Investigating Albedo & Ocean Feedback Loops

Grade Level

5–8 or higher

Timeframe

50 minutes or more

Materials

- Materials that students can use to test the effects of albedo on temperature, such as black and white fabric or
- paper and thermometers
- Computer, projector and screen
- Text documents (all available to download)

Key Words

Absorption, albedo, albedo effect, climate, data, dependent variable, feedback loop, hypothesis, independent variable, reflection, sea ice

Standards

NGSS: MS-ESS2.D1.
CCSS: W.6.10. SL.6.4.
Ocean Literacy Principles: 1, 3.
Climate Literacy Principles: 3, 7.
Details at end of lesson

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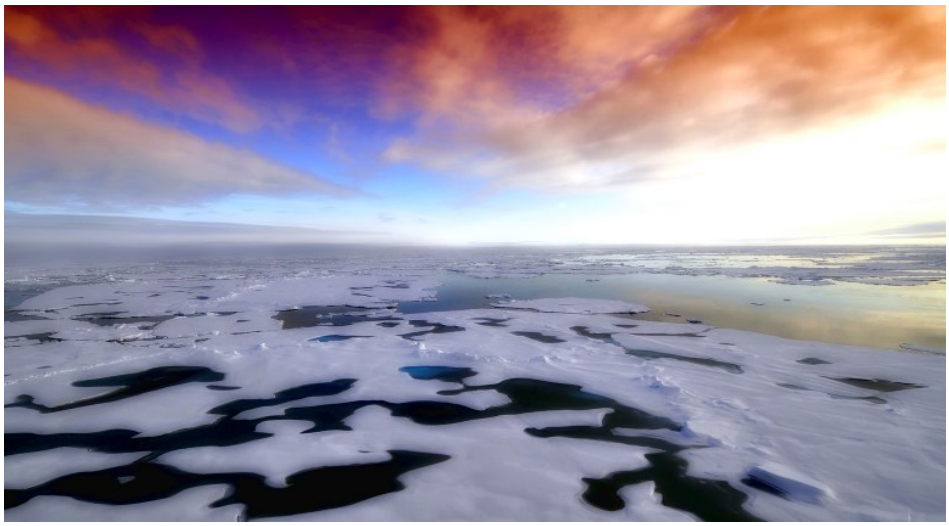
&

National Marine Sanctuary Foundation



How do changes in the color of surfaces—like sea ice and open ocean water—impact temperature, climate and Earth's system? This lesson models similar phenomena in schoolyards and classrooms. Photo: David Mark from Pixabay

Activity Summary

Students investigate effects of shining light on differently colored materials on temperature. They design experiments to test the important role albedo plays in determining how much radiation is absorbed by a substance. They analyze a diagram that illustrates the concept of feedback loops, which magnify changes over time. Enrich/Extend options at the end of the lesson include a simple version of one experiment students can conduct and ways they can take action to mitigate the impacts of climate change.

Learning Objectives

Students will:

- Design and conduct an experiment to test the effects of light shining on differently colored materials
- Argue from evidence about how differences of albedo could impact Earth's system, including the ocean
- Explain the importance of feedback loops to the ocean and Earth's system, orally and in writing
- Discuss how the ocean moderates climate and makes life on Earth habitable

Background Information

The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth. However, many factors impact the amount of radiation absorbed, especially the amount of sea ice. The amount of sea ice at Earth's Poles and on the Great Lakes has a dramatic impact on the ocean and thus marine sanctuaries.

Albedo: Impacting the Ocean and Climate

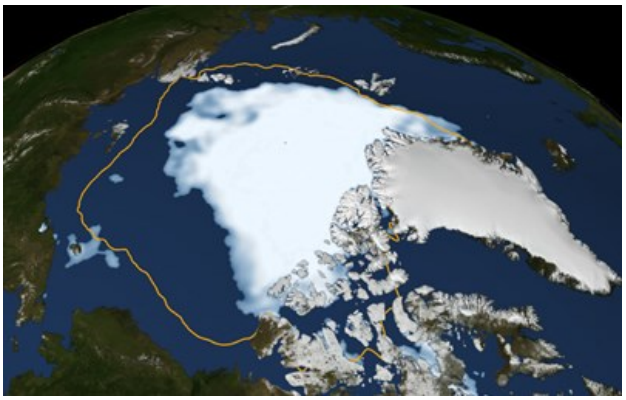
Albedo is defined as the ratio between solar radiation reflected by Earth's surface and solar radiation absorbed at the surface. It is an essential variable linking the earth surface and the climate system. In other words, it is a measure of how much radiation (energy) is reflected off a substance. When 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).

