UCAR CENTER FOR SCIENCE EDUCATION

TEACHER ANSWER KEY

LEARNING SEQUENCE 1

LESSON 2 What causes storms to form?

LESSON 3 How does temperature relate to cloud formation?

LESSON 4 What is different about a sunny day and a stormy day?

LESSON 5 How does air move and change when a storm is forming?

LESSON 6 Can we identify the best conditions for storms?

BSCS SCIENCE LEARNING

NASA

THE GLOBE PROGRAM

Name Period Date

LESSON 2

What causes storms to form?

Watching cloud shapes and how they change over time can give you clues about what's happening in the sky.

STEP 1: What can we learn about storms by watching clouds in the sky?
Working in pairs or small groups, write your ideas below. (Use complete sentences.)

Storms happen when there are clouds in the sky. The clouds associated with rain/thunderstorms are different than other types of clouds (dark, gray, tall anvil-shaped clouds are associated with storms). Building clouds in the sky can signal that a storm is likely.

STEP 2: What do you notice about the sunny day compared to the stormy day?
Observe the clouds in the time-lapse videos and record your observations below.

SUNNY DAY

On a sunny day, there can be some clouds that form throughout the day, mostly in the afternoons, but the clouds are small and white.

STORMY DAY

On a stormy day, many clouds develop in the sky throughout the day. By the afternoon, the sky is mostly filled with clouds that appear dark or gray. There is precipitation falling from the sky at least once during the day.

Why do you think that the storm formed on one day and not the other?
Write your ideas below, using complete sentences.

Answers will vary. Look for an understanding of stormy days associated with having many clouds that are dark/gray (compared to a sunny day without many clouds). An advanced understanding would mention the relationship between heat needed for evaporation of water from the surface and cloud formation as well.

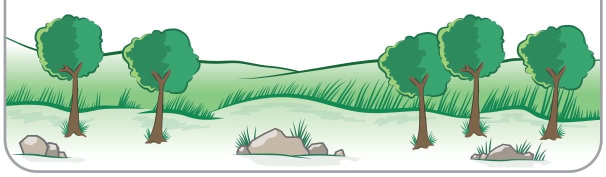
LESSON 2 What causes storms to form?

STEP 3: Draw how a storm forms throughout the day.
Think about the time-lapse video of a stormy day. Draw what the weather is like at different times throughout the day, using each of the boxes below. Include what you know about how clouds, water, air, and sunshine move and change throughout the day.

**Drawings should match the descriptions in each of the boxes.*

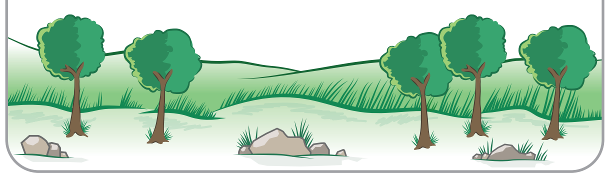
MORNING 9:00AM

Clear sky. Surface and air temperatures are rising as the Sun rises into view, which will lead to the evaporation of water at the surface and the beginning of cloud formation.



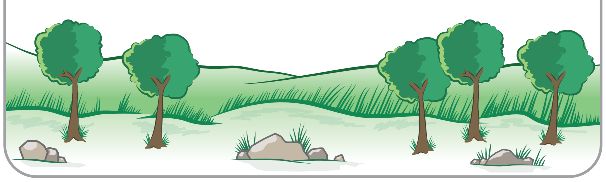
MID-DAY 12:00PM

More clouds develop because water is evaporating from the surface when there is lots of sunlight reaching the ground.



AFTERNOON 3:00PM

The sky is filled with many dark clouds. A rainstorm happens--water moves from the sky to the ground.



NIGHTTIME 9:00PM

After sunset, the air is cooler, and there is less evaporation from the surface. Clouds dissipate. The sky is clear by late evening.

What causes storms to form?

STOP AND THINK

Answer the questions below.

Clouds and storms are typically high above the ground. If you could investigate the air up high compared to the air near the ground, what do you think you would notice?

Students may know that the air is colder higher up in the atmosphere. This question will document their understanding as they get ready to go into Lesson 3, where they will investigate the relationship between elevation and temperature. Since clouds are made of water, students may reason that the air higher up might contain more water too.

What measurements about the air would you want to take from different altitudes?

Though students have not learned about air measurements at this point, answers might include:

- *Temperature*
- *Air Pressure*
- *Humidity*
- *Wind speed*

How might those measurements help us figure out how clouds form?

Changes in the air might help us understand what conditions are needed for clouds to form. If clouds always form when the air drops below a certain temperature, or when there is a certain amount of water in the air (relative humidity). This information could provide clues about how clouds form.

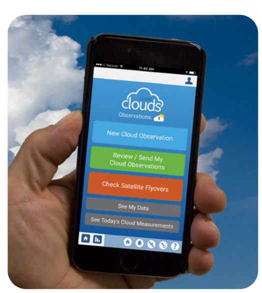
STEP 4: Make observations of clouds in the sky!

Watch the sky for clues about what's happening with weather in your community. Follow your teacher's instructions for making observations and remember **to never look directly at the Sun**.

Remember to look for:

- How much of the sky is covered with clouds?
- What types of clouds are in the sky?
- Are the clouds opaque or can you see through them?

Identify clouds using the GLOBE Cloud Chart (globe.gov/globecloudchart).



Download the GLOBE Observer Clouds App (observer.globe.gov) to make cloud observations and take pictures that can be compared with NASA satellite images. This helps scientists understand the sky from above and below.

Name Period Date

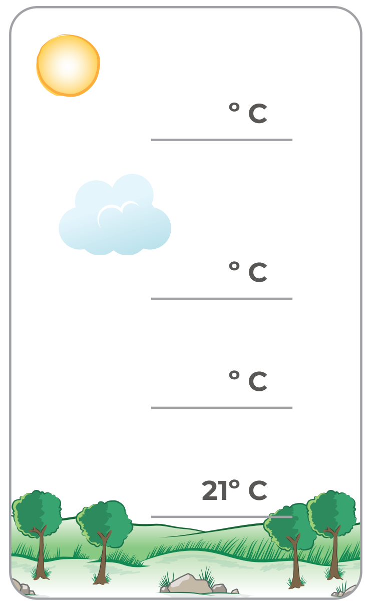
LESSON 3

How does temperature relate to cloud formation?

