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WHAT DO WE MEAN BY "CLIMATE" AND "CLIMATE CHANGE"?

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Climate change is all over the news. But what exactly do we mean by "climate" and "climate change?" The word "climate" describes the average state of the atmosphere. It is a result of the composition and interactions between the natural elements: the air, oceans, plants and animals, ice and snow, and rocks. There are several different climate zones around the world. The state of the global climate is described by the average global air temperature. This temperature depends on how much heat the Earth receives from the Sun and how much of this heat is sent back to space. If the amount of heat received through the sun's rays or the composition of one or several of the natural elements changes, the amount of heat taken up by the Earth changes. All elements are connected and constantly interacting, and this has consequences for the whole planet: climate change.

CLIMATE IS NOT WEATHER

You might have heard or read about climate change or global warming in the media. Scientists from all around the world say that the Earth is warming and Earth's climate is changing. They predict that these changes will probably continue over the coming decades to centuries. But, if scientists cannot predict the weather over more than a couple of days, how can they know what the temperature on Earth will be in several years?

WEATHER

Current state of the atmosphere (what you see when you look out of the window). If it is a rainy or sunny day, for example.

CLIMATE

Average state of the atmosphere, meaning typical weather conditions a in region for a very long time.

Such predictions can be made because *weather* and *climate* are different things. In scientific words, **weather** is the *current* state of the atmosphere and **climate** is the *average* state of the atmosphere. For example, the clothes you wear today or tomorrow are a response to the weather you see when you look out the window. On a rainy, cold day, you will wear something different than you would on a sunny, warm day. Climate, on the other hand, describes the typical weather conditions in a region for a very long time—30 years or more. That is how we define seasons—for example, in summer, the climate is hotter than it is in winter. So, in winter, we know that we must wear warmer clothes than we do in summer. Climate describes the average characteristics of the weather over a long time at a specific place.

THE CLIMATE SYSTEM

Weather, and therefore climate, is a consequence of interactions between the atmosphere and the environment around us: the oceans, lakes, and rivers (also called the hydrosphere); the vegetation and animals (biosphere); the mountains, volcanoes, and ocean floor (lithosphere); and the ice and snow surfaces (cryosphere). These components continuously exchange things like heat, water, or gases. Together, these elements form the **climate system** (Figure 1A). These elements influence the average weather and are important to understand if we want to understand what climate is and how it can change.

CLIMATE SYSTEM

Interactive system consisting of five major components: atmosphere, hydrosphere, biosphere, lithosphere, and cryosphere.

The components of the climate system are constantly interacting. Because the atmosphere covers the whole globe, it is an important means of transport for heat, water, and gases between different regions. When transported, these components affect the state of the atmosphere and influence the average weather. As an example, let us look at how water (Figure 1B) and carbon dioxide (CO_2) (Figure 1C) are exchanged within the climate system.

The oceans are the largest water reservoir on Earth. Every day, due to the heat reaching the Earth from the Sun, water from the oceans, lakes, and rivers evaporates to become water vapor in the atmosphere. The clouds and the moist air are then transported by winds to other regions of the Earth. At some point, the water vapor cools down and falls back

