GLOBE Educator One-Week Pacing Guide: *Clouds and Energy Budget*

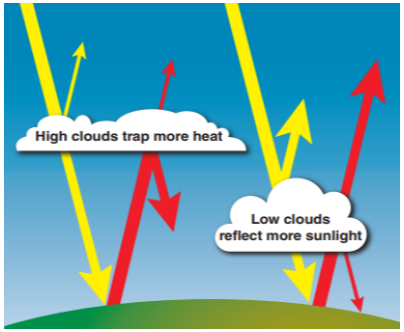
Phenomenon: Clouds, Energy Budget **Grade Level:** 6-12	**Guiding Question:** What is the role of clouds in Earth's energy budget?	**Contact:** Reach out to the NASA GLOBE Clouds Team if you have questions.
Further Investigation: NASA GLOBE Clouds main website and The GLOBE Program's main website		
Optional: Become a GLOBE Trained Teacher: GLOBE Clouds Protocol Training		
Access GLOBE Pacing Guides: https://www.globe.gov/web/nasa-langley-research-center/home/resources		
Revision Date: 2-27-2022		

Standards - These standards are supported by the activities in this guide but not completely covered.		
Middle	**Performance Expectations:** • MS-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives the process. • MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. • MS-ESS2-5 Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions. • MS-ESS2-6 Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. • 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.	**Disciplinary Core Ideas:** • ESS2.A Earth's Materials and systems • ESS2.C The Roles of Water in Earth's Surface Processes • ESS2.D Weather and Climate • PS1.A Structure and Properties of Matter • PS3.A Definitions of Energy • PS3.B Conservation of Energy and Energy Transfer

This work was supported by GLOBE Mission Earth, award No. NNX16AC54A, in collaboration with NASA Earth Science Education Collaborative.

	● MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. ● MS-PPS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. ● MS-PS3-5 Construct, use and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.	● PS4.B Electromagnetic Radiation ● ETS1.B: Developing Possible Solutions
	Science and Engineering Practices: ● Developing and Using Models ● Planning and Carrying Out Investigations ● Constructing Explanations and Designing Solutions ● Engaging in Argument from Evidence	**Crosscutting Concepts:** ● Energy and Matter ● Cause and Effect ● Stability and Change ● Systems and System Models
High School	**Performance Expectations:** ● 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. ● HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface properties. ● HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	**Disciplinary Core Ideas:** ● ESS2.C The Roles of Water in Earth's Surface Processes ● ESS2.D Weather and Climate ● PS3.A Definitions of Energy ● PS3.B Conservation of Energy and Energy Transfer
	Science and Engineering Practices: ● Developing and Using Models ● Planning and Carrying Out Investigations ● Using Mathematics and Computational Thinking	**Crosscutting Concepts:** ● Cause and Effect ● Structure and Function ● Systems and System Models

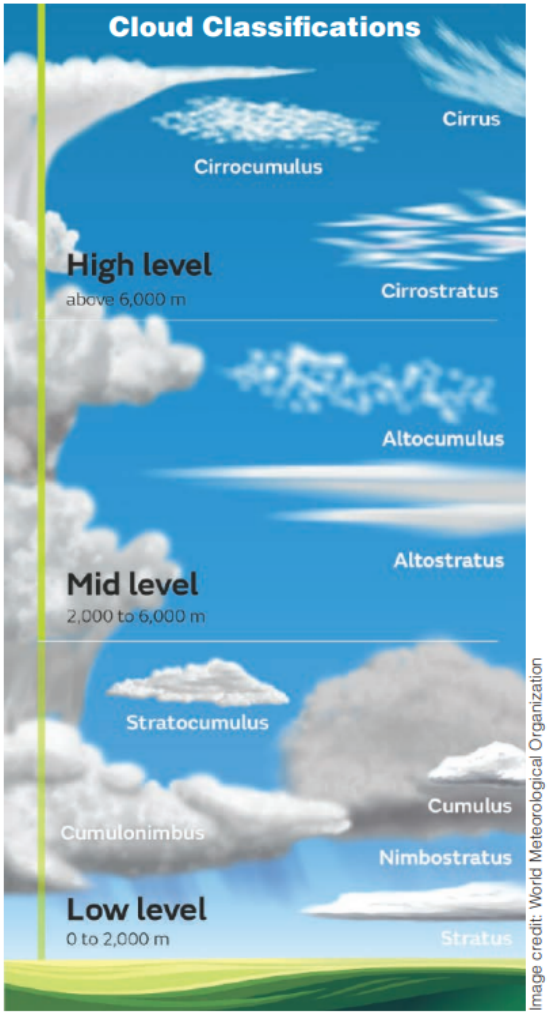
Background Information and NASA Connection