Weather balloons carry instruments into the atmosphere to collect temperature data at different altitudes – from near the ground to up where clouds form and even higher. In this lesson you'll explore data collected by a weather balloon to learn about how air changes with altitude.

STEP 1: Use the temperature near the ground to predict the other temperatures.
Fill in the blanks in the graphic at the right to make a prediction about how air temperature changes with altitude.

Predicted values will vary. Look for a pattern in the students' predictions: do they think air gets colder, warmer, or stays the same as altitude increases?



STEP 2: Collect temperature data.
At a computer or tablet, open the Virtual Ballooning interactive (scied.ucar.edu/virtual-ballooning). With this simulation you can launch virtual weather balloons and record the temperature at different altitudes in the atmosphere.

1. **Click "Explore the Troposphere"** to get into the game.
2. **Get to know the graph.** Notice that altitude is on the vertical axis (the y-axis) and temperature is on the horizontal axis (the x-axis).
3. **Choose settings for a balloon launch.** Each balloon you launch will make three measurements of temperature. Set the altitude to start recording the temperature by dragging the "Collect Data" arrow up or down the y-axis.
4. **Click the "Launch Balloon" button** and watch as your balloon collects temperature data.
5. **Record that temperature in the table on the next page.** Read the points that the balloon made on the graph to find the temperature at different altitudes.
6. **Click the "New Flight" button** and choose new settings for another balloon launch to collect more data. Collect as much data as you can with four balloon launches.

LESSON 3 How does temperature relate to cloud formation?

STEP 2 CONTINUED: Collect temperature data.

high clouds

low clouds

ALTITUDE	TEMPERATURE (˚C)
10 km	-38
9 km	-32
8 km	-25
7 km	-19
6 km	-12
5 km	-7
4 km	0
3 km	7
2 km	12
1 km	17
0 km	22

STEP 3: Analyze and interpret the data.

1. Describe the pattern you see in the temperature data from the ground to where storm clouds form.

   Air temperature decreases as you go higher up in the atmosphere.

2. Is this the pattern you predicted? Why or why not?

   Answers will vary. Students should compare observed patterns to their predictions.

3. What do you think is *causing* the temperature pattern?

   Students have not yet learned about air pressure, but look for answers that would explain why it is colder at higher altitudes, such as:
   - *The air at higher altitudes is further from the ground. The ground is warmer than the air because it absorbs heat from the Sun.*
   - *There is less air (because there is less air pressure) at higher altitudes and therefore less heat.*

4. How does the temperature pattern relate to storms forming? (Draw or write your ideas below.)

   Answers will vary. Storms happen when there are lots of clouds in the sky. Clouds form when water vapor condenses into liquid water droplets high in the atmosphere. Air moving from a lower altitude to a higher altitude would have a temperature drop. When the air temperature drops, condensation occurs. So, in order for clouds and storms to form, the air temperature must drop.

LESSON 3

How does temperature relate to cloud formation?

STEP 4: How do air and surface temperatures change during a day?

To learn why air temperature changes with altitude, take a look at how the temperature of the ground (surface temperature) relates to the temperature of the air just above the ground (air temperature) in the graph below. Students at Westview Middle School in Longmont, Colorado, collected the data in this graph. Every hour during a day they measured surface temperature and air temperature outside their school.

Compare the two data trends in the graph by following these directions:

WHAT I SEE

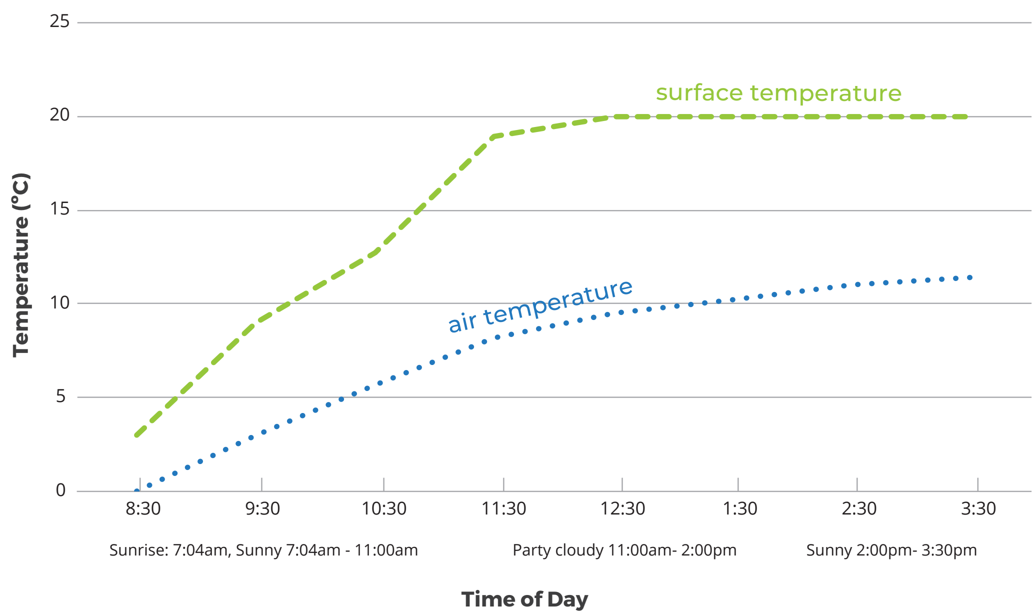
1. Look at different parts of the graph. Do you notice patterns? Do you notice interesting differences? Write **What I See** statements on the graph to record your observations.
2. Share your statements when directed by your teacher.

WHAT IT MEANS

1. Next to each **What I See** statement, write a **What It Means** statement to explain what you think is happening in each part of the graph.
2. Share your statements when directed by your teacher.

