VQA Level: 1

Learner Guide

Certificate I in Climate Change and Disaster Risk Reduction

Units 2 & 3: CGCK0216 & CGCV0316

Demonstrate knowledge of climate

Demonstrate knowledge of climatic variations

Table of contents

Cover pictures: Effects of cyclones and droughts
(SPC & GIZ 2013: Learning about climate change the Pacific way: A visual guide: Pictures 9 and 10)

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First published 2017

Introduction

This Learner Guide supports the units of competency CGCK0216 (***Demonstrate knowledge of climate)*** and CGCV0316 ***(Demonstrate knowledge of climatic variations)***, which specify knowledge, skills and attitudes associated with learning about the features of Vanuatu's climate and its variations in time and space. These units are the second and third 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 second unit, CGCK0216, defines the standard required to: differentiate between weather and climate; differentiate between climate variability and climate change; demonstrate the seasonal changes in Vanuatu's temperature and rainfall; demonstrate processes in the water cycle; and demonstrate factors that cause variations in climate within Vanuatu. The third unit, CGCV0316, defines the standard required to: demonstrate the key drivers that control climate variability in the tropical Pacific; illustrate the main features of a tropical cyclone and its associated weather; and demonstrate long-term climatic change in Vanuatu.

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.

Ministry of Education & Training
Government of Vanuatu

SPC Secretariat of the Pacific Community
EUROPEAN UNION
USP THE UNIVERSITY OF THE SOUTH PACIFIC
EU PacTVET
European Union Pacific Technical and Vocational Education and Training on Sustainable Energy and Climate Change Adaption Project

Pacific Community
Communauté du Pacifique

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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 climate	
VQA Level: 1	Credits: 3

Title: Demonstrate knowledge of climatic variations	
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.

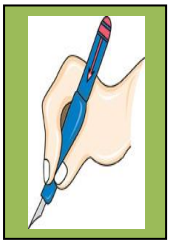
You will be assessed during the course of your study. This is called formative assessment. You will also be assessed on completion of this unit standard. This is called summative assessment. Before your assessment, your assessor/ trainer/ facilitator will discuss the unit standard with you.

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 weather and climate in Vanuatu, their variations and the effects of these variations.***
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 features, climatic variability and climate change in Vanuatu.*** • ***Communicate personal experiences which demonstrate an understanding of local climatic variations and their effects.***
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 discussions and activities in pairs and groups regarding findings related to learning about world climatic zones and the water cycle.*** • ***Cooperate in a small group to draw a map of an island in Vanuatu showing areas liable to drought and flooding.*** • ***Undertake discussions and activities in pairs and groups regarding learning on climate variability and 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 discover examples of features and variations in weather and climate in Vanuatu and the Pacific.*** • ***Use phones, email and social media to access information on weather, climate and climatic variations.*** • ***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 • ***Determine areas of Vanuatu that have a greater likelihood of flooding and drought as a result of climate change and El Nino and La Nino periods*** • ***Apply knowledge of tropical cyclones to assess the changes in weather that may occur as a cyclone approaches.***
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 weather and climate.*** • ***Reflect on knowledge and understanding of climate and its variations and the effects of these variations 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 about weather in the local area.*** • ***Plan, collect and collate information from documents and oral discussions in order to make decisions about local issues affected by climatic variability and climate change.***
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 in relation to weather and climate, as well as to help communities prepare for 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 classroom and in communities are inclusive of both male and female perspectives on weather, climate, climate variability and climate change.***

What am I going to learn?

Section 1: Differentiate between weather and climate

Section 2: Differentiate between climate variability and climate change

Section 3: Demonstrate the seasonal changes in Vanuatu's temperature and rainfall

Section 4: Demonstrate processes in the water cycle

Section 5: Demonstrate factors that cause variations in climate within Vanuatu

Section 6: Demonstrate the key drivers that control climate variability in the tropical Pacific

Section 7: Illustrate the main features of a tropical cyclone and its associated weather.

Section 8: Demonstrate long-term climatic change in Vanuatu

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 processes in the water cycle, seasonal climatic variations and tropical cyclones
- have basic skills in mapping and the construction and interpretation of graphs

What are my learning outcomes?

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

- state the difference between weather and climate;
- explain the difference between climate variability and climate change;
- describe seasonal changes in Vanuatu's temperature and rainfall;
- explain the processes involved in the water cycle;
- identify other factors that cause variations in climate within Vanuatu;
- explain four "drivers" that control the variability of climate in the tropical Pacific;
- outline the main features of a tropical cyclone and its associated weather;
- provide evidence for long-term climatic change in Vanuatu.

Introduction to the Unit

You are about to start on the second and third Units of the Certificate I course on Climate Change and Disaster Risk Reduction. In these Units, you are going to find out more about the features of Vanuatu's climate and how it varies from season to season within a year. You will find out about the water cycle and its influence on climate, and how climate varies from island to island and within islands. Later, you will study how variations in our climate from season to season and from year to year are due to four important "drivers" that operate in the tropical Pacific - the Trade winds, the Inter-Tropical Convergence Zone, the South Pacific Convergence zone and the El Nino Southern Oscillation, or ENSO. These drivers help to explain why Vanuatu suffers from two important climatic hazards - long periods of heavy rain, with cyclones, and long periods of drought. You will find out more about the weather associated with tropical cyclones. And finally, you will learn how to analyse evidence that is pointing to long-term climatic change in Vanuatu, with warmer temperatures and a greater frequency of extreme climatic events.

When we talk about weather and climate, we refer to conditions in the lower part of earth's atmosphere -

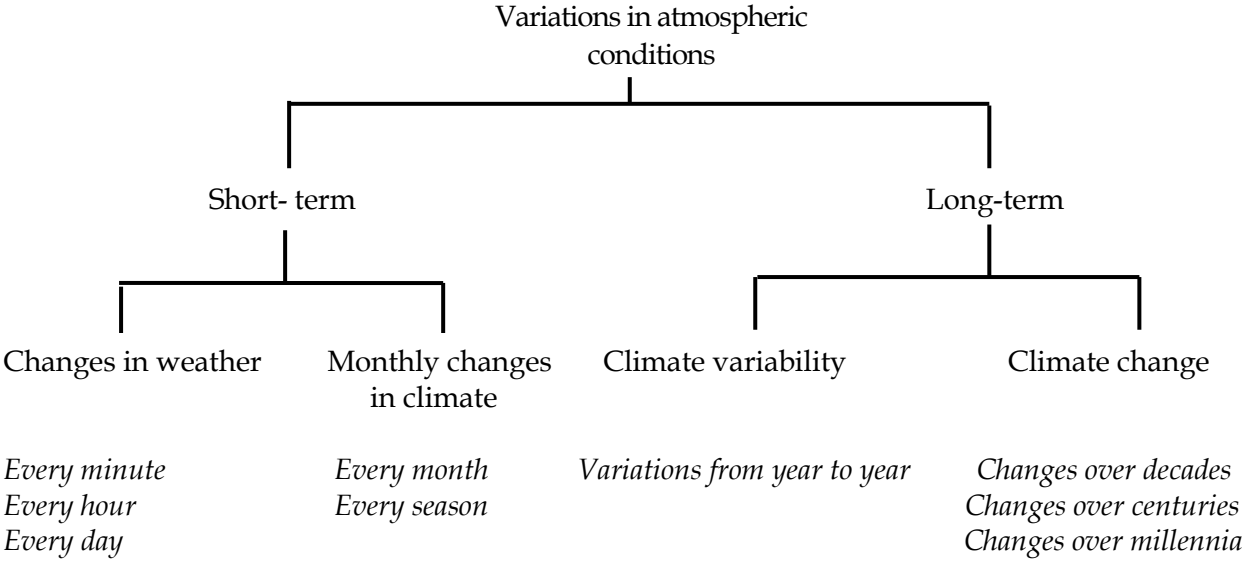
temperature, humidity, precipitation (rainfall), winds, atmospheric pressure, and so on (Fig. 1). These conditions are changing all the time.

Fig. 1

Classroom Printables, 2014

There is an important difference between weather and climate. Weather refers to the state of the atmosphere at a given moment in time, and it changes from minute to minute, hour to hour and day to day. Climate, on the other hand, refers to weather conditions over a longer period such as one month or one year. Key indicators of climate are average monthly figures of temperature and rainfall. What is important is that when scientists look at these monthly figures over many years, they can analyse long-term changes that are taking place. This is referred to as "climate change". It is not the same as climate variability.

The word "variation" means the way in which something changes from time to time or from place to place. Here is a diagram that will help you to understand how information about variations in weather and climate has been organized in this Unit:



When you have completed these Units, you will understand much more about the main features of Vanuatu's climate and its short-term and long-term variations. You will also be better able to talk to other people about the meaning of "climate change".

Section 1 Differentiate between weather and climate

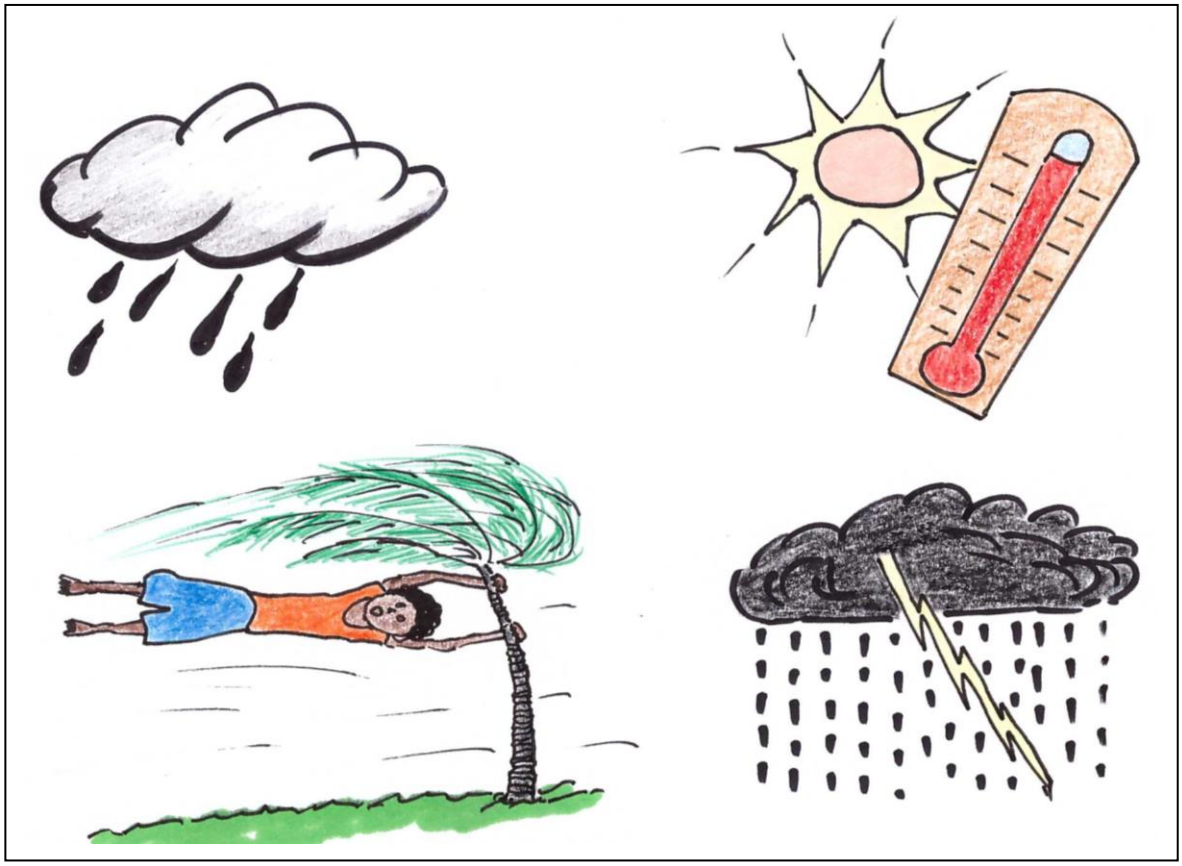
After completing this section, you should be able to:

1.1 state the main elements of weather and climate;
1.2 describe the weather at a place at a particular moment, and compare this with the climate of that place;
1.3 describe and locate the earth's principal climatic zones;
1.4 give a concise explanation of the difference between weather and climate.

1.1 The main elements of weather and climate

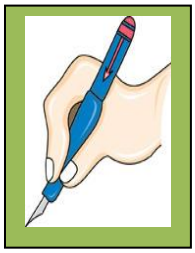
Which elements are shown by these cartoons (Fig. 2)?

Fig. 2



Pierce, C., 2014

Which other elements of weather and climate can you think of?



Now please complete Activity 1.1 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 Elements of weather and climate		

1.2 Describing the weather and the climate of a place

Go outside your classroom and look at the weather. How would you describe it? Is it raining? Is it hot? Do you feel sticky? How much of the sky is covered in cloud? Which way are the winds blowing? Is the weather different now to what it was first thing in the morning? Is it different to the weather yesterday?

Yes, the weather changes all the time - every minute, every hour, every day.

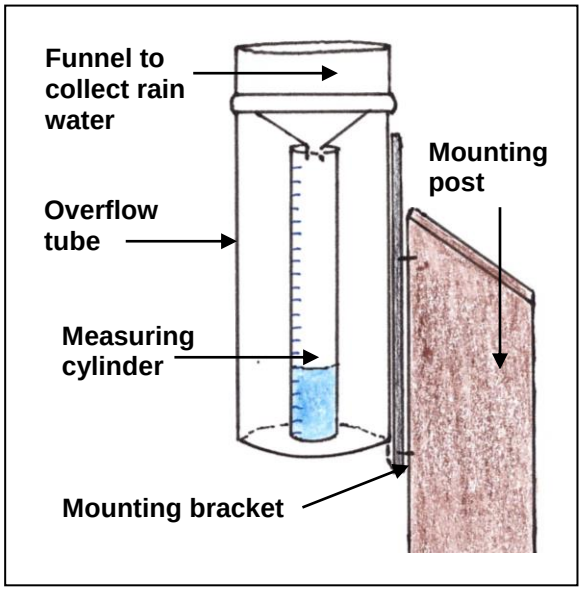
Let us look a little bit more at one of the most important elements of weather - the temperature. We measure temperature on the **Celsius or Centigrade scale**, using a thermometer. At 0°, water will freeze into ice, and at 100°C water will boil and become steam. The blood in your body normally has a temperature of 37°C.

In Vanuatu, the air around us has a day-time temperature that varies between about 32°C and 20°C, depending on where we live and the season. In comparison with other places in the world, this is hot.

The other very important element of weather is the **precipitation**. This refers to the water that comes out of the clouds through the process of condensation. The water is normally in the form of liquid droplets, which we call rain. But when the temperature of the atmosphere is below 0°C, the water droplets freeze and come down as flakes of **snow** or little balls of ice called **hail.** We never get snow in Vanuatu, but there have been occasional reports of hailstorms in southern islands such as Tanna.

We measure rainfall in a rain gauge, which is simply an open container that collects the water falling down from the sky. Every 24 hours, we measure how much rain is held in the container, and this measurement is given in millimetres. On average, Port Vila receives a total precipitation of about 2000 mm in one year. Vanuatu is one of the wettest places in the world.

Fig. 3: Diagram of a rain gauge



Pierce, C., 2014

Fig. 4: Rain collected in a rain gauge

Bidgee, 2003

To get figures of climate for a place, we normally just look at temperature and rainfall. For temperature, we first find out the **maximum and the minimum temperatures** each day, then take an average to get the **mean daily temperature**. To calculate the **mean monthly temperature**, we add up all the mean daily temperatures for the month and divide by the number of days in the month. To get figures of monthly rainfall, we simply add up the total rainfall for each day in that month. Then the monthly figures for both temperature and rainfall are averaged out over a period of at least 30 years.

Here are the average monthly figures of temperature and rainfall for Port Vila for the last 60 years (Fig. 5).

Fig. 5

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Temp (°C)	26.8	27.0	26.7	25.7	24.5	23.6	22.7	22.7	23.4	24.2	25.3	26.1	
Rainfall (mm)	279	290	321	221	164	155	100	93	93	106	144	184	2,147

VMGD, 2014

When describing the average figures of temperature and rainfall of a place, in other words the climate of that place, we can refer to the following table (Fig. 6), which is based on several sources (e.g. Think Metric, 2005; Grosz-Ngaté et al, 2014).

