Today I Learned About Winter Storms

Description:

We know Earth is warming, so why do we still get extreme winter storms? Students learn about albedo, climate, weather, the jet stream, and the polar vortex through hands-on demonstrations, data visualizations, and reading scientific writing.

Skills & Objectives

SWBAT

- Define albedo
- Explain the difference between climate and weather
- Understand the concepts of the jet stream and polar vortex

Skills

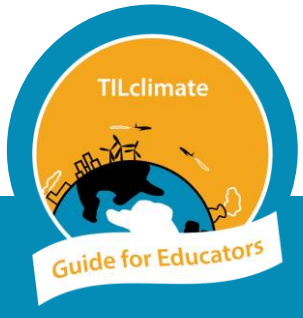
- Reading scientific texts
- Map reading
- Graph reading

Students Should Already Know That

- Global temperatures are rising due to excess carbon dioxide and other heat-trapping gases from human activities.

Standards Alignment:
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
RST.9-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Disciplinary Core Ideas:
ESS2.A Earth Materials and Systems
ESS2.D Weather and Climate
ESS3.D Global Climate Change



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How To Use These Activities:

Pages with the circular "TILclimate Guide for Educators" logo and dark band across the top are intended for educators. Simpler pages without the dark band across the top are meant for students.

Each of the included activities is designed to be used as a standalone, in sequence, or integrated within other curriculum needs. A detailed table of contents, on the next page, explains what students will do in each activity.

A Note About Printing

All student pages are designed to be printable in grayscale.

The worksheets do not leave space for students to answer questions. Students may answer these questions in whatever form is the norm for your classroom – a notebook, online form, or something else. This allows you, the teacher, to define what you consider a complete answer.

A Note About Materials

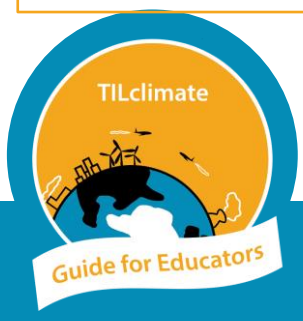
Three versions of the hands-on demonstration of albedo are included. Each one requires different amounts of time, space, and materials.

a) Hand-held infrared thermometers (also called no-contact thermometers) can be bought from hardware and office supply retailers for $15-30 each. One thermometer is needed for each group, depending on class and group size.

b) A standard desk or clamp lamp with an incandescent (not CFL or LED) lightbulb is perfect for this demonstration.

c) T-shirts, paper, or painted cardboard all work well for this activity. It can be done outside in the sun or in a sunny windowsill.

Podcasts in the Classroom: Throughout these Guides for Educators, we invite students to think about how they would share their learning with family and friends. One way to do this is to encourage your students to create their own podcasts - they're shareable, creative, and have multiple options for embedded assessment. We would love to hear any podcasts or see any other projects you or your students create! Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.



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Detailed Table of Contents

A Note About Internet Use

Various activities in this Guide require internet use. In classrooms with limited internet access, the following modifications may be made:

- Project the videos and data visualizations for Albedo, Jet Stream, and Polar Vortex on the wall for all students.
- Generate and print one graph for Weather vs Climate.

Many activities in this Guide take about the same amount of time and could be done as stations or by student teams in a jigsaw, with time for shared learning after the activity.

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Winter Weather and Atmospheric Science

This Educator Guide includes readings, data investigations, and data visualizations. Educators may pick and choose among the pieces of the Guide, as suits their class needs.

Parts of this Guide may align with the following topics:

- Physical science: Atmospheric science, pressure, and temperature.
- Life/environmental science: Weather and climate.
- History/social science: Effects of extreme winter weather on communities.
- ELA/nonfiction: Understanding scientific writing.

