Climate Change and Coral Reefs

A Teacher's Guide for
Middle and High School
American Samoa

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For the Teacher:

The purpose of the Climate Change and Coral Reefs Teacher's Guide is to provide teachers in American Samoa with lesson plans that will facilitate instruction on climate change and, more specifically, its impacts on the Territory's coral reefs. Coral reefs are an integral part of South Pacific island communities such as American Samoa, and it is important for students to have a basic knowledge of the likely effects of climate change on these valuable ecosystems. The provided lesson plans are themed and consist of an objective, relevant vocabulary words, presentation points, and interactive classroom activities complete with materials lists and worksheets. While the lessons are designed so that no outside knowledge on climate change and coral reefs is required, it is recommended that teacher's review other relevant information on this subject matter. This guide is intended for students between grades 7 and 12 in American Samoa, and can be adapted to suit different grades.

Vocabulary by Lesson:

Introduction:

- Climate
- Weather
- Atmosphere
- Climate Change
- Global Warming
- Industrial Revolution

Lesson 1:

- Carbon Dioxide
- Greenhouse Gases
- Greenhouse Effect
- Carbon Source
- Carbon Sink
- Photosynthesis
- Fossil Fuels

Lesson 2:

- Emissions
- Carbon Footprint

Lesson 3:

- Reservoir
- Carbon Cycle
- Saturation
- Acidic
- Basic
- pH Scale
- Ocean Acidification
- Carbonic Acid

Lesson 4:

- Specific Heat Capacity
- Polyp
- Zooxanthellae
- Symbiotic Relationship
- Nematocysts
- Coral Bleaching

Lesson 5:

- Glacier
- Ice Sheet
- Thermal Expansion

Lesson 6:

- Mitigation
- Adaptation
- Resilience

GLOSSARY:

Acidic: Term that describes substances such as lemons and vinegar that have a pH less than 7.

Adaptation: Efforts to cope with the effects of climate change by reducing community vulnerability.

Atmosphere: The layer of gasses that surrounds the planet.

Basic: Term that describes substances such as soap and detergents that have a pH greater than 7.

Calcium Carbonate: Mineral dissolved in seawater that is used by marine organisms to make skeletons and shells.

Carbon Cycle: The constant movement of carbon between the oceans, atmosphere, and land.

Carbon Dioxide: A chemical compound made of two oxygen atoms and one carbon atom. It naturally exists as a gas in earth's atmosphere.

Carbon Footprint: The amount of carbon dioxide released by an individual, household, or business.

Carbonic Acid: Substance created when carbon dioxide dissolves in the ocean. Also used for carbonating soft drinks.

Carbon Sink: Anything that captures and holds carbon dioxide.

Carbon Source: Anything that releases CO_2 into the atmosphere, including living, dead, or non- living.

Climate: The long term average of a region's weather patterns.

Climate Change: A change in a region's long- term weather patterns.

Coral Bleaching: When coral polyps under stress expel their symbiotic algae and turn white.

Ecosystem Services: The benefits a natural resource provides for humans.

Emissions: Carbon Dioxide released from activities such as driving and burning trash.

Food Chain: A representation of the interactions between predators and prey in an ecosystem.

Fossil Fuels: Natural resources such as coal and petroleum. These substances are formed over millions of years when the fossilized remains of plants and animals are exposed to heat and pressure in the earth's crust.

Glacier: A giant mass of ice that moves over land.

Global Warming: An increase in earth's average temperature.

Greenhouse Gases: Gases in the atmosphere that absorb and hold heat from the sun.

Greenhouse Effect: The process where CO_2 in the atmosphere absorbs heat from the sun and naturally warms the earth.

Ice Sheet: Massive glaciers that cover over 20,000 square miles as land. Also known as continental glaciers

Industrial Revolution: The period from the 18th to 19th century when there were major changes in technology, manufacturing, agriculture and transportation, beginning in Europe and eventually spreading around the world.

Limestone: A rock composed mostly of calcium carbonate.

Mitigation: Addressing the cause of climate change by reducing CO_2 and other greenhouse gas emissions into the atmosphere.

Nematocysts: Stinging cells found on coral tentacles.

Ocean Acidification: The decrease in the pH of the world's oceans, due to their absorption of excess carbon dioxide from the atmosphere.

pH Scale: Scale used to measure how acidic or basic a substance is. It ranges from 0 to 14, with 7 being neutral, 0 to 7 being acidic, and 7 to 14 being basic.

Photosynthesis: The process where energy from the sun is used to convert carbon dioxide into sugars.

Plankton: Drifting, aquatic organisms.

Polyp: Marine animal that makes a coral reef.

Reservoir: Places where carbon is stored on earth, such as in the atmosphere, oceans, and in plants on land.

Resilience: The ability to recover from and adjust to a change.

Saturation: The limit beyond which oceans will no longer be able to take up more CO_2.

Specific Heat Capacity: The amount of energy required to raise the temperature of a substance by one degree.

Symbiotic Relationship: When two different species work together and benefit each other.

Thermal expansion: The increase in volume that occurs when water absorbs heat.

Weather: The general atmospheric conditions at a particular place and time.

Zooxanthellae: Marine algae that lives inside a coral polyp.

INTRODUCTION: WHAT IS CLIMATE CHANGE?

OBJECTIVE: Review the topic of climate change with students and ensure that they know the difference between climate and weather, and climate change and global warming.

VOCABULARY: Climate, Weather, Atmosphere, Climate Change, Global Warming, Industrial Revolution

PRESENTATION:

- **Climate** is the long-term average of a region's weather patterns. In American Samoa the climate can be described as tropical, hot, and humid.
- This is different from **weather**, which describes the general atmospheric conditions at a particular place and time. Remember, the **atmosphere** is the layer of gases that surrounds the planet. So the weather basically describes what it is like outside, such as rainy, sunny and hot, or breezy and cool.
- **Climate change** is what happens when there is a change in a region's long term weather patterns. When climate change occurs it affects the whole world, although different regions may be affected in different ways.
- **Global warming**, which is a part of climate change, is when there is an increase in Earth's average temperature.
- Climate change is not new to the earth. In fact, climate has historically varied throughout space and time, from factors such as volcanic eruptions, differences in the amount of energy released from the sun, and changes in earth's orbit. These have resulted in both ice ages and warm periods. For example, during the last ice age 20,000 years ago, ice covered much of the North American continent, including parts of the United States mainland. In fact, the remains of woolly mammoths have been discovered as far south as New York and Virginia, which suggests that these states used to be covered in ice. Since that time, the earth naturally and gradually warmed up to more modern temperatures.
- However, recently observed changes in climate are not caused by these natural factors, but by changes in the atmosphere caused by humans since the **Industrial Revolution**. Does anyone know what the Industrial Revolution is? It is the period from the 18th to 19th century when there were major changes in technology, manufacturing, agriculture and transportation. It began in Europe and eventually spread around the world.
- Scientists estimate that Earth's temperature is increasing much more quickly than in the past, about 1°F over the past 100 years, largely as a result of human activities.
- This rapid change in climate will have consequences for humans and the earth system.

ACTIVITY: CLIMATE VS. WEATHER IN AMERICAN SAMOA

Materials: Climate Worksheet; colored pencil/markers; recent weather report

Pre-Class Preparation:

- Look up yesterday's weather report prior to class.
- Use the newspaper or go to http://www.weather.gov/data/obhistory/NSTU.html for information on temperature, wind speed, and rainfall.
    - Determine minimum and maximum temperature by looking for the highest and lowest numbers in the "air temperature" column for yesterday's date.
    - Determine average temperature by adding up all the numbers in the "air temperature" column for yesterday's date and dividing by the number of values in the column for that date.
    - Determine wind speed by adding up all the numbers in the "wind" column for yesterday's date and dividing by the number of values in the column for that date.
    - Determine total rainfall by adding up the 1 hour rainfall values for yesterday's date.
- Go to http://www.surf-forecast.com/breaks/Utulei/seatemp for the current sea surface temperature.

  Note: You can also bring a printout of the temperature, wind speed and rainfall data and have the students compute the averages in class.

In Class:

1. Have students get into groups of 2 - 4. Hand each student a Climate Worksheet.
2. Explain that they will look at data that represents the average climatic conditions in American Samoa for each month of the year.
3. Have the students use the information to create a line graph on the provided American Samoa Climate Graph. Remind them to use different colors for each variable, and to label the Key with the appropriate color.
4. Have students discuss in their groups the trends that they observe in the data.

   For example: When is it windiest in American Samoa? What is the hottest month, on average? At what time of year does it rain the most?
5. Next, provide the values for yesterday's weather. Have the students fill these numbers into the space provided on the first page of the Climate Worksheet.
6. Tell students to graph these numbers as stars (*) on the graph in the column that corresponds with the current month. They should use the same colors they initially used for each variable.

In their groups, have students discuss how this data compares to the monthly averages. Was yesterday hotter than the average? Colder? How does the air temperature compare to the minimum and maximum that usually occurs during that month of the year

Follow-up:

- As a class, discuss the trends that students observed in average monthly data, and how that information compares to yesterdays weather.
- Remind the class about the difference between weather and climate.
- Remind students that one day of weather data doesn't indicate a change in climate (for example, if yesterday's high temperature was higher than the monthly average, that does not necessarily prove global warming).

Climate Worksheet

Name: **Date:**

American Samoa Climate Chart; Pago Pago, Tutuila

	Average Minimum Temperature (°F)	Average Maximum Temperature (°F)	Average Temperature (°F)	Average Sea Surface Temperature (°F)	Average Rainfall (inches)	Average Wind Speed (Beaufort Scale)*
January	75	88	82	84	11.7	2
February	75	88	82	84	13.4	2
March	73	88	81	84	12.6	2
April	75	86	81	84	13.4	2
May	75	86	81	82	10.2	3
June	75	84	80	81	9.4	3
July	73	84	79	81	7.5	3
August	73	82	78	81	7.9	3
September	73	84	79	81	5.5	3
October	75	84	80	82	12.6	3
November	75	86	81	82	9.8	3
December	75	86	81	84	14.2	2

Source: http://www.climatetemp.info/american-samoa/

The Beaufort Scale:

Beaufort Number	Wind Speed (Miles/Hour)
0	<1
1	1 - 4
2	5 - 7
3	8 - 11
4	12 - 18
5	19 - 24
6	25 - 31
7	32 - 38
8	39 - 46
9	47 - 54
10	55 - 63
11	64-73
12	74+

Current Weather; Pago Pago, American Samoa:

Date:

