Australian Government
Department of Climate Change

CLIMATE CHANGE SCIENCE

FREQUENTLY ASKED QUESTIONS

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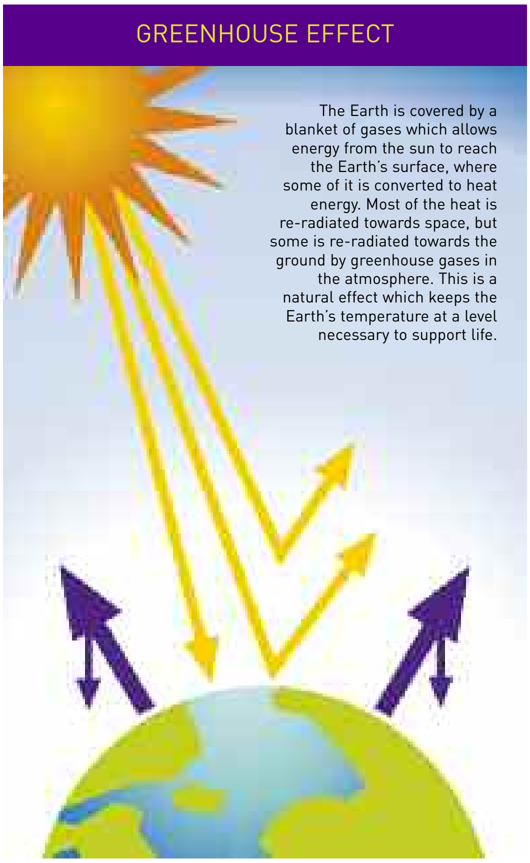
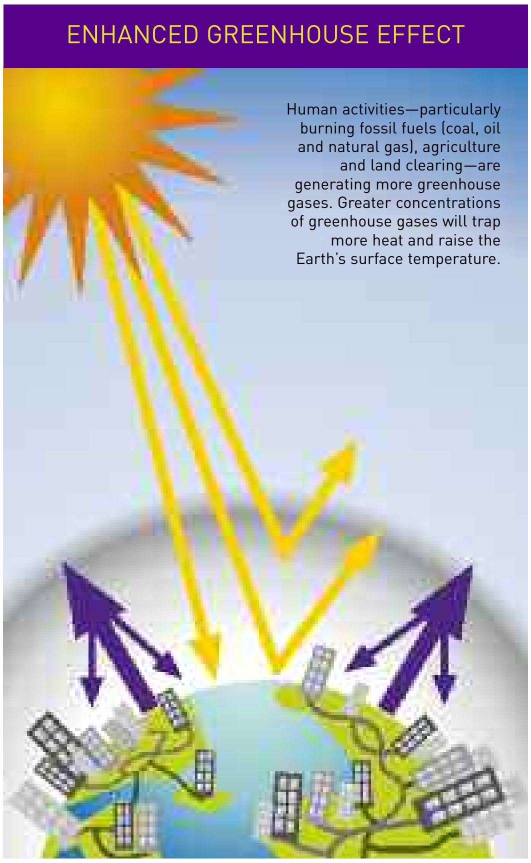
Q1: What is the greenhouse effect?

Greenhouse gases are a natural part of the atmosphere. They absorb and re-radiate the Sun's warmth, and maintain the Earth's surface temperature at a level necessary to support life. The problem we now face is that human actions—particularly burning fossil fuels (coal, oil and natural gas), agriculture and land clearing—are increasing the concentrations of the gases that trap heat. This is the enhanced greenhouse effect, which is contributing to a warming of the Earth's surface.

Water vapour is the most abundant greenhouse gas. Its concentration is highly variable and human activities have little direct impact on its amount in the atmosphere. Humans have most impact on carbon dioxide, methane and nitrous oxide. Various artificial chemicals such as halocarbons also make a small contribution to the enhanced greenhouse effect.





Q2: Is the Earth's climate really hotting up?

The global average surface temperature has increased since reliable measurements began in the late 1800s.

During the past 100 years, global average surface temperature increased by about 0.7°C. Tree rings and other records tell us that average Northern Hemisphere temperatures during the second half of the 20th century were *likely to have been* the highest in at least the past 1300 years. Eleven of the past 12 years were the warmest we have experienced since around 1860.

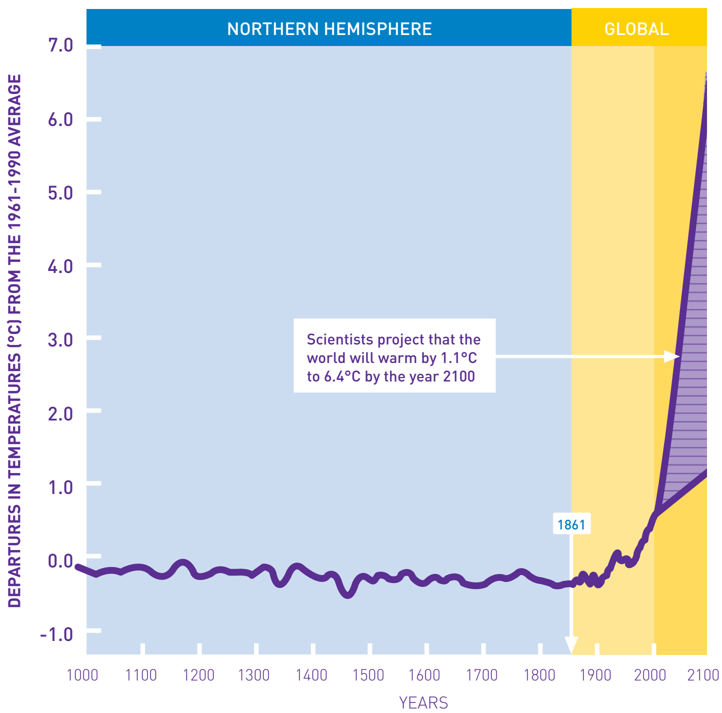
In addition to warming of the Earth's surface, there has been an increase in heatwaves, warming of the lower atmosphere and deep oceans, fewer frosts, retreat of glaciers and sea ice and a rise in sea level during the 20th century of approximately 17 cm. Many species of plants and animals have changed their location or the timing of seasonal activities in ways that provide further evidence of climate change.

Although many natural factors influence the Earth's climate, a majority of the world's scientists have determined that greenhouse gas increases were the main factor contributing to climate change since the 1950s.

In its Fourth Assessment Report released in 2007, the Intergovernmental Panel on Climate Change—an international body that assesses the latest science of climate change—stated that 'Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in [human produced] greenhouse gas concentrations".

Scientists consider that warming will continue as a result of past, current and future emissions. Question 15 addresses how much warming is likely this century.

Earth's Temperature 1000–2100



This graph indicates how the Earth's surface temperature has increased since the mid 19th century. Scientists have projected a range of possible temperatures based on a number of future greenhouse gas emission scenarios. Scientists believe that the Earth's average temperature will rise by 1.1 to 6.4 °C by 2100 if nations around the world do not act to control greenhouse emissions.

This graph has been adapted and simplified from the Intergovernmental Panel on Climate Change Third Assessment Report 2001. The original graph can be accessed at: www.ipcc.ch/

Q3: Hasn't the Earth's climate always changed with ice ages and interglacial periods?

Throughout history, the Earth has experienced cold and warm periods, including ice ages and interglacial periods. Over the past million years, these natural climate changes were due to periodic variations in the Earth's orbit that affect the amount of sunlight reaching the surface. Ice ages historically have extended over about 90,000 years and the warmer interglacials have lasted about 10,000 years or less. Globally averaged, ice ages have been up to 10°C cooler than present, while interglacials have been about the same temperature as today. Greenhouse gas concentrations changed in concert with the temperature variations and caused about half of the magnitude of the climate changes.

