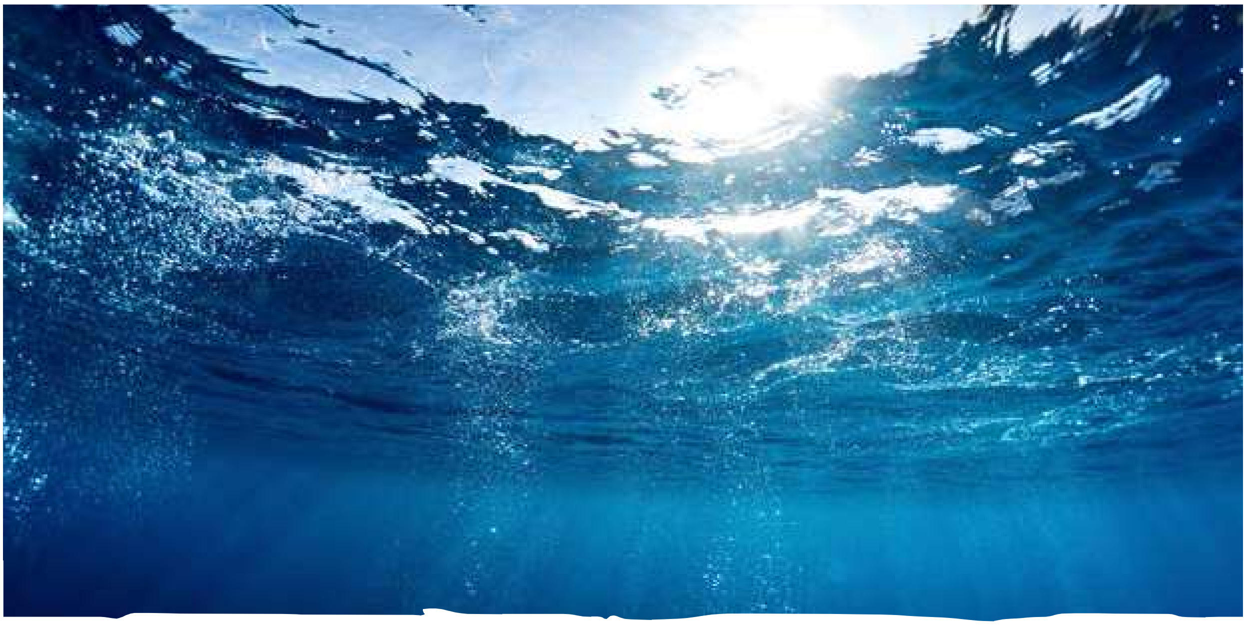


Oceans: The stories and science

Introduction

All our rivers lead into our oceans transporting anything that enters them to the sea, whether this is animal or plant life, chemicals or foreign objects. Our five major oceans are all connected and with the smaller seas, more than 70% of our planet's surface is covered with water. These oceans are essential for the survival of all life on Earth so NERC scientists are monitoring our oceans, lakes, and rivers to identify how they are changing and what this might mean for the future..

Why are oceans important?

Oceans underpin our global economy, with millions of people relying on ocean systems every day for their livelihoods. Oceans provide a food source, with more than one billion people relying on the oceans for their primary source of protein. They provide recreational opportunities many of us will explore throughout our lives, a world-wide transportation system and, perhaps most significantly, oceans are key drivers in Earth's climate system, playing a crucial role in maintaining a habitable Earth which sustains life in all forms.

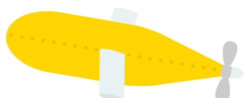
However, our lakes, rivers and oceans are changing, from pH and temperature to composition and from salinity to plastic pollution, we are facing significant changes and challenges as a result of human activity.

What issues are scientists researching?

