

# CLIMATE SCIENCE TRAINING FOR SECTORS



## SESSION 4 - Climate in Vanuatu



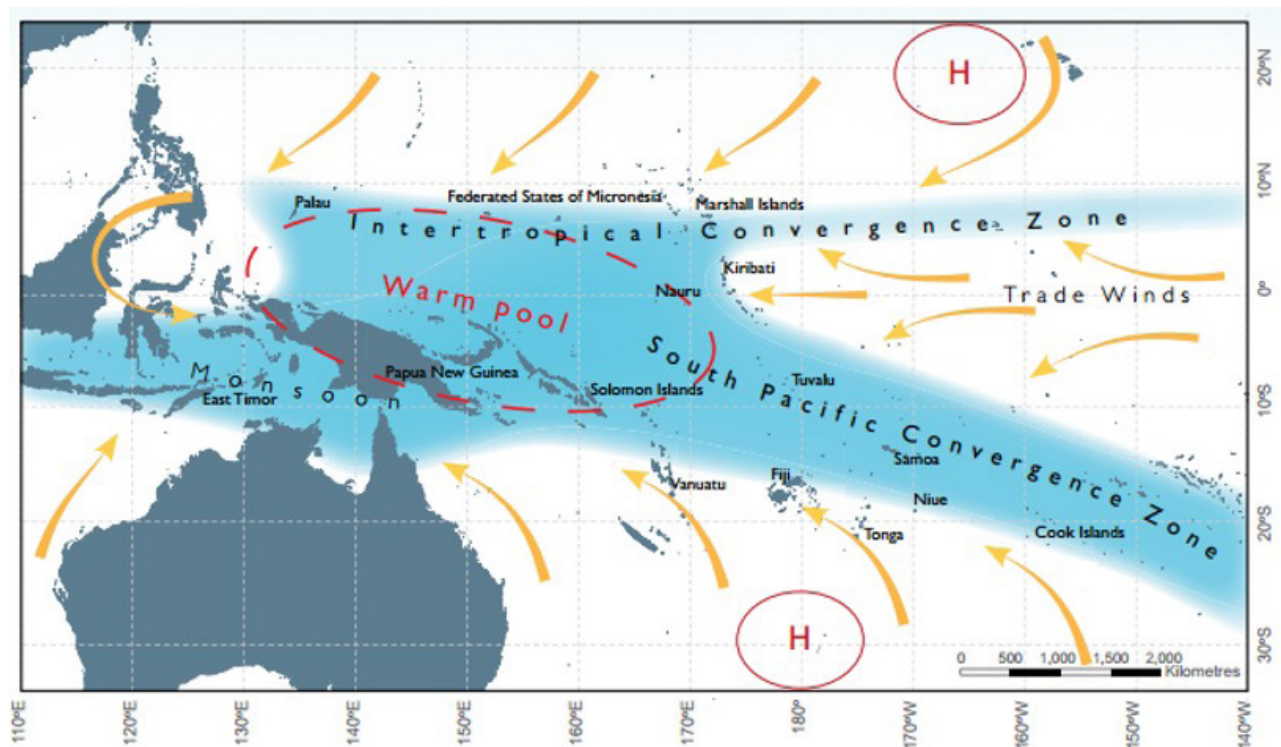
# Climate in Vanuatu

### TOPICS

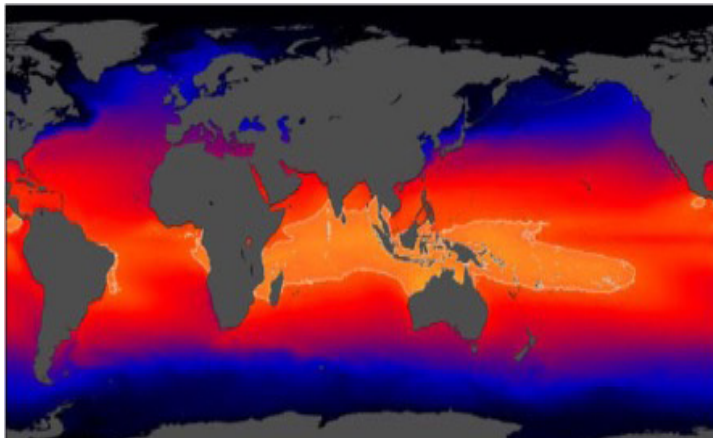
- Recap
- Climate of Vanuatu
- Vanuatu's changing climate
- Vanuatu's future climate
- VMGD climate products

### RECAP

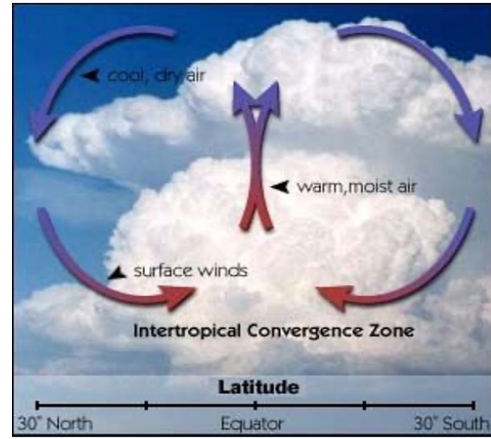
#### Key Climate features in the Pacific



The water in the Indonesian Pacific tends to be warmer and hence creates a warm pool (area marked in the dashed circled). The Western Pacific Warm Pool has two zones of convergence extending from it. The Intertropical Convergence Zone (ITCZ) and the South Pacific Convergence Zone (SPCZ). A convergence zone in meteorology is a region in the atmosphere where two prevailing flows (wind) meet and interact, usually resulting in cloudiness and rainfall.



This body of water, (orange) which spans the western waters of the equatorial Pacific to the eastern Indian Ocean, holds the warmest seawater in the world.



This diagram illustrates convergence of northeasterly and southeasterly winds at the equator, leading to convection (i.e. warm moist air raises) forming cloudiness and rain.

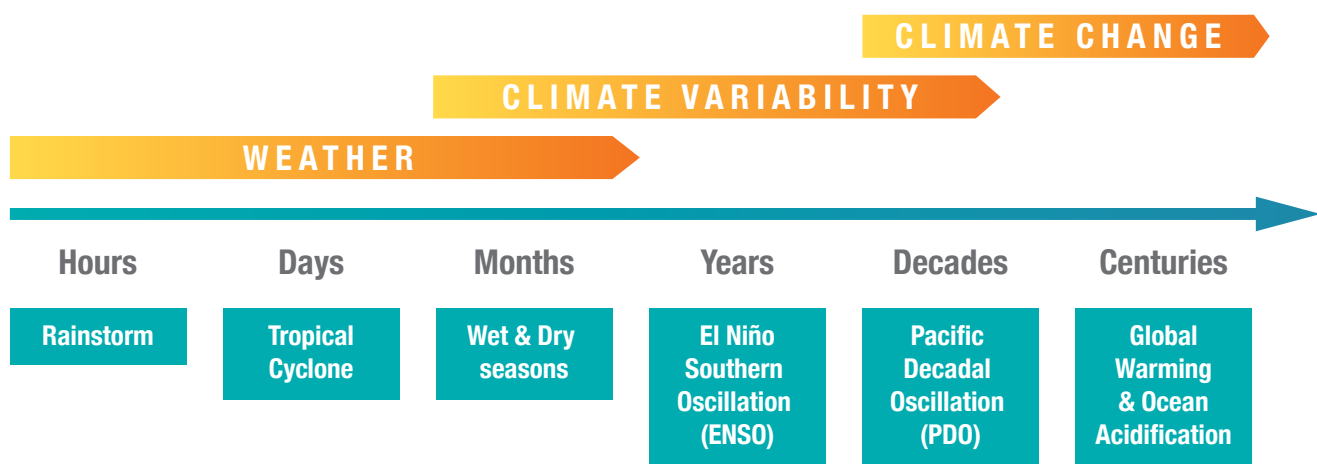
ITCZ is the zone in the central and eastern Pacific. In the western Pacific it becomes broad in association with the West Pacific Warm Pool to the north and south.

