Sea Level on the Rise

Synopsis of the Activity

Through the use of physical models and map exploration, learners explore the causes and effects of sea level rise, globally and locally. They also learn about some ways they might lessen human impact on future sea level rise.

Audience

This activity is designed for the general public and is best accessed by learners in middle school or older. It is best done with small groups of visitors**.**

Setting

This activity works well at a large table anywhere in an informal science setting.

Activity Goals

Learners will gain a deeper understanding of:

a. What sea level and sea level rise are and how they are measured
b. The underlying causes of sea-level rise (melting land ice and thermal expansion caused by increased human activity related to increasing atmospheric CO_2 levels)
c. Global and local affects of sea level rise
d. What actions they might take to decrease sea level rise in the future

Concepts

1. Rising temperatures due to increased CO_2 in the atmosphere, a result of human industry, is the main cause of rising sea level.
2. Climate change is causing glaciers to melt, which causes sea level to rise.
3. When heat energy is added to water, the water molecules move more and get farther apart from one another. This causes the water to expand, which causes sea level to rise.
4. Global average sea level is rising, with the level rising more in some parts of the ocean than in others.
5. Coastal locations around the world have large populations of people living at or near sea level.
6. People can take action to combat climate change, which causes sea level rise. Some locations are also working to directly combat sea level rise.

Climate Literacy Principles

Some of the following Principles will be more relevant to different audiences, depending on their prior knowledge and the direction of the conversation between the audience and the facilitator.

6. Human activities are impacting the climate system.

a. The overwhelming consensus of scientific studies on climate indicates that most of the observed increase in global average temperatures since the latter part of the 20th

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

century is very likely due to human activities, primarily from increases in greenhouse gas concentrations resulting from the burning of fossil fuels.

c. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.

7. Climate change will have consequences for the Earth system and human lives.

a. Melting of ice sheets and glaciers, combined with the thermal expansion of seawater as the oceans warm, is causing sea level to rise. Seawater is beginning to move onto low-lying land and to contaminate coastal fresh water sources and beginning to submerge coastal facilities and barrier islands. Sea level rise increases the risk of damage to homes and buildings from storm surges such as those that accompany hurricanes.

Ocean Literacy Principles

1. The Earth has one big ocean with many features.

d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as seawater expands and contracts when ocean water warms or cools.

6. The ocean and humans are inextricably interconnected.

f. Much of the world's population lives in coastal areas. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges).

g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Materials:

For the whole activity:

Station sign that reads: *Sea level rise: What is it? What causes it? Why should I care about it? And what can I do about it?*

For Exploration Question #1:

- Exploration Question #1 sheet
- land/ocean tub model filled with water to where the land starts to rise
    - see-through plastic tub approximately 6 inches deep and 18″W X 29″H

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

    - piece of foam that is about the same depth as the plastic tub and about half the length and width
- pitcher full of water
- straw with tick marks evenly spaced and numbered (about .5 cm apart—each tick mark represents one meter)
- thumbtack to tack straw onto foam land
- scratch paper
- writing implement
- "What is sea level rise?" sheet
- sheets C, L-1, G-1, G-2, G-3
- 3 heat lamps (clamp lamps work well, but you will need something to attach them to, such as a bookend)
- one test tube filled with water with a stopper that has a small hole in it and a glass pipette or other small clear tube tightly fit into the hole
- two 6-8 oz clear plastic solo cups with about 2-3 inches of water in them
- cooler full of ice cubes (not crushed ice)
- rock that fits in the bottom of the clear plastic solo cup and takes up most of the bottom of the cup (the rock should not be large enough to emerge from the cup)
- colored tape or masking tape
- printed copy of directions for "Possible Causes of Sea Level Rise" investigation
- "Glaciers" sheet
- "Carbon cycle" interactive color print outs (2 sheets: Natural flows and Human Industry)
- Optional: interactive carbon cycle diagram computer model url:
    - http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit2
    - Scroll down to *Session 2.7: Investigating Combustion and the Carbon Cycle*; then click on *Simulation: Interactive Carbon Cycle Diagram*.
- Manila folder

For Exploration Question #2:
-Exploration Question #2 sheet
-plastic topographic map of your local area
-computer (to access http://sealevel.climatecentral.org/)
-sheets L-2, L-3, L-4, and L-5
-Manila folder

For Exploration Question #3:
-Exploration Question #3 sheet
-computer
-"What can you do?" sheet (enough copies for all visitors to take their own
-EPA information sheets (home, school, office, on the road)—enough copies for learners to take copies home if they are interested
-4 pencils
-Manila folder

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

Getting Ready

1. Prepare the land/ocean tub model. Place the foam in the plastic tub and decide how you would like to carve it to represent a landmass. The landmass should have a variety of topographical features so that it has different elevations at different points. The empty part of the tub represents an ocean basin. The land mass should rise rather abruptly along the coastline so that it represents a continental shelf, with the lowest point on the coastline being roughly 3 inches from the bottom of the tub. Once you have carved the foam landmass hot glue it into the tub so that it is permanently in place. (See image on right)
2. Print out all single-copy paper sheets and place them in sheet protectors or laminate them. Put them in the appropriate manila folders labeled with the Question #1, #2, and #3 for easy access during the activity.
3. Just before the activity, use the thumbtack to affix the straw with tick marks to the foam so that the straw is vertical. The bottom of the straw should be about two inches lower than the lowest point on the surface of the foam land. Add enough water to the tub so that the lowest part of the coastline is about level with the water, not submerged. It should look like ocean water meeting the land.
4. Plug in heat lamps. If they are clamp lamps, you will need to clip them to something like a bookend.
5. Set out all of the materials for each of the Exploration Questions so that they are clustered for easy access when you are exploring a particular question.
6. Have the url for sea level rise ready to go on your computer http://sealevel.climatecentral.org/.

Invite learners to participate.

When learners approach the station, greet them and let them know that you are exploring sea level rise at this station. Ask, **"What have you heard about sea level rise?"** Accept all responses because this question is just asking for the learner's prior knowledge. If the learner hasn't heard anything about sea level rise, ask them if they are interested in learning a bit about sea level rise and start with Exploration Question #1. If the learner knows quite a bit, ask them which of the questions they are interested in exploring and start there. You may not complete all exploration questions depending on the learner's interest and prior knowledge. If the learner has many alternate or misconceptions, thank them for sharing their ideas and suggest an appropriate starting point based on what you heard.

Exploration Question #1: What is sea level rise? And what causes it?

1) **Introduce the definition of sea level.** If the learner was unclear about what sea level rise is, you may need to help them understand what sea level is and how it is measured. Tell them that you will start with exploring what is meant by sea level.

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

2) **Introduce the land/ocean tub model.** Show learners the large tank with the foam land mass and water. Tell learners that this model represents the ocean and coastline. Land is elevated in some areas and lower in others. Point out the straw with tick marks. Have learners note the number at the water level on the straw. Tell them that this represents high tide for that portion of the day in meters. Record this number on a sheet of paper.

3) **Represent low and high tides.** Using a pitcher, remove a few cups of water (enough so the water level drops a couple of tick marks). Tell learners that the tide has gone out and this new water level represents low tide about six hours later. Have learners record the new water level tick mark number on their scratch paper. Add some of the water back and record that water level. This is the next high tide about 6 hours later.

4) **Calculate average sea level.** Repeat the step of lowering and raising the water level 2-3 more times. Each time make it clear that you are demonstrating high and low tide, and record the numbers. When you are done, have the learners average the numbers. This will give you the average sea level at that particular location.

5) **Share about global average sea level.** Explain that each area in the world has an average sea level that is determined in a similar way. You might share that local mean (average) sea level is defined as the height of the sea with respect to a land benchmark, averaged over a period of time (such as a month or a year) long enough that fluctuations caused by waves and tides are smoothed out. Tell participants that you've been using a rough model of a tide gauge to determine sea level in this activity. Tell them that since the late 1900s scientists have also collected sea level data using satellites. Show a picture of a real tide gauge and a satellite (shown on "What is Sea Level Rise?" sheet).

6) **Examine what is meant by sea level rise.** Ask learners, **"Based on what you know about sea level, what do you think sea level rise might mean?"** Let learners share their ideas. Then show them the graph (sheet L-1) and ask them to describe what they think it shows. You may need to explain that the 0 on the graph indicates where average global sea level (the average of all local average sea levels) was in 1870. You might also need to point out that the measurements are in millimeters and that the gray areas around the whitish-yellow average line show uncertainty, accounting for inaccuracies from older equipment. Explain any other aspects of the key or the graph that are confusing to the learner. Make sure to give learners a chance to share their interpretation of the graph before sharing some of the key information. If learners don't mention it, make sure to point out that sea level has been rising pretty steadily since 1870. If they don't bring this up, make sure to point it out.

7) **Explore what causes sea level rise.** Ask learners, **"What do you think might cause sea level to rise?"** Give them a chance to share some ideas. Accept all responses. Tell the learners that they are about to have a chance to use some materials to investigate this question further.

