Climate: How Is Climate Really Changing?

Lesson Question
How is climate really changing?

Lesson Task
Students analyze historical temperature data to determine how climate is changing and to forecast what it will look like in the future for their home state, the rest of the United States, and the world. Using that information and their knowledge about the difference between weather and climate, students write a rebuttal to a false claim about climate change.

Standards

Performance Expectations
HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

Disciplinary Core Ideas
ESS3.D Global Climate Change

Science and Engineering Practices
Analyzing and Interpreting Data
- Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal solution.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Crosscutting Concepts
Stability and Change
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-5)

TABLE OF CONTENTS

OVERVIEW

Content Objectives

Students will understand the difference between climate and weather, how local climate differs from global climate, and how long-term historic trends in temperature can be used to forecast what temperatures are likely to be in 100 years.

→ **Weather** includes short-term changes in temperature and precipitation.

→ **Climate** is the average weather over 30 years or more.

→ **Local climate** is determined by temperature or precipitation measurements averaged over 30 or more years.

→ **Global climate** is determined by temperature or precipitation averaged over 30 or more years for the surface of the entire planet.

→ A **forecast** is a prediction or estimate of future events based on trends in data..

Data Skill Objectives

Using the historical temperature data, students will apply the following data skills:

Developing and Using Models

- Students will be asked to create visual representations of concrete events of weather patterns by looking at two variables: temperature variable and year variable.

Analyzing and Interpreting Data

- By analyzing and interpreting historical temperature data, students will have an opportunity to notice and examine patterns.
- Students will be asked to analyze and interpret data from the perspective of trends—that is, weather data collected in successive time periods.
    - › Examples include traditional scatterplots and a color chart of slope of weather change of 50 states.

Instructional Sequence

Before you begin the lesson you should share a brief agenda with students:

→ **HOOK** We'll start together by thinking about how it's possible for New York to have had near-record snowfalls in the winter of 2017–2018 if the climate is getting warmer.

→ **BACKGROUND** We'll go over background information about the about the difference between weather and climate, the difference between local and global climate, and how variability and trends in data help us understand and describe how climate is changing over time.

→ **DATA ORIENTATION** We'll familiarize ourselves with global temperature data, and practice using data analysis tools that will be useful in your investigation. You will learn how to make and interpret a trend line of past data and how to use that trend line to forecast global temperatures in the future.

→ **INVESTIGATION** On your own, you'll analyze state temperature data from the last 120 years and forecasts of what average temperatures are expected to be 100 years from now. You'll then compare trends for individual states to draw conclusions about how climate is changing in the United States.

→ **WRITING** Using the evidence collected during your investigation, you'll write a rebuttal to a false claim about climate change and explain why it is flawed.

Lesson Background for Teachers

There is a common misconception that individual weather events, or anomalies, can be used to prove or disprove climate change. Although weather and climate are closely related, they are not the same thing. Weather describes the atmospheric conditions at a specific place at a specific point in time, whereas climate is the long-term average of weather conditions in a particular location or region at a particular time of the year. Climate is typically measured in increments of time of 30 years or longer. Therefore, evidence of climate change should come from long-term trends in temperature, precipitation, and other climate factors—not through single weather events, such as a heat wave or a snow storm.

To learn more about climate, look at NOAA's Climate Data Primer:
https://www.climate.gov/maps-data/primer/climate-data-primer

Student Background Knowledge

Before starting this module, students should understand

- Weather is a state of the atmosphere at a place and time, and is described by measures such as temperature and precipitation.
- How the slope of a line is calculated.

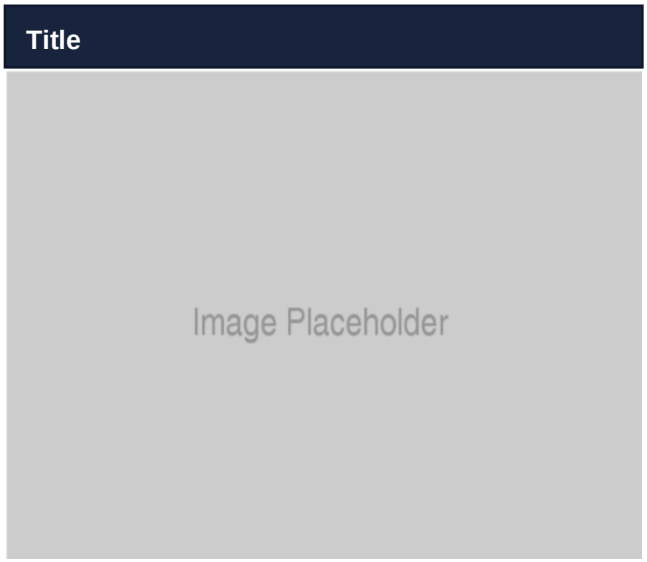
THE HOOK

[Estimated time: 15 minutes]

Snowy winter, warming climate?