Ocean acidification

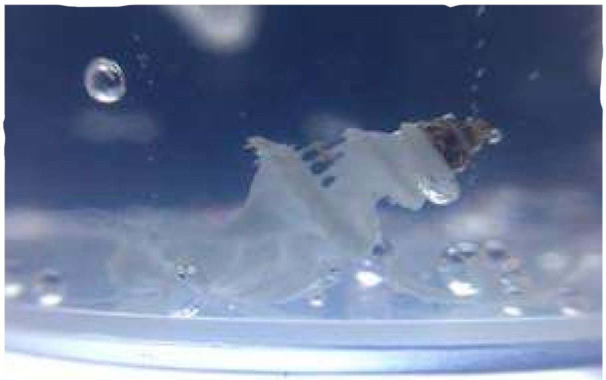
Scientists know that human activity, such as burning fossil fuels, has increased the concentration of carbon dioxide gas in Earth's atmosphere and this is having an impact on our planet's climate, increasing average global temperatures.

Earth's oceans have played a crucial role in slowing this rate of change by absorbing more than a quarter of the carbon dioxide produced from human activity. However, when oceans absorb carbon dioxide gas from the atmosphere, a series of chemical changes occur. When carbon dioxide mixes with seawater it forms carbonic acid. This process is called ocean acidification.



Scientists measure the acidity of a substance using the pH scale of 1 to 14. A substance that is neither acidic (less than 7) nor basic (greater than 7) is pH neutral at position 7. The ocean itself is not acidic and is unlikely to ever have a pH of less than 7. However, the pH scale is logarithmic, so very small changes on the scale can have profound effects on the survival of particular species of life on Earth.

For marine life, ocean acidification impacts the chemical processes required for plants, animals and microbes to grow, reproduce and survive. One of the biggest issues facing marine life is the ability of particular species (such as oysters, mussels, urchins and starfish) to build their skeletons and shells. The increasing acidity of seawater means that less carbonate molecules are available for shell production in animals. Corals face a similar issue, with acidification limiting their growth by corroding pre-existing structures, and slowing the growth of new ones. Species most sensitive to any decreases in pH include corals, calcifying algae, molluscs, coccolithophores and echinoderms.



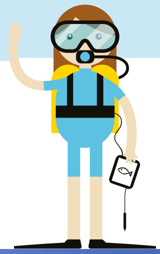
The acidity of the surface ocean has increased by about 30%, mostly over the past 30 years, a relatively fast change in ocean chemistry for a system which has been evolving over many millions of years. The implications of ocean acidification have only been explored and recognised recently, with more than 75% of the total scientific literature on the subject being published over the past 5 years. Based on historical evidence from natural ocean acidification events of the geological past, we know that recovery from changes in ocean pH can take thousands of years and that ocean acidification can result in many marine organisms becoming extinct.

Plastic Pollution

The accumulation and fragmentation of plastics caused dramatic global change. Plastic pollution is found in rivers, lakes, coastlines, the open ocean, the deep sea and, now, in our drinking water.

The pollution can take the form of larger pieces of plastic (mega-plastic) or smaller pieces that are harder to detect (micro-plastic). Plastic pollution poses a substantial threat by choking wildlife through entanglement, inducing harm through toxicity and through potentially degrading to micro-plastics which can later be ingested by sea life, and in turn humans.

Plastic production has increased from 0.5 million tonnes per year in 1950, to over 300 million tonnes per year today.



Its versatility and cheap cost has meant that it is a product that is found everywhere in our daily lives. Despite having a longevity measured in hundreds or even thousands of years, the majority of plastic is still used for single-use items.

In the UK over 38 million plastic bottles are used each day. More than 16 million of these end up in landfill or leak into the environment as pollution every day. Globally about 20,000 bottles are purchased every second.

Ocean temperatures and coral bleaching

Even a slight temperature increase can have a severe impact on aquatic life. Warmer water holds less dissolved oxygen than cold water, affecting the organisms that rely on oxygen within the water to breath.

