INTEGRATING TECHNOLOGY

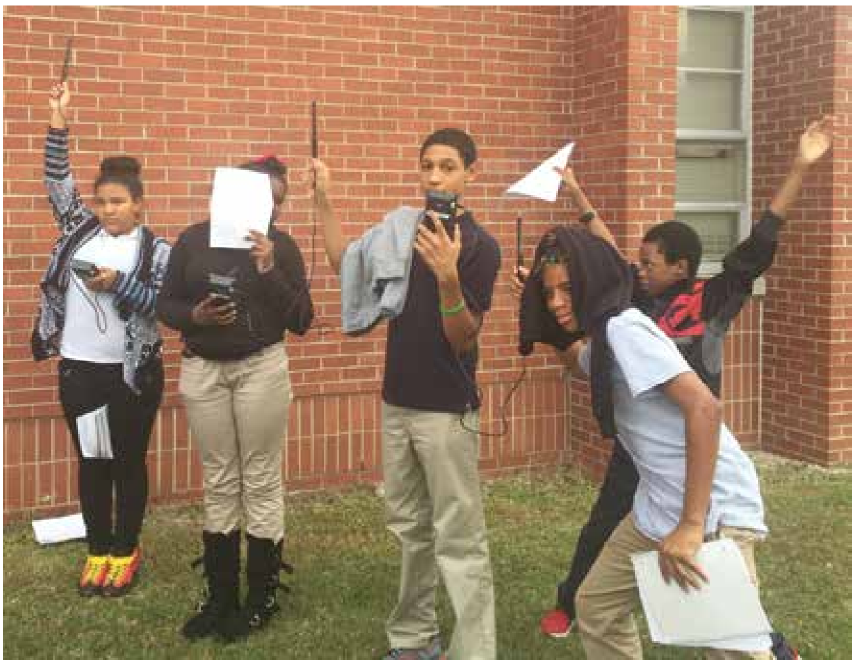
Weather versus climate

Helping middle school students distinguish the differences during an after-school STEM career club

BY KRISTIE S. GUTIERREZ, MARGARET R. BLANCHARD, AND KYLIE S. HOYLE

But it snowed three times last winter! There's no way the Earth is warming!

Similar to some adults, some middle school students are skeptical of climate change, and they often confound their understandings of *weather* and *climate* (Bodzin et al. 2014; Leiserowitz, Smith, and Marlon 2011). Although the *Next Generation Science Standards* (NGSS Lead States 2013) introduce the terms *weather* and *climate* prior to middle school, many states that have not adopted the standards fail to integrate more than basic weather terms prior to secondary school. In some states, the term *climate* does not appear in the science curriculum until middle school and *climate change* is not typically discussed until high school. This article describes activities that approximately 200 middle school students (grades 5–8) from four schools participated in during a two-hour, after-school STEM career club meeting (Blanchard et al. 2017). The club focused on climate change topics for three meetings as part of a National Science Foundation, Innovative Technology Experiences for Students and Teachers grant-funded project, but this activity can easily be done over four one-hour class periods if there is access to the outdoors. The sequence of activities led our students to significantly increase their content knowledge about weather and climate (Gutierrez 2016). Figure 1 shows the activity agenda of this club meeting.



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Students collecting weather data.

Students may have learned basic weather parameters in elementary school (e.g., temperature, types of precipitation, cloud types); however, to scaffold learners and assess preconceived knowledge during this series of activities, students gather their own authentic weather data, as suggested in the literature (Beatty 2012; Hestness et al. 2014). Once students are comfortable with the equipment, instructors can then challenge students with extension activities such as determining weather patterns, comparing their authentic data to that of the National Weather Service, or expanding communication skills through a schoolwide daily video weather forecast. Additionally, as students move into the National Oceanic and Atmospheric Administration (NOAA) historical climate activity, they must understand the basic concepts of temperature (i.e., minimum, maximum, average), precipitation, and humidity.