The SPCZ is another convergence zone and is most clearly defined and active in the Southern Hemisphere summer, although it is evident all year round.

## Time scales

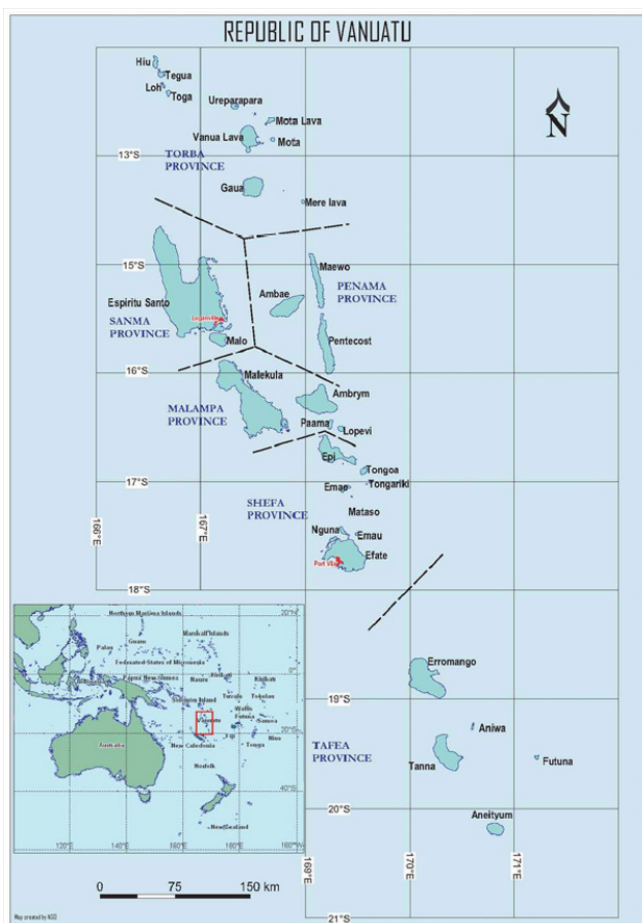
Climate variability and climate change operate on different time scales, it should be remembered climate variability and climate change are not the same and should NOT be used interchangeably but they can occur in parallel.

Climate change occurs over decades and centuries, and refers to things which happen over centuries, like global warming. In simple terms climate change describes a change in the average conditions — such as temperature and rainfall — in a region over a long period of time.



# Climate of Vanuatu

## Key factors affecting climate in Vanuatu



- Location



- Topography
- Climate Drivers e.g. ENSO events
- Tropical Cyclones/ Low Pressure systems/ Storms

Vanuatu is located 15.3767° S, 166.9592° E. within the tropical climate zone. As such across Vanuatu the annual average temperatures are between 23.5–27.5°C and rainfall all year round.

When looking at the climate of each island in the archipelago other factors such as altitude, topography, wind patterns, ocean currents, the proportion of land to water masses, geomorphology, vegetation patterns, and more recently by large-scale=man-made environmental changes.

### Tropical Climate

Much of the equatorial belt within the tropical climate zone experiences hot and humid weather. There is abundant rainfall due to the active vertical uplift or convection of air that takes place there, and during certain periods, thunderstorms can occur every day. Nevertheless, this belt still receives considerable sunshine, and with the excessive rainfall, provides ideal growing conditions for luxuriant vegetation. The principal regions with a tropical climate are the Amazon Basin in Brazil, the Congo Basin in West Africa and Indonesia.

Because a substantial part of the Sun's heat is used up in evaporation and rain formation, temperatures in the tropics rarely exceed 35°C; a daytime maximum of 32°C is more common. At night the abundant cloud cover restricts heat loss, and minimum temperatures fall no lower than about 22°C. This high level of temperature is maintained with little variation throughout the year. The seasons, so far as they do exist, are distinguished not as warm and cold periods but by variation of rainfall and cloudiness. Greatest rainfall occurs when the Sun at midday is overhead. On the equator this occurs twice a year in March and September, and consequently there are two wet and two dry seasons. Further away from the equator, the two rainy seasons merge into one, and the climate becomes more monsoonal, with one wet season and one dry season. In the Northern Hemisphere, the wet season occurs from May to July, in the Southern Hemisphere from November to February.

<http://www.ecoca.ro/meteo/tutorial/Climate/Older/TropicalClimate.html>

The tropical climate zone occupies ca. 40% of the surface of the earth and is located between the Tropics of Cancer (latitude 23.5 °N) and Capricorn (latitude 23.5 °S). The main ecological driving forces within this zone are relatively stable high temperatures and air humidity. Although there are variations in climate within the tropics, 90% of tropical ecosystems are hot and humid, whether permanent or

seasonal, and the remaining 10% are hot and dry and include mainly desert-like ecosystems. These variations are determined by altitude, topography, wind patterns, ocean currents, the proportion of land to water masses, geomorphology, vegetation patterns, and more recently by large-scale=man-made environmental changes.

## Seasonal Variation: Wet season and Dry Season

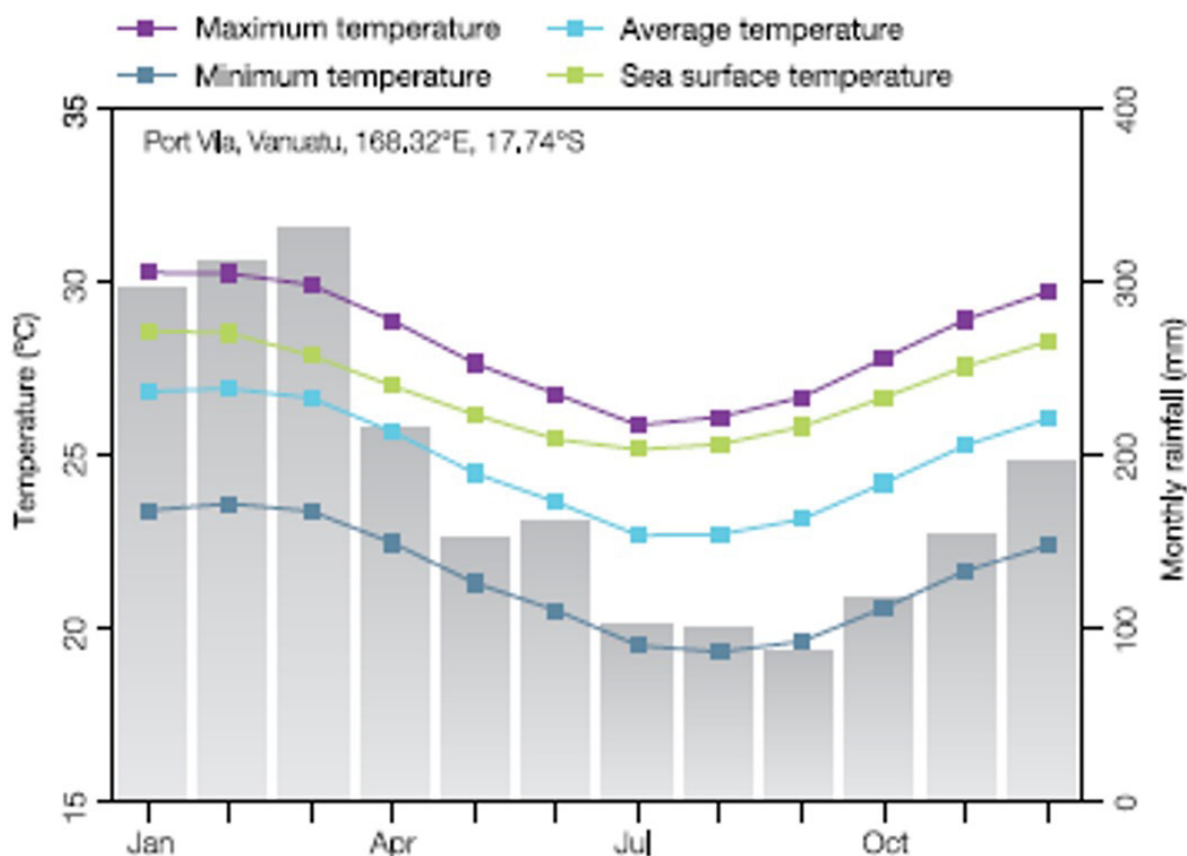


Figure 1: Seasonal rainfall and temperature at Port Vila.

