EARTH'S SYSTEMS

Grade 5 - Engineering

TRAINER GUIDE

CONTENT AND PEDAGOGY
PROFESSIONAL DEVELOPMENT

Smithsonian
Science Education Center

The **Smithsonian Science Education Center** (SSEC) is an education organization within the Smithsonian Institution. The SSEC's mission is to transform K–12 *Education Through Science*™ in collaboration with communities across the globe. The SSEC promotes authentic, interactive, inquiry-based K–12 STEM teaching and learning; ensures diversity, equity, accessibility, and inclusion in K–12 STEM education; and advances STEM education for sustainable development. The SSEC achieves its goals by developing exemplary curriculum materials and digital resources; supporting the professional growth of K–12 teachers and school leaders; and conducting outreach programs through LASER (Leadership and Assistance for Science Education Reform) to help schools, school districts, state education agencies, and ministries of education throughout the world implement inquiry-based science education programs.

The **Smithsonian Institution** was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge . . ." This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

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Earth's Systems

Grade 5—Engineering

Trainer Guide

INTRODUCTION

In 2019, the US Department of Education awarded the Smithsonian Science Education Center an early-phase Education Innovation and Research (EIR) grant to support the development, implementation, and initial evaluation of evidence-based innovations to improve student achievement. The project, called Smithsonian Science for North and South Carolina Classrooms (PR# U411C190055), took place between October 2019 and September 2024 in third-, fourth-, and fifth-grade classrooms in North and South Carolina.

Between 2020 and 2023, participating teachers in implementation schools received curriculum professional development tied to two Smithsonian Science for the Classroom curriculum modules and content and pedagogy professional development tied to the content of each module to implement in their classrooms. The Center for Research in Educational Policy (CREP) at the University of Memphis evaluated the impact of these modules and professional development on student achievement using standardized assessments, classroom observations, and teacher focus groups.

This guide was developed as a support for trainers leading content and pedagogy professional development for fifth grade teachers implementing the Smithsonian Science for the Classroom Engineering module *How Can We Provide Freshwater to Those in Need*?

HOW TO USE THIS TRAINER GUIDE

This guide shares important ideas and strategies for effectively delivering content and pedagogy professional development in connection with a Smithsonian Science for the Classroom module with educators. The professional development plan is outlined within a table on the following pages. The first column notes approximate timing for each activity and connections to standards or pedagogical strategies. The second column provides the trainer with additional directions in concise bullet points.

ROOM SETUP

To set up a classroom for this workshop:

- Move tables or desks so groups of three or four can work together.
- Locate the nearest restrooms and evacuation routes.
- Make sure speakers are working.
- Post a piece of chart paper labeled "Parking Lot" for participants to record questions and ideas for follow up later.

WORKSHOP OVERVIEW

This trainer guide provides direction on facilitating the sessions highlighted in the table below.

Day 1		Day 2	
10:00 a.m.	Welcome Session	**10:00 a.m.**	Engineering Content Session 2
11:00 a.m.	Misconceptions and Student Work	**12:00 p.m.**	Lunch
12:00 p.m.	Lunch	**12:45 p.m.**	Reflections
12:45 p.m.	Misconceptions and Student Work, continued	**1:30 p.m.**	Break
1:30 p.m.	Break	**1:45 p.m.**	Concurrent Sessions: Planning Ahead and Principal’s Meeting
1:45 p.m.	Engineering Content Session 1	**2:30 p.m.**	School Breakouts
3:45 p.m.	Wrap Up	**3:15 p.m.**	Closing Session
4:00 p.m.	Adjourn	**4:00 p.m.**	Adjourn

SCIENCE CONCEPTS AND STANDARDS

See Appendix 1 for the complete state standards listed here.
[†] *SC science standards connections are based on the 2018 Academic Standards Support Document.*
[‡] *NGSS/SC science standards refer to both NGSS and the most recent 2021 SC Science Standards.*

Sessions	Science Concepts	Standards
Day 1: **Earth’s Systems and Their Interactions**	**1.1. Earth Spheres and Interaction** There are four major Earth systems: hydrosphere (water and ice), geosphere (solid and molten rock, soil, and sediments), atmosphere (air), and biosphere (living things, including humans). All these systems interact with one another. • Earth spheres: hydrosphere, geosphere, atmosphere, and biosphere • Earth system interaction • Water cycle (including evaporation, transpiration, condensation, precipitation, and runoff)	**NC:** 5.P.2.1 **SC[†]:** 4.E.2A **NGSS/SC[‡]:** 5-ESS2-1

	1.2. Earth Surface Affected by the Earth System Interaction
	The systems' interactions affect Earth's surface materials and processes. Water flow (hydrosphere) shapes landforms and influences climate, and winds and clouds (atmosphere) interact with the landforms to determine patterns of weather.
	• Movement of water and watershed
	• Formation of landforms
	• Natural processes affecting Earth's surface
	    • Constructive and destructive ways
	    • Natural processes: weathering, erosion, deposition
		SC: 5.E.3A.1, 5.E.3B.1
		NC: 4.E.2.3
		NGSS/SC: 5-ESS2-1

Day 2: **Weather and Human Interaction**	**2.1. Air and Weather** Weather changes day to day and moment to moment. There are many factors that are measured to describe and predict weather conditions (e.g. wind speed and direction, precipitation, temperature, and air pressure). • Weight of air • Air pressure • Movement of air and wind direction • Air mass and weather fronts	**NC:** 5.E.1.1, 5.E.1.2 **SC:** 4.E.2A.1, 4.E.2B.1 **NGSS/SC:** 3-ESS2-1, 3-ESS2-2
	2.2. Weather and Human Activity There are many factors that affect local weather, and there are also global factors that affect weather and climate, such as ocean currents, jet streams, and El Niño. Human activities can affect Earth systems in positive and negative ways. • Weather vs. climate • Factors that affect weather • Global factors such as ocean currents, jet streams, El Niño • Impacts of human activities and global warming • Conservation efforts	**SC:** 5.E.3B.3, 4.E.2A.1, 3.E.4B.3 **NC:** 5.E.1.3 **NGSS/SC:** 5-ESS3-1

MISCONCEPTIONS AND STUDENT WORK

Throughout this professional development, the trainer leads the sessions as a facilitator (modeling the teacher role) with teachers acting as learners. Though the content is designed for adult learners, the practices used by the facilitator may be used with grade 3-5 students.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
Housekeeping and Introductions	20 minutes	• Chart paper
Reflections	10 minutes	• Chart paper
Conceptual Change	30 minutes	• *Good Thinking!* video
Lunch	45 minutes	
Misconception Identification	45 minutes	• Chart paper • Sticky notes • Colored dot stickers (5 colors) • Markers • "Misunderstanding Misconceptions" article

