CHANGING CLIMATE

OUR FUTURE, OUR CHOICE

K-12 Teachers Guide

MUSEUM OF THE EARTH

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CHANGING CLIMATE

OUR FUTURE, OUR CHOICE

An exhibit at the Museum of the Earth in Ithaca, NY and online at: https://www.museumoftheearth.org/changing-climate

Changing Climate: Our Future, Our Choice helps viewers understand how the Earth's climate has changed in the past, how it is changing very rapidly now, what causes climate change, how it impacts people and other life, and what we can do about it. The exhibit also allows viewers to see other people's reactions to news about climate change and energy, and to share their own views.

This guide provides descriptions of the sections of this exhibit, discussion questions for students, and suggested learning activities to accompany each section. You can find additional learning activities and resources on our Teach Climate Science webpage: https://www.priweb.org/tcs .

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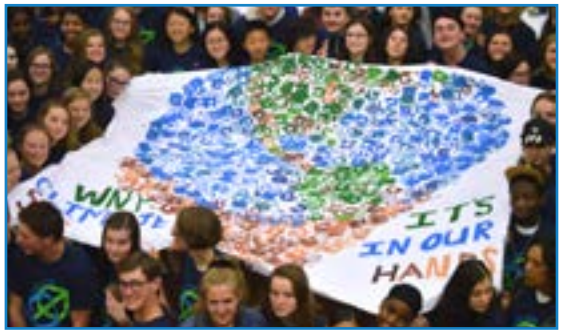
How could this guide be more useful to you?
Please let us know by contacting us at teacherPD@priweb.org.

Introduction

THE EXHIBIT opens with a brief overview of the relationship between our planet's climate and the life that has evolved on it. This includes humans. We are rapidly changing the Earth's climate right now, mostly by burning fossil fuels (coal, oil, and natural gas) for energy. This releases carbon dioxide, which builds up in the atmosphere and warms up the surface of the Earth.

VIEW ONLINE



Western New York Youth Climate Summit, photo by Kelli Grabowski

ACTIVITY

(K-12) Finding Climate's Fingerprints in the Environment

Scroll down to the Sample Labs section on this page: https://earthathome.org/virtual-labs/

DISCUSSION QUESTIONS

SECONDARY SCHOOL

A One way to think about the difference between climate and weather is this: *Knowing what the weather is like tells you what kind of clothes to wear. Knowing what the climate is like tells you what kind of clothes to own.* What does this mean? What clothes do you own that people from very different climates do not? Is there anything not in your wardrobe that people in other climates might have?

B The Introduction states that "climate affects life, and life affects climate," and an example of life affecting climate is that the world cooled when huge forests which lived around 300 million years ago were buried and did not decompose, capturing the carbon dioxide they had absorbed from the atmosphere. What are some other examples of how climate affects life, or life affects climate?

DISCUSSION FOR TEACHERS

Examples of climate affecting life could relate to adaptations to heat and cold, and limitations on where life can live (e.g., very dry or very cold climates might limit which organisms can survive). Examples of life affecting climate may be less familiar to students—a short-term example is moisture release from leaves of tropical forests into the atmosphere and changes in heat absorbed by plants relative to dry ground (which is more reflective); long-term, microbes break down organic matter and release CO_2, while plants and phytoplankton take up CO_2 (most is recycled, but some may be stored in sediments in soils.)

C Fossil fuels took millions of years to form below ground. In contrast, we've been burning them in very large quantities for only about 150 years. Because they form so slowly, fossil fuels are not renewable on a human timescale; at some point we will run out of them. Burning them also heats up our atmosphere. What are some of the reasons that we continue to burn fossil fuels?

DISCUSSION FOR TEACHERS

Reasons might include: skepticism about the necessity for change; reluctance to change lifestyles; willingness to change, but challenges in what's possible given current infrastructure; and uses of fossil fuels that are not easily replaced by other existing energy technologies.

ELEMENTARY SCHOOL

A One way to think about the difference between climate and weather is this: *Knowing what the weather is like tells you what kind of clothes to wear. Knowing what the climate is like tells you what kind of clothes to own.* What does this mean?

