Lesson 1: Our Unique Atmosphere
How does our atmosphere keep the Earth warm?

Reading 1: The Structure of the Atmosphere

The atmosphere is about 372 miles (600 kilometers) thick. While this may seem like a lot, when compared to the size of the Earth, the atmosphere is a relatively thin layer of gases. In the photo on the left, you can see how relatively thin the atmosphere is.

Based on temperature, the atmosphere is divided into four layers. The layer closest to Earth’s surface is the troposphere. The troposphere is thickest in the tropics (about 9 miles/14.5 kilometers thick) and thinnest at the poles (about 5 miles/8 kilometers thick). Most weather happens in the troposphere. The troposphere is the densest of all the layers of the atmosphere and it contains about 80% of the mass of the atmosphere and almost all of the water in the atmosphere. The average temperature in the troposphere is highest at ground level and decreases to about negative 57 degrees F (-52 degrees C) in the uppermost parts of the troposphere.

At the very top of the troposphere is the tropopause. This layer is very stable and separates the troposphere from the next layer, the stratosphere. Have you ever seen a thunderhead (cumulonimbus cloud) with a flat top? Sometimes this flat top is caused by winds, but sometimes it is caused by the top of the cloud reaching the tropopause and not being able to go up any further.

Together, the troposphere and the tropopause are known as the lower atmosphere. It is in the lower atmosphere that heat-trapping gases (some people refer to these as greenhouse gases) accumulate. Above the tropopause is the stratosphere and the mesosphere. Together they are known as the middle atmosphere. Chemicals in the middle atmosphere absorb and scatter the ultraviolet radiation coming in from the sun.

Above the middle atmosphere is the thermosphere or upper atmosphere. Temperatures increase the higher you go in the thermosphere because of the incoming energy from the sun. Temperatures can reach over 3140 degrees F (1700 degrees C).

Study the graph on the left. The red line represents the average temperature.
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Reading 2: Heat-Trapping Gases In the Atmosphere

Heat-trapping gases collect in the troposphere and include carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄), water vapor (H₂O), ozone (O₃) and chlorofluorocarbons (CFCs). These gases act like a blanket in the atmosphere trapping heat and warming the planet. Some scientists have also called these gases “greenhouse” gases, because akin to an actual greenhouse made of glass and used to grow plants when it would be too cold outside, these gases trap heat and help regulate the temperature on Earth.

Air is made up of different gases, and gases are made up of molecules (which are, in turn, made up of atoms). These molecules are so small that they cannot be seen with the naked eye and there is a lot of space between individual molecules; that is why air is transparent.

Based on the structure of the molecules, some gases are more effective at trapping heat than others and stay in the atmosphere longer than others. The better a gas is at trapping heat and the longer it stays in the atmosphere, the more potential it has for aiding climate change (we will learn more about this works in the next lesson).

We use the climate change potential of carbon dioxide (CO₂) as a standard against which we can compare other trace gases. To make comparisons easily, we label carbon dioxide (CO₂) as having a Climate change Potential (GWP) of 1. We can compare this to other greenhouse gases. Methane (CH₄) has a GWP of 23 (measured over a 100 year period). Other gases have much longer atmospheric residence times, like sulfur hexafluoride which has a GWP of 22,000 over 100 years. We don’t hear much about hexafluoride, however, because it has very low concentrations in the atmosphere.

One heat-trapping gas that has a low GWP because its atmospheric residence time is only a few days is water vapor (H₂O). Even though it has a low GWP, there is a lot of it in the atmosphere at any given time. Water vapor is the most common heat-trapping gas.

As we learn more about the greenhouse effect and climate change, we will be hearing a lot more about carbon dioxide and methane. Both of these gases have a big impact on how much heat is trapped in the lower atmosphere.

The concentration of gases in the atmosphere is measured in parts per million (ppm), parts per billion (ppb) or parts per trillion (ppt). For reference, concentrations of carbon dioxide are currently about 388 ppm and concentrations of methane are about 1800 ppb.
Reading 3: The Greenhouse Effect

Everyone experiences the greenhouse effect everyday. It keeps the Earth relatively warm. It’s natural and was here long before humans.

The Earth has a greenhouse effect that keeps the temperature warmer than the temperature in space. The Earth has a layer of gases that, although it is not a perfect analogy, act like the layer of glass on a greenhouse or in your car and trap heat that would otherwise be lost to space. The way it works is that energy, in the form of light and heat, comes from the sun. That energy is either reflected by the Earth or absorbed and then re-radiated back towards space. When this out-going energy hits the layer of heat-trapping gases, some of it passes through back out into space, but some of it gets trapped and re-reflected back to Earth.

The atmosphere and this heat-trapping effect makes life as we know it possible on Earth. Without the heat-trapping gases in our atmosphere, temperatures on Earth would average around 0 degrees F (-18 degrees C) and the surface of the Earth would be frozen.

Without an atmosphere, the temperatures on the Earth would be more like the Moon. Because the Moon doesn’t have the same atmosphere and greenhouse gases, temperatures vary dramatically between the side of the Moon that faces the sun and the dark side that faces away. In fact, on the side of the Moon that faces the sun, the temperatures can reach 260 degrees F (water boils at 212 degrees F). On the dark side of the Moon, it can get as cold as -280 degrees F.

On the Earth there is a difference in temperature between the day and the night (this is called diurnal variation), but it is nowhere near the difference in temperatures experienced on the Moon between the light side and the dark side. This is because of our atmosphere and our heat-trapping gases.

If a planet has a lot more heat-trapping gases, the temperature would be much hotter. For example, Venus has a much higher concentration of heat-trapping gases and temperatures on the surface of Venus are above 350 degrees F (177 C). That is hot enough to melt lead!