Timing	Key Points
Housekeeping and Introductions 20 minutes	**Introductions** Welcome participants to your session. Remind them that this professional learning workshop is meant to be an experience for adult learners to support their understanding of pedagogical content knowledge underlying a Smithsonian Science for the Classroom module. next page →

Timing	Key Points
	Educators may feel some discomfort as they are confronted with the limits of their own content understanding just as their students do. Reassure them that this is part of the learning process and that it may help them build empathy for the students in their classrooms. **Icebreaker Activity** Participants introduce themselves through an icebreaker activity. Ask each participant to share what they remember about the last time they were taught this subject. **Housekeeping** Preview the agenda. Verify the safety protocols in the classroom and locate the nearest restrooms, fire exit, and tornado shelter.
	Establish the Tone for the Day Divide participants into small groups and ask them to think about what they want to achieve today. What norms do they think will encourage a positive learning environment? Introduce group norm ideas: • Be brave • Be present • Ask questions • Be respectful Have each small group discuss the suggested norms and add to the whole group list of norms. Once everyone has added their ideas, ask if there are any changes, additions, or modifications that need to be made. Once the discussion is finished, this will be the social contract the group abides by for the next two days.
Reflections 10 minutes	Have participants turn to their shoulder partner and discuss their successes and challenges when teaching these units. Pairs can also discuss how they overcame challenges they faced. After partners have had time to talk, ask them to share their main points with the whole group. Record the main ideas on chart paper so everyone in the room can benefit from the shared learning.

Timing	Key Points
Conceptual Change 30 minutes	Ask participants to write down in their notebooks their ideas in response to the following questions: • How would you describe a scientific misconception? • How do you think student preconceptions can affect their understanding of new scientific concepts? Introduce the *Good Thinking!* Conceptual Change video. *Good Thinking!* is a video series created by the Smithsonian Science Education Center to support K–12 science educators through targeted short-format videos that explore common student ideas and misconceptions about a range of science topics, such as energy, chemical reactions, and natural selection, as well as pedagogical subjects such as student motivation and the myth of left- and right-brained people. Explain that the video we're about to watch is about conceptual change and explores the way students learn and develop new conceptual understanding, and shows how student misconceptions can be uncovered and addressed as part of effective learning. Show *Good Thinking!* Conceptual Change (run time: 6:26) https://s.si.edu/4dfqcQS Debrief the video by asking the participants to share how the video changed their definition of misconceptions and how preconceptions affect new learning. Have participants share anything else they found interesting or helpful. Before ending the session, let participants know that in the next session they will have a chance to explore student work and identify misconceptions. If your group is small and you're done before lunch, introduce the Keeley framework to allow more time for exploring student work after lunch.
Lunch 45 minutes	

Timing	Key Points
Keeley Framework 10 minutes	Hand out the "Misunderstanding Misconceptions" article by Page Keeley. In the article, Keeley introduces a loose framework of five types of misconceptions: conceptual misunderstanding, factual misunderstanding, naïve idea, vernacular misconceptions, and fragmentary knowledge. These different types represent a misconception based on where it comes from, how it is expressed, and what impact it has on continued learning. Understanding which type of misconception students have can assist in determining where the misconception is coming from and what the impact on learning might be.
Exploring Student Work 30 minutes	To help prepare for content sessions and future implementation, have table groups read student work and mark misconceptions with colored dot stickers, indicating which type from the framework they think the misconception falls into. Each misconception could be multiple categories in the framework.
Wrap Up 5 minutes	Ask participants to write misconceptions they found and their category from the framework on sticky notes and post them on a piece of chart paper. Let the group know they will revisit these ideas tomorrow, after they have completed the content sessions.
Trainer Note: Possible Misconceptions	Some misconceptions participants may identify include: • The water cycle students learn about in school has little to do with their daily experiences. • Humans do not play a role in the water cycle. • Groundwater is not part of the water cycle. • Groundwater is always found as a static, subsurface lake. • The Earth system is a collection of unrelated parts or pieces of information. • Groundwater only exists under the rocks, not within the rocks. next page →

Timing	Key Points
	• Earth (and its landforms) is very stable and does not change often. • Water evaporates into the air only when the air is warm. • All pollution is stuff that can be seen, such as trash people throw into the water. • When water dries (evaporates), it disappears.

CONTENT SESSION 1:

Earth's Systems and Their Interactions

SESSION GOALS

- Observe natural phenomena and experience science and engineering practices.
- Develop conceptual understanding about four major Earth systems: hydrosphere (water and ice), geosphere (solid and molten rock, soil, and sediments), atmosphere (air) and biosphere (living things, including humans), and the interaction between them, especially the interaction with the hydrosphere.
- Understand that the interaction of these systems affects Earth's surface materials and processes.
- Understand the crosscutting concept of "system"—that a system is a group of components that work together within a boundary.
- Integrate modeling of a concept map to represent relationships between elements of science concepts and discuss limitations of the concept map.
- Practice argumentation using the Claim-Evidence-Reasoning (CER) method to articulate the natural processes that affect Earth's surface in constructive and destructive ways.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
1.1 Earth Spheres and Interaction	60 minutes	• Chart paper • Smithsonian Science for the Classroom Grade 5 Engineering Module • Grade 5 Engineering Student Reader
1.2 Earth Surface Affected by the Earth System Interaction	60 minutes	• Landform activity images and Claim-Evidence-Reasoning template • Chart paper • Sticky notes (yellow and blue)

1.1 Earth Spheres and Interaction

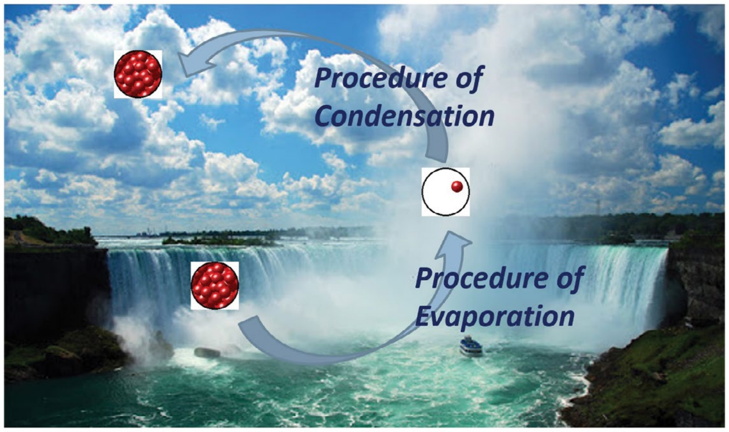
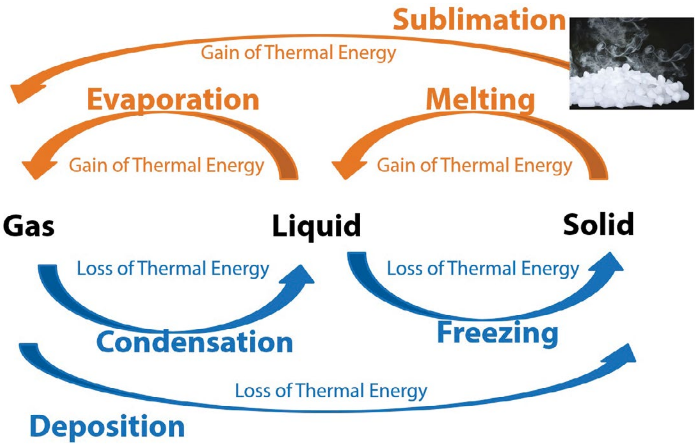
60 minutes