### Seasonal Variation

Vanuatu’s climate varies considerably from year to year due to the El Niño- Southern Oscillation. This is a climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the El Niño-Southern Oscillation: El Niño and La Niña.

There is also a neutral phase. In both Port Vila and Aneityum El Niño events tend to bring drier conditions as well as a late start to the wet season and cooler than normal dry seasons. The opposite occurs during La Niña events.

### Temperature

Across Vanuatu the annual average temperatures are between 23.5–27.5°C. Changes in the temperature from

season to season are strongly tied to changes in the surrounding ocean temperature. The country has two distinct seasons – a warm wet season from November to April and a cooler dry season from May to October

### Rainfall

Rainfall in Vanuatu is affected by the South Pacific Convergence Zone. During the wet season ( Nov – April) the South Pacific Convergence Zone intensifies and moves further south, bringing higher rainfall to Vanuatu. Low pressure systems embedded in this band of heavy rainfall often become tropical cyclones during the cyclone season

## Seasonal Variation : La Nina generates above normal rainfall



### 2010 -2012 La Niña Impacts

Extreme rainfall periods resulting in damage to infrastructure.

Flooding at Teuma bridge (B,C), Homes (A,D), Roads, Gardens. (Photo: Erie Sami)

**El Niño-Southern Oscillation** Vanuatu's climate varies considerably from year to year due to the El Niño-Southern Oscillation. This is a climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the El Niño-Southern Oscillation: El Niño and La Niña. There is also a neutral phase. More than 100 Years of climate data from Port Vila and Aneityum show that El Niño events tend to bring drier

conditions as well as a late start to the wet season and cooler than normal dry seasons. The opposite occurs during La Niña events.

Here are pictures of a La Nina event that occurred in 2010-2012 and the impacts observed around Efate.

## Seasonal Variation : El Niño results in below normal rainfall



### 2015 -2016 El Nino Impacts

Drought in Santo affecting water sources (A) (Photo: DOWR)

Drought affecting soil quality on and root crops (B,C). ( Photo: DARD)

Here are pictures of an 2015-2016 El Nino event and the impacts observed around Vanuatu.

Santo rural dwellers had to get water from questionable water sources.

Tanna root crops where unable to grown well.

## Seasonal Variation; Tropical Cyclones bring a lot of rain, strong winds and warmer temperatures

### Tropical cyclones

When tropical cyclones affect Vanuatu they tend to do so between November and April. Occurrences outside this period are rare. The tropical cyclone archive for the Southern Hemisphere indicates that between the 1969/70 and 2010/11 seasons, 101 tropical cyclones developed within or crossed the Vanuatu EEZ. This represents an average of 24 cyclones per decade.

The interannual variability in the number of tropical cyclones in the Vanuatu EEZ is large, ranging from zero in 2001/02 to six in 1991/92 (Figure 16.7). The difference between tropical cyclone average occurrence in El Niño, La Niña and neutral years are not statistically significant.

\*[www.bom.gov.au/cyclone/history/tracks/index.shtml](http://www.bom.gov.au/cyclone/history/tracks/index.shtml)

With 280 km/h winds, Tropical Cyclone Pam was the second most intense tropical cyclone on record in the South Pacific Ocean. At least fifteen people lost their lives, making it one of the worst natural disasters in the history of Vanuatu. The storm not only resulted in damage to people and infrastructure on land; it also damaged coral reef by dislodging massive corals and moving boulders along the reef flat and down the reef slope. This is a stark example of how climate change effects such as the increasing intensity of tropical cyclones threaten reefs. Other effects that put reefs at risk, such as coral bleaching, are much more subtle, but nonetheless lethal to Vanuatu's vast reef system—the largest in the South-West Pacific (Spalding et al., 2001; see also chapter “Shaping Pacific Islands”).

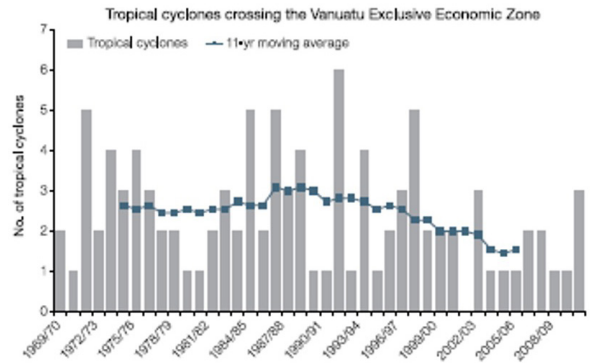
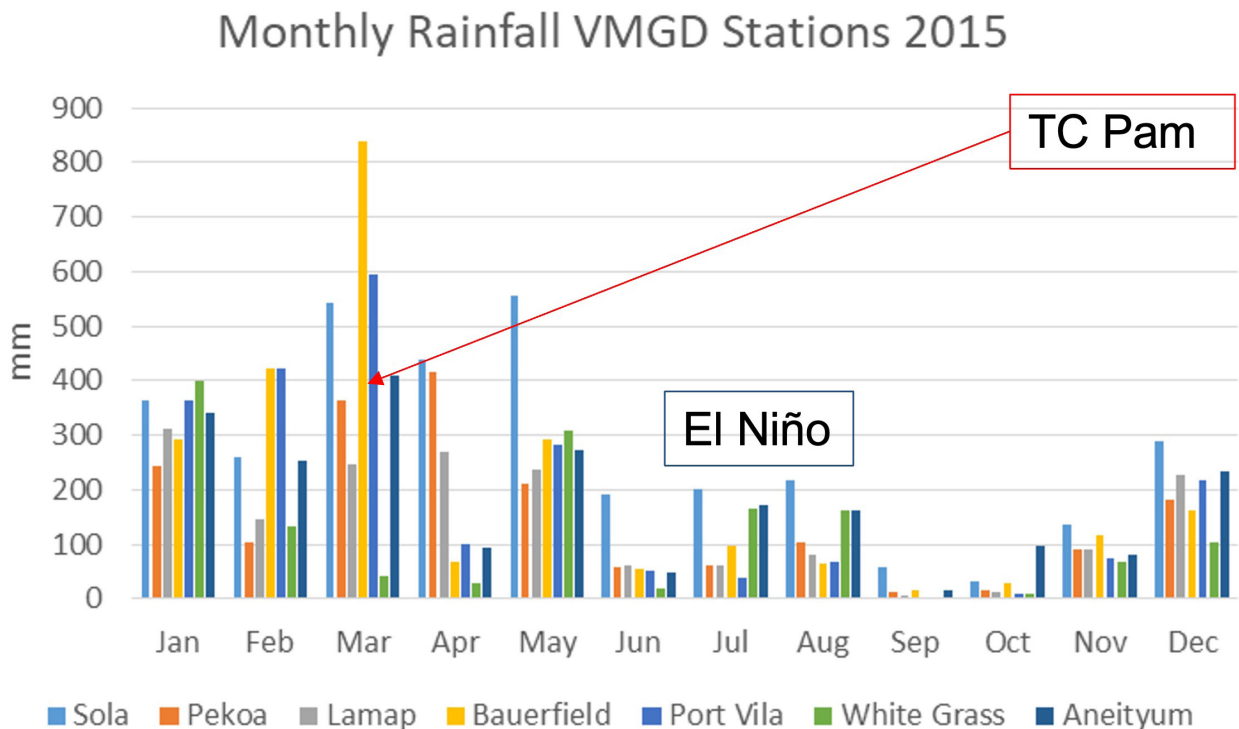


Figure 3: Number of tropical cyclones developing within and crossing the Vanuatu Exclusive Economic Zone per season. The 11-year moving average is in blue.

