More Hurricanes and Blizzards in NYC? - Student Materials

Unit 5	Earth and Space Science

Student Materials Table of Contents

Performance Task Organizer

Unit 5 More Hurricanes and Blizzards in NYC?	**Earth and Space Science**
Student Name:	

Tell the Story: Blizzards

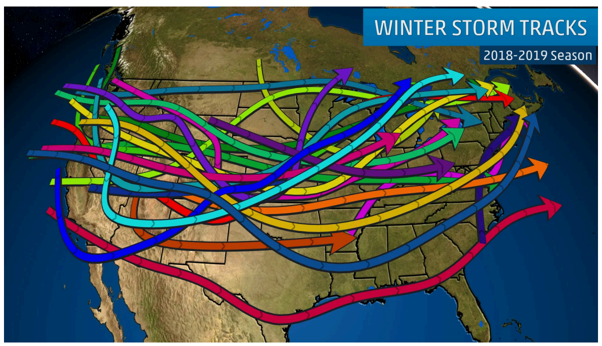
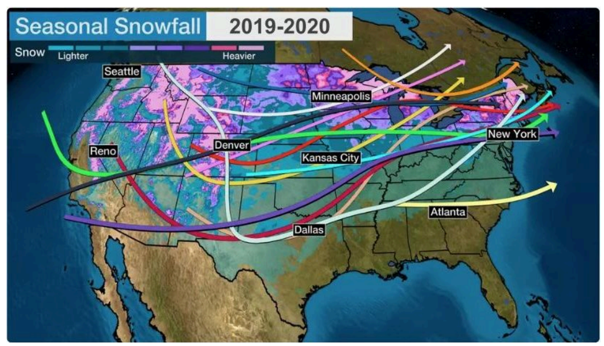
Directions:

1. Silently watch the video and analyze the maps and related graphs that follow.
2. For each video/graphic highlight, comment on, or jot down 2-3 important details about recent blizzards seasons in the US.

As you watch the video A Deadly Winter Storm Heads to the East Coast , in the boxes below jot 2-3 observations related to the following:

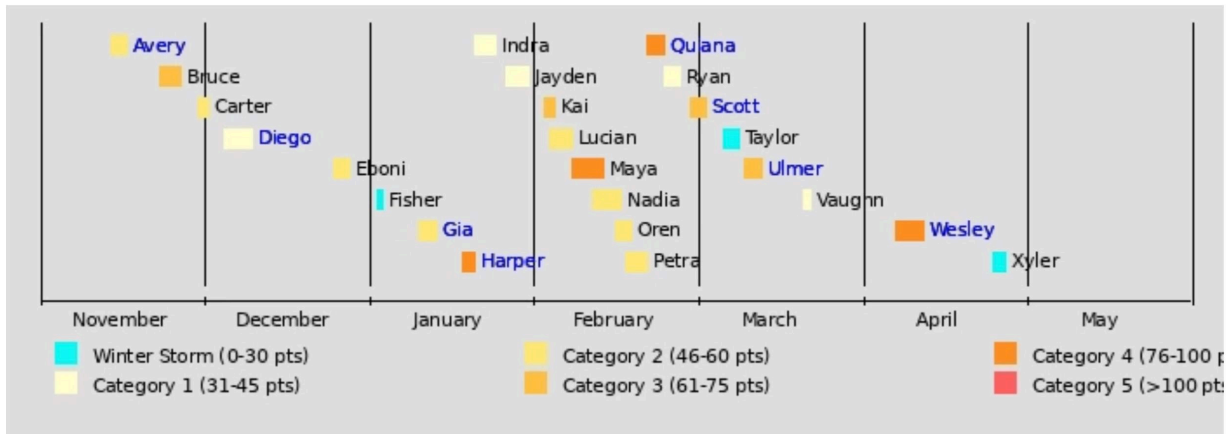
- Characteristics of the storm
- Damage/problems caused by the storm

1. ______
2. ______
3. ______

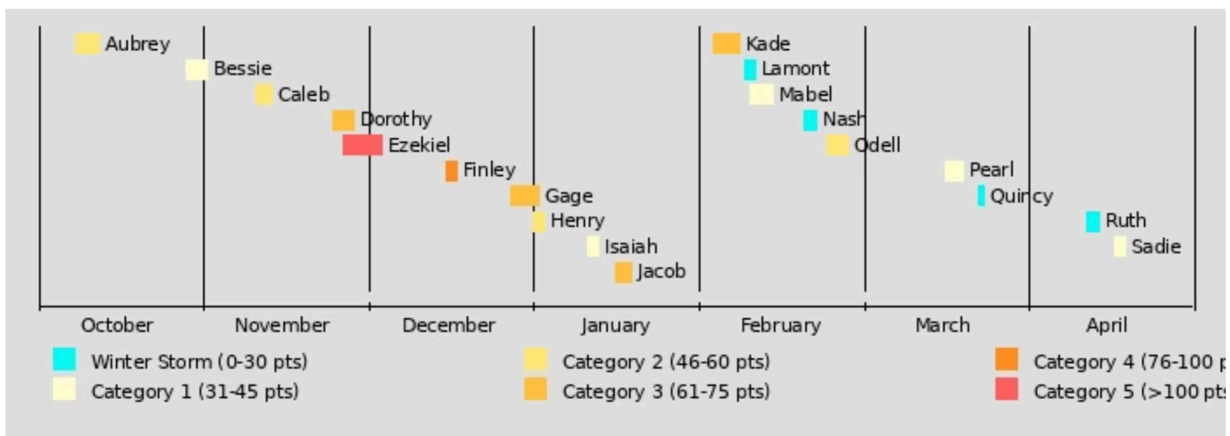
2018 - 2019	2019 - 2020
	

Text 2 Continued: 2018-2019 and 2019-2020 US Winter Storms Season Graphs
Hint: the length of each bar indicates how long the storm lasted

2018 - 2019 Winter Snowfall Total (pts = inches of snow)



2019 -2020 Winter Snowfall Total (pts = inches of snow)



1. ____________________

2. ____________________

3. ______________________________

What is the overall story of the 2018-2019 and 2019-2020 US blizzard seasons?

Directions: In your group, take turns sharing your important observations. As a group, decide which 3-5 observations are most important to the story of the 2018-2019 and 2019-2020 US blizzard seasons and why it matters.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Tell the Story: Tropical Storms

Directions:

1. Silently watch the video and analyze the maps and related graphs that follow.
2. For each video/graphic highlight, comment on, or jot down 2-3 important details about recent US tropical storm seasons.

As you watch the Island of Puerto Rico destroyed by Hurricane Maria , in the boxes below jot 2-3 observations related to the following:

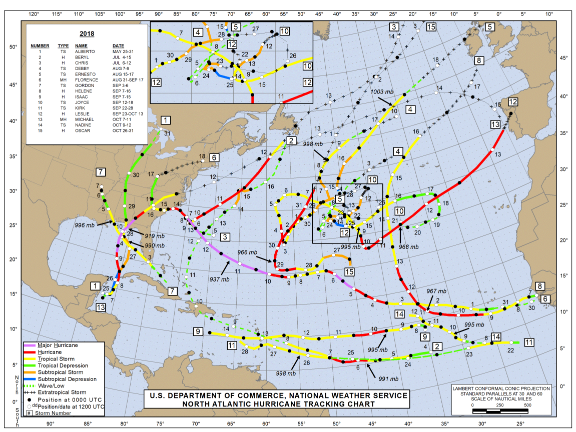
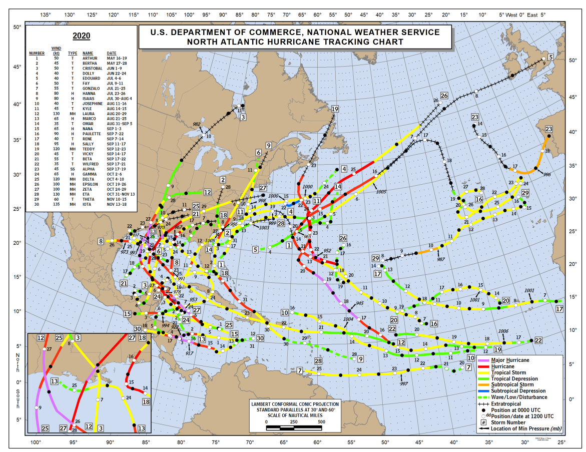
- Characteristics of the storm
- Damage/problems caused by the storm

1. ______________________________

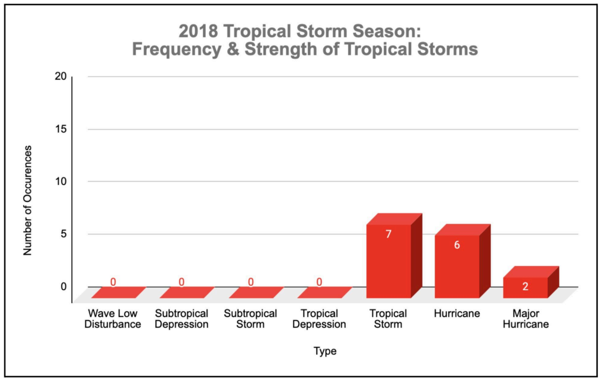
2. ______________________________

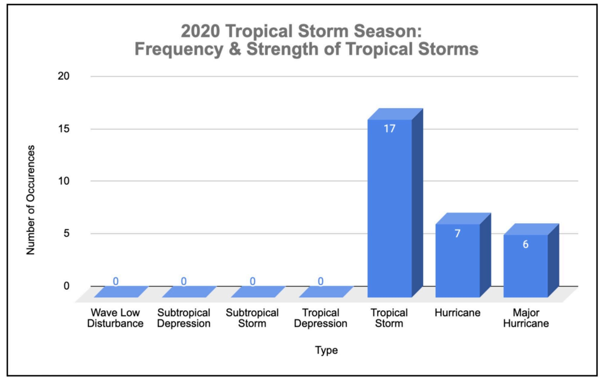
3. ______________________________

Analyze the maps and corresponding graphs on the next page. Then jot 2-3 observations you think are telling the story of recent tropical storm seasons and record them in the boxes below the graphs. Hint: The storms start from the lower latitudes (the south!).

 2018 Click here to view large version	 2020 Click here to view large version

Text 1 Continued: 2018 and 2020 Atlantic Tropical Storm Graphs





1. ______
2. ______
3. ______

What is the overall story of the 2018 and 2020 US tropical storm seasons?

Directions: In your group, take turns sharing your important observations. As a group, decide which 3-5 observations are most important to the story of the 2018 and 2020 US tropical storm seasons and why it matters.

1. ______
2. ______
3. ______
4. ______
5. ______

Introduction to the Performance Task and Initial Ideas

In this unit, your task will be to write an argument about how storms will change in frequency and intensity as global temperatures continue to rise.

Individually brainstorm ideas and predictions in response to the prompts:

- Will hurricanes happen more often in the future?
- Will hurricanes be more intense in the future?
- Will blizzards happen more often in the future?
- Will blizzards be more intense in the future?