This white sand beach in Florida Keys National Marine Sanctuary has a high albedo. Most solar energy is reflected off it, keeping it cooler for people and wildlife. Photo: Franz Stellbrink CC BY 3.0

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.

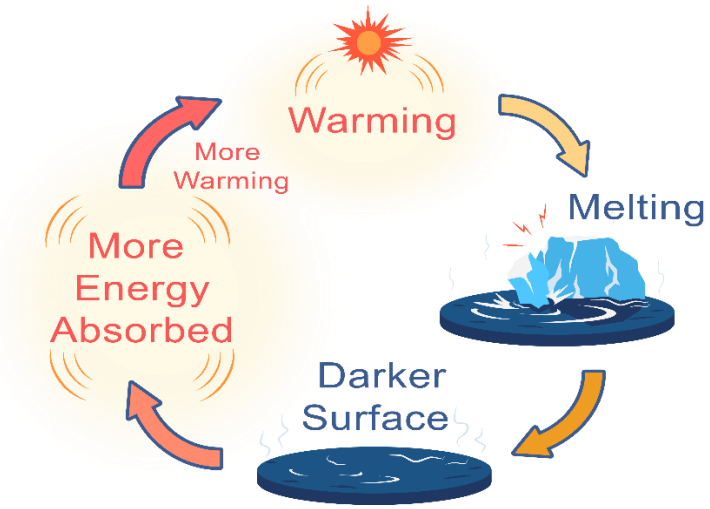
Positive & Negative Feedback Loops

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).



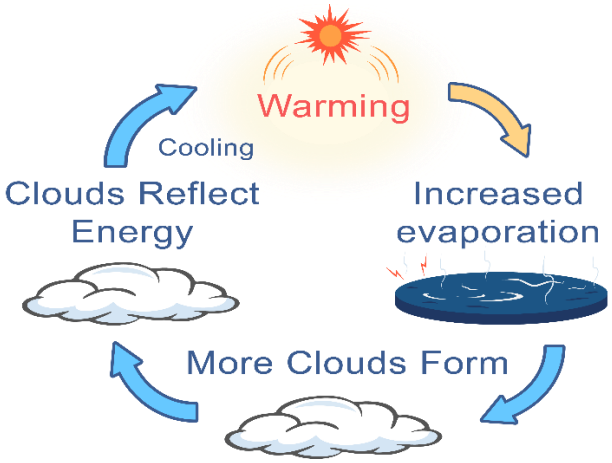
Sea ice has a much higher albedo than open ocean. It reflects 50–70% of incoming solar energy, while the darker ocean reflects only 6% of the energy and absorbs the rest. Snow-covered sea ice reflects up to 90% of incoming solar radiation. Image: NASA

A feedback that increases an initial warming is called a positive feedback.



Melting sea ice creates a positive feedback loop: as it melts, more energy is absorbed, which melts more ice and so on, accelerating the amount of warming. Illustration: Rick Reynolds CC-BY-3.0

A feedback that reduces an initial warming is a negative feedback.



Warming can also create negative feedback loops. For example, warming the ocean and Great Lakes leads to increased evaporation, which leads to more cloud cover. More sunlight is reflected, which can lead to cooling. Illustration: Rick Reynolds CC BY 3.0

The positive and negative naming of feedback loops does not indicate whether the feedback is good or bad. In climate change, a feedback loop is usually something that speeds up or slows down a warming trend. A positive feedback accelerates a temperature rise, whereas a negative feedback slows it down.

National Marine Sanctuaries

National marine sanctuaries are a network of underwater areas in the ocean and Great Lakes that protect America's most iconic natural and cultural marine resources. Albedo not only affects the open ocean. It can also directly affect landmasses. Our national marine sanctuaries contain diverse and dynamic coastal environments: from black sand beaches near Hawaiian Islands Humpback Whale National Marine Sanctuary to white sand beaches at Florida Keys National Marine Sanctuary. This results in areas with higher and lower albedo. Sanctuaries are also being impacted by changes in Earth's system such as sea level rise and more extreme weather events.

