AmplifyScience

Weather Patterns:

Severe Storms in Galetown

Investigation Notebook with Article Compilation

These materials are based upon work partially supported by the National Science Foundation under grant numbers DRL-1119584, DRL-1417939, ESI-0242733, ESI-0628272, and ESI-0822119. The Federal Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

These materials are based upon work partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A130610 to The Regents of the University of California. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

Amplify.
55 Washington Street, Suite 800
Brooklyn, NY 11201
1-800-823-1969
www.amplify.com

Weather Patterns: Severe Storms in Galetown
ISBN: 978-1-64089-872-1
AMP.NA18

Weather Patterns:

Severe Storms in Galetown

Investigation Notebook

Table of Contents

Table of Contents (continued)

Chapter 2: Investigating Temperature

Table of Contents (continued)

Chapter 3: Exploring Wind and Pressure

Chapter 4: Mystery of the Carson Wilderness Education Center

Table of Contents (continued)

Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____ Date: _____

Weather Patterns: Severe Storms in Galetown
Unit Overview

What is causing Galetown to have more severe rainstorms? A short time ago, the town of Galetown did not have such severe storms. Now the amount of rain has increased so much that it has caused flooding that has damaged cars, homes, crops, and trees. The citizens of the town have called upon you to work with a team of forensic meteorologists to help solve this weather mystery. Using a digital simulation, hands-on activities, models, science articles, and weather data, you will investigate several of the factors involved in weather patterns and use what you learn to find the reason why rainstorms in Galetown have recently become more severe. In this unit you will learn how energy transfer, air temperature, water vapor, and wind can contribute to the amount of rain.

Name: _____ Date: _____

Chapter 1: Understanding Rain Clouds
Chapter Overview

Welcome to the *Weather Patterns* unit! You will take on the role of student forensic meteorologists called upon to solve a mystery about rainstorms. To begin your investigations and help the people of Galetown, you will first learn about the causes of rain and then learn what can cause an increase in the amount of rain. The people of Galetown are relying on you to help them figure out why their rainstorms have become much more severe. Good luck!

Name: _____ Date: _____

Lesson 1.2: Welcome to the *Weather Patterns* Unit

Welcome to the *Weather Patterns* unit! You are about to take on the role of a student forensic meteorologist. You will be learning how and why weather, specifically rainstorms, happen. You have been called upon to explain why the rainstorms in the town of Galetown have become so severe, with especially heavy rainfall in the most recent summer storm. In this lesson, you will learn more about Galetown and the role you will take on in this investigation. You will also explore the *Weather Patterns* Simulation.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 1 Question

- What causes the rainfall in Galetown?

Vocabulary

- condensation
- evaporation
- water vapor
- weather

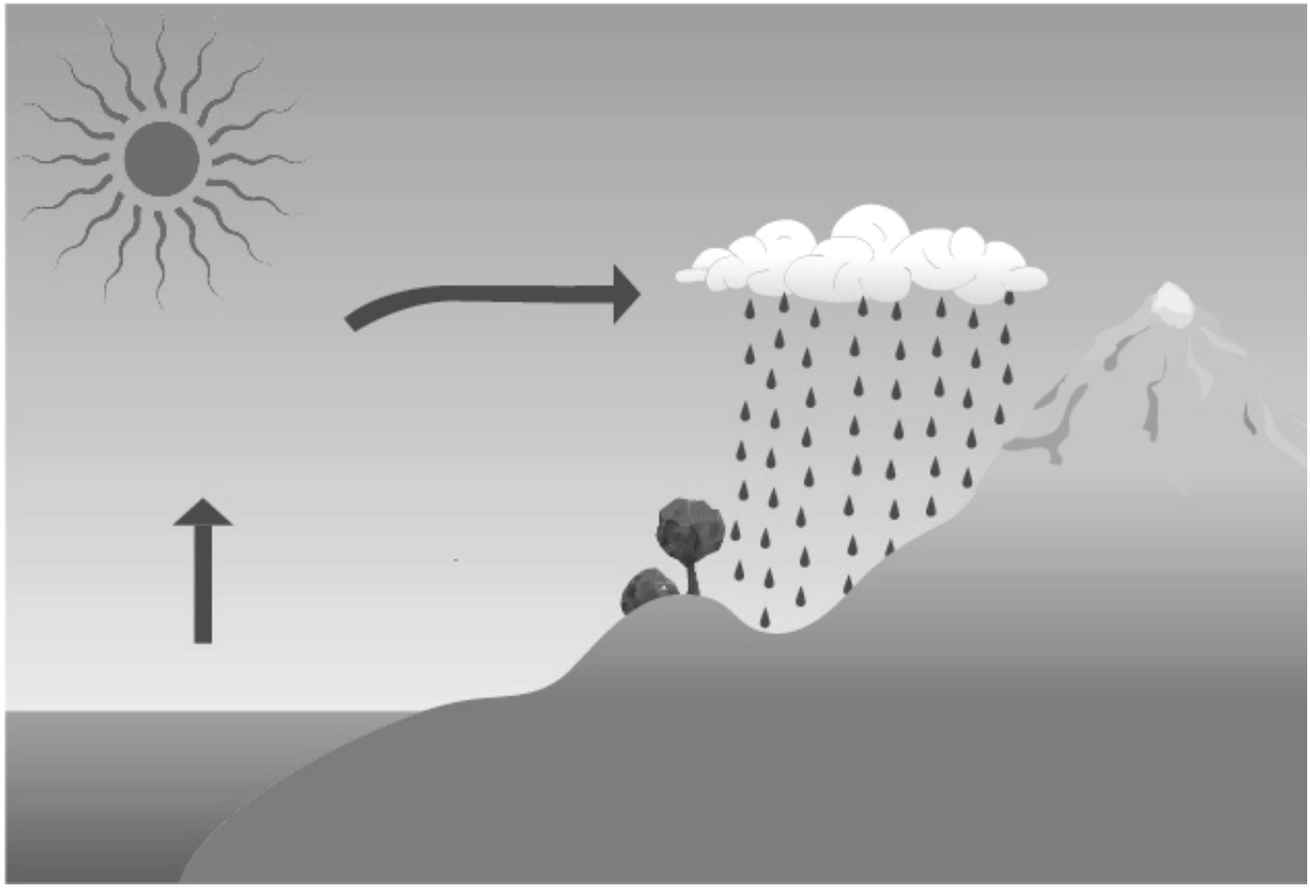
Digital Tools

- *Weather Patterns* Simulation

Name: _____ Date: _____

Warm-Up

You may have seen a diagram like this before. What does this diagram show? Explain your thinking below.



_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Exploring the *Weather Patterns* Simulation

Part 1: Exploring Regional Weather 1

1. Launch the *Weather Patterns* Simulation.
2. With a partner, explore Regional Weather 1 mode of the *Weather Patterns* Sim to become familiar with its features.
3. When you make any discoveries about the Sim or notice anything interesting, be sure to share with your partner.

Part 2: Water Cycle in the Sim

1. Launch the *Weather Patterns* Simulation.
2. Go to Regional Weather 1 mode.
3. Use the Sim to investigate how the amount of surface water can affect the amount of water vapor in the air.
   - In Build, set the level of surface water.
   - Decide on a level of sunlight (this should stay the same for both test 1 and 2).
   - Switch to Run, press Pause when the temperature turns red.
   - Record the amount of water vapor at that moment. (If needed, go to Analyze and use the time slider to rewind the Sim.)
   - Repeat with a different amount of surface water.

	Surface water level	**Water vapor (kg)**
Test 1		
Test 2		

How did the level of surface water affect the amount of water vapor in the air?

_____

_____

_____

Name: _____ Date: _____

Homework: Identifying Water on Earth

Water is an important part of weather.

Look at the images below and answer the questions.

A

B

C

1. In which of the images is water present? (You may choose as many as you think are correct.)

   ☐ A

   ☐ B

   ☐ C

2. Where is there water in the images? (You may choose as many as you think are correct.)

   ☐ in the air

   ☐ in the lake

   ☐ in the clouds

   ☐ in the snow

3. List the images in order from where you think there is the **least** water to where you think there is the **most** water:

   Least _____

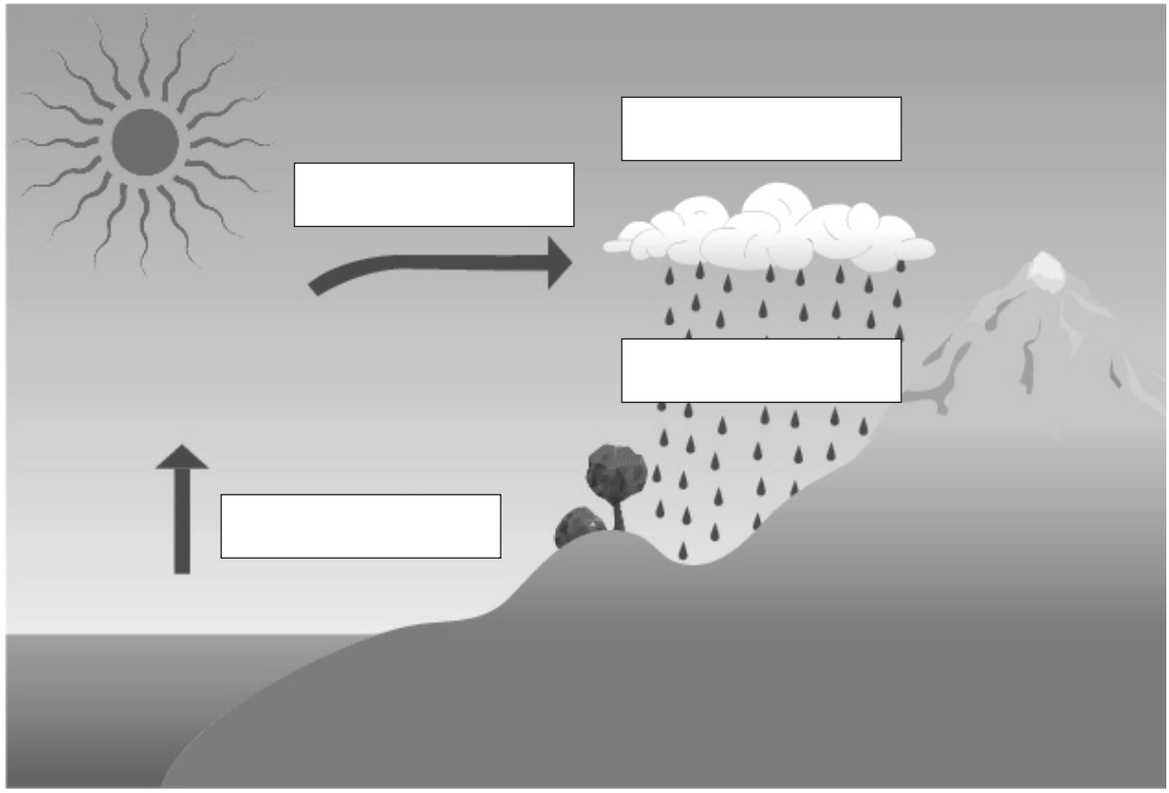
   _____

   Most _____

Name: _____ Date: _____

Homework: Identifying Water on Earth (continued)

Annotate the image below with the words in the word bank and then explain the image.



Word Bank

condensation	evaporation	condensed liquid water	rain

Explain the image above using the words from the Word Bank.

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 1.3: Investigating Condensation

It is time to begin investigating what caused Galetown to have more severe rainstorms. You know that rain falls from clouds, but have you ever wondered what causes rain? In this lesson, you will do a hands-on investigation about how and when condensation happens. You'll then use the *Weather Patterns* Simulation to help answer the Investigation Question: *What makes it rain?*

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 1 Question

- What causes the rainfall in Galetown?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.

Vocabulary

- air parcel
- condensation
- energy
- evaporation
- temperature
- transfer
- water vapor
- weather

Digital Tools

- *Weather Patterns* Simulation

Name: _____ Date: _____

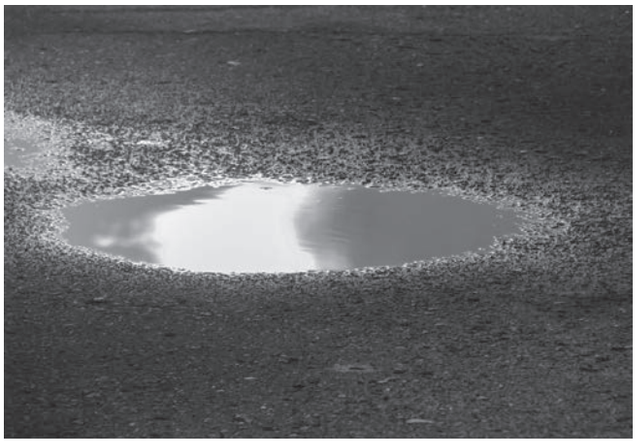
Warm-Up

Thinking About Water

Water is an important part of weather. After a rainstorm, rainwater gathers on the pavement, but soon after, it is gone.

Look at the images and answer the questions below.

Day 1



Day 2

What happened to the water in the puddle? Why?

_____

_____

_____

Where did the water go?

_____

_____

_____

Name: _____ Date: _____

Investigating Condensation

Why and when does condensation happen?

- Label both of your bags with the initials of a group member.
- Label one bag "cooler" and the other "room temp."
- Leaving part of the bag sealed, open the bag just enough to blow air into it.
- Blow up each bag so that it is fully inflated and seal it right away. **It is important that the same person blows into each bag.**
- When you are finished, discuss the following question with your group: *What do you think will happen to the air inside each bag?*

Name: _____ Date: _____

Simulating Condensation

Before setting up your tests, make a prediction about what you think will happen.

I predict there will be more condensation in the test that represents the air parcel (check one)

- ☐ at room temperature.
- ☐ in the cooler.

I predict more energy will transfer in the test that represents the air parcel (check one)

- ☐ at room temperature.
- ☐ in the cooler.

Why and when does condensation happen?

1. Launch the *Weather Patterns* Sim in Lab Mode.
2. With your partner, build Test 1 in the Sim.
3. Run the Simulation and observe what happens in the parcel.
4. Analyze your results. Record data in the table on the next page.
5. Repeat steps 2–4 for Test 2.
6. Answer the questions on the next page.

Test 1: This test represents the air parcel at room temperature.

- Surrounding Air Temperature: 20°C
- Air Parcel Temperature: 37°C
- Air Parcel Water Vapor: between medium and high

Test 2: This test represents the air parcel in the cooler.

- Surrounding Air Temperature: 4°C
- Air Parcel Temperature: 37°C
- Air Parcel Water Vapor: between medium and high

Name: _____ Date: _____

Simulating Condensation (continued)

Test	Surrounding air temperature	Air temperature in the bag	Energy transferred out	Liquid water (cloud)	Liquid water (rain)	Total liquid water (cloud + rain)
Test 1	20°C (room temperature)	37°C				
Test 2	4°C (in the cooler)	37°C				

Which test had more condensation (water vapor turning to liquid)? (check one)

- ☐ Test 1 (room temperature)
- ☐ Test 2 (cooler)

In which test was there more energy transferred out? (check one)

- ☐ Test 1 (room temperature)
- ☐ Test 2 (cooler)

Think about the different factors in the two tests. What do you think caused one to have more condensation?

_____

_____

_____

_____

Name: _____ Date: _____

Observing and Reflecting on Condensation

Observe the bags from both tests and discuss the questions below with your group.

- **Test 1:** bag at room temperature
- **Test 2:** bag in the cooler

Discuss these questions with your group:

1. What do you observe about the results of each test?
2. What evidence do you have of energy transfer?

Name: _____ Date: _____

Homework: Applying What You Learned

Read the prompt and circle the bolded words that accurately complete the paragraph below.

One morning Alisha woke up and opened her curtains and couldn't see out of her window. Her window was covered with liquid water droplets like in the image below. She wondered why this happened. Select from the words below to complete the paragraph and help explain why the inside of Alisha's windows are covered with liquid water.

The air in Alisha's house is just like an air parcel. The reason liquid water formed on her window is because the temperature of the air inside her house is (**warmer than / colder than / the same as**) the temperature outside. The water vapor in the air in her house (**condensed / evaporated / stayed the same**) and became liquid water drops on her window. Energy was transferred from the air **inside / outside**) her house to the air (**inside / outside**).

Name: _____ Date: _____

Homework: Reading "What Makes Water Move?"

Read and annotate the "What Makes Water Move?" article. Then, answer the questions below.

What does gravity do to cause rain to happen?

_____

_____

_____

_____

How does gravity affect water that is on the surface of Earth?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 1.4: Reading "What Are Clouds?"

You may have seen many types of clouds in the sky—sometimes they look like thin, wispy strings, and other times like full, puffy cotton balls. In this lesson, you will explore how these different types of clouds are formed. As you read, you will use what you know about water condensation and how it relates to cooling and cloud formation to think about the question *What causes an air parcel to cool?* The article will introduce you to a pioneering scientist who first studied clouds over 50 years ago. Reading about her work and the discoveries she and others made will help you to better understand clouds and how they form.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 1 Question

- What causes the rainfall in Galetown?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.

Vocabulary

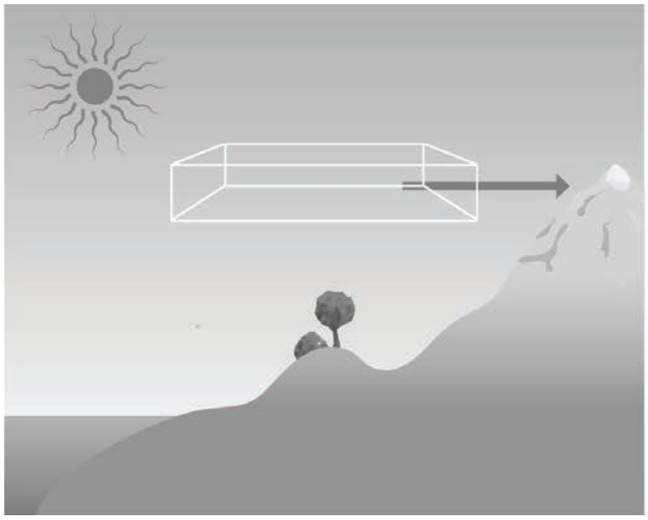
- air parcel
- condensation
- energy
- evaporation
- temperature
- transfer
- water vapor
- weather

Name: _____ Date: _____

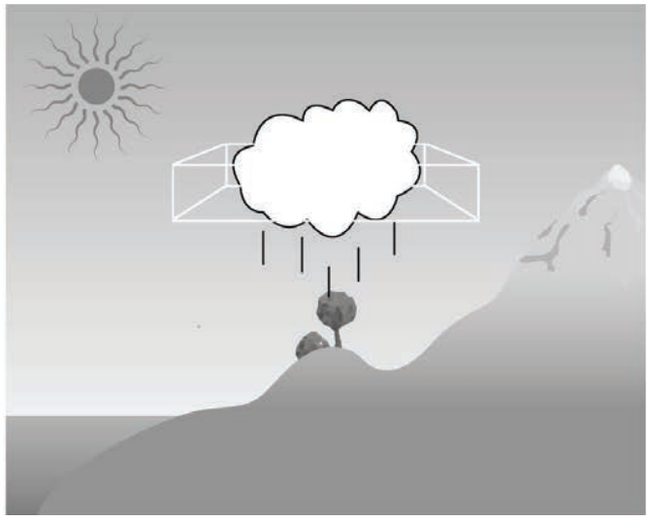
Warm-Up

Observe the image and answer the questions below.

