BIG DATA

SMALL DEVICES

INVESTIGATING THE NATURAL WORLD USING REAL-TIME DATA

Donna Governor
Michael Bowen
Eric Brunsell

NSTApress
National Science Teachers Association

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Arlington, Virginia

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1840 Wilson Blvd., Arlington, VA 22201
www.nsta.org/store
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ABOUT THE AUTHORS

Donna Governor is an assistant professor of science education at the University of North Georgia (UNG). Before joining UNG in the fall of 2016, she was a high school Earth and advanced placement environmental science teacher in Cumming, Georgia. She has taught all grade levels as a K–12 classroom teacher for more than 30 years. Donna holds a PhD in Science Education from the University of Georgia and has won multiple awards, including the Presidential Award for Excellence in Science Teaching (2007) and the Outstanding Earth Science Teacher for Georgia (2014). Donna is a past president of the Georgia Science Teachers Association and has served as a district director for the National Science Teachers Association (NSTA). She also has been a presenter at local, state, and national conferences for more than 20 years.

Michael Bowen holds a doctorate from the University of Victoria in Canada. After studying the research practices of field biologists, he developed curricula for middle school students that were tested with sixth- and seventh-grade students in the classroom and outdoors. Following a postdoctoral fellowship in the sociology department at Trent University in Ontario, he became a member of the faculties of education at three Canadian universities: Lakehead University, the University of New Brunswick, and Mount Saint Vincent University (where he is now an associate professor). His research has been presented at national and international conferences in Canada, Europe, and the United States. Michael has served as a district director for NSTA and has co-authored two other books for NSTA Press and numerous articles for its journals.

Eric Brunsell is an associate professor of science education in the Department of Teaching and Learning and the director of the professional education programs at the University of Wisconsin Oshkosh in Oshkosh, Wisconsin. Eric earned his EdD in curriculum and instruction with an emphasis in science education from Montana State University. He is a former high school science teacher and has served as NSTA district 12 director and on the NSTA Board of Directors as the professional development division director. He is also the chief operations officer for the Wisconsin Society of Science Teachers. Eric has written two other books, edited two book compilations, and provided professional development sessions and presentations throughout the United States and internationally.

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Donna would like to acknowledge Dr. Tim Slater for introducing her to the world of real-time data when the internet was still new. Dr. Slater has been an important mentor to Donna over the years and given her multiple opportunities to grow and develop as an education professional.

Mike's interest in real-world "messy" data and how that could be represented in complex graphs heightened during his MSc(Res) with encouragement from his supervisor, John Sprague. During his work as a middle school science teacher, his eighth-grade students inspired him further in this area, and his PhD supervisor, Wolff-Michael Roth, was a wonderful mentor and supported his later research and writing about graphing, data table use, and other data literacy areas.

Eric would like to acknowledge David Braunschweig for showing him the power of having students use data to create and revise models of scientific phenomena. Eric was a student teacher with David in his Madison, Wisconsin, physics classroom 20 years ago.

PREFACE

In the HBO (Home Box Office) series *From the Earth to the Moon*, there is a dramatization of the field geology training that was provided to the Apollo astronauts assigned to the final three missions. Geologist Lee Silver (played by David Clennon) offered an analogy about "context." He said, "If you brought me a dead cat, I can tell you two things about it: It was a cat, and it is dead. If you told me you found it in the middle of the road … what killed the cat? What if you found it in the kitchen of your favorite restaurant?" He was referring to context as the difference between road kill and a meal.

And what does access to large data sets provide to students? It provides a number of supports for learning—most importantly, context. As has been frequently cited in science education reform documents, science learning has often been approached in a manner that has been very broad at the expense of depth. Coverage, it seems, can be the enemy of understanding (Gardner 1991). Context can provide the necessary depth for understanding by making explicit the connections between the science content that we wish for students to learn and the real world. The real world is complex and defies simple understandings—or rather, simple understandings are inadequate for grasping the complex, multivariate patterns that are inherent to the natural world.

This volume embraces the fact that the natural world is complex and multivariate, but through the three-dimensional learning structure of *A Framework for K–12 Science Education* (*Framework;* NRC 2012), this complexity is not necessarily complicated. Complex systems operate on a variety of scales and evolve over time with the amount of energy present in the system (Fichter, Pyle, and Whitmeyer 2010). Understanding systems, a fundamental part of the crosscutting concepts, does not mean that a deterministic outcome is available. Rather, recognizable patterns can be displayed by comparing data related to natural Earth phenomena, whether they are the mapped distribution of earthquake epicenters or the variations in temperature and humidity with altitude across locations. The more data that are available, the more robust are the inferences that can be made regarding complex relationships, and the clearer is the pattern that can emerge. By analyzing changes in the patterns, other crosscutting concepts can be accessed, such as stability and change; cause and effect: mechanism and explanation; and scale, proportion, and quantity.

The other critical aspect of the *Framework* that goes beyond the disciplinary core ideas is the practices employed by scientists and engineers as they go about their work. This volume is well-positioned to use the science and engineering practices to provide context as well. As was illustrated in the now infamous "climategate" email hacking incident (Cook 2016), the public has a different understanding of "data manipulation" than scientists employ. To properly analyze and interpret data, particularly large data sets, scientists have to organize the data in a manner that makes sense for generating and testing models, as well as for generating arguments from these data. A connective practice is the use of mathematical and computational thinking, which not only provides context to scientific thinking, but also provides a platform for teachers of mathematics and science to reconcile language and terminology differences that cause students to have endless frustration.

Context for large data sets thus is critical not only to scientific understanding, but also to learning how to understand the natural world from a scientific standpoint. Fundamentally woven in the performance expectations within the *Next Generation Science Standards* (*NGSS;* NGSS Lead States 2013), context is the basis by which we can distinguish ourselves from the automated devices we use to collect such data and evaluate whether or not the data are accurate, valuable, and sufficient. I trust you will find this volume useful not just in teaching science, but also in using science as a way to grasp the complexity of the natural world with awe and wonder, instead of fear.

Eric J. Pyle, PhD
NSTA Division Director, Preservice Teacher Preparation
Professor, Department of Geology and Environmental Science
Coordinator, Science Teacher Preparation, College of Science and Mathematics
James Madison University

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PART 2

SAMPLE ACTIVITIES USING REAL-TIME DATA

INTRODUCTION

This is the section you have been waiting for! Here, we provide sample activities for more than two dozen real-time investigations in your classroom. Each activity includes teacher notes that provide information for three-dimensional learning (disciplinary core ideas [DCIs], science and engineering practices, and crosscutting concepts), as well as background and technology information, an explanation of the data, and suggestions for scaling the lesson up or down.

Each activity also has a student handout that generally was developed at Level 1 or 2 of Tamir's Levels of Inquiry (see Table 3.1, p. 28). In most activities, both the problems and the procedures are given. Teachers who want to boost the level of inquiry might choose to forego the worksheet and initiate investigations that require greater student involvement in identifying problems and/or developing procedures. The data notes include information about the type of data, how to sample it, and what issues might need clarification. In addition, data enrichment exercises suggest other ways to explore the data.

The technology notes provide appropriate websites and apps (when available) from which to retrieve the data. We have attempted to use the most stable sources and to suggest multiple app options. Generally, websites for government agencies are stable for long periods—some, such as the National Oceanic and Atmospheric Administration (NOAA) and U.S. Geological Survey (USGS), have used the same internet domain for decades—however, over time, some URLs are likely to change. Should that occur with a resource provided in our activities, a web search often can provide the site's updated website link. Apps are much newer than internet domains in the world of technology; while you are using this book, newer, better apps might become available and some that we suggest here might be phased out. Again, a simple search through a browser can provide up-to-date resources.

Activities are grouped into chapters by the sphere of Earth they investigate: atmosphere, biosphere, geosphere, hydrosphere, and celestial sphere. These are tied directly to the DCIs that are connected to the *Next Generation Science Standards (NGSS)*. Although not every state has adopted or will adopt the *NGSS*, many of the DCIs are parallel to core ideas represented in state standards. The crosscutting concepts and science and engineering practices are not just integrated in *NGSS*, but are part of true three-dimensional learning as outlined in *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC 2012). Although most of these investigations use multiple practices and concepts, we have narrowed the focus to one or two of each. We did this to emphasize the corresponding practices and concepts in the activities and analysis questions presented for students to address. For all websites, teachers should provide students with QR Codes for easy website access. Every activity provides links to the online sources it uses, and at the end of each chapter there is a table with the QR Codes for those online activity resources. If you are using a website not included in this text, you can easily make QR Codes for it. Just do an internet search for "QR Code generator" and several websites will appear in your search results that will allow you to generate your own QR Codes.

As you review these activities, you will see other ways to address the investigations and use the data. Good! We want these activities to be starting points for conducting real-time investigations, and hope we have given you the tools in the preceding chapters to develop inquiry activities that are well suited to your curriculum and students.

