.

Global sea levels are rising. Since the industrial revolution, sea levels globally have risen by about 20cm.

- Arctic sea ice cover is decreasing. Although scientists observe seasonal variation in Arctic sea ice cover each year, average annual cover has been decreasing over the past century.
- Glaciers are losing ice at an accelerated rate.
- Incidences of extreme weather, such as heat waves, are increasing in frequency.
- The average global temperature of Earth is increasing.
- Increasing ocean acidification – the acidity of Earth's ocean systems are increasing as a result of rising carbon dioxide levels in Earth's atmosphere.

One of the strongest indicators we have that human activity is increasing concentrations of greenhouse gases in Earth's atmosphere are polar ice cores. Ice cores are large cylinders of ice extracted from both the North and South poles which act as frozen time machines of atmospheric make-up and temperature throughout the history of Earth. By drilling and extracting cores from ice sheets, scientists can examine air bubbles and other materials trapped in the ice and determine the temperature and composition of Earth's atmosphere as far back as 800,000 years ago.

A new research initiative funded by NERC will see environmental scientists drill and extract an ice core long enough to give us a 1.5 million year perspective on the history of Earth's climate. Polar ice cores tell us that the levels of greenhouse gases present in Earth's atmosphere today are higher than at any other point in the past 800,000 years.

How is climate influencing other processes on our planet?

All the different factors which influence the climate can be thought of as operating in a 'climate system'. These different factors include our atmosphere, our oceans, our continents and land masses and all of the plants and ice sheets that cover our planet's surface.

The climate system is a key driver of other natural systems and processes on Earth, such as the health and stability of the biosphere (land) and cryosphere (ice). All of Earth's environmental systems work together, and are dependent on each other.

The potential impacts of climate change

Although climate change tends to be expressed as a single figure, that is, the average temperature or temperature increase of Earth, it's important to remember that because climate influences all of Earth's natural systems, its effects will vary geographically across different parts of Earth. What's clear for Earth as a whole however, is that the effects of climate change will be adverse and widespread, and that no living thing will be exempt from the changes it brings.

Temperature changes will affect each biome differently, and will result in rising sea levels and extreme weather events. Coastal regions will experience further erosion as a result of rising sea levels, threatening people's homes and costing economies millions of pounds each year. Oceans will continue to acidify and threaten marine organisms and ecosystem services. A general and sustained rise in Earth's temperature will create issues with food and fresh water security, and make it harder for living things to survive.

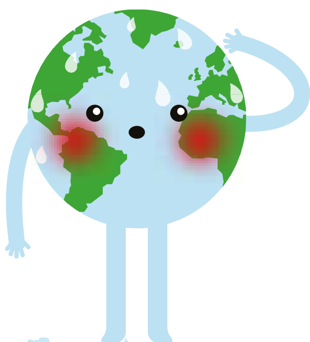
Controlling climate change

The range of people involved in climate change discussions, including scientists, economists, business leaders and politicians means that managing and mitigating climate change and its effects is a multi-pronged approach often with conflicting viewpoints and preferences. Creating a joined-up approach to managing climate change is a time consuming and intense process, with much work still needing to be done for effective and meaningful action to take substantial effect.

International agreements between nations are one example of a strategy to help manage and offset the effects of climate change, with individual nations often implementing their own legislation or practices to help meet international targets. However, as these agreements are voluntary, getting politicians onboard with implementing them can be challenging.

Corporations often outline their own social responsibility statements detailing how they're seeking to act upon climate change in their own businesses; however, these are frequently refuted by environmental pressure groups as tokenistic, with limited meaningful impact on reducing greenhouse gas emissions in production processes or supply chain management.

All of us in our everyday lives can help offset the effects of climate change, and help prevent further warming through changing our everyday behaviours, for example, by recycling our waste or using public transport instead of the car.