Earth works to maintain a balance between the overall amount of incoming and outgoing energy at the top of the atmosphere. This is called Earth's energy budget. Earth receives incoming energy from the Sun which is mostly in the visible (shortwave) part of the electromagnetic spectrum. Earth also emits energy back to space in the infrared (longwave) part of the electromagnetic spectrum. For Earth's temperature to be stable over long periods of time, in other words, for the energy budget to be in balance, incoming energy and outgoing energy have to be equal. If incoming energy is more than outgoing energy, Earth will warm. If outgoing energy is greater than incoming energy, Earth will cool. (For more information, access the source of this information in the CERES Clouds and Earth's Radiant Energy System document.)

Clouds have different impacts on Earth's energy budget. For example, low thick clouds (e.g., stratocumulus clouds) are opaque and do not allow as much incoming solar energy (yellow arrows) to reach Earth's surface. This is shown by yellow arrows found on the top of the low thick cloud in the first image in this section. The thickness of the yellow arrow also shows the amount of energy going back to space. This has a net cooling effect. High, thin clouds (e.g., cirrus clouds) are transparent and allow most shortwave radiation through to Earth's surface. Notice the thickness of the yellow arrows above and below the high thin cloud in the left of the image. Outgoing infrared energy cannot go out to space in the presence of high thin clouds. Notice the thickness of the red arrows below and above the high thin cloud. This has a net warming effect. Understanding the characteristics of clouds (e.g., amount, composition, thickness, cloud particle size), where they form (e.g., height), how they move, and the radiative properties of clouds (i.e., how they reflect, absorb and emit energy), is key to understanding Earth's energy budget and climate.

Observations of clouds help us know how much sunlight is reaching the ground and how easily heat from the ground and lower atmosphere can escape to space. Clouds play a central role in controlling

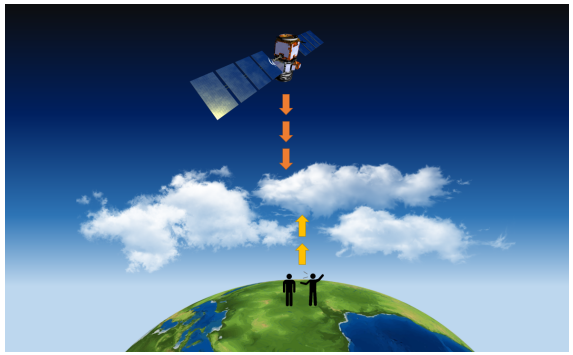


the exchange of heat in the atmosphere and changes in clouds over time can have significant climate impacts. To understand the impact of clouds over time, satellites observe the planet's clouds and energy from space. Data from multiple research and weather satellites have made and continue to make significant contributions to our understanding of clouds.

Clouds play a complex role in climate. They are the source of precipitation, affect the amount of energy from the Sun that reaches Earth's surface, and insulate Earth's surface and lower atmosphere.

While the satellites deployed by NASA and worldwide space agencies give us a big picture of climatic cloud effects, they struggle at times to provide a detailed analysis of what's happening in specific locations. That's why it's so crucial for researchers to have ground truth data gathered from the Earth's surface.

The GLOBE Program is NASA's largest and longest lasting citizen science program about the Earth. Through the program's GLOBE Observer app, you can submit cloud reports and photographs of clouds and sky. After you submit your observations, the NASA GLOBE Clouds team at NASA Langley Research Center compares your observations with satellite data. The results of the satellite measurements compared to your ground report are then sent to you via a NASA personalized email.



