PReSto*

Student Guide

*Paleoclimate Reconstruction Storehouse of Proxy and Model Data:
An Earth Science Curriculum

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Wupatki Pueblo and National Monument near Flagstaff, Arizona. In the Hopi language, *wupatki* translates to “tall house.”

People have lived in the Southwest since time immemorial. They have built simple and intricate structures. These sites are sacred to the modern Indigenous peoples, especially to the Hopi, Navajo, Ute, and Apache peoples. Their livelihoods continue to be linked to the climate. When it is wet, they take advantage of the environment’s resources while dry spells create opportunities to either invent innovative ways to live or move on to other places.

At places like Wupatki National Monument, people took advantage of the pluvial during 1075-1121 CE and they moved on during the megadrought 1122-1299 CE. The pluvial brought a surplus of water to the region releasing nutrients into the soil for agriculture. However, by 1250 CE, the people moved to other places in search of better opportunities to live.

In first part of this curriculum, we will investigate how scientists decode the climate of the past and how the duration of wet and dry periods may impact how people live. Generally, more water in the environment, or pluvial, means better opportunities to extract resources, whereas a lack of water, or drought, means a stressful time to live and people can and continue to make choices based on better ways to live with their environment or to move to other places where those resources are available.

In the latter part of this curriculum, we will study the properties and behavior of how dust impacts our lives through scientific inquiry and respecting the cultural significance it holds for Indigenous communities, we can work towards mitigating its negative impacts while preserving the invaluable traditional knowledge that has guided sustainable living in harmony with the environment for generations.

1. Ancient Dust: Unlocking the Secrets of the Past
2. Wisdom of the Trees: Dendrochronology
3. Wisdom of our Ancestors
4. Dust in a Box
5. Dust to Cloud
6. Why do Dust Storms Happen?

Name: _____

1. Ancient Dust: Unlocking the Secrets of the Past

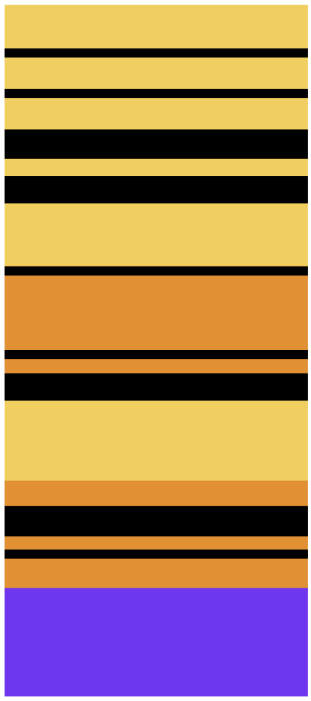
Do Now:
Take a look at the sediment core and respond to the questions below.

1. What do you notice about the sediment core?

2. How many layers do you see?

3. What do you think each layer represents?

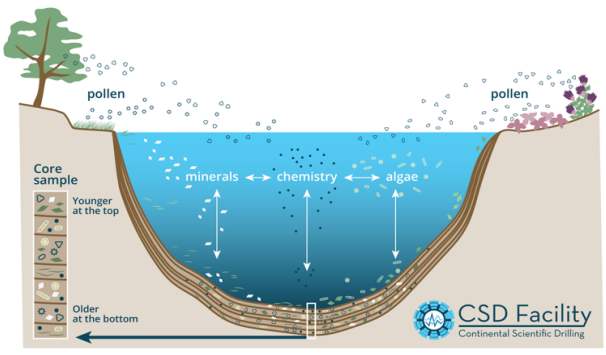
Sediment Core
Top



Bottom

Introduction:

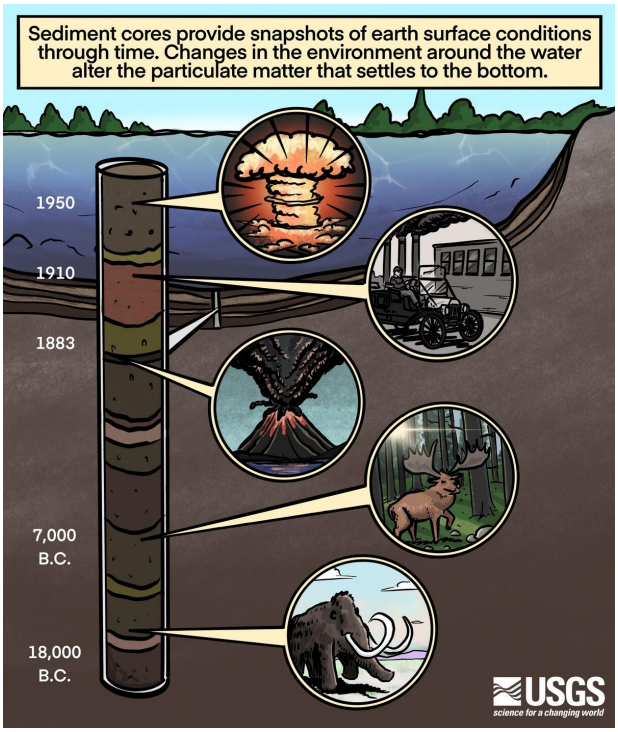
Lakes are excellent dust catchers, collecting and preserving a record of the surrounding environment. By studying lake sediment cores, scientists can reconstruct past environments and understand how they have changed over time. In this activity, you will collect and analyze a simulated lake sediment core to learn about past plant communities and environmental conditions.



