Albedo, Melting Ice, and Feedback Loops

Overview

Students gain experience with the scientific method while they do two experiments to learn about how changing the reflectivity of Earth's surface materials and feedback loops impact Earth's systems:

1. Albedo (differences in reflectivity of surfaces)
2. Melting of ice on land and sea
3. Feedback loops

First, the class goes outside to observe the phenomenon of albedo first-hand. Then they design experiments to test the important role albedo plays in determining how much incoming solar radiation is absorbed by a substance. They create diagrams to illustrate the process and the concept of feedback loops.

In Part II of the lesson, students investigate two ways that the melting of ice impacts Earth's systems. They test how floating ice in a container (representing sea ice) and ice melting from outside a container (representing ice on land) affect the container's water level.

- Students discover that melting land ice (glaciers) raises sea level, but the melting of sea ice does not.
- Melting sea ice does, however, reduce albedo and thus lead to more absorption of solar radiation and more warming.

They connect their results to the concept of a positive feedback loop and how it can greatly magnify the impact of an initial change in a system, in this case how warming leads to melting ice, lowered albedo, and more warming. Enrich / Extend activities are listed to help you meet the needs of all learners.

Subjects: Science, Writing, Speaking & Listening, Art, Environmental Education

Grades: 4 – 12

Duration: Two 50-minute class periods on one long period

Vocabulary

- Absorption
- Albedo
- Aerosols
- Dependent variable
- Experimental question
- Experimental design
- Hypothesis
- Feedback loops
- Glacier
- Independent Variable
- Radiation
- Reflection
- Sea ice

Guiding Questions

- How does the reflectivity (albedo) of different substances affect the amount of energy they absorb?
- How does melting of ice in the sea and on land affect Earth systems?
- How can feedback loops impact Earth's systems?
- How can changes in albedo and the amount of ice impact Earth's climate and vice versa?

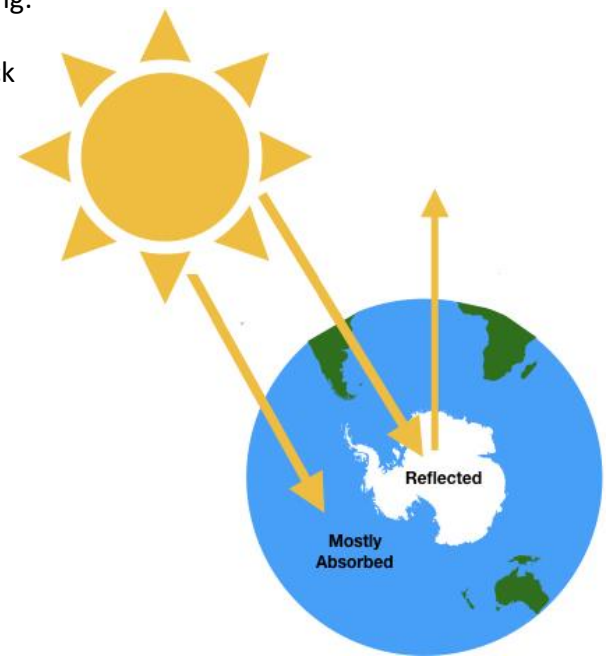


Illustration showing effect of differences in albedo
commons.wikimedia.org/wiki/File:Ice_albedo_feedback.jpg

Objectives

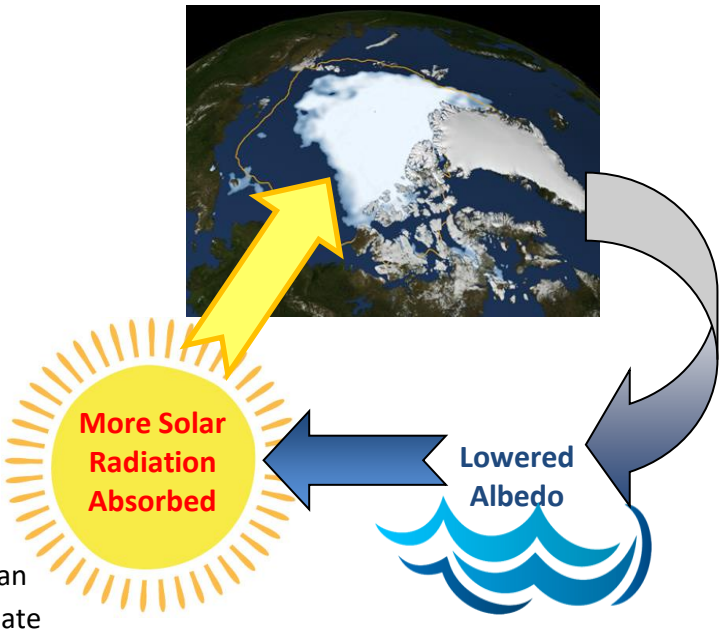
- Students will plan an experiment to:
  - Test the effect of albedo on the temperature of different substances.
  - Help them understand how the reflectivity of different types of planetary surfaces can have enormous impact on Earth's systems.
- Students will create models of sea ice and glaciers in two containers, testing how the melting of each affects water levels.
- Students will form hypotheses about the possible connections between albedo, melting ice, and sea level and communicate their ideas orally and in writing.
- Students will be able to explain the connections among albedo, melting ice, sea level, feedback loops, and climate change orally and in writing.

