"Seeing" What You Can't See"

How do we know what's underneath the ice?

By Tim Spuck - PolarTREC Teacher 2012

NASA-IceBridge Mission - Greenland

Mountain Glacier in Greenland - Photo by Tim Spuck

Have you ever wondered how polar scientists do it? How do they really know if the planet is loosing vast quantities of ice anyway? Sure you can use pictures from satellites to monitor the surface from year to year, but the vast majority of ice is hidden from view; buried beneath the surface in some of the most inhospitable and inaccessible corners of our Planet.

I used to ask myself that question until spending 10 days in Greenland with the NASA IceBridge Mission as a PolarTREC Teacher. PolarTREC is a program funded by the National Science Foundation to partner science teachers with polar researchers in the field. My field experience took me to Kangerlussuaq, Greenland where I had the rare opportunity to fly with the Mission to some of the most spectacular parts of Planet Earth; places where humans have never laid foot. And being locked inside an airplane for eight-hour blocks of time with IceBridge scientists and engineers, you learn a bit about the project.

NASA P-3 Aircraft - Photo by Tim Spuck

NASA's Operation IceBridge is the largest airborne survey of Earth's polar regions ever conducted. The mission flies a sophisticated array of instruments, including high resolution cameras, LIDAR for surface mapping, ice penetrating RADAR, and a magnetometer and gravimeter, onboard a P-3 aircraft previously used by the Navy to hunt submarines. The primary goal of the project is to provide valuable data to the scientific community on snow and ice properties (e.g. thickness, internal structure, etc.) and how those properties are changing over time.

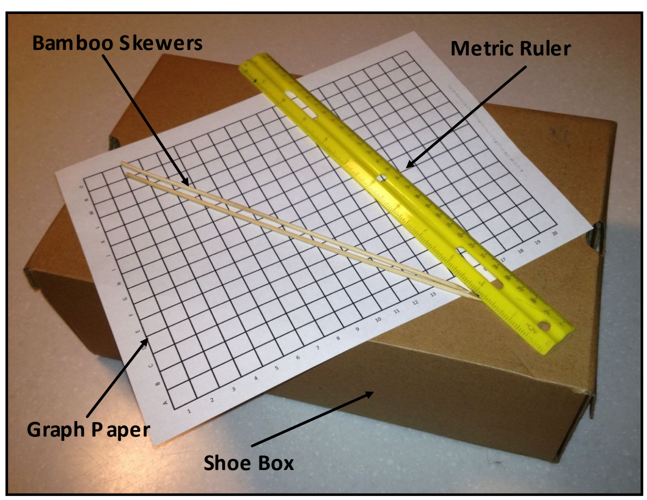
FOR INFORAMATION ON THE MISSION PLEASE VISIT - http://www.polartrec.com/expeditions/airborne-survey-of-polar-ice

What's inside the ice … the mystery box … what's the difference?

Materials Needed

NOTE: The activity is designed as a classroom activity so you'll need one set of materials for each group of students. It's ideal to have students work in groups of two; three at most.

1 - smaller box with a lid on it. A shoe box is ideal.
1 - metric ruler
2 - bamboo skewers (as long as they are sturdy enough to punch through the box lid, you may substitute the bamboo skewers)
1 - sheet of graph paper (provided)
1 - Microsoft Excel or other software that can do a surface plot.
- Several items of various size, shape, and composition (e.g. wood blocks, erasers, roll of tape, etc.) that can be glued
- Wood glue or regular Elmers glue



Objectives

Learners will improve their understanding of the NASA-IceBridge mission and how instruments are used to determine the terrain underneath the surface of the ice.

Learners will be able to use Microsoft Excel to create 3-D surface plots and interpret these plots.

Science Standards Targeted

Science Standards will vary from state to state, but most all States target the following; 1) geographic features on Earth, 2) Climate change, 3) process of science inquiry, 4) using data for graphing or creating models, and 5) the application of technology. This activity addresses each of these areas, so please consult your individual State learning standards for the appropriate links. In addition this activity can be used to target the engineering concepts in the Next Generation Science Standards.