Your observations are very important because they provide scientists with a fuller perspective on how cloud cover affects our climate. Additionally, when you submit frequent observations over time, your data provides NASA with greater detail on how our climate is changing.

Sky photographs are one of the most requested portions of a GLOBE Clouds observation. This is because there is so much you can do with them. Photographs give scientists the opportunity to be right there with you. Details within a photograph can be used to compare with satellite data, confirm dust or haze observations, and give insight to unique cloud types like lenticular and noctilucent clouds over the polar regions.

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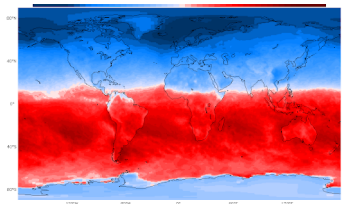
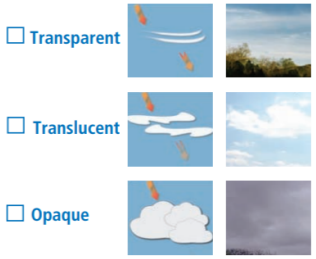
Activities		Assessment Options
Day 1: Explore NASA Data for Cloudy vs Clear Skies Students use map visualizations to analyze NASA satellite data of net energy flow toward Earth for clear days and cloudy days. **Materials:** online activity		• Questions included in the activity. ***Connection to guiding question:*** *Write one sentence describing the difference in the energy from the Sun on cloudy versus clear days in July. (This is the second question for the exit ticket.)* ***Answer:*** *Clouds **overall** tend to have a cooling effect on Earth.*
Activities		**Assessment Options**
Day 2: Visual Opacity Experiment Cloud Clues by SciGirls • Students design a test to identify opacity of various materials and then compare to clouds • Students complete the journal pages **Materials:** materials list and journal pages found in activity		• Journal pages ***Connections to guiding question:*** *Do all clouds have the same opacity?* ***Answer:*** *No* *What is the opacity of different types of clouds?* ***Answer:*** *High level (example cirrus) tend to be transparent, mid level (example altostratus) tend to be translucent, and low level (example clumule) tend to be opaque.*

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Activities		Assessment Options
Day 3: Cloud Opacity Experiment Students conduct an experiment outside or with a lamp with an incandescent bulb as a heat source and compare three atmospheric conditions: clear skies, cumulus clouds and cirrus clouds. **Tip:** For cirrus clouds the cotton balls must be pulled apart significantly to make them much thinner than the cotton balls. In addition, use an incandescent bulb, and place the lamp close to the "clouds". **Materials:** materials list found in activity	 Cumulus Clouds top view  Cirrus Clouds top view	• Draw Conclusions questions in activity answer key ***Connection to guiding question:*** *What is the effect on surface temperature of clouds with different opacities?* ***Answer:*** *Cloud types that are transparent or translucent allow more energy through them resulting in higher surface temperatures. Opaque clouds allow less energy through resulting in cooler surface temperatures.*
Day 4: Observe Clouds Students use the GLOBE Observer App or GLOBE Clouds Data Sheet to record sky observations. If they use the GLOBE Clouds Data Sheet, remember to enter the data. ***Be sure to include opacity in the observations.*** **Materials:** Recommendations found in Figure 3 of NSTA paper Making Science Come Alive with Clouds. **Only make observations if you can do so safely and legally.**		• Within groups, develop consensus on observations using evidence and submit observations. • Discuss the cloud observations based on the opacity of the clouds. ***Connection to guiding question:*** *How might the clouds be impacting the energy received at your location at the surface today?* ***Answer:*** *Answers will vary depending on the cloud types. Transparent and translucent clouds will be allowing energy to reach the surface and reradiating energy. Opaque clouds will block some of the energy.* Optional Instructional Video: How to use the GLOBE Observer Clouds Tool