Fig. 6

Temperature in degrees C	**Description of average monthly temperature**	***Total annual rainfall in mm***	***Description of annual rainfall***
30 and over	Very hot	*Over 2000*	*Humid / very heavy*
20-29	Hot	*1500-1999*	*Sub-humid / heavy*
10-19	Warm or mild	*1000-1499*	*Sub-humid /moderate*
0-9	Cool	*500-999*	*Semi-arid / light*
-10 to -1	Cold	*250-499*	*Semi-arid /very light*
Below -10	Very cold	*Below 250*	*Arid / desert*

Pierce, C., 2014

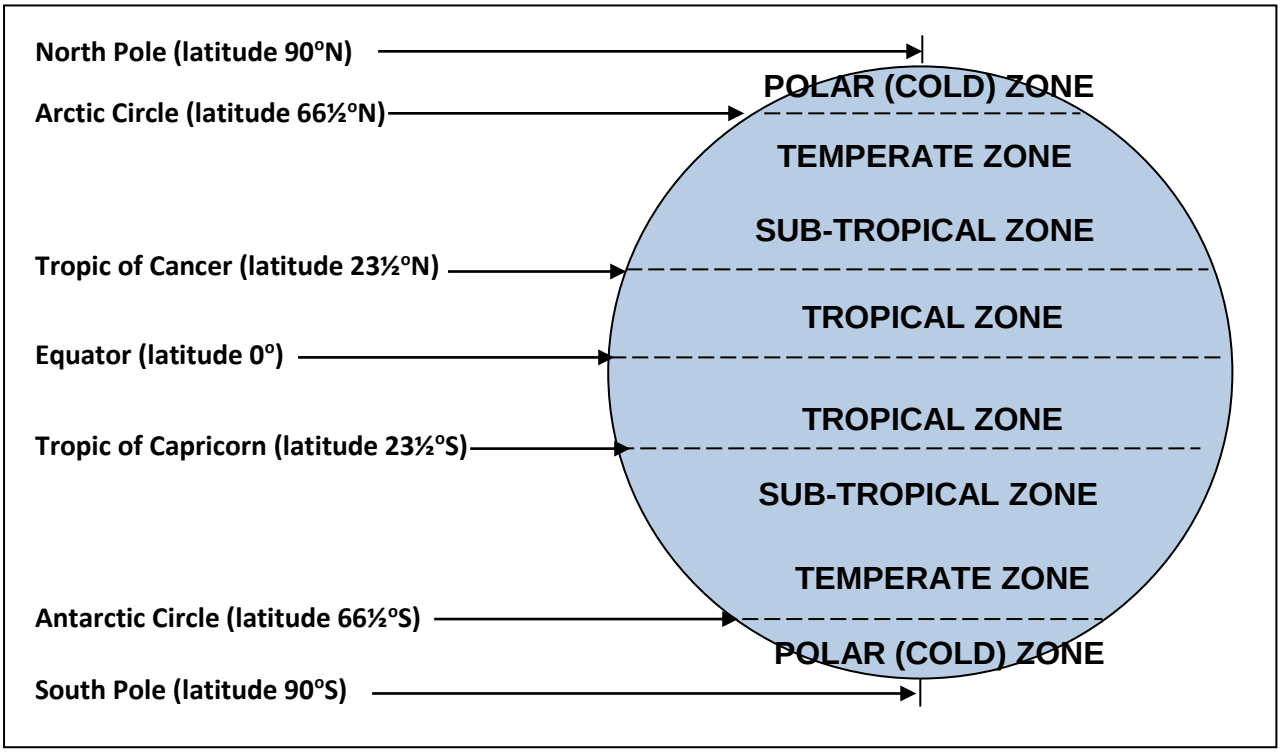
For rainfall, we must also look at its **seasonal distribution**. Some places have rainfall in all months of the year. Some have most rainfall in the months when the temperature is the hottest. Some have most rainfall in the months when the temperature is the coolest. Some have hardly any rainfall at all and have a desert climate.

So how would you describe the climate of Port Vila? What words would you use for its temperature in the hottest month and in the coldest month? How would you describe Port Vila's total rainfall in one year? In which 5 months does Port Vila have the most rain? Is this the hotter season or the cooler season?

1.3 World climatic zones

Fig. 7 shows how the world can be divided up into major **climatic zones**, based on average temperatures. As you go further away from the equator, the temperatures decrease.

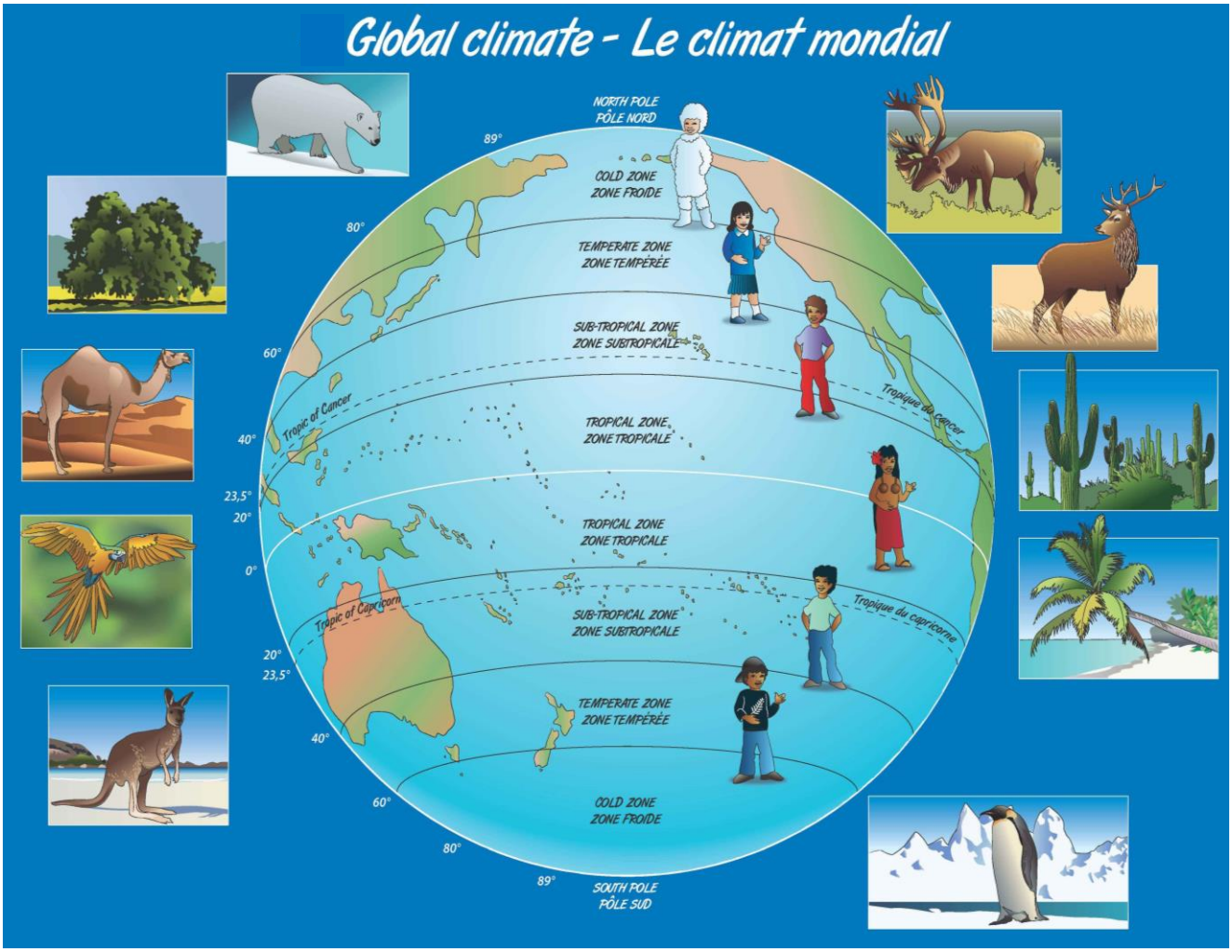
Fig. 7



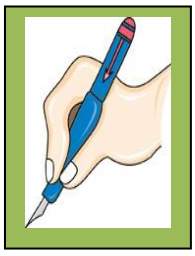
Pierce, C., 2014

Here is a more detailed diagram of the climatic zones (Fig. 8). You can see how the temperatures in each zone affect people's lives, as well as the natural vegetation and animal life. Which is the hottest zone? In which zone is Vanuatu? What about Australia?

Fig. 8



SPC & GIZ, 2014



Now please complete Activities **1.2a, 1.2b** and **1.3** 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 Describing weather and climate 1.3 The earth's principal climatic zones		

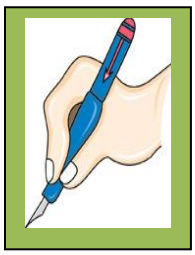
1.4 Difference between weather and climate

Now let's summarize the difference between weather and climate. When we talk about weather, we are looking at the current atmospheric conditions at a place - temperature, rainfall, wind and humidity. If you stand outside, you can feel how hot it is, and you can tell whether it is raining, windy, sunny or cloudy. Weather is what is happening right now, or likely to happen tomorrow or in the next few days.

Climate, on the other hand, refers to the general weather conditions. It looks at average figures of temperature and rainfall over a month, a year, or over many years.

Some **meteorologists** say that "climate is what you expect, and weather is what you get!"

For example, you might live on the west side of Tanna and find that according to figures of climate, August is a month when there are clear sunny days with very little rainfall. But you could go out one day in August and experience cloudy skies, strong winds and a heavy rainstorm that brings much more rainfall than the average. So your weather is different to your climate!



Now please complete Activity **1.4** your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
1.4 Difference between weather and climate		

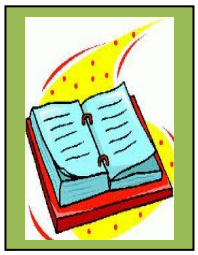
Section 2 Differentiate between climate variability and climate change

After completing this section, you should be able to:

2.1 define "climate variability" and "climate change";

2.2 demonstrate how climate variability and climate change can be shown on graphs.

2.1 Definitions



Climate variability means the way that 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.

Climate change refers to a long-term continuous change (increase or decrease) in the climate, or average weather conditions. It can also refer to a long-term change in the **range** of weather (for example, more frequent and severe cyclones). Climate change happens very slowly.

2.2 Further explanations, with statistics and graphs

Climate variability

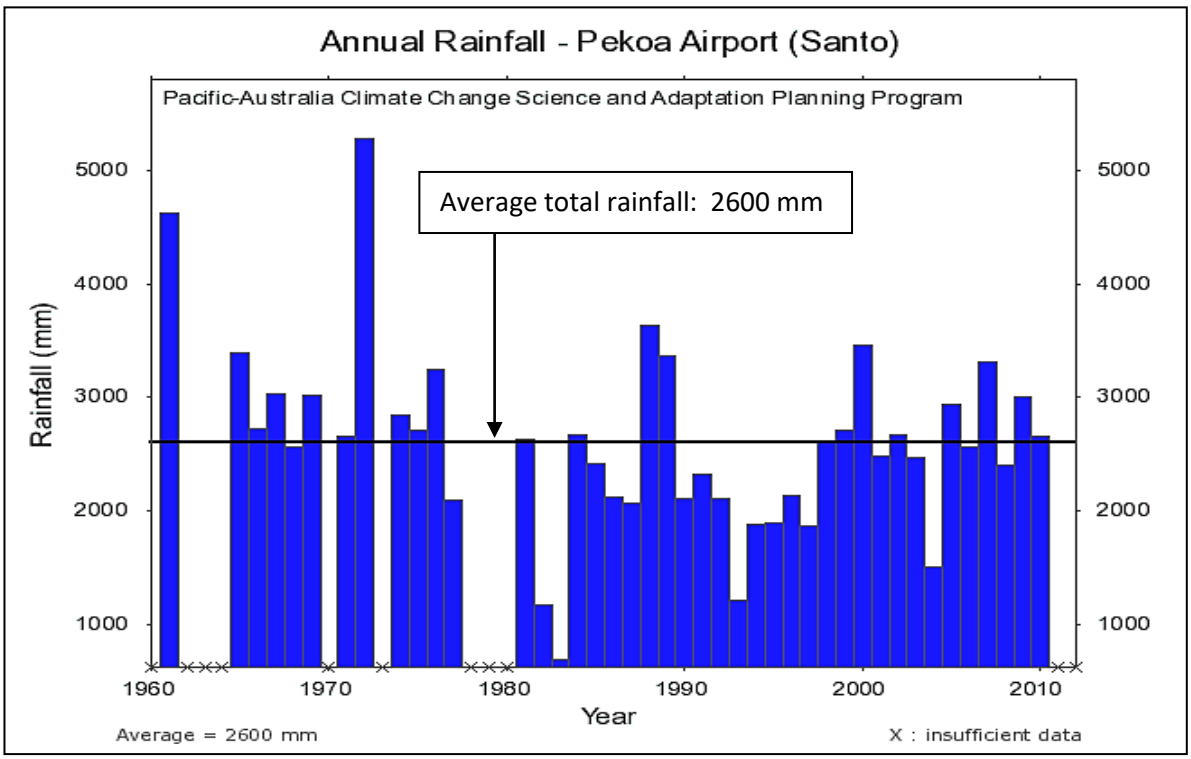
Just as weather varies from hour to hour and day to day, so does the average weather or climate. The average monthly temperature and monthly rainfall change during the year, and this is quite normal. Also, the figures for each month will be different to those of the same month in the following year. For example, look at these figures for Bauerfield, Efate, for the month of December in three consecutive years (Fig. 9):

Fig. 9

Month	Average monthly temperature	Total monthly rainfall (approximate)
December 2010	25.4°C	200 mm
December 2011	26.8°C	20 mm
December 2012	26.6°C	190 mm

In the same way, average annual temperatures and annual total rainfall for a place will vary from year to year. Look at this example of the variability of rainfall from year to year at Pekoa airfield, Santo, between 1960 and 2010 (Fig. 10). Note that the horizontal black line refers to the average total rainfall, which is 2600 mm.

Fig. 10



Climate variability in the South Pacific takes place because of the way in which the waters of the Pacific ocean and the lower atmosphere affect each other. These **interactions** between ocean and atmosphere are controlled by four important factors, or **"climate drivers"** - the Trade winds, the El Niño Southern Oscillation (ENSO), the South Pacific Convergence Zone (SPCZ) and the Inter-Tropical Convergence Zone (ITCZ). We shall learn more about these four drivers in Section 6 of this unit.

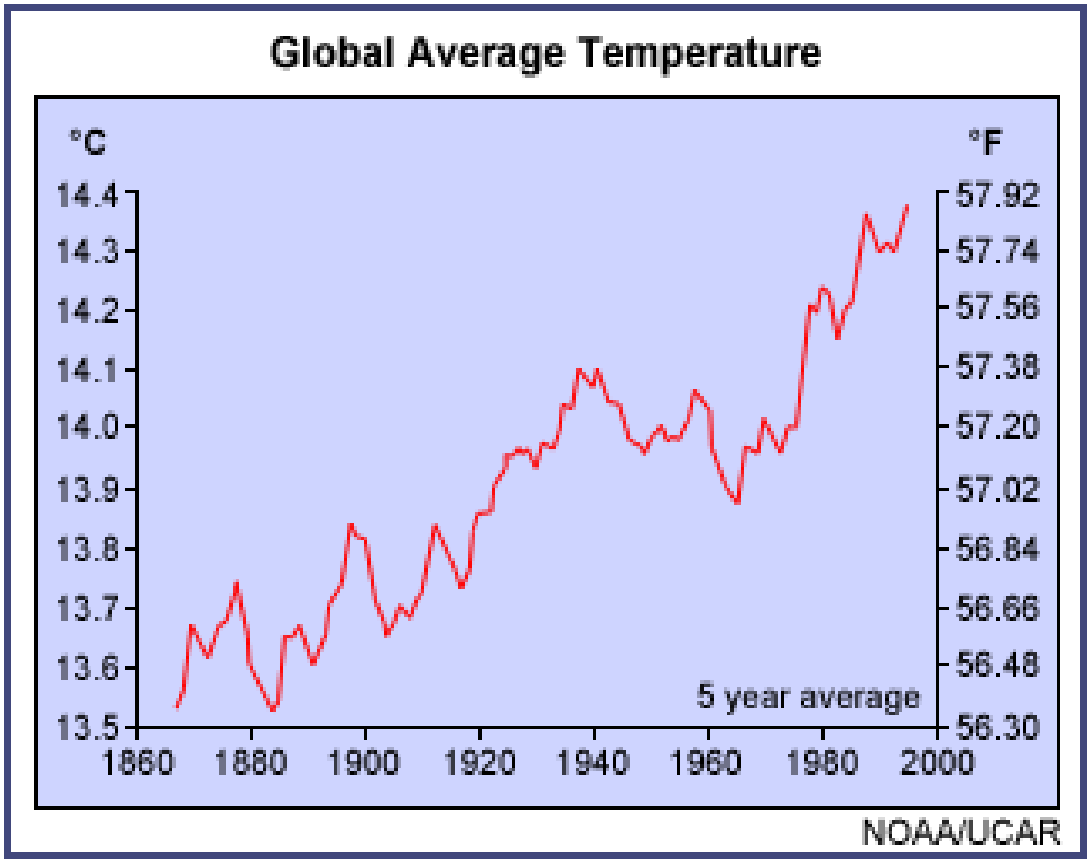
Climate change

This refers to any change in climate over a long period of time, demonstrated by statistical evidence. According to the Intergovernmental Panel on Climate Change (IPCC), a body set up by the United Nations, climate change is a ***"change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."*** (IPCC, 4th Assessment Report, 2007)

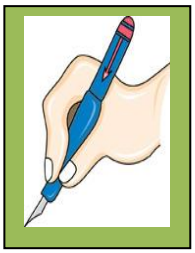
In simple language, climate change is a change in average temperatures or total rainfall that takes place over tens, hundreds, thousands or millions of years. It also refers to changes in the number of extreme weather events, for example, very high temperatures, droughts, severe storms. Climate change is caused by both natural and human factors.

