VQA Level: 1

Learner Guide

Certificate I in Climate Change and Disaster Risk Reduction

Units 4 & 5: CGCC0416 & CGCE0516

Demonstrate knowledge of the causes of climate change Demonstrate knowledge of the effects of climate change

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Cover photo: Coal-burning factory in China

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First published 2017

Introduction

This Learner Guide supports the units of competency CGCC0416 (***Demonstrate knowledge of the causes of climate change)*** and CGCE0516 ***(Demonstrate knowledge of the effects of climate change)***, which specify knowledge, skills and attitudes associated with learning about the causes and effects of climate change. These units are the fourth and fifth in a series of eleven units that comprise a training programme on climate change and disaster risk reduction at Certificate Level 1.

The Learner Guide provides guidance and relevant educational resources that address the required elements and performance criteria. It is accompanied by a Learner Workbook that provides learner-centred activities and assessment tools to foster learning of key concepts and skills. The competencies developed are in line with the key competencies promoted by VQA to foster greater empowerment and success in the work place. Additionally, a Facilitator Guide for this unit provides further background knowledge and teaching notes for facilitators, trainers and teachers.

The fourth unit, CGCC0416, defines the standard required to: demonstrate that the earth's climate has been constantly changing; state some natural causes of climate change; demonstrate knowledge of the natural greenhouse effect and its importance for life; illustrate how human activities in the last 200 years are contributing to the enhanced greenhouse effect; and differentiate between the natural and enhanced greenhouse effects. The fifth unit, CGCE0516, defines the standard required to: demonstrate the links between greenhouse gases, global warming and climate change; provide reasons for rising sea levels and oceanic acidification; and provide an overview of future climate change projections.

The development of all units was guided by consultations with government and non-government stakeholders in Vanuatu and was based on the SPC's Community Education Training Centre draft training unit *Community Based Disaster Risk Management and Climate Change* (SPC/GIZ/USP, 2013). The units have been produced with technical and financial assistance from EU PacTVET and the SPC/GIZ's Coping with Climate Change in the Pacific Island Region (CCCPIR) programme. The University of the South Pacific's Pacific Centre for Environment and Sustainable Development (USP PACE SD) contributed to its technical review. The curriculum writer is Charles Pierce.

Icons

Activity to complete in the workbook

How am I doing?

Definition

Example

Course Outline

Before we start…

Dear Learner - This Learner Guide contains all the information to acquire all the knowledge, skills and attitudes leading to these unit standards:

Title: Demonstrate knowledge of the causes of climate change	
VQA Level: 1	Credits: 3

Title: Demonstrate knowledge of the effects of climate change	
VQA Level: 1	Credits: 3

The full unit standards will be handed to you by your trainer/facilitator. Please read them in your own time. Whilst reading the unit standards, make a note of your questions and aspects that you do not understand, and discuss it with your trainer/facilitator.

These unit standards are two of the building blocks in your qualification at Certificate level 1 listed below. Please write in the names of all the units of competency that you are currently doing:

Title	VQA Level	Credits
Certificate I in Climate Change and Disaster Risk Reduction	1 & 2	46
……..	…	…
……	…	…

You will also be handed a Learner Workbook. This Learner Workbook should be used in conjunction with this Learner Guide. The Learner Workbook contains the activities that you will be expected to do during the course of your study. Please keep the activities that you have completed as part of your Portfolio of Evidence, which will be required during your final assessment.

You will be assessed during the course of your study. This is called formative assessment. You will also be assessed on completion of this unit standard. This is called summative assessment. Before your assessment, your assessor/ trainer/ facilitator will discuss the unit standard with you.

Enjoy this learning experience!

How to use this guide …

Throughout this guide, you will come across certain re-occurring "boxes". These boxes each represent a certain aspect of the learning process, containing information that will help you with the identification and understanding of these aspects. The following is a list of these boxes and what they represent:

What does it mean? Each learning field is characterized by unique terms and **definitions.** It is important to know and use these terms and definitions correctly. They are highlighted throughout the guide in this manner.

You will be requested to complete **activities**, which could be group activities or individual activities. It is important to complete all the activities as your facilitator will assess them and they will become part of your portfolio of evidence. Activities, whether group or individual, will be described in this type of box.

Examples of certain concepts or principles will be shown in this type of box. Examples help you to relate what you are learning to a real life situation.

This type of box indicates a **summary** of concepts that have been covered, and offers you an opportunity to ask questions to your facilitator if you are still feeling unsure of these concepts.

My Notes …

You can use this box to jot down questions you might have, words that you do not understand, instructions or explanations given by the facilitator, or any other remarks that will help you to get a better understanding of what you are learning.

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Key competencies / employability skills to be acquired

Competency/skill	Example of application
Initiative	Adapting to new situations • developing a strategic long-term vision • being creative • identifying opportunities not obvious to others • translating ideas into action • generating a range of options • initiating innovative solutions • ***Initiate and carry out enquiries and independent research into changes in climate during the Earth's history.*** • ***Initiate and carry out experiments and independent research into the impacts of increasing levels of greenhouse gases on oceans and reefs.***
Communication	Verbal or non-verbal that includes: • speaking clearly and directly • writing to the needs of the audience • understanding the needs of internal and external parties • persuading effectively • establishing and using networks • ***Present information both visually (using hand-drawn illustrations and technology) and verbally to explain climatic conditions during different times in the Earth's history.*** • ***Give a talk to explain the natural greenhouse effect.*** • ***Present information both visually (using hand-drawn illustrations and technology) and verbally to explain problems that people in Vanuatu are going face in the future because of climate change.***
Teamwork	Working with people of different ages, gender, race, religion or political persuasion • working as an individual and as a member of a team • knowing how to define a role as part of a team • applying teamwork skills to a range of situations • ***Undertake fieldwork in small groups to investigate ways in which activities in the local community are contributing towards the enhanced greenhouse effect.*** • ***Undertake discussions and activities in pairs and groups regarding findings related to learning on the effects of climate change.***
Information & Communication Technology	Having a range of basic IT skills • applying IT as a management tool • using IT to organise data • being willing to learn new IT skills • having the occupational health and safety knowledge to apply technology • having the appropriate physical capacity • ***Use the internet and print materials to investigate the causes of climate change.*** • ***Use the internet and print materials to find examples of the impacts of climate change in Vanuatu and the Pacific region.***

	• ***Use phones, email and social media to access information on local impacts of climate change.*** • ***Use computer applications to construct climatic graphs, maps and diagrams.***
Problem solving	Developing creative, innovative solutions • developing practical solutions • showing independence and initiative in identifying problems solving problems in teams • applying a range of strategies to problem solving • applying problem-solving strategies across a range of areas • ***Create a diagram to show the water cycle during a glacial period of the last Ice Age.*** • ***Determine the likely consequences of increasing atmospheric and ocean temperatures for the world, for Vanuatu and for the local area.***
Self-management	Having a personal vision and goals • evaluating and monitoring own performance • having knowledge and confidence in own ideas and vision • articulating own ideas and vision • taking responsibility • ***Reflect on knowledge and understanding of the causes of climate change, both natural and human-made.*** • ***Reflect on knowledge and understanding of climate change and its effects on communities in the local region.***
Planning	Managing time and priorities – setting timelines, coordinating tasks • being resourceful • taking initiative and making decisions • establishing clear project goals and deliverables • allocating people and resources to tasks • participating in continuous improvement and planning • developing a vision and a proactive plan to accompany it • ***Plan, collect and collate information from observations and oral discussions in order to assess ways in which activities in the local community is contributing towards climate change.*** • ***Plan, collect and collate information from documents and oral discussions in order to make decisions about the effects of climate change on islands and oceans.***
Learning (gaining new skills and knowledge)	Managing your own learning using a range of learning options suited to the individual learning style– mentoring, peer support, networking; • having enthusiasm for ongoing learning; • being willing to learn in any setting• being open to new ideas and techniques • being prepared to invest time and effort in learning new skills • ***Participate in group discussions to share knowledge and gain new skills and learning on the causes and effects of climate change.***

GESI (Gender Equity and Social Inclusion)	Valuing and supporting women and disadvantaged persons and equal opportunity for all in workplaces and communities • mentoring younger people • valuing and respecting older people • having respect for different cultural, social, religious and political values • ***Ensure that discussions in the communities are inclusive of both male and female perspectives on the causes and effects of climate change.***

What am I going to learn?

Section 1: Demonstrate that the Earth's climate has been constantly changing

Section 2: State some natural causes of climate change

Section 3: Demonstrate knowledge of the natural greenhouse effect and its importance for life

Section 4: Illustrate how human activities in the last 200 years are contributing to the enhanced greenhouse effect

Section 5: Differentiate between the natural and enhanced greenhouse effects

Section 6: Demonstrate the links between greenhouse gases, global warming and climate change

Section 7: Provide reasons for rising sea levels and oceanic acidification

Section 8: Provide an overview of future climate change projections

What do I need to know?

Before you start these two units, you should:

- be able to read, write and handle numbers
- have knowledge and experience of some of the factors that influence climate change (deforestation, volcanic eruptions, burning of fossil fuels, etc.) and of the links between the atmosphere and the oceans (evaporation, precipitation, heating of surface water by solar radiation, etc.)
- have basic skills in mapping and the construction and interpretation of graphs and diagrams

What are my learning outcomes?

When you have achieved these unit standards you will be able to:

- describe changes in the Earth's climate during geological history;
- explain some of the natural factors or forcings that cause climate change;
- describe the natural greenhouse effect and its importance for life;
- explain the contribution of human activities to the enhanced greenhouse effect during the last 200 years;
- identify differences between the natural greenhouse effect and the enhanced greenhouse effect;
- demonstrate the link between increased quantities of greenhouse gases (GHGs), global warming and climate change;
- explain the way that increased levels of GHGs and increasing temperatures are leading to rising sea levels and oceanic acidification;
- summarize future climate change projections for Vanuatu.

Introduction to the Unit

You are about to start on the fourth and fifth Units of the Certificate I course on Climate Change and Disaster Risk Reduction. In these Units, you are going to find out much more about climate change, its causes and some of its effects. You will first look at how the Earth's climate has always been changing throughout geological history, in other words ever since the Earth began approximately 4.6 billion years ago, and you will discuss reasons for these natural changes in climate. You will study how the earth is heated, how the earth heats the atmosphere, and how there are certain gases in our atmosphere that can absorb outgoing heat and keep our atmosphere warmer than it should be. This is called the natural "greenhouse effect". You will then look at signs showing how human activities have been increasing this natural greenhouse effect in the last 200 years, so making our atmosphere warmer. This is called the "enhanced greenhouse effect".

After summarizing the differences between the natural and the enhanced greenhouse effects, you will look at evidence pointing to the connection between increased levels of greenhouse gases (GHGs) in the atmosphere and global warming. Following on from this, you will learn how rising global air and sea surface temperatures are having an impact on other aspects of climate - changing rainfall patterns, more frequent extreme events, humidity, and atmospheric and oceanic circulation. In addition to looking at these aspects of climate change, you will learn how increased air and sea surface temperatures are causing rising sea levels through the thermal expansion of oceans and the melting of land-based ice (the ice cover in polar regions and glaciers). You will also discover the connection between increasing levels of carbon dioxide, increasing sea surface temperatures, oceanic acidification and the degradation of coral reefs.

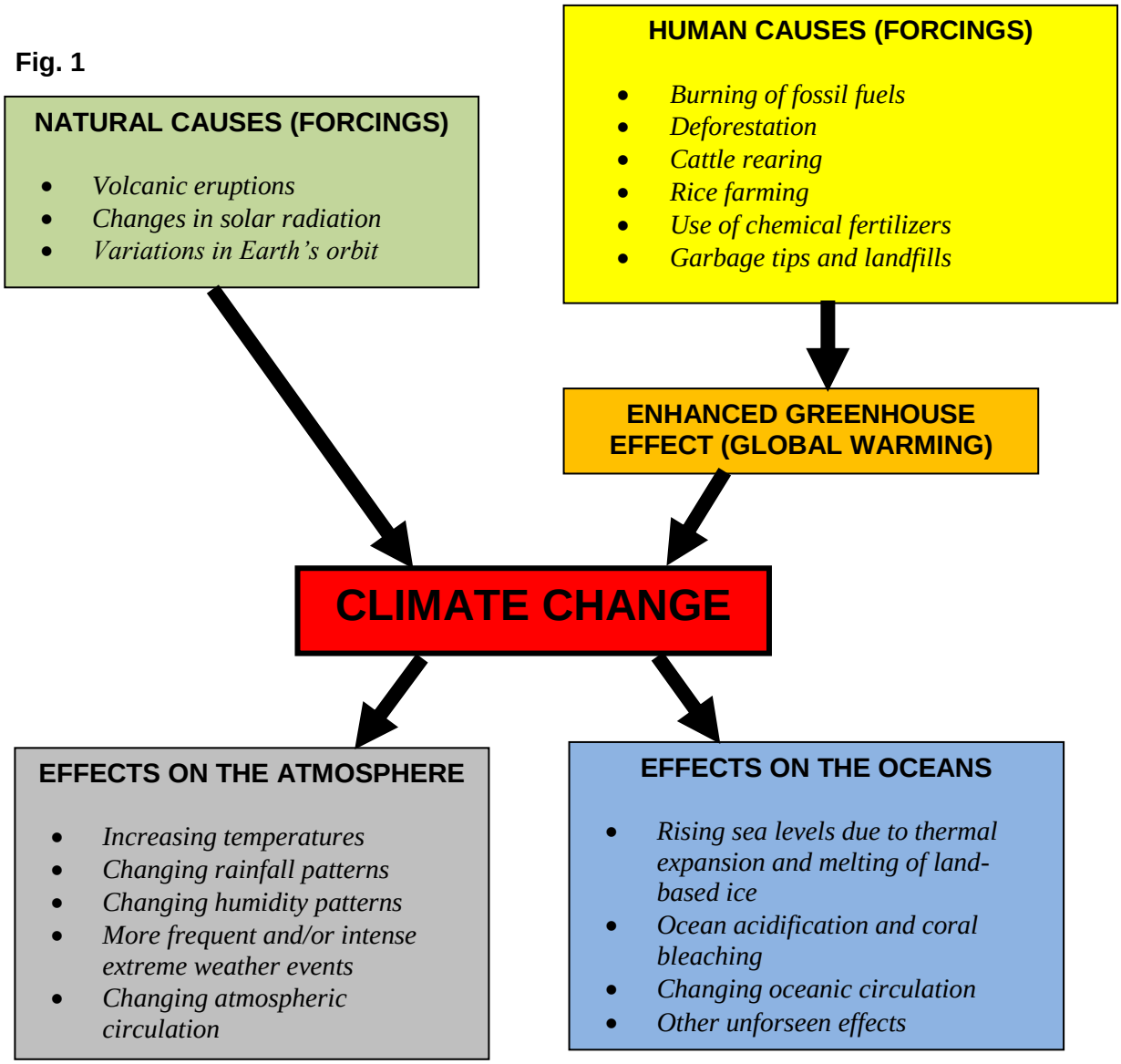
Finally, you will build on knowledge and skills gained in the previous Unit, CGCV0316, and consider how meteorologists are making projections of future temperature and rainfall patterns in Vanuatu, as well as predictions of future sea level rise and ocean acidification.

All these concepts are essential for you to grasp. They will enable you to better understand the various actions that can be taken to mitigate greenhouse gas emissions and to reduce the negative effects of present and future climate change. And, more importantly, they will give you background knowledge that will help you to work with your local community to prepare for, and adapt to,

the changes that are going to come. These topics will be covered in more detail in later units in this course.

Here is a diagram (Fig. 1) that will help you to understand how information about climate change has been organized in this Learner Guide.

Fig. 1



After completing these two Units, you will be better able to talk to other people about the meaning of climate change, its causes and some of its effects.