MIT Resources

We recommend the following as resources for your own better understanding of climate change or as depth for student investigations. Specific sections are listed below:

- Climate Science, Risk & Solutions, an interactive introduction to the basics of climate change. https://climateprimer.mit.edu/

  Chapter 02b

  Chapter 03a

  Chapter 06

  Chapter 08c

- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. New Explainers are posted monthly. https://climate.mit.edu/explainers

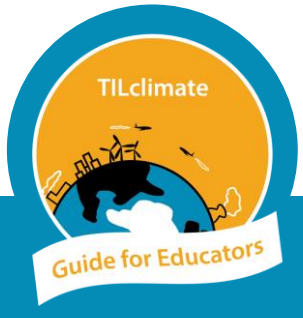
  Heating and Cooling

  Extreme Heat

  Permafrost

  Climate Models

  Climate Sensitivity



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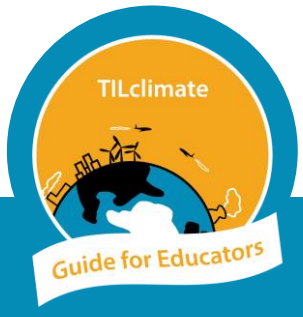
Wrap-Up Discussion Questions

- The Arctic is warming faster than any other region of Earth. How would you expect this to affect albedo?
- What are some other effects of albedo? (Think about summer heat, as well.)
- How is the arctic ice melting a positive feedback loop?
- What is the jet stream? What does it have to do with weather?
- What is the polar vortex? How does it affect winter storms?
- If the temperature is going up in general due to global warming, why can we still have colder-than-average winters?

Climate Solutions

Climate solutions can be thought of as falling into four categories outlined below. Across all categories, solutions at the community, state or federal level are generally more impactful than individual actions. For example, policies that increase the nuclear, solar and wind mix in the electric grid are generally more effective at reducing climate pollution than asking homeowners to install solar panels. For more on talking about climate change in the classroom, see “How to Use This Guide”.

- **Energy Shift**
  How do decision-makers make the switch from carbon-producing energy to carbon-neutral and carbon-negative energy?
- **Energy Efficiency**
  What products and technologies exist to increase energy efficiency, especially in heating and cooling buildings?
- **Adaptation**
  How can cities and towns adapt to the impacts of climate change?
- **Talk About It**
  Talking about climate change with friends and family can feel overwhelming. What is one thing you have learned that you could share to start a conversation?



What solutions are the most exciting in your classes? We would love to hear from you or your students! Images, video, or audio of student projects or questions are always welcome. Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

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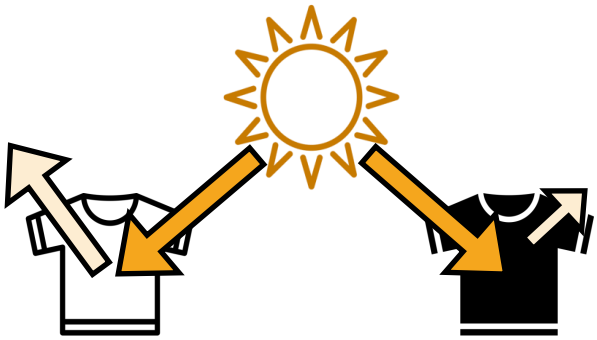
"Instead of having this reflective white surface that sends most of the sun's energy that hits it right back to outer space. When we have less of that ice, that sun's energy instead goes into the ocean and warms it up, which melts even more ice."

Dr. Jennifer Francis, Woodwell Climate Research Center

TILclimate podcast: Today I Learned About Winter Storms



Albedo

If you're planning to sit outside in the sun, do you grab a light-colored or dark-colored shirt? It may depend on whether it is summer or winter. In the summer, many people wear lighter-colored clothes to stay cool, while they may wear darker colors to warm up in the winter. The ability of a surface to reflect sunlight is called *albedo* (al-BEE-doh). Reflective surfaces have high albedo, and dark surfaces have low albedo. A surface with low albedo only reflects some of the sun's energy as light, and absorbs the rest of it as heat, warming up the surface.

Explore the Data

On Earth, different surfaces reflect and absorb light. Light surfaces such as ice, clouds, and sand have a higher albedo than dark surfaces such as the ocean.

1. Visit https://neo.gsfc.nasa.gov/view.php?datasetId=MCD43C3_M_BSA
2. From the drop-down menu, select a year between 2001 and 2016.
3. Click through the months to observe the changes in Earth's albedo over a year.

- Where on Earth is albedo high? Where is it low?
- How does this shift with the seasons?
- The Arctic is warming faster than any other region of Earth. How would you expect this to affect albedo?