AVOIDING ASSUMPTIONS

Before we move on, there are two instructional implications that merit discussion. Having taught students at all levels from kindergarten through high school, Donna has some insights to share about working with big data that will make it easier for students to understand those data. The first one is that real-time data investigations can be used with students as young as third grade, depending on the investigation and the data. In some cases, the same data can be used at different levels for different purposes. At other times, you will need to filter the data or tailor the questions about a phenomenon to the level of your students. Regardless, let the purposes of your investigation drive your decisions about what data to use and how students should work with it.

Second, geography skills might also be an obstacle for your students when working with real-time data. Depending on the students, there might be significant gaps in their ability to locate events on a map and/or in their general understanding of the location where the data were produced. Although latitude and longitude are often introduced in elementary social studies, with mastery expected in middle school, many high school students struggle with this skill. Maps deal with information that is very abstract, for example, large distances; places students have never been; and information from within Earth, where even pictures provide little useful context.

MAPS AS ABSTRACTIONS

To help students deal with the abstract nature of maps, consider having them construct a to-scale map of a small local park or of the school grounds or even part of the school building. You will notice that in their maps, students leave blank areas, that is, areas with no content. You can engage students in talking about these blank areas, transition zones (outside), and other map-related issues. That conversation and problem solving, that is, the work of getting the map right, will give students understanding and context for thinking about and discussing maps they will use for activities in this book and elsewhere.

Whether you are discussing photoperiods at different latitudes; radiosonde data over Little Rock, Arkansas; ocean acidification in Grey's Reef; or plate tectonics off the coast of Australia, it helps to have a globe and a map handy. When possible, use local data. When you are not using local data, be sure to point out the location where data were generated and to discuss its relative location, using maps and a globe. Spend a minute reviewing how to find latitude and longitude on a map and choose a map projection that is easy for students to use. Sharing relevant news articles also engages your students and helps them see that the data they are using are current and are happening in real time and in real locations. This type of application integrates concepts across disciplines and engages students in authentic learning experiences.

USING GATHERED RESOURCES IN THE CLASSROOM

Data from government-funded research are public (in the public domain) and are not protected by copyright; however, you should always look for current content copyright policies on the relevant websites and apps. There are many resources for learning more about fair use for educational purposes. For example, Stanford University provides an online handbook on copyright for educational use (*http://fairuse.stanford.edu/overview/academic-and-educational-permissions*). Also, Cornell University provides an online checklist for conducting a fair-use analysis before using copyrighted materials (*http://copyright.cornell.edu/policies/docs/Fair_Use_Checklist.pdf*).

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5

INVESTIGATIONS USING REAL-TIME ATMOSPHERE DATA

Real-time atmosphere data covers a broad range of phenomena, including weather, air quality, ozone, climate, and more. Weather data are collected by satellites, radar, ground-level instruments, and radiosondes (instruments attached to weather balloons that collect and transmit data about atmospheric conditions).

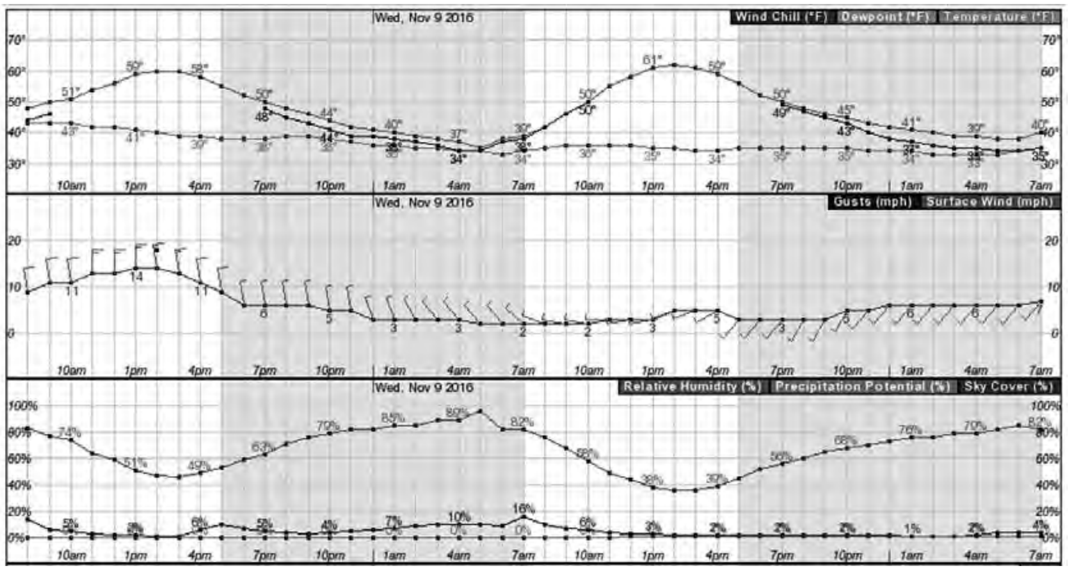
Real-time weather data are probably the most familiar. Long before "the internet" was a household term, weather data were reported in near real time in daily newspapers, on the radio, and on television news. Today, available weather data are much more comprehensive, and can easily be obtained for any city in any country, including past observations and predicted conditions. Public sources of atmospheric data include the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (EPA), NASA, and the National Weather Service (NWS). Other sources include the American Meteorological Society (AMS) and other nonprofit organizations, The Weather Channel, public and private colleges and universities, and private corporations.

Below, we share some of the most useful sources through which weather data that are accessible; in addition, Tables 5.1 and 5.2 (pp. 108 and 109, respectively) list all digital resources used in the chapter. Then, the rest of the chapter contains sample activities. You might want to use these activities as-is or modify them to fit your instructional purposes and students' ability levels. You might also find that our suggestions for using the data will trigger ideas for other investigations with those data.

The primary source of weather data is the NWS (*www.weather.gov*), whose website provides data for current conditions, including cloud cover, temperature, wind speed, wind direction, air pressure, and dew point. On their site, you will also find weather maps showing current conditions, locations of fronts, and predicted climate trends. In addition, past and predicted data are available there in multiple formats—text, charts, maps, tables, and graphs.

The NWS provides predictions in meteogram format (Figure 5.1, p. 72). Meteograms are a graphical model of weather and are used to analyze hourly data over a short period of time. One way to use a predictive meteogram is to have students use current weather maps to explain what factors might be influencing a forecast. For example, if students know that mid-latitude weather comes from the west, can they develop an argument that supports the predicted weather trends? Another possible activity would be for students to compare the weather outlook with actual weather data, and to assess whether temperatures rose and fell as expected, whether predicted precipitation arrived, and how accurate the outlook was.

Figure 5.1. National Weather Service meteogram for Des Moines, Iowa

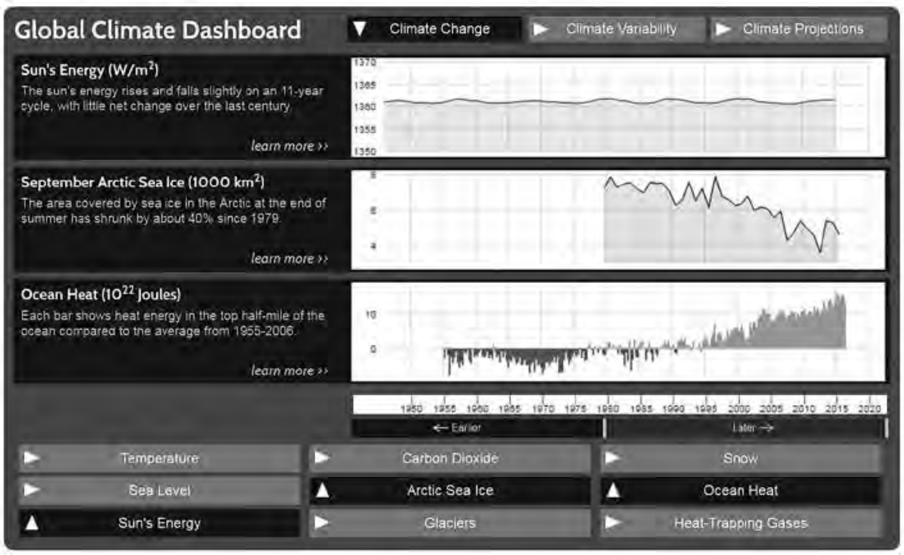


Source: http://forecast.weather.gov/MapClick.php?lat=41.57263&lon=-93.61571&unit=0&lg=english&FcstType=graphical

One of Donna's favorite websites for real-time weather data is *DataStreme* from the AMS (*www.ametsoc.org/amsedu/dstreme*). The *DataStreme* site was developed for use with a continuing education meteorology course for teachers, sponsored by the AMS. In addition to the meteorology course, they also have continuing education courses about oceans and about climate. The *DataStreme* site includes data provided for teachers enrolled in their course, but Donna has used it with middle and high school students. Their maps with surface data can be used to create isotherms or isobars (bands of equal temperature or equal pressure, respectively) and to explore wind patterns. Blank charts are available for students to create their own Stüve diagrams illustrating the vertical atmospheric temperature profile, or to create meteograms using NOAA data. In addition, educational materials are available from the *DataStreme* website and if you are interested, you might want to explore some of their continuing education courses for teachers.