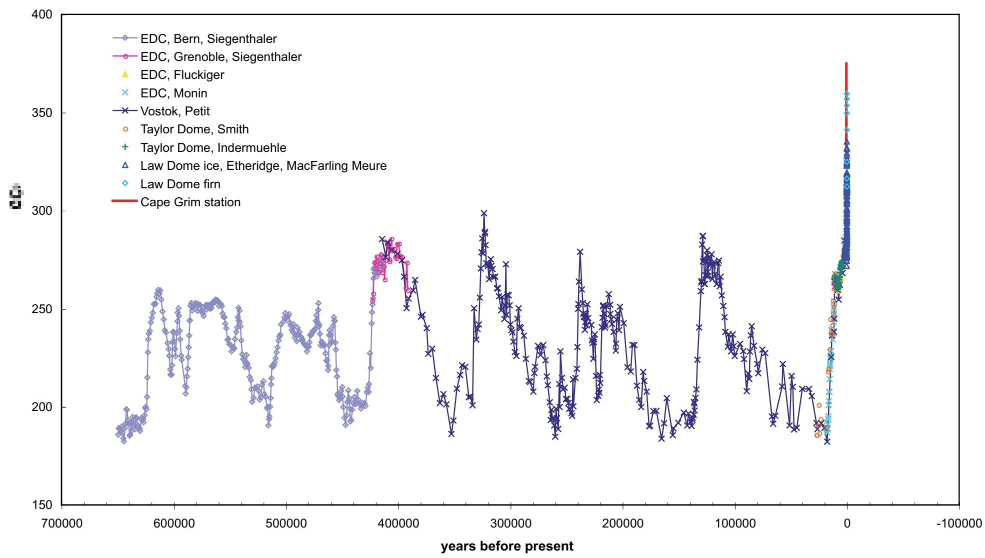
The past 11,000 years is known as the Holocene Warm Period. Over the past 2000 years, regional fluctuations of 1.0–1.5°C have occurred. For example, northern Europe was cold until the 7th century, after which temperatures warmed to a peak, known as the Medieval Warm Period (900–1300 AD).

Complex natural fluctuations still affect the Earth's surface temperature and climate over long timescales. However, simulations using sophisticated computer-based climate models confirm that global warming during the past 50 years was mainly caused by human activities that have increased atmospheric concentrations of greenhouse gases, while the variations in the Sun's output, aerosols and land use have had smaller impacts.

The current global concentrations of carbon dioxide in the atmosphere (approaching 380 parts per million) are the highest in the last 650,000 years. The rate of increase in carbon dioxide during the industrial era is very likely to have been unprecedented in more than 10,000 years.

Climate models driven by scenarios of greenhouse gas emissions indicate that, over the next century, a global warming of 1.1–6.4 ºC will occur. This rate and magnitude of warming are significant in the context of the past 400,000 years. History has shown us that a warming of 1–2°C can have dramatic consequences. Even the 0.7°C warming in the past 100 years has been associated with increasing heat waves and floods, fewer frosts, more intense droughts, retreat of glaciers and ice sheets, coral bleaching and shifts in ecosystems. A further warming of 1.1–6.4 ºC could challenge the adaptive capacity of a range of human and natural systems.

Atmospheric CO_2 concentrations from ice cores over the past 650,000 years



Carbon dioxide concentrations from the Vostok, Dome C, Taylor Dome and Law Dome ice cores in Antarctica and from the Cape Grim station in Tasmania. The current global concentrations of carbon dioxide in the atmosphere (approximately 380 parts per million) are the highest in the last 650,000 years.

Q4: How do we know that most recent global warming is attributable to human activities rather than natural causes?

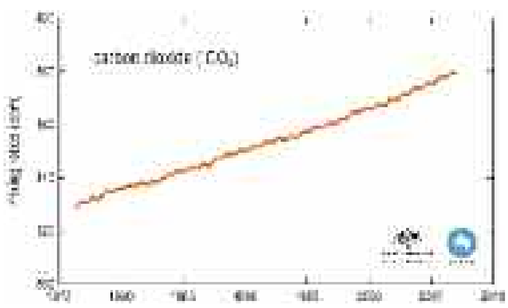
The present atmospheric concentration of carbon dioxide has not been exceeded for the past 650,000 years, and possibly not for 20 million years. Ice core records show that carbon dioxide levels in the atmosphere varied between 180 and 280 parts per million (ppm) due to glacial cycles. For the past 10,000 years global atmospheric carbon dioxide has been quite stable at between 260 and 280 ppm, and level at about 280 ppm from 1000 to 250 years ago. However, since the beginning of the Industrial Revolution, some 250 years ago, the concentrations of greenhouse gases in the atmosphere have increased dramatically. Human activities, such as burning fossil fuels (coal, oil and gas), land clearing and agricultural practices have increased carbon dioxide concentrations by more than a third (to approximately 380 ppm), nitrous oxide levels by about 19 per cent and methane concentrations have more than doubled. The rate of increase in carbon dioxide during the industrial era is very likely to have been unprecedented in more than 10,000 years.

The observed changes in climate, especially temperature increases since about 1970, cannot be explained solely by natural causes such as solar activity. Reconstructions of climate data for the past 1000 years indicate that this recent warming is unusual and is unlikely to have resulted from natural causes alone.

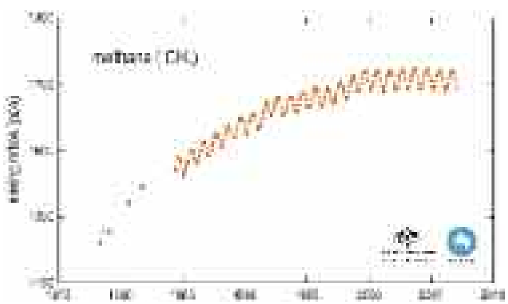
Scientists use computer models to simulate past and future climate variations. Simulations of the 20th century have been driven by observed changes in various factors that affect climate. When only natural factors, such as volcanic aerosols and solar activity, are included in the models, the simulations do not explain the observed warming in the second half of the century. The warming in the second half of the century can only be explained if human-induced changes in greenhouse gases are included in the models.

Global atmospheric concentrations of three greenhouse gases

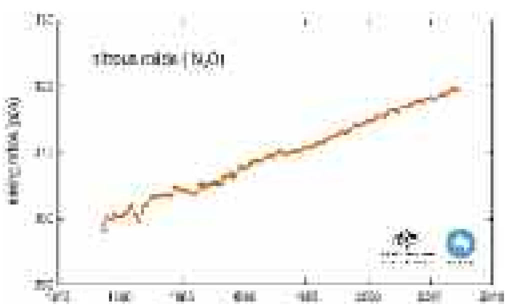
Carbon Dioxide



Methane



Nitrous Oxide



Q5: What is the carbon cycle? How does human activity contribute to the carbon cycle?

Carbon, in various forms, continuously circulates between the living world, the atmosphere, oceans and the Earth's crust. There are many different processes by which carbon is exchanged between these locations. Events, such as fires, which release carbon dioxide into the atmosphere, are known as 'sources'. The oceans and growing trees remove carbon dioxide from the atmosphere and are known as 'sinks'.

Each year human activity adds several billions of tonnes of carbon in the form of carbon dioxide to the atmosphere. A little over half of this carbon dioxide remains there, while the rest is absorbed by plants and the oceans (and ultimately some of this is returned to the Earth's crust).

More than 120 billion tonnes of carbon are exchanged each year between all living things during photosynthesis and respiration. Plants absorb about 61 billion tonnes of carbon and respire about 60 billion tonnes. Plants grow by absorbing carbon dioxide from the air or water and converting it to plant tissue through photosynthesis. Some of this carbon is used to supply the plant with energy. This process, known as respiration, releases carbon dioxide back into the atmosphere. The carbon from carbon dioxide absorbed by a tree may be stored as wood for hundreds of years. Or the carbon may become part of a leaf that dies and decomposes, with the carbon returning to the atmosphere relatively quickly.