Coring operation at Crater Lake, Colorado. 2016. Source: Nicholas McKay, Northern Arizona University

Core samples are taken by inserting cylindrical tubes into the bottom of a lake bed. When a stopper caps the top of the tube, the sediment is trapped inside the tube and can be pulled out of the lake bottom. This is like what happens if you use your thumb to cover the top of a straw in a drink - you can lift the liquid out of the glass due to the suction.

There are many different questions about the Earth and its environments that can be answered by studying lake cores. Researchers can learn about when earthquakes occurred in the past, how large volcanic eruptions were, what the temperature and rainfall were like, and what kinds of plants and animals lived in and around the lake. In this activity, you will be collecting a lake sediment core sample to examine what kinds of plants lived around the lake at different times by studying pollen.



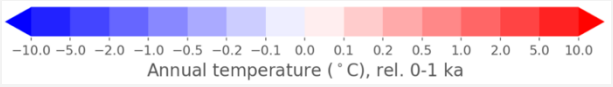
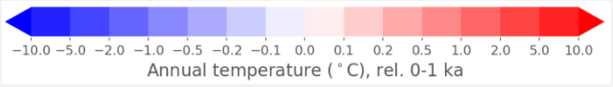
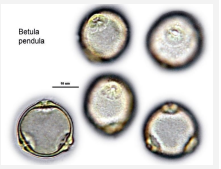
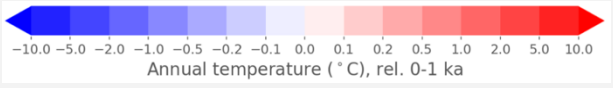
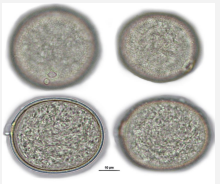
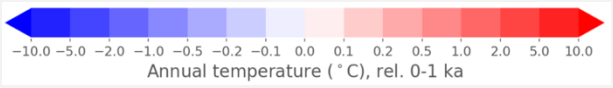
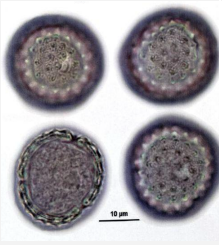
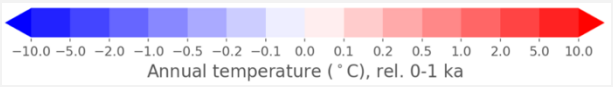
Before you collect your core sample, let's learn about pollen.

What is Pollen?

Have you ever noticed the yellow dust on the surface of a car that has been parked outside in the spring? Or perhaps you've heard of people suffering from pollen allergies? What is pollen anyway? Pollen is a powdery substance produced by flowering plants for reproduction. When viewed under a microscope, that powder consists of tiny grains of different shapes and sizes. Different plants create different pollen grains. A trained researcher can identify which plant produced which pollen. Pollen in lake sediments indicates that a certain kind of plant was growing in an area at the time it was deposited in the lake.

Plants in the Environment

What can plants reveal about where they live? Are these places cold? Warm? Wet? Dry? Write down your responses - perhaps in a chart with plant types on one side and environment on the other.

Plant Type	Pollen	Environment 4. Mark an "x" to select the environment where each plant is found
Pine Trees		
Oak Trees		
Birch Trees		
Grass		
Ragweed		

Part I: Collecting your Core Sample

Materials:

1. Lake Model: Tube of layered "sediments"
2. Large boba-tea-sized straw
3. White paper for extrusion of core sample
4. Colored pencils
5. Core description sheet
6. Pollen microscope printouts and radiocarbon dates
7. Magnifying glass or hand lens
8. Toothpicks for dissection/smearing
9. Metric ruler

Procedure:

Collect and Extrude a Core Sample

1. Insert the straw into the lake sediment model as far as possible while still holding the top.
2. Use your thumb to create suction and carefully pull up the core sample.
3. Extrude the core onto white paper by pinching the straw and pulling back.
4. Use toothpicks (or spatula) to carefully smear each layer for observation.