A more visible impact is that of coral bleaching. Corals are marine invertebrates made up of polyps that live in colonies that make up reefs. They produce a hard exoskeleton from calcium carbonate and live symbiotically with algae (dinoflagellates). The algae give the corals some of their colour and, through photosynthesis, they produce energy for themselves and also the corals. Although the corals feed themselves, many corals require the extra energy from the algae to help build exoskeletons.

When corals become stressed through factors such as increased water temperature, they eject the algae. This causes the corals to look bleached. If the environment stabilises then the corals can regain the algae, but if they do not the coral polyps eventually die.

As well as providing a home for a range of marine life, the coral reef's structure buffers shorelines and coastal communities against waves, storms, and floods, helping to prevent loss of wildlife and property through damage and erosion.

Sea level rise

Sea level rise is usually associated with melting icecaps and glaciers. However, sea level rise can also occur through a process called thermal expansion. This effect can be calculated from observed changes in ocean temperature, and simulated changes using global climate models that are the main tool for making climate predictions.

Despite some uncertainty due to sparse sampling of the deep ocean and difficulties with instrumental calibration, models and observations agree on a 1-2 mm per year sea level rise due to thermal expansion in recent years.

Even a small increase in sea level has severe impacts for coastal areas and results in damage due to flooding and loss of low lying communities.

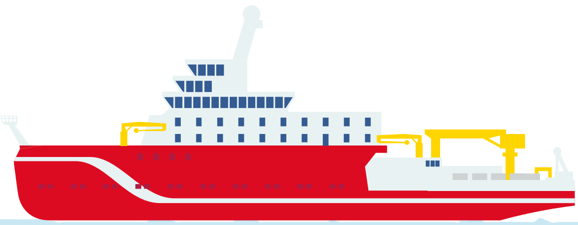
How does NERC help?

The National Oceanography Centre and Centre for Ecology and Hydrology currently study all these changes to identify what is happening, why it is happening and what the future impacts will be. Through using advanced equipment such as remote long range submarines, advanced technology research ships, such as the future RSS Sir David Attenborough, and remote monitoring stations across the world, scientists are studying the earth's global water in more detail than ever before.

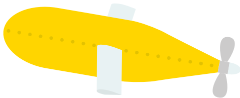
Current research topics include:

- The likelihood and effects of global sea level rise.
- How to minimise the loss of coral reefs.
- The impact of ocean acidification on marine organisms.
- The effects of micro plastics and microfibers on the marine ecosystem.
- Studying the flow of deep water in the Antarctic to see how winds affect warming of deep water masses.
- Studying the connectivity of marine protected areas to establish if protected areas are close enough to share genetic materials.
- Developing genetic tools to help identify illegal trading in marine life.

Continued research into the issues facing Earth's oceans will not only help us understand the complexities of the ocean system, but also its relationship with other physical systems, humankind, and allow us to work towards solutions that will create a sustainable future for the wide variety of life on Earth.



Plastic pollution



Links with Nerc

NERC researchers are investigating the effects of plastics on ocean health, especially plastic that has broken down into microscopic pieces. Scientists have found that marine creatures such as fish and birds are eating this microscopic waste, which is harming their health. Scientist have explained that 'Almost like a Trojan horse, microplastics can help transfer potentially dangerous chemicals to animals'.

What is it?

Highly durable and flexible, synthetic plastics are vital part of our everyday lives. They're in thousands of products – from cars to medical equipment – and many types of packaging. When they were first developed synthetic plastics actually helped to save wildlife by offering an alternative to animal products like ivory and tortoiseshell, but they now offer a very real threat to marine life and our own health.

While natural materials break down into other biodegradable compounds, plastic just breaks up – into smaller and smaller pieces (even vegetable-based plastics can take a decade to break down). That's why most of the synthetic plastic created is still around in one form or another and every year 8 million tonnes of plastic ends up in our oceans.

Why is there so much of it?

Humans have produced 8.3 billion tonnes of synthetic plastic since the 1950s and more of it was produced in the last 10 years than in the 20th century as a whole. Around half of what's produced today is single-use plastic – for things like plastic bags – but only 20% of used plastic is recycled in the UK.