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Section 1 Demonstrate that the Earth's climate has been constantly changing

After completing this section, you should be able to:

1.1 identify examples of periods in the Earth's history when temperatures were warmer and cooler than those of today;

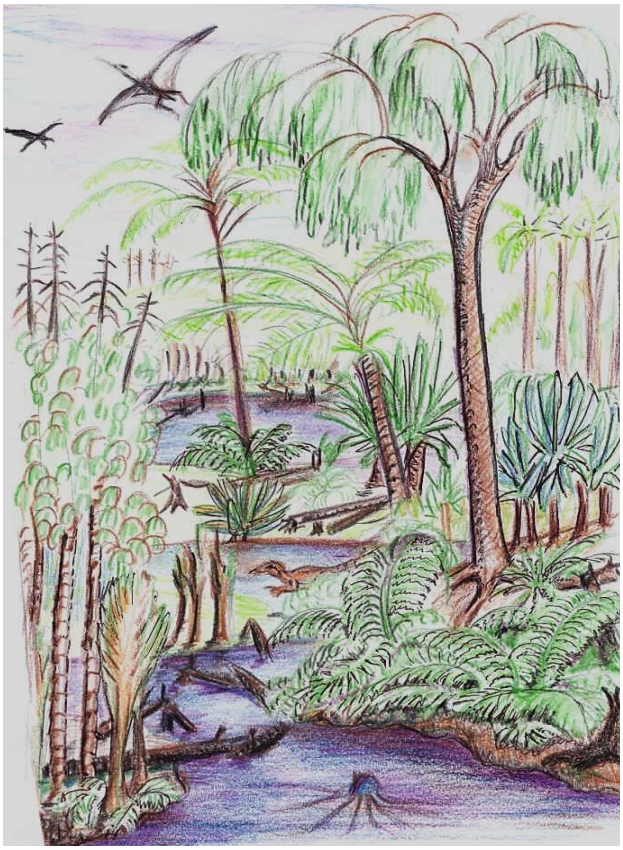
1.2 demonstrate changes in world-wide sea levels during the last Ice Age.

1.1 Our planet's changing climate

Geologists tell us that our Earth began approximately 4.6 billion years ago as a swirling cloud of dust and gas particles, at a temperature of thousands of degrees Celsius. Since then, its atmosphere has gradually cooled down, as has its surface. But this cooling has not been constant, and the Earth's surface has warmed up and cooled down many times.

One example is approximately 360 million years ago, at the start of the **Carboniferous period**. At that time, Earth was much warmer than at present, and there was more oxygen in the atmosphere than at any other time in history, so that there were ideal conditions for plant growth (Fig. 2).

Thick rain forests covered the land masses, and eventually, these forests decayed to become coal. The first reptiles appeared at this time.



Morgan, B., 2014

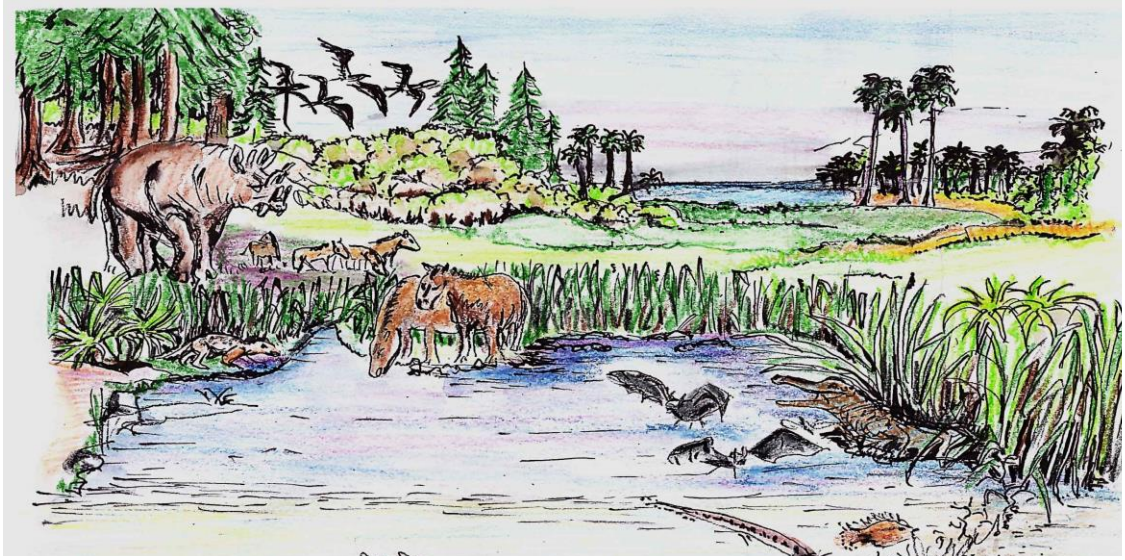
Fig. 2:

An artist's impression of the Carboniferous period

The Carboniferous period started off warm, but soon temperatures began to cool, and by the end of this period, 300 million years ago, the polar regions of the Earth were covered in ice.

At the start of the **Eocene epoch**, approximately 49 million years ago (Fig. 3), there was little or no ice on Earth, with hardly any difference in temperature between the Equator and the poles. There were high levels of carbon dioxide and methane in the atmosphere and the climate was so warm that forests covered the Earth and palm trees and crocodiles were found at high latitudes. Some scientists say that the Earth's average temperature could have been as high as 30°C (UCMP, 2014). But as time progressed, the climate became cooler, and by the end of the Eocene, there were ice sheets again in polar regions. At this time, of course, there were no humans on the planet.

Fig. 3: An artist's impression of the start of the Eocene period



Morgan, B., 2014

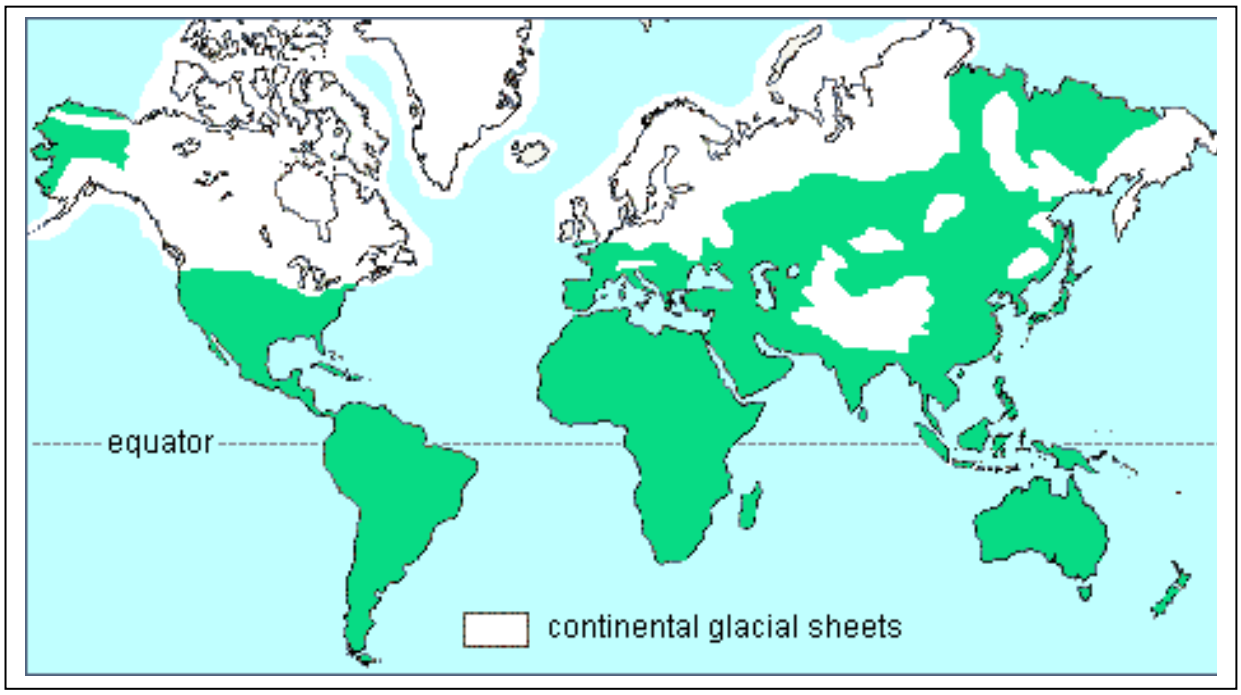
At the start of the Eocene period, 49 million years ago, forests covered the Earth from pole to pole and sea levels were much higher than at present

As well as warm periods in the Earth's history, geologists have found evidence of at least five major **Ice Ages** during the last 4.6 billion years. The most recent Ice Age started approximately 2 million years ago, just as the humans first appeared on Earth, and ended 11,700 years ago. Known as the **Pleistocene Ice Age**, it consisted of at least four **glacial** periods when average world temperatures were about 5°C lower than at present and ice covered large parts of the northern hemisphere. Between these periods when ice advanced there were **interglacial** periods when temperatures were similar to those of today. Some scientists believe that we are still in an interglacial period, and that another glacial period will return in the future!

During the glacial periods, world sea levels were much lower than at present. During the interglacial periods, they were similar to those of today.

This map (Fig. 4) shows the extent of the big continental ice sheets approximately 20,000 years before the present. At that time, one quarter of the Earth's land surface was covered in ice, and sea levels were much lower than today.

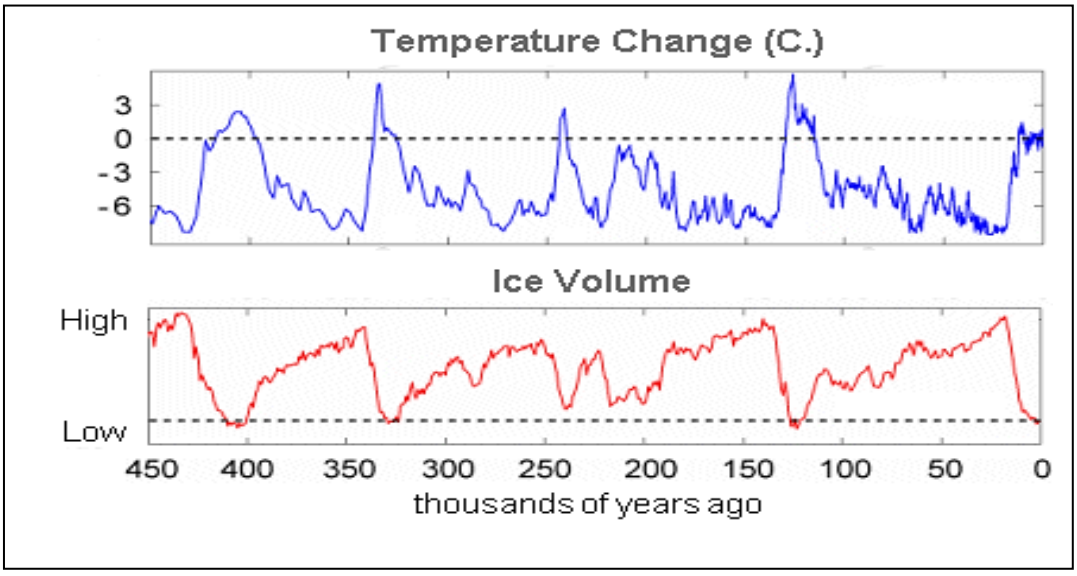
Fig. 4



O'Neil, D, 2008-2013

The two graphs in Fig 5 below show how temperature and the volume of ice changed during the last 450 thousand years. In the top graph, the dotted line represents the world's average temperature today. During interglacial periods, temperatures were up to 3°C higher than today, while in the glacial periods, they reached 6°C lower than today. The bottom graph shows how the volume of ice present on the earth increased and decreased according to the temperature changes.

Fig. 5

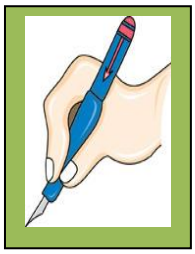


O'Neil, D., 2008-2013

Fig. 6: An artist's impression of northern Spain during a glacial period of the Ice Age

Anton, M., 2004 / Public Library of Science

The picture shows the landscape in northern Spain during one of the glacial periods in the recent Ice Age. The large animals are woolly mammoths (now extinct)



Now please complete Activities **1.1a** and **1.1b** in your Learner Workbook

My Notes:

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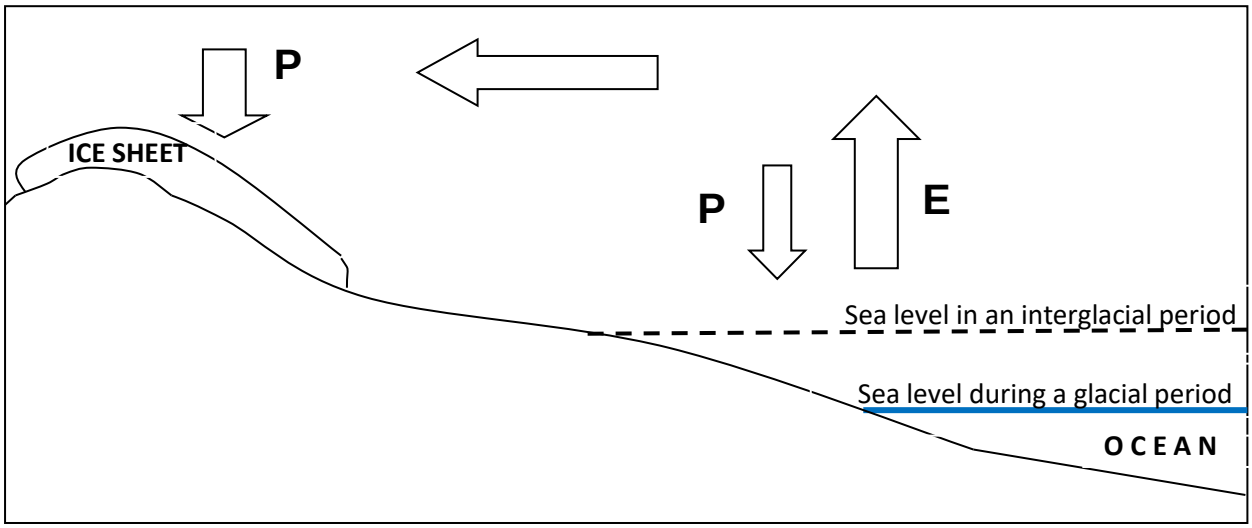
Concept	I understand this concept	Questions that I would still like to ask
1.1 Examples of periods in the Earth's history when the climate was much warmer or cooler than today		

1.2 Changes in sea levels during the last Ice Age

As you have discovered, the Earth's climate changed a lot during the most recent Ice Age. During the glacial periods, average world temperatures fell by as much as 6°C, while during the interglacial periods, average world temperatures may have risen some 3°C higher than they are today. These changes had big effects on sea levels. Let us look at what happened to the water cycle during a glacial period. As you can

see from the diagram (Fig. 7), the oceans did not freeze, and so water continued to evaporate from them. However, when the air moved from the oceans over the land, the colder temperatures meant that any precipitation fell down as snow, not rain. The snow stayed on the surface and froze into ice, and there was very little run-off or underground flow back to the oceans. This meant that water was evaporating from the oceans, but not being returned to it. So there was a large drop in sea levels throughout the world.

Fig. 7: The water cycle during a glacial period of the last Ice Age



During the final period of the Ice Age, sea levels in the western Pacific were about 130 metres below the present height (Nunn, P. 1997, *Human and Non-Human Impacts on Pacific Island Environments,* USP, Suva.) Many islands joined together and it became possible for early humans to walk from PNG to Australia and Tasmania.