If climate data are what you need, then NOAA is the most comprehensive source for long-term climate trends. One of its divisions, the National Climate Center (*www.climate.gov*), provides data on historical temperature, precipitation, drought, snow cover, carbon dioxide (CO_2) concentrations, solar energy output, and more. Using their *Global Climate Dashboard*

Figure 5.2. Screenshot from the NOAA Global Climate Dashboard



Source: www.climate.gov

(Figure 5.2), students can compare current data to overall trends and construct arguments that support or refute claims about the possible variables influencing climate change.

The NOAA *Environmental Visualization Laboratory* (*www.nnvl.noaa.gov*) is a rich source of atmospheric data for clouds, wind currents, stratospheric ozone, snow cover, and more, provided in graphic and animated formats. NOAA also provides real-time data on space weather (*www.swpc.noaa.gov*), which affects our atmosphere in multiple ways. For example, magnetic storms on the Sun interact with Earth's upper atmosphere to generate beautiful auroras, and long-term trends in the sunspot cycle have correlations with climate variations.

Air quality information is important in any environmental study of our atmosphere. The AIRNow website (*www.airnow.gov*) provides air-quality data hourly that includes tropospheric ozone and particulate matter ($PM_{2.5}$ and PM_{10}). The EPA website (*www.epa.gov/air-data*) provides daily concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), particulate matter (PM), and other pollutants. Student investigations can connect weather patterns to air quality, seasonal variations, and population, and can compare urban and rural areas. Want to know what the sources of air pollution are your area? The EPA website provides information about specific pollutants on their *Where You Live* page (*www3.epa.gov/air/emissions/where.htm*).

Webcams cannot be overlooked as a source of real-time data for weather. The NWS has webcams in many locations that students can use to correlate weather variables, such as cloud cover and air pressure data. Traffic, school, and other webcams can also help students to investigate weather trends, track local storm systems, and observe the effects of weather on the environment and the behaviors of people and animals.

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Climate.gov. *www.climate.gov*.

TEACHER NOTES: AIR QUALITY

Learning Goal	Students will explore the relationship between tropospheric ozone and temperature and how human populations affect ozone levels.
Disciplinary Core Ideas	• Weather and climate • Human impacts on Earth systems
Science and Engineering Practices	• Analyzing and interpreting data • Engaging in argument from evidence
Crosscutting Concepts	• Energy and matter: Flows, cycles, and conservation • Stability and change
Background Information	Tropospheric ozone is a gas that occurs naturally in the atmosphere in small amounts. It is also produced by photochemical reactions when sunlight interacts with pollutants such as nitrous oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs) produced by automobiles, industry, and other human activities. High levels of ozone in the troposphere present a health risk to humans and other organisms. In people, respiratory problems are more likely to occur when ozone levels are elevated, which can be especially problematic for people with asthma. Because sunlight and heat increase ozone formation, ozone levels are often higher in summer than in winter. Also, because it is formed from pollutants such as CO, NO_x, and VOCs, ozone levels are usually higher in high-population areas than in rural areas.

DATA AND TECHNOLOGY

Online Sources	• AIRNow website (*www.airnow.gov*) for air-quality data • Weather Underground website (*www.wunderground.com/history)* for climate data • QR Codes: See Table 5.1 (p. 108).		AIRNow website screenshot  Source: www.airnow.gov.
App and Device Sources		*Weather History Explorer* app for weather history data Device platforms: Android, iOS	
		AIRNow app for air-quality data Device platforms: Android, iOS	

DATA AND TECHNOLOGY (*continued*)	
Technology Notes	Although there are dozens of apps that provide current air-quality data, the authors found no apps that provide historical data. The EPA *AIRNow* app provides current data. To find historical data, students should access the EPA AIRNow website through a browser on a computer or their device. This should not present much of a problem, because the data are easy to access through the website.
About the Data	**Data Sampling:** You might need to help students determine how to sample fairly. For instance, students might pick a particular day of the month to sample at a particular time or if there are multiple measures each day, they might calculate the mean (average) temperature for the day. **Data Type:** Temperature and ozone level are interval–ratio (measured) types of data. **Data Issues:** More-astute students might notice that the months being different lengths could cause minor data variation on the horizontal axis. One solution to this is to divide the number of days in a year by 12 and then measure at the same point in each of those periods. This will result in 12 evenly spaced measures; note they will be on different dates of each calendar month.
USING AND ADAPTING THE ACTIVITY	
About the Activity	Ozone levels are reported using an air quality index (AQI) that corresponds to actual ozone levels. The EPA AQI of 100 represents ozone levels of 0.075 parts per million (ppm) averaged over an 8-hour period. Levels of 0.070 ppm are considered the standard for EPA regulations. Students will need to understand that the method of data sampling will present outliers, because air quality is also affected by weather conditions such as wind, sky cover, and precipitation, which affect the availability of pollutants and/or the amount of sunlight available for photochemical reactions.
Scaling Down	Use a jigsaw activity by having students work in pairs, with each pair collecting one data point and sharing with the class. You can also use an app and track data over long periods of time, starting early in the year. Have students collect daily data and record it on a class weather calendar to correlate temperature and ozone only, without comparing it to less-populated areas. By the end of a full semester, the amount of data collected will be sufficient for analysis.

USING AND ADAPTING THE ACTIVITY (*continued*)	
Scaling Up	Have students collect other weather data, such as precipitation or wind speed. Then, they can compare data from sunny dates to data from rainy dates as an additional variable in producing photochemical ozone, or explore the role of wind in reducing pollutants. Students can also collect data related to population density for urban areas.
Extending	**Ozone Monitoring:** Students in urban areas can use ozone test strips to monitor ozone levels near their school. **Ozone Up High:** If it is the same molecule, why is ozone considered bad low in the atmosphere but good when up high in the atmosphere? Students can investigate stratospheric ozone using the NASA app *Earth Now,* and compare stratosphere and troposphere ozone levels. **Enrichment Using Data:** Have students construct a meteogram for temperature and ozone level (with the time variable on the horizontal axis) to examine variation over the year.

ASSESSMENT NOTES
Although ozone levels vary seasonally, they will be higher in the summer than at other times of the year because of increased ultraviolet light levels. Generally, trend lines should show a greater correlation between ozone and temperature in urban areas than in rural ones.

Name: ___________________________

STUDENT HANDOUT: AIR QUALITY

Activity Goal	In this activity, you will explore the relationship between tropospheric ozone and temperature, as well as the effect of human activity on air quality.
Technology Notes	• Collect air-quality data from the EPA AIRNow website (*www.airnow.gov*). • Retrieve climate data from the *Weather History Explorer* app or the Weather Underground website (*www.wunderground.com/history*).
Orientation Questions	• Why are air-quality alerts more common in the summer than in the winter? • Why are urban areas (cities) more likely than rural areas to have air-quality alerts? • How do urban populations affect air quality?
Directions	1. From the list of monitored cities and states provided on the AIRNow website, choose a major city for which to collect data on ozone levels and temperature. In the data table, write that city beside the column heading "Urban Area." Groups should collect data from different locations. 2. From the same list of monitored cities and states, choose a rural area or a national park station that is geographically outside your chosen city. In the data table, write that location beside the column heading "Rural Area." You might have to look at locations in more than one state to find an acceptable location. 3. Using the Weather Underground website or the Weather History Explorer app, collect high-temperature data for both locations on the first Wednesday of every month for the past 12 months. Record the data in the data table, using °C or °F, as instructed by your teacher. 4. Using the AIRNow website, collect the ozone-level data for the same dates in both locations. 5. Complete the Data Analysis scatter plots for your data. 6. Complete the Analysis Questions, Conclusion, and Reflection Question sections.

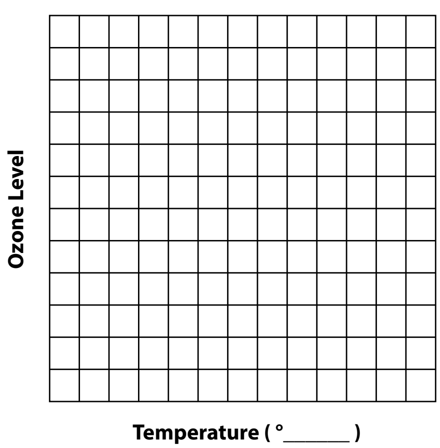
Data Table

Month	Urban Area:		Rural Area:	
	High Temperature (°______)	Ozone Level	High Temperature (°______)	Ozone Level
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

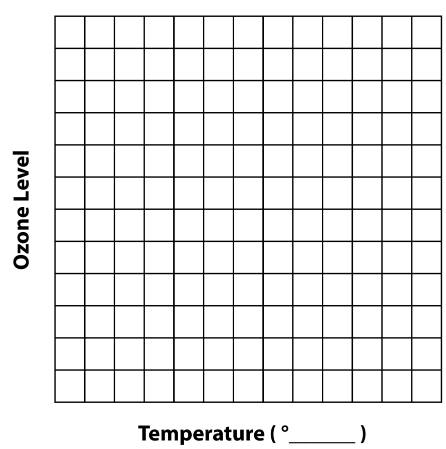
Data Analysis

To present your data, create a scatter plot showing results for each location, and then draw a best-fit trend line on each graph.

