# Climate Change in the Territory of Guam

## Pacific Islands Climate Education Partnership

You may have heard the term **climate change**. What does this term mean? In what ways is the climate changing? How does climate change affect the Territory of Guam? The purpose of this booklet is to answer these questions.

## What are weather and climate?

To learn about climate change we need to understand the difference between weather and climate. **Weather** is the short-term condition of the atmosphere in a specific place, such as where you live. Is it raining today? Where is the wind blowing from and how strong is it blowing? Is the air hot or cool? How cloudy is the sky?

**Climate** is the long-term average weather pattern in a specific place or region. When scientists describe the climate in a place, they use measurements and observations of the weather that have been made over periods of decades or longer. The climate in a place has very big effects on the plants, animals and people who live there.

The Territory of Guam has a climate where the weather changes over the course of a year from a wetter season to a drier season (**Figure 1**). Among most islands in the northern hemisphere Pacific Ocean, the more northward the island, the longer and drier the drier season tends to be. Other places on our planet have climates where the weather changes a lot over the course of a year. For example, many places have very cold snowy winters, and very hot summers.

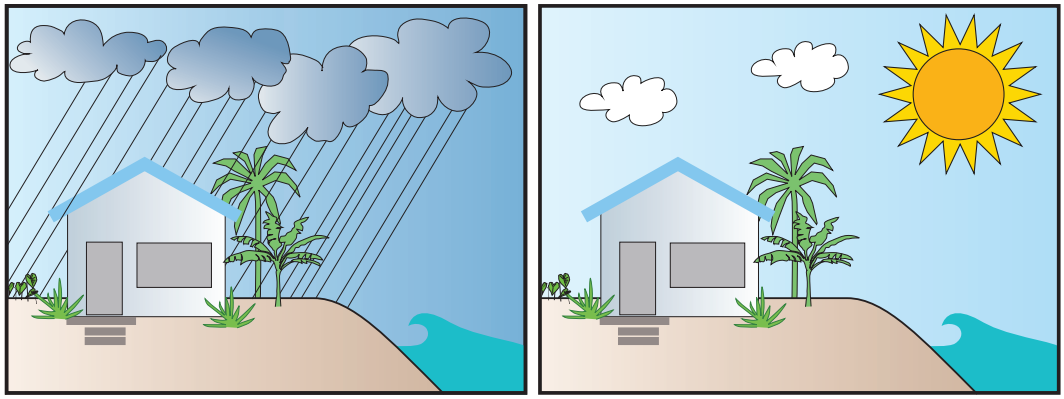

**Figure 1** *In Guam, the weather changes from a wetter season (July through December) to a drier season (January through June). On average, two-thirds of Guam's total annual rainfall occurs in the wetter season.*

Climate describes what kind of weather you can expect to happen. Weather describes what is actually happening. If you visit a place in the wetter season, you should expect that it will be rainy. However, the days that you visit, the weather could actually be dry. It was probably rainy the week before you visited, and it will probably become rainy again after you leave.

**Figure 2** *Guam is located in the northwest Pacific Ocean near the equator*

## What is the climate in Guam?

### Warm and Humid

The climate in Guam is generally warm with windy conditions and with lots of water vapor in the air (this is known as high **humidity**). The map (**Figure 2**) shows two factors that play the biggest roles in causing this climate:

- Guam is located near the equator
- Guam is surrounded by the ocean in all directions

Places near the equator get a lot more energy from the Sun than places that are farther away from the equator. This location is the main reason that Guam is warm. The average annual temperature is 81°F (27°C). Warm ocean water heats the air above it and also puts a lot of water vapor into that air. The warm ocean around Guam helps keep the temperature warm at night, and makes the air feel warm and humid.

## High Islands and Low Islands

There are two main kinds of islands in the Pacific Ocean: high islands and low islands. Communities of people on both kinds of islands have homes, grow food, go fishing, and drink fresh water. The fresh water that they have comes from the rain that falls on their island.

**Figure 3** shows the two different kinds of rain that fall on Pacific islands. One kind of rain happens everywhere: over the open ocean, on low islands, and on high islands. This kind of rain happens because the air has so much water vapor in it that when the air rises above the ocean surface into cooler air above, the water vapor condenses, forms clouds, and then precipitates. This is called **convective rain**.

High islands cause a second type of rain. When warm humid air is forced to rise up the slopes of a high island the cool air it encounters causes the water vapor to condense, making clouds and rain. This is called **orographic rain**.

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High mountains get more rain (sometimes averaging 200 to 300 inches per year) than coastal areas (about 100 inches per year). The reason for this is that air is much colder near the top of a high mountain compared with the air at sea level. When warm, humid air blowing in from the ocean hits a mountain, that air is forced upward into the colder mountain areas. When warm humid air becomes colder, its water vapor condenses from the gas state into the liquid state, and forms water droplets. These water droplets become clouds that rain on the island.

Guam generates an orographic effect in the southern portion of the island, which is higher than the northern portion. The northern portion of the island has elevations ranging from about 300 to 600 feet (91 to 183 meters) and annual rainfall averages range from 95 inches per year (241 centimeters per year) in the interior to 85 inches per year (216 centimeters per year) on the west coast. The southern portion of Guam is the location of Mount Lamlam, an extinct volcano, which is 1,334 feet (406 meters) high. It creates an orographic effect under normal conditions where winds arrive from the east and northeast. The average annual rainfall on the southern portion of Guam is over 115 inches per year (292 centimeters per year) in the interior and about 90 inches per year (229 centimeters per year) along the coast.