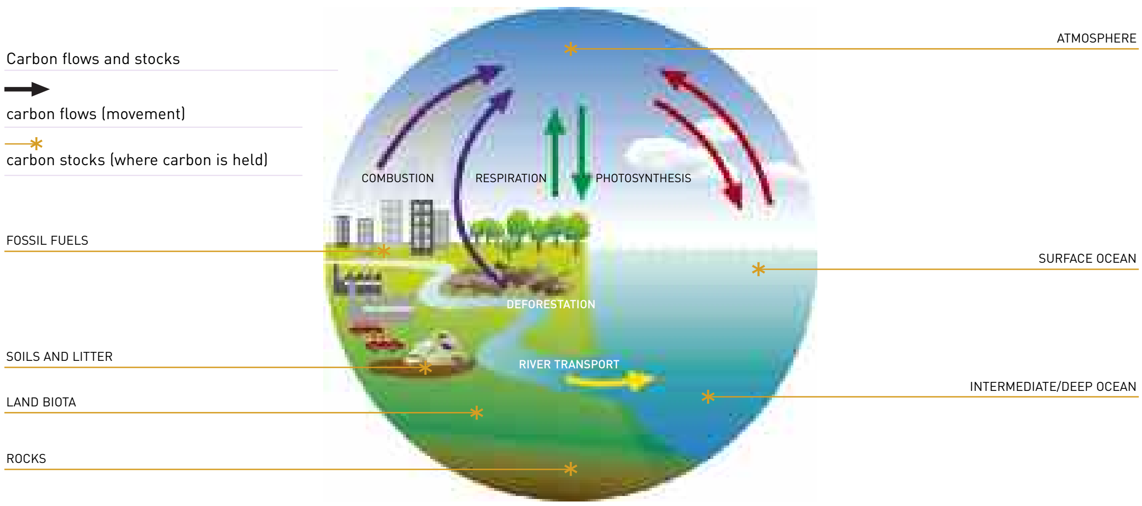
The surfaces of the oceans release about 90 billion tonnes of carbon to the atmosphere and absorb about 92 billion tonnes each year. This absorption occurs when carbon dioxide in the air dissolves in the top layer of sea water and through photosynthesis by marine plants.

The amount of carbon dioxide that people add to the atmosphere may seem very small in comparison to the amounts being added and absorbed by natural processes, but it only takes a small change to upset the balance.

The burning of fossil fuels by humans adds about 6.5 billion tonnes of carbon each year in the form of carbon dioxide. Land clearing, reduced soil humus and the erosion of topsoil account for one to two billion tonnes of carbon a year.

Proof that more carbon dioxide is being added to the atmosphere than removed is the fact that concentrations of the gas continue to rise. Furthermore, scientific techniques reveal that this additional carbon dioxide originates from fossil fuel combustion. However, most of the observed warming over the past 50 years is very likely to have been due to the human-induced increase in greenhouse gas concentrations.

The carbon cycle



Q6: Will a few degrees warming have a significant impact on our climate?

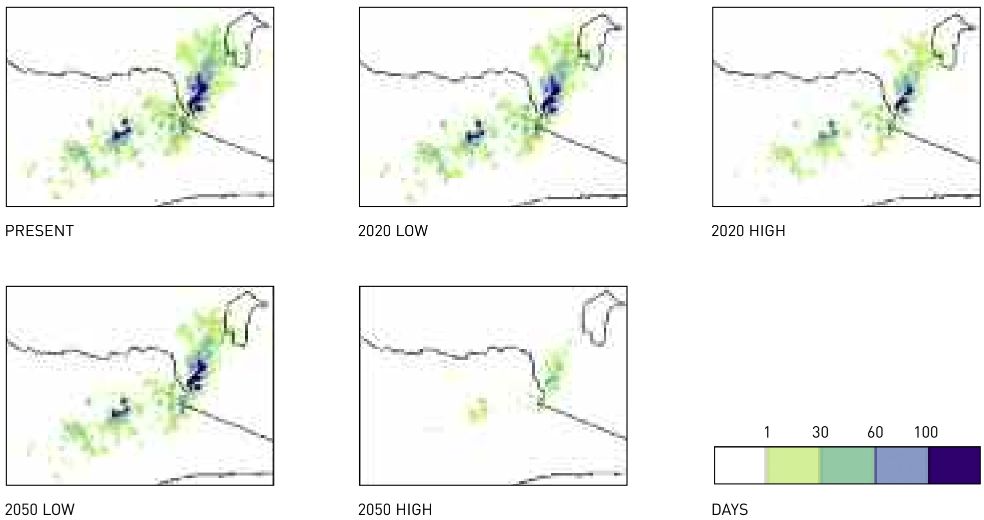
The world has warmed 0.7°C in the past century. Scientists are confident that the world will get warmer in the 21st century due to further increases in greenhouse gas concentrations, with globally averaged surface temperatures likely to increase by 1.1–6.4 ºC from 1990 to 2100. Warming of a few degrees may seem minor compared with day-to-day or seasonal variations in temperature. However, in global climate terms it is much larger than any of the climatic changes experienced during the past 10,000 years.

During the last ice age, which was at its maximum about 70,000 years ago, surface temperatures were on average about 5°C lower than today, and much colder in the polar regions. Sheets of ice covered almost one-third of the world's land. The global warming projected in the 21st century would occur at a time that is already one of the warmest for hundreds of thousands of years, with current levels of carbon dioxide not exceeded for the past 650,000 years, and not likely exceeded during the past 20 million years.

A few degrees of global warming will lead to more heat waves and fewer frosts. In Australia, the projected average warming of 0.4 to 2.0°C by the year 2030 would lead to a 10–50 per cent increase in days over 35°C at many places, and a 10–80 per cent decrease in frosts.

More fires and droughts are expected in some regions of the world and more intense rainfall and resultant flooding in other areas. Australia's alpine regions are expected to have less snow cover. Higher latitudes of the globe would receive more rainfall while middle latitudes, including parts of Australia, would be likely to receive less. Tropical cyclones may become stronger. The Intergovernmental Panel on Climate Change Fourth Assessment Report says that sea level is likely to rise by 18 to 59cm by 2100, but this does not include possible changes in big ice sheets such as Greenland and the Antarctic that could lead to more rapid sea level rise. Low-lying coastal areas and islands will be inundated more often by storm surges.

Simulated snow-cover duration (days) for present, 2020 and 2050



A low impact climate change scenario for 2020 leads to a 10% reduction in the area with at least one day of snow cover, while a high impact climate change scenario leads to a 40% reduction in area. By 2050, there may be a 20–85% reduction in area.

Graphic courtesy of CSIRO

Q7: How do scientists measure global surface temperatures?

The Earth's surface temperature is measured in many ways. Thermometers have recorded air temperature at weather stations or surface seawater temperature from ships for many decades, with almost global coverage extending back to 1861. Instruments on satellites have monitored infrared radiation for many years, which is then converted to temperature to provide global records back to 1979. In addition, proxy records—data relating to climate, such as tree rings and ice cores—extend the global surface temperature record back hundreds and even thousands of years.

Urbanisation, with its heat-absorbing structures and materials such as concrete, can change the local climate by raising local temperatures. Researchers take into account such changes when looking for long-term trends in regional and global temperatures. Satellites and weather balloons record average temperature in the lower atmosphere and at the Earth's surface. Measurements from the satellites and weather balloons show warming rates that are similar to those directly recorded at the surface.

Q8: How reliable are climate models?

Computer-based climate models use mathematical formulae to represent the important physical and chemical processes that drive the world's climate. They are the best tools available for making climate change projections. While the models still have shortcomings, there has been enormous progress over past years in our understanding of important climate processes and their representation in climate models.

Confidence in the reliability of these models for climate projections has also improved, based on tests of the ability to simulate:

- the present average climate, including the annual cycle of seasonal changes;
- year-to-year variability;
- extreme events, such as storms and heatwaves;
- climates from thousands of years ago;
- observed climate trends in the recent past.