Urban area scatter plot



Rural area scatter plot



Analysis Questions

1. What relationship is there between temperature and ozone level?

2. Based on what you understand about ozone production, how would you explain the outliers?

3. Describe the differences between an urban ecosystem and a rural ecosystem.

4. What difference, if any, did you note in the ozone-level data between the urban and rural areas?

5. Based on what you understand about ozone production, how would you explain the difference?

6. Compare your data to other groups. What similarities did you find in the data for urban and rural areas? What differences? How would you explain the differences?

Conclusions

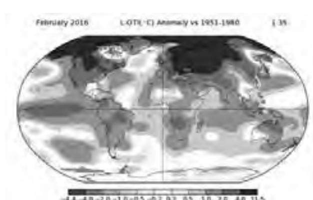
Construct an argument based on the data you and your classmates collected, that explains the effects of human activity on air quality. Use examples from all of the data (yours and others') to support your claim. Describe how your understanding of energy and matter flow in a system is related to your findings.

Reflection Questions

1. Why is population density in urban areas a factor in tropospheric ozone production?

2. What is the role of seasonal solar energy input in tropospheric ozone production?

TEACHER NOTES: CLIMATE FROM POLE TO POLE

<table>
<tr><td>Learning Goal</td><td colspan="2">Students will use mean (average) temperature data to determine changes in surface temperature over time in different areas of Earth.</td></tr>
<tr><td>Disciplinary Core Ideas</td><td colspan="2">• Earth’s systems
• Weather and climate</td></tr>
<tr><td>Science and Engineering Practices</td><td colspan="2">• Using mathematics and computational thinking
• Engaging in argument from evidence</td></tr>
<tr><td>Crosscutting Concepts</td><td colspan="2">• Cause and effect: Mechanism and explanation
• Systems and system models</td></tr>
<tr><td>Background Information</td><td colspan="2">The Goddard Institute for Space Science (GISS) Surface Temperature Analysis project (GISTEMP) monitors surface temperatures across the globe and publishes those data in a variety of ways. They offer access to over 135 years of data by month and region. In this activity, students will examine the mean surface temperature in three different regions of the globe—northern latitudes, middle latitudes, and southern latitudes. Students will explore the data set to determine differences in climate changes over time in these regions. Then, they will attempt to explain these differences, for example, decreased ice cover in the Arctic resulting in less sunlight being reflected and increased warming.</td></tr>
<tr><td colspan="3">DATA AND TECHNOLOGY</td></tr>
<tr><td>Online Sources</td><td>• GISTEMP: http://data.giss.nasa.gov/gistemp. Under Table Data: Global and Hemispheric Monthly Means and Zonal Annual Means for the Land-Ocean Temperature Index, access the downloadable file http://data.giss.nasa.gov/gistemp/tabledata_v3/ZonAnn.Ts+dSST.txt
• QR Codes: See Table 5.1 (p. 108).</td><td rowspan="2">GISTEMP Team, 2015 screenshot

Source: http://data.giss.nasa.gov/gistemp.</td></tr>
<tr><td>App and Device Sources</td><td>No appropriate apps were located.</td></tr>
<tr><td>Technology Notes</td><td colspan="2">The GISTEMP website is not responsive in design, so students might find it a challenge to view on small devices. Students can explore multiple data sets on the website; however, this activity uses only the data set for zonal annual means, accessible at http://data.giss.nasa.gov/gistemp/tabledata_v3/ZonAnn.Ts+dSST.txt</td></tr>
</table>

DATA AND TECHNOLOGY *(continued)*	
About the Data	**Data Sampling:** The GISTEMP project data set is very large, containing over 135 years' worth of data for multiple regions of Earth. If students do not have access to a graphing tool, you will need to help them select a sampling technique that will yield a manageable data set. **Data Type:** The data used in this activity are the interval–ratio (measured) data type, graphed in a scatter plot, with time in years on the *x*-axis. In this type of graph, the data are often joined point to point. **Data Issues:** Students might be confused by the temperature data displayed in the table. The data represent the amount above or below the mean global temperature, which is estimated to be 14°C (57°F), derived using temperature data for the years 1951 to 1980. The multiplier for the data is 0.01 and the unit is °C. **Enrichment Using Data:** Have students use the monthly northern and southern hemisphere data to determine whether there is a seasonal pattern for climate change.
USING AND ADAPTING THE ACTIVITY	
About the Activity	It might be helpful for students to have an understanding of global climate change. Students should have some idea that large bodies of water change temperature more slowly than land does. Use a jigsaw activity to help students more efficiently process data. Divide the class into initial groups of three. Assign each person in the initial groups a letter: A, B, or C. Now, have the students gather in different groups by letter to create graphs. Group A should graph the northern latitudes; Group B, the middle latitudes; and group C, the lower latitudes. When the graphs are completed, students return to their initial groups to compare graphs.
Scaling Down	Simplify this activity by using only the data for the Northern and Southern Hemispheres, instead of using data for the three latitude bands.
Scaling Up	Have students examine all eight latitude bands instead of just three. How might the differences in climate change in different regions affect ecosystems in those regions?
Extending	Have students conduct background research to explain the differences that they see in impacts of climate change across different latitude bands.
ASSESSMENT NOTES	
Regardless of which data set is used, trends will show an increase in mean temperatures. The Southern Hemisphere will show less change than the Northern Hemisphere.	

Name: ___________________________

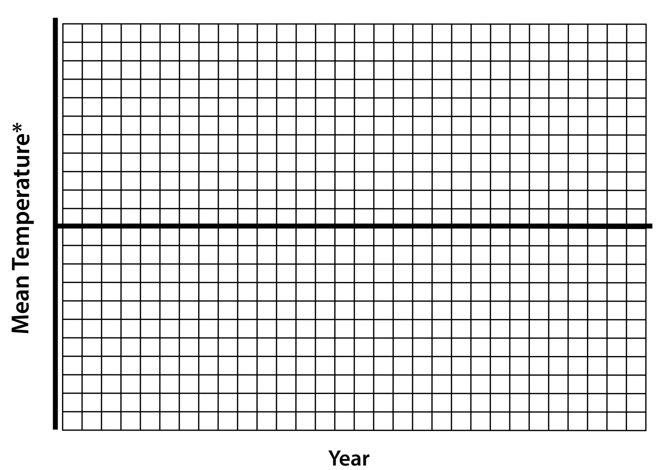
STUDENT HANDOUT: CLIMATE FROM POLE TO POLE

Activity Goal	In this activity, you will explore differences in climate change over time in different latitudes.
Technology Notes	Data for this activity will come from the Goddard Institute for Space Science (GISS) Surface Temperature Analysis (GISTEMP) at *http://data.giss.nasa.gov/gistemp*. The direct link to the data is *http://data.giss.nasa.gov/gistemp/tabledata_v3/ZonAnn.Ts+dSST.txt*.
Orientation Questions	• How have mean (average) temperatures changed over the past 120 years? • Are there differences in mean temperature changes in different latitudes?
Directions	Your teacher will assign you to an initial group and then to a graphing group that will look at data for a specific region of Earth. Your teacher also will help you determine how to sample your assigned data set. 1. In your graphing group: a. Graph the data for your region using a graphing tool or the graph provided. b. Answer the Regional Analysis Questions for your region. 2. Reconvene as your initial group. Each initial group will have at least one person from each region of Earth. In your initial group: a. Answer the Global Analysis Questions by comparing the graphs from each region. b. Complete the Conclusion and the Reflection sections.

Data Analysis

I am exploring the _________________ region (for example, Northern Hemisphere [NHem], 24N to –24S).

Graph the mean temperature differences for your region:



*compared to the 1951–1980 global mean in the 0.01°C

Regional Analysis Questions

The temperatures you graphed in this activity are shown as the difference from the global mean of temperatures measured from 1951 to 1980 (that is, 14°C). The multiplier for the temperature differences in the data table is 0.01 and the unit is °C.

1. What was the mean temperature for your region in the following years?

   1880 _________ 1947 _________ 2015 _________

2. What general trend did you notice in your data?

Global Analysis Questions

1. How did the general trend for your data compare with the trends in other regions?

2. How is the change in temperature different across different regions of Earth?

3. Describe the differences in geography (for example, amount of land versus the amount of water, quantity of ice cover) for the different regions represented in your group.

Conclusions

Use your answer to question 3 to explain the differences that you saw in question 2.

Reflection Question

How does thinking about Earth as a system help you explain the differences that you found?