Low islands are usually made of coral sand and gravel. Low islands do not cause humid air to condense because they do not extend into the cold air at high elevations. The main source of fresh water on a low island comes from convective rain that moves across the ocean and happens to run over the island.

**Two Types of Rain on Pacific Islands**

Everywhere (convective)

Air has so much water vapor that clouds form, and rain falls on the open ocean and on any low or high islands that the clouds blow over.

Caused by Mountains (orographic)

Warm humid air becomes colder when it rises up the slopes of a high island mountain. Cooled water vapor condenses and falls as rain on the high island.

**Figure 3** *The fresh water on Pacific islands comes from two types of rain.*

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## Wetter and Drier Seasons with Variable Rainfall from Year to Year

The weather and climate in Guam (**Figure 4**) have been observed and analyzed for centuries, and have been scientifically measured for decades. There are several patterns in addition to being generally warm and humid. One of the most important climate patterns is that during the year there is a wetter season and a drier season.

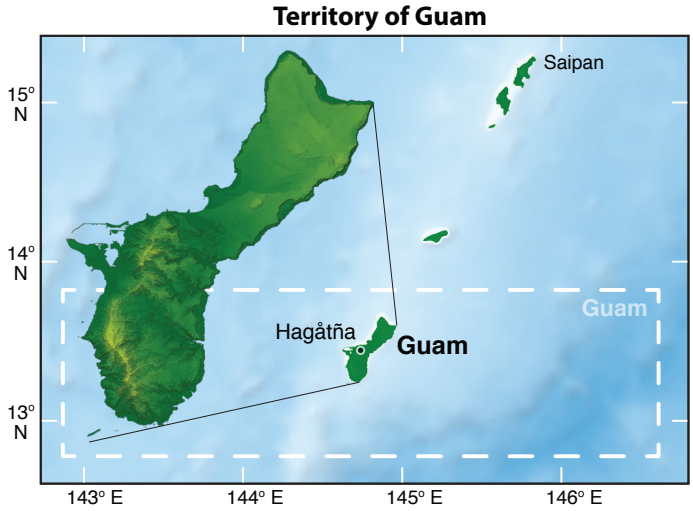


**Figure 4** *The territory of Guam is located just south of the Commonwealth of the Northern Mariana Islands.*

About one-third of the annual rainfall on Guam occurs during the drier season months of January through June, and about two-thirds during the wetter season months of July through December. Most Pacific Islands near the equator also have wetter and drier seasons.

During the drier season, most rainfall occurs as light showers in amounts typically no more than 0.25 inch per day.[1] During the wetter season, the atmosphere over the island is more humid and unstable. As a result, convective rainfall occurs in moderate to heavy down-pours, or as larger weather systems that affect the entire island associated with storms. At times in the wetter season, storms can produce torrential downpours with rainfall exceeding 6 inches (15 centimeters) in an hour and 20 inches (51 centimeters) in 24 hours.

**Figure 5** shows the monthly rainfall in inches measured at Guam International Airport between the years 1953 and 2014. Note that the amount of rain changes a lot from year to year. Some years had 120 inches (305 centimeters) or more of rain, while other years had 80 inches (203 centimeters) or less of rain. This kind of change in rainfall is also a natural feature of the climate inmany Pacific islands that are near the equator. Scientists say that the amount of rainfall has a lot of **variability** (natural change from year to year).

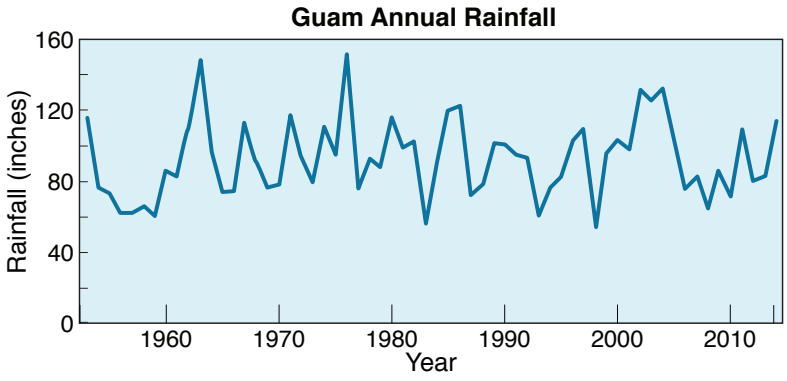


**Figure 5** *The amount of rainfall in Guam has a lot of variability from one year to the next.*

1 Johnson, A.G., 2012, A water-budget model and estimates of groundwater recharge for Guam: U.S. Geological Survey Scientific Investigations Report 2012–5028, 53p.

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## Regional Wind and Rain Patterns: The North Pacific High and El Niño

Seasonal differences in rainfall and wind define the distinct wetter and drier seasons on Guam. Throughout most of the year winds can blow from the east or northeast. These winds are called **trade winds** and they are responsible for creating a lot of the orographic rain on the island. During the dry season, northeasterly trade winds are persistent. But during the wet season, trade winds sometimes weaken and may veer to the southeast, and the atmosphere over the island is more humid and unstable and may experience storms. These bring heavy showers, or steady and sometimes torrential rain.[2]

The trade winds are created at the **North Pacific High**, an area to the northeast of Hawaii (far to the east of Guam) where air descends through the atmosphere onto the ocean surface. When air descends through the atmosphere to Earths surface it creates an area of high atmospheric pressure. It is this feature that creates the trade winds because the air will flow away from the high pressure toward areas of lower pressure.

