In this activity students will analyze authentic ice sheet elevation data from the Pine Island Glacier (PIG) and then develop ‘hands-on’ models to support their hypothesis for the ice sheet behavior.

Pine Island Glacier Oct. 2009 © M. Studinger

Antarctic Map – NASA image

INTRODUCTION:
Scientists are measuring the polar ice sheets to determine both the rate and the total amount of any change that is occurring. One of the most efficient ways to collect measurements in the poles is through the use of remote sensing from satellites and aircraft since the areas are large, the weather unforgiving and the terrain difficult.

Beginning in 2003 NASA launched ICESat “Ice, Cloud and Land Elevation Satellite” to collect measurements of the polar-regions, including surface elevation measures of the polar ice sheets. Scientists have noted that an Antarctic area of interest is the Pine Island Glacier (PIG), which drains part of the West Antarctic Ice Sheet (see image above).

Evidence suggests that warmer ocean water is being forced onto the Antarctic continental shelf by shifting ocean currents and is melting the ice around the continent. Ice shelves exist around much of Antarctica proving a buffer from the ocean contact, but Pine Island Glacier and Thwaites Glacier are two major West Antarctic ice streams that flow directly into the Amundsen Sea. There is concern that without an ice sheet to buffer these ice streams from direct ocean contact, they may cause a quick ice retreat in West Antarctica. In this activity you will review some of the data to see if there are changes taking place.

PART 1: WORKING WITH ICESat DATA
Activity: Are changes occurring in the elevation of Pine Island Glacier (PIG)? Scientists hope that by collecting a time series of data on the surface elevation of PIG they can determine if there is a loss of ice. A time series is a sequence of data measured at successive times. This time series was collected along a line, so that we will visualize a slice across the glacier.
This exercise includes two sets of real data collected over PIG. Data set PIG 279 includes data from Nov. 2003, April 2007 and Oct. 2007. Data set PIG 362 contains data from Nov. 2003, Mar. 2004, April 2007 and Nov. 2007. We examine this data to see if there are changes occurring in the Pine Island glacier in this time period.

PIG 279
1. Starting with Data Set PIG 279 examine the data. The information is presented in rows of numeric data that you will analyze to determine if it is worth further study.

2. What does each column represent?
   - **Lat** = Latitude reading of the data point. Note that latitudes South of the equator are listed as negative numbers.
   - **Lon** = Longitude reading of the data point. Note that longitudes West of the prime meridian are listed as negative numbers.
   - **X** = Easting - a geographic coordinate for a point referring to the eastward-measured distance, or the x-coordinate. This is one way to locate your data on the Earth using a flat gridded projection, which is beneficial when moving away from the equator.
   - **Y** = Northing - expressed here in kilometers (km) - a geographic coordinate for a point referring to the northward-measured distance, or the y-coordinate. This is one way to locate your data on the Earth using a flat gridded projection, which is especially useful when you move further away from the equator.
   - **Data columns** – for PIG 279 these are labeled Nov-03, April-07 and Oct-07 representing the ice elevation for these three time periods expressed in meters of height.

3. What is the first step in analysis? When scientists collect data series like these they would want to look at them in a plot or graph to see if there is a relationship. Plots can graphs can help us to visualize data, using the human mind’s ability to recognize patterns and trends. If there does seem to be a visible relationship we can go a step further by quantifying these relationships through applying additional mathematically tests.

4. Use the Excel charting function to chart the three sets of data as presented with the ‘X’ axis being ‘Northing’ and the ‘Y’ axis being the three separate years of ice elevation measured by ICESat, each data set will be a separate line with its own label and color.

5. Examine your chart. Can you tell if there is a story in the data displayed? Are deviations evident in the overlapping time series or does it appear that the ice surface has been fairly stable? Discuss what you see and suggestions you might have on an alternative approach to visualizing the data.