B How does the climate where you live affect your life? Think about people who live somewhere else in the world where the climate is very different from where you are. What are three ways the climate makes their lives different from yours?

DISCUSSION FOR TEACHERS

Example talking points include clothes, types of buildings, heating and cooling needs, growing seasons, kinds of transportation.

C The exhibit's Introduction says that the Earth's climate is changing today, and this change is "driven mainly by human activity." What does it mean for something to be "driven" by something else? What is this human activity that is causing change?

Temperature & Carbon Dioxide Through Time

THIS SECTION shows graphs of two key data sets in climate science: past temperatures in Antarctica and the concentration of carbon dioxide in the atmosphere. The data are plotted through time, from 800,000 years ago to today. Added to the graphs are timeline points, highlighting key events in natural history, human history, and climate history.

Most of the data points come from climate information captured in ice from the Antarctic ice sheet (see the section on Climate Proxies). The very recent data points come from carbon dioxide measurements made at the Mauna Loa Atmospheric Observatory in Hawaii, and from satellite and ground measurements of temperature.

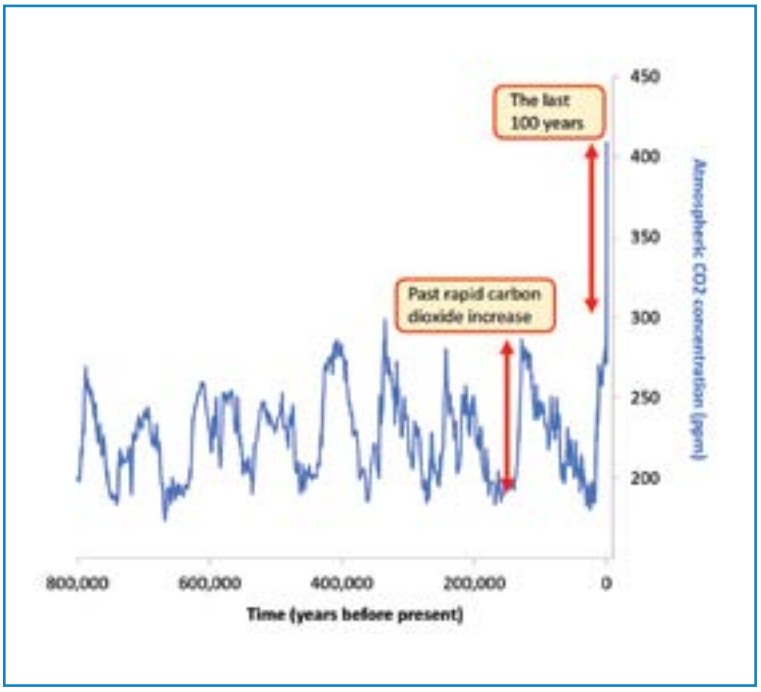
VIEW ONLINE

Wooly Mammoths, painting by Charles R. Knight

ACTIVITY

(8-12) Rates of change of atmospheric carbon dioxide

The graph below zooms in on just one part of what you see in the exhibit; specifically, it shows the concentration of carbon dioxide in the atmosphere over time.



DEFINITIONS

Δt = change in time [years]
= final time – initial time

ΔCO2 = change in CO_2 concentration [ppm]
= final CO_2 concentration
– initial CO_2 concentration

(**ppm** = parts per million)

Rate Of Change Of CO_2 Concentration
= ΔCO_2 / Δt [ppm/year]

On the carbon dioxide graph in the exhibit you can see that from about 140,000 years to ago to about 129,000 years ago, carbon dioxide (CO_2) concentration increased rapidly. You can also see that CO_2 concentration has increased rapidly in the last hundred years. With the data provided below, calculate the rates of change of CO_2 concentration during these two time periods, and compare. Write your answers in the empty boxes in the table below.