Note: Although the Weather Parameter Lab we describe was completed using probeware, it can also be done on a shoestring budget using simple lab equipment, such as alcohol thermometers, a psychrometer, and a wet-bulb/dry-bulb relative humidity table. In this case, teachers would need to adjust the provided data tables to reflect less accurate measurements.

Climate or Weather? Wildlife Quiz Game

Students are paired off (they can self-select, or teachers can organize them) in preparation for the Climate or Weather? Wildlife Quiz Game (see Resources to download the game cards). Although we added cards to extend the game and provide additional weather and climate vocabulary, the idea and main components of the game are borrowed from the Project WILD curriculum "Weather, Wildlife, Climate, and Change, Lesson 1: Weather, Climate, and Wildlife," (Project Wild 2014) as shown in Figure 2.

Students compete against each other in pairs to see who knows more about the difference between weather and climate (groups of three are fine for odd numbers of students). Each student receives up to 12 cards (there are 24 cards total in the modified version). One student reads a statement printed on a card to his or her partner, and the partner indicates whether he or she thinks the statement refers to weather or to climate. Many of the wildlife mentioned on the cards can be found in students' neighborhoods. If a student correctly answers the question (answers are on the back), he or she keeps the card. When all cards have been read, the partner who

FIGURE 1: Agenda for the Weather versus Climate STEM career club meeting

Activities	Time required
1. Snack and attendance	5 minutes
2. Climate or Weather? Wildlife Quiz Game	20 minutes
3. Science Girl: Climate Reality video	5 minutes
4. Weather Parameters Lab using probeware	60 minutes
5. NOAA: Climate at a Glance activity	30 minutes
6. Professional speaker: Climatologist or local meteorologist	20–25 minutes
7. Group discussion using provided questions	10 minutes

CONTENT AREA

Physical science and Earth science

GRADE LEVEL

6–8

BIG IDEA/UNIT

Weather and climate are terms that are often incorrectly interchanged. This activity explores weather and climate using authentic, student-generated data sources generated and a national database.

ESSENTIAL PRE-EXISTING KNOWLEDGE

Collecting, analyzing, and interpreting data; basic weather vocabulary (e.g., temperature, precipitation, cloud types)

TIME REQUIRED

4 hours

COST

Varied; dependent on level of technology use (probeware vs. traditional instrumentation)

SAFETY

Students should be reminded of proper outdoor behavior and potential allergens or insects in the environment. Teachers should make their best judgment on days with extreme hot or cold temperatures or inclement weather.

has the most cards is the winner. Teachers should discuss a subset of the cards with the whole group to identify and address alternative conceptions before moving forward. Often, students are unsure of how long ago or what time span constitutes "climate." For example, if one summer is abnormally hot, or if it snows an abnormal number of times during one winter season, students may consider it "climate change." Teachers should probe students individually or take a poll to gauge student understanding following this activity. Teachers should focus on a subset of 5–10 statements from the cards that they think reveal typical alternative conceptions. They can then have students complete a Kahoot (see Resources) or other game-based learning platform to gain a general understanding of what students understand prior to beginning the main activity. Based on student responses, teachers can then have individual students support their answers through class discussion.

Science Girl: Climate versus weather video

Before moving on to the Weather Parameter Lab, all students should understand the difference between *weather* (the atmospheric conditions at a specific place and specific point in time, often including daily temperature and precipitation activity) and *climate* (average conditions expected at a specific place at any given time, based on an aggregate of weather over 30 years).

Students watch a short video about weather and climate change entitled "Science Girl: Climate Reality" (see Figure 3 and Resources). The video features actress Yara Shahidi as a middle school student who is presenting her science fair project about climate change. After students watch the video, the teacher assesses their understanding of weather and climate through discussion. Some discussion questions teachers may ask include:

- What examples did the video give for weather?
- What examples did the video give for climate?
- What is considered "dirty energy" in this video and what is it doing to our climate?
- What types of events are expected to increase as a result of climate change?

