Dry, Drier, Drought in Colorado

Setting the Stage

The 2012-13 North American Drought originated in the midst of a record-breaking heat wave, and was an extension of the 2010-13 Southern United States Drought. In 2018, Colorado drought conditions were the worst since that time. By the end of 2018, the Southwest Region was experiencing “exceptional drought," which is the most severe intensity of drought. The 2018 drought is part of a trend towards increasing frequency and severity of drought globally. This lesson will investigate the causes, effects, and impacts of this phenomenon in Colorado.

Impacts of drought on the Colorado River in the Southwest U.S.
Photo Credit: USGS https://pubs.usgs.gov/fs/2004/3062/

Lesson Overview

Students will build understanding about drought in Colorado through the following learning activities:

- *Activity 1 – Engage (15 minutes) Drought in Colorado*
  As a class, watch videos about drought in Colorado, and have a class discussion on what students know and wonder about drought.
- *Activity 2 – Explore (35 minutes) Drought & Case Study Data Analysis*
  In teams, analyze drought information and data to build understanding of the causes, impacts, location, and frequency of drought in Colorado.
- *Activity 3 – Explain (50 minutes) Local Drought News Story*
  In teams, create a communication product educating your community about the causes and impacts of drought, past and current drought status, and tips on preparing and responding to drought.

Instructional Overview	
Grade Level	Middle School
Instructional Time	100 minutes
Standards Alignment	NGSS: MS-ESS3-2 CDE: MS3.ESS.GLE9
Anchoring Phenomenon	● Causes and effects of drought can be identified and measured ● Natural factors, such as weather and climate, affect the potential and severity of drought ● Natural and human-impacted environments, including agriculture, tourism, and residential development, are affected by drought
Driving Questions	● What causes drought? ● How is drought measured and monitored? ● Which areas in Colorado are more vulnerable to drought impacts? ● In what season are drought impacts most likely to occur?
Learning Goals	● Students will understand the basic causes and impacts of droughts ● Students will analyze case study and current drought data in Colorado ● Students will summarize the main preparedness steps and response strategies for drought events
Materials	❑ *Students:* One student handout per student (digital access or printed copy & pencil) ❑ Individual student computer devices or classroom computer with projector, and internet ❑ *Entire class:* For the Activity 2 wrap-up discussion,12 large Post-Its or pieces of poster size paper, 12 packs of sticky notes, and 12 felt markers ❑ Materials for Activity 3, depending on the format each group chooses (e.g., poster paper, access to slide presentation and word processing software, audio/video recording, internet, etc.)
Material Preparation	❑ Print student handouts if needed ❑ Ensure computer access ❑ Cue and test web links ❑ Plan vocabulary integration ❑ For Activity 2 stations: If internet is available, use student handouts with embedded activity links with student personal devices or two to four shared devices with activity links bookmarked at each station. If internet is unavailable, print two copies of materials located in the MS Drought Resources Folder per station and show video links as a class. Set up two sets of large Post-It or poster size paper, sticky notes, and markers.
Vocabulary	Natural hazards are naturally occurring phenomena such as drought,

	wildfire, extreme heat, or flood, which may disrupt or damage a community. Drought is a prolonged drier-than-normal period in a natural climate cycle that results in water-related problems. GIS is an abbreviation for *Geographic Information System*, which is a computer-based process that gathers, manages, analyzes, and visualizes spatial data. Precipitation is any type of water that forms in the Earth's atmosphere and then drops onto the surface of the Earth (e.g., rain, snow, sleet, or hail). Snow Water Equivalent (SWE) is the amount of water contained in the snowpack at a location (if the entire snowpack were to melt). Water Year is a 12-month period that runs from October 1 through September 30 each year.
Instructional Strategies	• Jigsaw (optional, used in Activity 2): A cooperative learning strategy in which each group is responsible for learning one "piece of the puzzle" and then sharing that information with other groups to complete the whole picture. Consider using Activity 3 for students to present the information they learned at their stations. Teachers can choose to use this strategy if time is limited, and stations can be differentiated for different student abilities and levels of teacher assistance. • Mind mapping (optional; used in Activity 2): A creative way to "map out" students' thoughts and ideas. Similar to a concept map, multiple formats can be used to develop students' trains of thought and make connections between main ideas or concepts.

