

IPY/NSTA Symposium
Arctic Feedback Loops and Sea Ice Extent
Friday, Dec. 7, 2007
Teacher Activity Guide

Presenters: Debbie Chalmers & Dayna Weiler

UNIT LESSONS: Grade Level 5-9

Activity 1: Radiation and Reflection: Exploring Albedo

Activity 2: Graphing Arctic Sea Ice and Air Temperatures

Activity 3: Modeling Arctic Feedback Loops

UNIT SUMMARY:

Arctic sea ice is sensitive to climate change. This unit examines conditions in the Arctic that affect climate change. *Activity 1* allows students to simulate albedo feedback in a hands-on lab experiment. Students utilize satellite maps and Arctic temperature data in *Activity 2* to illustrate changes in the extent of Arctic summer sea ice over time. *Activity 3* allows students to examine and determine positive and negative feedback processes and identify relationships among albedo, sea ice extent and temperature that make-up the Arctic feedback loop. Students examine their findings and make predictions on world climate change and ecosystems.

Students will access observational records, GIS satellite data, feedback loop models and weather data while completing the unit activities. The scientific data is analyzed and interpreted to form hypotheses and increase understanding of scientific processes that contribute to global climate change.

UNIT OBJECTIVES:

- To examine and illustrate feedback loop processes and variables that influence climate change in the Arctic.
- To illustrate the relationships between *albedo*, temperature, *feedback loops* and climate change.

UNIT GUIDING QUESTIONS:

- Why is it important to study Polar Regions in order to understand climate change?
- How does an understanding of Polar Region processes help increase our understanding of cause-effect relationships that contribute to climate change?
- Why is the Arctic Region an important indicator of climate change?

UNIT CONCEPT:

Regions of sea ice, which reflect sunlight back into space and provide a cooling impact, are disappearing while areas of open water, which are expanding, absorb sunlight and increase temperatures. This decrease in *albedo* (less reflection) causes increased absorption of solar radiation leading to increased ice melt and open water, resulting in

increased air temperatures, which in turn causes more ice to melt. This creates a *positive feedback loop* that contributes to recent rapid loss of sea ice and results in climate change.

BACKGROUND INFORMATION

Albedo and climate change

- Albedo is the percentage of incoming sun light that is reflected, rather than absorbed.
- In general, more lightly-colored surfaces (snow and sea ice) have a higher Albedo than darker –colored ones (soil, trees, tundra).
- Albedo is represented as a percentage of the Earth’s total incoming energy. Thus, an Albedo of 50% would indicate that half of all incoming radiation is reflected. In general, the more radiation that is reflected usually means lower overall surface temperatures.
- Albedo represents an important aspect in the understanding of climate change and the radiation budget.
- The Earth’s Radiation Budget is a concept that uses the amount of energy the Earth gets from the sun and the amount of energy it sends back into space. If the Earth receives more solar energy than it sends back into space, we expect the Earth to warm. If the Earth sends more energy back into space than it receives from the Sun, we expect the Earth to cool.
 - Even though the Arctic receives a large amount of solar energy in the summer, the high reflectivity (albedo) of snow and ice surfaces keeps absorption of solar energy low.
- The temperature difference between the Tropics and the Poles is the driving force behind the circulation of the Earth’s atmosphere and oceans, thus creating winds that carry excess heat and moisture. Any change in surface albedo will alter climate by changing the amount of solar energy absorbed by the Earth.
- The overall albedo of the Earth is thought to be about 30%.
- Wet snow absorbs more radiation than dry snow.
- The amount of solar radiation absorbed or reflected impacts the global climate. The summer Arctic ice cover is not uniform. Surface conditions vary from deep snow to bare ice to melt ponds to open leads in the ice. Ice thickness ranges in open water to ridges tens of meters thick within an area less than a square mile.
<http://www.arctice.org/brwweb/icealbed.htm>

Arctic Sea Ice and Climate Change

- “A new study by NOAA scientists shows that aerial sea-ice coverage of the Arctic Ocean will decline by more than 40 percent before the summer of 2050, compared to a 1979-1999 base period.”
<http://www.noaanews.noaa.gov/stories2007/s2915.htm>
- “Arctic pack ice has formed progressively later, melted earlier and lost much of its older and thicker multi-year component. Together, these changes have resulted in pack ice that is a less stable platform on which to give birth and raise new cubs. Previous research had already shown that unstable ice can result in failures of on-ice denning attempts. Less ice that is suitable for denning apparently has led to an

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increased frequency of pregnant polar bears in this region choosing to den on land.” (http://www.doi.gov/news/07_News_Releases/070712.html)