At present, statistical evidence is showing that all over the world, temperatures in the lower atmosphere have been slowly rising during the last 200 years. The following graph (Fig. 11) shows how the earth's average temperature has increased since 1860:

Fig. 11



UCAR, 2014



Now please complete Activities **2.1** and **2.2** 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 Difference between climate variability and climate change 2.2 Climate variability and climate change as shown on graphs		

Section 3 Demonstrate the seasonal changes in Vanuatu's temperature and rainfall

After completing this section, you should be able to:

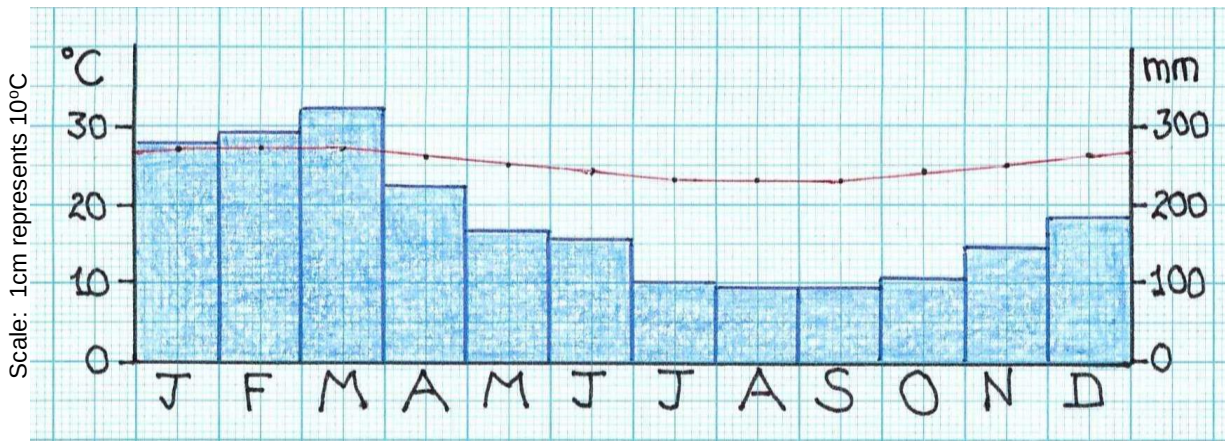
3.1 use a climograph to show how Vanuatu's temperature and rainfall change during the year;

3.2 construct a climatic graph for one of the meteo stations in Vanuatu.

3.1 Monthly changes in temperature and rainfall during the year

Let us see how temperature and rainfall change during the year, using a **climograph**. A climograph (also known as a climatic graph) is a graph that shows both temperature and rainfall together. Usually, temperature is shown by a line, and rainfall by bars. Here is a climograph for Port Vila (Fig. 12), based on data in the table below:

Fig. 12: Climograph for Port Vila



	J	F	M	A	M	J	J	A	S	O	N	D	Total
Temp (°C)	27	27	27	26	25	24	23	23	23	24	25	26	
Rainfall mm)	279	290	321	221	164	155	100	93	93	106	144	184	2,147

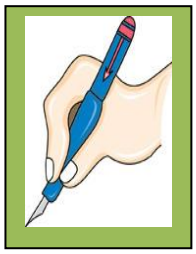
Look at the graph. Which are the hottest and the coldest months? What is the **range of temperature** (the difference in °C between the hottest and the coolest months?) Do you think that the average monthly temperature changes very much during the year? Which are the wettest months? Which are the driest? Can we say that Vanuatu has a hot, wet season and a cooler, drier season? Which are the months in each season?

3.2 Constructing a climograph

Now you are going to construct a climograph of your own.

Choose one of these meteorological stations, depending on where you live - Sola, Pekoa, Lamap, Bauerfield, Whitegrass, Anelgowhat - and refer to the statistics in your Learner Workbook. Use a vertical scale of 1 cm to 10°C for temperature and 1cm to 100 mm for rainfall.

Plot the dot for monthly temperature in the middle of the space allocated for each month. Make sure the temperature line is at the same level when it enters and leaves the graph. Use the whole of each monthly space for the bar of rainfall, and shade all bars in the same colour. *(See the example above.)*



Please complete Activities **3.1** 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 Monthly changes in temperature and rainfall during the year in Vanuatu 3.2 Construction of a climograph		

Section 4 Demonstrate processes in the water cycle

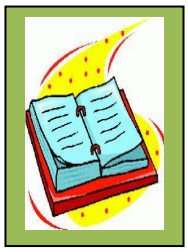
4.1 Water vapour, humidity and evaporation

After completing this section, you should be able to:

4.1 define humidity and explain how heating can convert liquid water into water vapour through the process of evaporation;

4.2 demonstrate, using a diagram, that warm air can hold more water vapour than cold air;

4.3 draw a diagram to explain the water cycle and the processes of evapo-transpiration, condensation, precipitation, run-off and underground flow.



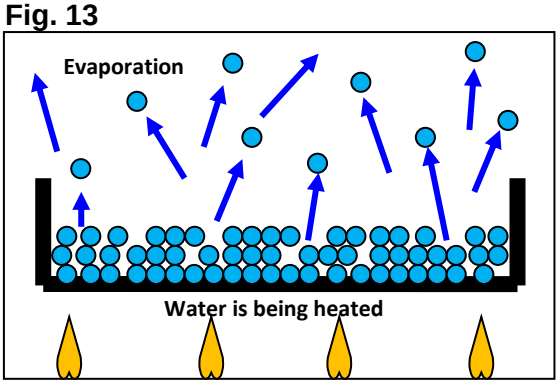
Water vapour is water in its gaseous state. It is an invisible gas that is all around us.

Humidity refers to the amount of water vapour that is in the air. If we say that the air is humid, we mean that it is containing a lot of water vapour. If it is dry, it is not holding much water vapour. The amount of water vapour that the air can hold depends upon its temperature. The warmer the air, the more water vapour it can contain.

Evaporation is the change of water from a liquid state to a gaseous state. When the sun shines on liquid water, the water is heated: some of the molecules change into gas and enter the atmosphere. If the air is dry, then it has room for a lot of water vapour, and evaporation can take place. If the air is already humid, then not much evaporation will occur.

Fig. 13 shows how heating converts liquid water into water vapour through the process of evaporation. The little blue circles represent molecules of H_2O (water). When the liquid water is heated, some of the molecules escape into the atmosphere as water vapour.

Fig. 13



Pierce, C., 2014

4.2 Warm air can hold more water vapour than cold air

The atmosphere can only hold a certain amount of water vapour. How much it can hold depends upon the temperature. In the diagram below (Fig. 14), the black line shows the maximum amount of water vapour that can be held at different temperatures.

At a temperature of 0° (freezing point), the air can hold 4 grams of water vapour per cubic metre. How much can it hold at 15°C? At 30°C?

Fig. 14

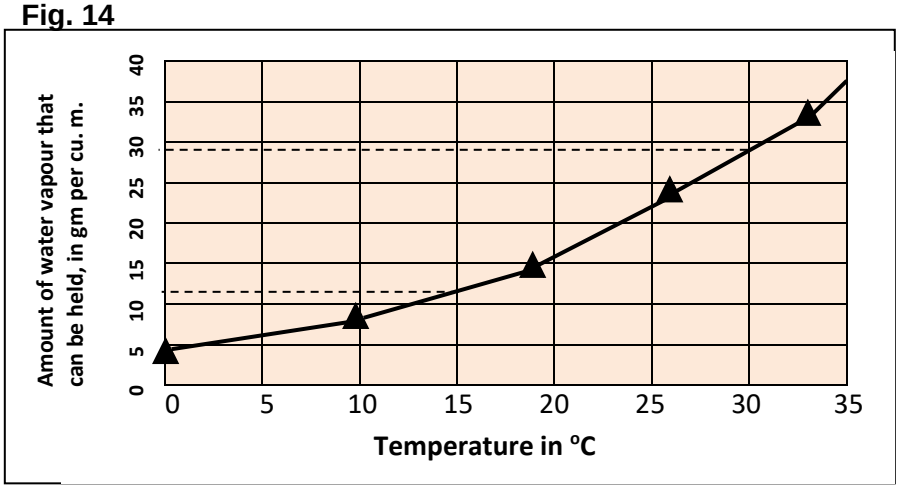
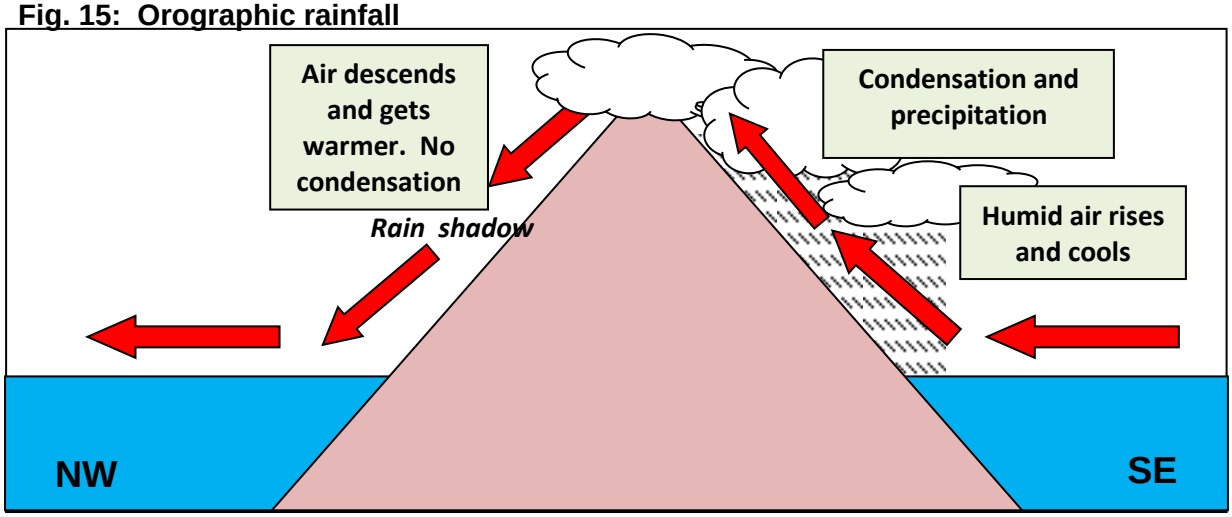


Fig. 14 shows that the warmer the air, the more water vapour it can hold.

If warm air moves to a place where it is cooler, for example when it rises up a mountain, the cooler air cannot hold so much water vapour, and some of the gas molecules change back into little drops of water again. This process is called **condensation.** The little droplets of water are very light and stay up in the atmosphere to form **clouds**, but as more and more condensation takes place, the droplets in the clouds join together and eventually form bigger, heavier drops that fall down to the ground or the sea as **precipitation**.

Fig. 15 shows a high island in the South Pacific where the south-east Trade winds are moving across the island from south-east to north-west. As the air flows over the mountain, condensation and precipitation occur on the south east side of the island. But when the air moves down the other side of the mountain, there is not much rain, and a "rain shadow" occurs. This type of rainfall is called **orographic rainfall**.

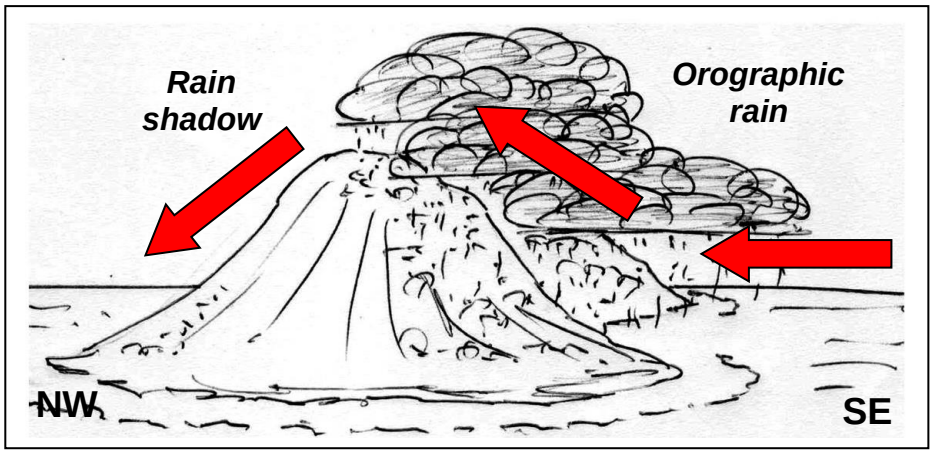
Fig. 15: Orographic rainfall



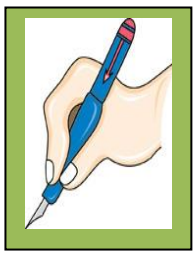
Orographic rainfall is very common in Vanuatu. Fig. 16 shows what happens when the air in the south-east Trade Winds rises over high islands such as Tanna, Erromango, Efate, Malakula and Santo. The south east side of the island facing the onshore wind receives more rainfall, and its natural vegetation is forest. But the north west side of the island is in the rain shadow and is much drier; the natural vegetation is often grassland and low bush.

Fig. 16:

Rainfall on high islands in Vanuatu



Pierce, C., 2014



Please complete Activities **4.1** and **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
4.1 Water vapour, humidity and evaporation 4.2 Warm air can hold more water vapour than cold air; condensation; orographic rainfall		

4.3 The water cycle

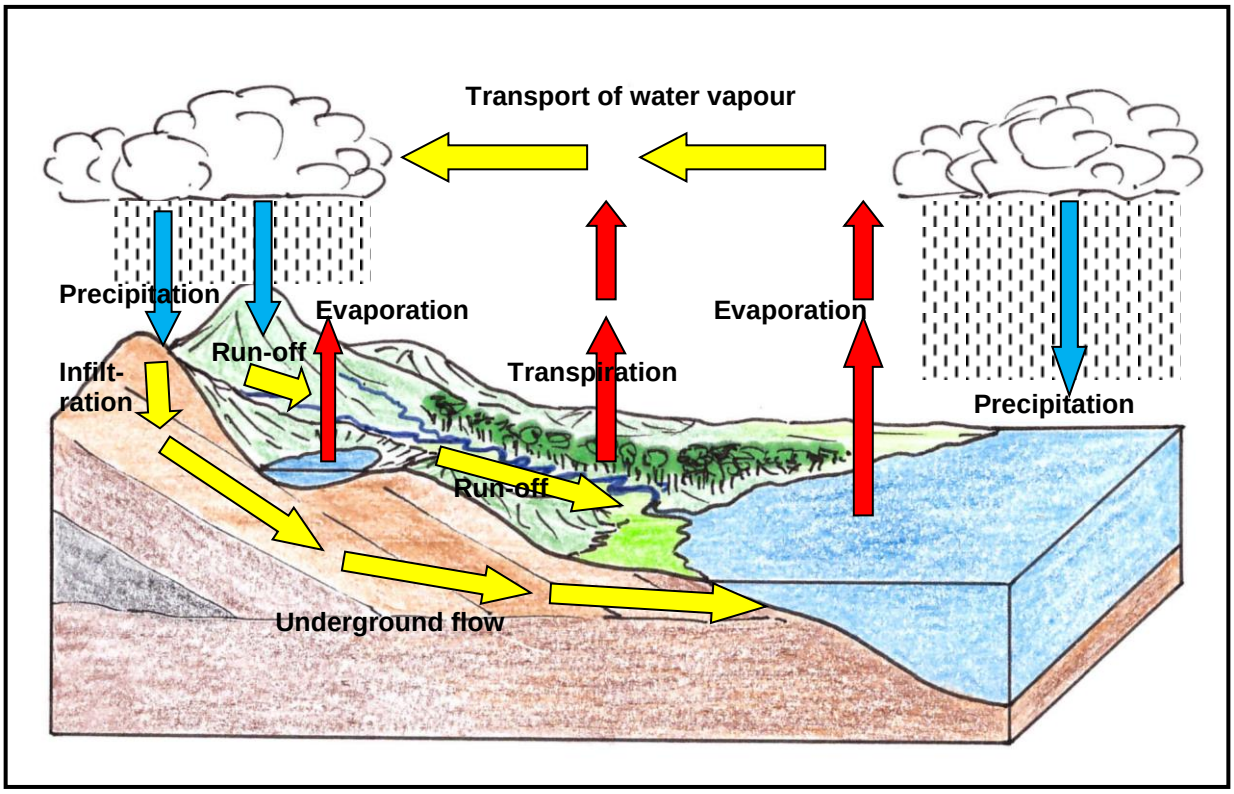
Earth is the only planet in the our solar system where water exists in all three states - solid, liquid and gas. This water is continually changing between the three states, as well as moving between ocean, atmosphere and land in a series of pathways. This continuous movement of water on, above and below the surface of the Earth is called the **water cycle**, or the **hydrologic cycle**.

It is interesting to note that it is the same water that is going round and round in a cycle, as shown in Fig. 17:

- The movement is triggered by heat received from the Sun.
- This heat warms liquid water in the oceans and on land and causes some of it to evaporate into the atmosphere.
- Plants also give off water into the atmosphere, and this is called **transpiration**.
- Atmospheric water condenses over land and sea and leads to precipitation.
- As the precipitation falls down on land, some of it enters the ground through **infiltration**, and gradually returns to the oceans as **underground flow**.
- Some water runs over the ground surface as **run-off** and enters rivers and lakes.

Most of Earth's water is held in four major **reservoirs** - ice, fresh water, saline (ocean) water and atmospheric water.