Before



After



What is the **Before** image showing?

_____

_____

What is the **After** image showing?

_____

_____

What does the **arrow** show?

_____

_____

Name: _____ Date: _____

Reading "What Are Clouds?"

1. Read and annotate the article "What Are Clouds?"
2. Choose and mark one or two of your annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is something about the text that you discussed with your partner?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Modeling Condensation

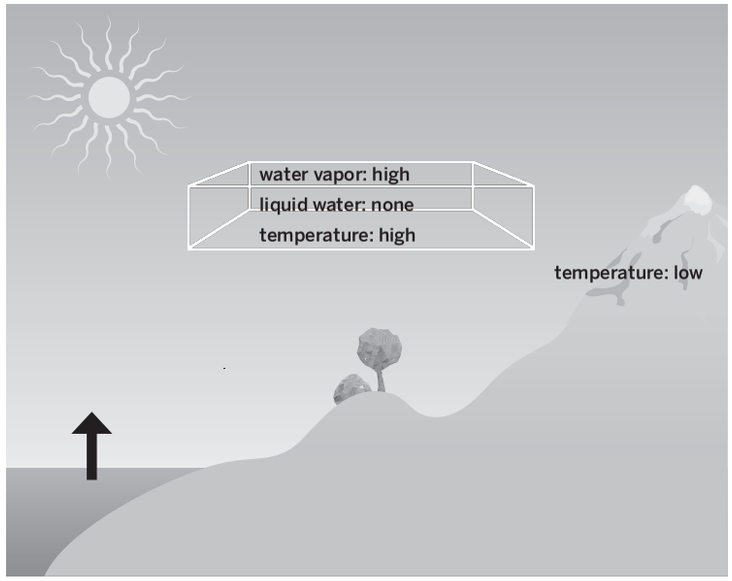
Goal: Make a model that shows how condensation occurs.

Do:

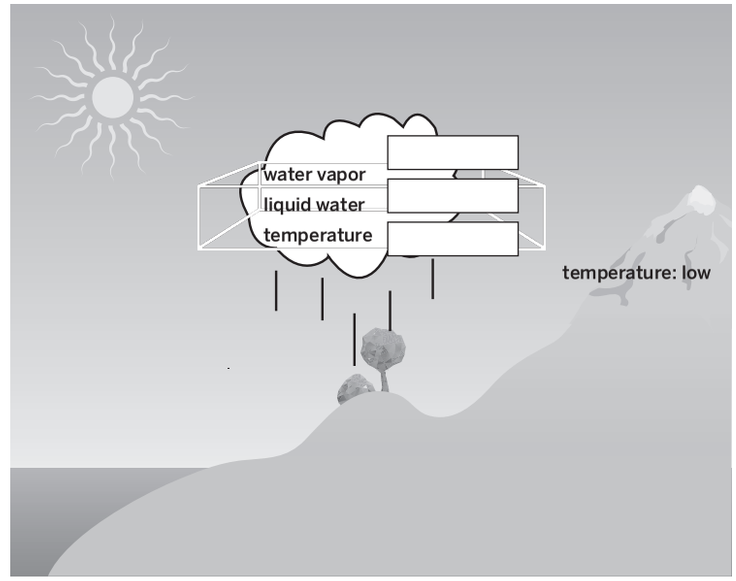
- Show the temperature of the air parcel and the surrounding air after condensation takes place.
- Show the amount of liquid water.
- Use the words in the Modeling Tool Key to fill in the boxes.

Weather Patterns Modeling Tool: Condensation

Before



After



Modeling Tool Key

Temperature:
high or low

Liquid water (cloud and rain):
high or low

Water vapor:
high or low

Name: _____ Date: _____

Homework: Reading "Why Don't All Clouds Produce Rain?"

Read and annotate the "Why Don't All Clouds Produce Rain?" article. Then, answer the question below.

Name three reasons why a cloud might form without rain happening.

_____

_____

_____

_____

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 1.5: Investigating Why Clouds Produce Rain

The residents of Galetown are counting on you to help them figure out what is causing the severe rainstorms they have been experiencing. As you investigate today, you'll find out more about what is involved in severe rainfall. Soon, you'll be able to explain to the residents how the lake might be affecting the weather, bringing you one step closer to solving the mystery of Galetown's severe rainstorms.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 1 Question

- What causes the rainfall in Galetown?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools it can condense into liquid water which can form a cloud and fall as rain.

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- stability
- temperature
- transfer
- water vapor
- weather

Digital Tools

- *Weather Patterns* Simulation

Name: _____ Date: _____

Warm-Up

Energy is an important part of weather. For example, energy is involved in forming clouds and in rainfall. Answer the following questions to help you think about how energy works when it comes to weather.

What happens when water vapor cools? (choose all that apply)

- ☐ It becomes liquid water.
- ☐ It stays the same.
- ☐ Energy transfers.
- ☐ Clouds form.

The energy that transfers out of an air parcel to form clouds originally comes from . . . (check one)

- ☐ people
- ☐ the sun
- ☐ electricity

Notice the clouds of different sizes in the photos below. In which photo do you think the most cooling and energy transfer occurred to form the clouds? (check one)

- ☐ A
- ☐ B
- ☐ C

A

B

C

Name: _____ Date: _____

Rereading "What Are Clouds?"

Read the section "Cloud Formation and Energy" in the article "What Are Clouds?" and gather evidence to help you answer the Investigation Question. As you read you may want to highlight parts of the text or add annotations that help you to answer the question.

Investigation Question: *What causes an air parcel to cool?*

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Making Different Weather Events

Launch Lab mode in the *Weather Patterns* Sim. Make three different weather events: clouds with some rain (Rainfall Level = 1 or 2), clouds with no rain (Rainfall Level = 0), clouds with a lot of rain (Rainfall Level = 3 or 4).

1. Follow along with your teacher and record the data for the first weather event: cloud with some rain.
2. Go to Build and set the water vapor between medium and high.
3. Refer to the first weather event and decide how to change the surrounding air temperature and air parcel temperature to make a cloud with no rain.
4. Run the Simulation.
5. Go to Analyze and check if you have the desired weather event. If you do, fill out the information in the data table. If you do not, go back to Build and change the conditions.
6. Repeat steps 2–5 for a cloud with a lot of rain.

Weather event	**Surrounding air temperature**	**Starting air parcel temperature**	**Final air temperature**	**Air parcel temperature difference**	**Energy transferred out**
Cloud with some rain (Rainfall Levels 1–2)					
Cloud with no rainfall (Rainfall Level 0)					
Cloud with a lot of rain (Rainfall Levels 3–4)					

Name: _____ Date: _____

Making Different Weather Events (continued)

The starting temperature of the air parcel was _____ the surrounding air temperature. (check one)

- ☐ greater than
- ☐ less than
- ☐ equal to

The final temperature of the air parcel was _____ the surrounding air temperature. (check one)

- ☐ greater than
- ☐ less than
- ☐ equal to

Using the temperature data, describe the direction that energy transfers and when it stops.

_____

_____

_____

_____

Use evidence from the Sim to answer the Investigation Question: *What causes an air parcel to cool?*

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Investigating the Effect of Water Vapor

Launch Lab mode of the *Weather Patterns* Sim. Conduct three tests to investigate the effect of the amount of water vapor on the amount of rain.

1. In Build, set the surrounding air temperature to -25°C and set the air parcel temperature to 35°C. Set the water vapor level as indicated in the data table below.
2. Press Run.
3. Press Analyze and record the rainfall level.
4. Repeat steps 1–3 for the second and third tests.

Weather event	Air parcel water vapor	Rainfall level
Test 1	low	
Test 2	medium	
Test 3	high	

When the amount of water vapor increased in the air, the rainfall level . . . (check one)

- ☐ decreased.
- ☐ increased.
- ☐ stayed the same.

Explain how building the lake near Galetown (Claim 1) could affect the amount of water vapor and the amount of rain.

_____

_____

_____

Name: _____ Date: _____

Lesson 1.6: Explaining Surface Water and Rain in Galetown

Student meteorologists, we are getting closer to understanding what caused Galetown to have more severe storms. First, however, you'll need to review some new data that Dr. Emerson sent. Using the data, you'll create two models of different storms that happened in Galetown, one before the lake and one after the lake. You'll then use this information to write to the citizens and explain what is causing the rainfall in Galetown.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 1 Question

- What causes the rainfall in Galetown?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.
- Energy transfers from warm air to cold air until their temperatures become equal.
- The more an air parcel loses energy and cools, the more rainfall can happen.

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- stability
- temperature
- transfer
- water vapor
- weather

Name: _____ Date: _____

Warm-Up

From: Dr. Kenji Emerson
To: Student Meteorologists
Subject: Data About the Rainfall in Galetown

We've put together this data table for you. It has data about the amount of rain from Galetown's recent rainstorms. It also includes information about the amount of surface water in Galetown. Remember, local surface water is all of the water that is at the surface and that can evaporate, including water from the lake.

Weather Event	Local Surface Water	Amount of Rain
Storm 1 (before lake)	low	mild, 6 cm (2.4 in)
Storm 2 (after lake)	high	moderate, 12.7 cm (5 in)
Storm 3 (after lake)	high	severe, 20.3 cm (8 in)
Storm 4 (after lake, July of this year)	high	very severe, 30.5 cm (12 in)

One of the claims that is used to explain the severe rainstorms in Galetown is this: The lake that was built near Galetown caused it to have more severe rainstorms.

Do you think the lake is affecting the amount of rain in Galetown? (check one)

- ☐ yes
- ☐ no
- ☐ not sure

Explain your answer using evidence from the table above.

_____

_____

_____

_____

_____

Name: _____ Date: _____

Word Relationships Routine

In order to prepare to explain why rainfall happens, use the Word Relationships cards to create sentences that answer the question *What causes the rainfall in Galetown?*

- Use at least two different Word Relationships cards in each sentence. In your group of four, take turns as both the speaker and the listener.
- Your group may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different ways to answer the Chapter 1 Question, and you will need to create more than one sentence in order to express your ideas completely.

Word Bank

air parcel	water vapor	energy	temperature	transfer

Name: _____ Date: _____

Modeling Galetown

In Chapter 1, you have been investigating what caused the rainfall in Galetown. Use the Modeling Tool activity: Effect of Surface Water (on the next two pages) to show how the amount of surface water caused different amounts of rain during two different storms in Galetown.

Goal: Show how the amount of surface water caused different amounts of rain in Galetown, using the items in the Modeling Tool Key.

Do:

- Label your model Storm 1 or Storm 2
- Show the temperature of and water vapor inside the air parcel
- Show the temperature of the surrounding air
- Show the direction of energy transfer, using the arrow
- Show the amount of liquid water inside the air parcel
- Show the amount of cloud and rain
- Show the amount of surface water

Tips:

- Use information from the data table to complete your model.

Weather event	Local surface water	Amount of rain
Storm 1	low	mild, 15 cm (6 in)
Storm 2	high	moderate, 38 cm (15 in)

Modeling Tool Key

temperature:
high, low

water vapor:
high, low

liquid water:
high, low

energy transfer:

amount of cloud and rain:

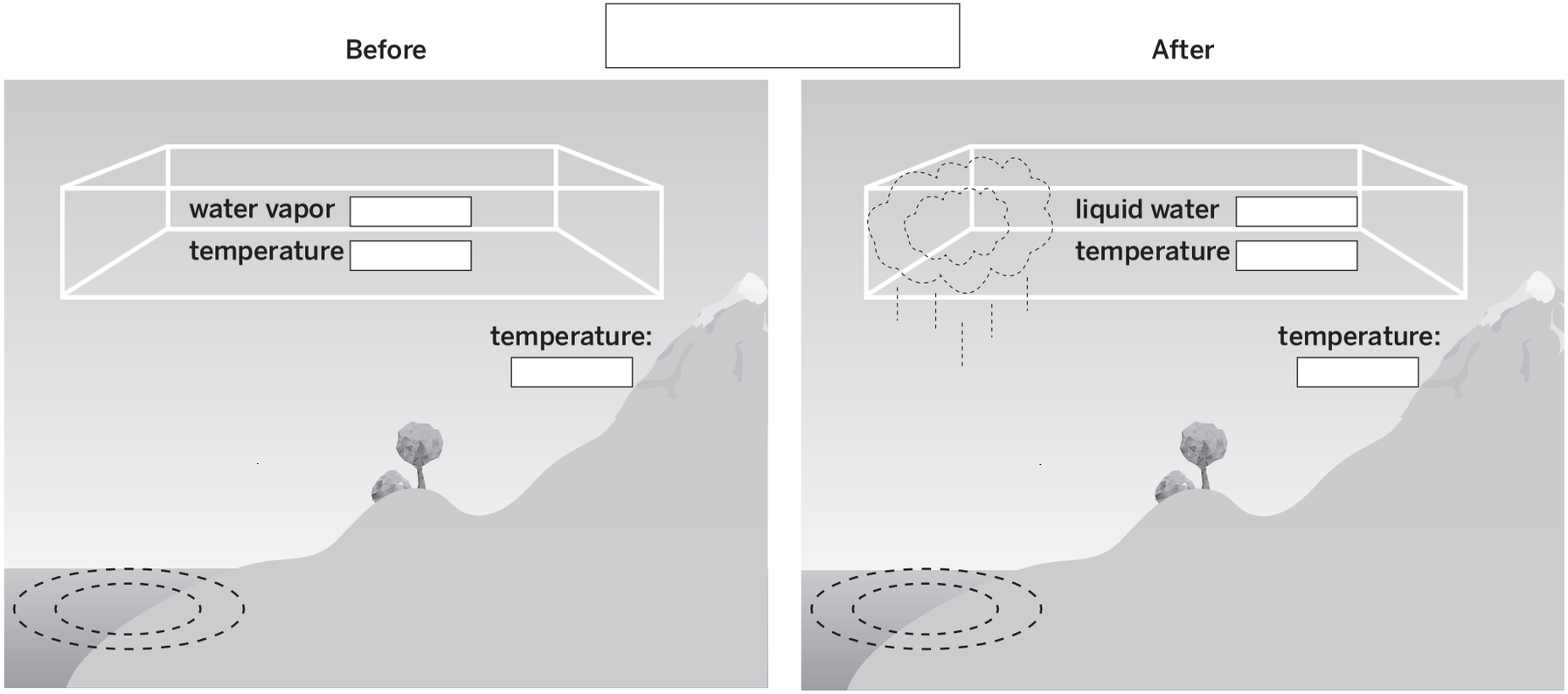
amount of surface water:

Name: _____ Date: _____

Modeling Galetown (continued)

Weather Patterns Modeling Tool: Effect of Surface Water

Goal: Show how the amount of surface water caused different amounts of rain in Galetown.

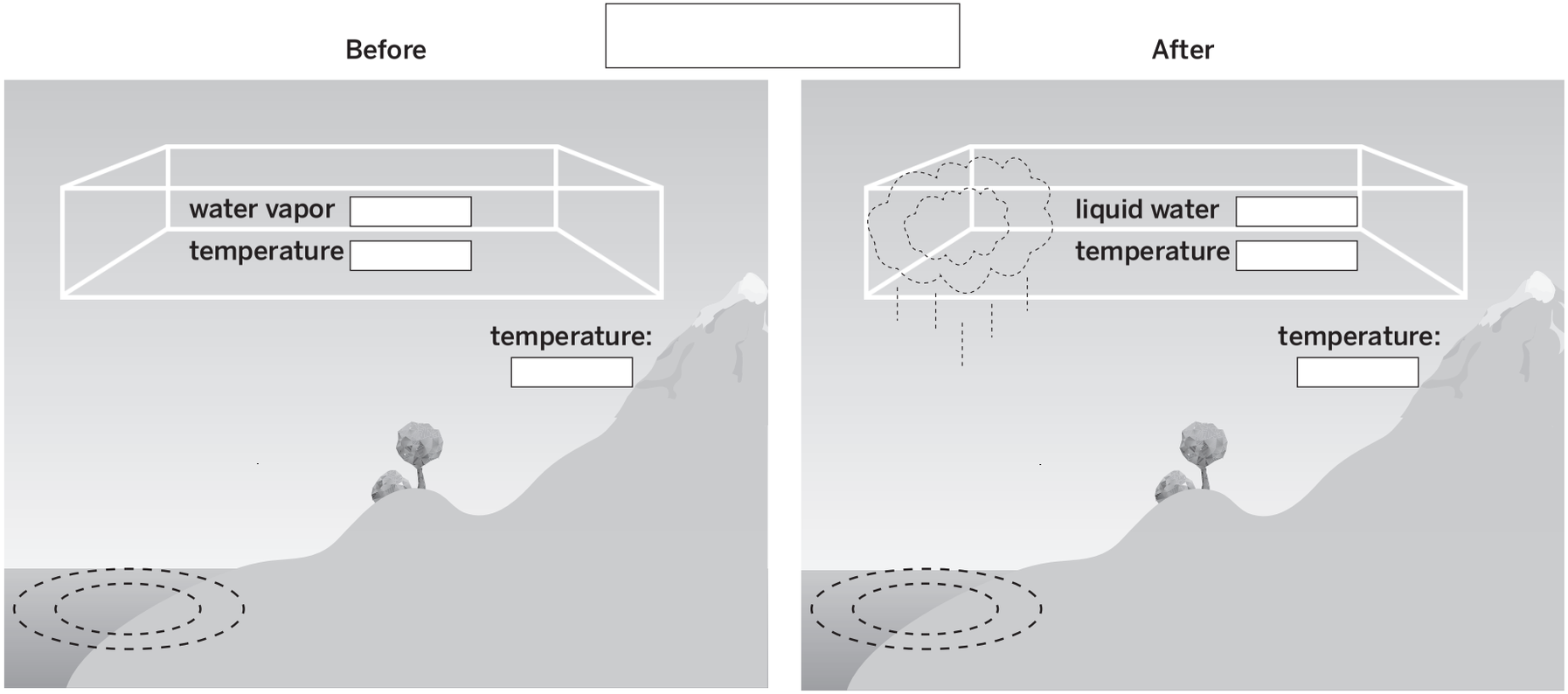


Name: _____ Date: _____

Modeling Galetown (continued)

Weather Patterns Modeling Tool: Effect of Surface Water

Goal: Show how the amount of surface water caused different amounts of rain in Galetown.



Name: _____ Date: _____

Homework: Writing to the People of Galetown

Use the information you've learned in this chapter, along with the new data you received from Dr. Emerson and the model you created in class today, as evidence to explain to the citizens how the lake that was built near Galetown caused it to have more severe rainstorms. You can use the words in the word bank to support your answer.

