Is the Climate Changing Where We Live?

Using data to investigate local climate change

Sarah J. Fick

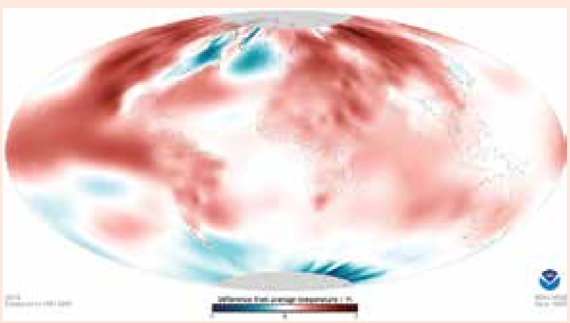
I recently overheard a student say a 70-degree day in February was perhaps a positive effect of global warming. He should have realized, however, that the weather on any given day is not evidence of climate change. It must first be averaged with that of other days to show a change in trends. Casual conversations about climate change tend to focus on daily high temperatures, when, in fact, researchers have found that average low temperatures are increasing at a faster rate, narrowing the range of temperatures over time (Davy et al. 2017).

One way to tackle such climate misconceptions is to have students work with data to show how the climate is changing in their local community. The National Oceanic and Atmospheric Administration (NOAA) has weather stations nationwide that collect data on air temperature and precipitation that are freely available online. This article describes a lesson in which students use this data to observe and analyze climate trends and investigate how local climate trends may (or may not) differ from those in other parts of the country and the world (Figure 1).

The raw data from NOAA require labor-intensive processing. This work has been pre-completed to make the data understandable and usable in the classroom. The prepped data are available online in a series of folders for selected locales across the country (see "On the web"). Within each folder are six files—two each for the minimum, maximum, and average temperatures for that location. In each pair, the filename ending in "_analyzed" is the pre-analyzed data with the averages calculated and graphs generated (as described below); the other file in the pair has no analysis completed. (Of course, you are welcome to clean and prepare your own data files; see "On the web" for guidelines.)

FIGURE 1

Global differences in average temperature.



NOAA

The following lesson, presented in the 5E format, is one possible approach to using these data that aligns with the *Next Generation Science Standards* (NGSS Lead States 2013; see box, p. 31). Figure 2 lists goals for the lesson. See “On the web” for a worksheet to hand out before the students begin.

FIGURE 2

Learning and performance goals.

Possible science content learning goals for this lesson include:

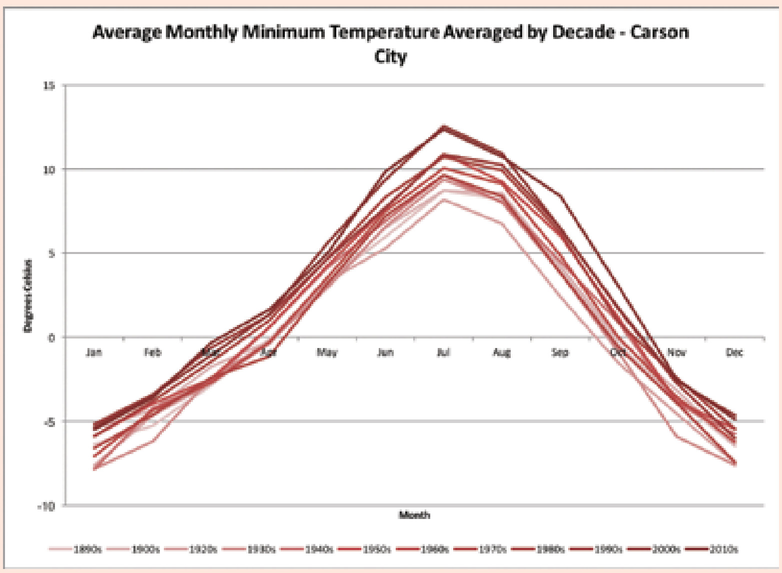
- The climate is changing in most locations throughout the United States, but depending on your location those changes might be more or less extreme than changes in other locations.
- The climate is not changing equally between high and low temperatures, with lows increasing at a faster rate in most locations than high temperatures.

