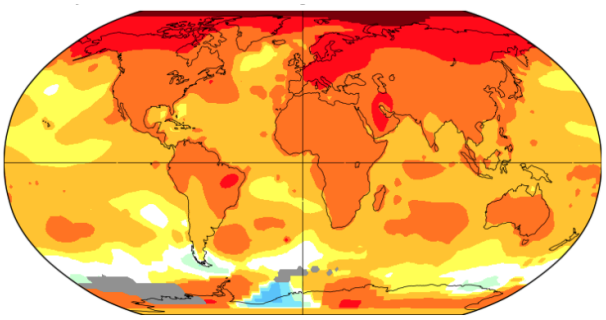
Data Puzzles

On a Budget - Teacher Guide

Setting the Stage



Earth receives almost all of its energy from the Sun in the form of shortwave energy which is either reflected or absorbed by the Earth's surface. Shortwave energy absorbed by the Earth's surface causes the surface to heat up. The Earth releases (emits) this heat back into the atmosphere as longwave energy (heat). The balance between the energy that is reaching the Earth from the Sun and the longwave energy that is flowing back into space from Earth is called Earth's energy budget. If the amount of incoming shortwave energy from the Sun is equal to the amount of outgoing energy emitted by the Earth, Earth's temperature should stay constant. Rising global temperatures over the past century indicate that Earth's energy budget is out of balance, with the Arctic heating up at a rate faster than the global average. *Photo Credit: NSIDC*

Lesson Overview

In this Data Puzzle, students analyze and interpret authentic incoming shortwave energy (from the Sun) and outgoing longwave energy (from the Earth) gathered from the Arctic to explain why the Arctic is heating up so rapidly.

Part 1 – (10 minutes) Eliciting Students' Ideas
Access students' prior knowledge about an opening scenario.

Part 2 – (30 minutes) Identifying Important Science Ideas
Students engage with a contemporary science investigation through an interactive reading in which students are tasked with 1) making connections between the science investigation and the opening scenario, and 2) identifying an investigative question.

Part 3 – (50 minutes) Supporting Ongoing Changes in Thinking
Students test/compare their current understandings of the investigative question against authentic data.

Part 4 – (30 minutes) Constructing Evidence-Based Explanations
Students finalize new understandings as they relate to the investigative question to create an explanatory model.

Data Puzzles

Data used in this data puzzle was collected by scientists that are part of the MOSAiC research project. The materials were developed by CIRES Education and Outreach at CU Boulder with support from AGS 1554659 and OPP 1839104. Find more MOSAiC curriculum at http://mosaic.colorado.edu

Instructional Overview	
Grade Level	Middle/High School
Instructional Time	~120 minutes
Building Toward	**NGSS Disciplinary Core Idea:** • ESS2D: Weather and Climate **NGSS Science and Engineering Practices:** • Analyzing and Interpreting Data • Obtaining, Evaluating, and Communicating Information • Constructing Explanations **NGSS Crosscutting Concepts:** • Energy and Matter • Stability and Change
Driving Question	• Why might the Arctic be warming faster than other places on Earth?
What Students Will Do	• Analyze and interpret incoming and outgoing energy data from the Arctic to evaluate amplified warming in the Arctic. • Construct a model to explain how outgoing longwave energy (heat) from the Arctic is contributing to the Arctic amplification.
Materials	❏ Slide deck ❏ Student worksheet ❏ Answer Key
Material Preparation	❏ Print student worksheets ❏ Review presenter notes in Lesson slides ❏ Review Answer Key ❏ Gather public record materials (e.g., butcher paper and markers, Google Doc, Jamboard, etc.)
Vocabulary	• Earth's energy budget - Balance between the energy that is reaching the Earth from the Sun and the energy that is emitted by the Earth, which flows back out into space. • Wavelength - Distance between one peak of a wave of energy and the next peak. • Shortwave energy - Most of the energy emitted by the Sun is shortwave energy (e.g., visible light). • Longwave energy - Earth emits longwave energy (e.g., infrared energy) back out into space.

	• Arctic amplification - a phenomenon where the Arctic is warming at a rate much faster than the rest of the globe.

Part 1 - Eliciting Students' Ideas
10 minutes

Refer to Part 1 slides included in the slide deck. See presenter notes for additional information.

1. Utilize the slide deck to introduce the Data Puzzle and explain that the purpose of the opening scenario is to identify times in the students' own lives where they may have experienced ideas/concepts similar to what they will explore later in the Data Puzzle.