Models do a better job of simulating average temperature and pressure than rainfall. Simulation of climatic variability due to monsoons, the El Niño Southern Oscillation and the North Atlantic Oscillation has improved. Small-scale extreme events are harder to simulate, but models can simulate features of tropical cyclones.

Simulations that include estimates of natural and human influences can reproduce the observed large-scale changes in surface temperature over the 20th century, including the global warming that has occurred during the past 50 years.

Climate models are good at simulating most climatic variables that are needed for studying global and continental climate change. Climate models are also useful tools for exploring likely regional changes to climate.

Q9: How do scientists project future climate?

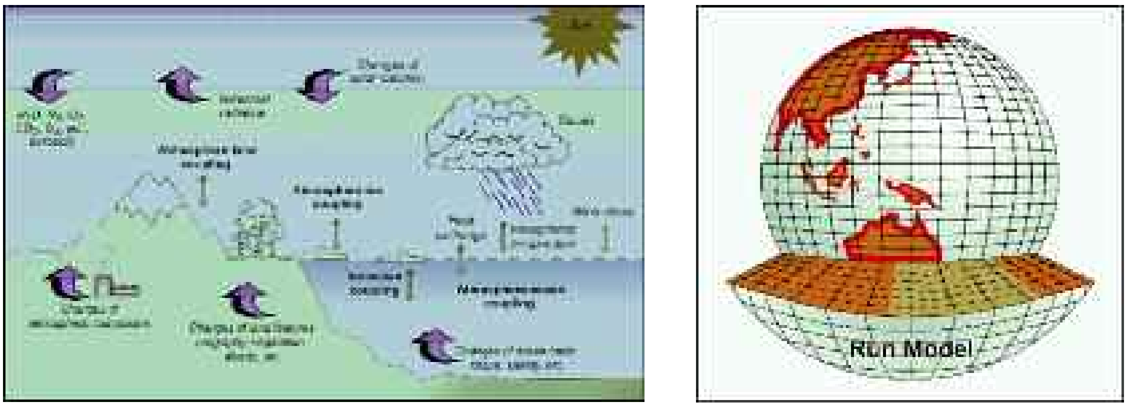
Our climate is the result of the interaction of the Sun's radiation with the atmosphere, oceans, polar ice and the land. Many processes contribute to our climate, including the absorption and emission of heat by materials such as gases and water, reflection of heat from different surfaces such as snow and trees and the circulation of the oceans and atmosphere.

Climate models are the best tools we have for projecting future climate. This includes assessing the effect of human activities on climate over the coming decades, and explaining the causes of climate change over past decades.

A climate model is a simplified mathematical representation of the Earth's climate system. Models have a three-dimensional grid of points over the globe, extending into the ocean and the atmosphere. Regional models can provide more detailed information over a smaller area. Since regional models operate at finer resolution than global models, they give a much better representation of the effect of topographic features such as mountain ranges and local variations in climate. Climate models can reproduce present climatic features reasonably well, along with past climatic changes such as the last Ice Age and the global warming of the 20th century.

Economists and other experts have developed a number of scenarios or possibilities for how the world might develop over the next century based on a set of assumptions, such as how fast population might increase and how quickly renewable energy sources might replace fossil fuels. In 2000, a set of greenhouse gas and aerosol emission scenarios for the 21st century were developed for use in climate model simulations. Research groups around the world use these scenarios to project climate changes. The results are featured in the report of the Intergovernmental Panel on Climate Change (www.ipcc.ch/).

A wide range of scenarios for global temperature rise is possible, the lowest are the most likely to be exceeded. However, even the most optimistic scenario for stabilising carbon dioxide concentrations at 450–550ppm in the atmosphere would lead to a warming of 1 to 3°C by the year 2100. This level of warming is considered by some scientists to represent a major threat for some regions and some ecosystems. Other systems may benefit from warming e.g. high latitude agriculture. The challenge facing us now is to determine how much we need to reduce our carbon dioxide emissions to minimise the risk of dangerous climate change.



Schematic representation of a climate model. Various physical quantities such as temperature and rainfall are typically computed in half-hour time steps over a three-dimensional grid.

Q10: How much will sea levels rise as the world warms?

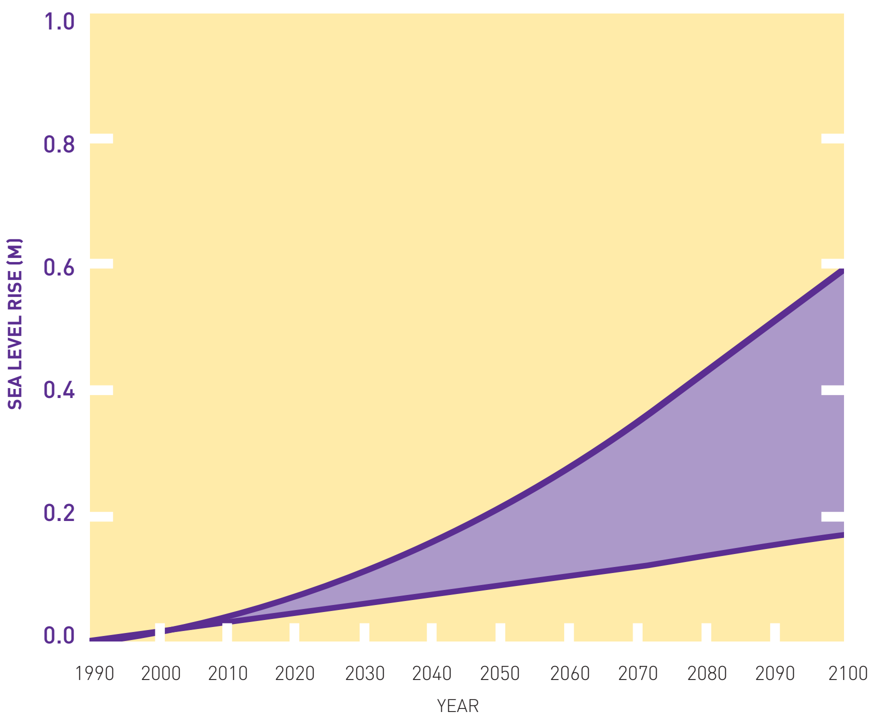
Global average sea level rose by approximately 17 cm (the range was 12–22 cm) during the 20th century. It is very likely that increasing temperatures in the 20th century contributed to this sea level rise through thermal expansion of seawater and widespread loss of land ice (retreating glaciers).

The IPCC Fourth Assessment Report says that sea level is likely to rise by an additional 18 to 59 cm by the year 2100, but this does not include possible changes in big ice sheets such as Greenland and the Antarctic that could lead to more rapid sea level rise. This rise may affect low-lying islands and coastal settlements throughout the world.

As the Earth's surface warms, the oceans slowly absorb heat and expand, causing the sea level to rise. This thermal expansion of the ocean will be a major contributor to sea level rise during future centuries.

Melting of glaciers is also expected to contribute to rising sea levels. Melting ice from Greenland is expected to make a small contribution to rising sea levels this century, offset in part by increased snow on the Antarctic ice sheet. Very little melting is expected to occur over the Antarctic mainland during the next century because of the very long response time to atmospheric warming and the low temperatures there.

Future Scenarios for Sea Level Rise



Based on a range of possible future scenarios for global warming, scientists estimate that sea levels will rise between 18 and 59 cm by the year 2100 as oceans expand and glaciers melt.

This graph is based on information from the Intergovernmental Panel on Climate Change Fourth Assessment Report 2007.
The original graphs can be accessed at: www.ipcc.ch/

Q11: What is thermohaline circulation?

The world's oceans transport massive amounts of heat. Differences in seawater density, which depend on differences in temperature (thermo) and salinity (haline), drive global ocean currents known as the thermohaline circulation or the *meridional overturning circulation*. Part of the thermohaline circulation is the Gulf Stream, which warms Western Europe.