Timing	Key Points
Introduction 2 minutes	Introduce the topic and science concepts that will be covered in this section.
Identification of Earth Systems 13 minutes	1. Show the photos of the natural world (Figures 1-3) and ask, "What do you see in the pictures?"  *Figure 1. Nature 1 (credit: https://pixabay.com)*  *Figure 2. Nature 2 (credit: https://pixabay.com)*  *Figure 3. Nature 3 (credit: https://pixabay.com)* next page →

Timing	Key Points
	• Collect their responses, such as flowers, water, trees, lake, mountain, clouds, rocks, etc. Ask them to write down their observations in their notebook. 2. On a piece of chart paper, write down words such as grass, cow, sky, lake, rocks as examples, and ask: • How do you want to categorize them? Sort what you observe in the pictures and write them on the chart paper. • Discuss the similarities and differences between the categories that they have grouped, which are the components of the Earth's spheres. 3. Explain Earth's spheres: geosphere, hydrosphere, biosphere, and atmosphere, using the examples identified from the pictures and referencing Table 6.3 of the Smithsonian Science for the Classroom Grade 5 Engineering Module, Lesson 6. 4. Introduce the teaching tip about the difference between top-down and bottom-up approaches. • The traditional way of teaching scientific terminology is the top-down approach. • The bottom-up approach provides students with an opportunity to observe the natural world. By identifying objects, comparing similarities and differences, categorizing them, and defining terminologies, students can better understand the scientific concepts. This is what scientists do, and it's also a strategy for ELL students.
Earth Systems Interaction 25 minutes	1. Show the image of the watershed from the Smithsonian Science for the Classroom Grade 5 Student Reader and ask: • What components of the Earth system can you identify? • What interactions can you identify between components? next page →

Timing	Key Points
	2. Briefly discuss the components and interactions that participants identify from the picture, and mention that this is the topic we are going to cover during this professional development. 3. Tell participants that they will be drawing a concept map of the interactions between components that they identify in the picture. 4. Explain what a concept map is. • Draw arrows and write words to describe a cause-and-effect or other relationship between objects. • Show the exemplary concept map. 5. Explain how to draw a concept map (either individually or in small groups). • Identify components and which of Earth's spheres each component belongs to. • Identify relationships between components. • Ask participants to draw a concept map on their notebook (or on a chart paper as a group) to represent the interactions of the Earth's spheres. 6. Allot approximately 10 minutes for individuals or small groups to finish their concept maps. 7. Once the drawings are complete, ask participants to share their drawings with the whole group. 8. Explain that Earth's different spheres interact with one another and that there are also interactions between components within the same sphere. 9. Ask what they found useful when drawing a concept map, such as: • It can clearly show relationships visually. • It helps to identify cause-and-effect relationships. next page →

Timing	Key Points
	10. Ask what limitations they found/experienced while using a concept map, such as: • It can show simplified relationships, but representing all complicated interactions in one drawing has limitations. 11. Wrap-up the question, "What is a system?" "System" is a very important concept in science, and one that is widely used and implemented in scientific concepts, as well as in the process of doing science, technology, engineering, and mathematics—which is called a crosscutting concept (CCC) in NGSS. 12. Show a short video about systems: https://www.youtube.com/watch?v=vyldH1qExsc 13. Explain what a system is, the boundaries of a system, and the components and interactions of a system.
Water Cycle 20 minutes	1. Show the photo of Niagara Falls (Figure 4) and ask what they notice in the picture. There are clouds, waterfalls, and water droplets in the air that are in the process of evaporation. Tell them that this image shows one aspect of the water cycle.  *Figure 4. Niagara Falls (credit: https://pixabay.com)* next page →

Timing	Key Points
	2. Explain the concepts of evaporation and condensation using the image of Niagara Falls with the molecular view of H_2O (Figure 5).  *Figure 5. Evaporation and Condensation (credit: https://pixabay.com and Smithsonian Science Education Center)* 3. Explain the summary of condensation, evaporation, freezing, melting, sublimation, and deposition processes using the diagram (Figure 6).  *Figure 6. Evaporation and condensation procedure diagram (credit: Smithsonian Science Education Center)* • When liquid gains thermal energy, it evaporates into a gas. • When gas loses thermal energy, it condenses into a liquid. • When the solid state of water (ice) gains thermal energy, it melts into a liquid. next page →

Timing	Key Points
	• When liquid loses thermal energy, it freezes into a solid state. • When a solid gains thermal energy and becomes a gas, it's called sublimation. • When a gas loses thermal energy and becomes a solid, it's called deposition. 4. Explain the water cycle using the simplified water cycle model. • The vapor condenses, and when it's heavy enough, it falls down to the surface as rain or snow, which is called precipitation. • Precipitation infiltrates the ground, but some of the groundwater gets discharged and creates springs. • Stored groundwater goes to seas and lakes, and there is also surface runoff to streams. • Water evaporates from oceans, lakes, and streams, but there is also transpiration from plants. • Transpiration is the process of water moving through a plant and its evaporation from aerial parts, such as leaves, stems, and flowers. • Some of the snow and ice on top of mountains and in icebergs sublimates directly from ice (a solid state) to gas. • This cycle is continuous and is called the water cycle.

1.2 Earth Surface Affected by the Earth System Interaction

60 minutes

Timing	Key Points
Introduction of the Earth Surface Affected by the Earth System Interaction 5 minutes	1. Show the two pictures of different landforms (Figures 7 and 8) and ask:  *Figure 7. Cliff with sea waves (credit: https://pixabay.com)*  *Figure 8. Landforms shaped by wind in the desert (credit: https://pixabay.com)* • What do you notice in the pictures? • What do you think is happening or has happened? 2. Show the two pictures together and ask: • What similarities can you find in the pictures? • What differences can you find in the pictures? • How do you think the shape of the landforms was created? • How can you connect it to the Earth system interaction? next page →

Timing	Key Points

	3. Expected responses:
	• Similarity: erosion
	• Differences:
	  • Interaction between hydrosphere and geosphere
	  • Interaction between atmosphere and geosphere
	
	4. Explain that a similarity between the two pictures is that erosion has affected the land's shape. A difference is that in one erosion is caused more by the hydrosphere (water waves) and in the other erosion is caused more by the atmosphere (wind). There can be some other responses for the second image, as well, such as weathering.
	
