My NASA Data - Lesson Plans

Graphing Sea Ice Extent in the Arctic and Antarctic

Grade Band

- 6-8
- 9-12

Lesson Duration

- 30 minutes

Sphere(s)

- Cryosphere

Phenomenon

- Changes in Snow and Ice Extent

Science and Engineering Practices

- Asking Questions and Defining Problems
- Developing and Using Models
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Engaging in Argument from Evidence
- Obtaining, Evaluating and Communicating Information

NGSS Performance Expectation

- 5-ESS1-2: Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.
- 4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- ESS2A: Earth Materials and Systems

Related Resources

- Data Literacy Cubes Page

Teacher Resource(s)

- Data Literacy Cubes

Purpose

Students graph sea ice extent (area) in both polar regions (Arctic and Antarctic) over a three-year period to learn about seasonal variations and over a 30-year period to learn about longer-term trends.

Learning Objectives

- Students will practice graphing skills.
- Students will make and test hypotheses.
- Students will have their understandings of seasons reinforced.
- Students will learn about variations in the climate of Earth's polar regions.

NASA Phenomenon Connection

Located in the Arctic near the North Pole, Greenland is covered by a massive ice sheet three times the size of Texas and a mile deep on average. Greenland is warming almost twice as fast as Antarctica, which is causing the ice to melt and raise global sea levels. NASA is monitoring Greenland’s ice sheet from high up in space to the ocean floor below to provide data for scientists studying the global impact of all its melting ice.

The creation of ICESat-2 is allowing NASA's scientists to make accurate maps of polar ice sheets. These maps help them make informed predictions about weather patterns, climate change, and the effects of changing ice structures. The maps are so accurate they can measure to within 3 centimeters of an ice sheet's actual thickness from a huge distance!

Learn how the second generation of the Ice, Cloud, and Land Elevation Satellite, better known as ICESat-2, is being used to map the ice structures in the world's polar regions. Manipulating the distribution of photons by lasers to create accurate images of these frozen structures allows scientists to study their changes and impact on Earth's climate.

Essential Questions

- How large are the ice sheets?
- How fast are the ice sheets changing?
- How does change in the Cryosphere affect changes in other parts of the Earth System?
- How and why does NASA monitor the cryosphere?

Materials Required

- Colored pencils (at least 4 different colors per student)

- Graphing worksheets (2) or graph paper
- Data table sheets
- Student instructions sheet

Worksheets:

- Graphing worksheets (2) or graph paper
  - Monthly graphing worksheet
  - Yearly graphing worksheet
- Data tables sheet
- Student instructions sheet

Teacher Preparation and Background:

1. **Print out copies of the** student instructions sheet**.**
2. Print copies of the two graphing worksheets (monthly graphing worksheet and yearly graphing worksheet).
3. Print copies of the data tables. Cut these sheets into three pieces, so you can hand out the data tables at appropriate times during the lessons without "giving away" what is coming next. One piece should have Data Table #1; a second piece should have Data Table #2; and a third piece should have Data Tables #3 and #4.
4. When students first estimate the seasonal time variation (from 2005 through 2007) of the extent of sea ice in the Arctic (before they are given data), they should realize that the ice melts and shrinks in the summer and freezes and grows in the winter. Thus, their predicted minima should be somewhere around the summer, and their predicted maxima should be somewhere around the winter. In the Arctic, the yearly maximum generally occurs towards the end of winter or early spring, usually in March. The maximum is **not** in the middle of winter, when the temperatures are coldest. The ice pack continues to grow throughout the winter, thus reaching its maximum extent late in the winter season. Also, realize that water has a lot of thermal inertia; the Arctic Ocean does not cool down as quickly as does the air in the Arctic. Most students probably will not take these factors into account when they make their predictions, and may thus predict that the sea ice maximum occurs in December, January, or February. If some perceptive students do take this lag into account in their predictions, it would be good to call upon them to explain their predictions to the rest of the class. If none of your students take this lag into account when forming their hypotheses, make sure to point out the discrepancy between their predictions and the plot of actual data. Lead the students through a discussion of this lag and the causes of it. Likewise, their predictions for the time of minimum sea ice extent may be sometime in the middle of the summer, instead of the actual minimum which usually occurs in September. In a manner similar to the winter "lag", the summer temperatures, though highest in mid-summer, remain above freezing throughout the summer and into early fall, so the sea ice continues to melt and its extent continues to shrink. Also, the Arctic Ocean, which warms throughout the summer, holds its heat longer than does the atmosphere into the cooling autumn.
5. If you want to shorten the duration of this activity, you can have students plot just one or two years of data on a monthly basis, instead of having them plot the entire 36 months from January 2005 through December 2007. Or, you could divide the class into 2 or 3 groups. If you divide into three groups, have the first group plot the 2005 data, the second group 2006, and the third group 2007. If two groups, have one group plot 2005 and 2006, and the second

group plot 2006 and 2007. Then combine the plots (cut and tape them together, or just view them side-by-side).