Images by Karamat Ali and Deemak Daksina from the Noun Project.

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Albedo: Take it Outside

On a sunny day, use handheld infrared thermometers to measure the temperature of various surfaces outside. In the chart below, note the material the surface is made of, whether it is light or dark, and any other observations.

Location	Surface	Light/ Dark	Temp	Notes

Questions

- Which surfaces reflect the most light (are the lightest)?
- Which surfaces absorb the most light (are the darkest)?
- Which surfaces warmed up the most?
- What factors other than color affect how a surface reflects or absorbs light energy?
- How else could you model or test albedo?
- As the climate is warming up, many cities are trying to beat the heat during the summer. Based on what you have learned today or heard elsewhere, what are some methods cities could use to do this?

Citation

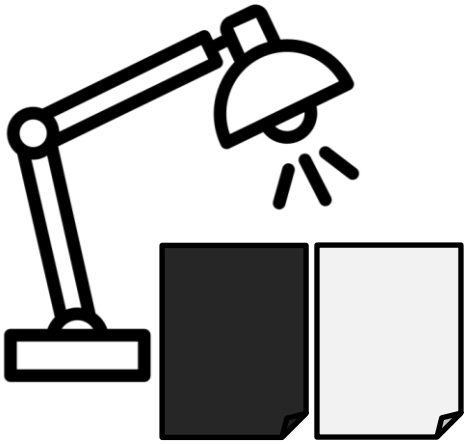
Today I Learned About Winter Storms

Albedo: Model It

Lay pieces of white and black paper next to each other and position an incandescent (not LED or CFL) lamp equally above them.

Allow them to sit for at least 15 minutes.

Using a handheld infrared thermometer or by touching the two papers with your hands, measure which surface has gotten warmer.



Bonus: Try other objects made of materials other than paper, or with color values between black and white. (Examples: Try metal, glass, cardboard, stone, etc.)

You can also use a handheld light meter or light metering app (used for photography) to measure the amount of light reflected by different surfaces.

Questions

- Which surfaces reflect the most light (are the lightest)?
- Which surfaces absorb the most light (are the darkest)?
- Which surfaces warmed up the most?
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Image from Atif Arshad from The Noun Project

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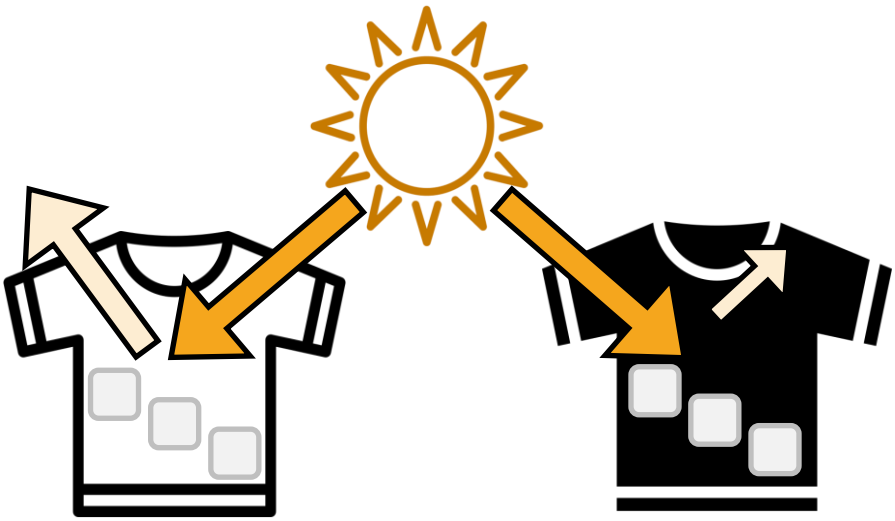
Albedo: Melt It

For this experiment, you will need two surfaces made of the same material – one white and one black. This could be pieces of fabric (such as t-shirts), paper, or cardboard painted.

Lay your two surfaces side-by-side outside on a sunny day in direct sunlight. Place 4-5 ice cubes on each surface. Watch to see what happens to the ice cubes.



Questions

- Which surfaces reflect the most light (are the lightest)?
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Images by Karamat Ali and Deemak Daksina from the Noun Project.