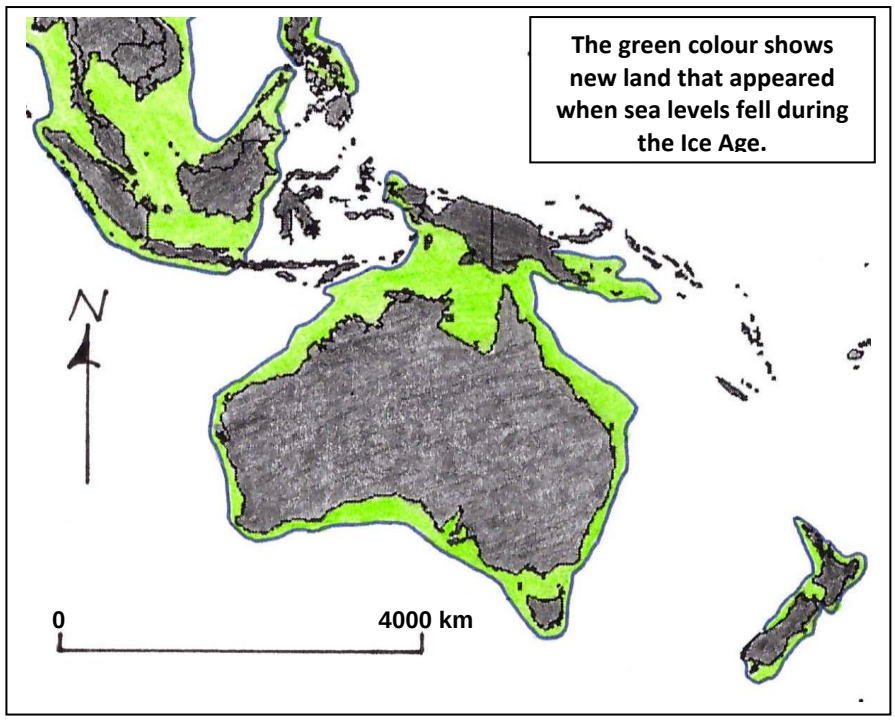
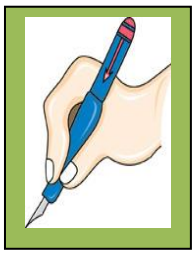


Fig. 8:

South East Asia and the South West Pacific during the last Ice Age



Now please complete Activities **1.2a** and **1.2b** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
1.2 World wide sea levels fell during the last Ice Age when temperatures were much cooler		

Section 2 State some natural causes of climate change

After completing this section, you should be able to:
2.1 identify reasons for natural changes in climate

2.1 Natural factors or forcings causing climate change

There are two types of factors or forcings that can change the Earth's climate - **natural forcings** and **human forcings**. Human forcings are also known as **anthropogenic forcings**. Natural forcings have occurred throughout the 4.6 billion years that our planet has existed. Human forcings date from the time when humans first appeared on Earth, about 2 million years ago, but have only become important in the last 200 years.

Here are some of the natural forcings that have been causing long-term changes in the Earth's climate throughout **geological history.**

Volcanic eruptions: Volcanoes put large quantities of gases such as carbon dioxide, sulphur dioxide and water vapour into the atmosphere. Carbon dioxide and water vapour are **greenhouse gases** that can absorb the outgoing radiated heat from the Earth's surface, so keeping the atmosphere warm. But in addition, dust clouds emitted by volcanoes can block incoming solar energy and so reduce the power of the sun's heating, making the Earth cooler.

Fig. 9

USGS, 1991

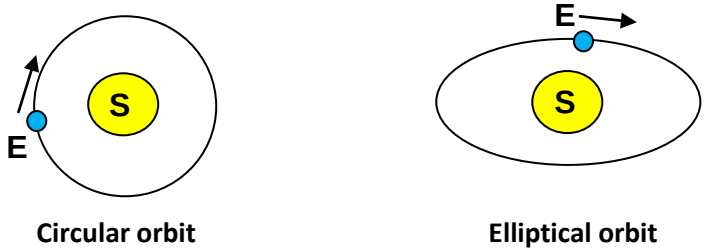
The eruption of Mount Pinatubo in the Philippines on 15th June 1991 released a huge volume of dust and sulphur dioxide gas into the air.

The dust cloud spread right around the earth and reduced the normal amount of sunlight reaching the earth by 10%. This led to a global fall in temperature of about 0.4°C during the next two years. The whole planet was cooled (Rosenberg, M., 2014)

Changes in the amount of sunlight reaching the Earth: The amount of energy emitted by the Sun **fluctuates** and is not constant. If more energy is emitted, then all the planets in the solar system will get warmer, and if less is emitted, then they will get cooler.

Also, the Earth's **orbit** around the Sun is not constant. Today, and during some periods in the past, the orbit is roughly in the shape of a circle. But at other times, the orbit is elliptical. Such an elliptical path means that twice during the year, the Earth comes closer to the Sun than it does at present, which will cause higher temperatures in those seasons.

Fig. 10



Pierce, C., 2014

Scientists have found that the Earth also wobbles on its axis, meaning that sometimes, parts of the surface face the Sun more directly, and receive more energy.

Changes in the reflecting power of the Earth's surface: Another forcing of climate change comes when the reflecting power of its surface changes. Forests and oceans are darker in colour and can absorb more heat, while surfaces covered in snow or sand will reflect the heat and remain cold. So once a large part of the Earth's surface is covered in ice, the ice reflects incoming heat energy, there is less heat radiation from the earth, and the climate is cooler. The ability of a surface to reflect or absorb heat is called its **albedo**.

Meteorites and asteroids: These are pieces of rock and/or ice that move about in space. Each day, the Earth is hit hundreds of times by small meteorites, and nothing happens. But once every few million years a really huge meteorite or asteroid comes along (Fig. 11). When it hits the Earth, it generates so much dust and steam that sunlight cannot reach the surface. The Earth cools down very rapidly and plants and animals suffer and die. Scientists think that that the last major impact from a meteor or asteroid happened 66 million years ago, at the end of the Cretaceous period. It caused a major period of cooling and was responsible for the extinction of three quarters of all plant and animal species, including the dinosaurs, on the planet (Fig. 12).

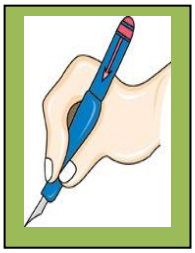
Fig. 11:

Artist's impression of the asteroid striking the earth 66 million years ago

Morgan, B., 2014

Changes in the composition of the atmosphere: At certain times in the Earth's history, the atmosphere has contained greater quantities of greenhouse gases such as carbon dioxide and methane. Such gases make the atmosphere much warmer. This happened, for example, about 49 million years ago during the early part of the Eocene epoch, when the climate became so warm that there was little or no ice on the Earth.

ENSO: As you saw in the previous Unit, the El Niño-Southern Oscillation is a powerful forcing that affects climate variability not only in the Pacific area, but also throughout the world. However, these changes are probably short-term rather than long-term.



Now please complete Activities **2.1a** and **2.1b** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
2.1 Natural forcings of climate change - volcanic eruptions, changes in solar radiation, variations in the earth's orbit, meteorites and asteroids, changes in the composition of the atmosphere, etc.		

Section 3 Demonstrate knowledge of the natural greenhouse effect and its importance for life

After completing this section, you should be able to:

3.1 identify processes in the natural greenhouse effect;

3.2 identify the major greenhouse gases that contribute to global warming.

3.1 The natural greenhouse effect

Before moving on to the study of human forcings of climate change, let us examine a very important aspect of atmospheric heating **- the natural greenhouse effect.**

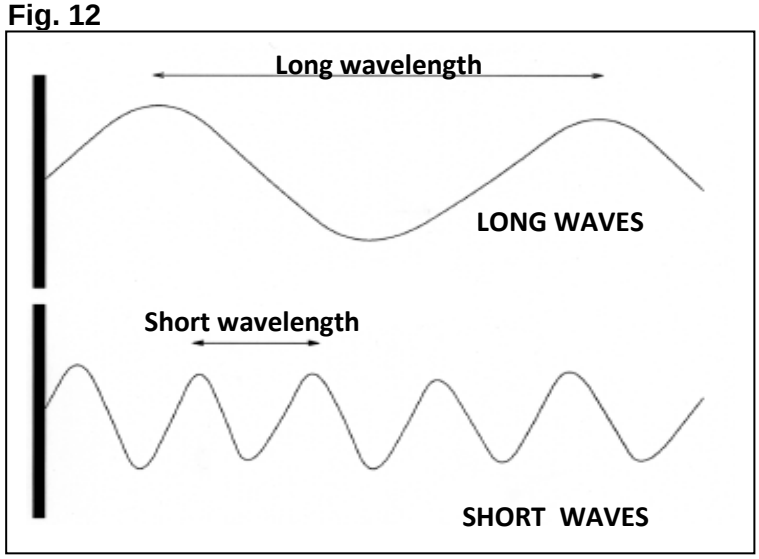
In CGCK0216, you found out that the Earth's atmosphere is heated from the ground upwards. Energy from the Sun is received by the land or the oceans, which then heat up the atmosphere above them. We will now study this in more detail.

The energy that come from the Sun is known as **electromagnetic radiation**, or **solar radiation**.

Solar radiation consists of waves of energy that have different **wavelengths**, varying from very short to very long (Fig. 12).

The shortest waves have a wavelength of 0.000000000001 metres. They are called Gamma rays and are very dangerous to life. The longest waves have a wavelength of 10-100 metres, and are known as radio waves.

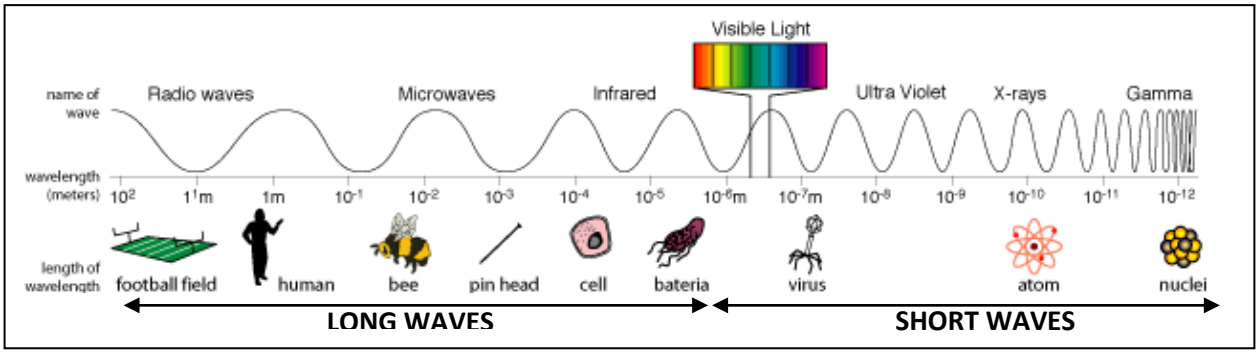
Fig. 12



Pierce, C., 2014

The diagram below (Fig. 13) shows all the waves that make up solar radiation. Most solar radiation consists of the shorter wavelengths, including infrared, visible light, ultra violet, X-rays and gamma rays. Incoming solar radiation gives both heat and light.

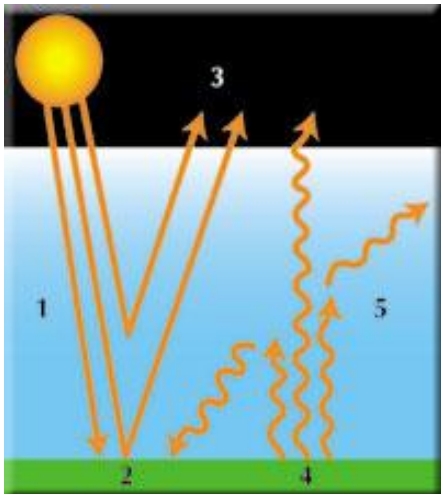
Fig. 13



NASA/ Pierce, C., 2014

Fig. 14

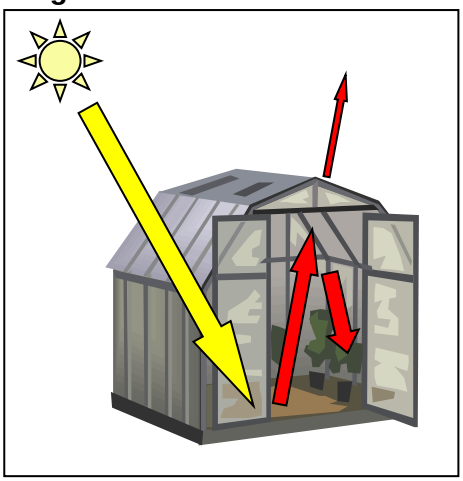
Fig. 14 shows that when solar radiation reaches the Earth's atmosphere, some of it is immediately reflected back into space (3). Most passes through the clear atmosphere (1), but the shortest wavelengths are reflected back by the atmosphere and the Earth's surface (3). About half of the solar radiation is absorbed by the Earth's surface (2), where it is converted into heat. The ground then sends back this heat into the atmosphere in the form of long-wave radiation (4). Certain gases in the atmosphere absorb some of this outgoing heat (5) and keep the lower atmosphere warm. This is the **natural greenhouse effect**.



NASA, 2014

So why is this called the "greenhouse effect"?

Fig. 15

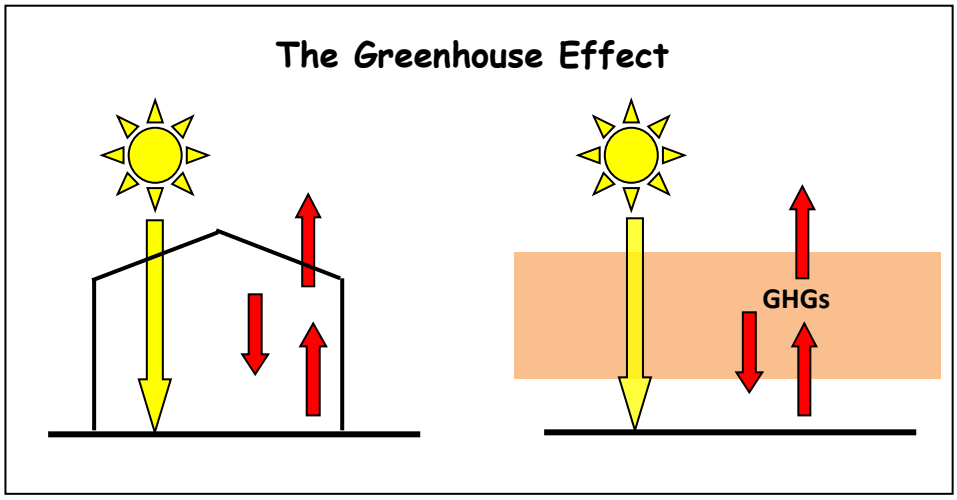


Pierce, C., 2014

A greenhouse is a building made of clear glass or plastic that allows short-wave solar radiation to pass inside (Fig. 15). However, after the heat is absorbed by the floor and is radiated back, the glass stops most of it from escaping. This keeps the inside of the greenhouse warm. In cool climates this means that plants can be grown inside the greenhouse while outside it is too cold for vegetation to grow.

In the same way, the Earth's atmosphere lets in the short-wave and long-wave radiation from the Sun, but certain gases in the atmosphere absorb some of the **long-wave infra-red (heat) energy** coming from the Earth (Fig. 16). These gases are called **greenhouse gases (GHGs)**. Examples are carbon dioxide, methane and water vapour. The gas molecules trap heat and send some of it back to the Earth, making our atmosphere act like a blanket that keeps us warm.

Fig. 16



Pierce, C., 2014

Without these greenhouse gases, the average temperature on the surface of the Earth would be -18°C. With them, Earth's average temperature is about 15°C, and this makes it possible for life to exist.

3.2 Greenhouse gases

The four main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapour (H_2O).