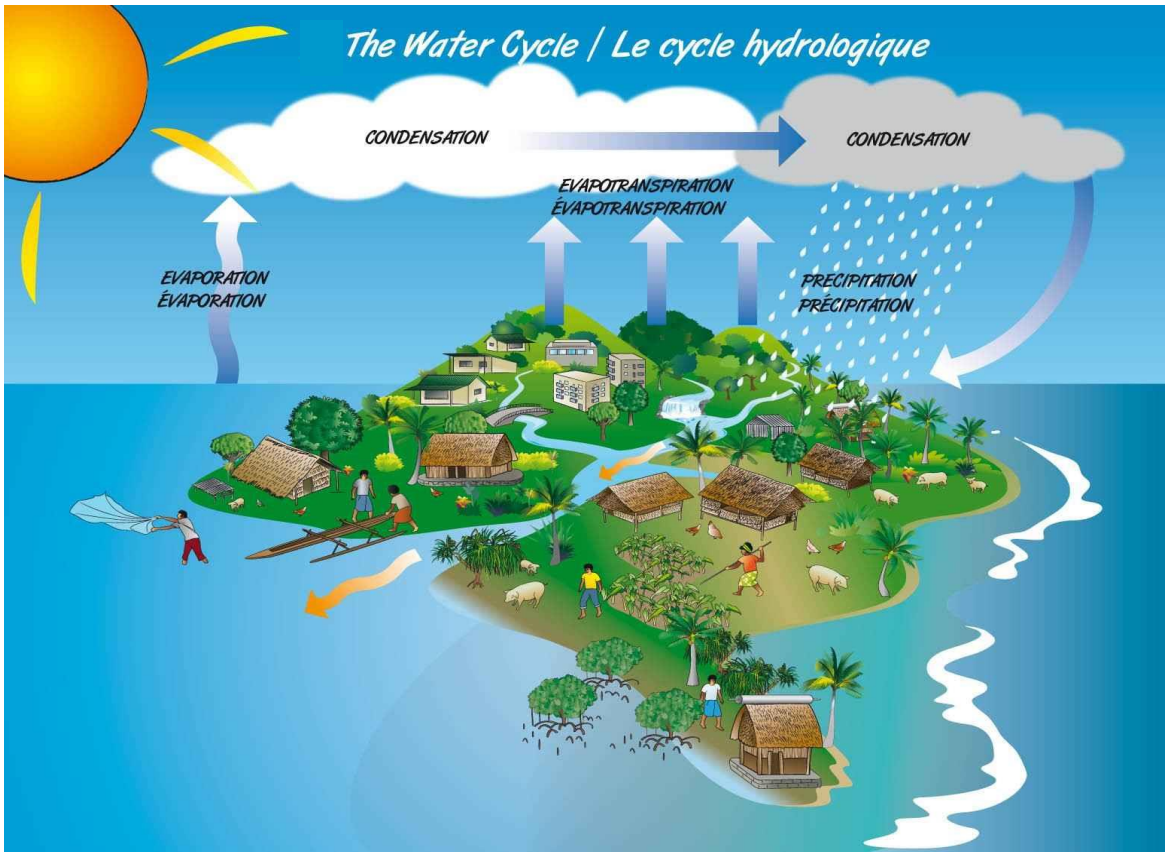
Fig. 17: The water cycle

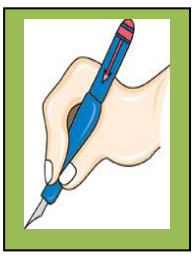


Pierce, C., 2014

In the Pacific islands, all processes in the water cycle take place. However, precipitation falls as rain, not as snow, and on smaller islands, there are few or no rivers. Fig. 18 is a diagram of the water cycle on a typical Pacific island:

Fig. 18: The water cycle on a Pacific island





Please complete Activity **4.3** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
4.3 The water cycle and processes of evapo-transpiration, condensation, precipitation, run-off and underground flow		

Section 5 Demonstrate factors that cause variations in climate within Vanuatu

After completing this section, you should be able to:

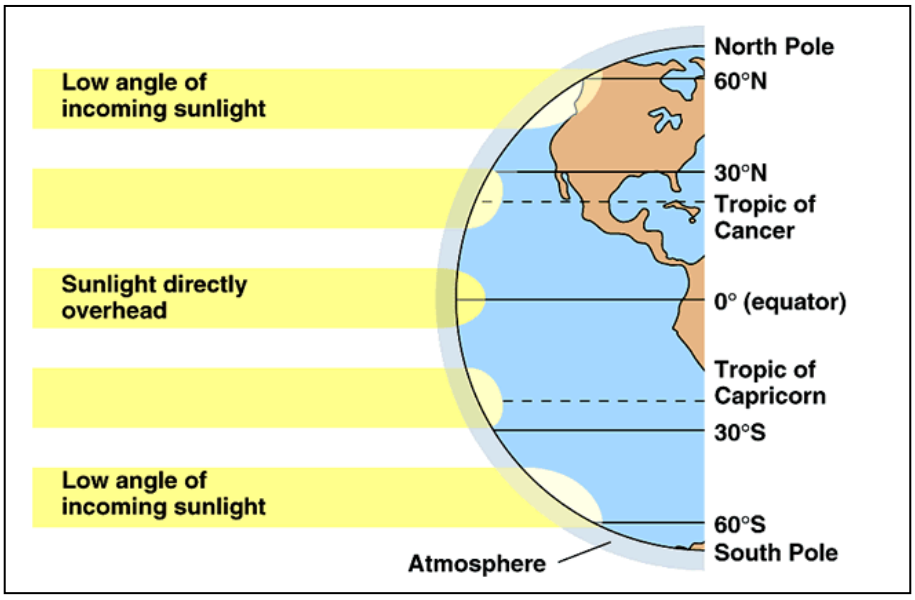
5.1 demonstrate how and why latitude and altitude cause differences in climate from island to island and within islands;

5.2 identify those areas and seasons in Vanuatu that are more liable to experience drought, and those that may have problems of flooding.

5.1 How latitude and altitude affect climate

As the sun's rays reach the earth, the zone of greatest heating is near the Equator. This is where the sun's rays are most concentrated. Please look at this diagram (Fig. 19).

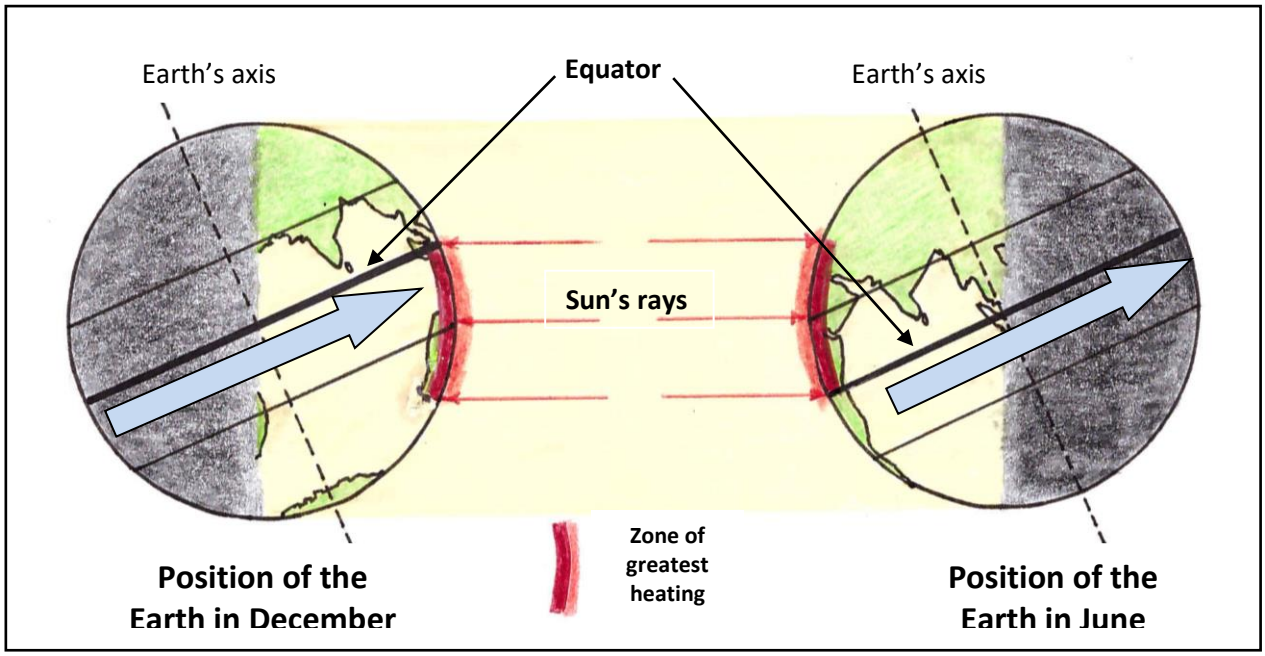
Fig. 19



For places near the Equator, the sun's energy is concentrated into a small area, whereas at higher latitudes, the energy is spread over a much wider area, so is weaker. So the closer you are to the Equator, the hotter it gets. This is how **latitude** affects temperature.

Because the earth orbits around the sun during the year, this zone of greatest heating moves to the north and south, but always includes places near the Equator (Fig. 20).

Fig. 20

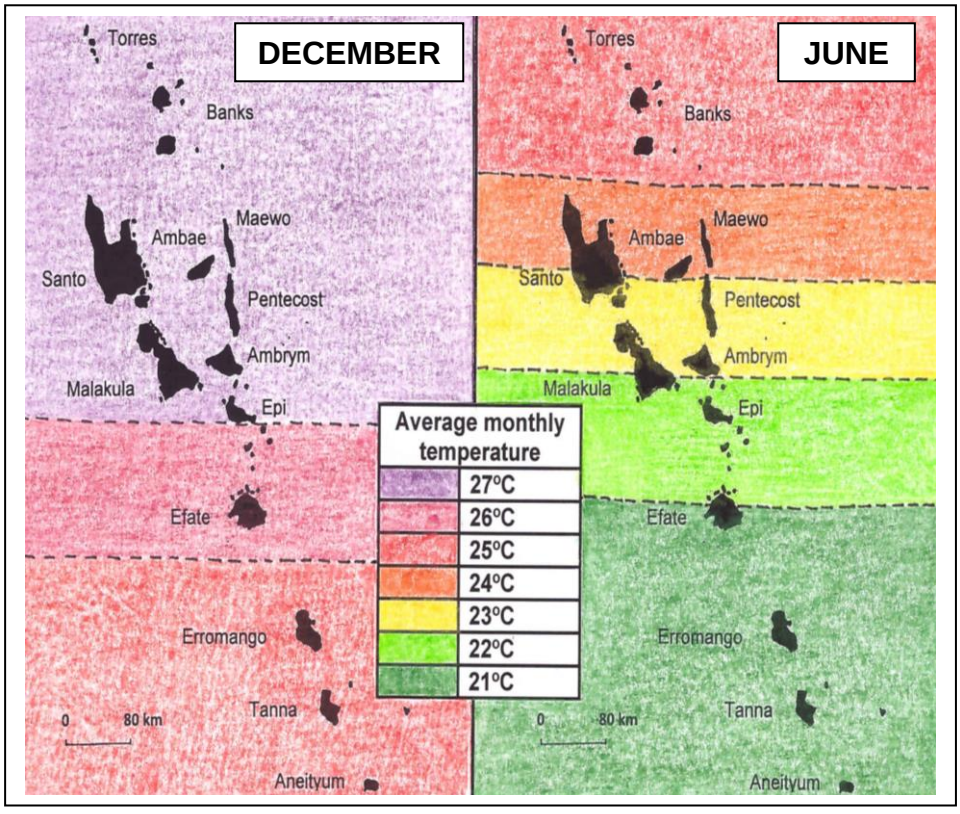


Pierce, C., 2014

Vanuatu is in the Southern Hemisphere. So the islands in the north of Vanuatu are always closer to the zone of greatest heating and are warmer than those further south.

Fig. 21:

Average monthly temperatures at sea level in December (hot season) and June (cool season)

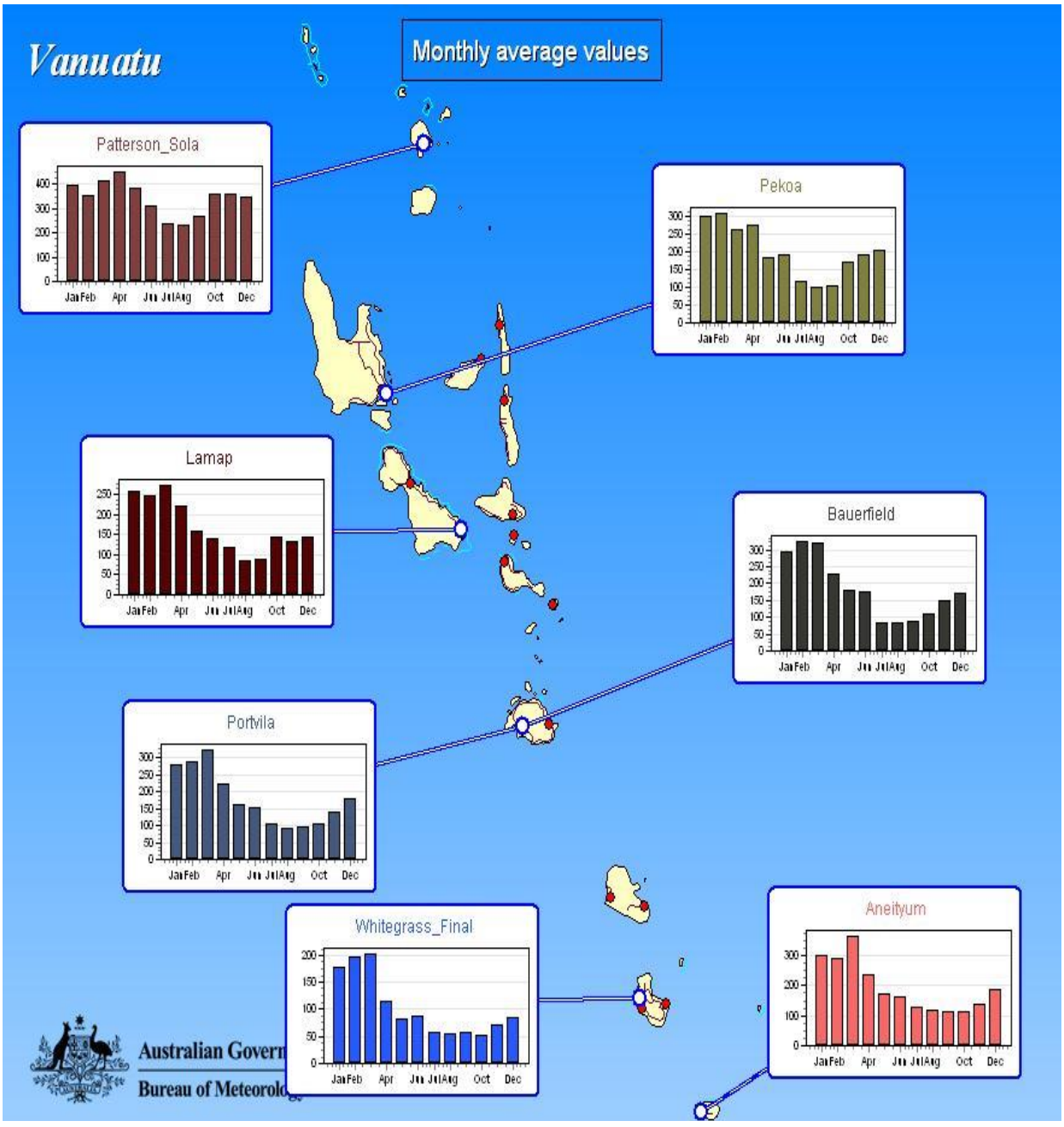


Pierce, C., 2014

What is the temperature in the Banks islands in December and in June? What about Aneityum?

Just as temperatures decrease from north to south in Vanuatu, so does rainfall. This is because the further south you go, the further you move away from the zones of rising air and heavy rainfall known as the Inter-Tropical Convergence Zone (ITCZ) and the South Pacific Convergence Zone (SPCZ). Study this map of Vanuatu (Fig. 22):

Fig. 22

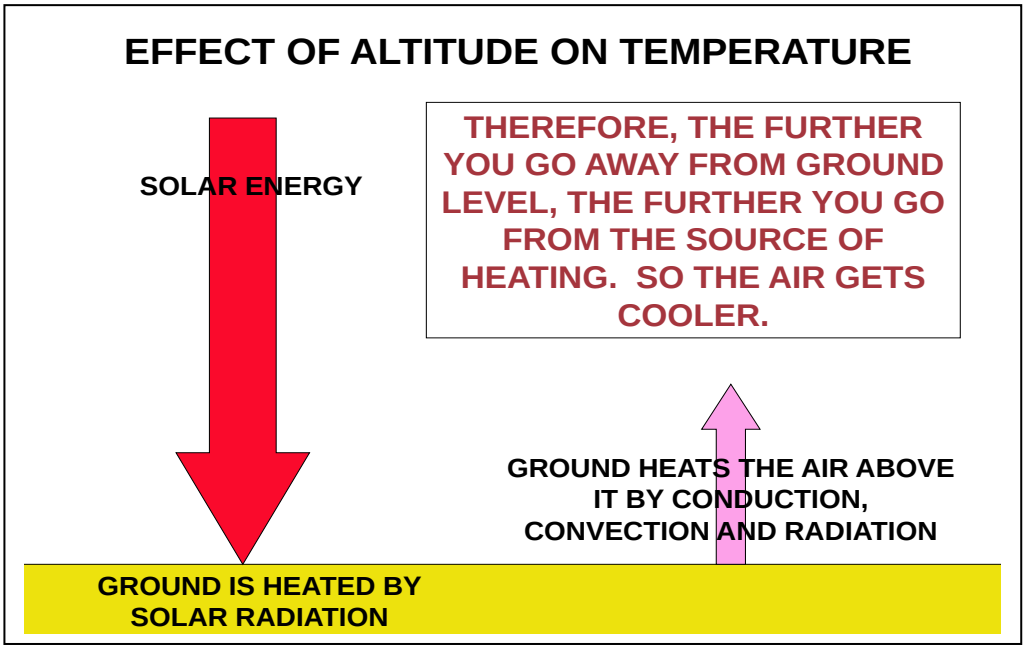


Look at the height of the bars of rainfall, noting that the scale is not the same on all the graphs. What do you notice about the monthly rainfall totals in Sola as compared with those in Aneityum? Which place has only about 50mm of rainfall in each of the months of July, August, September and October? Which are the four wettest months in all places?