TEMPERATURE MEASUREMENTS

Westview Middle School, Longmont, CO • March 20, 2018



What I see...	*What it means..*
The blue air temperature line is always below the green surface temperature line.	*As the surface is warmed by sunlight, some heat from the surface goes into the air.*
The green line increases until about 11:30 and then starts to level out.	*The surface warms rapidly until about noon and then stays the same temperature through the mid-afternoon.*
The blue line follows a similar, but not identical, pattern to the green line.	*Air temperature is related to surface temperature, but the air continues to warm a small amount even after the surface stops warming.*

Write a caption for the graph that compares the two data trends.

Both surface temperature and air temperature increase from the morning until afternoon, but the surface temperature is always above the air temperature.

LESSON 3

How does temperature relate to cloud formation?

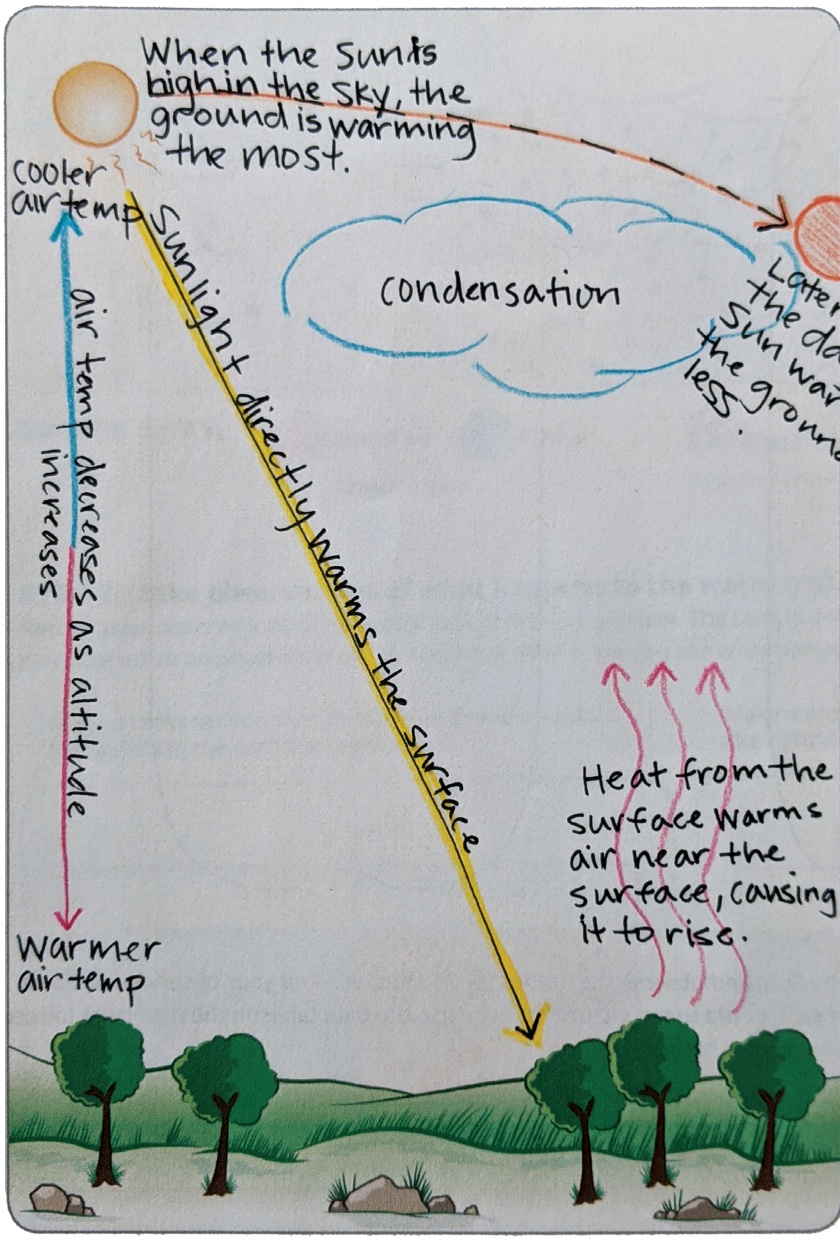
STEP 5: Make a model of how sunlight warms the atmosphere.

Draw a model in the box below that helps to answer the following question:

Why does the surface temperature warm over the day, and why is the surface warmer than the air above it?

Your model should explain:

- How surface temperature is related to the sunlight
- How air temperature is related to surface temperature
- How the air temperature changes from the ground to higher altitudes
- How you know the above three things using evidence from temperature data



KEY
(Choose colors to represent sunlight and temperature.)

☐ sunlight

☐ temperature

Write a caption for your model that describes how sunlight warms the atmosphere.

Sunlight travels through the atmosphere to the surface. Energy from the Sun is absorbed by the ground. This energy is given off as heat, which warms the air near the ground. The warmed air rises into the atmosphere where it cools due to colder temperatures at high altitudes.

LESSON 3

How does temperature relate to cloud formation?

STEP 6: How does your model relate to storms?

There wasn't a storm on the day when the Westview Middle School students collected surface temperature and air temperature data, but it did get cloudy in the afternoon.

The time-lapse video showed that clouds started to build in the morning and by afternoon there was rain.

Write a sentence to answer the question: How do you think temperature relates to the clouds and storm forming?

In order for clouds to form, the ground must get warm enough to evaporate water into the air. At higher temperatures, there is more evaporation of water at the surface. Evaporation of water at the surface leads to the formation of clouds and sometimes storms.

List evidence from your model to support your answer above.

Answers will vary. Look for references to specific aspects from student models created in Lesson 3: Step 5.

For example:

- *Heat rising from the ground.*
- *Air temperature decreasing with altitude.*

Describe the reason that the evidence you listed supports your answer.

Answers will vary. Students should explain how the evidence listed above supports their idea(s) about the relationship between temperature and cloud formation.