Connect to the Performance Task: Hurricanes 5E

Choose one of the two tasks below and apply what you figured out from the Blizzards 5E to complete the task. Each task involves the following:

- identifying the independent and dependent variable in the task prompt
- developing a model for how climate change will impact winter storms in your region in the future based on evidence from the investigation
- writing an argument based on evidence for how climate change will impact winter storms in your region in the future based on evidence from the investigation

Task 1 Prompt
Will the frequency of winter storms per year where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable:

Dependent variable:

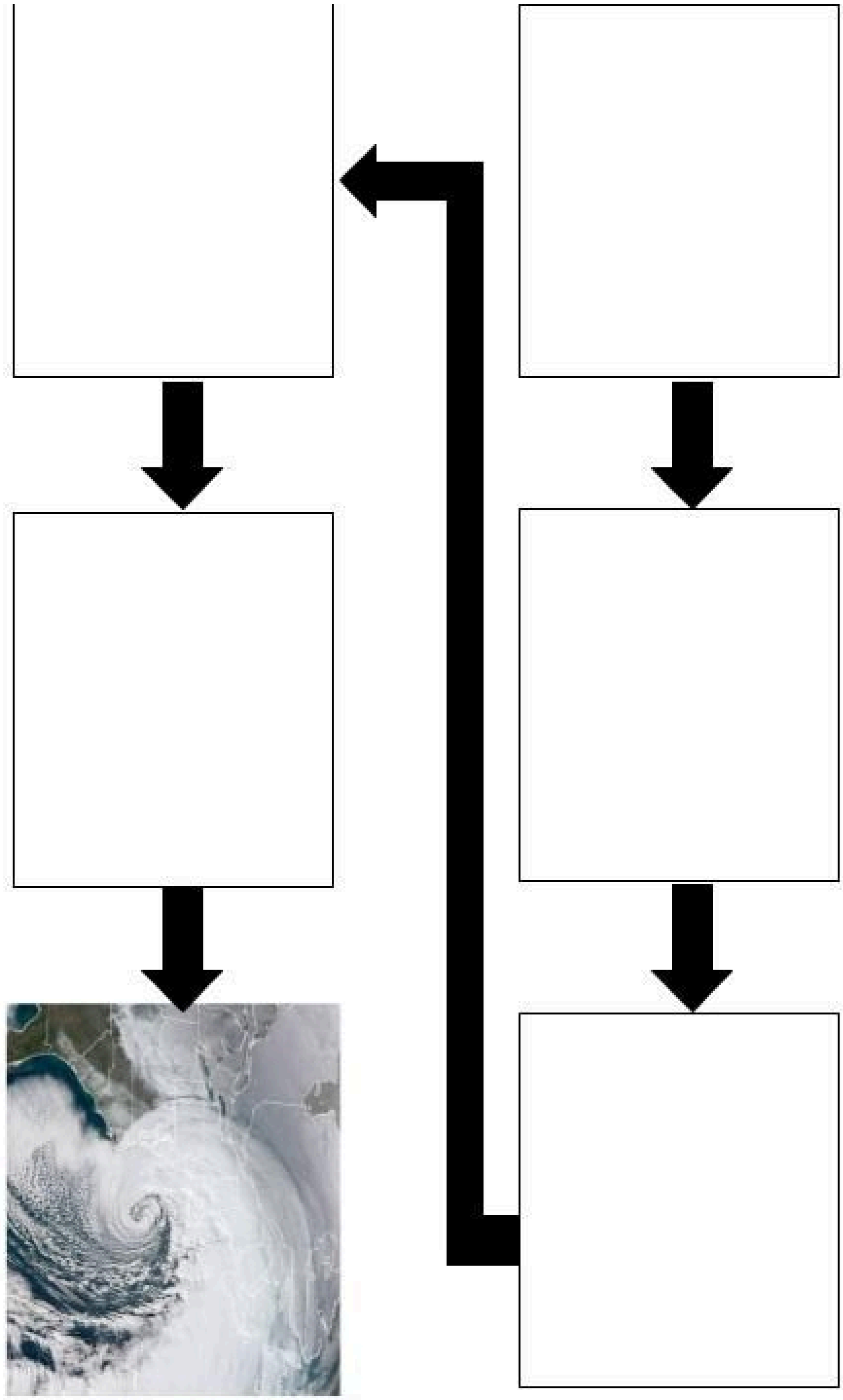
Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?

2. Review your model for how a winter storm forms from the investigation, then develop a model that illustrates what you think will happen to the frequency of winter storms per year where you live based on evidence regarding the independent variable. Be sure to include:
    - how and why energy and matter flow within the storm system and relevant surrounding systems
    - small scale mechanisms that explain what you are representing at the macro scale

Modeling Frequency of Winter Storm in the Future



Part 3: Engage in an argument from evidence regarding whether the frequency of winter storms per year where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical winter storm frequency data
- the conditions necessary for a winter storm to form
- relevant data from global climate models, such as projections of future temperatures
- how your prediction has limited precision and reliability due to the assumptions and approximations inherent in global climate models you used

Task 2 Prompt
Will the intensity of winter storms where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable:

Dependent variable:

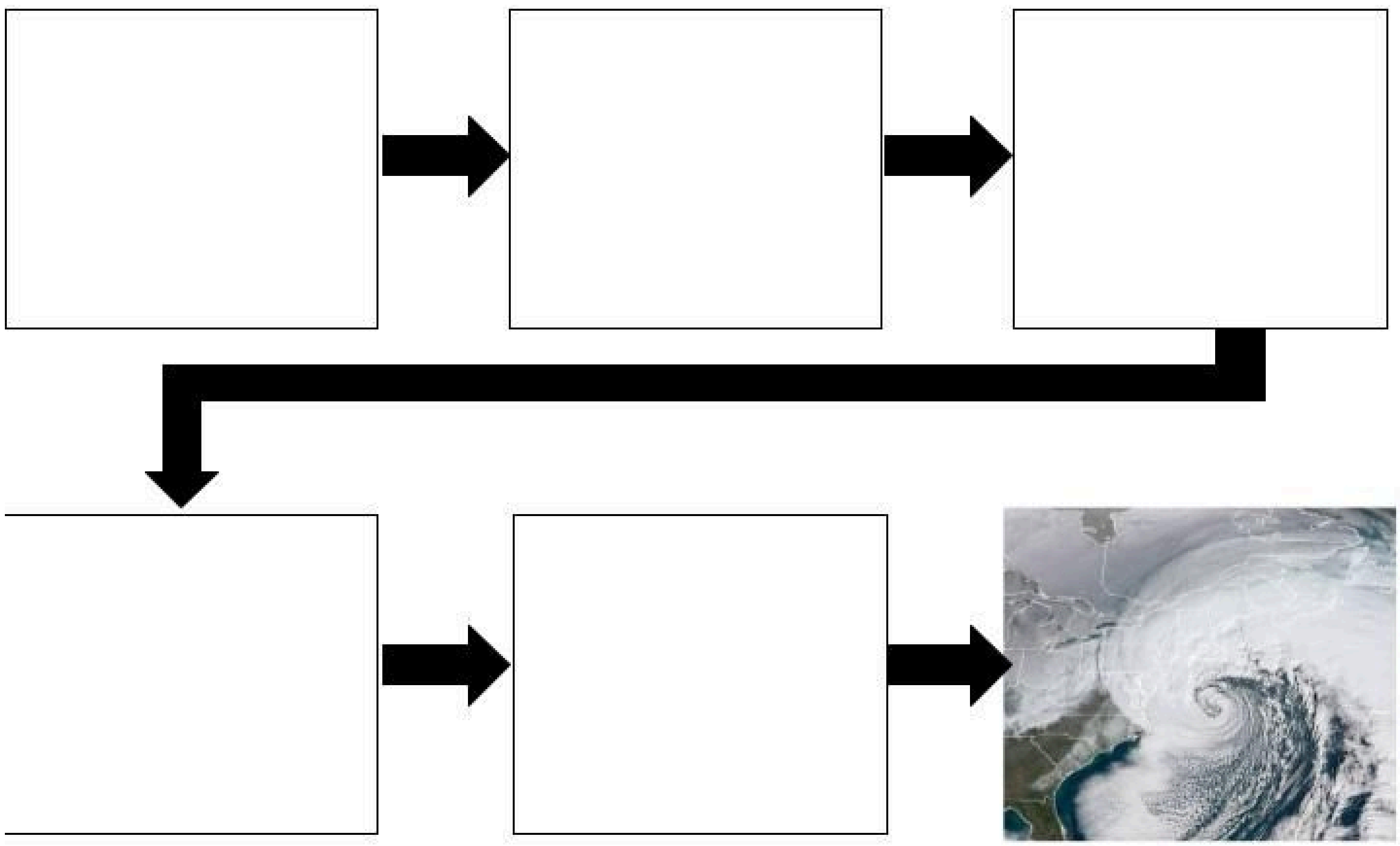
Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?

1. Review your model for how a winter storm forms from the investigation, then develop a model that illustrates what you think will happen to the intensity of winter storms where you live based on evidence regarding the independent variable. Be sure to include:
    - how and why energy and matter flow within the storm system and relevant surrounding systems
    - small scale mechanisms that explain what you are representing at the macro scale

Modeling Intensity of Winter Storms in the Future



Part 3: Engage in an argument from evidence regarding whether the intensity of winter storms where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical winter storm intensity data
- the conditions necessary for a winter storm to to produce intense snowfall
- relevant data from global climate models, such as projections of future temperatures
- the precision and accuracy of the global climate models you used

Connect to the Performance Task: Paths of Severe Storms 5E

Apply what you figured out from the Paths of Severe Storms 5E to respond to the prompt below.

Will the frequency of winter storms per year where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable:

Dependent variable:

Part 2:
Gather evidence from the investigation and note it below.

What is the evidence?	Which resource did the evidence come from?

Part 3: Engage in an argument from evidence regarding whether the frequency of winter storms where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. You may use pictures to help illustrate your claims and support your reasoning. Consider the following:

- historical winter storm frequency data
- the conditions necessary for a winter storm to form
- relevant data from global climate models, such as projections of future temperatures
- the reliability of the models used to make predictions

Connect to the Performance Task: Hurricanes 5E

Choose one of the two tasks below and apply what you figured out from the Hurricanes 5E and the Paths of Severe Storms 5E to complete the task. Each task involves the following:

- identifying the independent and dependent variable in the task prompt
- developing a model for how climate change will impact hurricanes in your region in the future based on evidence from the investigation
- writing an argument based on evidence for how climate change will impact hurricanes in your region in the future based on evidence from the investigation

Task 1 Prompt
Will the frequency of hurricanes per year where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable:

Dependent variable:

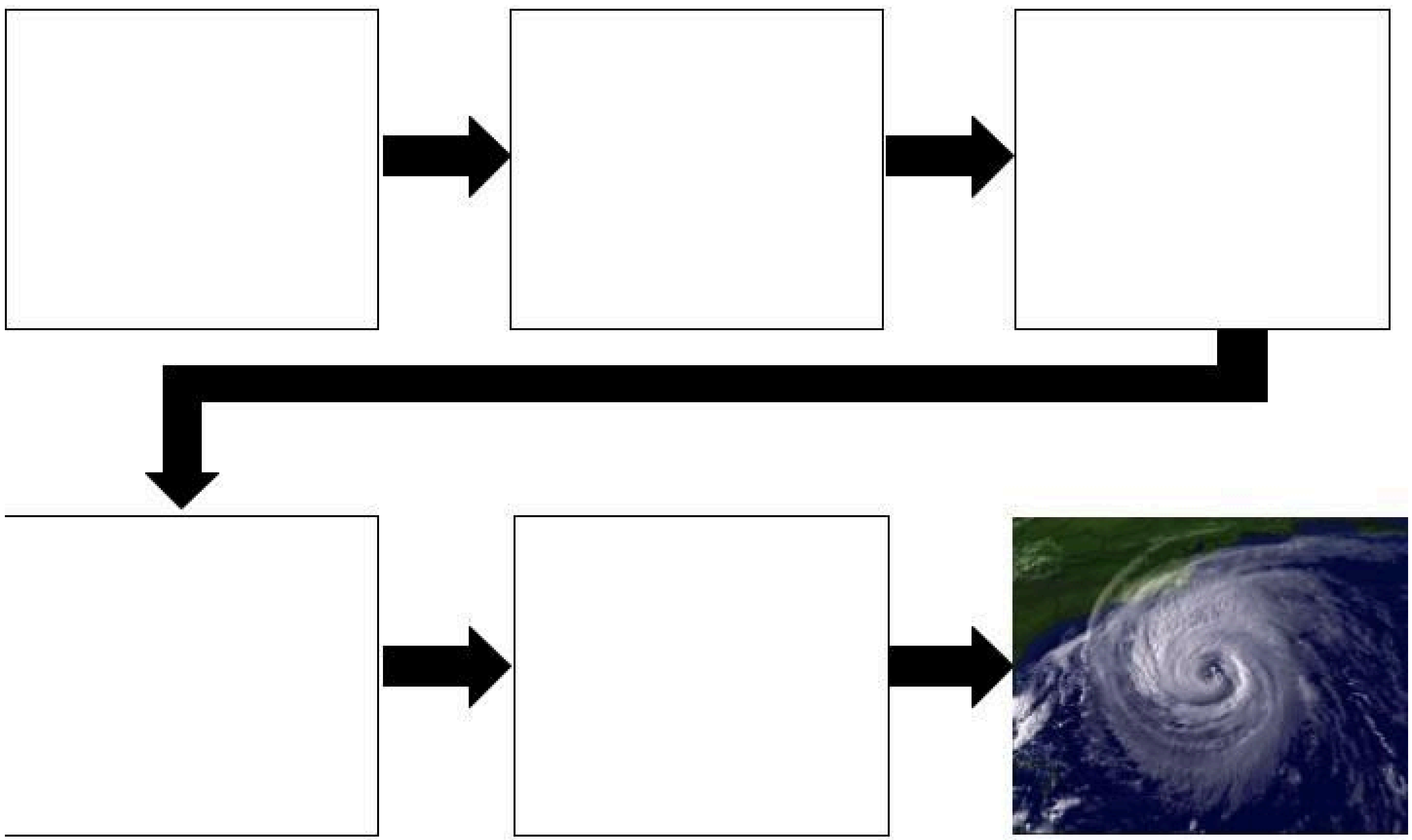
Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?