Teachers can unearth students' alternative conceptions (e.g., all the

FIGURE 2: Excerpt from Climate or Weather? Wildlife Quiz Game (see Resources to download the full game)

Front	Back	Front	Back
This winter it snowed 5 times.	**Weather**	**It has never gone above 100°F in the month of May.**	**Climate**
Over the last several years warmer winters allowed alligators to expand their ranges further north and inland.	**Weather**	**Decades of warmer winters allows for Carolina wrens to expand their normal range further north.**	**Climate**

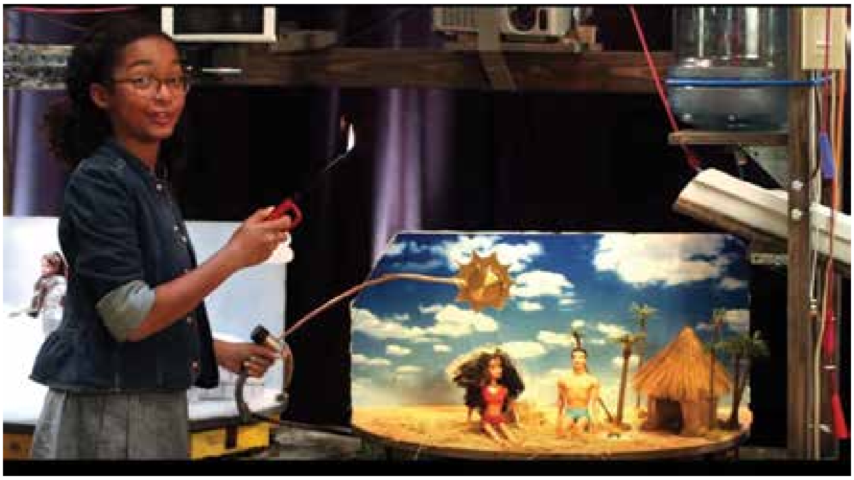
Directions: In pairs, students quiz each other to determine whether an event should be categorized as *weather* or *climate*. The cards should be cut along the dashed lines, folded along the solid lines, and then glued. Each card should have a statement on the front and the correct answer on the back.

Earth will burn or flood as a result of climate change, extreme weather is the same as climate change) and present students with vocabulary to help them distinguish between weather and climate, such as *coal*, *oil*, *dirty energy*, *clean energy*, *weather*, *climate*, *dynamic changes*, *time*, *extreme weather*, *heat waves*, *drought*, and *wildfires*.

Weather parameter lab using probeware

Probeware allows students to measure, record, and analyze authentic weather parameters, such as temperature, relative humidity, and wind speed (see Figure 4), on their school grounds. Emphasize to students that the data they are gathering are weather conditions or *parameters* (e.g., wind speed and direction, air temperature, air pressure, air humidity, precipitation), not to be confused with climate records collected over decades. It is extremely important that teachers practice using the equipment prior to using it with students. Although today's students are digital natives, they will still need teacher guidance and troubleshooting when equipment glitches or they are unsure about next steps. Thus, students should be advised to stay within the teachers' line of sight at all times throughout this outdoor activity. (*Safety note*: Teachers should discuss any safety considerations, such as stings from insects, with students prior to going outdoors. Be aware of any student allergies and any other outdoor hazards, such as heat and the need

FIGURE 3: Screenshot from "Science Girl: Climate Reality"



About cold and warm fronts

When a cold front moves into an area:

- **Ahead of the front** (before the front reaches an area): Temperature is warmer, humidity is higher, winds may be from the southwest, high clouds may be present, and the barometric pressure (air pressure) may be falling.
- **Front is passing through:** Gusty winds may be present, rain clouds and thunderstorms may be present along the frontal boundary, and air pressure reaches a minimum.
- **Behind the front** (after the front has moved through): Temperature is initially cool and becomes increasingly colder, humidity is lower, winds may be from the northwest, skies are clear, and air pressure may be rising.