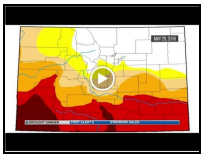
Activities	**Web Links for Lesson Resources** Note: all resources are downloaded as pdfs in the *Activity Resources Folder*
Activity 1	• Video: KOAA 5 News, Drought conditions in June 2018 similar to 2012-13 https://www.youtube.com/watch?v=7NERthvNN_I • Video: Assessing Drought in the United States https://www.youtube.com/watch?v=i7F6QwRqyVI
Activity 2	Station 1 • Text: Drought in America: Slow moving, far reaching https://www.noaa.gov/explainers/drought-in-america-slow-moving-far-reaching Station 2 • Video/Data Visualization: Drought Monitor Time Lapse Nov. 2011-Dec. 2012 https://www.youtube.com/watch?time_continue=36&v=O88n48q1za0 • Data Visualization: Drought History in Colorado graph https://www.drought.gov/drought/states/colorado?places=colorado • Data Visualization: Drought Data Snapshots https://www.climate.gov/maps-data/data-snapshots/usdroughtmonitor-weekly-ndmc-2019-05-07?theme=Drought Station.3 • Text (map included): Dry Southwest still waiting on winter in January 2018 https://www.climate.gov/news-features/event-tracker/dry-southwest-still-waiting-winter-january-2018 • Text (map included): Intense drought in the U.S. Southwest persisted throughout

	2018, lingers into the new year https://www.climate.gov/USdrought2018 Station 4 ● Data Visualization: CoCoRaHS Condition Monitoring Map https://www.cocorahs.org/Maps/conditionmonitoring/ Station 5 ● Website & Data Visualization: Drought.gov Portal for local drought conditions https://www.drought.gov/drought/ Station 6 ● Video: To Escape Drought, Slow and Steady Wins the Race https://www.climate.gov/news-features/videos/video-escape-drought-slow-and-steady-wins-race ● Text: Drought Ready https://www.ready.gov/drought
Activity 3	● Video: HEART Force Drought Expert https://www.youtube.com/watch?v=P-8GCtfP8K4&feature=youtu.be Optional Resources: ● Text: Colorado Planning for Hazards - Drought https://www.planningforhazards.com/drought ● Website: Drought for Kids https://drought.unl.edu/Education/DroughtforKids.aspx ● Data Visualization: NOAA Science on a Sphere-Drought Risk in Real Time https://sos.noaa.gov/datasets/drought-risk-real-time/

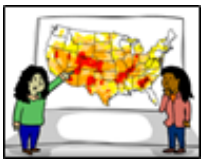
Activity 1 (Engage)
Drought in Colorado (15 minutes)
Drought, wildfire, and weather: What's the connection in Colorado?

Think: What do you know about drought?

1. In one minute, jot down as much information as you know about droughts in the "What I Know" section of the KWL Chart in your student handout.
   Responses vary.



First, watch the drought news clip (2:43) to get a feel for the impacts of drought on people and the environment, and how drought conditions are mapped. Make mental notes about what you see and hear in the video.



Next, watch Assessing Drought in the United States to learn how scientists assess the causes and impacts of drought in our country, including Colorado.

Pair: Discuss your observations and wonderings about the drought videos with a partner.

2. Write down your observations and questions about drought as a natural hazard in the "What I Wonder" section of the KWL Chart in your student handout.
   Responses vary.

Share: As a class, briefly discuss observations and wonderings about the drought videos. Individually answer the following questions about measuring drought in your *Drought Diary* student handout, and then share responses as a class.

3. List the four categories of drought, in order from the least to greatest level of drought, and their color coding.
   DO=Abnormally Dry (yellow)
   D1=Moderate Drought (light orange)
   D2=Severe Drought (orange)
   D3=Extreme Drought (red)
   D4=Exceptional Drought (dark red)

4. Which organization tracks the level of drought across our country?
   The U.S. Drought Monitor

KWL Chart	
1. What I Know	
2. What I Wonder	
What I Learned (Activity 3)	

Activity 2 (Explore)
Drought Data Analysis Jigsaw (35 minutes)

Activity 2 is designed as a jigsaw in which students work in small groups to complete the activities at four different stations and then share out. Alternatively, teachers may decide to run some stations as whole-class, teacher-led activities before assigning the remaining stations as a student-led, small-group jigsaw.