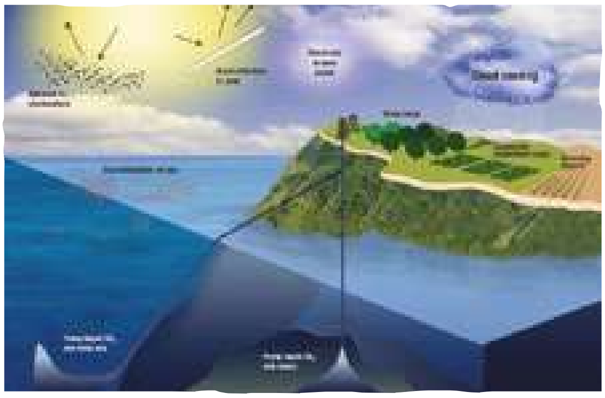


'Geoengineering' our climate: a future option

Along with mitigation and adaptation, geoengineering presents a possible third pathway to help reverse the harmful effects of climate change.

Geoengineering is the large scale and deliberate intervention into Earth's climate system to help lower the temperature of Earth. There are two main groups of technology for geoengineering, carbon dioxide removal technologies (CDR) and solar radiation management practices (SRM).

CDR Technologies would help tackle the root cause of climate change by reducing the high levels of carbon dioxide we find in Earth's atmosphere. Some early examples of CDR include carbon capture and storage technologies. SRM involves increasing the reflectivity of Earth's surface so that increasing quantities of sunlight are reflected off Earth's surface back into outer space. Geoengineering technologies are

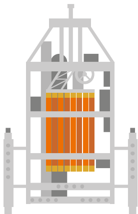


controversial, and raise their own unique set of questions relating to the scientific feasibility, economic costs and benefits as well as presenting complex governance and ethical issues. At present, no nation on earth is seriously considering geoengineering technology as their preferred method of reversing the effects of climate change.

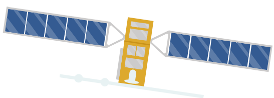
Is there a consensus on climate change?

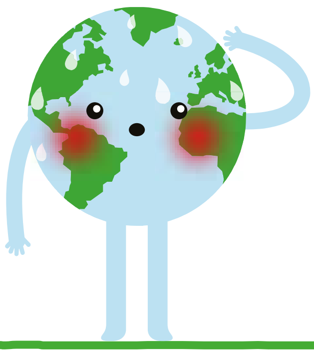
From the scientific community, yes. More than 97% of publishing climate scientists agree that human beings are causing global warming and climate change. Most international scientific bodies throughout the world have published statements and reports which affirm this, including the United Nations Intergovernmental Panel on Climate Change.

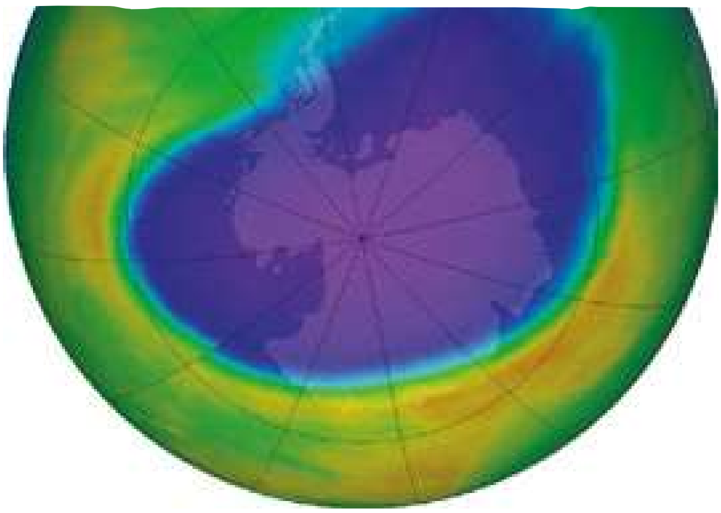
Environmental science allows us to understand our changing planet by giving us the evidence we need to make informed decisions about our future, as individuals, nations and as an international community. Further research into climate change, its causes and effects will help us all to make evidence based decisions into safeguarding our planets future.



The ozone layer







Overview

The ozone layer is located in the Earth's atmosphere, and is a layer of the atmosphere that contains ozone (O_3). It is sometimes referred to as the ozone shield, which describes the role it plays in protecting life on earth from the sun's potentially damaging ultraviolet rays. Various humanmade chemicals can deplete the ozone layer and create ozone holes, as a result of this risk it has been carefully studied and monitored by scientists.

