Chapter 1 Project: Melting of the Ice Caps

Name _____ Name _____

Background: About 77% of the world's freshwater is stored as snow and ice, with most of it located in the vast ice sheets of Antarctica and Greenland. Antarctica contains about 85% of the world's frozen freshwater, whereas Greenland contains about 11%. Most scientists agree that if global warming continues, shrinking of the world's glaciers and ice sheets will accelerate, and sea levels will rise.

There are two principal climate variables that affect the volume of ice in a glacier or ice sheet: temperature and precipitation. Precipitation that falls in the form of snow adds to the volume of ice. Air temperatures above freezing that cause ice to melt or sublimate, and ice falling or "calving" into the ocean, contribute to volume loss. There are other factors such as solar radiation, air and ocean currents, and cloud cover that impact the ice balance. It is important to understand that the volume of ice also affects these climate factors—everything in nature is tied together.

In this project, you will first estimate the amount of ice in Greenland from a map, then calculate the total amount of freshwater ice in the world. Finally, you will compute the sea level rise should all the freshwater ice melt. The reason that you will work with the map of Greenland rather than Antarctica is that its topography is much simpler. Predicting the rate at which a body of ice will diminish is a difficult task, but we know that glaciers and ice sheets will not disappear overnight. An April, 2004 scientific report claimed that global warming could start runaway shrinking of the Greenland ice sheet within 50 years, but that a total meltdown is likely to take at least 1,000 years![1]

Directions: Obtain the map of the Greenland ice sheet, and then work through the following questions. Show steps that you take to make your computations. Always show and label units whenever appropriate. The last question is "open ended," and will require searching the internet for information.

[1] Gregory J., Hubrechts, P. and Raper S. *Threatened loss of the Greenland ice-sheet*. Nature vol. 428, April 8, 2004, p 616.

1. The Greenland map

Greenland is an island that lies between northern Canada and western Europe, and is about three times the size of Texas. Greenland is not, by any means, green, as over 80% of the country is covered in ice. Most of the ice is contained in the vast Greenland ice sheet, which covers the interior of the island, and extends to the surrounding North Atlantic Ocean in some locations. Narrow bands of mountains are exposed along most of Greenland's coasts, and make up the 20% of Greenland which is not ice-covered.

On the map, the coast of Greenland is indicated by a faint, grey curving line. Also on the map are perpendicular grid lines spaced 200 km apart to indicate horizontal distances.

a) Estimate the maximum north-south distance of Greenland:

b) Estimate the maximum east-west distance of Greenland:

c) What is the area of each grid square?

In the interior of the Greenland map several **contours** are drawn (darker curved lines) with numbers that indicate ice thickness in meters. Anywhere on the same contour the ice thickness is the same. Contours of constant ice thickness are called **isopachs** (*eye-so-packs*).

Between the coast of Greenland (faint grey line) and the 0 km contour (the dark curved line just inside the coast) is land that *is not* covered by ice. Any location inside the 0 km contour *is* covered in ice.

d) On your map, lightly shade *with pencil* the small regions that have ice thicknesses between 0 km and 1 km.

e) On your map, lightly shade *with pencil* the large region with ice between 2 km and 3 km thick.

f) Inside the 3 km contour, the location with the maximum ice thickness is indicated by a solid circle. What is the maximum thickness of the Greenland ice sheet in meters and kilometers?

Note that the thickness of the ice at any location *between* contours cannot be exactly determined from the map. In this project, assume that the *average* thickness of the ice between any two contours is half-way between the contour values. For example, assume that the average ice thickness of the region between the 0 km and 1 km contours is 0.5 km. For the region whose ice thickness is greater than 3 km, assume that the average thickness is half-way between 3 km and the maximum thickness of the ice sheet.

g) Label each of the 4 regions on the Greenland ice sheet map with average thickness values in kilometers.

2. Estimating the volume of Greenland's ice

You need to estimate each region's area by using the map's grid. Start with the simplest region, the one with ice thickness greater than 3 km. Estimate the total number of grid squares that this small region covers. *There are several ways to do this – be creative!*

a) How many grid squares are covered?

b) What is the total area of the region? *Include units!!*

c) Describe in a few sentences your method for estimating areas of regions. Be sure to comment on how you counted grid squares that do not fall entirely in one region.

d) Using the same method, estimate the areas of the other three ice-covered regions. Record average ice thicknesses and areas in the table below. Then multiply the area by the average thickness to determine the ice volume for each region.

Ice thickness	average thickness (km)	area (km^2)	volume of ice (km^3)
0 km to 1 km			
1 km to 2 km			
2 km to 3 km			
greater than 3 km			

e) What is the total volume of ice in the Greenland ice sheet? *Write your answer in scientific notation using 3 decimal places.*

3. Estimating the world's ice

We noted earlier that Greenland holds approximately 11% of the world's freshwater ice. Compute the total volume of the world's freshwater ice using your estimate for the volume of Greenland's ice. *Write your answer in scientific notation using 3 decimal places. Note: if you need help with simple percentages, browse through Chapter 2.*

4. Melting the ice

As you've certainly noted after placing a bottle of water in your freezer, when water turns to ice it expands. Less noticeable is the fact that when ice melts back to water it contracts. When glacier ice melts, the resulting volume of water is about 90% of the original volume of ice.

Determine the volume of water contained in all of the world's freshwater ice. *Again, use scientific notation with 3 decimal places of precision.*

5. Calculating the rise in sea level

a) Determine the surface area of the world's oceans in units of square kilometers. *Report in scientific notation with 3 decimal places of precision. The average radius of Planet Earth is 6,370 km, and the oceans cover an estimated 2/3 of its surface. The formula for the surface area of a sphere is* $A = 4\pi r^2$.

b) Now compute the average rise in sea level if all freshwater ice were to completely melt. Give your answer in kilometers, meters and feet. Use a reasonable amount of precision in stating your answers. *Hint: Imagine a bathtub with a bottom that has the same area as the world's oceans. Now pour the water from all of the world's ice into the bathtub. What height will the water reach in the bathtub?*

6. The effects of sea level change

A rise in sea level will certainly cause flooding in coastal regions around the world. To explore the severity of flooding, search the World Wide Web to find and compare the **elevations of 2 coastal cities, 2 coastal U.S. states, or 2 coastal countries**. Of course, the elevation of any region is not constant, but varies according to local topography.

For U.S. cities, a good website that has elevations and topographic maps is www.topozone.com. An excellent website for U.S. statewide topography is NOAA's National Geophysical Data Center. In 2005, the website was: http://www.ngdc.noaa.gov/mgg/topo/state.html. Finding elevations of regions outside the U.S. will require some internet searching. Beware that some maps give elevations in feet and some in meters, but will not indicate which unit is being used! Also note that downloading maps efficiently will require a fast internet connection.

a) List the 2 locations that you are comparing, along with their average elevations:

location #1 _____ elevation _____

location #2 _____ elevation _____

Now answer the following 2 questions on the next page. Attach relevant supporting information that you find on the internet or elsewhere (no more than 3-4 pages in total).

b) Which of the 2 coastal regions that you found will be most impacted by the calculated sea level change? Which will be impacted the least? Explain.

c) Describe 2 different ways that you might measure the environmental damage of flooding in coastal regions.