Next Generation Science Standards + Common Core State Standards		
NEXT GENERATION SCIENCE STANDARDS	**Performance Expectations**	**5-ESS2-1.** Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **MS-PS1-4.** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **HS-ESS2-1.** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
	Crosscutting Concepts	• Cause and Effect • Energy and Matter • Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	**ESS2.A: Earth's Materials and Systems** **ESS2.D: Weather and Climate** **ESS3.C: Human Impacts on Earth Systems** **ESS3.D: Global Climate Change**
COMMON CORE STATE STANDARDS INITIATIVE ELA	**Writing**	4, 10
	Speaking & Listening	1, 2
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10

California's Environmental Principles and Concepts	**Principle III** **Natural Systems Change in Ways that People Benefit from and Can Influence** Natural systems proceed through cycles that humans depend upon, benefit from, and can alter. **Concept A.** Natural systems proceed through cycles and processes that are required for their functioning. **Concept B.** Human practices depend upon and benefit from the cycles and processes that operate within natural systems.

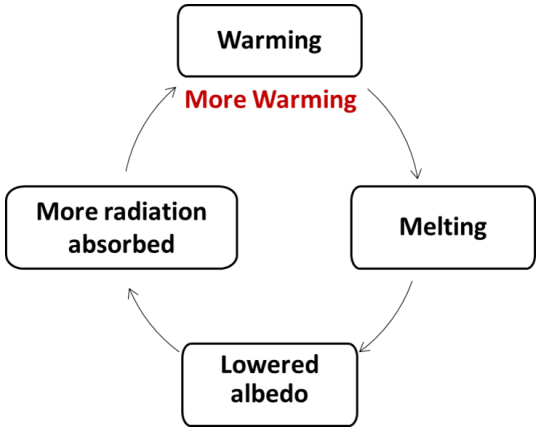
Teacher Background

You may want to start by reading the two student activity handouts at the end of the lesson if you are less familiar with the concepts described in the lesson. Students will plan and conduct their own experiment to test how light and dark surfaces affect how much solar radiation is absorbed. This important concept will help students understand how air temperatures can change rapidly due to changes in **albedo** (reflectivity) from processes such as ice melting, creating a **feedback loop** which results in more warming and more melting.

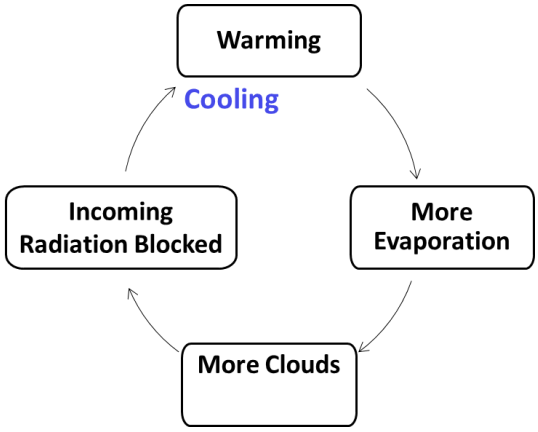


Model of a feedback loop
Melting sea ice image from NASA:
nasa.gov/topics/earth/features/arctic-seaice-2012.html

Feedback loops involve processes that either amplify (increase) or counterbalance (diminish) the effects of an initial change to a system. For example, in Earth's climate system, feedbacks can either amplify or diminish the effects of climate forcings (factors that drive the climate to change). A feedback that increases an initial warming is called a **positive feedback**. A feedback that reduces an initial warming is a **negative feedback**.



Positive feedback loop



Negative feedback loop

Melting sea and land ice

In the second part of this lesson, students conduct an experiment to compare the effects of melting two different types of ice: ice floating in the ocean and ice on land.

The melting of icebergs does not significantly affect sea levels because the volume of water displaced by the floating ice equals the volume of water added when the ice melts.[1] In contrast, melting glaciers are adding more water to the oceans.