What is the ozone layer?

The ozone layer's exact location is within the stratosphere, a major layer of the atmosphere, sandwiched between the troposphere below and the mesosphere above. Although the ozone layer covers the whole earth, its thickness and location varies. It is thinner at the equator and thicker at the poles. Most ozone is found between 20 – 40 km above the earth's surface.

The ozone layer has less ozone in it than you might think, just 10 parts per million. This is still a far higher concentration than elsewhere in the atmosphere (an average of 0.3 parts per million).

In fact, there is so little ozone layer, that if all of the ozone were compressed to the pressure of the air at sea level, it would be only 3 millimetres (1/8 inch) thick! That doesn't stop it being hugely important for life on Earth, especially life on the surface.

How does the ozone layer protect us?

Ozone absorbs harmful ultraviolet (UV) radiation from the sun. UV is a form of radiation that we cannot see. Too much exposure to UV can cause genetic damage, premature ageing, damage to your eyes, and also skin cancer. It is also what gives you a tan and sun burn.

Luckily, the ozone absorbs between 97-99% of the sun's damaging UV rays so only a small amount makes it to the Earth's surface.

How was it discovered?

The ozone layer was first discovered by two French physicists, Charles Fabry and Henri Buisson in 1913. They realised that there was a disparity between the amount of radiation emitted by the sun and the amount reaching the ground and that this could only be accounted for by something absorbing this radiation. This was deduced to be the chemical ozone.

What is the 'ozone hole'?

Since the discovery of ozone, scientists have continued to study and monitor ozone, due to the important protective function it has. This includes work conducted by NERC scientists since 1957, including the discovery of the 'ozone hole' in 1985, a large springtime decrease in ozone at the Earth's Poles.

What causes depletion of the ozone layer?

Humanmade chemicals, called ozone depleting substances (ODS), often found in refrigerants, solvents and propellants, are blown up to the stratosphere and once there, they react with the ozone to break it down. This is a real problem as a thinning ozone layer is less effective at protecting the Earth from UV radiation.

The Montreal Protocol

As a result of the discovery of the ozone hole and its connection to humanmade chemicals such as CFCs, the Montreal Protocol was adopted in 1987, which banned the use of these harmful chemicals. Since then the ozone layer has slowly recovered. As a result, the Montreal Protocol, which was influenced by NERC's ozone research, is considered the most successful international environmental agreement to date and has helped save thousands of lives.

Ozone depleting substances controlled by the Montreal Protocol include:

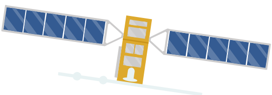
- Chlorofluorocarbons (CFCs)
- Halon
- Carbon tetrachloride (CCl_4), methyl chloroform (CH_3CCl_3)
- Hydrobromofluorocarbons (HBFCs)
- Hydrochlorofluorocarbons (HCFCs)
- Methyl bromide (CH_3Br)
- Bromochloromethane (CH_2BrCl)

Continuing NERC research

It is important that we continue to study and monitor the ozone layer, something that is carried out by NERC research scientists, particularly at the British Antarctic Survey research facilities, where the ozone hole was first discovered. For example, a group of NERC scientists from the University of Lancaster recently published research showing that a chemical not included in the Montreal Protocol, dichloromethane, is contributing to ozone depletion, and if not controlled, could jeopardise the progress made in ozone recovery.

Ozone as a pollutant

When ozone occurs naturally high up in the stratosphere, it is very beneficial. However, ozone can also form at ground level when oxides of nitrogen (NOx) and volatile organic compounds (VOC) react in the presence of sunlight. These are often formed as pollutants, emitted by cars, power plants, industrial boilers, refineries, or chemical plants. This ground level ozone is a harmful air pollutant, and is the main ingredient in 'smog'. It is most likely to reach unhealthy levels on hot sunny days in urban environments.