Estimated Time - 1 hr 20 min Total

Discipline - Earth Science, Physical Science, General Science, Integrated Science

Grade Level - The activity could be used with students from late elementary school through high school, and up.

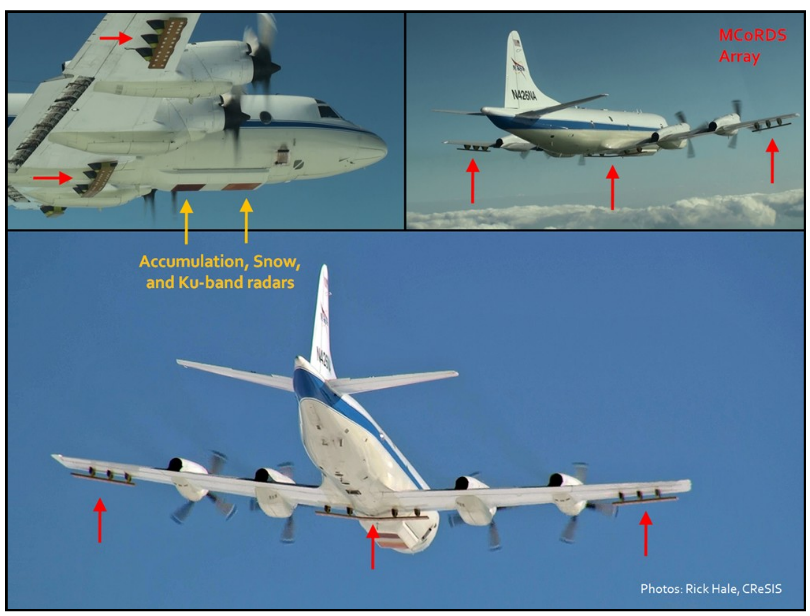
STEP ONE - Making up the mystery box!

- The first thing that needs to happen is Mystery Boxes need to be constructed. I like to let my students design the boxes because it turns into a bit of a competition with other groups in the class … who can figure what's inside the others box? It's best to have the boxes made up the day before measurements are made so that the glue has time to dry, but if you're rushed for time, you can always have students tape the items in the box as well.

- Each student group should include between two and four items in the box depending on available space. The picture to the left gives you an example. In this case I used a roll of masking tape, a piece of wood, and 1/2 of a foam ball. Once all of the items are in place and secured, <u>seal the box with tape so that it can't be opened</u>.

Multi-channel Coherent Radar Depth Sounder (MCoRDS) . . . Have you ever asked yourself, "Why don't they just use a really bright light to look through your skin and see if your bone is broken?" You know; sort of like they do in cartoons. The problem is visible light can't make it through all your skin, muscle, and bone because the wavelength of visible light radiation is just too long. So doctors use x-rays that have a much smaller wavelength and can make it all the way through your body to a special film that is sensitive to x-ray light.

The NASA IceBridge mission flies an array of snow and ice penetrating radar on the P-3 aircraft. (*Photo right*)



MCoRDS Radar system onboard the NASA Ice Bridge P-3 Aircraft - Photo by Rick Hale

This is where the Multi-channel Coherent Radar Depth Sounder (MCoRDS) comes in. Although it doesn't use x-rays it uses RADAR firing approximately 12,000 pulses per second. MCoRDS uses four radar systems operating at different frequencies (wavelength) allowing scientists to image below the surface of the ice. These particular radar frequencies can penetrate through snow and ice, but can't make it through rock. As soon as the signal hits rock (e.g. a mountain top buried by snow and ice), the signal is reflected back to the RADAR detectors onboard the P-3. And similar to a police officer using a radar gun to measure your vehicle's speed, MCoRDS measures how long it takes each pulse to leave the aircraft and make it back, and from that data, depth to the rocky surface below can be calculated. MCoRDS can see anywhere from a few centimeters below the surface of the ice, all the way down to a depth of 4 KM. This is especially helpful to scientists because now we can accurately measure the thickness of ice and how it might be changing over time.