2. Review the model for how a hurricane forms from the investigation, then develop a model that illustrates what you think will happen to the frequency of hurricanes per year where you live based on evidence regarding the independent variable. Be sure to include:
   - how and why energy and matter flow within the storm system and relevant surrounding systems
   - small scale mechanisms that explain what you are representing at the macro scale

Modeling Frequency of Hurricanes in the Future



Part 3: Engage in an argument from evidence regarding whether the frequency of hurricanes per year where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical hurricane frequency data
- the conditions necessary for a hurricane to form
- relevant data from global climate models, such as projections of future temperatures

Task 2 Prompt
Will the intensity of hurricanes where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable:

Dependent variable:

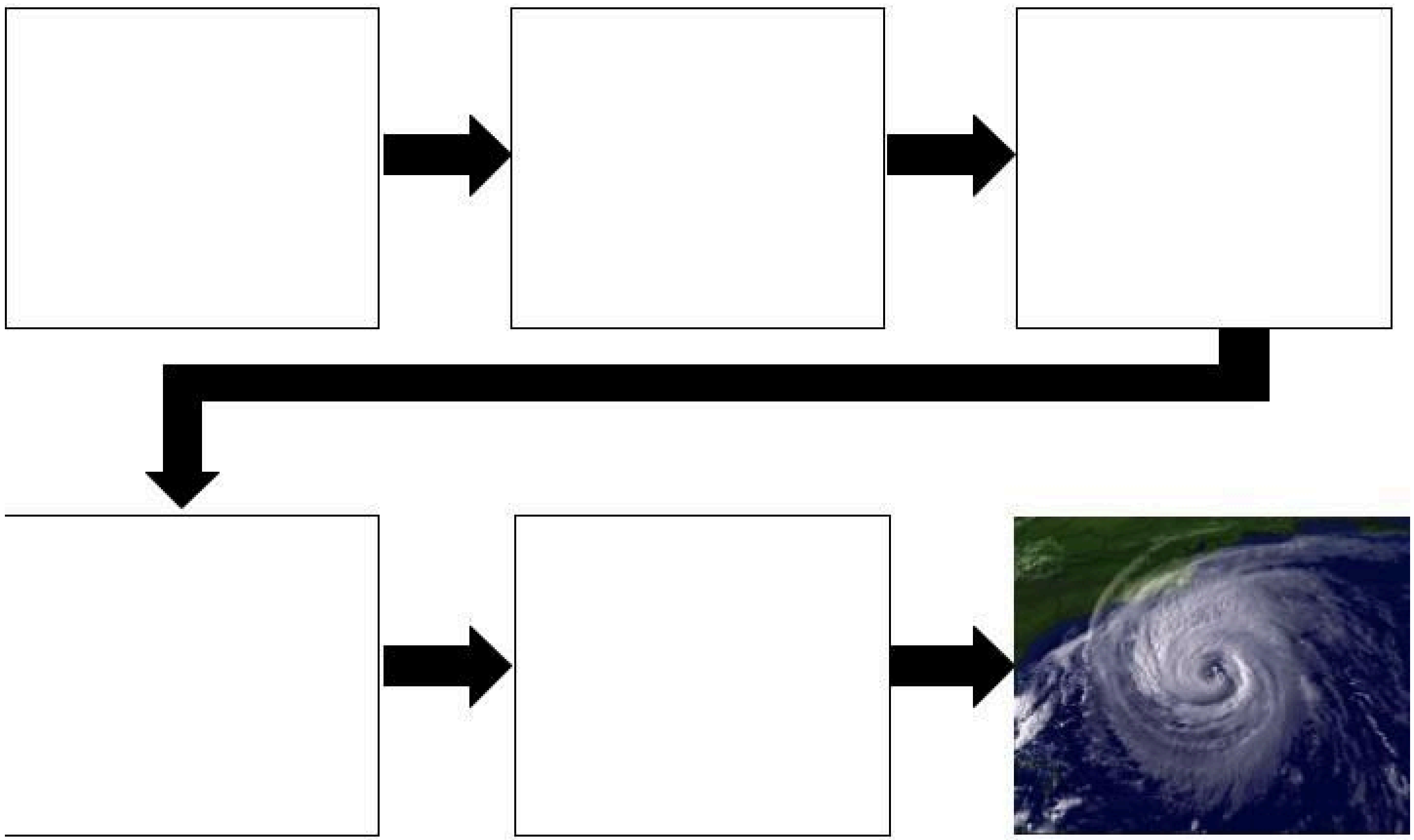
Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?

2. Review the model for how a hurricane forms from the investigation, then develop a model that illustrates what you think will happen to the intensity of hurricanes per year where you live based on evidence regarding the independent variable. Be sure to include:
   - how and why energy and matter flow within the storm system and relevant surrounding systems
   - small scale mechanisms that explain what you are representing at the macro scale

Modeling Intensity of Hurricanes in the Future



Part 3: Engage in an argument from evidence regarding whether the intensity of hurricanes where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical hurricane intensity data
- the conditions necessary for a hurricane energy to increase
- relevant data from global climate models, such as projections of future temperatures
- the reliability of the global climate model you used to make predictions

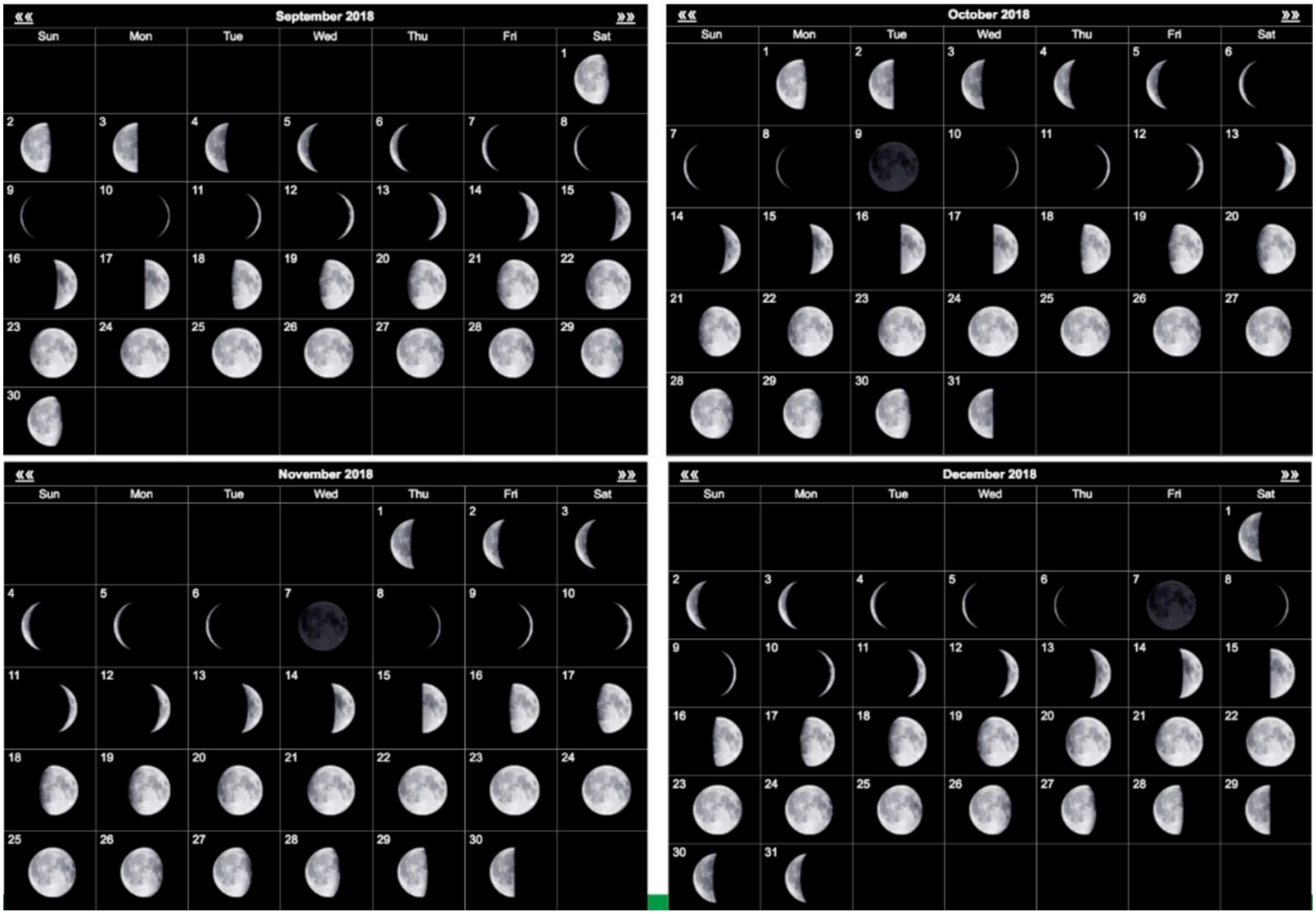
Moon Phases Optional 3E (Optional)

Unit 5 More Hurricanes and Blizzards in NYC?	**Earth and Space Science**

Student Name:

Why does the moon look different over the course of the month?

Examine the images of the moon over the course of 4 months. What patterns do you see? Note the patterns you observe below the moon calendars.

