

Climate Change in

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 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 30 years 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**). 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.

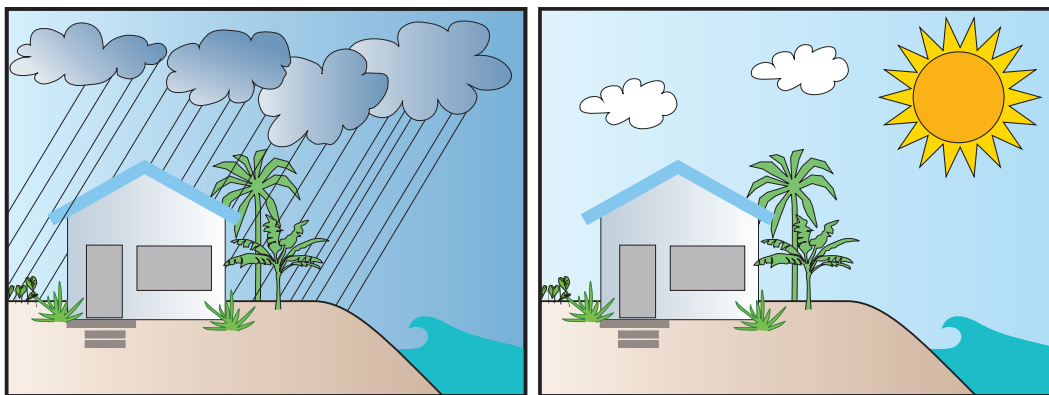


Figure 1 In Guam, the weather changes from a wetter season (July through December) to a drier season (January through June). On average, two-thirds of Guam's total annual rainfall occurs in the wetter season.

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

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.

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).

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**.

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 (266 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.*



Wetter and Drier Seasons and 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.

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.

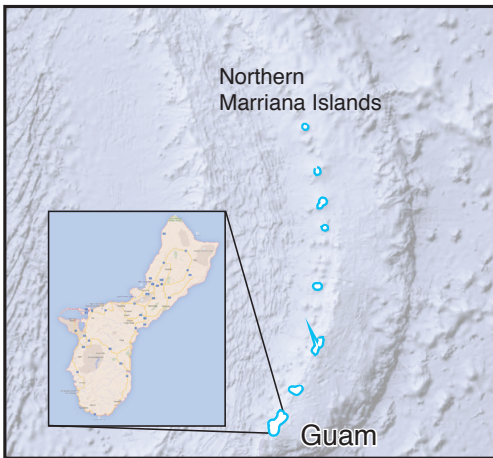


Figure 4 The Territory of Guam is located just south of the Commonwealth of the Northern Marinas Islands.

During the drier season, most rainfall occurs as light showers in amounts typically no more than 0.25 inch per day¹. 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 in an hour and 20 inches in 24 hours

Figure 5 shows the monthly rainfall in inches measured at Guam International Airport between the years 1961 and 2005. 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 in many 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).

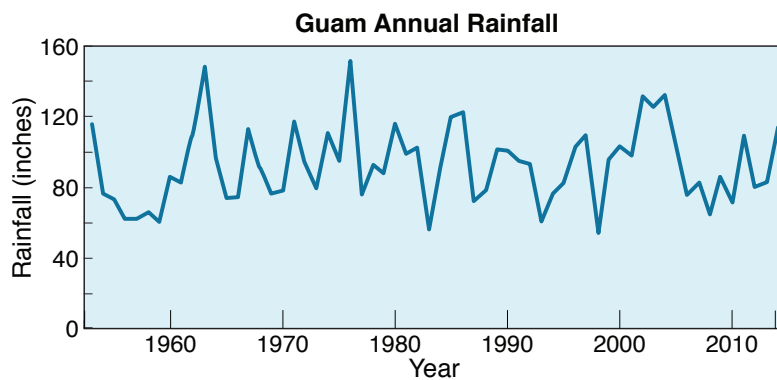


Figure 5 The amount of rainfall in Guam has a lot of variability from one year to the next

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.

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, **northeast** 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.

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 Earth's 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 North Pacific High creates the trade winds

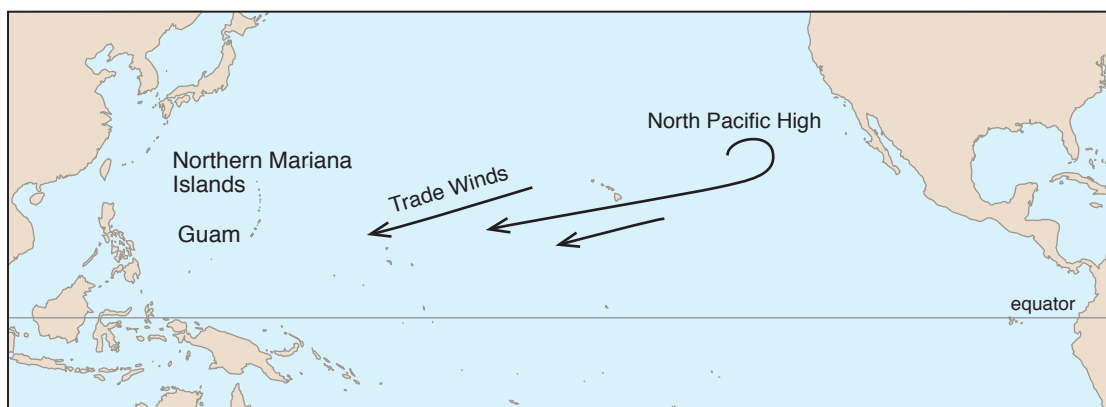


Figure 6 The North Pacific High is a high-pressure region in the atmosphere that is located to the northeast of Hawaii. Air in the North Pacific High rotates in a clockwise direction making the trade winds that travel outward and arrive in Guam and Micronesia from the east and **northeast**.

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** (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	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, strong 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). An El Niño year is usually drier and there is a greater chance of **drought** (an extended period of little rain). In addition, warm ocean water moves away from Guam toward the eastern Pacific Ocean, and causes sea levels to decrease.

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 season³. 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>

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 models⁴ 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 year⁵ 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.

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, Chapter 12 - Samoa, 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