Unlike melting glaciers, melting icebergs do not significantly affect sea levels.
pixabay.com/photos/iceberg-ice-greenland-frozen-cold-4498677

Materials + Preparation

- Copies of the "Investigating Albedo and Feedback Loops" handout for each student
- Copies of the "Melting Ice Models" handout found at the end of the lesson for each student
- Albedo activity materials for student groups to share:
  - 2 Thermometers (mercury-free); Prepare to take them outside with you if you will be doing the "Engage" activity below.
  - Construction paper of different colors
  - Scissors
  - Clear tape
  - Different containers such as large cups, beakers or jars
  - Foam caps, heat-resistant plastic lids, and/or cardboard scraps
  - Lamp with high wattage incandescent or heat bulb
  - Stopwatch or smart phone to precisely record passing time
  - Colored pencils, markers, and/or crayons to create graphs and feedback loop diagrams

[1] Note, however, that the dilution of salty ocean water with fresh water from the melting sea ice (when seawater freezes, salt is excluded from the resulting ice) may slightly increase (by 2 – 3%) the volume of the displaced ocean water. See nsidc.org/news/newsroom/20050801_floatingice.html.

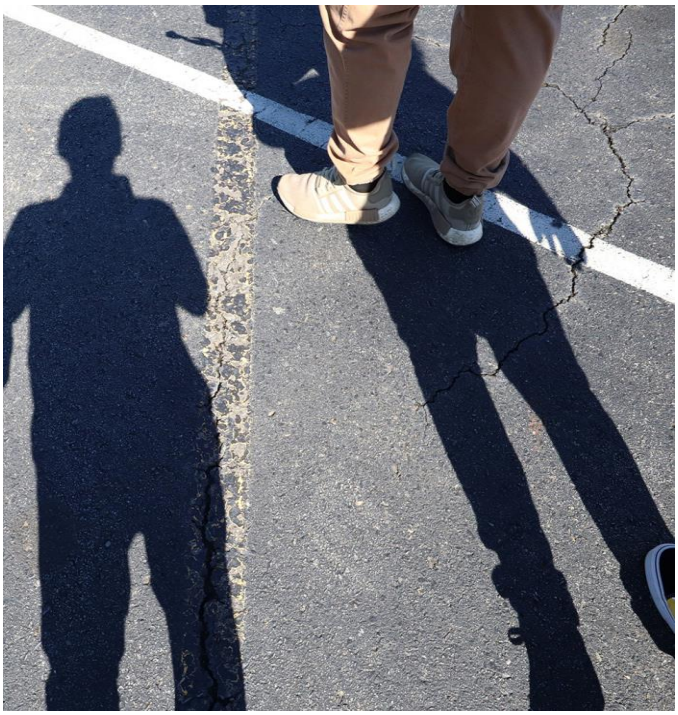
- Melting ice experiment materials for each student group (2 – 4 students):
    - 2 clear cups or beakers (glass or plastic)
    - 4 ice cubes of similar size
    - Water
    - 2 Popsicle sticks
    - Marker (such as a Sharpie)
    - Ruler
- ***Optional:*** Make your own experimental models ahead of time to show students before they make their models.
- ***Optional:*** Review the sources and watch the videos listed at the end of the lesson for additional background information. You could also share one or more of the videos with your students and discuss them.
- ***Optional:*** Watch the videos below as additional background. You could also share one or more of them with your students and discuss them.
    - "Surface Matters" (1:21). California Academy of Sciences: calacademy.org/educators/surface-matters
    - "120 Seconds of Science: What is the Ice Albedo Feedback?" Learn More about Climate. Univ. of Colorado: youtube.com/watch?v=5rqREjFaRho
    - "Scientists Link Earlier Melting of Snow to Dark Aerosols." NASA: Global Climate Change: climate.nasa.gov/news/2314/scientists-link-earlier-melting-of-snow-to-dark-aerosols/
    - "Arctic Amplification: How the Albedo Effect Speeds Up Global Warming." bigthink.com/videos/albedo-effect
- ***Optional****:* Review/make copies of glossary of terms at end of lesson

Teaching Suggestions in the 5E Model

Part I

Engage

1. This lesson is best done on a sunny day, when you can walk outside with the class to directly observe the scientific phenomenon of the **albedo effect**: how brightly colored surfaces reflect more light than dark surfaces. Take the thermometers and stopwatches—and ask students to take their science notebooks and pencil—and go to an area near black asphalt, where there is also another observable surface or two, such as lightly-colored concrete and/or a lawn.
2. Ask the students to work in small groups of 2 – 4 to explore the area for a couple of minutes, making **observations**, such as:



Get students outside to test the phenomenon!
pixabay.com/photos/shadow-playing-hanging-out-friends-4151268

- What do you observe about the different surfaces?
- Which surface(s) feel warmer? Why?