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

8) **Introduce Possible Causes of Sea Level Rise Investigation.** Point out the direction card for the "Possible Causes of Sea Level Rise" investigation. Ask learners to make a prediction about which of the following may contribute to sea level rise—warming water, melting land ice (glaciers and ice caps), melting sea ice (icebergs). Accept all responses. Tell them that they will use this investigation to gather some evidence.

9) **Set up the investigation.** Have learners set up the investigation as called for on the direction card.

10) **Share observations.** After they have completed the investigation (each experiment has had about 2-5 minutes to run), ask them to share their observations. [The water in the test tube rose into the glass tube at the top; the water level in the land ice cup rose; the water in the sea ice cup stayed the same]. Ask, **"Based on the available evidence, what do you think might cause sea level rise?"** [water takes up more space/rises when it gets warmer; ice melting on land goes into the ocean]. Share these ideas if the learners don't mention them. You might also share that many scientists estimate that warming water taking up more space (thermal expansion) is responsible for around 50% of sea level rise. If learners ask why the water in the sea ice cup didn't rise, explain a little bit about water displacement—that the ice in the cup was pushing an equal volume of water out of the way to its volume, so no new water volume was added when the ice melted. Ask, **"Did anything in this investigation surprise you?"** Accept all responses.

11) **Introduce glaciers.** Show the learners what melting land ice might look like by sharing the pictures of melting glaciers (sheets G-1, G-2, and G-3). You may also wish to share the sheet labeled "Glaciers," which defines a glacier.

12) **Share a bit about underlying causes of rising temperatures.** If you have other stations set up, tell learners that if they want to find out more about what causes ocean water to warm, they should visit both the Carbon Cycle and Greenhouse Effect stations. If these stations are not set up *and learners want this information*, briefly explain that carbon dioxide from human activities such as transportation, making cement, deforestation, and many other parts of human industry goes into the atmosphere faster than the rate at which it can be removed by natural processes, such as photosynthesis. Carbon dioxide is one of a number of heat trapping gases. Because carbon dioxide traps heat in the atmosphere, Earth gets warmer and warmer as atmospheric carbon dioxide levels increase. You might share the circle graph on sheet C to explore the different contributors to global atmospheric carbon. You might also share the "Natural Flows" and "Human Industry Flows" from the carbon cycle interactive. These can be shown as static images or through some exploration time with the Carbon Cycle interactive (see Carbon Cycle write up for more information on how to use the Carbon Cycle interactive).

13) **Investigating something else.** After the learner finishes with Exploration Question #1, ask if there are any other questions (s)he would like to explore.

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

Exploration Question #2: Why does sea level rise matter? Which areas will be affected?

1) **Explore sea level rise locally.** Show learners the plastic topographic map of your area. Tell them that global sea level is projected to rise between 2.5 and 6.5 feet by 2100—enough to submerge many cities on the east coast of the United States. Ask, **"How do you think areas near where you live may be affected by sea level change?"** Encourage learners to use the topographic map to discuss their predictions with others. You may have to help them figure out how to use the key on the map. Have learners share their ideas. Make sure to ask for evidence to support their predictions.

2) **Explore local sea level rise with a computer model.** Open this link on your computer: http://sealevel.climatecentral.org/. Find your state and then enter your local region or any other locality the learners are interested in. Allow learners to move the slider on the top of the page so that they can increase sea level. Point out the different parts of the page that show how many people, homes, and acres of land will be impacted by different amounts of water inundation. Also point out the information toward the bottom of the page that describes more about sea level projections for that region. Allow learners to look at as many locations as they find interesting. Ask, **"Is anything surprising or interesting to you?"** Learners may share any number of ideas here, and you should accept all responses. Depending on learner responses, you might ask follow up questions, such as, "What makes you think that? What's your evidence for that? What did other people think about that? What made you find that interesting/surprising?" If it doesn't come up, you may want to mention that you noticed different areas might experience different amounts of sea level rise based on the projections.

3) **Examine how sea level has changed globally.** Tell learners that although the average global sea level has risen pretty steadily since 1870, sea level is not changing the same everywhere. Show sheet L-2: Sea Level Change 1993-2008. Ask learners to look at the color key at the bottom and discuss what they think the figure is showing. Point out that the black areas are continents and the colored areas are ocean water. You might also need to point out that 0 is the average global sea level for that time period. If the learners don't point this out in their discussion, ask, **"Which places have experienced the largest amount of sea level rise? How do you know?"** [learners will likely note that sea level has risen in some places and dropped in others; they might also notice that some islands north of Australia have experienced the greatest degree of sea level rise]

4) **Look closely at some parts of the world that may be heavily impacted.** Share sheet L-3. L-3 gives elevation data for several places around the globe. Have learners use L-2 to predict which of the regions on L-3 might be the most heavily impacted in the future. Let learners discuss their ideas with each other or with you. Ask, **"What do you think would happen if sea level rose 6 feet? Which areas might be affected? How do you think this would impact people living there? How many people live in that region?"** Give learners a minute to share their ideas. Then show them sheets L-4 and L-5. Ask, **"How might sea level rise impact people in areas like these?"** Give learners a minute

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

to look through the images, read the text, and share some ideas with each other or you. If it doesn't come up, you might mention that some of the poorest nations in the world, island nations in the South Pacific, are encountering some of the biggest effects of sea level rise. Aside from their roads being flooded, their fresh water supplies are being impacted when seawater moves inland and mixes with fresh water sources. Sea level rise is already causing people of some island nations to have to leave and become climate change refugees.

5) **More information on local effects of sea level rise.** If the learner seems interested you may wish to share any or all of the following:
    - **a.** When sea levels rise rapidly, as they have been doing, even a small increase can have devastating effects on coastal habitats.
    - **b.** As seawater reaches farther inland, it can cause destructive erosion, flooding of wetlands, contamination of aquifers and agricultural soils, and lost habitat for fish, birds, and plants.
    - **c.** When large storms hit land, higher sea levels mean bigger, more powerful storm surges that can strip away everything in their path.
    - **d.** In addition, hundreds of millions of people live in areas that will become increasingly vulnerable to flooding. Higher sea levels would force them to abandon their homes and relocate.
    - **e.** Low-lying islands could be submerged completely.

14) **Investigating something else.** After the learner finishes with Exploration Question #2, ask if there are any other questions (s)he would like to explore.

Exploration Question #3: What can I do about sea level rise? What are communities doing to prepare for it?

1) **Explore some personal actions individuals can take to confront global warming.** If the learner wants to explore what (s)he can do about sea level rise, tell him/her the best thing to do is focus on actions that can decrease global warming. Since global warming causes sea level rise, and global warming is largely caused by human activities that increase the amount of carbon dioxide in Earth's atmosphere, their actions should take steps to reduce the amount of carbon put into the atmosphere. Share the relevant EPA solution sheet(s) (home, school, office, on the road—whichever makes sense for learner).

2) **Have learners create a personal action plan.** Give the learner the "What can you do?" worksheet, and have them talk to a partner and read over the relevant solution sheets to help complete it. Tell them all of the things listed are actions they can take, but it's hard for any one person to do all of these things. Ask them to select just one or two things they think they really want to try to do and create an action plan for themselves using the worksheet. After completing this activity, ask if the learner wants to explore one of the other questions they might not have explored yet.

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

3) **Examine some plans for combating sea level rise.** If the learner is interested in finding out about what his/her community or other communities are doing to combat some inevitable sea level rise, you can share the "responses" tab at http://sealevel.climatecentral.org. This portion of the website discusses some of the action plans various communities have for combating sea level rise. For example, some places are building things higher above sea level than they did in the past, such as wastewater treatment plants. Other places are building levees and sea walls. Learners can explore their local region's plan by going to their regions portion of the website and clicking on "plans." They can also influence their region's plans by contacting their local government representatives.

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

Science Background

Sea level is a measure of the average height of the surface of the ocean. Scientists measure sea level using several different techniques. They can measure sea level using tide gauges, which are machines that sit at the edge of the water and bob up and down with the tides. They record the changing water levels over a long period of time, and provide a good estimate of the average sea level for an area. Since 1992, scientists have used satellites to measure sea level with great precision. Scientists use the average sea level as a baseline for other measurements. When we say that Mt. Everest is about 5 miles high, it means that the peak of Mt. Everest is 5 miles above sea level.

Earth's sea level changes both on a seasonal scale and a long-term scale. The seasonal changes happen at opposite times of the year in the Northern and Southern Hemispheres. As ocean water cools during the winter months, it contracts because molecules are moving closer together, making the sea level lower in colder regions. More water is also stored on land during these cold months in the form of snow and ice, which decreases the sea level by inches. During the warmer summer months, the water stored on land melts and returns to the ocean, raising the sea level by inches. Ocean water also expands as it gets warmer, raising the sea level.

Long-term sea level rise is also caused primarily by ice melt on land and thermal expansion (water expanding when it warms). However, in long-term changes in sea level rise, the average sea level throughout the year continues to increase from year to year. As global temperatures continue to rise on average, ocean water will continue to warm and expand. Thermal expansion's contribution to sea level rise has been increasing, now possibly contributing up to 50 percent of measured sea level rise. Glaciers in both polar and non-polar regions have been melting recently. Ice sheets in Greenland and Antarctica have been melting more rapidly than scientists were originally aware. Recent data has shown that the ice sheets are not only melting from the outside in, they are also melting from the inside out. This new information has lead to a lot of uncertainty over how fast and how much sea level may rise, which is part of the reason sea level rise projection graphs have such large bands of uncertainty.