The North Pacific High rotates in a clockwise direction (**Figure 6**) creating winds that travel to the west and southwest. These winds become the trade winds that blow across the tropical Pacific region to Guam and Micronesia and beyond. A similar situation exists south of the equator where the South Pacific High creates trade winds in the southern hemisphere. Where the two trade winds from the southern and northern hemispheres come together they create a band of thunderstorms known as the **Intertropical Convergence Zone** or ITCZ. The ITCZ is characterized by a lot of rainfall and the fact that it migrates to the north between June and December is why the wetter season exits.

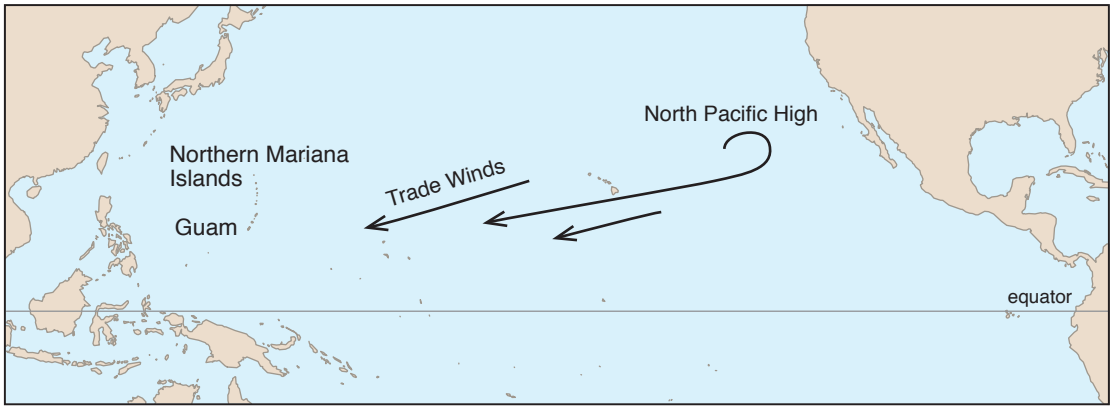


**Figure 6** *The North Pacific High is a high-pressure region in the atmosphere that is located to the northeast of Hawaii. Air in the North Pacific High rotates in a clock-wise direction making the trade winds that travel outward and arrive in Guam and Micronesia from the east and northeast.*

The east to west trade winds play a large role in the climate of the equatorial Pacific Ocean. These winds can change during a climate pattern that is called the **El Niño Southern Oscillation**

2 Pacific RISA, Territory of Guam: http://www.pacificrisa.org/places/territory-of-guam/

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(ENSO). When trade winds are weaker than usual, scientists say that it is an **El Niño** year. When the trade winds are stronger than normal, scientists call it a **La Niña** year. When the winds are normal it is called a **neutral** year. **Table 1** summarizes the differences between El Niño years, La Niña years, and neutral years.

**Table 1 ENSO Conditions and the Effects of ENSO Changes**

| Feature | Neutral ENSO Year | El Niño ENSO Year | La Niña ENSO Year |
|---|---|---|---|
| Wind | Normal east to west trade winds | Weaker east to west trade winds; can even blow from west to east | Stronger east to west trade winds |
| Rainfall | Usual amounts of rainfall with normal variability | Following an El Niño year, Guam tends to be drier than usual, and can experience drought | Guam tends to be wetter than usual and can experience damaging floods |
| Sea Level | Usual sea level with normal tide variability | Lower sea levels so that high tides tend to cause less flooding | Higher sea levels so that high tides tend to cause more flooding |

**Table 1** *lists the differences between neutral years, El Niño years, and La Niña years.*

In a neutral year (normal winds), the waters in Guam are much warmer than waters in the central or eastern portions of the Pacific Ocean. The warm water leads to strong evaporation and there is abundant rain.

In a La Niña year, trade winds blow across the ocean surface into the region of Guam. This raises the level of the ocean and can cause **coastal erosion** (land loss due to wave action) and damaging **king tides** (the highest tides of the year). La Niña years also tend to be rainy in Guam.

In an El Niño year, trade winds are weaker than normal (or absent). In addition, warm ocean water moves away from Guam toward the eastern Pacific Ocean, and causes sea levels to decrease. The year following an El Niño year is usually drier and there is a greater chance of **drought** (an extended period of little rain).

## Extreme Weather Events

Extreme weather events are another important climate feature. An extreme weather event is the kind of weather that can cause a lot of damage and problems for ecosystems and people. The main extreme weather events that happen in Guam are droughts and big storms.

Despite relatively high annual rainfall amounts, Guam suffers negative effects of drought almost every dry season[3]. During drought, wildfires increase, grasslands and certain tree species tend to dry out and defoliate, stream flow is reduced, and Guam's wells show a decrease in water level.

3 Water and Environmental Research institute of the Western Pacific (WERI), University of Guam, Report No. 75, 1994: http://www.weriguam.org/reports/item/meteorological-factors-associated-with-drought-on-guam.html

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Every three or four years, the drought is especially severe. Droughts typically occur in the drier season months of January through June, especially in the year during or following an El Niño.

During particularly strong El Niño drought, the rainfall can decrease during the dry season and the length of the dry season can be extended. The worst recorded drought was in 1998 when Guam received only 65% of the average rainfall. However, it is not clear how drought will change in the future. Some climate models predict an increase in El Niño conditions in the future, which suggests that drought will increase as well. To the south, in Micronesia, climate models[4] predict that drought will decrease and rainfall will increase. But Guam lies in a somewhat different climate region and future conditions are uncertain.