6. We have provided yearly data for 1980 through 2010 at 5-year intervals, plus data for 1979 (the first year data was available) and for 2006 through 2009 (some of the most recent years' data at the time of this writing). We recommend just plotting 1980 through 2010, for simplicity's sake. However, we've included the 1979 and 2006-2009 data in case you want to use that as well. Note that the trends in the variation of both the minimum and maximum sea ice extent in the Arctic look quite a bit different depending on whether you include the 1979 and 2006-2009 data or not.
7. When making predictions (hypotheses) about Antarctic sea ice extent on a monthly basis, many students may not take into account (or may not understand) the differences in seasons between the Northern and Southern Hemispheres. This can provide you with a very "teachable moment", and a great opportunity to discuss the cause of the seasons (the Earth's axial tilt, **NOT** variations in Earth's distance from the Sun; if the latter was the cause, both hemispheres should have the same seasons).
8. There are substantial differences between the Arctic and Antarctic that influence the extent of sea ice packs in the two opposite polar regions. The central portion of the Arctic is all ocean, whereas Antarctica has a continent in the middle. The sea ice area in the Arctic includes the area closest to pole, while the sea ice area in the Antarctic is just the fringes around the edge of the continent and doesn't include the coldest region in the "center" nearest the South Pole. Also, the heat retention properties of a large land mass and huge ice sheet (in Antarctica) are very different than those of a large body of water (the Arctic Ocean). The net effects of these differences are not straightforward but can be used as discussion points with your class.
9. If you want to extend this activity, the website of the National Snow and Ice Data Center (NSIDC) at http://nsidc.org/data/seaice_index/ has more data than that which we have presented here. You could have your students look up data for years or months that our data sets do not include, or for the most recent months that are currently available, to plot and analyze.
10. You could have mathematically advanced students do a least-squares fit of a line to each (maximum and minimum) of the trends in the Arctic sea ice extent data to be more rigorous in their estimates of when the sea ice might be expected to disappear in the summer. You could have them do this for the 1980 through 2010 data, then with the 1979 and 2006-2009 data added in, to see how the inclusion of four more data points alters their fit line.
11. Our website, Windows to the Universe (www.windows2universe.org), has numerous resources you can use in support of this activity. They include animated maps of monthly sea ice extent for both hemispheres from 2002 through 2008; interactives that allow you to compare maps of sea ice extent in various years and months side-by-side; numerous background info pages on the polar regions, sea ice, and the Arctic and Southern Oceans; and several pages on global climate change. See the links at the bottom of this page for more.

RELATED SECTIONS OF THE WINDOWS TO THE UNIVERSE WEBSITE:

- Movie of Yearly Changes in Sea Ice in the Arctic
- Movie of Yearly Changes in Sea Ice around Antarctica
- Compare Images of Arctic Sea Ice Extent Side-by-side
- Compare Images of Antarctic Sea Ice Extent Side-by-side
- Sea Ice in the Arctic and Antarctic
- The Arctic Ocean
- The Southern Ocean

- Earth's Polar Regions

Technology Requirements

- Standalone Lesson (no technology required)

Background Information

Arctic sea ice extent is declining while permafrost is warming and thawing over parts of the Arctic. Some of these changes, such as the replacement of white reflective sea ice with dark open water, are set in motion feedbacks that contribute to even further warming. As the Arctic warms, some animal species are finding the region more hospitable, while others are seeing declines in their habitat. The Arctic region is becoming imbalanced, with ramifications for the rest of the hemisphere.

The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost 150 to 250 cubic kilometers (36 to 60 cubic miles) of ice per year between 2002 and 2006, while Antarctica lost about 152 cubic kilometers (36 cubic miles) of ice between 2002 and 2005. Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades.