Station 1: Drought Causes and Impacts

Build your understanding of the causes, effects, and historical impact of drought by watching the National Geographic Droughts 101 clip.

Next, use the Drought in America: Slow moving, far reaching website to build your knowledge about drought.

5. What is drought?
   Drought is when less than normal or no precipitation falls for an extended period of time (usually a season or longer), and results in a water shortage.

   Additional details: Drought is caused by below-normal precipitation (rain and snow), leading to a shortage of water in the soil and in streams, rivers, and lakes. Unusual heat is often part of drought, since dry weather is associated with sunny and warm conditions. This heat makes the impacts of drought even worse. Drought is called a "creeping" hazard; its impacts emerge slowly compared to flooding or wildfire.

6. What are some causes and impacts of drought?
   Changes in normal weather and precipitation patterns (e.g., El Niño/La Niña) can lead to drought, as can overuse of water resources by humans. In ecosystems, lack of water can affect animals and plants by reducing food supplies, increasing wildfire risk, and damaging habitats (e.g., decreased streamflow affects fish). Drought can affect the health and safety of people due to heat-related illnesses and conflicts over water resources. Drought is one of the most expensive natural hazards due to the costs of crop failure, increased energy and water use, and infrastructure and human property losses from drought-related wildfires.

   Additional details:

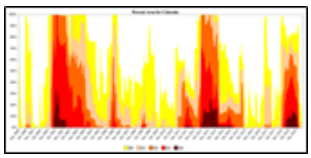
Drought vulnerability varies from place to place, depending on what drives the local economy. In general, cities with more diverse economies are less vulnerable than rural areas dependent on agriculture or outdoor tourism and recreation.

Water supplies for communities can be threatened by severe drought. Most communities have reservoirs to store surplus water and buffer the impacts of drought, but droughts lasting 2 years or longer may use up that buffer. Similarly, irrigated agriculture is vulnerable to drought. Many farmers don't have water stored in reservoirs, so they may have to stop irrigating crops during droughts.

Dryland agriculture and ranching are also at risk from drought. Additionally, outdoor recreation and tourism that rely on water are also impacted by drought (e.g., rafting, skiing, fishing, boating, swimming, etc.).

Station 2: Drought History in Colorado

Review the graph of Drought History in Colorado graph (scroll down the webpage and click the "Percent Area for Colorado" graph). Record your observations about the drought trends and patterns that you notice in Colorado from 2000 to the present.



7. Which years did Colorado experience extreme drought (D3) and exceptional drought (D4)? Which specific timeframe had the greatest level of exceptional drought (D4)?
   Colorado was in extreme and exceptional drought during 2002-2004, 2006, 2011-2014, 2018-early 2019. July 2012 to July 2014 had the greatest amount of exceptional drought.

8. When Colorado is experiencing drought (D1-D4), especially intense drought (D3, D4), what percentage of the state is generally affected?
   When Colorado is experiencing drought, a majority of the state is affected.

Next, explore the Drought Data Snapshots interactive to analyze the 2012 drought in Colorado.

Use the adjustable timeline located below the map screen to move the "Year" tab over two marks to the right to select 2012, and slide the "Day" tab from the far left (January) to the far right (December) to observe changes in the map data (spatial data) over the year.

9. During 2012, which month and what general location in Colorado first experienced extreme drought (red)?

Colorado first experienced extreme drought in May 2012 and it was located in northwest Colorado.

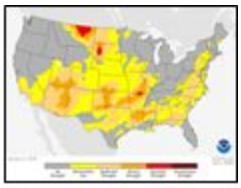
10. During 2012, which month and what general location in the state was first affected by exceptional drought (dark red)?
    Exceptional drought first affected the state in July 2012 in the northwest and southeast areas of the state.

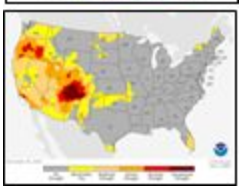
11. In which month of 2012 was the severity and expanse of drought the greatest in Colorado, and what was the primary level of drought?
    In July 2012, all of Colorado was experiencing the greatest severity and expanse of drought. Most of the state was in extreme drought status and the remaining areas were in severe drought.

12. What was the statewide level of drought in Colorado at the end of December 2012?
    At the end of 2012, the entire state of Colorado was in drought (moderate to exceptional drought).