TEACHER NOTES: EXTREME WEATHER

Learning Goal	Students will use a National Oceanic and Atmospheric Administration (NOAA) database to identify extreme weather events throughout the United States in different locations or over time.
Disciplinary Core Ideas	• Earth's systems • Weather and climate
Science and Engineering Practices	• Analyzing and interpreting data • Using mathematics and computational thinking
Crosscutting Concepts	• Cause and effect: Mechanism and explanation • Patterns
Background Information	The NOAA *Storm Events Database* contains records of significant weather events that have occurred in the United States since 1950. Significant weather events include severe weather (dangerous meteorological phenomena that cause significant property damage, injury and/or death, and/or social and business disruption) and extreme weather (weather events extremely unusual for a given area, for example, snow in San Diego). NOAA attempts to format and standardize event data. Event data are recorded geographically by county and state.
DATA AND TECHNOLOGY	
Online Sources	• NOAA National Centers for Environmental Information *Storm Events Database* website: *www.ncdc.noaa.gov/stormevents*. • QR Code: See Table 5.1 (p. 108).
App and Device Sources	No appropriate apps were located for this activity.
Technology Notes	The *Storm Events Database* does not have a responsive design, so students might find it a challenging to view on small devices. Students can use the database to explore multiple types of events (for example, hail, tornado, heavy precipitation, dense fog, extreme heat or cold) nationwide, by state, or for a specific county within a state. Each event describes the date, location, magnitude, and damage (property, death, injury). The database search function only returns 500 data points per search, so students will need to pay attention to how they sample and collect data.

DATA AND TECHNOLOGY (*continued*)	
About the Data	**Data Sampling:** The NOAA *Storm Events Database* is huge. It contains tens of thousands of storm events that have occurred throughout the United States over more than 60 years. A variety of information is collected for each storm event. As a result, students will need to give careful consideration to how they constrain their data sampling. **Data Type:** The database contains all three types of data: Nominal, ordinal, and interval–ratio. **Data Issues:** Students might need to revise their sample size or conduct multiple searches to acquire the data they need to answer their investigation question. The NOAA *Storm Events Database* only displays 500 weather events for each search.
USING AND ADAPTING THE ACTIVITY	
About the Activity	• This activity is designed to allow students significant freedom in their exploration (Tamir, Level 3; see Table 3.1, p. 28). Students will be able to explore the data set, determine a question to guide their investigation, define the data sample to collect, and analyze their data. • Student investigations will focus on comparing weather events in different regions within the same time frame, or over time in the same region.
Scaling Down	Students who do not have experience creating their own investigation questions will need support in this activity. One possible support would be for students to generate questions individually or in small groups and then publicly share those questions with the class. Students could then use one of their own questions or select an interesting question shared by another student.
Scaling Up	The complexity of the activity can be increased by challenging students to look at larger samples of data.
Extending	**Enrichment Using Data:** The open-ended nature of this activity should provide plenty of opportunities for student enrichment.
SAMPLE INVESTIGATION QUESTIONS	
The NOAA *Storm Events Database* provides an opportunity for students to craft many unique questions. The process described in the student handout will give them a sense of what is possible, but they may need support crafting and revising their question. A good question provides guidance for how students will sample data. Some sample questions are as follows: • Have the number of tornados per year in Oklahoma increased over the past 20 years? • Have the number of extreme heat days per year in Nevada increased over the past 50 years?	

SAMPLE INVESTIGATION QUESTIONS (*continued*)
• Have the number of deaths from extreme heat in the United States increased or decreased over the past 30 years? • Over the past 20 years in Wisconsin, which month has experienced the most heavy-precipitation days (rain and/or snow)? • Over the past five years, which has caused more property damage, tornados, or floods? • Over the past five years, which county in Illinois has had the most floods? • Has there been an increase in heavy snow events in Massachusetts over the past 30 years?
ASSESSMENT NOTES
Because this activity is designed as an open-ended investigation, the data produced can vary widely. Assessment should be based on student interpretation of data and presentation of their research project.

Name: ___________________________

STUDENT HANDOUT: EXTREME WEATHER

Activity Goal	In this activity, you will design an investigation to determine whether there are patterns in extreme weather events.
Technology Notes	The National Oceanic and Atmospheric Administration (NOAA) *Storm Events Database* contains information about extreme weather events in the United States since January 1950. Data can be accessed at *www.ncdc.noaa.gov/stormevents*.
Orientation Questions	What patterns (either location-based or over time) can you identify by using the NOAA *Storm Events Database*?
Directions	1. Begin by conducting a few searches using different criteria (location, type of weather, varying time ranges) to orient yourself to the type of data in the *Storm Events Database*. 2. Complete the Investigation section, based on data available in the database. In general, investigation questions will compare weather events in different locations within the same time period or compare weather events in one location over a long time period.

Investigation

1. After conducting a variety of searches, list the types of data that you could compare (for example, time of year versus heavy snow event, change in the number of extreme heat days over time). Include at least five possible comparisons.

2. Select the comparison you listed in question 1 that interests you the most. Think about how you will sample (select) data from the database for analysis. For example, if you are comparing weather events at two locations, what will the time period be? Or, if you are comparing changes in a weather event over time in one location, will you use data for 20 years, 30 years, or longer?

3. Write your investigation question. It should provide information about the location, weather event or other information, and the time period for the data sample that you will use.

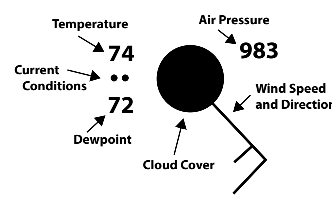
4. Draw a data table to use to collect your data. Before collecting data, have your teacher approve your responses to questions 3 and 4.

5. Collect your data and display them in a graph.

6. From the data you collected, what claim (that is, what answer to your investigation question) can you make? How is this claim supported by evidence from your data? What might be the cause of the patterns that you found?

7. Create a poster that includes your investigation question, data table, graph(s), and conclusion.

TEACHER NOTES: WEATHER MAPPER

Learning Goal	Students will use weather data to create a current weather map by drawing station models for multiple locations.	
Disciplinary Core Ideas	• Earth materials and systems • Weather and climate	
Science and Engineering Practices	• Developing and using models • Engaging in argument from evidence	
Crosscutting Concepts	• Cause and effect: Mechanism and explanation • Systems and system models	
Background Information	Station models are used to show the current conditions on a weather map. They include symbols and data to show current temperature, dew point, air pressure, cloud cover, wind speed, and wind direction. A sample is shown to the right. These station models provide an overview of easy-to-read data that can be used not only to understand current conditions, but also to predict future conditions.	Sample weather station model 
DATA AND TECHNOLOGY		
Online Sources	• National Weather Service (NWS) website: *www.weather.gov* • Weather Underground website: *www. wunderground.com* • QR Codes: See Table 5.1 (p. 108).	*NWS* website screenshot  *Source:* National Weather Service. *www.weather.gov.*
App and Device Sources	*Storm* app Device platform: iOS	
	Weather Underground app Device platform: iOS, Android	

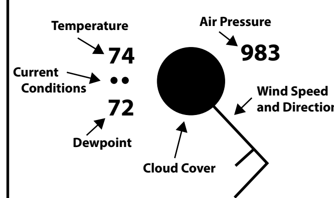
DATA AND TECHNOLOGY *(continued)*	
Technology Notes	The NWS website has a responsive design and can be used easily on small devices. All data are presented in text form (see the website screenshot above). The *Storm* and *Weather Underground* apps show wind direction as pointers on a 360° compass to make it easier for students to identify wind direction. If you are using these apps, have the students open the app settings and change the units for air pressure from inches to millibars so that they will be using scientific units rather than U.S. customary ones.
About the Data	**Data Sampling:** No sampling problems anticipated. **Data Type:** Wind direction, wind speed, temperature, and air pressure are all the interval–ratio data type. **Data Issues:** No data issues anticipated.
USING AND ADAPTING THE ACTIVITY	
About the Activity	Before conducting this investigation, students should have an understanding how weather data are collected and what they mean. They should understand the difference between temperature and dew point. Students must also understand the difference between high and low air pressure, how air pressure is measured (millibars rather than inches). In addition, they should understand that air pressure data values omit the leading “9” or “10” and are extended to one decimal place.
Scaling Down	You can simplify this activity by having each student collect data from one location and contribute it to a class map for discussion and analysis, rather than producing individual maps.
Scaling Up	Make this investigation more complex by increasing the number of locations for which models are provided so that there is one model per state. Another option to increase complexity is to have students draw either isobars or isotherms on their maps based on the data collected.
Extending	**Weather Channel News:** Students can use the maps they create to produce weather report videos explaining the current weather conditions around the country and in specific cities. **Go International!:** Students can collect and analyze data for locations worldwide using the website *http://weather.org*. **Station Model Journals:** Have students keep a station model journal for the weather in a specific location for a week. Then they can describe the changes that occur over time.

USING AND ADAPTING THE ACTIVITY *(continued)*	
Extending *(continued)*	**Enrichment Using Data:** Have students use the station models to identify areas of high pressure and low pressure, predict a weather track (that is, how those highs and lows will move), and then create station models on subsequent days along the tracks to observe the changes.

ASSESSMENT NOTES
In general, low pressure is associated with cloudy skies and high pressure with clear skies. Students should see patterns emerge, such as counterclockwise winds around areas of low pressure or clockwise winds around areas of high pressure, and should be able to answer questions about current weather in specific locations based on data collected.

