UCAR CENTER FOR SCIENCE EDUCATION

LEARNING SEQUENCE 2

LESSON 7 — What other types of storms cause precipitation?

LESSON 8 — How is air changing before, during, and after a cold front?

LESSON 9 — What causes precipitation along a cold front?

LESSON 10 — What causes fronts to move?

LESSON 11 — What could cause a front to stall?

BSCS SCIENCE LEARNING

NASA

THE GLOBE PROGRAM

Name Period Date

LESSON 7

What other types of storms cause precipitation?

STEP 1: What do you notice about the cold front?

Watch the time-lapse video of a day when a cold front moved through Lyons, CO and observe how weather changes over time.

	SUNRISE TO NOON	NOON TO 4:00PM	4:00PM TO SUNSET
WIND Wind speed:	○ high ○ low	○ high ○ low	○ high ○ low
Wind direction: *does it change?*			
CLOUDS Cloud type: *what types are visible?*			
Amount: *how much sky is covered with clouds?*			
PRECIPITATION *When did precipitation happen?*			
Could you tell what kind: rain, snow, or other?			
Was there a lot or a little?			

1. How is the storm in the time-lapse video different from an isolated storm?

STEP 2: Brainstorm different kinds of storms.

Have you been in storms that are different from the isolated storms you investigated before?
Describe storms that you experienced, and explain what made them different from an isolated storm.

DESCRIBE THE STORM YOU EXPERIENCED.	HOW IS IT DIFFERENT FROM AN ISOLATED STORM?

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What other types of storms cause precipitation?

STEP 3: Interpret a weather forecast for a cold front.

The seven-day forecast below shows a cold front moving through an area. Work with your group to interpret what is happening before, during, and after the front.

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Mostly Sunny	Partly Cloudy	Partly Cloudy	Mostly Cloudy	Mostly Cloudy	Rain Showers	Sunny
Hi 68° Lo 55°	Hi 75° Lo 60°	Hi 74° Lo 60°	Hi 70° Lo 56°	Hi 70° Lo 55°	Hi 60° Lo 31°	Hi 47° Lo 30°

	BEFORE THE COLD FRONT (Sat. to Wed.)	DURING THE COLD FRONT (Thurs.)	AFTER THE COLD FRONT (Fri.)
Temperature: The highest temperature was:			
The lowest temperature was:			
Humidity & Clouds We don't have humidity data, but we know clouds form with higher humidity. *When was humidity likely high or low?*	○ high humidity ○ low humidity	○ high humidity ○ low humidity	○ high humidity ○ low humidity
Precipitation *When did precipitation happen? When did it not happen?*	○ yes ○ no	○ yes ○ no	○ yes ○ no

1. What do you think the air was like (temperature and humidity) in this location before the front?

2. What do you think the air was like (temperature and humidity) in this location after the front?

3. What do you think caused the precipitation during the front?

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Name Period Date

LESSON 8

How is air changing before, during, and after a cold front?

STEP 1: Describe the air temperature before, during, and after the cold front.
Imagine your town has just received a weather report that a cold front is heading your way. Read the weather report and analyze temperature, humidity, and wind data to figure out what happened during this storm.

WEATHER REPORT

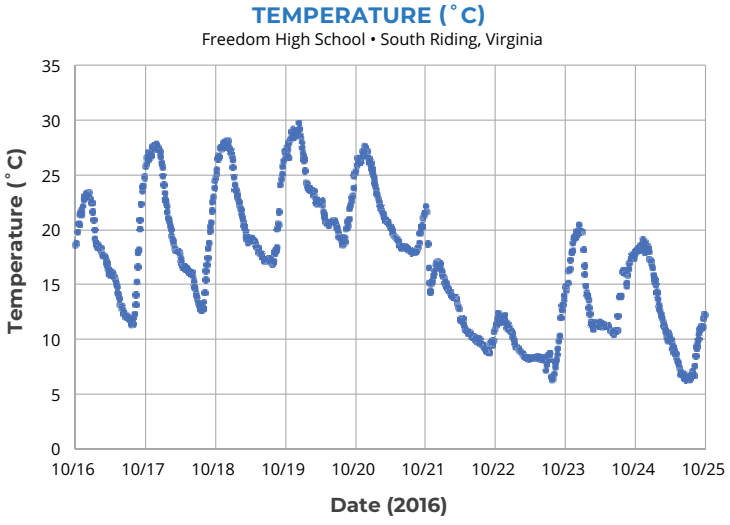
A cold front is expected to change temperatures in the area after an extended warm-up. The cold front will arrive in South Riding, Virginia, on the morning of October 21, 2016. Be prepared for a change in temperature over two days as the front passes through the area, replacing a warm air mass with a cold air mass.

Circle the data on the graph that shows when the cold front passes through South Riding, VA. Describe the graph using the What I See and What It Means statements.

WHAT I SEE: 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.

WHAT IT MEANS: 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.

Note: The vertical lines on the graph indicate noon on each of the dates listed on the x-axis.