The Atlantic thermohaline circulation acts like an oceanic conveyer belt, carrying heat from the tropics to the North Atlantic. As warm water moves into the northern Atlantic, it cools, sinks to the ocean floor, and then returns southward.

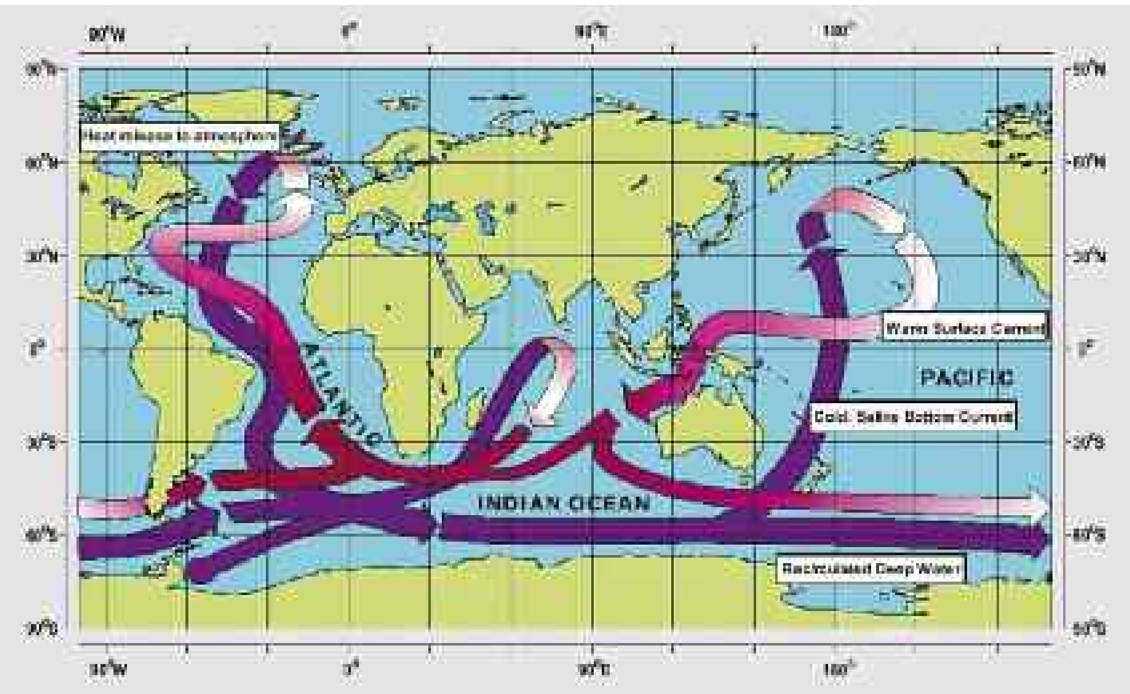
The Southern Ocean is also a significant contributor to the thermohaline circulation, linking the shallow and deep 'limbs' of the ocean conveyor belt, and playing a major role in the 'heat engine' that influences global climate patterns.

There are concerns that climate change may slow or even halt the thermohaline circulation. This could occur through changing salinity of the oceans due to greater rainfall and influxes of fresh water from melting ice. Surface ocean waters are becoming less salty in some places, and a key current in the North Atlantic appears to have slowed.

The thermohaline circulation has changed abruptly in the distant past; disruption of the thermohaline circulation could lead to rapid changes in the Earth's climate.

A shutdown in thermohaline circulation within decades is most unlikely. However, the Intergovernmental Panel on Climate Change states that it is very likely that the meridional overturning circulation of the Atlantic Ocean will slow during the 21st century. Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases of greenhouse gases. It is very unlikely that there will be a large abrupt change in circulation during the 21st century.

Schematic diagram of the global ocean circulation pathways



Schematic diagram of the global ocean circulation pathways, the 'conveyor' belt (after W. Broecker)

Q12: What is the El Niño—Southern Oscillation (ENSO)?

The El Niño-Southern Oscillation (ENSO) is a variation in normal sea surface temperatures in the equatorial Pacific Ocean. Pacific Ocean trade winds propel surface water in a westerly direction along the equator. As a result warm water accumulates in the western equatorial Pacific, to the north-east of Australia, heating air in contact with it. The warm, moist air produces clouds and rain.

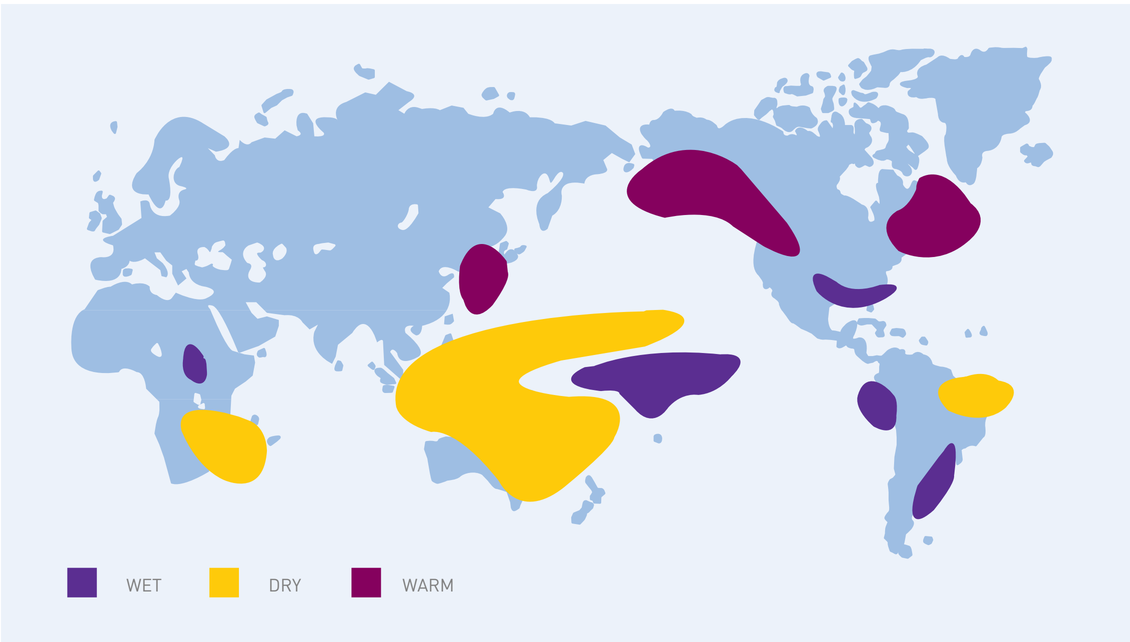
During the El Niño phase of ENSO the Pacific trade winds and tropical currents weaken, and the warm water in the western Pacific is displaced to the central Pacific. Clouds disappear and parts of Australia may experience drought. Simultaneously, parts of Northern and Southern America experience above-average rainfall.

In the opposite phase of ENSO, La Niña, the ocean surface in the equatorial eastern Pacific Ocean cools. Meanwhile, the western equatorial Pacific warm pool, north of New Guinea, warms. This in turn warms the air in contact with it which rises, lifting tonnes of moisture that condenses in the atmosphere forming massive cloud banks. These clouds bring rain to eastern Australia and parts of South-East Asia. La Niña's warmer seas usually generate more tropical cyclones around Australia.

Typically, El Niño and La Niña events occur every two to seven years.

The El Niño effect

Areas most consistently affected by El Niño



The Southern Oscillation Index (SOI) is a measure of the strength of ENSO. Visit the Australian Bureau of Meteorology's website for the latest SOI data (www.bom.gov.au) . CSIRO has a graph showing SOI monthly values from January 1866 through to the present (www.cmar.csiro.au).

Source: Bureau of Meteorology

Q13: Apart from ENSO, how do the oceans affect Australia's climate?

The oceans store a lot of the Sun's energy and transport this heat around the planet through massive currents. A slight temperature change in ocean surface waters can have a major impact on the atmosphere and rainfall patterns over vast areas.