You have seen that latitude affects both temperature and rainfall. As you move further south in Vanuatu and the latitude increases, so temperatures become lower and rainfall decreases. Another factor causing differences in climate from island to island, and especially within islands, is **altitude**.

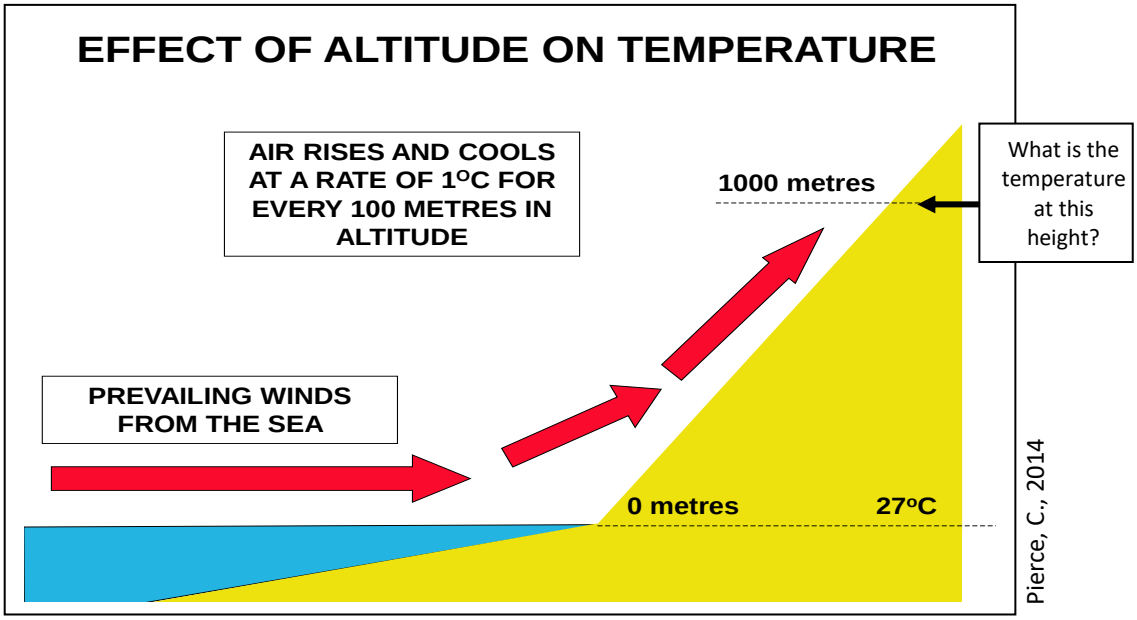
The **altitude** of a place means its height above sea level. As you go higher, so you get further away from the ground, and the temperature decreases. Remember that the sun's rays are first received by the ground, and it is the ground that heats the air above it. So the air is warmest close to the ground, and quickly gets cooler as you go up (Fig. 23).

Fig. 23



The rate at which temperature decreases with height is about 1°C for every 100 metres, although it is less than this if the air is very humid.

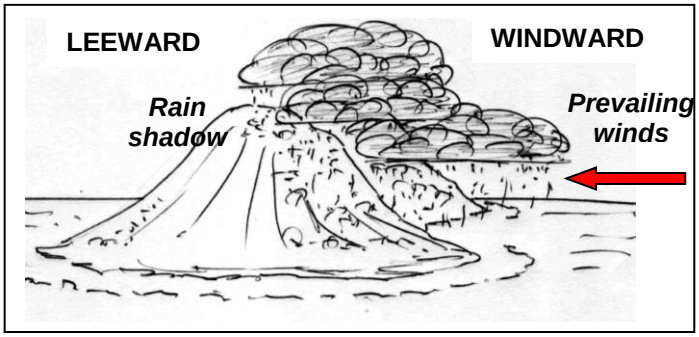
Fig. 24



The effect of altitude is noticeable on all high islands in Vanuatu. For example, Lamnatu in Middle Bush, Tanna, is at a height of about 400 metres. So how much lower will its temperature be than the temperature at Lenakel? On Santo, Mt Tabwemasana reaches a height of almost 1900 metres; if you stood on the top when the temperature at Luganville was 30°C, what temperature would you record?

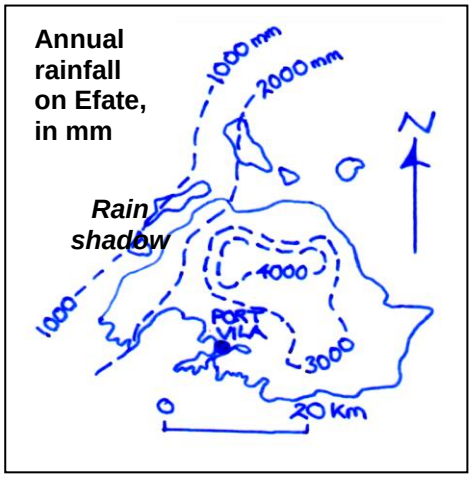
Altitude also affects rainfall. In section 4, you found out that when winds move from the ocean and rise up over high ground, the rising air is cooled, condensation occurs and precipitation falls. The side of the mountain facing the wind is called the windward slope, and receives rain. The other side of the mountain, called the leeward side, does not receive much rain, and is in the rain shadow (Fig. 25). In Vanuatu, this can be seen on larger islands such as Santo, Malakula, Efate, Erromango and Tanna, where the prevailing winds come from the south-east: thus the south-east and central parts of these islands have much more rain, while the north-western parts are in the rain shadow, have much less rainfall and may suffer from drought. See Fig. 26.

Fig. 25



Pierce, C., 2014

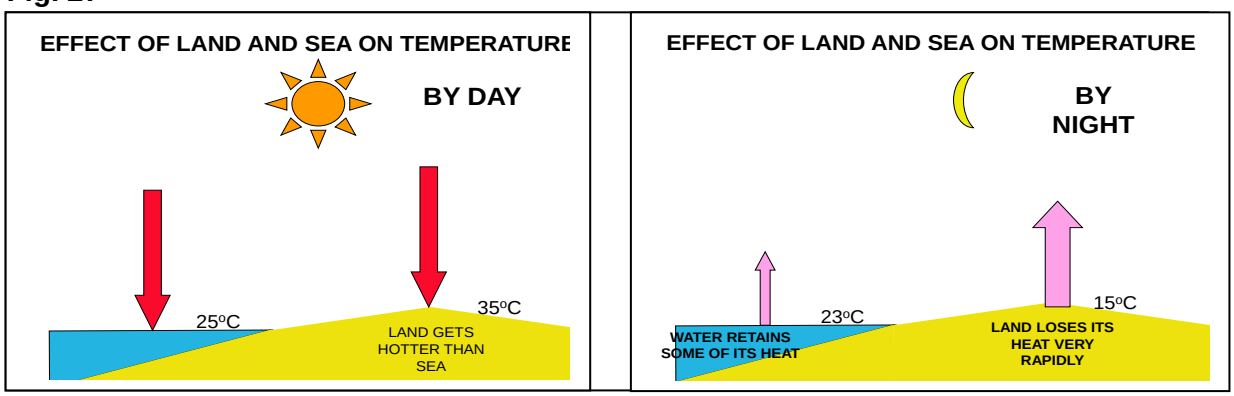
Fig. 26



Pierce, C., 2014

Another factor that affects temperature and humidity is the distance of a place from the ocean. When land and sea are heated by the sun, the sea is slow to warm up and slow to lose its heat. So places that are close to the sea have a smaller **range of temperature**. By day they do not get so hot, and by night they do not get so cold (Fig. 27).

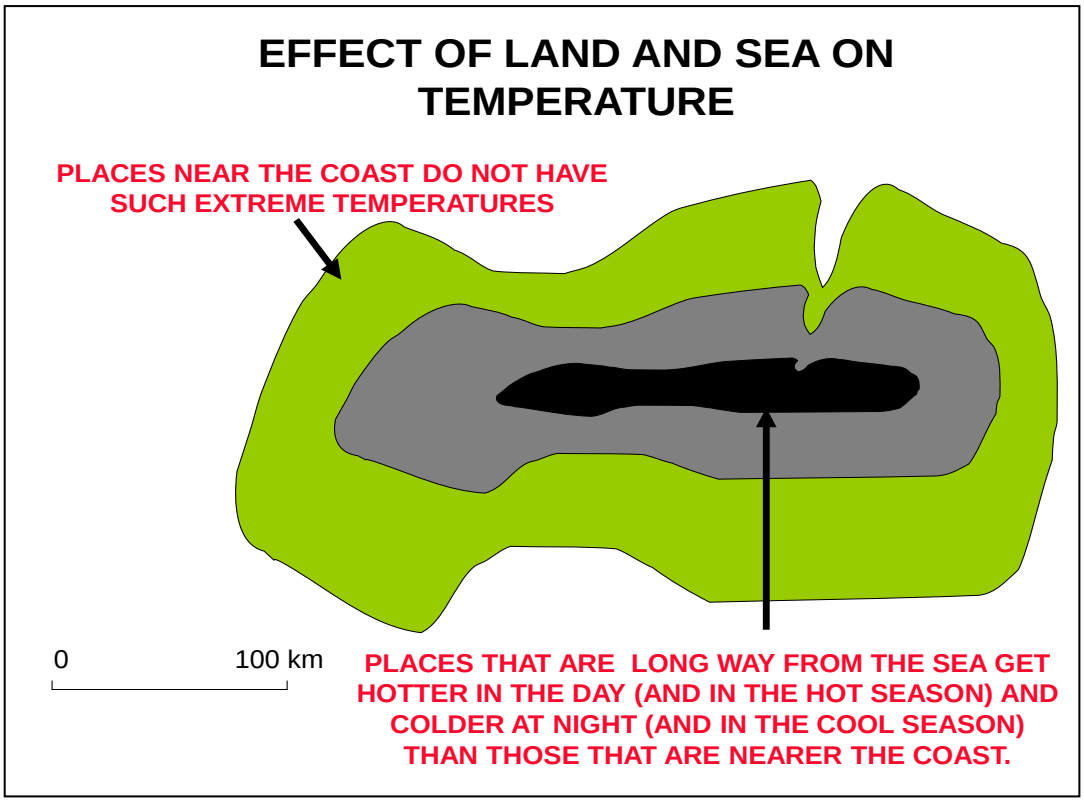
Fig. 27

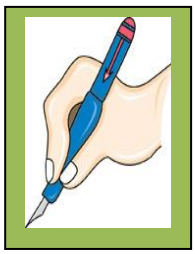


Pierce, C., 2014

In the hot season, coastal areas are not as hot as places inland, and in the cool season they are not so cold. This is shown in Fig. 28.

Fig. 28





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

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
5.1 How latitude, altitude and distance from the sea cause differences in climate from island to island in Vanuatu.		

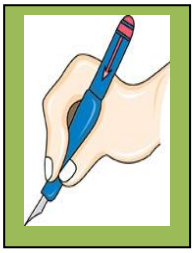
5.2 Areas and seasons in Vanuatu liable to experience drought and flooding

In 5.1, you discovered that in general, rainfall decreases as you move southwards in Vanuatu, and that rain shadow areas on the larger islands have the least rainfall. You found that rainfall increases as you go northwards, and that it is heaviest on the windward sides of high islands.

So which areas are liable to drought, and during which months of the year? Discuss this with your tutor.

And which areas are most liable to flooding, and during which months of the year? Remember that cyclones bring large quantities of rainfall, and that the run-off from this torrential rainfall will cause rivers to swell, increase in volume and flood over on to any flat land on their sides.

After this discussion, you will be ready to complete the activities in your Learner Workbook.



Please complete Activities **5.2a** and **5.2b** in your Learner Workbook

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Concept	I understand this concept	Questions that I would still like to ask
5.2 Areas in Vanuatu that are liable to drought and areas facing problems of flooding.		

Section 6 Demonstrate the key drivers that control climate variability in the tropical Pacific

After completing this section, you should be able to:

- **6.1 explain the meaning of a convergence zone and "climate drivers";**
- **6.2 identify the Trade winds, the Inter-Tropical Convergence Zone and the South Pacific Convergence Zone on a large map of the Pacific;**
- **6.3 give simple definitions of an "El Niño" season and a "La Niña" season;**
- **6.4 give a talk on "ENSO" and the movement of the warm pool in the South Pacific.**

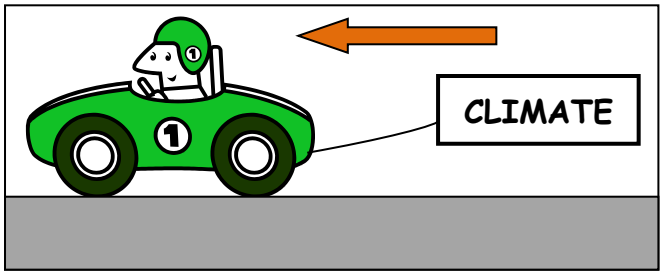
6.1 Convergence zones and climate drivers

Can you remember the definition of "climate variability" from Section 2 ?

Yes, it means the way that 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. In the tropical Pacific, there are natural variations from year to year in our hot, wet season and cooler, drier season. Sometimes, the hot, wet season comes later than it did the previous year, and sometimes it comes earlier. Sometimes, we experience long periods of drought, while at others, the wet season is wetter than expected.

These annual variations are due to the way in which the atmosphere interacts with the ocean. In particular, we can talk about four main "drivers" of this variability. By "driver", we mean something that causes, shapes or has a strong influence over the climate (Fig. 29).

Fig. 29: Climate drivers



Pierce, C., 2014

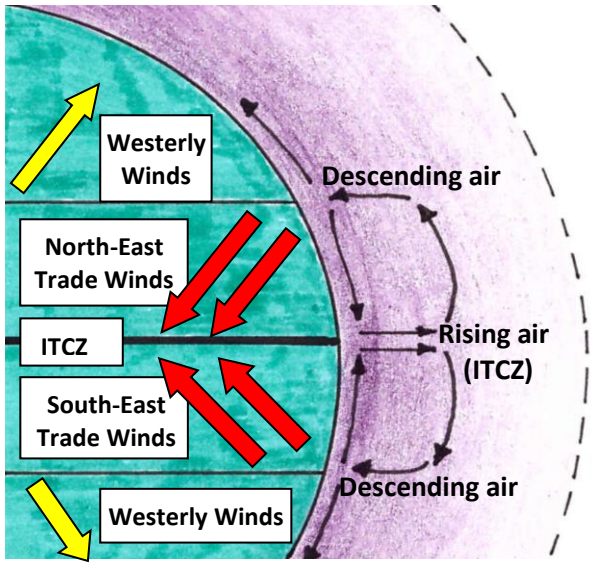
A **climate driver** can also be referred to as a climate **"forcing"** or "forcing mechanism".

In the Pacific islands, meteorologists say that there are four main drivers of climate variability: the Trade winds, the Inter-Tropical Convergence Zone (ITCZ), the South Pacific Convergence Zone (SPCZ), and the El Niño-Southern Oscillation (ENSO).

The Trade winds: These are winds that blow towards the Equator from latitudes of approximately 30°N and 30°S. In the southern hemisphere, the Trade winds come from the south-east. This diagram shows how the Trade winds are part of the Hadley cell circulation in the planetary wind system.

The Inter-Tropical Convergence Zone (ITCZ) is a zone close to the Equator where warm, moist air is rising up, with heavy rainfall. As the air rises up, the North-East and South-East Trade Winds move in to take its place. This meeting together of two air masses is called a **convergence zone**. The ITCZ moves north and south during the year, following shifts in the zone of greatest heating (as shown on page 31).

Fig. 30: The Trade winds and the ITCZ

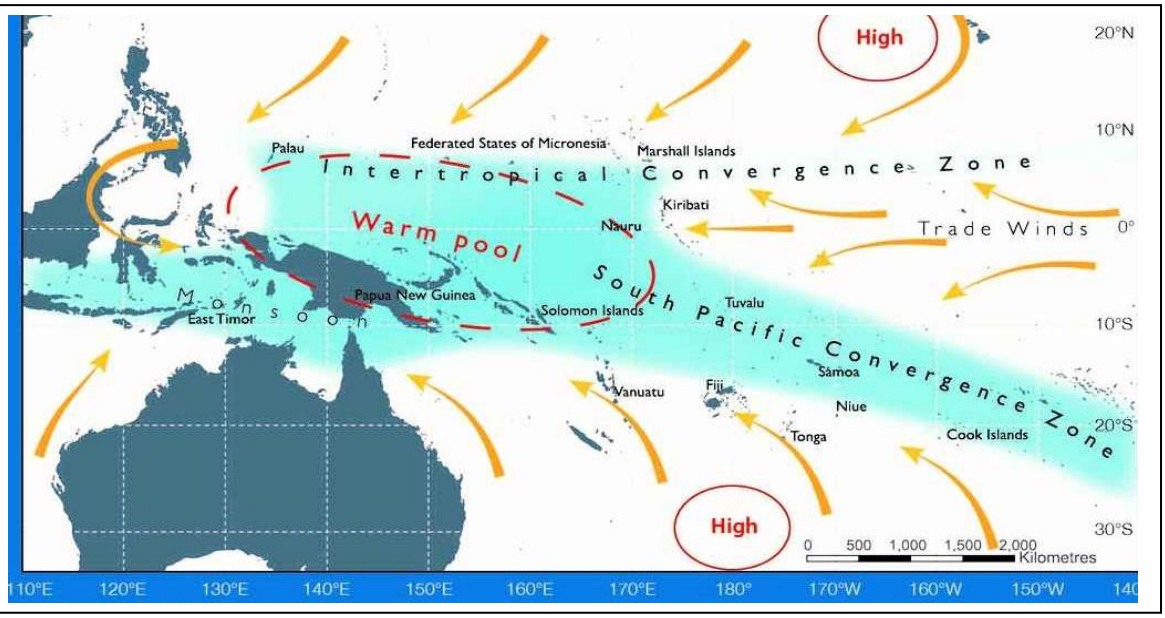


This diagram shows a map of the Earth (in green) and a cross-section through the atmosphere (in purple). Find the ITCZ and the Trade winds on the map and the cross-section.