For additional background information on the NASA IceBridge Mission, please visit
http://www.nasa.gov/mission_pages/icebridge/index.html

STEP - TWO - Relating the Mystery Box activity to Polar Science

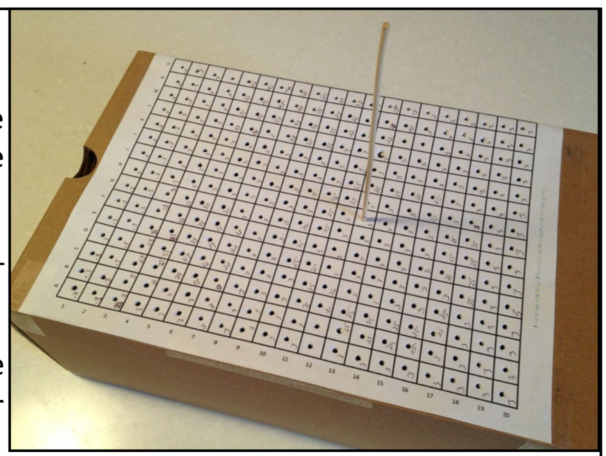
- Consider the information above about MCoRDS and other background from the IceBridge Mission website provided at the beginning of the lesson plan.

- Open a discussion with a question, "How do polar scientists know what's under the surface of the ice? How do we actually know if the thickness of the ice is changing?

- Distribute the sealed boxes to the groups and if you had students design their own mystery box make sure they don't get the one they built.

- Spend some time discussing how they could determine what's in the box. Give them three rules 1) They can't open the box, 2) they can not distort the SHAPE of the box in any way, and 3) they can not shake the box.

STEP THREE - Observations and Measurements



- After sufficient discussion has taken place, have students tape the graph paper included at the end of this lesson plan to the top of the box.

- Measure the height of the box in ___ mm and record this value.

- Using the bamboo skewers punch a hole big enough for the opposite end of the skewer to fit through the hole in the center of each square. (see picture to the right)

- With all the holes punched through, drop the skewer (non-pointed end down) through each hole and measure how far it goes into the box before it stops. (hits something). Measure and record the depth in ___ mm.

Height of the surface in the box __ mm = Height of box __ mm — Depth Skewer goes into hole __mm

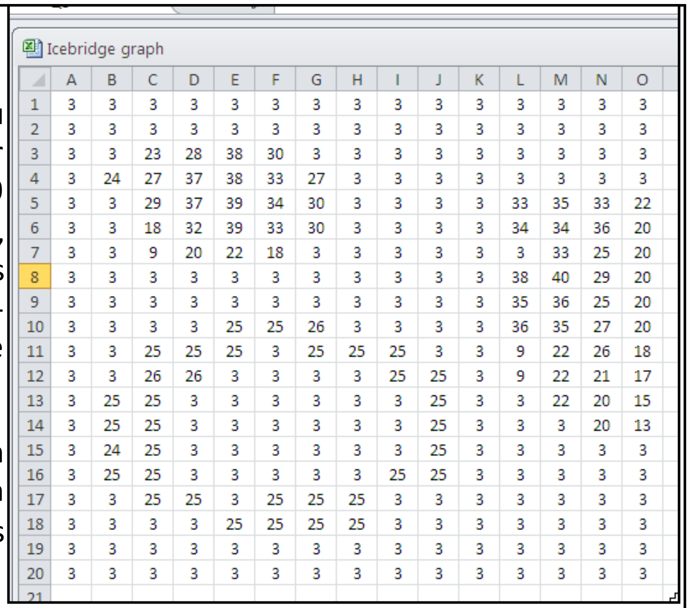
- Record the "height of surface in the box" in ___ mm at each square. I usually just record the value on the graph paper next to the hole in the center of each individual square.