Sea level does not change uniformly across the globe. Some places experience decreases in sea level, while others experience increases. While the average global sea level has been rising steadily since the late 19th century, some of the places that are experiencing increased sea level are experiencing even greater amounts of sea level rise than the average. This means that some regions of the world may experience sea level rise that is much more dramatic than any of the average global sea level projections in the future.

About underlying causes of climate change: Some human-made processes transfer carbon from one reservoir to another much faster than it would happen naturally, such as the burning of fossil fuels. Naturally, carbon from fossil fuels that took millions of years to form would remain sequestered for around 100,000 years and be released by natural leakage and breakdown. However, combustion of fossil fuels releases carbon into Earth's

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

atmosphere immediately, which rapidly increases the amount of carbon in Earth's atmosphere because it builds up there faster than it can flow into other reservoirs. The increase of carbon in the atmosphere is causing an increase in global average temperatures. Increasing temperatures cause the melting of glaciers and sea ice, rising sea level, changes in regional climates and patterns of ocean currents, and can have large impacts on people and other organisms.

About Glaciers: Glaciers are large bodies of ice. They are formed over time on land because snow that falls during the winter doesn't completely melt during the summer. Over the course of many years, snow piles up. Because of the weight of snow above, the bottom layers of snow become compressed. The snow crystals are squeezed together into very dense ice. As the years go on and snow continues to accumulate, glaciers grow and become very heavy. They start to move downhill, due to their enormous weight. Many glaciers have been retreating (decreasing in size) in the past century, while some have disappeared altogether.
Many more are retreating so rapidly that it is possible they will vanish within just a few decades. Glacial retreat affects the availability of fresh water for irrigation and for people to drink as well as animals and plants that depend on glacier melt for survival. When glaciers melt, the water contributes to sea level rise.

About the Greenland ice sheet: The Greenland ice sheet is a large mass of ice covering over 600,00 square miles or about 80 percent of the land surface of Greenland. It ranges from 1 to 2 miles in thickness and is the second largest ice body in the world. Greenland is particularly susceptible to the effects of climate change and has experienced a record level of ice melt in recent years. Scientists predict that if global temperatures continue to rise, the entire sheet could melt (over a period of centuries) and this would lead to a rise in sea level of about 7 meters (23 feet), as well as changes to ocean water circulation.

The background section is taken from Ocean Sciences Sequence: The Ocean–Atmosphere Connection and Climate Change. Used by permission from the Regents of the University of California. For more information and additional resources from this instructional material, see: http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview.

"This material is based upon work supported by NOAA Environment Literacy Grant for the Ocean Sciences Sequence, and also from the National Science Foundation Grant No. GEO-1202741."

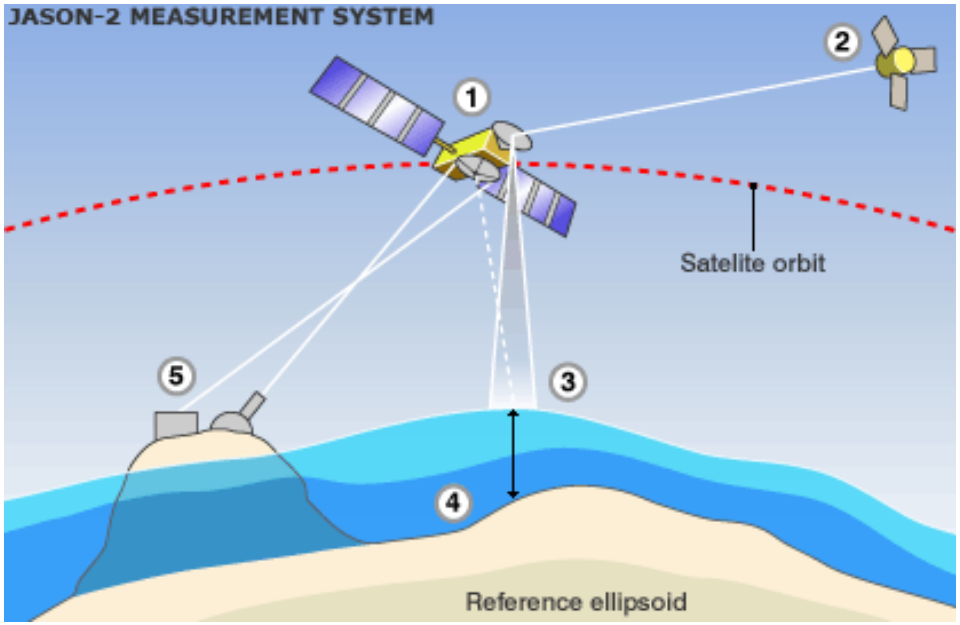
Sea level rise

- What is it?
- What causes it?
- Why should I care about it?
- And what can I do about it?

What is sea level rise? And what causes it?

What is sea level rise?

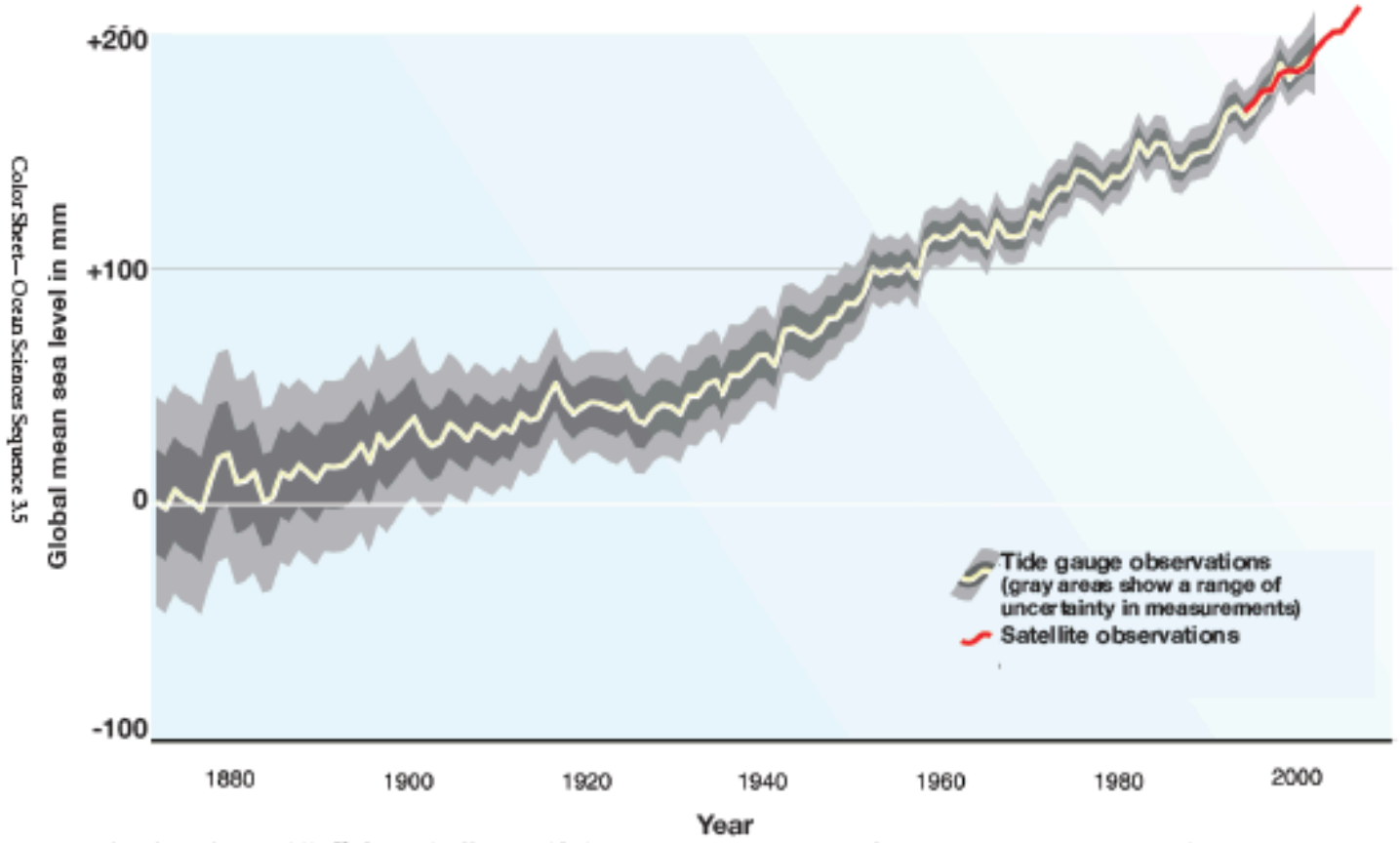
Sea level is the average height of the ocean in a particular area. Scientists measure sea level using tools called tide gauges, which they place in the water near the shore. They record the water level over time, and then calculate the average sea level for an area. Scientists also use satellites to measure sea level. *When sea level increases over time, this is referred to as* ***sea level rise****.*