Why are plastics a problem?

The problem is that although synthetic plastics are disposable, they're also indestructible. Every piece of plastic ever made is still on the planet in some form or another because plastic breaks up, rather than breaks down. It's estimated that there are almost 600,000 pieces of plastic per km^2 of water. Around 90% are microplastics – tiny pieces of plastic that have either broken down or entered the water in the form of nurdles.

Plastics are killing marine wildlife. Around 180 species of marine animals have been found to have ingested plastic, including seabirds, fish, invertebrates and mammals – even whales. Plastics can entangle turtles and seabirds, but they also mistake it for food. Many ocean plastics can also release toxins into the water and almost all plastic can soak up harmful bacteria like a sponge. As plastic breaks down into microscopic pieces, it becomes easier to ingest. Seabirds, in particular, are attracted to brightly coloured fragments of plastic which resemble their usual prey. Microplastics have also been found in sea salt.

Plastic bags

Probably the most visible example of plastic consumption and pollution, plastic bags are mistaken by marine life for a food. Plastic bags look like jellyfish to a turtle. A trillion plastic bags are used every year, that's 2 million a minute. On average, they're used for just 12 minutes before being discarded.

Progress has been made: plastic bag usage has dropped by 85% since the introduction of a plastic bag tax in England in 2015. Amongst the first countries to introduce a tax were Ireland (2002), the same year Bangladesh banned them outright after floods caused by plastic bag litter. In Kenya, selling or buying plastic bags now carries a jail sentence of up to 4 years or a fine of £30k.

Plastic bottles

The UK uses over 38 million plastic bottles a day, accounting for 40% of all litter. Scotland has just launched a deposit scheme for plastic bottles, but some soft drinks companies are lobbying and resisting schemes like these.

Nurdles

Nurdles are lentil-sized pieces of plastic that are used to form larger plastic products. They can escape into water sources at any point in the manufacturing process. A container ship spillage can release millions of nurdles into the sea. Over 400,000 nurdles were collected from a single cove in Tregantle, Cornwall by the Rame Peninsula Beach Care group.

Microbeads

Included in a range of products from shower gels to toothpaste they go straight into our local water supplies. Manufacturers are gradually phasing them out in 'rinse-off' products but claim it is too expensive to remove from products like makeup and sunscreen.

Earbuds

Campaigners have pressured manufacturers to replace the plastic stick with a paper equivalent.

Microfibres

Clothes that contain nylon – and pretty much anything that gives your clothes 'stretch' like skinny jeans, shed microscopic pieces of plastic called microfibres when you wash them. Like most synthetic plastics they absorb toxins and they have been discovered in drinking water around the world.

What is being done to solve this issue?

Based on advice from scientific research, world governments are banning or taxing single use carrier bags, reducing the number that reach the ocean.

In the UK, bans on using plastic microbeads are coming into force, removing this direct source of pollution.

Start-up companies such as coraball, now offer solutions to capturing microfibers from washing machines. However, scientists are still researching how to remove microplastics from the ocean. In order to do this the large plastic soup-like areas within the sea are being identified and the study into the effects of these plastics on marine life is ongoing.

Research is key to understanding the full impact of this problem and environmental scientists are at the heart of this.

Investigating ocean pollution

Overview:
Investigate the Earth's oceans and see what you can find.

In this demonstration, a volunteer is selected from the audience to help investigate the Earth's 'water sample' in a water tank, to determine the health of the oceans. They fish out separate items from the tank piece by piece, that are briefly discussed and looked at by the doctor, trainee and Earth.

Programme use:
Family show.

Overview:

In this demonstration, a volunteer is selected from the audience to help investigate the Earth's 'water sample' in a water tank, to determine the health of the oceans. They fish out separate items from the tank piece by piece, that are briefly discussed and looked at by the doctor, trainee and Earth.

Main stories:

Climate change, ocean acidification and overfishing are all serious problems, but one of the main ways that humans are impacting the oceans is through plastic pollution. An enormous amount of the plastic produced each year will end up in the ocean, where it breaks up into tiny pieces.