Carbon dioxide: This is perhaps the most important GHG. It is released naturally into the atmosphere through volcanic eruptions, natural fires and animal and plant respiration, and spends a long time in the atmosphere. It is also released through human activities such as the burning of fossil fuels for energy and deforestation.

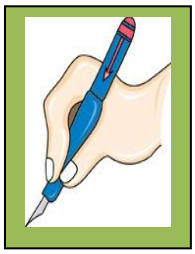
Methane is the second most important GHG. It is produced naturally through the decomposition of organic matter, for example, from rotting trees. It is also emitted through human activities such as rice cultivation, the rearing of cattle and other **ruminants**, and garbage tips. It is a stronger GHG than CO_2 because it absorbs more heat, but is less abundant.

Nitrous oxide is a very powerful GHG, mostly produced by human activities. Examples are the production and use of chemical fertilizers, the burning of fossil fuels and the treatment of waste.

Water vapour has the same effect as a GHG, but only spends a short time in the atmosphere. It is not influenced very much by human activities.

Other important GHGs are the **chlorofluorocarbons** (CFCs), which are human-made compounds that are used in refrigerators and air conditioners. **Aerosols** are tiny particles of solid or liquid suspended in the air, and are mostly a consequence of human activity; they can absorb solar radiation and so behave like GHGs.

(WMO; SPC & GIZ, 2014)



Now please complete Activities **3.1a, 3.1b** and **3.2** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
3.1 The natural greenhouse effect, incoming energy from the Sun and outgoing energy from the Earth. 3.2 Greenhouse gases (GHGs) that contribute to atmospheric warming.		

Section 4 Illustrate how human activities in the last 200 years are contributing to the enhanced greenhouse effect

After completing this section, you should be able to:

4.1 demonstrate ways in which humans are contributing to increased emissions of greenhouse gases;

4.2 carry out a field investigation in the local area to find out how human activities are contributing to the enhanced greenhouse effect.

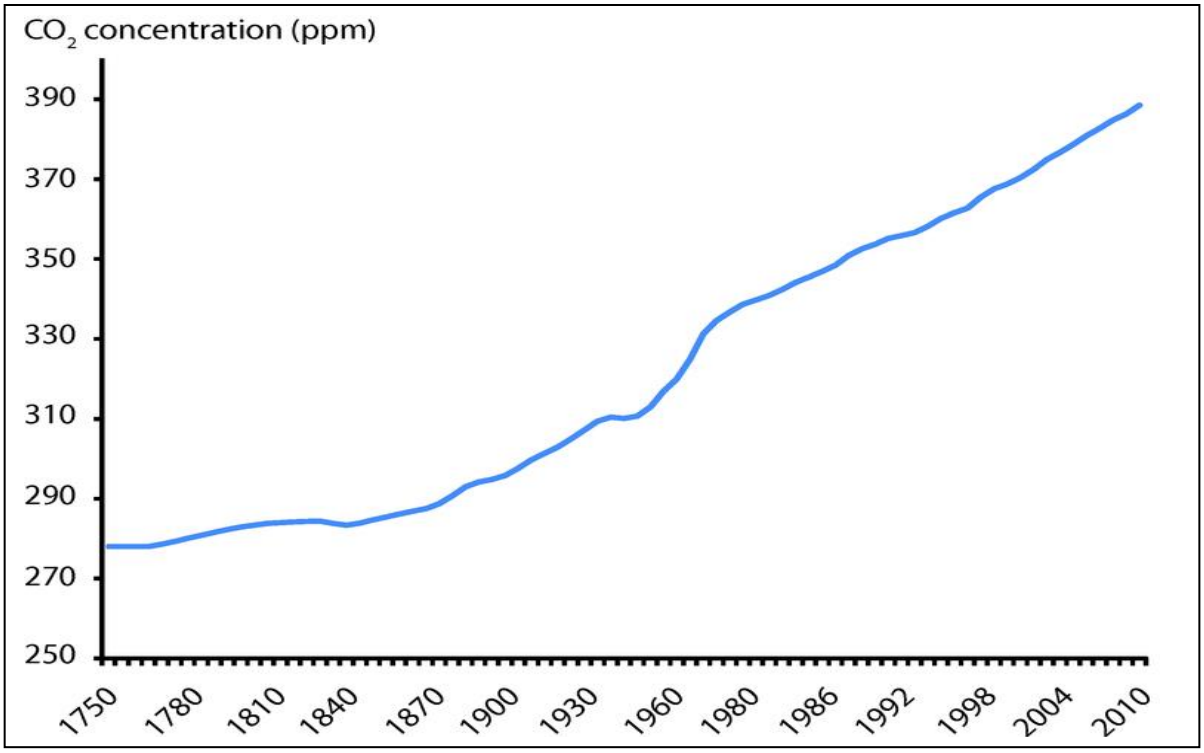
4.1 Human activities that contribute to GHG emissions

Now let us see how human activities are releasing greenhouse gases into the atmosphere, so increasing the greenhouse effect and influencing climate change.

There is evidence that our species, *Homo sapiens*, has existed on this planet for some two million years. For most of this time, humans used only simple technology and had little impact on their environment. They moved about in small family groups in search of food and water and did not start to settle down in villages until about 12,000 years ago, after the end of the last glacial period in the Pleistocene Ice Age. Once people started to clear and burn forests for farming, more carbon dioxide was released into the atmosphere, but the general effect on the greenhouse effect remained small.

But when the Industrial Revolution started in Europe during 1750-1800, a major change began. Coal was burnt to create steam power for operating the new machines, and before long the burning of other **fossil fuels** such as oil and natural gas became widespread throughout the world, so adding vast quantities of carbon dioxide to the atmosphere. At the same time, deforestation rapidly increased, so reducing the number of trees that could absorb the carbon dioxide. There was also an important rise in emissions of methane through agricultural activities such as rice farming and cattle ranching and through the decomposition of rotting waste in garbage tips. The result was a rapid build-up in the amount of carbon dioxide and methane in the atmosphere, as shown in the following graph (Fig. 17).

Fig. 17: Carbon dioxide content of the Earth's atmosphere from 1750 to 2010



European Environmental Agency, 2011

So how exactly do human activities increase GHG emissions?

Burning of fossil fuels: The burning or **combustion** of fossil fuels such as coal, petroleum (oil) and natural gas releases large quantities of carbon and carbon dioxide into the atmosphere. Some of this carbon dioxide is absorbed by vegetation and ocean water.

The combustion occurs in industries, power stations (Fig. 18), motor vehicles (Fig. 19), trains, ships, and aircraft.

Fig. 18

Andreas / Wikimedia Commons, 2014

Fig. 19

Pierce, C. , 2014

Clearing and burning of vast areas of forest (deforestation): Humans and animals breathe in oxygen and breathe out carbon dioxide. Plants absorb carbon dioxide and release oxygen. But if the planet's trees and forests are removed or disturbed, this natural balance is upset, and there are fewer plants to take in the carbon dioxide through the process of photosynthesis. The deforestation that has occurred all over the planet, especially in the last 50 years, is adding to the build-up of CO_2 (Fig. 20). Also, the burning of vegetation releases additional carbon to the atmosphere.

Pierce, C., 2015

Fig. 20:

Deforestation near Lae, Papua New Guinea.

In the Pacific islands and many other tropical areas, the clearing and burning of forest and bush for food gardens is a common form of deforestation (Fig. 21).

Pierce, C., 2007

Fig. 21:

Food garden near Lolowai, Ambae, Vanuatu.

Agriculture: The rearing of domestic animals such as cows and goats is responsible for the production of methane, which is emitted from both ends of these animals as they digest food. They are **ruminants**, meaning that they eat plants, ferment the plant material in a section of their stomach, then regurgitate this material back into their mouths in order to chew and obtain nutrients. In recent years, large areas of tropical rain forest in South America have been cleared in order to make way for cattle ranches that feed the world's increasing demand for meat. Cattle plantations are also found in Pacific island nations such as Vanuatu, New Caledonia and Fiji. (Fig. 22)

Fig. 22:

Cattle near Duck Lake, Efate, Vanuatu

Pierce, C., 2006

Another huge source of methane is from the cultivation of "wet" or **"padi"rice**, which is grown under water (Fig. 23). Remember that rice cultivation feeds more than half of the world's population, and that 90% of the world's rice is grown in Asia, mostly from flooded fields in the south-east.

Fig. 23: Rice fields in North Vietnam

Quynh Anh Nguyen, 2014,

As the world's population grows, so more and more rice must be cultivated, and more and more methane will be emitted.

Additionally, the manufacture and use of chemical fertilizers for agriculture releases nitrous oxide, a powerful GHG, into the atmosphere.

Land fills and garbage tips: When organic wastes are left to rot in landfills or open garbage tips, their decomposition puts large quantities of methane into the air (Fig. 24). As the world population increases, so too does the amount of waste generated, and many countries are unable to dispose of this waste in a proper manner. This is another reason for rising amounts of methane in the atmosphere.

Fig. 24

Karthikeyan, A.K. / Wikimedia, 2012

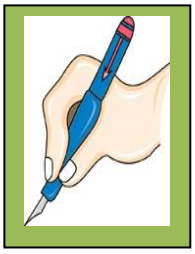
Industry: Vast quantities of carbon dioxide are emitted by the iron and steel industry, oil refining, paper manufacturing and by power stations making electricity from coal, oil and natural gas. Although these industries and power stations are not common in the Pacific islands, they are part of the industrial landscape of Europe, North and South America and Asia, and are major contributors to increasing emissions of GHGs.

Urbanization: Over half the world's population now lives in towns and cities. As the urban population increases, so too do emissions of greenhouse gases from greater volumes of motor vehicles and greater production of waste. Urbanization also leads to more deforestation, as land is cleared for buildings, roads, motorways and airports.

Domestic activities: Almost everyone contributes, even in a small way, to the emission of greenhouse gases. Think about piles of rotting waste around the house and fires for cooking in outdoor kitchens, for example. When we burn plastic bags or vehicle tyres, we put small quantities of greenhouse gases into the atmosphere.

The enhanced greenhouse effect

Human emissions of greenhouse gases in the last two hundred years, as well as changes made by people to the surface vegetation of the land, mean that the natural greenhouse effect has increased, and our atmosphere is getting warmer and warmer. We call this the **enhanced greenhouse effect**. These **human or anthropogenic forcings** are changing the composition of the atmosphere and the reflectivity of the Earth's surface, and contributing to climate change.



Now please complete Activities **4.1a**, **4.1b** and **4.1c** in your Learner Workbook

My Notes:

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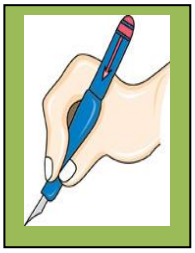
Concept	I understand this concept	Questions that I would still like to ask
4.1 Ways in which humans are contributing to increased emissions of greenhouse gases.		

4.2 Survey of human activities in the local area

To help you understand that almost everyone today is contributing to the enhanced greenhouse effect, you are going to carry out a field survey in your local area.



Now please complete Activity **4.2** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
4.2 Local examples of ways in which humans are contributing to increased emissions of greenhouse gases.		

Section 5 Differentiate between the natural and enhanced greenhouse effects

After completing this section, you should be able to:

5.1 clarify two ways in which the natural greenhouse effect is different to the enhanced greenhouse effect.

5.1 Differences between the natural greenhouse effect and the enhanced greenhouse effect

You have studied the reasons for the natural greenhouse effect. You have also discovered many ways in which humans are currently contributing to the build-up of greenhouse gases in the atmosphere and so causing the enhanced greenhouse effect.

At this point, you can discuss with your fellow-trainees the differences between the natural greenhouse effect and the enhanced greenhouse effect. You will be able to find at least two differences, and probably many more. For example, for how long has each of these two effects been taking place? Are they having positive or negative impacts? What are the causes of each?

To help you in your discussions, please look at these two photos. They show models made by trainee teachers at the Vanuatu Institute of Teacher Education in 2010 for "Science Week". The first one (Fig. 25) shows the natural greenhouse effect. The atmosphere is represented by the chicken wire that covers the "Earth". Notice the healthy vegetation, the lake and river, and the harmony between humans and their environment.

Fig. 25

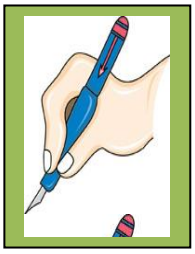
Pierce, C., 2010

The second model (Fig. 26) shows how human activities are adding to the natural greenhouse effect. Again, the atmosphere is represented by the semi-circle of chicken wire. What human activities are shown? What is the temperature like?

Fig. 26

Pierce, C., 2010

Now you are ready to do the activities for this section.



Please complete Activity **5.1a** and **5.1b** in your Learner Workbook

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Concept	I understand this concept	Questions that I would still like to ask
5.1 Differences between the natural greenhouse effect and the enhanced greenhouse effect.		

Section 6 Demonstrate the links between greenhouse gases, global warming and climate change

After completing this section, you should be able to:

6.1 demonstrate, through statistical evidence, that increased levels of GHGs in the atmosphere are leading to global warming;

6.2 demonstrate how rising global air and sea surface temperatures impact on other aspects of climate - changing rainfall patterns, more frequent extreme events, humidity, atmospheric and oceanic circulation, etc.

6.1 Increased levels of greenhouse gases and global warming

As you saw in section 3, there are certain "greenhouse gases" in the atmosphere whose molecules have the ability to capture the heat energy that is emitted from the Earth. Examples are carbon dioxide, methane, nitrous oxide, water vapour, CFCs and aerosols. When these molecules capture the heat energy, they not only keep the atmosphere warm, but also return some of the heat to the Earth. This is called the **greenhouse effect**.

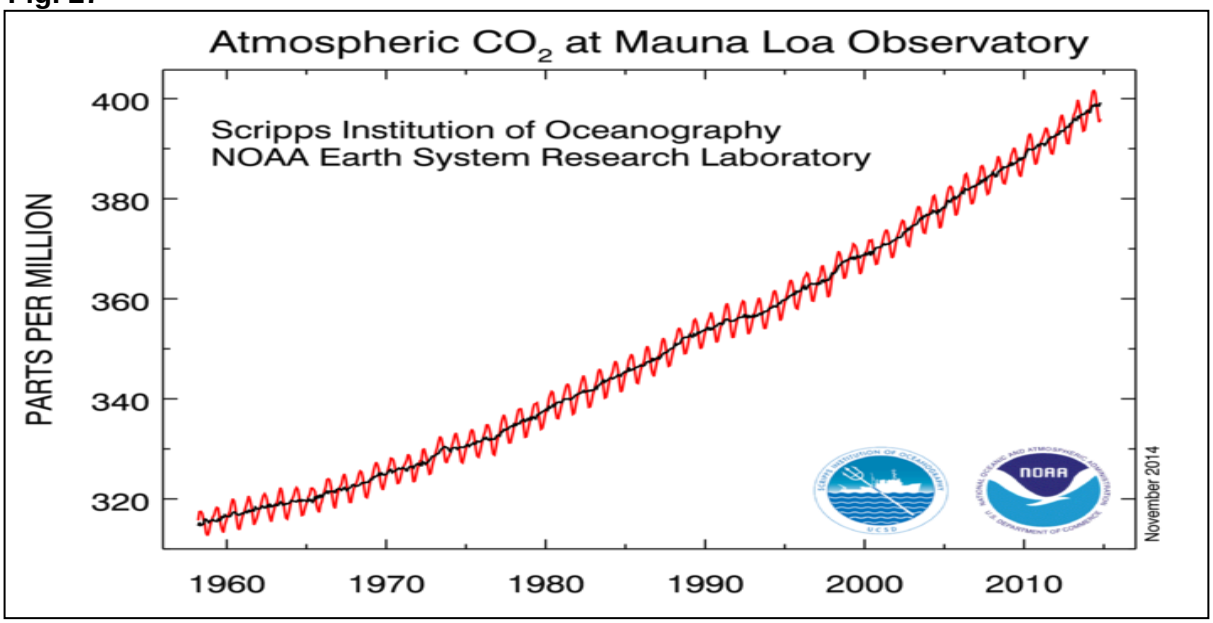
In section 4, you found out that human activities are increasing the amounts of these greenhouse gases that are held in the atmosphere, and that this in turn is leading to the **enhanced greenhouse effect**, also known as **global warming**.