Word Bank

air parcel	change	cloud	condensation
energy	evaporation	stability	temperature
transfer	water vapor	weather	

Write a short explanation to support the claim: The lake that was built near Galetown caused it to have more severe rainstorms.

If you don't believe that the evidence you were given supports this claim, you can make another claim and write an explanation to support it. If you choose to do this, you must include evidence in support of your new claim.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand how the lake that was built near Galetown can affect the amount of rain in Galetown. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how transfer of energy causes water vapor to turn into rain. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand how warmer weather can affect the amount of rain in Galetown. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how wind can affect the amount of rain in Galetown. (check one).

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand why the amount of energy transfer is different depending on how high an air parcel travels. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What are you still wondering about why Galetown had more severe rainstorms this year than previous years?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Chapter 2: Investigating Temperature
Chapter Overview

Great job in figuring out the lake caused an increase in rainfall! In this chapter, you will further explore what other factors could have influenced the amount of rain. Even after the lake was built, the rainfall levels still increased. You will investigate what determines how much an air parcel cools to learn more about why the rainstorms were getting more severe.

Name: _____ Date: _____

Lesson 2.1: Air Parcels in the Troposphere

Great work investigating how the lake affected the amount of rain in Galetown! Next, you will investigate why the amount of rain was different from storm to storm even after the lake was built. In earlier lessons, you learned that the cooling of an air parcel causes rain; now you will find out what factors determine how much an air parcel cools. Today you will use the *Weather Patterns* Simulation and make observations as your teacher shows you a demonstration with an air parcel. These activities will help you better understand what affects how an air parcel cools.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 2 Question

- Why is the amount of rain in Galetown different from storm to storm?

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather

Digital Tools

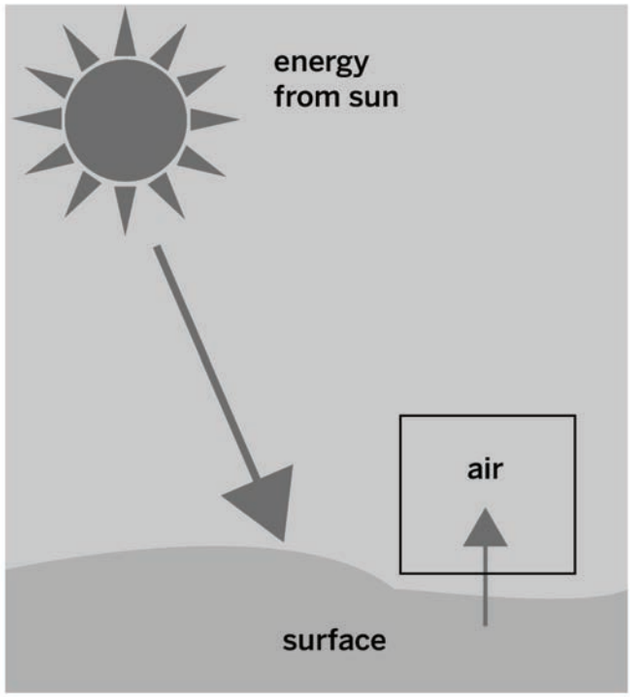
- *Weather Patterns* Simulation

Name: _____ Date: _____

Warm-Up

Heating Air

Review the diagram and answer the question below.



Which statement best describes how the sun heats the air? (check one)

- ☐ Energy from the sun is transferred to Earth's surface, and some of this energy is then transferred to the air.
- ☐ Energy from the sun is transferred to the air.

Name: _____ Date: _____

Cooling Air Parcels

Part 1

1. Launch the *Weather Patterns* Simulation and go to Regional Weather 1 mode.
2. Make parcels of different temperatures and observe how high each one rises. Fill out the data table and answer the question below.

	Temperature of surrounding air at 0 km	**Starting air parcel temperature**	**Final height of air parcel**
Test 1: Hot air parcel	15°C		
Test 2: Warm air parcel	15°C		
Test 3: Cold air parcel (sunlight at 0)	15°C		

Look back in the table at the starting temperature of each air parcel and the final height of each air parcel. What pattern do you notice?

_____

_____

Part 2

We are investigating *what determines how much an air parcel will cool.*

- Observe the Sim to collect information: Launch the *Weather Patterns* Simulation and go to Regional Weather 1 mode.
- Create an air parcel and press RUN.
- Observe the temperature of the surrounding air (troposphere) on the right side of the screen.
- Answer the question below.

What do you notice about the temperature of the surrounding air at different heights above Earth's surface?

_____

_____

Name: _____ Date: _____

Warm Air Parcel in the Classroom

The plastic bag is a model of an air parcel. Hot air will be added to the plastic bag as students hold the bag down toward the floor.

Predict what will happen when the plastic bag is let go.

_____

_____

_____

What happened to the plastic bag? Why did this happen?

_____

_____

_____

Name: _____ Date: _____

Homework: Hot-Air Balloons

This balloon is like an air parcel. Explain why it rises.

_____

_____

_____

If two hot-air balloons are filled at the same time, but one is filled with warm air and one is filled with hot air, which balloon do you think will rise higher? (check one)

- ☐ the balloon with hot air
- ☐ the balloon with warm air

Explain your answer choice below.

_____

_____

_____

Name: _____ Date: _____

Lesson 2.2: Reading "Disaster in California!"

You may have heard about severe storms causing destruction and damage to an area, and you may have even been in a major storm yourself. In this lesson, you will read "Disaster in California!" to learn about a megaflood that happened over 150 years ago that was caused by severe storms. As you read, you will use what you know about air parcels and energy transfer to take a close look at what caused these storms to be so intense. Reading about this megaflood will help you to better understand how the warming of an air parcel can affect the weather.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 2 Question

- Why is the amount of rain in Galetown different from storm to storm?

Key Concepts

- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.

Vocabulary

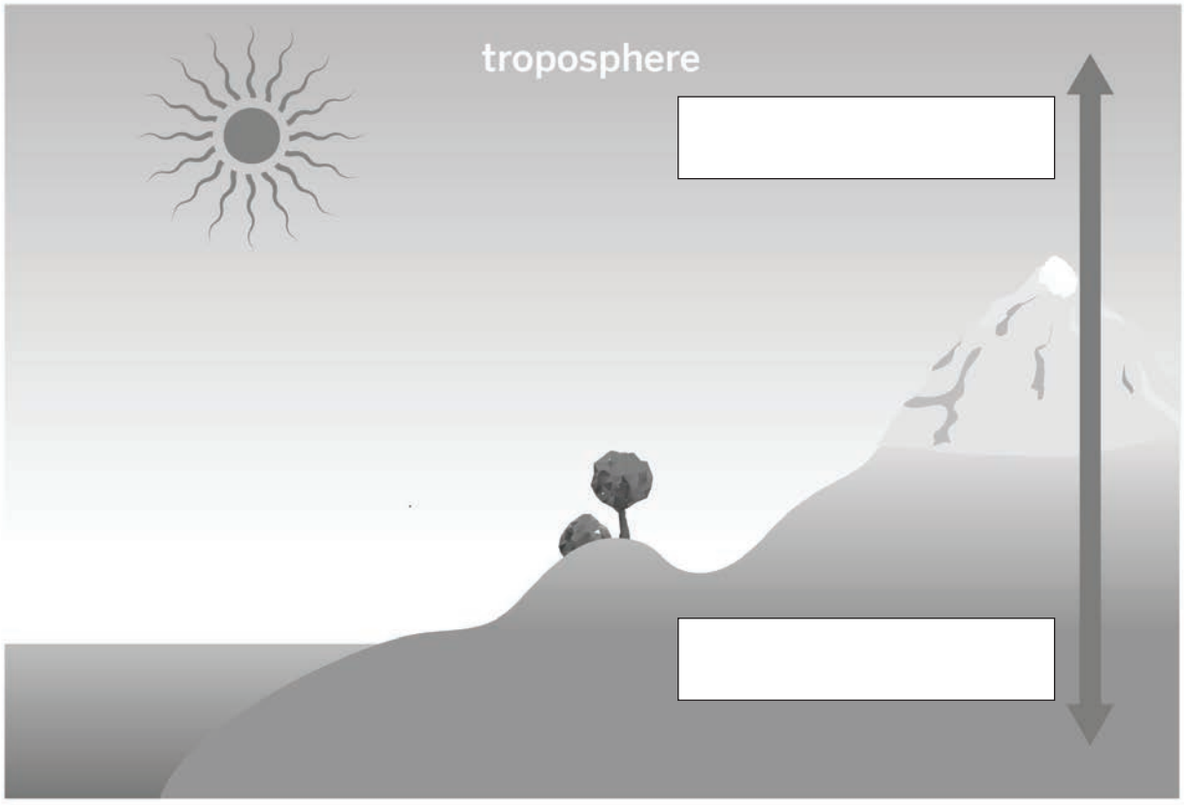
- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather

Name: _____ Date: _____

Warm-Up

Model of the Troposphere

Below is a model of the troposphere. Use the words in the word bank to label the image and then answer the question below.



Word Bank

colder	warmer

How does the temperature of the air in the troposphere change from the bottom of the arrow to the top of the arrow?

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Disaster in California!"

1. Read and annotate the article "Disaster in California!"
2. Choose and mark one or two of your annotations to share with a partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is something about the text that you discussed with your partner?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Researching Rainfall in Your Area

Use the Internet to research climate data about your state and town. Some terms and phrases to use to help you in your search include:

- (your state/town) climate data
- average rainfall in (your state)
- United States climate data

What is the average annual rainfall in your state? _____

What is the average annual rainfall in your city? _____

What day had the highest rainfall? _____

How many inches of rain fell on that day? _____

Name: _____ Date: _____

Lesson 2.3: Simulating a Large Storm

Can warm air temperature contribute to massive floods? In this lesson, you will reread part of the article "Disaster in California!" with a focus on the science behind what led to the megaflood in California. This learning will add to what you already know about what the recipe for a warm weather rainstorm is.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 2 Question

- Why is the amount of rain in Galetown different from storm to storm?

Key Concepts

- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather

Digital Tools

- *Weather Patterns* Simulation

Name: _____ Date: _____

Warm-Up

In the last lesson, you read about a megaflood that happened in California in 1862. The flood happened because of a series of huge rainstorms that occurred.

Below is a set of weather events that caused the Great Flood of 1862. The list of weather events is not in the correct order. Number the events from 1–6 in order of what happened.

_____ The warm air parcel rose into the troposphere and lost energy, forming clouds as it rose.

_____ Severe flooding happened.

_____ Energy transferred from Earth's surface to the air parcel, warming the air.

_____ The sun heated the surface of Earth.

_____ A lot of rain fell.

_____ The air parcel stopped when it reached the same temperature as the surrounding air high in the troposphere.

Name: _____ Date: _____

Rereading "Disaster in California!"

Reread the section "What Caused the Great Flood of 1862?" in the article "Disaster in California!" and answer the questions below. As you read you may want to highlight or annotate parts of the text that help you to answer the questions.

Why did the warm temperatures lead to more rainfall?

_____

_____

_____

_____

What happens when an air parcel rises higher in the troposphere?

_____

_____

_____

_____

When does the air parcel stop losing energy?

_____

_____

_____

_____

Name: _____ Date: _____

Simulating Rainstorms

Make three weather events: cloud with severe rain, cloud with moderate rain, and cloud with very severe rain.

Launch the *Weather Patterns* Simulation.

1. Follow along with your teacher to set up the Sim for the first weather event: cloud with severe rain.
2. For the second weather event, return to Build. Leave the surface water level at 5.
3. Refer to the first weather event and decide how to change the amount of sunlight to make a cloud with moderate rain.
4. Run the Simulation.
5. Go to Analyze and check if you have the desired Rainfall Level. If you do, fill out the information in the data table. If you do not, go back to Build and change the conditions.
6. Repeat steps 2–5 for a cloud with very severe rain.

Weather event	**Temperature of troposphere where the parcel stops**	**Parcel height**	**Starting air parcel temperature**	**Final air parcel temperature**	**Air parcel temperature difference**	**Energy transferred out**
Test 1: Cloud with severe rain (Rainfall Level 3)						
Test 2: Cloud with moderate rain (Rainfall Level 2)						
Test 3: Cloud with very severe rain (Rainfall Level 4)						

Name: _____ Date: _____

Simulating Rainstorms (continued)

What causes the parcel to stop rising?

_____

_____

_____

_____

In which test did the air parcel rise the highest? Is there a pattern in the relationship between starting air temperature and parcel height?

_____

_____

_____

_____

What pattern is there in the relationship between parcel height and rainfall level? Why?

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reflecting on the Investigation Question

- Reread the Investigation Question below.
- Use what you have learned in this chapter to write a response.
- Use the words in the word bank to help you with your answer.

Word Bank

energy	temperature	air parcel	troposphere

Investigation Question: *What determines how much an air parcel will cool?*

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.4: Analyzing New Data About Galetown

Student meteorologists, now that you have learned more about weather, it is time to create a more complete explanation about why the rainstorms in Galetown have become more severe. Today you will review important new temperature data about Galetown that Dr. Emerson has sent. From this data and all that you have learned, you will be able to explain how temperature affects the amount of rain in Galetown.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 2 Question

- Why is the amount of rain in Galetown different from storm to storm?

Key Concepts

- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.
- As an air parcel rises, energy transfers from the warm air parcel to the cold surrounding air until their temperatures become equal.
- When an air parcel starts with a higher temperature, it will rise higher and lose more energy, causing more rainfall.

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather

Name: _____ Date: _____

Warm-Up

From: Dr. Kenji Emerson
To: Student Meteorologists
Subject: Temperature Data for Galetown

We've gathered data about the air temperature before the storms started in Galetown and added it to this data table. Look carefully at the data for Storms 2 and 3 below. We think the temperature differences could be an important factor that can help explain the severe storms Galetown has been experiencing.

Weather Event	Local Surface Water	Amount of Rain	High Temperature Before the Storm
Storm 1 (before lake)	low	mild, 6 cm (2.4 in)	very high, 39°C (102°F)
Storm 2 (after lake)	high	moderate, 12.7 cm (5 in)	high, 27°C (81°F)
Storm 3 (after lake)	high	severe, 20.3 cm (8 in)	very high, 40°C (104°F)
Storm 4 (after lake, July of this year)	high	very severe, 30.5 cm (12 in)	high, 39°C (102°F)

How does this increase in temperature affect rainfall?

One of the claims that is used to explain the severe rainstorms in Galetown is this: Warmer weather caused Galetown to have more severe storms. Do you think that a higher temperature is affecting the amount of rain? (check one)

- ☐ yes
- ☐ no
- ☐ not sure

Explain your answer, using evidence from the table above.

_____

_____

_____

_____

_____

Name: _____ Date: _____

Word Relationships Routine

In order to explain and compare Storms 2 and 3 in Galetown, use the Word Relationships cards to create sentences that answer the question *Why is the amount of rain in Galetown different from storm to storm?* You can focus on explaining the differences between Storms 2 and 3 with your classmates.

Use at least two different Word Relationships cards in each sentence. In your group of four, take turns as both the speaker and the listener.

- Your group may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different ways to answer the question, and you will need to create more than one sentence in order to express your ideas completely.

Word Bank

air parcel	temperature	troposphere
energy	transfer	water vapor

Name: _____ Date: _____

Modeling Galetown

Part 1: Modeling the Effects of Temperature

In Chapter 2, you have been investigating how the temperature of an air parcel can affect the amount of rain in a storm. Use the Modeling Tool activity: Effect of Temperature on pages 59 and 60 to show how warmer weather caused different amounts of rain during two different storms in Galetown.

Goal: Using the items in the Modeling Tool Key, show how warmer temperatures caused different amounts of rain for Storms 2 and 3 in Galetown.

Do:

- Show the temperature of the troposphere at each height.
- Show the amount (and direction) of energy transfer using the arrows **before** the parcel stops rising.
- Show the parcel temperature **after** the parcel has stopped rising.
- Show the amount of liquid water **after** the air parcel has stopped rising.
- Show the amount of condensation and rain **after** the air parcel has stopped rising.

Weather event	Local surface water	Amount of rain	Highest temperature before the storm
Storm 2 (after lake)	high	moderate, 12.7 cm (5 in)	warm, 27°C (80°F)
Storm 3 (after lake)	high	severe, 20.3 cm (8 in)	hot, 40°C (104°F)

Modeling Tool Key

temperature:
very low, low, medium, high, very high

water:
low, medium, high

energy transfer:

low: →

medium: ⇒

high: ⇒

amount of cloud and rain:

Name: _____ Date: _____

Modeling Galetown (continued)

Part 2: Differences in Parcel Temperature Between Storms 2 and 3

Examine your models for Storm 2 and Storm 3 and compare how much the air parcel changed temperature. Answer the questions below:

Which storm had a greater change in temperature? (check one)

- ☐ Storm 2
- ☐ Storm 3
- ☐ Both storms had the same change in temperature.

What explains the greater temperature change? (check one)

- ☐ There was more surface water.
- ☐ Surrounding air temperature at the surface was different.
- ☐ The air parcel lost more energy.

Name: _____ Date: _____

Weather Patterns Modeling Tool: Effect of Temperature

Goal: Show how temperature caused different amounts of rain in Galetown.

Before [ ] **After**

troposphere temperature: [medium]

water vapor: [high]

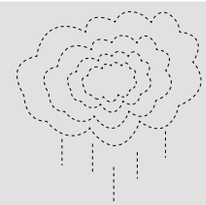
parcel temperature: [high]

surface water

troposphere temperature: [ ]

liquid water: [ ]

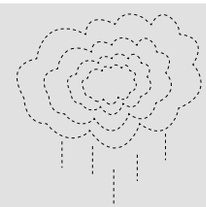
parcel temperature: [ ]



troposphere temperature: [ ]

liquid water: [ ]

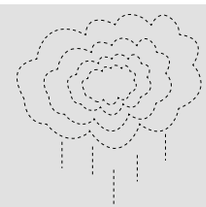
parcel temperature: [ ]



troposphere temperature: [medium]

liquid water: [ ]

parcel temperature: [ ]



surface water

Name: _____ Date: _____

Weather Patterns Modeling Tool: Effect of Temperature (continued)

Goal: Show how temperature caused different amounts of rain in Galetown.

Before [ ] **After**

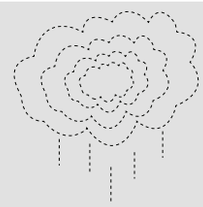
troposphere temperature:
[medium]

water vapor:
[high]
parcel temperature:
[high]

surface water

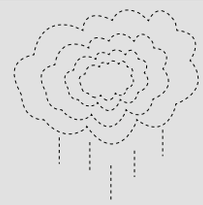
troposphere temperature:
[ ]

liquid water:
[ ]
parcel temperature:
[ ]



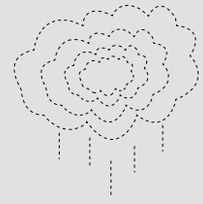
troposphere temperature:
[ ]

liquid water:
[ ]
parcel temperature:
[ ]



troposphere temperature:
[medium]

liquid water:
[ ]
parcel temperature:
[ ]



surface water

Name: _____ Date: _____

Homework: Writing to the People of Galetown

Use the information you've learned in this chapter along with the new data you received from Dr. Emerson as evidence to explain to the people of Galetown how warmer temperatures are affecting the amount of rain Galetown is experiencing.

