

UNDERSTANDING CLIMATE CHANGE & THE ROLE OF NATURE IN CREATING RESILIENCE

Subject Area: Science – Biology, AP Environmental Science

Grade Levels: 9-12

Essential Questions:

- What is climate change?
- What is responsible for climate change?
- How will climate change impact our world?
- What is climate resilience?
- How can we become more resilient in the face of climate change?
- What is the role of nature in increasing climate resilience?
- What can citizens do to make an impact where climate change is concerned?



Conservancy staff, partners, and volunteers work to build the foundation for a living oyster reef shoreline in Alabama

Purpose and Overview:

This lesson is divided in to six parts. In Part 1 of the lesson students use local data to explore the difference between climate and weather and to derive definitions of the two.

In Part 2 of the lesson, students explore common questions about climate change using the EPA’s website as a starting point for researching the questions. Students create a climate change answers wall or story map with their research.

In Part 3 of the lesson, students learn why scientists are calling our present time “The Anthropocene” in a short video. They then explore real data and online, interactives from NASA and NOAA to construct a picture of how humans are changing the Earth while learning about concepts like the Keeling Curve.

In Part 4 students examine how their state will be impacted by climate change by examining various online resources including the States at Risk report card. They will see how their state stacks up against other states in terms of preparedness and can examine in more detail the areas where the state is ill-prepared. They will find climate resilience stories for areas with similar threats and then share the inspirational stories they have found.

In Part 5 students will explore sea level rise under different carbon emission scenarios and look at the impacts in global, coastal cities. They will also learn about a coastal resilience strategy in Florida that uses nature-based solutions to protect cities from storm surge and sea level rise.

Finally, in Part 6 students will explore resources for becoming informed citizens and citizen activists. They will determine their own carbon footprint and describe their strategies for reducing it.

Time:

- Part 1 – One 45-minute class period
- Part 2 – Two to four 45-minute class periods depending on level of presentation
- Part 3 – Two to four 45-minute class periods
- Part 4 – One 45-minute class period
- Part 5 – Two 45-minute classes for parts A and B
- Part 6 – One 45-minute class period

Materials:

Part 1

- Internet, computer for teacher and students
- Projector
- MS Excel or other spreadsheet and graphing software
- Copies of the student handout “Weather vs Climate”

Access to the following websites:

- <http://www.wunderground.com/history/>
- <http://www.ncdc.noaa.gov/cdo-web/datatools/normals>

Part 2

- Internet, computer for teacher and students
- Projector
- Access to the following websites:
 - <http://www3.epa.gov/climatechange/basics/facts.html>
 - Optional - <http://storymaps.arcgis.com/en/#>
 - Optional – Copies of storyboard handout

Part 3

- Internet, computer for teacher and students
- Projector
- Copies of student handout “Humans and the Earth”
- Access to the following websites:
 - <http://www.smithsonianmag.com/science-nature/video-what-anthropocene-and-why-does-it-matter-180957493/?no-ist>
 - <http://climate.nasa.gov/causes/>
 - <http://climate.nasa.gov/interactives/climate-time-machine>
 - <http://www.esrl.noaa.gov/gmd/ccgg/trends/graph.html>
 - <http://climate.nasa.gov/>
 - <http://climate.nasa.gov/effects/>
 - <http://storymaps.esri.com/stories/2015/atlas-for-a-changing-planet/>

Part 4

- Internet, computer, projector for teacher
- Access to the following websites:
 - <http://www.climatecentral.org/states-of-change#/nation>
 - <http://statesatrisk.org/>
 - <https://toolkit.climate.gov/taking-action>

Part 5

- Internet, computer, projector for teacher
- Nature Works Everywhere **Coastal Resilience** video <https://vimeo.com/154663129>
- Access to the following websites:
 - <http://ss2.climatecentral.org/#13/38.8819/-77.0286?show=satellite&projections=0-RCP85-SLR&level=1&unit=feet&pois=hide>
 - <http://choices.climatecentral.org/#12/38.8905/-77.0322?compare=scenarios&carbon-end-yr=2100&scenario-a=unchecked&scenario-b=extreme-cuts>
 - <http://www.nytimes.com/2014/09/24/upshot/flooding-risk-from-climate-change-country-by-country.html?hp&action=click&pgtype=Homepage&version=HpSum&module=second-column-region®ion=top-news&WT.nav=top-news&abt=0002&abg=1>
 - <http://www.carbonmap.org/>
 - <https://toolkit.climate.gov/image/478>

Part 6

- Internet, computer, projector for teacher
- Computer and internet for students is optional
- **New York City's Greenhouse Gas Emissions as One-Ton Sphere of Carbon Dioxide Gas** by Carbon Visuals <https://www.youtube.com/watch?v=DtqSlpIGXOA>
- Carbon Footprint Calculator
 - <http://www3.epa.gov/carbon-footprint-calculator/>
 - http://www.greenprogress.com/carbon_footprint_calculator.php
- TED Talk **Let's prepare for our new climate** by Vicki Arroyo https://www.ted.com/talks/vicki_arroyo_let_s_prepare_for_our_new_climate?language=en
- Center on Congress - Informed Citizen video <http://centeroncongress.org/becoming-informed-citizen>.

Themes:



Oyster reefs, mangroves, and salt marshes provide natural protection from coastal storm surge and reduce flooding.



Reducing our greenhouse emissions will help improve our air quality and slow the rate of climate change.

Objectives:

The student will...

1. Explore common climate change questions and discover their answers.
2. Create presentations using real data and other artifacts to disseminate information about common climate change questions.
3. Describe the difference between climate and weather using real data.
4. Explore resources on climate and describe how ecosystem services will be impacted by climate change.
5. Define the terms “Anthropocene” and “anthropogenic” and describe how they relate to climate change.
6. Explore NASA and NOAA data to determine how humans are shaping the Earth and impacting climate.
7. Identify the trends in their home state’s climate.
8. Research their home state’s climate preparedness and reflect.
9. Explore the concepts of sustainability, climate resilience, and nature-based solutions to climate change.
10. Identify ways to get involved either through personal change and/or community action.

Next Generation Science Standards

Disciplinary Core Ideas:

- ESS2.D: Weather and Climate
- ESS3.C: Human Impacts on Earth Systems
- ESS3.D: Global Climate Change
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS4.D: Biodiversity and Humans
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts:

- Cause and Effect
- Stability and Change

Science and Engineering Practices:

- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Developing and using models

Performance Expectations:

High School

- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate.
- HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of global or regional climate change and associated future impacts to Earth systems.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Common Core Standards

Grades 9-10

- CCSS.ELA-LITERACY.RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- CCSS.ELA-LITERACY.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- CCSS.ELA-LITERACY.RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- CCSS.ELA-LITERACY.RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
- CCSS.ELA-LITERACY.RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Grades 11-12

- CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
- CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- CCSS.ELA-LITERACY.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

AP Environmental Science

- Ecosystem Diversity – Ecosystem Services
- Global Change – Impacts and Consequences of Global Warming, Reducing Climate Change

Vocabulary:

- **Climate:** Long-term changes in the weather of a particular location.
- **Climate Normals:** Created every ten years by the National Climate Data Center in the U.S. These are 30 year averages for variables like temperature and precipitation.
- **Climate resilience:** The ability of a system to absorb stresses imposed by climate change and to maintain its function while adapting and evolving to become better prepared for future climate impacts.
- **Greenhouse gases:** Gases that contribute to the greenhouse effect by absorbing infrared radiation and releasing it back to the Earth's atmosphere. Include carbon dioxide and methane among others.
- **Weather:** The state of the atmosphere at a particular time and location.

Part 1: LEARN - The Difference Between Weather and Climate

Teacher Background

In order for students to fully grasp climate change they must first understand the difference between climate and weather. It is this basic understanding that helps to demystify statements we hear like “We had record snowfall this year! How can there be global warming?”

Essentially, weather is short-term – it represents the conditions of the atmosphere over a short period of time. Weather is made up of sun, rain, clouds, wind, snow, flooding, blizzards, thunderstorms and so forth.

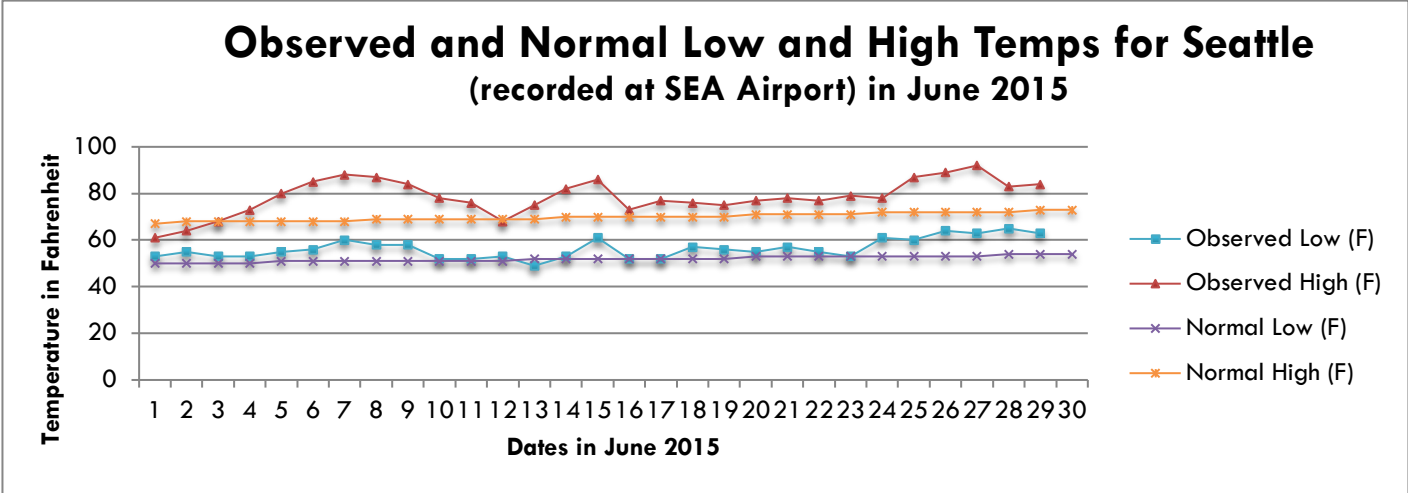
Climate is how the atmosphere behaves over a long period of time. When talking about climate scientists usually refer to the averages of precipitation, temperature, and other factors that occur over a long period of time in a particular place. Climate change refers to changes in these long-term daily averages of weather.