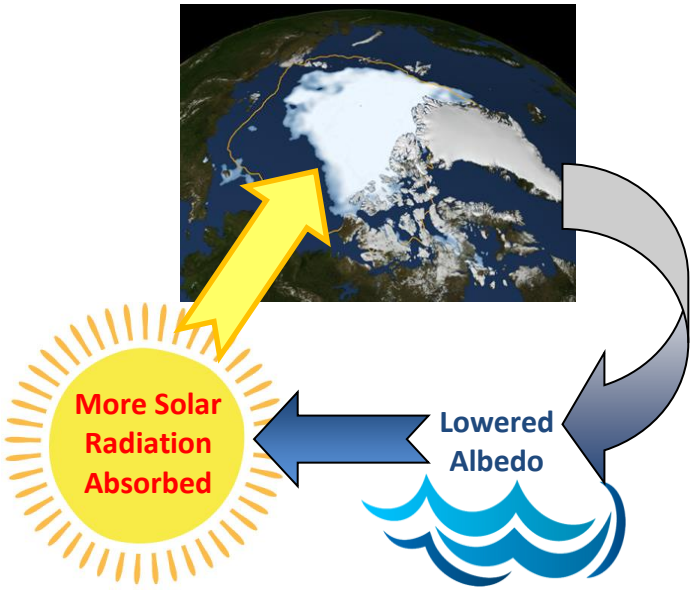
3. Tell students that they should record their observations in writing. Circulate to answer any questions.
4. After a minute or two, ask a couple of the partners to share their ideas. Discuss how asphalt and other dark surfaces heat up quickly in direct sunlight. By how much do they predict the temperatures of different surfaces will vary on sunny days in degrees Celsius and Fahrenheit?

Explore

5. Ask the students to discuss with their partner how they could conduct a quick experiment to test the effect of the Sun's warming radiation on different surfaces more precisely. Tell them that when they have a good idea for an experiment, they should come to you to explain their idea.
6. Discuss the student ideas as they come to you. Provide thermometers and stopwatches for them to conduct their experiments. (Smart phone stopwatches can also be used.) Groups may ask for 2 thermometers, but one per group will work if you are short on them.
7. After all the groups have had a chance to finish (or at least have a couple minutes to work on) their experiments, ask a few groups to share their results with the rest of the class.
   Ask questions to facilitate discussion, such as:
   - How did the temperature of black asphalt in sunlight compare to bright concrete or grass?
   - Were the differences in line with their predictions, or more or less pronounced?
   - How do they explain the differences?
   - Are there other variables that could have impacted their results? (other variables include the substance receiving the energy—such as asphalt vs. living plants, the angle at which the substance is hit by solar energy, and changing amounts of cloud cover)
   - Might the differences be more or less extreme in summer or winter? (summer, because the Sun's radiation hits Earth's surface at a more direct angle, and is therefore more concentrated, rather than spread out, as when the rays hit at a low angle in winter)
8. Ask students:
   - How would they be able to get more reliable results for an experiment comparing the effect of reflectivity (albedo) on the temperature of different substances?
   - What are the parts of a good science experiment? Direct them to first think about the question on their own for a minute, jotting down their ideas on a piece of paper, then discuss the question with their group while you circulate to answer any questions.
9. After a couple minutes, ask for a few volunteers to share their ideas and discuss.
10. Tell students that they will now get to practice conducting an experiment in a laboratory environment, in which the number of variables can be limited to be able to produce more reliable results. They will be going back inside to conduct an experiment to model how melting ice in water and on land affects sea levels.

Explain

11. Back inside, tell students they will now have the opportunity to work in their groups to design another, more reliable experiment to investigate **albedo**, which is a measure of how much radiation is reflected or absorbed by a surface.
12. Pass out copies of the "Investigating Albedo and Feedback Loops" handout. Explain that students should read the background information and then follow the steps to design their experiments. Before starting the experiment, they should show you their proposed experimental design and setup. Provide constructive feedback for students which acknowledges the good parts of their plan and what steps might result in more reliable data collection. Stress the importance of recording reliable data by using the chart on the handout or another method, such as a computer spreadsheet.
13. At some point in the class, such as when student groups have finished their experiments and they are plotting their data or writing about their results, ask them to take a break and lead a discussion about how changing albedos might lead to more changes. For example, what would happen if fine, darkly-colored airborne particles such as dust (technically referred to as **aerosols**) settle on white snow and ice (a phenomenon happening around the world due to air pollution)?
14. Explain the concept of **feedback loops**, and how one change, such as melting sea ice (or darkening snow and ice), can cause an effect such as decreased albedo, which can lead to the absorption of more radiation and the effect of more melting ice. Draw a diagram on the board to show how this concept can be represented visually, or direct students to the diagram at the end of their handouts.
15. Explain that students will be creating their own diagrams which show one or more feedback loops affecting Earth's system. They can use colored pencils, crayons, and/or markers to color the illustrations—or computers with illustration software, if available. Have volunteers share their illustrations with the class.
16. Give students a warning five minutes before they will have to stop working. At that time, direct them to finish cleaning up, answering the questions, and completing their diagrams.
17. Close Part I of the lesson by having students share their diagrams with each other and/or the class and discuss them. Why are feedback loops something to be concerned about, and what are some ideas students have for addressing the challenges they present?