Climate scientists are providing clear evidence that the amount of carbon dioxide in the atmosphere has shown a marked increase in the last 200-250 years. At the same time, they are demonstrating that atmospheric and sea surface temperatures have also been increasing over the same time period. They are also proving that during the last 50 years or so, worldwide sea levels have been slowly rising, while the volume of ice and snow on the planet has been decreasing. These two changes can be linked to rising temperatures.

Let us now look at this evidence.

Increasing CO_2 levels: The following graph (Fig. 27) shows the carbon dioxide content of the atmosphere between 1958 and 2014, measured in ppmv (parts per million by volume). Measurements were taken at the meteorological observatory on the top of Mauna Loa, Hawaii. This observatory is at a height of 3,397 metres on a small island in the middle of the Pacific ocean, remote from any continent. There are few industries nearby and the air is pure. For this reason, scientists believe that the observed increase in CO_2 represents what is happening throughout the whole planet.

Fig. 27



ESRL/NOAA, 2014

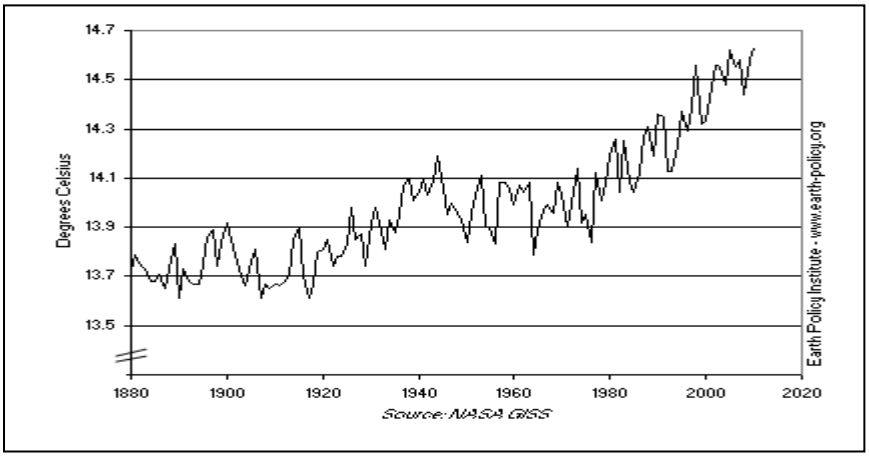
The observations show that there is an annual fluctuation (an up and down movement) in the measurements of CO_2. This is because many trees in the northern hemisphere lose their leaves in the cool season and so do not take out CO_2 from the atmosphere through **photosynthesis**. This means that atmospheric CO_2 levels rise. But during spring and summer, the new leaves absorb more CO_2 from the air through photosynthesis, and the carbon dioxide content of the atmosphere goes down. This happens every year.

On Fig. 27, what do you think the black line represents? What then was the CO_2 content of the atmosphere in 1960? What was it in 2014?

Fig. 28: Average global temperature, 1880-2010

Rising temperatures: Now look at Fig. 28. This graph shows changes in the average annual temperature at the Earth's surface between 1880 and 2010.

What do you notice?

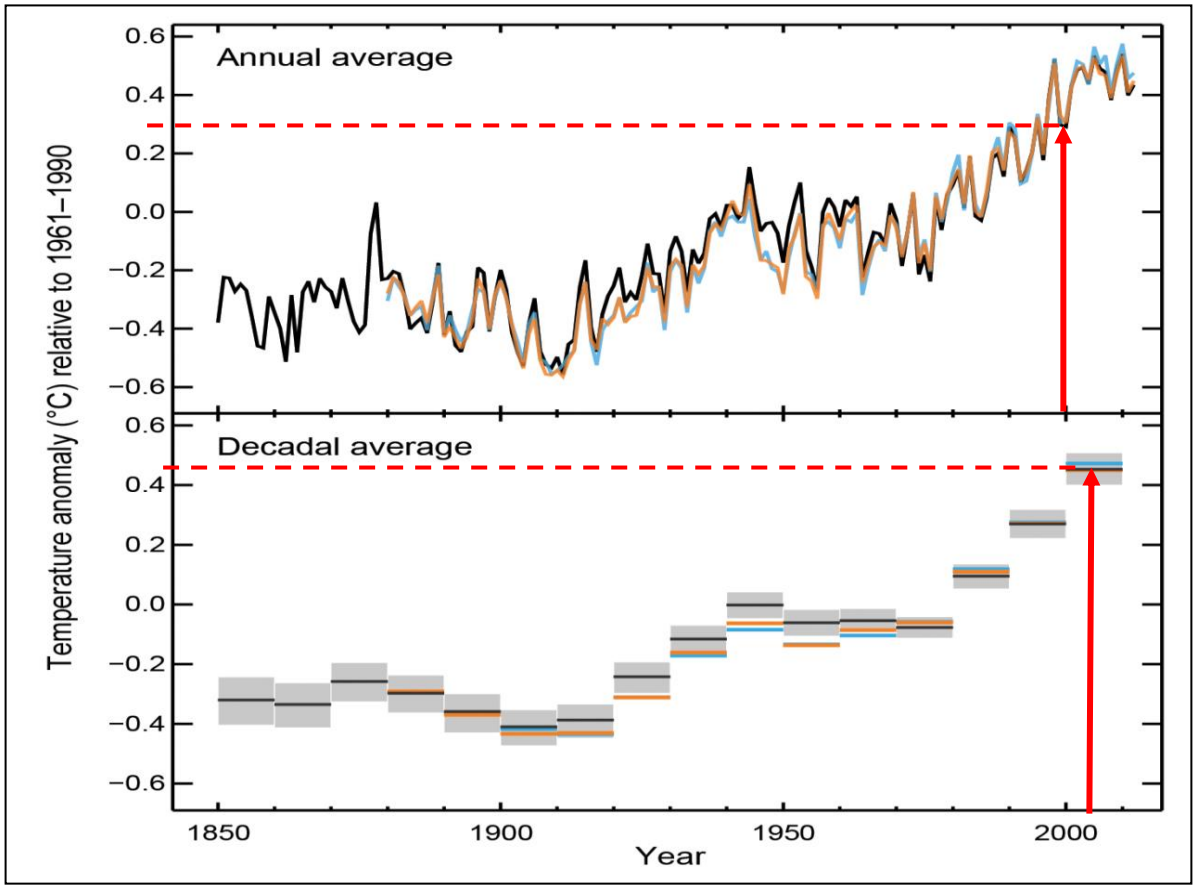


Earth Policy Institute, 2014

In Fig. 29, you can see two more graphs that show global changes in temperature. They were produced by the Intergovernmental Panel on Climate Change (IPCC) in 2013. The term "**temperature anomaly**" means the difference between the temperature and the average temperature for the period 1961 to 1990, which is shown by the value 0.0 on the vertical axis. The different colours refer to the different sources of evidence that were used.

In the top graph of Fig. 29, the average temperature for each year is shown. If you find the year 2000, you can see that the temperature was between 0.2°C and 0.4°C higher than the average for 1961-1990.

Fig. 29



In the bottom graph of Fig. 29, the average for each **decade**, or period of 10 years, is shown. So if you look at the black line for the decade 2000-2010, you can see that the average temperature was between 0.4°C and 0.6°C higher than the average for 1961-1990.

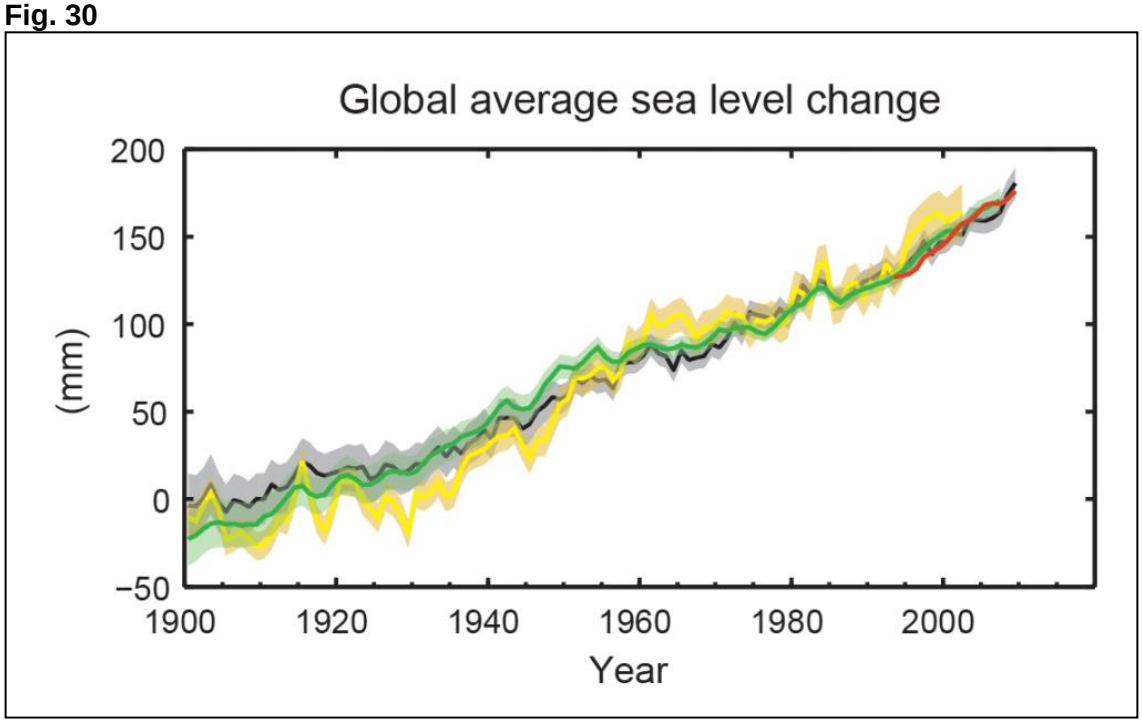
Evidence of global warming also comes from several other indicators. Two of these are **sea level rise** and **the decline in the Earth's covering of ice and snow.**

Sea level rise: The Earth's geological history has shown that whenever there are long-term changes in temperature, sea levels will rise. This is caused by two things: firstly, the upward expansion of ocean waters as they become warmer; secondly, the melting of ice sheets and glaciers covering the land in polar and mountainous regions. Note that when there is melting of ice sheets that are already floating in the sea, this does not cause any sea level rise.

Decline in the extent of ice and snow: When temperatures are warmer, ice and snow will melt.

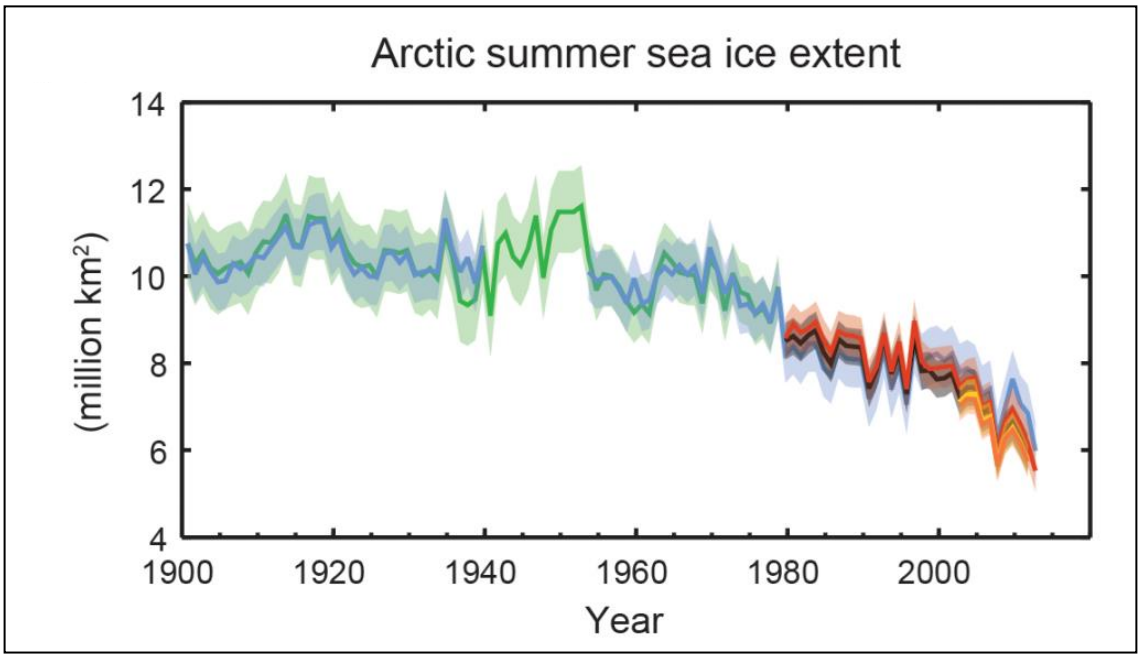
Here are two graphs (Figs 30 and 31) produced by IPCC in 2013. Fig. 30 shows how global average sea levels have changed since 1900. Fig. 31 shows how the amount of ice present around the North Pole in summer has changed over the same time period. The colours simply refer to the different sources of data that have been used.

Fig. 30



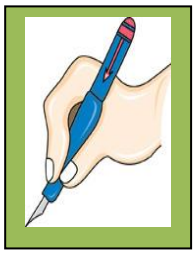
IPCC, 2013

Fig. 31



IPCC, 2013

What evidence do these graphs provide to show that our climate is getting warmer?



Please complete Activities **6.1a** and **6.1b** in your Learner Workbook

My Notes:

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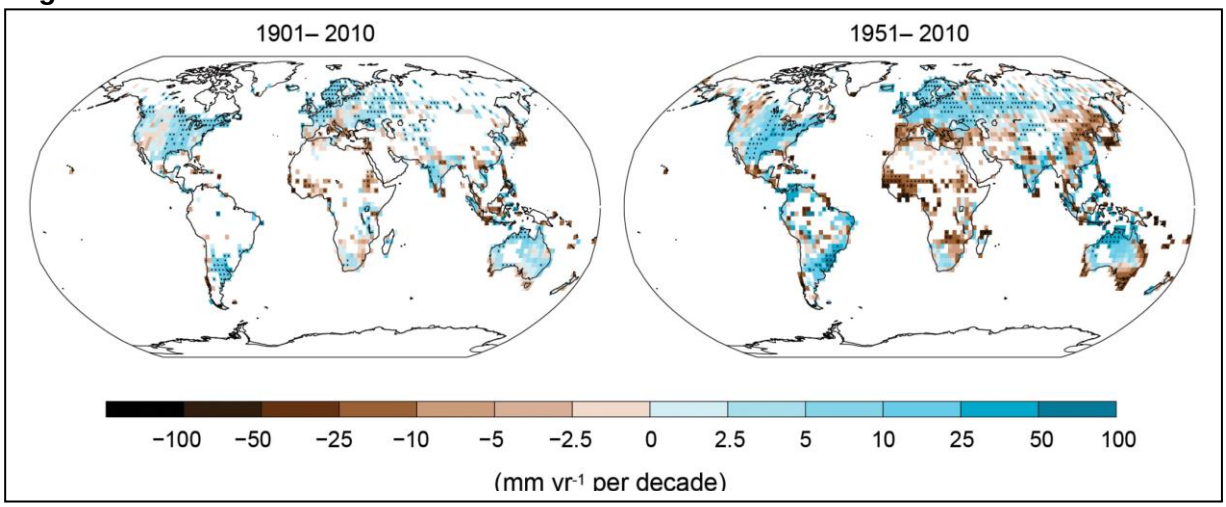
Concept	I understand this concept	Questions that I would still like to ask
6.1 Evidence of increased levels of GHGs and of global warming		

6.2 Impacts of rising temperatures on other aspects of climate

Humidity and rainfall patterns: There is evidence that the current warming of our planet is having an impact on humidity and rainfall. Remember that the warmer the air, the more water vapour it can hold, and so the greater the humidity. This should lead to greater amounts of rainfall throughout the world. However, weather systems are complicated and are also influenced by winds, ocean currents, the intensity of solar radiation and the shape of the land. The changes in weather that have been recorded show that while some areas have received increased rainfall, others are recording less, with more frequent droughts.