Minimum Temperature: ___________________________

Maximum Temperature: ___________________________

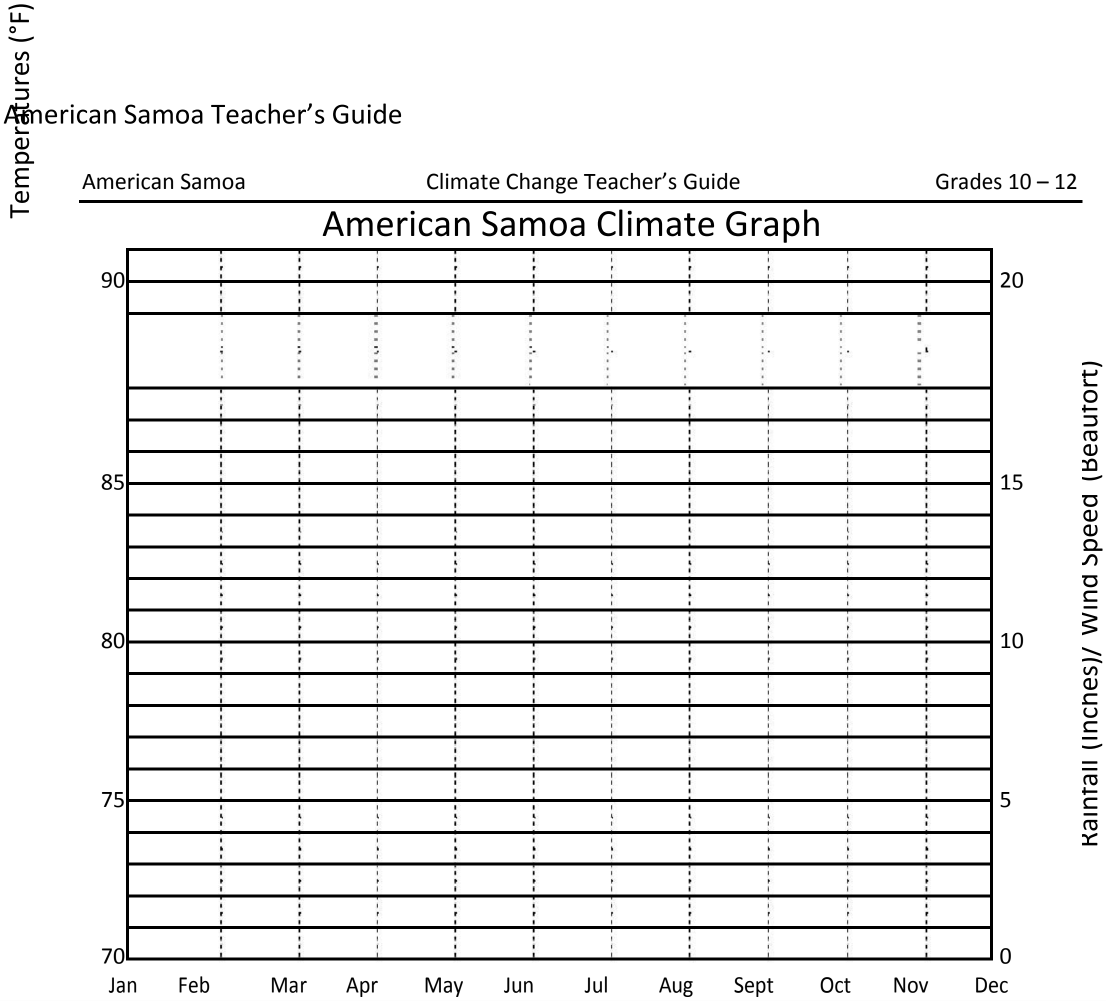
Average Temperature: _____________________________

Sea Surface Temperature: __________________________

Rainfall: ____

Average Wind Speed: ______________________________

American Samoa Climate Graph



Key

Average Minimum Temperature	
Average Maximum Temperature	
Average Temperature	

Average Sea Surface Temperature	
Average Rainfall	
Average Wind Speed	

1. What trends do you notice in the American Samoa Climate Graph?

2. How does yesterday's weather compare to the climate averages?

LESSON 1: CARBON DIOXIDE AND THE GREENHOUSE EFFECT

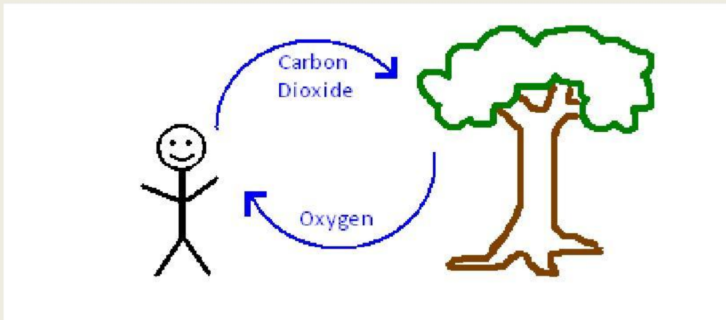
OBJECTIVE: Students will understand that gases such as carbon dioxide naturally exist in the atmosphere and create a greenhouse effect. They will also learn the ways in which humans increase CO_2 in the atmosphere, intensify the greenhouse effect, and contribute to climate change. They will conduct two activities to observe the greenhouse effect and the influence of CO_2 on temperature.

VOCABULARY: Carbon Dioxide, Greenhouse Gases, Greenhouse Effect, Carbon Source, Carbon Sink, Photosynthesis, Fossil Fuels

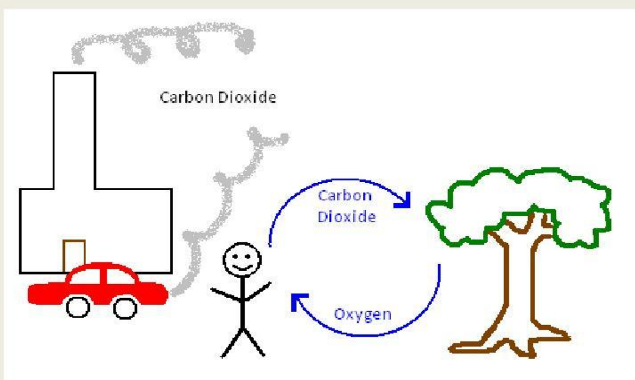
PRESENTATION 1A:

- What is carbon dioxide? **Carbon dioxide** is a chemical compound made of two oxygen atoms and one carbon atom. It naturally exists as a gas in earth's atmosphere. Its chemical formula is CO_2 (Write *CO_2* on the board so students are familiar with it). Carbon dioxide makes up only a small amount, 0.039%, of the air in the atmosphere. It is also in the air humans and animals breathe out.
- What is a greenhouse? A greenhouse is a small glass house used to grow plants, especially during the winter in cold places, because they trap the sun's heat. (Draw a picture on the board of a little house, with arrows representing the sun's light and heat entering and being trapped inside).
- CO_2 and several other gases are known as **greenhouse gases** because they absorb and hold heat from the sun, just like a greenhouse. (Draw a picture of the earth, with a circle representing the atmosphere around it. Explain that CO_2 exists in the atmosphere. Draw similar arrows representing the sun's light and heat entering and being trapped in the atmosphere). Some other natural greenhouse gases are water vapor and ozone. Without these gases, heat would escape back into space and the earth's average temperature would be approximately -18°C or 0°F.
- The process where CO_2 in the atmosphere absorbs heat from the sun and naturally warms the earth is known as the **greenhouse effect**.
- Describe the greenhouse effect by discussing what happens to a car that is left in the sunlight with its windows rolled up. The car is hotter than it is outside because heat from the sun enters through the glass and is not able to escape again.
- Remind students that there are many natural sources of CO_2 in the atmosphere, including human respiration, volcanic eruptions, the decay of dead plant and animal matter, and forest fires. Anything that releases CO_2 into the atmosphere, including living, dead, or non-living, is a **source** of carbon dioxide.
- Because the level of CO_2 in the atmosphere is relatively constant, there are also natural ways that it is removed from the atmosphere. These are known as "**carbon sinks**" and include anything that absorbs and holds CO_2. Discuss with the class what some sinks might be.
- Two major sinks include absorption by seawater and its use for **photosynthesis** by plants, algae and bacteria. Who knows what photosynthesis is? It is the process where energy from the sun is used to convert carbon dioxide into sugars. Photosynthesis releases oxygen as a waste product.

- Sources constantly release CO_2 and sinks constantly take it in, so that carbon dioxide is always cycling through the earth and atmosphere.



- Many human activities release CO_2 into the atmosphere (Discuss what, like burning fossil fuels for electricity and driving, cement production, and waste incineration). One of the main sources of CO_2 is from burning **fossil fuels**. What are fossil fuels? When plants and animals die, their bodies turn into fossils. Over millions of years, these fossilized remains are exposed to a lot of heat and pressure in the earth's crust, and turn into fossil fuels such as coal and petroleum. These fuels have a lot of carbon in them, so when we burn them, a lot of carbon dioxide is released into the atmosphere.
- Combined, human activities release so much CO_2 that there are not enough sinks to balance it out. As a result, the amount of carbon dioxide in the atmosphere is higher, which intensifies the greenhouse effect.



- A stronger greenhouse effect means that heat which would have otherwise escaped into space is now trapped in earth's atmosphere. This is causing the earth to get warmer (remind students that this is called global warming).

ACTIVITY 1: MODELING EARTH'S ATMOSPHERE

***Materials* (*for each team of 4 students*):** two plastic 2-liter soda bottles (with caps); two 14oz or 16oz plastic containers of similar color (deli or sour cream containers work well); scissors or knife; clear tape; 2 thermometers; vinegar; baking soda; portable table lamp with 150 watt floodlight bulb; data collection sheet; Watch (or other timer); 2 colored pencils/markers.

Note: If not enough materials are available for smaller groups, you can do one experiment as a demonstration in front of the class. Encourage student involvement by designating roles.

- Remove labels from plastic bottles by soaking them in water.

In class:

1. Remind students about the greenhouse effect.
2. Explain that you will conduct an experiment to observe if increased greenhouse gases (i.e. CO_2) really do have an impact on earth's temperature. You will use earth's temperature under the "normal" greenhouse effect as a basis of comparison.
3. Split students into teams of four and distribute the required materials.
4. Tell students that they will construct "experiment chambers". Have each team cut off the bottom 2 inches of each of the 2-liter soda bottles.
5. Tape a thermometer, facing out, to the inside of each bottle. Make sure that the temperature can be seen easily, without touching the bottle. Place each capped bottle into a 14oz or 16oz plastic container base, and tape to seal.
6. Tell students that these experiment chambers represent identical models of earth's atmosphere. Now we will generate carbon dioxide in one chamber to simulate the increase in CO_2 that humans have caused in the atmosphere.
7. In one experiment chamber, first ensure that the 2L bottle is firmly taped to the plastic container base. Next, remove the cap and add 2 tablespoons of vinegar. Finally, add ½ a teaspoon of baking soda and quickly re-cap the bottle. Explain to students that mixing vinegar and baking soda together creates a simple reaction that generates carbon dioxide and water.
8. Cut out the labels provided on the data collection sheet and use them to mark which bottle is normal air and which bottle has increased-CO_2.
9. Place experiment chambers, with taped thermometers, under the portable table lamp. Ensure that the thermometers are facing toward the students, and turn on the light.
10. Have students collect temperature data from each thermometer every minute for 20 minutes, and record on the data collection sheet.
11. Turn off the portable lights. Have students graph their results on their data collection sheet, using a different color for each bottle. Make sure to point out that the x-axis and y axis are labeled, but that students need to fill in numbers for the temperature on the y-axis based on the data they collected. Also be sure to remind them to use the key to show which color represents each bottle.

Follow Up:

- Discuss as a class the graphed data from the normal air and increased CO_2 bottles. What happened? Why?
- How does this compare to the greenhouse effect of the earth's atmosphere? Note: The intact plastic bottle acts as a rough, simple model, but in reality the earth's atmosphere is much more complicated

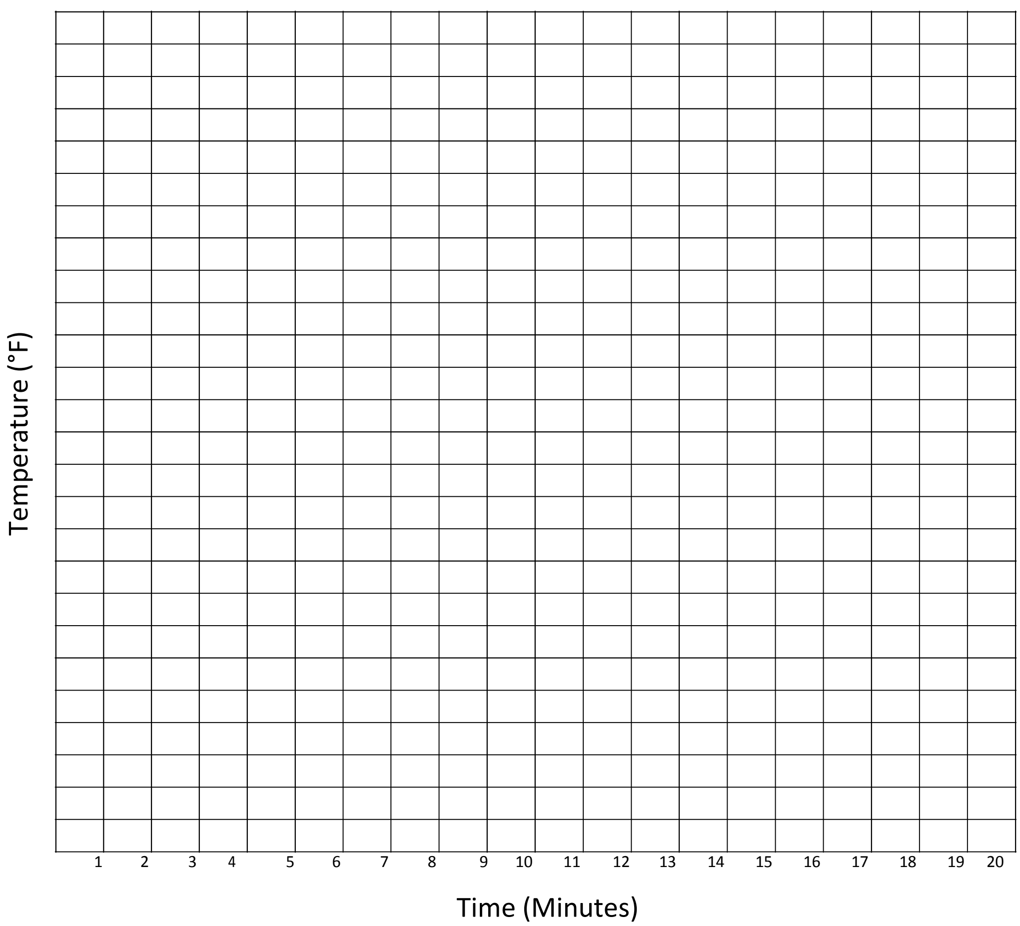
Modeling Earth's Atmosphere: Data Collection Sheet