- Arctic sea ice is defined as a thin, fragile, solid, layer that forms and floats in polar oceans. Sea ice forms and melts with the polar seasons. Some Arctic sea ice remains year after year while Antarctic sea ice is “seasonal ice” and melts and reforms each year.
- Icebergs are not considered sea ice because they originate from glaciers. Antarctic icebergs usually calve from Antarctic ice shelves.
<http://nsidc.org/icebergs/questions.html>
- Arctic sea ice extent includes areas of ocean that are covered by at least 15 percent ice. Arctic sea ice is melting at a much faster rate than projected by computer models.
- On average, sea ice covers about 25 million square kilometers (9,652,553 square miles) of the earth, or about two-and-a-half times the area of Canada.
<http://nsidc.org/seaice/>
- Summer and winter Arctic Sea Ice extent is measured at its greatest extent during the month of March and its least extent during the month of September at the end of the summer melt season.
- Average surface air temperatures from January to June 2005 were 3.6-5.4 degrees Fahrenheit warmer than average temperatures compared with temperature averages over the past 50 years.
- Arctic mammals such as polar bears, seals and walrus depend on sea ice for their habitat where they hunt, feed and breed on the ice. Early spring melt and summer sea ice melt force polar bears to remain on land and live off their stored fat until the winter ice returns.
- Sea ice typically covers about 14 to 16 million square kilometers in late winter in the Arctic and 17 to 20 million square kilometers in the Antarctic Southern Ocean. The seasonal decrease is much larger in the Antarctic, with only about three to four million square kilometers remaining at summer's end measured in September, compared to approximately seven to nine million square kilometers in the Arctic.
- Satellite data imagery tracks sea ice cover and helps scientists measure seasonal changes in sea ice extent. Since 1979 Arctic ice extent has decreased about 3.6 per cent per decade. Continued shrinking of Arctic ice extent since 2002 has speeded the rate of end-of-summer sea ice loss to 8 percent per decade. A new record of Sea ice extent loss was set in the summer of 2005.
- Arctic sea ice thickness has decreased about 1.3 meters over the past 30-40 years.

Feedback Loops and Climate Change

- In order to model and predict Arctic (and global) climate variability correctly, feedback loops must be understood.
- Positive feedback can be described as the amplification of naturally occurring interactions.

- In a climate system a “feedback loop” refers to a pattern of interacting processes (naturally occurring in this case) where change in one variable, through interaction with other variables in the system, either reinforces the original process (positive feedback) or suppresses the process (negative feedback).
http://nsidc.org/arcticmet/patterns/feedback_loops.html.
 - In the example described above and as illustrated in the unit diagram, increased temperature causes more ice melting, which causes less reflection of solar radiation back to space, which in turn causes more warming (a positive feedback). Taken from the NSIDC Arctic Climatology and Meteorology Primer (<http://nsidc.org/arcticmet/>)
- “Temperature / Albedo Feedback”-Rising temperatures increase melting of snow and sea ice, reducing surface reflectance, thereby increasing solar absorption, which raises temperatures, and so on. The feedback loop can also work in reverse. For instance, if climate cools, less snow and ice melts in summer, raising the albedo and causing further cooling as more solar radiation is reflected rather than absorbed. The temperature - albedo feedback is positive because the initial temperature change is amplified.”
http://nsidc.org/arcticmet/patterns/feedback_loops.html)
- Negative Feedback suppresses naturally occurring feedback process. (this can be visualized as a reversal of the occurring process).
- Research indicates that the effect of temperature-cloud cover-radiation feedback in the Arctic may be different than in other latitudes.
- The Arctic plays a key role in the earth's heat balance by acting as a "heat sink." The global earth-atmosphere system gains heat from incoming solar radiation, and returns heat to space by thermal radiation. Most of the heat gain occurs in low latitudes, and this gain is balanced (on average) by heat loss that takes place at latitudes north and south of about 40 degrees. Therefore the Arctic is said to act as a "heat sink" for energy that is transported from lower latitudes by ocean currents and by atmospheric circulation systems.
http://nsidc.org/arcticmet/patterns/heat_sink.html

Culminating Understanding

Regions of sea ice, which reflect sunlight back into space and provide a cooling impact, are disappearing while areas of open water, which are expanding, absorb sunlight and increase temperatures. The interaction of decreased *albedo* (less reflection) causes increased absorption of solar radiation leading to increased ice melt and open water. This results in increased air temperatures, which in turn causes more ice to melt. This creates a *positive feedback loop* that contributes to recent rapid loss of sea ice and results in climate change.

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ACTIVITY 1: *Radiation and Reflection: Exploring Albedo* Teacher Lesson Guide

GRADE LEVEL: 5-9

CONTENT OBJECTIVE:

To illustrate how dark colored surface absorb solar energy while light colored surfaces reflect solar energy. This will illustrate that snow and ice act as a cooling system for the Earth.

GUIDING QUESTIONS:

- What effect does Albedo have on surface temperature?
- What observations can you make from the graphed data?

CONCEPT: Albedo is the percentage of incoming sunlight that is reflected, rather than absorbed.

TIME REQUIRED:

60 minutes- if they start the graphing in class and finish it and the questions at home
Plan 40 minute to record data at 5 minute intervals. If time is limited to one 50-minute class period, start activity and discuss student predictions and background information between timing intervals.