Purpose

Have students think about the information they will need to solve the lesson task—determining how climate is really changing.



Big Ideas

- **Weather and climate** are not the same thing.
- Weather can be cold and snowy **even if the climate is warming.**

Facilitation Suggestions

- **Pose the Think About It question** for discussion: New York saw near-record snowfalls in the winter of 2017–2018. Yet we constantly hear that our climate is getting warmer. How is this possible?
- **Collect** students' answers, which may include things such as "It was just one winter" or "Maybe climate change isn't real.".

TRANSITION TO BACKGROUND

Explain that the slides will provide useful information for understanding how weather and climate are related to one another and how we determine how they are changing over time.

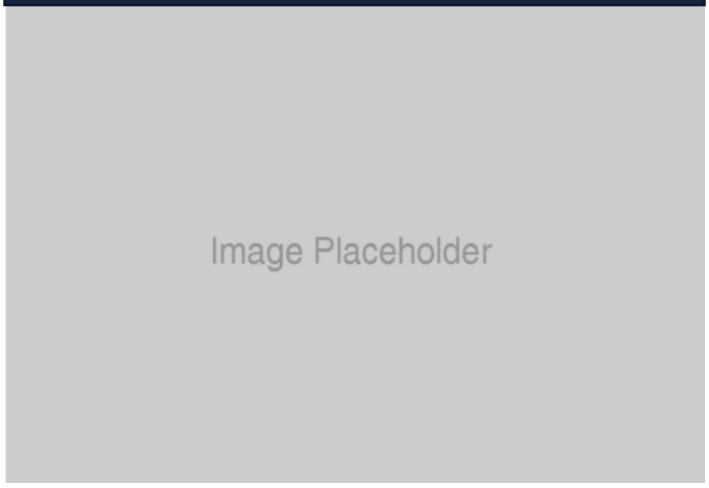
Background

[Estimate time: 30 minutes]

Show the background slides to the class. Have students actively read and discuss the content and questions so they develop background knowledge needed in the investigation.

Background 1: Weather

Title



Purpose

Explain the difference between weather and climate.

Big Ideas

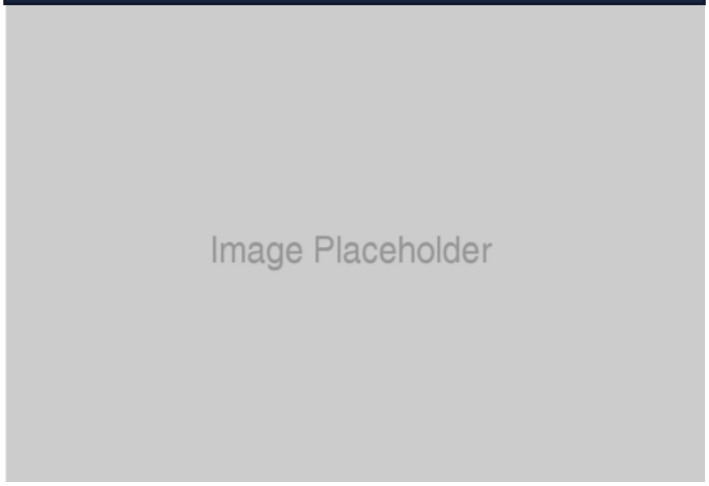
- The difference between weather and climate is time: **weather occurs on short timescales** (days, weeks, years).

Facilitation Suggestions

- **Review** the three graphs, which are each examples of weather in New York City on different timescales.
  - **Graph 1** shows daily average temperature measurements over 1 month (January 2016).
  - **Graph 2** shows monthly average temperatures over 1 year (2016).
  - **Graph 3** shows annual average temperatures over 10 years (2007–2017).
- **Ask:** "What are some other examples of weather?"