Name: Date:

	Temperature	
Minute	Normal Air Bottle	Increased CO_2 Bottle
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Normal Air	Increased CO_2

Temperature Change Over Time in a Simulated Atmosphere



Key	Normal Air	Increased CO_2

LESSON 2: HOW MUCH CARBON DO YOU GENERATE?

OBJECTIVE: Students will gain a better understanding of their personal CO_2 contribution to the atmosphere by calculating their personal carbon footprint based on vehicle, electricity and natural gas use in their household.

VOCABULARY: Emissions, Carbon Footprint

*This lesson uses math skills, such as addition, multiplication, and division.

PRESENTATION 2:

- Remind students that many human activities release carbon dioxide into the atmosphere.
- Have class brainstorm some of the human sources of CO_2.
- The CO_2 released from activities such as driving and burning trash are known as **emissions**. They contribute to global warming by enhancing the greenhouse effect.
- The amount of CO_2 released by an individual, household, or business is known as a **carbon footprint**. This is usually measured in pounds emitted per year. For example, every day, Fatima drives her car 20 miles to go to work, go to church, or visit her family and friends. Over the course of a year, this releases 7,300 pounds of CO_2 into the atmosphere. Fatima also uses electricity at work to run her computer, and at home she uses electricity for her refrigerator, fan, lights and TV. Combined, this releases another 5,200 pounds of CO_2 over the entire year. Combined, these carbon dioxide emissions are Fatima's carbon footprint. Fatima's carbon footprint is about 12,500 pounds of CO_2 per year.

ACTIVITY 2: CALCULATING PERSONAL CARBON FOOTPRINTS

Materials: Chalkboard; calculators (at least 1 per group of 2 or 3 students); Carbon Footprint Worksheet (1 per student).

Pre-Class Preparation:

- Pass out the Carbon Footprint Worksheet at least 2 days before you plan to do this activity, so that students can take it home and ask their family members to help them fill it out, if necessary. It may be a good idea to assign it as homework to make sure students complete the assignment. **Only have students complete Section 1 at home**. The rest of the worksheet will be completed in class.
- Prior to the lesson, draw a chart on the chalkboard that it will be visible to the whole class. Include "Name" and "Carbon Footprint" as column headings (see "Carbon Footprints" example chart provided). This chart will be used to compare the students' yearly carbon emissions.
- Also, it may be handy to have the following information available to help students complete sections 2 and 3 of their worksheets (numbers are approximate).

Type of Vehicle	Miles per Gallon	Pounds of $C0_2$ Emitted/Gallon
Compact Car (Toyota Corolla)	24	20
Full Size Car (Honda Accord)	16	20
Truck/Van (Dodge Ram)	13	21

1 kWh = 1 lb of CO_2

$1 spent on natural gas = 8.5 lb of CO_2

In Class:

1. Explain to students that you will determine their approximate carbon footprint by calculating the pounds of CO_2 their household emits each year from vehicle, electricity and natural gas use.
2. Tell students to follow the directions on their worksheets. Go through one vehicle example in Section 2 as a class so that the class understands how to complete the worksheet. For example:
   - Let's say that your home's main vehicle is a pick-up truck. You should have the box next to Truck/Van checked in Section 1 where it says "Vehicle 1".
   - Underneath this box, look and see what number you wrote down for "# of miles Vehicle 1 is driven per week." Write this number down in the first blank space in Question #6, under Section 2.
   - Next, using the chart provided in Section 2, determine the approximate miles per gallon this vehicle gets. In this case, a Truck/Van gets 13 miles per gallon. Write this number down next to "Miles per Gallon" in Question #6.
   - Using your calculator, divide these numbers to determine "Gallons per Week." Write this number down.
   - Next you will use your calculator to multiply this number you just calculated (emphasize that they should rewrite this answer in the next blank space) by the approximate pounds CO_2 per gallon. Using the chart, we can determine that this is 21 for a Truck/Van. Write your answer down in the blank space next to "Pounds CO_2 per Week."
   - Finally, multiply this number by 52 (there are 52 weeks in a year) to determine "Pounds CO_2 per Year."
3. Tell students to repeat this process for their families other vehicles (if they have others).
4. Section 3 can be completed in a similar way; students will take the information they already have written in Section 1 and use the calculator to follow the instructions given.
5. Similarly, in Section 4 they use their previous answers to determine their carbon footprint. When they are done, students should go to the board and write their name and carbon footprint (in lbs of CO_2 per year) into the chart that you have drawn on the board.
6. When all the students are done and have written their information on the board, have the class add up all of individual carbon footprints to determine the total carbon footprint for the class.

Follow-up:

- Discuss why the number generated in class does not include their total emissions (discuss the fact that they live on an island and all oil, food, clothing etc. must be shipped there, which increases the CO_2 contribution/ person).
- Discuss as a class the ways that students can reduce their carbon footprint. Include methods such as walking and riding bikes, or taking the bus/carpooling, with more general strategies, such as turning off lights and fans when they leave a room. Students should talk with their family and friends about how they can all work together to reduce the size of their carbon footprint.

Carbon Footprint Worksheet

Name: **Date:**

Section 1.

1) How many people live in your home? ____________________

2) How much electricity does your household use every month? ____________________
*Note: Check your house's ASPA bill. Write down the number of kilowatt-hours (kWh) used.

3) Does your household use natural gas? ☐ Yes ☐ No

If "Yes," how much does your household use every month? ____________________
*Note: Check your ASPA bill. Write down the number of dollars spent on natural gas.

4) How many vehicles does your family have? ____________________

5) What types of vehicles does your family have, and approximately how many miles do you drive each vehicle per week? *Note: A Toyota Corolla is an example of a compact car, and a Honda Accord is an example of a Full Size Car.

Vehicle 1: ☐ Compact Car ☐ Full Size Car ☐ Truck/Van

# of miles Vehicle 1 is driven per week: __________

Vehicle 2: ☐ Compact Car ☐ Full Size Car ☐ Truck/Van

# of miles Vehicle 2 is driven per week: __________

Vehicle 3: ☐ Compact Car ☐ Full Size Car ☐ Truck/Van

# of miles Vehicle 3 is driven per week: ______________

Section 2.

Use the following chart to answer Question 4.

Vehicle Type	**Miles per Gallon**	**Pounds CO_2 per Gallon**
Compact Car (ex. Toyota Corolla)	24	20
Full Size Car (ex. Honda Accord)	16	20
Truck/Van (ex. Dodge Ram)	13	21

6) Divide the number of miles each vehicle is driven per week (Question #5) by the "Miles per Gallon" listed in the chart above to determine the number of gallons used per week. Next, multiply this answer by the "Pounds CO_2 per Gallon" to determine pounds of CO_2 released each week. Multiply this number by 52 to determine the yearly emissions for each vehicle.

Vehicle 1:

# of Miles (________) ÷ Miles per Gallon (_______) = _________ Gallons per Week

Gallons per Week (_______) x Pounds CO_2 per Gallon (_______) = _______Pounds CO_2 per Week

Pounds of CO_2 released per week (_______) x 52 weeks per year = _______ **Pounds CO_2 per Year**

Vehicle 2:
# of Miles (________) ÷ Miles per Gallon (_______) = _________ Gallons per Week

Gallons per Week (_______) x Pounds CO_2 per Gallon (_______) = ______ Pounds CO_2 per Week

Pounds of CO_2 released per week (_______) x 52 weeks per year = _______ **Pounds CO_2 per Year**

Vehicle 3:
# of Miles (________) ÷ Miles per Gallon (_______) = _________ Gallons per Week

Gallons per Week (_______) x Pounds CO_2 per Gallon (_______) = ______ Pounds CO_2 per Week

Pounds of CO_2 released per week (_______) x 52 weeks per year = _______ **Pounds CO_2 per Year**

Section 3.

Each kilowatt-hour of electricity used creates approximately 1 pound of carbon dioxide. Multiply the number of kilowatt-hours of electricity your household uses each month (the answer to Question #2 above) by 12 to determine the pounds of carbon dioxide your household generates each year from electricity use.

7) Kilowatt-hours of electricity used per month (________) x 12 = ________ **Pounds CO_2 per Year**

For each dollar spent on natural gas, approximately 8.5 pounds of carbon dioxide are emitted. Multiply the amount of money your family spends on natural gas each month (the answer to Question #3 above) by 8.5 to determine the pounds of carbon dioxide your household generates each month from natural gas use. Then multiply this number by 12 months to get the pounds of carbon dioxide per year.

8) Dollars spent on natural gas per month (________) x 8.5 = ________ Pounds CO_2 per

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Section 4.

Add up the "Pounds CO_2 per Year" your household generates from each vehicle, electricity, and natural gas use. Divide this number by the number of people that live in your home (the answer to Question #1 above) to determine your personal carbon footprint.

Total Pounds CO_2 per Year (________) ÷ Number of people living in your home (________) =

Your Carbon Footprint:________ Pounds CO_2 per Year

LESSON 3: OCEAN ACIDIFICATION

OBJECTIVE: Students will learn that some of the extra atmospheric CO_2 is being absorbed by the oceans, and that this extra CO_2 can cause oceans to become more acidic. These points will be illustrated through two experiments.

VOCABULARY: Reservoir, Carbon Cycle, Saturation, Acidic, Basic, pH Scale, Ocean Acidification Carbonic Acid

PRESENTATION 3A:

- As we discussed earlier, oceans are considered a "sink" of carbon dioxide. In fact, the ocean is the largest **reservoir** of carbon dioxide on the planet and capable of absorbing great amounts of CO_2 from the atmosphere. Reservoirs are places where carbon is stored on earth, such as in the atmosphere, oceans, and in plants and sediments on land. Carbon Dioxide is constantly cycled between the oceans, land, and atmosphere. This movement is known as the **carbon cycle**.
- Oceans absorb large amounts of CO_2 from the atmosphere because the gas pressure of CO_2 is often less in the ocean than the gas pressure of CO_2 in the air. Human activities have released more CO_2 into the atmosphere so that the pressure of CO_2 in the atmosphere has increased, which allows more carbon dioxide to disperse into the oceans. However, some scientists believe that the oceans are reaching **saturation**, which is the limit beyond which oceans will no longer be able to take up more CO_2. This may increase global warming because more carbon dioxide will stay in the atmosphere and increase the greenhouse effect. A good way to describe saturation is to have students think about what it is like when they eat candy. At first it is really tasty and they want to eat lots and lots. However, at a certain point, they might start to feel sick and not want to eat any more.
- Cold polar waters are capable of absorbing more excess CO_2 from the atmosphere than warmer tropical waters. This is because gases are more easily dissolved in cool water.