Carbon dioxide and the greenhouse effect

The effects of increasing levels of CO_2

Overview:

Since the industrial revolution, and especially over the last 100 years humankind has emitted unprecedented levels of additional greenhouse gases into the atmosphere. Many climate models suggest an increase of 2-4°C in worldwide temperature over the next 100 years; this is ten times faster than the warming experienced over the past 10,000 years. NERC scientists are involved in gathering evidence from Earth which tells us how our atmosphere is changing.

What is the atmosphere?

Surrounding Earth, we have our atmosphere, a layer of gases protecting us from the sun's harmful radiation, and helping our planet stay at a habitable temperature. Most sunlight passes through the atmosphere, warming Earth, and is 'trapped' by the gases in the atmosphere called greenhouse gases. Greenhouse gases prevent our planet from cooling, and help provide a temperature on Earth which can support life. Greenhouse gases in our atmosphere include carbon dioxide, methane, ozone and water vapour, and occur naturally. The name 'greenhouse gas' arises because glass also absorbs heat, and glass panels in a greenhouse have exactly the same effect as Earth's atmosphere, on a much smaller scale.

Evidence provided from environmental science tells us that current levels of greenhouse gases in our atmosphere are higher than at any other point in the human history, and that natural drivers of climate variation could not produce the rates of change we're observing.

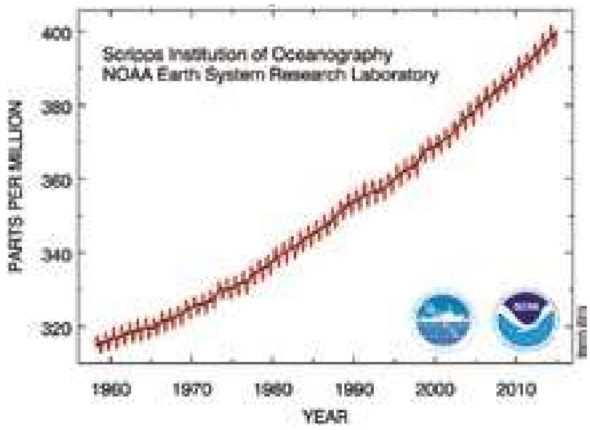
One of the most staggering increases we have observed is in concentrations of carbon dioxide in the atmosphere.

How do we measure carbon dioxide in the atmosphere?

The level of carbon dioxide in our atmosphere is measured in 'parts per million' which is abbreviated to ppm. A concentration of 350ppm means that for every million particles of air, 350 of them are carbon dioxide molecules.

In 1958, Charles Keeling, a doctor of Oceanography at the Scripps Institute, USA, began the first reliable measurements of carbon dioxide concentrations at Mauna Loa in Hawaii; a barren lava field of an active volcano. The Mauna Loa atmospheric CO_2 measurements are the longest running record of atmospheric CO_2 in the world. This location allows for the collection of undisturbed air as there is minimal influence from plants and human activity, and any volcanic emissions can be easily excluded from the data sets. Hourly measurements

of the air at Mauna Loa are taken from the top of five different towers using gas analysers capable of determining the CO_2 concentration of the air.



The graph produced from data plotted showing the changing concentrations of carbon dioxide over the past 50-60 years produces the curve outlined above. This graph is known as the 'Keeling curve'. The Keeling curve is one of the most compelling pieces of evidence that human activity is responsible for rising concentrations of greenhouse gases in the atmosphere. In 1958, when measurements began, the concentration of CO_2 in the atmosphere was around 317ppm. Today, it's over 400ppm. Many scientists argue that atmospheric CO_2 will now not fall below 400ppm in our lifetime. This is an unprecedented change when set against the wider context of carbon dioxide concentrations over previous centuries.

What evidence exists that rising concentrations of carbon dioxide are contributing to a warming world?

One of the most compelling lines of evidence that human activity is contributing to a warming world is through running climate models, which simulate production of greenhouse gases, like carbon dioxide. When these models are run, they show the same pattern of warming as that currently being observed around the world. Furthermore, when the models are run without the addition of anthropogenic warming through greenhouse gases, the models show no change in Earth's climate.