Today I Learned About Winter Storms

"And so we get this vicious cycle. And all that extra energy that's going into the Arctic ocean, where that ice used to be, is the main contributor to the fact that the Arctic is warming so much faster."
Dr. Jennifer Francis, Woodwell Climate Research Center
TILclimate podcast: Today I Learned About Winter Storms

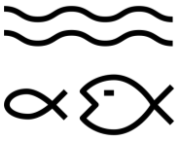
Feedback Loops

Any change to a system causes other changes to that same system. A pebble thrown into a pond causes ripples. A tree falling in the forest opens new space for other trees. If these related changes build on each other or further interact, they are called *feedback loops*. Confusingly, *positive feedback loops* can often cause harm, while *negative feedback loops* often maintain balance in a system.

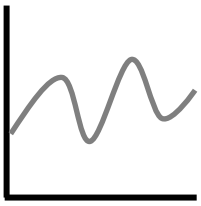
Positive Feedback Loop: One Bad Apple

The idiom "one bad apple spoils the barrel" refers to a positive feedback loop. An overripe apple (the "bad apple" in the idiom) releases ethylene gas, causing the other apples stored with it to ripen too quickly. Even though the result might not be good, this is a positive feedback loop because the changes to the system add to each other. Each new overripe apple in the barrel sends out more ethylene gas, ripening more apples, as well as the original apple, which feeds back into the system.

Negative Feedback Loop: Predator/Prey Relationships



Predator and prey populations are opposite of each other – too many predators reduces the prey population, causing a crash in the predator numbers, which then allows the prey species to grow. This *negative* feedback loop keeps the habitat balanced over time.



Questions

- Explain the idea of a feedback loop to a partner.
- What other examples of positive and negative feedback loops can you think of?
- How is the arctic ice melting a positive feedback loop?

Images by Ian Rahmadi Kurniawan and Chanut is Industries from The Noun Project

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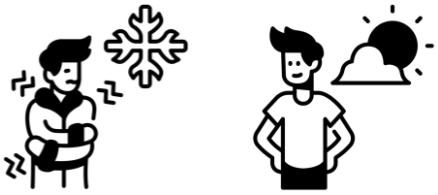
"It was an incredible winter back in 2021 with that amazing cold spell, it wasn't just in the center of North America. At the same time they were having an extremely devastating cold spell in Eurasia."
Dr. Jennifer Francis, Woodwell Climate Research Center
TILclimate podcast: Today I Learned About Winter Storms

Weather vs. Climate

You know you can check the weather report, but what is the difference between *weather* and *climate*? It's all a matter of scale. Weather happens on the small scale – changes in weather happen hour-to-hour, day-to-day, and season-to-season. Climate is measured on long scales – tens, hundreds, and thousands of years.

Your climate determines what's in your closet.

A location's *climate* influences what kinds of clothes a person might have in their closet. If they live in a generally warm climate, such as Florida, they might have more t-shirts, shorts, and sandals. If they live in a more variable climate, such as Minnesota, they probably have a mixture of warm- and cold-weather clothes, including both shorts and heavy winter jackets.



Checking the weather helps you decide what to wear.

The *weather* on a given day influences what kinds of clothes a person chooses to wear for the day. Even if it is a warm season where you live, the temperature and precipitation change day-to-day, and you might need to grab a jacket in the summer.

The Climate is Changing

As we burn fossil fuels like coal, oil, and natural gas, and cut down forests, we release carbon dioxide (CO_2) into the atmosphere. This carbon dioxide acts as a blanket in Earth's atmosphere, trapping heat. Trapped heat is warming our Earth and ocean. While the *climate* is warming year-to-year and decade-to-decade, the *weather* is becoming less stable and more variable day-to-day and month-to-month. Even as the climate gets warmer it doesn't mean that there won't be cold weather.

Images by Eucalyp and Maxicons from The Noun Project

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Climate vs Weather: Graph It!

1. Visit the National Centers for Environmental Information 'Climate at a Glance Statewide Time Series' at https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series
2. Choose the following:
   - Parameter: Average Temperature
   - Time Scale: 1-Month
   - Month: *Choose a winter month*
   - Start Year: *Earliest available year*
   - End Year: *This year*
   - State: *Choose a state*

   Options
   ✓ Display Trend
   ○ per Decade
3. Click "Plot". (Optional: Click "Download CSV" and plot the data yourself.)