The maps in Fig. 32 show world changes in rainfall between 1901 and 2010 and between 1951 and 2010. Since 1951, which areas have shown more rainfall (blue)? Which have shown less rainfall (brown)?

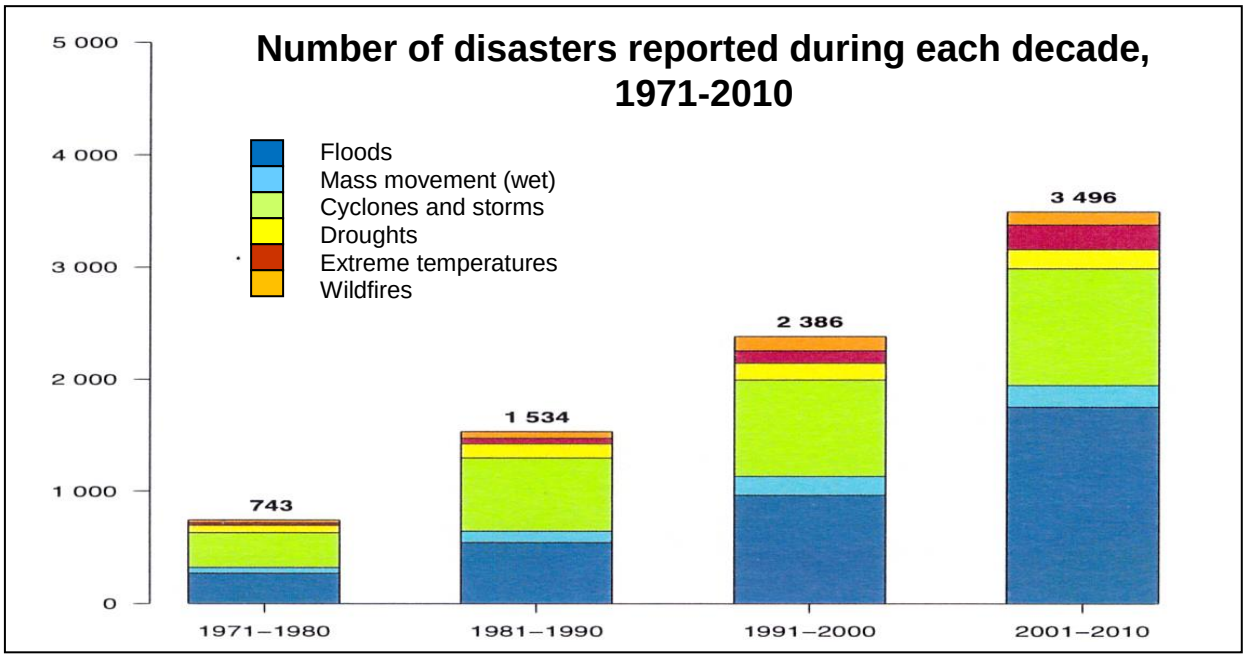
Fig. 32



More frequent extreme climatic events: By extreme climatic events, we mean times when the weather is much hotter, much colder, much wetter or much drier than usual. For example, a place may be experiencing an increase in the number of very hot days in one year, or an increase in the number of cyclones in one year.

The following graph (Fig. 33) shows how the number of disasters resulting from extreme weather events has increased during each decade since 1971. However, we should also remember that the reporting of such events has become much more accurate in recent years, and this might account for some of the increase.

Fig. 33

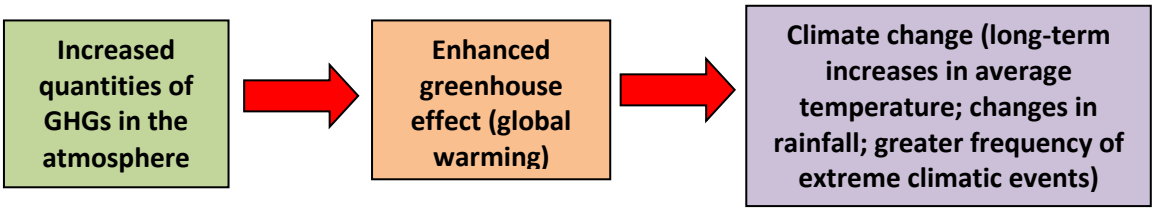


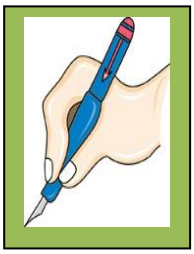
Changes in atmospheric and oceanic circulation: We have already seen that the alternation of El Niño and La Niña events is a driver of climate variability in the Pacific and other parts of the world. However, there is not yet enough evidence to show that a warmer climate is affecting the ENSO cycle. Neither is there enough proof as yet of any long-term change in the global circulation of winds and ocean currents. However, scientists believe that such changes are likely to occur in the future.

Summary

In summary, Section 6 of this Unit has demonstrated the following (Fig. 34):

Fig. 34





Please complete Activities **6.2a** **6.2b** and **6.2c** in your Learner Workbook

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Concept	I understand this concept	Questions that I would still like to ask
6.2 Impact of rising temperatures on other aspects of climate		

Section 7 Provide reasons for rising sea levels and oceanic acidification

After completing this section, you should be able to:

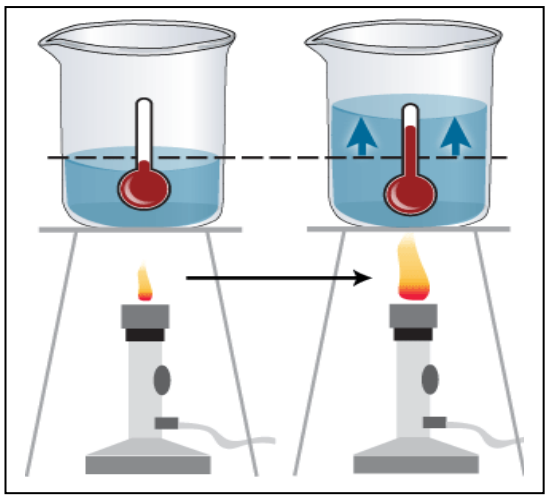
7.1 demonstrate the effect of increasing levels of greenhouse gases on rising sea levels through the thermal expansion of oceans and the melting of polar ice;

7.2 demonstrate the links between increased greenhouse gases, warmer sea-surface temperatures, oceanic acidification and the degradation of coral reefs.

7.1 Increased greenhouse gases and rising sea levels

We have seen that as the amounts of carbon dioxide, methane and nitrous oxide in the atmosphere increase, the temperature of both the atmosphere and the oceans will rise. This is already affecting sea levels around the world, and will continue to do so in the centuries ahead, even if the emissions of greenhouse gases are reduced. There are two basic reasons for sea level rise - thermal expansion of the oceans, and melting of land-based ice.

Fig. 35



UMCES, 2014

Thermal expansion: This means that as the oceans get warmer, they expand. Because of the solid sea floor, the water cannot expand downwards, so must rise up. Fig. 37 shows water being heated in a container. When the temperature rises, so does the water level in the container. The same thing happens in the Earth's oceans as temperatures get warmer, so making sea levels rise up.

Melting ice: Warmer temperatures will also cause ice sheets and glaciers to melt, when temperatures in very cold areas rise above 0°C. There is evidence that this is already happening with the huge ice sheets in Antarctica and Greenland, with sea ice around the North Pole, and in high mountain areas that contain glaciers. As the ice sheets melt, so more water pours into the sea, and sea levels rise. Remember that it is only the melting of ice that is found <u>on land</u> that will contribute to sea level rise. The melting of sea ice (ice floating in the sea) will not change the volume of the surrounding sea water.

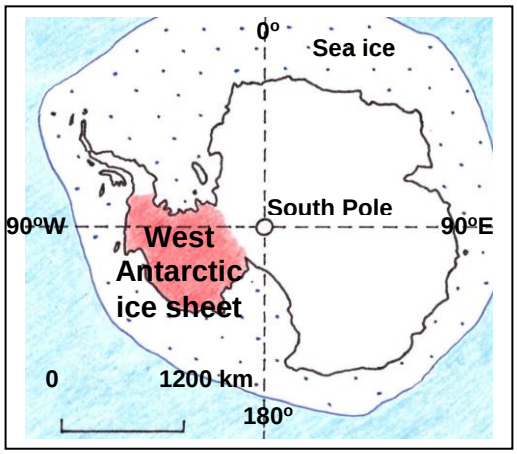
Fig 36 explains what is happening to the West Antarctic ice sheet.

Fig. 36

ANTARCTIC WARMING WILL NOT WAIT FOR US

Last week, we announced that we had collected enough evidence to show that the retreat of ice in the Amundsen sea sector of West Antarctic was unstoppable. It will cause sea levels to rise one metre worldwide. What's more, its disappearance will likely trigger the collapse of the rest of the West Antarctic ice sheet, which comes with a sea level rise of between three and five metres. Such an event will displace millions of people worldwide. Two centuries may seem like a long time, but there is no red button to stop this process.

Eric Rignot, NASA

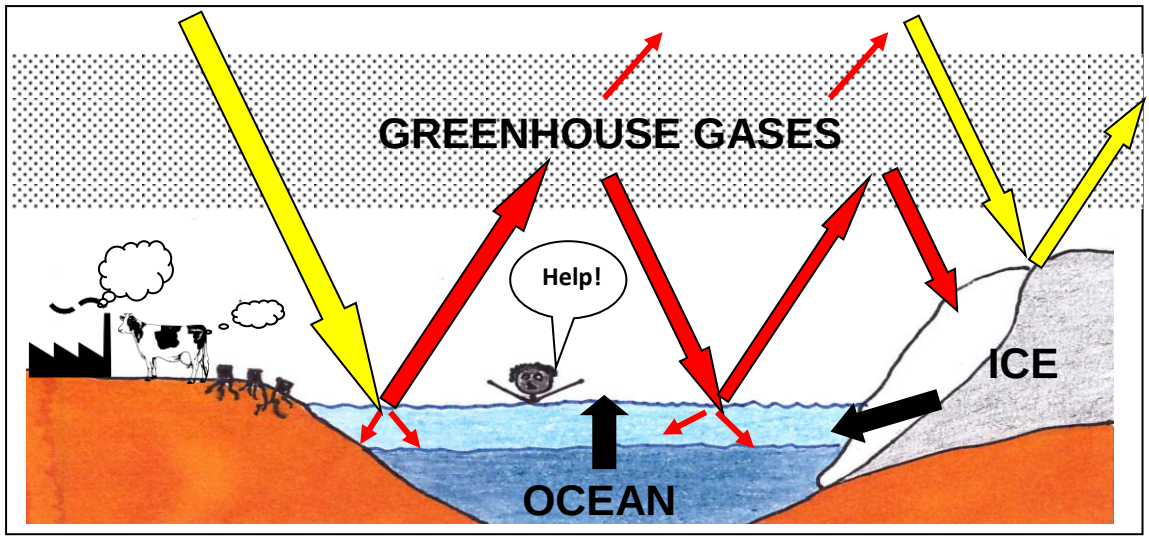


Pierce, C., 2014

Adapted from an article in *The Observer*, printed in *The Guardian Weekly*, 23rd May 2014

This cartoon (Fig. 37) shows why sea levels are rising. Can you explain what is happening ?

Fig. 37



Pierce, C., 2014

Although there is evidence that worldwide sea levels are rising by about 3 mm per year, there are local variations. In some areas of the planet, the land is rising because of tectonic movements. Vanuatu is one of these areas.

When the land is also rising, this means that sea-level rise is not so noticeable. But if the land is sinking, sea-level rise will be rapid (Fig. 38).

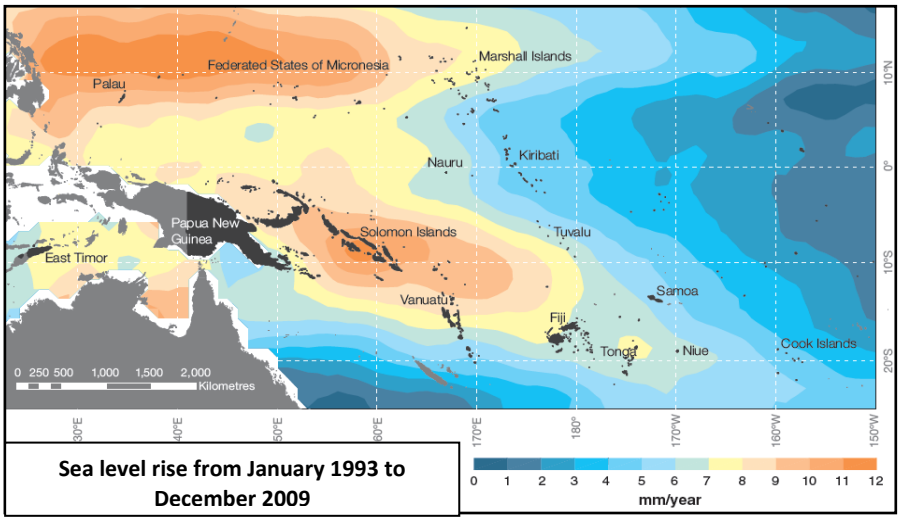
Fig. 38

EPA, 2014

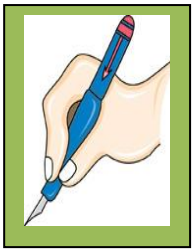
The variation in observed sea level rise in the South Pacific is shown in this map (Fig. 39).

Which island groups are most affected by sea level rise?

Fig. 39



ABM and CSIRO, 2011



Please complete Activities **7.1a** and **7.1b** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
7.1 Impact of increasing levels of GHGs on sea levels		

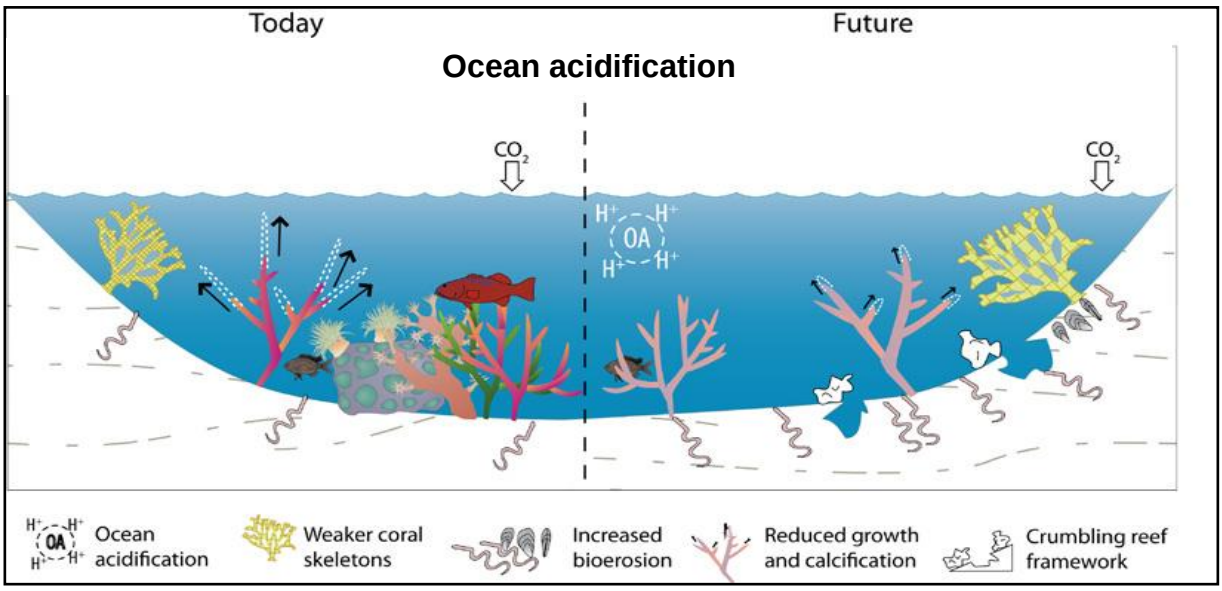
7.2 Oceanic acidification and the degradation of coral reefs

As human populations produce more and more additional carbon dioxide, about 25-30% of this is absorbed in sea water. When this happens, the CO_2 dissolves into the water, and this forms carbonic acid (H_2CO_3). In this way, the sea water becomes more acidic. Its pH decreases. This process is called **oceanic acidification**. Coral and marine organisms that live in shells are affected, because the acidic water means that there is not enough calcium carbonate available to build their skeletons and shells (SPC & GIZ, 2014). Coral reefs are severely damaged.