MATERIALS NEEDED:

- Clap Lamp and at least a 100-w bulb (we used a 250 W heat lamp)
- Black polyethylene cutting board, white polyethylene cutting board and blue cutting board to simulate water(you could put water in a clear dish and place it on top of the blue cutting board so that the color is more similar to that of the ocean), all at room temperature
- Thermometer (we used a non-contact infrared thermometer)
- Stop watches or a large clock with second hand

TEACHER DIRECTIONS FOR INSTRUCTION/ACTIVITY:

This lesson shows how dark colors (tundra, rocks, and soil) absorb more heat than that of light colors (sea ice and snow), which reflects the solar energy back into space. And provides a simulated demonstration of albedo, which is a leading factor in the increased melting of Arctic sea ice. As air temperatures are rising do to the increased amounts of CO₂, sea ice which has a high albedo (large reflectivity) is melting. As the sea ice melts, less solar radiation is reflected, increasing the amount of absorption and increasing temperature, which causes more ice to melt. This activity can be used in conjunction with “Graphing Arctic Sea Ice and Air Temperatures” when studying Arctic Feedback Loops and Climate Change

1. Emphasize that it important that the cutting boards start at the same temperatures.
2. Have students gather materials and check to make sure set up is correct (most importantly that the heat source is directly over both boards evenly!). Make sure each group has a reliable timekeeper and that they all know how to read the thermometers.
3. Once the set-up has been checked, the temperature of the cutting boards should be taken **before** the light is turned on. The light is then turned on and the temperature of both cutting boards should be taken every 5 min.
4. After 40 min (9 data points), the students will make a line graph of the data showing the increase of temperature over time for both the white and black cutting boards. (At this point many students will need help with making the line graph depending on the level of the students.)

EVALUATION:

Graphs should generally show the black cutting board heats up the faster than the white cutting board.

Answers to Analysis questions:

1. This answer should describe the results shown in the table and on their graph (as explained above). The graph, of course, should match with the numbers in the table.
2. Students should conclude that the black cutting board absorbed more of the energy from the light and that the white cutting board reflected more of the energy from the light.
3. Areas covered by ice and snow will reflect most of the solar energy back out into space cooling the Earth, but areas that are covered with darker materials will absorb more of the solar energy thus heating the Earth.
4. As the Arctic Ice decreases the overall temperature will increase causing more ice to melt which will increase the temperature.

Lesson Plan adapted from *Project Earth Science Meteorology*, 1994, NSTA Publications.

STUDENT PAGES FOLLOW:

Arctic Feedback Loops and Sea Ice Extent

Name: _____

Date: _____

ACTIVITY 1: *Radiation and Reflection: Exploring Albedo*

OBJECTIVE: You will determine if snow and ice or land absorbs heat faster and discuss the implications of your findings.

GUIDING QUESTIONS:

- What effect does Albedo have on surface temperature?
- What observations can you make from the graphed data?

MATERIALS: Obtain 2 cutting boards (black and white), a non-contact infrared thermometer, a clamp light, and a light bulb (min 100w).

PREPARATION: Take the temperature of the cutting boards (making sure they are both the same temperature) then place the cutting boards under the light source so that they obtain equal amounts of light rays. Make a hypothesis on what you expect to observe.

PROCEDURE: Before you turn the light on, take the initial temperature of the cutting boards. Turn the light on and measure the temperature of each material in degrees Fahrenheit every 5 minutes. Record temperatures on the data table below (Be sure to make the temperature readings from the same angle and distance). After 40 minutes, turn off the light. Graph the results on the graph paper provided, using different colors or patterns for each material. Answer the questions below.