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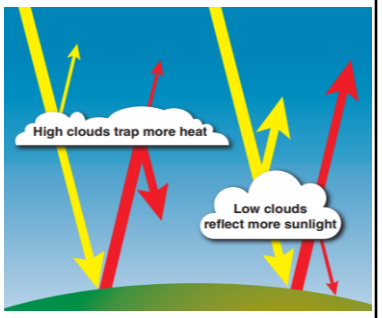
Activities		Assessment Options
Day 5: Cloud Impacts on Earth's Energy Budget Students watch the Clouds & Earth's Climate video with Dr. Patrick Taylor My NASA Data Mini Lesson Students then complete the Examining a Simplified Model of Cloud Effects on Earth's Energy Budget Student Activity, a My NASA Data Mini Lesson.		• Notes from Clouds and Earth's Budget video • Questions from Examining a Simplified Model of Cloud Effects on Earth's Energy Budget Student Activity ***Connection to guiding question:*** *How might the clouds be impacting the energy received at your location at the surface today? Is it different from the day the cloud observation was made?* ***Answer:*** *Answers will vary depending on the cloud types. Transparent and translucent clouds will be allowing energy to reach the surface and reradiating energy. Opaque clouds will block some of the energy.* ***Connection to NASA:*** *Why does NASA study clouds and Earth's energy budget?* ***Answer:*** *NASA is trying to understand Earth as a system and the impact of clouds in that system. The impact of changing clouds on Earth's energy budget is related to changes in our climate.*

Additional Resources		
Online Activities	Audience	Description
My NASA Data mini lesson Clouds and Climate Impacts	Grades 6-12	Watch a video and use a Jamboard or worksheet to brainstorm the potential impacts of changing clouds.

Additional Resources (continued)		
Online Activities	Audience	Description
NASA GLOBE CLOUD GAZE	Upper Elementary through Adult	Identify clouds and percent cloud cover online.
Cloudy vs. Clear - Graphs My NASA Data	Grades 3-12	Analyze and interpret graphs of the average net atmospheric radiation to compare the flow of energy from the sun toward Earth in different months and for cloudy versus clear days.
Analyzing Global Patterns with Earth System Poster Cards	Grades 3-12	Analyze satellite images of Cloud Cover and Surface Temperature variables which are available in Google Sheets or as PDF files.
Modeling Cloud Cover	Upper Elementary through High School	Using the Interactive Google Slides, select a percentage as a multiple of 10% (or fraction) of cloud cover to approximate and estimate percent cloud cover of a particular area.
Hands-On Activities	Audience	Description
Estimating Cloud Cover	Upper Elementary through High School Individual, group and large group	Students use construction paper to simulate cloud cover. They estimate the percentage of cloud cover represented by torn pieces of paper on a contrasting background and assign a cloud cover classification to the simulations created by their classmates.
Investigating the Climate System - CLOUDS and the Earth's Radiant Energy System	Grades 5-8	A series of six activities designed to explore cloud formation, cloud classification, and the role of clouds in heating and cooling the Earth, how to interpret TRMM images and data, and the role clouds play in the Earth's radiant budget and climate.

Additional Resources (continued)		
Videos and Reading	Audience	Description
NASA's Earth Minute: Cloudy Forecast	Ages 9-adult	Clouds are complicated when it comes to climate science, as they both warm and cool Earth. NASA is studying these atmospheric masses of condensed water vapor with satellites and aircraft.
Science of Clouds Videos	Ages 9-adult	Join different NASA scientists and learn how to look at clouds with a new perspective. Follow along with a GLOBE educator on how to do a cloud related activity.
EOKids From School to NASA Earth Scientist	Ages 9-14	NASA EO (Earth Observatory) Kids is written for audiences aged 9 to 14. In this issue, find out what three NASA scientists wanted to be when they were young and discover what they do now. Then, be a scientist yourself! Learn how to use the GLOBE Observer app to collect your own scientific observations.
NASA's CERES Mission Brochure	Ages 11-adult	Read about theNASA CERES (Clouds and Earth's Radiant Energy System) mission and why it is important to study clouds and Earth's energy budget.

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