	5. Explain that we will explore these landform shapes and how they are affected by Earth system interactions more in this session.

Landform Formation Activity 30 minutes	1. Show the landform activity images. Ask participants to cut out each image or use the number on each image to sort them. 2. Ask, "What has affected the formation of Earth's surface in each image?" Let them think about the similarities and differences between the images. 3. Ask them to sort the images into groups, based on their observations of similarities and differences on the images in terms of the formation process. • There are various ways they can be categorized, so let everyone know that there is no right or wrong answer. • Ask them to use argumentation to explain their reasoning. next page →

Timing	Key Points

4. Explain claim-evidence-reasoning (CER).
   - A claim is a statement that answers a question or a problem.
   - Evidence is the data collected to support the claim.
   - Reasoning is a justification that connects the evidence to the claim. It's a logical explanation of how the evidence supports the claim, based on scientific rules or principles.

5. Ask them to use the CER template (Figure 9) for each category into which they have sorted their landform images.

Landform Formation Activity

Claim (Formation process)	
Evidence (Images and observed similarities)	
Describe your reasoning why you categorize them.	

Figure 9. Claim-Evidence- Reasoning (CER) activity template (credit: Smithsonian Science Education Center)

   - Write a claim about a formation process.
   - Collect images (or image numbers) and write down the similarities you observe in those images.
   - Describe why you grouped those images into the same category.

6. Give everyone about 15 minutes to complete their work. This activity can be done individually or in small groups, depending on the group size.

next page →

Timing	Key Points
	7. After completing their work, ask participants to share how they categorized the images and what evidence and reasoning they used. Use these guiding questions: • What is your claim? • What is the evidence that supports your claim? • How does your evidence connect to your claim? • Did anyone work similarly? • Did anyone work differently?
Formation Processes of Landforms 10 minutes	1. Explain that natural processes affect Earth's surface in both constructive and destructive ways. • Constructive: Processes that create landforms, such as deposition, landslides, volcanic eruptions, and floods • Destructive: Processes that destroy landforms, such as weathering, erosion, landslides, volcanic eruptions, floods, and earthquakes 2. Explain deposition, erosion, and weathering. • Deposition: Sediment and rocks transported by flowing ice or water, wind, or gravity, are deposited and build up new land on Earth's surface. Examples: a delta at the end of a river, accretion of a sand dune in the desert, glacial moraines when a glacier moves over a landscape, shells on the beach deposited by ocean waves • Erosion: The process of being worn down and transported away by natural forces such as wind, water, moving ice (glaciers), and gravity; it's the opposite of deposition. Examples: splash erosion by falling raindrops, valley erosion by rushing streams and rivers that wear away banks and create larger valleys, sheet erosion (uniform removal of soil) by runoff, wind erosion next page →

Timing	Key Points
	• Weathering: The process of decomposing, breaking down into smaller pieces, or changing the color of rocks by water, air, chemicals, plants, or animals. Examples: mechanical weathering, chemical weathering, organic weathering • Clarify the difference between erosion and weathering. 3. Show the video about the formation process of the Arches: https://www.nps.gov/arch/learn/photosmultimedia/geologyvideo.htm
Landforms Affected by Hydrosphere Interactions 10 minutes	1. Go back to the image of the water cycle model that was shared before the break. This time, ask participants to focus on the landforms affected by water—in other words, by hydrosphere interactions. Explain: • The water (that is, precipitation) falls as rain, snow, sleet, or hail. • A small amount of water from precipitation evaporates and moves back into the atmosphere immediately, some enters the ground, and the rest is runoff. 2. Explain the concept of a watershed and its relationship to landform formation. • A watershed is an area of land that drains all the local streams and rainfall to a common outlet. So the watershed acts as a funnel that collects water and channels it into a waterway. • Each basin is sectioned by a watershed boundary, or water divide, such as a ridge, hill, or mountain. • Watersheds can be large or small, and large basins are made up of many smaller basins. • Water from streams flows downward and meets with other water flows, becoming creeks or rivers. So this moving water eventually flows to lakes, seas, or the ocean. • Landforms affect the path of the watershed, and the moving water flows affect the surface of the landforms. next page →

Timing	Key Points
	3. Explain that the movement of water affects the landscape. • Deposition happens when sediments pile up, and erosion happens when sediments are washed away by water. • When water flows and passes through a curved area, the water slows down in the inner side and speeds up in the outer side. • There is more water flowing faster in the outer edges, which creates erosion. • There is less water flowing slower in the inner part, which creates deposition.
Reflection 5 minutes	Learner Reflection Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as: • Any questions about the content covered in the session? • What new learning did you encounter today? • What misconceptions did you debunk today? Teacher Reflection Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as: • Where can you tie these concepts back to the curriculum module? Address content and practices. • Any misconceptions that teachers may expect from their students on the science concepts covered in the session? Exit Ticket Ask participants to record their "sunshines and blues" for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a piece of chart paper before leaving for the day.

CONTENT SESSION 2:

Weather and Human Interaction

SESSION GOALS

- Observe natural phenomena and experience science and engineering practices.
- Develop a conceptual understanding of the weight of air, air pressure, movement of air, air masses, weather fronts, and their associated weather.
- Understand the difference between weather and climate.
- Identify factors that affect weather locally and globally and understand how ocean currents, jet streams, and El Niño affect weather and climate globally.
- Understand how to implement a zone of proximal development by scaffolding instruction to observe the natural world, elicit prior knowledge, and connect that prior knowledge with a new science concept.
- Discuss how human activities affect climate and environment in negative and positive ways.
- Draw models to represent the movement of air in different conditions and discuss the limitations of using models.
- Run a computer simulation by providing different variables (ocean currents and air masses) and their resulting effects on weather.
- Integrate teacher actions that encourage student participation in classroom discussions.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
2.1 Air and Weather	60 minutes	• Activity Sheet (Appendix 2)
2.2 Weather and Human Activity	60 minutes	• Smithsonian Science for the Classroom, G5 Engineering Student Reader (or Carolina Science Online) • Chesapeake Bay Case Study Worksheet (optional)