There is a saying on NOAA’s National Ocean Service [website](#) “Climate is what you expect, weather is what you get.” For example, if you live in Boston you might expect it to be cold and snowy in January based on the historical weather data for the last 30 years, which define the climate for the area. However, there could be a day in January where it’s 75 degrees Fahrenheit. That would be the weather for the day and would most likely be considered an anomaly based on historical trends.

In this activity, students will explore their local weather and climate using data obtained from Weather Underground and the National Weather Service (NWS). Note that Weather Underground is being used the daily highs and lows because the National Weather Service local weather data comes in a variety of formats for each city. Weather Underground is more uniform in its presentation of this information. Climate Normals will be obtained from NWS.

Suggested Flow

1. You can increase or decrease the complexity and amount of interactivity of this lesson depending on the resources available to you. At minimum, you can use the example graph for Seattle, Washington below (a larger, projectable image is on page 8) to start a dialogue on weather and climate. The data for this graph is on page 9.



2. If you use the Seattle example – ask students the questions below. Answers are in red.

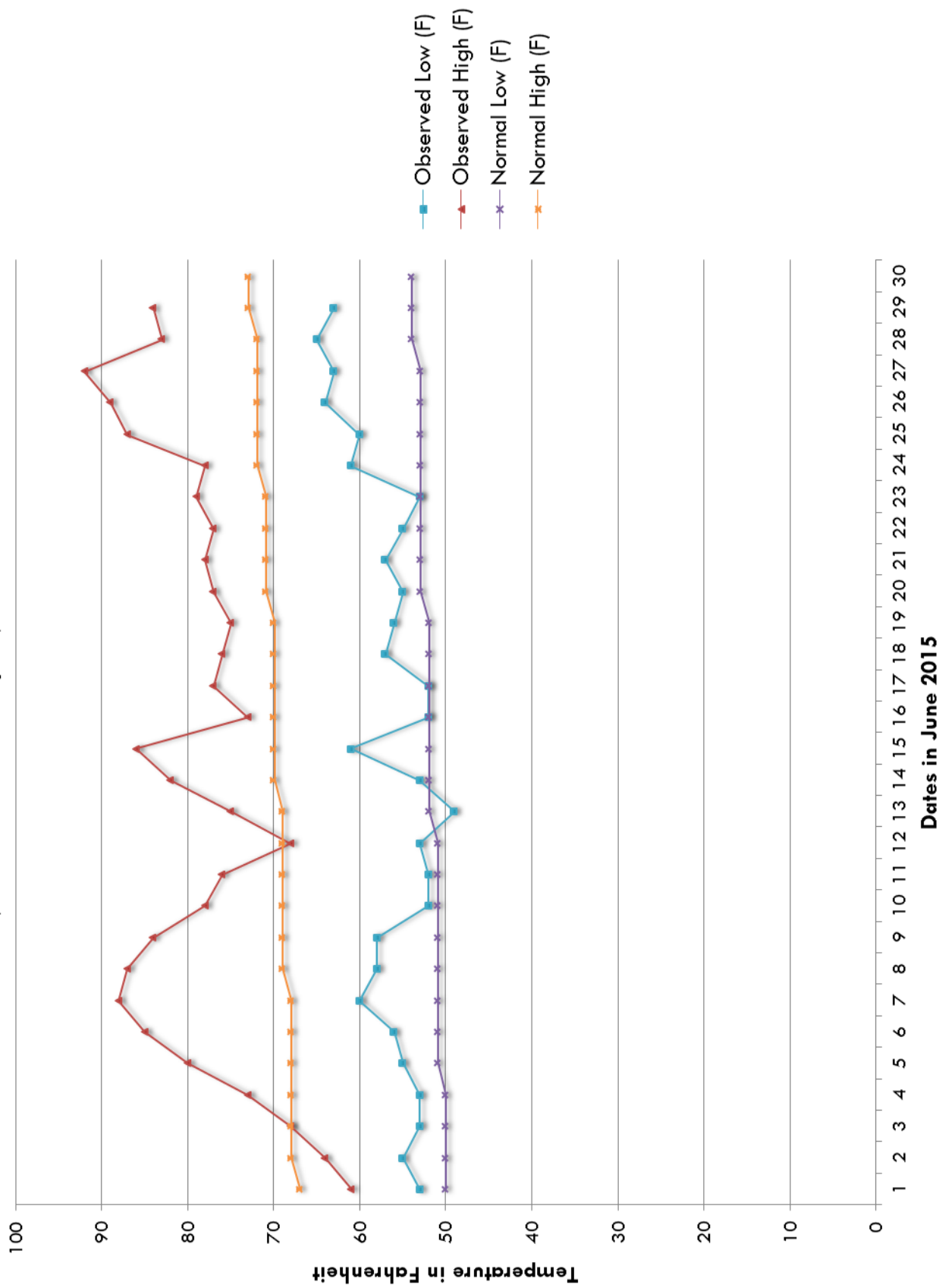
Student Questions:

- a. Which line on your graphs is more variable? The line for the observed temperature or the line for the climate normal? Explain why you think one is more variable than the other.
The observed temperature is more variable because it's one fixed point in time whereas the Climate Normals are 30 year averages and are less extreme because they are an average of several temperatures including abnormally high and low temperatures as well as more typical temperatures for a region.
- b. Based on the information in your graph, provide a definition of weather and a definition of climate.
Weather is what's happening on a particular day in a particular location. Climate takes into account the weather for a region over a long period of time. In this case, Climate Normals represent 30 years of data for a location.
- c. Can you make any conclusions about climate change in your region based on one month's weather data?
Absolutely not. It is too short of a period of time.
- d. If you hear on the news that this year was warmer than last year, what kind of information do you need to have to determine if the climate in your region is actually changing?
You need to look at historical records for several years to see this type of departure from normal appears to be a trend.
- e. What kind of information do you need to have to determine if the global climate is changing?
You need to examine historical weather data from around the world to see if global average temperatures depart from normal over a longer period of time.
3. Alternatively, to increase local relevance, you can follow the steps on the student handout to create a local graph for your city and share it with your students for discussion. With time and technology allowing, you can have your students follow the steps on the handout 'Weather vs. Climate' and create their own data table and graph for the locations, weather data, and time period of your choice. They can use graph paper or MS Excel for the exercise. A blank data table is provided on page 4 of the student handout if they do this activity on paper. If they use MS Excel, they can cut and paste the data into MS Excel file.
4. No matter which approach you take, you should follow up with a discussion of the data using the questions on the student handout, which are the same as those in step 2 a-e. There is no answer key provided for your local area, but the student answers will be similar to those above.

Additional Resources:

- Weather Shift – Interactive web tool shows local weather and trends including temperature and precipitation by zip code
<http://wxshift.com/climate-change/local>

Observed and Normal Low and High Temps for Seattle (recorded at SEA Airport) in June 2015



Example Data Table for Seattle:

DAY	Observed Daily Temperature (°F) in June 2015 - Seattle		Climate Normals (°F) for June - Seattle	
	MIN	MAX	MIN	MAX
1	53	61	50	67.4
2	55	64	50.2	67.6
3	53	68	50.3	67.7
4	53	73	50.4	67.9
5	55	80	50.6	68
6	56	85	50.7	68.2
7	60	88	50.8	68.3
8	58	87	50.9	68.5
9	58	84	51.1	68.6
10	52	78	51.2	68.8
11	52	76	51.3	69
12	53	68	51.4	69.1
13	49	75	51.6	69.3
14	53	82	51.7	69.5
15	61	86	51.8	69.7
16	52	73	51.9	69.8
17	52	77	52.1	70
18	57	76	52.2	70.2
19	56	75	52.3	70.4
20	55	77	52.5	70.6
21	57	78	52.6	70.8
22	55	77	52.7	71
23	53	79	52.9	71.3
24	61	78	53	71.5
25	60	87	53.1	71.7
26	64	89	53.3	71.9
27	63	92	53.4	72.2
28	65	83	53.6	72.4
29	63	84	53.7	72.6
30	59	87	53.8	72.8

Part 2: LEARN – Common Climate Change Questions

1. The first part of the activity can take place in the classroom if students have access to computers or it can be assigned as group homework. The end goal of this activity is to create a “climate change answers” wall where each group provides a synopsis of the main answer to their question and then 2-3 artifacts that support their answer. These artifacts could be in the form of charts, graphs, images, maps, and/or additional short narratives based on research. In a classroom with computer access, teachers have the option of assigning the creation of a story map for students to display their answers. Classrooms without computer access can literally create a wall of answers with the artifacts. See instructions in step 6 for the story map creation option.
2. Place students in groups of 2-3 and assign the groups two questions from the EPA Climate Change website to research further. The questions addressed in detail on the website are:
 - Is there scientific consensus on climate change?
 - What is the evidence that proves the climate is changing?
 - Are human activities or natural variations in climate responsible for the climate change being observed today?
 - Is climate change influenced more by human activities and excess greenhouse gases or changes in the sun’s energy?
 - How can carbon dioxide hurt us?
 - How can a change of one or two degrees in global average temperatures have an impact on our lives?
 - Do a few extra cold or snowy winters in your hometown mean that climate change is not happening?
 - How does water vapor in our atmosphere contribute to global warming?
 - Do emissions of carbon dioxide from human activities have a big impact on Earth’s climate?
 - In the past, has Earth been warmer than it is today? If so, does that mean we shouldn’t worry about global warming?
 - Is the hole in the ozone layer related to the climate change we are seeing today?
 - Will a small rise in sea level affect people (even in the United States)?
 - Are the temperature records showing that global warming is happening reliable?
 - Is it too late to do anything about climate change?
3. Have students begin by going to the EPA Climate Change website (<http://www3.epa.gov/climatechange/basics/facts.html>) to find their assigned questions and begin gathering information about the answers. Remind them that this is just the starting point for their research – they must find 2-3 more artifacts online from reputable science sources to support the answers.
4. After students have finished their research and created their artifacts (either physically or in a story map) have them do short presentations of their products.
5. While students are presenting, the viewers should take note of the facts that most surprised them or that they found interesting and wish to know even more. The other parts of this lesson plan will explore some of the concepts more and you can select activities based on student interest or use some of the resources for further investigation, which are divided out by topic to create your own explorations.