For example:

- *They explain that surface heat allows water to evaporate from the surface.*
- *They explain that decreasing air temperature with altitude is necessary for condensation to happen, which is how clouds form.*

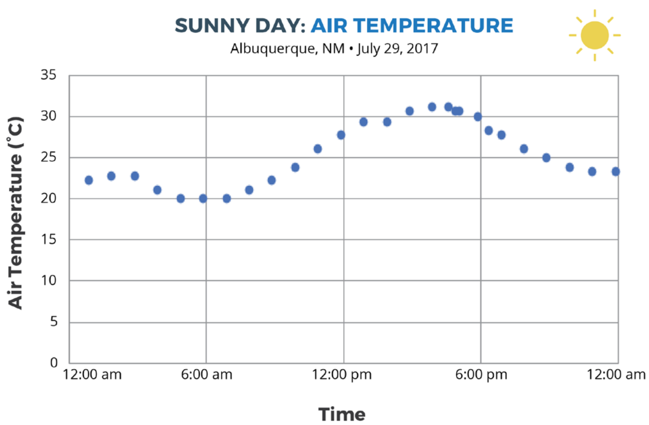
Name Period Date

LESSON 4

What is different about a sunny day and a stormy day?

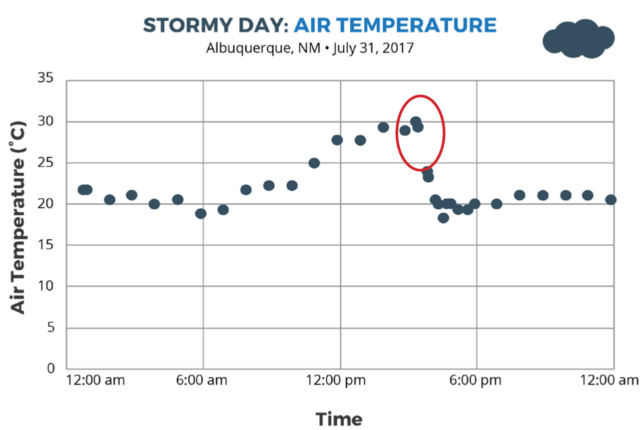
STEP 1: Compare air temperatures on a sunny day and a stormy day.

Do stormy days have a different pattern than sunny days? Answer the questions using the graphs of temperature data below.



1. Describe the sunny day pattern.

Air temperature begins to rise as the Sun rises, reaching a peak warmth in the late afternoon, and then cooling as the Sun sets.



2. Describe the stormy day pattern.

Air temperature begins to rise as the Sun rises, reaching a peak warmth in mid-afternoon, and then drops suddenly and drastically around 4 pm. Air temperature remains cooler for the rest of the night.

3. Looking only at the temperature data, when do you think the rain happened, and why? Circle where the rain begins on the stormy day graph.

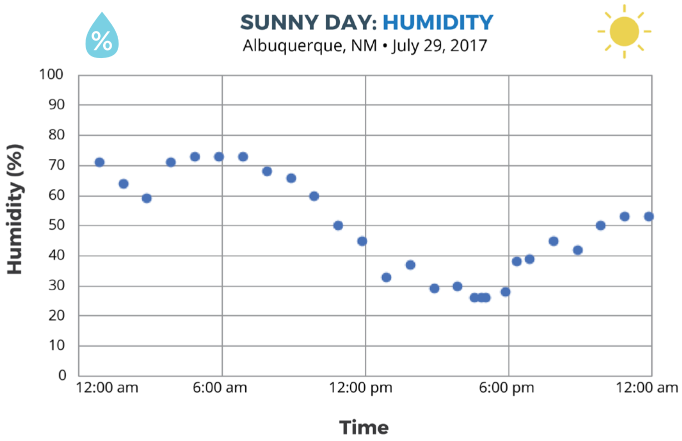
The rain happened between 4:00-5:00 pm, as indicated by the rapid drop in air temperature. By this time in the day, the heat had evaporated lots of water into the air. Students may suspect that the sudden drop in temperature caused condensation and then precipitation. In Lesson 5, they will build an understanding of how and why air moves via convection, which can cause a drop in temperature.

What is different about a sunny day and a stormy day?

STEP 2: Compare the humidity on a sunny day and a stormy day.

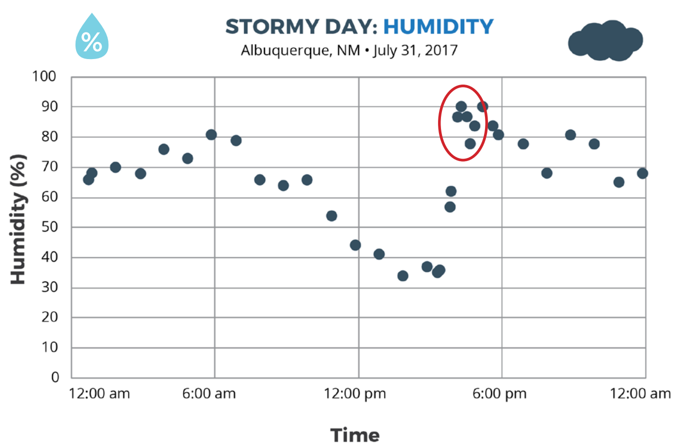
Humidity is the amount of water vapor in the air. If the humidity is 100%, then the air cannot take in any more water vapor (and you are probably in a cloud). If the humidity is less than 100%, then the air could take in more water vapor. Warm air has the energy needed to evaporate more water than cold air. That's why a hot and humid day is more common than a cold and humid day. When humidity is low, people say that the air is dry because it doesn't have much water vapor.

Do stormy days have a different pattern than sunny days? Answer the questions using the graphs of humidity data below.



1. Describe the sunny day pattern.

Humidity is highest in the morning when the air is cool, and decreases as the air warms throughout the day, reaching its lowest point in the late afternoon and then rising again gradually as the air cools into the evening.



2. Describe the stormy day pattern.

Humidity is high in the morning when the air is cool, and decreases as the air warms throughout the day. There is a drastic spike in humidity in the late afternoon at the time of the storm. Humidity fluctuates during the next few hours and into the evening but remains high overall.