Learn more:

"Albedo." National Snow and Ice Data Center: https://nsidc.org/learn/cryosphere-glossary/albedo

"Climate Feedback Loops and Tipping Points." UCAR Center for Science Education: https://scied.ucar.edu/learning-zone/earth-system/climate-system/feedback-loops-tipping-points

"How Does Sea Ice Affect Global Climate?" NOAA: https://oceanservice.noaa.gov/facts/sea-ice-climate.html

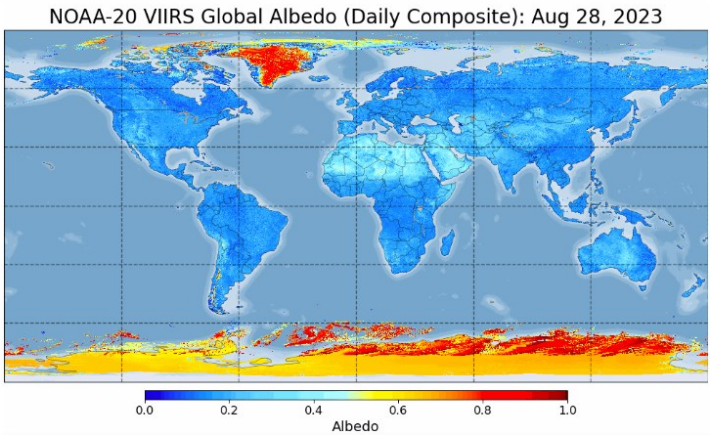
"Sea Level Rise and Coastal Cities." National Geographic Society: https://education.nationalgeographic.org/resource/sea-level-rise-and-coastal-cities

Vocabulary	
Absorption (of energy)	Process in which matter converts the energy of photons to internal heat energy
Albedo	Ratio of how much radiation (such as sunlight) is reflected by a surface or body; measured from 0 (black: all energy absorbed) to 1 (bright white: complete reflection)
Albedo effect	Phenomenon of light-colored surfaces reflecting more light and heat than dark-colored surfaces
Climate	Long-term average of temperature, precipitation, and other weather variables at a given location

Data	Evidence, facts, and statistics collected for analysis or reference
Dependent variable	Outcome measured in an experiment that changes depending on other factors
Feedback loops	Processes that either amplify (increase: positive feedback) or counterbalance (diminish: negative feedback) the effects of an initial change to a system
Hypothesis	A tentative statement about the relationship between two or more variables that can be tested by experiment or observation
Independent variable	The variable that is controlled or manipulated in a scientific experiment to determine its effect on the variable of interest
Reflection	The return of light, sound or heat by a surface
Sea ice	Frozen water on the ocean's surface
Variable	Part(s) of an investigation that an experimenter measures

Preparation

- Print copies of the "Investigating Albedo & Ocean Feedback Loops" handout for each student, or distribute it electronically.
- Collect materials that student groups of 2–4 can use to test the effects of albedo on temperature, such as:
    - Pieces of fabric and/or construction paper of different colors (such as black and white)
    - Scissors
    - Clear tape
    - Containers such as large cups, beakers or jars
    - Thermometers (ideally two identical laboratory thermometers per group)
    - Heat-resistant plastic lids, cardboard and/or foam caps that could be used to cover cups
    - Lamps with high wattage incandescent or heat bulb (ideally one per group)
    - Stopwatch or smart phone to precisely record passing time (one per group)
    - *Optional:* Ice
- Prepare to show these with a data projector (if available) or ask students to view them on other devices:
    - A NOAA animation of measured albedo, such as current land surface albedo (LSA) available here: https://www.star.nesdis.noaa.gov/smcd/emb/land/animation.php?sat=JPSS1&product=LSA



Scroll down on the page to see additional daily animations.

- "ClimateBits: Albedo" video from NASA (2:01): https://mynasadata.larc.nasa.gov/mini-lessonactivity/what-albedo

- Review the Enrich/Extend options at the end of the lesson.
- *Optional:* Identify a suitable outdoor area to take the class (see below).
- *Optional:* Document camera

Procedure

Engage

- We suggest doing this lesson 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. You could take thermometers and stopwatches—and ask students to take their science notebooks and pencils—and go to an area near black asphalt. There should be a different observable surface or two nearby, such as lightly-colored concrete and/or a green lawn.
- Ask the students to work in small groups of 2–4 to explore the area for a couple of minutes, making observations, such as:
    - What do you observe about the different surfaces?
    - Which surface(s) feel warmer? Why?
    - Tell students that they should record their observations in science notebooks.