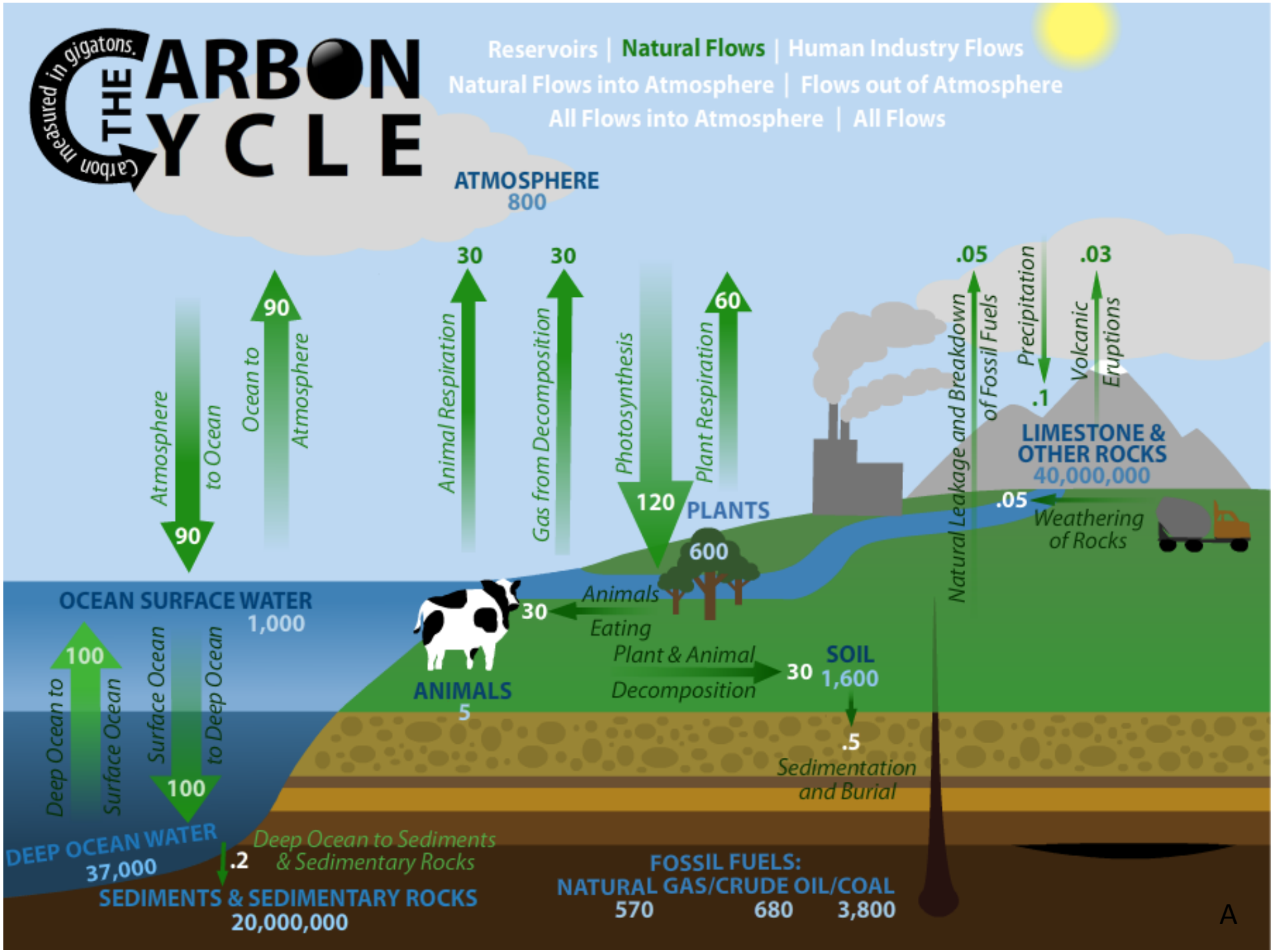
L-1

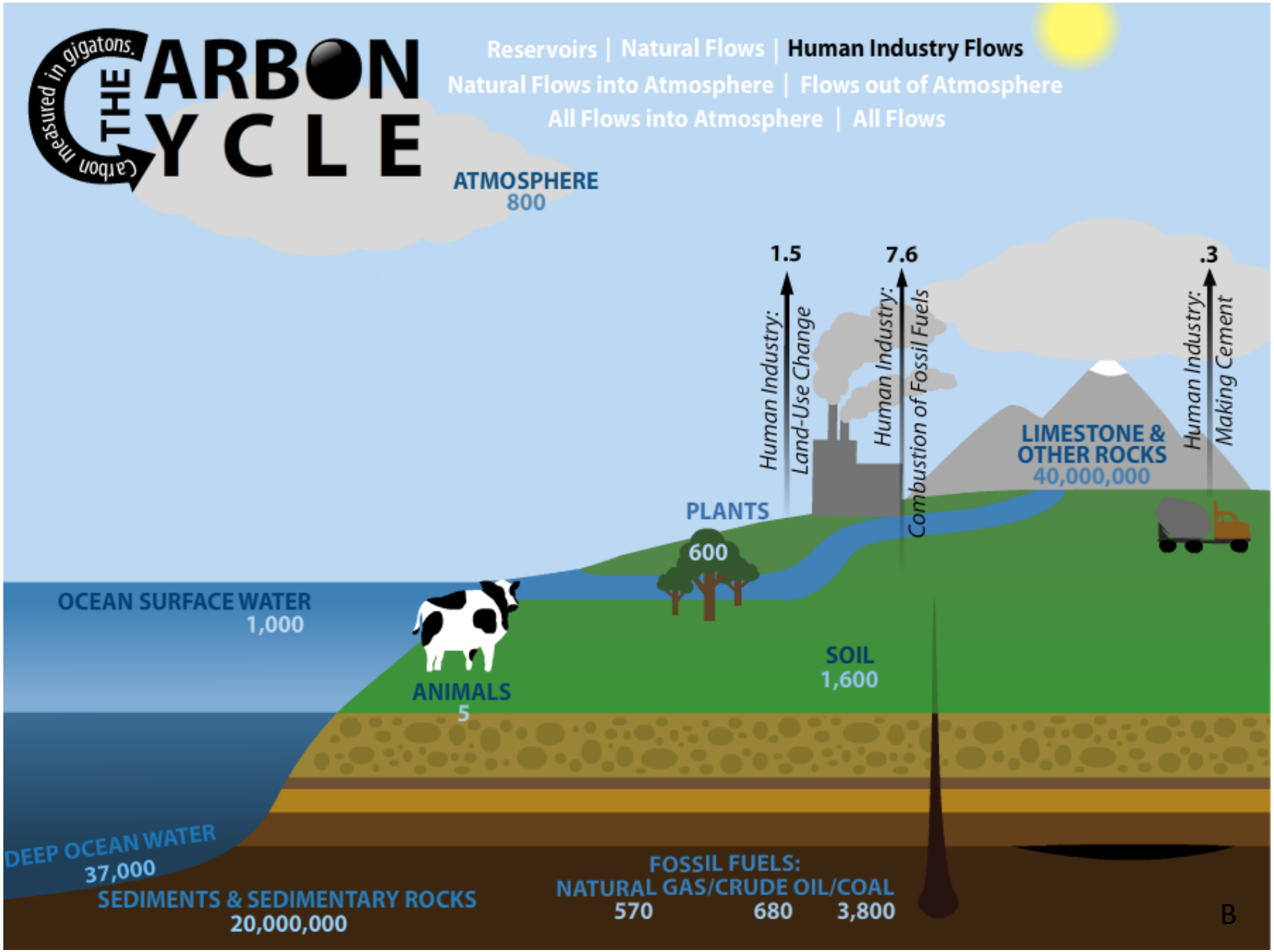
Sea Level Change

1870–2006

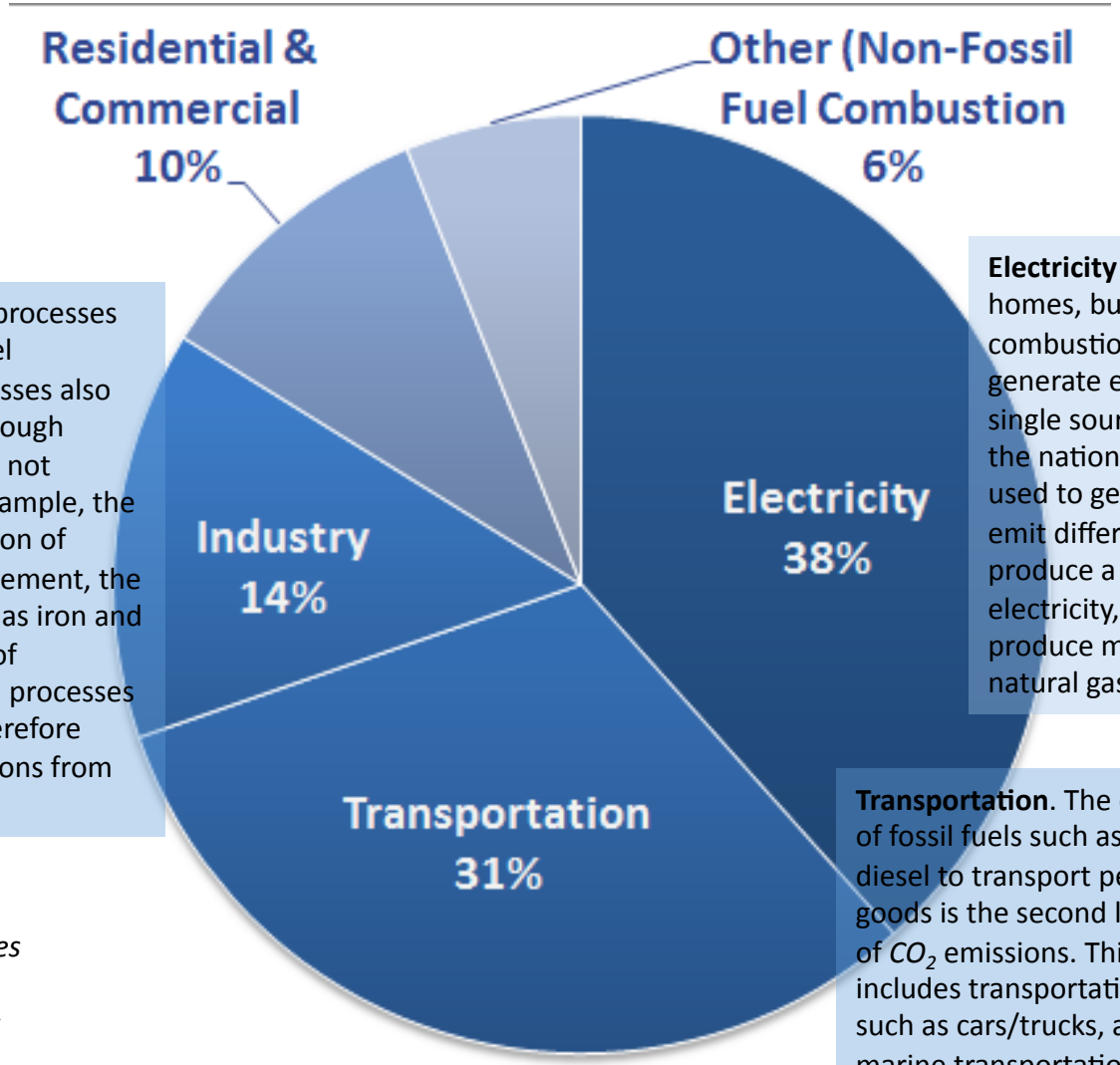


Color Sheet—Ocean Sciences Sequence 3.5


THE CARBON CYCLE
Carbon measured in gigatons.
Reservoirs | Natural Flows | Human Industry Flows
Natural Flows into Atmosphere | Flows out of Atmosphere
All Flows into Atmosphere | All Flows
ATMOSPHERE
800
Atmosphere to Ocean
90
90
Ocean to Atmosphere
30
Animal Respiration
30
Gas from Decomposition
Photosynthesis
120
60
Plant Respiration
PLANTS
600
.05
Natural Leakage and Breakdown of Fossil Fuels
Precipitation
.1
.03
Volcanic Eruptions
LIMESTONE & OTHER ROCKS
40,000,000
.05
Weathering of Rocks
OCEAN SURFACE WATER
1,000
Animals Eating
30
ANIMALS
5
Plant & Animal Decomposition
30
SOIL
1,600
.5
Sedimentation and Burial
100
Deep Ocean to Surface Ocean
Surface Ocean to Deep Ocean
100
DEEP OCEAN WATER
37,000
.2
Deep Ocean to Sediments & Sedimentary Rocks
SEDIMENTS & SEDIMENTARY ROCKS
20,000,000
FOSSIL FUELS:
NATURAL GAS/CRUDE OIL/COAL
570
680
3,800
A


THE CARBON CYCLE
Carbon measured in gigatons.
Reservoirs | Natural Flows | Human Industry Flows
Natural Flows into Atmosphere | Flows out of Atmosphere
All Flows into Atmosphere | All Flows
ATMOSPHERE
800
1.5
Human Industry:
Land-Use Change
7.6
Human Industry:
Combustion of Fossil Fuels
.3
Human Industry:
Making Cement
LIMESTONE & OTHER ROCKS
40,000,000
PLANTS
600
OCEAN SURFACE WATER
1,000
ANIMALS
5
SOIL
1,600
DEEP OCEAN WATER
37,000
SEDIMENTS & SEDIMENTARY ROCKS
20,000,000
FOSSIL FUELS:
NATURAL GAS/CRUDE OIL/COAL
570
680
3,800
B

*The main human activity that emits CO_2 is the **combustion of fossil fuel**s (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO_2 . The main sources of CO_2 emissions in the United States are described below.*



Industry. Many industrial processes emit CO_2 through fossil fuel combustion. Several processes also produce CO_2 emissions through chemical reactions that do not involve combustion, for example, the production and consumption of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Many industrial processes also use electricity and therefore indirectly cause the emissions from the electricity production.