Between 1969 – 2010 (41 Yrs) 94 Tropical cyclones have passed within 400km of Port Vila during the wet season ( Nov –Apr)

## Effects of El Niño and Tropical Cyclones on Rainfall in Vanuatu

This graph shows the performance of rainfall during an El nino year. Notice the poor rainfall performance from June till December. The spike in the bar graphs in March is the result of Tropical Cyclone Pam. VMGD put out a media release about the El nino in May 2015.

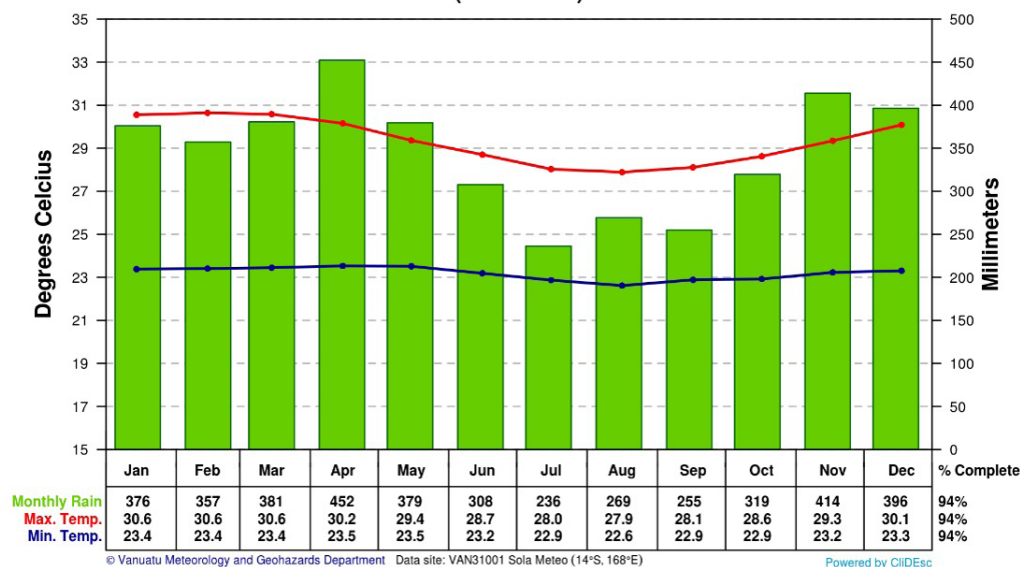


Tropical Cyclone Pam brought a lot of rainfall (March). El Nino caused below normal rainfall (Sept, Oct)

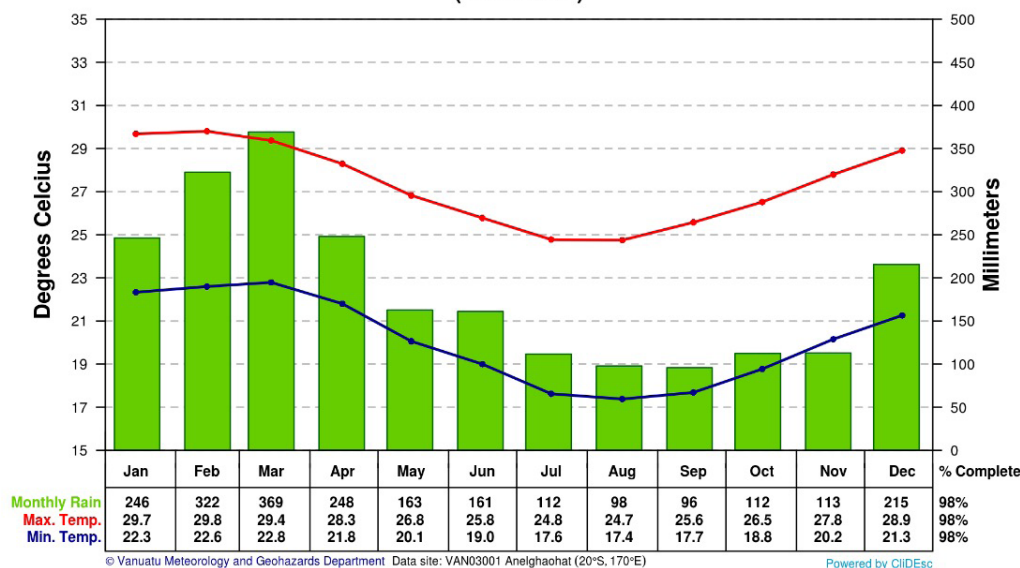


# Climate Variation Across Vanuatu

Sola Meteo - Climate Normals  
(1981 - 2010)



Anelghaohat - Climate Normals  
(1981 - 2010)



**Rainfall** - Sola receives more rainfall than Aneityum on average

**Temperature** - Sola records slightly higher average temperatures than Aneityum

The location of the Island determines the dominant climate driver.

**Vanuatu Group is divided into the north and southern region and are affected by different climate drivers which have a major influence on the climate of each area.**