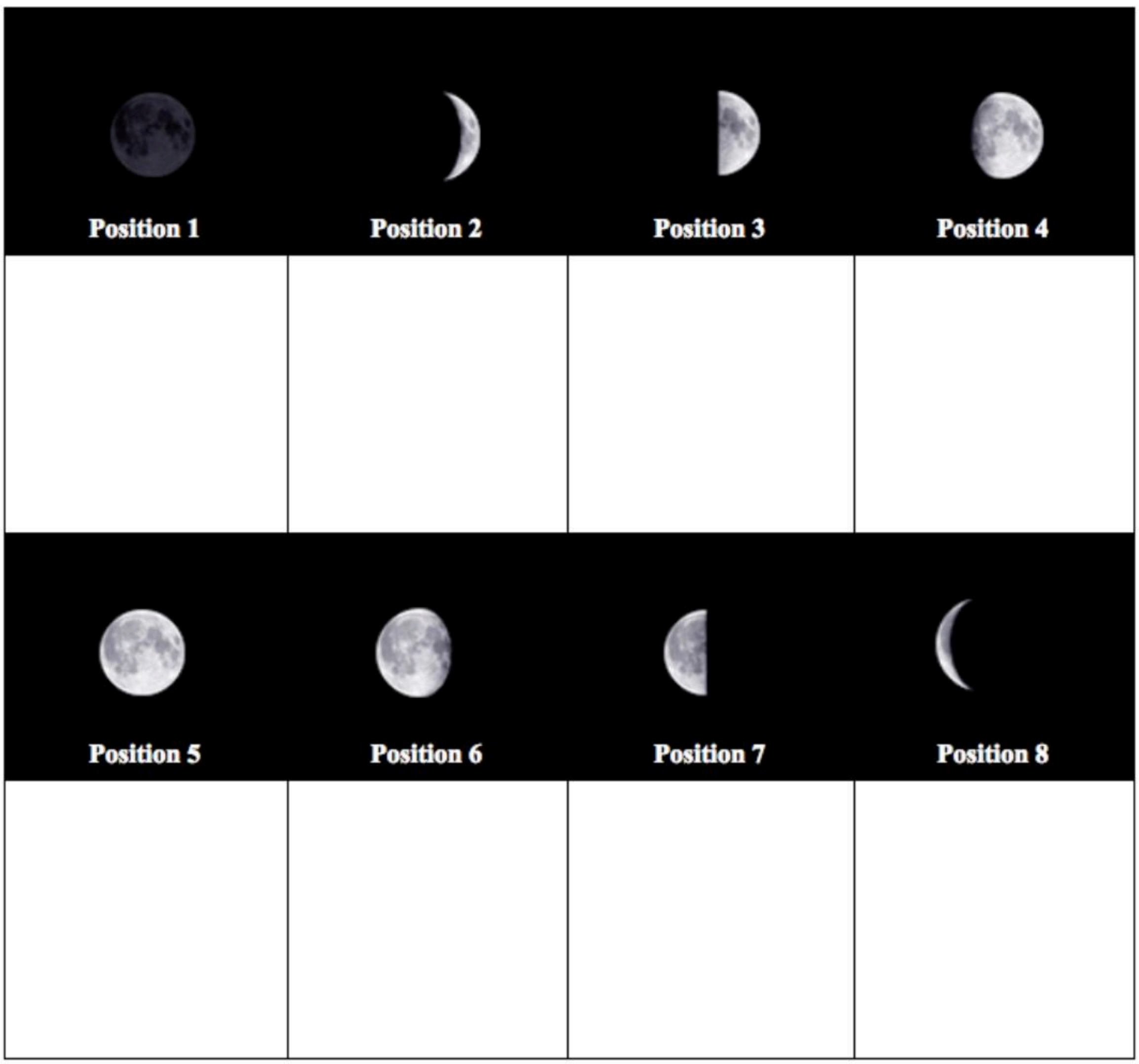


How Do We Use Modeling to Explain Patterns in Observations of the Moon?

1. Your task for this Explore phase is to develop a model that explains the patterns we see in observations of the moon. Use the materials you have been provided to recreate the moon images you see below. The images are in the sequence they are observed from Earth, so you must use your model to recreate the images in that sequence.

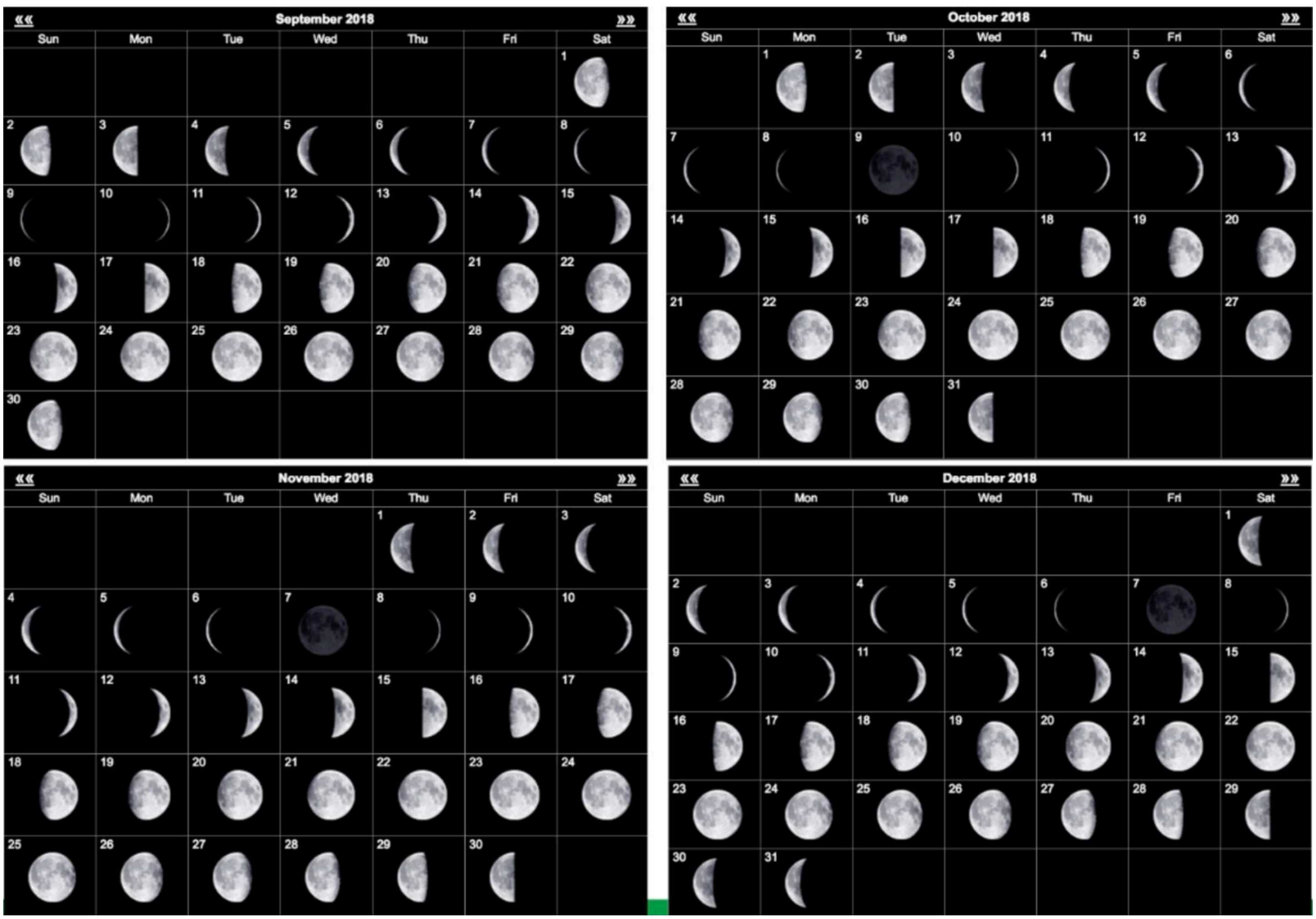
Model	Target
Ball on stick with one side marked	Moon
Lamp	Sun
Someone other than the person holding the moon	Earth

Draw a diagram below each image to show how you modeled that image. Be sure to label and describe the diagram.



2. You have now modeled the pattern in the images of the moon seen on the previous phase, but what does the moon have to do in order for the pattern to repeat itself?

3. Look at the moon calendar again. How long does it take for the pattern to start repeating itself? Consider using the frequency of a full moon to help you determine this.



4. Another pattern your class noticed was that we always see the same side of the moon from Earth. Do you think the moon would have to rotate (spin) in order for this to happen or is it fixed on its access?

Add to your original model by trying both scenarios and deciding which scenario is more consistent with the pattern of always seeing the same side of the moon from Earth. Note what you decide below.

Model	Target
Ball on stick with one side marked	Moon
Lamp	Sun
Someone other than the person holding the moon	Earth

See-Think-Wonder

See What did you observe?	Think What does each observation make you think?	Wonder What questions do you have?

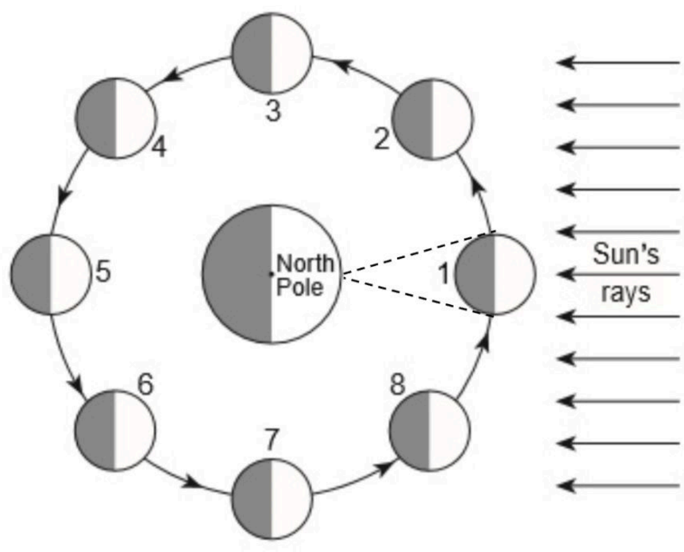
What is Your Explanation for Patterns in Observations of the Moon?

1. If you could view the moon from the perspective of the Sun, how much of the moon would be illuminated (lit up) at each position you modeled?

2. Why does the amount of the moon illuminated at each position appear different from Earth?

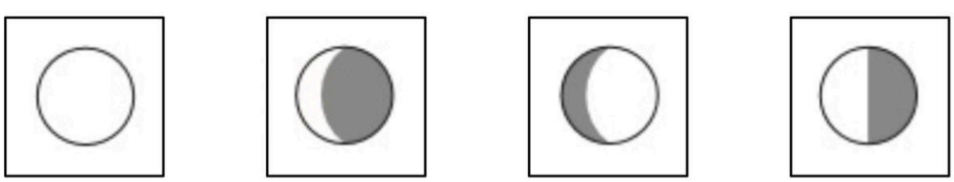
3. Predict what the moon looks like from Earth when the moon is at positions 1, 2, 3, and 6 and draw it in the boxes. Notice that what we see from Earth when the moon is at position 1 is shown with the dotted lines. You can draw dotted lines to help you determine what you see of the moon from Earth when the moon is at different positions.

1	2	3
		6



(Not drawn to scale)

4. Use what you understand about how the moon phases change and the diagram to predict the position of the moon when we see each of the moon phases below from Earth. Write the position number below each box.



5. Imagine you're out at night with a group of friends and one of them points out that the moon is full. Then all your friends start to wonder aloud why the moon looks different on different nights. Use what you have learned so far to explain the patterns in moon observations over the course of a month to your friends. Be sure you include the following terms in your explanation:
    a. Moon
    b. Sun
    c. Earth
    d. sunlight
    e. orbit
    f. position
    g. visible
    h. illuminated

Can the Moon cast shadows?

Of course! A **full moon** is very bright. It is bright enough to cast shadows. If you are out away from city lights and the Moon is full you might cast your own Moon shadow.

The Phases of the Moon

The Moon does not produce any light of its own. It only reflects light from the Sun. The Moon has phases because it orbits around Earth. One orbit takes about 28 days. As the moon moves around Earth, different parts of it appear to be lit up by the Sun. The Moon sometimes appears fully lit and sometimes completely dark. Sometimes it is partially lit. The different appearances of the Moon are referred to as phases of the Moon (**Figure** below).

A **full moon** occurs when the whole side facing Earth is lit. This happens when Earth is between the Moon and the Sun.

About one week later, the Moon enters the quarter-moon phase. Only half of the Moon's lit surface is visible from Earth, so it appears as a half circle. Another week later, the Moon moves between Earth and the Sun. The side of the Moon facing Earth is completely dark. This is called a **new moon**. Sometimes you can just barely make out the outline of the new moon in the sky. This is because some sunlight reflects off the Earth and hits the Moon. One week after that, the Moon is in another quarter-moon phase. Finally, in one more week, the Moon is back to full.

Before and after the quarter-moon phases are the **gibbous** and **crescent** phases. During the **crescent** moon phase, the Moon is less than half lit. It is seen as only a sliver or crescent shape. During the **gibbous** moon phase, the Moon is more than half lit. It is not full. The Moon undergoes a complete cycle of phases about every 29.5 days.

Think about the steps you went through to develop a model that explains the patterns in moon observations from Earth. How did you use these patterns to help you develop and revise your model?

Pattern	How did this help you develop/revise your model?

High Tides and Moon Phases

In this investigation, you will observe the relationship between tides and moon phases in New York City.