Another factor leading to the **degradation of coral reefs** is the rise in water temperature. Coral reefs are made up of millions of small animals called coral polyps. These polyps use calcium carbonate to make complicated skeletons. Each coral polyp has microscopic algae living inside it, which give the coral its colour. When the sea temperature rises, corals become stressed and spit out the algae. This turns the corals white in a process called **coral bleaching**. The white coral polyps cannot survive for long without their algae and slowly starve to death (SPC & GIZ, 2014). So global warming will eventually lead to the world-wide degradation of coral reefs and the decline of coastal fisheries.

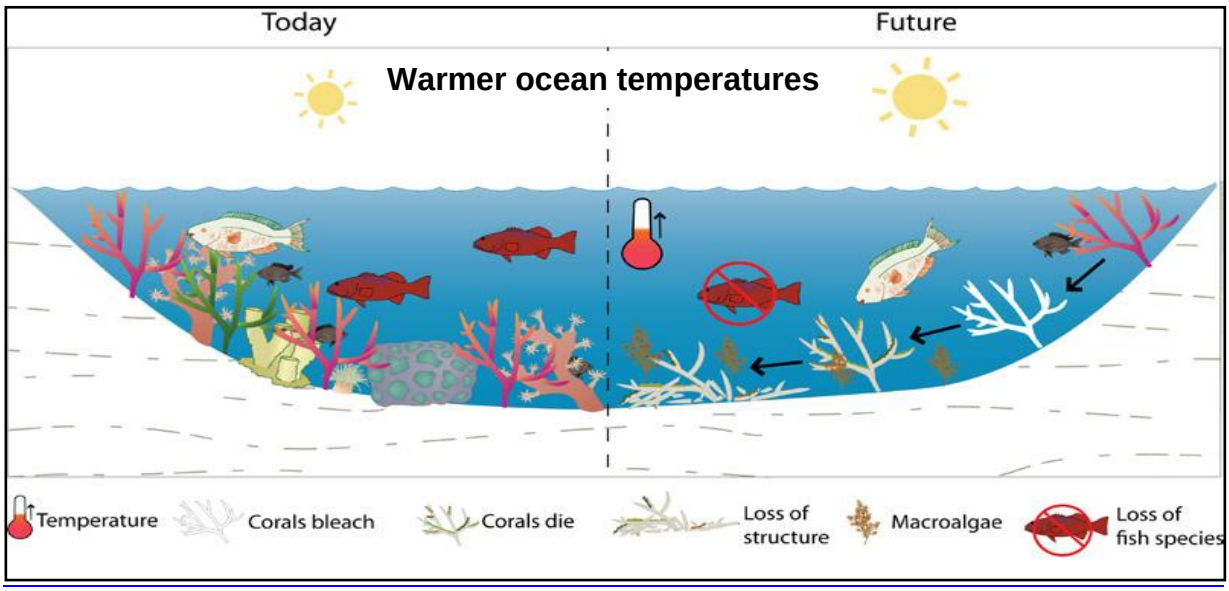
Here are two pictures (Figs 40 and 41) that show the likely effects of ocean acidification and warmer ocean temperatures on reef systems in the Pacific.

Fig. 40



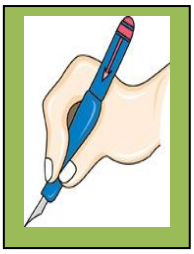
SPC, 2011

Fig. 41



SPC, 2011

Discuss these two pictures with your facilitator.



Please complete Activities **7.2a** and **7.2b** in your Learner Workbook

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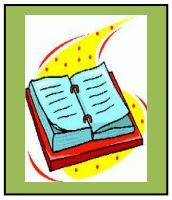
Concept	I understand this concept	Questions that I would still like to ask
7.2 Connection between increased GHGs, warmer ocean temperatures, oceanic acidification and degradation of coral reefs		

Section 8 Provide an overview of future climate change projections

After completing this section, you should be able to:
8.1 outline future projections of climate change in Vanuatu;
8.2 clarify the likely effects of climate change on islands and seas.

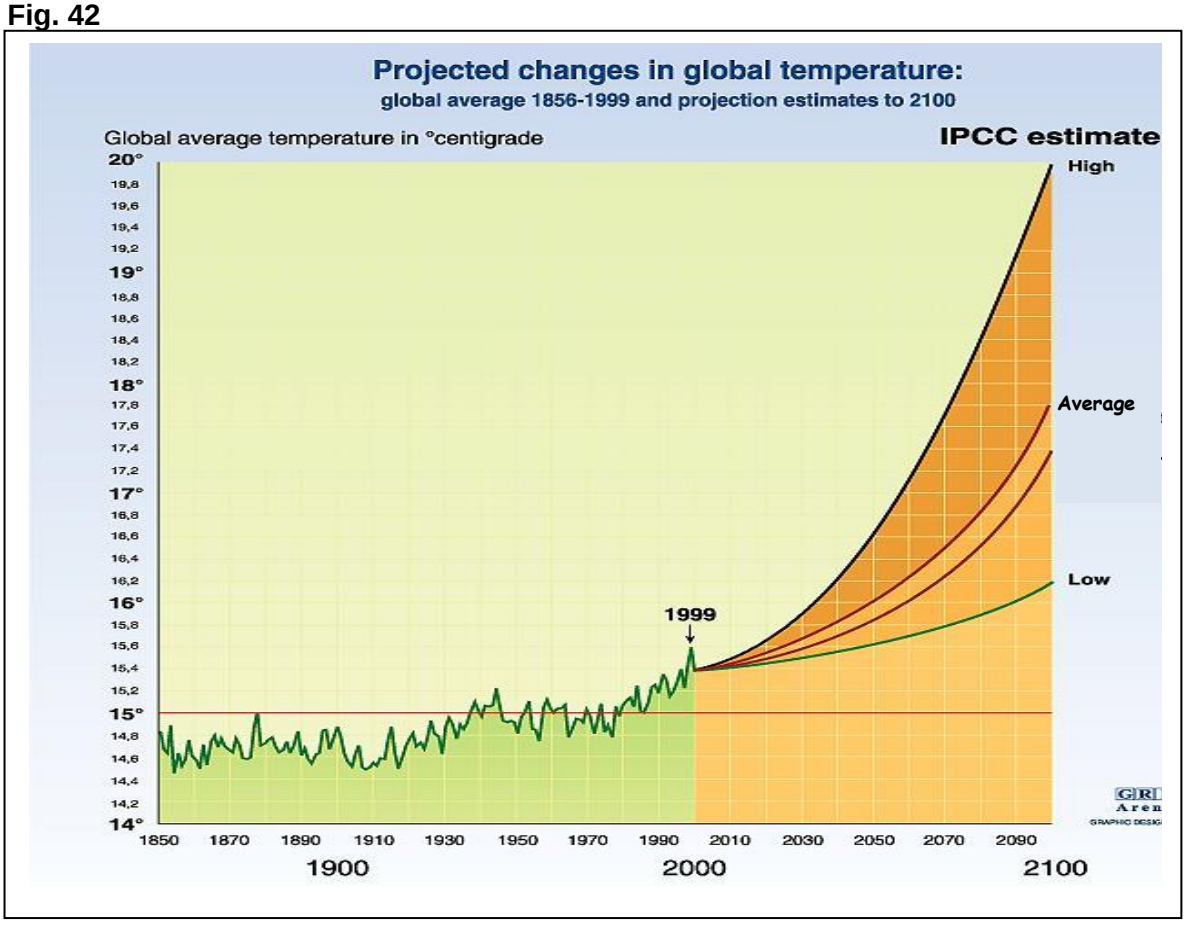
8.1 Projections of climate change



The term **"projection"** means a description of the future and the pathway that leads to it. In terms of climate change, it is "an estimation of future climate that is derived from models" (simplified definition based on IPCC, 2013). This means that scientists represent the climate system by mathematical equations that are based on physical, biological and chemical laws; they use computers to calculate these equations and **predict**, or say in advance, what they think will happen in the future.

This graph (Fig. 42), based on findings of the Inter-Governmental Panel on Climate Change in 2000, gives future projections of average world temperatures. The vertical axis shows the average temperature of the whole planet in °C. The horizontal axis shows the time.

Fig. 42



The wavy green line shows that between 1850 and 1940, the average global temperature was between 14°C and 15°C. It started to rise above 15°C after 1980. During the century between 2000 and 2100, the projections refer to three possible **scenarios** for future world-wide GHG emissions:

- LOW - GHG emissions are reduced from their current levels
- AVERAGE or MEDIUM - GHG emissions remain at their current levels
- HIGH - GHG emissions increase from their current levels

As you can see, if GHG emissions continue to increase, the world's average temperature in 2100 could be as high as 20°C - some 4-5°C higher than at present. Even if we manage to reduce global GHG emissions, the IPCC says that the effects of global warming and climate change will continue long after 2100 :

"Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped." (IPCC, 2013)

Projections of future climate change in Vanuatu have been made by the Vanuatu Meteorological and Geo-hazards Department (VMGD) in cooperation with the Australian Bureau of Meteorology (ABM) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). They can be accessed on the internet at www.pacificclimatechangescience.org.

They are based on information drawn from as many as 18 global climate models, and refer to an average change over the whole of Vanuatu and its surrounding ocean. The projections refer to three possible scenarios for future world-wide GHG emissions - low, medium and high, as explained on the previous page.

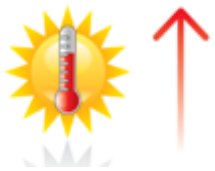
Fig. 43 gives a summary of the projections for Vanuatu for the present century (from now to the year 2100) (ABM, CSIRO, VMGD, 2011).

Fig. 43

VANUATU

Temperature

- Surface air temperature and sea-surface temperature will continue to increase. Under the high emissions scenario, temperatures will be more than 2.5°C higher in 2090 than they are at present. However, there will be variability from year to year because of ENSO.
- There will be an increase in the number of days of extreme heat.

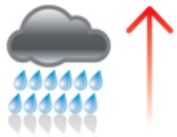


Rainfall

- There will be an increase in wet season rainfall and total annual rainfall, but a decrease in dry season rainfall. There will be little change between now and 2030, but by 2090, an increase of at least 5% in rainfall is predicted. There will be variability from year to year because of ENSO.
- There will be an increase in the number of days of extreme rainfall.
- The frequency of droughts is expected to remain about the same.

Increase in wet season rainfall :

Decrease in dry season rainfall :



More extreme rainfall days :

Symbols: SPC & GIZ, 2014

(Continued on page 49)

- The number of tropical cyclones each year is expected to decrease, but those cyclones that do affect Vanuatu will be stronger.

Sea levels and ocean acidification

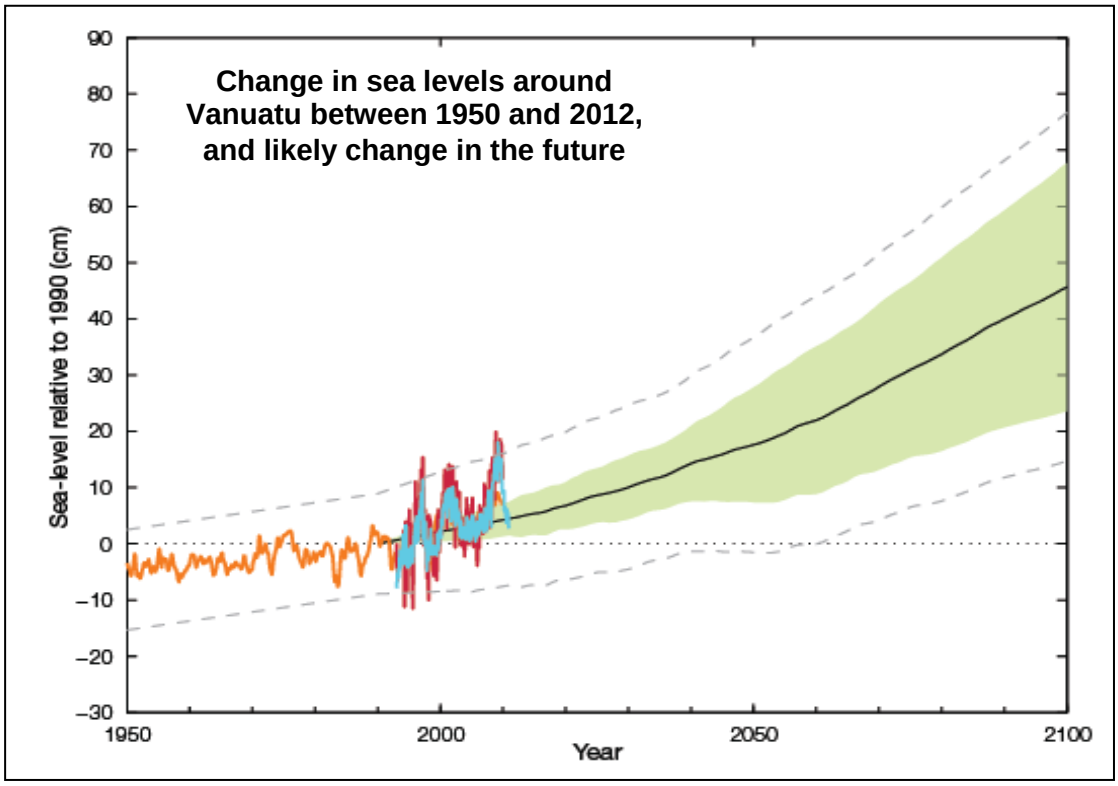
- The acidification of the ocean will continue to increase.

- Mean sea level will continue to rise. Under the high emissions scenario, it will rise by 5-15 cm by 2030 and by 20-60 cm by 2090.

Symbols: SPC & GIZ, 2014

This graph (Fig. 44) shows what is likely to happen to sea levels around Vanuatu. The value "0" on the vertical axis shows the sea level in 1990. The orange line is an estimation of what happened before then. The black line is what has happened since, based upon satellite observations (blue) and from measurements of tides (red), and what is likely to happen in future. The top of the green zone shows the highest level that might occur in the future, while the bottom of the green zone shows the lowest level that might occur. On average, sea level has risen by 6mm per year since 1993.