Word Bank

air parcel	cloud	condensation	energy	evaporation
transfer	water vapor	weather	troposphere	

Use data you were given today about Galetown's storms (especially about Storms 2 and 3) and information you have learned in this chapter to write a short argument supporting the claim: Warmer weather caused Galetown to have more severe storms. You may use the words from the word bank, above, to help you with your argument.

If you don't believe that the evidence you were given supports this claim, you can make another claim and write an explanation to support it. If you choose to do this, you must include evidence in support of your new claim.

Name: _____ Date: _____

Lesson 2.6: Reviewing Key Ideas About Weather

In this lesson, you will play a game with a partner that requires you to use everything you have learned so far about weather and helps you to learn more about why some storms have more rainfall than others. You will then use the *Weather Patterns* Simulation to get your results and see who won each round. This deeper investigation into weather will help you to better understand how rainstorms happen.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 2 Question

- Why is the amount of rain in Galetown different from storm to storm?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.
- The more an air parcel loses energy and cools, the more rainfall can happen.
- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.
- As an air parcel rises, energy transfers from the warm air parcel to the cold surrounding air until their temperatures become equal.
- When an air parcel starts with a higher temperature, it will rise higher and lose more energy, causing more rainfall.
- Systems go through periods of stability and periods of change.

Name: _____ Date: _____

Lesson 2.6: Reviewing Key Ideas About Weather (continued)

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather

Digital Tools

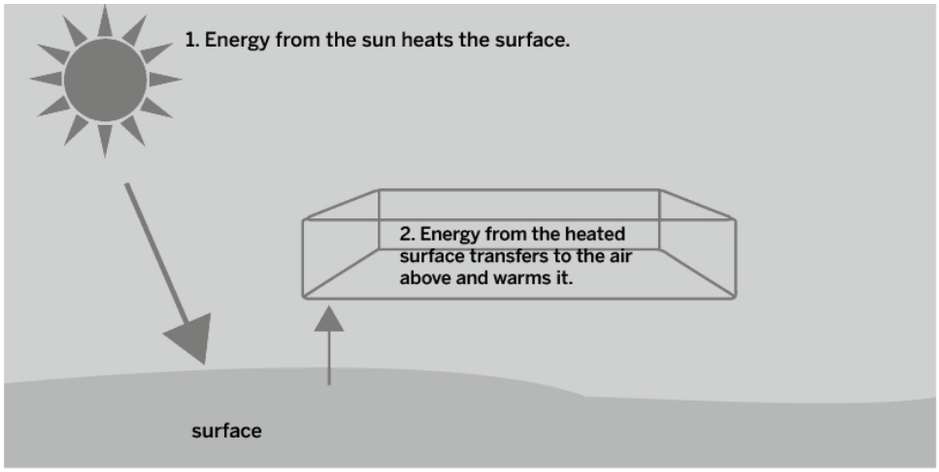
- *Weather Patterns* Simulation

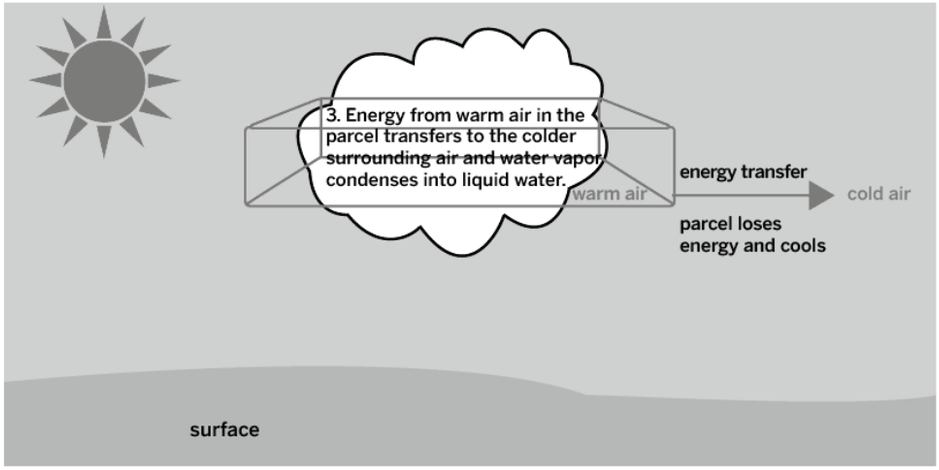
Name: _____ Date: _____

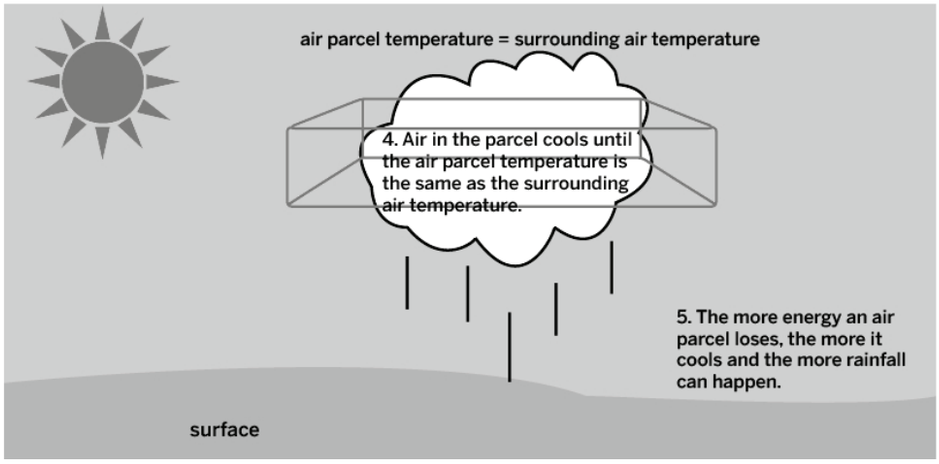
Purple Group: Warm-Up

Reviewing Energy Transfer

Use the Active Reading Guidelines on the next page to read and annotate the diagrams below.







Name: _____ Date: _____

Purple Group: Warm-Up (continued)

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Purple Group: Making it Rain

Game Instructions

Goal: Make the highest amount of rainfall over a series of storms.

Preparing to Play the Game

1. **Setup.** Shuffle the Air Parcel Temperature cards and place them face down in a stack. Shuffle the Water Vapor cards and place them face down in a stack. Shuffle the Surrounding Air Temperature cards and place them face down in a stack. Each player takes four cards from each stack (each player should have 12 cards total). You will need one scorecard and a writing utensil.
2. **Decide who goes first.** The partner whose birthday is closest to today's date goes first. This partner will lay down his cards first during each round.
3. **Launch the Sim.** Each player should launch the *Weather Patterns* Sim and go to Lab Mode.

Playing the Game

1. **Play.** Choose one Air Parcel Temperature card, one Water Vapor card, and one Surrounding Air Temperature card from your cards that you think will make the most rainfall and place them face up so your partner can see them.
2. **Test.** In Lab Mode of the Sim, your partner will enter the information from the three cards you chose and press RUN and then ANALYZE. You will test your partner's cards in the Sim.
3. **Score.** Find the rainfall level in ANALYZE, record that number as your score on the scorecard. Place the cards you played in a discard pile.
4. **Draw.** Take one card from each stack to replenish your hand (you should have 12 cards total).
5. **Play five rounds.** The person with the highest score at the end of the game wins!
6. **Reset the cards.** Return the discarded cards to each stack, shuffle each stack, and play the game again with a new scorecard until time runs out!

Name: _____ Date: _____

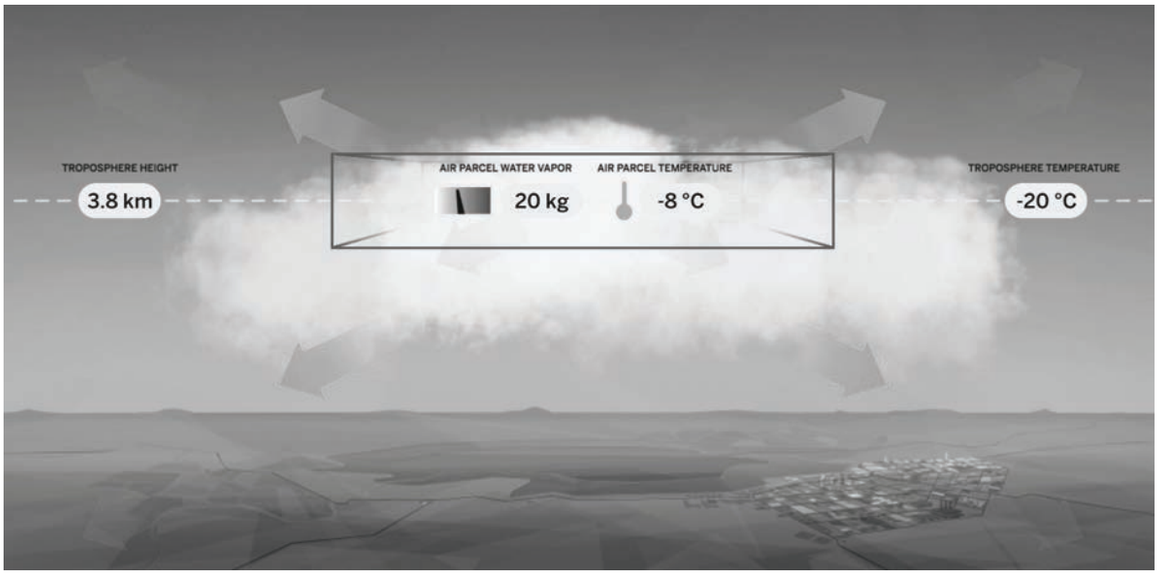
Purple Group: Reflection

Reflecting on Rain

1. Do you think the air parcel shown above will rise? Why or why not?

_____

_____



2. What do the arrows represent in the image above?

_____

_____

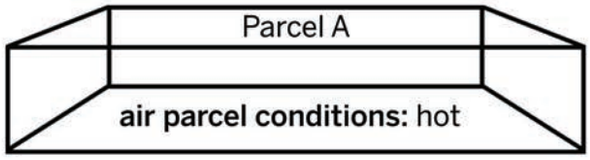
3. When will the parcel shown above stop rising?

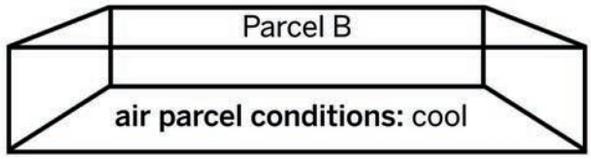
_____

_____

Name: _____ Date: _____

Purple Group: Reflection (continued)





4. Which parcel will rise higher? (check one)

   ☐ Parcel A

   ☐ Parcel B

5. Which parcel will lose more energy? (check one)

   ☐ Parcel A

   ☐ Parcel B

6. If Parcel A and Parcel B have the same amount of water vapor at the surface, which one would have more rainfall? (check one)

   ☐ Parcel A

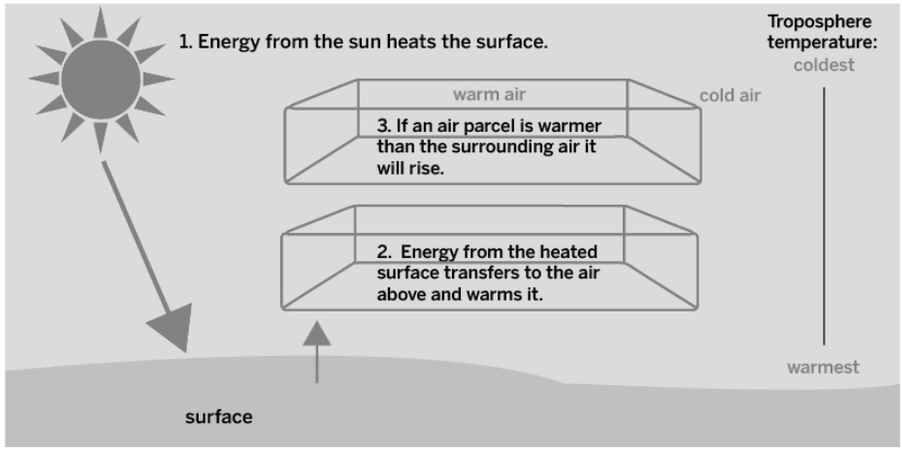
   ☐ Parcel B

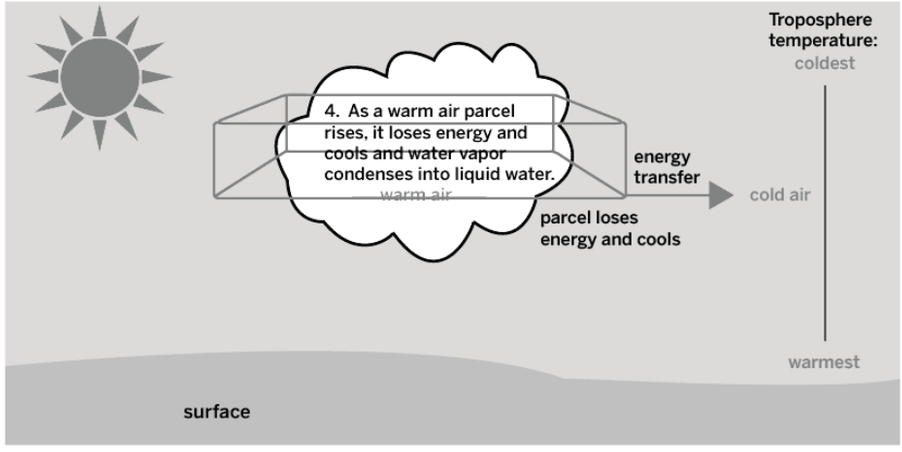
Name: _____ Date: _____

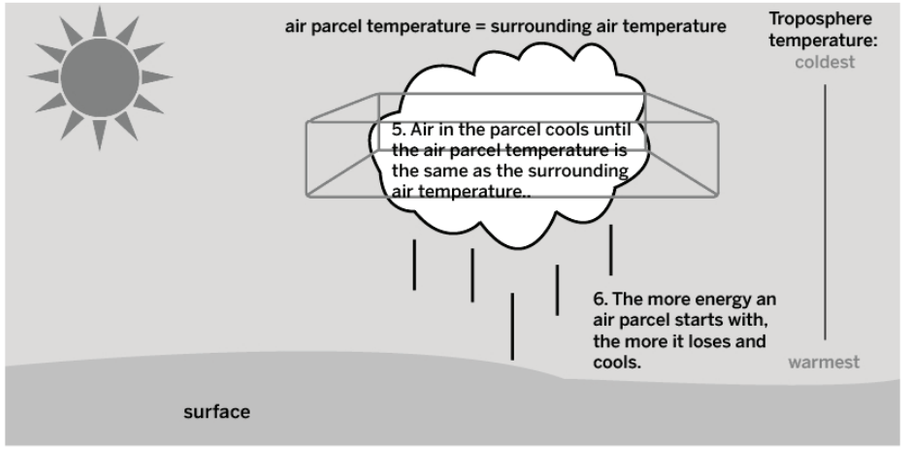
Blue Group: Warm-Up

Reviewing Energy Transfer

Use the Active Reading Guidelines on the next page to read and annotate the diagrams below.







Name: _____ Date: _____

Blue Group: Warm-Up (continued)

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Blue Group: Reaching the Target

Game Instructions

Goal: Get closest to the target.

Preparing to Play the Game

1. **Setup.** Shuffle the Target cards and place them face down in a stack. Shuffle the Sunlight cards and place them face down in a stack. Shuffle the Surface Water cards and place them face down in a stack. Each player takes three cards from the Sunlight stack and three cards from the Surface Water stack (each partner should have six cards total). You will need one scorecard and a writing utensil.
2. **Launch the Sim.** Each player should open the *Weather Patterns* Sim and go to Regional Weather 1.

Playing the Game

1. **Play.** Flip over a Target card. Both players should choose one Sunlight card and one Surface Water card from their cards which they think will get closest to the target. Players should place their chosen cards face up at the same time so both partners can see them.
2. **Test.** In Regional Weather 1 of the Sim, enter the information from the two cards your partner chose, while your partner enters the information from your cards. Press RUN and then ANALYZE.
3. **Score.** Look at ANALYZE to determine which partner got closest to the target. The player who got closest to the target won the round and should check a box on their scorecard. Place the cards you played in a discard pile.
4. **Draw.** Both partners should take one card from the Sunlight cards and one card from the Surface Water cards to replenish your hand (you should have six cards total).
5. **Play five rounds.** Continue playing until both players are out of cards. The person who won the most rounds at the end of the game wins!
6. **Reset the cards.** Return the discarded cards to each stack, shuffle each stack, and play the game again with a new scorecard until time runs out!

Name: _____ Date: _____

Blue Group: Reflection

Reflecting on Rain

1. Do you think the air parcel shown above will rise? Why or why not?

_____

_____

2. What do the arrows represent in the image above?

_____

_____

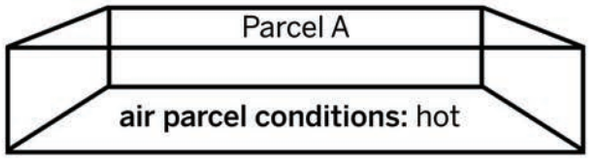
3. When will the parcel shown above stop rising?

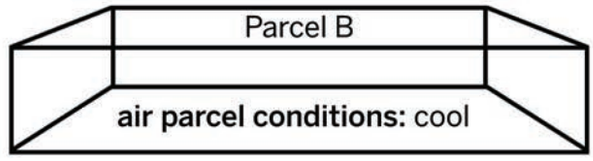
_____

_____

Name: _____ Date: _____

Blue Group: Reflection (continued)





4. Which parcel will rise higher? (check one)

   ☐ Parcel A

   ☐ Parcel B

5. Which parcel will lose more energy? (check one)

   ☐ Parcel A

   ☐ Parcel B

6. If Parcel A and Parcel B have the same amount of water vapor at the surface, which one would have more rainfall? (check one)

   ☐ Parcel A

   ☐ Parcel B

Name: _____ Date: _____

Green Group: Warm-Up

Reviewing Energy Transfer

Actively read the text below and use it to help you annotate the diagrams on the next page.

