

# Climate



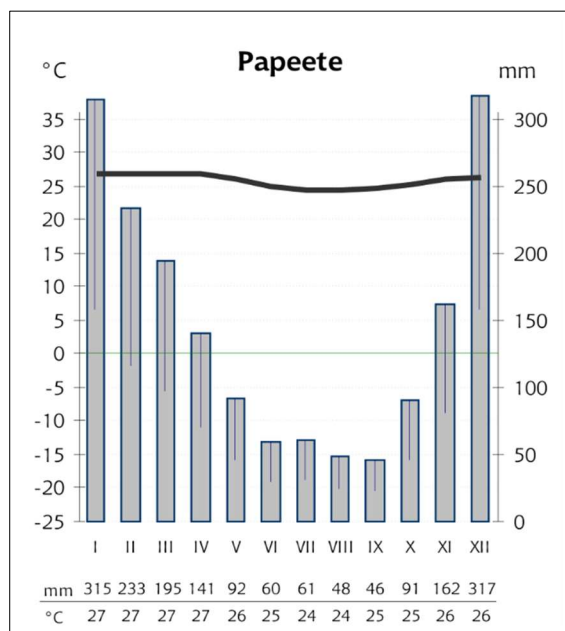
Climate is the long-term average of the weather. It is observed over periods of many years, decades, and centuries. In many areas of the United States, the daily high temperature or the daily low temperature can vary by as much as 30 degrees F from day to day.

Figure 1. Stratocumulus clouds. Credit: M. Collier

## What is the difference between weather and climate?

Weather is the state of the atmosphere from day to day. It includes temperature, atmospheric pressure, clouds, wind, and precipitation. Climate is the long-term average of the weather. It is observed over periods of many years, decades, and centuries. In many areas of the United States, the daily high temperature or the daily low temperature can vary by as much as 30 degrees Fahrenheit from day to day. In contrast, the average temperature for a whole year seldom varies by more than one degree.

## What factors determine the climate?



The two most important factors in the climate of an area are temperature and precipitation (reported in a climatogram, as in Figure 2). The yearly average temperature of the area is obviously important, but the yearly range in temperature is also important. Some areas have a much larger range between highest and lowest temperature than other areas. Likewise, average precipitation is important, but the yearly variation in rainfall is also important. Some areas have about the same rainfall throughout the year. Other areas have very little rainfall for part of the year and a lot of rainfall for the other part of the year.

Figure 2. Climatogram of Papeete, Tahiti. Credit: Urmaz, CC 3.0.

### **How does climate affect vegetation?**

The plant community in an area is the most sensitive indicator of climate. Areas with moderate to high temperatures and abundant rainfall throughout the year are heavily forested (unless humans have cleared the land for agriculture!). Areas with somewhat less rainfall are mainly grasslands, which are called prairies in North America. Humans have converted grasslands into rich agricultural areas around the world (Figure 3). Even in areas with high yearly rainfall, trees are scarce if there is not much rainfall during the warm growing season. Regions with not much rainfall and scarce vegetation are called deserts, or arid regions. Areas with somewhat greater rainfall are called semiarid regions. When humans use semiarid regions for agriculture, the loss of natural vegetation can cause the areas to become deserts.



*Figure 3. A grassland that has been converted into farmland. Credit: Minnesota Pollution Control Agency.*

### **How can local climates vary over very short distances?**

It is easy to understand how climate can vary over very large areas, because of slight changes in temperature or rainfall. Climates can also vary over very short distances. Local differences in climate are described by the term "microclimate." Low-lying areas are often colder at night than higher ground nearby. On clear nights, the ground is chilled as its heat radiates out to space. The cold ground then chills the air near the ground. The chilled air is slightly denser than the overlying air, so it tends to flow slowly downhill, in the same way that water flows downhill. The cold air "ponds" in low areas. These are places where the first frosts of autumn are earliest and where the last frosts of spring are latest.

If you ever have a chance to plant fruit trees, plant them on the highest ground around! In hilly areas, north-facing slopes get less sunshine than south-facing slopes. Local temperatures on the north-facing slopes are colder than on south-facing slopes in both summer and winter. In areas with winter snowfall, the snow melts much later north-facing slopes.

## What is a climate proxy?

The Earth's climate has changed greatly through geologic time, and even in recent centuries. The study of past climates is called paleoclimatology ("paleo-" means "early" or "past").

Something that represents something else indirectly is called a proxy. In some elections, a voter can choose another person to cast the vote. That vote is called a proxy. There are many proxies for past climate. They provide a lot of information, although none is perfect. Some, like kinds of past plants and animals, are easy to understand. For example, the rings in a tree show annual growth, which is associated with annual rainfall (Figure 4). Some important proxies, involving the chemical element oxygen, are more difficult to understand.



Figure 4. Trees rings can be used as a climate proxy. Credit: Bill Kasman, Public Domain.

## How do scientists use ice cores to determine past climates?

Thin cores of ice, thousands of meters deep, have been drilled in the ice sheets of Greenland and Antarctica. They are preserved in special cold-storage rooms for study. Glacier ice is formed as each year's snow is compacted under the weight of the snows of later years. Light bands correspond to the relatively fresh, clean snows that fall in the summer when warmer conditions bring more moisture and precipitation. Dark bands mark the polar winter season, when little new snow falls on these frigid deserts and blowing snow is mixed with dust, discoloring the white snow. The layers are only millimeters to centimeters thick. Counting the yearly layers can date them. The oxygen in the water molecules also holds a key to past climate. Scientists are able to use the oxygen atoms in the glacial ice as a proxy for air temperature above the glacier.