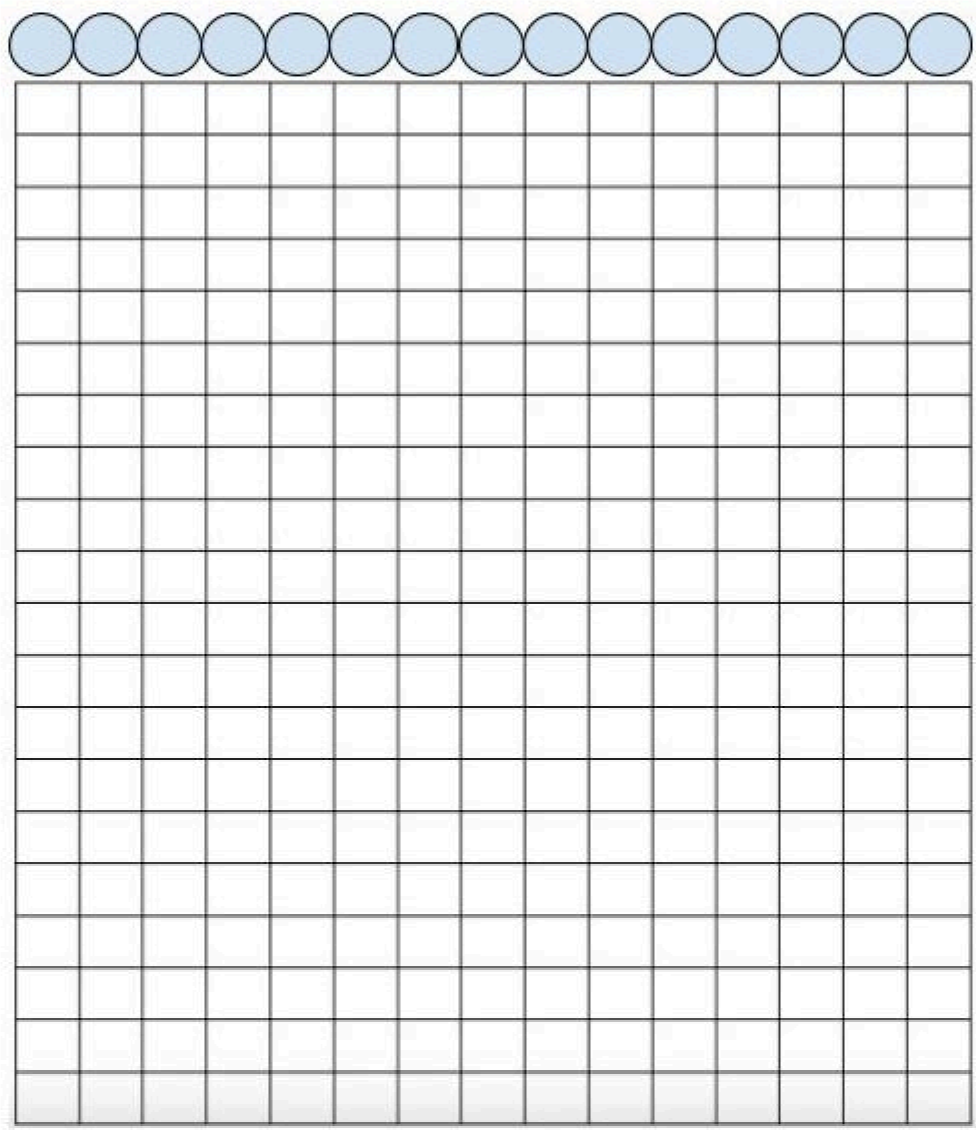
Open the data found found here: New York (The Battery), NY - Local Tide Times, Tide Chart | US Harbors

Use the information you find there to complete the table below

Date	Height of High Tide (feet)		Moon Phase
	AM	PM	

On the graph paper below, plot the data from your data table using the following steps:

1. Looking at the data above, add the dates to the x axis of your graph.
2. Add a title to your x axis "Dates"
3. Draw the phases of the moon for each corresponding date
4. On the y axis, add the increments for feet. Be sure to evenly space numbers.
5. On the y axis, add your title "Height of Water in Feet"
6. Using a red colored pencil, add the data points for the high tides for AM
7. Connect the data points using a smooth/wavy line
8. Using a blue colored pencil, add the data points for the high tides for PM
9. Connect the data points using a smooth/wavy line



Analysis: Answer the questions below using your data chart and graph. Be sure to list the date, time of day (am/pm), feet, and moon phase in your answer as needed.

1. When did the highest high tide occur? When did the lowest high tide occur?

2. When did the largest difference in high tide occur on the same day?

3. When did the smallest difference in high tide occur on the same day?

4. Were Neap Tides or Spring Tides higher? Explain.

5. Were there any other patterns that you noticed?

Why was Hurricane Sandy so Bad

1. Read the text, Tides . Using what you learn in the text, independently respond to the prompt: why was hurricane Sandy, which happened on a Spring Tide, so damaging?

In your response, be sure to include

- what a spring tide is
- What causes a spring tide
- How a spring tide could cause the effects of a storm to be worse

2. Use the routine think-talk-open exchange to share your ideas with your groupmates

3. After discussion, revise your response using new ideas from your discussion

What Causes Lunar and Solar Eclipses?

Directions for Read-Generate-Sort-Solve:

1. Read: Read the text about eclipses [ESS.U5.L1.Elaborate.TXT001] silently.
2. Generate: On your group's chart paper, generate ideas about what causes lunar and solar eclipses?
3. Sort: Have everyone in the group star one idea that they think is most relevant to the question.
4. Solve: As a group, discuss the ideas you deemed most important, and come up with a response to the question.

What causes lunar and solar eclipses?
Generate Ideas.

Name:	**Name:**
Name:	**Name:**

What causes lunar and solar eclipses?

Blizzards 5E

Unit 5 More Hurricanes and Blizzards in NYC?	Earth and Space Science
Student Name:	

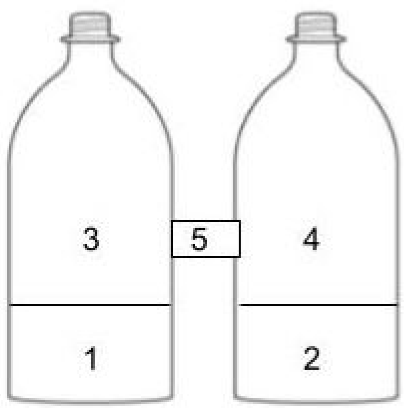
Explore 1: Wind Formation Investigation
Model 1: Wind Formation

1. Obtain a piece of tubing and two empty 1-liter bottles from your teacher.
2. The bottles each have a hole in the side that will allow you to fit the tubing. Connect the bottles like the ones seen on the right.
3. Fill one bottle with hot water and the other with cold water, up to about an inch below the tubing.
4. Light an incense stick and allow it to burn about 5 seconds, then blow it out. It should be producing smoke instead of fire at this point. This smoke will be representing the atmosphere in your model.

Note: the incense is not heating the air at this point. It is simply helping us visualize how air is moving because the smoke is visible.

5. Insert the smoking incense stick into the bottle with cold water and hold it just above the water for about 15 seconds. Pull the incense stick out and observe the movement of the smoke. **Record your observations below.**

Observations: Sketch and describe air movement from the model



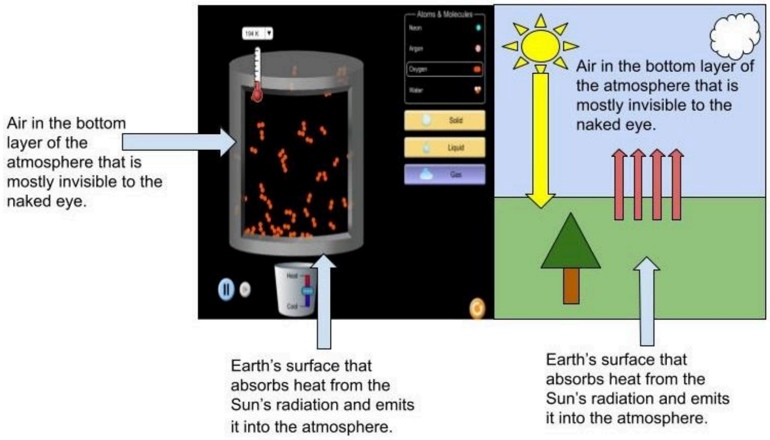
Model of Air Movement

Use the choices in the box on the right to make connections to what the different parts of the model represent in real life.

1 = **2 =** **3 =** **4 =** **5 =**	• **Warm air** • **Air moving across the surface of Earth** • **Very warm land** • **Cool air** • **Very cool land**

See What did you observe?	Think What does each observation make you think?	Wonder What questions do you have about each observation?
What did you notice was happening to the air in the bottle where the air was being heated by ‘warm land’?		
What did you notice was happening to the air in the bottle where the air was being cooled by ‘cool land’?		
Which direction was the air flowing horizontally across the ‘Earth’s surface’?		

Model 2: What effect does heating and cooling have on air molecules?
Recall that heat energy from the Earth's surface is transferred to the air above it which raises the air's temperature. Use this States of Matter Simulator to better understand how changes in temperature affects air.



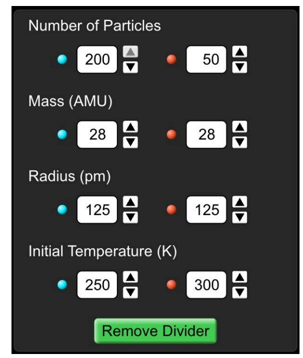
1. From the initial screen, click 'States'.
2. Then click 'oxygen' and 'gas' since we know one molecule in the atmosphere is oxygen in gas form.
3. Cool and heat the air between about 80K and 200K and note observations of what is changing

See **What did you observe?**	**Think** **What does each observation make you think?**	**Wonder** **What questions do you have about each observation?**
What did you notice was happening to the air molecules in the atmosphere as you cooled them?	What does this make you think about the air in the wind model we observed in bottles?	
What did you notice was happening to the air molecules in the atmosphere as you heated them?	What does this make you think about the air in the wind model we observed in bottles?	
What happened to the density of the air molecules at 'Earth's surface' as you cooled them?	What does this make you think about the air in the wind model we observed in bottles?	

What happened to the density of the air molecules at ‘Earth’s surface’ as you heated them?	What does this make you think about the air in the wind model we observed in bottles?	
What happened to the pressure the air molecules were applying at ‘Earth’s surface’ as you cooled them?	What does this make you think about the air in the wind model we observed in bottles?	
What happened to the pressure the air molecules were applying at ‘Earth’s surface’ as you heated them?	What does this make you think about the air in the wind model we observed in bottles?	

Model 3: What causes movement of air across Earth's surface?

1. Open the Diffusion Simulator . We will be recreating model 1 with this simulation so we can see what was occurring at a particle level. Think about the conditions in the left bottle where air was over "cool land" and the conditions where air was over "warm land". Play with the simulation for a couple of minutes to recreate those conditions. Note what you did below.



2. Reset the diffusion simulator and set it to the number of particles (air molecules) and temperature seen in the screenshot.

The mass and radius will stay the same since air molecules are roughly the same mass and radius anywhere in the atmosphere.

3. Which side of the container has more air pressure? Explain your thinking.

4. Make a prediction. What do you think will happen to the movement of air molecules when you remove the divider? Write your prediction below.

5. Test your prediction. Remove the divider and note your observations below.

See **What did you observe?**	**Think** **What does each observation make you think?**	**Wonder** **What questions do you have about each observation?**
In which direction do most of the molecules flow?	Why do you think most air molecules flowed in that direction?	

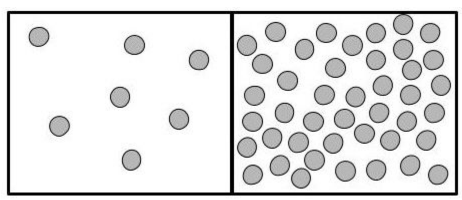
Explaining Wind Formation

Turn to a partner and discuss any ideas you have about the following two questions, then write your ideas in the space below.

- What causes air to sink or rise?
- Why would air molecules move horizontally to create wind?

Movement of Air Molecules Due to Pressure Differences: Respond to the following three questions to check your understanding of how differences in air pressure cause air to move.