6. Let’s look a little deeper. We are looking at data collected over an area of ~ 20 kms and with altitude changes of ~500 meters. This is a fairly large scale to examine in a small chart or graph. We need to determine the best way to look at the data given this...
large-scale comparison. Can you suggest ways to scale or reference the data to make it easier to see if there are differences or changes?

7. One approach is to establish a mean of the data points – and then compare each set of collected data against that mean for the difference.
   - **Mean** - Since some of the years are missing data points calculating the mean in Excel works best if you use the ‘average’ function.
   - **Calculating change for each data set** - In order to best visualize change over time subtract the mean from each column of data.
   - Then chart this in Excel with the ‘X’ axis being ‘Northing’ and the ‘Y’ axis being the change from mean for each of the three separate years of ice elevation measured by ICESat. Each data set will be a separate line with its own label and color.

8. Examine your chart. Can you find a story in the data displayed? Do the time series overlap, or are there deviations? Describe the changes, if any, in the data from Nov. 2003, April 2007 and Oct. 2007? Be sure to use measurements in your answer.

9. What does this data tell you about the ice sheet? Has the ice surface been fairly stable or is the elevation changing? Is it lowering or is it rising, and what does that mean about this area of Antarctica?

10. Discuss what you see, and any suggestions you might have for analyzing this data further.

11. We have looked at one series of PIG data, however scientists would want to look at more than one data set. Why would this be important?

12. The second series of data labeled PIG 362 is collected in approximately the same area of the glacier, and has an intersecting point with PIG279. Follow steps 4-7 from the activity above creating display charts of this second set of data.

13. Examining the new set of data charts, what is the story in the data displayed? Is the data from PIG 362 consistent with the data from PIG 279?

14. What could cause the glacier to behave this way? Let’s test a few different options using a model.

**PART II: WORK WITH GLACIER GOO TO DEVELOP A MODEL TO SUPPORT YOUR DATA**

**Framing the question:** Using goo to represent polar glaciers answer the following questions:

1. Describe glacier movement. Are glaciers stagnant blocks of ice? Or does the glacier move?
2. If the glacier does move, how would you describe the movement? Does it flow smoothly? Does it start and stop?
3. What behavior is needed by the glacier in order to maintain a steady elevation?
4. Can a change at the foot (toe) of the glacier cause a change in the elevation of the glacier?
5. Create a hypothesis on how the behavior of your model of glacier goo might relate to the behavior of the PIG glacier.

Activity:
- Using an aquarium or plastic container with clear walls, set up a ramped surface for the goo (glacier) to flow on.
- Arrange the Goo (glacier) next to the wall of the container so that any change in elevation will be clearly visible.
- Place ¾ of the goo (glacier) at the top of the ramp and watch to see if it moves.
- Glaciers flow under their own gravitational pull – does the goo have this same behavior?
- Once the goo (glacier) reaches the base level on the wall of the aquarium place a piece of clear tape along the height of the top of the glacier – then using a marker draw a line noting the height of the goo (glacier). This will be our ‘base level’. We will see what happens to this base level with changes we make in the conditions.
- If you leave the goo (glacier) alone what happens to the surface elevation? Does it begin to drop as all the material continues to flow downhill? Or does it stop flowing once it touches the bottom of the container?
- What happens if you add small pieces of your remaining goo to the top of the glacier on a regular ongoing basis. Does this addition of ‘new snow’ to the glacier affect the elevation?
- What if the ice sheet at the base of the glacier were to melt from the ocean water warming it? Remove some of the ice sheet at the foot of the glacier by cutting a bit off with a plastic knife. Watch what happens. Does the glacier speed up to fill in the removed ice and thin out losing elevation? Reexamine the marking on the wall of the container. Is the glacier height the same? Higher? Or Lower?
- Can you think of other experiments to try with your goo?

6. We have been using Glacier Goo as a model for glacier activity. If the glacier goo does behave like the PIG can you hypothesize what might be the cause of the elevation changes in the PIG? What other data would we need to test your hypothesis?