Melting sea ice image from NASA: nasa.gov/topics/earth/features/arctic-seaice-2012.html

Part II

18. On the next class day, or after a short break during a long period, demonstrate the experiment explained on the "Melting Ice Models" handout found at the end of the lesson. Explain that they can use it or another experiment they devise to model melting sea ice and glaciers (ice sheets found on land) and their effects on sea level.

19. Pass out copies of the handout. Explain that students can use it to help them remember the steps to create the models and conduct the experiment. Explain to students where they can pick up the other materials that they need to complete the activity.
20. Circulate through the room; answer questions—and ask them—to help students complete the project and better understand the concepts. They can then clean up and finish completing the questions on the handout.
21. Close with a "Think, Pair, Share" and/or class discussion about what the students learned and if any of the results of the experiment were unexpected. Then discuss how melting ice and changing sea levels are impacting Earth's systems and what actions might be taken to help restore balance to the systems.

Extend / Enrich

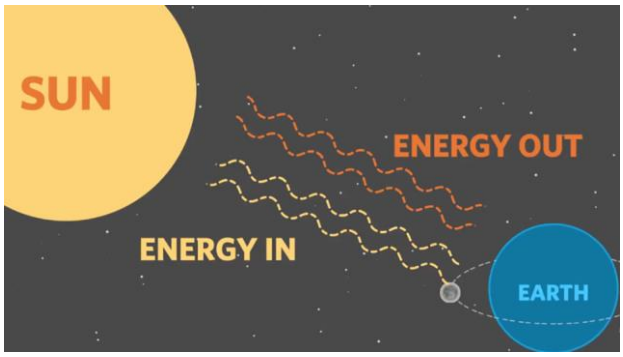
- For younger students, provide more explicit instructions for setting up the experiments, such as to wrap pieces of black and white paper around two different cups, cover the cups with foam lids, insert the thermometer in the lid, etc. You may wish to cut the construction paper pieces for the students ahead of time, and/or use a model you have made as a demonstration for the class.
- Explain that **"positive" feedback loops** are those that amplify (increase) an initial change, such as melting sea ice leading to increased albedo, more absorption of radiation, and more melting. **"Negative" feedback loops** are those which have a buffering effect on a system, such as if more sea ice froze, resulting in an increased albedo and more ice freezing. Clarify for students that positive feedback loops paradoxically often result in negative changes to Earth's system, because they can create imbalances and instability. Negative feedback loops, on the other hand, tend to moderate processes and hold systems in equilibrium.
- Ask students to brainstorm, research, and/or investigate other examples of positive and negative feedback loops in the Earth system. Options might include feedbacks related to:
    - Changes to ocean evaporation
    - Increases in water vapor and cloud cover in the atmosphere
    - Higher wind speeds, ocean waves, and salt particles in the air that can increase condensation and cloud cover
    - Methane emissions from soils and permafrost
    - Dilution of salty ocean water with fresh water from melting glaciers and sea ice
    - Increases of aerosols like smoke and other pollutants in the atmosphere due to increased forest fires and industrial pollution

What other feedback loops can students research and/or investigate?
pixabay.com/photos/shadow-playing-hanging-out-friends-4151268

- Show a short video about the albedo effect to provide extra background for your students. An excellent option is the University of Colorado's "120 Seconds of Science: What is the Ice Albedo Feedback?" It is linked from NOAA's Climate.gov site with additional information: climate.gov/teaching/resources/what-ice-albedo-feedback

Dr. Julienne Stroeve explains her research on albedo.

- Have students explore this feedback loop activity and scenario from NOAA: esrl.noaa.gov/gmd/education/info_activities/pdfs/PSA_analyzing_a_feedback_mechanism.pdf. Other great NOAA earth science activities are found here: esrl.noaa.gov/gmd/education/info_activities.
- Use a document camera or photographs of student feedback loop diagrams to more easily share them with the rest of the class. Completed diagrams can also be displayed on classroom walls or in hallways to reinforce the learning and help to educate others in the school community about the role of feedback loops on Earth's systems.
- Have students demonstrate the effect of albedo by placing two substances of different colors, such as white and black pieces of construction paper, on top of snow or boxes filled with ice. These can be placed in direct sunlight or under another heat source. Observe the results.
- Explore the possible links between changing albedo of Earth's polar regions and climate more fully with students. Ask them to read and discuss one or more articles about the topic, such as:
    - Lightle, Kimberly. "Solar Energy, Albedo, and the Polar Regions." Ohio State University. beyondpenguins.ehe.osu.edu/issue/energy-and-the-polar-environment/solar-energy-albedo-and-the-polar-regions
    - "Arctic Sea Ice Shrinks to New Low in Satellite Era." NASA. nasa.gov/topics/earth/features/arctic-seaice-2012.html
- Connect this lesson with physical science through further exploration of Earth's energy budget and concepts such as the electromagnetic spectrum, wavelengths, and energy transfer.
  "Earth's Delicate Energy Balance" lesson from the California Academy of Sciences also includes a good video and still images: calacademy.org/educators/earths-delicate-energy-balance



An image from "Earth's Delicate Energy Balance" lesson and video from the California Academy of Sciences: calacademy.org/educators/earths-delicate-energy-balance

- Connect this lesson with life science by having students research how different organisms, such as polar bears, seals, and other animals found in the Arctic, are being impacted by the phenomena discussed in the lesson and what actions might be taken to help them—and all life on Earth, including us.