Pierce, C., 2014

The South Pacific Convergence Zone (SPCZ) is a branch of the ITCZ in the South Pacific, extending roughly south-eastwards from Papua New Guinea. See Fig. 31.

Fig. 31: Map of the western Pacific during November - April

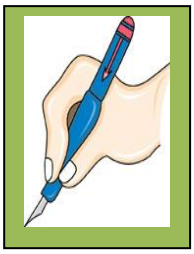


ABM & CSIRO 2011

Note: In this map, the yellow arrows represent the Trade Winds

6.2 Identifying the ITCZ and the SPCZ on a map of the South Pacific

Look back again at the map of the South Pacific on page 38 (Fig. 31). Find the Inter-Tropical Convergence Zone. Remember that it shifts northwards and southwards during the year. Now find the South Pacific Convergence Zone. Remember that a **convergence zone** is a line or area where two air masses, or winds from different directions, are meeting together. In this case it is the Trade winds.



Please complete Activities **6.1** and **6.2** in your Learner Workbook

My Notes:

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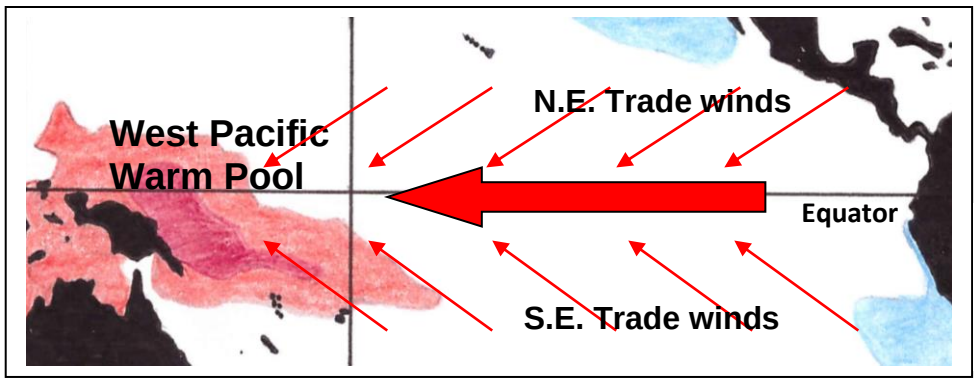
Concept	I understand this concept	Questions that I would still like to ask
6.1 Convergence zone and "climate drivers" 6.2 Identification of Trade winds, the ITCZ and SPCZ on a map of the Pacific		

6.3 El Niño, La Niña and the El Niño-Southern Oscillation

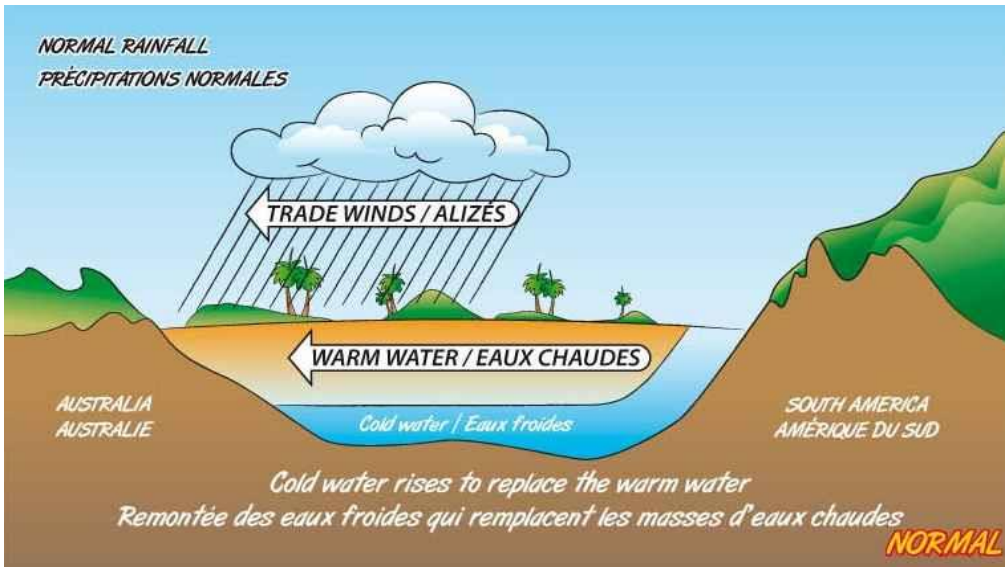
Normally, there is a zone of very warm water that occurs near the Equator in the western Pacific, known as the "warm pool". It occurs because the Trade winds blow from east to west and push the warm water westwards (Fig. 32)

Fig. 32



This makes the sea level near Indonesia and Papua New Guinea almost one metre higher than the level of the sea on the eastern side of the Pacific. While the warm pool piles up in the western Pacific, cooler water is drawn up from the ocean depths in the eastern Pacific. This deep cool water is rich in nutrients and feeds an important fishing industry along the coasts of Peru and Ecuador.

Fig. 33

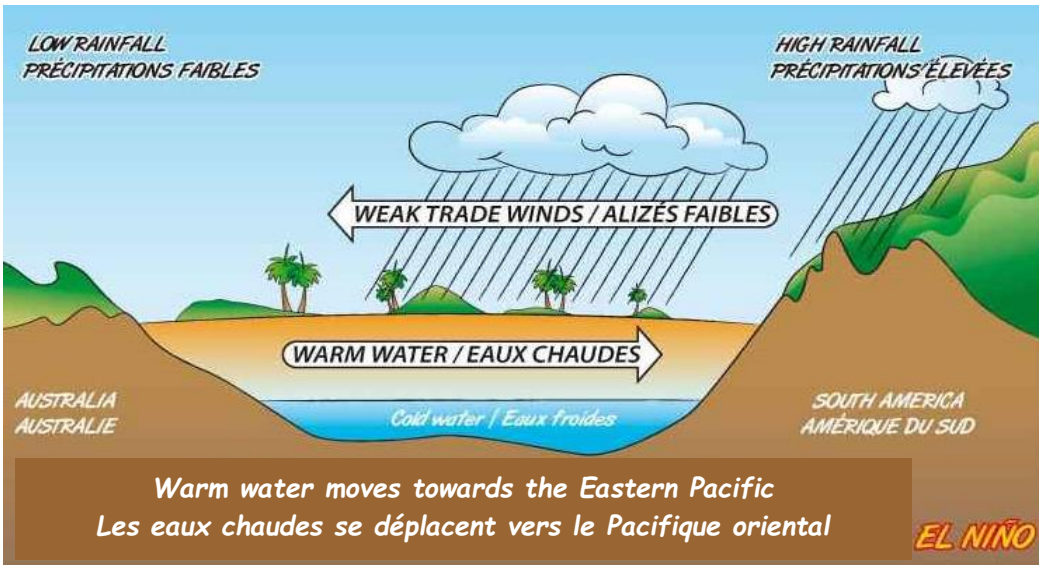


SPC & GIZ , 2014

The warm pool contains an enormous amount of heat energy and also puts a lot of warm moist air into the atmosphere, which can lead to the development of cyclones in the western Pacific. It also means that islands in the western Pacific receive a lot of rain, while the coast of Peru in the eastern Pacific is dry (Fig. 33).

But from time to time, the Trade winds weaken, and the warm pool of water moves back eastwards across the Pacific, sometimes reaching Peru (Fig. 34). This causes the South Pacific Convergence Zone to shift to the north and east. This is called an **"El Niño"** period.

Fig. 34

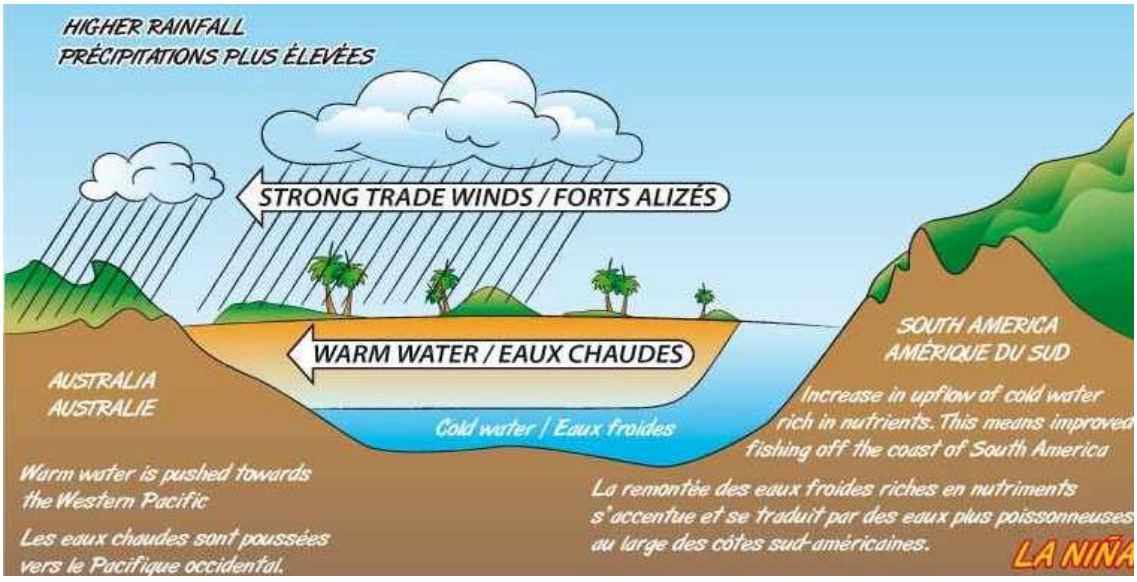


SPC & GIZ, 2014

In this way, the western Pacific becomes much drier and may suffer from drought, while the eastern Pacific becomes wetter. Because the rains often came at Christmas time, Peruvian fishermen called this period "El Niño", meaning the Christ-child.

At the end of an El Niño period, the Trade winds become stronger again and push the warm pool back to the west. But often they become even stronger than usual, pushing more and more warm water westwards. This makes the SPCZ move back to the south and west, bringing wetter conditions to the western Pacific islands and tropical Australia, with more cyclones and flooding. This is called a **"La Niña"** period (Fig. 35).

Fig. 35



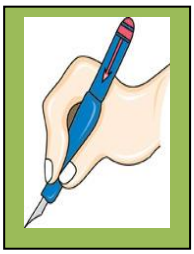
SPC & GIZ, 2014

The word "**oscillation**" means a movement from side to side that repeats itself. So the movement of the warm pool and rainy zone eastwards and westwards across the Pacific is an oscillation.

Meteorologists tell us that the El Niño Southern Oscillation (ENSO) has always been a feature of climate in the Pacific and usually has a three to seven year cycle. It is a very important driver of climate in Vanuatu. In an El Niño period, our islands may suffer from drought. In a La Niña period, our islands suffer from more cyclones and flooding (ABM- CSIRO 2011 and SPREP 2012).

6.4 Talk on the effects of the El Niño-Southern Oscillation

Read through the information on El Niño and La Niña again. Reflect on how the movement of the "warm pool" affects the variability of rainfall in Vanuatu and the South Pacific. Also, watch the cartoon film "*Klaod Nasara*". Then prepare to give a talk on ENSO to a group of people.



Please complete Activities **6.3a**, **6.3b** and **6.4** in your Learner Workbook

My Notes:

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Concept	I understand this concept	Questions that I would still like to ask
6.3 and 6.4 El Niño and La Niña periods, movements of the "warm pool", and the El Niño Southern Oscillation		

Section 7 Illustrate the main features of a tropical cyclone and its associated weather

After completing this section, you should be able to:

7.1 draw a diagram of a tropical cyclone in the southern hemisphere;

7.2 demonstrate features of the weather associated with a tropical cyclone;

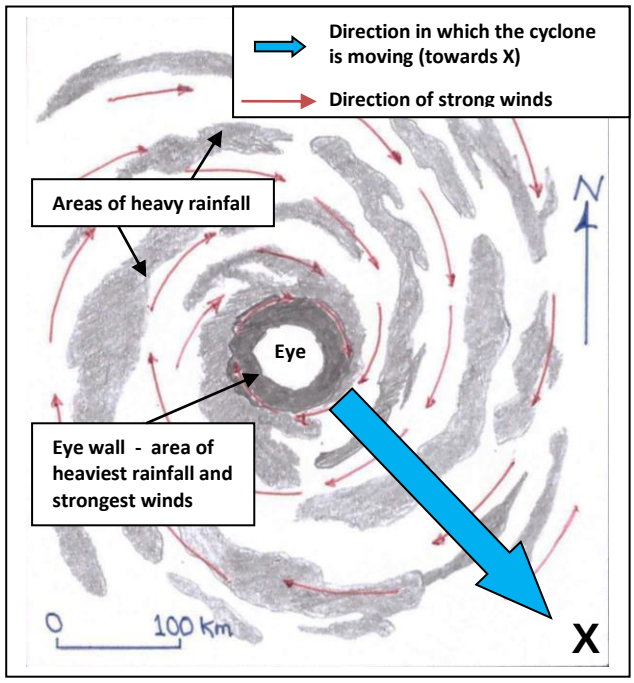
7.3 tell stories of personal experiences during a tropical cyclone.

7.1 Structure of a tropical cyclone in the southern hemisphere

Tropical cyclones are an important feature of Vanuatu's weather and climate. On average, Vanuatu experiences 3 cyclones per year, although they do not always pass close to all islands. There is great variability in the number and intensity of cyclones from year to year, and this variability is related to movements of the South Pacific Convergence Zone, where most cyclones originate, and to the El Niño Southern Oscillation.

Because tropical cyclones are such an important feature of Vanuatu's climate, and are such a hazard risk, it is important that you understand the weather patterns associated with them, and the damage that they can do to life, property and the environment.

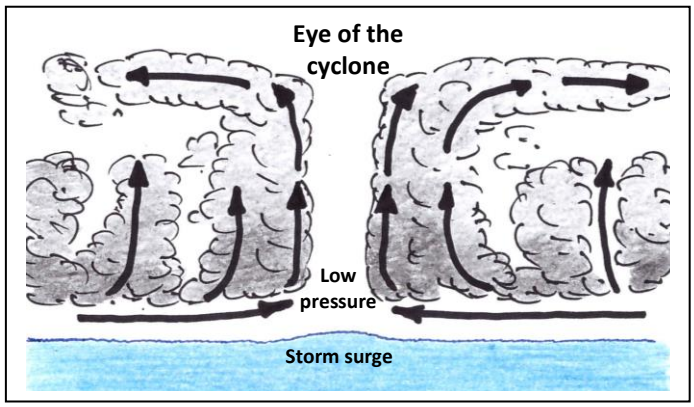
Fig. 36: Map of a tropical cyclone in the S. Hemisphere



Pierce, C., 2014

As you saw in Unit CGHR0116, tropical cyclones are centres of **low** atmospheric pressure that may form over the oceans when sea temperatures rise over 27° C. Air is drawn into the area of low pressure and starts rising upwards. More air is drawn in, and the winds start spiraling around this low pressure centre, picking up more moisture from the sea. In the southern hemisphere, winds spiral in a clockwise direction. Around the centre, or "eye" of the cyclone, the water vapour in the rising air condenses to give dense cloud and heavy rainfall. Now the low pressure centre starts to move, generally in a southerly direction. As long as it remains over the warm ocean, there is always energy to feed the system.

Fig. 37: Cross-section through a tropical cyclone



Pierce, C., 2014

The amount of water in the system builds up, and wind and rain become stronger. The system becomes a tropical cyclone. Under the eye, the level of the sea rises up to give a "storm surge" (Fig. 37). The strong winds, heavy rainfall and storm surge can bring great damage to islands in the path, or "track" of the cyclone.

Tropical cyclones are divided into categories, with category 1 being the least severe and category 5 the most dangerous. Tropical cyclone Pam, on 12-14th March 2015, was a category 5 cyclone, with sustained winds of over 240 km per hour and gusts of up to 340 km per hour.

When the tropical cyclone moves over land or cooler water, there is not enough energy to feed the system and the cyclone dies away.

7.2 Weather associated with a tropical cyclone

Tropical cyclones are a disaster risk because of the destruction done by wind, rain and the storm surge.

Wind speed will increase as a cyclone approaches, but winds are gusty, in other words there are short periods of strong winds followed by short periods when winds are less strong. Winds are most violent in the eye wall, when they can reach as much as 300 km per hour in a category 5 cyclone. If a cyclone passes directly overhead, then an observer on the ground would notice the winds becoming stronger and stronger until the eye arrives. Then there will be a short period of calm before the other side of the eye wall arrives, when the winds will come from the opposite direction and be very violent. As the cyclone moves away, wind strength will gradually decrease.

Pierce, C., 1987

Fig. 38:

Damage done by strong winds during Cyclone Uma, 6th February 1987

During Cyclone Uma, which brought enormous damage to central and southern islands of Vanuatu, winds reached an estimated speed of 300 km per hour. Fig. 38 shows how the UNELCO electricity posts in the Nambatri area of Port Vila were bent to the ground. The photograph was taken the morning after the cyclone had passed.