Name: ___________________________

STUDENT HANDOUT: WEATHER MAPPER

<table>
<tr><td>Activity Goal</td><td colspan="2">In this activity, you will construct a weather map with station models to show current weather conditions around the country.</td></tr>
<tr><td>Technology Notes</td><td colspan="2">• Data for this activity will come from the National Weather Service website: www.weather.gov.
• Your teacher might instruct you to use an app instead.</td></tr>
<tr><td>Orientation Questions</td><td colspan="2">• How are weather maps produced?
• What information is included on a weather map?</td></tr>
<tr><td>Directions</td><td>1. Collect weather data for 25 cities from the website or with an app. Try to spread your locations around the country so that your data are spread out on the map.
2. Construct a station model for each location on the map.
3. Draw a large L on the location with the lowest air pressure and an H on the location with the highest air pressure.
4. Complete the Analysis Questions, Conclusions, and Reflection Question sections.</td><td>Sample weather station model

</td></tr>
</table>

Analysis Questions

1. What patterns do you notice when comparing locations with different air pressures (lowest versus highest) and amounts of cloud cover (cloudy versus sunny)?

2. Do winds move clockwise or counterclockwise around areas of low pressure?

3. How do winds move around areas of high pressure?

4. When the temperature and dew point are the same or very close, precipitation is likely. According to the data you collected, where was it most likely to be raining or snowing? Was that precipitation rain or snow? How do you know?

5. What evidence does your map show that supports a cause-and-effect relationship between air pressure and cloudy weather?

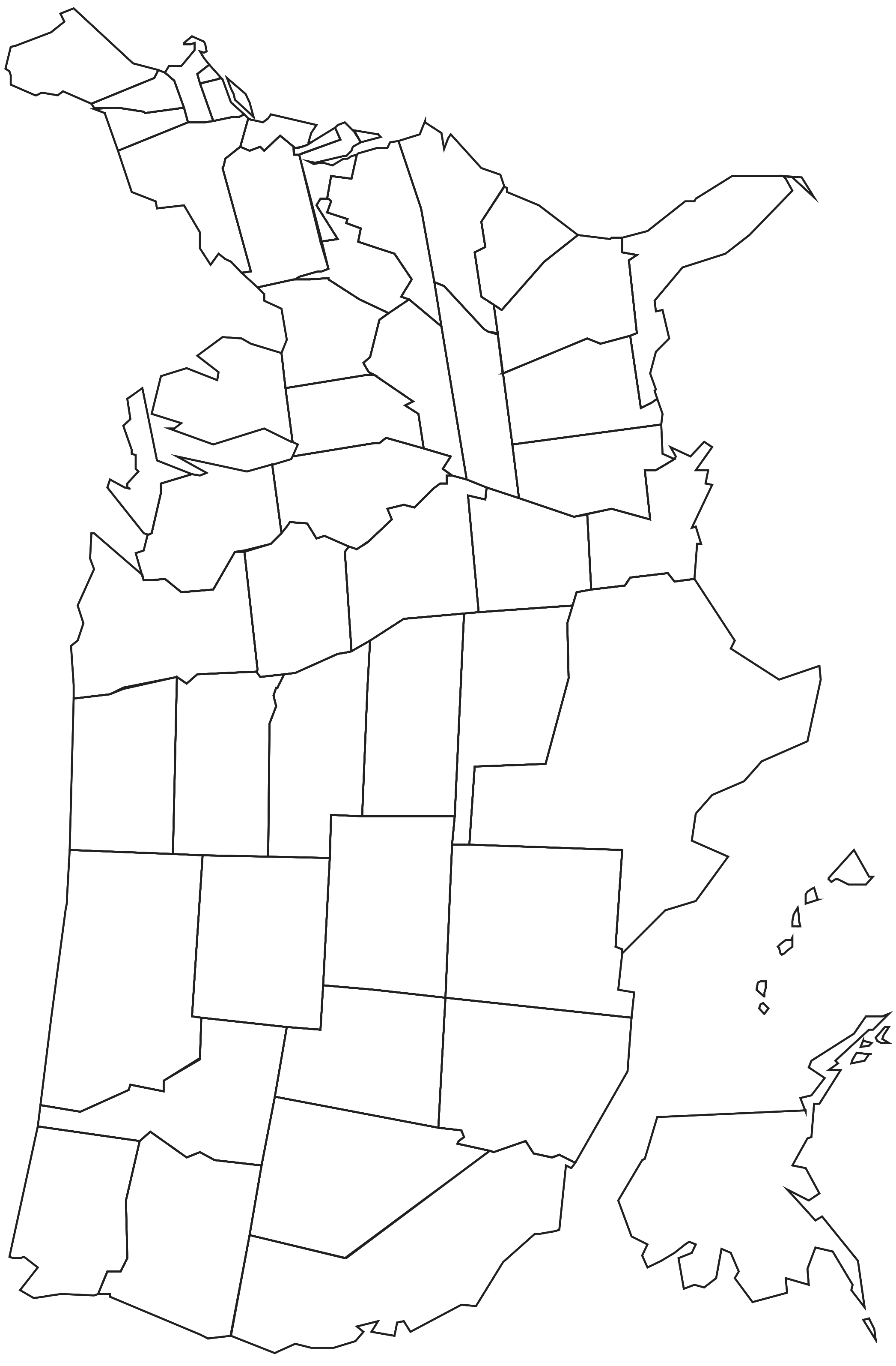
Conclusions

Predict how you think the weather where you live will change over the next day or so. Use what you know about weather and evidence from your weather map to support your claim.

Reflection Question

What advantage does the station model presentation have over a text presentation in showing weather data?

MAP



TEACHER NOTES: WEATHER STORIES

Learning Goal	Students will develop and analyze meteograms for select cities to construct a 24-hour history for a specific location.		
Disciplinary Core Ideas	• Earth materials and systems • Weather and climate		
Science and Engineering Practices	• Developing and using models • Constructing explanations and designing solutions		
Crosscutting Concepts	• Systems and system models • Stability and change		
Background Information	Meteograms are graphical models of weather data produced for a single location over a 24-hour period. Although there might be some variation in how meteograms are produced, they usually present temperature, dew point, wind speed, wind direction, precipitation, and air pressure data. Wind speed and wind direction can be shown using numeric data (knots and azimuth) or a station model symbol ( ). The data are graphed from left to right in order of oldest to most recent. The models show changes in conditions and can reveal the effects of storms and fronts.		
DATA AND TECHNOLOGY			
Online Sources	• National Weather Service (NWS) website: *www.weather.gov* • QR Code: See Table 5.1 (p. 108).		*NWS* website screenshot  *Source:* National Weather Service. *www.weather.gov.*
App and Device Sources		*Weather Underground* app Device platform: iOS, Android	
		Weather Mate app Device platform: iOS	
Technology Notes	On the NWS website, you must select the "3 Day History" of a city to see data from the past. In the iOS-based app *Weather Mate*, you can see hourly data by choosing "Weather History" in the top menu bar and then selecting the date. The Android-based *Weather Underground* app displays the past several days of all relevant data except for air pressure.		

DATA AND TECHNOLOGY *(continued)*	
About the Data	**Data Sampling:** Teachers need to help students determine geographic location and day for which they will collect their data. **Data Type:** Temperature (often in °F), dew point (°F), wind speed (mph), precipitation (in.), and air pressure (millibars) are all the interval–ratio (measured) data type, and in a meteogram these are graphed against time (on the horizontal axis, another interval–ratio variable type), which is "sequential." Temperature, dew point, and air pressure are shown as a line graph. Wind speed, cloud cover, and wind direction are shown using symbols (wind barbs) and precipitation is shown using symbols representing the precipitation type. **Data Issues:** The value of the *y*-axis is determined individually for each data set, depending on the range of the data.
USING AND ADAPTING THE ACTIVITY	
About the Activity	This activity is most appropriately used at the end of a weather study unit because students should understand weather variables and know how to draw a station model. This is a two-part activity. First, students create a meteogram for a specific location using 24-hour data, and then they describe the changes that have occurred during that period. A very effective way to use this activity is to select cities where specific weather events have occurred during the past 24 hours. This allows students to see the effects from passage of cold fronts, land and sea breezes, storms, and more.
Scaling Down	Instead of having students create their own meteograms, have them locate and collect meteograms for specific cities from the *DataStreme* website (*www.ametsoc.org/amsedu/dstreme/metgram.html*). Then, have students construct explanations of how weather has changed in these locations. Teachers should provide sample meteograms that illustrate specific weather phenomena, such as the passing of a front.
Scaling Up	Ask students to identify cities in which a weather event has occurred over the past 24 hours and produce a meteogram to show the event. After they have interpreted their own data, students can trade meteograms with each other for interpretation. They should compare their explanations and construct arguments to defend their interpretations. In addition, students can compare meteograms for different cities experiencing the same phenomenon to see how different locations experience the same event.

USING AND ADAPTING THE ACTIVITY *(continued)*	
Extending	**Comparing Cities:** Comparing data from different cities experiencing the same event could be useful to help students see changes that occur as a result of weather systems. **Personalized Meteograms:** Students can construct personalized meteograms with data they collect themselves over a period of hours or days. **Enrichment Using Data:** In addition to the data already discussed, some meteograms could include humidity and visibility data.