DISCUSSION - Ask students how the task they just completed is similar to the MCoRDS radar system used by IceBridge. Snow and ice penetrating radar onboard the aircraft fires about 12,000 pulses per second. Measuring the surface underneath the ice and snow. Each of these pulses is analogous to the measurements students made by dropping the bamboo skewer into each of the holes. Now to make sense of it all.

STEP Four - Entering the data into Excel

NOTE: If you do not have access to Microsoft Excel you can have students color each square on the graph paper based on it's height (e.g. squares with height between 10 -15 mm are green, 15-20 mm yellow, 20-25 mm orange, etc.), or you could have them make a model of what's inside the box out of clay, etc.. I like using Excel to generate a computer model because scientist primarily use computers to model such data.

- At this point each of the squares (cells) on the graph paper should have a "Height value" in mm. The graph paper I provided is set up just like an Excel Table (rows are numbers and columns are letters).


Icebridge graph

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3	3	3	23	28	38	30	3	3	3	3	3	3	3	3	3
4	3	24	27	37	38	33	27	3	3	3	3	3	3	3	3
5	3	3	29	37	39	34	30	3	3	3	3	33	35	33	22
6	3	3	18	32	39	33	30	3	3	3	3	34	34	36	20
7	3	3	9	20	22	18	3	3	3	3	3	3	33	25	20
8	3	3	3	3	3	3	3	3	3	3	3	38	40	29	20
9	3	3	3	3	3	3	3	3	3	3	3	35	36	25	20
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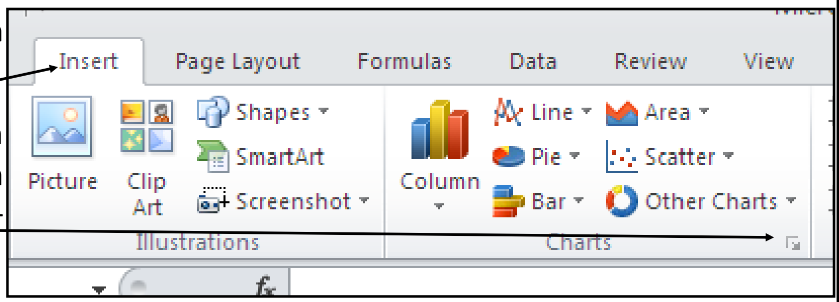
15	3	24	25	3	3	3	3	3	3	25	3	3	3	3	3
16	3	25	25	3	3	3	3	3	25	25	3	3	3	3	3
17	3	3	25	25	3	25	25	25	3	3	3	3	3	3	3
18	3	3	3	3	25	25	25	25	3	3	3	3	3	3	3
19	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
20	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

- Have students enter their data into a normal Excel worksheet. The image above is the data from my Mystery Box example.

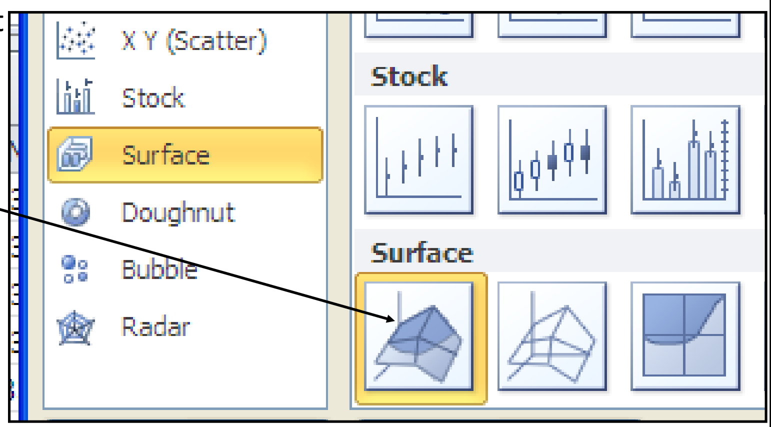
STEP FIVE - Making the Computer Model

Highlight all of the cells that have data in them. This should be cells A1 through O20.