6. If you choose to have students design a story map using Esri's platform, you can go here to have them create accounts: <http://storymaps.arcgis.com/en/#>

Students should choose the option to “create a free non-commercial public account to ArcGIS Online” which they will use to sign into the story map platform. The story map tutorial is a great resource that walks users through account set-up and story map building and sharing. The tutorial is located here:

<http://www.arcgis.com/home/item.html?id=d4a2705a8b224e71961404542ae94c6f> is

Examples of award-winning story maps can be found here:

<http://www.esri.com/landing-pages/story-maps/contest-winners>.

If you have students create a story map, it can be useful to have them storyboard out their map by on a three column chart where they type the text in the left column, images URLs or citation information, and URLs for clickable in text links to direct the reader to another website for more information on a topic. A storyboard template is included below.

Story Map Text	Images with URLs or Citation Information	URLs for In-text Links

Additional Resources:

General Educational Resources about Climate:

- Climate Interpreter – A website with Educational Resources on Climate Change
<http://climateinterpreter.org/>
- NASA Climate Quizzes
http://climate.nasa.gov/climate_resources/96/
- Materials for Debates: Pro and Con Arguments For and Against Anthropogenic Climate Change
<http://climatechange.procon.org/>

Part 3: EXPLORE – How have humans changed the Earth?

1. Show students the Smithsonian produced video *What is the Anthropocene and Why Does it Matter?* (3:14) found here: <http://www.smithsonianmag.com/science-nature/video-what-anthropocene-and-why-does-it-matter-180957493/?no-ist>
2. The short animation explains why scientists think that we are entering a new chapter in Earth’s history called “The Anthropocene”. After the video concludes, have students summarize the reasons given for giving this time period the name “Anthropocene”. Possible answers may include:
 - rise of fossil fuels
 - industrialization of agriculture
 - urbanization
 - changing landscape by decreasing forest cover and clearing fields
 - damming rivers
 - mining
 - emissions
 - animal extinction rates are higher than before humans
3. The video ends with an important question – “what do we want our future too look like?” Pose this question to students and discuss before moving onto the next section.
4. Distribute the student handout “How Have Humans Changed the Earth?” (below) Students can complete the rest of this activity individually or with a partner or it can be completed for homework. In this activity, students will explore NASA’s Climate Time Machine and actual atmospheric CO₂ data from NOAA to see for themselves how humans have shaped the Earth. The answer key is on pages 13-19.

Additional Resources:

Visualizations and Maps:

- Anthromes: The Global Ecological Patterns Created by Humans
<http://ecotope.org/anthromes/maps/>

Articles:

- City Dwellers have lower carbon Footprint
<http://www.theguardian.com/environment/2009/mar/23/city-dwellers-smaller-carbon-footprints>
- Hot Times, Summer in the City: Understanding the Urban Heat Wave
<http://blog.nature.org/science/2015/07/15/hot-times-summer-in-the-city-understanding-the-urban-heat-wave/>
- Humanity’s Coming of Age on Earth
<http://www.npr.org/sections/13.7/2015/12/08/458825867/childhood-s-end-the-planetary-meaning-of-climate-change>

How Have Humans Changed the Earth?

Student Handout – Teacher Answer Key

Scientists have proposed that we have entered a new era – the Anthropocene. They have named it as such because this era is defined by how humans have affected the Earth. In this activity, you will explore the ways in which human activities have shaped the Earth.

The Greenhouse Effect

1. Visit the web page <http://climate.nasa.gov/causes/> and read about the greenhouse gas effect. Explain how the greenhouse gas effect contributes to climate change.

The greenhouse gas effect is when a layer of greenhouse gases acts as a thermal blanket for the Earth. The sun's light normally passes through the atmosphere, warms the Earth's surface and is then radiated back out to space. But when the layer of greenhouse gases is thicker, it traps the sun's heat in the lower atmosphere and creates a warming effect.

2. List the gases that contribute to the greenhouse effect and describe their sources.
 - Nitrous oxide (N₂O): comes from use of fertilizer, fossil fuel combustion, nitric acid production, and biomass burning
 - Carbon dioxide (CO₂): released through natural processes (respiration, volcanic eruption), deforestation, land use changes, burning of fossil fuels
 - Water vapor (H₂O): increases when Earth's atmosphere warms, most abundant greenhouse gas, has a feedback effect – more water vapor can mean more precipitation
 - Methane (CH₄): decomposition of wasters, agriculture (especially rice), ruminant digestion and livestock manure
 - Chlorofluorocarbons (CFCs): industrial compounds

Carbon Dioxide

3. Go to NASA's Climate Time Machine <http://climate.nasa.gov/interactives/climate-time-machine> and open the "Carbon Dioxide" viewer. Play the video or drag the slider to see how the Earth's CO₂ levels have changed between 2002 and 2014. Describe the trend that you observe in CO₂ concentration over time. Also compare and contrast what you observe between the Northern and Southern Hemispheres of the Earth as well as between different seasons.

Over time the global levels of CO₂ increase. In most parts of world, in 2002, levels are around 365-380 ppm. Around April 2005, the Northern Hemisphere has levels between 385-395 ppm. Levels continue to increase, especially in the Northern Hemisphere but by around March 2006 the Southern Hemisphere also sees CO₂ levels nearing 395 ppm in some places. There is some seasonal variation in the Northern Hemisphere where there appears to decrease of CO₂ in the summer months and subsequent increases in the winter months. By March and April of each year, the level seems to be the highest in the Northern Hemisphere. Overall, the levels of CO₂ seem to fluctuate the most significantly and reach the greatest extremes in the Northern Hemisphere. By April 2009, levels appear to be reaching 400 ppm and even higher in the Northern Hemisphere close to the pole.

Levels of CO₂ appear to decrease throughout the summer months (N. Hemisphere) and then by March 2011, levels increase in spots. Globally, by this time, few places in the world appear to have levels below 385 ppm. By April 2011, over North America and Greenland, levels have reached upwards of 405 ppm. By May 2014, most parts of the world show levels above 400 PPM.

4. Why do you think there is a difference between the levels of CO₂ between hemispheres during different seasons?

For hints, check out these resources:

- Science Bulletin: “Earth’s Green Carbon Machine” by the American Museum of Natural History: <https://www.youtube.com/watch?v=geR2KsF53y4>
- Earth’s Green Carbon Machine Backgrounder: <http://www.amnh.org/content/download/43544/660599/file/Earth's%20Green%20Carbon%20Machine%20Backgrounder.pdf>
- Article “Why are Seasonal CO₂ Fluctuations the strongest at Northern Latitudes”: <https://scripps.ucsd.edu/programs/keelingcurve/2013/05/07/why-are-seasonal-CO2-fluctuations-strongest-in-northern-latitudes/>

The Northern Hemisphere has more vegetated land mass than the Southern Hemisphere. Regions with more plants experience greater fluctuations with seasonal CO₂ swings. In the Northern Hemisphere in particular (compared with equatorial regions), the seasonal temperature fluctuations that result in very dramatic differences in plant photosynthesis from summer to winter cause the CO₂ fluctuations to be even more pronounced.

During the summer months in the Northern Hemisphere, plants grow and flourish and absorb carbon from the air. When plants aren’t growing, they release carbon. Atmospheric carbon is lowest during the summer “green-up” phase and this summer growth begins to fade, atmospheric carbon reaches its highest level. When it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere but since there is less vegetation in the Southern Hemisphere, less carbon is absorbed during its summer months compared to the Northern Hemisphere, thus carbon levels don’t appear to decrease much during this time.

Mauna Loa CO₂ Measurements

The graph at the right shows a portion of CO₂ data recorded at Mauna Loa Observatory in Hawaii and represents part of the “Keeling Curve”.

Charles Keeling was a scientist famous for his work measuring the amount of CO₂ in the atmosphere. He began taking these measurements in California and later expanded his network of monitoring stations worldwide.

The monitoring station at Mauna Loa Observatory in Hawaii is significant because it has been measuring CO₂ since the 1950's and has the longest continuous record of measurements. This location is considered to be ideal for measuring CO₂ because of its distance from large population centers and the prevailing winds on the island blow from land to sea, so the effects from local vegetation are minimized.

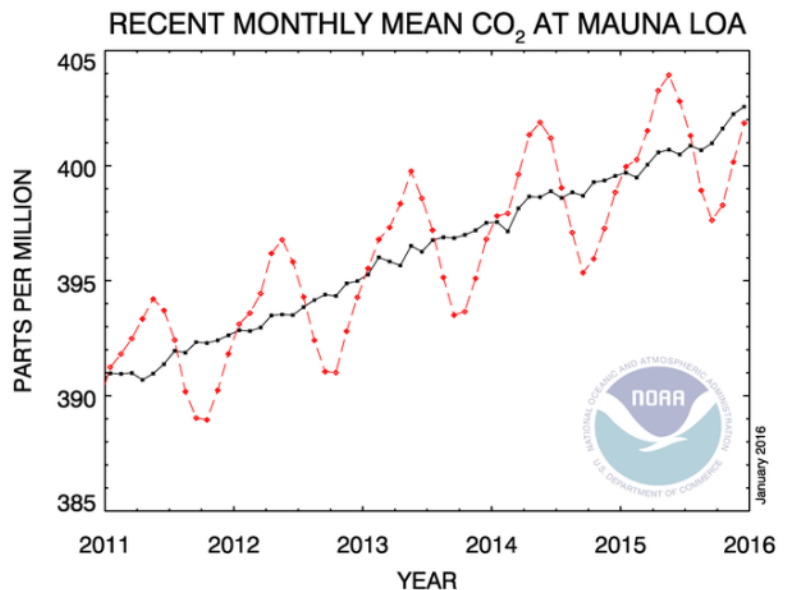


Image credit: [NOAA Earth Systems Research Lab](#)

The red line on the graph represents the actual measurements and the black line indicates the trend.