1. Describe the air temperature pattern before the cold front.

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How is air changing before, during, and after a cold front?

STEP 1 CONTINUED: Describe the air temperature before, during, and after the cold front.

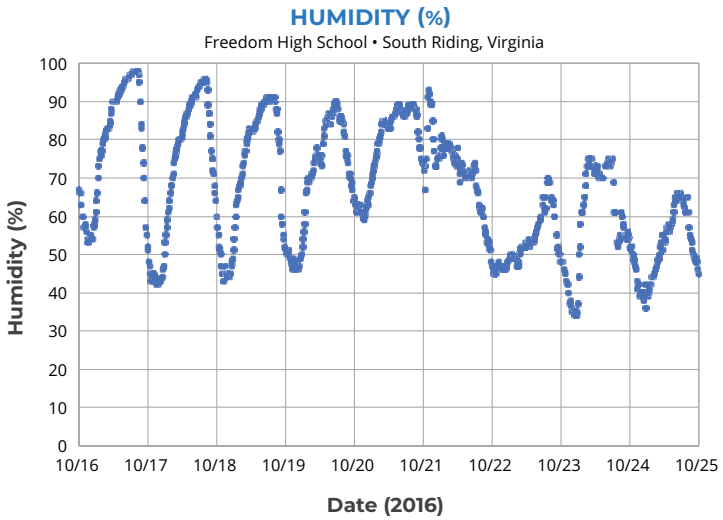
2. Describe the air temperature pattern after the cold front.

3. How does air temperature change when the front moves through?

STEP 2: Describe the humidity before, during, and after the cold front.

Circle the data on the graph that shows when the cold front passes through South Riding, VA.
Write **What I See** and **What is Means** statements on the graph.

Note: The vertical lines on the graph indicate noon on each of the dates listed on the x-axis.



1. Describe the humidity pattern before the cold front.

2. Describe the humidity pattern after the cold front.

3. How does humidity change when the front moves through?

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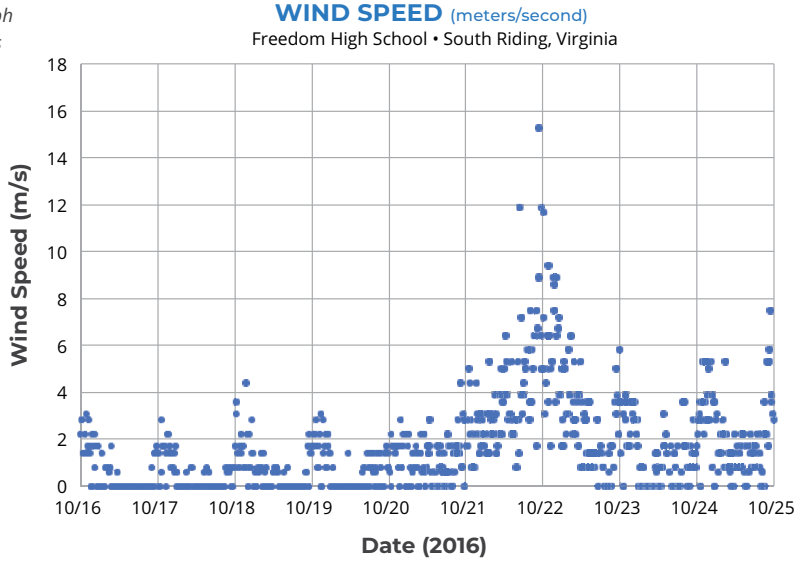
How is air changing before, during, and after a cold front?

STEP 3: Describe the wind speed before, during, and after the cold front.

Circle the data on the graph that shows when the cold front passes through South Riding, VA.
Write **What I See** and **What is Means** statements on the graph.

Note: The vertical lines on the graph indicate noon on each of the dates listed on the x-axis.



1. Describe the wind speed before the cold front.

2. Describe the wind speed after the cold front.

3. How does wind speed change as the front moves through?

WEATHER REPORT

…bring your umbrellas for the morning of October 21. The chance of rain is high.

DISCUSS WITH YOUR CLASS:

Why do you think the chances are high for precipitation the morning of October 21?

How is this storm similar to, or different from, the isolated storm that you investigated before?

Students at a high school in Virginia collected the weather data that's in this lesson's graphs.
If you collected weather data at your school, what types of weather events would you likely observe?

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Name Period Date

LESSON 9

What causes precipitation along a cold front?

STEP 1: How does the air change as a front moves through a place?

Illustrate the weather conditions (temperature, humidity, and wind) you might see a day before the front, during the front, and a day after the front arrived at Freedom High School, South Riding, Virginia. Use color and symbols to show changes in temperature, humidity, and wind.

BEFORE	DURING	AFTER

CREATE A KEY:

◯ Warm air ◯ Cool air ◯ ◯

(choose a color) *(choose symbols to show changes in humidity and wind)*

STEP 2: Make observations of what happens to the warm and cool fluids in the tank.