Initial Core Description

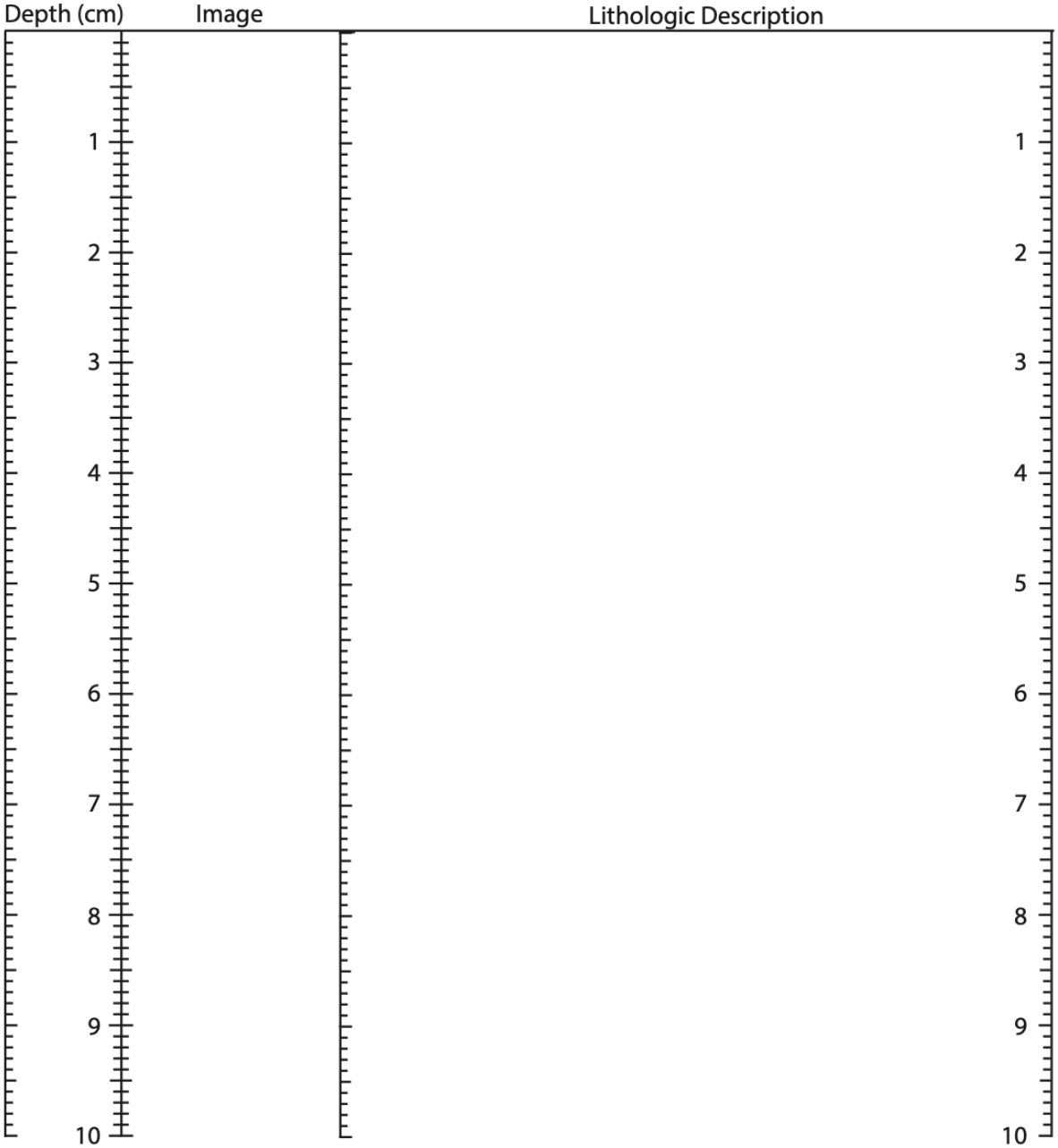
You can now identify the different pollen types in each layer. Using colored pencils and a ruler, fill out the **Initial Core Description** sheet, starting with the top of the core. Draw what you see in each layer, then write the name of the pollen type from each layer.

Part II: Core Description and Analysis

Initial Core Description

Lake:_____	Sediment Core Length (cm):_____

Use color pencils to differentiate layers



5. What part of your core is the oldest and which part is youngest? Explain your reasoning.

6. Do you see layers? If so, why do you think they formed? If not, explain your reasoning.

7. Describe any patterns you notice in the thickness of the layers. What might these patterns indicate about environmental conditions?

8. Based on the pollen types you identified, how do you think the plant communities changed over time? What might this suggest about climate changes?

9. Do you see any other materials (e.g., dust, ash, or small particles) in the core? What could these represent, and what might they tell us about past events?

Part III: Comparative Analysis (Group Work)

10. Compare your core with those of your classmates. What similarities and differences do you notice?

11. Based on your observations and comparisons, what can you learn about Earth's history by studying lake sediment cores?

Part IV: Connections to Traditional Knowledge

In several Indigenous cultures of the Southwest, there are stories of emergence from other worlds.

12. How does this activity connect to your culture's worldview? You may include a drawing to respond to this question.

Part V: Cores into the Ancient Past - Presto

According to the Principle of Superposition, the lower layers are older than the ones above them. Scientists working in lakes have extracted cores to look into the ancient past. They know when it was warmer and colder than today.

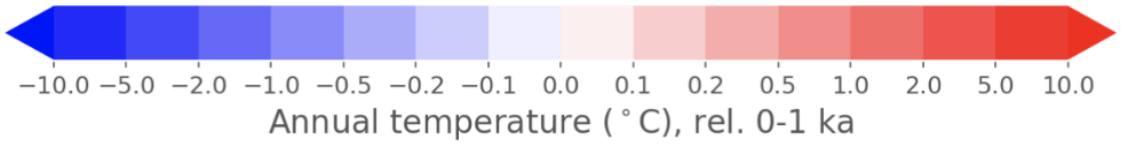
Using your mobile device, visit the Presto visual application:
https://paleopresto.org/visualizer.html?dataset=daholocene

This is the Holocene Reconstruction visualizer, which goes back 12,000 years! In the beginning of the activity, you used seeds as proxies for pollen. Scientists also use pollen from lakes and models to reconstruct past climate. Pollen, which are sensitive to temperatures, make them useful to recreate the past.

The temperature is set to -5 yr BP (years before the present) or 5 years before 1950. The map is showing the year 1945. Cold is blue, while warm is red.

Toggle the switch to the beginning, -11995 yr BP (also 12,000 years before 1950).