ACTIVITY 3A: WATER ABSORBS CO_2 FROM THE AIR

Materials: Two 1- liter plastic bottles; CO_2 bottle or 2 sodas/mineral waters; rubber tubing; cold water; warm water (not hot).

In Class:

1. Tell students that they will observe how water absorbs CO_2 from the air, and compare absorption by cold and hot water.
2. Fill both plastic bottles about ¼ full of water: one with warm water and one with cold water
3. Add equal amounts of carbon dioxide to both bottles by using the CO_2 bottle, or by shaking a soda/mineral water bottle and using the rubber tubing to transfer it to a plastic bottle.
4. Cap both bottles and shake them vigorously for the same amount of time.
5. Have students make observations about what happens to the bottles (the sides of the bottles are sucked inwards).

Follow-up:

- Discuss with the class why the sides of the bottle were sucked inwards. This happens because the water absorbs the carbon dioxide gas from the air, so the gas volume inside the bottle decreases. This is a rough approximation of what happens to some of the CO_2 in the atmosphere (it is absorbed by the oceans). Shaking the bottle makes more water surface area available to absorb the carbon dioxide gas from the air, so the absorption happens more quickly (and is, therefore, easier to observe). Cold water absorbs more CO_2 than warm water, so this bottle is sucked inwards more.
- Remember, although the oceans take up CO_2, with more and more being taken up every day, they may reach saturation and not be able to absorb more.

PRESENTATION 3B:

- What is an acid? Substances can be either **acidic** or **basic**. Acidic things include lemons, vinegar, and some basic things include soap and detergents. The **pH scale** is used to measure how acidic or basic a substance is. It ranges from 0 to 14, with 7 being neutral, less than 7 being acidic, and greater than 7 being basic.
- Draw this diagram on the board:
- Each number on the pH scale is an order of magnitude different (which means ten times greater or less) than the ones next to it. Therefore, each pH value below 7 is ten times more acidic than the next higher value. For example, a pH of 4 is ten times more acidic than a pH of 5, while a pH of 3 is ten times more acidic than a pH of 4, and 100 (10 x 10) times more acidic than a pH of 5. Similarly, a pH of 9 is ten times more basic than a pH of 8, while a pH of 10 is ten times more basic than a pH of 9 and 100 times more basic than a pH of 8. Therefore, some things are much more acidic or basic than others. Pure water is neutral and ocean water is slightly basic (around a pH of 8).
- Have the class guess the pH of other common substances: lemon Juice-2, black coffee-5, urine-6, baking soda-9, soapy water-12, bleach-13.
- We've already observed how the ocean can absorb CO_2 from the atmosphere and discussed how the oceans absorb greater amounts of CO_2 when more is present in the atmosphere. This can cause ocean acidification, which is a secondary impact of climate change. **Ocean acidification** is the decrease in the pH of the world's oceans, due to their absorption of excess carbon dioxide from the atmosphere.
- When CO_2 dissolves in the ocean it reacts with seawater to create what is known as **carbonic acid.** This is the same acid that is used for carbonation in soft drinks. Although it naturally forms in the ocean, with higher levels of CO_2 more acid is produced, which causes the ocean to become more acidic. In fact, since the industrial revolution, the ocean's pH has decreased from 8.179 to 8.069. While this decrease of 0.11 does not look like a lot, because the numbers on the pH scale are different from one another by an order of magnitude, this change means that the ocean has gotten 30% more acidic. Scientists project that this increase in acidity will continue, which may have consequences for marine life and corals.

ACTIVITY 3B: CARBON DIOXIDE MAKES WATER MORE ACIDIC

Materials: Three wide-mouth, clear containers, preferably with screw caps (large peanut butter or jelly containers with labels removed work well); drinking straw; pH indicator solution; pH indicator strip (this is not entirely necessary since the indicator solution shows a very general pH, but they are useful for providing a more accurate pH reading); pipette or medicine dropper; floating candle; matches or lighter; seawater (enough to fill each jar about ½ full); Acidification Worksheet.

> *Note:* If enough materials are available, this activity can be done by the students in groups of 2-4, with one set of materials per group.

Pre- class preparation:

- If necessary, remove labels from plastic bottles by soaking them in water.

In Class:

1. Tell students that they will observe and measure how carbon dioxide can increase the acidity of seawater. They will introduce CO_2 both directly into the water, and into the air above it.
2. Explain that you will measure the approximate acidity of the water by using a pH indicator strip, which turns different colors depending on the pH of the substance. Students will also be able to observe changes in pH by adding an indicator solution, which turns yellow when water is acidic.
3. Fill all three containers approximately half full of seawater. Cut or tear out the labels provided on the Acidification Worksheet (Control, Container #1, Container #2). Use them to label the containers.
4. Measure the starting pH of all three containers. Dip a pH indicator strip into the water for 1 – 2 seconds and compare the color to the provided color chart to determine the approximate pH.
5. Record these numbers in the "Before" column in the pH Chart provided on the Acidification Worksheet.
6. Use pipette or medicine dropper to add several drops of indicator to the water until they are the same shade of green/blue. Be sure to add the same amount of indicator to each container.
7. Screw the cap on the container labeled "Control" and set aside. You may want to review the concept of setting a control with the class. Discuss how the Control Container will be used as a basis of comparison.
8. Use the straw to blow air (i.e. add CO_2) into the seawater in Container #1. Blow until the indicator changes from green to yellow (basic to acidic).
9. Measure the pH using a pH indicator strip and record in the "After" column in the pH Chart provided on the Acidification Worksheet.
10. Screw the cap onto Container #1 and set aside. Observe how much the color of the water changed by comparing it to the Control Container.
11. Point out that, although this demonstrates the concept that CO_2 can increase ocean acidity, we will not be blowing, or pumping, carbon dioxide directly into the ocean from the atmosphere. Therefore, we will conduct a second test to see what happens when carbon dioxide increases in the air *above* the water.
12. We will use a floating candle to represent human emissions into the atmosphere.
13. Place the floating candle in Container #2 and light it.
14. Screw the cap onto Container #2 and place it next to the Control Container (for easy comparison). *Note the candle will go out once all the oxygen inside the container is consumed. This is supposed to happen.
15. The pH will decrease much slower in this experiment, so it is best to let Container #2 sit for an hour before measuring the "After" pH.
16. Every 15 minutes, have students observe to see if there is any change in the indicator color by comparing it to the color of the Control Container.

17. Finally, after an hour, measure the pH of Container #2 and record it in the "After" column of the pH Chart.
18. Re-measure the pH of the Control Container for comparison and record this number as well.

Follow-up:

- Discuss with the class the difference between the containers.
- Explain that the water in the Container #1 changed color to yellow quickly because, by directly adding CO_2, you made the water acidic with carbonic acid.
- In Container #2, it took longer for the pH to decrease because the CO_2 was added to the air rather than directly into the water. This is more representative of the actual earth system and what is currently happening with ocean acidification.
- Remind students that the point of this experiment was to show that ocean acidification can occur with higher levels of CO_2 in the atmosphere, and that even small decreases in pH lead to large increases in acidity

Acidification Worksheet

Name: **Date:**

Container #1	Container #2

Control

	pH Chart		
	Before	After	
Control			Container
Container			#1
Container			#2

LESSON 4: OCEAN WARMING AND CORAL BLEACHING

OBJECTIVE: Students will learn more about the structure of coral, the importance of their symbiotic algae, and how ocean warming due to climate change can cause corals to bleach.

VOCABULARY: Specific Heat Capacity, Polyp, Zooxanthellae, Symbiotic Relationship, Nematocysts, Coral Bleaching

PRESENTATION 4A:

- In addition to causing atmospheric temperatures to rise, climate change can also lead to ocean warming.
- Oceans have a high **specific heat capacity**. This is the amount of energy required to raise the temperature of a substance by one degree. A high specific heat capacity means that it takes a lot of heat to raise the temperature of water even a little bit. Therefore, the ocean can absorb a lot of heat before its temperature rises.
- Because of this, there is a lag time between when extra CO_2 is added to the atmosphere and when changes are observable in the ocean's temperature. The effects of human activities are not instantly noticeable.
- Still, because water is a naturally capable of absorbing heat, extra CO_2 and heat in the atmosphere will mean more heat in the oceans.
- On the same note, even if all inputs of CO_2 to the atmosphere stopped today, because of the ocean's ability to hold heat, it would take a long time for the ocean's temperature to decrease again.
- Scientists believe that oceans are already warmer than they were historically. This is a big deal because the ocean covers 70% of the earth's surface and can absorb a lot of heat
- It is interesting to point out that, because colder waters absorb more CO_2 than warm waters (as discussed earlier), warmer oceans in the future may not be able to absorb as much CO_2 from the atmosphere, which may increase the greenhouse effect.

Activity 4A: The Specific Heat Capacity of Water

Materials: A pack of latex party balloons (white or clear is good so that students can see inside the balloon); food coloring (optional, to make water easier to see); a small candle (a votive candle is best because it is difficult to knock over); tap water; matches or lighter; fire extinguisher (precautionary).

In-Class:

1. Explain to students that you will demonstrate how water has a natural ability to absorb heat.
2. Choose 2 balloons. Inflate the first with air. If desired put a few drops of food coloring in the second balloon, then fill it with water until it is approximately the size of a grapefruit (this requires stretching the mouth of the balloon over the tap, and may need to be done prior to class if there is no sink in the classroom). Now inflate the water balloon until it is the same size as the first.
3. Light the candle.
4. Ask the class what they expect will happen to the air-only balloon when it touches the candle flame. After they have come up with an answer, warn students that the balloon will pop and that they may want to cover their ears.
5. Hold the air-only balloon over the flame. It will pop almost instantly.
6. Now, show the class the water-filled balloon and ask them what they expect to happen when it touches the candle flame.
7. Hold the water-filled balloon over the candle. Be sure that the flame is only touching the part of the balloon that is filled with water by lowering it over the candle (if the flame touches sides of the balloon where there is air, it will pop).
8. Show the class that the balloon does not pop. Remove the balloon from the flame. The black mark on the bottom of the balloon is not a burn mark, but is soot from the candle. You can demonstrate this fact to the students by rubbing your finger over the mark.

Note: This activity should only be conducted as a demonstration. Be sure to highlight the safety precautions you are taking and remind students to not conduct this experiment without adult supervision.

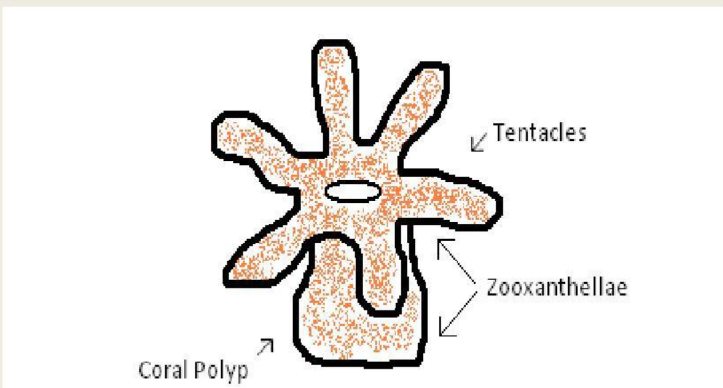
Follow-up:

- Ask students why they think the balloon with the water did not pop.
- Explain that water has a higher specific heat capacity than air. The air in the first balloon quickly heated up, which caused the latex to melt and the balloon to pop. In contrast, the water inside the balloon absorbed the heat from the candle and transferred it away from the latex. This prevents the latex from heating up enough to melt, so the balloon does not pop.
- Relate this activity back to climate change. Because water has a high specific heat capacity, it takes a lot of heat to raise the temperature of the oceans. But, because of human-caused climate change, warming trends in tropical oceans have already been observed. It is important to emphasize that the oceans are huge and the fact that we have seen warming means that considerable warming has occurred.
- Because oceans are naturally able to absorb heat, a consistently warmer atmosphere will also mean a warmer ocean.