Pieces of plastic in the ocean can cause many problems, but a key issue is that it is eaten by marine life, often making them ill or killing them. The plastic also makes its way up the food chain, and so impacts upon entire ecosystems, including humans that eat the fish and other marine animals. The pollution can be seen as larger pieces of plastic, like plastic bags, or plastic straws (mega-plastic) or smaller pieces that are harder to detect, like microfibers (micro-plastic).

Environmental scientists don't have answers to the problem of plastic in the ocean, but can help find solutions, by studying the impacts closely through careful monitoring and research, from the ocean surface to the deep, using high tech research vessels and remotely operated vehicles.

How it works:

Before the show:

1. Fill up the water tank to a safe level, so that it can easily still be wheeled around.

2. Place it out of sight from the audience but somewhere it can easily be moved into view.

3. Inside the water tank, place the fish models, a plastic bag (from local shops ideally), and a couple of plastic straws.

4. Have the rubber gloves, goggles, pipet and microscope ready to the side.

During the show:

1. The doctor asks the Earth to provide a water sample. The Earth goes out of sight to collect the tank full of water.

2. Invite a volunteer down to the stage and give them their goggles and rubber gloves.

3. Explain that they are going to help check the Earth's water sample, to determine how healthy the oceans are.

4. Get the volunteer to take out objects one at a time to hand to the doctor for inspection.

5. Discuss each item in turn with the trainees and the Earth then place in a separate container for recycling, apart from the fish that are placed back in the tank.

6. Once the straw, fish, and plastic bag have been inspected, thank the volunteer and send them back to their seat.

7. Explain that some plastic pollution is small, so we should look at some of the sample under microscope.

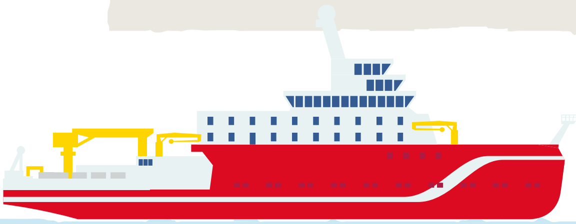
8. Use a pipette to take a sample and place under the 'microscope', with image appearing on the PowerPoint slide behind of microfibers.

9. Explain where microfibers come from, their dangers, and what scientist are trying to do to stop them going into the ocean.

Key take home messages:

- A healthy ocean is biodiverse and abundant with life.
- Plastic pollution has a negative impact on the health of the ocean.
- Environmental scientists carefully monitor and study marine biodiversity and the impacts of plastic in the ocean so we understand the health of the ocean and take the best action to improve it.

"Investigate the Earth's oceans and see what you can find"



Dissolving shells

Overview:
See the effect of ocean acidification of marine life.

The Earth's oceans are becoming more acidic as more CO_2 in the atmosphere dissolves into our ocean. This experiment highlights the effect of a weak acid on marine life especially molluscs and corals. For this demonstration shells are placed in two small containers; one containing water and the other containing vinegar. The vinegar will cause the shell to start to fizz and dissolve. After 2 hours holes will have appeared in the shell.

Equipment needed:

- Shells (whelks work best).
- Distilled Vinegar (acetic acid).
- Light box.
- Stop clock.
- Water.
- 2 small screw top containers.
- pH paper.

How it works:

1. Add water to one of the containers and add distilled vinegar to the other.

2. Place a similar sized and shaped shell into each container.

3. Place both containers on the light box and turn the light on.

4. Start the stop clock.

5. Ask visitors to see if they can see anything happening. They should be able to see the shell in the vinegar fizzing and dissolving.

6. The calcium carbonate in the shell is reacting with the vinegar (acetic acid) to produce water, carbon dioxide and calcium acetate. This reaction neutralised the acid but also breaks down structures made of calcium carbonate such as shells and corals.

How does this relate to NERC science?