Record your observations of the water tank in the space below. The tank is a model that uses warm and cool water to simulate warm and cool air in the atmosphere. With it, we can see what happens when warm air and cool air meet.

Make a cross section that shows what the tank looks like **BEFORE** the partition is removed.

Make a cross section that shows what the tank looks like right **AFTER** the partition is removed.

DISCUSS AS A CLASS:

What happened when the cold and warm fluids met?

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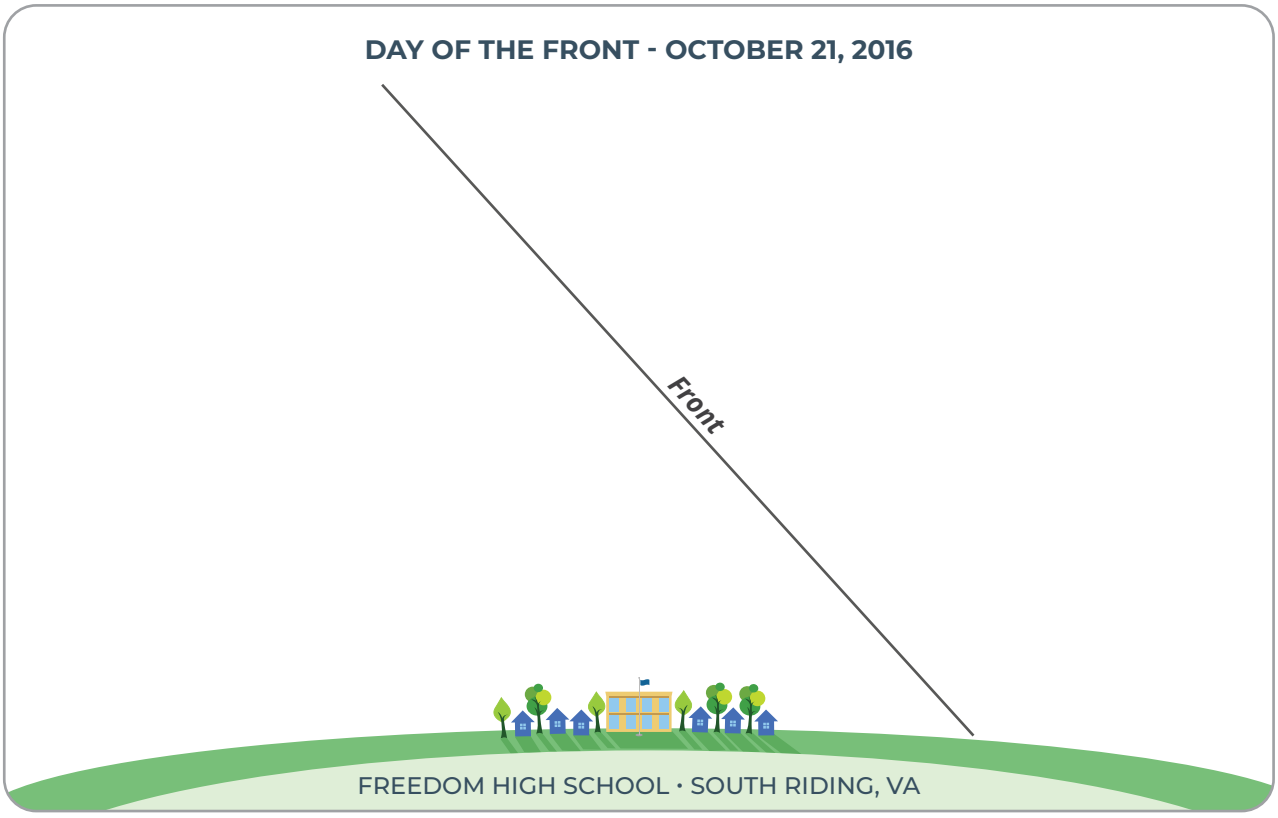
What causes precipitation along a cold front?

STEP 3: Develop a model for explaining precipitation during the cold front.
This model is a cross section of the atmosphere, just like the water tank that showed a cold front. Draw on the model to explain:

1. The location of the cold air mass.
2. The location of the warm air mass.
3. The direction that each air mass is moving.
4. Where you'd expect clouds to form.



EXPLANATION: Write a caption for your model to explain why Freedom High School had precipitation on October 21, 2016.

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What causes precipitation along a cold front?

STEP 4: Investigate air masses and fronts.

Over large areas, air can have similar temperature and moisture. Air with similar characteristics is called an **air mass**. For example, air over northern North America can form a cold, dry air mass. It is cold because it forms at high latitude, near the Arctic. It is dry because it forms over land, and there is little moisture evaporating from the land as compared with the ocean. Air over the Gulf of Mexico and the southern United States can form a warm, moist air mass. It is warm because it forms at a lower latitude, closer to the equator. Water evaporating from the Gulf of Mexico makes the air mass moist. The two kinds of air masses often "bump" into each other as they move, forming fronts.