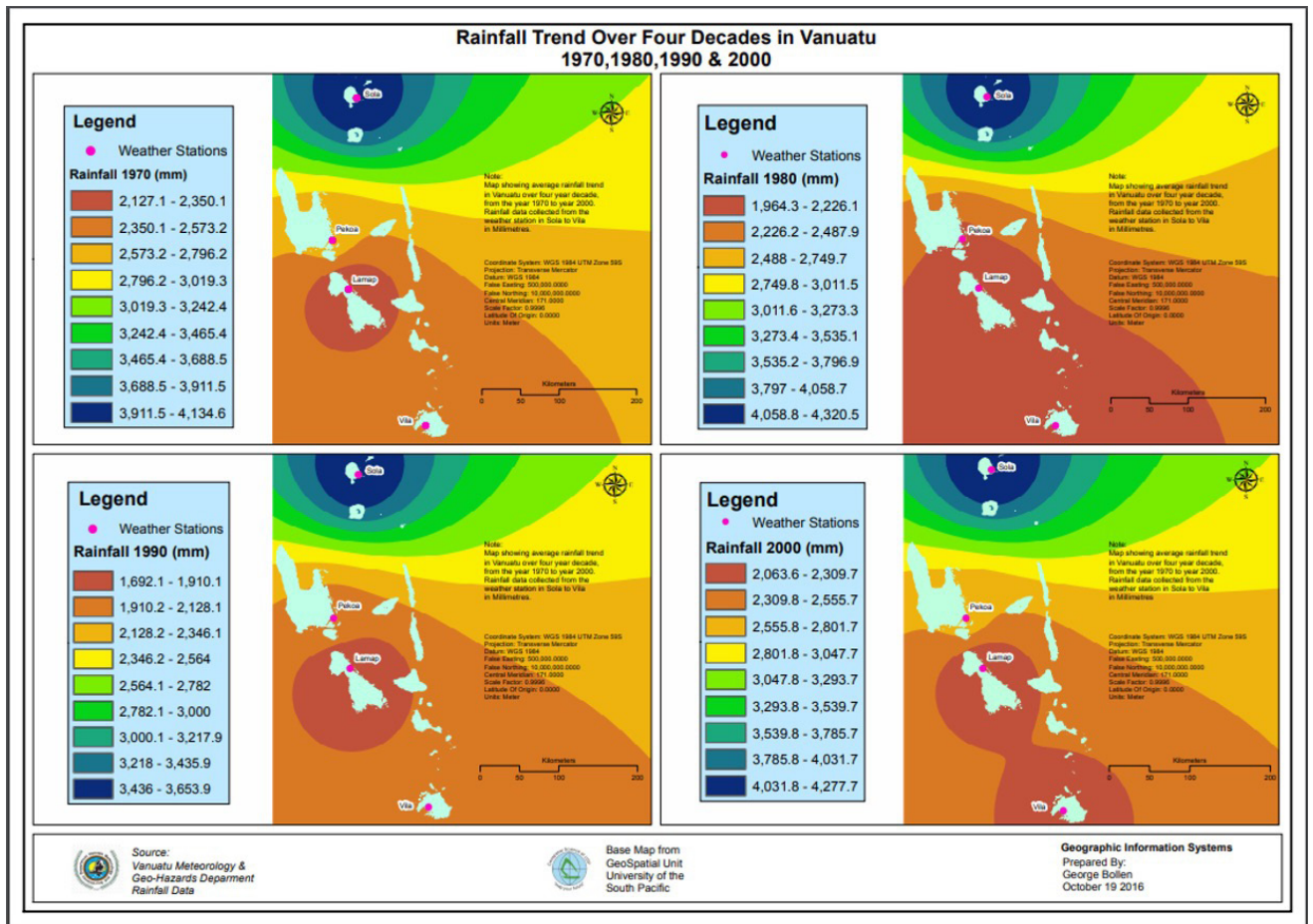
## Northern Region

Highest average rainfall is received by the northern islands of Vanuatu. This is due to the location and movement of the South Pacific Convergence Zone that is located further up north of the Torba Province. The SPCZ has greater influence over the climate of the northern region than the southern region of the group.

## Southern Region

The climate of the southern region is influence most by the movement of the high pressure cells during the winter/spring of the southern hemisphere ( May – Oct) and South East Trades. Historical records from Met stations location in this region show the seasonal pattern of rainfall for the wet season being higher than the Low season.

# Climate Variation Across Vanuatu



## North Vanuatu receives higher rainfall than southern Vanuatu

The Map above shows the rainfall trend over 4 decades. The maps show that the Northern parts of Vanuatu receive a lot more rainfall compared to the southern part of Vanuatu.

## Climate Variation Across Vanuatu

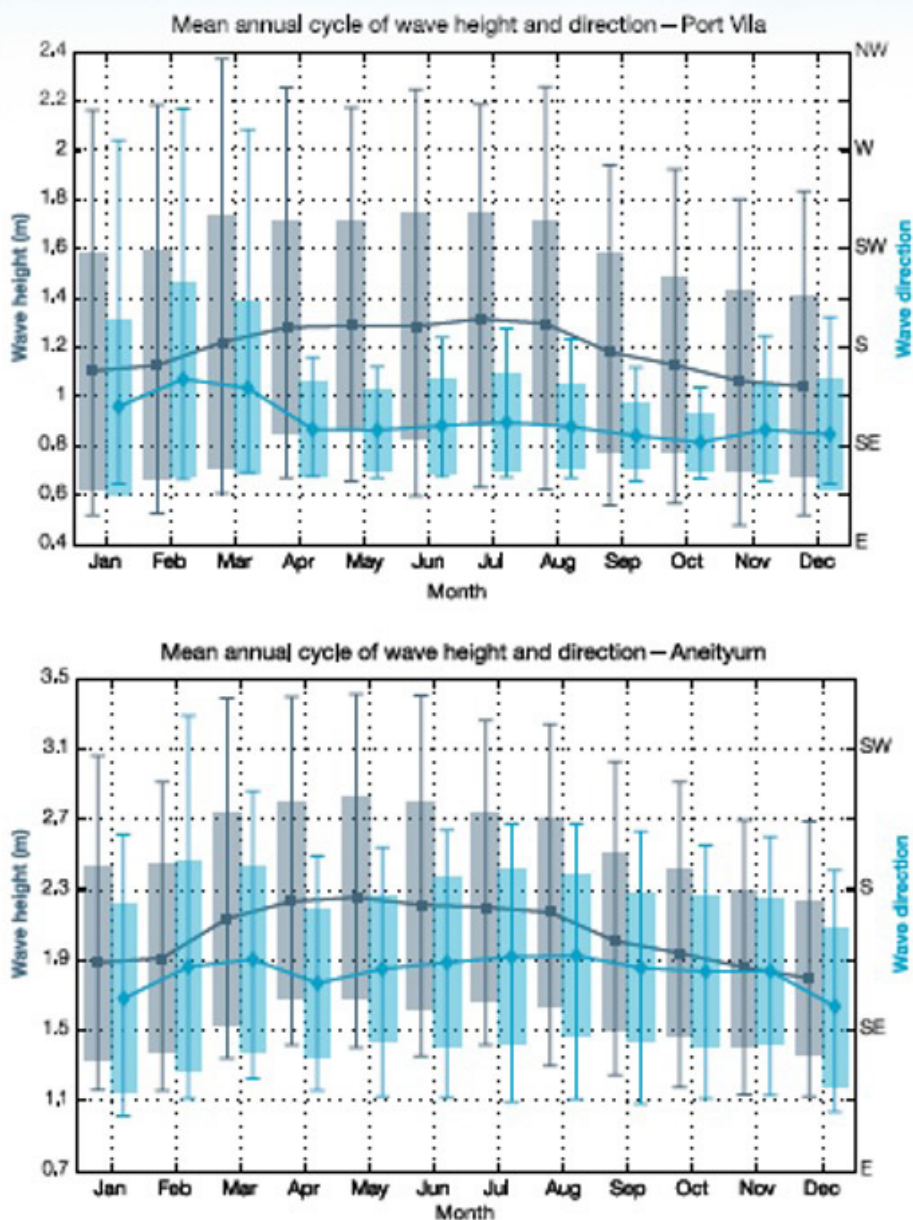


Figure 4: Annual cycle of wave height (grey) and wave direction (blue) at Port Vila (top) and Aneityum (bottom) based on data from 1979–2009. The shaded boxes represent one standard deviation around the monthly means, and the error bars indicate the 5–95% range, showing the year-to-year variability in wave climate. The direction from which the waves are travelling is shown (not the direction towards which they are travelling).

Wave height. Source: <http://www.pacificclimatechangescience.org/>

### Wind-driven waves

Wind-waves around Vanuatu do not vary significantly throughout the year, having fairly constant wave heights and periods. Waves are influenced by the southern trade winds and movement of the South Pacific Convergence Zone. They display some variability from year to year with the El Niño–Southern Oscillation and Southern Annual Mode. Waves come mainly from the south-east, consisting of trade wind generated waves and a component of swell propagated from storm events in the Southern Ocean. Wave heights are typically greater in the south at Aneityum (Figure 4, bottom) than at Port Vila in the north (Figure 4, top).

# Vanuatu's Changing Climate

## Observed Changes in Temperature

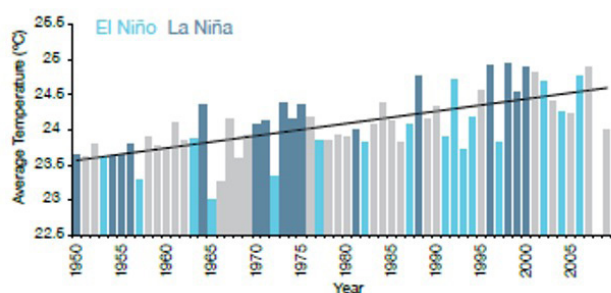


Figure 4: Annual average temperature for Bauerfield Airport, Port Vila. Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and the grey bars indicate neutral years.