Why does this matter?

Greenhouse gases can linger in the atmosphere for decades, or even centuries. This means that even if we take action to cut emissions right now, there will be a delay or lag time before the effects are realised in atmospheric concentrations or in temperature reductions. As greenhouse gases like carbon dioxide are also interconnected into other processes e.g. the carbon cycle, there are further environmental implications for increasing their concentrations in the atmosphere which can influence the climate further in a feedback loop, complicating the situation further.

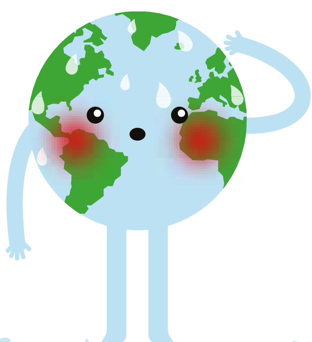
Links

www.esrl.noaa.gov/gmd/ccgg/trends/index.html

www.ipcc.ch/report/ar5/syr/

https://climate.nasa.gov/climate_resources/24/

www.pnas.org/content/104/11/4249.full



Acid rain

Links with NERC

NERC research fed into the first international treaty on acid rain, the 1979 Convention on Long-range Transboundary Air Pollution (CLRTAP), which obliges countries to cut emissions of sulphur oxides, nitrogen oxides, volatile organic compounds, ammonia, heavy metals and persistent organic pollutants. From 1983 NERC scientists pioneered the first truly international project on acid rain, leading the UK to begin a £6bn programme to cut air pollution.

What is it?

Unpolluted rain is usually mildly acidic with a pH of no lower than 5.7. This is due to carbon dioxide and water in the air reacting to form carbonic acid. Acid rain is a form of precipitation that is more acidic and has been recorded on occasion to have pH readings below 2.4. It can have harmful effects on plants, animals and infrastructure.

What causes it?

Acid rain is caused by emissions of sulphur dioxide and nitrogen oxide that react with water molecules in the atmosphere to produce sulphuric acid or nitric acid. Most of these emissions come from the burning of fossil fuels. Since the industrial revolution began in the 1760's, emissions of sulphur dioxide and nitrogen oxide have increased resulting in more occurrences of acid rain.

Although originally discovered in 1853, the term 'Acid Rain' was devised in 1872 by Robert Angus Smith. However it wasn't until the 1960's that scientists really began studying this phenomenon.

The chemistry behind the process

Sulphur dioxide reacts with a hydroxyl radical (formed when oxygen reacts with water) in the atmosphere to form Sulphuric acid via a sequence on reactions

1. $SO_2 + OH\cdot \rightarrow HOSO_2$
2. $HOSO_2 + O_2 \rightarrow HO_2 + SO_3$
3. $SO_3\,(g) + H_2O\,(l) \rightarrow H_2SO_4\,(aq)$

Nitrogen dioxide reacts with water in the atmosphere to form Nitric acid
$NO_2 + OH \rightarrow HNO_3$

Natural events can increase atmospheric sulphur dioxide and nitrogen oxide. Volcanic eruptions can produce large quantities of sulphur dioxide to be released into the atmosphere and lightning can produce nitrogen oxides. The rapid increase of these chemicals above a natural level causes global damage to vegetation, soils, aquatic ecosystems and buildings.

What has been done to prevent or limit this problem?

As a result of research by environmental scientists the following treaties and agreements were signed to reduce the level of these emissions:

- 1985 – Helsinki Protocol on the Reduction of Sulphur Emissions, addition to the 1979 Convention on Long-Range Transboundary Air Pollution.
- 1991 – Air Quality Agreement.

Many coal-firing power stations use flue-gas desulphurisation (FGD) to remove gases containing sulphur from the chimney stacks. An example of this is a wet scrubber which is a reaction tower which injects lime to react with any sulphur dioxide to create calcium sulphate. Calcium sulphate is a pH-neutral compound.

Vehicle emission controls have also been put in place to reduce the levels of nitrogen oxides from exhaust gases.

Links

www.nerc.ac.uk/research/impact/casestudies/society/air-pollution