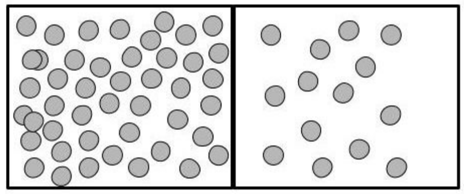
The container below has two sides separated by a wall. The gray dots represent air molecules.



1. Label the side of the container you think has a higher air pressure as 'high pressure'. Then label the side you think has lower air pressure as 'low pressure'. **Be sure to explain your thinking in the space below**.

2. If the wall separating the two sides of the container was removed, in what direction do you think more air molecules would move? **Be sure to explain your thinking in the space below**.

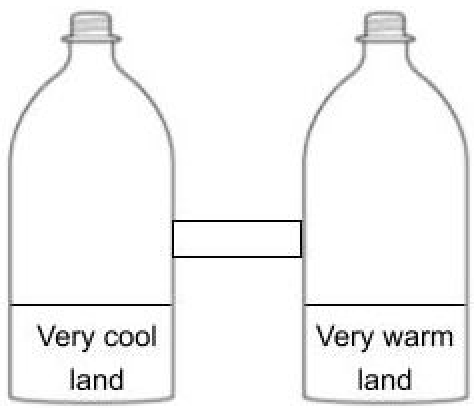
3. Examine the container below. If the wall was removed from each, in what direction do you think more air molecules would move? **Be sure to explain your thinking in the space below**.



What caused the rising and sinking of air in the bottles?

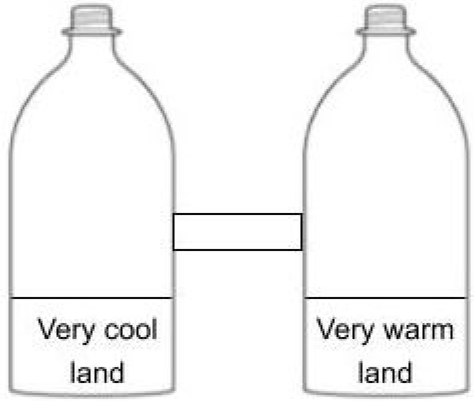
1. Think back to the simulator you were using as you explored how heating and cooling affect air. In which bottle do you think the air molecules are initially further apart due to the difference in heating?

Be sure to make your thinking visible by drawing the air molecules on each side and explaining what you drew in words.



2. Now think about what you know about how density of air affects whether it sinks or rises. On which side was the air rising and on which side was it sinking due to differences in density?

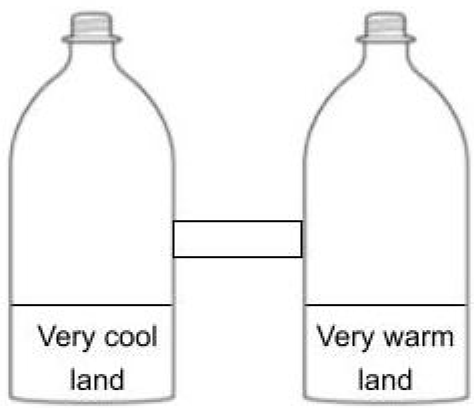
Be sure to make your thinking visible by drawing the air molecules on each side and using arrows to show the movement of the air molecules. Explain your drawing with words.



What caused the air to move horizontally from one bottle to the other?

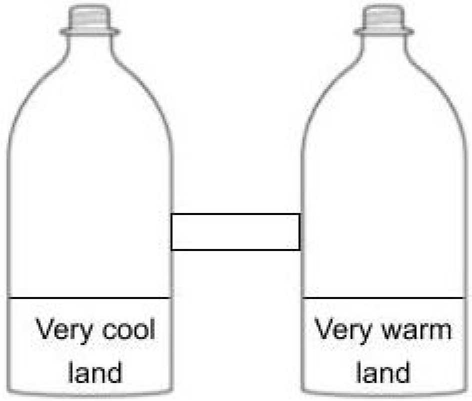
1. What effect do you think the sinking and rising of air had on the air pressure in each bottle?

Be sure to make your thinking visible by drawing the air molecules on each side and explaining what you drew in words.



2. In what direction did the difference in pressure cause the air to flow?

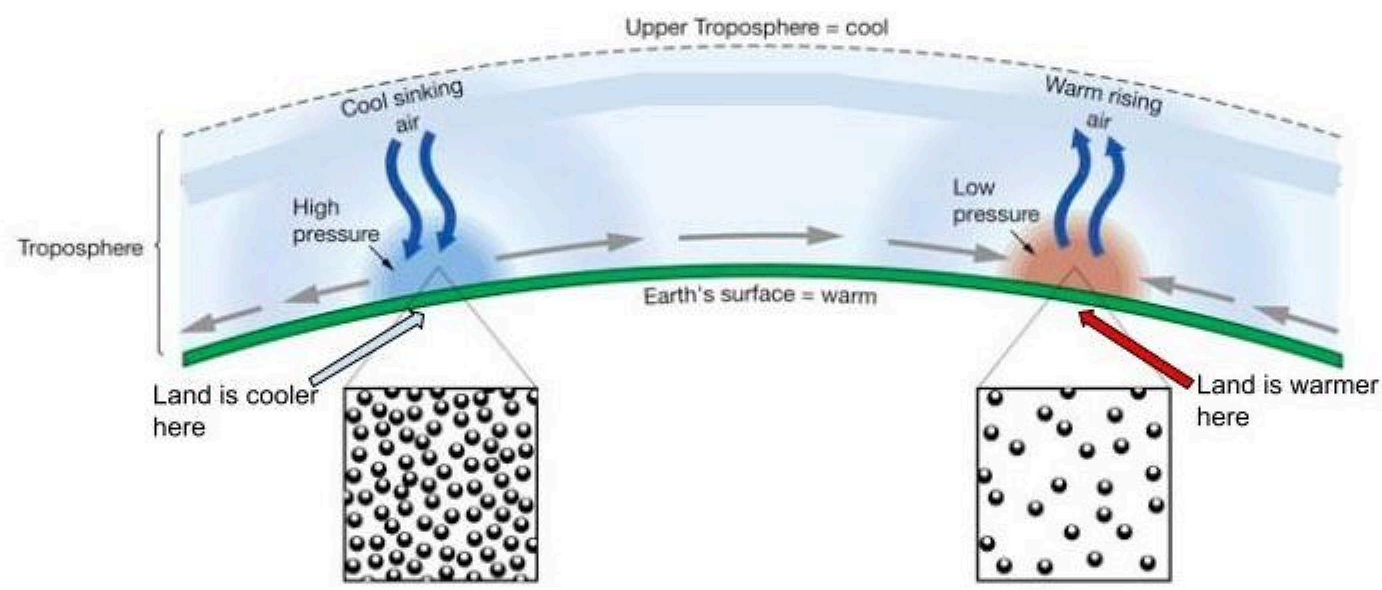
Be sure to make your thinking visible by drawing the air molecules on each side and using arrows to show the movement of the air molecules. Explain your drawing with words.



Explaining Wind from Winter Storm Jonas

Prompt: What causes the wind from Winter Storm Jonas to occur?
You will be participating in a small group discussion with the goal of explaining the movement of air across Earth's surface (wind) shown by the arrows in the diagram below.

1. Before you discuss, independently annotate the diagram by:
    - Labeling things you recognize
    - Explaining things that you know
    - Jotting down remaining questions



2. Based on what you have learned from the previous activities and discussion with your classmates, work in groups to collaboratively develop an explanatory model for the movement of air across Earth's surface (wind), then respond to the three questions that follow.

In your model, be sure to include the following:

- Explain why the warm air is rising. Be sure to depict and describe what is happening to the air molecules.
- Explain why the cool air is sinking. Be sure to depict and describe what is happening to the air molecules.
- Label the high pressure region at the Earth's surface and explain why that region is high pressure. You should be including the concepts of heating/cooling and density.
- Label the low pressure region at the Earth's surface and explain why that region is low pressure. You should be including the concepts of heating/cooling and density.
- Using the concept of pressure, explain why the wind is moving across Earth's surface in the direction shown in the diagram.

Now use your model to construct a causal relationship that could make predictions about future storms.

3. First, identify the dependent variable in the explanatory model. This is the part of the model that would be changed by something else changing; it is dependent on another factor in the system. It is the "effect" of something else.

Write the dependent variable below.

Dependent variable:

---

4. Next, identify the independent variable in the model you developed. This is the part of the model that is driving the change, and it is not dependent on anything else in the system. It is the “cause” of the dependent variable.

Write the independent variable below.

Independent variable(s):

---

5. State the relationship between these two variables.

Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following question, based on what we discussed today:

1. How have we used *mechanisms at a molecular scale* to figure out what causes wind to move across Earth's surface?

2. In what ways did your model of wind formation show how energy and matter interact within the storm system? Describe this at both a large observable scale and at a molecular scale?

3. Making claims about the relationship between independent and dependent variables.

   a. How did you identify the independent and dependent variable in your claim?

   b. Go back and review what you identified as the independent and dependent variables in your claim. In your own words, how did you decide which variable was the independent vs the dependent variable?

Precipitation Formation Investigation

Model 1: Air Masses and Their Interactions
Air in our atmosphere varies in temperature and moisture level. Sometimes large amounts of air will have uniform temperature and moisture levels -- we call these air masses. When air masses of different temperature and moisture levels meet, there are observable patterns in the way they interact and resulting weather.

You will use a simulator to observe and identify patterns when a relatively cold dry air mass interacts with a relatively warm moist air mass.

1. Open the Weather Fronts Simulator . Play the simulator for each of the four types of fronts and record your observations in the table below.

Front Type	Observation of warm air mass	Observation of cool air mass	Observation of resulting weather
Cold Front			
Warm Front			
OccludedFront			
Stationary Front			

2. What patterns did you notice when observing all the fronts? In other words, what were some things you observed when observing all the front types?

Model 2: How Water Behaves in the Air/Atmosphere

How is water vapor different from the rest of the air in Earth's atmosphere?

Procedure:

1. Fill a wide clear plastic cup about 2/3 full of hot tap water.
2. Quickly place a taller clear plastic cup upside down on top of it, so they form a closed container.
3. Watch the cups for 1–2 minutes.
4. Use a magnifier to look at the sides and top of the cup.
5. Take the top cup off and feel the inside surface.

Observations

What did you notice at the surface of the warm water in the bottom cup?	What did you notice on the inside surface of the top cup?	What other observations did you make?

1. What do you think was happening to the hot water in the bottom cup?

2. How do you think the tiny drops of water on the inside of the top cup got there?

How does water temperature affect the amount of vapor in the Earth's atmosphere?

Procedure:

1. Fill one wide clear plastic cup about 2/3 full of hot tap water, one cup about 2/3 full of cold tap water, and one cup about 2/3 full of warm tap water.
2. Quickly place a taller clear plastic cup upside over each cup, as before.
3. Watch the cups for 1–2 minutes.
4. Use a magnifier to look at the sides and top of the cup.
5. Take the top cups off and feel the inside surface.

Observations

What did you notice at the surface of each temperature of water in the bottom cup?	What did you notice on the inside surfaces of each top cup?	What other observations did you make?
Hot water: Warm water: Cold water:		

1. What do you think caused the differences you observed inside the top cups?

2. What does this tell you about the relationship between water in the air and temperature of the water beneath? Explain your response using evidence from the lab.

3. What could you do to water vapor to increase the rate at which it becomes liquid again?

How does air temperature affect the state of water in the atmosphere?

Procedure

1. Fill two wide clear plastic cups about 2/3 full of hot tap water.
2. Quickly place the taller, clear plastic cups (with smaller rims) upside down on each cup, as before.
3. Place a piece of ice on top of one of the cups.
4. Wait 2–3 minutes
5. Remove the ice and dry the place where the ice was with a paper towel.
6. Use a magnifier to examine the tops of the two upper cups.

Observations

Compare the amount of water on the inside surface of the top of each cup. Which top cup has more water on it?	
Diagram and description of outcomes from setup **without** ice on top	Diagram and description of outcomes from setup **with** ice on top

1. Does cooling water vapor increase the rate at which it becomes a liquid? Explain your answer based on your observations.