2. Facilitate a whole-class discussion around the prompt, "What does it mean when someone says they are "on a budget"?"

3. Segue to the next slide by saying, *"Usually it means that they want to maintain a certain amount of money in their wallet or bank account, which in turn means that they have to balance how much money they spend vs. how much money they save. Just like you and I might have a financial budget, Earth has an energy budget."*

4. Introduce students to Dr. Jen Kay, the scientist featured in this Data Puzzle, who uses satellite data to monitor changes to Earth's energy budget.

Part 2 - Identifying Important Science Ideas
30 minutes

Refer to Part 2 slides included in the slide deck. See presenter notes for additional information.

1. Students read the puzzle plot text included in the student worksheet either individually, in small groups, or as a whole class. While reading, students are asked to do the following tasks:
    a. Circle the investigative question the scientists are investigating.
    b. Identify similarities between the reading and the opening scenario.

2. Show the following videos (*the links are also embedded in the puzzle plot text*) to help students visualize concepts presented in the text.
    a. Global Temperature Anomalies from 1880 to 2023 (0:30 minutes)

3. Facilitate a whole-class discussion to help make connections between the reading and the opening scenario by utilizing the following prompts:
    a. How would you know if your financial budget is out of balance?

b. How would scientists know if Earth's energy budget is out of balance?

4. Students summarize important science ideas presented in the puzzle plot by drawing and describing Earth's energy budget when it is perfectly balanced.

5. Students make a prediction for the investigative question that they will test in Part 3 by analyzing real data.

Part 3 - Supporting Ongoing Changes in Thinking

50 minutes

Refer to Part 3 slides included in the slide deck. See presenter notes for additional information.

1. The datasets students will analyze were collected from CERES instruments that were attached to different NASA satellites. Introduce students to the datasets by watching this video (0-1:53 minutes) about how scientists are monitoring Earth's energy budget from space.

2. Model for students or give students time to explore the NASA satellites (Aqua, Terra, and Suomi NPP) that CERES instruments were attached to.

3. Use the prompts embedded in the slide deck to help orient students to the incoming shortwave energy and outgoing longwave energy graphs (*note that these data were collected by CERES instruments*) by giving them an opportunity to study and discuss the graphs both individually and with a partner.

4. Students work in pairs to identify patterns in the datasets.

5. Based on the patterns identified, students create a rule (if present) to describe the relationship between the factors represented in the graph.

6. Students cite evidence from the graph to evaluate whether or not the data supported or refuted their initial prediction for the investigative question.

Part 4 - Constructing Evidence-Based Explanations

30 minutes

Refer to Part 4 slides included in the slide deck. See presenter notes for additional information.

1. Utilize the slide deck to describe what should be included in a scientific model and analyze an example of an explanatory model.

2. Students work in pairs to construct their explanatory models for the investigative question.

Note: If there is disagreement amongst students about what should be included in their explanatory models, consider creating a “Gotta-Have Checklist”, a whole-class public record in which students collaboratively identify the parts and conventions (signs/symbols connecting parts) that you just gotta have in your model.

3. Students share their explanatory models.
    a. Model sharing can be facilitated as a gallery walk, in small groups, or as a whole class.

4. Digging Deeper - Students consider how declining Arctic sea ice might lead to more longwave energy (heat) being emitted from the Arctic?

Additional Teacher Resources

Videos

- Learn more about the Clouds and Earth's Radiant Energy System (CERES) project in this video produced by NASA: Tracking Earth's Heat Balance
  https://www.youtube.com/watch?v=uVkfh89iyeU&feature=emb_logo
- "Earth's Delicate Energy Balance" video produced by the California Academy of Sciences
  https://www.youtube.com/watch?v=U2CPwWgY_G4
- Tour of the Electromagnetic Spectrum
  https://science.nasa.gov/ems/01_intro

Data visualizations

- Change in temperature and atmospheric CO_2
  https://drive.google.com/file/d/1QavorSU_SVSLEXge53lielyu8HUoOUcC/view
- Global Temperature Anomaly
  https://climate.nasa.gov/vital-signs/global-temperature/

Interactives

- NASA Satellites Now (*note that the CERES instruments are located on Aqua and terra satellites*)
  https://climate.nasa.gov/earth-now/?vs_name=air_temperature&dataset_id=820&group_id=46&animating=f&start=&end=#/vitalsign?vitalsign=satellites&altid=0&animating=f&start=&end=