3. Circle where the rain begins on the stormy day graph. Considering both air temperature and humidity, what pattern do you think creates the highest chance for storms to form?

Chances are greatest for a storm to form when the air temperature is low and humidity is high, which are the conditions present between 4:00-5:00 pm in our graphs above.

LESSON 4

What is different about a sunny day and a stormy day?

STEP 3: Make a storm in a bottle.
Using what you know about temperature and relative humidity, create a model of a sunny day and a stormy day using clear bottles with different contents.

1. Draw what you put inside each of your bottles. Label the materials that you added.

2. Turn on the lamp (to represent the Sun) and observe the bottles for 20 minutes. Add your observations about the temperature and humidity of each bottle to the pictures above. Use the data table on the next page to record temperature and humidity changes in your bottles.

Students should observe a temperature increase in each of the bottles. In the stormy day bottle, they should also observe water droplets forming (humidity) on the inside of the bottle (on the sides and near the top).

LESSON 4

What is different about a sunny day and a stormy day?

Measure the temperature with your thermometer and record. Look for evidence of humidity, such as condensation on the inside of the bottle, and make notes about it in the table below.

	SUNNY DAY BOTTLE		STORMY DAY BOTTLE	
MINUTE	TEMPERATURE (˚C)	HUMIDITY	TEMPERATURE (˚C)	HUMIDITY
2		**Students should not observe any humidity in the sunny day bottle.*		**Students should note when humidity (condensation) is first observed in the stormy day bottle.*
4				
6				
8				
10				
12				
14				
16				
18				
20				

3. Discuss the following questions with your peers:

- Did the sunny day bottle match what you expected? If not, what happened?
- Did the stormy day bottle match what you expected? If not, what happened?
- Using evidence from the bottles and the temperature and humidity data, what conditions are best for storms?

Name Period Date

LESSON 5

How does air move and change when a storm is forming?

Your teacher will demonstrate how air changes as it is heated or cooled. This will help you figure out what happens to air that warms near the surface, and air that cools at higher altitudes.

STEP 1: Observe warmed and cooled air.

Draw the lab set-up and what happens to the balloon during the demonstration. Add your observations to your drawing as you make them. Remember to label what is happening.

LAB SET-UP	MYLAR BALLOON BEING HEATED	MYLAR BALLOON AS IT COOLS
Students should describe the lab set-up, which includes the partially inflated balloon and the hairdryer.	*During heating: The balloon begins to rise up into the air. It expands and appears more inflated.*	*After heating: The balloon begins to sink again. As it sinks, the balloon contracts and appears only partially inflated again.*

1. Why does the heated balloon go up? Think about what is happening inside the balloon.

   Air molecules within the balloon are gaining energy as they are heated. The air within the balloon expands, becoming less dense than the air outside of the balloon, and rises.

2. What is happening inside the balloon when the balloon starts to sink?

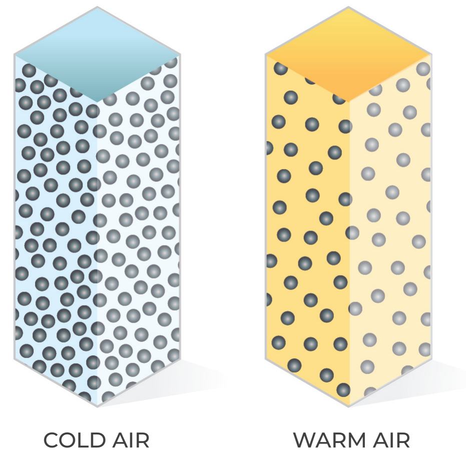
   Air molecules within the balloon lose energy as they cool. The air within the balloon contracts and becomes more dense than the air outside the balloon, and sinks.

How does air move and change when a storm is forming?

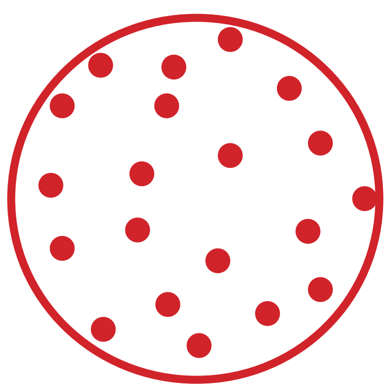
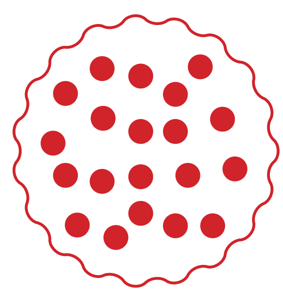
STEP 2: Air on the Move

There is something different between warm and cool air that causes warm air to go up and cool air to go down. When the air inside the balloon was warmed, the balloon expanded and went up. When the air inside the balloon cooled, the balloon started to shrink and go down. Let's think a little more about this air and what is happening when it is warmed and cooled. To understand this, we are going to need to zoom in and think about what's happening to the air molecules.

Imagine you can see a pocket of air molecules heated up. When air is heated, the heat energy is absorbed by the individual molecules, causing them to move around more quickly. The molecules move faster and farther apart. When molecules release their energy, they start to slow down and cluster closer together. This happens when the molecules no longer have a heat source and are "cooling."



Draw a diagram that shows what 20 warmed air molecules look like inside the mylar balloon compared to 20 cooler air molecules.

BALLOON WITH WARM AIR	BALLOON WITH COOL AIR
Air molecules are spread further apart. 	*Air molecules are closer together.* *Ballon appears less inflated.* 

So, that's how warm air and cool air are different. But why do they move in different directions? To understand that, we're going to need to zoom out and think about the whole planet and gravity.

