Name Date

POLAR I.C.E. (Interactive Climate Education)

REMOTE SENSING: USING RADAR TO LOOK THROUGH ICE

BUILD A 3D MODEL OF THE LANDSCAPE THAT LIES UNDER THE ICE!

INTRODUCTION: It is hard to believe that melting ice from Greenland or Antarctica could affect sea levels all around the world, but with increasing amounts of polar ice sliding from land into the world's oceans, sea level is rising. Knowing what is under the ice is important in predicting how quickly glaciers can move ice into the oceans, and what might cause them to accelerate. Learn how scientists 'look through ice' to hidden landscapes.

Image 1) Greenland's Ice Sheet **(from R. Bell, The Unquiet Ice, Scientific American, 2/08)**

Image 2) Antarctica's Ice Sheet **(edited from R. Bell, The Unquiet Ice, Scientific American, 2/08)**

HOW CAN WE LEARN WHAT IS BENEATH POLAR ICE?

The Ice Covers a HUGE Area! Greenland and Antarctica are home to the last ice sheets on Earth. An ice sheet is any mass of glacial ice larger than 20,000 square miles (50,000 sq. kms)…that's twice the size of Massachusetts! The two continental size sections of polar ice shown above (*Image 1 & 2*) are easily this large. But just how big are they? ***Check this out!*** **Greenland's** ice sheet is 660 thousand square miles (1.7 million km^2), if you dropped it onto New York City it would cover the entire east coast from Manhattan to Havana Cuba, and across to the Pennsylvania/Ohio border. The **Antarctic** ice sheet is over eight times larger, at ~5.4 million square miles (~ 14 million km^2). It would cover the whole of the United States and extend well into Canada! Imagine ice sheets larger than countries! We want know what is under the ice, but how can we study something that is completely buried?

The Ice Depth is Thick! The ice sheets are not only large they are deep! At its thickest the Greenland ice sheet measures up to 2 miles thick (3.2 km), and the Antarctica ice sheet measures up to 3 miles thick (4.8 km)! These cover all our tallest buildings and entire landforms! Think of an ice sheet covering the United States. The ice would hide deep canyons, most of our mountain ranges, flat prairies, miles of streams, pockets of lakes and steep fjord-like cuts in the topography. The land beneath the ice is too large and varied for scientists to understand by just measure around the ice edges.

The Age of the Ice is Old! In the polar regions ice has been covering the land for several million years, long before the first humans were on Earth. It takes many years, in fact many centuries to build ice sheets. We can't look though old photos of the land from that time since there were no people around to take pictures or write narratives before the ice formed. ***So what can we do?***

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REMOTE SENSING IS A TOOL THAT CAN LOOK THROUGH THE ICE

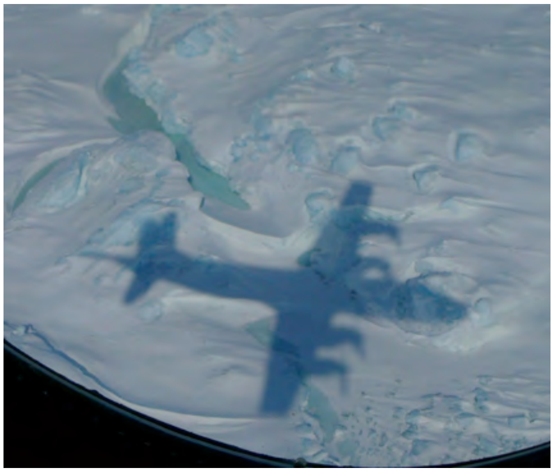

Image 3) Shadow image of aircraft flying over Greenland as it sends out and collects energy signals as it gathers data on the ice sheet and underlying surface (Image by M. Wolovick)

How do scientists study the polar ice sheets, and what's beneath the ice? Since ice sheets are large, deep and very old we need new tools to measure and look beneath them. Using geophysics (the physics of the Earth and its environment) scientists have developed a range of tools to collect these measurements.

Satellites from space, and aircraft flying over the ice sheet carry geophysical tools & instruments that collect information about the Earth *(Image 4).* This type of data collection is called 'remote sensing' and allows us to better understand areas that are difficult to reach, or extremely large to monitor.