Credit: NASA Satellite Comparisons of Arctic Change

Prerequisites Student Knowledge

Procedure

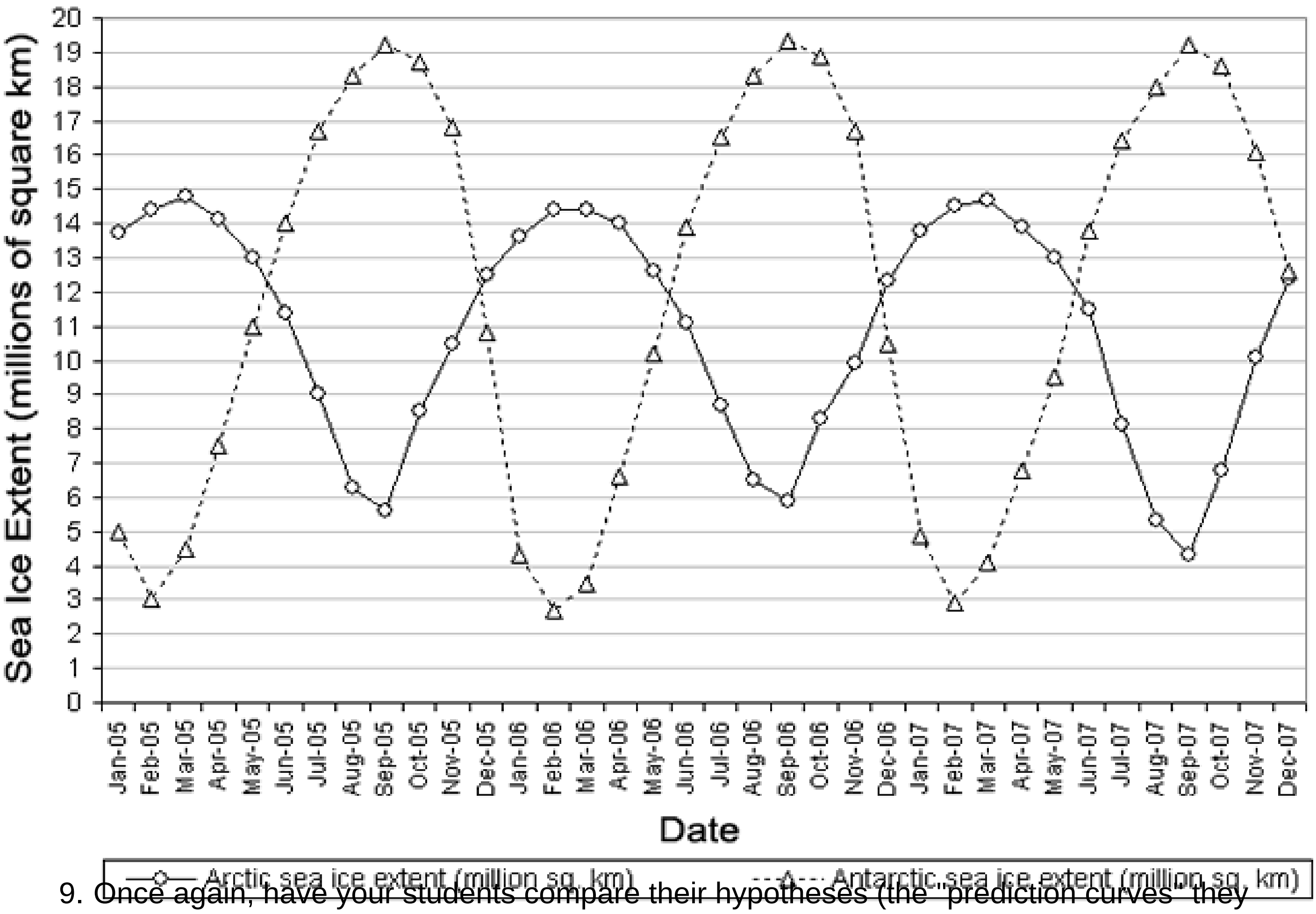
Modified from Window To The Universe:

1. Engage prior knowledge of students' ideas about changes in the Arctic Ocean' sea ice pack by having students work in small groups on a What Do You Know (K) and What Do You Want to Learn (W) in a K-W-L chart. Briefly have students share out their ideas and questions.
2. Tell your students that they will be doing a graphing activity in which they will first predict, and then use actual data to study, the variation in extent of sea ice near the poles over time.
3. Give your students Graph Sheet #1 (the x-axis on this sheet spans January 2005 through December 2007 on a month-by-month basis). Do **NOT** give your students any of the actual sea ice data yet.
4. Ask your students to make a hypothesis about the extent of sea ice throughout the year. Have them predict which month will have the greatest amount of sea ice, and which month will have the least. Tell them that during the time period represented by their graphs (2005 through

2007) the maximum extent was about 15 million km^2, and the minimum was about 4 million km^2. Give your students Graphing Worksheet #1. Have the students predict the shape of the graph of sea ice extent over time by sketching in a curve on Graphing Worksheet #1 of how they think the sea ice extent varied during this three-year time period.