PRESENTATION 4B:

- Corals naturally live in warm, shallow ocean waters, like those in the South Pacific Ocean around American Samoa. But, if waters get too warm, they are unhappy.
- It is important to understand a little more about the structure of coral to understand the effect that warmer oceans may have.
- Are corals an animal, a plant, or a mineral? In fact, they are all three. Corals are made up of a mineral (limestone which we already discussed), an animal (known as the **polyp**), and an algae. Most coral is made up of a lot of polyps, which live together in a colony. The algae, called **zooxanthellae** (have the class repeat this word), has what is called a symbiotic relationship with the coral polyps. A **symbiotic relationship** is when two different species work together and benefit each other. In the case of corals, the polyp provides protection for the algae, while the algae provides nutrients for the coral polyp. Coral polyps also have tentacles with stinging cells, known as **nematocysts**, which help them to catch some plankton for food, but the zooxanthellae provide most of their energy (make sure students remember what plankton is). These zooxanthellae live inside the coral polyp.

- It may be helpful to draw the following diagram on the board:



- A good way for students to remember the word 'zooxanthellae' is to have them repeat after you, "Zooxanthellae lives in the belly!" Have them say it several times, ending with them saying it as loudly as they can.
- With climate change, if the ocean water warms up too much, the corals become stressed and spit out their symbiotic algae. Because the algae gives coral its color, when coral polyps spit out their algae, they turn white. This is known as **coral bleaching**. For reference, have students think about bleach that is used for doing laundry and what effect it has on clothes (it makes them white). The name 'coral bleaching' is a similar idea—it makes corals turn white.
- Zooxanthellae form the base of the coral reef food chain and without it, corals do not get enough food, they become less healthy, and can die.

ACTIVITY 4A: CORAL POLYP FEEDING GAME

Materials: A box of Fruit Loops; small paper Dixie Cups (enough so that each student has one).

In-Class: (This activity is best conducted outdoors)

1. Have students stand in a large group, facing the teacher.
2. Explain to the students that they are going to pretend that they are a healthy coral reef. Each student is now a polyp and the whole class is "underwater".
3. Ask students to remind you how coral polyps get their food (they should say by algae/ zooxanthellae, and by their tentacles. You may need to ask questions to lead them to this correct answer).
4. Remind students the corals get the majority of their food from the zooxanthellae.
5. Pass out a small Dixie Cup full of Fruit Loops to each student (tell them not to eat it yet). Have them hold the cup in front of their stomachs. This represents the food provided to the coral by the zooxanthellae.
7. Have students hold their other hand up into the air to represent the coral polyp's tentacles. Tell students that there is plankton in the water, and that they should try to catch them with their "tentacles". (It may be necessary to remind students that coral polyps do not push each other to get their food.)
8. Throw several handfuls of Fruit Loops into the air, over the group of students. The students should try to catch them with their one extended hand. (Do not let students pick cereal up from the ground. Tell them that a coral polyp would not be able to do that).

Follow-up:

- Ask students how mach "plankton" (i.e. Fruit Loops) they caught from the "water". Ask if they got more food by catching it with their tentacles, or from their zooxanthellae (i.e. the Dixie Cup).
- Students should not be very successful at catching Fruit Loops with one hand. Remind them that zooxanthellae are very important for corals to live.
- Now, ask the students to remind you what happens when corals get stressed by ocean water that is too warm (coral bleaching happens, where corals spit out their zooxanthellae). Tell them that this would be like if you came around and collected all the Dixie Cups full of Fruit Loops. Ask them what effect this might have on a coral polyp (i.e. Do you think you would be hungry?).
- Remind students that in the oceans, when corals bleach, they can die.
- Tell students they can now eat the Fruit Loops from their Dixie Cups. You may want to have them help you pick up the Fruit Loops from the ground to throw away.

Heat Capacity Worksheet

Name: Date:

Experiment 1:

Heat Level: ____________ Volume: ____________

Starting Time:

____

Boiling Time:

____

Time	Temperature (°C)
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
22	
24	
26	
28	
30	
32	
34	
36	
38	
40	
42	
44	
46	
48	
50	
52	
54	
56	
58	
60	
62	
64	
66	
68	
70	

Experiment 2:

Heat Level: ____________ Volume: ____________

Starting Time: ____________

Boiling Time: ____________

Time	Temperature (°C)
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
22	
24	
26	
28	
30	
32	
34	
36	
38	
40	
42	
44	
46	
48	
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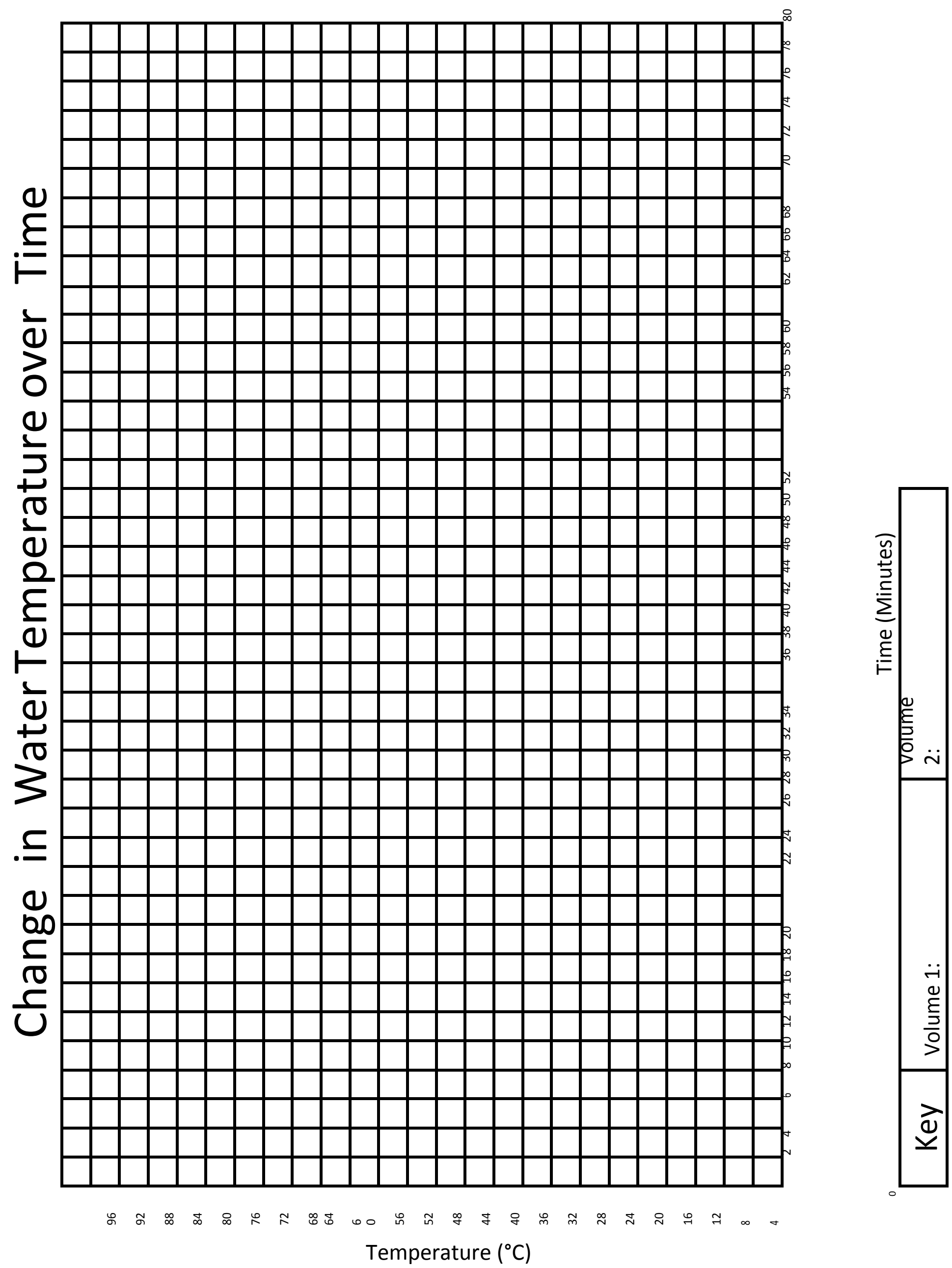
74	
76	
78	
80	


Change in Water Temperature over Time
Time (Minutes)
Temperature (°C)
Key
Volume 1:
Volume 2:

LESSON 5: CLIMATE CHANGE AND SEA LEVEL RISE

OBJECTIVE: Students will learn two ways that climate change can cause sea level to rise, and the potential impacts of sea level rise to an island community.

VOCABULARY: Glacier, Ice Sheet, Thermal Expansion

PRESENTATION 6:

- Another side effect of increasing global temperatures is sea level rise.
- How do warmer temperatures cause the sea level to rise? There are 2 ways.
- 1) Warmer temperatures cause glaciers and ice sheets to melt. **Glaciers** are giant masses of ice that move over land. **Ice sheets**, also known as continental glaciers, are massive glaciers that cover over 20,000 square miles of land. The Antarctic Ice Sheet is the largest in the world, which holds about 90% of the fresh water on earth's surface. If it gets too hot, glaciers and ice sheets will melt, which will add large amounts of water to the ocean. Scientists estimate that if the Antarctic Ice Sheet melted completely, sea level would rise by about 200 feet.
- Unlike glaciers and ice sheets, melting *sea* ice (ice that floats in the ocean, like giant ice cubes) will not cause sea level to rise. This is because the amount of water created when the sea ice melts is exactly the volume that was previously displaced by the ice. Water cannot exist in the same place where the ice, so it moves out of the way, or is displaced.
- 2) The second way that warmer temperatures can cause sea level to rise is by **thermal expansion** in the oceans. This thermal expansion occurs because when water absorbs heat, its volume increases. (Remind students that we already discussed that, even though water has a high specific heat capacity, oceans can absorb heat).
- Tell students that they have all most likely experienced this thermal expansion. Discuss how there is a lot of water in the human body, and when we get hot, things like our fingers and feet expand a little bit. Tell students to think about what happens when they wear rings or how their feet feel in their sneakers after they have been playing sports.
- The Intergovernmental Panel on Climate Change (IPCC) estimates that sea level could rise between 0.6 and 2 feet or more in the next century.
- Sea level rise will impact American Samoa and other South Pacific islands by causing increased coastal erosion, and flooding of low-lying homes, villages and roadways. In American Samoa, like other small tropical islands, our freshwater comes from underground and could be contaminated by salt water from a higher sea level.
- Coral reefs help protect coastal areas from erosion. (Point out that waves break offshore, instead of directly onto the seawall, because of corals). Therefore, if coral reefs are weak and dying, the impacts of sea level rise could be worse.

ACTIVITY 6A: GLOBAL WARMING CAUSES SEA LEVEL RISE

Materials: A wide mouth, clear, container with screw-top; hot plate (or other heating source); large pot; ice cubes in a small bowl; tap water; blue food coloring; clear ruler; clear tape; narrow, clear straw; clay; thermometer; Sea Level Rise Worksheet.

> *Note*: If enough materials are available, this activity can be done by the students in groups of 3 or 4, with one set of materials for each group except for the hot plate and large pot. All handling of the hot plate will be conducted by the teacher in this activity. Be sure to give a safety briefing about the dangers of the hot plate and handling hot substances.

Pre-Class Preparation:

- Prior to class, the teacher should make a hole in the screw-top to fit the narrow straw, and seal it with clay. If this activity will be done in smaller groups, all of the screw-tops should be prepared for each group.