Environmental scientists understand that carbon dioxide in the atmosphere is absorbed by the oceans; this is a natural process which helps maintain a stable level of CO_2 in the atmosphere. However, they also understand that increase in CO_2 emissions through the burning of fossil fuels has led to greater levels of CO_2 that dissolve into the oceans. This increase level of CO_2 in the water is causing the oceans to become less alkaline (more acidic). Although the oceans are still alkaline (8.06 on pH scale), this reduction in pH is already having adverse consequences to marine life. By 2100 it is estimate that the pH could reduce to 7.76-7.86.

Key take home messages:

- Our oceans play an important role as a 'Carbon sink' – they absorb CO_2 from our atmosphere.
- When CO_2 in the atmosphere dissolves into our oceans it makes the water more acidic.
- This can affect a range of marine organisms.

Health and safety

Activity - Electrical Equipment.

Hazard | Precaution

Electric Shock - Take care not to spill liquid on lightbox, annual PAT test, adult supervision.

Risk - Low.

> "This experiment highlights the effect of a weak acid on marine life especially molluscs and corals"

Ocean acidification

Overview:
Discover how the oceans become more acidic as CO_2 in the air dissolves into them.

The oceans play a key role as a 'carbon sink' in removing carbon dioxide from the atmosphere. As the carbon dioxide dissolves in the oceans, the sea water becomes more acidic. This acidification affect has consequences for our sea life. This activity demonstrates how CO_2 in the atmosphere dissolves into water changing the pH by making it more acidic.

Equipment needed:

- Large (transparent) plastic beaker (e.g. 500ml).
- Small plastic beaker (e.g. 200ml).
- Plastic Circular Plate.
- Bicarbonate of Soda.
- Vinegar.
- Bromothymol Blue 0.04%aq.
- Sticky Tape.
- Measuring cylinder.
- Light box.
- Safety Goggles (PPE).
- Protective gloves.

How it works:

1. Wear goggles and protective gloves.

2. Inform the visitor: Environmental scientists know that ocean environments on Earth are becoming more acidic, and that this is due to carbon dioxide in our atmosphere dissolving in them.

3. Set-up a 500ml beaker on top of a light box. Pour in 100ml of diluted 0.04% aq Bromothymol Blue into the beaker.

4. Stick a smaller beaker to the inside rim of the larger beaker using sticky tape. Make sure the smaller beaker is about 1-2 cm below the top of the larger beaker.

5. Add 2 teaspoons of bicarbonate of soda into the smaller beaker.

6. Measure 40ml of vinegar and add this into the smaller beaker containing the bicarbonate of soda. Take care not to add this into the indicator solution. Explain to the participant that this will produce CO_2.

7. Once you've added the vinegar to the bicarbonate of soda, quickly place the plastic plate face-side down over the top of the large beaker to trap the CO_2. You will need to hold this in place.

8. Ask the participant to observe the Bromothymol Blue and what they see happening to the solution. What do they think is happening? Why is this happening?

How does this relate to NERC science?

Increasing concentrations of carbon dioxide in Earth's atmosphere are causing the average temperature on Earth to rise. However, this is not the only change these increased gas concentrations cause.

Carbon dioxide in the atmosphere is absorbed by the oceans through a natural process which helps maintain a stable level of CO_2 in the atmosphere. However, increases in CO_2 emissions through the burning of fossil fuels has led to increased levels of CO_2 dissolving into the oceans. This increase level of CO_2 in the water is causing the oceans to become less alkaline (more acidic). Although the oceans are still alkaline (8.06 on pH scale), this reduction in pH is already having adverse consequences to marine life. By 2100 it is estimated that the pH could reduce to 7.76–7.86.

Key take home messages:

- Our oceans play an important role as a 'Carbon sink' – they absorb CO_2 from our atmosphere.
- CO_2 in the atmosphere dissolves into our oceans making them more acidic.
- This can affect a range of marine organisms.

Health and safety ⚠

Activity - Bromothymol Blue.