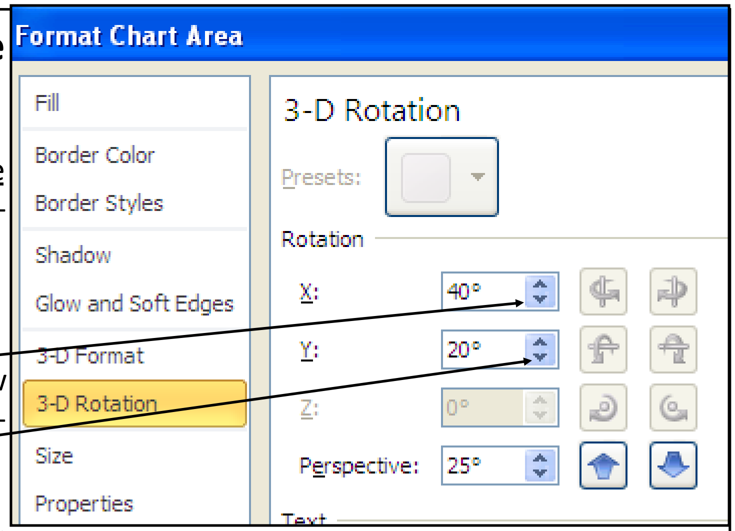
With cells A1 through O20 selected, click on the "**Insert**" Tab (see image right) and then under "**Charts**" click on the lower right corner arrow to get more chart options.



Scroll down to the Surface chart option, and select the 3-D Surface Option Chart



STEP SIX - Manipulating the Surface Graph



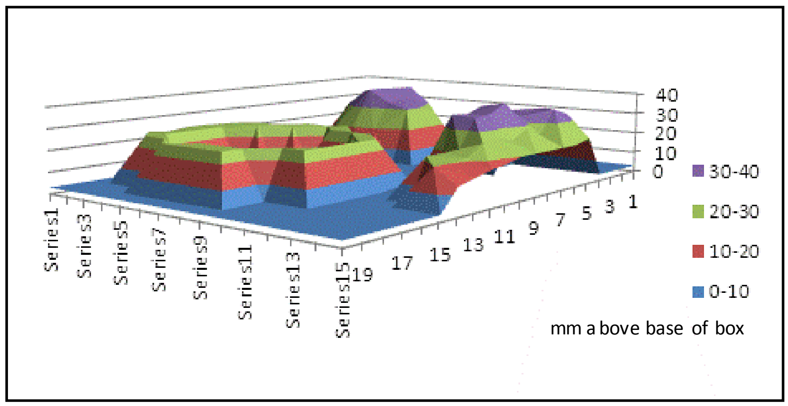
- Right Mouse CLICK on the center of the surface graph that comes up, and in the dialog box that appears scroll down and select "Format Chart Area".

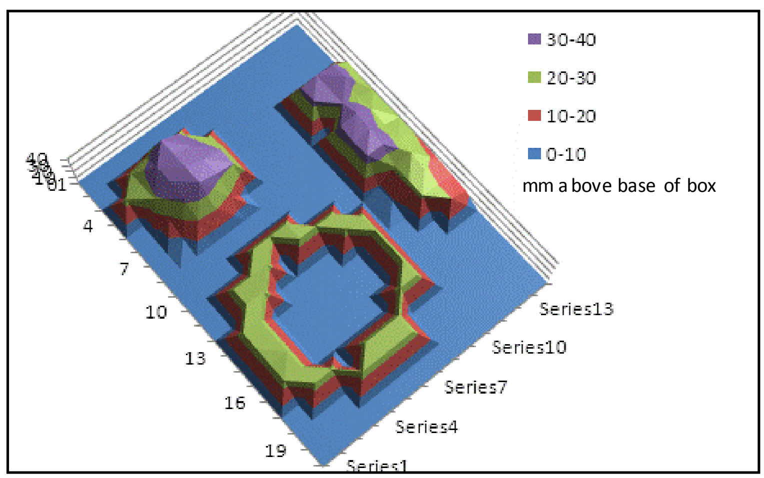
- Then scroll down and select 3-D Rotation.