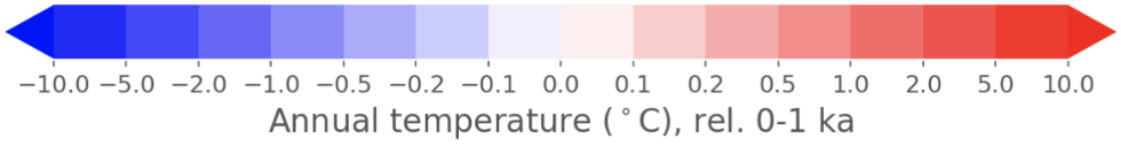
13. What color does the map show?



Around this time, the last of the giant animals, mastodons and mammoths, roamed Turtle Island (what is now known as North America).

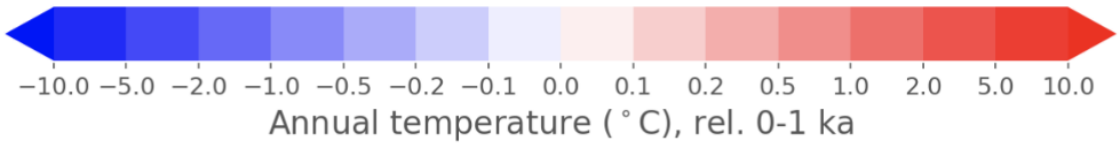
Now toggle the switch towards the future.

14. Go to -8285 years BP. Does the Southwest show relatively warmer (red) or colder (blue) than the average of the last 1000 years?



Now toggle the switch towards the future.

15. Go to -5 years BP. Does the Southwest show relatively warmer (red) or colder (blue) than the average of the last 1000 years?



Part V: Conclusion

16. Based on your analysis of the sediment core and the Holocene Reconstruction, what conclusions can you draw about how the environment in this area has changed over time? Consider changes in plant communities, climate, and any other evidence you observed.

17. How might studying lake sediment cores and maps help us understand and predict future climate changes?

18. What did you find most interesting or surprising about this activity?

Further Investigation

As a class, watch the film:
Taking Earth's Temperature: Delving into Climate's Past
Length: 1 hour

Respond to the question below:

19. Why is it important to study the climate of the past?

This lesson is being developed in collaboration with the Continental Scientific Drilling Facility, University of Minnesota.
https://cse.umn.edu/csd

Name: _____

2. Wisdom of the Trees

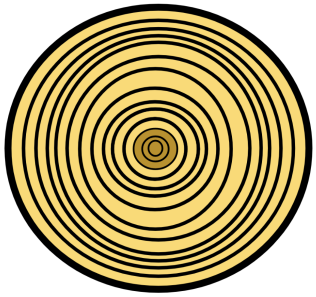
In this activity, you will study the tree rings of the Grand Canyon region like a dendrochronologist (tree ring scientist). By analyzing the rings in tree cookies and cores, you can discover the age of trees and learn about environmental conditions over many years. Trees are sacred beings in Navajo and Hopi cultures that provide valuable teachings if we observe them carefully.

Do Now:

1. How old are you?

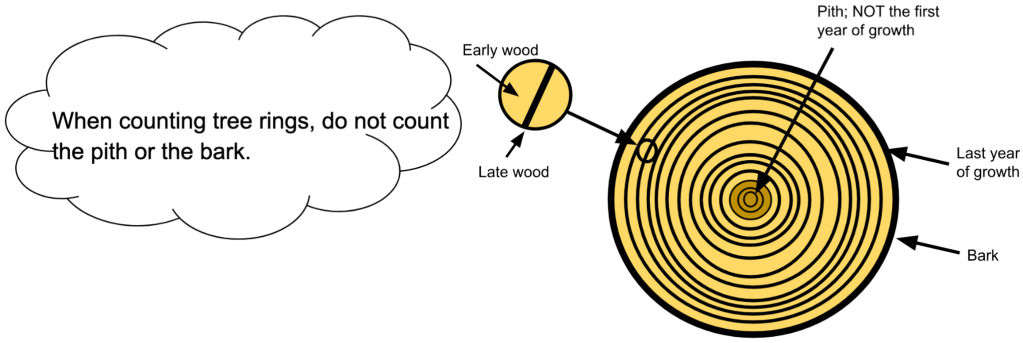
Take a look at the cookie on the right and respond to the questions below.

2. Count the number of rings. How many rings do you see?



3. What do you think each ring represents?

4. Highlight/Circle the tree rings that correspond to your age.



Now, we are going to get into groups.
You should have the following materials:

- Tree cookie
- Hand lens
- Ruler

Part 1 - Tree Cookie Analysis:

1. Examine your group's tree cookie closely with a hand lens. Find the innermost ring, which is the pith, which is the spongy part of the tree. The first ring, which is the oldest ring, is this next ring, which represents the tree's first year of growth.

2. Now locate the outer ring at the inner bark edge, which shows the tree's most recent growth.

3. Count the number of rings from the first ring to the bark edge. This equals the tree's age in years when it was cut down.

Record the age: ☐

4. Look closely at the ring spacing and thickness. Do you notice any patterns or changes over time?

5. If rings are wider or more narrow during certain years, what might that tell you about growing conditions like water/rainfall?

_____

_____

_____

Did you know that trees can tell us their stories with their rings?