2.1 Air and Weather

60 minutes

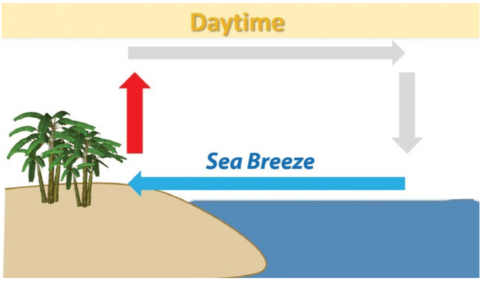
Timing	Key Points
Introduction 2 minutes	Introduce the topic and science concepts that will be covered in this section.
Weight of Air 8 minutes	1. Show the picture of a dog (Figure 10) and ask:  *Figure 10. Photo of a dog in the window of a moving car (credit: Hyunju Lee, Smithsonian Science Education Center)* • What do you think this dog is doing? • Explain that although we can’t see it, there is air/wind that the dog can feel. 2. Ask the question: • Does air have weight? • Some may say no, some may say yes. Wait to hear various responses and reasons why they think so. 3. After hearing their responses, ask: • How do you know air has weight? • Show the video: https://youtu.be/26Z3qnpVeD8 Explain that this is indirect evidence that air has weight. 4. Explain: • Air is matter. • Air has mass (which we measure as weight on Earth) and takes up space. • Air is mostly gas (78% nitrogen, 21% oxygen), with tiny particles/dust and small amounts of other gases.

Timing	Key Points
Air Pressure and Movement of Air 40 minutes	1. Explain about air pressure: • Because air has mass, although it seems light, it exerts air pressure. • Air molecules are not evenly distributed, and there are more as you get closer to the surface of Earth, due to the gravity. • Usually pressure decreases with increasing elevation because there is less air above (in the atmosphere) at high elevation. • On top of a mountain there is less air pressure pushing down, and at sea level there is a more air pressure. • This can be observed with a plastic bottle that is sealed at high altitude on a mountain; as it is brought to the bottom of the mountain, it collapses. • Air pressure is also called atmospheric pressure or barometric pressure, because barometers are used to measure air pressure. • Show the two pictures a pot of boiling water with steam (Figure 11) and a swimming pool (Figure 12).  *Figure 11. Boiling water (credit: https://popularmechanics.com)*  *Figure 12. Swimming pool (credit: https://pixabay.com)* next page →

Timing	Key Points

	• For the first picture, ask, "Why do you think the steam rises when water is boiled?"
	• Explain that air works the same as water vapor; when it warms up, it gets lighter and rises.
	• For the second picture, ask, "On a hot sunny day, when you're walking on the deck area of the pool barefoot, how does that feel? What about when you're in the water?"
	• Explain that water warms up more slowly than the deck (which is a solid surface) in the daytime and also cools down more slowly after the sun has set. In other words, a solid surface gets heated faster than water when there is a heat source, and a solid surface cools down faster than water when the heat source is removed.
	
	2. Air Movement Activity
	• Remind the group of the two concepts you just covered: hot air rises, and a solid surface gets hot faster and cools down faster than water.
	• Hand out the Movement of Air Activity Sheet, or ask participants to prepare two blank pages in their notebook similar to the activity sheet.
	• Ask, "Given what you just learned, how would air move in daytime and nighttime?" Draw two pictures of air movement—one for daytime and the other one for nighttime.
	• Work individually or in small groups.
	• Allot about 15 minutes to complete the activity.
	
	3. Ask participants to share their drawings and explain why they drew their pictures that way.
	
	4. After sharing, clarify any misconceptions and summarize air movements using Figures 13 and 14.
	• Daytime: Sea Breeze
	  • The land gets heated fast, so the air rises on the land side.
	  • As the air rises, it creates an empty space. The air above the sea sinks to fill in the space.
	
	next page →

Timing	Key Points

	• Then the air above the land will flow to the sea to fill in the space created when the air above the sea moved.
	• So there is going to be constant movement of the air. And if you're sitting at the beach at noon, you'll feel the wind, which is the movement of air, from the sea, which is called a sea breeze.
	• In a very simple analogy, the movement of air is like a sliding puzzle.
	• Water also moves from high pressure to low pressure; this is the same phenomenon as air flowing from high pressure to low pressure.
	
	
	Figure 13. Sea Breeze (credit: Smithsonian Science Education Center)
	• Nighttime: Land Breeze
	  • The water is still warm, because it cools down more slowly than the land, so there is warm air right above the sea.
	  • The warm air above the sea will rise.
	  • Then the empty space right above the sea will be filled up by the air from the land.
	  • The air far above the land will sink, because there is empty space below it.
	  • The empty space that has now been created far above the land is going to be filled up by the air from the sea.
	  • So in this case, you'll feel the wind coming from the land to the sea, which we call land breeze.
	  • Again, it's helpful to use the analogy of a sliding puzzle to understand how the air moves.
	next page →

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
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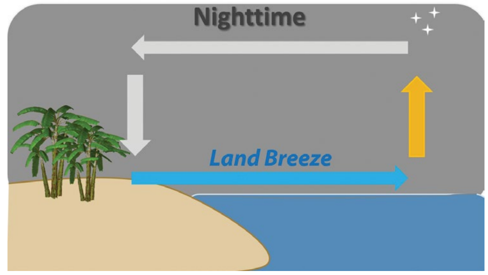

Figure 14. Land Breeze (credit: Smithsonian Science Education Center)

- Wind Direction
  - The wind direction is reported as the direction *from which* the wind originates.
  - For example, a northwest wind means the wind is blowing *from* the northwest.
  - Sea breeze is the wind that blows *from* the sea.
  - Land breeze is the wind that blows *from* the land.
  - Explain how wind speed and direction are symbolized
  - An anemometer measures wind speed, and a wind vane measures wind direction.

5. Wrap-Up: Scaffolding
Ask participants to identify how the session was scaffolded and whether they can take away any pedagogical tips. Explain the instructional scaffolding as:

- Observe what is in the world.
- Elicit prior experience and knowledge.
- Connect the prior knowledge with a new science concept in the zone of proximal development (Vygotsky, 1978).
- Use analogies and modeling to aid understanding.

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Air Mass and Weather Fronts

10 minutes

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1. Explain what an air mass is.

- A large volume of air in the atmosphere that is mostly uniform in temperature and moisture content.
- Air masses form over large surfaces at source regions (thousands of kilometers across the surface of the Earth, or from ground level to 16 kilometers into the atmosphere).

next page →

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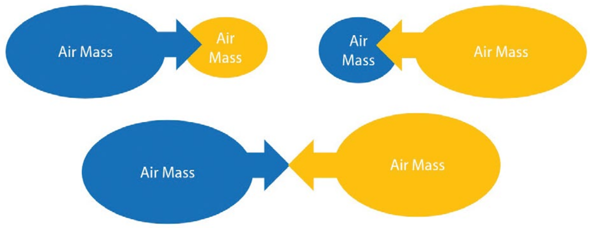
</table>

Timing	Key Points

	• Air masses carry weather conditions from the source region to a new region.
	