Very strong storms in the equatorial Pacific Ocean region are called **tropical cyclones**. The western north Pacific, where Guam is located, is the most active cyclone region. These storms typically affect Guam between July and December with the greatest frequency in August. Tropical cyclones have strong, damaging wind and very heavy rainfall. An average of three **tropical storms** and one **typhoon** pass within 180 miles (330 kilometers) of Guam each year. The number of cyclones varies widely from year to year[5] but directly to the south, in the Federated States of Micronesia, it was found that tropical cyclones were most frequent in El Niño and neutral years, and least frequent in La Niña years. In Guam, tropical cyclones tend to be more intense in El Niño years.

**Table 2** lists the main features of the climate in Guam.

**Table 2 Main Climate Features**

We can now list the main features of the climate in Guam

- Warm and humid days and nights all year
- Wetter and drier seasons
- Lots of variability in annual amounts of rain
- Breezy with trade winds normally blowing east to west
- Lots of variability in wind speed and wind direction
- Extreme weather events: drought and tropical cyclones
- Strong influence by climate conditions known as El Niño, La Niña and the North Pacific High

**Table 2** *lists the main features of the climate in Guam.*

4 Pacific Climate Change Science Program, Australian Govt., 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports, www.pacificclimatechangescience.org

5 NOAA Tech. Rept. NESDIS 142-8, 2013, Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: https://www.google.com/search?q=noaa_nesdis_tech_report_142-8-climate&ie=utf-8&oe=utf-8

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## What is happening to climate on our planet?

Our planet has been around for a very long time (more than four billion years). During that time the climate of the planet has changed many times. Sometimes the climate has been very cold, with large amounts of ice covering most of the land and even large parts of the ocean. Sometimes the climate has been very warm when even the polar regions had little or no ice.

For the past 10,000 years, Earth's climate has been very comfortable for people and for ecosystems. However now, the climate is beginning to change because of human activities, especially our burning of fossil fuels (oil, coal and natural gas, which are made of fossil plankton and plants). Since our human activities are causing the global climate to become warmer, this change is often called **global warming**.

We use oil to make the fuel that provides the power for transportation (such as gasoline for cars, boats and trucks). People also burn fossil fuels to make electricity. When we burn oil and coal, the burning produces gases (especially carbon dioxide) that trap heat in the atmosphere. Other human activities are also producing gases that go into the atmosphere and trap heat (**Figure 7**). This trapping of heat in the atmosphere is causing Earth's climate to get warmer.

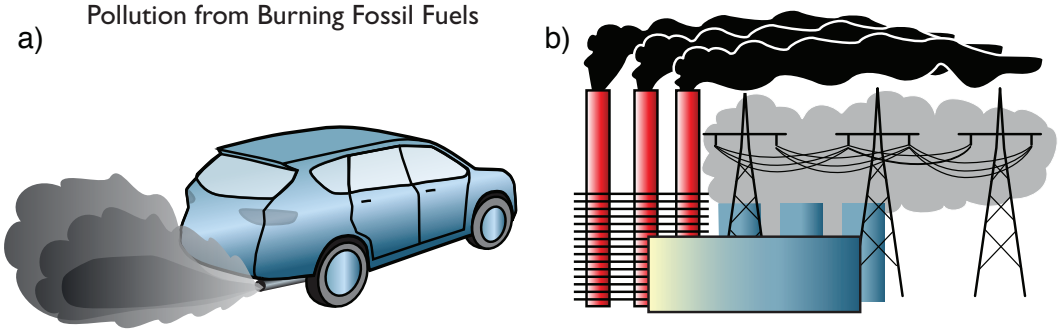


**Figure 7** *When we burn fossil fuels (oil, coal and natural gas), they produce gases that stay in the atmosphere and trap heat, causing global warming. a) Oil is used to make gasoline to run cars and trucks. b) Oil, coal and natural gas are burned to make electricity.*

The graph of average global temperature over the past century shows that the global temperature has been increasing (**Figure 8**). The temperature data are collected from weather stations around the world. There is a lot of variability from year to year. However, over all the years in the graph, there is a clear trend that Earth's climate has been getting warmer. Global temperatures in the last ten years are significantly higher than they have been for any other ten-year period.

Over the past 100 years, Earth's temperature has increased about 1.6°F (0.9°C). While this amount may not seem very much to us, it is actually a lot for planet Earth. A decrease in global temperature of about 10°F (5.6°C) can cause an ice age. In the geologic past when Earth's average temperature was 10°F higher, most of Earth's ice was gone and sea levels were 100 feet (30 meters) higher.

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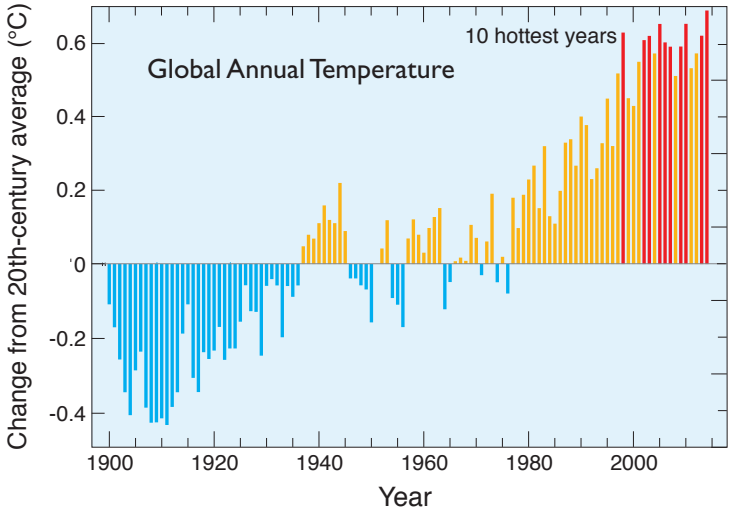


**Figure 8** *The annual average temperature of the air close to Earth's surface.*

The higher global temperatures cause many other changes to weather patterns and conditions on the planet. As a result, scientists tend to use the broader term "climate change" to describe this issue, rather than global warming. These global climate changes include:

- Glaciers everywhere in the world are melting.
- Sea level is rising.
- The oceans are getting warmer.
- Ecosystems are moving away from current locations toward locations that are not as hot.
- Warm seasons are starting earlier and lasting longer.
- More of the planet is having tropical climate.
- Generally, wet places are getting wetter (flooding) and dry places are getting dryer (drought).