Part 2 - Tree Core Analysis:

1. Now analyze the mounted tree core sample from a living tree in the region using your hand lens.

2. Measure the **length** of the core sample in **centimeters**: →

3. Estimate the age of this tree based on the **number of rings** in the core:

_____ rings

Discussion

4. Compare the core's ring spacing and patterns to those in the tree cookie. Do you notice similar years of wider/narrower rings?

5. What potential events or environmental changes could the ring patterns be recording over the years?

Understanding from Nature – Traditional Knowledge:

In Navajo and Hopi cultures, trees are viewed as sacred beings to be respected. Traditional ecological knowledge values learning from observing nature closely over many years.

6. You may draw and/or respond in words to the following question: How might studying tree rings and their patterns connect to these cultural values of **patience** and **respect** for nature's teachings?

Name: _____

3. Ancient Wise Ancestors

In this activity, you will study rings in tree cores like a dendrochronologist (tree ring scientist). By analyzing the rings in cores, you can discover the age of trees and learn about environmental conditions over many years. Trees are sacred beings in Navajo and Hopi cultures that provide valuable teachings if we observe them carefully.

Do Now:

Take a look at the following photo from National Geographic Expeditions.

Photograph by Hugh Stevens Bell

1. Look at the photograph and think about what parts used to be living trees.

_____

_____

_____

_____

Imagine you are in the Painted Desert of Arizona and you want to find the age of one of the Juniper trees.

2. Select one of the following:

☐ Draw a cookie showing the age of 20 years.

☐ Draw a core showing the age of 30 years.

Now, we are going to get into groups.
You should have the following materials:

- Tree cores (digital images glued/taped on boba straws)
    - Navajo National Monument
- Hand lens
- Ruler

Trees tell us about their stories through their rings.

Scientists who study tree rings are called **dendrochronologists**. By looking at the rings, they can translate (decode) what the trees are trying to tell us.

Let's look at these cores and see what they can tell us about their lives.

Navajo National Monument Tree Cores

3. How old is this core? (How old was this tree when it was brought down to build a house?)

4. Do you see any thin rings?

5. What can they be telling us about the environment at that time?

Modern core

6. How old is this core?

7. What year was this core obtained?

Hint: 2020 – (age of the core)

8. Do you see any thin rings?

9. What can they be telling us about the environment at that time?

Virtual Dendrochronology

Visit the Presto Project and load the North American Drought Atlas (NADA): https://paleopresto.org/visualizer.html?dataset=nada

The NADA is a map and was created using about 1845 trees, consisting of Ponderosa Pines, Bristlecone Pines, Oaks, Junipers, and Douglas Fir. The NADA is used to estimate soil moisture and climate of the past.

10. In the area of Arizona and New Mexico in 2005, what do you notice about the soil moisture? Mark an "x" on the color bar below.

11. Now, go back to 1934, what do you see? Mark an "x" below.

12. Now, let's go back to the year 1100, what do you see? Mark an "x" below.

13. What do you see in year 1251? Mark an "x" below.

The Dust Bowl happened 1929-1940 and it affected the climate of North America.

Structures at Navajo National Monument, Wupatki, and Chaco Canyon were built beginning about the year 850.

14. By the end of the 1200s, the ancestors of the Hopi, Diné, Apache, Pueblo, Yavapai, and Ute migrated to other places. Look at the NADA map, where do you think they moved to? Hint: Look for the bluish-green areas.

Understanding from Nature – Traditional Knowledge:

In Navajo and Hopi cultures, trees are viewed as sacred beings to be respected. Traditional ecological knowledge values learning from observing nature closely over many years.

15. You may draw and/or respond in words to the following question: How is knowing about the age of trees relate to where you come from?

Dust surrounds the lower regions of Dook'o'ooslííd ("the summit that never melts") in Diné; Nuvatukya'ovi ("where the clouds live") in Hopi.

Łeezh is the Diné word for dust, while the Hopi call this same word: Qö'angw.

In the arid regions of the Southwest, dust has long been recognized as an integral part of the natural environment by the Diné and Hopi peoples. Their traditional ecological knowledge teaches that dust is a sacred element, carrying the essence of the lands their ancestors inhabit. However, modern scientific understanding reveals that dust, comprised of tiny particles suspended in the air, can have detrimental effects on air quality, climate, and public health.

Dust particles, ranging from microscopic mineral fragments to biological materials like pollen and spores, can act as carriers for pollutants and allergens, contributing to respiratory issues and exacerbating conditions like asthma. Additionally, these airborne particles can absorb and scatter solar radiation, influencing the Earth's energy balance and potentially impacting climate patterns.

By studying the properties and behavior of dust through scientific inquiry and respecting the cultural significance it holds for indigenous communities, we can work towards mitigating its negative impacts while preserving the invaluable traditional knowledge that has guided sustainable living in harmony with the environment for generations.
You will work on activities developed at Northern Arizona and beyond to learn about what it's like to be a scientist and have an opportunity to relate your knowledge about the natural world.