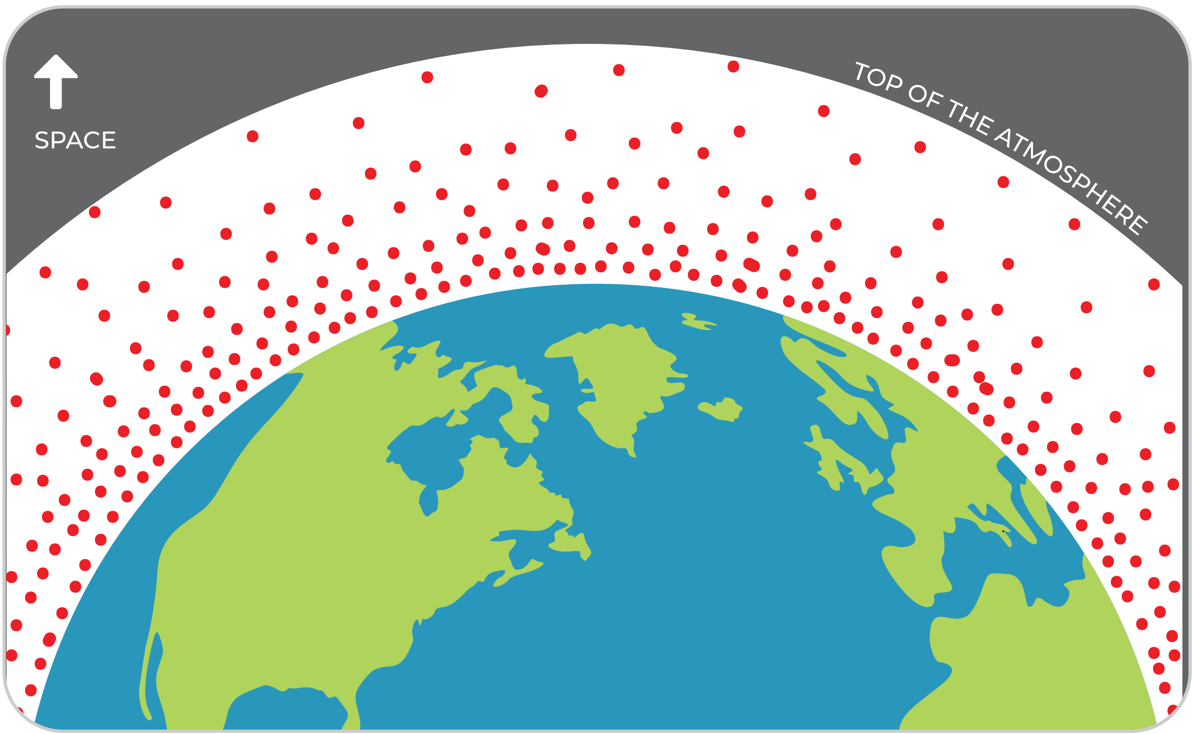
How does air move and change when a storm is forming?

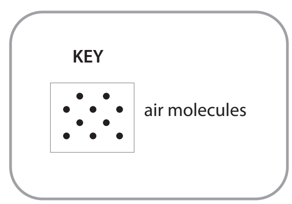
STEP 2 CONTINUED: Air on the Move

Gravity is the force that draws all objects towards the center of the planet. Even tiny things like air molecules are affected by gravity and pulled downward. The weight of the air molecules higher in the atmosphere pushes air molecules lower in the atmosphere closer together. High in the atmosphere, they are spaced farther apart. Air molecules pushed close together are at high pressure. Air molecules spread apart are at low pressure.

Draw air molecules between the planet and the top of the atmosphere. Remember that they will be spaced differently depending on whether they are close to the ground or higher in the atmosphere.

**Air molecules are drawn closer together near the surface and further apart at the top of the atmosphere.*





How does air move and change when a storm is forming?

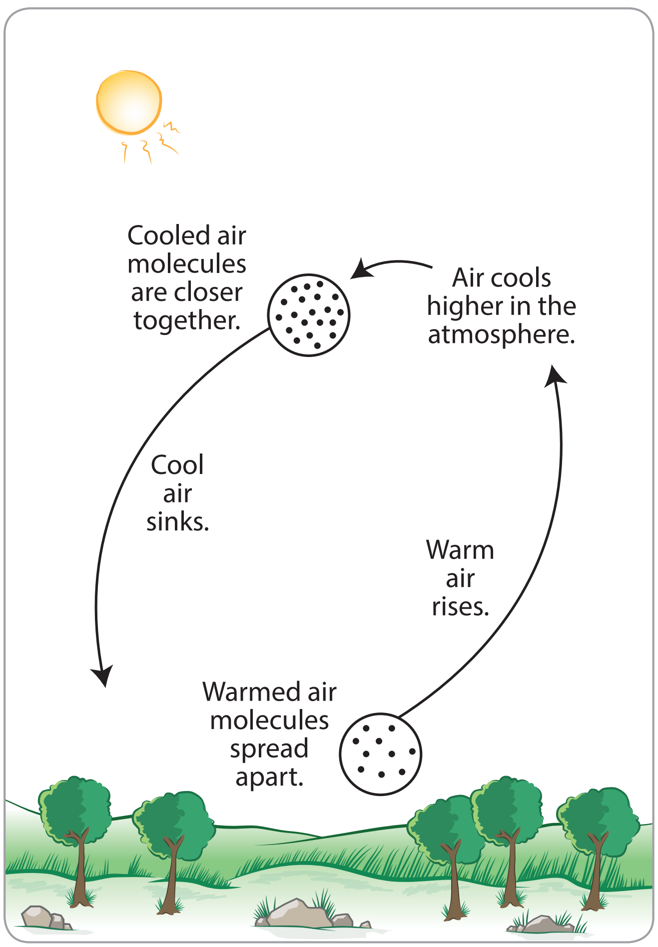
STEP 2 CONTINUED: Air on the Move

When sunlight warms the land, and then warms the air near it, the molecules spread out a bit, taking up more space, just like the air at high altitude. The warmed air has lower pressure than the air around it, so it rises in the atmosphere, like the warmed balloon in the previous activity.

As the warmed air rises in the atmosphere, it cools down, because air at higher altitudes is cooler. Remember that cool air doesn't hold as much water vapor as warm air, so as warm air cools, some of the water vapor condenses into the tiny water droplets that make up clouds.