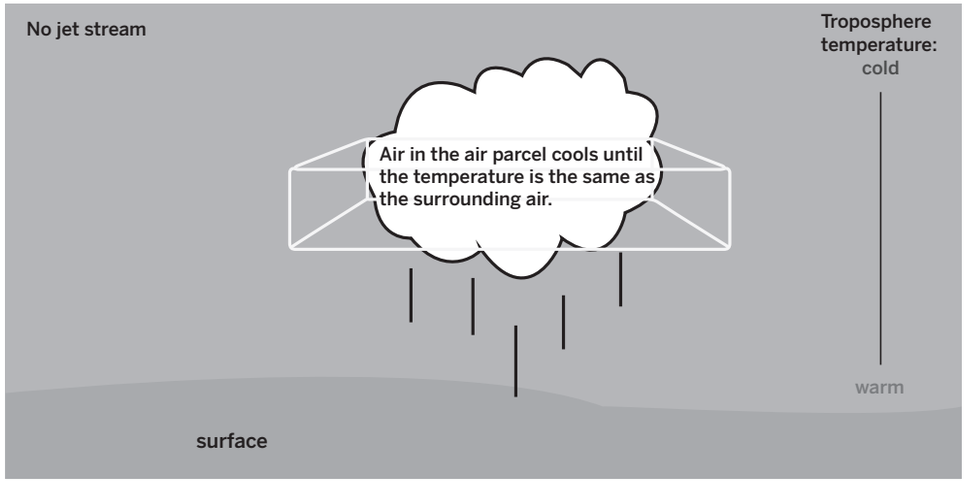
Jet streams are large bands of strong winds in the upper levels of the troposphere. In general, the troposphere is cooler as it gets farther from the surface of Earth, but sometimes, a jet stream blows in air that disrupts that predictable pattern, causing changes to the normal weather in a given place. There are two types of jet streams that can cause these disruptions: polar and subtropical. Polar jet streams bring in cold air, making the upper troposphere cooler than usual. In contrast, subtropical jet streams bring in warm air, making the upper troposphere warmer than usual.

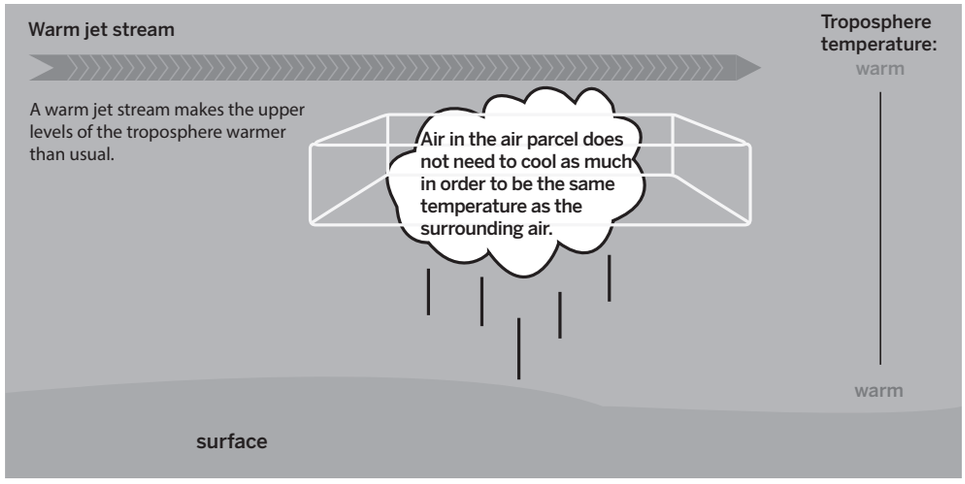
Active Reading Guidelines

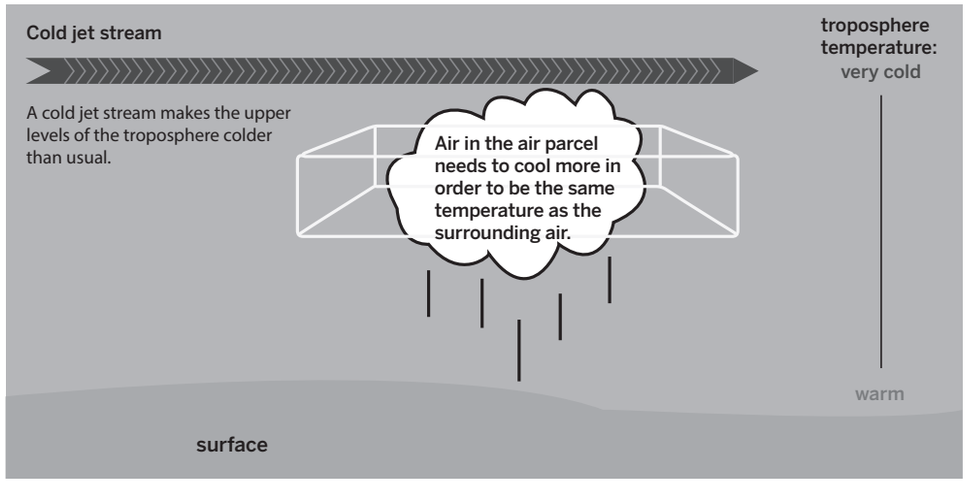
1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Green Group: Warm-Up (continued)







Name: _____ Date: _____

Green Group: Making it Rain with Jet Streams!

Game Instructions

Goal: Make the most rainfall.

Preparing to Play the Game

1. **Setup.** Shuffle the Air Parcel Temperature cards and place them face down in a stack. Shuffle the Water Vapor Cards and place them face down in a stack. Shuffle the Surrounding Air Temperature cards and place them face down in a stack. Each player should take four cards from each stack (each player should have 12 cards total). You will need one scorecard and a writing utensil.
2. **Decide who goes first.** The partner whose birthday is closest to today's date goes first. This partner will lay down their cards first during each round.
3. **Launch the Sim.** Each player should launch the *Weather Patterns* Sim and go to Lab Mode.

Playing the Game

1. **Play.** Choose one Air Parcel Temperature card, one Water Vapor card, and one Surrounding Air Temperature card from your cards that you think will make the highest level of rainfall and place them face up so your partner can see them.
2. **Partner Play.** At this point, if your partner has a wild card, they can put it down and change your weather conditions.
3. **Test.** In Lab Mode of the Sim, your partner will enter the information from the three cards you chose and press RUN and then ANALYZE. You will test your partner's cards in the Sim.
4. **Score.** Find the rainfall level in ANALYZE, and record that number as your score on the scorecard. Place the cards you played in a discard pile.
5. **Draw.** Take one card from each stack to replenish your hand (you should have 12 cards total).
6. **Play five rounds.** The person with the highest score at the end of the game wins!
7. **Reset the cards.** Return the discarded cards to each stack, shuffle each stack, and play the game again with a new scorecard until time runs out!

Name: _____ Date: _____

Green Group: Reflection

Reflecting on Air Motion

How can jet streams affect local weather conditions?

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand how the lake that was built near Galetown can affect the amount of rain in Galetown. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how transfer of energy causes water vapor to turn into rain. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand how warmer weather can affect the amount of rain in Galetown. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how wind can affect the amount of rain in Galetown. (check one).

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand why the amount of energy transfer is different depending on how high an air parcel travels. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What are you still wondering about why Galetown had more severe rainstorms this year than previous years?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Chapter 3: Exploring Wind and Pressure
Chapter Overview

Now that you know more about what determines how much an air parcel will cool, it's time to investigate other factors that can make an air parcel move higher up into the troposphere, where it will lose more energy and lead to more condensation which will increase the amount of rain. You'll decide if wind played a role in the severity of the rainfall in Galetown.

Name: _____ Date: _____

Lesson 3.1: Investigating Wind

You know that Galetown has experienced an increase in the amount of rain. In the last two chapters you learned about how the lake and temperature affected the amount of rain. Today, you will begin to consider one claim we have not yet discussed: that wind affects amount of rain. In this lesson, you will first complete activities to familiarize yourself with how wind behaves before using the *Weather Patterns* Simulation to investigate whether wind is connected to increased rainfall.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 3 Question

- Why did the most recent storm in Galetown have the greatest amount of rain?

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather
- wind

Digital Tools

- *Weather Patterns* Simulation

Name: _____ Date: _____

Warm-Up

Thinking About Wind

From: Dr. Kenji Emerson
To: Student Meteorologists
Subject: Temperature Data for Galetown

Remember the claims below are ideas we are considering about why the rainfall in Galetown has become severe:

1. The lake that was built near Galetown caused it to have more severe rainstorms.
2. Warmer weather caused Galetown to have more severe rainstorms.
3. Stronger winds caused Galetown to have more severe rainstorms.

Recently, you created models and wrote short arguments for the citizens of Galetown, explaining how the lake and the recent higher temperatures could be contributing to the town's severe storms. We have talked about the lake and the warmer weather, and now we will focus on this last claim. Let's start by thinking about wind.

What is wind?

_____

_____

How do you think wind could be related to severe rainstorms?

_____

_____

_____

_____

Name: _____ Date: _____

Exploring Wind

- Push down on the plunger to push out the air in the barrel.
  - What do you notice?
  - What do you feel?
- Block the tip of the syringe with your finger. Push down on the plunger.
  - What do you notice?
- Push down on the plunger as far as you can and then remove your finger from the end of the syringe.
  - What happens to the air inside the barrel?

When you blocked the tip with your finger, what did you feel?

_____

_____

What happened when you removed your finger?

_____

_____

_____

_____

Name: _____ Date: _____

Wind and Air Parcels

Part 1: Make Wind!

- Explore the new mode: Regional Weather 2 in the *Weather Patterns* Sim.
- Work with a partner to explore this new mode. Try to make wind.

Part 2: Make Two Air Parcels

Use the *Weather Patterns* Sim to gather evidence that will help you answer the Investigation Question: *How can wind affect the cooling of an air parcel?*

- Set the sliders for Sunlight to Surface and Surface Water to level 3.
- Set Pressure at Parcel and Pressure around Parcel to create wind that blows toward the parcel.
- Press RUN, and then ANALYZE.
- Complete the first row of the table below.
- Repeat the process to create a parcel with no wind.
- Complete the second row of the table below.

		Parcel height	**Air parcel final temperature**	**Energy released**	**Amount of rain (cm)**
Parcel 1	wind				
Parcel 2	no wind				

Use your data table to describe how wind can affect the cooling of an air parcel.

_____

_____

How does wind affect the amount of rain?

_____

_____

Name: _____ Date: _____

Homework: Reading "Types of Rain"

You have been learning about one type of rain which occurs when warm air parcels rise in the atmosphere and their water vapor condenses into liquid water. This is known as convection rain.

Read the "Types of Rain" article to learn about other types of rain. Annotate the article as you read.

Then, answer the questions below.

What type of rain do you think you normally experience?

_____

What is **orographic** rain and how does it happen?

_____

_____

_____

What is **frontal** rain?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.2: Analyzing Data About Storms

Today you'll look at weather data from several storms around the world to figure out if the severe rainfall in each storm was caused by a change in temperature, water vapor, or wind. You will also learn more about how scientists think about the sources where they get their data before deciding if they actually want to use and trust that data.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 3 Question

- Why did the most recent storm in Galetown have the greatest amount of rain?

Key Concepts

- Air moving from areas of high pressure to areas of low pressure is wind.
- Air parcels can be pushed up into the troposphere by wind (moving air).

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- source
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather
- wind

Name: _____ Date: _____

Warm-Up

Introducing Sources

Below are descriptions of two different groups, or sources, that collected data about birds. Read about both sources, then answer the question below.

Source 1
A blog written by a hiking club where club members regularly report the number of different birds they see.

Source 2
An article in a science journal where biologists report observations they collected about birds during a research study.

Source 1 and Source 2 are both groups of people who collected data about birds and then published their data. Which of these sources do you think would be able to give you better evidence? Why do you think that?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Evaluating Sources with the Evidence Gradient

Using the Criterion: Reliable Sources

Soon you will be asked to analyze data from different storms. Before you analyze the data, you first need to decide if the data comes from a reliable source. You will use the Evidence Gradient and discuss each source with your partner in order to decide which sources are the most reliable.

1. **Read Side 1 of the Storm Evidence Cards.** With your partner, carefully read the sources described on Side 1 of each card. Consider the Evidence Criterion as you sort the cards: *Evidence is higher quality if it comes from a reliable source.*

2. **Evaluate the Storm Evidence Cards and place them on the Evidence Gradient.** As you sort discuss the following questions with your partner:

   - Which sources are more reliable?
   - How do you know?

Name: _____ Date: _____

Analyzing Data from Severe Storms

Analyzing Evidence

In the next part of this activity, you will be reading and looking closely at the weather data on the cards you have determined to be from reliable sources.

1. **Read and discuss Side 2 for each card you have left.** With your partner, carefully read and discuss the weather data on Side 2 for each card. Identify which storms were largest and look for patterns in the data about those storms.

2. **Look back over each card and discuss the following questions with your partner:**

    - What do all of the big storms have in common?
    - In which storm do you think the most energy was transferred? Why?

Name: _____ Date: _____

Homework: Looking Back at the Article for Sources

Below is a paragraph from the article "Disaster in California!" that you read in a previous lesson. Reread the passage then answer the questions.

> "Using **sources** such as newspaper reports, data collected by scientists, and diaries and letters from people living in California at the time, people have reconstructed the kinds of damage done in this two-month period. Because of the massive rainfall and flooding, entire towns were destroyed. In some places, the water from the flood was 30 feet deep, covering the telephone poles that had just been put in place. Farmers and ranchers all across the state reported that they lost their homes, barns, farm equipment, and most of their animals. The devastation was so great and affected so many people that the state of California went bankrupt trying to support the people who were affected by the flood."

The authors of the article explain that different sources were used to understand what happened during the flood in California.

Which sources do you think are the most reliable scientific sources? Why do you think this?

_____

_____

_____

Which are the least reliable scientific sources? Why do you think this?

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "How We Predict the Weather"

Read the "How We Predict the Weather" article to learn about how weather is predicted. Annotate the article as you read, then answer the questions below.

What are the different tools that modern meteorologists use to predict weather?

_____

_____

_____

Why are meteorologists' weather predictions sometimes wrong?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.3: Creating a Report for Galetown

It's time to create your final report to the citizens of Galetown! In this lesson, you will have an opportunity to review more evidence about the recent storms in Galetown. You will then create another model to add to the final report you are making for the citizens of Galetown. The report will also include a written argument about what caused the storms in Galetown to be more severe and what you think will happen next.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 3 Question

- Why did the most recent storm in Galetown have the greatest amount of rain?

Key Concepts

- Air moving from areas of high pressure to areas of low pressure is wind.
- Air parcels can be pushed up into the troposphere by wind (moving air).

Vocabulary

- air parcel
- change
- claim
- cloud
- condensation
- energy
- evaporation
- pattern
- source
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather
- wind

Name: _____ Date: _____

Warm-Up

Reflecting on Data from Galetown

Weather Event	Local Surface Water	Amount of Rain	High Temperature Before the Storm	Wind Strength
Storm 1 (before lake)	low	mild, 6 cm (2.4 in)	very high, 39°C (102°F)	light
Storm 2 (after lake)	high	moderate, 12.7 cm (5 in)	high, 27°C (81°F)	strong
Storm 3 (after lake)	high	severe, 20.3 cm (8 in)	very high, 40°C (104°F)	light
Storm 4 (after lake, July of this year)	high	very severe, 30.5 cm (12 in)	very high, 39°C (102°F)	very strong

How could an increase in wind strength affect rainfall?

The last claim that is used to explain the severe rainstorms in Galetown is: *Stronger winds caused Galetown to have more severe rainstorms.*

Do you think the wind is affecting the amount of rain in Galetown? (check one)

☐ yes ☐ no ☐ not sure

Explain your answer using evidence from the table above.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Modeling Severe Rainstorms in Galetown

Part 1: Modeling the Effect of Wind

In Chapter 3, you have been investigating how wind can affect how an air parcel cools. Use the Modeling Tool activity: Effect of Wind (on pages 96 and 97) to show how wind caused different amounts of rain during two different storms in Galetown.

Goal: Show how wind caused different amounts of rain in Galetown.

Do:

- Label your model Storm 3 or Storm 4.
- Show the amount of wind in the Before panel.
- Show the amount (and direction) of energy transfer using the arrows.
- Show the parcel temperature after the parcel has stopped rising.
- Show the amount of liquid water after the air parcel has stopped rising.
- Show the amount of condensation and rain after the air parcel has stopped rising.

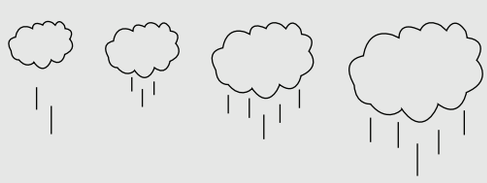
Weather event	Local surface water	Amount of rain	High temperature before the storm	Wind strength
Storm 3 (after lake)	high	severe, 20.3 cm (8 in)	very high, 40°C (104°F)	light
Storm 4 (after lake, July of this year)	high	very severe, 30.5 cm (12 in)	very high, 39°C (102°F)	very strong

Modeling Tool Key

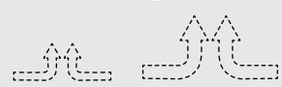
temperature:
extremely low, very low, low, medium, high, very high

water:
low, medium, high, very high

amount of cloud and rain:



wind strength:



Name: _____ Date: _____

Modeling Severe Rainstorms in Galetown (continued)

Part 2: Differences in Parcels Between Storms 3 and 4

Examine your models for Storm 3 and Storm 4 (on pages 96 and 97) and compare how much the air parcel changed temperature. Answer the questions below.

1. Which storm had a greater change in temperature? (check one)

   ☐ Storm 3

   ☐ Storm 4

   ☐ Both storms had the same change in temperature.

2. What explains the greater temperature change? (check all that apply)

   ☐ Wind pushed the air parcel higher.

   ☐ There was more surface water.

   ☐ Surrounding air temperature at the surface was different.

   ☐ The air parcel lost more energy.

Name: _____ Date: _____

Weather Patterns Modeling Tool: Effect of Wind

Goal: Show how wind caused different amounts of rain in Galetown.

[ ]

Before

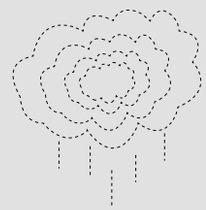
water vapor:
high
parcel temperature:
very high

surface water

After

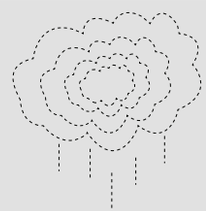
troposphere temperature:
extremely low

liquid water:
parcel temperature:



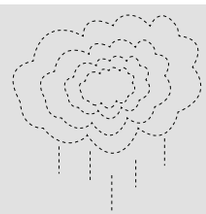
troposphere temperature:
very low

liquid water:
parcel temperature:



troposphere temperature:
low

liquid water:
parcel temperature:



surface water

Name: _____ Date: _____

Weather Patterns Modeling Tool: Effect of Wind (continued)

Goal: Show how wind caused different amounts of rain in Galetown.