When a warm front moves into an area:

- **Ahead of the front** (before the front reaches an area): Temperature is cooler, humidity is low, winds may be from the east or southeast, a variety of clouds may be present (with possible precipitation), and the air pressure may be falling.
- **Front is passing through:** Air pressure reaches a minimum.
- **Behind the front** (after the front has moved through): Temperature is warmer, humidity is higher, winds move from the south or southwest, skies may clear, and the air pressure may be rising.

(Information on frontal system weather parameters from Hydrology and Atmospheric Science 2012.)

FIGURE 4: **Students measuring, recording, and analyzing temperature at their school site using probeware**

for sunscreen and eye protection in strong sunlight. Tell students to keep electronic instruments (e.g., calculator, laptop) dry, keep all probeware with points (e.g., stainless steel temperature probe) away from eyes, and use all probeware only as instructed by the manufacturer. (Students should report any damaged or malfunctioning equipment to their instructor.)

Once outside, students work in small groups of two to four students to review related vocabulary and answer the prelab questions (Figure 5) to assess their understanding prior to data collection. Students use one clipboard and help each other collect and record data. They use probeware to determine atmospheric temperature, relative humidity, atmospheric pressure, and wind speed. Temperature, humidity, and pressure are recorded for three minutes each. The maximum, minimum, and average temperature; percent humidity; and atmospheric pressure should be recorded for each minute. Students can then calculate an average minimum, maximum, and overall average for the entire three-minute time period.

Students are also tasked with finding wind direction using simple tools such as a compass and a flag or pompoms. Students should use the compass to position themselves so that they are facing north. (*Note*: Students should be instructed on how to use the compass, as many students have not had previous opportunities to do so.) One student in each group should then hold the pompom straight toward the sky, over his or her head. Other students in the group will record, every 10 seconds for five minutes, which direction the streamers are blowing. If there is no movement, students should make a slash through the corresponding box in Figure 6. Because wind direction measurements can be difficult if there is not a consistent wind current on the day of measurement, students

FIGURE 5: **Weather parameters preactivity questions**

Predict the following measurements prior to using your instruments. Don't forget your units!

a. Temperature (°F): _______/(°C):______
b. Relative humidity (%): ___________
   (*Hint*: 100% humidity usually means there is some form of precipitation occurring.)
c. Wind speed (m/s): ____________
d. Wind direction: ___________________
   (*Hint*: north, southeast, northwest, west, etc.)
e. Cloud type(s): ___________________________________
   (*Hint*: Use your descriptions in the introduction.)
f. Cloud cover (%): ________

Do these measurements indicate weather or climate at your location? What is the difference between weather and climate?

FIGURE 6: Weather data table

Temperature	**Minimum** (°F/°C)	**Maximum** (°F/°C)	**Average** (°F/°C)
Minute 1			
Minute 2			
Minute 3			
Average			
Relative humidity	**Minimum** (%)	**Maximum** (%)	**Average** (%)
Minute 1			
Minute 2			
Minute 3			
Average			
Atmospheric pressure	**Minimum** (Hg)	**Maximum** (Hg)	**Average** (Hg)
Minute 1			
Minute 2			
Minute 3			
Average			

Wind Direction	10 s	20 s	30 s	40 s	50 s	60 s
Minute 1						
Minute 2						
Minute 3						
Minute 4						
Minute 5						

Average wind direction: ___________

(Most frequent direction recorded in the table above.)