Observe Weather

Describe the year-to-year average temperature (weather) line.

Have average temperatures for this month been the same every year, or have they varied?

Observe Climate

Describe the decade-to-decade trend (climate) line.

Have average temperatures across decades stayed the same, gone up, or gone down?

Analyze

Describe the relationship between year-to-year variation in average temperature for this month and decade-to-decade trends in average temperature.

Based on what you learned from the podcast episode, what could explain years with extremely cold average temperatures?

Extend

Explore the other data available on this page. What other questions could you ask using this tool?

Today I Learned About Winter Storms: Polar Vortex

"[During] the Texas cold spell of February, 2021, we had one of these pieces of the polar vortex that drifted down over the middle of North America."

Dr. Jennifer Francis, Woodwell Climate Research Center
TILclimate podcast: Today I Learned About Winter Storms

What is the Polar Vortex?

Though it sounds like something planned by a comic book villain, the polar vortex is a normal part of Earth's air patterns. It is a loop of swirling cold air around the North and South poles. The vortex around the North pole can split or expand, reaching into North America and causing periods of extreme cold.

- Read the explanation from NOAA's SciJinks at https://scijinks.gov/polar-vortex/
- Discuss the topic with your group until every member of the group feels they understand what the polar vortex is. Be prepared to share your understanding with the class.

Visualize It

1. To see the effect of the polar vortex on the winter weather of February 2021, visit https://earth.nullschool.net/. Move the globe around and zoom until you have North America in the middle of your screen.
2. Click 'earth' and choose these options to compare February 15 in 2020* and 2021. Use the calendar icon next to **Control** to change the date.

Mode: Air
Animate: Wind
Height: Sfc
Overlay: Temp

Observe

Describe the surface temperature, comparing the two years. How far does the cold temperature area extend in each map? *Hint: If you click on a location, it will display the temperature in °C.*

3. To see the high-level winds that form the polar vortex itself, change **Height** to **70hPa**. Readjust the globe on the screen so that you are looking down at the North Pole and can see the entire North Polar Vortex. Where is the swirl of high winds centered?

Observe

Compare the Polar Vortex wind location and temperature between the two years.

Extend

What other questions can you investigate using this tool?

*February 2020 had an average temperature of 49.4°F, close to the 2002-2022 average temperature of 50.1°F, while February 2021 had an average temperature of 43.9°F. (National Centers for Environmental Information.)

Today I Learned About Winter Storms: Jet Stream

"The jet stream is this fast moving river of wind high over our heads. The winds blow from west to east. The reason it's called a jet stream is because it exists up where jets tend to fly."
Dr. Jennifer Francis, Woodwell Climate Research Center
TILclimate podcast: Today I Learned About Winter Storms

What is the Jet Stream?

If you've ever flown West to East in the US, you may have harnessed the power of the jet stream. There are actually four jet streams on Earth, but in the US, we are usually referring to the northern polar jet stream. A jet stream is a strong river of wind in the atmosphere.

- Read the explanation from NOAA's SciJinks at https://scijinks.gov/jet-stream/
- Discuss the topic with your group until every member of the group feels they understand what the jet stream is. Be prepared to share your understanding with the class.

Visualize It

1. To see the current and effect of the jet stream on weather, visit https://earth.nullschool.net/. Move the globe around and zoom until you have North America in the middle of your screen.
2. Click 'earth' and choose these options. (By default, **Control** is set to Now.)

Mode: Air
Animate: Wind
Height: 250 hPa
Overlay: Wind

Observe

Describe the movement and direction of the strongest winds across North America. Note where the most consistent band of winds are found. This is the jet stream.

3. Click somewhere in the middle of the jet stream. The green circle will stay there, to help you orient as you change settings on the map.
4. To see the effect of the jet stream on temperatures in North America, change these options while leaving the others the same.

Height: Sfc
Overlay: Temp

Observe

How are surface temperatures related to where the jet stream is?

Extend

What other questions can you investigate using this tool?