These and many other observations show that Earth's climate system is rapidly changing because of global warming. Global climate change affects Guam in many ways. The rest of this booklet focuses on the changes that are already happening and the climate changes that are predicted to happen. We will also discuss what people in Guam can do to help protect themselves from the impacts (damaging effects) of climate change.

## What impacts of climate change are happening in Guam?

As shown in **Figure 9**, the four most important impacts (damages) of global climate change in Guam are:

- Higher air and ocean temperatures
- Changing rain patterns
- Sea level rise
- Ocean acidification

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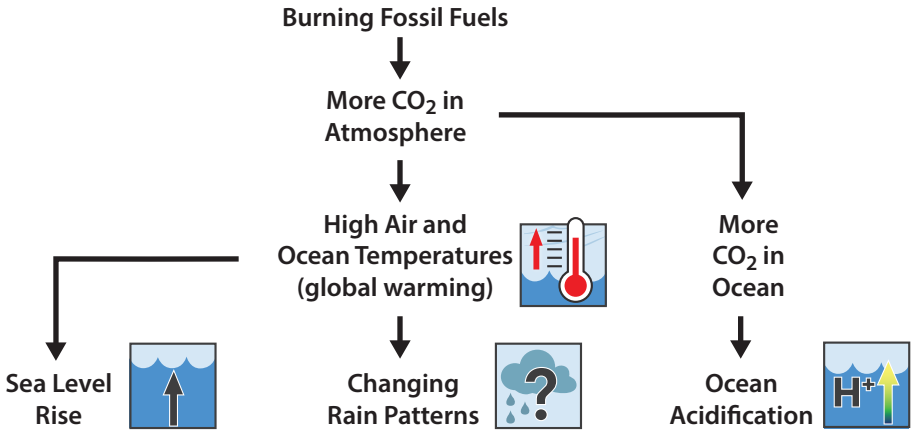


**Figure 9** *Human activities, mainly burning fossil fuels, are putting more heat-trapping gases, especially carbon dioxide, into the atmosphere. These activities are causing global warming. The four major impacts of climate change in Guam are shown with a graphic image next to each one.*

Global warming means that **air and ocean temperatures are warmer**. These higher temperatures can directly harm ecosystems and human communities. For instance, warmer ocean water is an unhealthy condition for coral reefs and fish. In addition, these higher temperatures are causing one of the most serious climate impacts: **sea-level rise**.

Higher ocean temperatures cause the oceans to have a larger volume.[6] Thus, the ocean surface rises. This accounts for about 1/3 of the amount of global sea level rise. Higher air temperatures also cause mountain glaciers to melt, and this water flows into the ocean (accounting for another 1/3 of global sea level rise). The last 1/3 of global sea level rise comes from melting ice on Greenland and Antarctica. As a result of warming seawater and melting ice, oceans have a higher volume, and sea levels around the world are rising.

Rising sea level causes coastal erosion and flooding by waves and high tides. During heavy rainstorms it can prevent the rain from draining into the sea, causing more flooding. This sea level rise is one of the most damaging impacts of climate change, especially for island communities.

Global warming can also cause changes to rain and storminess. Rainfall and tropical cyclones are significant aspects of the climate on Guam. However scientists are still uncertain about how global warming will influence rainfall and tropical cyclone patterns. One study[7] predicts that there will be fewer, but more intense, storms, and they will probably follow new tracks. The study also predicts that there will be a moderate increase in daily and annual average rainfall.

**Ocean acidification** is another major impact caused by higher carbon dioxide levels. When carbon dioxide dissolves in the ocean, it forms a weak acid. As excess carbon dioxide in the atmosphere dissolves in the ocean, it changes the acid-base chemistry of the ocean, and causes seawater to become more acidic. Ocean acidification is included as a climate change impact

6 When something gets warmer, it expands (gets larger) in size. This increase in size happens with solids, liquids, and gases.

7 Keener, VW, Gingerich, SB, Finucane, ML. April, 2015. Climate Trends and Projections for Guam. East West Center information sheet, Honolulu, HI. http://www.pacificrisa.org/resources/publications/

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because it is caused by the same increase in carbon dioxide that causes the other climate change impacts. Ocean acidification also harms many of the same marine ecosystems, especially coral reefs, plankton, and shellfish that are additionally harmed by higher ocean temperatures.

## How do these climate change impacts harm ecosystems and human systems in Guam?

Many people think that humans should protect the natural world. All four of the climate change impacts shown in Figure 9 (sea level rise, higher temperatures, changes in rainfall, and ocean acidification) harm Guam ecosystems. These impacts harm the organisms that live there and the human communities that get many benefits from these ecosystems. These benefits include cultural and spiritual values, food, and income from fishing and tourism (**Figure 10**).