2. What does this tell you about air's ability to hold water at different temperatures? Does it hold water more effectively at high or low temperatures? Explain your response using evidence from the investigation.

See-Think-Wonder

See **What did you observe?**	**Think** **What does each observation make you think?**	**Wonder** **What questions do you have about each observation?**
What are the characteristics of the different air masses in the fronts simulation?		
What do you observe about the movement of air masses in the fronts simulation?		
What happened to the warm water in the bottom cup?	Consider what you know about how heating affects matter at the molecular level. What do you think explains what you observed?	
What did you observe in the top cup?	Consider what you know about how heating affects matter at the molecular level. What do you think explains what you observed?	

What differences did you observe when the cups had cold, warm, or hot water?	Consider what you know about how heating affects matter at the molecular level. What do you think explains what you observed?	

Explaining Precipitation Formation

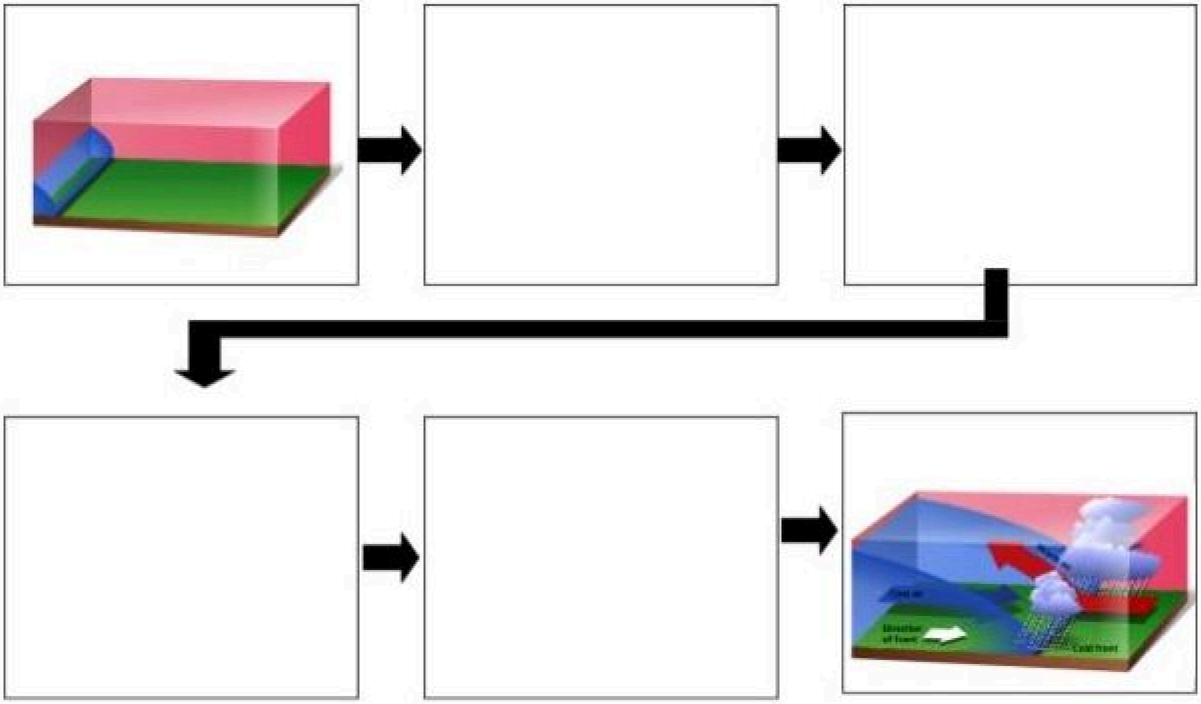
Part 1: Watch ESS.U5.Explain2.VID001 in order to better understand how clouds are part of the water cycle and how the lab you did during the explore phase models cloud formation. **As you watch the video be sure to jot down any connections between the video and the lab you carried out below.**

1. The video mentioned that clouds form through condensation. Why does condensation happen? **Be sure to cite evidence from your lab activity observations.**

2. The video said that water turns into vapor through evaporation. Based on the lab activity, think about the relationship between air temperature, water temperature, and evaporation. Under what conditions does evaporation increase, and what effect would that have on cloud formation?

3. Think about the relationship between altitude and air temperature. Why do clouds tend to form at high altitudes within the troposphere?

Use what you have learned so far about how matter behaves at the molecular level when heated and cooled to create a cause and effect model that explains how clouds formed and why precipitation happens when a **cold dry air mass** interacts with a **warm moist air mass**. Be sure to annotate the storyboard section to ensure your thinking is visible. Use as many boxes as you need to express your ideas clearly; it is ok if you do not need all four empty boxes.



Part 2: Where and When do Blizzards Occur?

We know from experience and our learning in this unit that blizzards occur over much of the United States, but where else in the world do they occur?

You will now use what you have learned so far about blizzards, climate, and seasons to make claims about where and during what time of year blizzards occur around the world.

1. Based on both the simulation and the cups experiment, what kind of air masses are necessary for precipitation (rain or snow) to occur? Below are characteristics of different types of air masses. Select the two types of air masses you think are necessary. Be sure to explain your reasoning.

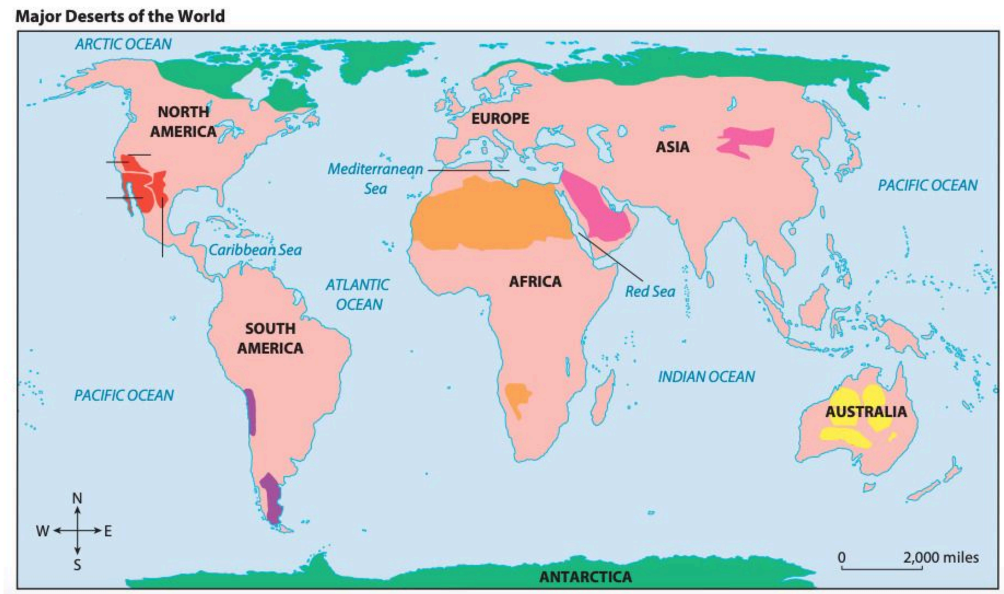
   moist cold air   dry cold air   moist warm air   dry warm air

2. Examine the surface air temperature maps on the following page and compare the temperature of air around the US during the summer to the temperature of the air around the US during the winter. What do you notice?

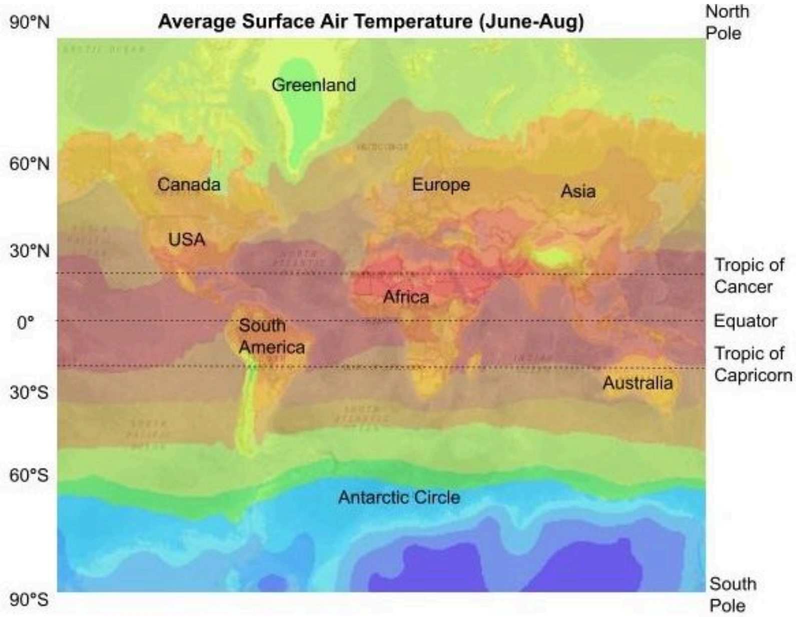
3. The freezing point of water is 32F. Why do you think that most winter storms in the United States occur between November and April in the northern states? Be sure to cite evidence from the maps and explain your reasoning.

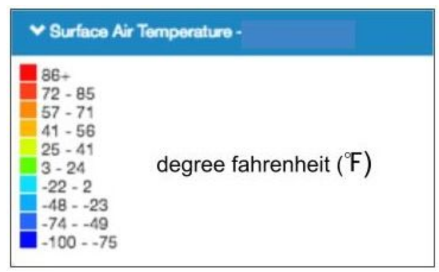
4. Based on the air surface temperature maps and your understanding of what is required for a blizzard to form, where else in the world do you think blizzards occur? During what time of year? Be sure to cite evidence from the maps and explain your reasoning.

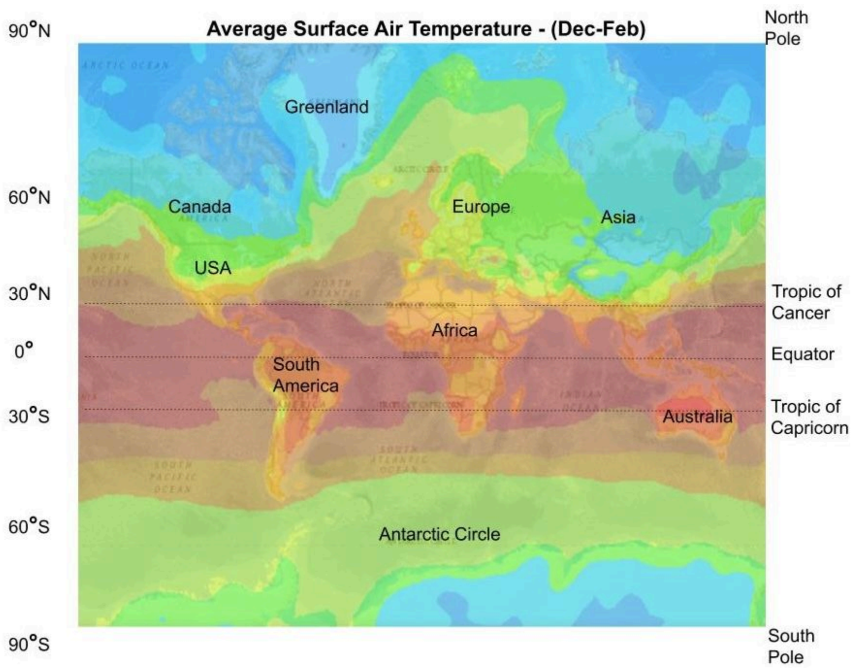
5. There are parts of the arctic circle (shown across the top in green) that are considered a desert, because they only get 4-10 inches of snow every year, even though it is always below freezing. Based on your understanding of how storms form, what factor is missing that prevents blizzards from forming there?



Surface Air Temperature Maps







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What did you learn from this person?

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    a. How did you identify the independent and dependent variable in your claim?

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Identifying Winter Storm Jonas on a Map

Part 1

Representing and Analyzing Air Pressure on a Weather Map
This map shows the sea level pressures for various locations over the contiguous U.S. The values are in whole millibars.