[ ]

Before

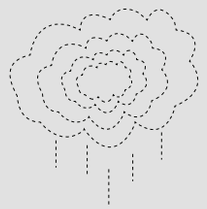
After

water vapor:
high
parcel temperature:
very high

surface water

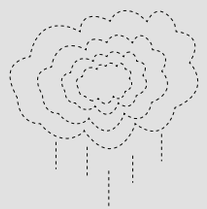
troposphere temperature:
extremely low

liquid water:
parcel temperature:



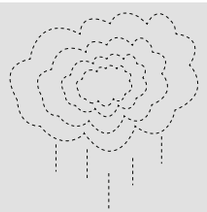
troposphere temperature:
very low

liquid water:
parcel temperature:



troposphere temperature:
low

liquid water:
parcel temperature:



surface water

Name: _____ Date: _____

Discussing Models of Galetown

Part 1

Use each of your models as you discuss the prompts with your partner.

Effect of Surface Water

- Begin with the models of Galetown showing rainfall before and after the lake.
- With your partner, use the models to answer the question *How did the addition of the lake affect the amount of rain in the rainstorms?*

Effect of Temperature

- Examine the models of Galetown showing how different temperatures affected rainfall.
- With your partner, use the models to answer the question *How did the differences in temperature affect the amount of rain in the rainstorms?*

Effect of Wind

- Examine the models of Galetown with light wind and strong wind.
- With your partner, use the models to answer the question *How did wind affect the amount of rain in the rainstorms?*

All Models of Galetown

- All of the models show factors that are part of causing storms.
- Can you have a storm if just one of these factors is happening? Why or why not?
- Could Galetown have severe storms without all of these factors?

Part 2: Preparing to Write a Final Report About Galetown

The claims below describe possible ideas about why the storms have become more severe in Galetown. Choose the claim or claims below you think best explain what is happening in Galetown.

Claims

1. The addition of the lake caused Galetown to have more severe rainstorms. (check one)

   ☐ supported by evidence ☐ not supported by evidence

2. Warmer weather caused Galetown to have more severe rainstorms. (check one)

   ☐ supported by evidence ☐ not supported by evidence

3. Stronger winds caused Galetown to have more severe rainstorms. (check one)

   ☐ supported by evidence ☐ not supported by evidence

Name: _____ Date: _____

Homework: Writing an Argument About Galetown's Severe Storms

In your final report to the citizens of Galetown, you will discuss the three claims and explain how all three factors can contribute to severe storms. Then, you will predict if the storms will always be severe.

What caused Galetown to have more severe rainstorms this summer than in previous years?

Claim 1: The lake that was built near Galetown caused it to have more severe rainstorms.

Claim 2: Warmer weather caused Galetown to have more severe rainstorms.

Claim 3: Stronger winds caused Galetown to have more severe rainstorms.

Weather event	Local surface water	Amount of rain	High temperature before the storm	Wind strength
Storm 1 (before lake)	low	mild, 6 cm (2.4 in)	very high, 39°C (102°F)	light
Storm 2 (after lake)	high	moderate, 12.7 cm (5 in)	high, 27°C (81°F)	strong
Storm 3 (after lake)	high	severe, 30.3 cm (8 in)	very high, 40°C (104°F)	light
Storm 4 (after lake, July of this year)	high	very severe, 30.5 cm (12 in)	very high, 39°C (102°F)	very strong

Be sure to use some of the vocabulary words you have learned in both of your writing assignments:

Word Bank

air parcel	cloud	condensation	energy	evaporation	temperature
transfer	troposphere	water vapor	weather	wind	

Name: _____ Date: _____

Homework: Writing an Argument About Galetown's Severe Storms
(continued)

Recall from the previous activity which claims you think are best supported by evidence. Use these claims to explain what is happening in Galetown. You can use the data table and the words listed in the word bank on the previous page to help you with your report that answers the question: *What caused Galetown to have more severe rainstorms this summer than in previous years?*

Name: _____ Date: _____

Homework: Will Galetown's Storms Always Be Severe?

The citizens of Galetown want to know if they should expect more severe storms. Do you think the storms that are happening in Galetown will always be this severe? Circle an answer and then explain it below.

Claim: The storms in Galetown (**will / will not**) always be this severe.

Be sure to use some of the vocabulary words you have learned in both of your writing assignments:

Word Bank

air parcel	cloud	condensation	energy	evaporation	temperature
transfer	troposphere	water vapor	weather	wind	

Explain your thinking about your answer above to the citizens of Galetown by writing a short argument. You can use the words from the word bank above to help with your writing.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand how the lake that was built near Galetown can affect the amount of rain in Galetown. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how transfer of energy causes water vapor to turn into rain. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand how warmer weather can affect the amount of rain in Galetown. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how wind can affect the amount of rain in Galetown. (check one).

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand why the amount of energy transfer is different depending on how high an air parcel travels. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What are you still wondering about why Galetown had more severe rainstorms this year than previous years?

_____

_____

_____

_____

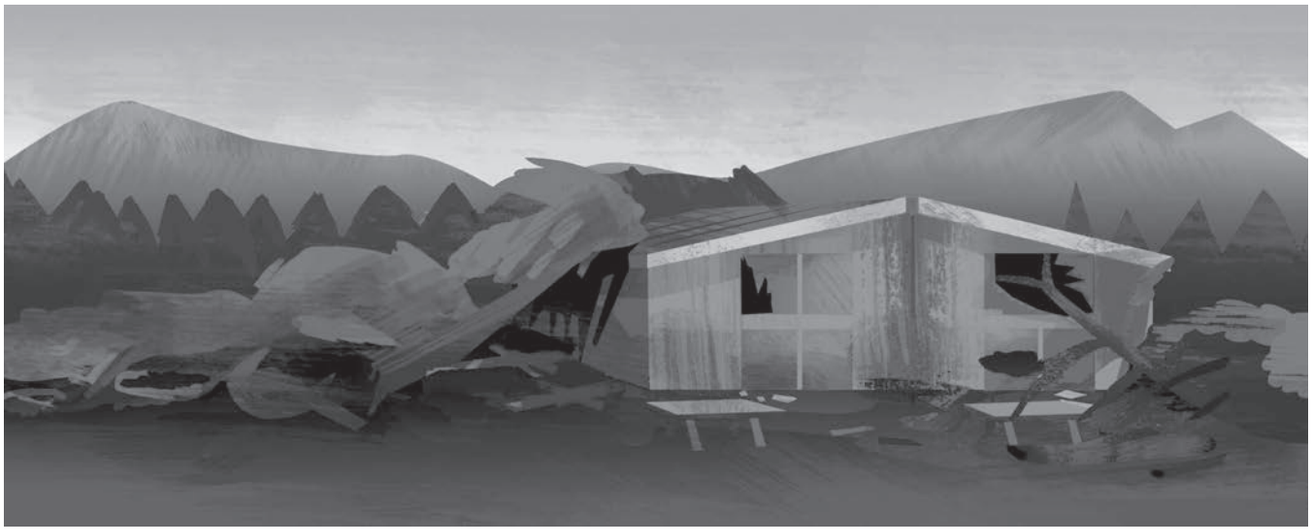
_____

_____

Name: _____ Date: _____

Chapter 4: Mystery of the Carson Wilderness Education Center
Chapter Overview

Dr. Kenji Emerson commends you on your great work in helping solve the mystery of the rainstorms in Galetown! He wants you to now help the people at the Carson Wilderness Education Center. The Center was damaged during a time when few people were around and they want to know if one severe rainstorm or several moderate rainstorms caused damage to the Center. They need your help in solving this new mystery!



Name: _____ Date: _____

Lesson 4.1: Evaluating Evidence from the Center

Now that you have prepared a report for the people of Galetown explaining what has been happening to the town's weather, it's time to move on to your next challenge: What caused the damage to the Carson Wilderness Education Center? Today you will get evidence from several sources. In this lesson, you will decide which sources of information are reliable and should be used to solve the mystery, and which are unreliable and should not be considered when solving the mystery.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 4 Question

- How was the Carson Wilderness Education Center damaged?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.
- The more an air parcel loses energy and cools, the more rainfall can happen.
- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.
- As an air parcel rises, energy transfers from the warm air parcel to the cold surrounding air until their temperatures become equal.
- When an air parcel starts with a higher temperature, it will rise higher and lose more energy, causing more rainfall.
- Systems go through periods of stability and periods of change.
- Air moving from areas of high pressure to areas of low pressure is wind.
- Air parcels can be pushed up into the troposphere by wind (moving air).

Name: _____ Date: _____

Lesson 4.1: Evaluating Evidence from the Center (continued)

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- source
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather
- wind

Name: _____ Date: _____

Warm-Up

Examine the image below and then answer the questions below the image.

The Carson Wilderness Education Center was damaged by rainstorms sometime during May. No one was around to see what happened. Do you think this type of damage can happen from just one very severe rainstorm, or could have been caused by a series of smaller rainstorms throughout the month? Why?

_____

_____

_____

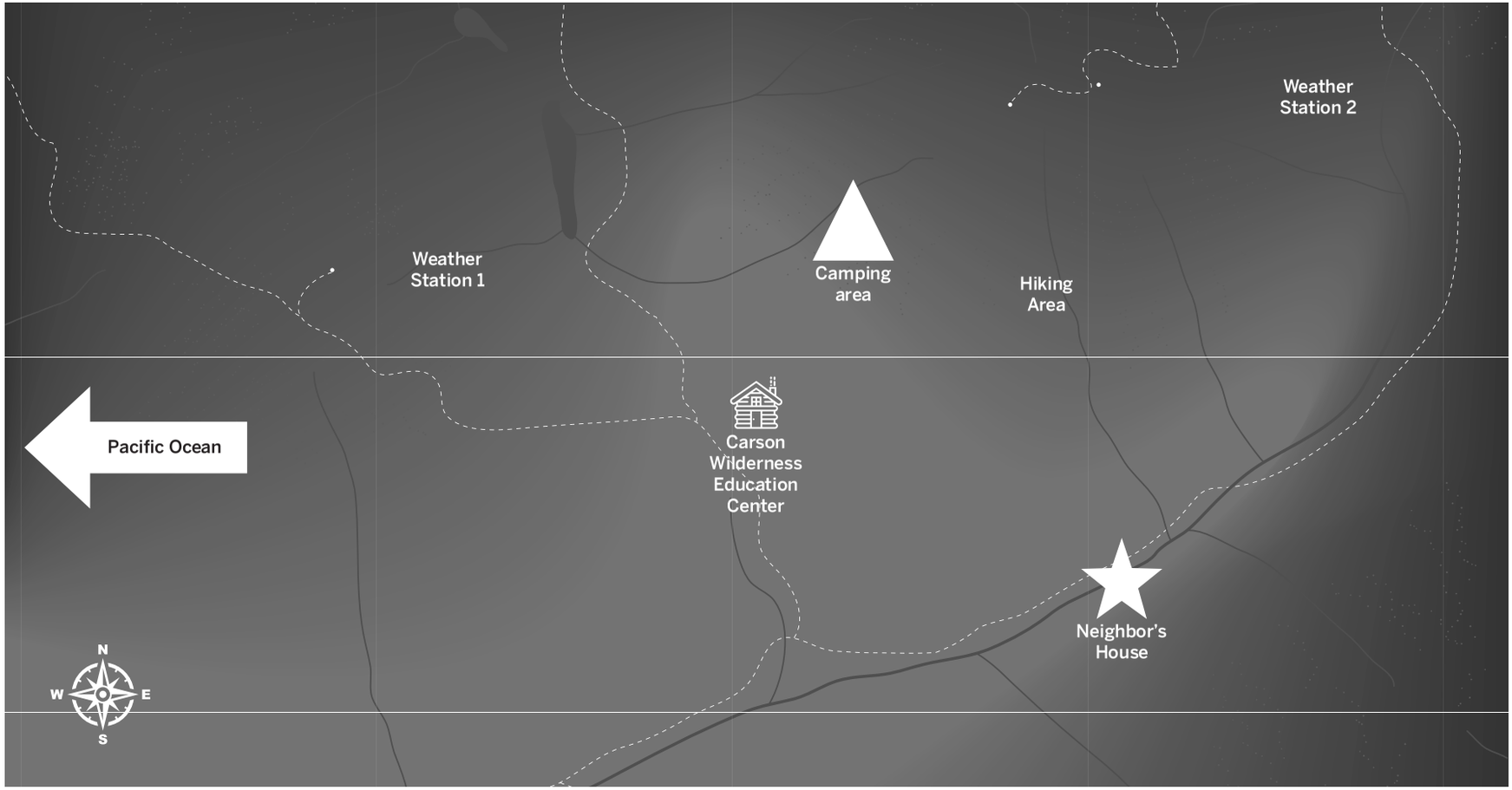
_____

_____

_____

Name: _____ Date: _____

Map of the Carson Wilderness Education Center Area



Name: _____ Date: _____

Choosing Reliable Sources

Choose the best responses below.

1. Which source did you and your partner think was the **most** reliable (you may choose more than one):

   - ☐ **Card A:** neighbor's data
   - ☐ **Card B:** hiker's observations
   - ☐ **Card C:** Station 1 (run by university students)
   - ☐ **Card D:** *The Beauty and Terror of Nature* blog entry
   - ☐ **Card E:** Station 2 (run by NOAA)

2. Which source did you and your partner think was the **least** reliable (you may choose more than one):

   - ☐ **Card A:** neighbor's data
   - ☐ **Card B:** hiker's observations
   - ☐ **Card C:** Station 1 (run by university students)
   - ☐ **Card D:** *The Beauty and Terror of Nature* blog entry
   - ☐ **Card E:** Station 2 (run by NOAA)

Name: _____ Date: _____

Homework: Reading "Hail, Snow, and Sleet"

Rain is one kind of precipitation that you have been learning about. Today you will read an article to learn about what happens when a cloud becomes very cold and other forms of precipitation happen.

Read the article to learn about other types of precipitation. Annotate the article as you read, then answer the questions below.

What is different about the conditions when hail, snow, and sleet form compared to when rain forms?

_____

_____

_____

How does hail form?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 4.2: Considering Evidence from the Center

Today you will get more evidence about weather conditions in the area of the Carson Wilderness Education Center. You will analyze this evidence and then, with a partner, discuss how this new evidence relates to the claims made about the damage done to the Carson Wilderness Education Center. Was the damage caused by several moderate rainstorms? Was it one severe rainstorm that caused the damage? Today you will work with all the evidence and begin to decide which claim is strongest and why.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 4 Question

- How was the Carson Wilderness Education Center damaged?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.
- The more an air parcel loses energy and cools, the more rainfall can happen.
- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.
- As an air parcel rises, energy transfers from the warm air parcel to the cold surrounding air until their temperatures become equal.
- When an air parcel starts with a higher temperature, it will rise higher and lose more energy, causing more rainfall.
- Systems go through periods of stability and periods of change.
- Air moving from areas of high pressure to areas of low pressure is wind.
- Air parcels can be pushed up into the troposphere by wind (moving air).

Name: _____ Date: _____

Lesson 4.2: Considering Evidence from the Center (continued)

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- source
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather
- wind

Name: _____ Date: _____

Warm-Up

Maya Zamora is a ranger who has worked at the Carson Wilderness Education Center for five years. She was asked which claim she thought best explained the cause of the damage to the Center:

Claim 1: The Carson Wilderness Education Center was damaged by one very severe rainstorm.

Claim 2: The Carson Wilderness Education Center was damaged by several moderate rainstorms that happened throughout the month.

Read what Ranger Maya Zamora said about the claims, then answer the questions.

Maya Zamora's Comments:

"I am not sure which claim is the best one. I have worked here for five years, and I've seen both situations cause a lot of damage. For example, two years ago, we had four moderate storms in a month. All the rainfall and wind over those weeks caused many trees and branches to fall down. I've also seen one huge storm cause damage like this. I guess we'll have to go to the data and figure out what happened."

Ranger Zamora is not sure which claim is the best one; her experiences working at the Center have shown her that either claim could be true. Using what you have learned, what conditions would you expect if there was one very severe rainstorm?

_____

_____

_____

What conditions would you expect if there were several moderate rainstorms throughout the month?

_____

_____

_____

Name: _____ Date: _____

Examining Evidence About the Center

Analyzing Evidence About the Wilderness Education Center

You will use the Carson Wilderness Education Center Evidence Cards you evaluated in the previous lesson. In addition, your teacher will give you some new Evidence Cards.

- Carefully read and annotate each card.
- Write connections and questions that you think of as you read that might help you determine if one very severe rainstorm or multiple moderate rainstorms that happened throughout the month damaged the Carson Wilderness Education Center.
- If you come across words you do not know, circle them.
- Try to write one short summary sentence on each card.

Name: _____ Date: _____

Discussing and Organizing Evidence

Part 1: Discussing and Organizing Data

Use the data on the Evidence Cards to fill out the Evidence from May Data Table on the next page.

- Examine each card with your partner and decide if it contains useful data that can be used to complete the data table.

Part 2: Looking for Patterns in the Data

Look closely at your Evidence from May Data Table and look for patterns.

- Examine the data table and look for any patterns in the data that may suggest a very severe rainstorm occurred or several moderate rainstorms occurred throughout the month.
- Circle or annotate the evidence in the data table that may support each claim.

Part 3: Evaluating the Claims

At this point, which claim do you think is best supported by evidence and explains how the Carson Wilderness Education Center was damaged? (check one)

☐ **Claim 1:** The Carson Wilderness Education Center was damaged by one very severe rainstorm.

☐ **Claim 2:** The Carson Wilderness Education Center was damaged by several moderate rainstorms that happened throughout the month.

What evidence supports your answer?

_____

_____

_____

_____

Name: _____ Date: _____

Evidence from May at the Wilderness Education Center

	May 1–5	May 6–10	May 11–15	May 16–20
Temperature (average high)			15°C (59°F)	
Wind				no data
Water vapor		medium		

Total rainfall in May: 40cm

Name: _____ Date: _____

Lesson 4.3: Participating in the Science Seminar

How was the Carson Wilderness Education Center damaged? Today, you will participate in a Science Seminar to discuss the evidence that will help you answer this question. Listening to one another and sharing your own thoughts during the Science Seminar will help you to decide which claim is stronger and better supported—the claim that one storm caused the damage to the Carson Wilderness Education Center, or that several moderate storms are responsible for the damage. Once you've decided which claim best explains what happened, you will be ready to explain to the people at the Carson Wilderness Education Center what caused the damage.

Unit Question

- Why do some rainstorms have more rain than others?

Chapter 4 Question

- How was the Carson Wilderness Education Center damaged?

Key Concepts

- When liquid water becomes warmer it can evaporate and become water vapor in the air. All air contains water.
- When water vapor in an air parcel cools, it can condense into liquid water which can form a cloud and fall as rain.
- The more an air parcel loses energy and cools, the more rainfall can happen.
- The troposphere is warmest at the surface and coldest at its highest point.
- If an air parcel is warmer than the surrounding air it will rise.
- As an air parcel rises, energy transfers from the warm air parcel to the cold surrounding air until their temperatures become equal.
- When an air parcel starts with a higher temperature, it will rise higher and lose more energy, causing more rainfall.
- Systems go through periods of stability and periods of change.
- Air moving from areas of high pressure to areas of low pressure is wind.
- Air parcels can be pushed up into the troposphere by wind (moving air).