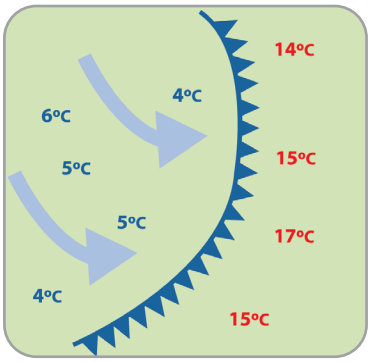
STOP AND THINK

What type of air mass was over Freedom High School before the front moved through the area?

What type of air mass was over Freedom High School after the front moved through the area?

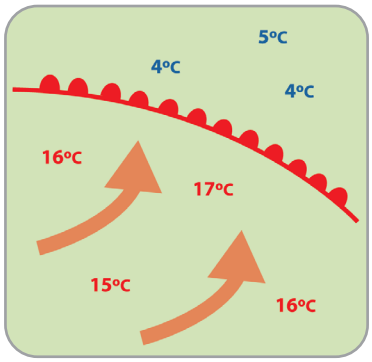
There are several different types of fronts. The type of front depends on how the air masses interact. The pictures below show how different types of fronts are shown on weather maps using symbols.

COLD FRONT



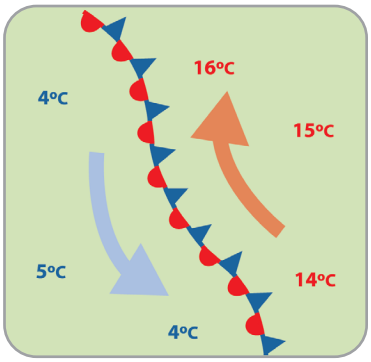
At a cold front, a colder air mass moves into a warmer air mass. A cold front is shown on a weather map as a blue line with triangles in the direction of movement.

WARM FRONT



At a warm front, a warmer air mass moves into a colder air mass. A warm front is shown on a weather map as a red line and half circles in the direction of movement.

STATIONARY FRONT



At a stationary front, a cold air mass and warm air mass are side by side. Both might be moving, but neither has enough force to move into the other's space. A stationary front is shown on a weather map with both red half circles and blue triangles.

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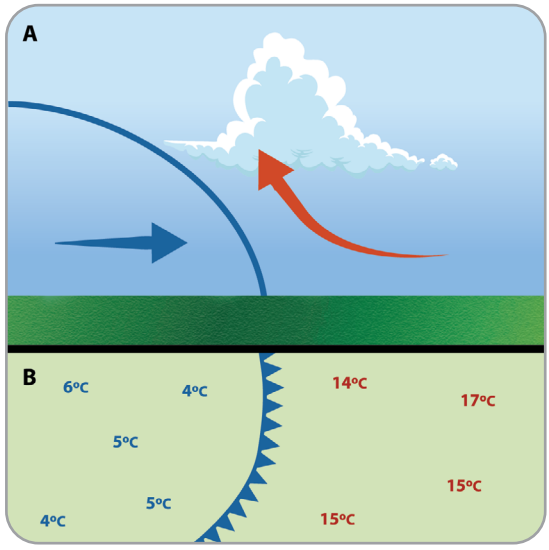
What causes precipitation along a cold front?

In this investigation, we are focusing on cold fronts.

Cold fronts can produce dramatic storms. Winds become gusty, and there is a sudden drop in temperature. There can be heavy rain, hail, thunder, and lightning. As warm air is pushed up at a cold front, cumulus clouds form just as they did in the isolated storms you learned about before – as the air moves upward it cools, and water vapor becomes liquid water droplets that make up clouds. The clouds may grow into cumulonimbus clouds and cause rain, or snow if the temperature is below freezing. After a cold front moves through, you may notice that the temperature cools down, the rain stops, and clear skies or other types of clouds replace the cumulus clouds.

STOP AND THINK

What happened as the cold air mass moved into the warm air mass at Freedom High School?



(A) The upper part of this image shows a cross section of a cold front. This is where a cold air mass is pushing into a warm air mass. The warm air is pushed upward where it cools, and water vapor condenses into clouds.

(B) The lower part of this image shows a weather map view of a cold front. The cold air mass is on the left side, pushing into a warm air mass. The blue line with triangles along it indicates the location where cool and warm air meet.

A cold front (and the cold air mass that moves in) may not be cold. During the summer, temperatures might be quite warm, but we can still have cold fronts. A cold front in the summer typically brings cooler weather compared with the previous days.