  Circulate to answer questions and encourage critical thinking.
- After a minute or two, ask students to share their ideas. Discuss how asphalt and other dark surfaces heat up quickly in direct sunlight. Ask:
    - How much do you predict the temperatures of different surfaces will vary on sunny days in degrees Celsius and Fahrenheit?
- After a couple of minutes, ask students to share their ideas with the class.

Explore

- Ask students to discuss with their partner or group 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.
- Discuss student ideas as they come to you. Show them the thermometers and stopwatches that are available to help them conduct their experiments. (Smart phone stopwatches can also be used.) Groups may ask for 2 thermometers, although one per group will also work.
- After you have approved their ideas, students may conduct their experiments.

- After all groups have had a chance to finish their experiments (or at least have a couple of minutes to work on them), 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 lighter concrete or grass?
    - Were the differences in line with your predictions, or more or less pronounced? How do you explain the differences?
    - Are there other variables that could have impacted your 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? (In 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.)
- Ask students:
    - How might you be able to get more reliable results for an experiment comparing the effect of different reflectivity of substances on temperature?
    - What are the parts of a well-designed science experiment? Direct them to first think about the question on their own for a minute, recording ideas in notebooks, then discuss the question with their group.
    - Circulate to answer questions. After a couple of minutes, ask for a few volunteers to share their ideas and discuss.
- 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.
- Go back inside and pass out the "Investigating Albedo & Ocean Feedback Loops" handout for each student, or distribute it electronically. Show students the available materials and ask them to work with a partner or small group to design and conduct controlled experiments to precisely test the effect of differing albedo when substances are exposed to light energy. Tell them they should use the handout questions to help guide them through the process, recording their ideas on the handout or in notebooks.
- For younger students and those that need more support, talk them through one specific way in which they could conduct the lab experiment:
    - Use black and white fabric or construction paper to create two differently colored rectangles that are 10 cm x 5 cm.

- Fold the rectangles in half to cover the ends of two thermometers. Use a stapler or clear tape to secure the paper over the bulbs of the thermometers. Ideally, the paper should touch the bulbs of the thermometer.
- Record the starting temperature of each thermometer in the table on the handout or in science notebooks.
- *Note:* Ice is an optional addition that can be placed in cups (or sections of ice cube trays) underneath the covered thermometers. It is not necessary for an experiment, but it does let students observe that ice melts more rapidly under the dark setup when light shines on it. It also helps connect the experiment with melting ice in the ocean and the positive feedback loop that results.
- Move a heat lamp so it is ready to shine directly on the thermometers from a distance of about 60 cm (2 feet).
- Ask students to predict how the temperature of the two different thermometers will change over time, recording their ideas in science notebooks.
- Turn on the lamp and ask students to record the different temperatures every 2 minutes, continuing the process for 10 minutes or more.
- Ask students to graph the data using the grid lines on the handout, in notebooks or with a spreadsheet.
- Ask students to analyze their results, recording their ideas on handouts or in notebooks. Did they match their predictions?

- More details and visuals are shown on the "Amazing Albedo" lesson from American Museum of Natural History and Rice University: https://www.climate.gov/teaching/resources/amazing-albedo-21149
- Circulate to answer questions and help guide the learning process. When groups are close to completing their experiments and handouts, give them a 3-minute warning. Tell them they should be ready to discuss their ideas and results of their experiments with the class.

Explain

- Ask students to share the results of their experiments and discuss them.
- Show a NOAA animation of measured albedo, such as current land surface albedo (LSA) measured via satellite available here: https://www.star.nesdis.noaa.gov/smcd/emb/land/animation.php?sat=JPSS1&product=LSA
  - Ask students to think about what they are observing and discuss the reasons for the observed differences shown on the maps with a partner.
  - After a minute, ask students to share their ideas about the observed phenomenon, what albedo is, and how it helps explain the results of their experiments.