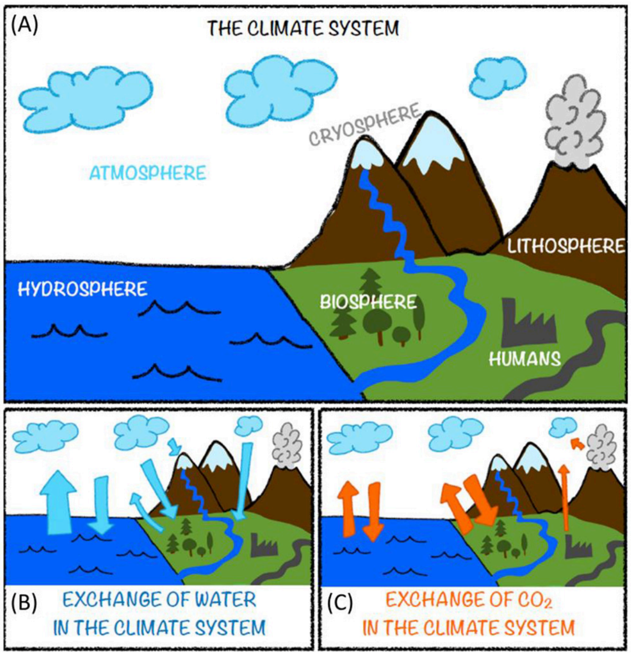

Figure 1

Figure 1

(A) The climate system includes the atmosphere, the hydrosphere (oceans, rivers, and lakes), the biosphere (vegetation and animals), the lithosphere (mountains, volcanoes, rocks, and the ocean floor), and the cryosphere (ice sheets, glaciers, and snow). **(B)** The water cycle: Water is exchanged between the five components of the climate system, mainly between the hydrosphere, the biosphere, the atmosphere, and the cryosphere. **(C)** The carbon cycle: CO_2 is exchanged between the five components of the climate system, mainly between the hydrosphere, the biosphere, the atmosphere, and the lithosphere.

to Earth. If this happens in a cold region over land, it falls as snow and accumulates either on the ground or on glaciers and larger ice sheets. If rain falls over a region covered by vegetation, the water will be taken up for plant growth. Part of the rain also falls directly into rivers and the ocean. Additionally, plants "sweat" and "breathe." Through these processes, plants release water vapor into the atmosphere. The exchange of water between the hydrosphere, atmosphere, biosphere, and cryosphere is called the **water cycle** and it is one example of the interactions between the various elements of the climate system.

The atmosphere is a thin layer of gas surrounding the Earth. It contains the oxygen we breathe and other gases, including CO_2. CO_2 is a **greenhouse gas**, which means that it helps keep the planet warm enough for us to live on. But CO_2 is not only present in the atmosphere—large amounts of carbon are stored in the oceans and in vegetation and are constantly exchanged with the atmosphere in the form of CO_2. This is called the **carbon cycle**. But human activity is throwing this balance off. Every year, as we burn fossil fuels, we release large amounts of CO_2 into the air. The large amounts of CO_2 that we continually release make it very difficult for the exchange between the atmosphere, ocean, and vegetation to readjust and find balance. The excess CO_2 accumulates in the atmosphere, which causes Earth's temperature to rise and results in climate change.

WATER CYCLE

Regular exchange of water between the hydrosphere, atmosphere, biosphere, cryosphere, and lithosphere.

GREENHOUSE GAS

Gas that traps heat and makes the planet warm enough for us to live on.

CARBON CYCLE

Regular exchange of carbon between the atmosphere, hydrosphere, biosphere, cryosphere, and lithosphere.

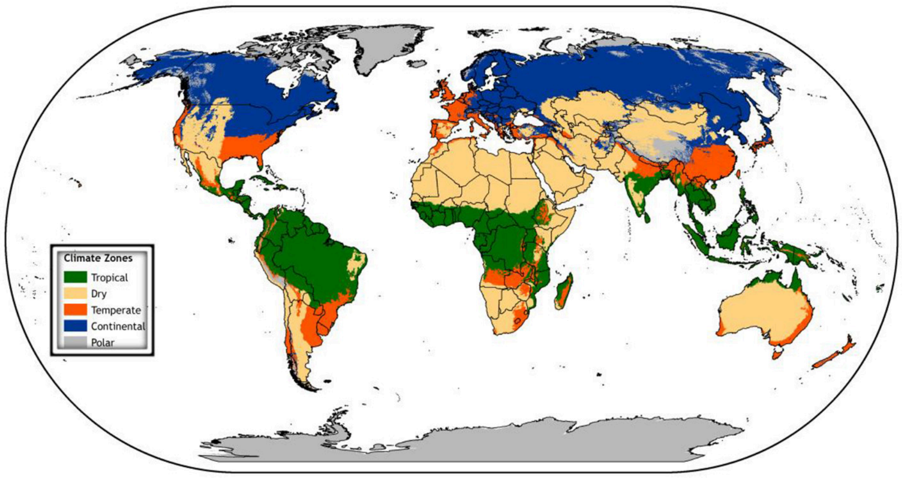

Figure 2

Figure 2

The five main climate zones around the world, as defined by Wladimir Köppen. The zones are in various colors, explained in the key on the left [1].