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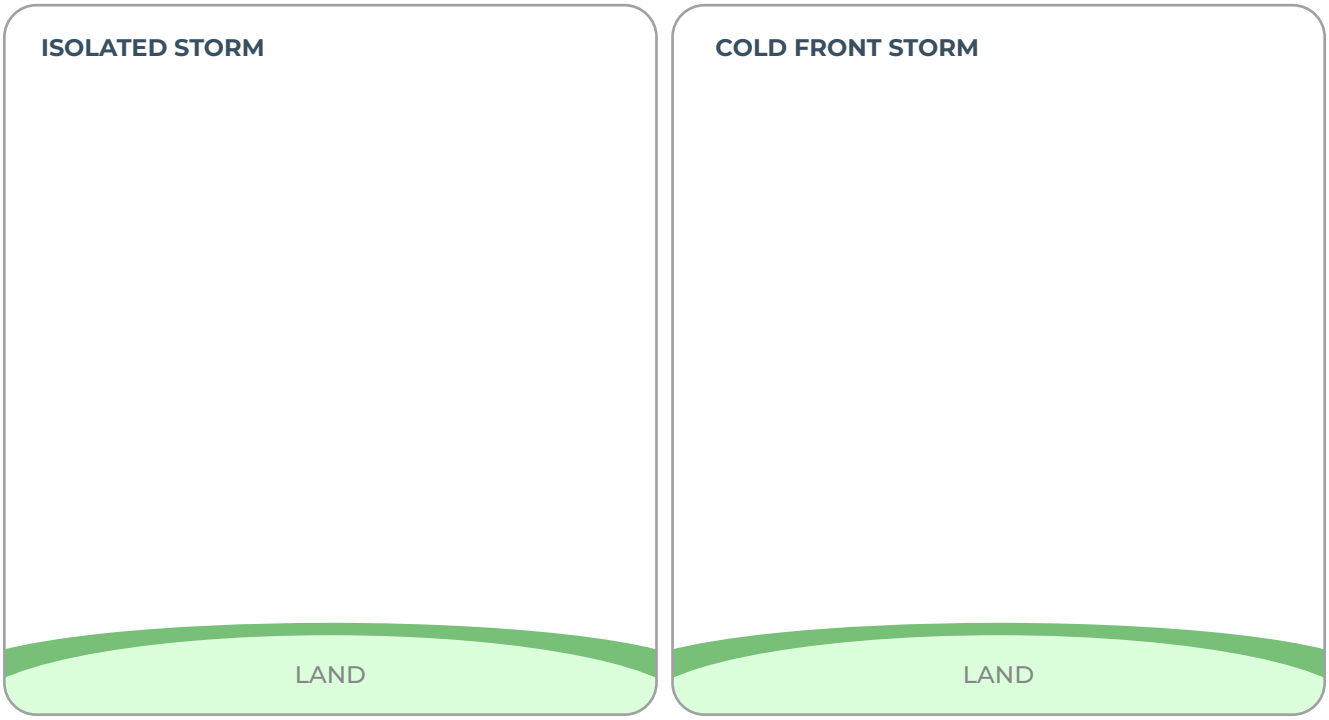
What causes precipitation along a cold front?

STEP 5: Let's compare our two types of storms: isolated storms and storms that form along a cold front.

Draw cross section models to explain how precipitation could happen in each kind of storm.

- Use the other models you've made and the reading in this lesson to help you decide what to draw.
- Indicate where air is warmer and where it is cooler.
- Use arrows to show how air moves.
- Show where clouds form in both types of storms.



1. How are isolated storms and cold front storms similar?

2. How are they different?

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What causes precipitation along a cold front?

STEP 6: Focus on the big picture using our cold front model.

Your teacher will assign you to a group. Each member of your group will map weather data for one day over a four-day time period on the map on the following page. Then you'll look at all four maps together to see what happened as a cold front moved through this area, the Midwest, and Northeast.

1. **Choose a day.** Each member in your group will choose one day of data to map. On the next page, circle your day on the Maximum Temperature and Precipitation Tables and write the date on your map.

2. **Color and label your map.**
   a. Color locations where the temperature is greater than 30°C RED.
   b. Color locations where the temperature is equal to, or less than, 30°C BLUE.
   c. Draw slanted rain lines near the location if it had precipitation.
   d. Add the red and blue colors to the key.

3. **Compare maps.** When your group completes all four maps, line them up in order beginning September 8 and ending with September 11.

4. **Determine where the cold front is located.** Draw the front on each map using the blue line/blue triangle symbol.

5. **Determine where the cold air mass is located.** Shade the cold air mass BLUE on each map.

6. **Determine where the warm air mass is located.** Shade the warm air mass RED on each map.

7. **Make observations of how the front and air masses move over time.** Be prepared to discuss your ideas.