	2. Explain that an air mass can be categorized depending on its temperature and moisture.
	• By temperature:
	  • Arctic (A): arctic region, very cold
	  • Polar (P): high-latitude regions, cold
	  • Tropical (T): low-latitude areas, moderately warm
	  • Equatorial (E): near the equator, warm
	• By moisture:
	  • Maritime (m): forms over water, humid (moist)
	  • Continental (c): forms over land, dry
	• A cold air mass is usually heavy and is usually created over land, so it's dry. A hot air mass is usually lighter and is usually created over the ocean, so it's humid.
	• Ask about a few examples from the map (https://mountwashington.org/what-is-a-front/), such as what cT, mE, cA, etc., mean.
	
	3. Explain what a weather front is using Figure 15:
	• A weather front is a boundary or a transition zone between two air masses at Earth's surface.
	• When two air masses meet, how might they be different? (One is cooler and the other is warmer.)
	• Show the images of the three different cases when air masses meet.
	
	
	
	Figure 15. Three scenarios in which a cold air mass (blue) and a warm air mass (orange) meet (credit: Smithsonian Science Education Center)
	
	next page →

Timing	Key Points
	- When a cold air mass is stronger than a warm air mass, the cold air mass pushes the warm air mass. - When a warm air mass is stronger than a cold air mass, the warm air mass pushes the cold air mass. - When the two air masses' strengths are similar, they don't get pushed in either direction. • Ask the group to think about what would happen in those three different cases and have a whole-group discussion as time permits. 4. Explain the four different kinds of weather fronts. • Cold front - A cold front forms when a cold air mass pushes into a warmer air mass. - As a cold front moves into an area, the heavier (more dense) cold air pushes under the lighter (less dense) warm air, causing it to rise into the atmosphere. - The lifted warm air produces clouds, which develop vertically. - As the cold front passes, winds become gusty, temperature drops, and there is heavy rain, sometimes with thunder and lightning. • Warm front - A warm front forms when a warm air mass pushes into a cooler air mass. - Warm fronts tend to move slower than cold fronts because it is more difficult for the warm air to push the cold, dense air. - Clouds develop as the warm air pushes into the cold air and warm, moist air slides over the cool air. - It produces gentle weather with light to moderate continuous rain in large regions. next page →

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<tr><th>Timing</th><th>Key Points</th></tr>
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Stationary front

A stationary front forms when two air masses meet but are not strong enough to move each other.
Winds on the cold air and warm air sides often flow nearly parallel to the stationary front, often in nearly opposite directions along either side of the front.
Mild precipitation can occur along a stationary front.

Occluded front

An occluded front forms when a warm air mass gets caught between two cold air masses.
A warm air mass pushes into a colder air mass (created the warm front), and then another cold air mass pushes into the warm air mass (created the cold front).
Cold fronts move faster than warm fronts, and sometimes a cold front follows right behind a warm front. Because the cold fronts move faster, the cold front is likely to overtake the warm front.
When this happens, it forces the warm front up into the air, which leads to heavy rain. After the front passes, the sky is usually clearer and the air is drier.

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2.2 Weather and Human Activity

60 minutes

Timing	Key Points
Weather vs. Climate 5 minutes	1. Ask participants: • What is weather? • What are the factors that affect weather? • What's the difference between weather and climate? 2. Explain the difference between weather and climate. • Weather: Short-term conditions, so weather can change from hour to hour, day to day, and season to season. • Climate: The average daily weather for a longer period of time at a certain large location; the average weather over time and space. 3. Show the image of the layers of the atmosphere (https://www.worldatlas.com/articles/what-are-the-5-layers-of-the-earth-s-atmosphere.html) and explain: • Scientists divide the atmosphere into five layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere. • Weather and climate both refer to natural phenomena that occur in the troposphere. • Note that the scale in the image is exaggerated; the troposphere is the thinnest layer.
Factors of Weather 10 minutes	1. Explain that there are many factors that affect the weather. • These include temperature, atmospheric pressure, wind, humidity, precipitation, and cloudiness. • How far or close you are from the sea, the shape of the land, the altitude of the land, and your distance from the equator can also affect the weather. • Taking a more global perspective, ocean currents, air currents such as jet streams, and complex patterns such as El Niño affect the weather. next page →

Timing	Key Points

	2. Ocean currents
	• Explain that ocean currents are the patterns of water movement that influence climate zones and weather patterns around the world. They are continuous, predictable, directional movements of seawater.
	• Show the video about ocean currents and air movements: https://youtu.be/A2nEh0Zlqo8
	• Ask participants what they observed in the video.
	• This video shows two similar phenomena.
	    • Hot water rises and cold water sinks. It's similar to how air moves: hot air rises and cold air sinks. This is because hot air and water are less dense, so they are lighter and rise; cold air and water are more dense, so they are heavier and sink.
	    • When hot water and cold water meet, they circle around and form swirls. It's similar to the air movement we observed in the earlier session about how air moves on land and over the ocean during the day and at night. Hot air rises and cold air moves to fill the space horizontally, then cold air that is up higher sinks to fill the space, and the whole pattern of movement looks like the air is swirling.
	
	3. Jet streams
	• Explain that jet streams are fast-flowing, strong, narrow, meandering air currents in the atmosphere, which generally blow from west to east across the globe.
	• They transport weather systems, affecting temperature and precipitation.
	• Show an image of the jet stream (https://scijinks.gov/jet-stream/) and explain that the green area is warm, moist, tropical air, and the orange and red areas are cold, dry, polar air. The moving band of air between the two is the polar jet stream.
	
	next page →

Timing	Key Points
	4. El Niño • Explain that El Niño is unusual warming of surface waters in the eastern tropical Pacific Ocean. El Niño is the warm phase and La Niña is the cool phase. • This phenomenon affects ocean temperatures, the speed and strength of ocean currents, the health of coastal fisheries, and local weather from Australia to South America and beyond. • Warm and cool phases of a recurring climate pattern can shift irregularly every two to seven years, and each phase triggers disruptions of temperature, precipitation, and winds. • Show the two-minute minute video that explains El Niño and La Niña: https://oceanservice.noaa.gov/facts/ninonina.html 5. Weather Lab • Briefly introduce the computer weather simulation tool that was developed by the Smithsonian Science Education Center: http://ssec.si.edu/weather-lab • In the simulation, select an ocean current and two different air masses, then run the simulation. It will show how those selections will affect the weather in the North America. • This is a fun way for kids to learn about how different combinations of ocean currents and air masses affect the weather.
Impacts of Human Activities 5 minutes	1. Human activities also affect weather, climate, and the environment in many ways. Some examples: • Power plants and factories create air pollution. • Things that people use every day create gases that can cause global warming. These include cars and the refrigerants that are used in refrigerators and freezers. • People cut trees down and clear land for agriculture, farming, and houses. Deforestation affects environments and climate. • Farms where animals are raised can also affect climate. next page →