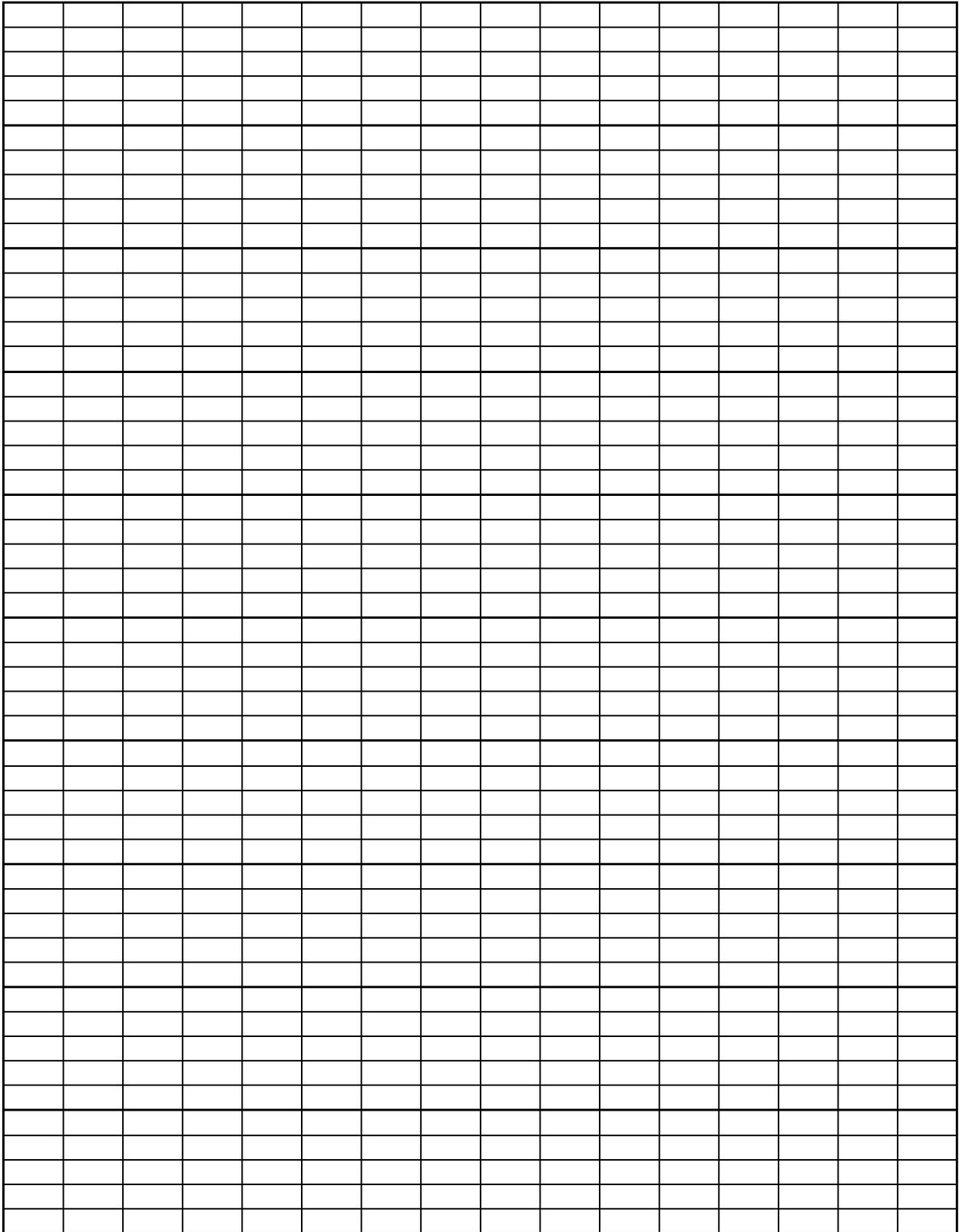
DATA:

Time	0 min	5 min	10 min	15 min	20 min	25min	30min	35min	40min
White cutting board									
Black cutting board									

ANALYSIS:

1. Please describe the results of your experiments.
2. What can you conclude from these results? (i.e., which colors absorb and which colors reflect?)
3. What do these results indicate about the heating of the Earth?
4. Explain how these results affect the Arctic. What do you think would happen if the amount of ice and snow was decreased?

Temperature (degrees F)



Time (min)

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ACTIVITY 2: *Graphing Arctic Sea Ice and Air Temperatures*

Teacher Lesson Guide

GRADE LEVEL: 5-9

TIME REQUIRED: One hour (Plan for two hours with preceding lesson on graphing data if needed.)

LESSON SUMMARY: During this lesson, students will examine GIS mapped data of Arctic Sea Ice Extent from 1979-2007, graph data over four-year intervals, observe patterns of change in Arctic sea ice extent over time and form an understanding of the relationship between sea ice extent, surface temperatures, and albedo.

CONCEPT: Arctic air temperature influences the extent of Arctic sea ice.

CONTENT OBJECTIVES:

- To interpret and plot GIS mapping data for Arctic sea ice extent and surface air temperatures.
- To illustrate the relationship between Arctic temperature and sea ice extent and changes over time.
- To identify the value/role of Arctic Sea Ice in Arctic climate, ecosystems and in research.

GUIDING QUESTIONS:

1. What is sea ice?
2. Why is Arctic sea ice extent data measured during the months of September and March?
3. What patterns did you observe when plotting Arctic sea ice extent and temperature data?
4. What is the relationship between Arctic sea ice extent and Arctic air temperatures?
5. What predictions can you make about how observed patterns from Arctic sea ice and temperature data influence ecosystems in the Arctic?
6. What does sea ice have to do with climate change?

MATERIALS NEEDED:

1. September Arctic sea ice extent data: Photocopy maps, located at the *National Snow and Ice Data Center* web site. http://www-nsidc.colorado.edu/cgi-bin/wist/wist.pl?annot=1&legend=1&scale=100&tab_cols=2&tab_rows=8&wcf=seaiice_index&submit=Refresh&mo0=03&hemis0=N&j
2. *Activity 2 Temperature Table*
3. *Activity 2 Data Table*
4. *Activity 2: Arctic Sea Ice Extent and Air Temperatures Graph.*
5. Ruler, colored pencils or fine-tip markers, pencils.