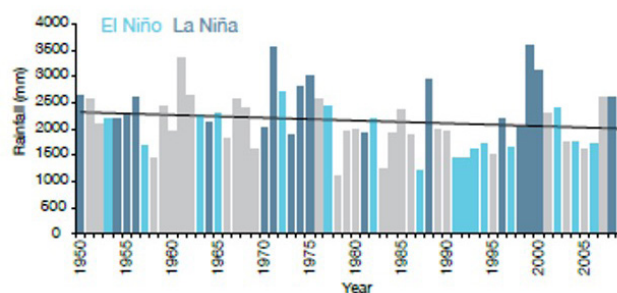


Figure 5: Annual rainfall for Port Vila. Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and the grey bars indicate neutral years.

### Temperatures have increased

Annual maximum and minimum temperatures have increased in both Port Vila and Aneityum since 1950 (Figure 4). At Bauerfield Airport in Port Vila, maximum temperatures have increased at a rate of 0.17°C per decade and at Aneityum the rate of increase has been 0.18°C per decade. These temperature increases are consistent with the global pattern of warming.

### Port Vila's wet season rainfall has decreased

Data since 1950 for Port Vila show a decreasing trend in wet season rainfall (Figure 5). However, there are no clear trends in annual and dry season rainfall at Port Vila or annual and seasonal rainfall at Aneityum. Over this period, there has been substantial variation in rainfall from year to year at both sites.

## Vanuatu's changing Climate



Sea Level rise near Saratamata, Ambre, Vanuatu



Epi Islands, 7 Aug 2011

Photo Source: <https://www.sprep.org/news/residents-epi-island-vanuatu-have-all-weather-roads-come-2013>

[https://dailypost.vu/news/impact-of-climate-adaptation-methods-used-for-nguna-and-pele/article\\_c97930df-a21f-5a71-88c2-a5ad4c755482.html](https://dailypost.vu/news/impact-of-climate-adaptation-methods-used-for-nguna-and-pele/article_c97930df-a21f-5a71-88c2-a5ad4c755482.html)

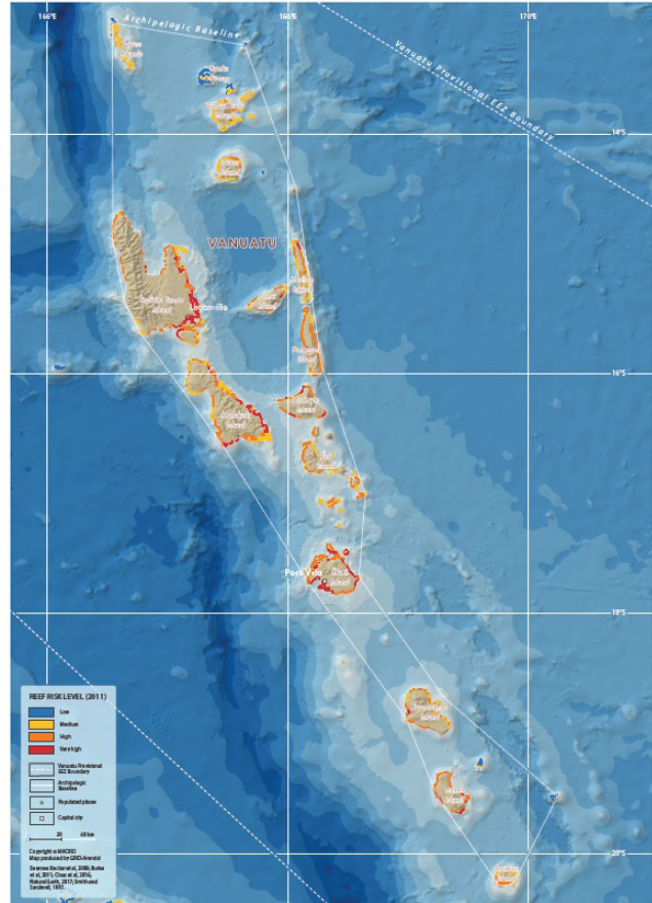
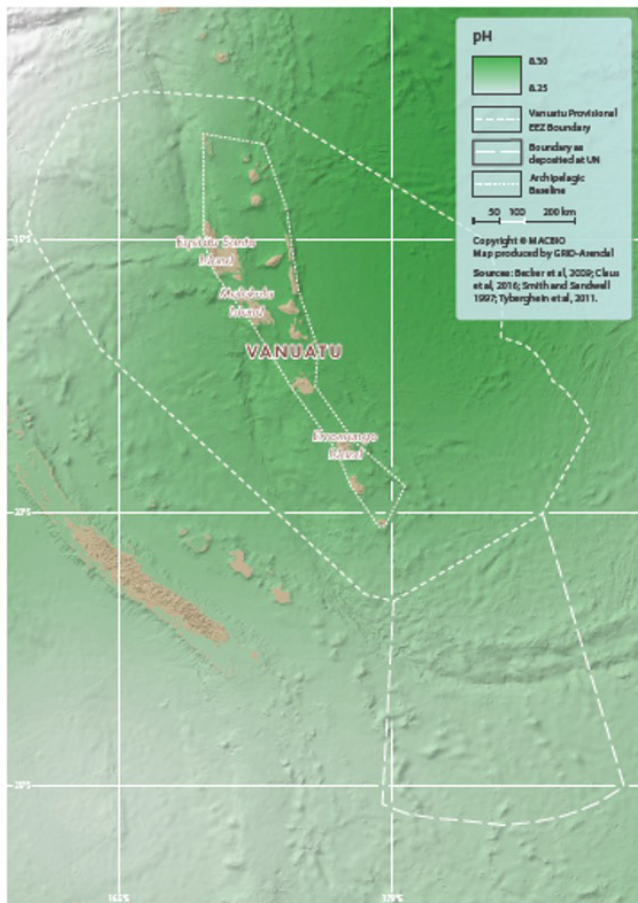
### Sea level has risen

As ocean water warms it expands causing the sea level to rise. The melting of glaciers and ice sheets also contributes to sea-level rise. Instruments mounted on satellites and tide gauges are used to measure sea level. Satellite data indicate the sea level has risen near Vanuatu by about 6 mm per year since 1993.

T

his is larger than the global average of 2.8–3.6 mm per year. This higher rate of rise may be partly related to natural fluctuations that take place year to year or decade to decade caused by phenomena such as the El Niño–Southern Oscillation. This variation in sea level can be seen in Figure 7 which includes the tide gauge record and the satellite data since 1993.

## Ocean acidification has been increasing



**As CO<sub>2</sub> in the ocean increases, ocean pH decreases, resulting in the water becoming more acidic.**

**Coral bleaching is the silent reef killer, caused by rising sea temperature as well as ocean acidification.**

pH value of Vanuatu EEZ → Vanuatu Reef risk level → CO<sub>2</sub> words → Coral Bleaching words → Species adaptation to ocean acidification

As CO<sub>2</sub> in the ocean increases, ocean pH decreases, resulting in the water becoming more acidic. This is called ocean acidification, the “evil twin” of sea temperature and sea level rise, described in the previous maps.

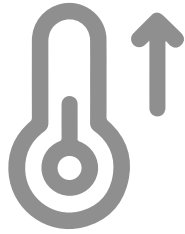
### Ocean acidification

Vanuatu is suffering the effects of global warming, with greenhouse gas emissions not only heating the nation’s sea, but also ending up in it. In fact, worldwide the oceans have absorbed about one third of the carbon dioxide (CO<sub>2</sub>) produced by human activities since 1800 and about half of the CO<sub>2</sub> produced by burning fossil fuels (Sabine et al., 2004).