Remote Sensing collects information about an object or phenomenon without physical contact. It measures energy. There are two types of remote sensing, **active** and **passive**. **'Active'** is when the energy being used is actively sent or transmitted, collected and measured, like in a microwave oven. **'Passive'** is when the energy is naturally occurring radiation that is reflected, collected and measured, like in film photography.

Image 4) The radar gun pictured here is used to measure speed of a baseball pitch.

This activity looks at **radar**, **active** remote sensing, where energy is sent out as radio waves, and measured as it is collected back. Are you familiar with radar? Your local police might use radar to catch speeding cars, or your favorite baseball team may use radar to measure how fast a baseball is being pitched. Radar has many uses.

But what is radar? And what does the word radar actually stand for?

The term 'radar' was first used by the Navy in 1940 to refer to their **RA**dio **D**etection **a**nd **R**anging equipment. So radar can be used to both 'find' (detect) our target, and provide distance (range) information which we can then use to build images. Radar uses a radio frequency pulse to send and receive a series of microwave signals that travel at the speed of light to locate the target and reflect back.

Certain types of radar can transmit right through the ice. Scientists send out a 'pulse' of radar and measure the time delay and the direction of the returning radio frequency to create an image of the land underneath the ice. In this activity you will use remote sensing data from **ice penetrating radar** to create an image of our target, the **hidden landscape** underneath the ice sheet.

What do you think? Why would remote sensing be useful for work in the polar regions?

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USING RADAR TO IMAGE THROUGH THE ICE:

Image 5) The Ice Pod project LC130 Aircraft outfitted with radar mounted on an external 'pod' to collect images of the ice layers and the bedrock surface below. **(edited image by R. Bell)**

HOW DOES RADAR WORK? Just how does Radar tell what is under the ice surface? Radar works much like an ultrasound from the doctor's office. *Image 6* shows the stomach of an expectant mother just as you would see it without using special instruments. Below that is an image created using ultrasound showing the baby inside. An ultrasound uses high-frequency sound waves sent through the body and reflected back off internal objects to measure distance, size and shape, creating the detailed image you see below. This process is similar to a radar pulse sending microwaves through the ice, and receiving them back to an antenna mounted on our aircraft. The depth of the ice sheet, and the land surface below becomes visible (*Image 7)*.

Image (6 top) Expectant mother and an ultrasound image of the baby (6 bottom). The ultrasound allows us to see below the surface to the baby.

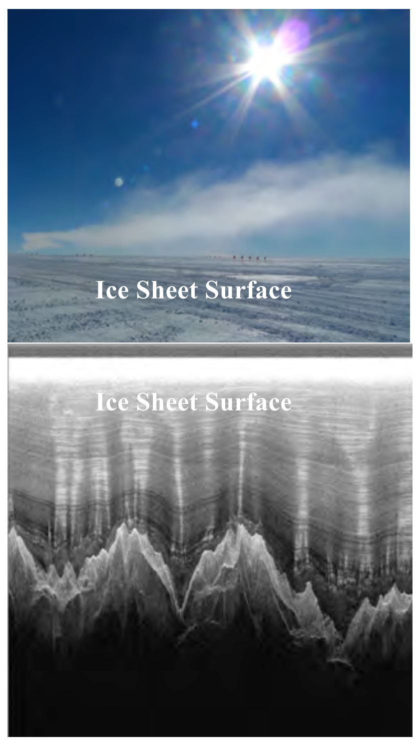

Image (7 top) The East Antarctic ice sheet and a radar image (7 bottom). Radar allows us to see through the ice layers to mountains ~2000 m below!

What does ice-penetrating radar have in common with an ultrasound?

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THE ICEPOD PROJECT WILL LOOK THROUGH THE ICE!

Image 8) The New York Air National Guard flies a large LC130 aircraft over the ice sheets. (Image courtesy of E. Lewis at Airdyne)

IcePod is a project using an LC130 aircraft outfitted with an equipment pod, called the 'icepod', to hold science instruments to gather remote sensing information from the ice below. Attached to the pod will be radar antenna. Each instrument will collect a different piece of information about the surface of the ice sheet and the land below it. As the LC130 aircraft fly their missions in the polar regions, they can collect data on the ice sheet as they travel.