Evaluate

22. Review student notebooks, completed handouts, diagrams, and any other projects.

23. Lead a discussion about the guiding questions of the lesson, upon which students could also reflect in writing and record student participation.

- How does the reflectivity of different substances change the amount of energy they absorb?
- How does melting of ice in the sea and on land Earth's systems?
- How can feedback loops affect Earth's systems?
- How can changes in albedo and the amount of ice impact Earth's climate and vice versa?

Expand Knowledge + Skills

Background on Albedo + Other Scientific Concepts Discussed

- "Albedo." North Carolina Climate Office. North Carolina State University: climate.ncsu.edu/edu/Albedo
- "Albedo." Academic Kids: academickids.com/encyclopedia/index.php/Albedo
- "Albedo." Encyclopædia Britannica: britannica.com/science/albedo
- "Arctic Sea Ice Shrinks to New Low in Satellite Era." NASA: nasa.gov/topics/earth/features/arctic-seaice-2012.html
- "Atmospheric Aerosols: What Are They, and Why Are They So Important?" NASA: nasa.gov/centers/langley/news/factsheets/Aerosols.html
- "Earth's Energy Budget." NASA Earth Observatory: earthobservatory.nasa.gov/Features/EnergyBalance/page4.php
- "Feedback Loops." Starting Point: Teaching Entry Level Geoscience. Science Education Resource Center (SERC). Carlton College. serc.carleton.edu/introgeo/models/loops.html
- Lightle, Kimberly. "Solar Energy, Albedo, and the Polar Regions." Ohio State University. beyondpenguins.ehe.osu.edu/issue/energy-and-the-polar-environment/solar-energy-albedo-and-the-polar-regions
- "Sea Ice." National Snow and Ice Data Center: nsidc.org/cryosphere/seaice/index.html
- Short videos for extra background for you and your students:
  - "120 Seconds of Science: What is the Ice Albedo Feedback?" video: youtu.be/5rqREjFaRho
  - "Albedo experiment" video from the City College of New York: youtu.be/xHFmVvDS8rQ
  - "What if All the Ice Melted on Earth? Featuring Bill Nye." AsapSCIENCE: youtu.be/b6CPsGanO_U
  - "The End of The Arctic" documentary: youtu.be/CrRDtZp96jw
- "Thermodynamics: Albedo" National Snow and Ice Data Center.: nsidc.org/cryosphere/seaice/processes/albedo.html

Lessons / Units

- Lesson inspired in part by these resources:
  - "Arctic Feedback Loops and Sea Ice Extent." Teacher Activity Guide. NSTA Learning Center: learningcenter.nsta.org/products/symposia_seminars/fall07/IPY_Birmingham/files/Arctic-Feedback-Loops-and-Climate-Change-Unit.pdf
  - "Heating Earth's Surfaces: Albedo" lab from NASA, which provides more explicit instructions for students to conduct the albedo experiment in a prescribed way: pmm.nasa.gov/education/sites/default/files/lesson_plan_files/Global%20Energy%20Budget/GPM%20Global%20Energy%20Budget%20-%20Albedo%20Lab.pdf
  - "Investigating Albedo." JASON Digital Learning Resources. gated.jason.org/digital_library/23686.aspx
- "Impacts of a Warming Arctic." NASA: climate.nasa.gov/resources/education/pbs_modules/lesson2Engage
- "Earth's Albedo and Global Warming." Interactive visuals and support materials: cleanet.org/resources/42888.html
- "Albedo Effect Lesson for Kids." Study.com: study.com/academy/lesson/albedo-effect-lesson-for-kids.html
- California Education and the Environment Initiative curriculum: californiaeei.org/curriculum
- "Think, Pair, Share" cooperative learning strategy details: teachervision.com/group-work/think-pair-share-cooperative-learning-strategy

Standards

- More examples of what NGSS looks like for high school students can be found in Chapter 7 of the *2016 Science Framework for California Public Schools:* cde.ca.gov/ci/sc/cf/documents/scifwchapter7.pdf
- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned, can be found at nextgenscience.org/framework-k%E2%80%9312-science-education.
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Appreciation + Thanks

Thank you for using Bay Area E-STEM Institute resources and helping to inspire the next generation of thinkers and scientists! We also greatly appreciate the support of the National Science Foundation, San José State University, and NASA.

We welcome your questions or comments.