CLIMATE ZONES

The climate is different all around the world. Scientists have classified the regions that have similar patterns of temperature and rain into **climate zones**. The scientist Wladimir Köppen defined five main climate zones (Figure 2).

CLIMATE ZONE

Regions around the world that have similar patterns of temperature and rainfall.

The tropical climate, found around the Equator, is warm and wet year-round. The dry climate, such as that of deserts, is usually warm, with large variations of temperature between day and night, and has very low rainfall. The temperate climate, such as that of Western Europe, typically has warm summers and mild winters, without a dry season; but for some places, like the Mediterranean, the summers are dry. The continental climate, seen in Russia and Canada, has cooler summers and very cold winters, without a dry season; but in areas like northeastern China, the winters are dry. Finally, the polar climate, seen at the North and South Poles, is very cold year-round.

HOW CAN CLIMATE CHANGE?

The evolution of the global climate is usually monitored by measuring the average global air temperature. This temperature is obtained by measuring the temperatures at various locations worldwide. The average global air temperature represents the amount of heat trapped near the Earth, and it is determined by how much heat from the Sun reaches the Earth and how much heat the Earth releases back to space (Figure 3). Climate has been changing continuously since the formation of the Earth, due to changes in three factors: the position of the Earth compared to the Sun; interactions within the climate system near the Earth's surface; and the gases in Earth's atmosphere. Let us look a little closer at each of these factors.

Figure 3

Heat from the Sun reaches the Earth's surface and warms it. The Earth emits heat back into space. Some of that heat is trapped by greenhouse gases and sent back to the Earth's surface. This is the "greenhouse effect" and makes Earth warm enough to live on.

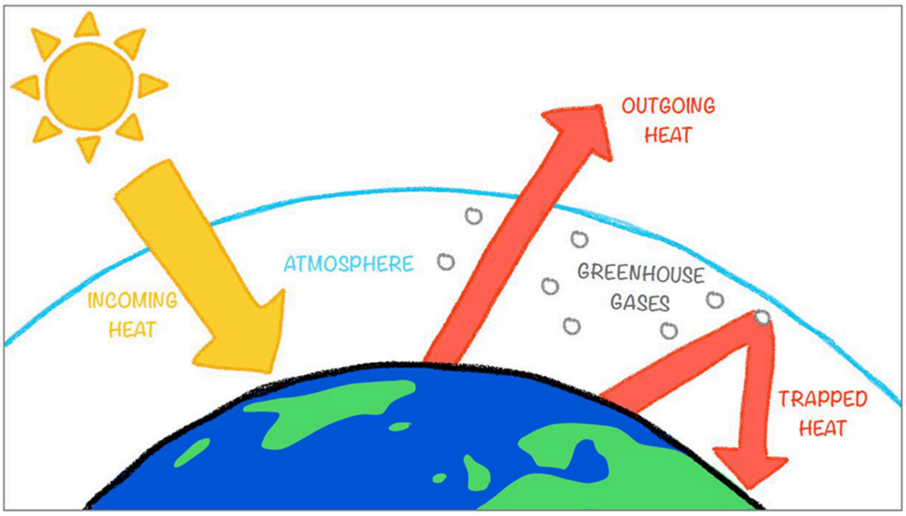

Figure 3

The Position of the Earth Compared to the Sun

Although it is about 150 million kilometers away from the Earth, the Sun provides the Earth with huge amounts of heat. Over the course of the past 4.5 million years, the Earth has sometimes moved a tiny bit closer to the sun, and sometimes a tiny bit further away from it, or has changed its angle toward the Sun very slightly. These small positional changes led to small variations in the heat that reached the Earth. These tiny heat variations were enough to cause ice ages or hot periods.