This activity focuses on the **deep ice radar** that sends out a series of radio signals that reach all the way to the bottom of the ice sheet and bounces back to the receiver. The length of time for the signal return gives us depth information on the ice sheet. From this we can piece together a picture of what the land underneath looks like.

We created a model demonstrating how the LC130 aircraft will collect radar data while flying over the polar ice sheets (*Image 9)*. An instrument mounted beneath the small model plane (*Image 10)* sends, collects and records energy pulses measuring the depth to the 'ice sheet' below as the plane moves across the ice surface. At the end of each 'flight path' a set of depth measures is posted to the monitor as individual points that can then be displayed as a flight line (*Image 11)*. The plane moves to fly over different areas of the ice sheet collecting multiple lines of data. You will plot the depths on a graph to build an image of the topography lying beneath the ice.

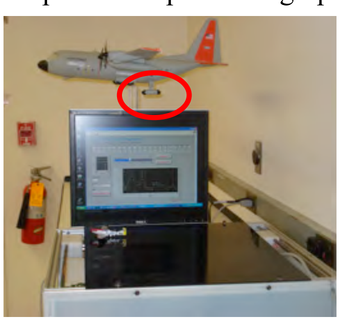


Image 9) Model (back to front) an LC130 aircraft (pod circled below); flight recording monitor; small plane on simulated ice sheet.

Image 10) A small plane (circled) travels across the ice sending down a pulse or energy that measures the depth to the land beneath.

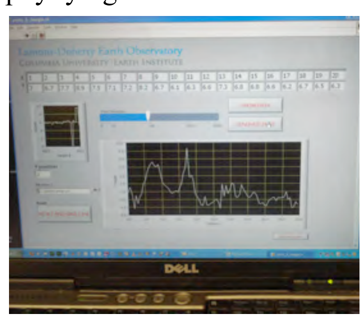


Image 11) The data is transmitted back as numbers along the flight path (top of screen), which are used to create a graph of the surface.

Turn the page to see data from 9 flights collected over the ice sheet.

FOR PART I: CHARTING THE DATA

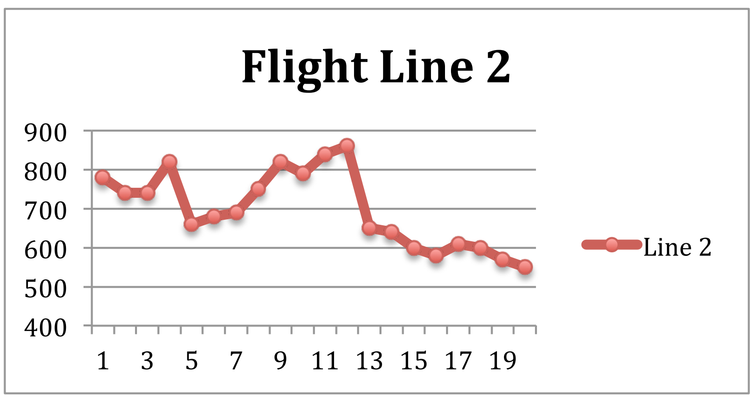
<u>ICE POD SURVEY RESULTS</u>

-Data Points 1 to 20 Collected From Each Flight-

Number of flight lines collected

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	560	670	780	850	640	570	580	550	570	550	550	540	550	540	520	540	530	530	530	540
2	780	740	740	820	660	680	690	750	820	790	840	860	650	640	600	580	610	600	570	550
3	660	650	620	580	570	570	640	740	810	760	620	610	570	570	570	650	610	540	510	530
4	600	610	610	620	580	690	790	640	800	640	570	600	600	600	600	610	570	530	520	530
5	760	630	600	580	580	580	550	540	560	550	550	540	540	540	520	530	540	530	540	540
6	760	750	690	650	820	650	620	590	590	560	560	540	550	560	550	550	540	520	500	530
7	610	630	700	620	590	620	610	600	630	610	670	610	600	620	590	620	610	600	590	600
8	710	750	720	640	640	640	610	600	610	600	680	760	660	660	600	580	650	720	600	660
9	740	710	630	640	640	600	600	600	610	670	750	660	690	580	570	610	750	640	630	630

Chart 1. Nine flight lines of data (shown as lines 1 through 9 on the left column) were collected from our model LC130. Each line shows 20 elevation measurements for the land surface below the ice sheet. The plane flew 9 separate survey lines across the ice sheet and recording elevation measurements of the land surface below as it flies. Elevations are recorded in meters.