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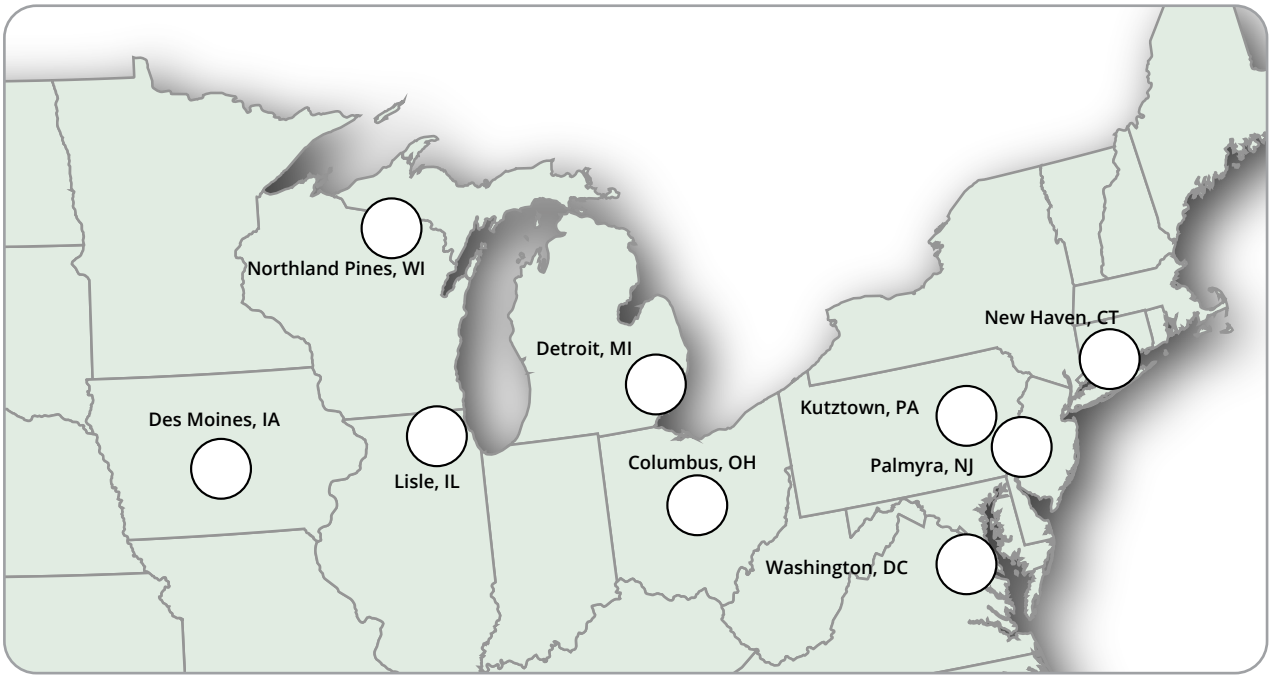
LESSON 9

What causes precipitation along a cold front?



DATE:

- Max temperature above 30°C
- Max temperature equal to or less than 30°C
- Precipitation

MAXIMUM TEMPERATURE (˚C)

	9/8/15	9/9/15	9/10/15	9/11/15
Des Moines, IA	27.8	27.8	28.9	21.1
Northland Pines, WI	25.4	22.7	19.6	16.9
Lisle, IL	31.7	23.3	25.6	19.6
Detroit, MI	31.2	30.1	24.7	25.8
Columbus, OH	32.7	30.9	26.1	28.2
Washington, DC	33.3	34.4	28.9	30.5
Palmyra, NJ	32.2	32.7	33.9	26
Kutztown, PA	31.2	32.5	32.7	22
New Haven, CT	32.8	30	25	26.7

PRECIPITATION (cm)

	9/8/15	9/9/15	9/10/15	9/11/15
Des Moines, IA	0.3	0	0	0
Northland Pines, WI	0.5	0.1	0	0.1
Lisle, IL	2.2	0	0.9	1.5
Detroit, MI	0	0.1	0	0.6
Columbus, OH	0	0	0	1.6
Washington, DC	0	0	0.3	0
Palmyra, NJ	0	0	3.6	0.1
Kutztown, PA	0	0.6	3.6	0
New Haven, CT	0	0	0	0

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Name Period Date

LESSON 10

What causes fronts to move?

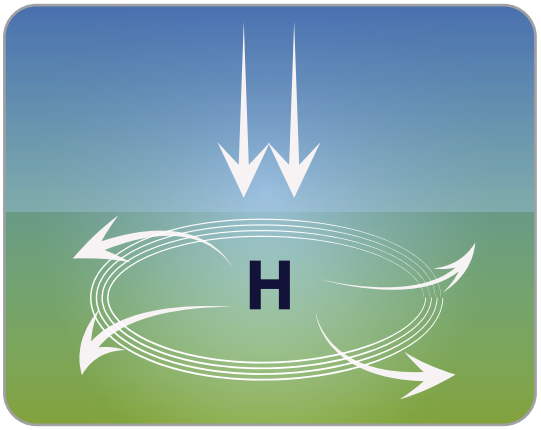
STEP 1: Remember air pressure? There's more to it.

In Lesson 5 you learned that air pressure causes air to move.