As air gets cooler, the molecules come closer together. The air has higher pressure than the air around it, so it sinks in the atmosphere, like the cooled balloon in the previous activity. Then, it can be warmed and rise again.

This cycle of rising and falling air is called **convection.**



EXPLAIN: Why does warm air go up and cool air go dow

Heated air molecules move around faster, which causes them to spread apart. When they spread apart, they become less dense than the air around them and rise. Air higher in the atmosphere is cooler than the air near the ground. As the heated air from the surface rises, it cools as it comes in contact with the cooler, high altitude air. The cooled air molecules slow down and move closer to one another, causing the air to become more dense. The dense, cooled air sinks back towards the surface where it is heated once again. The cycle of convection continues in this manner.

How does air move and change when a storm is forming?

STEP 3: Create a model to describe how precipitation happens in an isolated storm.

To get started, **draw and write** in the illustration to explain how precipitation happens in an isolated storm.

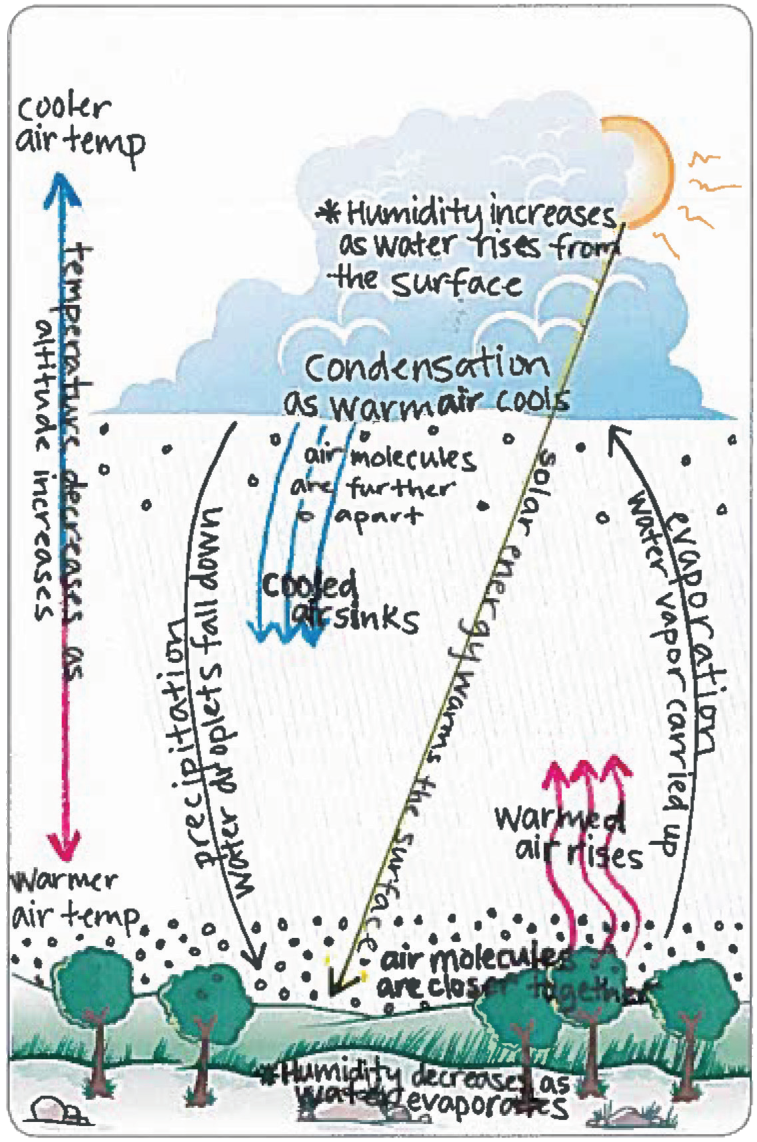
Make sure your model explains:

- What happens to energy from the Sun that leads to an isolated storm?
- What happens to water at the surface and clouds that lead to the isolated storm?
- How does air temperature and humidity change as air moves from the ground to the cloud?
- How does air move between the ground and where the storm forms?

Write an explanation that goes with your model and answer the question below:

EXPLAIN: What has to happen for an isolated storm to form?

Temperatures must we warm enough to evaporate lots of water from the surface so that humidity is high in the atmosphere. The warmed air and water vapor rise up to where the air is cooler (because air temperature decreases as altitude increases), which causes condensation and the formation of clouds. If the temperature drops enough and the humidity is high enough, a storm will occur.



Name Period Date

LESSON 6

Can we identify the best conditions for storms?

STEP 1: Make predictions.
Use your model for an isolated storm, and what you know about temperature and humidity, to predict the very best conditions that would lead to an isolated storm.

A strong storm would form if the temperature high in the atmosphere near the clouds was

- [x] **much colder than**
- [ ] **much warmer than**
- [ ] **about the same as**

the temperature near the ground because *water vapor suspended in the warmer, rising air will condense to form clouds when it rises and reaches the much colder air high in the atmosphere.*

A strong storm would form if humidity was

- [x] **high**
- [ ] **moderate**
- [ ] **low**

because *moisture, or humidity, is necessary to form a storm with precipitation. The more humidity in the air, the more likely precipitation will form.*

Can we identify the best conditions for storms?

STEP 2: Record and explain your observations.

Now you can test your predictions with the Make a Thunderstorm simulation (scied.ucar.edu/make-thunderstorm). Follow your teacher's instructions for collecting data from the simulation. Record your observations of five trials in the table below. Then explain why a storm did or did not form.