DATA FOR TIME INTERVALS OF RAPID CO_2 INCREASE						RATE OF CHANGE
Initial Time [year]	**Final Time** [year]	**Δt: Change In Time** [years]	**Initial CO_2 Concentration** [ppm]	**Final CO_2 Concentration** [ppm]	**ΔCO_2: Change in CO_2 Concentration** [ppm]	**ΔCO_2 / Δt** [ppm/year]
- 140,019 (140,019 years ago)	- 128,536 (128, 536 years ago)		192.75	285.76		
1919	2019		304.61	411.50		

How many times faster is the recent rate of change of CO_2 concentration than the past rate of change of CO_2 concentration? To find out, divide the recent rate of change by the rate of change from the older time period. What are the implications of an increasing rate of CO_2 change?

ΔCO_2: 140,019-128,536 years ago	ΔCO_2: 1919-2019	Comparison of Rates

ACTIVITY

(6-12): NOAA Mauna Loa data and rate of CO_2 increase (video and activity)
https://www.priweb.org/science-education-programs-and-resources/teach-climate-science#MaunaLoa

DISCUSSION FOR TEACHERS

The rate of CO_2 change influences the rate of temperature and other environmental changes. If environmental changes are quicker, they are harder to adapt to, both for people and organisms. Populations of some organisms may be able to adapt genetically over millenia, but not over decades or a few centuries. Humans and organisms changing their geographic location is also more challenging.

ACTIVITY

(K-8): Animal adaptations to climate change

Research an animal that lives in a very cold or very warm climate today, and describe some of the characteristics of that animal that help it survive in its environment. Have everyone in the class share their own findings, and then see if you can identify patterns.

DISCUSSION QUESTIONS

SECONDARY SCHOOL

A Notice the relationship between the graphs of atmospheric carbon dioxide (in blue) and Earth's surface temperature (in red)? What process might cause the graphs to be related as they are?

ELEMENTARY SCHOOL

A When the carbon dioxide graph (in blue) goes up or down, does the temperature graph (in red) also go up or down? What might this mean?

B The temperature graph shows times when humans existed and the Earth's average temperature was much colder than today. How might humans have survived during such cold times and how might we figure out how they survived?

DISCUSSION FOR TEACHERS

Talking points may include clothing, shelters, and fire. We know about these from archaeological artifacts, but most made of organic materials are likely to have rotted away. We can also speculate from ways that humans in cold climates survive today.

Climate Proxies

COMPARING HOW our climate is changing today with past climate change on Earth helps put today's changes in perspective. But how do we know what past climates and levels of carbon dioxide were? We only have reliable direct measurements of temperature going back to about 1880, and instruments to measure temperature were only invented in the late 1500s. For most of Earth's history, humans were not around to measure or record temperature, rainfall, or carbon dioxide.

Ice core section from Clark Glacier, Antarctica, photo by Emily Stone, National Science Foundation

Luckily, nature has provided us with climate proxies: records from the past that preserve Earth's climate history in tree-rings, fossils, sediment, rocks, glaciers, and ice sheets. A proxy is a substitute for something else, and a climate proxy is some chemical, physical, or biological information that substitutes for a direct measurement of climate parameters or carbon dioxide. Scientists can analyze these proxies to extract estimates of Earth's past climate and carbon dioxide

VIEW ONLINE

ACTIVITY

(K-12): Observing leaf edges

Go outside and collect leaves (or photos of leaves) from trees in an area such as your schoolyard or a park. Later, sort them into two groups: ones with smooth edges and ones with toothed edges. Did you find more of one type? Scientists have found that in warmer climates a higher proportion of leaves tend to have smooth edges than have toothed edges. Is that what you found? Do you think you collected leaves in the same way as scientists?

DISCUSSION FOR TEACHERS

Scientists have collected large number of leaves from large numbers of forest trees to figure out whether leaf types are related to climate. Examples of reasons your data might show something different include: you might be missing a lot of trees that grow in your region but aren't in the area where you were collecting; you might be collecting leaves from planted trees that are not native to the area and growing outside of their natural range of climates; you might be collecting leaves in proportions that don't reflect the actual abundance of local trees, for example, if you collected a lot of leaves from just one or two trees.