Timing	Key Points
	2. Describe examples of massive animal factory farms that create lots of methane gas. • There are 1.3 to 1.5 billion cows on Earth. • One cow produces 30 to 50 gallons of methane gas a day. • Collectively, cows produce 39 to 75 billion gallons of methane gas per day! 3. Explain global warming. • When sunlight reaches Earth, some gets reflected back into space by Earth's atmosphere and some reaches Earth's surface. • Of the sunlight that reaches the surface, some gets reflected back up through the atmosphere and escapes into space and some stays within the atmosphere. • The greenhouse effect, where the atmosphere holds in some of this thermal energy, is a natural process that keeps Earth's temperature stable and warm. • As people use fossil fuels, cars, modern industry, animal factory farms, and all our convenient machines, it creates carbon dioxide, methane, nitrous oxide, and hydrochlorofluorocarbons. (Hydrochlorofluorocarbons are used in refrigeration and a wide variety of manufacturing processes.) • These gases trap thermal energy within Earth's atmosphere—more than would be there naturally, which we call the enhanced greenhouse effect. • This enhanced greenhouse effect is also known as global warming, and it is driving climate change.
Conservation Efforts 30 minutes	1. Ask participants to read the Smithsonian Science for the Classroom, Grade 5 Engineering Module, Student Reader, Chapter 7: Something In the Water: Chesapeake Bay Case Study. next page →

Timing	Key Points

	2. Ask participants to work together as a small group to find out:
	• What is the problem at the Chesapeake Bay?
	• What solutions have been found to resolve the problem?
	• What does nature do?
	• How does human activity help resolve the problem?
	
	3. Distribute the Chesapeake Bay Case Study Worksheets or have them draw a table in their notebook to answer the questions. After each small group has completed the table, ask them to share with the whole group. Answers can vary, but may include:
	• Problem: People used fertilizers in the Chesapeake Bay watershed farmland, and it caused a lot of algae to grow. The algae makes the water cloudy and collects on the surface and blocks sunlight from getting to the grasses in the water. It causes a decrease in oxygen levels in the Chesapeake Bay that prohibits organisms from living in the water.
	• What nature does:
	  ◦ Forests help decrease the nitrate levels in the watershed.
	  ◦ Oysters can clean the bay water naturally.
	• What humans can do:
	  ◦ Increase forest conservation efforts in the bay region.
	  ◦ Grow more oysters in the region.
	  ◦ Desalinate saltwater to make freshwater.
	  ◦ Use renewable energy such as solar, wind, and wave energy.
	
	4. Summarize that human activities can affect climate and environment in both negative and positive ways, as seen in the reading about the Chesapeake Bay Case Study. Ask the whole group to think of what other positive ways people can contribute to conservation. It is an open-ended question, so expect to hear various responses.

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td>Teacher Talk Moves and Reflection
10 minutes</td><td>Explain some of the teacher talk moves that are helpful for encouraging classroom discussion (National Research Council, 2008, p. 91).

<table>
<tr><th>Teacher Talk Move</th><th>Example</th></tr>
<tr><td>Revoicing</td><td>So, let me see if I've got your thinking right. You're saying ___? (Leave space for students to follow up.)</td></tr>
<tr><td>Asking students to restate someone else's reasoning</td><td>Can you repeat what he just said in your own words?</td></tr>
<tr><td>Asking students to apply their own reasoning to someone else's reasoning</td><td>Do you agree or disagree? Why?</td></tr>
<tr><td>Prompting students for further participation</td><td>Would someone like to add on?</td></tr>
<tr><td>Asking students to explain their reasoning</td><td>Why do you think that? What evidence helped you arrive at that answer? Say more about that.</td></tr>
<tr><td>Using wait time</td><td>Take your time . . . we'll wait.</td></tr>
</table>

Ask participants to share any other teacher talk moves they use in their class to encourage students to get engaged in classroom discussion.

Learner Reflection

Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as:

Any questions about the content covered in the session?
What new learning did you encounter today?
What misconceptions did you debunk today?

next page →</td></tr>
</table>

Timing	Key Points
	Teacher Reflection Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as: • How confident are you feeling about the science concepts underlying the module *How Can We Provide Freshwater to Those in Need?* • Where can you tie these concepts back to the curriculum module? Address content and practices. • Any misconceptions that teachers may expect from their students on the science concepts covered in the session? • Any other general questions?

REFLECTIONS

Before this session, consolidate the misconceptions from the first day into a number appropriate for your group.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

Timing	Key Points
Addressing Misconceptions 30 minutes	1. Refer back to the misconceptions that were collected in the first session. 2. Break into small groups and have each group select a misconception to work on. 3. Give the groups time to discuss the misconceptions, what factors are part of the misconception, and how they might address it in the classroom based on their experiences during the content sessions or other resources they may have access to. Ideally, groups are leveraging activities from their Smithsonian Science for the Classroom modules. 4. Have groups share out.
Grade Level Planning 15 minutes	Discuss what the next school year looks like, including when participants might implement the lessons, what testing is upcoming, if there are any interesting resources available, etc.
Exit Ticket	Ask participants to record their "sunshines and blues" for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a chart paper before leaving for the day.

APPENDIX 1: SCIENCE STANDARDS

NORTH CAROLINA SCIENCE ESSENTIAL STANDARDS

5.E.1 Understand weather patterns and phenomena, making connections to the weather in a particular place and time.

5.E.1.1 Compare daily and seasonal changes in weather conditions (including wind speed and direction, precipitation, and temperature) and patterns.

5.E.1.2 Predict upcoming weather events from weather data collected through observation and measurements.

5.E.1.3 Explain how global patterns such as the jet stream and water currents influence local weather in measurable terms such as temperature, wind direction and speed, and precipitation.

5.P.2.1 Students know that the sun provides the energy that is a driving force for most biotic and abiotic cycles on the surface of the earth. Students know that the sun's energy fuels the water cycle and impacts different aspects of the water cycle (evaporation, transpiration, condensation, precipitation)

4.E.2.3 Give examples of how the surface of the earth changes due to slow processes such as erosion and weathering, and rapid processes such as landslides, volcanic eruptions, and earthquake.

SOUTH CAROLINA SCIENCE STANDARDS (SC†)

† *SC science standards connections are based on the 2018 Academic Standards Support Document.*

5.E.3A.1 Construct explanations of how different landforms and surface features result from the location and movement of water on Earth's surface through watersheds (drainage basins) and rivers.