Name: _____

4. Dust in a Box

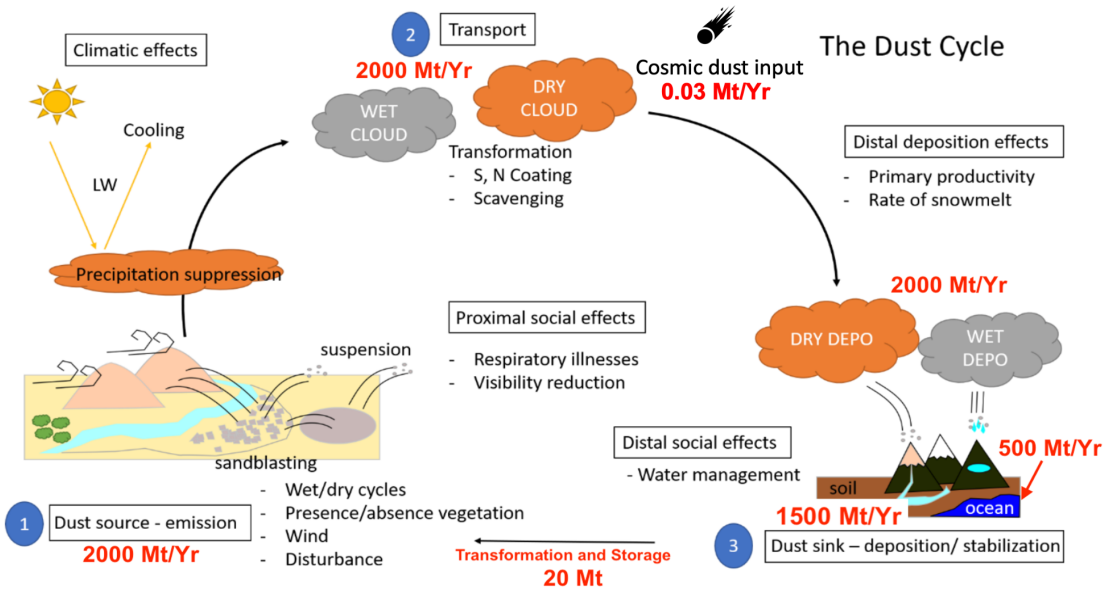
In this activity, you will be able to use a physical model to represent how wind moves sediment (dust) and how dust can influence air quality.

I. Engage

1. Imagine you're outside on a windy day. Describe what you see, hear, and feel when the wind is blowing. What kinds of things does the wind move or push around? Why do you think the wind is important in nature?

2. Which of the following pictures shows a phenomenon and which one shows a model? Explain why.

Source: Google Stock Photos



3. What questions do you have about how dust moves?

Discussion: Share out

II. Explore

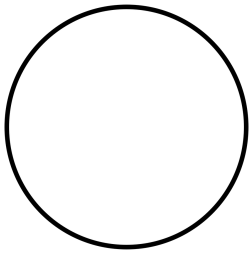
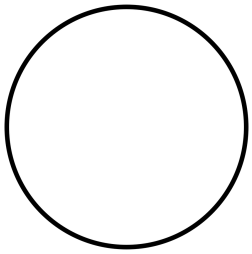
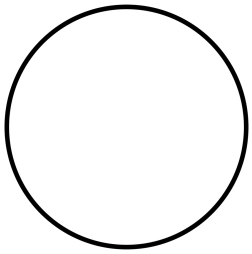
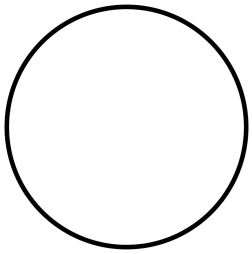
For this portion of the lesson, you will need the following materials:

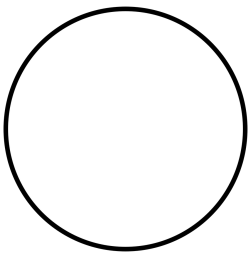
- Sand/Silt/Clay/Dirt (unconsolidated clay is preferred)
- Water
- Plastic storage box with a hole at one end
- Hair drier
- Extension cord
- Glass gems (quantity: 10)
- Forks (3)
- Pipette (and spray bottle)
- Adhesive tape
- This worksheet

Procedure:

1. Box #1: Hold the hair dryer above the dirt.
2. Using the hairdryer (on the "cool" setting), blow lightly and increase wind for 10 seconds. Remove the tape. Then, place your tape on the "Stick em' up Collector."
3. Lightly spray box with dirt so the soil absorbs the moisture. Remove the tape. Then, place your tape on the "Stick em' up Collector."
4. Hold hair dryer above the dirt.
5. Blow lightly and increase wind for 10 seconds.
6. Replace the tape each time you blow wind. Then, place your tape on the "**Stick em' up Collector**."
7. Respond to the prompts below each circle that has dust.
8. Try different situations: wetter, with glass gems, with forks

Stick em' up Collector

Dry Box		Wet Box	
Trial #1	Trial #2 (with q-tips and/gems)	Trial #3	Trial #4 (with q-tips and/gems)
			
How much dust was collected by the tape?	**How much dust was collected by the tape?**	**How much dust was collected by the tape?**	**How much dust was collected by the tape?**
☐ A lot of dust	☐ A lot of dust	☐ A lot of dust	☐ A lot of dust
☐ Some dust	☐ Some dust	☐ Some dust	☐ Some dust
☐ No dust	☐ No dust	☐ No dust	☐ No dust

Very Wet Box (Flood)	Explain which environment created the most dust:
Trial #5	
	
How much dust was collected by the tape?	
☐ A lot of dust	
☐ Some dust	
☐ No dust	

III. Explain

Questions and Further Research

5. Which box contributed the most sand to the air?

6. How does dry and wet dust influence how dust moves?

IV. Elaborate

7. What more can you say about how dust moves in the environment?

V. Evaluate

8. Draw a model about how dust is transported across the landscape:

9. Explain how you would modify the box model (What would you do differently?)

Vocabulary:

Wind/Niyol	model	gustnado
dust	process	haboob
aeolian	phenomenon	Níłtsą (Diné) and Qötö (Hopi)

SEP: Asking questions and defining problems, Developing and using models
CCC: energy and matter, cause and effect, structure and function

Name: _____

5. Dust to Cloud

You will develop and use a model to demonstrate that atoms and molecules can be combined or rearranged in chemical reactions to form new compounds with the total number of each type of atom conserved. Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change.