ACTIVITY

(6-12): Researching leaf proxies

This section of the exhibit talks about leaves, and how in warmer climates a higher proportion of leaves tend to have smooth edges rather than toothed edges. Why is this the case? Do some research and find out scientists' explanations for this phe-

TEACHERS

You can find education resources for sediment cores at:
https://joidesresolution.org/for-educators

DISCUSSION QUESTIONS

SECONDARY SCHOOL

A One thing many of the climate proxies in this section have in common with each other is a way to track time, that is, to know which observations are younger or older in an object or layers of rock. How is time tracked in sediment cores, clam shells, ice cores, and tree rings? How do we know the geological age of those specimens? And why is this important?

DISCUSSION FOR TEACHERS

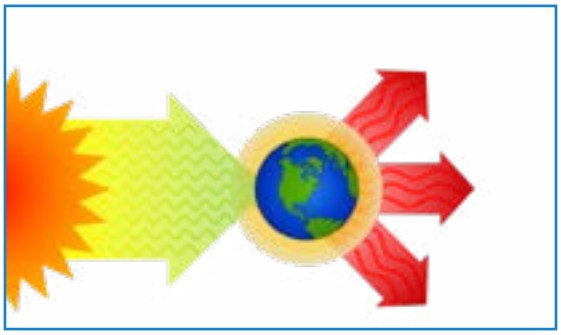
In sediment and ice cores, younger layers are above older layers, but the layers are dated geologically using a wide variety of methods. In most cases, ultimately radiometric dating is responsible for placing actual numerical values on the age. Clams and trees both grow "rings" along their outer edge of the shell and trunk, respectively (of course, the biological processes for doing this are completely different). The oldest part of a tree trunk is at the center, they add rings annually, and the outer ring is the living tissues. The oldest part of the shell is at near their hinge, but the ring-like ridges on the shell surface are not generally annual; microscopic bands of growth we can see in shell cross sections, however, allow us to estimate their annual growth. The geologic age of fossil clams and trees is determined by knowing the age of the rock layer they are found in; since the fossil trees we use for rings are both organic and geological young, we can use ^{14}C directly on the tree material to estimate age.

ELEMENTARY SCHOOL

A Humans have existed for about 300,000 years. Why do we only have reliable measurements of temperature for about the last 150 years?

Understanding the Greenhouse Effect

THIS SECTION explains the greenhouse effect, one of the reasons the Earth's atmosphere is the temperature that it is (the other reason is the distance of the Earth from the Sun.) Understanding the greenhouse effect involves understanding the different forms of radiation that make up sunlight, the concept of energy balance, the chemical composition of the atmosphere, the way that solids and gases absorb, emit, and transmit energy, and what defines temperature. That's a lot to understand, but the exhibit's diagrams and the analogy of a glass greenhouse help to clarify these concepts.



Sunlight and infrared radiation from the Earth, diagram by Alexandra Moore

VIEW ONLINE

ACTIVITY

(6-12): Greenhouse in a Beaker (video and activity)

https://www.priweb.org/science-education-programs-and-resources/teach-climate-science#CO2andTemp

ACTIVITY

(6-8): Infrared Energy (videos and activity)

https://www.priweb.org/science-education-programs-and-resources/teach-climate-science#InfraredEnergy

DISCUSSION QUESTIONS

SECONDARY SCHOOL

A Think about the diagram that showed where human-caused greenhouse gases come from. What are some of the biggest greenhouse gas emitters in your community?

B If there were no atmosphere around the Earth, so no greenhouse effect, our planet would be too cold to support life as we know it. In this sense, we depend on the greenhouse effect in the atmosphere. If we depend on the greenhouse effect, why are we concerned about harmful consequences of the greenhouse effect in the 21st century?

DISCUSSION FOR TEACHERS

Answers might include influence on the natural world of geologically high rates of atmospheric change and the issue of human suffering associated with climate change.

ELEMENTARY SCHOOL

A The Earth's atmosphere contains very small amounts carbon dioxide (0.04%). The planet Venus's atmosphere is the opposite: it is mostly carbon dioxide (96%). Both planets experience the greenhouse effect, but which planet's atmosphere gets heated more from the greenhouse effect?