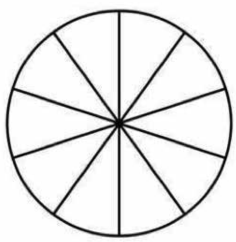
Wind speed	**Minimum** (m/s)	**Maximum** (m/s)	**Average** (m/s)
Wind speed measurement			
Time at measurement			
Cloud type name	Detailed description of cloud		

Cloud coverage

Looking directly overhead, shade in areas of the pie chart below where you see clouds. Fill in the fraction of the pie filled with clouds and convert that to a percentage. Then, indicate the classification of cloud cover (clear, fair, mostly sunny, partly cloudy, mostly cloudy, broken, overcast).

Approximately how long of a span of years do climatologists need to study trends in weather patterns to determine a region's climate or changes in climate?

Why can't we just use the weather results from one day?



Fraction _____/10

Percentage ______%

Clarification of cloud cover:

are asked to record wind direction measurements over the course of five minutes to gain a general idea of wind direction. Once they have recorded wind direction, students can use probeware to collect wind speed data for a period of five minutes, pointing the anemometer in the predetermined direction. They are asked to find the maximum, minimum, and average wind speed using graphing analysis tools. Students can also follow the line graph on their probeware interface to determine the time at which the maximum and minimum wind speed measurements were reached during their five-minute interval.

Finally, students assess cloud cover and cloud type(s). Following the instructions and diagrams provided in Figure 6, students look directly overhead, "divide" the sky into 10 imaginary "pie" slices, and count the number of pieces that are covered with clouds (i.e., four out of 10 = 4/10). The percentage can then be easily calculated by adding a zero to the number of cloud-covered pie slices (i.e., 4/10 = 40%). To conclude the activity, students examine the sky to identify cloud type(s) using the Weather Data Table shown in Figure 6.

Climate at a Glance activity

Following the Weather Parameter Lab, students can further assess the climate of their local region from 1895 to present using the NOAA website, Climate at a Glance (see Resources). Students can explore differing climatic variables, including average temperature, maximum and minimum temperatures, precipitation amounts, and degree of drought. To compare the variables for the specific region from which students gathered data in the Weather Parameter Lab, students should search data at the "divisional" region size. They should research and document (see Figure 7) current climatic data, data from 15 years ago, and data in increments of 30 years from present to 1895. Students should observe and make note of any differences and similarities among the data throughout the 120-year time span. Students can also make a line graph of the data to show trends in their local region throughout the last 120 years. They can graph by hand or use a graphing program. Students should consider questions such as:

- Why do you think you were asked to record the variable measurements in increments of 30 years? (Climate patterns are averaged over many years.)
- Are there trends in any of the variables over 120 years? If so, what do you think might contribute to these trends? (Answers will vary based on location examined. Students may note that temperature

FIGURE 7: NOAA: Climate at a Glance worksheet

	Average temperature (°F/°C)	**Maximum temperature** (°F/°C)	**Minimum temperature** (°F/°C)	**Precipitation amount** (in.)	**Palmer Drought Severity Index (PDSI)** (−10 [dry] to +10 [wet])
Current year					
15 years ago					
30 years ago					
60 years ago					
90 years ago					
120 years ago					
Average					

Note: Select "divisional" for region size and the same month for each year's data at NOAA's Climate at a Glance website (see Resources).

decreases, then increases. Industrialization has led to the burning of fossil fuels for travel, manufacturing, heating, and cooling. Increases in population are adding to these upward trends.)

- What role do humans play in the rise in global temperatures over the past century? (This information is in the Science Girl video. Choices have an impact, such as driving a car that uses a lot of gas, wasting energy, and eating a high-meat diet.)
- What is *weather*? What is *climate*? How are these two terms alike, and how are they different? (Weather and climate are based on similar parameters [temperature, rainfall, humidity, wind speed]. Weather is what is happening short-term; climate is weather patterns over long periods of time [generally 30 years or more].)
- How do the data you collected compare to the data (from the same geographic location) from this year? How do they compare to 15 years ago? One hundred and twenty years ago? (Students may note that temperatures, precipitation, and drought severity are different for other years and whether there are trends toward warmer or colder average temperature.)