Wind direction will change during a cyclone. Look back to Fig. 36 on page 43. People at point X will first experience winds coming from the north-east. These winds will get stronger and stronger until the eye arrives. Then after about half an hour of calm, the winds will be very strong again, but this time coming from the south-west. Gradually, the winds will become weaker as the cyclone moves away.

Rainfall in a cyclone is **torrential**, in other words it is extremely heavy. Most rain falls in the eye wall, but there are rain belts everywhere in the area occupied by the cyclone. A cyclone can bring hundreds of millimetres of rainfall to a place in just one day. The heavy rainfall will cause rivers to flood and often produce landslides (Fig. 39). Heavy rain and strong winds will also damage and destroy food gardens (Fig. 40).

Fig. 39:

Remains of the village of Puarante, South Santo, after cyclone Lusi caused river flooding and landslides on 10th March 2014

Vanuatu Daily Post, 2014

Fig. 40:

Damaged food garden on Tanna after cyclone Pam. Photo taken on 17th March 2015.

Isso Nimhei, 2015

The storm surge associated with a cyclone can be very dangerous. In the eye of a cyclone, where the atmospheric pressure is very low, the sea water actually rises up by several metres. So if the eye passes over a village on the coast, the storm surge underneath it will make the sea flood over the land with high and destructive waves. It will be worse if the eye arrives at a time when the tide is high!

Pierce, C., 1987

Fig. 41:

Damage to the sea front in Port Vila caused by the storm surge associated with Cyclone Uma, 6th February 1987

7.3 Your experience of a tropical cyclone

Think about your own experience of a tropical cyclone. Were there any warnings? What did you and your community do to prepare and to protect yourselves? What were the weather conditions like? What kind of damage was done?

Please complete Activities **7.1, 7.2a, 7.2b** and **7.3** 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 Structure of a tropical cyclone in the southern hemisphere 7.2 and 7.3 Weather associated with a tropical cyclone, including variations in winds		

Section 8 Demonstrate long-term climatic change in Vanuatu

After completing this section, you should be able to:

8.1 use graphical data to show that key climate indicators are changing in Vanuatu.

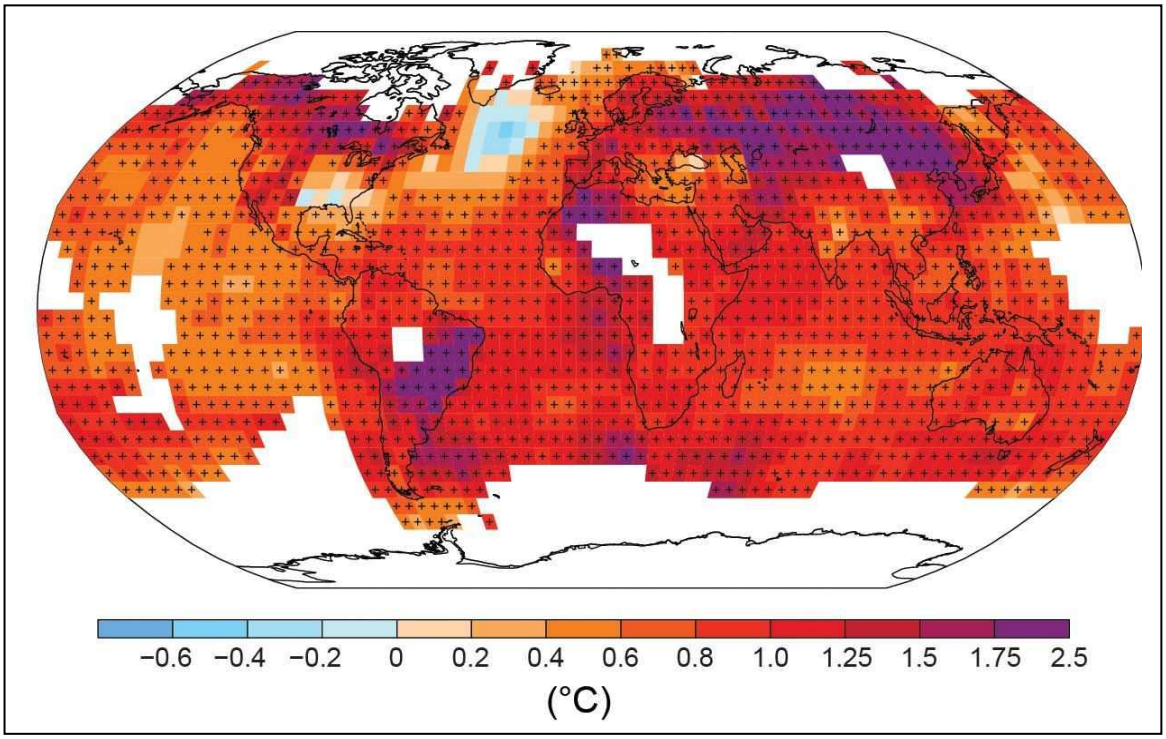
8.1 Long-term changes in weather patterns, sea levels and ocean pH

Now that we have looked at climate variability, it is time to find out more about climate change. In section 2, we saw that climate change refers to any long-term continuous change in the climate, or average weather conditions, as well as to a long-term change in the range of weather. Such long-term changes over decades or hundreds of years can normally be supported by statistical or other evidence.

The Earth's climate has shown long-term changes ever since the creation of our planet. There have been periods when temperatures were much warmer than today, and periods when they were colder, and large parts of the Earth were covered in ice. But in the last 200 years, there is clear evidence that the temperature of the atmosphere and the oceans has been increasing at a faster and faster rate, and is expected to continue to increase.

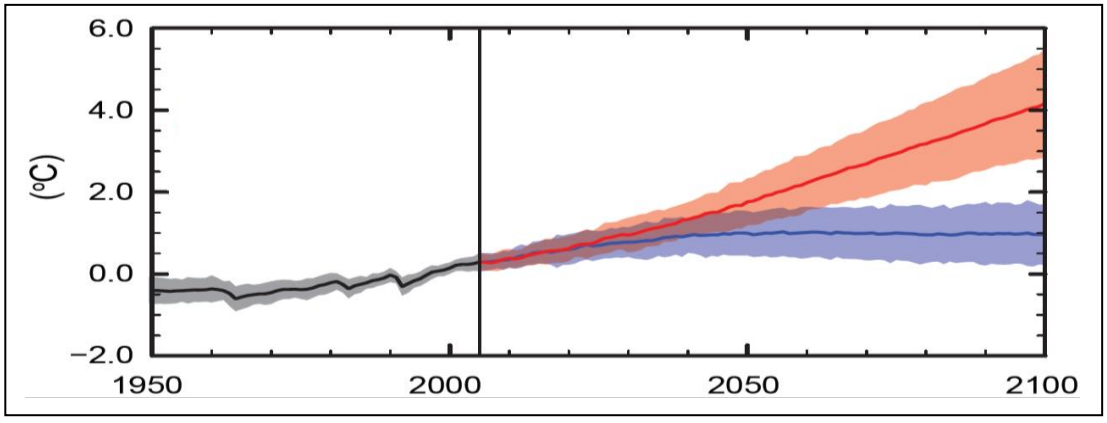
Look at this map (Fig. 42), which shows how surface temperatures on Earth have changed in the last 110 years. Have most places become warmer or cooler? Where has the greatest heating occurred?

Fig. 42: Observed change in surface temperature, 1901 - 2012



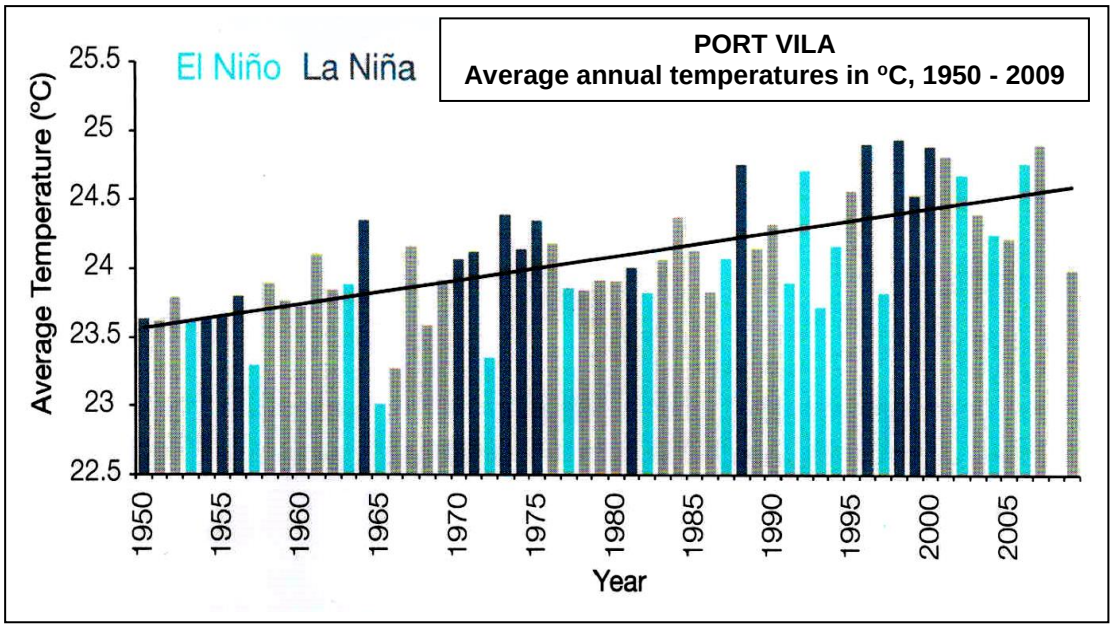
Now look at this graph (Fig. 43). The black line shows how average temperatures (land and sea combined) have increased between 1950 and 2005. The red line shows how they will continue to rise if humans do not change the quantity of greenhouse gases they are putting into the atmosphere. The blue line shows what will happen if we reduce our **emissions** of **greenhouse gases**. As you will find out in the next unit, "**greenhouse gases**" like carbon dioxide absorb outgoing heat from the Earth and make the atmosphere warmer.

Fig. 43: Global average surface temperature change



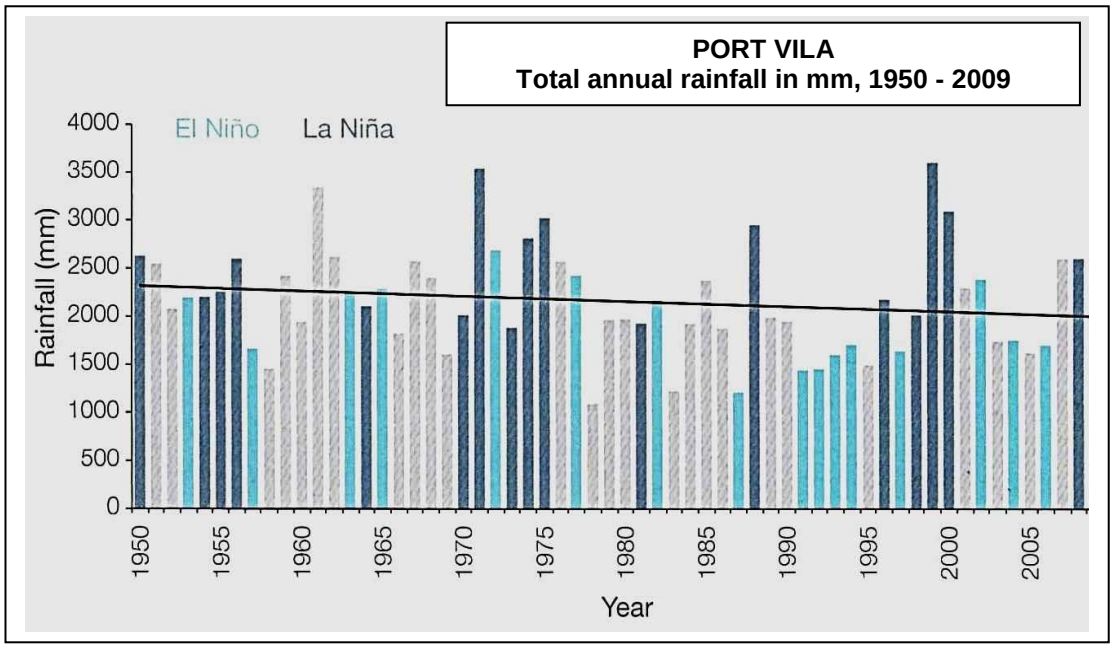
Now let us look at what is happening in Vanuatu. These two graphs (Figs. 44 and 45) show temperature and rainfall figures for Port Vila between 1950 and 2009. The black lines show the trend, in other words, what is happening over a long period. Notice too that there is an indication of whether it was an El Niño year (light blue), a La Niña year (dark blue) or a normal year (grey).

Fig. 44



ABM & CSIRO, 2011

Fig. 45



ABM & CSIRO, 2011

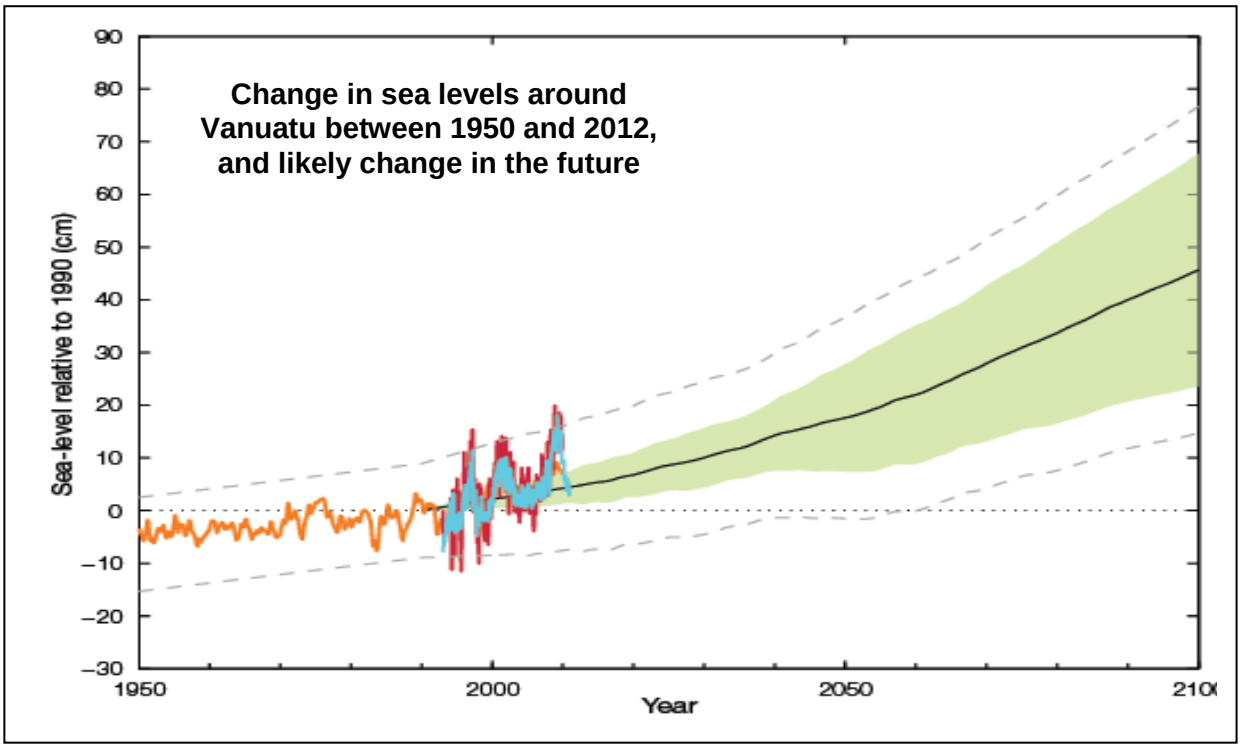
So what do you notice about the long term change in temperature in Port Vila over the last 50 years? What about the long-term change in rainfall?

And what can you say about temperatures and rainfall in an El Niño year, and in a La Niña year?

One consequence of rising temperatures is that sea levels will also rise. This is because when you heat something, it expands. Ocean water cannot expand downwards into the hard sea floor, so when the water gets warmer it will expand upwards, leading to a rise in sea level. Another reason why sea levels will rise is because warmer temperatures will cause the melting of ice sheets covering the land masses of Greenland and Antarctica. This is already happening!

This graph (Fig. 46) shows what has happened to sea levels around Vanuatu since 1950. 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 6 mm each year since 1993.

Fig. 46: Change in sea levels round Vanuatu 1950 - 2012, and likely future change



One more long-term change that can be observed is an increase in the acidity of the ocean. The acidity of a liquid is indicated by its pH value. A pH of 7 means that the liquid is neutral. Any value above this means that the liquid is alkaline. Anything below 7 means that the liquid is acid. So if the pH is getting less, this means that the liquid is becoming more and more acid. What seems to be happening around the world in recent years is that as more and more carbon dioxide accumulates in the atmosphere, so more of the CO_2 is absorbed by the oceans, making them more acidic and causing their pH to drop.

