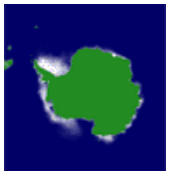
Investigation Four:
How are sea ice and climate related?

Getting Your Bearings

> Fifteen miles northeast of Sanders Island, the Endurance was confronted by a belt of heavy pack-ice, half a mile broad and extending north and south. There was clear water beyond, but the heavy southwesterly swell made the pack impenetrable in our neighborhood. This was disconcerting. The noon latitude had been 57° 26' S., and I had not expected to find pack-ice nearly so far north, though the whalers had reported pack right up to South Thule.

Ernest Shackleton's account in *South*, p. 6

Shackleton had been warned of severe sea ice conditions and an unusually long season of cold weather in Antarctica, so he delayed his departure for a month, finally setting sail for Vahsel Bay in early December 1914. Shackleton hoped to find some way around or through the sea ice in summer, for he needed to reach land in time to set up winter quarters.



Remember that winter comes to Antarctica in June. This is when the South Pole begins to point away from the Sun as Earth, tilted on its axis, makes its orbit around the Sun. As winter progresses, the Sun's rays strike Antarctica at lower and lower angles, providing less and less energy per square kilometer. Temperatures drop. It gets so cold that the ocean begins to freeze, forming sea ice. Sea ice continues to form throughout the winter months. As the ice forms it moves northward, creating regions of open water that then freeze and form more sea ice. Eventually, the ice extends over millions of square kilometers of ocean around Antarctica.

Sea ice tends to keep Antarctica cold even in summer. How does it do that? Two properties of sea ice come into play. First, sea ice is highly reflective. Second, sea ice provides insulation between the ocean and the atmosphere. Because of something called positive feedback, the more sea ice there is in Antarctica, the colder the climate tends to remain.

In this investigation, you will explore how reflectivity and insulation affect the transfer of heat energy. You will also learn more about positive feedback. When you are done, you will have a better idea of how sea ice and climate are related and why Shackleton had so much trouble with sea ice in Antarctica.

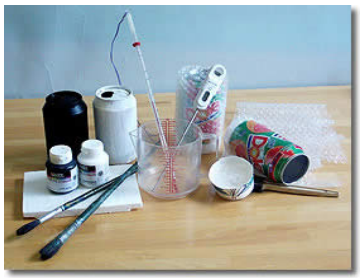
Goals

1. You will see how reflectivity and insulation affect heat transfer.
2. You will learn how sea ice reflects sunlight and insulates the ocean from the air, keeping Antarctica cold.
3. You will discuss some historical evidence that suggests there has been a recent climate change in Antarctica. You will also discuss sea ice's role in global climate change.

Exploring and Discovering

You will do one of two explorations of heat transfer. Your teacher will tell you which one. Other students in your class will do the other exploration. When you are done, you will all share your results.

Exploration 1: Reflectivity



In Investigation One, you looked at a photograph of Antarctica. You saw that snow and sea ice appeared white, while the oceans appeared darker. In this activity, you will explore the following question:

Are white surfaces more reflective than dark surfaces?

Materials

- 2 uninsulated containers—one white, one black (e.g., 12 oz. soda cans)
- 2 container covers—one white, one black—each with a hole just big enough to allow a thermometer to be inserted into the container
- cold water
- measuring cup or graduated cylinder
- 1 or 2 thermometers
- lamp with a bright light

Procedure and Record Sheet

1. Fill the two containers with equal amounts of cold water. Cover both containers.
2. Insert a thermometer into each container through the opening in the cover.
3. Record the water temperature of each container on the first line of the data table below.

Water Temperature and Reflectivity

	Temperature (degrees Celsius)	
Time (minutes)	Black container	White container
0		
5		
10		
15		
20		
25		
30		

4. Place the containers under a bright lamp.
5. Make a prediction by choosing the container you think will warm up faster.

   The temperature of the water in the ☐ black container ☐ white container (check one) will rise faster.

4. Measure and record the water temperature of both containers every 5 minutes for 30 minutes.
5. Between measurements, read about reflectivity.

   Reflectivity reading

6. Graph your results on paper or use the online graphing tool.

Questions

1. *Look again at your prediction in Step 5. Does your evidence confirm your prediction? Explain.*

2. *If your experiment does not confirm your prediction, what explanation(s) do you have?*

3. *If you had time to explore reflectivity again, what changes would you make in the experiment? Why would you make the changes?*

4. *How did reflectivity affect the way the two containers of water absorbed heat?*

5. *Sea ice is very reflective. Explain how large expanses of sea ice tend to keep the temperature cold in Antarctica.*

Exploration 2: Insulation

Sea ice acts as an insulator, keeping heat trapped in the ocean. By blocking heat transfer to the air, sea ice helps keep the local climate cool. In this activity, you will explore the following question:

Does insulation inhibit heat transfer?