Hazard | Precaution

Eye Irritation - PPE: Goggles.

Skin Irritation - PPE: Disposable Gloves.

Respiratory Irritation - Adult Supervision.

Digestive Irritation - Adult Supervision.

Electric Shock - Annual PAT, Adult Supervision.

Risk - Low.

Polar ice caps and sea level rise

Why are the icecaps melting and what is causing the sea to rise?

Overview:

The impact of humans on the climate is clear and environmental scientists have a wide variety of evidence to support this. We know that humans are emitting more greenhouse gases into Earth's atmosphere now than at any other point in our history, causing changes which have widespread effects on Earth's physical and human systems. The Intergovernmental Panel on Climate Change (IPCC) 5th assessment report outlines the evidence scientists from a wide range of disciplines have found which supports this. Average changes in global sea levels and ice cover at Earth's poles are two fundamental changes scientists have observed in response to a warming world.

What's going on with sea levels and how do we know this?

Over time significant changes have been taking place throughout Earth as a result of anthropogenic (human caused) warming of the climate system. A key change relates to the rate and scale of change in Earth's sea levels. Environmental Scientists can use various methods for exploring rising sea levels, including extracting core samples, tide gauges and using satellite measurements.

Throughout the course of the last century, the average global sea level has risen by almost 20cm, with the rate of sea level rise in the last 100 years being greater than the average rate over the past two thousand years. Rising sea levels can be caused by two main factors, both of which relate heavily to climate change. These are melting ice, and thermal expansion of water.

Melting ice:

More water is being added to Earth's oceans from melting land ice and glaciers across the globe. However, not all of this melting contributes to rises in sea levels. Icebergs and frozen sea water are melting in the warmer climate. However, they are not contributing to sea level increases. This is because they are already in the water, and the volume of water they move (displace) whilst frozen as ice is the same as the volume of water they displace when the ice melts and becomes a liquid. In contrast, melting ice on the land (such as ice sheets in Greenland or Antarctica) which flows into the oceans is additional water entering this environment, and is contributing to rising sea levels.

Thermal expansion:

Seawater is expanding due to being warmed up; around half of Earth's sea level rise over the past century is attributed to the water being warmer, and occupying more space.

The IPCC predict that we can expect oceans to rise between 28-98cm by 2100. Rising

sea levels cause coastal erosion and the destruction of habitats, wetland flooding, soil contamination (affecting agriculture and food security), as well as increasing the likelihood of destructive flooding for hundreds of millions of people.

Changes to the polar ice caps

Ice sheets in Greenland and Antarctica are losing mass, with glaciers worldwide shrinking. Snow cover in the Northern Hemisphere is decreasing, and scientists are confident that permafrost (a thick subsurface layer of soil, remaining below zero degrees) temperatures have been getting warmer in most regions over the past 40 years; in response to warming temperatures and decreasing snow cover.

Although sea ice in the Arctic has annual seasonal fluctuations, the annual average Arctic sea ice cover has been decreasing in every season and in every successive decade since 1979. Across the 33 year period 1979–2012, the rate of sea ice decrease was likely to be between 3.5–4% each decade.

Research indicates that there are strong regional differences in changing ice cover in different parts of Antarctica, with extent increasing in some areas but decreasing in others. It's important to remember that although Earth's polar regions have similarities, they also have differences which play a part in explaining why scientists observe differing responses to climate change.

Key take home messages

- Human beings are causing the Earth's climate to change.
- The effects of climate change are widespread and far reaching, and manifest themselves in different ways on different parts of our planet.
- On average, global sea level is rising.
- Although there is variation between the Arctic and Antarctica, globally, sea ice cover is declining. The decreases in Arctic sea ice cover far exceed gains made in parts of Antarctica.

Links to more information

www.nasa.gov/content/goddard/antarctic-sea-ice-reaches-new-record-maximum

www.nasa.gov/content/goddard/qa-what-is-happening-with-antarctic-sea-ice/

www.ipcc.ch