Extension activities

To conclude the activity, students revisit the difference between the terms *weather* and *climate*. Teachers should assess student understanding at the conclusion of the activity to address any alternative conceptions students may have in distinguishing between *weather* and *climate*. Given more time, teachers could provide opportunities for students to do the following extension activities on subsequent days:

- Assign alternating student groups to go out each day for a one- or two-week period, record weather parameters using the same protocols as for the lab activity, and report back to the class. (Note: Remind students of the safety precautions mentioned earlier. Some classrooms have a view of a courtyard or other outdoor space, if students cannot go outside. Parent volunteers or faculty on hall duty can help supervise students.)
- Students can create and broadcast schoolwide weather reports each morning based on their measurements and data recording.
- Prior to watching a local meteorologist's report, students can use their authentic local weather data and weather maps from previous days to predict pressure systems and frontal system movements.
- Students can learn how to draw weather station models (e.g., amount of cloud cover, temperature, precipitation type, wind speed, wind direction) and create local weather station diagrams using their authentic data (see Resources).
- The class groups can assess how closely their measurements align with a local meteorologist's recordings.
- Students can learn how to draw isobar lines (e.g., atmospheric pressure, temperature, humidity) across the United States (see Resources).
- Students can use the variation in recorded weather parameters to explore large-scale changes in weather patterns exhibited through the movement of high and low pressure systems and regional frontal movement.

Example extension activity: Frontal system puzzler (one week of data collection and one week of analysis)

As an extension activity, ask students to use a week's worth of weather parameters, similar to what was recorded in Figure 6, to determine whether a frontal system (i.e., warm front, cold front) has moved through the area (see sidebar on page 79). You may need to review with students the characteristics of *air masses* (body of air with uniform temperature, humidity, and pressure) and their relationship to fronts that are *warm* (forward edge of an advancing mass of warm air that rises over and replaces a retreating mass of cooler air), *cold* (forward edge of an advancing mass of cool air that drops below and pushes up a retreating mass of warmer air), *occluded* (two cooler air masses occlude and push up a warmer air mass in between the cool masses), and *stationary* (when two air masses meet and neither is strong enough to overtake the other, remaining in a location). Students should then hypothesize which of the frontal systems has moved through (unless there was evidence of a stationary or occluded front) the area.

After making predictions of frontal movement in their region, students should access the weather reports for the days recorded at Weather Underground (see Resources). Students will be able to determine if their weather parameter recordings were similar to those of Weather Underground meteorologists. Students should then visit the NOAA/Department of Commerce website (see Resources) to examine maps of frontal system movement from the days recorded. Students may also be able to access archived meteorological data from their local news stations to determine frontal system activity. Students should compare and contrast their weather measurements and frontal system predictions to those of the websites provided and brainstorm why they may have noticed discrepancies in their data or incorrect frontal predictions.

Climate or weather professional speaker

Toward the end of the club meeting, our students had the opportunity to speak with the state climatologist to help connect them to a related career. Teachers can conduct an online search to find climatologists in their state; such professionals may work with state government or a local university. Teachers can also arrange for students to speak with a meteorologist from a local television station. Normally, this can easily be arranged online, but it will need to be done well in advance of the planned activity day. We have found that students best receive speakers when they are able to talk with students in person; however, we have also had success with virtual meetings through Google Hangouts and Skype. Additionally, in our experiences with STEM professionals meeting middle school students, students have been more interested in asking questions, and less interested in learning about the intricate details of the profession. We encourage speakers to share what they were like as middle school students and what made them interested in their career.