5. Give your students Data Table #1, which lists sea ice extent in the Arctic on a monthly basis over a three-year period from January 2005 through December 2007. Ask your students to plot this data on Graphing Worksheet #1. Have them use a colored pencil of a different color than the one they used to sketch in their hypothesis.
6. Have your students compare their hypotheses (the "prediction curves" they sketched in) with the plots of actual data. Discuss with your class any discrepancies between predictions and results based on data and the significance of those discrepancies.
7. Next, have your students make a hypothesis about the variation, on a monthly basis over the same three-year period, of sea ice extent around Antarctica. As before, have them sketch in their "prediction curves" on the same graph, using a third colored pencil different from the first two. Tell them that the maximum extent of sea ice in the Antarctic during that time was about 19 million km^2, and the minimum was about 3 million km^2.
8. Give your students Data Table #2, which lists sea ice extent in the Antarctic on a monthly basis over the same three-year period (from January 2005 through December 2007). Ask your students to plot this data on Graphing Worksheet #1. Have them use a (fourth) different colored pencil. Figure 1 shows a plot of the actual data from Data Tables #1 and #2.

Figure 1: Monthly Sea Ice Extent vs. Time

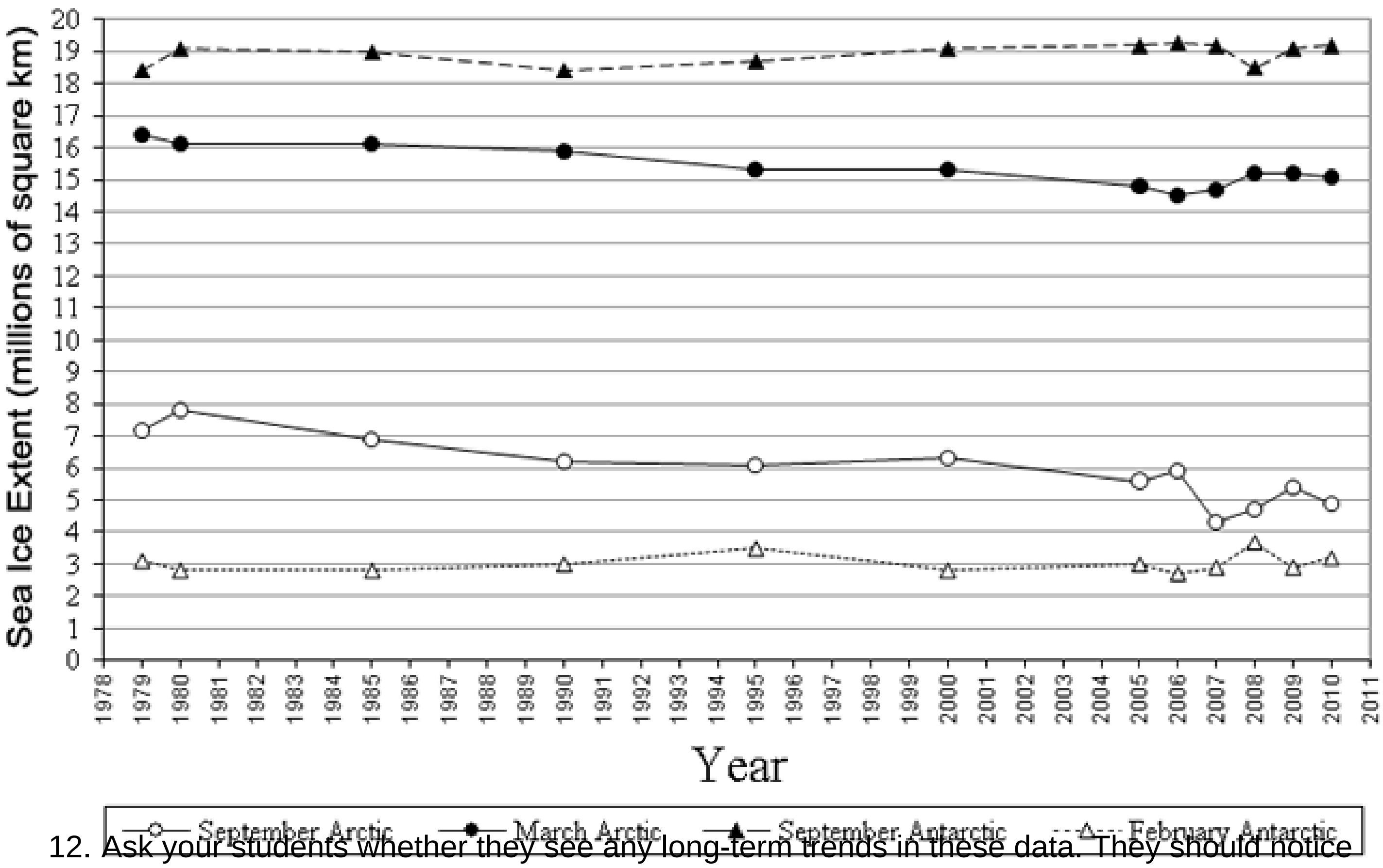


9. Once again, have your students compare their hypotheses (the "prediction curves" they sketched in) with the plots of actual data for the Antarctic. Also, have them compare the curves for the Antarctic with those for the Arctic. Again, discuss any discrepancies between predictions and results, differences between the curves for the opposite hemispheres, and

possible sources of those discrepancies and differences. It is likely that students may have some confusion regarding the causes of seasons and how the seasons differ between the Northern and Southern Hemispheres; you may want to review these concepts at this point in the lesson.

10. Now that students have a sense of the seasonal variation in sea ice extent in each of the two hemispheres, let's have them look at longer-term trends in the data. Give your students Graphing Worksheet #2. The x-axis on this worksheet lists individual years from 1978 through 2010. Also give your students Data Tables #3 and #4. These tables show the sea ice extent in the Arctic and the Antarctic during the months when the ice extent is at its minimum (September in the Arctic, February in the Antarctic) and at its maximum (March in the Arctic, September in the Antarctic) for a number of different years. The tables provide data at 5-year intervals starting in 1980 (1980, 1985, 1990, ... , 2010). They also provide data for 1979 (the first year for which this data was available) and for 2006 through 2009 (some of the most recent years for which this data is available).