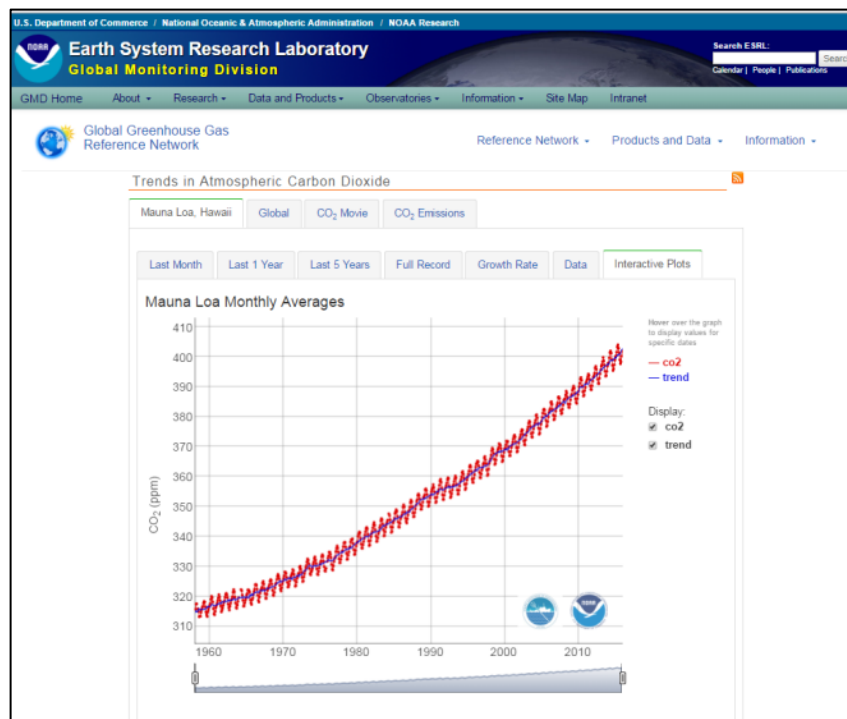
5. Relate the data you see in the graph to your observations in questions 3 and 4. Do these data confirm that there are seasonal fluctuations in CO₂?

Yes, the red line fluctuates seasonally with the highest points in any year occurring in around May-July (summer in N. Hemisphere) and the lowest points occurring around November-December (winter in N. Hemisphere).

6. What does the trend line in the graph above indicate about CO₂ levels?

The trend line shows that though monthly means may fluctuate throughout the year, the overall trend is an increase of CO₂ as the years progress.

Go to the interactive version of the Keeling Curve here (screenshot shown below):
<http://www.esrl.noaa.gov/gmd/ccgg/trends/graph.html>



Use the interactive version to examine the CO₂ month/year data by mousing over the dots on the graph. Make sure you are on the “Mauna Loa, Hawaii” tab and the “Interactive Plots” tab as pictured in the screenshot below. You can also use the slider at the bottom to zoom in on a decade.

7. Describe the trend line from 1960 to present.
The trend line for this time period indicates an increase in CO₂ from 1960 until present.
8. Now click on the tab “CO₂ Movie” and play the short video (3:44) and answer the questions below.

What does this animation depict? *In the beginning, the animation shows atmospheric CO₂ measurements taken at Mauna Loa and South Pole Stations between the years 1979-2014, it also includes Keeling data taken from 1958-1979. It works back in time and shows data from ice cores and concludes with data taken from the Vostok ice core.*

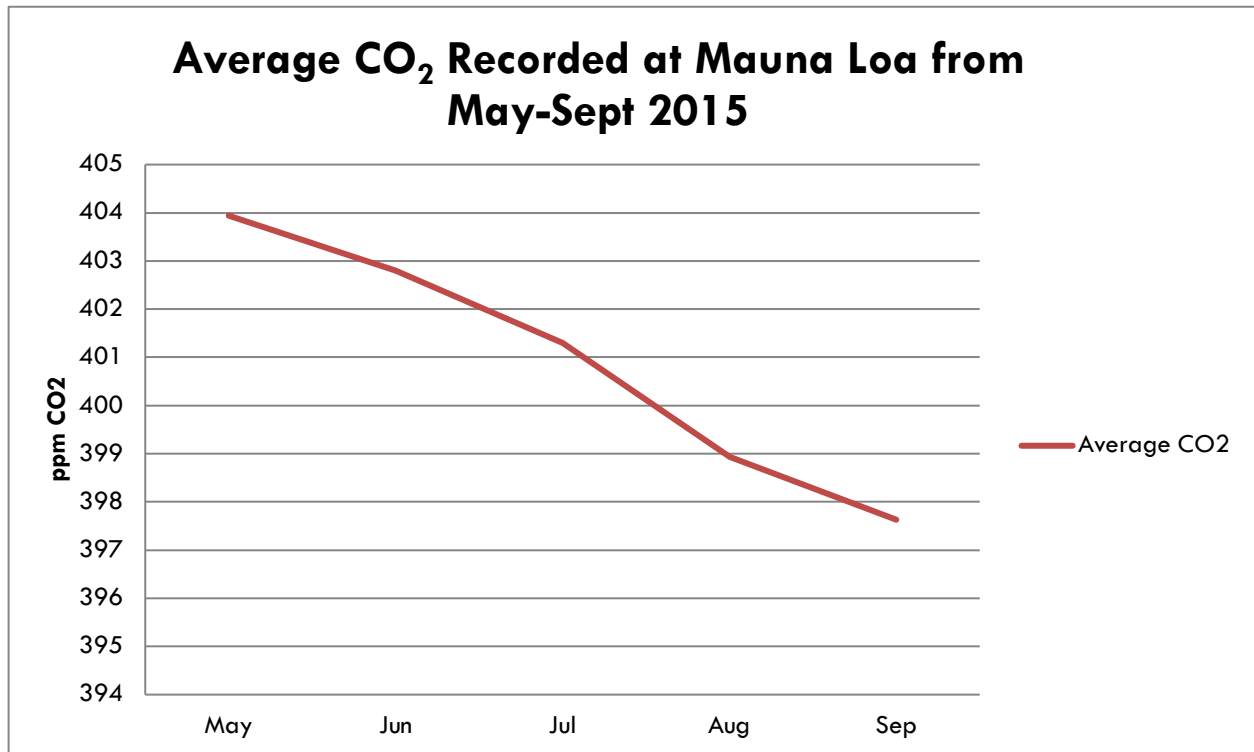
How far back in time does it go? *880 kyBCE, which is 800,000 years before the Common Era*

Where are these ancient measurements obtained? *Ice cores*

What is the highest level of CO₂ recorded in ppm? What is the lowest level on record?
The highest level recorded is 398 ppm and the lowest level is during the Ice Ages at 185 ppm.

9. Why is the information in the CO₂ movie graph important for us to understand?

Ice core data goes back to a time before humans evolved. Homo sapiens first appeared on Earth around 200,000 years ago and the industrial revolution began to happen around the 1760's. Ice core data from 800,000 years before the Common Era shows what the Earth was like when it was untouched by humans. Pre-industrial levels of CO₂ were about 278 ppm. Since the industrial revolution, levels of CO₂ have continued to climb.



Graph made from data obtained from [NOAA ESRL](http://noaa.esrl.noaa.gov/mlo/cdr/)

10. In the graph above, you can see the average CO₂ recorded at Mauna Loa for the months of May-September 2015. Why would it be inappropriate to examine such a short period of time if your goal was to understand a larger trend in CO₂ levels? What kind of biological event does this graph capture?

CO₂ data viewed at such a short time scale can easily be misconstrued to show a decrease. However, when a larger time scale is observed, the yearly trends are unmistakable. The decrease in CO₂ levels shown in this graph indicate the increased levels of photosynthesis of plants in the Northern Hemisphere during the summer months.

NASA's Vital Signs of the Planet and Climate Time Machine

11. Go to NASA's Vital Signs page (<http://climate.nasa.gov/>) and record the carbon dioxide levels for the present day and the global temperature rise since 1880.

As of the time of this writing, the CO₂ level was 402.56 parts per million and the global temperature rise was 1.4 degrees Fahrenheit (0.8 degrees Celsius)

12. Go to NASA's Climate Time Machine <http://climate.nasa.gov/interactives/climate-time-machine> and open the "Global Temperature" viewer. On this visualization, what do white, dark blue and dark red areas signify? Describe the general trend in global surface temperature between 1884 and 2014.

Dark blue shades signify areas cooler than average, dark red shades indicate areas warmer than average and white indicates no departure from the average temperature. While some areas show no departure from average and some areas appear cooler than average, the trend over time is an increase in areas that are warmer than average.

13. In question 11, you noted the Earth's average global temperature rise since 1880. It may seem like a small amount – but even a small temperature change can be significant. Visit NASA's Vital Signs page at <http://climate.nasa.gov/effects/> and describe why this small change is significant.

It is significant because even 1 degree is an unusual event in the Earth's recent history. Tree rings, ice cores, and corals reefs show that the global average temperature has been fairly stable over long periods of time. Small changes in temperature can lead to massive changes in the environment. During the last Ice Age the average temperatures were only 5-9 degrees cooler than today, but the Northeastern U.S. was covered in more than 3,000 feet of ice.

14. What are some of the long-term effects of climate change described by the Vital Signs of the Planet website (<http://climate.nasa.gov/effects/>)?

- *Temperatures will continue to rise*
- *Growing season will lengthen*
- *Precipitation patterns will change – in some areas there will be a decrease, in some an increase*
- *More intense weather – hurricanes stronger, more droughts and heat waves*
- *Sea level rise*
- *Ice melt in the Arctic*

15. In which part of the US do you live? What are the U.S. regional effects of climate change currently visible for your area (<http://climate.nasa.gov/effects/>)?

Answers will vary by region.