Performance goals for the lesson include:

- Students analyze weather data for a variety of locations throughout the United States (or the world) to support an explanation that there is a national (or global) trend of climate change showing small increases in high temperatures, and larger increases in low temperatures.

FIGURE 3

Average monthly low temperature averaged by decade: Carson City, Nevada.



GRAPHS GENERATED WITH DATA SUPPLIED BY NOAA

Engage: Eliciting prior knowledge about weather and climate

Begin the lesson by introducing the investigation question: “Is the climate changing where we live?” Have students articulate the difference between weather and climate. Understanding this distinction will help them make decisions about how much data are needed to represent climate later in the lesson. The first two questions on the worksheet (see “On the web”) help students think about the difference between short- and long-term weather trends, what kind of data support claims about climate, and how it might be analyzed.

Describe to students the local data set they will work with. What kind and how much data are included? Where was it collected? Next, students should address question 3 on the worksheet, developing an initial plan for how the data might be analyzed. Then have the students predict what they will see. (They may need to be reminded about local seasonal temperature trends.)

Information about the data files

The spreadsheet files in the location folders include the daily high/low/average temperatures (depending on which file is opened) for the station. Within the file, the data are separated onto different sheets by decade, and within each sheet one month of one year is represented across a row. Reviewing the analyzed file will show you that for each day of a month, the monthly high/low/average temperatures were calculated and then averaged by decade.

Explore: Developing a plan for analysis and then analyzing the data

Remind students again about the investigation question, then give them one of the data spreadsheet files. The data sets allow for differentiated instruction according to experience level.

Supply students with either the analyzed or unanalyzed data. Students using the unanalyzed files will need to determine how much data to use in their averages, whether to average by day or by month, and how to represent the data (share with them tips for using spreadsheets; see “On the web”).

If you provide the analyzed files instead, the “average monthly temperatures arranged by decade” is probably the easiest graph for students to use. For advanced students, consider deleting the supplied graphs so they can determine for themselves how best to represent the data to illustrate patterns.

Explain: Finding patterns in the data and building arguments

Remind students that they should be looking for patterns that help answer the investigation question. The variation in the data from month to month can be messy, which could lead students to miss the broader patterns, yet working with and explaining messy data is an important part of generating science knowledge.

Explain to students that in the graphs (as shown in this article), the darker the line color, the more recent the data. For example, Carson City, Nevada, has seen an increase in low temperatures (Figure 3) at a higher rate than high temperatures (Figure 4). This can be seen when comparing the two graphs because all of the lines in the high temperature graph seem to overlap almost directly throughout the year (Figure 4), while the lines in the low temperature graph are much more spread out, with the more recent decades showing significantly higher temperatures than the earlier ones (Figure 3).

After analyzing the initial local data set, have students develop an explanation, supported by evidence, about whether the climate shown in the data sets is changing. Encourage students to look for potential seasonal differences in the data trends and to be specific when identifying the trend line from the earliest (likely this time period includes several overlapping decade lines) and the trend line from the most recent data, and the difference between these trends at different points in the year.

Students should then consider whether the data they observed is sufficient to verify global climate change. Have them think through what data they would need to confirm this trend on a larger scale. Ideally, students will realize that they need to consider data from other locations and other representations of climate such as extreme events and precipitation.

FIGURE 4

Average monthly high temperature averaged by decade: Carson City, Nevada.