Station 3: 2018 American Southwest Drought

The American Southwest is defined as New Mexico, Colorado, Utah, Nevada, Southern California, and Arizona.





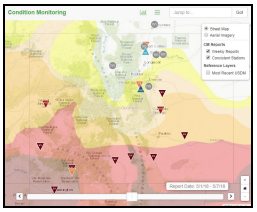
Review the maps of the 2018 southwest drought; first, the map from the start of the year and, then, at the map at the end of the year:

- Dry Southwest still waiting on winter in January 2018 (start of 2018)
- Intense drought in the U.S. Southwest persisted throughout 2018, lingers into the new year (end of 2018)

13. What were the drought categories throughout Colorado at the start of 2018? Which areas of the state had the greatest drought level, and which areas had the lowest? *Note: the dates for each map are in the bottom left corner of the animation.*
    The drought categories in Colorado at the start of 2018 included abnormally dry (eastern, northwest corner, partial central area), moderate drought (western and southwestern area), and severe drought (southwest corner). A majority of the state was drier than normal and western, southwestern, and southern parts of the state were in drought at the start of 2018.

14. What were the drought categories throughout Colorado at the end of 2018? Which areas of the state had the greatest drought level, and which areas had the lowest?
    The drought categories in Colorado at the end of 2018 included abnormally dry (northeast and southeast areas), moderate drought (small portions of north central and southeast areas), severe drought (northwest and southeast areas), extreme drought (west and south central areas), and exceptional drought (southwest corner). A majority of the state was in drought and the level of drought was much greater at the end of 2018 than at the start of the year.

Station 4: Impacts of the 2018 Drought in Colorado



Visit the CoCoRaHS Condition Monitoring Map, a resource you can use to explore past drought conditions and read on-the-ground reports made each week by CoCoRaHS volunteer citizen scientist observers.

In the lower right, use the "+" symbol to zoom in on the map, the "-" symbol to zoom out, and the home icon to return to the default map view screen. Use the timescale slider at the bottom of the screen to change the date of the maps that you are viewing. Read volunteer observations by clicking on the upside down triangles.

Zoom into Colorado and use the timescale slider to view maps from June, July, and August 2018.

15. Read some observations from areas experiencing Extreme and Exceptional Drought (dark red areas). What are observers reporting? Include details of the impacts they see, and the date and general location of the observer (e.g., June 2018, SE Colorado).
    Answers vary. Details may include low rainfall, fire danger or wildfires occurring, and impacts to crops and gardens.

16. Read some observations from areas experiencing Abnormally Dry conditions or Moderate drought. What are observers reporting? Include details of the impacts they see, and the date and general location of the observer (e.g., June 2018, SE Colorado).
    Answers vary. Details should show less severe impacts than those listed in the question above.

Station 5: Current Drought Conditions in Colorado

Use the Drought.gov web portal to find out the current drought conditions in your community and in Colorado.

Enter your zip code into the box in the middle of the screen that says “Enter your city or zip code for current conditions,” and click the yellow “Get Conditions” box.

17. What is the current drought condition in your community? What is the precipitation total and average high temperature for the last 7 days?
    Answers vary.

Now, click on the brown box that says “Colorado Conditions.” A map of Colorado should appear, with an explanation of what percentage of the state is in each drought category.

18. What percentage of the state is Abnormally Dry? What percentage of the state is in Severe Drought? What percentage of the state is in Exceptional Drought?
    Answers vary.

19. Based on the time of year, and the recent weather in your community, are you surprised about the current drought conditions in Colorado? Why or why not?
    Answers vary.

Station 6: Drought Preparation & Response

Drought is described as a slow-moving and long-term natural hazard, which is a different experience from fast-acting and shorter-duration natural hazards, such as floods, wildfires, earthquakes. How does this difference affect how people are able to prepare for, respond to, and rebound from drought?

Watch the video To Escape Drought, Slow and Steady Wins the Race.

Then, review the Drought Ready.gov webpage. In your student handout, write down key tips for your community to manage drought.

20. What are ways that your family and community can conserve water during a drought?
    Take shorter showers, turn off the water while brushing teeth or shaving, wash full loads of laundry or adjust the water level for the size of load, use dishwashers only when fully

loaded or wash dishes by hand and rinse in a filled basin (not with running water), water lawns less and in the morning or evening hours (or not at all), catch and reuse any water from sinks and showers for watering plants, repair any indoor or outdoor plumbing and sprinkler leaks, etc.