Interactions Within the Climate System Near the Earth's Surface

When reaching the Earth's surface, some of the Sun's heat is reflected and bounces back into space. But the majority of the heat is absorbed by the natural elements at the Earth's surface. This heat powers the exchange of water and gases between the components of the climate system (atmosphere, hydrosphere, biosphere, lithosphere, and cryosphere), as described earlier.

The Gases in Earth's Atmosphere

The Earth's surface also emits heat back to space. If all the heat released by the Earth's surface were lost to space, it would be too cold for us to survive on Earth! This is where the Earth's atmosphere comes into play. The greenhouse gases in the atmosphere—water vapor, CO_2, and methane—absorb some of the heat released by the Earth's surface on its way to outer space and send that heat back toward the Earth's surface. This way, the Earth stays warm enough for us to live on. The warming caused by the heat trapped by greenhouse gases is what we call the **greenhouse effect**. It is a natural phenomenon that has always happened. By emitting more CO_2 into the atmosphere, humans are currently making the greenhouse effect

GREENHOUSE EFFECT

Warming process caused by the heat trapped by the greenhouse gases. It is a natural process but can be enhanced by the increase of greenhouse gases in the atmosphere.

stronger. These processes are described in more detail in other articles in this Climate Collection.

IN SUMMARY

Climate describes the average characteristics of the weather and it can be quite different all over the planet. Although we describe weather by the current state of the atmosphere (whether it is a sunny day or it is raining, for example), weather is strongly influenced by the cryosphere, hydrosphere, biosphere, and lithosphere. There is continuous exchange of water, heat, and gases between the various components of the climate system. Changes in these processes lead to changes in the average properties of the atmosphere and therefore in weather and climate.

The average global air temperature helps us to monitor the evolution of Earth's climate over time. This temperature describes the difference between the incoming heat from the Sun and the heat released into space. Changes in the average global air temperature, like global cooling or global warming, can be due to changes in Earth's position compared to the Sun, changes in interactions between the elements of the climate system, or changes in the amounts of greenhouse gases in the atmosphere. Such changes have happened in the past and are happening right now. Because all components of Earth's climate are linked, changes in the average global air temperature affect all other parts of the climate system. This is how we define and detect climate change.

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For this review a small group of Middle School students within the Mizzou Academy program at Colégio Maxi worked together to complete the review. Our program is an opportunity for students to experience an American classroom experience without leaving Brazil. We had lots of fun learning about climate, weather and how the scientific process works.

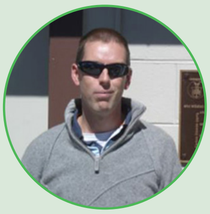
AUTHORS

PEDRO REGOTO

I am currently a PhD student in atmospheric sciences (meteorology). My main interest is in climate, with a focus on climate extremes in precipitation and temperature. I have been working on climate change detection for South America, but mainly in Brazil. One of my main professional goals is to understand more about the causes of climate extremes, like extreme precipitation and temperature events, which affect our daily lives. *pedro.regoto@yahoo.com.br

CLARA BURGARD

I am a climate scientist particularly interested in the climate of cold regions, where there is a lot of ice and snow, like the Arctic and the Antarctic. Particularly, I like to investigate the interactions between ice floating on the ocean and the ocean underneath. To better understand the consequences of climate change on the ice and the ocean at the poles, I use calculations done by large supercomputers and pictures taken by satellites from space.



CHRIS JONES
I am a climate researcher at the Met Office Hadley Center in Exeter in the UK. I have over 25 years of experience in writing computer programmes to model how climate affects our natural ecosystems and how the carbon cycle helps reduce the amount of CO_2 pollution in the atmosphere. I lead a research programme with partners in Brazil and have visited research sites in the Amazon rainforest. The photo here is on top of the Mauna Loa volcano in Hawaii, where CO_2 is measured.