In-Class:

1. Explain to students that they will observe the two ways that warmer temperatures will cause sea level to rise. First, they will look at the difference between melting sea ice and glaciers, and their effect on sea level.
2. To begin, tape the ruler to the clear container so that the numbers are clearly visible, and water level can be measured without touching the container.
3. Place half of the ice cubes in the clear container. Allow the rest of the ice cubes to remain in the bowl on the table.
4. Fill the clear container (where you have just placed several ice cubes) with water until the container is about 2/3 full, and add several drops of food coloring to make the water line more visible.
5. Immediately observe the height of the water in the container by looking at the ruler, and record this number on the Sea Level Rise Worksheet.
6. Take the temperature of the water for reference, and also record it on the Sea Level Rise Worksheet.
7. Explain to students that the clear container represents the ocean, the floating ice cubes represent sea ice, and the ice cubes in the bowl represent glaciers and ice sheets on land.
8. Based on the lesson just given, ask students to predict what they think will happen to the water level when the ice melts.
9. Allow the ice cubes in the clear container to melt and have students again record the water level. Once they have had an opportunity to make their own observations, discuss as a class what happened to the water level (it should be the same level: floating sea ice on the ocean will not raise the sea level when it melts).
10. By now, the remaining ice cubes in the bowl should have also melted. Remind students that this represents ice which was on land that has melted because of global warming.
11. Ask students what they think will happen to the ice that melts on land (it will run off into the oceans).

12. Pour the melted ice water into the clear container, explaining that this represents melted glacier water that is running off into the oceans.
13. Again, have students make note of the water level and record it on the Sea Level Rise Worksheet. Also, record the temperature again for reference.
14. Ask students what happened to the "sea level." It will have risen because more water entered the "ocean."

Follow-up:

- What are the two ways that global climate change leads to sea level rise?
- Remind students that this experiment is a very small scale model of what will happen with sea level rise. Although only small changes were observed in class, in reality glaciers and ice sheets hold large amounts of water, and the ocean has a lot of volume which can thermally expand and raise the sea level.
- Again, discuss the possible consequences of a higher sea level.

ACTIVITY 5B: SHORELINE TUG-OF-WAR

Materials: A strong rope that is long enough for tug-of-war (you may want to tie a piece of colored fabric or use colored tape to mark the middle).

In-Class: (This activity is best conducted outdoors)

1. Describe how corals are important to buffer wave energy to protect the shoreline from erosion. Have students imagine that the rope represents the shoreline/sediment on the coast.
2. Divide class into two teams: the Mighty Waves and the Colossal Corals. Have each team stand next to the rope, alternating sides.
3. Play tug-of-war. The teams should be well matched, so that the center of the rope doesn't move too much. Stop the game, and have the students place the rope back on the ground (they will listen better if they are not holding the rope).
4. Talk about how, in a healthy tropical ecosystem, the corals effectively protect the shoreline from erosion by wave action. This is illustrated by the fact that the rope, i.e. the shoreline, did not move very much.
5. Next, tell the students that climate change weakens the Colossal Corals and some of them die. Move a few students onto the Mighty Waves team, to signify that the corals have gotten weaker.
7. Play tug-of-war again. This time the Waves should win by a little bit. Stop the game, and ask the students why the Mighty Waves won. Tell the students that because the Coral was weakened, the Waves were able to pull the sediment (i.e. the rope) into the ocean. Then, tell students that more global warming causes sea level to rise. Move more Coral students to the Waves team and play again. Stop the game and discuss how a higher sea level and more waves lead to talk about more erosion.
8. Finally, talk about how people in American Samoa are working to protect corals and make them healthy. Therefore, the Colossal Corals get stronger. Move several students back from the Wave team to the Coral team and play again. This time the Colossal Corals should win. Discuss that healthy corals may resist the effects of warmer water and bleaching, and help protect the coastline from sea level rise and erosion.

Sea Level Rise Worksheet

Name: **Date:**

Condition	Water Level (mm)	Temperature (°F/°C)
Initial With "Sea Ice"		
After Sea Ice Melt		
After Glacier Melt		
After Thermal Expansion		

LESSON 6: PROTECTING CORALS FROM CLIMATE CHANGE

OBJECTIVE: Teach students ways that they can make a difference and protect coral reefs from climate change. This lesson includes an activity that recaps what they have learned in the previous climate change classes.

VOCABULARY: Mitigation, Adaptation, Resilience

PRESENTATION 6:

- We have spent the past several lectures discussing climate change and its impacts on coral reefs.
- In particular, ocean acidification, warmer oceans, and sea level rise will all have consequences for American Samoa.
- Luckily, it is not all hopeless. There are options for responding to climate change. In particular, humans can oppose climate change through mitigation and adaptation. **Mitigation** deals with the *cause* of climate change by reducing CO_2 and other greenhouse gas emissions. Meanwhile, **adaptation** involves coping with the *effects* of climate change by taking steps to reduce the vulnerability of our communities.
- What are some ways that we can mitigate climate change or, in other words, reduce our CO_2 emissions? Have students brainstorm ideas. Some examples include: driving less, walking and riding bikes more, using less electricity, and turning the lights off when you leave a room.
- Because American Samoa is an island, most of what we use must be shipped by boat or plane. This releases a lot of carbon dioxide into the atmosphere. Therefore, another way to reduce your carbon footprint is to eat more food that is grown locally.
- What about ways that we can adapt to climate change or, in other words, protect our communities? Have students brainstorm ideas. One way, which has already been done in American Samoa, is to install a seawall to protect the shoreline from sea level rise and erosion. Protecting and planting coastal trees, such as mangroves, can also protect the coast. Keeping the natural ecosystems, such as coral reefs, healthy is another way to help defend your community against the effects of climate change.
- The best way to protect corals is to keep them healthy in the first place. Besides climate change, other threats to coral reefs include overpopulation, fishing pressure, and land-based sources of pollution.
- Reducing the impacts of these threats will help keep corals strong and better able to withstand ocean acidification and warming. The ability to recover from and adjust to a change is known as **resilience**. If American Samoa's coral reefs are resilient, they will have a better chance of surviving the unavoidable consequences of climate change.
- What are some ways that we can improve coral reef resilience? We can improve coral reef resilience in several ways. First we can keep the water clean by not throwing trash on the ground, because it will end up as pollution in the ocean. We can also improve water quality by reducing pollution from piggeries. Several new management measures exist which will help

improve the operation of piggeries. It is also important not to stand or walk on live corals, which can harm the polyps.

- For more information on improved piggery practices in American Samoa, see: http://www.samoanews.com/viewstory.php?storyid=13539&edition=1268820000 or http://www.samoanewsonline.com/publicviewstory.php?storyid=6510&newspaperid=189 for reference.

Activity 6: Climate Lingo Bingo

Materials: Definition cards; bingo cards (one for each student); paper clips; pencils/pens for the students; answer sheet for the teacher.

Pre-Class Preparation:

- Cut out the definition cards.
- Print out enough bingo cards so that each student in the class will have one. Note that there are a few different bingo cards.
- Attach one definition card to the back of each bingo card using a paper clip (the definition should face outwards). If there are more definition cards than students, tape the remaining definition cards to the chalkboard. If there are more students than definition cards, make duplicates of a few of the definition cards and paper clip them to the bingo cards.
- It may be helpful to move desks to the sides of the room, or to play this game outside.

In Class:

1. Tell students you are going to play a version of bingo, using the vocabulary that they have learned over the past few climate change lessons.
2. The purpose of the game is to be the first student to fill in a horizontal, vertical, or diagonal row (Or, you can choose to play where the first student to fill in their entire card is the winner).
3. Give each student a bingo card with the attached definition card. Point out that each definition card has a number. Explain to the students that their job is to match the words on their bingo cards with their definition by writing down the correct number. Students will need to walk around the classroom and read the definitions on the back of their classmates' cards in order to complete the game. When a definition matches one of their bingo card words, the student should write down the person's name and the definition number in the correct spot on their bingo card. You should note that they will not find the answers to every definition on their card (there are 40 vocabulary words and only 36 spaces on their card).
4. The game ends when a student has filled in a full horizontal, vertical or diagonal row (or the entire card), and shouts "Climate Lingo Bingo!"
5. Tell students that it is best if the hold their bingo cards up in front of them so that the bingo card faces the student and the definition card faces out, towards the rest of the class.
6. When you are sure the students understand the directions, tell them to begin the game. When a student gets "Climate Lingo Bingo," be sure to check their answers using the answer sheet. The word's number should match the number it is given on the answer sheet. Continue playing if the student's answers are incorrect.

1 The long term average of a region's weather patterns.	**2** The amount of energy required to raise the temperature of a substance by one degree.	**3** Marine animal that makes a coral reef.
4 The process where CO_2 in the atmosphere absorbs heat from the sun and naturally warms the earth.	**5** The increase in volume that occurs when water absorbs heat.	**6** Term that describes substances such as lemons and vinegar that have a pH less than 7.
7 A chemical compound made of two oxygen atoms and one carbon atom. It naturally exists as a gas in earth's atmosphere.	**8** A representation of the interactions between predators and prey in an ecosystem.	**9** Marine algae that lives inside a coral polyp.

10 Addressing the cause of climate change by reducing CO_2 and other greenhouse gas emissions into the atmosphere.	**11** The layer of gasses that surrounds the planet.	**12** Anything that captures and holds carbon dioxide.
13 Gases in the atmosphere that absorb and hold heat from the sun.	**14** The ability to recover from and adjust to a change.	**15** The general atmospheric conditions at a particular place and time.
16 A rock composed mostly of calcium carbonate.	**17** A giant mass of ice that moves over land.	**18** Carbon Dioxide released from activities such as driving and burning trash.

19 Stinging cells found on coral tentacles.	**20** Substance created when carbon dioxide dissolves in the ocean. Also used for carbonating soft drinks.	**21** An increase in earth's average temperature.
22 Term that describes substances such as soap and detergents that have a pH greater than 7.	**23** Efforts to cope with the effects of climate change by reducing community vulnerability.	**24** Drifting, aquatic organisms.
25 The amount of carbon dioxide released by an individual, household, or business.	**26** The benefits a natural resource provides for humans.	**27** Mineral dissolved in seawater that is used by marine organisms to make skeletons and shells.

28 Massive glaciers that cover over 20,000 square miles as land. Also known as continental glaciers.	**29** When two different species work together and benefit each other.	**30** When coral polyps under stress expel their symbiotic algae and turn white.
31 The decrease in the pH of the world's oceans, due to their absorption of excess carbon dioxide from the atmosphere.	**32** A change in a region's long-term weather patterns.	**33** Anything that releases CO_2 into the atmosphere, including living, dead, or non-living.
34 Natural resources such as coal and petroleum. These substances are formed over millions of years when the fossilized remains of plants and animals are exposed to heat and pressure in the earth's crust.	**35** Scale used to measure how acidic or basic a substance is. It ranges from 0 to 14, with 7 being neutral, 0 to 7 being acidic, and 7 to 14 being basic.	**36** The limit beyond which oceans will no longer be able to take up more CO_2.

37 The constant movement of carbon between the oceans, atmosphere, and land.	**38** The period from the 18th to 19th century when there were major changes in technology, manufacturing, agriculture and transportation, beginning in Europe and eventually spreading around the world.	**39** Places where carbon is stored on earth, such as in the atmosphere, oceans, and in plants on land.
40 The process where energy from the sun is used to convert carbon dioxide into sugars.		