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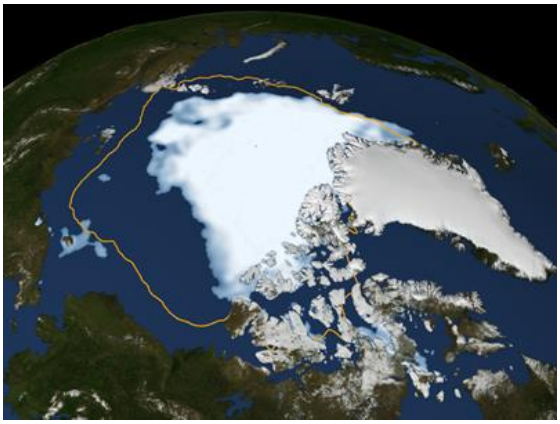
Name: _____ Period: ____ Date: _____

Investigating Albedo and Feedback Loops

Albedo is the measure of how much **radiation** (energy) is **reflected** off a substance. When something has a HIGHER albedo, it is "whiter" and more radiation reflects off. Therefore, the substance stays cooler. The darker the substance, the LOWER its albedo and the more solar radiation (energy) is absorbed. Albedo (reflectivity) is measured on a scale from 0 (black) to 1 (bright white).

When light from the Sun strikes Earth's surface, some of the energy is **absorbed** as heat. The rest is reflected back to space or the Earth's atmosphere.



NASA: nasa.gov/topics/earth/features/arctic-seaice-2012.html

Think About It!

1. **How does albedo affect YOU?** For example, which shirt would help you stay cool on a hot, sunny day: a light-colored shirt or a black shirt? Why?

   _____

   _____

2. **Design an experiment** to measure the effect of albedo. Use materials such as:
   - Construction paper of different colors
   - Scissors
   - Clear tape
   - Containers such as large cups, beakers or jars
   - Thermometers
   - Foam caps, heat-resistant plastic lids, and/or cardboard
   - Lamp with high wattage incandescent or heat bulb
   - Stopwatch or smart phone to precisely record passing time

3. What **experimental question** can you investigate to test the effect of albedo?

   _____

   _____

   _____

4. **Experimental Design:** How do you plan to conduct your experiment? Why do you think it will result in relevant (useful) **data** which may help you answer the experimental question? (Write your plan and draw your setup on the next page, then show it to your teacher.)

_____

_____

_____

_____

_____

5. **Experimental Setup:** Draw and label a diagram of your planned setup.

6. **Hypothesis:** What do you predict will happen?

_____

_____

_____

7. **Independent Variable** (factor you will change on purpose to test if it causes a different result):

_____

8. **Dependent Variable** (factor you measure to see if changing the independent variable has an effect; Suggestion: temperature over time):

_____

9. Carefully Record Your Data using the table below or another method.

Time (suggested)								
Condition 1: _____								
Condition 2: _____								

Time (suggested)								
Condition 1: _____								
Condition 2: _____								

10. Graph Your Data using the table below or another method. Be sure to fully label the X and Y axes.

11. Other **observations**:

_____

_____

_____

_____

12. **Results:** What do your data show?

_____

_____

_____

_____

_____

13. Was your hypothesis correct? _____

    How do you explain what you observed?

_____

_____

14. How might you change your experiment to improve the quality of your results?

_____

_____

15. Based on the results of your experiments and understanding of albedo and melting ice:
    a. Do you think melting sea ice and glaciers might result in other changes? If so, what changes and why?

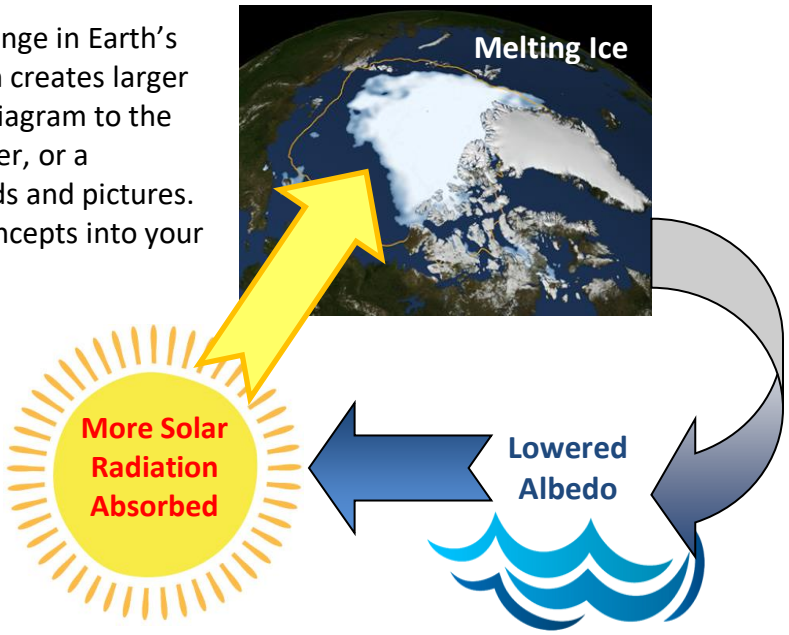
_____

_____

_____

_____

b. Create a diagram which shows how a change in Earth's system can create a **feedback loop** which creates larger changes, such as the loop shown in the diagram to the right. Use the space below, separate paper, or a computer to create your visual with words and pictures. Try to bring in one or more additional concepts into your diagram, such as rising sea level.