B Think about the diagram that showed where human-caused greenhouse gases come from. What are some of the biggest greenhouse gas emitters in your community?

Climate Change Affects All of Us

CLIMATE CHANGE affects all of us—people in all countries, and the interconnected web of animal and plant life on Earth. This section of the exhibit shows just a few examples of the impacts of climate change. For each example, it also shows several examples of how we can adapt and become more resilient to current and future climate changes.

VIEW ONLINE

Flooding in Montgomery, NY after Hurricane Irene, photo by Daniel Case (CC BY-SA 3.0)

ACTIVITY

(6-12): Adapting a school to extreme heat

(This activity is from Chapter 9 of The Teacher-Friendly Guide to Climate Change)

Scenario: A school is in a region that is experiencing more intense heat waves, especially during June when classes are wrapping up and students are taking final exams. The school has inadequate cooling systems, and people are concerned about heat-related illness affecting the staff and students. Several students have already been taken to the hospital, suffering from heat stress.

The administration is considering several options to deal with extreme heat. Evaluate the costs and benefits of each option, and come up with a recommendation for what action(s) to take based on this analysis. You can add options that are not listed here.

Options:

1. Install a building-wide central air conditioning system.
2. Install window air conditioners in classrooms, staff offices, the library, and the gym, but not elsewhere in the building.
3. Provide ice water stations in the hallways for students to use in between classes
4. Shorten winter break and spring break so that school can end earlier in May, when heat waves are less likely.
5. Start school two hours earlier, to avoid the afternoon heat.
6. Avoid the afternoon heat by ending the school day earlier, but add school on Saturday to make up for the lost time.

DISCUSSION QUESTIONS

SECONDARY SCHOOL

A What changes have you noticed in the climate in your region, or heard other people talk about?

B What can you do to prepare for climate change, or to help other people prepare?

DISCUSSION FOR TEACHERS

Your municipality may have a climate action plan. Preparations could include building infrastructure to help prevent damage from extreme weather events, heat emergency watch and warning systems, education programs, and more. are found in; since the fossil trees we use for rings are both organic and geological young, we can use 14C directly on the tree material to estimate age.

C Climate change affects some people more than others—this could be because of geographic location, but often it's because of inequalities in income and resources. People who have less income, limited options for employment, or pre-existing illnesses are likely to find it harder to cope when struck by extreme weather events or climate changes that damage their ability to make a living.

At the same time, the citizens of the wealthier countries in the world are responsible for more greenhouse gas emissions that cause warming and climate change, because they use more energy than people in poorer nations.

1 What do you think is the responsibility of the wealthier nations of the world to the poorer nations?

2 How can we ensure that the wealthier nations act responsibly?

ELEMENTARY SCHOOL

A What changes have you noticed in the climate in your region, or heard other people talk about?

B What can you do to prepare for climate change, or to help other people prepare?

We Can Do Something About Climate Change

THIS SECTION focuses on solutions to climate change, with the primary focus on ways to reduce greenhouse gas emissions by using less energy and moving away from burning fossil fuels. In order to make good choices about future energy systems, it's important to understand the ways in which our country currently produces energy. Students can explore an interactive energy map for the U.S. which shows the types of fuels we use to generate electricity, and the greenhouse gas emissions from those sources.

Wind turbines, pixabay.com

In addition, this section emphasizes that every person can take action to reduce greenhouse gas emissions. It helps students learn about actions they can take to reduce climate change, on both an individual and community level. An energy choice quiz for an imaginary home shows students the impacts of their actions.

VIEW ONLINE

ACTIVITY

(3-12): Your carbon footprint

Take the household energy quiz in the exhibit and notice which actions contribute the most to carbon dioxide emissions. What one action could you commit to doing?

ACTIVITY

(6-12): Where does your electricity come from, and how much carbon dioxide does it emit?

Using the energy map, zoom in to your location and find nearby power plants. Which ones emit a lot of carbon dioxide and which ones emit a little or none? What patterns do you notice in the different levels of carbon emissions from different power sources?