ASSESSMENT NOTES
For passage of a cold front through a specific location, students should note that the air pressure drops and then rises again when the front has moved through. Winds will shift from out of the south and east ahead of a front to out of the west and north behind it. Temperatures will drop and skies will often begin to clear after front has passed.

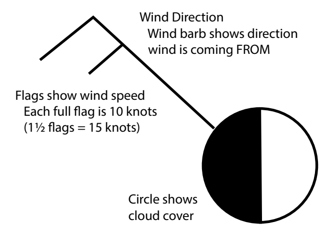
Name: ___________________________

STUDENT HANDOUT: WEATHER STORIES

<table>
<tr><td>Activity Goal</td><td>In this investigation, you will construct a meteogram from weather data and then construct an explanation for the changes that occurred during the period analyzed.</td></tr>
<tr><td>Technology Notes</td><td>For this activity, you will collect data from the National Weather Service (NWS) website at www.weather.gov or from a weather app suggested by your teacher.</td></tr>
<tr><td>Orientation Questions</td><td>How do local weather conditions change when a weather event occurs?

What relationships between air pressure, temperature, and wind speed and wind direction can be observed as the weather conditions change?</td></tr>
<tr><td>Directions</td><td>Identify a city in which, a specific weather event has occurred in the past 24 hours (for example, a storm, the passage of a cold front, or another event). Your teacher will direct you on whether to collect those data for a specific city or for a city of your own choosing.

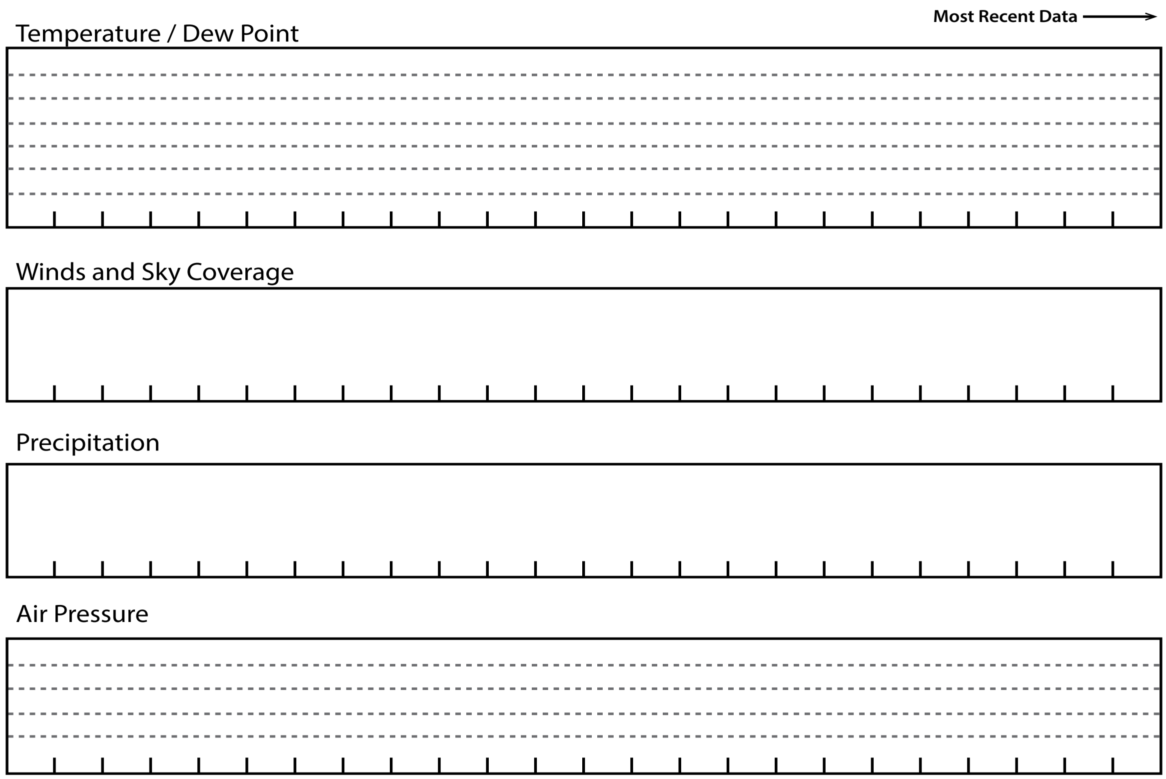
1. Gather hourly data for that city for the past 24 hours from the NWS website.

2. Construct and explain the meteogram.


a. Graph the data for temperature, dew point, wind direction, wind speed, precipitation, and air pressure into the meteogram on the reverse side of this handout. You will need to set your own scale for temperature and pressure based on the data you have collected. Use line graphs for temperature, dew point, and air pressure. Use station models to show wind speed and wind direction. Use raindrops and snowflakes to show precipitation: one for light precipitation, two for moderate, and three for heavy. Use the equal sign (=) to indicate fog.
b. Construct an explanation of the changes observed during the past 24 hours.

3. Complete the Analysis Questions, Conclusions, and Reflection Question sections.</td></tr>
</table>

Blank Meteogram



After completing your meteogram, construct an explanation of the changes observed during the past 24 hours.

Analysis Questions

1. What weather event were you collecting data for?

2. What changes did you note in the weather for the period over which this location experienced the weather event?

3. Were there any changes in one variable that seemed to correspond to changes in another variable? For example, did rising and falling of air pressure correspond to wind direction or sky cover?

4. How does a meteogram provide a record of meteorological changes that occur over time for a given location?

Conclusions

Compare your data and results with those of other students who explored the same or a similar event in other locations. What conclusions can you draw about how this type of weather event affects local conditions?

Reflection Question

How might the data you analyzed in this activity help with prediction of changes during future weather events?

TEACHER NOTES: WIND BENEATH OUR WINGS

Learning Goal	Students will use flight take-off and landing patterns to better understand wind.
Disciplinary Core Ideas	• Earth materials and systems • Weather and climate
Science and Engineering Practices	• Developing and using models • Engaging in argument from evidence
Crosscutting Concepts	• Cause and effect: Mechanism and explanation • Patterns
Background Information	Wind direction affects how airplanes take off and land. Generally, aircraft will take off into the wind, because that has the effect of increasing the speed at which the wind passes over the wings. A strong headwind when landing provides resistance and helps slow the aircraft for a smoother landing. Although taking off and landing into the wind is preferable, the orientation of the airport landing strips influences the direction of landing. For example, larger airports often primarily use east–west landing strips, because north–south landing strips are not long enough for larger aircraft. Generally, knowing the direction flights take off and land can provide information about wind direction. This, in turn, can provide the location of high- and low-pressure systems. If you face the wind, low pressure will be to the right and high pressure to the left.

DATA AND TECHNOLOGY

Online Sources	• FlightAware website: *https://flightaware.com/live* • Weather Underground website for wind-direction data: *www.wunderground.com* • QR Codes: See Table 5.1 (p. 108).		FlightAware website screenshot
App and Device Sources		*FlightAware* app for flight data Device platforms: iOS, Android	
		Weather Underground app for wind data Device platform: iOS, Android	

Source: FlightAware. *https://flightaware.com/live.*

DATA AND TECHNOLOGY (*continued*)	
Technology Notes	The FlightAware website and app allow students to see flight traffic in real time. There are usually so many flights that, to see individual aircraft, you must zoom in. Students should look for the major airports (indicated by white lines) designated in the activity, and identify planes landing or taking off by clicking on the airplane graphic. To find wind information, students can use many different websites and apps; however, the Weather Underground website and app allow students to view the information in map form.
About the Data	**Data Sampling:** No sampling issues are anticipated. **Data Type:** Wind speed is an interval–ratio type of data. Wind direction is often recorded as a cardinal direction (for example, north, south) or an intercardinal direction (for example, northwest, southwest), but these wind directions might also be recorded in compass degrees. **Data Issues:** Students might be familiar with only the coarser-grain cardinal and intercardinal directions and not with the finer-grain secondary-intercardinal directions (for example, south–southwest, west–southwest).
USING AND ADAPTING THE ACTIVITY	
About the Activity	In this activity, students will make inferences about wind direction and the location of high- and low-pressure systems from the landing and take-off patterns at various airports. Before participating in this activity, students should understand that winds blow clockwise around high-pressure systems and counter-clockwise around low-pressure systems in the Northern Hemisphere. Teachers might want to discuss how aircraft use the wind to assist in take-off and landing by flying into the wind when possible.
Scaling Down	Have students complete the investigation using landing and take-off paths to determine wind direction, without making conclusions about the location of high- and low-pressure systems.
Scaling Up	Have students predict the location of high- and low-pressure systems without verifying the wind direction for each airport. Airport runways are identified using numeric designations based on their compass setting (for example, runway 23 is at 230 degrees, runway 09 is 90 degrees). Students can find the designation for each runway at the airports shown to determine how it might affect flight take-off and landing.