- *NE: Heat waves, sea level rise, heavy rains, infrastructure/agriculture/fishing compromised*
- *NW: streamflow timing changes reduce water supplies, sea level rise, erosion, flooding, ocean acidification, wildfire, insect outbreaks, tree disease causing die-off, infrastructure risks*
- *SE: sea level rise, extreme heat, decreased water availability*
- *Midwest: extreme heat and heavy downpours and flooding affecting infrastructure/health/agriculture/forestry/transportation as well as air and water quality*
- *SW: increased heat and drought, insect outbreaks, wildfires, decreased water supplies, reduced agricultural yields, flooding, and erosion in coastal areas*

A Changing Planet

16. Go to <http://storymaps.esri.com/stories/2015/atlas-for-a-changing-planet/> and explore the Esri story map called *Atlas for a Changing Planet*. Describe some of the other ways that humans are changing our planet that haven't been discussed previously. Note that you can zoom in, click, and move around the maps on the right hand side.

- *Land cover is changing over time – there is widespread forest loss throughout the world*
- *Population density is increasing and cities are becoming bigger*
- *Ocean acidification is increasing, which can impact coral reef ecosystems*

17. Explore the Modeling Temperature and Precipitation Scenarios in the story map. These models were created by scientists to make projections about what the Earth's climate would be like under different scenarios ranging from "business as usual" models where humans don't try to decrease greenhouse gas emissions to scenarios with aggressive greenhouse gas emissions reductions. The three models in the story map are listed below with the assumptions that the models are based upon:

- 2.6 Greenhouse gas emissions peak between 2010-2020 followed by a steep decline
- 6.0 Greenhouse gas emissions peak around 2080 and then decline
- 8.5 Greenhouse gas emissions continue to increase through the 21st century

Zoom into the map and try to find your approximate location and click on it for each of the scenarios. When you click, a box will pop up and indicate the predicted temperature change for that location by 2050. For each scenario write the temperature change for your location in degrees Celsius, convert to Fahrenheit, and include the annual change in precipitation found in the next series of models in the story map.

Answers will vary; the example given is Washington, DC.

Scenario 2.6: *2.1 degrees Celsius (3.68 °F), 3 mm annual change in precipitation*

Scenario 6.0: *2.0 degrees Celsius (3.5 °F), 9 mm annual change in precipitation*

Scenario 8.5: *3.3 degrees Celsius (5.78 °F), 10 mm annual change in precipitation*

18. Based on the information you obtained from the models, under which scenario do you think your city will fare the best as we move into the future?

Answers may vary, but students will likely choose scenario 2.6. In the case of Washington, DC the temperature increase between scenarios 2.6 and 6.0 wasn't that drastic, but the change in precipitation is much greater for 6.0. This increase in precipitation could cause flooding and greatly affect the city's infrastructure.

19. Given that climate change affects the entire world, what are some of the ways that countries are cooperating to work towards a better future? Explore the story map some more and note these below.

- *There are international climate meetings like the COP21 in Paris in 2015*
- *There's the Kyoto Protocol which commits governments to reduce greenhouse gas emissions (though the US and Canada are not full participants)*

Additional Information:

Data:

- For more information on ice cores, their locations, and how the data was obtained, check out the Carbon Dioxide Information Analysis Center's website:
http://cdiac.ornl.gov/trends/co2/ice_core_co2.html
- The Complete Mauna Loa CO₂ records for download
<http://www.esrl.noaa.gov/gmd/ccgg/trends/data.html>
- Article: Human Impact Has Pushed Earth Into the Anthropocene
http://www.climatecentral.org/news/earth-pushed-into-the-anthropocene-19895?utm_content=buffereee7c&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

Interactives:

- Global Top 10 Greenhouse Gas Emitters Data Explorer
<http://www.fastcoexist.com/3048259/visualizing/what-and-who-are-actually-causing-climate-change-this-graphic-will-tell-you>
- CAIT Climate Data Explorer – Historical International Greenhouse Gas Emissions Tool
<http://cait.wri.org/>
- Carbon Map - The interactive maps on this site convey how countries fit into the climate change picture by using cartograms, which are maps that are distorted to reflect a specific dataset.
<http://www.carbonmap.org/>
- Carbon Emissions Past, Present, and Future – Shows how CO₂ emissions have changed over the past 150 years for different countries.
<http://www.wri.org/resources/data-visualizations/carbon-emissions-past-present-and-future-interactive>

Visualizations and Maps:

- World-wide Fossil Fuel Consumption
https://www.youtube.com/watch?v=RejAjfRkVuc&list=UUYJx-uToE_5NYUPwj2PJLLA&feature=iv&src_vid=1cOKfxShPMc&annotation_id=annotation_812605903

Part 4: How Will My State Be Impacted by Climate Change?

1. If possible use a projector and computer for this next exercise. Go to <http://www.climatecentral.org/states-of-change#/nation> and click on your state. Discuss the few “quick facts” about your state with students. This screen also shows a pie chart with electricity sources for your state. It may be interesting for students to note from where the majority of their state’s power comes.
2. Next go to <http://statesatrisk.org/> and look up your state’s report card by clicking on it. Make a list with students of the areas where your state excels and a list of those areas in which your state received a low grade. Explore each area by clicking on the letter grade. Note how many people are vulnerable or at risk where appropriate.
3. Have students choose a focus area from the areas that were graded (extreme heat, drought, wildfires, inland flooding, and coastal flooding) and then search using the U.S. Climate Resilience Toolkit (<https://toolkit.climate.gov/taking-action>) for examples of how other communities have developed resilience plans to mitigate these problems. Students can filter by region on this site, but it may be more useful to filter by climate threat/stressor first so that they can focus on the particular threat identified in States at Risk. If they can’t find enough information for their chosen threat, suggest that they browse the stories for something that they find inspirational.
4. Once students have identified their story of resilience, have them write a summary of how the location is developing climate resilience. You may wish to have them share their summaries with the class.

Additional Resources:

Data

- EPA State and County Emission Summaries
<http://www3.epa.gov/air/emissions/where.htm>

Part 5: Rising Seas and Coastal Resilience

A. Rising Seas – Background:

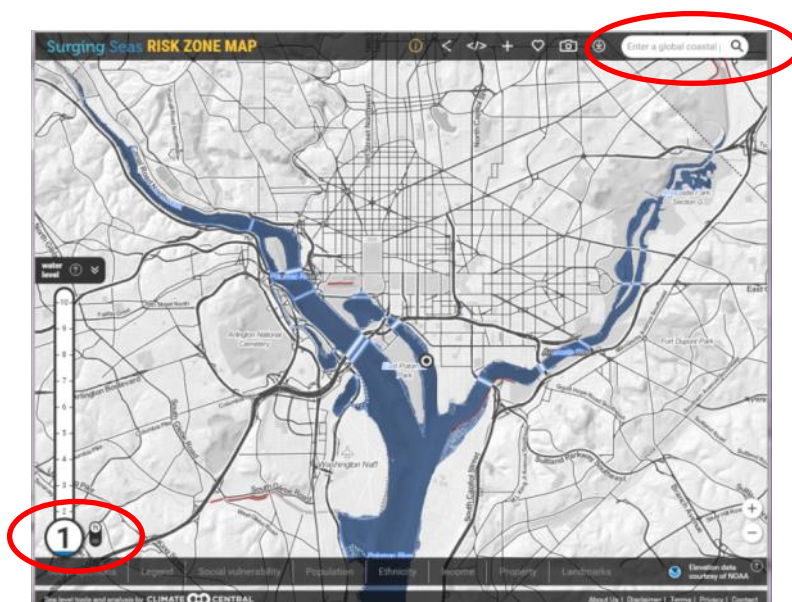
Since 1880, our changing climate has led to a global sea level rise of about 8 inches and recent research indicates that sea levels have been rising at a rate of 0.14 inches per years since the 1990's. Sea level rise greatly increases the risk of flooding for coastal cities.

Global climate change is the driver behind the melting of glaciers, ice loss in the Arctic and Antarctic, and thermal expansion and all of these factors are all contributing to our rising seas. This activity allows students to investigate a coastal community of their choice (preferably there home city if you are in a coastal area) and examine how rising seas will impact the community. They will also examine the impact of different carbon emissions reduction scenarios on sea level rise.

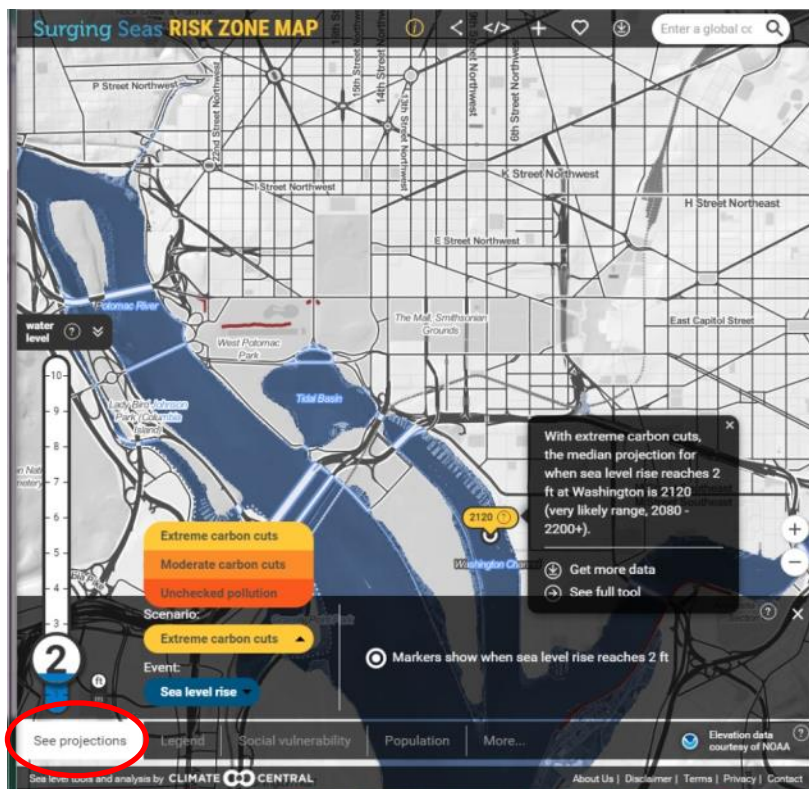
While the maps of flooding can be disturbing, it's important to note that we are at a crossroads where changes that we make now will greatly impact our future. These models bear witness to the effects of our decisions on the planet.