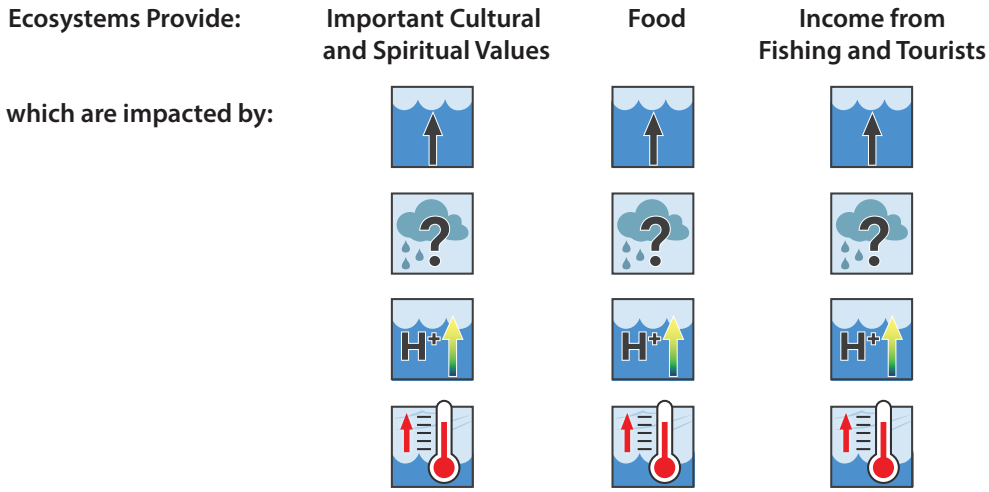


**Figure 10** *Sea level rise, changing rain patterns, ocean acidification and higher temperatures all damage major services that are provided by ecosystems.*

In addition, climate changes harm the human systems that people depend upon for their homes, food, fresh water, and transportation **(Figure 11)**.

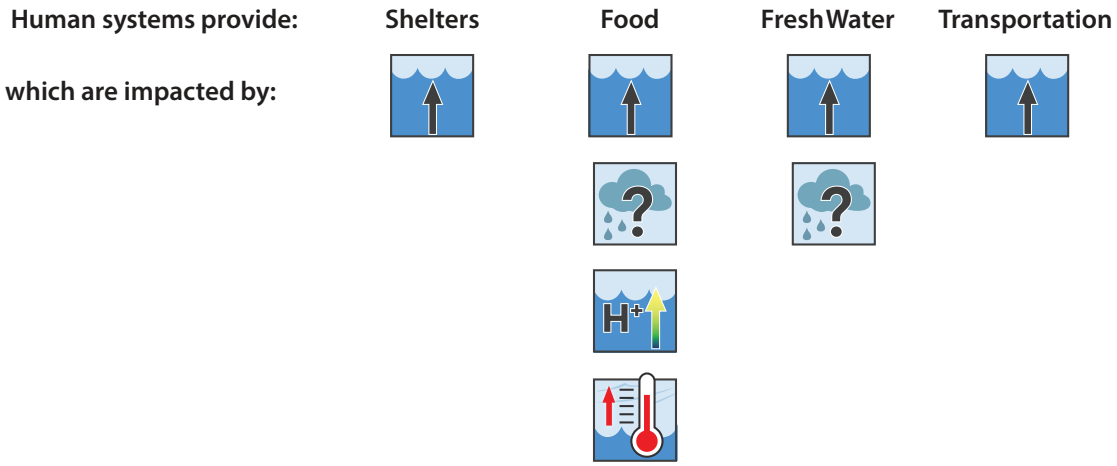


**Figure 11** *Climate change damages major services that are provided by human systems.*

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Sea level rise is especially important since it harms essential Guam ecosystems and human systems. Sea level has been increasing in Guam at about 0.3 inches per year. This may not seem like a very rapid increase, but its effects can quickly add up year after year. Sea level rise causes beach erosion (**Figure 12**), flooding during high tide, and increased flooding due to storm surge and tsunamis. Sea level is expected to continue rising, perhaps by more than 3 feet (1 meter) by the year 2100.

**Figure 12** *Sea level rise causes coastal erosion, which can make beaches get narrower and threatens coastal communities.*

This increase in sea level means that anything that makes the ocean waves reach farther inland (such as a high tide, a tsunami, or a tropical cyclone) will cause more flooding than when the sea level was lower. For example, sea level rise around Guam has been especially strong over the past 20 years. The next typhoon to pass over the island will generate a storm surge that is likely to do more damage than it would have if sea level had not been rising.

Higher sea level also affects the availability of food and water. On low coastal lands, when the ocean floods the land, the soil becomes salty, which damages the natural plants and trees, and also makes it much harder to grow food. The higher sea level can also reduce the amount and quality of the underground fresh water.

Often the different impacts of climate change harm the same ecosystem or human system, and cause more damage than either would by itself. For example, higher ocean temperatures and ocean acidification both harm local marine ecosystems such as coral reefs (**Figure 13**). Coral are very sensitive to increases in temperature. Since the 1970's, the Pacific Ocean has warmed by about 0.7°F (0.4°C). Warmer ocean water can lead to coral bleaching, and damage to local marine ecosystems and fishing.

**Figure 13** *Ocean acidification harms the coral, plankton, and other organisms that use calcium carbonate to make their shells and the reef. Coral reefs are also damaged by higher ocean temperatures.*

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The outside hard parts of many shelled organisms, such as plankton, and coral are made of carbon combined with calcium and oxygen in a solid form called calcium carbonate. As the ocean becomes more acidic, it is much more difficult for many marine organisms to make and keep their hard calcium carbonate shells. Since plankton and coral are very important for marine ecosystems, this ocean acidification also can decrease the populations of many marine organisms that do not have shells. One quarter of all sea animals spend time in coral reef environments during their life cycle.

## How can Guam communities adapt to the impacts of climate change?

We use the term **climate adaptation** to describe the things that people, communities and governments can do to help protect themselves from harmful climate impacts. A Pacific Island community that has planned and implemented climate adaptation strategies for their ecosystems, food supplies, homes, roads, and water supplies will suffer less damage and recover more quickly from climate change impacts.