Electricity is used to power homes, business, and industry. The combustion of fossil fuels to generate electricity is the largest single source of CO_2 emissions in the nation. The type of fossil fuel used to generate electricity will emit different amounts of CO_2 . To produce a given amount of electricity, burning coal will produce more CO_2 than oil or natural gas.

Transportation. The combustion of fossil fuels such as gasoline and diesel to transport people and goods is the second largest source of CO_2 emissions. This category includes transportation sources such as cars/trucks, air travel, marine transportation, and rail.

Note: All emission estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011.

C

Possible causes of sea level rise

Set up all experiments at the same time.

Warming water:

1) Turn on the heat lamp.
2) Note the water level in the test tube. If you can't see the top of the water, it is at the top of the test tube and below the small glass tube coming out of the top.
3) Place the test tube as close as you can to the heat lamp with the light shining on the water in the test tube, not the tube at the top.
4) Note the water level in the test tube after 2 minutes. Has it risen? Stayed the same? Fallen?

Melting land ice:

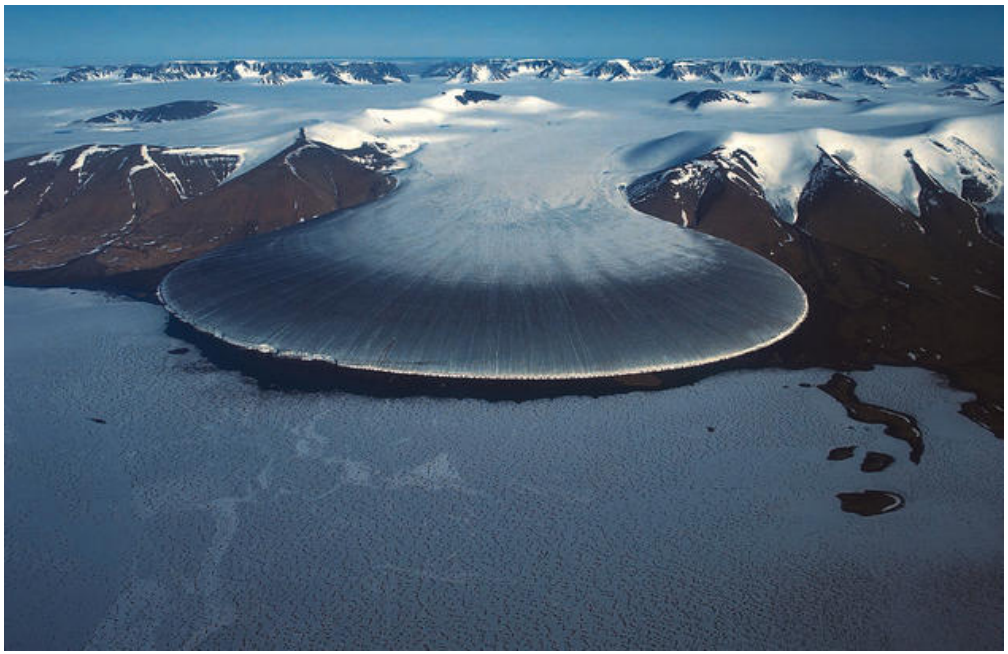
1) Turn on the heat lamp.
2) Select the cup with the rock at the bottom. Make sure the rock is sticking out of the water.
3) Use a piece of tape to mark the top of the water in the plastic cup. The top of the tape should line up with the top of the water.
4) Place a piece of ice on top of the rock, making sure that no part of the ice is in the water.
5) Move the cup under the heat lamp with the heat lamp as close to the cup as possible.
6) Note the water level in the cup after 2 minutes. Has it risen? Stayed the same? Fallen?

Melting sea ice:

1) Turn on the heat lamp.
2) Select the cup with just water and no rock.
3) Place two ice cubes in the cup.
4) Use a piece of tape to mark the top of the water in the plastic cup. The top of the tape should line up with the top of the water.
5) Move the cup under the heat lamp with the heat lamp as close to the cup as possible.
6) Note the water level in the cup after 2 minutes. Has it risen? Stayed the same? Fallen?

Glaciers

When winter snow doesn’t melt, it piles up over the years and the bottom layers turn into ice. A large area of longlasting ice on land is called a glacier (GLAY-shur). In the past, some glaciers were more than a mile thick. Glaciers have formed in parts of the world for millions of years.

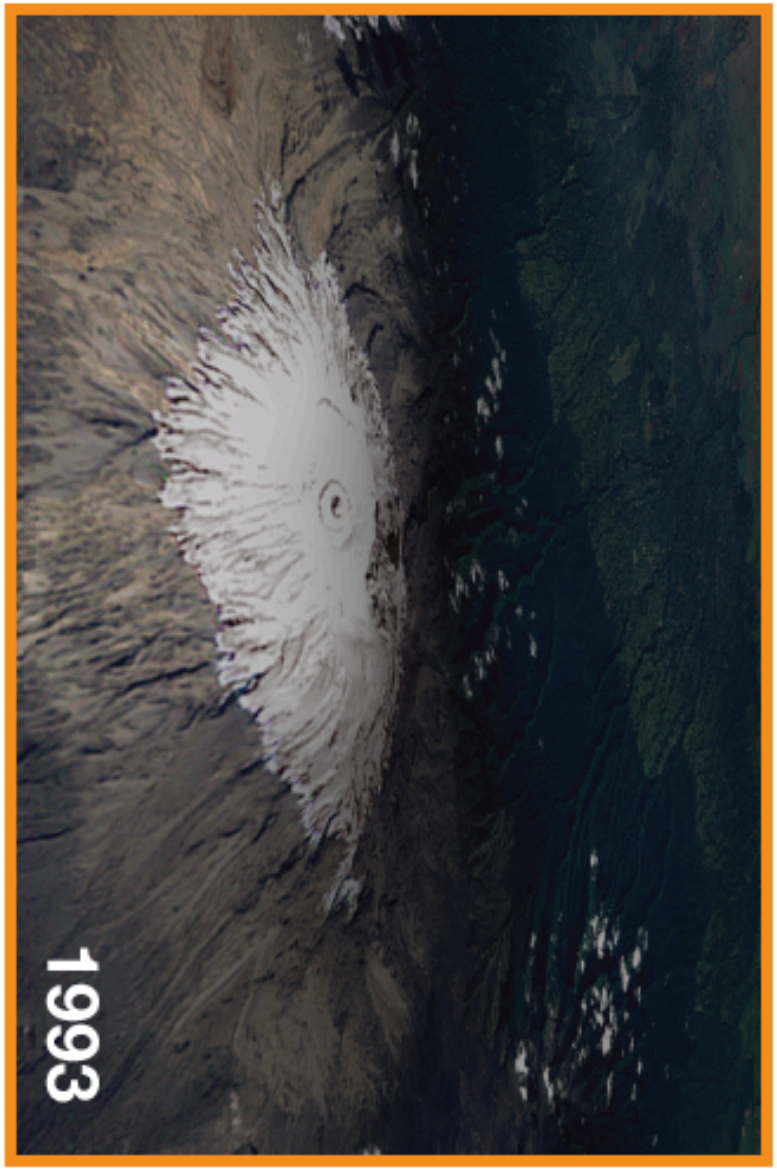


G-1

Qori Kalis Glacier, Peru

Color Sheet—Ocean Sciences Sequence 3.5

G-2 Mount Kilimanjaro, Tanzania



G-3

Boulder Glacier, Montana

Color Sheet—Ocean Sciences Sequence 3.5

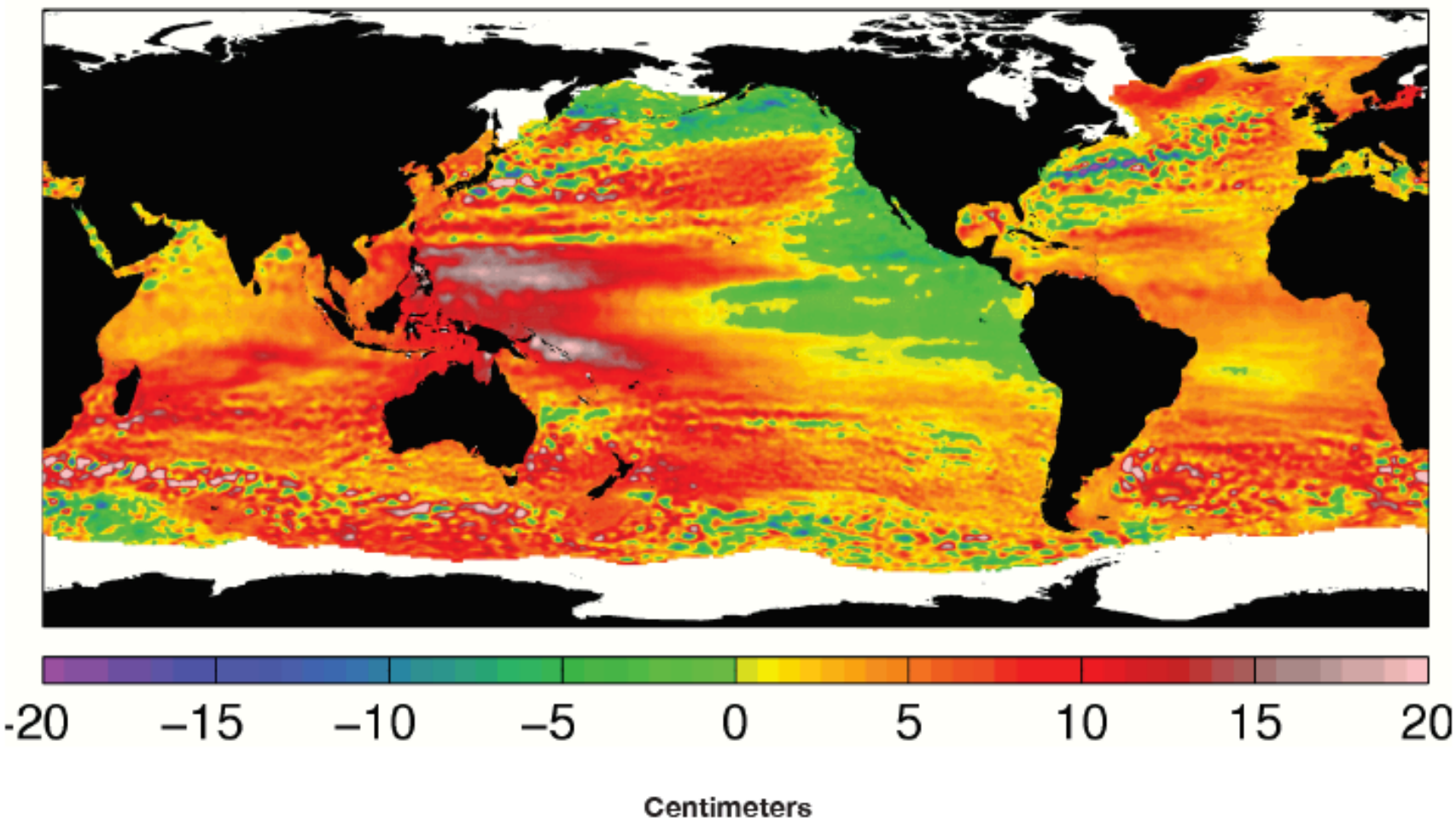
Greg Pederson photo, USGS

T.J. Hileman photo, courtesy of GNP archives

Why does sea level rise matter? Which areas will be affected?

L-2

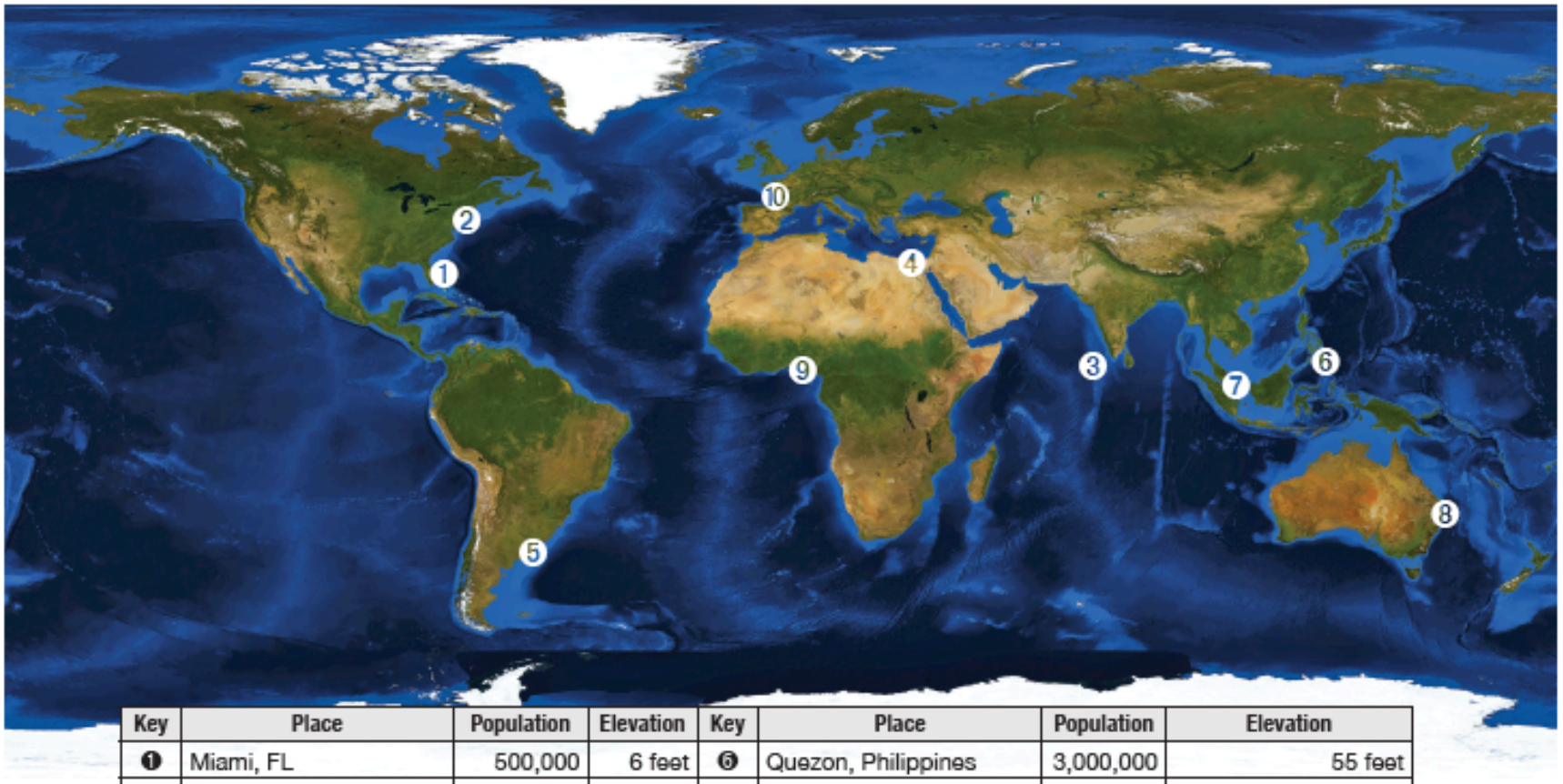
Sea Level Change
1993–2008



Color Sheet—Ocean Sciences Sequence 3.5

L-3

Some Places Vulnerable to Sea Level Change



Key	Place	Population	Elevation	Key	Place	Population	Elevation
❶	Miami, FL	500,000	6 feet	❻	Quezon, Philippines	3,000,000	55 feet
❷	New York, NY	8,175,000	33 feet	❼	Singapore	5,100,000	49 feet
❸	Maldives	330,000	5 feet	❽	Sydney, Australia	4,600,000	65 feet
❹	Cairo, Egypt	8,000,000	68 feet	❾	Lagos, Nigeria	9,000,000	114 feet
❺	Buenos Aires, Argentina	13,076,300	68 feet	❿	Amsterdam, Netherlands	741,636	6 feet *below* sea level

Color Sheet—Ocean Sciences Sequence 3.5

Mwaroni, 13, and Mareke, 14 in Kiribati. In the background, the newly furnished water reservoirs provided by the New Zealand High Commission that help with potable water supply. The community struggles to supply itself with freshwater, and the water provided by the government is insufficient, so the government of New Zealand installed rainwater collectors in front of the church of the Assembly of God.

Photo credit: Ciril Jazbec, WIRED

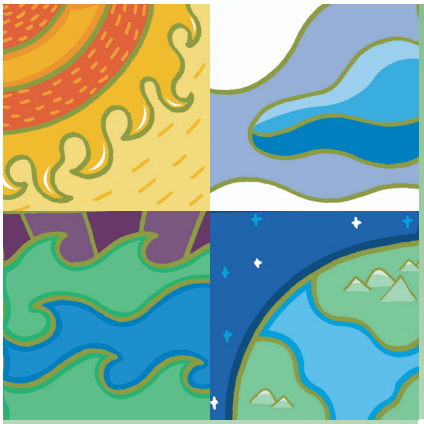
Photo credit: Jeremy M. Lange for The New York Times
Coinjock, North Carolina, was flooded in August 2011 during a storm surge from Hurricane Irene.

In the face of higher sea levels and more intense storms, coastal communities face greater risk of rapid beach erosion from destructive storms like the intense nor'easter of April 2007 that caused this damage. (Photograph ©2007metimbers2000.) *http://earthobservatory.nasa.gov/Features/GlobalWarming/page6.php*

What can I do about sea level rise? What are communities doing to prepare for it?

What can you do?

Something I can do	What steps do I have to take to make this happen?	When will I start?



Climate Change & You

WHAT YOU CAN DO on the road

The burning of fuels releases carbon dioxide into the atmosphere and contributes to climate change. By taking actions to reduce the amount of fuel you use, you can reduce your greenhouse gas emissions, reduce the nation's dependence on oil, and save money.

Resources

Federal Fuel Economy Guide: **www.fueleconomy.gov/**

Federal Bicycle and Pedestrian Program: **www.fhwa.dot.gov/environment/bikeped/**

Public Transportation Web site: **www.publictransportation.org/**

EPA's Green Vehicle Guide: **www.epa.gov/greenvehicles/**

DOE's Alternative Fueling Station Locator: **http://www.afdc.energy.gov/afdc/locator/stations/**

EPA's Climate Change: What You Can Do on the Road Web site: **www.epa.gov/climatechange/wycd/road.html**

1. Buy smart

Before buying a new or used vehicle (or even renting), check out EPA's Green Vehicle Guide and the jointly run EPA/DOE Fuel Economy Guide. These resources provide information about the emissions and fuel economy performance of different vehicles. The Green Vehicle Guide provides detailed information on emissions (including air pollution and greenhouse gas scores for each model), and the Fuel Economy Guide focuses on fuel efficiency (including side-by-side fuel economy comparisons and a customized fuel cost calculator).

2. Drive smart

To improve fuel economy and reduce greenhouse gas emissions, go easy on the brakes and gas pedal, avoid hard accelerations, reduce time spent idling, and unload unnecessary items in your trunk to reduce weight. If you have a removable roof rack and you are not using it, take it off to improve your fuel economy by as much as 5 percent. Use overdrive and cruise control on your car if you have those features.

3. Tune your ride

A well-maintained car is more fuel-efficient, produces lower greenhouse gas emissions, is more reliable, and is safer! Keep your car well-tuned, follow the manufacturer's maintenance schedule, and use the recommended grade of motor oil. Also check and replace your vehicle's air filter regularly.

4. Check your tires

Check your tire pressure regularly. Under-inflation increases tire wear, reduces your fuel economy by up to 3 percent, and leads to increased emissions of greenhouse gases and air pollutants. If you don't know the correct tire pressure for your vehicle, you can find it listed on the door to the glove compartment or on the driver's side door pillar.

5. Give your car a break

Use public transportation, carpool, or walk or bike whenever possible to avoid using your car. Leaving your car at home just two days a week will reduce greenhouse gas emissions by an average of 1,600 pounds per year. Whenever possible, combine activities and errands into one trip. For daily commuting, consider options such as telecommuting (working from home via phone or over the Internet) that can reduce the stress of commuting, reduce greenhouse gas emissions, and save you money.

6. Use renewable fuels

Both E85 and biodiesel are renewable fuels that can reduce greenhouse gas emissions from your vehicle. E85 is a fuel blend containing 85 percent renewable ethanol, and can be used in certain vehicles called flex fuel vehicles (FFVs). Biodiesel is a renewable fuel made from agricultural resources such as vegetable oils. DOE's Alternative Fueling Station Locator can help you locate both E85 and biodiesel fuel stations in your area.

Office of Air and Radiation (6207J)
EPA 430-F-07-008
www.epa.gov
June 2007

Printed with Vegetable Oil Based Inks on Recycled Paper (Minimum 50% Postconsumer)
Process Chlorine Free

Climate Change & You

WHAT YOU CAN DO *at home*

Making a few small changes in your home and yard can lead to big reductions of greenhouse gas emissions and save money.

Resources

ENERGY STAR Change A Light program: **www.energystar.gov/changealight**

EPA's Green Power Web site: **www.epa.gov/greenpower**

EPA's Reduce, Reuse, and Recycle Web site: **www.epa.gov/msw/reduce.htm**

EPA's WaterSense Web site: **http://www.epa.gov/watersense/**

EPA's GreenScapes program: **www.epa.gov/epaoswer/non-hw/green/index.htm**

EPA's Climate Change: What You Can Do at Home Web site: **www.epa.gov/climatechange/wycd/home.html**

EPA's Household Emissions Calculator: **www.epa.gov/climatechange/wycd/calculator/ind_calculator.html**

1. Change five lights

Replace your five most frequently used light fixtures or the bulbs in them with ENERGY STAR qualified options and you will help the environment while saving about $60 a year on energy bills. ENERGY STAR qualified lighting provides bright, warm light but uses at least 2/3 less energy than standard lighting, generates 70 percent less heat, and lasts up to 10 times longer.