Background 2: Climate

Title



Purpose

Further define the difference between weather and climate.

Big Ideas

The difference between weather and climate is time: Climate is an average of weather taken over 30 years or more.

Facilitation Suggestions

- **Have students carefully examine** the graph and describe what it is showing.
- **Ask:** "What features on the graph show weather? Which show climate?"
  (Hint: Climate is an average of weather over 30 years or more.)

Background 3: Variability and Trends

Purpose

Help students understand that short-term variability and long-term trends in data help us characterize how weather and climate change over time.

Big Ideas

- Variability and trends describe how weather and climate change over time.
    - Variability describes short-term differences (i.e., year-to-year).
    - A trend describes the general direction in which something is developing or changing over time.

Facilitation Suggestions

- LOOK **at the graph together**.
- ASK**: "What other examples of variability or trends can you think of?"** Examples might include things such as grades:
    - Your exact grade on each test might be different (variability), but your overall performance in the class is characterized by the mean of those scores. If you study hard and do your homework, you might see an overall upward trend in your test scores as the semester goes on.
- **Pose the Think About It questions for discussion:**
    - **How would you describe the trend in the data?**
      Collect students' answers, which may include things such as "Overall, temperature is getting warmer over time" or "Depending on what part of the graph you look at, sometimes the trend is getting warmer, sometimes cooler."
    - **What would the graph look like if there were no variability in the data? What would that mean?**
      Collect students' answers, which may include things such as "A horizontal line with no ups and downs" or "The average annual temperature would be exactly the same every year."

Background 4: Local vs. Global Climate

Title

Purpose

Help students understand the difference between local climate and global climate.

Big Ideas

- Global climate is determined by temperature or precipitation averaged over time for the entire planet.
- Local and regional climates are determined by temperature or precipitation averaged over smaller geographic areas.

Facilitation Suggestions

- **Read Panel 1. Have students look at the image and describe each of the local climates depicted**.
  ASK: "Which climate looks most like our own local climate?"
- **On Panel 2, pose the Think About It questions for discussion.**
  - How are local climate and global climate related to one another?
  - Will your local climate always be similar to global climate? Why or why not?
  - In your own words, summarize the difference between weather and climate.
- CHECK FOR UNDERSTANDING. **Before moving on, make sure that students are secure in their understanding of the difference between weather and climate.** Offer some typical sayings to help them remember as they move forward with the rest of the lesson. For example:
  - Climate is what you expect. Weather is what you get.
  - Weather tells you what to wear each day. Climate tells you what to have in your wardrobe.
  - Weather is the chocolate caramel truffle. Climate is the whole box of chocolates..

TRANSITION TO DATA ORIENTATION

Explain to students that scientists have been gathering local and global temperature data for more than 100 years. In the Data Orientation section, they will be learning techniques for interpreting these data from the past and how to use the data to forecast what temperatures are likely to be in the future..

DATA ORIENTATION

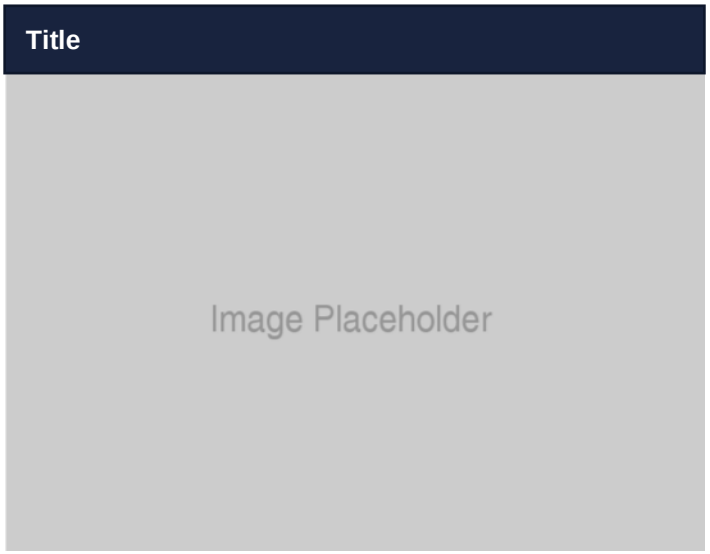
Estimated Time: 30 minutes

We recommend that you continue to show the Data Orientation activities to the class, and guide students as they practice manipulating the data. As students complete each exercise, allow them to explore each data visualization, show them how to use CODAP to construct a graph, and discuss how data trends can be used to forecast likely future conditions.