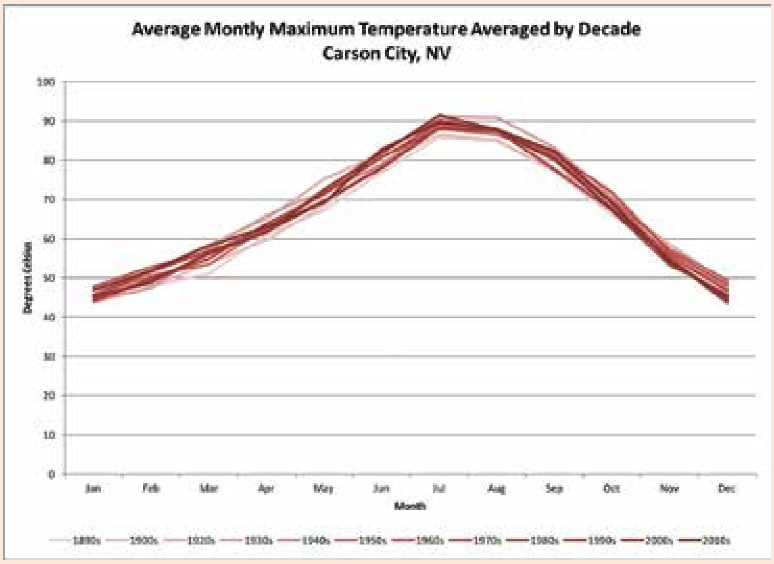
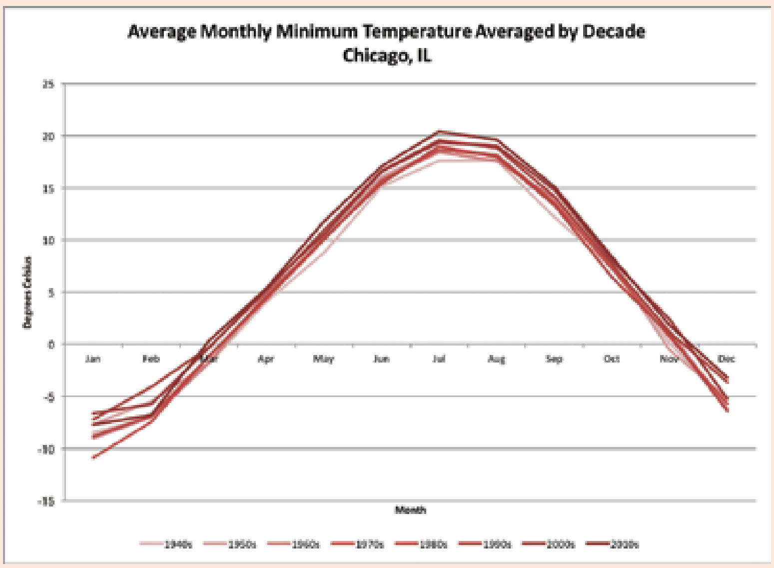


FIGURE 5

Average monthly low temperature averaged by decade: Chicago.



Analyzing complex graphs

Have students segment the graphs, say, by month or season, and review one section at a time. The graphs in the data sets are samples. Your class can choose to represent the data however they decide. (For books discussing the strengths and weaknesses of different representations, see "Resources.")

FIGURE 6

A sample scientific explanation.

Part of the scientific explanation	Sample response
Claim	The climate is changing in the United States and at different rates in different locations, with the overnight low increasing faster than the daily high across most locations studied.
Evidence	In three cities (Nevada City, High Point, and Portland), the 10-year-average low temperature is increasing at a faster rate than the 10-year-average high temperature over the last 40 years from the previous 40 years. For each of these cities, the greatest amount of increase is in the summer low temperatures. In some cities (for example, Chicago), there was no obvious change in the 10-year-average low or the high temperature over the last 40 years from the previous 40 years.
Reasoning	Climate is weather averaged over a long period. A 10-year average of the daily or monthly temperatures can be used to represent climate at a particular time point.
Counterargument	Not all of the cities have increasing average high or low temperatures.
Rebuttal	For there to be global climate change, there does not need to be consistent effects in all locations. It could be that the increase in some locations is so significant that it more than averages out decreases in isolated locations.

Elaborate: Comparing local conditions with national and global trends

Students should recognize that local changes in weather data might be more or less extreme than those elsewhere. For example, students in Chicago (Figure 5) might find that the average temperature stays roughly the same over time, unlike the trends in the western United States.