5.E.3B.1 Analyze and interpret data to describe and predict how natural processes (such as weathering, erosion, deposition, earthquakes, tsunamis, hurricanes, or storms) affect Earth's surface.

5.E.3B.3 Construct scientific arguments to support claims that human activities (such as conservation efforts or pollution) affect the land and oceans of Earth.

3.E.4B.3 Obtain and communicate information to explain how natural events (such as fires, landslides, earthquakes, volcanic eruptions, or floods) and human activities (such as farming, mining, or building) impact the environment.

4.E.2A Conceptual Understanding: Earth's atmosphere is a mixture of gases, including water vapor and oxygen. The movement of water, which is found almost everywhere on Earth including the atmosphere, changes form and cycles between Earth's surface and the air and back again. This cycling of water is driven by energy from the Sun. The movement of water in the water cycle is a major pattern that influences weather conditions. Clouds form during this cycle and various types of precipitation result.

4.E.2A.1 Obtain and communicate information about some of the gases in the atmosphere (including oxygen, nitrogen, and water vapor) to develop models that exemplify the composition of Earth's atmosphere where weather takes place.

4.E.2B.1 Analyze and interpret data from observations, measurements, and weather maps to describe patterns in local weather conditions (including temperature, precipitation, wind speed/direction, relative humidity, and cloud types) and predict changes in weather over time.

NEXT GENERATION SCIENCE STANDARDS (NGSS) / SOUTH CAROLINA COLLEGE- AND CAREER-READY SCIENCE STANDARDS 2021‡

‡ *NGSS/SC science standards refer to both NGSS and the South Carolina College- and Career-Ready Science Standards 2021*.

5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

5-ESS3-1 Evaluate potential solutions to problems that individual communities face in protecting the Earth's resources and environment.

3-ESS2-1 Represent data in tables and graphical displays of typical weather conditions during a particular season to identify patterns and make predictions.

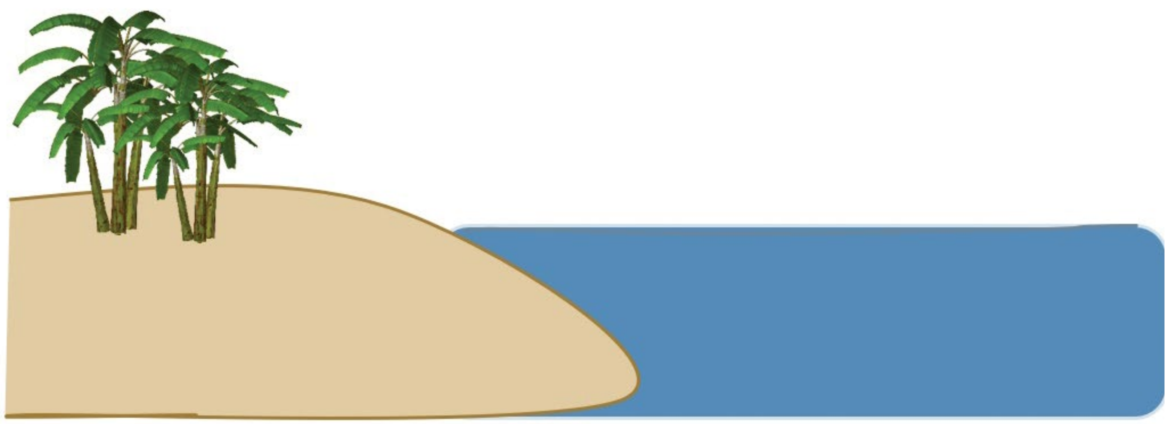
3-ESS2-2 Obtain and combine information to describe climate patterns in different regions of the world.

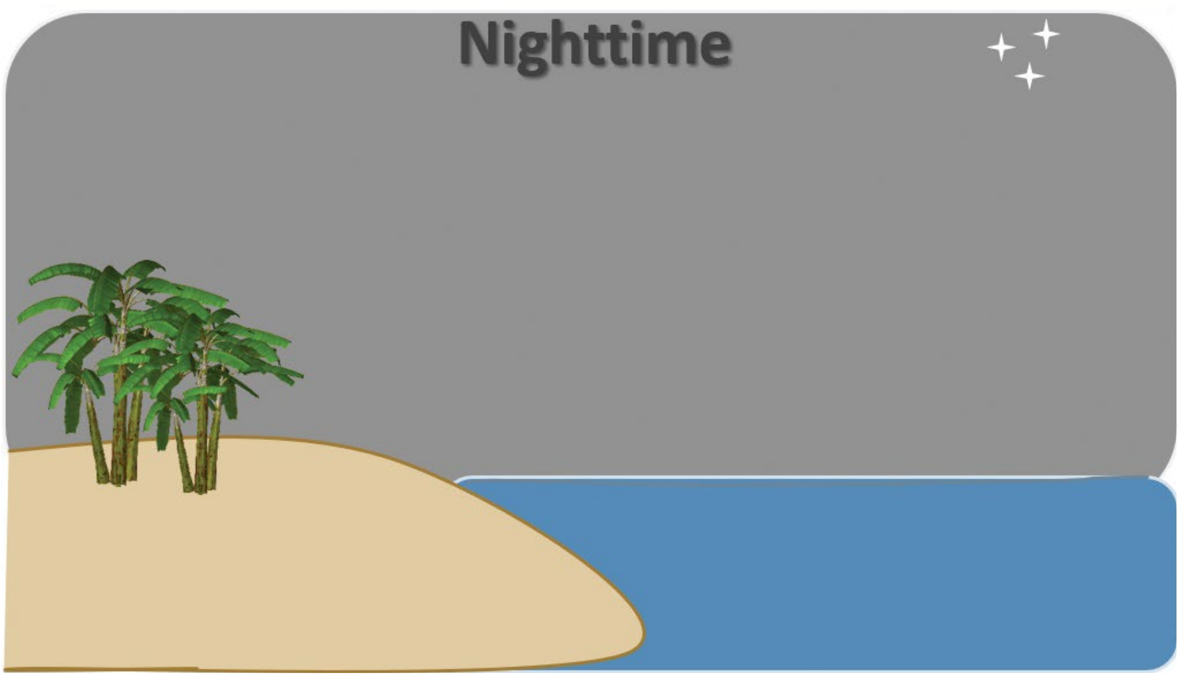
PS1.A Structure and Properties of Matter: Matter of any type can be subdivided into particles that are too small to see, but even then, the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space (and can be detected by their impact on other objects) can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects.

APPENDIX 2: ACTIVITY SHEET

MOVEMENT OF AIR

Daytime





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