Each flight line 1 through 9 contains many data points but the plane reported at intervals, posting only a total of 20 points per line.

How does our program work? The program was set up to collect each reading as a distance from the plane to the land surface, it then inverted (reversed) the reading so the that the number at each point in the chart above is actually showing land surface elevation. The larger the number reported in the box, the higher the elevation. Line 2 is drawn for you to demonstrate that data point #12 (860 meters elevation on the chart) is the highest point on the graph.

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PART I: GRAPHING THE DATA - Let's work with Ice Pod model data!

1. From the ICE POD SURVEY RESULTS on page 5 select the flight line with the **greatest difference** in elevation (maximum topographic relief) and with the **smallest difference in elevation** (minimum topographic relief). Highlight both lines with a highlighter. Use the chart below to help.

Line #	Highest Measure	Lowest Measure	Difference
1			
2			
3			
4			
5			
6			
7			
8			
9			

2. Use a different color pen for each of the two flight lines you chose and plot them on the graph paper provided. The cells labeled '1' to '20' on the data table will be your 'x' axis. Elevation will be your 'y' axis. You will select your 'y' range. See the sample graphed on page 7. Make a color key for the graph and label each line.

3) Note which 2 lines you selected and describe the topography for each.
Line #____

Line # ____

4a) What range did you use for your 'y' axis? ______________

4b) Why did you select that range? ____

4b) Compare the two lines. How do they differ? __________________________________

4d) Could the range you use in the 'y' axis affect your comparison?
Explain____

5) In **radar survey grids** the flight lines are often flown 10 kms (~ 6 miles) apart. A lot can change in the topography in that distance. Assuming our lines were 10 kms apart, how many total kms separated the two lines you graphed? _________________

6) Do you think these two lines give you a good understanding of the full survey area? Explain your answer.

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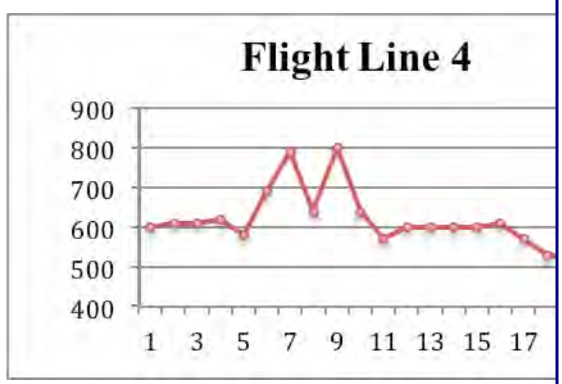
7) Learning what is under the ice will help us understand the ice movement. However, each flight has costs money in field time and fuel. Choosing the right number of flights is important. More flights equal **higher resolution data**, more information on the topography under the ice.

- Each flight line is one swath (strip) of data so it is like having one slice of a puzzle but not the full image.
- All the data lines are then geo-referenced (located in physical space) so they can be matched together.
- The data lines are then matched both directions to create a 3D image based on the information available *(Image below).*

Matching radar lines to develop a 3D understanding of the topography

Check how resolution can affect our understanding of the land surface by using the data from the two lines below. **They are currently mapped at 10 km resolution.** Now connect **every other** data point to drop the sample resolution in half to 20 km spacing. What do you think? How much did this affect your image?_______________________



8) **Now think about it!** You must design a field program for an uncharted region of Greenland's ice sheet. You will only get to fly this area once. Think about the data from flights 2 and 4. What resolution would you choose for your flight plan:
(a) 20 km spacing (as you edited above)________
(b) 10 km spacing (the original graphs)__________
(c) 5kms (twice the resolution and information? _________
Explain your choice to your science team.____

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PART II: WORKING IN EXCEL TO CHART THE DATA SET IN 3-D

Looking at the whole data set can help us fill in some of the missing pieces in the topography. Use the attached excel file (either .xls or .xlsx) to graph the full set of collected data for a 3-D image of the topography.