Name: _____ Period: ____ Date: _____

Melting Ice Models

Your Challenge

1. Create models of sea ice and glaciers (large ice sheets on land) melting.
2. Use them to help you answer the questions at the end of the handout.

Procedure

1. Label one cup "**A**" with a marker and place two ice cubes in it.
   Label the other "**B**," but leave it empty for the moment.
2. Fill both cups with water until the water level is even in both.
   (Cup A will contain ice cubes and water, while cup B will just contain water.)
3. Record the water level height in centimeters and/or millimeters (measure from the table top to the bottom of the **meniscus** (curved surface of the water): _____
4. Mark the water level of both cups with the marker.
5. Set both Popsicle sticks over cup B. Place them far enough apart so that they are not touching, but so that you can still rest ice cubes on top of them.
6. Set two ice cubes on top of the Popsicle sticks.

Think About It!

1. **Hypothesis 1:** What do you think will happen when the ice cubes floating in water melt?

   _____

   _____

2. **Hypothesis 2:** What do you think will happen when the ice cubes resting on the Popsicle sticks melt?

   _____

   _____

3. After the ice cubes melt, measure the water level of cup **A**: _____. Did the water level change at all? _____ If so, by how much?_____

   Was your Hypothesis 1 correct? _____

   How do you explain what you observed? _____

   _____

4. After the ice cubes melt, measure the water level of cup **B**: _____.

   Did the water level increase? _____ If so, by how much?_____

   Was your Hypothesis 2 correct? _____

   How do you explain what you observed?

   _____

   _____

5. Based on the results of your experiments:

   A. Do you expect that melting sea ice causes a rise in sea level? Why or why not?

   _____

   _____

   B. Do melting glaciers cause sea level to rise? Why or why not?

   _____

   _____

   C. Do you think melting sea ice might result in any other changes? Why or why not?

   _____

   _____

   _____

Let's Do the Math! (Please show your work.)

1. How much did cup A's water level change as a **percentage** of the starting water level?

2. How much did cup B's water level change as a **percentage** of the starting water level?

Glossary of Phenomena and Scientific Investigation Terms

absorption (of light) – process in which matter "captures electromagnetic radiation, converting the energy of photons to internal energy" (Chemicool Dictionary: chemicool.com).
Example: Snow absorbs as little as 10% of incoming solar energy, with up to 90% reflected ("Thermodynamics: Albedo" National Snow and Ice Data Center.: nsidc.org/cryosphere/seaice/processes/albedo.html).

albedo – the fraction of how much radiation (such as light) is reflected by a surface or body; measured from 0 (black: all energy absorbed) to 1 (bright white: complete reflection)
Example: The high albedo of snow helps keep it cool and frozen.

albedo effect – the phenomenon of light surfaces reflecting more light and heat than dark surfaces

aerosols (atmospheric) – tiny particles suspended in the atmosphere
Examples*: Volcanic ash, forest fires, and desert dust are a few of the largest sources of aerosols.*
Learn more: "Atmospheric Aerosols: What Are They, and Why Are They So Important?" NASA: nasa.gov/centers/langley/news/factsheets/Aerosols.html

data – evidence, facts, and statistics collected for analysis or reference

data analysis – process of evaluating data using statistics, graphs, etc. to determine trends and patterns

dependent variable – an outcome measured in an experiment that changes depending on other factors
Example: In an experiment into how screen time before bed affects amount of sleep, amount of sleep is the dependent variable.

electromagnetic radiation - Energy transfer in the form of waves or particles that move through space at the speed of light

experimental/testable question – one that can be answered by designing and conducting an experiment

experimental design – how experiments are planned so that results are objective and valid

feedback loops – processes that either amplify (increase: positive feedbacks) or counterbalance (diminish: negative feedbacks) the effects of an initial change to a system

glacier – a mass of ice on land formed by snow accumulating over the years; the force of gravity causes them to flow slowly downhill

hypothesis – a tentative statement about the relationship between two or more variables that can be tested by experiment or observation experiment

independent variable – a variable that does not vary because of changes in another variable during an experiment
Example: Amount of screen time is the independent variable in an experiment into its effect on sleep.

reflection – the return or light, sound, or heat by a surface

sea ice – frozen ocean water

variable – the part(s) of an investigation that an experimenter is trying to measure