- You can then change the X and Y Rotation to view the computer model of what's in the box from different angles.

- Have students experiment around with viewing their data using various surface plot settings. Have them take "screen shots" of images they feel are especially good or revealing, for use in their summary.

MY EXAMPLE





As you can see from the example above, I do get a pretty good matching with what's really in the box and the computer model. You students should get similar results.

STOP! BEFORE you let them open the box and see how close they were . . .

DISCUSSION - Before they open the boxes there are a few things you should do first.

Have student groups use MS Word or some other word processor to prepare a report of what they think is in the box. The report should include the following:

- Of course their name and all that good identification stuff
- Screen shots of their 3-D surface plots used
- A discussion of why the surface plots and any other evidence they used during the process brought them to their eventual conclusion.
- What they think the items in the box are and what they are made of. Students may have noticed that some of the items in the box were spongy while others were solid, etc..

Closing Questions

Are there other types of analysis that we could have done to provide more information or different information? (e.g. use a magnet to see if what's in the box was metal, tap on the bottom of the box and listen the sound made at different spots, etc.)

Discuss other instruments onboard IceBridge and how they compliment the MCoRDS. For example the magnetometer is basically a giant metal detector. So in a similar way students would use a magnetic to look for metallicity of objects in the box, IceBridge scientists and engineers use the magnetometer to search for metallicity in the rocks underneath the surface of the ice.

What other instruments are used by IceBridge to determine the shape of the surface of the ice and/or what lies below?

Please direct questions about this activity to Tim Spuck at tspuck@hotmail.com.

NOTE: The NASA IceBridge Lithograph is included at the end of this document. You may find it useful as it provides some additional background information.

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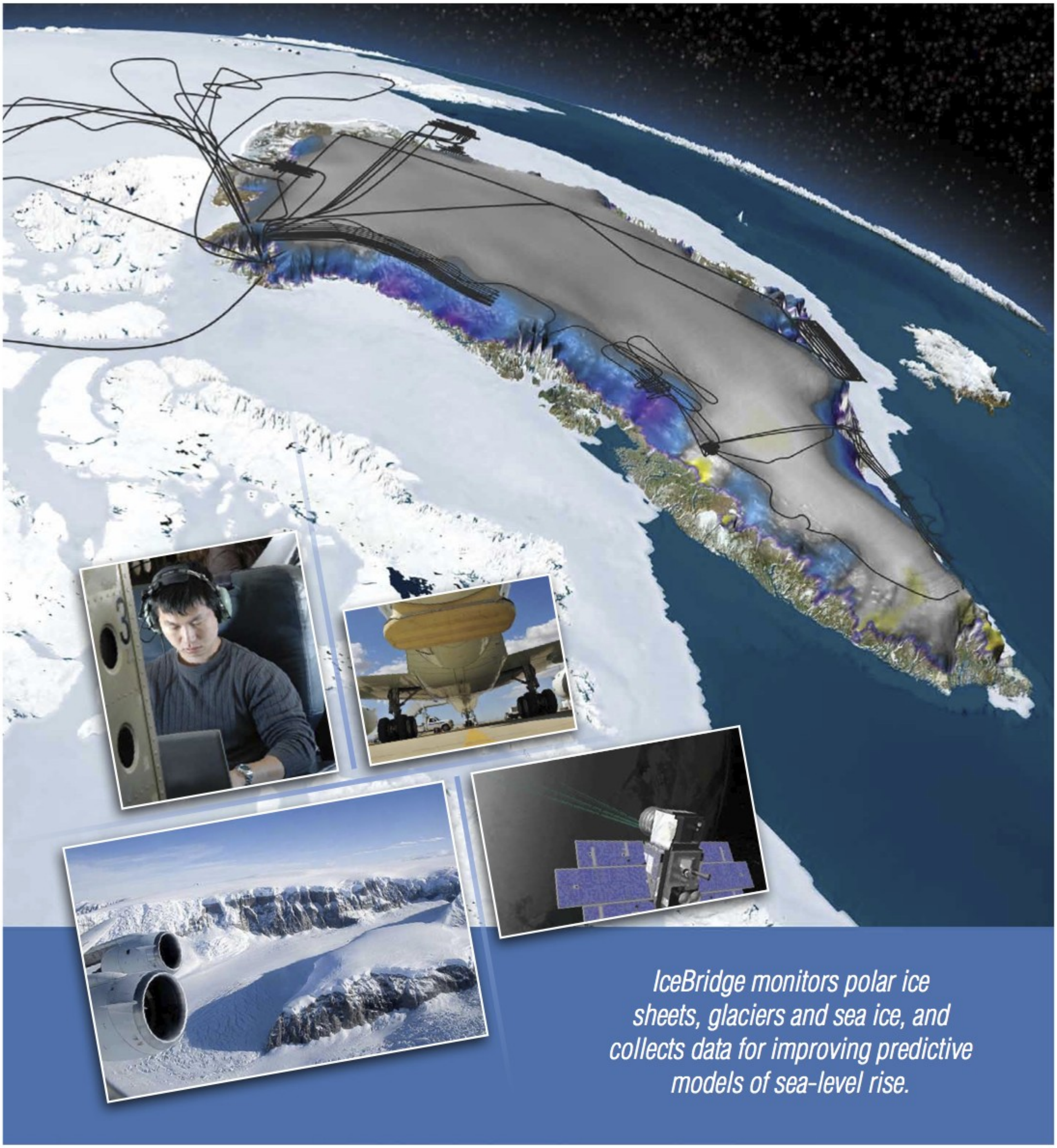
National Aeronautics and Space Administration