Working with the data in Excel! The data has been saved in two excel formats (A) .xlsx file and (B) .xls file. Both file formats will allow you to create 3D images, but the process and final image will differ slightly so select from below the write up that matches your files.

A) DIRECTIONS WORKING WITH .xlsx:
Select the full range of data points excluding line 1 (the header for the 20 points) and column A (the identification of the lines of data 1-9) as these are not part of the data.

Select the "**Charts"** heading and then **"Other"**
1) Select **3-D Surface** and you should see a 3-D surface appear.
The image you see is a reflection of the actual data measurements. You will see numbers 1-19 or 20 on the X axis. These numbers match to each of the measurement points recorded by the model plane. The Y elevation (series 1- series 9) matches each of the flight lines flown. You will probably see numbers 0-1000 on the Z axis. These numbers were selected by the computer to include the top elevation measurements the model plane collected. You can change this by clicking on the scale and adjusting the range.
2) You can change the image and rotate it to get a different view. Click on the image and you will get a pop up box offering to **"Format Chart Area"** with an assortment of options.
3) If you click on **3-D Rotation** you can **Free Rotate** the image. You can try rotating or tilting the image. Rotating the X coordinate moves the image so that you can view it face on and see down the low areas in the topography. Rotating the Y coordinates tips it down and up. Experiment a bit to get what you feel shows the land shape under the ice sheet. You can even shortening your Y axis.

When you have the image the way you like it save it. Check it against the image we created, and the actual land surface that was under the ice sheet by checking the link below. Remember there will be differences!

B) DIRECTIONS WORKING WITH .xls:
Select the full range of data points excluding line 1 (the header for the 20 points) and column A (the identification of the lines of data 1-9) as these are not part of the data.

Select **Insert** and then "**Charts".**
1) Step #1 of 4 under Chart Wizard - Under "**Standard type**" select "**Surface"** and **"3-D surface"**
2) Step #2 of 4 under Chart Wizard – Under **Data Range** select series in **"Rows"**
3) Step #3 of 4 under Chart Wizard - Enter A Chart Title. Your X axis will be **measured data points.** Your Y axis will be **lines flown.** Your Z axis will be **surface elevation.**
4) Step #4 of 4 under Chart Wizard – Select show as object in Sheet 1 and then click **Finish**.

You should see a 3-D surface appear. The image you see is a reflection of the actual data measurements. You will see numbers 1-20 on the X axis. These numbers match to each of the measurement points recorded by the model plane. The Y elevation (1-9) matches each of the flight lines flown. You will see numbers 0-900 on the Z axis. These numbers were selected by the computer to include the elevation measurements the model plane collected. You can change this by clicking on the scale and adjusting the range.

You can change the image and rotate it to get a different view. Drag the bottom corner and you can rotate and move it around. You can tip the front down to better see the elevation in your 3-D image. Experiment a bit to get what you feel shows the land shape under the ice sheet. You can shorten your Y axis. When you have the image the way you like it save it. You can check it against the image we created, and the actual land surface that was under the ice sheet by checking the link below. Remember there will be difference.

To see how your 3D image matches with the actual landscape go to:
http://www.ldeo.columbia.edu/edu/polareducation/Activities/Remote%20Sensing%20Radar/3Dimage.pdf

Resources & References

Ice Sheet Information: National Snow and Ice Data Center (NSIDC) http://nsidc.org/quickfacts/icesheets.html
RADAR: http://southport.jpl.nasa.gov/desc/imagingradarv3.htm
Ice Sheet Ages: Zachos et al., Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present, 2001, Science 292, 686.)
ODP website for graph: http://www-odp.tamu.edu/publications/202_SR/204/204_f1.htm
Remote sensing: http://wapi.isu.edu/Geo_Pgt/Mod07_RemoteSensing/mod7.htm
Electromagnetic Energy: http://missionscience.nasa.gov/ems/01_intro.html

LAND SURFACE MEASUREMENTS

ELEVATION - IN - METERS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

POINTS OF MEASUREMENT