Data Orientation 1: Global Annual Average Temperature Data Set

Purpose

Familiarize students with the global annual average temperature data set, the use of the CODAP tool for constructing graphs and analyzing and interpreting data, and the use of trends in past data to forecast future temperatures.



Big Ideas

- Historic data show us what global temperature values have been.
- Interpreting trends in data is an important step in understanding how climate has changed over time. Different time periods show different trends (e.g., 30 years vs. 120 years).
- Steeper trend lines mean faster change.

Facilitation Suggestions

- PANEL 1. Encourage students to use the **SHOW HOW** animation if they need help creating their graphs.
- **Point out** that clicking **SHOW DATA SOURCE +** will reveal more information about where and how the data were collected.
- If students make mistakes with their graphs and need to start over, or they just want to try something new, **point out the undo button at the top of the graph and the RESET GRAPH button at the bottom right corner of the browser window.**

Undo:

Start Over:

- PANEL 2. Pose the **Discuss** question**.**
  What do you think an individual data point in this graph represents?
- PANEL 3. Give students time to explore the data set by examining and interacting with the data table and graph to see how they are connected to one another.
- PANEL 5. Have students share the questions they have about the data with one another.

- **PANEL 6.** Demonstrate how to add a least squares line to the graph, and have students follow along. Remind them about the **SHOW HOW** animation if they get stuck. Remind students that the least squares line is a line of best fit that represents the overall trend in the data. A line of best fit is a straight line that may pass through some of the points, none of the points, or all of the points.
- **PANEL 7.** Have students record the slope of the least squares line. Have students share their values to ensure they all have the same result.
- **PANEL 8.** Pose the **Discuss** questions and have students share their responses.
    - What does the slope of a trend line tell you about how temperature is changing over time?
    - Write a sentence describing the trend in annual average global temperature over the time period shown.
- **When you reach SLIDE 11**, discuss the differences between the slopes of the least squares lines for the whole data set and for the last 30 years of data and what that difference means in the real world. Have students record their responses to the **Think About** It questions.

Data Orientation 2: Future Trends

Purpose

Compare trends in climate data and use them to forecast likely future temperatures.

Big Ideas

- By extending trend lines, we can forecast what future temperatures are likely to be if change continues at the same rate.

Facilitation Suggestions

- **Make sure students understand that they are calculating a forecasted temperature *change*.** In other words, the result of their calculation will tell them how many degrees Fahrenheit warmer or cooler the global average annual temperature is likely to be compared to today if the current trend continues.
- **Check for understanding.** Discuss students' results and have them share their explanations for the differences in the forecasts based on the trends from 1880 to 2017 and from 1987 to 2017. Make sure all students have the same forecasted values before moving on to the next section.

Data Orientation 3: Local Climate Change

Purpose

Have students construct hypotheses about how local climates are changing, based on what they know so far about how global climate is changing.

Big Ideas

Global climate is an average of many local climates.

Facilitation Suggestions

- Explain **to students that they will not be graded on their hypotheses.** The hypotheses are simply a way for them to record their initial ideas as something to refer back to and reflect on later.
- Remind **students that they can go back to the Background section (or any other sections) at any time** during the lesson by using the Navigation Bar at the top of the window**.**

TRANSITION TO INVESTIGATION

Now that students are familiar with the global temperature data set and know how to work with CODAP, explain that they will work on their own to investigate state temperature data and to characterize local climate change compared to global climate change to help them answer the lesson question, "*How is climate really changing?*"