Have students compare local changes with broader ones to make predictions about what they would observe in other parts of the country; then have them check those predictions by analyzing a data set from one of those other areas.

If your students analyze only local data, they may form inaccurate ideas about climate change, such as the climate is not changing or the climate is changing at the same extreme rate throughout the world. Examine climate information from multiple locations (Figure 6) for the lesson to work successfully.

Evaluate: Revisiting arguments for the existence of climate change

An important concluding activity is having students write scientific explanations about whether the evidence supports the claim that the climate is changing. Have students write explanations on large sheets of paper for display around the classroom and group their explanations by theme. Then have a group discussion about which claims are better supported by the evidence. After the discussion, have students write a final explanation individually. Then have students individually compare their initial ideas about climate change with those they developed mid-lesson and at the end. Students should describe how the lesson has changed their understanding of climate change.

Extension: Challenges with the data sources

Please note that data in each location is affected by specific geographic and environmental conditions. For example, in Los Angeles (Figure 7, p. 30), the highest average temperatures occurred in the 1990s, possibly related to local smog. While the low temperatures in Los Angeles have decreased more recently, the average remains higher than historical averages. Stations in urban areas likely experience elevated temperatures due to the heat island effect (see “On the web”). For areas where the temperature change is smaller and harder to distinguish, statistical tests might help students understand whether the difference in temperatures is significant (Bowen and Bartley 2013).

Extension: Discussing messy data

In the data sets, decades may have varying numbers of years of data. Decades with less than five years of data tend to make the average swing wildly, because each year is more heavily weighted, which can make a pattern difficult to see. Discuss with advanced students what to do with decades that have very few values making up the average. Likewise, when averaging daily data, you will need to determine what to do with values 28–31 each month and how they will contribute to the average. Daily averages (Figure 8) show more change over time. Making decisions about how to analyze daily averages, such as how many decades' worth of data is enough to be representative of climate, is also challenging.

Extension: Very little available time

If analyzing the data sets seems too advanced or time consuming for your class, a simplification is to provide them with the pre-made graphs of average monthly temperatures arranged by decade to analyze. ■

Sarah J. Fick (ficksj@wfu.edu) *is an assistant professor of science education at Wake Forest University in Winston-Salem, North Carolina.*

On the web

EPA Urban Heat Islands: *www.epa.gov/heat-islands*

Guidelines for preparing NOAA data yourself; worksheet handout: *www.nsta.org/highschool/connections.aspx*

NOAA climate data primer: *www.climate.gov/maps-data/primer/climate-data-primer*

NOAA data prepped for classroom use: *http://bit.ly/2tFUarW*

Tips for using spreadsheets: *http://bit.ly/2t5fqFR*

Resources

Information about data and statistical analysis:

Bowen, M., and A. Bartley. 2013. *The basics of data literacy*. Arlington, VA: NSTA Press.

Books about helping students develop and discuss representations of data:

Cartier, J.L., M.S. Smith, M.K. Stein, and D.K. Ross. 2013. *5 practices for orchestrating productive task-based discussion in science.* Reston, VA: National Council of Teachers of Mathematics and NSTA Press.

Michaels, S., A.W. Shouse, and H.A. Schweingruber. 2008. *Ready, set, science!: Putting research to work in K–8 science classrooms*. Washington, DC: National Academies Press.

References

Davy, R., I. Esau, A. Chernokulsky, S. Outten, and S. Zilitinkevich. 2017. Diurnal asymmetry in the observed global warming. *International Journal of Climatology* 37 (1): 79–93.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.

FIGURE 7

Average monthly low temperature averaged by decade: Los Angeles.