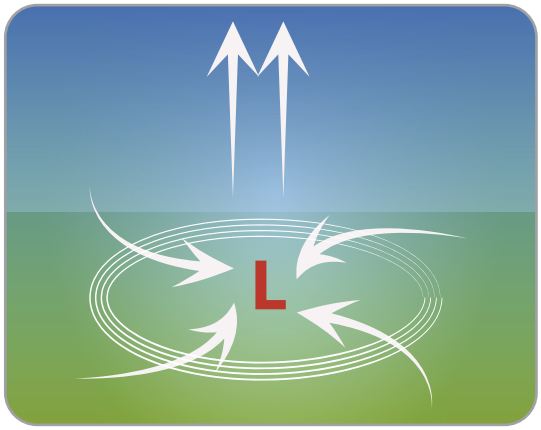
- Air rises in the atmosphere when it has lower pressure.
- Air sinks in the atmosphere when it has higher pressure.

You learned how air moving up and down is able to cause a small isolated storm. It turns out the same thing can happen over vast areas (the size of large US states), and this creates winds that can move fronts.

Air pressure isn't always the same from place to place. In one location, air might have somewhat lower pressure, which causes it to move upward. In another location, air might have somewhat higher pressure, which causes it to move downward.



In areas with high pressure, air moves downward and spreads outward once it gets to the land. High pressure is marked with a blue H on weather maps.



In areas with low pressure, air moves upward, so nearby air rushes in to fill the space. Low pressure is marked with a red L on weather maps.

The air rushing into low pressure and away from high pressure is wind.

Measurements of air pressure are made using an instrument called a barometer. Barometers used for weather measurements record the pressure in units called millibars (mb). The average air pressure at ground level is 1013.3 mb.

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What causes fronts to move?

STEP 2: Analyze pressure data over a region.

Follow the instructions to identify and analyze areas of high pressure and low pressure on the map below and figure out which direction the cold front is moving.

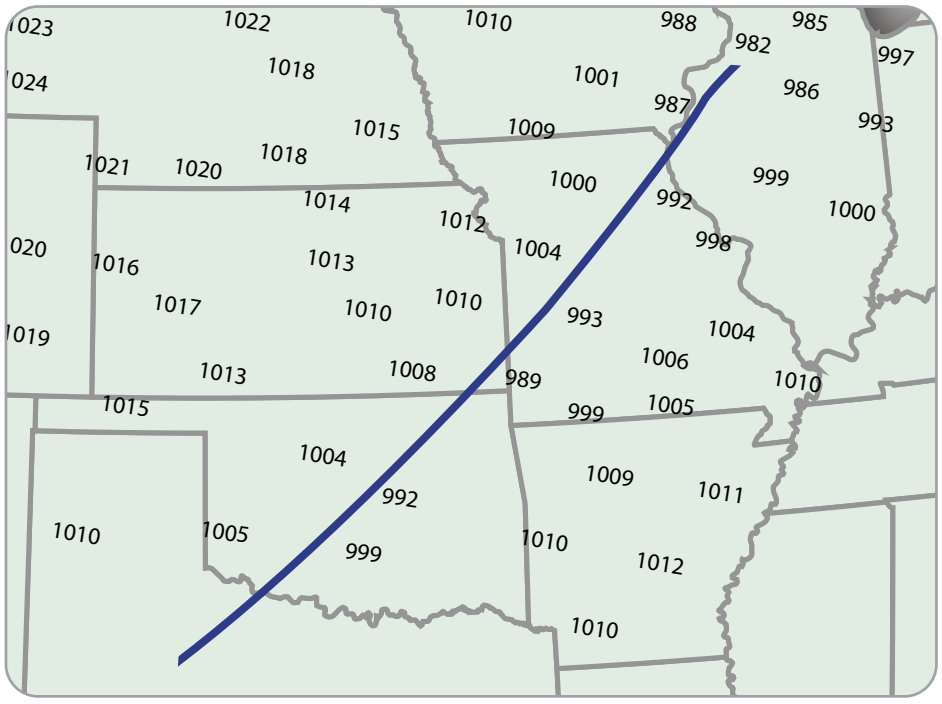
1. Color code the areas with high and low pressures (and add the colors to the key).
   a. Highlight the highest pressures on the map (more than 1015 mb) with a colored pencil.
   b. Highlight the lowest pressures (less than 995 mb) with a different colored pencil.

2. Draw arrows on the map to indicate the direction that the wind is blowing. Remember that wind flows away from high pressure and towards low pressure.

3. Based on the direction that wind is blowing, draw triangles on the front. (The triangles should point in the direction that the front is moving.)

4. The areas with the highest pressure and lowest pressure are labeled on a weather map (like the symbols in the key).
   a. Mark the location with the highest pressure on the map with a blue H.
   b. Mark the location with the lowest pressure on the map with a red L.

PRESSURE MEASURED IN MILLIBARS (mb)



KEY:

L — the center of an area of low pressure

H — the center of an area of high pressure

cold front

1014.4 1014.6 1015.8

barometric pressure (mb)

highest pressures - more than 1015 mb *(choose a color)*

lowest pressures - less than 995 mb *(choose a color)*

DISCUSS AS A CLASS:

Which way did the wind blow? What evidence do you have to support your claim?