Suggested Flow:

1. For a deeper examination on how sea-level rise will impact our coastal cities, have students explore the websites that follow. You can project this information and work through it with students or if they have computer access, they can explore on their own. If you live in a coastal area, have students investigate their home area as well as taking a global look at sea-level rise. If you don't live in a coastal area, you can explore Washington, DC, which will appear when you click on the links below, or you can choose another global location.
2. Go to <http://ss2.climatecentral.org/#13/38.8819/-77.0286?show=satellite&projections=0-RCP85-SLR&level=1&unit=feet&pois=hide> and enter a global coastal city in the top right box. See screenshot below.

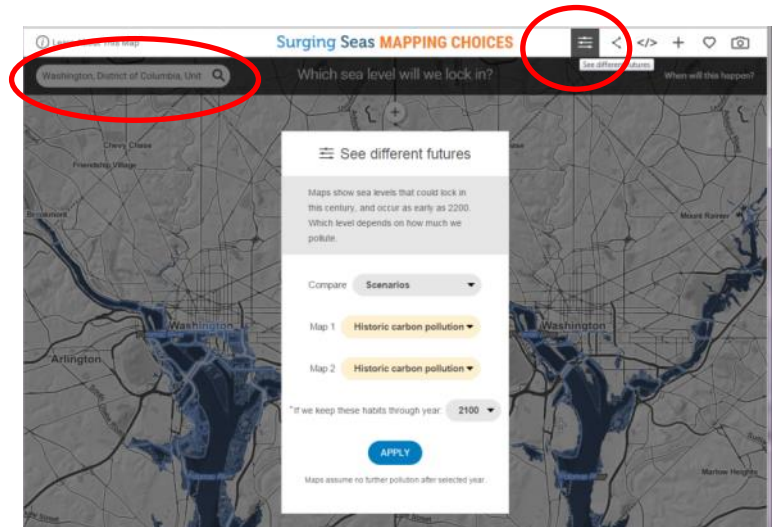


- You can use the slider on the bottom left to raise the water level in your city. You can also select units (feet or meters) as appropriate. Move the slider up one foot at a time and then have students reflect on how much your chosen city will be impacted.
- Have students make a list of infrastructural things to look for and zoom in on the map to see if those areas will be impacted and at what sea level rise will they be affected. At the bottom of the map, you can choose between “social vulnerability,” “ethnicity,” “income,” “property,” and “landmarks.” Clicking on landmarks will help pinpoint infrastructural locations like schools, hospitals, fire and police stations, government buildings, places of worship, cultural centers and more.
- Now toggle between population, ethnicity, income, and property and note the populations that will be affected have students draw conclusions about the level of impact on their communities.
- Click on “see projections” at the bottom of the screen (screenshot below). Make sure the event is set to “sea level rise” and then choose different scenarios. Obviously, the best scenario would be that the sea level doesn’t rise, but under our current greenhouse gas emissions, sea level rise is inevitable. The choices we and our elected officials make will determine where our planet is headed.
- Set the water level rise that you think your community can endure based on the impacts you noted in the previous steps and then choose click on each of the scenarios listed. The model will show you the median projection year for when the sea level will rise to the amount you picked on the slider. For example, in the screenshot below, 2 feet was chosen for the water level rise and extreme carbon cuts were chosen for the scenario. The model indicates that this level will likely be reached by 2120.



8. Note that the scenarios on the Surging Seas maps align with those presented in the [Atlas for a Changing Planet](#) story map used in Part 2 of this lesson. These scenarios are based on sea level rise projections from recent peer-reviewed research, which builds off of global projections from the Intergovernmental Panel on Climate Change. Read more about the panel here: <http://www.ipcc.ch/organization/organization.shtml>
 - **Scenario 2.6:** Extreme Carbon Cuts
 - **Scenario 4.5:** Moderate Carbon Cuts (not used in the Atlas)
 - **Scenario 6.0:** Minor Carbon Cuts
 - **Scenario 8.5:** Unchecked Pollution
9. To see the scenarios represented side by side, go to Climate Central's Surging Seas <http://choices.climatecentral.org/#12/38.8905/-77.0322?compare=scenarios&carbon-end-yr=2100&scenario-a=unchecked&scenario-b=extreme-cuts>

10. Enter the name of a coastal location in the box on the top left (see screenshot below). The default sea level rise that will appear on the left map is for “unchecked pollution” and the map on the right the default scenario is “extreme carbon cuts”. Choose other scenarios to view the side by side comparison.



11. To explore how the world population will be affected under different emissions scenarios, check out this graphic from the New York Times <http://www.nytimes.com/2014/09/24/upshot/flooding-risk-from-climate-change-country-by-country.html?hp&action=click&pgtype=Homepage&version=HpSum&module=second-column-region®ion=top-news&WT.nav=top-news&abt=0002&abg=1>. This interactive graphic shows the share of population expected to be exposed to regular flooding by 2100.
12. Have students reflect on the parts of the world that will be most impacted by sea level rise. Are these developing nations? Do they have the resources to deal with the results of climate change? You might refer students to the interactive carbon map found at <http://www.carbonmap.org/> and have them determine who bears the responsibility for carbon emissions and who bears the consequences of our changing climate.

B. Climate Resilience - Background:

While the previous information may seem a bit doom and gloom, there are ways to combat climate change and to make sure we are more prepared to deal with the changes already set in place. We all have a responsibility to reduce our carbon footprint, to become educated and informed voters, and to learn how we can protect our valuable ecosystems. These roles will be discussed in Part 6 of this lesson. One way to make ourselves more resilient in the face of climate change is to learn how we can harness the power of nature to literally shore up our coastal communities and protect them from things like the inevitable rising seas.

Explain to students that **climate resilience** is the ability of a system to absorb stresses imposed by climate change and still maintain function while adapting and evolving and becoming better prepared to handle future climate impacts. Climate resilience can come in many forms and efforts to increase resiliency include social, technologic, political, and economic strategies at every level of society. Using nature-based solutions to help us create resiliency is one of many efforts.

Suggested Flow:

1. A nature-based solution to creating climate resilience is described in the Nature Works Everywhere **Coastal Resilience** video (6:55) (<https://vimeo.com/154663129>). Coastal resilience is under the umbrella of climate resilience. Show this video and have students outline the ecosystem services (those services provided by nature) described in the video. They should identify the breakwaters created by oyster reefs, mangroves, and salt marshes that help to alleviate flooding from coastal storm surge.
2. Next have students list the ecosystem services that are present in their communities. You may wish to use the image to the above right (found here: <https://toolkit.climate.gov/image/478>) to help in the discussion.
3. One way that we can contribute to resilience is to protect these ecosystem services and to utilize natural systems to help solve our environmental challenges. In this case, nature should not be seen as a victim of climate change, but as an essential partner in helping us to become more resilient to changes. Strategies like conserving and managing habitats to



Image credit: [U.S. Climate Resilience Toolkit, NOAA](#)

support healthy ecosystems; learning how animals and plants respond to climate; increasing awareness and working to safeguard fish, wildlife, and plants and reduce non-climate stressors on these organisms will help to keep the nature around us strong and able to be part of the solution to a changing climate.

Additional Resources:

Interactives

- Interactive Article on Marshall Islands Disappearing Due to Sea Level Rise
http://www.nytimes.com/interactive/2015/12/02/world/The-Marshall-Islands-Are-Disappearing.html?_r=0
- Explore The Nature Conservancy's Coastal Resilience work in an interactive mapping portal
<http://maps.coastalresilience.org/network/>

Part 6: Get Involved

In Part 5 of this lesson, students learned that changes we make now will affect the future of the Earth. We can change the current trajectory we are on and we can all play a part. The steps below act as a guide for students to learn how to become engaged in climate issues at various levels.

1. Show the video ***New York City's Greenhouse Gas Emissions as One-Ton Sphere of Carbon Dioxide Gas*** by Carbon Visuals <https://www.youtube.com/watch?v=DtqSlpIGXOA> - this video helps to visualize the quantity of gas produced by a city in one year. In 2010, NYC added over 54 million metric tons of CO₂ to the atmosphere, which is approximately 2 tons per second. Seventy-five percent of the emissions came from the city buildings. Since we cannot see gas, this visualization attributes a sense of scale to these numbers by using blue spheres that are the equivalent of one ton of CO₂ gas at 59 °F and standard pressure.
2. After you show the video, ask students what they think about the visualization. Ask them what further questions they have and specifically check in to see if anything surprised them about the visualization. They might respond that they were surprised that the majority of the emissions came from the buildings. You can show them the EPA's website here: <http://www3.epa.gov/climatechange/ghgemissions/sources/commercialresidential.html> that has a table describing the source of emissions from commercial and residential buildings.

3. After seeing the video, students might be inspired to learn how to reduce their own carbon footprints. They can do this using one of the sites below. The EPA has a list (<http://www3.epa.gov/climatechange/wyacd/>) of things that people can do to help with climate change. Have students visit this site after they calculate their footprint and pick out a few things that they will do to make a positive change in their lives. They can do this for homework if there is no computer access at school.
 - <http://www3.epa.gov/carbon-footprint-calculator/>
 - http://www.greenprogress.com/carbon_footprint_calculator.php
4. Show the TED Talk “Let’s prepare for our new climate” by Vicki Arroyo (https://www.ted.com/talks/vicki_arroyo_let_s_prepare_for_our_new_climate?language=en (10:31). This talk gives examples of resilience, rebuilding, being proactive, and defines the biggest obstacle to creating resilience, which is stationarity or relying on the past to create the future. It is a great motivator and introduces inspiring projects from around the world.
5. In order for a democracy to function, citizens need to be informed about the issues and where those running for office stand. Share this short video (0:50 seconds) from the Center on Congress about becoming an informed citizen <http://centeroncongress.org/becoming-informed-citizen>.
6. Explain to students that they can become informed by watching the news or reading national newspapers. If they’re worried about bias in the U.S. news, check out what international news sources like [The Guardian](#), [BBC](#), or [Al Jazeera](#) are saying about an issue. By looking at international sources they may even learn about something that’s not even being discussed in American media. Websites like Vote Smart (<http://votesmart.org/>) and Govtrack (<https://www.govtrack.us/>), OpenCongress (<https://www.opencongress.org/>) and many others show the voting records of politicians and can help voters become more informed about their political leaders.
7. The group More than Scientists (<http://morethanscientists.org/get-involved/>) has an online list of organizations tackling climate issues. Have students visit this site and look for areas that interest them. A simple Google search on “climate activism” with your city’s name will also yield local results for groups working on climate issues.
8. After students have explored these resources and calculated their carbon footprints, have them write a short reflection on how they will live purposefully and what steps they will take in their lives to not only reduce their impact on their planet, but to become more informed as citizens, and to become active in the issues that matter to our planet.
9. You can use Padlet (<https://padlet.com/>) to have students create a class list of steps they will take. This makes it more transparent and by putting the ideas to “paper” they may feel more accountable. You can check in with the class in a month to see what actions they have taken.