Related Extension; Polar Region Map Skills

2007 Arctic Region Circumpolar map projection with summer isotherm extent.
http://www.lib.utexas.edu/maps/islands_oceans_poles/arctic_region_pol_2007.pdf

TEACHER DIRECTIONS FOR INSTRUCTION/ACTIVITY

1. Provide students with photocopy maps of Arctic Sea Ice Retreat 1979-2007 or access to the NDIS website link. Students should work with a partner to study the maps and make general observations of differences between March and September sea ice extent and changes over time. *Note:* If accessing the website, remind students to set the data fields for September and March sea ice extent years as labeled on the *Activity 2 Graph Template*. Hit *refresh* field to reset maps after selecting appropriate dates.
2. The September sea ice extent is the warmest month and shows the least extent of sea ice for each year. Students will plot the September sea ice extent data over four year increments from 1979-2007. An attached handout is printed to compare fall/spring data for 1979, 1983, 1987, 1991, 1995, 1999, 2003, and 2007. Data for all years is available in interactive maps on the NDIS website.
3. Direct students to record September mean Arctic sea ice extent data, and mean Arctic air temperatures at four-year intervals. See *Activity 2 Temperature Table* and *Activity 2 Data Table* (Average September Arctic air temperature data provided)
4. Review graphing skills for plotting line graphs. Explain purpose of plotting two data sets on separate left and right-hand y-axis to allow comparison of data.
5. Direct students to plot average September Arctic air temperatures over four-year increments on right-hand y-axis. See *Activity 2 Graph Template* and *Activity 2 Teacher Answer Guide*
6. Students should include a descriptive statement about the graph as well as a key to identify the plotted data sets on the line graph.
7. Students write responses to the analysis questions based on their findings.
8. Provide time for discussion of data findings and responses to analysis questions.

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EVALUATION:

1. Student graph should display decrease in average September sea ice extent and increase in average September Arctic air temperatures over four-year-intervals. Labels and key should clearly identify plotted data. (See attached *Activity 2 Teacher Table and Graph Guide*)
2. Descriptive statement or caption for individual graphs should describe observed trends and demonstrate understanding of findings.
3. Student responses to Activity 2 Analysis Questions or discussion should articulate the cause-effect relationship between Arctic sea ice extent and Arctic air temperatures. These should include:
 - Arctic Sea Ice is floating ice pack over a large area that increases in extent during the winter months and decreases in extent during the summer months.
 - Arctic sea ice extent data was selected during the months of minimum and maximum extent.
 - Student comments should note dramatic increase in temperature and decrease in sea ice extent after 2001. *This correlation will be examined further in Activity 3)*
 - A direct relationship between increased ice extent and lower Arctic air temperatures and a similar relationship between higher Arctic temperatures and decreased sea ice extent.

RESOURCES:

National Snow and Ice Data Center, September 28, 2005, Sea Ice decline Intensifies
http://nsidc.org/news/press/20050928_trendscontinue.html
http://nsidc.org/news/press/20050928_trendscontinue.html, NSDIC; *Sea Ice Decline Intensifies*, September 2005
<http://nsidc.org/seaice/>, NSDIC; *All About Sea Ice*

National Snow and Ice Data Center- WIST: Compare data: Sea Ice Index: Extent, Concentration, and Concentration Anomalies:

http://www-nsidc.colorado.edu/cgi-bin/wist/wist.pl?annot=1&legend=1&scale=100&tab_cols=2&tab_rows=2&wf=seaice_index&submit=Refresh&mo0=03&hemis0=N&img0=extn&mo1=09&hemis1=N&img1=extn&year0=2007&year1=2004&.cgifields=no_panel