21. Drought increases the risk of wildfire due to vegetation drying out and dying. What are some fire prevention actions you and your family can take during a drought?
    Do not use fireworks, completely put out campfires and fire pits, properly dispose of cigarettes, follow any fire ban and/or water use restrictions, etc.

Activity 2 Wrap Up Discussion

Have a 10-minute mind mapping session or consensus discussion session about your findings and learning from the activity sections. Start the class mind map with “Drought” labeled in the center of a large Post-It, poster size paper, or shared digital document.

As a class, briefly share findings for Stations 1-4 to check and correct your responses, as needed, and add key information to the drought mind map.

Collect student handouts and/or have them digitally share their copy with you. Student handouts will be used for Activity 3, and it is important for students to have complete and correct responses to communicate information.

Suggested discussion questions:

- What are key factors about the causes and impacts of drought?
- In which locations and at what time of year do most droughts occur in Colorado?
- How should people prepare for and respond to be safe in the event of a drought?

Activity 3 (Explain)
Drought Public Information Notification (50 minutes)
How can communities know about and manage their drought risk in Colorado?

For Activity 3, students will work in new groups, or hazard expert teams. Each hazard expert team is made up of one student from each of the jigsaw groups, so that the team consists of students that collectively completed each of the Activity 2 stations. The goal is to have an expert from each station in order to communicate key drought information to your (or another) community that faces wildfire risk and/or had experienced a drought in the past.

In addition to using their student handouts, use Activity 3.1 as a model for students to develop their ideas about how drought affects communities. See Activity 3.2 for the final product instructions (summative assessment for the lesson).

Activity 3.1 Drought Expert Interview (5 min)

First, watch the short video with Doug Kluck, who is the NOAA Regional Climate Services Director for the Central Region of the country. Doug talks about many of the drought concepts that you learned in the previous activities, and that you will present about in this activity:

Drought Expert Video

Activity 3.2 Local Drought News Story (45 min)

Prompt: Create a local news story in a format of your choice (see options below) that summarizes important information about for people in your community to be “drought wise” before, during, and after a drought. Use information from the Drought Expert Video and information gathered in your student handout to communicate information about:

- Causes and impacts of drought
- Historic drought: Highlights of the 2012 and 2018 Colorado droughts
- Recent and current drought conditions around Colorado and in your community
- Tips for people in preparing for and responding to drought

The format choices for the Local Drought News Story include (be creative but accurate):

- Newspaper article with one picture and one graph or map (one page)
- Radio story (2-3 minutes in length)
- Video newscast (2-3 minutes in length)

Additional drought resources:
Colorado Planning for Hazards—Drought
Drought for Kids

Local Drought News Story	
1) KWL Chart "What I Learned" (see page 2) ❑ Check when completed	As a group, reflect on what was learned in Activities 1, 2, and 3. Then independently complete the "What I Learned" section of your KWL Chart (see page 2 of the student handout) to summarize your learning. Use these prompts to reflect on what you learned: ● What important things do you now know about drought that you didn't know before? ● What should people do to be "drought wise" before, during, and after a drought?
2) Choose a Format ❑ Check when completed	As a team, choose one of the following formats for your group's Local Drought News Story: ● Newspaper article with one picture and one graph or map (one page) ● Radio story (2-3 minutes in length) ● Video newscast (2-3 minutes in length)
3) Create a Draft ❑ Check when completed	Referring to notes and responses in your student handout, make a quick draft of your group's product ideas. Your team's product should summarize and share information about: ● Causes and impacts of drought ● Historic drought: Highlights of the 2012 and 2018 Colorado droughts ● Recent and current drought conditions around Colorado and in your community ● Tips for people in preparing for and responding to drought
4) Create the Final Product ❑ Check when completed	Create your team's Local Drought News Story. Remember to keep your product brief and summarize the key elements for your community audience that you drafted in step 3 (above).
Lesson Rubric	Refer to the rubric to help you assess Activity 3.

If there is extra time, participate in a class gallery walk, where your team shares what they have learned about how people and communities prepare for, respond to, and rebound from drought.
Presentations will vary; they may be assigned as homework, if needed.
Post presentations in the classroom and/or online for hosting the class gallery walk.