Ice sheets on the continents have grown and then shrunk again four times in the past half million years. Several climate proxies make that very clear. Deposits of sediment left by these glaciers are present over large areas of North America and Eurasia. Proxies for global temperature show gradual cooling as the ice sheets form, and then very rapid warming as the ice sheets melt back. The periods of warm temperatures between glaciations within an ice age are called interglacial periods. Past interglacial periods have lasted only about twenty thousand years. Humankind developed civilization only within the very last interglacial- and you are still in it!

## What are the causes of climate change?

Two important things determine the Earth's climate. One is the amount of heat the sun delivers to the Earth (Figure 5). Also important is where the Earth's continents are located relative to the equator. Continental ice sheets cannot develop unless one or more continents are located at high latitudes.

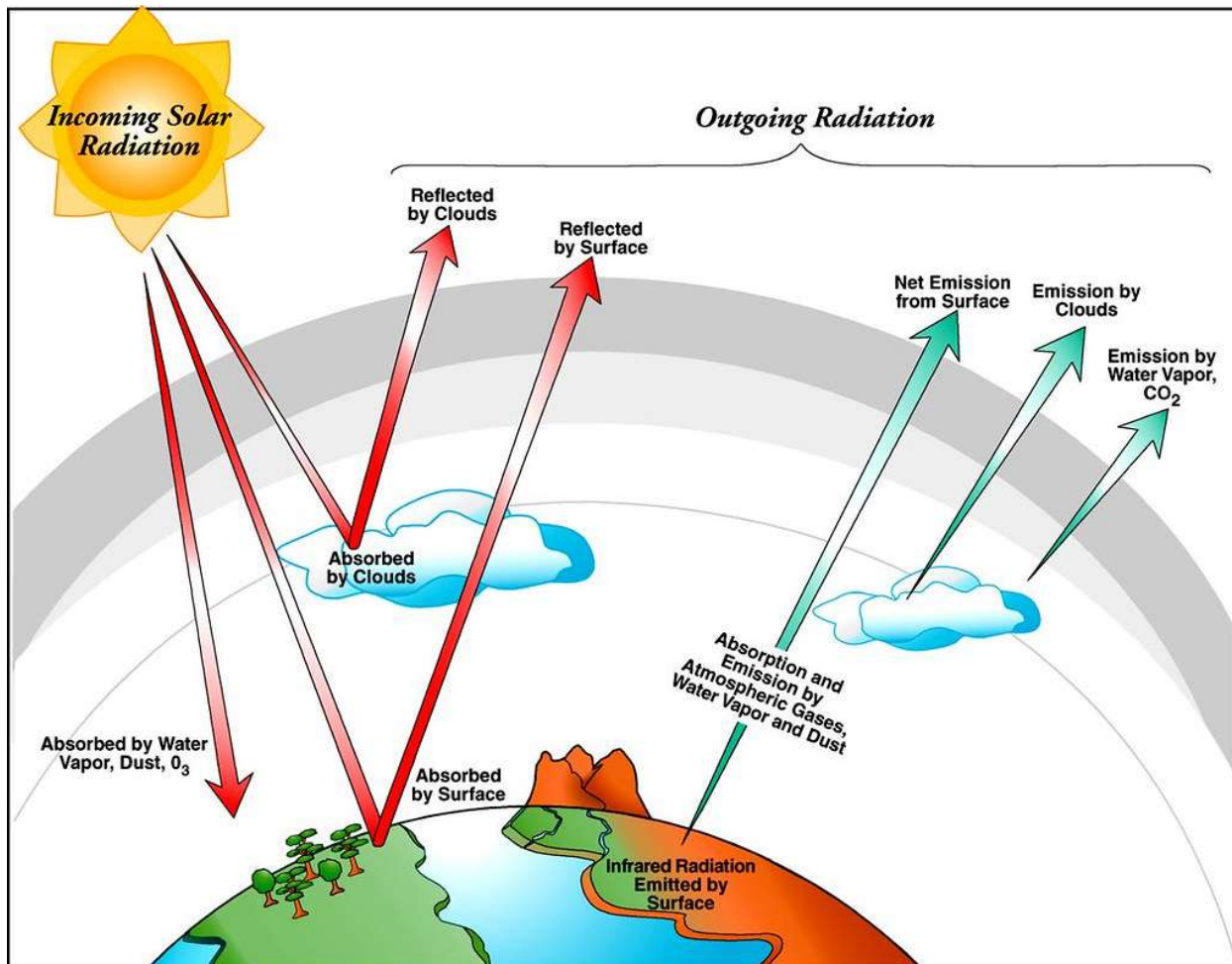


Figure 5. Earth's solar radiation budget, which affects climate. Credit: U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility.

The Earth revolves around the sun once a year. The orbit is almost a circle. If the Earth were the only planet, its orbit around the sun would be almost unchanging. The other planets exert a pull on the Earth. Although the pull is small, it makes the Earth's orbit much more complicated. The orbit changes slightly in several different ways. The changes occur over periods that range from about twenty thousand years to about a hundred thousand years. These changes cause slight differences in how much of the sun's heat the Earth receives, in winter vs. summer and at high latitudes vs. low latitudes.

The astronomical theory of the ice ages holds that the small changes in the Earth's orbit trigger the advance and retreat of ice sheets. Most scientists now accept this theory. The details of how the changes triggered the ice sheets are still only partly understood. For example, the very fast melting of the ice sheets, compared to the long times needed for them to form, is still a mystery.

The astronomical theory is only part of the story. Climate is known to change on time scales as short as centuries, and the cause (or causes) of these changes are still not clear. Here's a big question, and an important one. Has the increase in temperature since the beginning of the twentieth century been caused by human activity, or is it just another natural upward "spike" like several during the past two millennia? Most climatologists think that the upward trend in temperature during the twentieth century is at least partly caused by human activity.