Student Pages and Activity 2 Teacher Graph and Table Guide attached

Arctic Feedback Loops and Sea Ice Extent

ACTIVITY 2: Teacher Table and Graph Guide

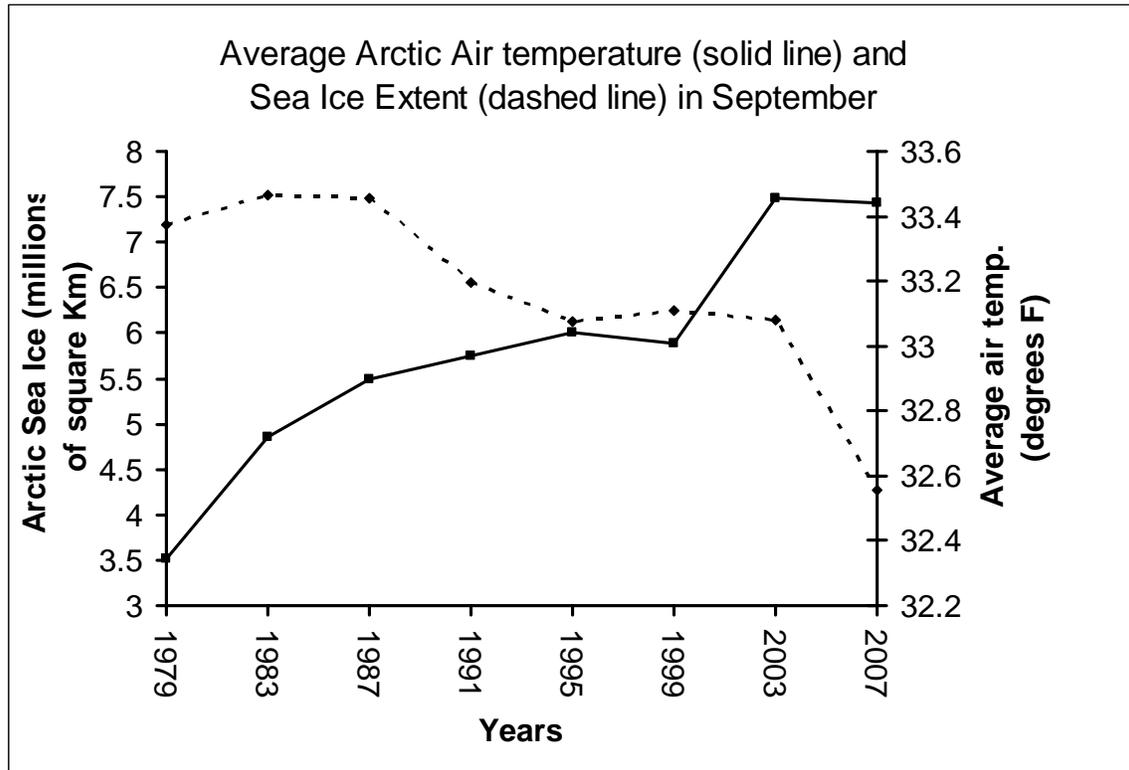


Table Data Guide:

Average Arctic Air Temperature and Sea Ice Extent data used for making the graph.

year	extent	Fahrenheit
1979	7.2	32.342
1983	7.52	32.72
1987	7.48	32.9
1991	6.55	32.972
1995	6.13	33.044
1999	6.24	33.008
2003	6.15	33.458
2007	4.28	33.44

Arctic Feedback Loops and Sea Ice Extent

NAME: _____

DATE: _____

ACTIVITY 2: *Graphing Arctic Sea Ice and Air Temperatures*

OBJECTIVE:

Your task is to determine the relationship between September Arctic sea ice extent and Arctic surface air temperatures over 4-year time intervals and discuss the implications of your findings.

GUIDING QUESTIONS:

- What is Sea Ice?
- What causes changes in Arctic Sea Ice Extent?
- What does sea ice have to do with climate change?

MATERIALS:

- September Arctic Sea Ice Extent Mapping data located at the National Snow and Ice Data Center web site. http://www-nsidc.colorado.edu/cgi-bin/wist/wist.pl?annot=1&legend=1&scale=100&tab_cols=2&tab_rows=8&wcf=seaice_index&submit=Refresh&mo0=03&hemis0=N&i
- *Activity 2 Arctic Sea Ice Extent and Temperature Graph*
- *Activity 2 Data Table:*
- *Activity 2 Temperature Table*
- Pencil, Ruler, 2 different colored pencils or fine-point color markers.

PROCEDURE:

1. View or print maps of March and September Arctic Sea Ice Retreat 1979-2007 at the NDIS website link. Examine the maps and make general observations of differences between March and September sea ice extent and changes over time.
Note: Data for all years is available in interactive maps on the NDIS website. If accessing the website, remember to set fields for September and March sea ice extent years as labeled on the *Activity 2 Graph Template*. Select the *refresh* field at the top of the page to reset maps after selecting appropriate dates.
2. Record the Arctic September sea ice extent data over four year increments from 1979-2007. Record your findings on the *Activity 2 Data Table*.
3. Record the Arctic September mean air temperature at four-year intervals on *Activity 2 Data Table* (Refer to *Activity 2 Temperature Table* for data).
4. Plot a line graph of your findings for the median September Arctic sea ice extent over four-year increments on *Activity 2 Graph Template*. Be sure to refer to left-side y-axis when plotting your data.

5. Plot a separate line graph of your findings for the mean September Arctic air temperatures over four-year increments on *Activity 2 Arctic Sea Ice and Air Temperature Graph*. Be sure to use right-side y-axis when plotting your data.
6. Include a key for your graph that clearly identifies your line graphs and a statement about your graph that explains your findings based on the plotted data.
7. Write responses to the analysis questions below when you have completed this activity.

DATA:

- *September Arctic Sea Ice Extent Maps* data from the National Snow and Ice Data Center web site. http://www-nsidc.colorado.edu/cgi-bin/wist/wist.pl?annot=1&legend=1&scale=100&tab_cols=2&tab_rows=8&wcf=seaice_index&submit=Refresh&mo0=03&hemis0=N&i
- Activity 2 Arctic Temperature Table

ANALYSIS:

1. What is sea ice?
2. Why is Arctic sea ice extent data measured during the months of September and March?
3. What patterns did you observe when plotting Arctic sea ice extent and temperature data?
4. What is the relationship between Arctic sea ice extent and Arctic air temperatures?
5. What predictions can you make about how observed patterns from Arctic sea ice and temperature data influence ecosystems in the Arctic?
6. What does sea ice have to do with climate change?

Arctic Feedback Loops and Sea Ice Extent

ACTIVITY 2 TEMPERATURE TABLE

Average September Arctic Air Temperatures from 1979-2007

<u>year</u>	Fahrenheit
1979	32.342
1980	32.216
1981	32.396
1982	32.216
1983	32.72
1984	32
1985	32.108
1986	31.946
1987	32.9
1988	32.612
1989	32.54
1990	32.846
1991	32.972
1992	31.712
1993	32.036
1994	32.702
1995	33.044
1996	32
1997	32.918
1998	33.404
1999	33.008
2000	32.666
2001	32.972
2002	33.188
2003	33.458
2004	33.152
2005	33.908
2006	33.458
2007	33.44