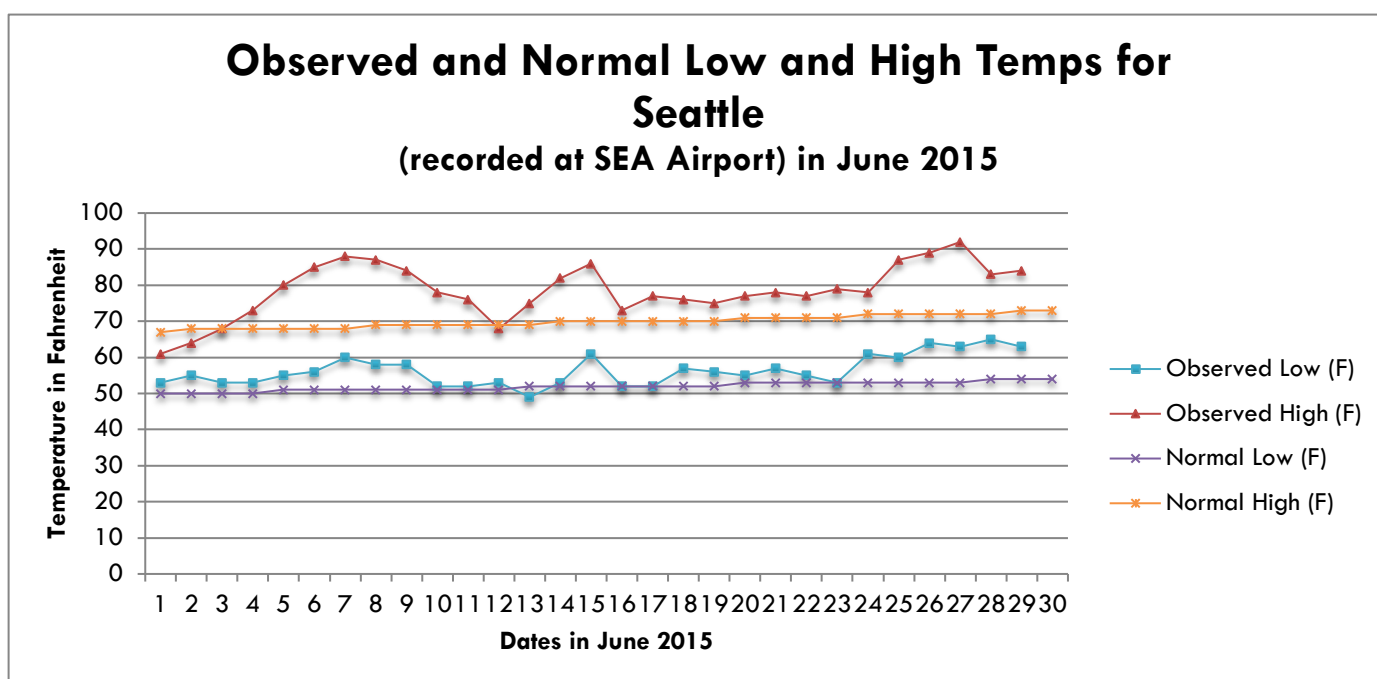
Understanding Weather and Climate Using Local Data

Student Handout

Our ability to understand climate change begins with an understanding of how weather and climate are related but different. We often hear soundbites like “We had record snowfall this year! How can there be global warming?” In order to understand why one weather event does not discredit the science of climate change altogether, we can begin with a simple investigation of our local weather and climate.

Procedure:

1. You are going to create a graph like the one below for Seattle. Note that the Seattle graph focuses on one month only from June 1, 2015 through June 30, 2015. It is recommended that you focus on one month at a time on the graph for your city.



2. You will either create a data table in MS Excel that is set up like the table on page 4 of this handout or you can do this activity on paper and use the attached data table and create the graph by hand. If you use MS Excel, the graph will be created using MS Excel.
3. Go to <http://www.wunderground.com/history/> to easily access local weather data. Enter your city and specify a date. You will be able to select a custom date range after you click “submit”.
4. On the tabs below the date choose “custom” and enter the date range for the month of your choice. When you’ve selected your range, click “get history”.
5. Scroll to the bottom of the page and you will see Weather History and Observations for your selected month.

6. For this exercise, we are focusing on the **high and low temperatures on each day**. Copy the high and low temperatures to your own table (in this handout). You may also use MS Excel to type the numbers into, or cut and paste the numbers, or download the Comma Delimited File at the very bottom of the page. Instructions for converting this type of file to spreadsheet can be found here <http://www.makeuseof.com/tag/how-to-convert-delimited-text-files-into-excel-spreadsheets/> if your teacher suggests that you use Excel.
7. The next step is to retrieve the **Climate Normals** for the days of the month you have selected. The Climate Normals are created every ten years by the National Climate Data Center in the US. These are 30 year averages for variables like temperature and precipitation. So if the Climate Normal minimum temperature for the 2nd of June is 50 degrees Fahrenheit, that is the average minimum temperature over thirty years of data. The Climate Normals we have at this time are calculated using weather data from 1981-2010.
8. Go to <http://www.ncdc.noaa.gov/cdo-web/datatools/normals> and select the “daily normal” tab. Then choose your state in the drop down menu. Next choose your city and the month you are researching. After the Normals have been found, scroll to the bottom of the screen to see the Normals for each day of the month you have selected. Now you can copy these numbers (minimum and maximum temps only) to your table or spreadsheet. Note that “high” and “maximum” are the same and “low” and “minimum” are the same.
9. Once you have completed your table, graph the observed daily temperatures on the same graph as the Climate Normals for the month and location you have chosen. Your graph should resemble the graph for Seattle below with the temperature graphed on the y-axis and the days on the x-axis.
10. Once you have completed your graph, answer the questions on the next page.

Daily Temperature in Year _____ and Climate Normals for the Month of _____ for the city of _____

Month: _____	Observed Daily Temperature (°F)		Climate Normals (°F)	
	Day	Minimum	Maximum	Minimum
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				

Name: _____ Date: _____ Period: _____

Storyboard for Esri Story Map Creation

Use the template below to create a storyboard for the text and images that will be part of your story map. Create rows in the storyboard below where each row represents a tab or section on the story map. A story map tutorial is located at the link below. The tutorial will walk you through account set-up to story map building and sharing.

Tutorial: <http://www.arcgis.com/home/item.html?id=d4a2705a8b224e71961404542ae94c6f>

To make your story map you will need to create an account on this site: <http://storymaps.arcgis.com/en/#> - choose the option to “create a free non-commercial public account to ArcGIS Online”

Story Map Text	Images with URLs or Citation Information	URLs for In-text Links

Story Map Text	Images with URLs or Citation Information	URLs for In-text Links

Story Map Text	Images with URLs or Citation Information	URLs for In-text Links

Story Map Text	Images with URLs or Citation Information	URLs for In-text Links

Story Map Text	Images with URLs or Citation Information	URLs for In-text Links

How Have Humans Changed the Earth?

Student Handout

Scientists have proposed that we have entered a new era – the Anthropocene. They have named it as such because this era is defined by how humans have affected the Earth. In this activity, you will explore the ways in which human activities have shaped the Earth.

The Greenhouse Effect

20. Visit the web page <http://climate.nasa.gov/causes/> and read about the greenhouse gas effect. Explain how the greenhouse gas effect contributes to climate change.

21. List the gases that contribute to the greenhouse effect and describe their sources.

Carbon Dioxide

22. Go to NASA's Climate Time Machine <http://climate.nasa.gov/interactives/climate-time-machine> and open the "Carbon Dioxide" viewer. Play the video or drag the slider to see how the Earth's CO₂ levels have changed between 2002 and 2014. Describe the trend that you observe in CO₂ concentration over time. Also compare and contrast what you observe between the Northern and Southern Hemispheres of the Earth as well as between different seasons.

23. Why do you think there is a difference between the levels of CO₂ between hemispheres during different seasons?

For hints, check out these resources:

- Science Bulletin: “Earth’s Green Carbon Machine” by the American Museum of Natural History: <https://www.youtube.com/watch?v=geR2KsF53y4>
- Earth’s Green Carbon Machine Backgrounder: <http://www.amnh.org/content/download/43544/660599/file/Earth's%20Green%20Carbon%20Machine%20Backgrounder.pdf>
- Article “Why are Seasonal CO₂ Fluctuations the strongest at Northern Latitudes”: <https://scripps.ucsd.edu/programs/keelingcurve/2013/05/07/why-are-seasonal-CO2-fluctuations-strongest-in-northern-latitudes/>

Mauna Loa CO₂ Measurements

The graph at the right shows a portion of CO₂ data recorded at Mauna Loa Observatory in Hawaii and represents part of the “Keeling Curve”.

Charles Keeling was a scientist famous for his work measuring the amount of CO₂ in the atmosphere. He began taking these measurements in California and later expanded his network of monitoring stations worldwide.

The monitoring station at Mauna Loa Observatory in Hawaii is significant because it has been measuring CO₂ since the 1950's and has the longest continuous record of measurements. This location is considered to be ideal for measuring CO₂ because of its distance from large population centers and the prevailing winds on the island blow from land to sea, so the effects from local vegetation are minimized.

The red line on the graph represents the actual measurements and the black line indicates the trend.