DISCUSSION QUESTIONS

SECONDARY SCHOOL

A Individual actions are important, and so are state and national-level actions. Discuss the role of each level of society – individual, family, community, commerce, state, nation – in mitigating against climate change. Which actions are easiest? Which have the biggest impact? How could you persuade one (or more) stakeholders to take action?

B Assume that you are coming up with a new energy and greenhouse emissions plan for your school. Where does you school get its electrical energy now? What other sorts of energy are required for your school to function? What could you do to decrease the energy your school uses and the greenhouse gases it emits?

DISCUSSION FOR TEACHERS

You may wish to go beyond the interactive map in the exhibit, to explore the detailed data of the eia.gov website or the analyses of Project Drawdown.

ELEMENTARY SCHOOL

A Can you think of ways to reduce carbon dioxide emission from your school or your community? What kinds of energy does you school use? Are there ways to reduce the energy your school uses?

Share Your Views on the News

ONE OF THE most important things we can do is talk about climate change. In this section of the exhibit, students will see some news on climate science or solutions, and they can submit their reactions to the news as well as see other people's reactions.

VIEW ONLINE

ACTIVITY

(3-12) Share Your Views on the News

Consider the question at the exhibit's feedback station (in the Museum) or online on the exhibit's Share page, and give a response.

NOTE: If students want their answers to be displayed online, students under age 13 must provide a parent/guardian email address in order for us to ask permission to share the student's response. However, teachers could guide students through this activity in the classroom and just share responses within the class.

DISCUSSION QUESTIONS

ELEMENTARY & SECONDARY SCHOOL

A Why is it important to talk about climate change?

B Who could you talk with about it?

Learn More

THIS SECTION provides more information for those who want to dig deeper. In the exhibit at the Museum of the Earth, students can choose pamphlets on a variety of topics to take home. In the online exhibit, the **LEARN MORE** webpage provides links to resources which students and teachers can explore, view, and/or download.

How could this guide be more useful to you?
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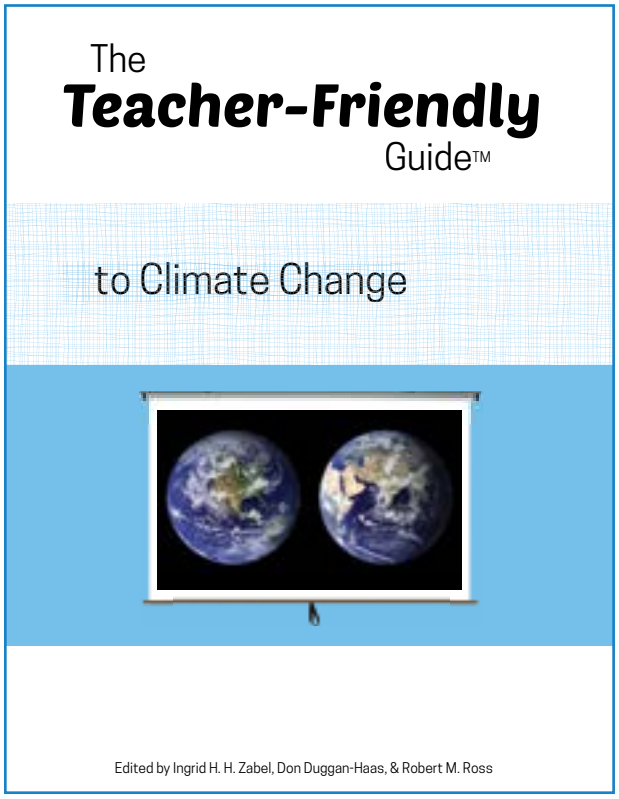

Information and free download here:
https://www.priweb.org/tfgclimate

The Teacher-Friendly Guide to Climate Change is a resource for teachers that includes both the basics of climate change science and perspectives on teaching a subject that has become socially and politically polarized. The focus audience is secondary school Earth science and environmental science teachers, and it is written with an eye toward the kind of information and graphics that a teacher might need in the classroom.

You will also find enhanced chapters from this book on PRI's Digital Encyclopedia of Earth Science on Earth@Home.