USING AND ADAPTING THE ACTIVITY *(continued)*	
Extending	**Comparing Aircraft Speed:** Have students use the FlightAware website or app to find pairs of eastbound–westbound aircraft that are close in proximity. Ask students to compare the aircraft speed of the two aircraft and construct an explanation about why there is a significant difference. Additional information provided for each flight provides a rich source of data for students to analyze, for example, by calculating flight times, altitude, and airport traffic. **Enrichment Using Data:** Have students convert the cardinal directions to polar measure (degrees) so they can calculate the "degrees incorrect" of their predictions. These could also have a +ve or –ve component (that is, over or under the actual, respectively).

ASSESSMENT NOTES
There will not always be an observable pattern tied to current high- and low-pressure systems because airports generally only have two runways, often running generally east–west and north–south. Smaller airports might only have one. For this reason, expect some variation in the data and discuss reasons for the outliers with students.

Name: ___________________________

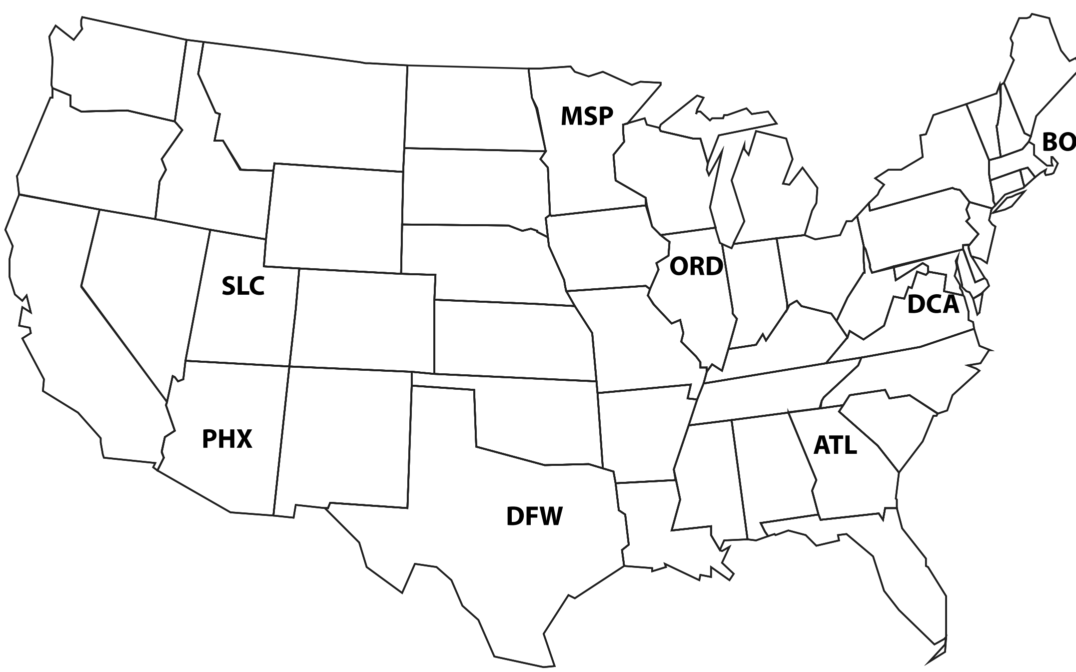
STUDENT HANDOUT: WIND BENEATH OUR WINGS

Activity Goal	In this activity, you will use the flight patterns of aircraft to gather information about current weather conditions and to predict the locations of pressure systems. Pilots take off and land into the wind to use wind speed to their advantage. By observing aircraft landing and taking off patterns, you can make inferences about wind direction. Wind direction will tell you the approximate location of high- and low-pressure systems.
Technology Notes	To find flight data, use the *FlightAware* app or website (*https://flightaware.com/live*). Wind-direction data can be obtained from the *Weather Underground* app or website (*www.wunderground.com*).
Orientation Questions	• What inferences can you make about wind direction based on the take-off and landing patterns of aircraft? • What information does wind direction provide about the location of high- and low-pressure systems?
Directions	**Part 1—Data Table** 1. For each airport in the data table, identify one aircraft approaching or departing the airport. Click on the plane to verify its flight path. 2. Record the flight information and direction in which the plane is moving in the data table. 3. Find two additional cities of your choosing and do the same. 4. Based on the direction at which each plane is landing, predict the direction from which the wind is blowing. Record your prediction in the data table. 5. Using the Weather Underground website link or app, locate each city. Record in the data table the direction from which the wind is actually blowing. **Part 2—Map** 6. Indicate the wind direction at each location on the map. 7. Once you know the wind direction at all of the airports, predict the location of high-pressure and low-pressure areas in the continental United States. Indicate your predictions on the map. 8. Go back to the Weather Underground website or app and select “Current Conditions” map. Compare the predicted locations of high- and low-pressure areas on your map to those on the website or app. 9. Complete the Analysis Questions, Conclusions, and Reflection Question sections.

Data Table

Airport	City, State	Flight Number	Plane Direction	Predicted Winds	Actual Winds
ATL	Atlanta, Georgia				
DFW	Dallas–Fort Worth, Texas				
PHX	Phoenix, Arizona				
SLC	Salt Lake City, Utah				
ORD	Chicago, Illinois				
DCA	Washington, District of Columbia				
BOS	Boston, Massachusetts				
MSP	Minneapolis, Minnesota				

Map



Analysis Questions

1. How accurately were you able to predict wind direction from aircraft landing and take-off patterns?

2. What explanation can you give to explain why some predictions were not accurate?

3. How accurately were you able to predict the locations of pressure systems?

4. How do air traffic controllers use weather data to regulate aircraft landing and take-off patterns?

5. How would airports near the coast need to adjust landing and take-off patterns based on summer land and sea breezes?

Conclusions

Construct an argument that explains the relationship between aircraft take-off and landing patterns and wind direction.

Reflection Question

Is the relationship between take-off and landing patterns coincidental or cause-and-effect? Explain.

Table 5.1. Data sources for atmosphere and climate investigations

Activity	Website	URL	QR Code
Air Quality	AIRNow	*www.airnow.gov*	
Climate From Pole to Pole	GISS Surface Temperature Analysis	*http://data.giss.nasa.gov/gistemp*	
Extreme Weather	NOAA *Storm Events Database*	*www.ncdc.noaa.gov/stormevents*	
Weather Mapper	National Weather Service	*www.weather.gov*	
	Weather Underground	*www.wunderground.com*	
Weather Stories	National Weather Service	*www.weather.gov*	
Wind Beneath Our Wings	FlightAware Flight Tracking	*https://flightaware.com/live*	
	Weather Underground	*www.wunderground.com*	

Table 5.2. Additional atmospheric and climate data sources

Website	URL	QR Code
American Meteorology Society	*www.ametsoc.org/ams*	
DataStreme	*www.ametsoc.org/amsedu/dstreme*	
EPA *Air Quality*	*www.epa.gov/air-data*	
NASA Earth Observations	*http://neo.sci.gsfc.nasa.gov*	
National Snow and Ice Data Center	*http://nsidc.org*	
NASA *Global Sulfur Dioxide Monitoring*	*http://so2.gsfc.nasa.gov*	
NOAA National Climate Center	*www.climate.gov*	
Air Quality—NOAA *Earth System Research Laboratory* Global Monitoring Division	*www.esrl.noaa.gov/gmd*	
NOAA *Environmental Visualization Laboratory*	*www.nnvl.noaa.gov*	

Table 5.2. (*continued*)

Website	URL	QR Code
NOAA *Climate Data Online*	*www.ncdc.noaa.gov/cdo-web*	
University of Wyoming Department of Atmospheric Science	*http://weather.uwyo.edu/upperair/sounding.html*	

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BIG DATA SMALL DEVICES

INVESTIGATING THE NATURAL WORLD USING REAL-TIME DATA

"As a classroom teacher with a background in instructional technology, I found smartphones and tablets to be the perfect devices for having students access real-time data for classroom investigations. I began using these in my own room, then started sharing ideas at teacher conferences. What I immediately found is that there is a great deal of interest in using personal technology devices as learning tools."

—Donna Governor, co-author of *Big Data, Small Devices*

Given the number of students with smartphones and tablets, it only makes sense for them to take advantage of the many websites and free apps that can teach them about the natural world. *Big Data, Small Devices* is designed for Earth and environmental science teachers who want to help students tap into, organize, and deploy real-time data sets. Students can learn to use their devices to detect patterns among phenomena related to the atmosphere, biosphere, geosphere, hydrosphere, and celestial sphere.

Written by veteran teachers, *Big Data, Small Devices* will help you understand both the technology you need and the ways to use it in classes at all levels, from elementary school through high school. The authors give tools, tips, and tricks for finding real-time data and using them to create your own investigations. Then, they provide sample activities that showcase specific data, as well as the websites and apps that provide them. You can use the activities as written, adapt them to your specific needs, or use them as inspiration for creating your own.

Big Data, Small Devices is a one-of-a-kind book for developing investigations with any data accessible online. It also helps you bring learning opportunities for your students as close to them as their personal technology devices.

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