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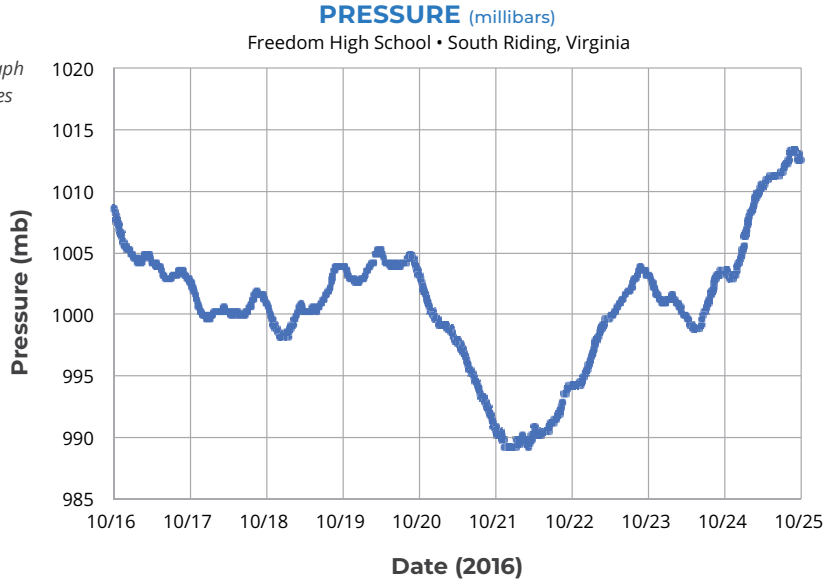
What causes fronts to move?

STEP 3: Analyze pressure data in one location.

In Lesson 8 you looked at weather data from Freedom High School in South Riding, Virginia, over a 10-day period, when a cold front passed through the area. The pressure data below was collected at Freedom High School during that same 10-day period. Remember that the cold front arrived at Freedom High School early on October 21.

How did the pressure change over time? Add **What I See** and **What It Means** statements to describe the pressure before, during, and after the cold front.

Note: The vertical lines on the graph indicate noon on each of the dates listed on the x-axis.



1. When was barometric pressure the lowest? When was it the highest?

2. Write a sentence to describe where pressure is lowest and highest around a cold front.

3. Take a look at the wind data in Lesson 8. The windiest time during this storm was when the pressure was lowest. Write a sentence to explain why winds happen when air pressure is low.

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Name Period Date

LESSON 11

What could cause a front to stall?

Even though Colorado is far from the ocean and other large bodies of water, there was an unusually high amount of moisture in the air above Colorado, and the storm didn't move for days, which led to the flooding event in September 2013. In this activity, you'll examine information about the storm. Your goal is to figure out what led to so much moisture in the atmosphere and to develop a model to show why this precipitation event lasted so long over Colorado.

STEP 1: Analyze data for the Colorado storm.

Using the table of daily rainfall totals collected during the storm at Centennial Middle School in Boulder, Colorado, choose which of the claims below you believe is true about the Colorado storm in September 2013.

DATE	RAINFALL* (mm)
9/10/2013	23.9
9/11/2013	35.1
9/12/2013	214.1
9/13/2013	84.1
9/14/2013	0.8
9/15/2013	4.8
9/16/2013	36.8

**Rainfall totals are for the same Colorado storm, which lasted for seven days.*

- ◯ The Colorado Storm in September 2013 was an isolated storm.
- ◯ The Colorado Storm in September 2013 was a cold front.
- ◯ The Colorado Storm in September 2013 was unlike either an isolated storm or a cold front

1. Explain why the claim you chose is true. Use evidence to support your claim.

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LESSON 11

What could cause a front to stall?

STEP 2: Interpret the storm report.
Read the storm report below to collect information about how the air was moving, how moisture was moving, and where rain was falling during the storm.

STORM REPORT

High Pressure: There was high pressure to the north, over Wyoming, which was pushing a cold air mass south and there was a high pressure area to the south, over Mexico, and high pressure to the east over Tennessee and the surrounding area. This caused the front to stall over Colorado.

Low Pressure and Moisture: Low pressure over Utah and Nevada pulled warm, humid air from the Gulf of Mexico and eastern Pacific into the storm.

The Effect of Mountains: As the air traveled up the eastern side of the Rocky Mountains, it formed clouds and then rain, and remained in place for days.

Create a model for the storm: Use the symbols from the key and the information in the storm report to develop a model. Indicate on the model the direction air is moving based on the highs and lows, and where the humid air that caused the storm is coming from.

KEY:

L — the center of an area of low pressure

H — the center of an area of high pressure

cold front

area of rain *(choose a color)*

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LESSON 11

What could cause a front to stall?

STEP 3: Use your model to explain what happened in Colorado.

Use your model of the Colorado storm to answer the questions below.

1. Where did the moisture come from for the storm?

2. What kinds of air masses interacted in the storm? Which air mass had the moisture for the storm?

3. What caused the precipitation at the front?

4. Why did the front stall, causing days of drenching rain in parts of Colorado?

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