INVESTIGATION: State Climate Data Trends

Estimated Time: 60 minutes

Data Task 1: Explore Temperature In Your Home State

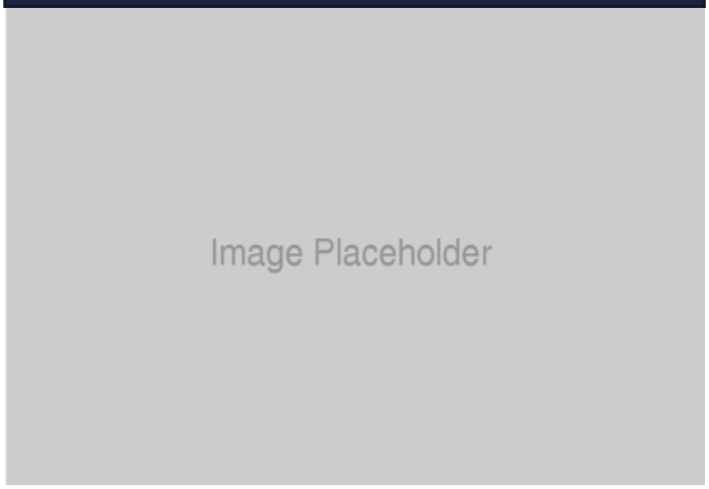
Purpose

Students begin to explore local climate change by using CODAP tools to investigate how temperature is changing in their home state.

Big Ideas

- Global climate is a composite of many local climates.
- Temperature trends in your home state may be similar to or different from global trends.

Title



Facilitation Suggestions

- Remind **students that they can revisit the Data Orientation section** if they need a refresher on how to use the CODAP tools.
- If students make mistakes with their graphs and need to start over, or they just want to try something new, point out **the undo button at the top of the graph and the RESET GRAPH button at the bottom right corner of the browser window.**

Undo:

Start Over:

Data Task 2: Compare Temperature Trends Across the States

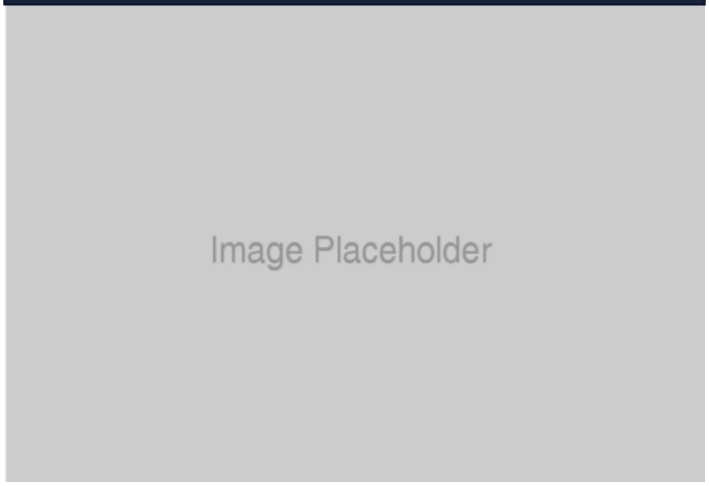
Purpose

Students compare temperature trends for different states and regions of the United States.

Big Ideas

- There is variability in local climate change.
    - Some states are warming, and some are cooling.
    - Rates of change vary by geographic region.

Title



Facilitation Suggestions

Check in **with students periodically to make sure they are able to successfully interpret the data.** When students get to the final steps, they will have to do some critical thinking about the data in order to arrive at a decision about how they would characterize climate change in the United States.

Without having them reveal their final choices, engage **students in a discussion around the patterns they see in the data and what criteria they are using to evaluate climate change for the country as a whole.**

Data Task 3: Compare Forecasts from 30- and 120-Year Trends

Purpose

Students compare forecasted temperature changes across the United States based on the most recent 30 years of data as well as the last 120 years of data.

Big Ideas

- There is variability in local climate change.
    - Some states are warming, and some are cooling.
    - Rates of change vary by timescale.

Facilitation Suggestions

- Check in **with students to make sure they understand what is being displayed in the maps and graphs**. Each map and accompanying graph shows forecasted temperatures based on trends in the data over two different timescales: 30 years and 120 years. Looking at these two climate timescales will show students that trends can change. In some cases, the forecasted temperatures may reflect that the trends for the two timescales differ in direction and/or steepness (rate of change).
- **When students get to the final steps, they will have to do some critical thinking about the data** in order to arrive at a decision about which timescale they think best supports their claim about how climate is changing in the United States.
- **Remind students that they should use the data to support and justify their claims,** not their opinions.

TRANSITION TO WRITING

Explain that students will next review their notes and complete a structured writing exercise to present their answers to the lesson question.

WRITING TASK: How is Climate Really Changing?