Coral bleaching is the silent reef killer, caused by rising sea temperature as well as ocean acidification. The earliest recorded coral bleaching events in Vanuatu occurred in 2001 (Erakor Island) and 2002 (Vila Harbour, Hat Island and Moso Island) (Sulu et al., 2002). While there have been fewer recorded bleaching episodes in Vanuatu than in some other locations in the Pacific, episodic warming events are known to cause stress to reefs

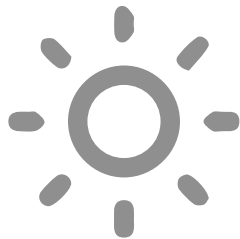
Photo Source: <https://www.sprep.org/news/residents-epi-island-vanuatu-have-all-weather-roads-come-2013>

# Vanuatu's Future Climate



## Temperatures will continue to increase

Projections for all emissions scenarios indicate that the annual average air temperature and sea-surface temperature will increase in the future in Vanuatu (Table 1). By 2030, under a very high emissions scenario, this increase in temperature is projected to be in the range of 0.5–1.0°C. Later in the century the range of the projected temperature increase under the different scenarios broadens.



## More very hot days

Increases in average temperatures will also result in a rise in the number of hot days and warm nights and a decline in cooler weather.



## Changing rainfall patterns

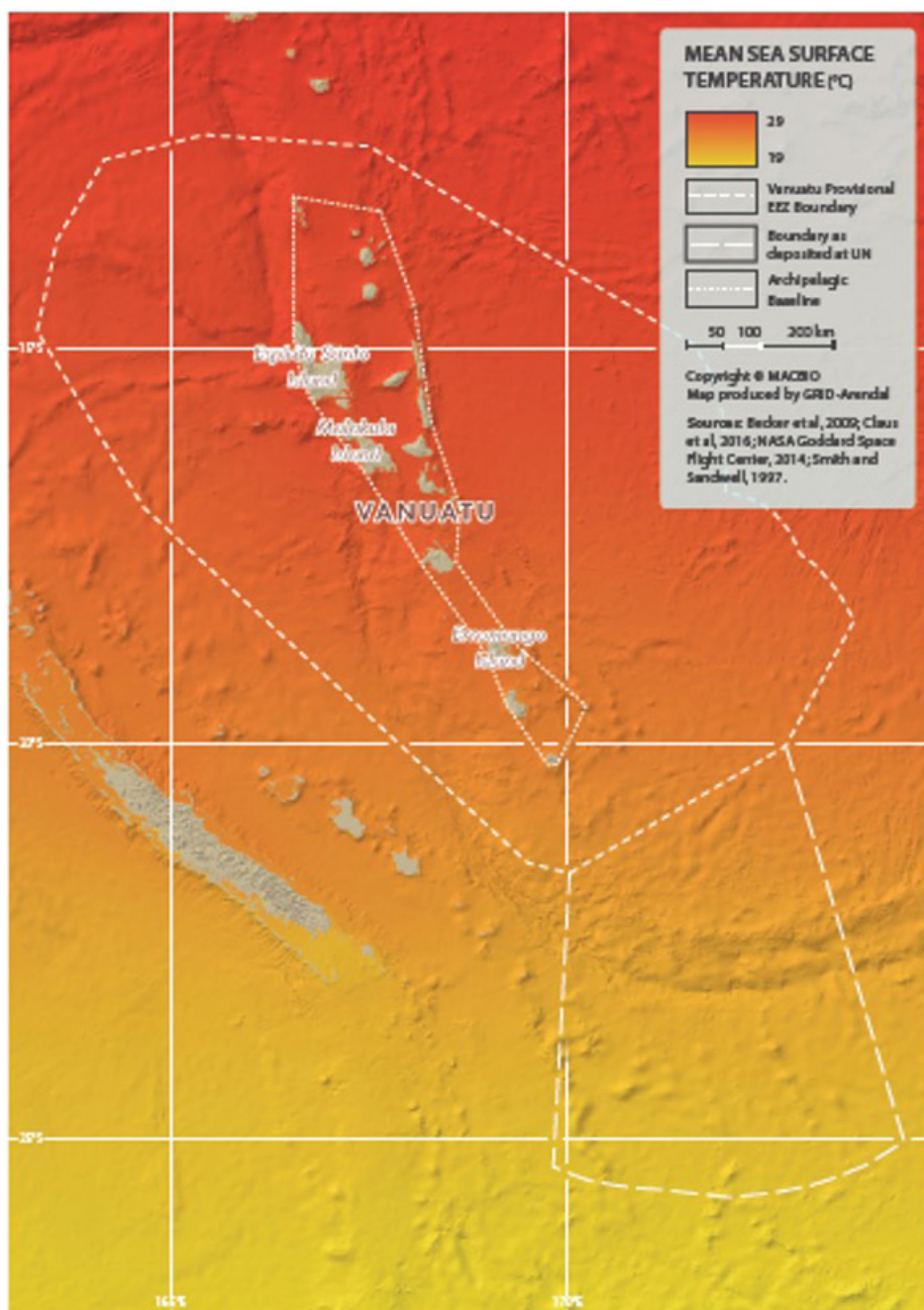
There is uncertainty around rainfall projections for Vanuatu as model results are not consistent. Some models suggest a slight increase in wet season rainfall and a decrease in dry season rainfall, however the overall projection is for little change. Wet and dry years will still occur in response to natural variability. Drought frequency is expected to decrease slightly by the end of the century.



## More extreme rainfall days

- El Niño and La Niña events will continue to occur in the future, but there is little consensus on whether these events will change in intensity or frequency.
- Annual mean temperatures and extremely high daily temperatures will continue to rise.
- Mean annual rainfall could increase or decrease with the model average indicating little change, with more extreme rain events.
- Incidence of drought is projected to decrease slightly under the high emission scenario and stay approximately the same under the other emissions scenarios.
- Sea level will continue to rise.
- Ocean acidification is expected to continue.
- The risk of coral bleaching is expected to increase.
- Wet season wave heights and periods are projected to decrease slightly, with no significant changes projected in the dry season.
- Tropical cyclones are projected to be less frequent but more intense.
- Projections show extreme rainfall days are likely to occur more often.

## Sea surface temperatures will increase



Sea level rise has the potential to negatively impact the low-lying coastal areas of Vanuatu, through flooding and wave inundation, with consequent shoreline erosion and groundwater salinization.

In February 2012, Vanuatu recorded its highest ever water temperature, 37.2°C in Lamap on Malekula. Such high temperatures heat the water in shallow reefs to uncomfortable temperatures for many of the inhabitants.

Was it just a few hot sunny days or global warming that warmed the water way above its average temperature?

To understand this, we need to look at two different things. On one hand climate variability, which refers to shorter term (daily, seasonal, annual, inter-annual, several years) variations in climate, including the fluctuations associated with El Niño (dry) or La Niña (wet) events.

On the other hand climate change, which refers to long-term (decades or longer) trends in climate averages such as the global warming that has been observed over the past century, and long-term changes in variability (e.g. in the frequency, severity and duration of extreme events).

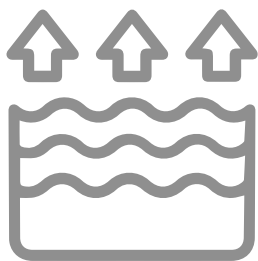
There may always be particularly rainy weather in Sola, or a particularly hot week in Lamap. Only by observing trends in the long term can we show how the climate is changing.

Source: <https://vanuatu-data.sprep.org>



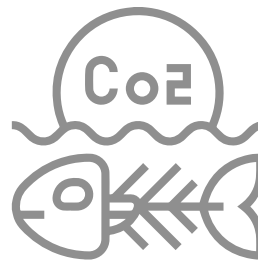
## Less frequent tropical cyclones

On a global scale, the projections indicate there is likely to be a decrease in the number of tropical cyclones by the end of the 21st century. But there is likely to be an increase in the average maximum wind speed of cyclones by between 2% and 11% and an increase in rainfall intensity of about 20% within 100 km of the cyclone centre. In the Vanuatu region, projections tend to show a decrease in the frequency of tropical cyclones by the late 21st century.