Plants and animals living in Pacific Island ecosystems are adapted to the current conditions, such as temperatures and rainfall patterns. Since temperatures normally do not change very much over the course of a year, many local plants and animals have never experienced the higher temperatures that may be happening already and that are predicted to happen even more in the future. Changes in sea level (**Figure 14**) and rainfall, higher temperatures, salt from ocean flooding, and a more acidic ocean all can cause very significant damage to land and marine ecosystems.

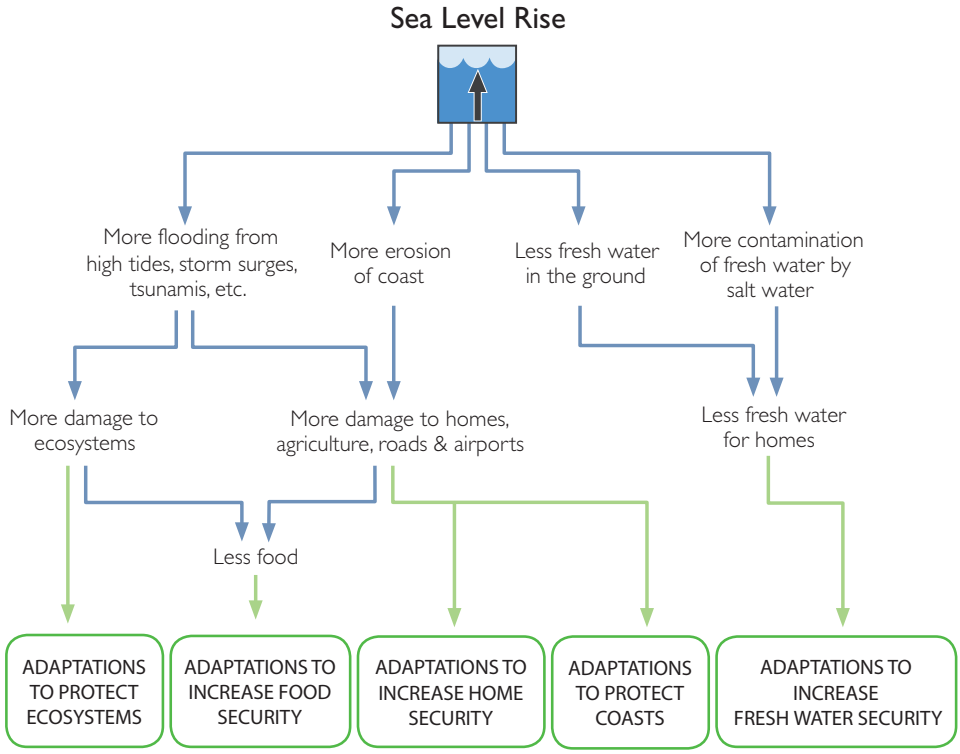


**Figure 14** *Impacts of sea level rise and kinds of adaptation strategies.*

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In addition to the stress from climate change impacts, these ecosystems are often already being harmed by other human actions. Activities such as polluting land or water, cutting down too many trees, catching too many fish, disturbing reefs, and replacing natural environments with industrial development all harm local ecosystems.

Ecosystems that are close to their natural condition are more **resilient** with respect to climate change. This means that they are damaged less by climate changes and can recover faster than ecosystems that are harmed by other human activities. The best climate adaptations for ecosystems are activities that help the ecosystems return to and keep their natural conditions. These activities include preventing and removing pollution, and carefully managing human interactions with the ecosystem such as fishing, cutting trees, and tourism.

Because ecosystems provide so many important benefits to island communities, these ecosystem adaptations also increase the resilience of human systems. In addition, human systems (such as homes, getting freshwater, getting food, and transportation) require other adaptation actions. These adaptation actions generally make the human systems more flexible, efficient and sustainable. In other words, these climate adaptations for human systems:

- Give the communities more ways to meet their needs (they are flexible),
- Do so in ways that provide the maximum benefits for the cost (they are efficient), and
- Rely more on island resources than on outside resources (they are sustainable).

Unfortunately, on low islands, communities have fewer choices and resources to reduce the impacts of climate change than do communities on high islands or continents. Low atolls lack the higher elevations that can provide much more security with respect to avoiding flooding, getting fresh water, growing food, and building roads. If the impacts of climate change continue to increase, the low islands in Micronesia to the south of Guam, and their way of life, will become increasingly threatened. This is likely to lead to increased immigration to Guam.

The Micronesia Conservation Trust has produced materials that help Pacific Island communities understand climate impacts. These materials provide guidance with respect to planning and implementing climate adaptation activities. Under the title *Adapting to a Changing Climate*, these materials include large flipcharts that can be brought to local communities and a booklet that summarizes and explains the information in the large charts.[8]

8 The booklet Adapting to a Changing Climate can be accessed at http://www.cakex.org/virtual-library/3439

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In general, there are three kinds of climate adaptation activities that can help make people, communities, and nations safer with respect to rising sea levels and other climate impacts. These kinds of adaptation activities are:

- Protecting local ecosystems to help these ecosystems be more resilient,
- Increasing the resiliency of the communities' physical systems such as homes, roads, water supplies, and food supplies,
- Making the community's cultural systems stronger and healthier so people in the community effectively plan and implement climate adaptation strategies that work for that community.

These climate adaptations can help make life in Guam safer and more comfortable for more years into the future.