Variations in Australian climate stem from changes in the Pacific, Indian and Southern Oceans. The effects of each of these can add to, or subtract from, each other.

The Indian Ocean Dipole is an important phenomenon. When it is present, the dipole consists of a warm water region in the area around Indonesia and New Guinea, and a relatively colder region in the central Indian Ocean west of Australia. The warm region is fairly common, particularly in La Niña years.

The Indian Ocean Dipole gives rise to rain-producing systems that extend across Australia from north-west to south-east. These north-west cloud bands are the principal means by which rain occurs in the dry centre, although most of the associated rain actually falls in the south-east of the country.

Q14: Is there a link between climate change and the ozone hole?

Global warming and ozone depletion (the 'ozone hole') in the upper atmosphere (stratosphere) are two different problems. However, chlorofluorocarbons (CFCs) play a role in both. Chemical reactions involving CFCs destroy ozone in the stratosphere. As a result, more of the Sun's ultraviolet radiation reaches the Earth, increasing our risk of skin cancer. The Montreal Protocol, an international agreement to protect the ozone layer, has led to concentrations of atmospheric CFCs and related substances beginning to decrease. Stratospheric ozone is likely to be restored to 1960s levels by about 2050.

CFCs also act as powerful greenhouse gases in the lower atmosphere by trapping heat energy which would otherwise escape to space. Some CFCs can remain in the atmosphere for many centuries before being broken down, so their contribution to global warming will persist for a long time.

Q15: What amount of warming is likely this century and can it be avoided?

Climate scientists say that the pivotal question regarding climate change is not whether the climate is changing and will continue to change in response to human activities, but rather how much, how fast and where.

Scientists are certain that climate change is already happening. Global average surface temperature increased over the past 100 years by about 0.7°C. There has also been an increase in heatwaves, a reduction in frosts, warming of the lower atmosphere and deep oceans, retreat of glaciers and sea ice, a rise in sea level of approximately 17 cm and increased heavy rainfall in many regions. There is extensive evidence of the impacts of global warming on the growth and distribution of plants and animals, as well as changes in events such as floods and droughts in some regions.

Once carbon dioxide—the main greenhouse gas increasing through human activity—is released into the atmosphere, it stays there for between 50 and 200 years. Hence further warming is already in the pipeline, regardless of what we do in the future. This is also because the deep ocean and the polar ice caps have massive thermal inertia, or heat-storing capacity, so they warm and cool more slowly than the atmosphere.

It is very likely that the warming will exceed 1°C over the next century. To quantify future warming, scientists have developed scenarios. These represent possible futures based on various assumptions about human behaviour, economic growth and technological change. Some scenarios assume 'business as usual' without actions specifically aimed at reducing net greenhouse gas emissions. These scenarios lead to a projected global-average warming of 1.1–6.4°C from 1990 to 2100. Other scenarios include actions to slow global warming by stabilising carbon dioxide concentrations. These scenarios will require substantial global greenhouse emissions reductions over the 21st century.

The level of action required to address the problem depends on the degree of climate change we are prepared to accept. Article 2 of the United Nations Framework Convention on Climate Change requires stabilisation of greenhouse gases at a level that prevents "dangerous human interference with the climate system". At this stage, "dangerous" is not well defined and will involve a mixture of scientific, economic, political, ethical and cultural considerations. However, a number of scientific assessments and governments have adopted a threshold for "dangerous" climate change of 2°C above pre-industrial levels. After accounting for the 0.7°C of warming that has already occurred, this allows less than 1.5°C of additional warming before the threshold is exceeded. Avoiding this level of warming by the year 2100 will require substantial global emissions reductions within the next 20–40 years.

The Australian Government is committed to climate change action, including helping Australia to adapt to the impacts of climate change as well as finding ways to reduce greenhouse gas emissions, domestically and globally through a range of international partnerships.

Q16: What is the contribution of methane to the enhanced greenhouse effect?

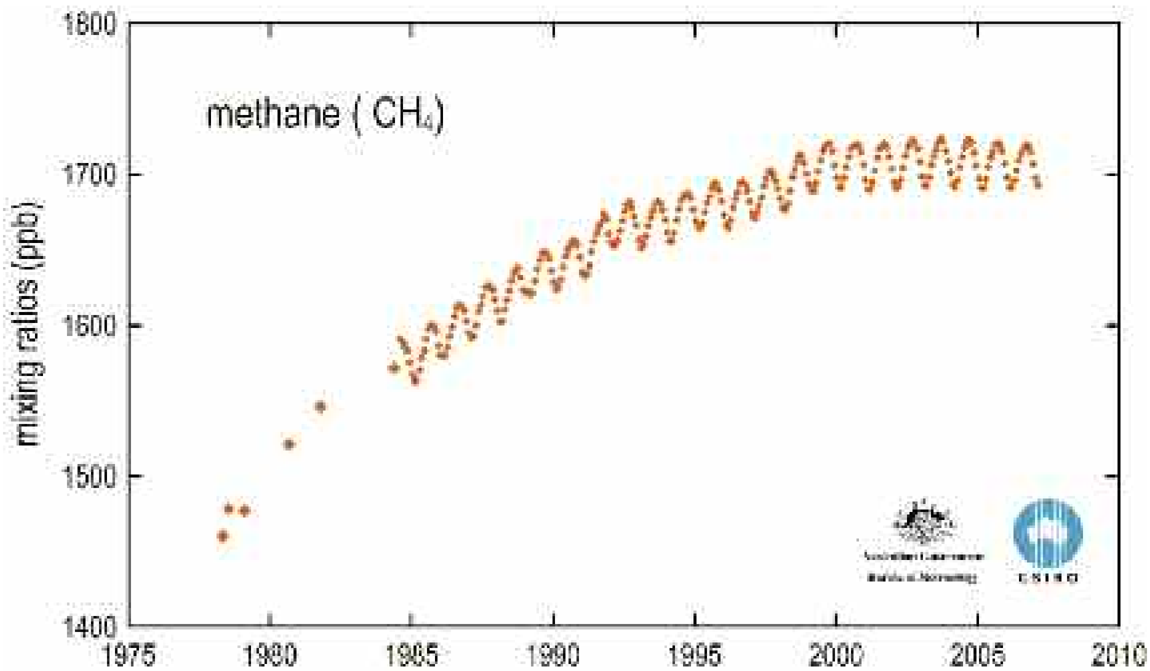
Methane is currently responsible for almost a fifth of the enhanced greenhouse effect, second in importance only to carbon dioxide. Methane has a warming potential more than 20 times greater than carbon dioxide on a volume basis. It is released into the atmosphere from agriculture—rice, cattle and sheep—from landfills, from biomass burning, from the mining and use of fossil fuels—coal, oil and gas—as well as from natural wetlands. Methane has an atmospheric lifetime of about ten years.

There has been a 150 per cent rise in atmospheric methane since pre-industrial times. The 1990s saw a decline in emissions of methane from human activities, resulting in the slower growth of methane in the global atmosphere in recent years. Since 1999 sources of methane from human activities have again increased, although atmospheric methane levels remain relatively stable due to drying of wetlands and consequent reductions in the amount of methane they release.

If the wetland drying trend reverses, and wetland methane emissions return to their normal levels, atmospheric methane levels may again increase. Methane may also be released in the future as tundra thaws in the northern hemisphere and perhaps as methane hydrates in ocean sediments destabilise due to oceanic warming.

Greenhouse gas emission scenarios for the 21st century indicate that changes in carbon dioxide will play the dominant role in future global warming. At present, carbon dioxide accounts for 60 per cent of the total greenhouse gas forcing (that is, the extra heat absorbed in the atmosphere as a result of atmospheric composition changes relative to pre-industrial times).

Methane concentrations since pre-industrial time from ice cores from Law Dome, Antarctica, and flasks from Cape Grim, Tasmania



Q17: What contribution do changes in the Sun's energy make to climate change?