Answer Key:

1. Climate
2. Specific Heat Capacity
3. Polyp
4. Greenhouse Effect
5. Thermal Expansion
6. Acidic
7. Carbon Dioxide
8. Food Chain
9. Zooxanthellae
10. Mitigation
11. Atmosphere
12. Carbon Sink
13. Greenhouse Gases
14. Resilience
15. Weather
16. Limestone
17. Glacier
18. Emissions
19. Nematocysts
20. Carbonic Acid
21. Global Warming
22. Basic
23. Adaptation
24. Plankton
25. Carbon Footprint
26. Ecosystem Services
27. Calcium Carbonate
28. Ice Sheet
29. Symbiotic Relationship
30. Coral Bleaching
31. Ocean Acidification
32. Climate Change
33. Carbon Source
34. Fossil Fuels
35. pH Scale
36. Saturation
37. Carbon Cycle
38. Industrial Revolution
39. Reservoir
40. Photosynthesis

Climate Lingo Bingo					
Calcium Carbonate #: Name:	**Ecosystem Services** #: Name:	**Symbiotic Relationship** #: Name:	**Emissions** #: Name:	**Resilience** #: Name:	**Carbon Footprint** #: Name:
Greenhouse Effect #: Name:	**Carbon Source** #: Name:	**Glacier** #: Name:	**Specific Heat Capacity** #: Name:	**Zooxanthellae** #: Name:	**Atmosphere** #: Name:
pH Scale #: Name:	**Mitigation** #: Name:	**Climate** #: Name:	**Plankton** #: Name:	**Global Warming** #: Name:	**Photosynthesis** #: Name:
Carbonic Acid #: Name:	**Fossil Fuels** #: Name:	**Saturation** #: Name:	**Acidic** #: Name:	**Polyp** #: Name:	**Thermal Expansion** #: Name:
Ice Sheet #: Name:	**Greenhouse Gases** #: Name:	**Weather** #: Name:	**Industrial Revolution** #: Name:	**Adaptation** #: Name:	**Coral Bleaching** #: Name:
Carbon Cycle #: Name:	**Basic** #: Name:	**Ocean Acidification** #: Name:	**Climate Change** #: Name:	**Food Chain** #: Name:	**Nematocysts** #: Name:

Climate Lingo Bingo					
Ecosystem Services #: Name:	**Carbon Cycle** #: Name:	**Ocean Acidification** #: Name:	**Emissions** #: Name:	**Nematocysts** #: Name:	**Reservoir** #: Name:
Weather #: Name:	**Greenhouse Gases** #: Name:	**Climate Change** #: Name:	**Limestone** #: Name:	**Acidic** #: Name:	**Adaptation** #: Name:
Food Chain #: Name:	**Ice Sheet** #: Name:	**Plankton** #: Name:	**Specific Heat Capacity** #: Name:	**Atmosphere** #: Name:	**Climate** #: Name:
Industrial Revolution #: Name:	**Carbon Dioxide** #: Name:	**pH Scale** #: Name:	**Greenhouse Effect** #: Name:	**Photosynthesis** #: Name:	**Zooxanthellae** #: Name:
Carbonic Acid #: Name:	**Thermal Expansion** #: Name:	**Carbon Footprint** #: Name:	**Mitigation** #: Name:	**Resilience** #: Name:	**Basic** #: Name:
Coral Bleaching #: Name:	**Saturation** #: Name:	**Carbon Sink** #: Name:	**Polyp** #: Name:	**Carbon Source** #: Name:	**Global Warming** #: Name:

Climate Lingo Bingo

Food Chain #: Name:	**Carbonic Acid** #: Name:	**Acidic** #: Name:	**Nematocysts** #: Name:	**Fossil Fuels** #: Name:	**pH Scale** #: Name:
Weather #: Name:	**Climate** #: Name:	**Plankton** #: Name:	**Symbiotic Relationship** #: Name:	**Industrial Revolution** #: Name:	**Ecosystem Services** #: Name:
Adaptation #: Name:	**Carbon Source** #: Name:	**Thermal Expansion** #: Name:	**Reservoir** #: Name:	**Carbon Sink** #: Name:	**Atmosphere** #: Name:
Resilience #: Name:	**Glacier** #: Name:	**Greenhouse Gases** #: Name:	**Saturation** #: Name:	**Calcium Carbonate** #: Name:	**Climate Change** #: Name:
Ocean Acidification #: Name:	**Photosynthesis** #: Name:	**Polyp** #: Name:	**Limestone** #: Name:	**Specific Heat Capacity** #: Name:	**Greenhouse Effect** #: Name:
Carbon Cycle #: Name:	**Global Warming** #: Name:	**Coral Bleaching** #: Name:	**Zooxanthellae** #: Name:	**Mitigation** #: Name:	**Carbon Dioxide** #: Name:

LESSON 8: CLIMATE CHANGE IN AMERICAN SAMOA AND THE WORLD

OBJECTIVE: Students will gain insight into the full range of impacts if no actions are taken to reverse or reduce the effects of climate change. They will then compare localized consequences to climate change in American Samoa with impacts that are likely to occur in various regions around the world. Students will realize that climate change is truly global in scale, and that communities worldwide are faced with various climate challenges.

VOCABULARY: None.

*This lesson requires some knowledge of world geography.

PRESENTATION 8A:

- In American Samoa, climate change will have impacts beyond those that occur on coral reefs.
- Although we have been discussing climate change impacts on coral reefs in American Samoa in particular, it is important to remember that climate change will have impacts beyond those that affect coral reefs.
- For example, water shortages may become more frequent in American Samoa and other South Pacific locations such as Papua New Guinea, the Marshall Islands, Micronesia, Tonga, and Fiji. These areas will also be faced with an increased risk of tropical cyclones.
- It is important to remember that climate change is a global event. Different areas of the world will be affected in different ways, with impacts varying both on a local and regional scale. Some areas will get a lot hotter, while others do not have much of a temperature change. Computer models predict that climate change will shift rainfall patterns so that some areas will suffer from prolonged drought, while others will have excessive rain and more frequent flooding. In addition, sea level will vary in different regions of the world.

ACTIVITY 8: WORLD CLIMATE CHANGE WORKSHEET

Materials (for each team of 2 – 4 students): IPCC projection maps for air temperature, sea level change, and precipitation patterns; blank world map; climate change "doodads"; scissors.

In Class:

1. Split students into groups of 2 – 4 students.
2. For each group, pass out the attached IPCC projection maps for air temperature, sea level change, and precipitation.
4. Explain that these are the projections for global changes in air temperature, sea level and rainfall patterns from the Intergovernmental Panel on Climate Change, which is a scientific body that reviews and assesses climate data produced by scientists all over the world to evaluate the risk of human-caused climate change. Next, pass out a blank world map, a "Climate Change Doodads" sheet, and scissors.
5. Within their groups, have students cut out the doodads and place them on the world map where they believe each climate change impact will take place, based on the IPCC projections data. For example, students might place a "flooding" doodad in an area where rainfall is projected to increase. It is not necessary to use all of the doodads.
6. You may want to help students brainstorm by going through each climate change doodad and discussing it as a class. For example, for the "Increased Disease" doodad, ask students questions such what causes disease, how are diseases spread etc. This way, students will be inspired to think about the cause-and-effect relationship of some of the changes displayed on the IPCC maps. Therefore, students may consider that mosquitoes carry

disease, and warmer temperatures mean more mosquitoes, so there will be more disease where temperature increase is the greatest. Similarly, they may know that mosquitoes breed in standing water, so increased rainfall might cause more standing water, and more disease. For the "Glacier Melting" it may be a good idea to have students think about where these exist as some may not be aware that both temperature and high altitudes allow glaciers to exist in places such as in the Andes in South America, the Himalayas in Asia, and even on Mt. Kilimanjaro in Africa.

Follow-up:

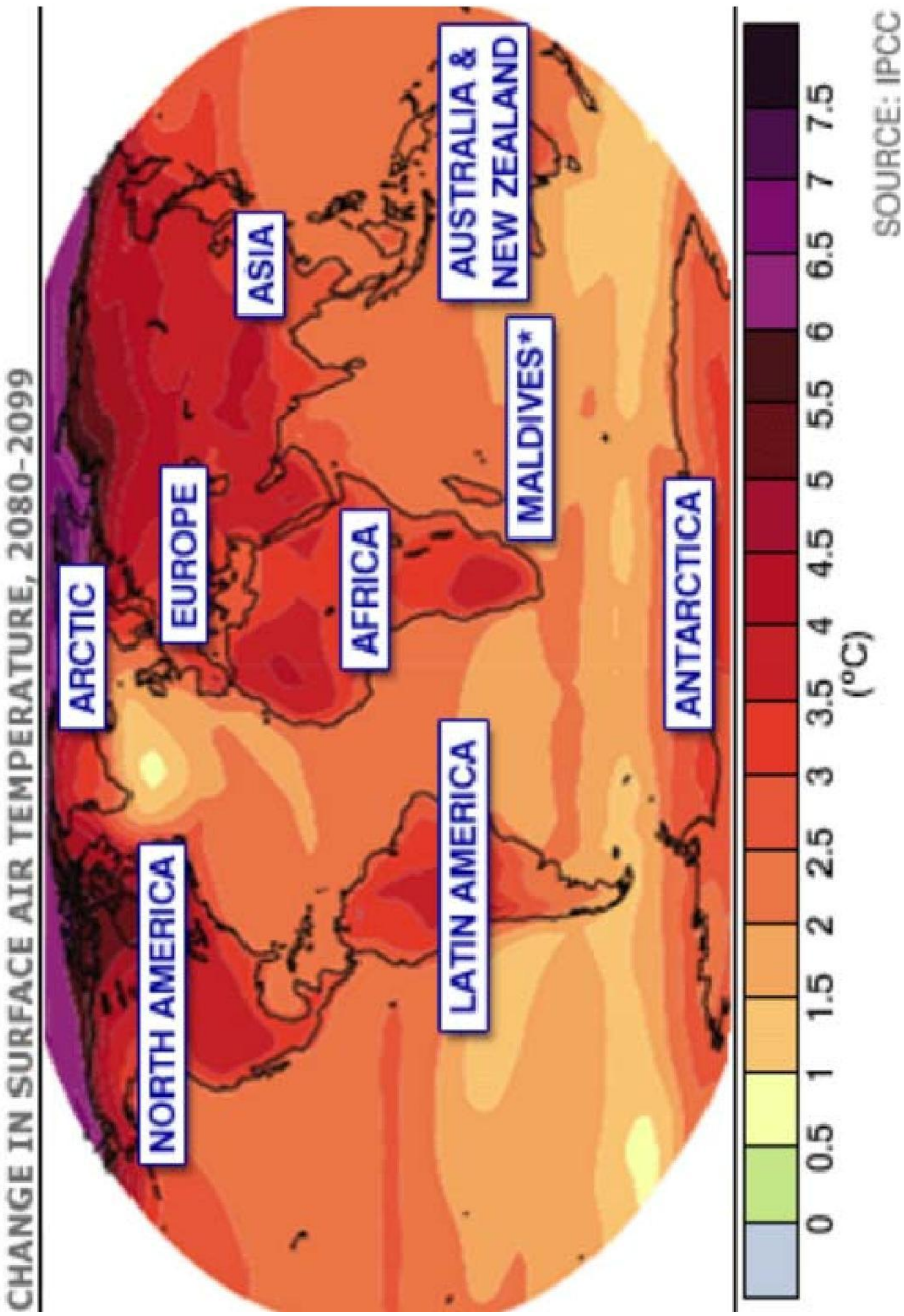
- Discuss as a class where the groups placed their climate change doodads. Have the groups each give at least one example that they came up with, including an explanation.
- Explain that you will now provide a brief description (see Presentation 8B) of some more detailed impacts that are projected in different regions around the world.
- Tell students that they can rearrange their doodads based on this new information.
- After you complete this brief presentation, ask students to discuss what projected impacts they found surprising, if there were any impacts they originally guessed correctly (using their climate change doodads) based on the IPCC maps, and what they guessed incorrectly.