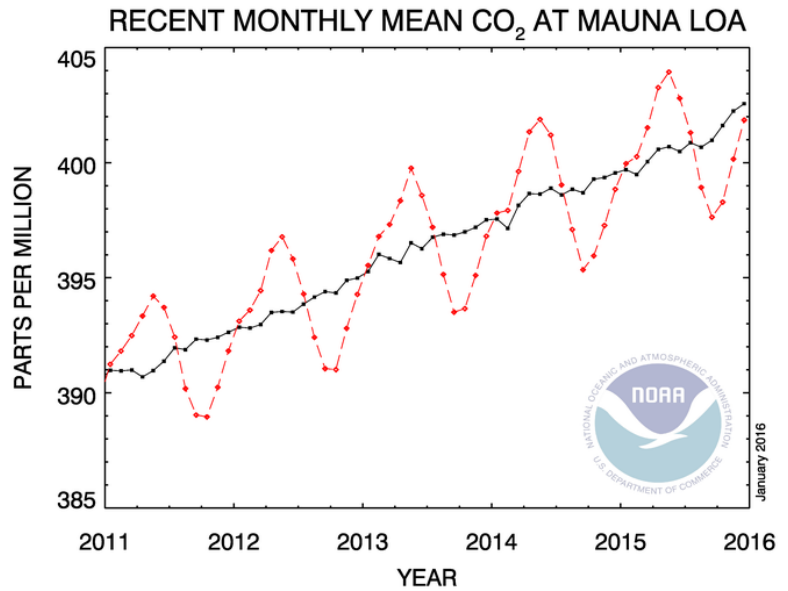
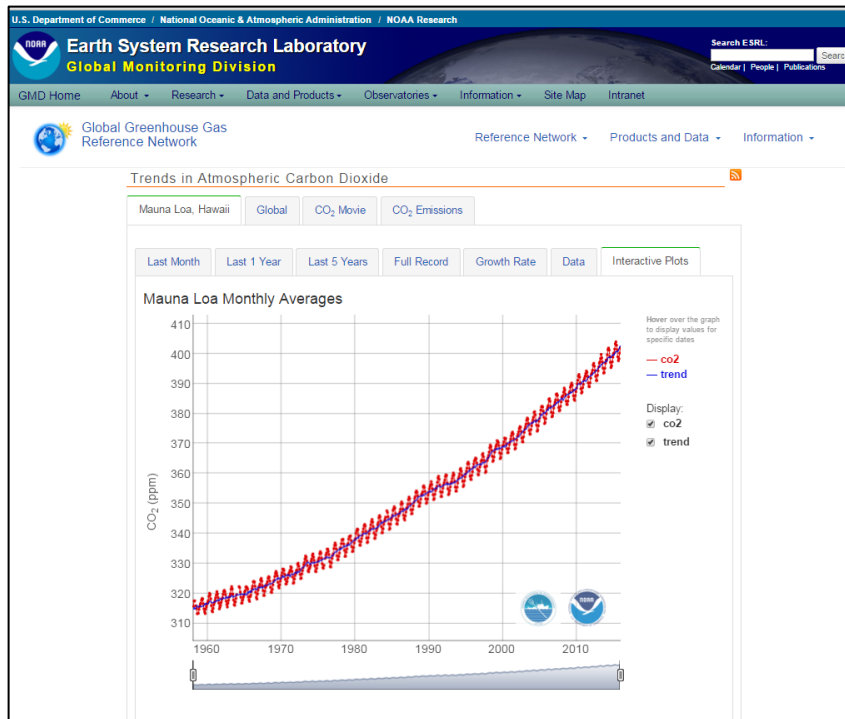


Image credit: [NOAA Earth Systems Research Lab](#)

24. Relate the data you see in the graph to your observations in questions 3 and 4. Do these data confirm that there are seasonal fluctuations in CO₂?

25. What does the trend line in the graph above indicate about CO₂ levels?

Go to the interactive version of the Keeling Curve here (screenshot shown below):
<http://www.esrl.noaa.gov/gmd/ccgg/trends/graph.html>



Use the interactive version to examine the CO₂ month/year data by mousing over the dots on the graph. Make sure you are on the “Mauna Loa, Hawaii” tab and the “Interactive Plots” tab as pictured in the screenshot below. You can also use the slider at the bottom to zoom in on a decade.

26. Describe the trend line from 1960 to present.

27. Now click on the tab “CO₂ Movie” and play the short video (3:44) and answer the questions below.

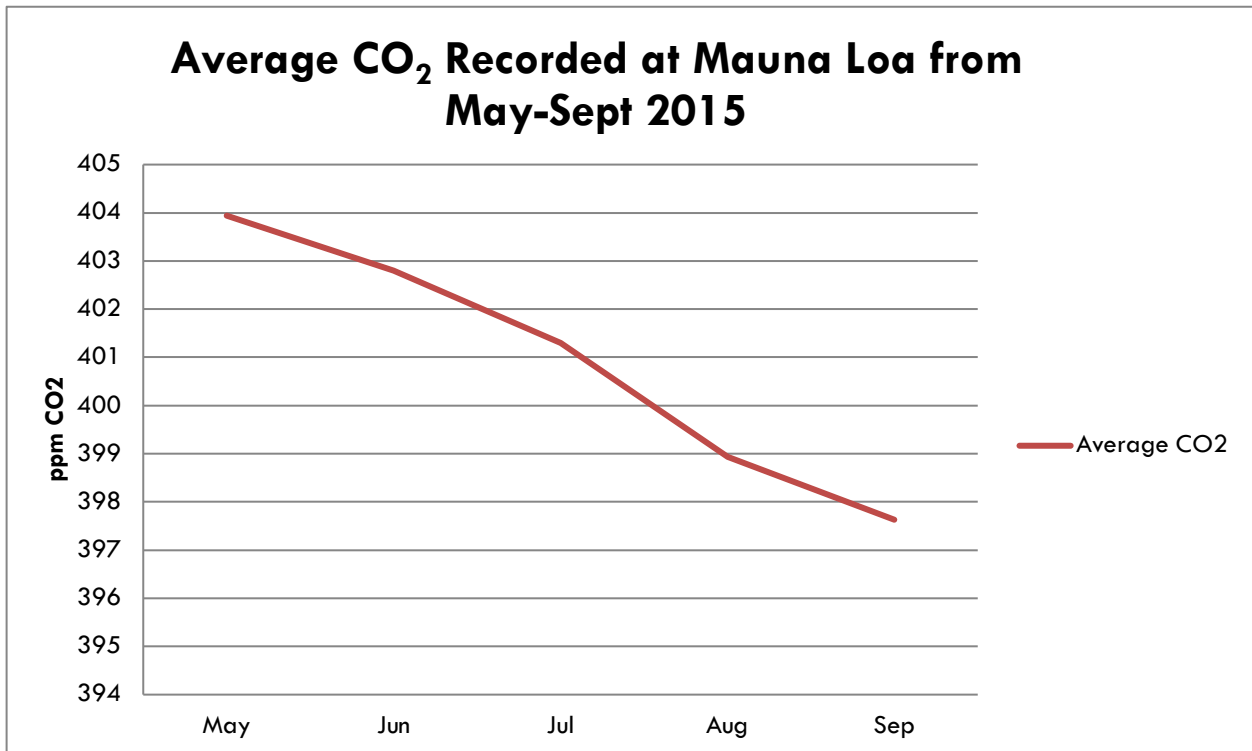
What does this animation depict?

How far back in time does it go?

Where are these ancient measurements obtained?

What is the highest level of CO₂ recorded in ppm? What is the lowest level on record?

28. Why is the information in the CO₂ movie graph important for us to understand?



Graph made from data obtained from [NOAA ESRL](http://noaa.esrl.noaa.gov/gmd/ccgg/trends/)

29. In the graph above, you can see the average CO₂ recorded at Mauna Loa for the months of May-September 2015. Why would it be inappropriate to examine such a short period of time if your goal was to understand a larger trend in CO₂ levels? What kind of biological event does this graph capture?

NASA's Vital Signs of the Planet and Climate Time Machine

30. Go to NASA's Vital Signs page (<http://climate.nasa.gov/>) and record the carbon dioxide levels for the present day and the global temperature rise since 1880.

31. Go to NASA's Climate Time Machine <http://climate.nasa.gov/interactives/climate-time-machine> and open the "Global Temperature" viewer. On this visualization, what do white, dark blue and dark red areas signify? Describe the general trend in global surface temperature between 1884 and 2014.
32. In question 11, you noted the Earth's average global temperature rise since 1880. It may seem like a small amount – but even a small temperature change can be significant. Visit NASA's Vital Signs page at <http://climate.nasa.gov/effects/> and describe why this small change is significant.
33. What are some of the long-term effects of climate change described by the Vital Signs of the Planet website (<http://climate.nasa.gov/effects/>)?
34. In which part of the US do you live? What are the U.S. regional effects of climate change currently visible for your area (<http://climate.nasa.gov/effects/>)?

A Changing Planet

35. Go to <http://storymaps.esri.com/stories/2015/atlas-for-a-changing-planet/> and explore the Esri story map called *Atlas for a Changing Planet*. Describe some of the other ways that humans are changing our planet that haven't been discussed previously. Note that you can zoom in, click, and move around the maps on the right hand side.
36. Explore the Modeling Temperature and Precipitation Scenarios in the story map. These models were created by scientists to make projections about what the Earth's climate would be like under different scenarios ranging from "business as usual" models where humans don't try to decrease greenhouse gas emissions to scenarios with aggressive greenhouse gas emissions reductions. The three models in the story map are listed below with the assumptions that the models are based upon:
- 2.6 Greenhouse gas emissions peak between 2010-2020 followed by a steep decline
 - 6.0 Greenhouse gas emissions peak around 2080 and then decline
 - 8.5 Greenhouse gas emissions continue to increase through the 21st century

Zoom into the map and try to find your approximate location and click on it for each of the scenarios. When you click, a box will pop up and indicate the predicted temperature change for that location by 2050. For each scenario write the temperature change for your location in degrees Celsius, convert to Fahrenheit, and include the annual change in precipitation found in the next series of models in the story map.

Scenario 2.6:

Scenario 6.0:

Scenario 8.5:

37. Based on the information you obtained from the models, under which scenario do you think your city will fare the best as we move into the future?
38. Given that climate change affects the entire world, what are some of the ways that countries are cooperating to work towards a better future? Explore the story map some more and note these below.