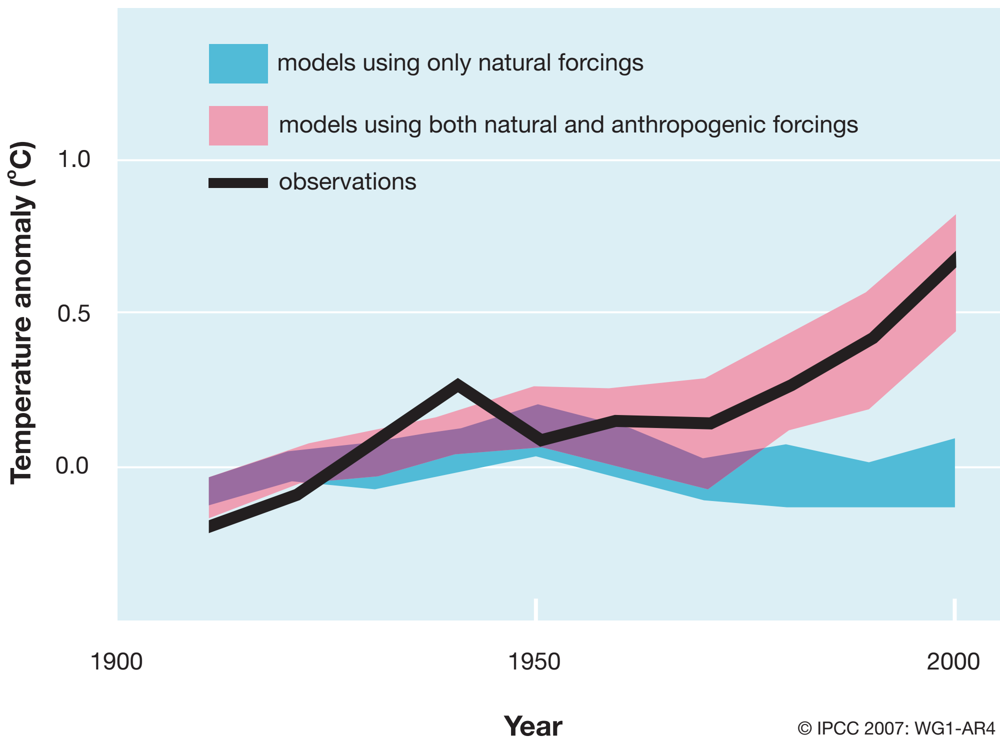
The Sun's energy drives the Earth's climate. The amount of energy received by the Earth varies due to changes in the Sun's activity and changes in the Earth's orbit around the Sun.

Annual mean total solar energy varies between the minimum and maximum of the 11-year sunspot cycle by about 0.1 per cent.

During the 20th century, the climatic influence of natural factors probably increased (a warming effect) up to about 1950 due to a period of low volcanism and a small rise in solar radiation.

Since the 1970s, global temperatures have risen significantly. Solar changes account for just a fraction of this recent warming. Rising concentrations of greenhouse gases are responsible for the bulk of the warming experienced in recent decades.

Global Average Temperature



Q18: What are the potential impacts of climate change?

The effects of climate change are already being felt by natural systems in many places. Glaciers in both the northern and southern hemispheres are shrinking, permafrost is thawing, growing seasons are lengthening and animals are shifting their ranges to higher and cooler ground.

While increases in intense rainfall events and heatwaves have happened in some regions, there is no clear global trend in smaller-scale severe weather events such as tornadoes, hail or dust storms. Tropical cyclones have increased in intensity since 1970, although there is no clear trend in their numbers. Climate models indicate that further increases in greenhouse gases will lead to continued global warming, more heatwaves, fewer frosts, less snow and a rise in sea level. Rainfall over most parts of the world may increase, but some places in the mid-latitudes, including parts of Australia, may become drier. Vulnerable natural systems, such as alpine fauna and coral reefs, are likely to suffer most as a result of climate change.

The world's poor and disadvantaged people and developing countries are likely to be affected much more than developed countries, which have the capacity to adapt to climatic changes. Projections for the 21st century suggest:

- More heatwaves could result in heat stress and heat-related deaths in humans and livestock, and damage to crops. The risk of bushfires is likely to increase in some areas.
- Fewer cold and frosty days would reduce cold stress and cold-related deaths in humans and livestock, and reduce frost damage, but may extend the range of pests and diseases. Yields of stone fruit such as apricots and nectarines in some locations may be reduced due to inadequate chilling.
- More intense and sporadic rainfall (including from tropical cyclones) would increase flooding and associated loss of life, property and productivity. It would also affect soil erosion and pollution of rivers and oceans.
- More frequent or intense droughts would increase loss of crops, livestock, fisheries and wildlife, and decrease river flows and water quality.
- Changes in rainfall patterns and reduced soil moisture in parts of Australia could reduce water supplies for agriculture, domestic and industrial uses, energy generation and biodiversity.
- The net effect of climate change on plant growth is dependent on interactions between carbon dioxide, temperature, nutrients and rainfall. High carbon dioxide concentrations and longer growing seasons due to higher temperatures increase plant productivity. However, reductions in rainfall and increased risk of drought would decrease plant growth as seen during 2002–3 and 2006–7.
- Like agricultural systems, Australia's natural forests may benefit from a carbon dioxide-enriched atmosphere, but the gains may be offset or even nullified by the impact of rising temperatures. Plantation forestry, however, may be able to adapt to changing climate conditions through management practices.
- In tropical rainforests, even a modest degree of warming is likely to significantly harm high altitude rainforest flora and fauna. In woodland ecosystems in south-western Australia, modest warming may harm most frog and mammal species.
- Projected global warming will contribute additional stress to coral reefs around the world due to ocean warming (causing coral bleaching), stronger tropical cyclones, sea level rise and higher levels of carbon dioxide which may reduce coral growth rates.
- All natural systems are vulnerable to invasion by exotic species. Disturbance by climate change is likely to increase vulnerability by increasing the stress on established vegetation. Warmer conditions will increase the likelihood of pests and diseases from tropical and sub-tropical Australia spreading southward. Some weeds may benefit from climate change and from reduced competition as unfavourable conditions weaken native species and perhaps crops.

- Less snow and a shorter snow season appear likely, threatening alpine ecosystems. Greater investment in snow-making will be needed by the ski industry.

Further details are available from:

Climate change: an Australian guide to the science and potential impacts (www.climatechange.gov.au/science/guide)

Intergovernmental Panel on Climate Change *Climate Change 2007: Impacts, Adaptation and Vulnerability*" WGII Chapter 11 www.ipcc.ch/

Q19: How can we live with climate change?

Scientists believe that further climate change is inevitable. Without actions to reduce greenhouse gas emissions, the Earth's surface temperature is likely to rise by 1.1 to 6.4°C by the year 2100 with more heatwaves, fewer frosts, less snow, more storms, stronger tropical cyclones and an 18 to 59 cm or greater rise in sea level. Therefore, strategies enabling adaptation to changes in climate will play an important part in reducing the damages and increasing the opportunities associated with the impacts.

Damages can also be reduced by slowing global warming and sea level rise through the stabilisation of greenhouse gas concentrations. The level at which greenhouse gas concentrations might be stabilised will depend on the actions the world takes to reduce emissions and how quickly this might happen. A reduction in emissions does not translate to an immediate reduction in concentrations because carbon dioxide has an atmospheric lifetime of 50–200 years. Once concentrations eventually stabilise, global temperature and sea levels will continue to rise for centuries because of the heat-holding capacity of the ocean.

Coping with climate change and a warmer world will mean changing the way we live.

For example, urban planning in coastal areas will need to consider beach erosion and flooding caused by rising sea levels. In some regions, buildings will need to be designed to cope with more intense tropical cyclones and storm surges. Areas prone to flooding may need to increase their drainage capacity, while drier areas will need to use water more efficiently.