Name: _____ Date: _____

Lesson 4.3: Participating in the Science Seminar (continued)

Vocabulary

- air parcel
- change
- cloud
- condensation
- energy
- evaporation
- pattern
- source
- stability
- temperature
- transfer
- troposphere
- water vapor
- weather
- wind

Name: _____ Date: _____

Warm-Up

To prepare to participate in the Science Seminar today, you will need to organize your evidence. While you wait to hear more about how to organize your Wilderness Evidence Cards, take them out and discuss with your partner which cards you think are strongest and why. You can refer to your evidence from your Evidence from May Data Table on page 116 to help you identify which evidence is strongest.

Name: _____ Date: _____

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: _____ Date: _____

Homework: Writing a Scientific Argument

Write your scientific argument to the Carson Wilderness Education Center on the next page. As you write, remember to:

- Include your strongest, most convincing evidence.
- Use the Scientific Argument Sentence Starters and the Word Bank below to help you explain your thinking.

How was the Carson Wilderness Education Center damaged?

Claim 1: The Carson Wilderness Education Center was damaged by one very severe rainstorm.

Claim 2: The Carson Wilderness Education Center was damaged by several moderate rainstorms that happened throughout the month.

Scientific Argument Sentence Starters

Describing evidence:	**Explaining how the evidence supports the claim:**
The evidence that supports my claim is . . .	If ___, then . . .
My first piece of evidence is . . .	This change caused . . .
Another piece of evidence is . . .	This is important because . . .
This evidence shows that . . .	Since, . . .
	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

Word Bank

air parcel	cloud	condensation	energy	evaporation
temperature	troposphere	water vapor	wind	

Name: _____ Date: _____

Homework: Writing a Scientific Argument (continued)

Part 1: Before you write your argument supporting Claim 1 or Claim 2, you will need to explain to the people at the Carson Wilderness Education Center what causes a rainstorm. Use the space below to write them an explanation. Be sure to tell them about all the factors that can cause a rainstorm (remember, they are not experts in meteorology). You will use information from the Evidence Cards to write your argument about what happened to the Carson Wilderness Education Center in Part 2.

Name: _____ Date: _____

Homework: Writing a Scientific Argument (continued)

Part 2: Write a scientific argument that addresses the question: *How was the Carson Wilderness Education Center damaged?* First, state your claim—you may choose to use one of the two claims given on page 121, or you can create your own. Then, use information from your Evidence from May Data Table on page 116 or the Evidence Cards to support your claim. You may want to refer to your writing in Part 1 to help explain why your evidence supports the claim.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that scientists have criteria for evaluating evidence. (check one)

   ☐ yes

   ☐ not yet

   Explain your answer choice.

_____

_____

_____

2. What are the most important things you have learned in this unit about why some rainstorms have more rain than others?

_____

_____

_____

_____

_____

_____

3. What questions do you still have?

_____

_____

_____

_____

_____

_____

Weather Patterns Glossary

air parcel: an amount of air that moves as a unit
parcela de aire: una cantidad de aire que se mueve como una unidad

air pressure: the force on a surface caused by the weight of the atmosphere pressing down on Earth
presión de aire: la fuerza sobre una superficie causada por el peso de la atmósfera ejerciendo presión sobre la Tierra

atmosphere: the mixture of gases surrounding a planet
atmósfera: la mezcla de gases que rodea a un planeta

change: when something becomes different over time
cambio: cuando algo se vuelve diferente con el tiempo

cloud: liquid water droplets suspended in the air
nube: gotitas de agua líquida suspendidas en el aire

condensation: the process by which a gas changes into a liquid
condensación: el proceso por el cual un gas se cambia a un líquido

energy: the ability to make things move or change
energía: la capacidad de hacer que las cosas se muevan o cambien

evaporation: the process by which a liquid changes into a gas
evaporación: el proceso por el cual un líquido se cambia a un gas

factor: one thing that contributes to causing an event
factor: una cosa que contribuye a causar un evento

forensics: scientific methods used to reconstruct and understand a mystery
ciencia forense: métodos científicos usados para reconstruir y entender un misterio

humidity: a measure of how much water vapor is in the air
humedad: una medida de qué tanto vapor de agua hay en el aire

meteorology: the scientific study of weather
meteorología: el estudio científico de condiciones atmosféricas

pattern: something we observe to be similar over and over again
patrón: algo que observamos que sea similar una y otra vez

precipitation: rain, snow, sleet, or hail that falls from clouds onto the ground
precipitación: lluvia, nieve, aguanieve o granizo que cae desde las nubes hasta el suelo

source: where something comes from
fuente: el lugar desde donde viene algo

stability: when something stays mostly the same over time
estabilidad: cuando algo permanece más o menos igual a lo largo del tiempo

temperature: a measure of how hot or cold something is
temperatura: una medida de qué tan caliente o frío está algo

transfer: to move from one object to another or one place to another
transferir: mover de un objeto a otro o de un lugar a otro

troposphere: the layer of the atmosphere closest to Earth, where weather happens
troposfera: la capa de la atmósfera más cercana a la Tierra, en donde el clima se manifiesta

water vapor: water as a gas
vapor de agua: agua en forma de gas

weather: conditions such as rain, clouds, and wind at a particular time and place
condiciones atmosféricas: condiciones como la lluvia, las nubes, y el viento en un momento y lugar determinados

wind: the movement of air in a particular direction
viento: el movimiento del aire en una dirección determinada

Lawrence Hall of Science:
Program Directors: Jacqueline Barber and P. David Pearson
Curriculum Director, Grades K–1: Alison K. Billman
Curriculum Director, Grades 2–5: Jennifer Tilson
Curriculum Director, Grades 6–8: Suzanna Loper
Assessment and Analytics Director: Eric Greenwald
Learning Progressions and Coherence Lead: Lauren Mayumi Brodsky
Operations and Project Director: Cameron Kate Yahr
Student Apps Director: Ari Krakowski
Student Content Director: Ashley Chase

Leadership Team: Jonathan Curley, Ania Driscoll-Lind, Andrew Falk, Megan Goss, Ryan Montgomery, Padraig Nash, Kathryn Chong Quigley, Carissa Romano, Elizabeth Shafer, Traci K. Shields, Jane Strohm

Weather Patterns: Severe Storms in Galetown **Unit Team:**

Richard T. Ables
Stacy Au-yang
Elizabeth Ball
Maite Barloga
Candice Bradley
Benton Cheung
Juliet Randall Dana
Paul Daubenmire
Jacqueline Felipe
Abigail Hines
Deirdre MacMillan
Amybeth O'Brien
Catherine Park
Roshanak Razavi
Natalie Roman
Patrice Scinta
Wendy Simard
Claire Spafford
Natalie Shea

Amplify:

Irene Chan
Samuel Crane
Shira Kronzon
Charvi Magdaong
Thomas Maher
Rick Martin
Matt Reed
Eve Silberman
Steven Zavari

Credits:
Illustration: Cover: Tory Novikova
Photographs: Pages 8, 11, 16, 24, 43, 107: Shutterstock

Weather Patterns:

Severe Storms in Galetown

Article Compilation

Table of Contents: Articles

Gravity causes drops of water to fall from the clouds and determines where the water flows after it reaches the ground.

What Makes Water Move?

Water is always on the move. In fact, water on Earth goes around and around in a cycle with no beginning and no end. This endless cycle is driven by many factors, including energy from sunlight and the force of gravity.

The water cycle doesn't really begin anywhere, but let's start by thinking of water in the soil. A process called transpiration moves water upward out of the soil. Through transpiration, plants suck up water from the soil with their roots. The water moves through a system of tubes inside the plants, from the roots upward into trunks, stems, branches, and leaves. The tallest trees carry water upward more than 100 meters (about 300 feet)! After it reaches the leaves, the water evaporates into the air.

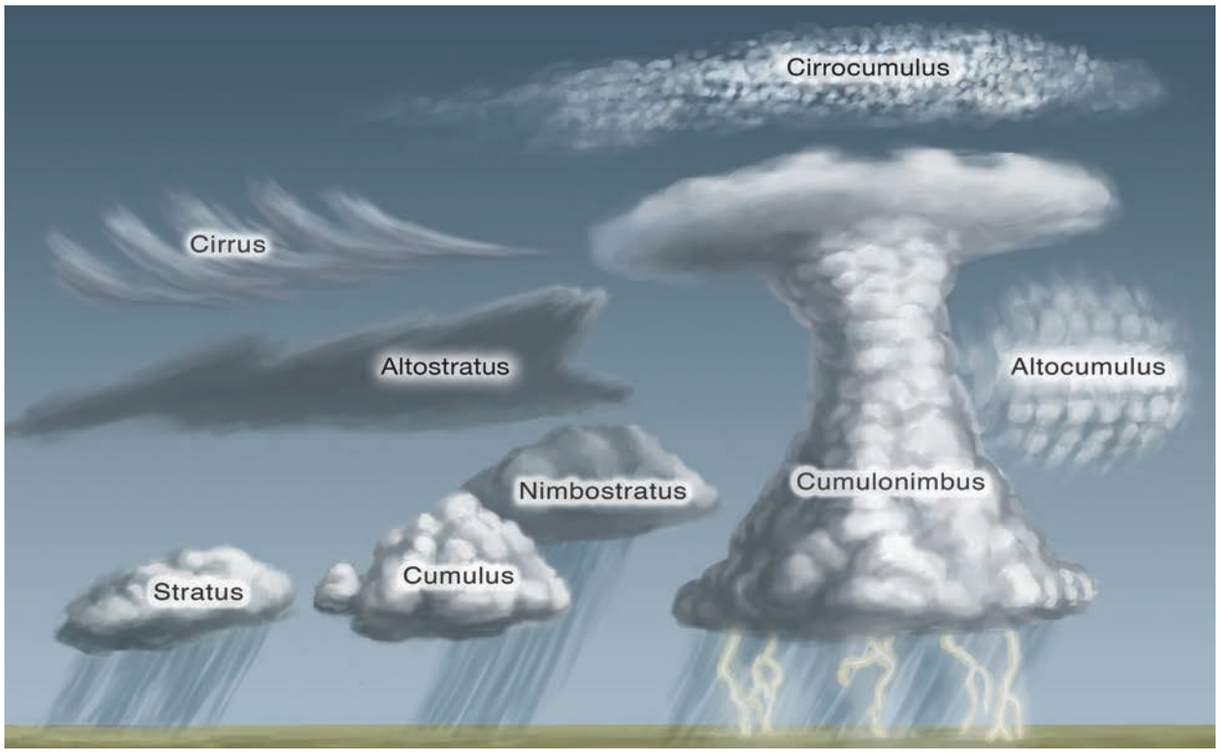
Evaporation moves water from Earth's surface into the atmosphere, and this part of the water cycle is powered by the sun. Energy from sunlight causes liquid water to evaporate from the leaves of plants, from bodies of water, and from Earth's surface, changing into a gas called water vapor. The water vapor moves upward into the atmosphere.

Gravity powers the next part of the water cycle. Water vapor high in the atmosphere condenses to form the droplets of liquid water that make up clouds. Earth is always pulling those droplets downward with the force of gravity, even when they are very tiny. However, the droplets are so small that the effect of that force isn't very strong and the droplets stay suspended in the air. It isn't until the droplets begin to stick together and gain more mass that the force of gravity on them is strong enough to make drops of water actually fall to the ground. These falling drops of water are known as precipitation.

Gravity causes rivers to flow downhill, sometimes for thousands of miles, until they reach the ocean.

The role of gravity in how and where water travels doesn't end when water leaves the clouds. When water hits the ground, some of it sinks right in. That's an effect of gravity—Earth is pulling the water down, forcing it between the particles of dirt and rock that make up the outer layer of Earth.

When the dirt and rock are full of water and can't hold any more, the water stops sinking in and begins to flow over the surface. Again, gravity comes in. Earth pulls the water downward with the force of gravity, so the water always flows downhill. All of the water flowing downhill tends to gather in certain low-lying areas and keep on flowing—that's how rivers form. All rivers flow downhill, sometimes for thousands of miles, until they reach the ocean. From the clouds to the ocean, gravity keeps water moving downward. Then transpiration and evaporation move it upward again, and the cycle continues on and on.



Clouds take different shapes depending on the temperature of the air around them.

What Are Clouds?

Looking Up at the Sky

Dr. Joanne Simpson became fascinated with clouds at an early age. Simpson would grow up to study clouds and become the first woman to earn a PhD in meteorology—but as a child, she simply loved how they looked. When she was a young girl, walking around her town and sailing on the nearby ocean, she noticed all kinds of unusual clouds. She saw clouds that looked like towers looming high, bunches of hanging grapes, and even UFOs! She wondered what they were made of and how they formed so many different amazing shapes.

When Simpson went to college in the 1940s, nobody thought clouds were important for scientists to study. However, Simpson's professors encouraged her to study clouds because she was a woman and they didn't think women could be serious scientists. Clouds seemed to them like a good unimportant subject for a woman to study. Simpson went on to prove her professors wrong about both clouds and female scientists.

Determined to succeed despite sexism, Simpson continued her study of clouds and cloud formation. She collected data as she flew in airplanes high above Earth's surface, taking notes and sketching in her field journal to document the cloud formations she saw. Most interesting of all to Simpson were the gigantic clouds she called hot towers. These cumulonimbus clouds looked like

skyscrapers sticking up above the clouds around them. Simpson wanted to know why hot towers were so unusual, so she set out to study them. She collected data about the temperature, wind conditions, and amount of water vapor in these unusual cloud formations. Eventually, she was able to explain that hot tower clouds form when warm air with lots of water vapor in it rises quickly from Earth's surface into the troposphere, the layer of the atmosphere closest to the Earth, cooling as it goes. Based on her research about hot towers and other kinds of clouds, Simpson is considered one of the most important weather scientists in the history of meteorology.

What All Clouds Share

Research by meteorologists like Simpson shows that all clouds, even the most unusual types, have a lot in common. Meteorologists use a helpful concept, the idea of air parcels, to study all kinds of clouds and track them as they move through the troposphere. An air parcel is an amount of air that moves as a unit.

All clouds form when the water vapor in air parcels comes into contact with colder surrounding air. When it meets the colder air, the water vapor in each air parcel becomes liquid in a process called condensation. In fact, all clouds are made of the same basic ingredient: visible droplets of water floating in the troposphere. If it's cold enough, the water droplets can freeze into tiny ice crystals. How does water vapor get into the troposphere in the first place? It comes from liquid water on Earth's surface. When liquid water gets warm enough, it turns into water vapor through a process called evaporation. The water vapor becomes part of the air and is ready to become part of a cloud when the conditions are right.

Joanne Simpson photographed and collected observations and evidence about all kinds of clouds.

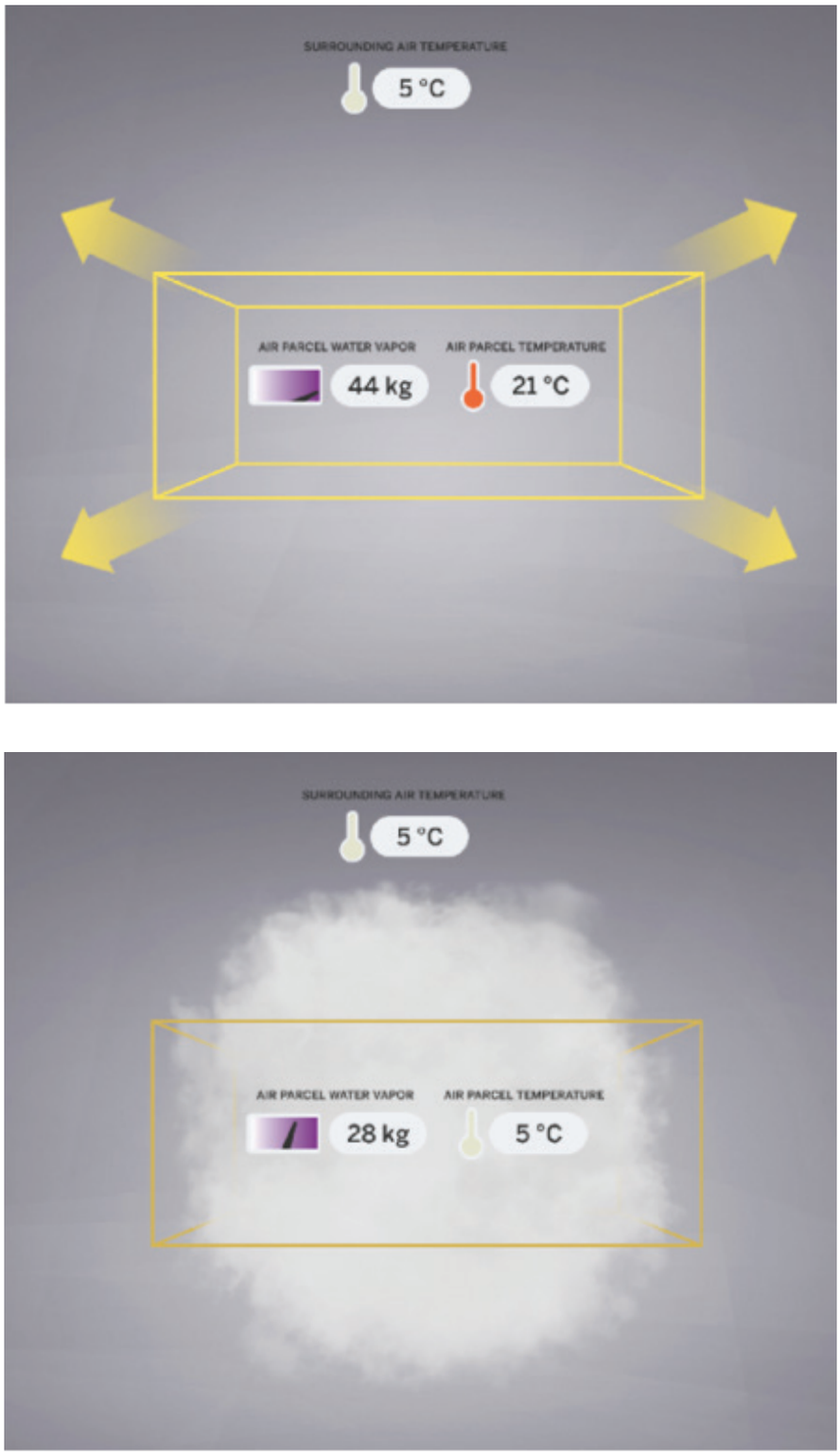
The hot tower clouds that Simpson identified are a type of cumulonimbus cloud.

Cloud Formation and Energy

Cooling is an important cause of rainfall—cooling air parcels can cause clouds to form and rain to fall. What causes an air parcel to cool? The process is driven by energy. When a warm air parcel is surrounded by colder air, the energy from the warm air parcel is transferred to the colder air until the temperature of all the air is equal. While an air parcel is losing energy, the temperature of the air parcel decreases. The energy transfer that causes the warm air parcel to cool can also cause the water vapor in the parcel to condense into liquid water. This liquid water is what forms a cloud. The more energy the air parcel loses, the more it cools and the more liquid water it forms, making more rainfall possible. When the droplets of liquid water in the clouds become big enough, they fall to the ground as rain.