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# Glossary

**Air and ocean temperatures are warmer** A direct effect of global warming is that the air gets warmer. Because the air and the ocean touch each other and are mixed together by winds and waves, heat can travel out of the air and into the water making the ocean warmer. Warmer temperatures in the air and ocean cause many changes to the worlds ecosystems, weather, climate, and human communities.

**Climate** The long-term pattern of weather in a particular area. Climate is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, and other properties of the weather in a given region over long periods of time.

**Climate adaptation** Actions taken by people, communities and governments that help protect themselves, and ecosystems, from harmful climate impacts.

**Climate change** A change in global or regional climate patterns. In particular a change apparent from the mid to late 19th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

**Coastal erosion** Wearing away and loss of beaches and land due to waves. Coastal erosion gets worse when sea level rises.

**Convective rain** Convection of the air occurs when hot air moves upward. This develops when Earths surface becomes heated more than its surroundings leading to strong evaporation that makes clouds. The clouds produce convective rain that falls as showers with rapidly changing intensity. Convective rain falls over a certain area for a relatively short time, because convective clouds have limited horizontal extent. Most precipitation in the tropics appears to be convective.

**Drought** An extended period of little rainfall.

**El Niño** A natural climate event, lasting typically less than 1 year, which occurs in the Pacific when the normal trade winds weaken (or die) and are replaced by monsoon winds. This causes warm water in the western tropical Pacific to surge into the central and eastern Pacific. El Niño can cause temporary global changes in the climate and weather.

**El Niño Southern Oscillation** (ENSO) Refers to a Pacific climate event that has two states: El Niño and La Niña. These states govern the movement of a large body of warm water to the eastern (El Niño) or western (La Niña) regions of the tropical Pacific Ocean. ENSO states cause strong climate and weather changes around the globe.

**Global warming** When the air in the lowest portion of the atmosphere (the troposphere) gets significantly warmer than normal. Global warming is caused by an increase in the amount of heat-trapping greenhouse gases when humans burn fossil fuels (coal, petroleum, natural gas) for energy. Other types of greenhouse gases produced by humans also contribute to the problem.

**Humidity** The amount of water vapor in the air.

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**Intertropical Convergence Zone** (ITCZ) Known by sailors as "the doldrums", the ITCZ is a belt of low air pressure which circles Earth generally near the equator where the trade winds of the northern and southern hemispheres come together. The ITCZ tends to be a region of thunderstorms and high rainfall.

**King tide** A term that describes an unusually high tide, usually the highest tides of the year. King tides may cause flooding on low-lying coastal lands.

**La Niña** A natural climate event, lasting typically less than 1 year, which occurs in the Pacific when the trade winds grow stronger than normal. This causes a body of warm water to accumulate in the western tropical Pacific and is an opposite state to El Niño.

**Neutral** A year in which ENSO conditions are neither in the El Niño or La Niña states.

**North Pacific High** An area of high atmospheric pressure to the northeast of Hawaii that generates the trade winds.

**Ocean acidification** Decrease in the pH of Earth's oceans, caused by the uptake of carbon dioxide ($CO_2$) from the atmosphere. An estimated 30–40% of the carbon dioxide released by humans into the atmosphere dissolves into oceans, rivers and lakes, lowering their pH.

**Orographic rain** Orographic rain occurs when humid air is forced upwards over rising terrain, such as a mountain, into colder air at higher elevations. This causes the rate of condensation to exceed the rate of evaporation, producing orographic clouds that yield orographic rain.

**Resilient** communities are better able to bounce back from disasters and disruptions, such as tropical cyclones, in a sustainable way and maintain a good quality of life for all. They are better prepared for uncertainties and able to adapt to changing conditions.

**Sea level rise** When the average level of the surface of the ocean rises, especially as a result of global warming that melts glaciers (increasing the amount of water in the ocean) and warms the ocean (causing ocean water to expand, upwards).

**Trade winds** A wind blowing steadily toward the equator from the northeast in the northern hemisphere or the southeast in the southern hemisphere, especially at sea.

**Tropical cyclone** A rotating system of strong winds, clouds and thunderstorms that produce heavy rain. Tropical cyclones are organized around a center, or eye, where there is low air pressure. Tropical cyclones cause storm surge and are responsible for severe damage where they make landfall in human communities.

**Tropical Storm** A tropical storm is a strong type of tropical cyclone. It is an organized system of powerful thunderstorms rotating counterclockwise with maximum sustained winds between 39 miles per hour (63 kilometers per hour) and 74 miles per hour (119 kilometers per hour).

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**Typhoon** Called a hurricane in the central and eastern Pacific Ocean. A typhoon is a strong type of tropical cyclone. An organized system of powerful winds rotating counterclockwise with maximum sustained winds of at least 74 miles per hour (119 kilometers per hour). A cyclone of this intensity tends to develop an eye, an area of relative calm (and lowest atmospheric pressure) at the center of circulation.

**Variability** Meaning that the state of the weather, or climate, has a high degree of change. Climate conditions that are variable are always changing.

**Weather** The state of the atmosphere at a place and time as regards heat, dryness, sunshine, wind, rain, and other conditions.

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### Photographs

**Figure 3.** Photograph of rain
http://1.bp.blogspot.com/-Db5Kw3lPBtc/TnusYWYDK2I/AAAAAAAADQU/UCVHft016iQ/s1600/7milebeach.jpg
Photograph of mountain
http://www.nbnweathershots.com.au/sites/default/files/20120410%20Bora%20Bora%2884%29.JPG"

**Figure 12.** Photograph of coastal erosion Tutuila, Thomas Smith, U.S. Army Corps.

**Figure 13.** Photograph of coral reef by Joe Ruhinski
https://fullhdwp.com/coral-reef-marshall-islands-majuro-atoll-wallpaper/

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