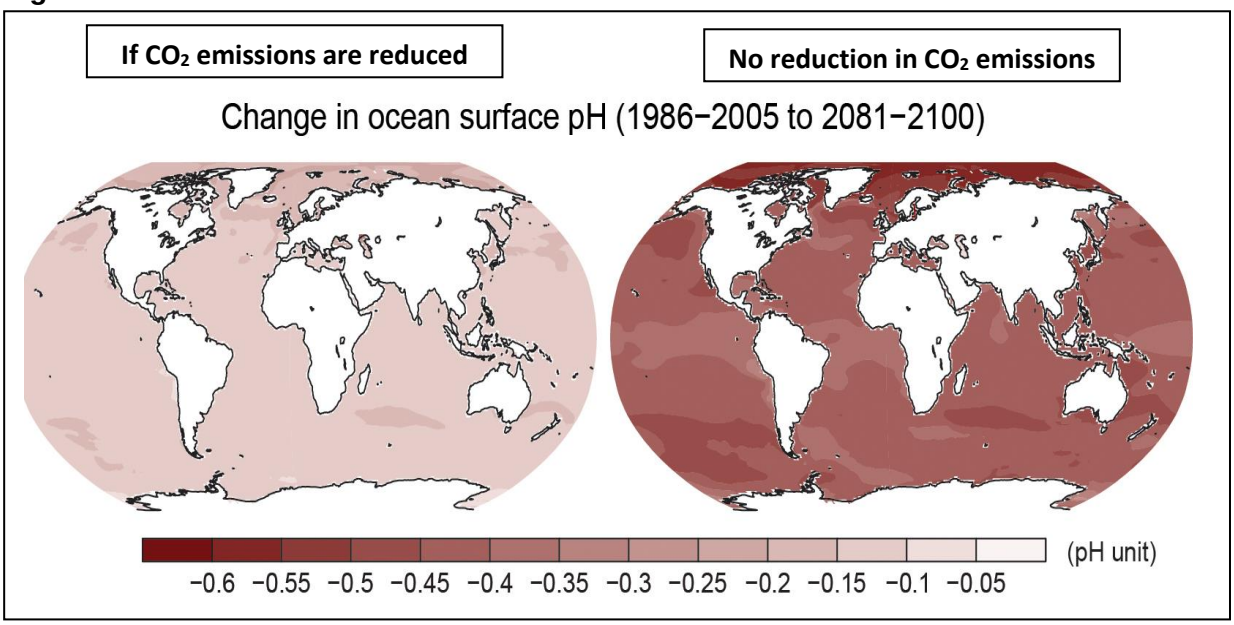
Fig. 47 is a map that shows how oceanic pH is expected to continue to fall during the rest of the present century, as more carbon dioxide is absorbed by the oceans.

The map on the left of Fig. 47 shows what might happen if we reduce our emissions of carbon dioxide into the atmosphere from the present levels. The map on the right shows what might happen if there is no reduction in emissions of CO_2 from their present level, and CO_2 levels continue to increase.

In both cases, oceanic pH will continue to fall, meaning that ocean acidity will increase. Increased acidity and warmer temperatures are likely to slow down the growth of coral and other organisms that build their skeletons out of carbonate minerals.

You will learn more in CGCE0516.

Fig. 47

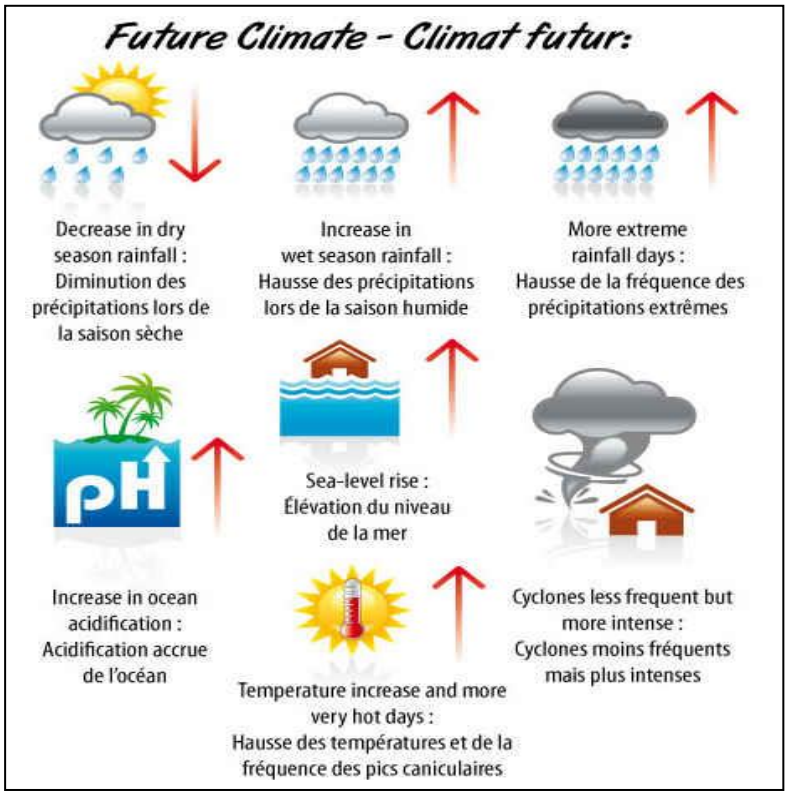


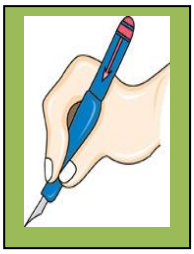
So what do all these changes mean for Vanuatu?

How will your lives, and those of your children and grandchildren, be affected by the future changes in air and sea temperature, rainfall, sea levels and ocean acidity?

Discuss these questions with your facilitator. You can also refer to Fig. 48 to help you.

Fig. 48





Please complete Activity **8.1a**, **8.1b** and **8.1c** 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 Evidence of changes in Vanuatu's temperature and rainfall patterns, sea levels and ocean pH. Likely future changes in Vanuatu's weather, sea levels and ocean pH.		

Glossary

Altitude	Height of a place above mean sea level.
Celsius (Centigrade) scale	Scale that measures temperature, with 0^{o} being the temperature at which water freezes, and 100^{o} the temperature when it boils.
Climate	General weather conditions over a month, a year or many years. Sometimes called "average weather".
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 driver or climate forcing	Something that causes, shapes or has a strong influence over climate.
Climate variability	How climate fluctuates (goes up and down) 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.
Climograph or climatic graph	Graph that shows monthly values of average temperature and total rainfall in one year .
Cloud	Collection of tiny droplets of water that are too light to fall down to the ground; clouds also contain water vapour.
Condensation	Change of water from its gaseous state into its liquid state, normally occurring when air is cooled and water vapour changes back into little drops of water that form clouds.
Convergence zone	Area where two air masses are meeting together; place or line where winds from different directions are meeting together.
El Niño period or season	Time when the Trade winds weaken and the warm pool moves eastward across the Pacific, making the western Pacific much drier and liable to drought, and the eastern Pacific much wetter.
Emission	When a gas is put into the atmosphere.
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.
Evaporation	Change of water from a liquid state to a gaseous state, normally caused by heating.
Evapotranspiration	All water transferred in gaseous form to the atmosphere, either by evaporation or through transpiration from plants.
Fluctuate	Vary, or move up and down, or rise and fall.

Greenhouse gases	Gases in our atmosphere that retain outgoing heat from the Earth, e.g. carbon dioxide (CO_2), so making the atmosphere warmer.
Hail	Little hard balls of ice that drop from clouds when the temperature is below 0^oC.
Humidity	Amount of water vapour that the air is holding.
Infiltration	Sinking of water into the ground after it has fallen down as precipitation .
Interaction	Way that one thing affects another thing.
Inter-Tropical Convergence Zone	Zone close to the Equator where warm, moist air is rising up, with heavy rainfall; it moves north and south during
La Niña period	Time when the Trade winds are much stronger and push more and more warm water westwards, making the western Pacific warmer and wetter than usual, with more cyclones
Latitude	Distance of a place north or south of the Equator, measured in degrees; Port Vila is 18^o south of the Equator.
Maximum temperature	Highest temperature recorded during a period of time, e.g. in one day, one month, one year.
Mean daily temperature	Average of the maximum and minimum temperatures during one day.
Mean monthly temperature	Average of all the mean daily temperatures during one month.
Meteorologist	Scientist who studies the weather and the climate.
Minimum temperature	Lowest temperature recorded during a period of time, e.g. in one day, one month, one year.
Molecule	Smallest possible particle of a chemical compound that exists in a free state, consisting of two or more atoms joined together by chemical bonds.
Orographic rain	Rainfall that comes when moist air is forced to rise up a hill or mountain and is cooled to the point where condensation and precipitation occur.
pH	Measurement of the acidity or the alkalinity of a liquid, with a neutral liquid having a value of 7.
Precipitation	Visible forms of water that drop from clouds - rain, snow, hail, sleet, etc.
Range of temperature	Difference in ^oC between the highest and lowest temperatures in one day, one month or one year.
Reservoir	Place where water is stored.
Run-off	When water runs down over the ground surface after falling down as precipitation, usually finding its way into rivers, lakes or the oceans.

Seasonal distribution of rainfall	When the rainfall comes during one year, e.g. all year round, or mostly in the hot season, or mostly in the cool season, or hardly any at all.
Snow	Soft, light crystals of frozen water that drop from clouds like feathers when the temperature is below 0^{o}C.
South Pacific Convergence Zone	Branch of the ITCZ in the South Pacific, where Trade winds meet together; extends roughly south-eastwards from PNG.
Storm surge	Zone associated with the eye of a cyclone in which sea levels are higher.
Torrential rainfall	Very heavy rainfall experienced during cyclones or severe storms.
Trade winds	Winds that blow towards the Equator from latitudes of approximately 30^{o}N and 30^{o}S.
Transpiration	Release of water vapour to the atmosphere by plants.
Tropical cyclone	Centre of low atmospheric pressure that develops over tropical oceans. It is characterized by strong winds, torrential rainfall and a storm surge.
Underground flow	Water that travels underground back to the oceans.
Warm pool	Zone of very warm water that occurs near the Equator in the western Pacific, caused when Trade winds push the waters of the Pacific ocean to the west.
Water cycle or hydrologic cycle	Continuous movement of water on, above and below the surface of the Earth along a series of pathways. During the cycle, water changes between its three states - solid, liquid and gas.
Water vapour	Water in the form of a gas. It is invisible.
Weather	Current atmospheric conditions at a place - temperature, rainfall, wind and humidity, etc.
Weather element	Feature of the atmosphere that is a part of the weather, e.g. temperature, humidity, wind speed, atmospheric pressure.

References

- Australian Bureau of Meteorology (ABM) and Commonwealth Scientific Industrial Research Organisation (CSIRO), 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2: Country Reports - Vanuatu*
- Australian Bureau of Meteorology, Government of Australia, *What are El Niño and La Niña events,* accessed on 12 December 2014 at www.bom.gov.au
- Community Education Training Centre (CETC)/Secretariat of the Pacific Community (SPC)/ Deutsche Gesellschaft für Internationale Zusammenarbait GmbH (GIZ) CCCPIR/University of the South Pacific (USP), 2014, *Training on Climate Change and Disaster Risk Management in Community Development,* Suva, Fiji.
- Grosz-Ngaté M., Hanson J., O'Meara P. (eds), 2014, *Africa, Fourth Edition*, Indiana University Press.
- 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
- Intergovernmental Panel on Climate Change (IPCC), 2007: *Climate Change 2007: Synthesis Report: An assessment of the Intergovernmental Panel on Climate Change,* accessed on 5 December 2014 at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf
- Oxford Dictionaries, 2014, accessed on 5 December 2014 at www.oxforddictionaries.com.
- Pacific-Australia Climate Change Science Adaptation Planning programme / Australian Bureau of Meteorology/ Commonwealth Scientific and Industrial Research Organisation /Red Cross Climate Centre/VMGD/GIZ/SPC, 2014, *Klaod Nasara video mo risos tul kit* (cartoon film and resources on ENSO)
- 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 14 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.*
- Siméoni P., 2009, *Atlas du Vanouatou,* Éditions Géoconsulte, Port Vila, Vanuatu
- Vanuatu Daily Post, Issue 4118, 18 March 2014, Port Vila.
- Vanuatu Institute of Teacher Education, 2013, *Course materials for SSD211*, VITE, Port Vila, Vanuatu.
- Vanuatu Meteorological and Geohazards Department (VMGD), 2014, *Statistics of temperature and rainfall for Sola, Pekoa, Lamap, Port Vila, Whitegrass and Aneityum,* Port Vila, Vanuatu.

Illustrations

Fig. number	Source
Cover	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
1.	Classroom Printables, 2015, *Weather elements,* accessed on 10 January 2015 at http://-www.classroom-printables.com
2.	Pierce, C., 2014, *Weather elements.*
3.	Pierce, C., 2013, *Diagram of a rain gauge.*
4.	Bidgee, 13 August 2003, *Rain collected in a rain gauge,* accessed on 10 January 2015 at http://commons.wikimedia.org/wiki/File:Rain_recorded_in_a_rain_gauge.jpg
5.	Vanuatu Meteorology and Geohazards Department, 2014, *Climatic statistics for Port Vila*
6.	Pierce, C., 2014, *Describing temperature and rainfall.*
7.	Pierce, C., 2014, *World climatic zones.*
8.	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
9.	Vanuatu Meteorology and Geohazards Department (VMGD), 2014, *December temperatures at Bauerfield, 2010-2012*
10.	Pacific Climate Change Data Portal, Bureau of Meteorology, Commonwealth of Australia, 2015, *Annual rainfall at Pekoa Airport (Santo),* accessed on 9 January 2015 at http://www.bom.gov.au/cgi-in/climate/pccsp/site_data.cgi?period=annual&variable=&nat_id=VUT&station=000003&ts_period=monthly
11.	University Corporation for Atmospheric Research (UCAR) & National Oceanic and Atmospheric Administration (NOAA), 2015, *Global average temperature,* accessed on 9 January 2015 at https://www.ucar.edu/learn/images/glabalt.gif
12.	Vanuatu Meteorology and Geohazards Department (VMGD), 2014 (statistics) & Pierce, C., 2014 (graph), *Climograph for Port Vila.*
13.	Pierce, C., 2014, *The process of evaporation.*
14.	Pierce, C., 2014, *Graph showing the maximum amount of water vapour that can be held at different temperatures.*
15.	Pierce, C., 2014, *Diagram of orographic rainfall.*
16.	Pierce, C., 2014, *Rainfall on the high islands of Vanuatu.*
17.	Pierce, C., 2014, *The water cycle.*
18.	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
19.	Noblett, P., Geogonline, 2015, *How latitude affects climate,* accessed on 9 January 2015 at http://www.geogonline.org.uk
20.	Pierce, C., 2014, *Position of the earth in December and in June.*
21.	Pierce, C., 2014, *Map of Vanuatu showing temperatures in December and June.*

22.	Vanuatu Meteorology and Geohazards Department (VMGD) & Australian Bureau of Meteorology (ABM), 2014, *Monthly average values of precipitation in Vanuatu,* accessed on 9 January 2015 at http://www.meteo.gov.vu/VanuatuClimate/tabid/196/Default.aspx
23.	Pierce, C., 2014, *The effect of altitude on temperature.*
24.	Pierce, C., 2014, *The effect of altitude on temperature - rate of change with height.*
25.	Pierce, C., 2014, *Orographic rainfall.*
26.	Pierce, C., 2014, *Map of rainfall on Efate.*
27.	Pierce, C., 2014, *The effect of land and sea on temperature.*
28.	Pierce, C., 2014, *Map showing the effect of land and sea on temperature.*
29.	Pierce, C., 2014, *Climate drivers.*
30.	Pierce, C., 2014, *The Trade winds and the ITCZ.*
31.	Pacific-Australia Climate Change Science and Adaptation Planning Programme (PACCSAPP), Australian Bureau of Meteorology (ABM) and Commonwealth Scientific, Industrial and Research Organisation (CSIRO), Vol. 1: 37, 2011, *Map of the Western Pacific during November – April.*
32.	Pierce, C., 2014, *Map of the West Pacific Warm Pool.*
33.	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
34.	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
35.	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
36.	Pierce, C., 2014, *Map of a tropical cyclone in the Southern Hemisphere.*
37.	Pierce, C., 2014, *Cross-section through a tropical cyclone.*
38.	Pierce, C., 1987, *Damage done by strong winds during Cyclone Uma.*
39.	Vanuatu Daily Post, 18th March 2014, *Remains of the village of Puarante, South Santo.*
40.	Isso Nimhei, 2015, *Damaged food garden on Tanna after Cyclone Pam.*
41.	Pierce, C., 1987, *Damage to the sea front in Port Vila during Cyclone Uma.*
42.	Intergovernmental Panel on Climate Change (IPCC), 2013, *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report, Observed change in surface temperature 1901 – 2012,* accessed on 5 December 2014 at http//: www.climatechange2013.org (power point presentation)
43.	Intergovernmental Panel on Climate Change (IPCC), 2013, *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report, Global average surface temperature change,* accessed on 5 December 2014 at http//: www.climatechange2013.org (power point presentation)
44.	Australian Bureau of Meteorology (ABM) & Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2 - Country Reports: Vanuatu: Port Vila – average annual temperatures in ^{o}C, 1950 – 2009.*

45.	Australian Bureau of Meteorology (ABM) & Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2 - Country Reports: Vanuatu: Port Vila – total annual rainfall in mm, 1950 – 2009.*
46.	Australian Bureau of Meteorology (ABM) & Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2011, *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2 - Country Reports: Vanuatu: Change in sea levels round Vanuatu 1950 – 2012, and likely future change.*
47.	Intergovernmental Panel on Climate Change (IPCC), 2013: *Climate Change 2013: The Physical Science Basis: Working Group 1 Contribution to the IPCC Fifth Assessment Report, Change in ocean surface pH (1986-2005 to 2081-2100),* accessed on 5 December 2014 at http//: www.climatechange2013.org (power point presentation).
48.	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