Operation IceBridge

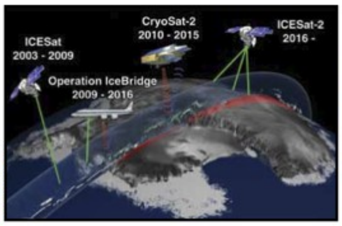


Operation IceBridge

An airborne mission monitoring Earth's ice sheets, glaciers, and sea ice

About these Images

On the front: With the aircraft resources of NASA's Airborne Sciences Program, Operation IceBridge is taking to the sky to ensure a sustained, critical watch over Earth's polar regions. Flight lines (black) are shown for the 2010 campaign over Arctic sea ice and Greenland's land ice. Many flights target outlet glaciers along the coast where NASA's Ice, Cloud and land Elevation Satellite (ICESat) shows significant thinning. Blue and purple colors, respectively, indicate moderate to large thinning. Gray and yellow, respectively, indicate slight to moderate thickening.



Credit: NASA

Operation IceBridge sustains measurements of polar ice during the period between NASA satellites.

Bridging the Gap

NASA's Operation IceBridge, a six-year mission of annual flights over the Arctic and Antarctic, is the largest-ever airborne survey of polar ice. The flights bridge the gap between ICESat—which stopped collecting surface elevation data in 2009—and ICESat-2, scheduled for launch in 2016. Scientists use surface elevation data to monitor changes to sea ice and land ice.

Credit: NASA

NASA's P-3B awaited the arrival of instrument teams and crew for a flight from Kangerlussuaq, Greenland, during IceBridge's Arctic 2010 campaign.

Airborne Laboratories

NASA's DC-8 and the P-3B are the workhorses of IceBridge. The DC-8, from NASA's Dryden Flight Research Center, is a 157-foot-long airborne laboratory adapted each year to accommodate the mission's instruments. The DC-8 carries enough fuel for the long Antarctic flights. The P-3B, from NASA's Wallops Flight Facility, is a smaller, maneuverable four-engine turboprop that carries instruments and researchers over Greenland's meandering outlet glaciers and Arctic sea ice. In future campaigns, unpiloted aerial vehicles and smaller aircraft will also be flown.