Estimated Time: 30 minutes

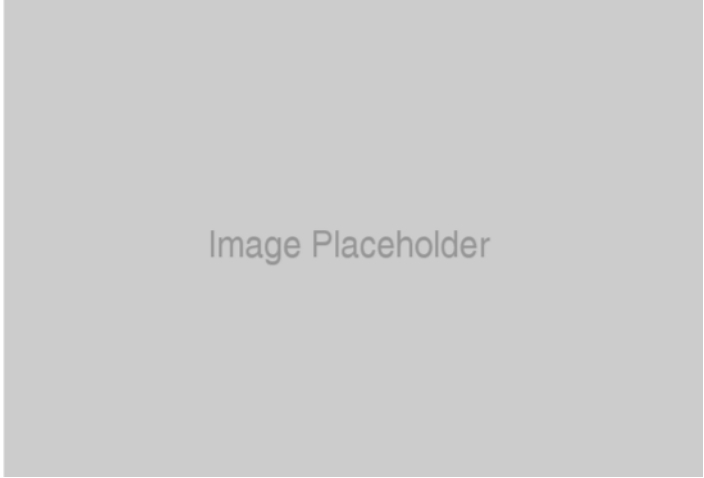
Purpose

Students synthesize what they have learned to address the lesson question.

Big Ideas

- Students can effectively communicate their answers to the lesson question by making evidence-based rebuttals to a false claim about climate change.
- Students use data as evidence and provide sound reasoning about how the evidence they chose supports their rebuttals.
- Students are able to pull together all pieces of the lesson to explain why understanding climate, weather, and climate change matters, or what people should do.

Title



Facilitation Suggestions

- Encourage **students to review their notes from the entire lesson and to revisit the Background section if they need a refresher** about the difference between weather and climate.
- Remind **students that there is no correct answer to this challenge**. The important part is to make a strong case for their choices using the data as evidence.

Assessment

Look for the following when evaluating students' writing tasks.

REBUTTAL

- Students should provide a clear definition of the difference between weather and climate and classify the events in the initial claim (cold temperatures and snow) as weather, not climate.
- Students should include information about timescale. Climate is an average taken over 30 years or more.

Sample Rebuttal:

Cold snaps and snow storms are examples of weather, not climate. Weather happens at a particular place and time, like a snow storm in New York City in April. Climate is an average of weather conditions taken over 30 years or more. Climate, both locally in New York and globally, can still be warming even if there are weather events that are opposite of what trends predict.

EVIDENCE

Students should provide **three** pieces of evidence to support their rebuttals, including at least one data visualization and specific data values and units.

Evidence could include:

- The slope of the trend line for global temperature data (in degrees Fahrenheit/year [°F/year])
- The slope of the trend line for state temperature data (in °F/year)

- Forecasted temperature change (in °F)
- Graph of global or state temperature data with trend line
- Map of forecasted temperature change

Sample Evidence:
My three pieces of evidence to support my rebuttal are the following:

1. *The trend line for global temperature shows warming of 0.0124* °F*/year from 1880–2017 and 0.0307* °F*/year over from 1987–2017.*
2. *State temperature data for New York show warming trends over the last 120 years and even faster warming over the last 30 years. From 1880–2017, the slope of the temperature trend was XX and from 1987-2017, it was XX.*
3. *The forecasted temperature changes based on the last 30 years of data are 0.02–7.13 °F warmer for all states, as shown in the map* Forecasted Change Based on 30 Years *in Data Task 3*.

REASONING
Students' reasoning should describe how their evidence supports their claim. Look for comparative language that shows students made their rebuttals by comparing trends in temperature over different timescales, geographic locations, and spatial scales.

Sample Reasoning:
My evidence supports my rebuttal because all of the climate data (data from 30 years or more) shows warming trends and forecasts both globally and locally.

CONCLUSION
Students' final conclusions about why understanding weather, climate, and climate change matters, or what people should do, should be written in clear, complete sentences.

Sample conclusion:
It is clear from the data that the planet is getting warmer. Changes in climate have the potential to have major impacts on the environment and human health and safety. Warmer temperatures could mean more extreme weather events, drought, shifts in animal habitats and migration patterns, coastal flooding, increases in infectious disease, and more. Because climate is a complex system, we cannot know exactly what will happen in the future, but we do know that many of the anticipated impacts of a warmer climate could be devastating. In addition to limiting things we know are contributing to global warming, like the burning of fossil fuels, we should work together to find additional creative solutions to slow and or stop warming.