Source: <ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/Sep/>

Arctic Feedback Loops and Sea Ice Extent

ACTIVITY 2 TEMPERATURE TABLE

Graphing Arctic Sea Ice Extent and Air Temperatures

Student Name: _____

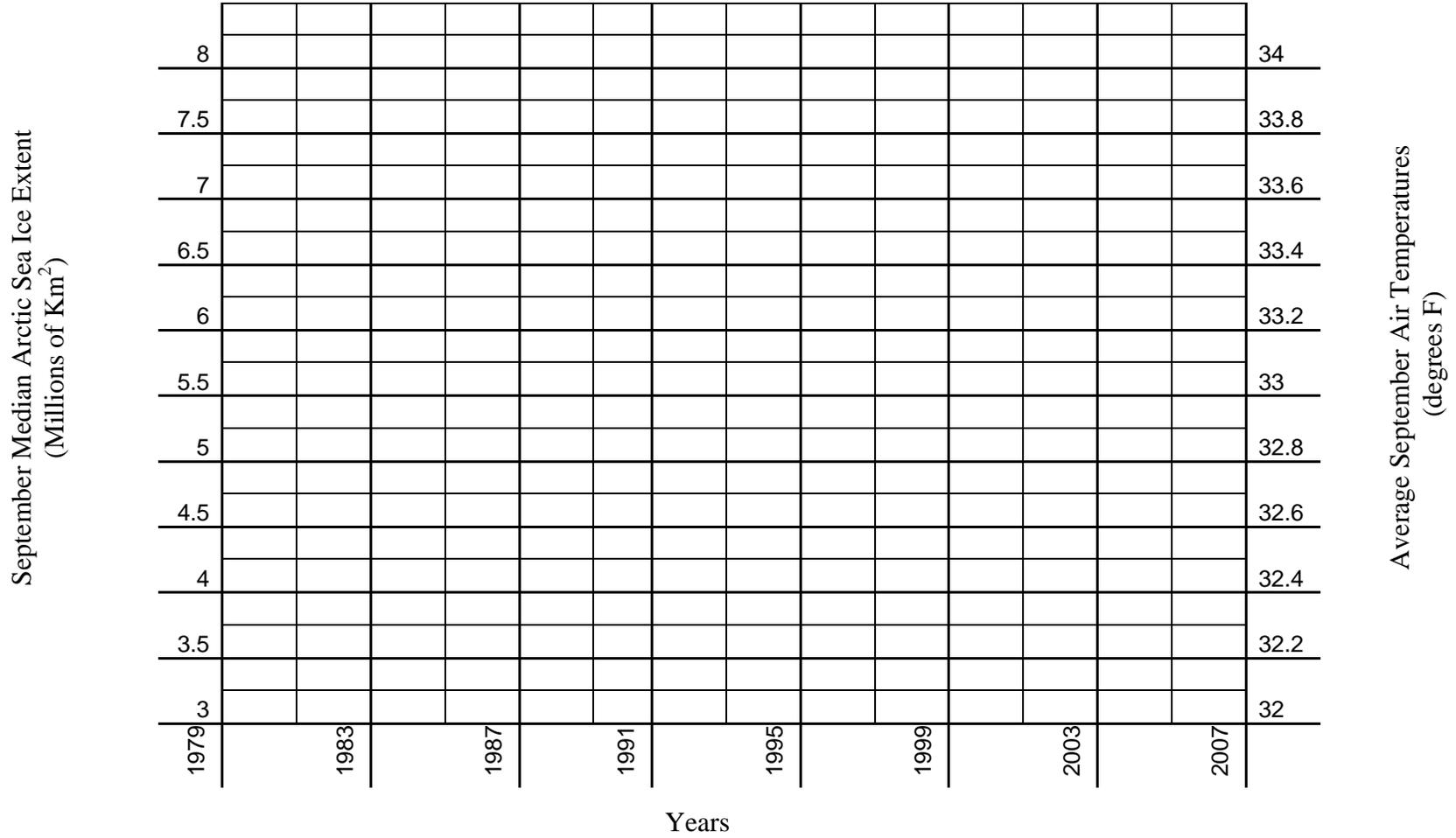
Date _____

Years	Mean September Sea Ice extent (millions of Km ²)	Average Air Temperature (degrees Fahrenheit)
<i>x-axis</i>	<i>y-axis (left)</i>	<i>y-axis (right)</i>
1979		
1983		
1987		
1991		
1995		
1999		
2003		
2007		

Arctic Feedback Loops and Sea Ice Extent

Name _____

Date _____



Arctic Feedback Loops and Sea Ice Extent

ACTIVITY 3: *Modeling Arctic Feedback Loops*

GRADE LEVEL: 5-9

CONTENT OBJECTIVE: To illustrate the positive and negative interactions that take place in an Arctic feedback loop and how these interactions influence climate change.

GUIDING QUESTION:

- What is an Arctic Feedback Loop?
- How do positive and negative feedback loops differ?
- How do feedback loops affect Earth's systems and climate?
- How are Arctic feedback loops impacted by climate change?

CONCEPT: Variables within the cryosphere are interdependent.