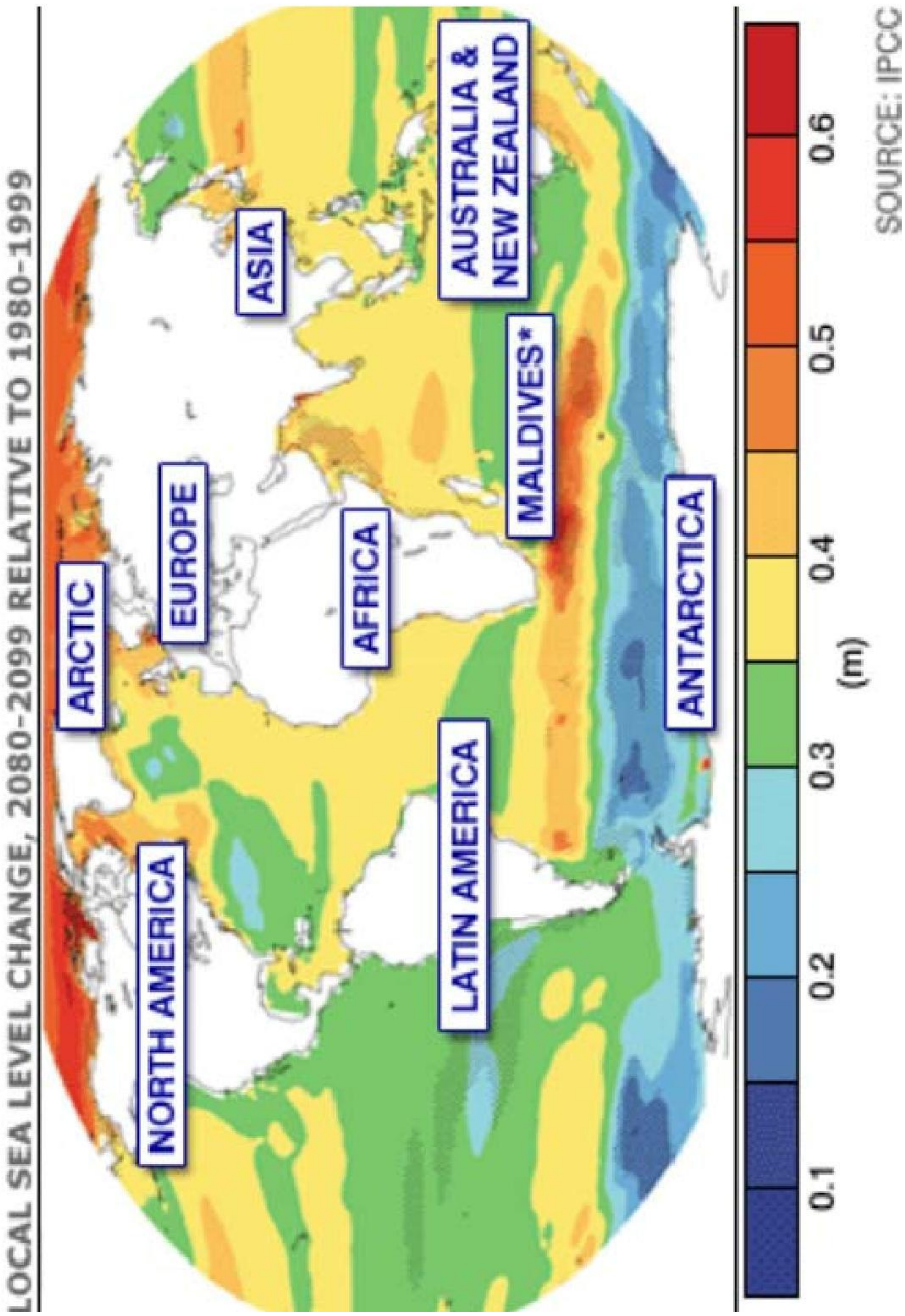
PRESENTATION 8B:

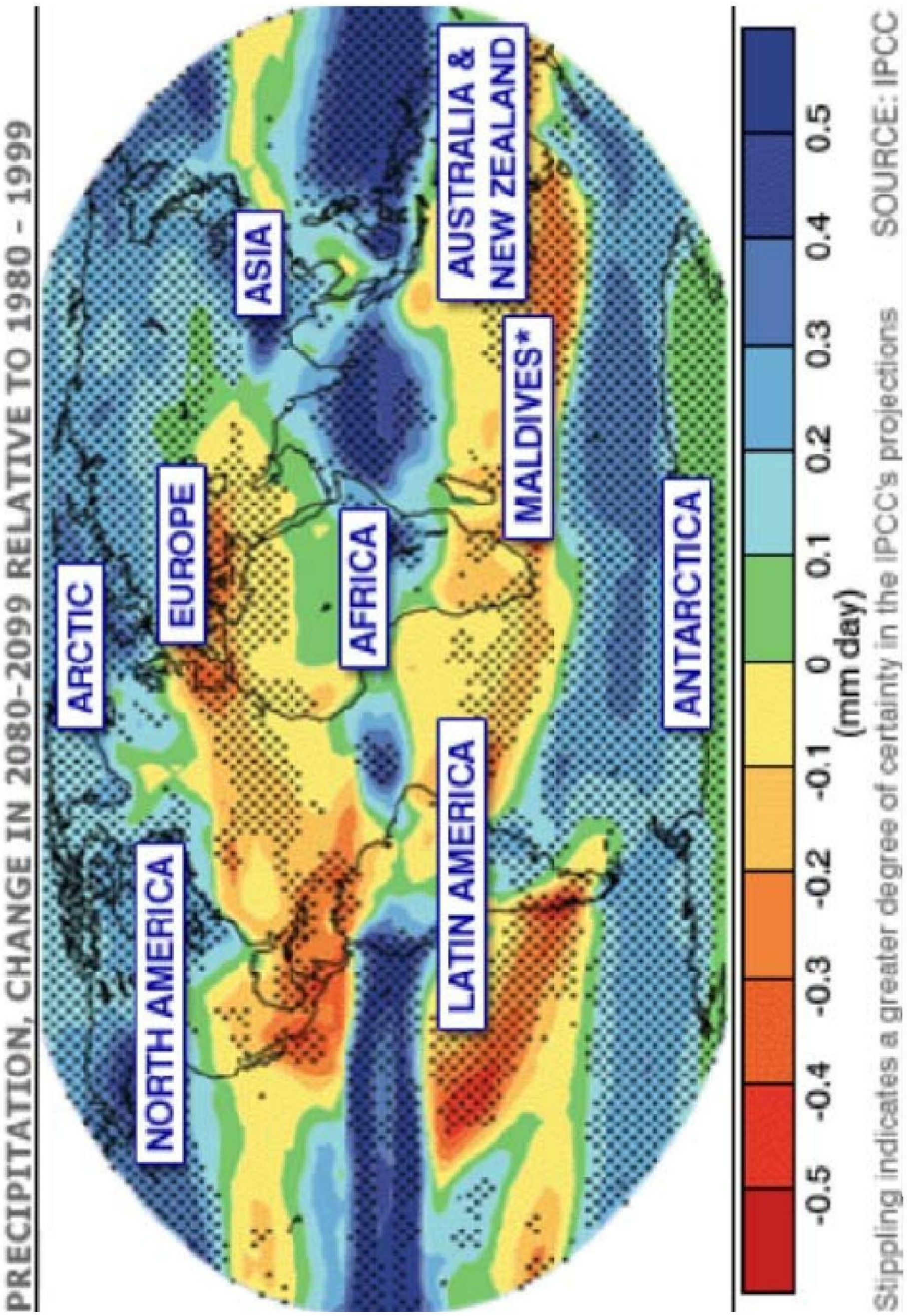
- Here is a brief overview of the impacts of climate change in different areas of the world:
- **Africa**: Some regions will experience a greater likelihood of drought and food shortages from shorter growing seasons and degraded fish populations. Arid and semi-arid regions in north, west and east Africa are becoming drier, while equatorial and parts of southern Africa are getting wetter. Coral and mangrove ecosystems will likely degrade. Overall, many of the problems that Africa already deals with will get much worse.
- **Asia**: Glaciers are melting in the Himalayan Mountains which, besides the polar ice caps, contain the greatest amount of fresh water on the planet and supply hundreds of millions of people. This will likely increase rock avalanches and flooding in the region in the short term, followed by drought in the future. Heavily populated coastal areas are also at risk of flooding, and food

shortages are likely due to decreased crop yields. The presence of disease is expected to rise in southeastern Asia, including an increase in cholera as coastal water temperature warms.

- **Australia and New Zealand**: South and eastern Australia will likely have water shortages. Warming will affect a large part of the Great Barrier Reef, resulting in the loss of many species of wildlife. Some coastal areas will have a higher risk of storms and flooding. Some cooler areas, such as in New Zealand, may benefit from global warming through longer growing seasons and greater crop yields.
- **Europe**: Reduced rainfall is predicted for central and eastern Europe, while more frequent heat waves are expected to pose a health risk. Reduced water supplies and crop production is likely in southern Europe, although northern Europe may benefit from a longer growing season and increased crop productivity. Many areas will be at risk of flooding in the future.
- **Latin America**: Higher temperatures and lower soil moisture may cause some tropical forests to be replaced by savannah (which means mostly grassland) ecosystems. Land in drier areas will likely be degraded, causing declines in crops and livestock production and food shortages. Some low-lying regions will be prone to flooding by sea level rise, including coastal areas in El Salvador, Uruguay and Argentina. Changing rainfall patterns and melting South American glaciers will ultimately affect future fresh water supplies.
- **North America**: In the west, higher rates of snow melt will cause winter flooding and summer droughts. The incidence of pests, disease, forest fires, and heat waves will likely increase, which will have human health impacts. Severe weather and sea level rise will affect coastal areas, such as in the southeast.
- **Polar Regions (The Arctic and Antarctica)**: These areas will see a reduction in the thickness and extent of ice sheets and glaciers, which will affect natural ecosystems and the habitat of polar species.
- **Small Islands**: Small islands, such as those in the South Pacific and Caribbean will be affected by sea level rise, increased storm activity, coastal erosion, and coral bleaching. Fresh water resources will also likely be compromised.
- At this point, many of the expected impacts of climate change are projections based on current data and computer models. The actual effects of climate change will vary regionally and depend on a variety of factors, including:
  -Mitigation: The extent of efforts to prevent climate change, such as policies to reduce future greenhouse gas emissions.
  -Adaptation: How effectively communities act to reduce expected damages.
- We still have an opportunity to reduce the harmful effects of climate change. The efforts made today will determine the extent of climate change impacts in the future.


CHANGE IN SURFACE AIR TEMPERATURE, 2080-2099
ARCTIC
EUROPE
ASIA
AUSTRALIA & NEW ZEALAND
MALDIVES*
AFRICA
NORTH AMERICA
LATIN AMERICA
ANTARCTICA
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)
SOURCE: IPCC

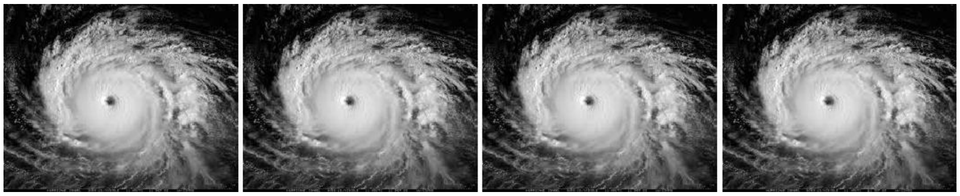

LOCAL SEA LEVEL CHANGE, 2080-2099 RELATIVE TO 1980-1999
ARCTIC
NORTH AMERICA
EUROPE
ASIA
AFRICA
LATIN AMERICA
AUSTRALIA & NEW ZEALAND
MALDIVES*
ANTARCTICA
0.1
0.2
0.3
0.4
0.5
0.6
(m)
SOURCE: IPCC


PRECIPITATION, CHANGE IN 2080-2099 RELATIVE TO 1980 - 1999
ARCTIC
NORTH AMERICA
EUROPE
ASIA
AFRICA
LATIN AMERICA
MALDIVES*
AUSTRALIA & NEW ZEALAND
ANTARCTICA
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
(mm day)
Stippling indicates a greater degree of certainty in the IPCC's projections
SOURCE: IPCC

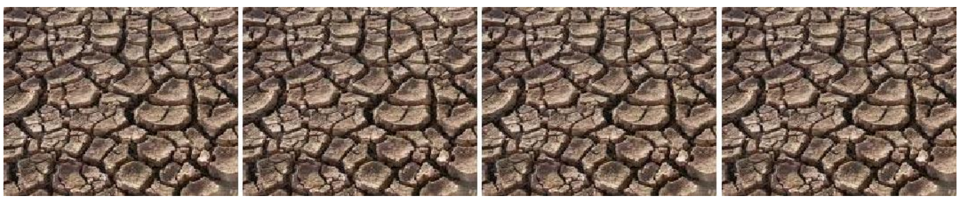

Arctic
Europe
Asia
Small Islands
Australia &
New Zealand
Africa
Antarctica
North America
Latin America

Climate Change Doodads

Extreme Storms:



Drought:



Flooding:

Sea Level Rise:

Elevated Sea Surface Temperature:

Increased Disease:

Food Shortages:

Glacier Melting:

Higher Crop Yield: