

Global Warming and Changing Sea Level

Name:

Part 1: Am I part of the problem?!

The consumption of energy in the form of fossil fuel combustion is the largest single contributor to anthropogenic greenhouse gas emissions in the U.S. and the world. Carbon dioxide (CO₂) is the largest source of U.S. greenhouse gas emissions. (EPA; IPCC, 2007). The global atmospheric concentration of CO₂ has increased from a pre-industrial value of about 280 ppm to 391 ppm in 2012, which exceeds by far the natural range over the last 650,000 years (180 to 300 ppm). Although short-term changes in CO₂ emissions can result from temporary variations in weather, power generation fuel mixes, and the economy, growth in CO₂ emissions in the longer term results largely from population and income-driven increases in energy use, as well as consumer choices of energy-using equipment. Each year about 50,000 lbs of carbon dioxide is released into the atmosphere for each person in the United States! The global average is about 8,000 lbs (3.8 tonnes; United Nations Environment Program). About a third of the six billion metric tons of CO₂ the U.S. emits each year comes from individuals. About half the CO₂ comes from our homes and half from our vehicles.

The greatest source of anthropogenic CO₂ emissions is from non-point sources. The major contributor to this is the automobile. Of course, individuals have many other activities that contribute CO₂ emissions to the atmosphere: using any gas engine, running any electrical appliance, etc. In this activity, you will look at your own driving habits and calculate the amount of CO₂ your car releases to the atmosphere annually. (Don't worry, you won't be graded on how low or high your emissions are!) This exercise is designed simply to give you a feeling for how much just one of your activities contributes to the changing composition of the Earth's atmosphere.

Part 1: Lab Exercise

1. From your pre-lab assignment, how many pounds of CO₂ do you produce each year due to your driving habits?
_____ lbs
2. The average person in the U.S. produces about 50,000 lbs of CO₂ per year.
 - a) What percentage of your "allotment" is attributed to your driving? Show your work.
 - b) Compare your answer to 3a to at least 5 of your classmates' answers (list their values). Is your percentage higher or lower than most others? **Why** do you think this is (what are *your* driving habits)?

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Part 2: Melting Glaciers

During the last glacial period, about 20,000-60,000 years ago, a portion of the world's oceans water was trapped on Eurasia and North America as huge continental glaciers, resulting in global sea level that was 85 to 120 m below today's level. In places, lowered sea level created land bridges between continents, affecting the migration of many species, including our own. The ice sheets and other smaller glaciers began to retreat about 18,000 years ago, and sea level rose rapidly. By 10,000 years ago, sea level was 20 m below present levels, and it continued to rise about 20-30 mm per year until about 5,000 years ago. Since then, sea level has been relatively stable.

Global sea level and the Earth's climate are closely linked. The Earth's climate has warmed about 0.8°C (1.4°F) during the last 100 years. If present trends continue, including an increase in global temperatures caused by increased greenhouse-gas emissions, many of the world's mountain glaciers are likely to disappear. For example, at the current rate of melting, all glaciers will be gone from Glacier National Park in Montana by the middle of the next century (USGS). In Iceland, about 11% of the island is covered by glaciers. If warming continues, Iceland's glaciers will decrease by 40% by 2100 and virtually disappear by 2200. Barring any catastrophic melting of large ice sheets, a sea level rise of 0.2 to 0.5 m (20-50 cm) is expected by the end of the century (IPCC, 2007).

Most of the current global land ice mass is located in the Antarctic and Greenland ice sheets. The probability of widespread deglaciation of the Greenland or Antarctic ice sheets is not well constrained, due to high levels of uncertainty in ice dynamic models. However, it is thought that widespread deglaciation of the Greenland or West Antarctic Ice Sheet may occur with polar warming less than 5°C (Overpeck et al, 2006) and global mean warming of 1°C (Hansen 2004) or 2°C (Oppenheimer and Alley, 2005) above recent temperatures. Such global mean warming will almost certainly occur during this century, given the most recent IPCC projections (IPCC, 2007). Potential rates of sea level rise are highly uncertain, but 1 m/century (10 mm/yr) has been suggested based on paleoclimate analogs (Overpeck et al., 2006) and by comparison to current rates of ice discharge from West Antarctica (Oppenheimer 1998). Given this information, sea level will most certainly rise over the next hundred years, although the rate of sea level rise is not well understood.

References

- J.Hansen, Climatic Change, 68, 269-279, 2005.*
IPCC: Climate Change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC, 2007.
M. Oppenheimer and R.B. Alley, Climatic Change, 68, 257-267, 2005.
J.Overpeck et al, Science 311, 1747-1750, 2006.
USGS: <http://pubs.usgs.gov/fs/fs2-00/>

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Part 2: Lab Exercise

Part A: Calculating Sea Level Rise Under a Range of Scenarios

In this activity, you will calculate how much sea level would rise if various scenarios of ice melted. We will divide the class into five groups. **Group 1** will calculate sea level rise following the melting of the **East Antarctic Ice Sheet** (ice volume 26,039,200 km³). **Group 2** will calculate sea level rise following the melting of the **West Antarctic Ice Sheet** (ice volume 3,262,000 km³). **Group 3** will calculate sea level rise following the melting of the **Antarctic Peninsula** (ice volume 227,100 km³). **Group 4** will calculate sea level rise following the melting of the **Greenland Ice Sheet** (ice volume 2,620,000 km³). **Group 5** will calculate the estimated sea level rise following the melting of all **other ice, including continental glaciers** (ice volume 180,000 km³).

You will be making several assumptions in order to simplify these calculations. These assumptions would, of course, mean the actual sea level rise would be different from what you calculate here. (But it still makes a good rough approximation). The assumptions are:

- No other ice sheets exist (or melt) than the one you are considering.
- The oceans would continue to occupy 70% of the surface area of the globe.
- The sides of the ocean basins are vertical.

You will do the calculation in three steps: 1) you will find the volume of water produced by the melting of the ice; 2) you will find the surface area of the ocean basins; and 3) you will calculate the rise in sea level. **Show your work at each step, and don't forget to include units!**

1. Change in Volume Converting Ice to Water

To determine how much sea level would rise as a result of a given volume of ice melting, you first need to calculate the volume of water that would result from melting. Ice is less dense than water. It has a density that is 0.9 times (90%) that of water. Therefore, when one km³ of ice melts, it will decrease its volume by 10%. Thus, the conversion factor you need is:

$$1 \text{ km}^3 \text{ of ice} = 0.9 \text{ km}^3 \text{ of water}$$

- a) To which group have you been assigned (1-5)? _____
- b) Volume of ice: _____ km³
- c) Calculate the **volume of water** resulting from the melting of "your" ice (show work and units!):

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2. Determine the Surface Area of the World's Oceans

Earth is a sphere. In order to calculate sea level rise, we need to find the area of Earth's surface that makes up the ocean basins. The radius (r) of the earth is 6,370 km. The surface area of a sphere is equal to $4\pi r^2$. The ocean basins make up 70% of the total surface area of the earth. With this information, calculate the **surface area of the ocean basins** (Show work and units). *Note: π stands for "pi," a constant value that describes the ratio of the circumference of a circle to its diameter. Pi is always the same number, no matter which circle you use to compute it. You should find the exact value for π on your calculator, but it can be approximated as 3.14159.*

3. Sea Level Rise

The height to which the water column would rise is the "Sea Level Rise" and can be calculated in the following manner:

$$\text{Sea Level Rise} = \frac{\text{Volume of Water (km}^3\text{)}}{\text{Surface Area of Ocean (km}^2\text{)}}$$

The answer you get will be in kilometers (km). For it to "make more sense", you need to convert it to meters (1 km = 1000 m). To put this number in terms you may better relate to, also convert it from meters to feet (1 m = 3.28 ft). Show your work and units for each step.

a) Sea Level Rise in kilometers (km):

b) Sea Level Rise in meters (m):

c) Sea Level Rise in feet (ft):

Once you have your values for a-c above, check them with the instructor to verify that they are accurate. Once every group is finished, we will move on as a class to Part B.

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Part C: Exploring how various scenarios of ice melting would affect California

Your instructor has provided a selection of bathymetric and topographic maps of the California coastline. Examine the map(s) with your group, and discuss how the various sea-level-rise scenarios (1-6, above) would impact the mapped area. What specific areas would be flooded and to what extent under this range of scenarios? Make some specific suggestions on how you think the communities will be affected. Responses must be thoughtful and complete to receive full credit.