Some farmers may need to adjust their cropping calendar, fertiliser application or varieties of crops to cope with climatic changes. Climate change may affect market prices for some commodities.

Putting in place strategies to adapt to climate change has the potential to reduce the adverse impacts as well as to capture possible benefits. Adapting to climate change will, however, incur costs and will not prevent all damage. The ability of different sectors, communities and countries to cope with climate change will vary widely.

Many natural systems will have difficulty coping with climate change, particularly those systems that are already vulnerable. Some Australian species could become endangered or extinct. For example, coral reefs may experience more frequent bleaching as ocean temperatures rise, and the mountain pygmy possum could become extinct.

Q20: What contributions do volcanic eruptions make to global warming?

Volcanoes emit water vapour and carbon dioxide, but contribute little to global changes in atmospheric greenhouse gas concentrations.

Large volcanic eruptions, however, can blast huge amounts of sulfur dioxide into the upper atmosphere (the stratosphere). There, the sulfur dioxide transforms into tiny particles of sulfate aerosol. These particles reflect energy from the Sun back into space, preventing some of the Sun's rays from heating the Earth.

Conversion of sulfur dioxide to sulfuric acid aerosol in the stratosphere takes some months, so maximum cooling occurs up to a year after the eruption. It may take many years before the cooling influence of the volcanic aerosol disappears completely.

When Mt Pinatubo in the Philippines erupted in 1991 it blasted up to 26 million tonnes of sulfur dioxide into the stratosphere. This led to a global surface cooling of 0.5°C one year after the eruption. This cooling offset the warming effects of both El Niño and human-induced greenhouse gases from 1991 to 1993.

Q21: Are recent droughts in Australia due to climate change?

Australian droughts are closely associated with natural variations in atmospheric and oceanic circulation, such as the El Niño-Southern Oscillation (ENSO). An El Niño event was the main cause of the drought experienced in south-east Australia in 2006.

Since 1975, Australia has experienced more frequent El Niño events than during previous years of the 20th century, but we are unable to say whether this is as a result of climate change. The relationship between long-term climate change and ENSO is a topic of ongoing research.

Although it's not yet possible to say that the frequency and duration of droughts are linked to climate change, there is evidence that rainfall changes in some parts of Australia are due to human influence, as is the warming trend in Australia. With this warming trend, droughts have become hotter. The 2003 drought (which coincided with an El Niño event) was the hottest in the past 100 years.

The decline in rainfall in south-western Western Australia is due to both natural variability and human-induced climate change.

Q22: What are the key climate change science findings in the IPCC Fourth Assessment Report?

In early 2007 Working Group 1 of the IPCC released its contribution to the fourth assessment report. The report, *Climate Change 2007: The Physical Science Basis*, found:

- There is now no question that the climate system has warmed.
- It is *very likely* that greenhouse gas emissions related to human activity caused most of the warming that has been observed since the mid-20th century. In their third assessment report in 2001, the IPCC had only considered it likely.
- Global climate change over the past 50 years is extremely unlikely to have been caused by natural variability alone.
- If greenhouse gas emissions continue at or above the current rate there will be further warming, and the changes that we will see during the 21st century would very likely be larger than those observed in the 20th century.
- Temperatures are projected to increase from 1.1°C–6.4°C by the end of the 21st century, depending on future greenhouse gas emissions.
- Global warming is expected to be greatest over land masses and in the Arctic, and least over the Southern Ocean and North Atlantic. As a result, snow cover is projected to contract, and sea ice is expected to shrink in both the Arctic and Antarctic. Late summer sea ice in the Arctic will disappear almost entirely by the latter part of the 21st century.
- Australia is expected to warm at a similar rate to the global average, with higher levels of warming expected in the north of the country.
- Global sea level rose during the 20th century by 12–22 cm. By the end of the 21st century, sea level is projected to rise by 18–59 cm but this does not include possible changes in big ice sheets in Greenland and Antarctica that could lead to more rapid sea level rise.
- The increases in greenhouse gases since 1750 are due primarily to emissions from fossil fuel use, agriculture, and land-use changes.
- Ice cores spanning the last 650,000 years indicate that current atmospheric concentrations of carbon dioxide and methane far exceed pre-industrial values.
- Since the 1970s droughts have been more intense and longer, and have been observed over wider areas, particularly in the tropics and subtropics. Higher temperatures and lower rainfall have contributed to these changes.
- Extreme climate events such as heatwaves and heavy rainfall are very likely to become more frequent.
- Although the number of tropical cyclones is expected to decrease, they are projected to be more intense, with larger peak wind speeds and more intense rainfall.
- Storm tracks are projected to move towards the poles. Rain-bearing storms over south-west Australia have already moved off the continent and reduced the once-reliable rainfall supply to south-west Western Australia.

The full report and summary for policymakers are available from the IPCC website at www.ipcc.ch/

Q23: What is Australia doing to address climate change impacts?

Dealing with the climate change challenge is one of the highest priorities of the Australian Government. The Government committed Australia to playing its part by ratifying the Kyoto Protocol in the Bali climate change negotiations in late 2007. Australia was instrumental in securing agreement on the Bali roadmap, which provides a pathway for the international community to agree on post 2012 action on climate change.

The Government is moving quickly and decisively to implement a comprehensive framework for tackling climate change. The key policy in this area will be the introduction of an emissions trading scheme, to commence in 2010.

In addition the Government supports continuing measures that encourage low emissions technology, energy efficiency, renewable energy, as well as research into climate change science and climate impacts and adaptation. The major climate change research effort is undertaken through the Australian Climate Change Science Programme. The programme is a collaboration between the Department of Climate Change, the Australian Bureau of Meteorology and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The research programme covers many aspects of the climate system and climate change including:

- Understanding the role of oceans in global and regional climate, the potential impacts of warming on the Southern Ocean thermohaline circulation and the capacity of the ocean to absorb carbon dioxide;
- Detection and attribution—determining the causes of recent climate shifts in Australia;
- Understanding the impacts of airborne particles and clouds on climate;
- Developing and improving global and regional climate models to provide more certainty in climate projections for Australia;
- Contributing our science to international climate change science forums, especially in the preparation of Intergovernmental Panel on Climate Change assessment reports; and
- Investigating the impacts of climate change and its potential impacts on the frequency and intensity of extreme climate events.

In April 2007 the Council of Australian Governments endorsed a National Adaptation Framework as the basis for jurisdictional actions on adaptation over the next five to seven years. The framework includes possible actions to assist the most vulnerable sectors and regions, such as agriculture, biodiversity, fisheries, forestry, settlements and infrastructure, coastal, water resources, tourism and health to adapt to the impacts of climate change.

The Australian Government has committed $126 million over five years to address climate change adaptation, including the establishment of a National Climate Change Adaptation Research Facility. The work will assist particularly affected sectors and regions, planning bodies, farmers, businesses and local government to understand better the impacts of climate change and to develop responses.

The Australian Government also announced funding of $44 million for a new CSIRO Adaptation Flagship which will provide more accurate information on localised climate changes.

For details of other Australian activities and actions refer to the Department of Climate Change website at www.climatechange.gov.au

Q24: What is the Intergovernmental Panel on Climate Change?

Recognising the problem of global climate change, in 1988 the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC).

The role of the IPCC is to assess the scientific, technical and socio-economic information relevant to understanding the threat of human-induced climate change. The IPCC does not carry out new research nor does it make climate-related measurements. It bases its assessments mainly on published and peer-reviewed scientific literature.

The IPCC has produced comprehensive assessment reports on the status of global climate change, with the Fourth Assessment Report released in 2007. Hundreds of the world's leading climate scientists, including many Australian experts, contributed to the production of these reports, which provide the authoritative, consensus account of global climate change.

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Further information

Department of Climate Change

www.climatechange.gov.au

CSIRO

www.csiro.au

Bureau of Meteorology Australia

www.bom.gov.au

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