Fig. 44

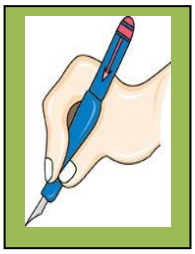


ABM and CSIRO, 2011

The effects of climate change on islands and seas

In your group, please reflect upon these projections of future climate change and how the islands and seas of Vanuatu are going to be affected. Here some issues that you may wish to discuss:

- How will warmer temperatures affect life in the oceans?
- How will warmer temperatures and more extreme temperatures affect the plants growing on the land?
- Will we be getting more floods? Why?
- How will the coastlines of our islands be affected?
- What other changes may occur to our environment?
- How will these changes affect our sources of food, fresh water and income?
- Will we need to make any changes to our way of life?



Please complete Activities **8.1a 8.1b, 8.1c, 8.1d** and **8.1e** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
8.1 Future projections of climate change in Vanuatu. The effects of climate change on islands and seas.		

Glossary

Albedo	Ability of a surface to reflect or absorb heat. White surfaces such as snow and ice reflect heat and have a high albedo. Dark surfaces such as oceans and forests absorb heat and have a low albedo.
Atmospheric circulation	Movement of air (wind) around the Earth. Air circulates within major wind belts; for example, the Trade winds are part of the Hadley cell circulation in tropical areas.
Carbon dioxide	The most abundant greenhouse gas, emitted into the atmosphere by volcanic eruptions, natural fires and human activities.
Carboniferous period	Period of time in the Earth's history from 360 to 300 million years ago, when the climate was much warmer than today, with ideal conditions for plant growth. The thick forests eventually decayed to form coal.
Chlorofluorocarbons (CFCs)	Human-made compounds that form one of the important greenhouse gases. They also destroy the ozone layer high up in the atmosphere.
Climate change	Long term continuous change in the climate or in the range of weather (e.g. more extreme events), measured over several decades, hundreds of years or millennia, and supported by statistical evidence
Climate change projection	An estimation of future climate that comes from the study of models and the use of computers to calculate mathematical equations.
Climate forcing	Something that causes, shapes or has a strong influence over climate
Climate variability	How climate fluctuates each year above or below a long-term average value. Warm and cold, wet and dry seasons are not the same from one year to the next.
Coral bleaching	Process that occurs when the water temperature becomes too warm and coral polyps throw out the algae living inside them, so losing their colour and becoming white.
Decade	Period of ten years.
Deforestation	Removal of bush and forest.
Degradation	When something loses its quality, or is spoilt.
El Niño Southern Oscillation (ENSO)	Movement of the warm pool and its associated rain belt to east and west across the Pacific. This movement has always been a feature of Pacific climates, and usually follows a cycle of between 3-6 years. The two extreme episodes of this movement are known as El Niño and La Niña.
Emission	When a gas is put into the atmosphere.

Enhanced greenhouse effect	Increase in the greenhouse effect caused by the emissions of greenhouse gases through human activities. Sometimes referred to as "global warming".
Eocene epoch	Period of time in the Earth's history from 55 to 34 million years ago.
Fluctuate	To go up and down, or to increase and then decrease.
Fossil fuel	Substance containing carbon that was once a living organism. Examples are coal, petroleum (oil) and natural gas. Fossil fuels can be burnt to provide energy, but at the same time, they give off CO_2.
Geological history	History of the Earth from when it began 4,600 million years ago until today.
Geologist	Scientist who studies the minerals, rocks and structures of the Earth, also the processes taking place in and on the Earth.
GHG	A short way of writing "greenhouse gas".
Glacial period	Part of an ice age when temperatures were much colder and ice advanced and spread over the continents.
Global warming	Increase in atmospheric temperatures caused by the enhanced greenhouse effect and largely due to human activities.
Greenhouse effect (or natural greenhouse effect)	Way that certain gases in our atmosphere trap outgoing heat energy from the Earth, so making the atmosphere warmer and returning some of the heat back to Earth. The greenhouse effect enables life to exist on Earth.
Greenhouse gas	Gas present in the atmosphere that can trap and absorb outgoing heat radiation from the Earth, so making the atmosphere warmer. Examples are carbon dioxide and methane.
Human or anthropogenic forcings of climate change	Human activities that affect, shape or have a strong influence over climate change, e.g. burning of fossil fuels, deforestation, cultivation of wet rice, rearing of cattle and goats, creation of organic and poisonous waste.
Humidity	Amount of water vapour in the air.
Ice Age	Period of time in the Earth's history when temperatures were much lower, resulting in the formation of ice sheets on the continents and glaciers in the mountains. Within an ice age, there are glacial and interglacial periods.
Infra-red energy	Heat energy with a wavelength that is longer than visible light.
Interglacial period	Part of an ice age when temperatures were warmer and similar to those of today. Ice melted and sea levels rose.
Land fill	Open pit where rubbish or garbage is dumped.
Long-wave radiation or energy	Heat energy sent back by the Earth into the atmosphere, with long wavelengths.

Meteorite	Piece of rock or ice that moves about in space.
Natural forcings of climate change	Natural processes or events that cause, shape or have a strong influence over climate change, e.g. volcanic eruptions, changes in energy emitted from the Sun.
Ocean acidification	Increase in the acidity of the oceans, caused when sea water absorbs the extra carbon dioxide produced by human populations.
Oceanic circulation	Movement of ocean waters around the Earth, caused by winds and differences in temperature and salinity.
Orbit	Path of the Earth as it travels once around the Sun each year. It varies from being roughly circular to an elliptical shape.
Padi or wet rice	Rice that is planted and grows under water.
Photosynthesis	Process whereby green plants use sunlight to extract nutrients from carbon dioxide and water vapour in the air. In this process, plants absorb the carbon dioxide and emit oxygen.
Pleistocene Ice Age	The most recent ice age in the Earth's history, lasting from about 2 million years ago to about 12,000 years ago. It is divided into glacial and interglacial periods.
Predict	Say in advance what you think is going to happen in the future, based on existing evidence or trends.
Projection	Description of the future and the pathway that leads to it.
Ruminant	Mammal that eats plants, ferments the plant material in a section of its stomach, then regurgitates this material back into its mouth and chews it to get nutrients. Examples of ruminants are cattle, goats, sheep and deer.
Scenario	Something that might happen in the future, or a possible sequence of events that might occur.
Solar radiation (electromagnetic radiation)	Waves of energy emitted by the Sun. The waves are of different wavelengths, varying from very short to very long. However, most of the solar energy is in the form of short-wave radiation that gives both light and heat.
Temperature anomaly	Difference between an actual temperature and the average value of temperature recorded for that place over a given time period.
Trend	Change over time
Thermal expansion	When things get bigger and expand because of being heated.
Urbanization	Way that more and more people are moving to live in towns.
Wavelength	Distance between the top of one wave and the top of the next wave.

References

- Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2: Country Reports - Vanuatu*
- Community Education Training Centre (CETC)/Secretariat of the Pacific Community (SPC)/ Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ)/University of the South Pacific (USP), 2014, *Training on Climate Change and Disaster Risk Management in Community Development,* CCCPIR, Suva, Fiji.
- Intergovernmental Panel on Climate Change (IPCC), Working Group 2, 2007, *Fourth Assessment Report (AR4): Impacts, Adaptation and Vulnerability: Glossary,* accessed on 19 January 2015 at http://www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-a-d.html
- Intergovernmental Panel on Climate Change (IPCC), 2013: *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Accessed on 6 December 2014 at http://www.ipcc.ch/working_groups/working_groups.shtml
- Nunn, P., 1997, *Human and Non-Human Impacts on Pacific Island Environments,* USP, Suva.)
- O'Neil, D., 2008-2013, *Climate Change and Human Evolution*, accessed on 6 December 2014 at www.anthro.palomar.edu/homo/homo_3.htm
- Oxford Dictionaries, 2014, www.oxforddictionaries.com
- Rosenberg, M., 2014, *Mount Pinatubo Eruption,* accessed on 6 December 2014 at http://geography.about.com/od/globalproblemsandissues/a/pinatubo.htm
- Secretariat of the Pacific Community (SPC) and Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ), 2014, *Learning about Climate Change the Pacific Way: A Visual Guide – Vanuatu.* Accessed on 12 December 2014 at http://www.spc.int/images/climate-change/cc-project/Vanuatu-complete.pdf
- Secretariat of the Pacific Community (SPC) and Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ), 2014, *Learning about Climate Change the Pacific Way: A Teacher Guide – Vanuatu.*
- University of California Museum of Palaeontology (UCMP), 2014, accessed on 10 December 2014 at http://www.ucmp.berkeley.edu/tertiary/eocene.php
- Vanuatu Meteorological and Geo-Hazards Department (VMGD) website, 2014, www.meteo.gov.vu/VMSLinks/Services/tabid/109/Default.aspx

Illustrations

Fig. number	Source
Cover	Andreas / Wikimedia Commons, 2014, *Coal-burning factory in China,* accessed on 15 January 2015 at http://www.esg-search.com/wp-content/uploads/ 2014/11/ Chinese_factory_ pollution_WikimediaCommons_Andreas.jpg
1.	Pierce, C., 2014, *Diagram showing how the information in Unit CCDRR03 is organized.*
2.	Morgan, B., 2014, *An artist's impression of the Carboniferous period.*
3.	Morgan, B., 2014, *An artist's impression of the start of the Eocene period.*
4.	O'Neil, D., 2008-2013, *Tutorial: Climate Change and Human Evolution,* accessed on 6 December 2014 at http://anthro.palomar.edu/homo/homo_3.htm
5.	O'Neil, D., 2008-2013, *Tutorial: Climate Change and Human Evolution,* accessed on 6 December 2014 at http://anthro.palomar.edu/homo/homo_3.htm
6.	Anton, M. (artist), c. 2004, Public Library of Science, USA, *An artist's impression of northern Spain during a glacial period of the Ice Age,* accessed on 1 December 2014 at www.Ice_age_fauna_of northern Spain_- Mauricio_Anton.jpg and at http://www.plosbiology.org/article/slideshow.action?uri=info:doi/10.1371/journal.pbio.0060099&imageURI=info:doi/10.1371/journal.pbio.0060099.g001
7.	Pierce, C., 2014, *The water cycle during a glacial period of the last Ice Age.*
8.	Pierce, C., 2014, *South East Asia and Australia during the last Ice Age.*
9.	United States Geological Survey (USGS), *Fact Sheet no. 113-97,* accessed on 5th December 2014 at http://pubs.usgs.gov/fs/1997/fs113-97/
10.	Pierce, C., 2014, *Variations in the Earth's orbit around the sun.*
11.	Morgan, B., 2014, *Artist's impression of the asteroid striking the earth 66 million years ago.*
12.	Pierce, C., 2014, *Long waves and short waves.*
13.	National Aeronautics and Space Agency (NASA), 2007, *The Electromagnetic Spectrum*, accessed on 4 December 2014 at http://science.hq.nasa.gov/kids/imagers/ems/ waves3.html. Annotated by Pierce, C., 2014
14.	National Aeronautics and Space Agency, 2005, *Global Change / Climate Change,* accessed on 4 December 2014 at http://asd-www.larc.nasa.gov/SOLAR/learning-warming.html
15.	Pierce, C., 2014, *How a greenhouse traps heat.*
16.	Pierce, C., 2014, *The greenhouse effect.*
17.	European Environmental Agency 2014, *Graph of Carbon Dioxide Concentration (ppm) 1750-2010*, accessed on 6 December 2014 at http://www.eea.europa.eu/data-and-maps/figures/atmospheric-concentration-of-co2-ppm/ csi013_fig04_co2_concentration. png/image_original
18.	Andreas / Wikimedia Commons, 2014, *Coal-burning factory in China,* accessed on 15 January 2015 at http://www.esg-search.com/wp-content/uploads/ 2014/11/ Chinese_factory_ pollution_WikimediaCommons_Andreas.jpg
19.	Pierce, C., 2013, *Buses in Port Vila.*
20.	Pierce, C., 2015, *Deforestation near Lae, Papua New Guinea.*
21.	Pierce, C., 2007, *Food garden near Lolowai, Ambae, Vanuatu.*
22.	Pierce, C., 2006, *Cattle near Duck Lake, Efate, Vanuatu.*
23.	Quynh Anh Nguyen, 2014, *Rice fields in Tu Le Valley, Yen Bai, Vietnam.*

24.	Karthikeyan, A. K. / Wikimedia, 2012, *Sithalapakkam Garbage Dump*, accessed on 15 January 2015 at http://commons.wikimedia.org/wiki/File:Sithalapakkam_Garbage_Dump_1.jpg
25.	Pierce, C., 2010, *Model of the natural greenhouse effect.*
26.	Pierce, C., 2010, *Model of the enhanced greenhouse effect.*
27.	Earth Systems Research Laboratory, National Oceanic and Atmospheric Administration, 2014, *Atmospheric CO2 at Mauna Loa Observatory*, accessed on 6 December 2014 at www.esrl.noaa.gov
28.	Earth Policy Institute / National Aeronautics and Space Administration (NASA) / Goddard Institute for Space Studies (GISS), *Average Global Temperature 1880-2010,* accessed on 6 December 2014 at http://www.earth-policy.org/indicators/C51/temperature_2011
29.	Intergovernmental Panel on Climate Change (IPCC), 2013: *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report,* power point presentation accessed on 5 December 2014 at http//: www.climatechange2013.org
30.	Intergovernmental Panel on Climate Change (IPCC), 2013: *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report,* power point presentation accessed on 5 December 2014 at http//: www.climatechange2013.org
31.	Intergovernmental Panel on Climate Change (IPCC), 2013: *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report,* power point presentation accessed on 5 December 2014 at http//: www.climatechange2013.org
32.	Intergovernmental Panel on Climate Change (IPCC), 2013: *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report,* power point presentation accessed on 5 December 2014 at http//: www.climatechange2013.org
33.	World Meteorological Organization, 2014, *Number of reported disasters by decade by hazard type (1971-2010), Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes,* page 9, accessed on 13 February 2015 at 2014.06.12-WMO1123_Atlas_120614.pdf
34.	Pierce, C., 2014, *Flow chart to show the relationship between greenhouse gases, global warming and climate change.*
35.	University of Maryland Centre for Environmental Science (UMCES), 2014, accessed on 5 December 2014 at http://teachoceanscience.net/teaching_resources/education_modules/barrier_islands_and_sea_level_rise/learn/
36.	Pierce, C., 2014, *Map of the West Antarctic ice sheet.*
37.	Pierce, C., 2014, *Cartoon to show why sea levels are rising.*
38.	Environmental Protection Agency (EPA), 2014, *A student's guide to climate change,* accessed on 6 December 2014 at epa.gov/climatestudents/impacts/signs/sea-level.html
39.	Australian Bureau of Meteorology (ABM) and Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2: Country Reports - Vanuatu.*

40.	Secretariat of the Pacific Community, 2011, *Ocean acidification*, reproduced in Community Education Training Centre (CETC)/Secretariat of the Pacific Community (SPC)/ Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ)/University of the South Pacific (USP), 2014, *Training on Climate Change and Disaster Risk Management in Community Development,* CCCPIR, Suva, Fiji.
41.	Secretariat of the Pacific Community, 2011, *Temperature*, reproduced in Community Education Training Centre (CETC)/Secretariat of the Pacific Community (SPC)/ Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ)/University of the South Pacific (USP), 2014, *Training on Climate Change and Disaster Risk Management in Community Development,* CCCPIR, Suva, Fiji.
42.	GRID Arendal /United Nations Environment Programme (UNEP), 2005, *Projected changes in global temperature,* accessed on 6 December at http://www.grida.no/publications/vg/climate/page/3076.aspx
43.	Secretariat of the Pacific Community (SPC) and Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ), 2014, *Learning about Climate Change the Pacific Way: A Visual Guide – Vanuatu.* Accessed on 12 December 2014 at http://www.spc.int/images/climate-change/cc-project/Vanuatu-complete.pdf
44.	Australian Bureau of Meteorology (ABM) and Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2: Country Reports - Vanuatu*