## Sea level will continue to rise

Sea level is expected to continue to rise in Vanuatu (Table 2 and Figure 6). By 2030, under a very high emissions scenario, this rise in sea level is projected to be in the range of 8–18 cm. The sea-level rise combined with natural year-to-year changes will increase the impact of storm surges and coastal flooding. As there is still much to learn, particularly how large ice sheets such as Antarctica and Greenland contribute to sea-level rise, scientists warn larger rises than currently predicted could be possible.



## Ocean acidification will continue

Under all four emissions scenarios the acidity level of sea waters in the Vanuatu region will continue to increase over the 21st century, with the greatest change under the very high emissions scenario. The impact of increased acidification on the health of reef ecosystems is likely to be compounded by other stressors including coral bleaching, storm damage and fishing pressure.

Wet season wave climate will change. Wet season wave heights and periods are projected to decrease slightly, with no significant changes projected in the dry season.

The map on the next page indicates that by 2030, Vanuatu will experience a minimum rise in sea level of 0.15 metres. This is likely to be accompanied by increases in episodes of flooding and wave inundation in some coastal areas. The southernmost islands in the archipelago will experience slightly greater sea level rise than those of the northern islands, but the overall difference between these two areas will be minimal. Pacific Island nations are therefore focused on developing adaptation strategies to address the predicted continued rise in sea level.

Sea level rise, as a consequence of global warming, threatens many low-lying regions of the world. The Fifth International Panel on Climate Change assessment projects a global rise in mean sea level for 2081–2100 relative to 1986–2005 of between 0.2 and 0.98 metres, depending on different emissions scenarios. Furthermore, the western tropical Pacific Island region is considered one of the most vulnerable regions under future sea level rise (Nicholls and Cazenave, 2010). Sea level rise is not uniform across the western Pacific and is affected by ENSO events. These have a strong modulating effect on inter-annual sea level variability, with lower than average sea level during El Niño and higher than average during La Niña events (of  $\pm 20$ – $30$  cm). In addition, there is also an observed low-frequency (multi-decadal) variability, which in some areas adds to the current global mean sea level rise due to ocean warming and ice melting (Becker et al., 2012).



Vanuatu is a mix of predominantly high volcanic islands and several low-lying coral atolls. Vulnerability to sea level rise is influenced by coastal geography and prevailing ocean currents. Islands exposed to higher wave energy in addition to sea level rise can experience higher rates of erosion than their more sheltered counterparts. However, the coral atolls of Vanuatu may be able to adjust their size, shape and position in response to sea level rise, as has been suggested for other reef islands such as Funafuti Atoll in Tuvalu (Kench et al., 2015). Vertical reef accretion that occurs in response to sea level rise may be able to prevent the significant increases in shoreline wave energy and wave-driven flooding that are predicted in the absence of reef growth (Beetham et al., 2017).

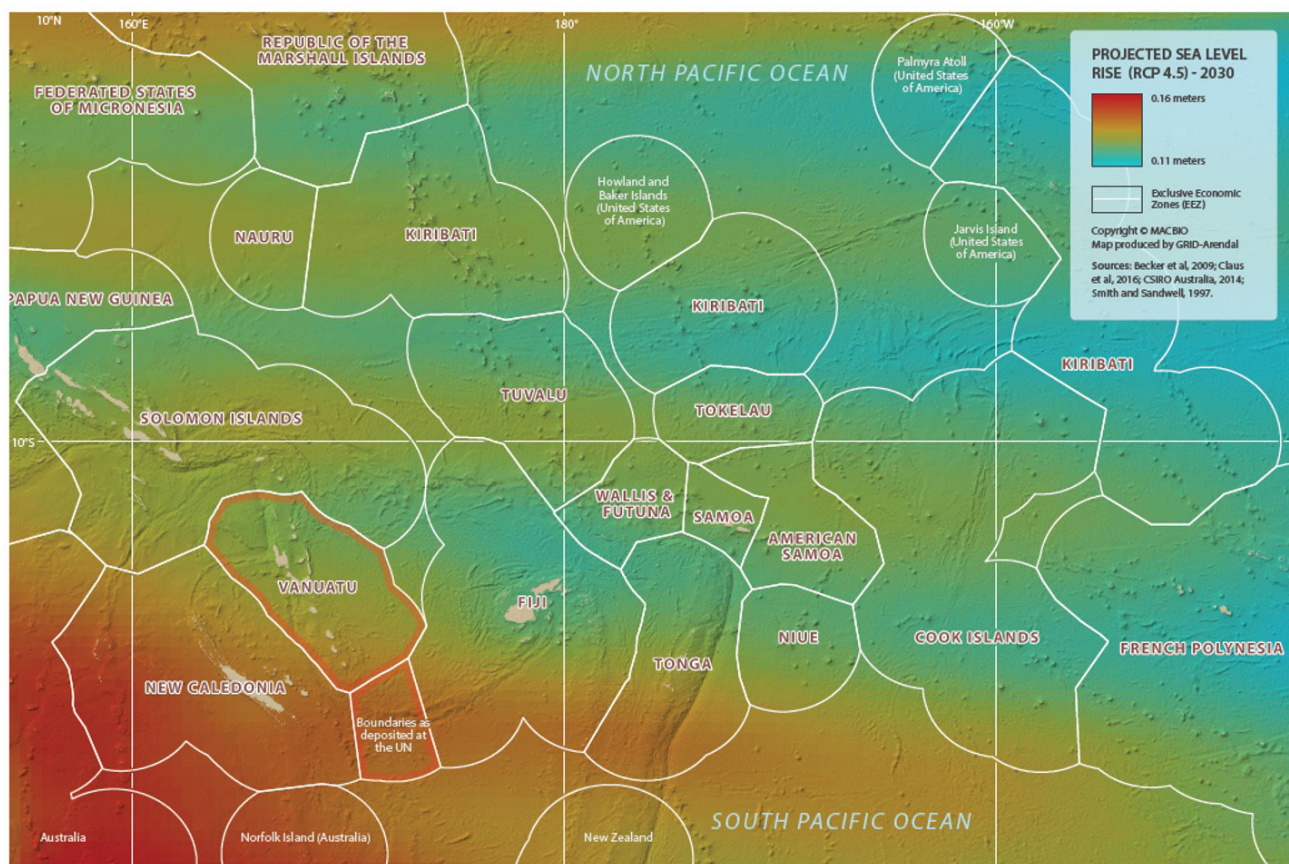


Photo Source:

<https://www.sprep.org/news/residents-epi-island-vanuatu-have-all-weather-roads-come-2013>

[https://dailypost.vu/news/impact-of-climate-adaptation-methods-used-for-nguna-and-pele/article\\_c97930df-a21f-5a71-88c2-a5ad4c755482.html](https://dailypost.vu/news/impact-of-climate-adaptation-methods-used-for-nguna-and-pele/article_c97930df-a21f-5a71-88c2-a5ad4c755482.html)

That in a warming world, Vanuatu's sea will become hotter and higher, with drastic consequences for coastal habitats and their inhabitants.



## EXERCISE 1: VANUATU CLIMATE

1. When is the dry season in Vanuatu?
2. When is the wet season in Vanuatu?
3. During what months do tropical cyclones tend to occur?
4. Which region of Vanuatu receives higher rainfall? North or South?

**Answers for exercise 1**  
1. Dry season – May to October  
2. Wet season – November to April  
3. November to April  
4. North

## EXERCISE 2: CLIMATE CHANGE IN VANUATU

Circle the correct answers for Vanuatu:

1. Sea surface temperature is increasing
2. Rainfall is decreasing
3. Sea level is decreasing
4. Wet season rainfall is increasing
5. Ocean acidification is increasing
6. More frequent and more intense tropical cyclone

**Answers for exercise 2**  
1. Correct  
2. Incorrect (changing pattern with no clear indication of increasing or decreasing)  
3. Incorrect  
4. Incorrect  
5. Correct  
6. Incorrect (Less frequent and more intense tropical cyclone)