TIME REQUIRED:

120 minutes

MATERIALS NEEDED:

- Colored construction paper
- Glue
- Scissors
- makers

TEACHER DIRECTIONS FOR INSTRUCTION/ACTIVITY:

This activity can be used in conjunction with “Radiation and Reflection: Exploring Albedo” and “Graphing Arctic Sea Ice and Air Temperatures” when studying Arctic Feedback Loops and Climate Change. This lesson focuses on creating a model for Arctic Feedback Loops and identifying positive and negative feedback. This culminating activity helps reinforce the understanding of albedo and the reactions of temperature and Arctic sea ice extent.

5. Before materials are distributed, draw and explain the provided “Arctic Feedback Loop” diagram. Remember to discuss the interactions that are taking place but **do not** identify the interactions as either positive or negative feedback. Allow the students to ask questions until they feel comfortable with each interaction on the diagram. You may want to refer to Brendan Kelly’s PowerPoint presentation located on the IPY/NSTA Symposium web page.
6. When everyone has finished asking questions, provide the materials that the students will use to make their own diagram. Every arrow indicating a feedback should be numbered and a key made on a separate sheet of paper indicating if the interaction is a positive or negative feedback and the reason for that choice.
7. The teacher diagram should be left on the board so that the students can copy from it.

EVALUATION:

Diagrams should look similar to that provided in the teacher materials. Also refer to the rubric provided for evaluating this project.

Answers to Analysis questions:

1. This answer should give a definition of what a feedback loop is and examples or explanations of what that looks like in the Arctic.
2. The student should give a definition of positive and negative feedback. In general positive feedback amplifies the occurring process while negative feedback suppresses the processes.
3. The student should conclude that feedback loops help maintain a balance or equilibrium in the Earth's systems. When variable are altered the balance is also altered.
4. Student should understand the cause – effect relationship of the variables within a feedback system. (A small change introduced in the feedback loop process can result in a globally significant impact on climate, i.e. climate change.

LESSON PLAN: Adapted from a diagram at <http://nsidc.org/arcticmet/>

STUDENT PAGES FOLLOW:

Name: _____

Date: _____

Activity 3: Modeling Arctic Feedback Loops

OBJECTIVE:

You will determine whether the interactions in an Arctic feedback loop are positive or negative feedback and explain your reasoning.

MATERIALS:

Colored construction paper, scissors, glue, and markers

PREPARATION:

Listen and observe the teachers explanation of the “Arctic Feedback Loop” diagram on the board. Remember to ask as many questions as necessary to understand the interactions taking place in the diagram.

PROCEDURE:

Use the colored construction paper to recreate the diagram on the board. Label all feedback interactions (positive or negative feedback) with a number. Make an additional table to go along with your poster. This table will include the number of the feedback interaction from the poster whether it is positive or negative feedback and an explanation as to why you chose your answer (what is taking place that tells you that it is positive or negative feedback). Refer to the project scoring guide for evaluation guidelines. Remember to always make the information clear and understandable while still being beautiful.

ANALYSIS:

1. What is an Arctic Feedback Loop?
2. How do positive and negative feedback loops differ?
3. How do feedback loops affect Earth’s systems and climate?
4. How are Arctic feedback loops impacted by climate change?

Student Activity 2- Graph Template

September Arctic Sea Ice Extent and Air Temperature

Student Name _____

Date _____

ACTIVITY 3: Modeling Arctic Feedback Loops Scoring Guide

<i>Category</i>	<i>4</i>	<i>3</i>	<i>2</i>	<i>1</i>	<i>Score</i>
Required Elements	The poster includes all required elements as well as additional information.	All required elements are on the poster.	All but 1 of the required elements are included on the poster.	Several required elements are missing.	
Labels	All feedbacks on the poster are clearly labeled with labels that can be clearly read from at least 3 ft. away.	Almost all of the feedbacks on the poster are clearly labeled with labels that can be clearly read from at least 3 ft. away.	Many of the feedbacks on the poster are clearly labeled with labels that can be clearly read from at least 3 ft. away.	Labels are too small to view OR no feedbacks were labeled.	
Content Accuracy	All feedback interactions are correct (positive or negative) and explanations of these choices are clear and accurate.	Several of the feedback interactions (positive or negative) are correct and most of the explanations have sound reasoning	Some of the feedback interactions (positive or negative) are correct but the explanations reasoning is not clear.	Feedback interactions (positive or negative) are not clearly presented and no explanations are given.	
Grammar/ Mechanics	There are no grammatical/mechanical mistakes on the poster.	There are 1-2 grammatical/ mechanical mistakes on the poster.	There are 3-4 grammatical/ mechanical mistakes on the poster.	There are more than 4 grammatical/ mechanical mistakes on the poster.	
Attractiveness	The poster is exceptionally attractive in terms of design, layout, and neatness.	The poster is attractive in terms of design, layout, and neatness.	The poster is acceptably attractive though it may be a bit messy.	The poster is distractingly messy or very poorly designed. It is not attractive.	
Use of Class Time	Used time well during each class period. Focused on getting the project done. Never distracted others.	Used time well during each class period. Usually focused on getting the project done and never distracted others.	Used some of the time well during each class period. There was some focus on getting the project done but occasionally distracted others.	Did not use class time to focus on the project OR often distracted others.	