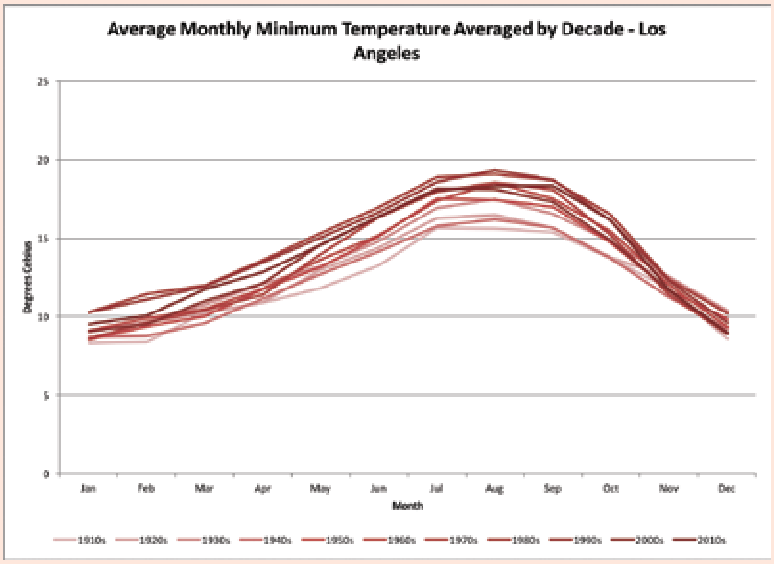
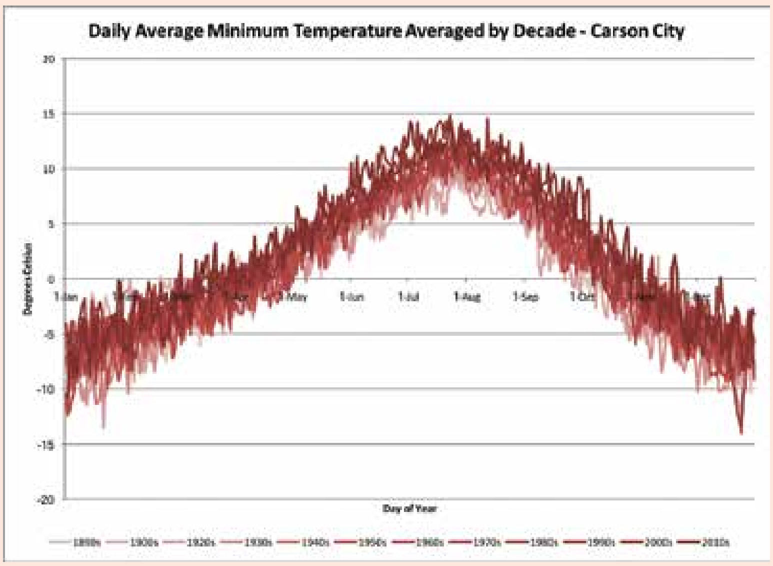


FIGURE 8

Daily average low temperature averaged by decade: Carson City, Nevada.



Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013).

Standards
HS-ESS2 Earth's Systems
HS-ESS3 Earth and Human Activity

Performance Expectations
The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities. The activities outlined in this article are just one step toward reaching the performance expectations listed below.
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.
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
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.

Dimension	**Name and *NGSS* code/citation**	**Specific connections to classroom activity**
Disciplinary Core Ideas	**ESS2.D: Weather and Climate** • The foundation for Earth's global climate systems is the electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's re-radiation into space. (HS-ESS2-4) • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-4) **ESS3.D: Global Climate Change** • Human activities, such as the release of greenhouse gases from burning fossil fuels are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5)	Students analyze evidence of recent climate change, which can be connected to changes in carbon dioxide concentrations. These activities show the heat is not being re-radiated into space at the same rate that it used to be, causing an increase in low and high temperatures.
Science and Engineering Practices	**Analyzing and Interpreting Data** • Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5) **Asking Questions and Defining Problems** • Ask questions to identify and clarify evidence of an argument. (MS-ESS3-5)	Students use evidence from historical weather data to show changes in local and national climate.
Crosscutting Concepts	**Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5) • 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)	Students analyze data to show that climate was historically more consistent than it is presently.