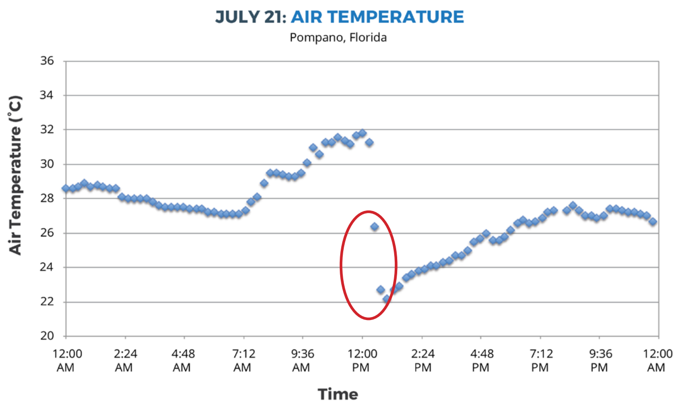
CONDITIONS	OUTCOME	WHY DID THIS HAPPEN? Explain what helped the storm or what was missing.
high-level temp: *very cold* humidity: *high* low-level temp: *warm*	○ no storm ○ small storm ○ medium storm ● big storm	*These are the conditions that result in a big storm. Warm temperatures at the surface allow for lots of evaporation. High humidity means that there is a lot of water available to be evaporated, and very cold high-level temperatures lead to lots of condensation, cloud formation, and a storm.*
high-level temp: *cool* humidity: *low* low-level temp: *cold*	● no storm ○ small storm ○ medium storm ○ big storm	*These are the conditions that result in no storm. Cold temperatures at the surface prevent much evaporation from occurring. Low humidity means that there is not a lot of water available to be evaporated, and cool high-level temperatures will not lead to much condensation, which means no cloud formation and no storm.*
high-level temp: humidity: low-level temp:	○ no storm ○ small storm ○ medium storm ○ big storm	****Note:** The scenarios above represent the extremes (big storm & no storm), but students should record the conditions that make small and medium storms too. Look for explanations that make a connection between increasing the amount of humidity and increasing the difference between low-level and high-level temperatures to affect the size of the resulting storm.*
high-level temp: humidity: low-level temp:	○ no storm ○ small storm ○ medium storm ○ big storm	
high-level temp: humidity: low-level temp:	○ no storm ○ small storm ○ medium storm ○ big storm	

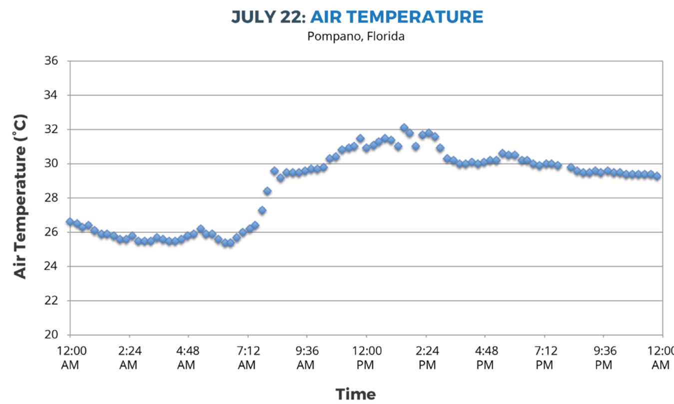
Can we identify the best conditions for storms?

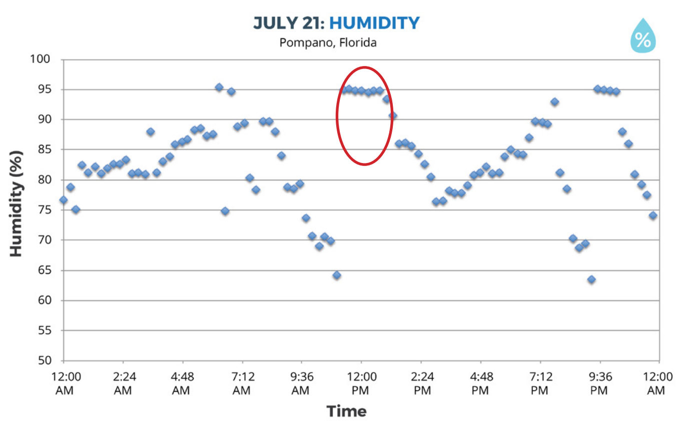
STEP 3: When did it rain?

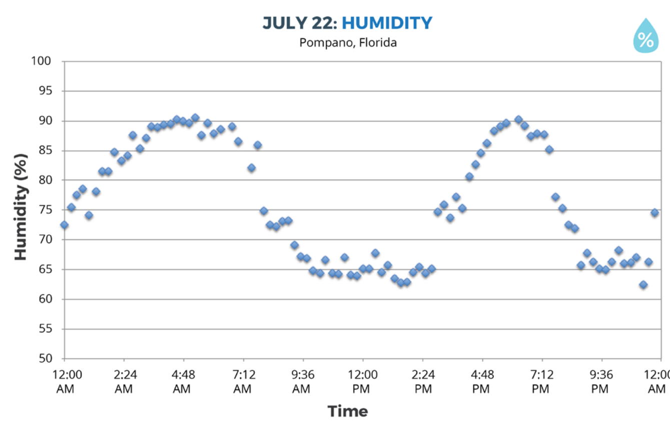
The air temperature and humidity data below is from two days in Pompano, Florida. It rained on one of these days. Identify the most likely day and time it rained.

1. Circle on the graph when the rain happened.









2. Explain what conditions were likely leading up to this rain event, and why you think the rain happened at this time. Use evidence from previous investigations and your model to develop your explanation.

It rained on July 21st. The day started warm and continued to get warmer throughout the day until the rain happened. There was also high humidity throughout the day. When the storm started, the air temperature dropped, and humidity increased rapidly. On July 22nd, there was not enough humidity for a storm to form. Students should mention elements from their model in Lesson 5: Step 3 that support their answer, including convection in the atmosphere, which causes cool air to flow downward. They should also mention learnings from other lessons as evidence to support their answer.

Examples of evidence students might include justifying their answer:

- *In Lesson 4, we learned that the building of heat throughout the day and high humidity is necessary for a storm to form, with a rapid drop in air temperature and a spike in humidity observed at the start of a storm.*
- *In the Make a Thunderstorm simulation, we learned that warm temperatures at the ground, high humidity, and very cold temperatures are ideal conditions for a storm to form.*