Joanne Simpson's Legacy

Joanne Simpson started her career focused on the beautiful shapes she saw in the sky, wondering how and why the amazing clouds that she saw might form. Simpson's curiosity as a child led her to a pioneering career in the field of meteorology. Her work helped us understand how energy, evaporation, and condensation form the clouds that we see in the sky. Meteorologists today still make use of Simpson's work as they study the weather.



This diagram shows how energy is transferred during cloud formation. As energy is transferred out of an air parcel, its temperature drops. When the air parcel has lost enough energy and become cold enough, water vapor in the parcel condenses, forming a cloud.

Thin, wispy clouds like these usually don't produce rain or other types of precipitation.

Why Don't All Clouds Produce Rain?

For precipitation to form and fall, there must be clouds—precipitation never falls from a clear blue sky. However, not all clouds produce precipitation. You probably see clouds every day, but you probably don't experience rain every day. Why do some clouds produce precipitation and others don't?

Clouds produce rain when tiny droplets of liquid water begin to stick together, forming larger and larger drops. When those drops get heavy enough, they fall as rain. However, the conditions have to be right for those processes to take place. If a particular cloud doesn't have the right conditions, it won't produce any rain. For example, if there aren't enough droplets of water in a cloud to collide and form large drops, the tiny droplets will stay suspended in the air and it won't rain. In some very hot and dry places, rain may start to fall from a cloud but the drops evaporate while they are still high in the air. Thin, wispy clouds are usually made up of tiny ice crystals, and the ice crystals are spread too far apart to collide and form snowflakes. These are just a few of the factors that can keep the water droplets in clouds from turning into precipitation that falls to the ground.

This photograph, taken during the Great Flood of 1862, shows people rowing boats in the flooded streets of Sacramento. Sacramento is the capital of California.

Disaster in California!

In 1862, a natural disaster in California caused thousands of deaths and destroyed the state's economy. This disaster wasn't an earthquake or a fire—it was an enormous flood that hit huge sections of the state. The Great Flood of 1862 was caused by a series of storms that brought more than double the normal amount of rain to California in a very short period of time.

Scientists and historians call the Great Flood of 1862 a "megaflood" because of the devastation it caused. Before the flood, there was an extensive period of time with little rain, and California farmers were struggling because there wasn't enough rain to water their crops. However, they probably weren't expecting what came next! During December 1861 and January 1862, so much rain fell that many of the dry, flat farms in the center of California were completely covered in water—the whole valley looked like a large inland sea. Rivers and streams all over the state swelled up and over their banks, causing dangerous water flow that destroyed homes and killed animals and people in its path.

Using sources such as newspaper reports, data collected by scientists, and diaries and letters from people living in California at the time, people have reconstructed the kinds of damage done in this two-month period. Because of the massive rainfall and flooding, entire towns were destroyed. In some places, the water from the flood was 30 feet deep, covering the telephone poles that had just been put in place. Farmers and ranchers all across the state reported that they lost their homes, barns, farm equipment, and most of their animals. The devastation was so great and affected so many people that the state of California went bankrupt trying to support the people who were affected by the flood.

What Caused the Great Flood of 1862?

The Great Flood of 1862 was caused by a series of powerful storms that began over the Pacific Ocean. These storms were so strong because local temperatures were higher than normal—the winter of 1862 was unusually warm in California. Out in the ocean, both the ocean surface water and the air above it were also warmer than usual. The higher temperatures caused more ocean water to evaporate into the air. These warm air parcels full of water vapor rose high into the troposphere above California. In fact, because they were warmer than usual, they rose higher in the troposphere than the cooler air parcels that cause normal rain storms. As they traveled up through the colder parts of the troposphere, energy transferred from the parcels to the surrounding air, lowering the temperature of the air in the parcels. The parcels cooled until they had the same temperature as the surrounding air, causing the water vapor inside to condense into liquid water. The higher they rose, the more energy the parcels lost and the more water vapor condensed. The clouds that formed from these air parcels were full of liquid water that would soon fall as rain.

The same pattern of high temperatures leading to more water vapor in the air continued through the winter, causing multiple storms and record rainfall in many parts of California. Los Angeles received over 167 centimeters (66 inches) of rain in just two months—four times the amount of rain that normally falls there each winter. Rivers and streams were already full of water, so there was no place for the extra water from the rainfall to go. The water stayed above ground for weeks and caused flooding all across the state.

The darker brown areas of this map show the parts of California that were underwater during the Great Flood of 1862.

Could the conditions that caused the Great Flood of 1862 happen today? Meteorologists say that the perfect conditions for these kinds of storms—surface air temperatures that stay warm for several months and a constant source of water for evaporation—happen once every 100–200 years, so it's possible that California will see this kind of rainfall again. However, we now have a better understanding of the pattern that leads to these storm clusters and can predict when and where they might happen. We can't avoid storms, but we can figure out when they might happen and help people prepare when they do occur.

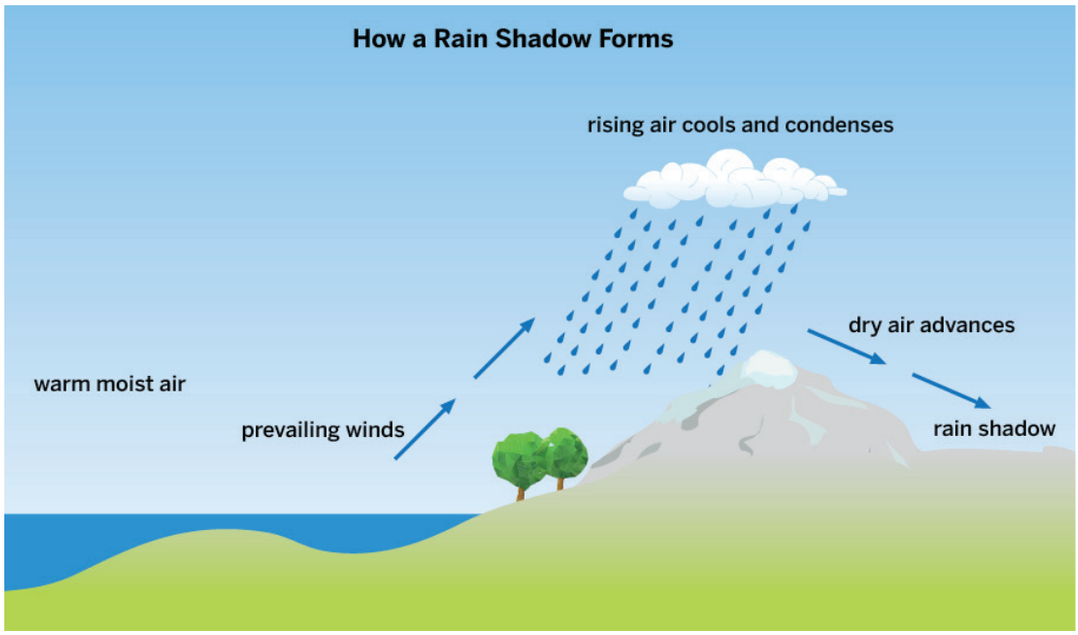
Types of Rain

What causes rain? Some rain forms when warm air parcels rise high into the troposphere and water vapor in the air condenses into liquid. However, that's not the whole story—the formation of rain can be more complicated than a single rising air parcel. One type of rain, called orographic rain, can form when air parcels run into certain landforms on Earth's surface. Another type of rain, called frontal rain, can form when air parcels of different temperatures collide.

Hilo, Hawaii, is one of the rainiest places on Earth, thanks to something called orographic rain.

Orographic Rain

Hilo, Hawaii, is one of the wettest places on Earth, receiving more than 100 inches of rain each year. However, just a few miles away from Hilo, on the same island, is a desert landscape that only gets about one tenth as much precipitation as Hilo does! How is this possible? The answer has to do with a kind of rain called orographic rain. Hilo is located on the eastern side of Hawaii, between the ocean and high mountain peaks. These landforms are an important factor in Hilo's weather. The wind almost always blows toward Hilo from the ocean, moving warm, humid air parcels in Hilo's direction. As air parcels hit the island, they are forced upward by the mountains. The air parcels lose energy as they rise, and water



When air parcels are forced upward by landforms such as mountains, they produce orographic rain on one side of the mountains. A dry area called a rain shadow forms on the other side.

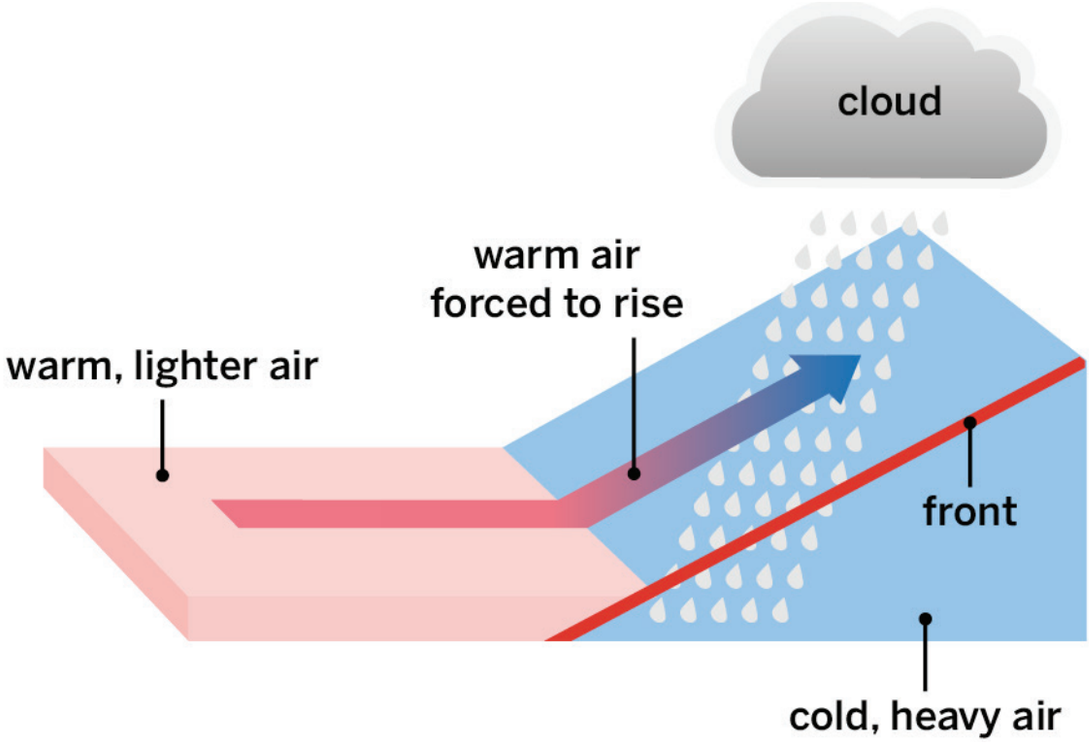
vapor in the parcels condenses into liquid water, producing clouds and frequent rain. This type of rain is called orographic rain.

Hawaii's mountains are also a factor in the weather on the other side of the island, where there is a desert landscape. Because the clouds produce so much rain on the Hilo side of the mountains, there is very little water left in the air once it reaches the other side. The mountains block rain from reaching the other side. This is called a rain shadow, and it means there can be a desert just a few miles across the mountains from one of the wettest places on Earth.

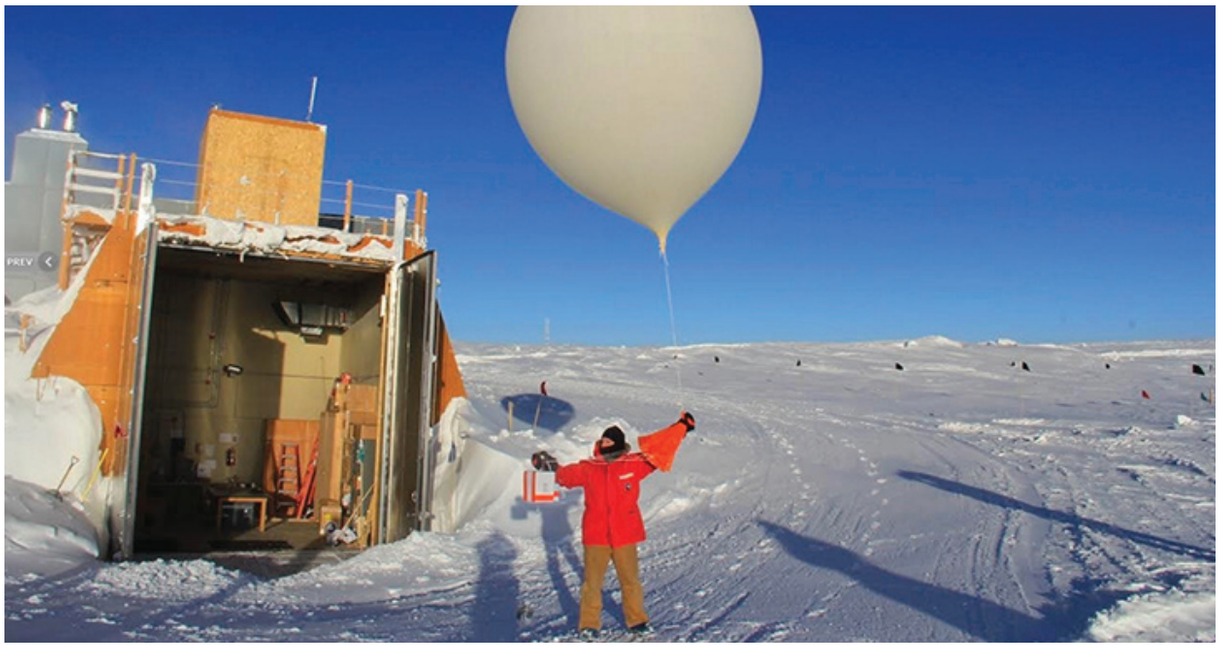
Frontal Rain

Wind is another factor that can contribute to rainfall. Winds can blow in all directions, moving air parcels around. Sometimes air parcels moving in different directions run into each other. A place where two air parcels meet is called a front, and fronts are places where dramatic weather tends to happen. Rain formed at fronts is called frontal rain.

Why does so much wet weather happen at fronts? Frontal rain can form when a cold air parcel and a warm air parcel meet. The air in cold air parcels is denser and heavier than the air in warm air parcels. When the parcels meet, the dense air of the cold front moves underneath the less dense air of the warm front, pushing the warm air up into the troposphere. From there, the story of frontal rain is just like other types of rain formation: the warm air cools as it rises, causing water vapor to condense and form droplets of liquid water. The droplets collide to form larger drops, and when they get heavy enough, they fall as rain.



The place where two air parcels meet is called a front. Frontal rain forms when a mass of cold, heavy air moves under a mass of warm, light air and forces the warm air parcel upward.



Meteorologists use basic tools like thermometers and barometers to measure conditions. Weather balloons like these can be used to carry those tools high into the atmosphere, where they can take measurements that can't be taken from Earth.

How We Predict the Weather

Have you ever listened to a stormy weather forecast and left the house wearing rain boots and carrying an umbrella, only to find the weather outside clear and sunny? Then you know that weather forecasts don't always match the weather that actually occurs. Since scientists haven't yet come up with a perfect way of predicting the future, they use information from past events to get as close as they can. Sometimes, that means meteorologists (weather scientists) get their predictions right. Other times, it means you end up carrying an umbrella on a day with no rain in sight.

So how does weather prediction work? For thousands of years, people have used careful observation and recording of weather information to understand weather patterns. Early on, people watched the sky to try to understand the weather, and later they used tools like thermometers (which measure temperature) and barometers (which measure air pressure) to gather information. Over time, they discovered some predictable patterns and learned to connect certain factors with the types of weather they produce. Today, meteorologists still watch the sky and make use of basic tools, careful observation, and record-keeping. However, modern meteorologists also use more advanced technology, such as computer models, to make even better predictions. Weather is caused by many different interactions, and a good computer model can calculate the outcome of all those interactions much more quickly than a human can. Predictions of the weather will never be perfect, but with better tools meteorologists are able to make better predictions.

Meteorologists use models that calculate probability—that is, how likely something is to happen. A meteorologist enters information about current conditions gathered by

thermometers, barometers, and other tools, and the model uses that information to calculate the likelihood of different weather events taking place in the near future. By changing just one piece of information that's been entered into the model, the meteorologist might cause the model to predict a totally different outcome!

Computer models have helped improve the speed and efficiency of weather prediction, but no computer model can predict the weather accurately all the time—humans are still needed as part of the process. In fact, most meteorologists use more than one computer model, or enter more than one set of information into a single model, so they have more than one forecast to choose from. Once the model has done its work, the meteorologist looks at the different forecast options and uses his or her knowledge and experience to choose the one he or she thinks is the most accurate. No combination of model and meteorologist is always right about the weather—but with some careful work and good estimates, they can get pretty close.

This truck is carrying tools that measure weather conditions. The tools will tell meteorologists what conditions are like in the big storm on the horizon.

Meteorologists use computer models to turn information gathered by thermometers, barometers, and other tools into weather reports that can help the public.

Rain isn't the only form of precipitation. Precipitation can also take the form of hail, snow, or sleet.

Hail, Snow, and Sleet

When people hear the word "precipitation," they often think of rain. Rain is one kind of precipitation, but there are also other kinds, including hail, snow, and sleet. How do these types of precipitation form? What factors make hail fall instead of rain, or sleet instead of snow?

One thing that all kinds of precipitation have in common is clouds. For clouds to form, air parcels need to rise into the troposphere and transfer energy so that the water vapor in the air changes phase. Temperature is one important factor in determining what kind of precipitation falls from a cloud. Another important factor is wind.

During a hailstorm, balls of ice fall from the sky. Although hail is a form of frozen precipitation, it usually falls during warm weather instead of in winter. Hailstones actually begin as raindrops. Hail forms when high winds blow raindrops upward into colder parts of the troposphere, where they freeze solid. Hailstones are often about the size of peas. In some cases, hailstones are blown up into the air many times, becoming coated with layer after layer of ice. In this way, a hailstone may grow as big as a baseball!

Sleet also involves balls of ice falling from the sky, but it's different from hail. Sleet falls in winter, and bits of sleet are much smaller than hailstones. Bits of sleet can be as small as grains of rice or even coarse sand. Temperature is the most important factor in sleet formation. Sleet forms when snow falls through a layer of warmer air and melts into raindrops, which then fall through a layer of colder air and freeze again into tiny ice pellets that bounce when they hit the ground.

Snow forms in clouds where the temperature is colder than 0°C (32°F), the freezing temperature of water. Instead of condensing into liquid droplets, the water vapor freezes into tiny crystals of solid ice. Those ice crystals may collide and stick together, forming larger snowflakes. The snowflakes fall when they become heavy enough. If the air is colder than 0°C (32°F) from the cloud all the way down to the ground, the snowflakes stay frozen and fall as snow.

Weather Patterns:
Severe Storms in Galetown

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Amplify.

Published and Distributed by Amplify.
www.amplify.com

AMP.NA18

ISBN 978-1-64089-872-1