- Show the "ClimateBits: Albedo" video from NASA (2:01) to help explain the concept of albedo and how it impacts the ocean and Earth's system: https://mynasadata.larc.nasa.gov/mini-lessonactivity/what-albedo
- Share an example of the high albedo of bright white snow and ice (close to 1) and how it helps keep snow and ice cool and frozen. Ask: What would happen if the snow and ice became dirty from wildfires, diesel exhaust or other pollution? Why?
    - Show one or more images of snow and/or sea ice to help facilitate discussion, such as the NOAA photo here: https://oceanservice.noaa.gov/facts/sea-ice-climate.html.
    - You might also show a short video that explores the phenomenon, such as "Extreme Weather: Climate Feedback Loops" (1:17) from National Geographic Society: https://education.nationalgeographic.org/resource/extreme-weather-climate-feedback-loops
- Ask students to share their descriptions of the feedback loop diagrams from their handouts and/or science notebooks. They can also share expanded diagrams (the bonus question) with the support of a document camera (if available). Discuss how changing albedo and feedback loops can impact the global ocean and Earth's system.
- Ask students to think about the huge scale of the Earth and global ocean. Ask:
    - How might small changes in factors like temperature and sea ice lead to big changes in Earth's system?
    - How does the ocean moderate climate and make life on Earth habitable?
- Ask students to think about and discuss how changing amounts of sea ice and other changes in Earth's system might impact national marine sanctuaries and monuments, as well as coastal communities.

Enrich/Extend

- Encourage students to think of solutions to mitigate the destructive impacts of climate change and ocean feedback loops, such as the positive feedback loop caused by melting sea ice.
    - They can share their ideas with the class, school and larger community through a medium of their choice, such as posters, public service announcement videos and/or audio recordings, games or skits.
    - Invite students to explore the *Climate Resilience in Your Community Activity Book* from NOAA to help give them ideas: https://www.noaa.gov/sites/default/files/2022-07/Activity_Book_Online_Final_Small_07.13.22.pdf
    - Ask the class to choose one or more projects you can do at your school or in your local community to help mitigate the impacts of climate change and make your community more resilient.

- Use Data in the Classroom resources from NOAA, which include constantly updated data in 5 Modules: https://dataintheclassroom.noaa.gov.
    - "Investigating Sea Level" is one good option: https://dataintheclassroom.noaa.gov/sea-level/investigating-sea-level-teacher-resources
    - Tie the lesson in with national marine sanctuaries by giving students the opportunity to check current data about the conditions at one of them.

Evaluate

- Ask students to write an exit ticket (or notebook entry) that argues from evidence to explain how the color and composition of substances can affect their temperature. If you have more time, ask them to go further to explain how melting ice in Earth's Polar regions is impacting Earth's global ocean and climate.
- Review student handouts and science notebooks. Provide feedback. You might offer students the opportunity to revise their answers and/or conduct additional experiments.
- Evaluate student contributions to group and class discussions, including about how they worked together to design and conduct their experiments.

Education Standards	
Next Generation Science Standards	Earth's Systems • MS-ESS2.D1: Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Science and Engineering Practices: • Analyzing and Interpreting Data • Asking Questions and Defining Problems • Constructing Explanations (for science) • Developing and Using Models • Engaging in Argument from Evidence • Obtaining, Evaluating and Communicating Information • Planning and Carrying Out Investigations Crosscutting Concepts: • Cause and Effect • Energy and Matter • Patterns • Proportion and Quantity • Scale • Stability and Change • Systems and System Models

Education Standards	
Common Core State Standards	Writing: W.6.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. Speaking and Listening: SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes.
Ocean Literacy Principles	1. Earth has one big ocean with many features. (d) 3. The ocean is a major influence on weather and climate. (a, b, f, g)
Climate Literacy Principles	3. Life on Earth depends on, is shaped by, and affects climate. (a, c) (If the second Enrich/Extend activity is completed.) 7. Climate change will have consequences for the Earth system and human lives. (a, b, c)

Additional Resources

"Changing Albedo Lab." My NASA Data: https://mynasadata.larc.nasa.gov/lesson-plans/changing-albedo-lab

"Feedbacks of Ice and Clouds." National Geographic Society: https://www.nationalgeographic.org/activity/feedbacks-ice-and-clouds/print

"Learning Lesson: Canned Heat." NOAA: https://www.noaa.gov/jetstream/ll-canned-heat

"Positive Feedback–Arctic Albedo." My NASA Data: https://mynasadata.larc.nasa.gov/lesson-plans/positive-feedback-arctic-albedo

"Problem Solving Activity: Climate Change and Feedback Loops." NOAA: https://gml.noaa.gov/outreach/info_activities/pdfs/PSA_analyzing_a_feedback_mechanism.pdf

"What is the Future of Earth's Climate?" National Geographic Education: https://education.nationalgeographic.org/resource/what-is-the-future-of-earths-climate

For More Information

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