I. Engage

1. **Draw** a picture and/or **explain** how dust can be good.

II. Explore

For this activity, you will need the following materials:

- Plastic bottle (1 or 2 liters)
- Plastic bottle caps with one that fits the needle of a pump valve
- Air pump
- Warm water (4 tablespoons)
- Can of hairspray
- Duct tape
- Optional: Funnel
- Optional: Isopropyl alcohol (Be careful, this is flammable)
- Optional: matches

Note: Never use matches with hairspray or alcohol!

Procedure

Pour the 4 tablespoons of warm water into the bottle. Close the bottle with a cap. Shake the bottle. Insert the needle into the cap. Pump the bottle with air. Ask your classmate to squeeze the bottle to make sure it is getting air. Once there is enough air inside the bottle, quickly release the cap.

III. Explain

2. Describe what happened?

Do the procedure again but add a spray of hairspray into the bottle prior to pumping air.

3. Describe what happened?

4. What was different about using the hairspray?

The teacher(s) will do it again with a match.

WARNING: Do not light a match in the bottle that previously had hairspray/alcohol or anything flammable.

5. Describe what happened?

6. What was different about using the match?

IV. Elaborate

7. What questions do you have about how dust is important in creating clouds?

8. How can you make a model about dust, clouds, wind, and rain?

V. Evaluate

9. Choose one of the following and then respond in the box below.

- ☐ Describe and explain what dust is and where it comes from
- ☐ Draw a picture of what you learned about dust
- ☐ How can dust particles affect health?
- ☐ How does dust affect the climate?
- ☐ Is all dust bad?

Vocabulary: wind, aeolian, clouds, process, energy, dust, dust cycle, model
SEP: Asking questions and defining problems, Developing and using models
CCC: energy and matter, cause and effect, structure and function

Name: _____

6. Why do dust storms happen?

You will obtain, evaluate, and communicate information about data and historical patterns to predict natural hazards and other geological events.

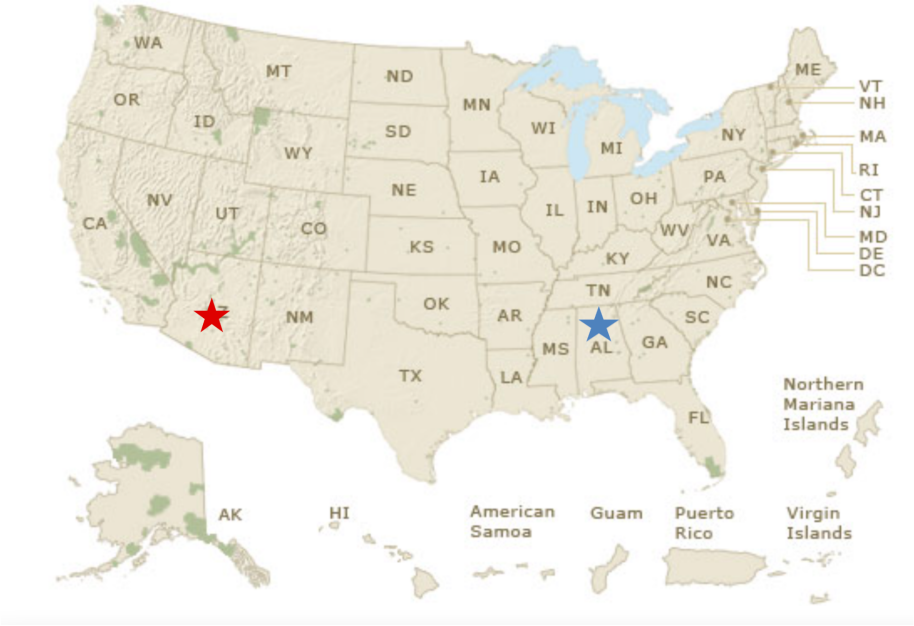
Source: United States Geological Survey (2011)

20. Write a 2-3 sentence description about the picture above.

Now, let's watch a clip from the following video:
"Our Beautiful Planet: Dust Rising"
Run time: 10:30
Source: National Science Teaching Association
Watch from the beginning to 2:00

21. What creates dust storms?

In your groups, let's look at two cities.
Note their differences and similarities.