The aircraft carry a full suite of instruments including lasers and radars, as well as a gravimeter, camera, and a magnetometer. The lasers measure the ice surface elevation while the radars peer into the ice, imaging the snow layers and the bedrock below the ice. The gravity instrument is used to see below floating ice tongues to determine the shape of the water-filled cavities below.

Credit: NASA

The DC-8 makes flights during Antarctic campaigns (mapped above for 2009) from the mission's base in Chile to science targets along the Peninsula and West Antarctica.

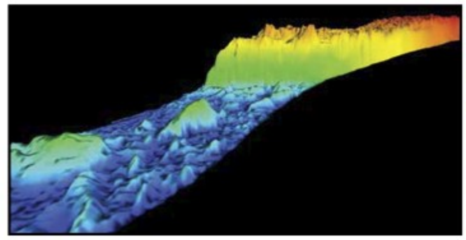
Polar Campaigns

Arctic: Throughout the duration of the mission, IceBridge annually surveys Arctic land ice and sea ice during a campaign that falls during the northern hemisphere's springtime, from March to May. Flights are most often made from Thule and Kangerlussuaq, Greenland, as these sites are home to airports from which the aircraft can reach the study targets.

Antarctic: IceBridge flies over Antarctica's land and sea ice during the annual campaign that falls during the northern hemisphere's autumn season from October to November, which is spring in the southern hemisphere. Each flight transits from the mission's base in Punta Arenas, Chile, to targets in Antarctica and back.

Mission collaborators fly smaller aircraft over ice in East Antarctica and Alaska.

Monitoring Change



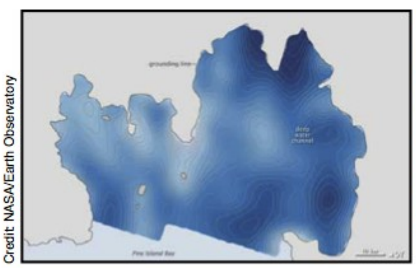
Credit: Kyle Krabill/NASA ATM team

A laser instrument flown during IceBridge's Arctic 2010 campaign mapped the 90-meter-tall calving front of Greenland's Jakobshavn Glacier.

Land ice: The airborne perspective allows a close-up look not possible from orbit. The suite of instruments on each flight provides detailed information about the surface, snow and bedrock. IceBridge mission planners carefully select targets most prone to change or where ice dynamics are not well understood, such as West Antarctica's Pine Island Glacier, the Antarctic Peninsula, and Greenland's many outlet glaciers.

Sea ice: Sea ice, too, is dynamic and contributes to climate feedback processes. How are the physical characteristics—age, thickness, and snow depth on top of sea ice—changing? Is Arctic sea ice continuing to shrink in extent and thin in thickness? Both seasonal (first-year) and perennial (multi-year) sea ice are targeted during IceBridge flights.

Sea-Level Rise



Credit: NASA/Earth Observatory

In October 2009, IceBridge instruments mapped areas of deep water (dark blue) and shallower water (light blue and white) beneath Antarctica's Pine Island Glacier, revealing a deepwater channel.

One of IceBridge's goals is to better constrain predictive models for sea-level rise. That requires a clear understanding of the factors that control ice dynamics and regular, detailed mapping of ice sheets and outlet glaciers.

For example, Antarctica's Pine Island Glacier drains more than 19 cubic miles of ice per year from the West Antarctic Ice Sheet, but how will that rate change in the future? Which of Greenland's glaciers will accelerate and which will slow? How does contact with the bedrock or melting from contact with a warm ocean impact these processes? Data from IceBridge will contribute to studies that seek to answer such questions.

Data Access

IceBridge data is available online from the National Snow and Ice Data Center in Boulder, Colorado. http://nsidc.org/data/icebridge/

On the Web

Operation IceBridge http://www.nasa.gov/icebridge

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