Discussion questions

Following the activities, teachers lead students through a series of reflection questions to informally assess understanding and help students reflect on the content covered. Students are encouraged to discuss answers with one another and then share with the larger group. Example discussion questions include:

- How are weather and climate related? How are they the same and how are they different? (Weather and climate are based on similar parameters [temperature, rainfall, humidity, wind speed]. *Weather* is what is happening short-term; *climate* is weather patterns over long periods of time [generally 30 years or more].)
- Why is it important to learn about your local weather? What factors (e.g., atmospheric conditions, geography) affect regional weather patterns? (So you will know what clothes to wear each day/season; for safety reasons such as tornado and hurricane alerts; factors such as locations near bodies of water and mountains affect regional weather patterns [e.g., lake effects increase precipitation, hurricanes in oceans on the East Coast, drier weather on the east side of mountains, air currents/rainfall moving from west to east].)
- How might a changing climate affect where you live? What benefits or harm might result from these changes? (Could affect rainfall on

plants/crops, increase allergic reactions, increase occurrences of respiratory illness, increase flooding, negatively impact lives of animals, etc.)

- How does climate affect the biosphere (e.g., plants, animals, fungi) in a region? (Changes in the growing season or amount of rainfall will affect where plants and fungi grow, as well as food sources and habitat for animals. Organisms' niches will change based on temperature and precipitation amounts.)
- What impacts could a changing climate have on a region's biome? For example, how might rising temperatures and drought affect a deciduous forest? Grasslands? Agricultural fields? (Biomes are covered in the *Next Generation Science Standards* [NGSS Lead States 2013; e.g., savannah, tundra, rainforest], but using more localized examples may be more meaningful for students. This response will vary dependent on the biome students choose to examine.)

Final thoughts and resources

The activities outlined here were conducted during a two-hour after-school STEM career club meeting; however, this activity suite could be broken down for use in a traditional classroom setting. For example, teachers can introduce the quiz game, watch the climate change video, and practice using the probeware in the classroom during a 60-minute traditional classroom session. During the next hour-long class period, students can prepare to go out and collect data. The activity can be wrapped up on a third day with a guest STEM professional speaker and a more formal assessment using discussion questions or multiple-choice content questions provided on the STEM career awareness website (see Resources).

The activity agenda, supplemental information, quiz game template, lab sheet, data sheets, and content questions can be accessed at the STEM Career Awareness website under "Weather & Climate Activities" on the right-hand side of the home page (see Resources). This website also provides additional information related to STEM Careers that may be easily integrated into other traditional and informal STEM settings. ●

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RESOURCES

Climate at a Glance—*https://gis.ncdc.noaa.gov/maps/ncei/cag*

Climate or Weather? Wildlife Quiz Game—*http://bit.ly/2tjYNHs*

Isobar lines activity—*http://bit.ly/2v2WaeN*

Kahoot!—*https://kahoot.com*

NOAA/Department of Commerce daily weather map—*www.wpc.ncep.noaa.gov/dailywxmap/index.html*

Science Girl: Climate Reality—*https://youtu.be/Eij91cInLHI*

STEM career awareness—*https://stemcareerawareness.wikispaces.com*

Weather station activity—*http://bit.ly/2gQVZ2D*

Weather Underground—*www.wunderground.com/history*

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

- 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 materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standard

MS-ESS2: Earth's Systems
www.nextgenscience.org/dci-arrangement/ms-ess2-earths-systems

Performance Expectation

MS-ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
Planning and Carrying Out Investigations Analyzing and Interpreting Data	Students use probeware to collect data on weather parameters such as temperature, wind speed, relative humidity, atmospheric pressure, wind direction, and cloud coverage. Students examine regional historical climatic data to determine trends and compare with data from a NOAA database.
Disciplinary Core Idea	
ESS2.D: Weather and Climate • Because these patterns are so complex, weather can only be predicted probabilistically	Students use historical data to determine how climate has changed over time. Students collect and use weather parameter data to observe local weather patterns for the purpose of identifying frontal systems that have moved through the area.
Crosscutting Concept	
Cause and Effect	Students use their knowledge of air masses to determine whether a frontal system has moved through the local area.

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