★ Phoenix, Arizona

★ Birmingham, Alabama

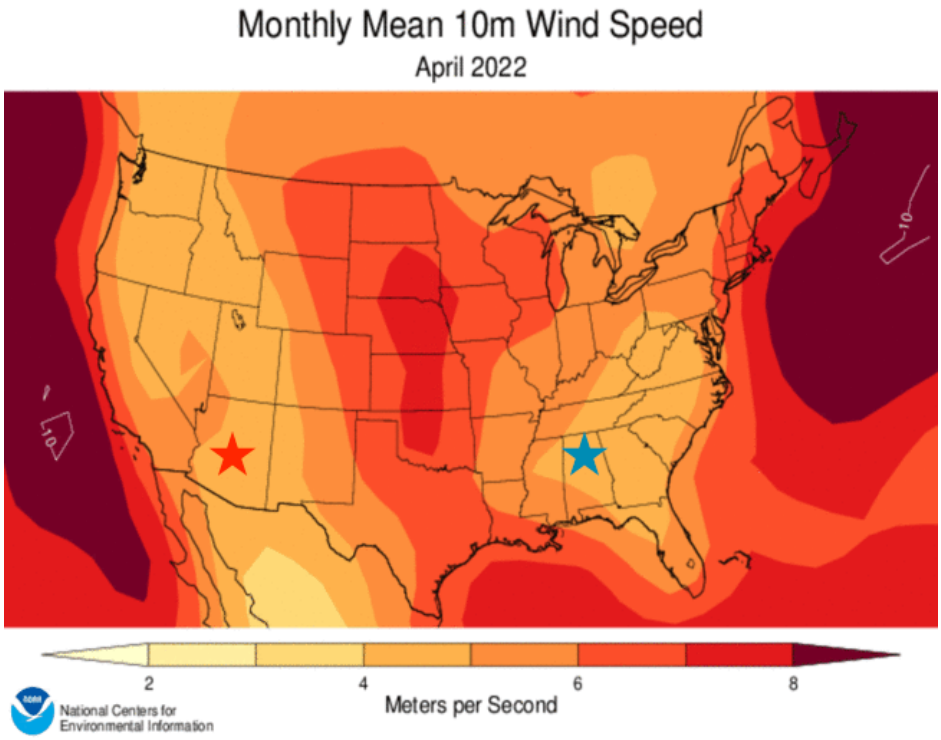
Source: NPS

Phoenix, Arizona	**Birmingham, Alabama**
Latitude: 33.45	**Latitude:** 33.54
Close to the Ocean? No	**Close to the Ocean?** No
Are Dust Storms Currently Common? Yes	**Are Dust Storms Currently Common?** No

22. How are these two cities similar and different?

23. Write down your questions about these two cities:

Let’s look at the wind map and photos:

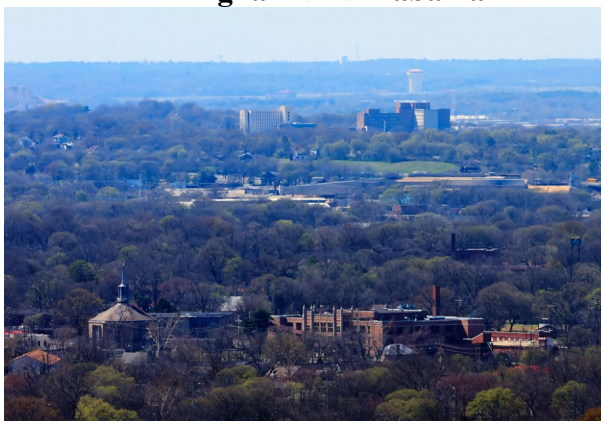


Source: NOAA Average Wind Speeds - Map Viewer

Phoenix **Arizona**

Source: Photo Journeys

Birmingham **Alabama**



Source: Rian Castillo (CC BY 2.0)

24. Look at the wind map and the photos, why does Phoenix have dust storms whereas Birmingham does not?

25. What two ingredients do you think are required for a dust storm?

Now, let's watch a clip from the following video:
"A Record of Change: Science and Elder Observations on the Navajo Nation"
Run time: 25:00
Source: United States Geological Survey and the Navajo Nation
Watch from the beginning to 07:00

26. What do the local people say about climate change?

27. Why are people on the Navajo Nation vulnerable?

28. Explain the difference between "traditional knowledge" and "conventional science"?

29. What are some examples of impacts of climate change happening on the Navajo Nation?

Further Investigation

In your groups, select one story, read about it, and then respond to the questions below.

- ☐ Sand Dunes on the Navajo Nation: An ITEP Story
- ☐ Dust Storm in Northeastern Arizona
- ☐ Dust Storm in Phoenix
- ☐ Dust Storm Blankets Middle East
- ☐ Sahara Dust Storm
- ☐ Dust Storm off West Africa
- ☐ Saharan Dust on the Move

30. What did you find interesting about the story?

31. Do you think all dust is bad? Or do you think some dust is good? Why?

Survey

Circle and respond to each of the following question:

1. After participating in today's activities, how much do you agree with the following statement: **"I can see myself pursuing a career in environmental science or a related STEM field."**

a) Strongly disagree
b) Disagree
c) Neutral
d) Agree
e) Strongly agree

What aspect of today's activities influenced your response?

_____

2. Which of the following best describes how you felt during the hands-on experiments today?

a) Confused and overwhelmed
b) Slightly interested but unsure
c) Engaged and curious
d) Excited and confident
e) Inspired to learn more

Can you describe a moment when you felt most like a scientist today?

_____

3. How has today's experience changed your perception of your ability to contribute to scientific research?

a) It hasn't changed my perception
b) I'm slightly more confident in my abilities
c) I feel moderately more capable
d) I feel significantly more confident
e) I'm now excited about my potential to contribute to science

What specific skill or knowledge did you gain today that makes you feel more capable in science?

_____