2. Look for ENERGY STAR qualified products

When buying new products, such as appliances for your home, get the features and performance you want AND help reduce greenhouse gas emissions and air pollution. Look for ENERGY STAR qualified products in more than 50 product categories, including lighting, home electronics, heating and cooling equipment, and appliances.

3. Heat and cool smartly

Simple steps like cleaning air filters regularly, installing adequate insulation, and having your heating and cooling equipment tuned annually by a licensed contractor can save energy and increase comfort at home, and at the same time reduce greenhouse gas emissions.

4. Use green power

Green power is electricity that is generated from renewable energy sources such as wind and the sun that don't contribute to climate change. Consider buying green power or modifying your house to generate your own renewable energy. EPA's Green Power Web site provides information on both options.

5. Reduce, reuse, and recycle

Reduce the amount of waste you generate and water you consume whenever possible. Pursue simple water saving actions such as not letting the water run while shaving or brushing teeth. If there is a recycling program in your community, recycle your newspapers, beverage containers, paper, and other goods. Reducing, reusing, and recycling in your home helps conserve energy and reduces pollution and greenhouse gases from resource extraction, manufacturing, and disposal.

6. Be green in your yard

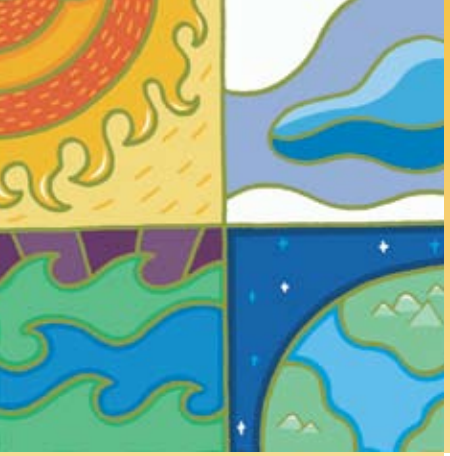
Composting your food and yard waste reduces the amount of garbage that you send to landfills and reduces greenhouse gas emissions. EPA's GreenScapes program provides tips on how to improve your lawn or garden while also benefiting the environment.

7. Calculate your household's carbon footprint

Use EPA's Personal Greenhouse Gas Emissions Calculator to estimate your household greenhouse gas emissions resulting from energy use, transportation, and waste disposal. This tool helps you understand where your greenhouse gas emissions come from and identify ways to reduce your greenhouse gas emissions.

Office of Air and Radiation (6207J)
EPA 430-F-07-006
www.epa.gov
June 2007

Printed with Vegetable Oil Based Inks on Recycled Paper (Minimum 50% Postconsumer) Process Chlorine Free



Climate Change & You

WHAT YOU CAN DO *at school*

Students, educators, and school administrators can all play a key role in reducing greenhouse gas emissions.

Resources

EPA's Climate CHECK Tool: **www.epa.gov/climatechange/wycd/downloads/ClimateCHECK_1.0.zip**

EPA's Global Warming Wheel Card Kit: **www.epa.gov/climatechange/downloads/ActivityKit.pdf**

ENERGY STAR for K-12 School Districts: **www.energystar.gov/index.cfm?c=k12_schools.bus_schoolsk12**

EPA's Reduce, Reuse, and Recycle Web site: **www.epa.gov/msw/reduce.htm**

EPA's Climate Change: What You Can Do at School Web site: **www.epa.gov/climatechange/wycd/school.html**

EPA's Climate Change Kid's Web site: **www.epa.gov/climatechange/kids/**

1. Power down your classroom

Remember to turn off computers, lights, and other devices that use energy when no one is in the classroom. Turning off just one 60-watt incandescent bulb that would otherwise burn eight hours a day can save about 1,000 pounds of carbon dioxide over the lifetime of the bulb.

2. Learn about climate change science, impacts, and solutions

Explore the many resources available to learn about climate change. Investigate what other schools and organizations are doing to educate their audiences on climate change. EPA's Climate Change Web site provides educational resources on the What You Can Do at School page.

3. Calculate your school's carbon footprint

Use EPA's Climate Change Emission Calculator Kit (Climate CHECK) (for high schools) or EPA's Global Warming Wheel Card Kit (for middle schools) to investigate the link between everyday actions at your school, greenhouse gas emissions, and climate change. These interactive tools help students learn about climate change and how to address it.

4. Ask your school administrators if your school has earned the ENERGY STAR

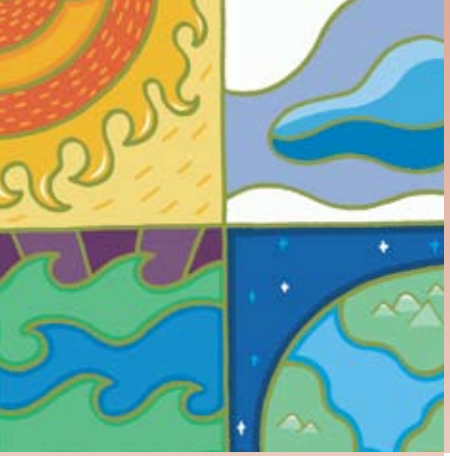
The least efficient schools use three times more energy than the best energy performers. By partnering with ENERGY STAR for K-12 program, school districts can serve as environmental leaders in their community, become energy efficient, reduce greenhouse gas emissions, and save 30 percent or more on energy bills.

5. Reduce, reuse, and recycle

Recycle school or classroom paper, newspapers, beverage containers, electronic equipment, and batteries. Reducing, reusing, and recycling at school and in the classroom helps conserve energy, minimize pollution, and reduce greenhouse gases. You can reduce, reuse, and recycle at school or in the classroom by using two-sided printing and copying, buying supplies made with recycled content, and recycling used electronics and printer cartridges.

Office of Air and Radiation (6207J)
EPA 430-F-07-007
www.epa.gov
June 2007

Printed with Vegetable Oil Based Inks on Recycled Paper (Minimum 50% Postconsumer) Process Chlorine Free



Climate Change & You

WHAT YOU CAN DO *at the office*

Business and home offices use a significant amount of electricity for heating and cooling, lighting, and operating equipment. Here are a number of easy ways to reduce greenhouse gas emissions and help make the air cleaner.

1. Manage office equipment energy use better

Office equipment and electronics use energy even when idle or on stand-by. To save energy and reduce greenhouse gas emissions at work, always activate the power management features on your computer and monitor, unplug laptop power cords when not in use, and turn off equipment and lights at the end of the day. Consider using a power strip that can be turned off when you're done using your computers, printers, wireless routers, and other electronics.

2. Look for ENERGY STAR qualified products for the office

When buying new products for your office at work or at home, get the features and performance you want and help reduce emissions of greenhouse gases and air pollutants. Look for ENERGY STAR qualified office equipment, such as computers, copiers, and printers, in addition to more than 50 product categories, including lighting, heating and cooling equipment, and commercial appliances.

3. Ask your office building manager if your office building has earned the ENERGY STAR

ENERGY STAR-labeled buildings provide safe, healthy, and productive environments that use about 35 percent less energy than average buildings. Their efficient use of energy also reduces the total operational cost of the building.

4. Use less energy for your commute

Switch to public transportation, carpooling, biking, telecommuting, and other innovative ways to save energy and reduce greenhouse gas emissions on your way to and from work. Encourage your employer to offer commuter benefits that address limited or expensive parking, reduce traffic congestion, improve employee recruiting and retention, and minimize the environmental impacts associated with drive-alone commuting. If you do drive, find out the fuel efficiency of your vehicle using EPA's and DOE's Fuel Economy Web site, and make more environmentally informed choices when purchasing your next vehicle by using EPA's Green Vehicle Guide.

5. Reduce, reuse, and recycle

Recycle office paper, newspapers, beverage containers, electronic equipment, and batteries. Reducing, reusing, and recycling in your office helps conserve energy, and reduces pollution and greenhouse gas emissions.
You can reduce, reuse, and recycle at the office by using two-sided printing and copying, buying supplies made with recycled content, and recycling used printer cartridges. For your old electronics, investigate leasing programs to ensure reuse and recycling or donate used equipment to schools or other organizations.

Resources

ENERGY STAR:
www.energystar.gov

Federal Fuel Economy Guide:
www.fueleconomy.gov

EPA's Green Vehicle Guide:
www.epa.gov/greenvehicles

EPA's Reduce, Reuse, and Recycle Web site: **www.epa.gov/msw/reduce.htm**

EPA's Electronics Recycling Web site: **www.epa.gov/eCycling**

ENERGY STAR Buildings Web site: **www.energystar.gov/buildings**

EPA's Climate Change: What You Can Do at the Office Web site:
www.epa.gov/climatechange/wycd/office.html

Office of Air and Radiation (6207J)
EPA 430-F-07-009
www.epa.gov
June 2007

Printed with Vegetable Oil Based Inks on Recycled Paper
(Minimum 50% Postconsumer)
Process Chlorine Free