11. Have your students plot the data from Data Tables #3 and #4 on Graphing Worksheet #2. Have them use different colored pencils for each of the four data sets (Arctic maximum, Arctic minimum, Antarctic maximum, and Antarctic minimum). Figure 2 shows a plot of these data. **Note:** Figure 2 includes data for 1979 and 2006 through 2009. You may choose to have students just plot data for 5-year intervals starting in 1980, **or** have them also include the 1979 and 2006-2009 data as well.

Figure 2: Sea Ice Extent vs. Time (years)



12. Ask your students whether they see any long-term trends in these data. They should notice that there appears to be a gradual decline in sea ice extent (both at the minimum in September and at the maximum in March) in the Arctic. Scientists who have done a rigorous mathematical analysis of this trend report an average rate of decrease in extent of the Arctic sea ice pack in September from 1979 through 2010 of 11.5% (with an uncertainty of ± 2.9%) per decade. On the other hand, there is not an obvious trend, either an increase or a

decrease, in the maximum or the minimum extent of Antarctic sea ice (within the levels of uncertainty or normal interannual variation).

13. The models that climate scientists use to predict the effects of global climate change indicate that warming of Earth's climate will be most severe at high latitudes, and that the effects will be noticed earlier in the polar regions than at other places on our planet. Most climate scientists believe these effects are already being felt in the Arctic, and that changes in sea ice extent are one such noticeable effect. You may want to discuss these issues with your students at this point.
14. Ask your students to predict, based on this data, in what year they think the Arctic would be ice-free in September if the current trend continues. Ask them how reliable they think their prediction might be. **Note:** A simple, linear extrapolation based on such a limited set of data probably is not especially reliable. You may want to discuss, at this point, various mathematical and scientific concepts, such as: functions/curves that are linear versus curves/trends that are not straight lines; uncertainty, error bars, and other intermittent fluctuations in data sets that make it difficult to make predictions based on small numbers of data points; the scientific phenomena that underlie these mathematical representations of sea ice extent, and how those phenomena are often complicated combinations that can have powerful feedbacks that produce non-linear effects (for example, less ice cover means that less incoming sunlight is reflected away, and thus more heat is absorbed, potentially speeding up the warming process in a positive feedback loop).
15. If you want to, you can have students go to the web site of the National Snow and Ice Data Center (NSIDC) at http://nsidc.org/data/seaice_index/ and collect more data (for example, for years or months that our data sets do not include; or for the most recent months that are currently available) to plot and analyze.