Materials

- 2 insulated containers (e.g. - 12 oz soda cans)
- very hot water
- measuring cup or graduated cylinder
- insulation material (e.g., Styrofoam, shredded newspaper, or bubble wrap)
- 1 or 2 thermometers
- can opener

Procedure

1. Make an insulated lid for one container, leaving a hole just big enough for the thermometer to pass through. Use the can opener to remove the top from the other container.
2. Fill the two containers with the same amount of hot water.
3. Cover one container with the insulated lid. Leave the other container open to the air.
4. Insert a thermometer into each container.
5. Record the water temperature of each container on the first line of the data table below.

Water Temperature and Insulation

	Temperature (degrees Celsius)	
Time (minutes)	Open container	Closed container
0		
5		
10		
15		
20		
25		
30		

6. Make a prediction by choosing the container you think will cool faster.

The temperature of the water in the ☐ covered container ☐ uncovered container (check one) will fall faster.

7. Measure and record the water temperature in both containers every 5 minutes for 30 minutes.
8. Between measurements, read about insulation.

Insulation reading

9. Graph your results on paper or use the online graphing tool.

Questions

1. *Look again at your prediction in Step 5. Does your evidence confirm your prediction? Explain.*
2. *If your experiment does not confirm your prediction, what explanation(s) do you have?*
3. *If you had time to explore insulation again, what changes would you make in the experiment? Why would you make the changes?*
4. *How did insulation affect heat transfer from the hot water in the containers to the cooler surrounding air?*

5. *Sea ice is an insulator. Explain how sea ice blocks heat transfer in Antarctica when the air temperature above the sea ice is colder than the temperature of the water underneath it.*

Exploration: Sharing Results

After everyone has finished the experiments, share your results with your classmates.

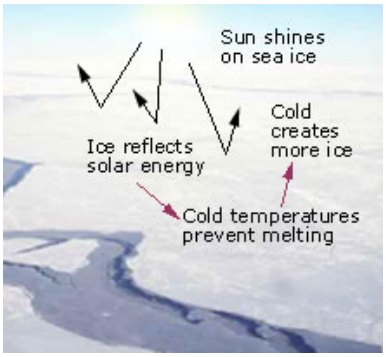
1. Pool all the results from the same experiment.

   Reflectivity groups. Using the evidence from all the groups, draft a statement about how black and white surfaces affect reflectivity.
   Insulation groups. Using the evidence from all the groups, draft a statement about how insulation affects heat transfer.
2. Teach and learn from your classmates. Reflectivity groups should explain their exploration, findings, and statements with the insulation groups and vise versa. Ask questions and debate ideas.

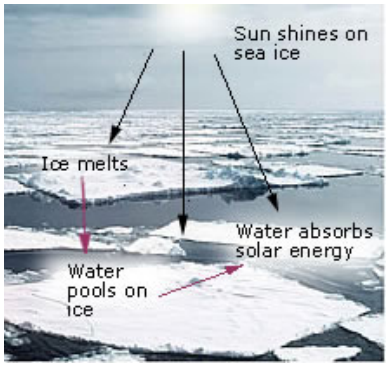
Learning about Positive Feedback

Positive feedback

Sea ice keeps the Antarctic region cold by reflecting solar radiation and insulating ocean warmth. The cold keeps the sea ice from melting; in time it creates even more ice, which results in still more cooling. This kind of cyclical cause-and-effect relationship is called positive feedback.



When sea ice begins to melt in spring, water from the ice melt pools on top of the ice. Like ocean water, melted sea ice is less reflective than frozen sea ice, so it absorbs more solar energy. As that energy is absorbed, it is transformed into heat, which warms the area and melts more sea ice. This is also an example of positive feedback.



Climate is the result of many interacting factors. Sea ice, the result of very cold climate, makes its own contribution to cold climate by reflecting solar energy into space and reducing the heat transfer from the ocean to the atmosphere.

Questions

1. *What are some examples of positive feedback in everyday life?*

2. *How does sea ice tend to keep the climate cold, even as the summer sun begins to shine on Antarctica?*

3. *How can positive feedback explain the persistent sea ice that trapped and finally crushed the Endurance?*

Looking Closer

When you explored reflectivity and insulation, you found some variation in your results. You had to evaluate all the evidence before you could write a summary statement. Scientists often have to wrestle with contradictory information like this.

There is solid evidence that the extent and duration of Antarctic sea ice varies from year to year. Recently, scientists have asked whether there has been any overall change in the sea ice season. They have looked at historical records for evidence and found that the answer is yes; Antarctica's sea ice season (the time from the first freezing of new ice to the time that ice begins to thaw) is now about 2 weeks shorter than it was 150 years ago. Scientists have also found that the average global temperature increased by 1.6°C during the same time period.

While they are confident that there are changes in sea ice and global temperatures, scientists cannot be absolutely sure what has caused these changes. They ask questions such as these:

- Is the global climate change we are observing now part of a natural cycle or is it caused by human activities?
- How does the decline in sea ice coverage affect Antarctic temperatures?
- How might temperature change in Antarctica affect temperatures around the globe?

You will now read an article, *Sea Ice and Global Climate Change*, that describes the current thinking of scientists concerned with these questions. When you are done, your teacher will lead a class discussion.

Global Climate Change Reading