Objective
Using a black colored pencil, lightly draw lines connecting identical values of sea level pressure. Remember, these lines, called isobars, do not cross each other. Isobars are usually drawn for every four millibars, using 1000 millibars as the starting point. Therefore, these lines will have values of 1000, 1004, 1008, 1012, 1016, 1020, 1024, etc., or 996, 992, 988, 984, 980, etc.

Procedure

1. Begin drawing from the 1024 millibars station pressure over Salt Lake City, Utah (UT) (highlighted in blue). Draw a line to the next 1024 value located to the northeast (upper right).

2. Without lifting your pencil, draw a line to the next 1024 value located to the south and then to the one located southwest, finally returning to the Salt Lake City value. Remember, isobars are smooth lines with few, if any, kinks.

The result is an elongated circle, centered approximately over Eastern Utah. The line that was drawn represents the 1024 millibars line and you can expect the pressure to be 1024 millibars everywhere along that line.

3. Repeat the procedure with the next isobar value. Remember, the value between isobars is 4 millibars. Since there are no 1028 millibars values on the map, then your next line will follow the 1020 millibars reports.

4. Continue with the remaining values until you have all the reports connected with an isobar.

5. Label each isobar with the appropriate value. Traditionally, only the last two digits are used for labels. For example, the label on the 1024 mb isobar would be 24. A 1008 mb isobar would be labeled 08. A 992 mb isobar will be labeled 92. These labels can be placed anywhere along the isobar but are typically placed around edges of the map at the end of each line. For closed isobars (lines that connect) a gap is placed in the isobar with the value inserted in the gap.

Analysis
Isobars can be used to identify "Highs" and "Lows". The pressure in a high is greater than the surrounding air. The pressure in a low is lower than the surrounding air.

1. Label the center of the high pressure area with a large blue "H".

2. Label the center of the low pressure area with a large red "L".

High pressure regions are usually associated with dry weather, and low pressure regions usually bring precipitation. Based on what you have learned so far, draw a model that explains this below.

3. Shade, in green, the state(s) where you would expect to see rain or snow.

4. Shade, in yellow, the state(s) where you would expect to see clear skies.

In the northern hemisphere, the wind blows clockwise around centers of high pressure. The wind blows counterclockwise around lows.

5. Draw arrows around the "H" on your map to indicate the wind direction.
6. Draw arrows around the "L" on your map to indicate the wind direction.
7. Check your work. Open the Surface Air Pressure Map Link , and look through the maps. Make sure your final map looks like the final map on the link. If it does not, retrace your steps to find and correct your mistake.

Representing and Analyzing Temperature on a Weather Map
This map shows the air temperature for various locations over the conterminous U.S. The values are in °F.

Objective
Using a blue colored pencil, lightly draw lines connecting equal values of temperatures, every 10°F. Remember, like isobars, these lines (called isotherms) are smooth and do not cross each other.

Procedure
You will draw lines connecting the temperatures, much like you did with the sea-level pressure map. However, you will also need to *interpolate* between values. Interpolation involves estimating values between stations which will enable you to properly analyze a map.

We will begin drawing from the 40°F temperature in Seattle, Washington (WA) (top left value). Since we want to connect all the 40°F temperatures together, the nearest 40°F value is located in Reno, Nevada (NV), (southeast of Seattle). However, in order to get there you must draw a line between a 50°F temperature along the Oregon (OR) coast and a 30°F temperature in Idaho (ID). Since 40°F is halfway between the two locations, your line from Seattle should pass halfway between the 50°F and 30°F temperatures.

1. Place a light dot halfway between the 50°F and 30°F temperatures. This is your interpolated 40°F location.

2. Next connect the Seattle 40°F temperature with the Reno 40°F temperature ensuring your line moves through your interpolated 40°F temperature.

3. Continue connecting the 40°F temperatures until you get to Texas.

Now your line will pass between two values, 60°F and 30°F. Like the last time, you should make a mark between the 60°F and 30°F but this time a 50°F is also to be interpolated in addition to the 40°F.

4. Between the 60°F and 30°F temperatures, place a small dot about 1/3 the distance from the 30°F and another small dot about 2/3 the distance from the 30°F. These dots become your interpolated 40°F and 50°F temperatures.

5. Finish drawing your 40°F isotherm passing through your interpolated 40°F value.

6. Repeat the above procedures with the other isotherms drawn at 10°F intervals. Label your isotherms.

Analysis
Isotherms are used to identify warm and cold air masses and where they meet.
- Shade in blue the region with the lowest temperatures.
- Shade, in red, the region with the warmest air.

2. Check your work. Open the Surface Temperature Map Link , and look through the maps. Make sure your final map looks like the final map on the link. If it does not, retrace your steps to find and correct your mistake.

Representing and Analyzing Dew Point Temperature on a Weather Map
This map shows the dew point temperature for various locations over the conterminous U.S. The values are in °F. Dew point is the temperature to which, if the air cooled to this value, then the air would be completely saturated.

Objective
Using a green colored pencil, lightly draw lines connecting equal values of dew point temperatures, every 10°F. Remember, like isobars, these lines (called isodrosotherms) are smooth and do not cross each other.

Procedure

1. Draw lines connecting the dew point temperatures, much like you did with the air temperature map. However, you will also need to interpolate between values. Interpolation involves estimating values between stations which will enable you to properly analyze a map.

2. Label the values.

Analysis
Isodrosotherms are used to identify surface moisture. The closer the temperature and dew point are together, the greater the moisture in the atmosphere. As the moisture increases so does the chance of rain. Also, since moist air is lighter than dry air, the greater the moisture, the easier for the moist air to lift into the atmosphere resulting in a better chance for thunderstorms. Typically, dew points 70°F or greater have the potential energy needed to produce severe weather.

1. Shade in green the region where dew point temperatures are 70°F or greater.

Check your work. Open the Dew Point Temperature Map Link , and look through the maps. Make sure your final map looks like the final map on the link. If it does not, retrace your steps to find and correct your mistake.

Representing and Analyzing Air Pressure Change on a Weather Map
This map shows change in surface pressure (in whole millibars) during the past three hours at various locations.

Objective
Using colored pencils, you will draw lines connecting equal values of pressure change for every two millibars. These lines are drawn for the -8, -6, -4, -2, 0, +2, +4, +6, +8, etc. values. Remember, like isobars, these lines (called isallobars) are smooth and do not cross each other.

Procedure

1. Using a blue colored pencil, beginning at any +2 value, lightly draw lines connecting equal values of the +2 millibars pressure change. Remember, you will need to interpolate between values to draw your lines correctly and the lines never cross. You should end up with a near oval shape, centered approximately around Kansas and Missouri.

2. Draw the remaining "positive" pressure change value(s) at two millibars intervals.

3. Using a black colored pencil, draw a line connecting the zero (0) line. Remember, this line represents where the air pressure is the same as it was three hours previously. The pressure could have risen then fallen, remained steady or could have fallen then returned to what was observed three hours previously.

4. Finally, using red colored pencils, lightly draw lines connecting equal pressure change values of less than zero (0), in intervals of 2; the air pressure is lower now than three hours previously.

Analysis
Cold fronts are often located in areas where the pressure change is the greatest. The front represents the boundary of different air masses. Cold air is more dense than warm air so when a cold front passes your location, the pressure increases. We analyze pressure change to look for these boundaries. We can also tell where high pressure and low pressure systems are moving by looking where the greatest change is occurring.

1. Shade, in red, the region where the surface pressure change is -4 millibars or less.

2. Shade, in blue, the region where the surface pressure change is +4 millibars or more.

3. Check your work. Open the Air Pressure Change Map Link , and look through the maps. Make sure your final map looks like the final map on the link. If it does not, retrace your steps to find and correct your mistake.

Analyzing a Complete Surface Observation Map

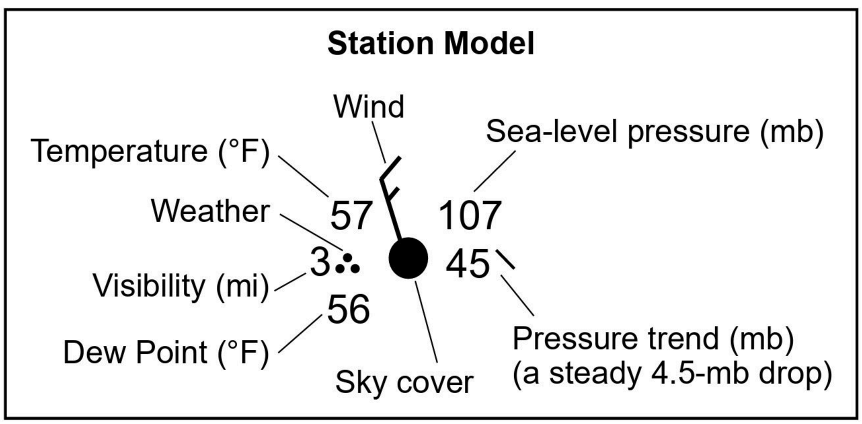
Objective
Now you will use what you have learned so far to analyze a weather map that consists of station models with all data relevant to representing weather conditions and making predictions.

Procedure
At commercial airports throughout the country the weather is observed, measured and recorded. In New York State alone there are over a dozen observation sites. These stations record temperature, dew point, cloud cover, visibility, height of cloud base, amount of precipitation, wind speed,and wind direction to name a few. The measurements are made every hour at every station around the world. This is a very large amount of data, which can be very useful in predicting the weather.

The challenge is that a large amount of data needs to be communicated to every weather station in the US. Because of the lack of space on weather maps, the weather information needs to be coded. In order to do this the information needs to be highly organized and standard throughout the country. By using station models the data can be represented by a symbol or number, and its meaning is easily understood by the location of the symbol or number on the station model.

Reading and Interpreting Weather Station Models:
The diagram below shows a weather station model which shows the weather conditions and variables for a specific area. Read the following to make sure you understand how to represent weather on a station model.

Key to Weather Map Symbols



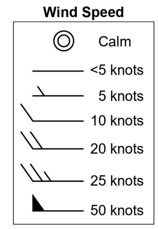
Using the information Key to Weather Map Symbols and the additional images below, annotate and analyze the Complete Surface Observation Map.

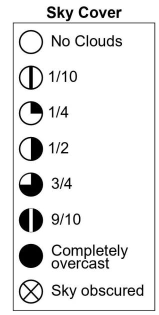
1. Looking at 1. Air Pressure Map and 5. Surface Observations Map, place a red "L" and a blue "H" on the Surface Observation map in the same location as you placed it on your Air Pressure map.

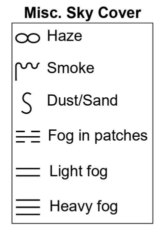
2. Looking at those same maps, circle one air pressure reading (sea-level pressure (mb) on the Key to Weather Map Symbols) on 5. Surface Observations Map, label it as "sea-level air pressure," and write the pressure reading listed on 1. Air Pressure Map.

3. Looking at those same two maps, compare the direction the wind blows around high and low pressure (based on the arrows you drew on the Air Pressure map) with the direction of the staffs on the Surface Observation map. What do you notice? What do you think the direction of the staff tells you?

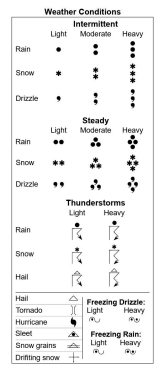
4. Use the Key to Weather Symbols to find how wind speed and direction are noted in the weather map staffs. Looking at 5. Surface Observations Map, how does wind speed relate to high and low pressure areas? Support your answer with evidence from the map and weather symbols key.







5. On the Surface Observations Map, find and label one place where you can see sky cover. Compare the sky cover in the areas with high and low pressure. How are they similar or different? Support your answer with evidence from the map and weather symbols key.



6. On the Surface Observation Map, find and label areas with:
   - Heavy fog
   - Haze or smoke

7. On the Surface Observation Map, find and label areas with
   - Steady rain
   - Freezing heavy drizzle
   - Thunderstorms
   - Tornadoes

8. Compare the weather found in areas of low and high pressure. How are they similar or different? Support your answer with evidence from the map and weather symbols key.

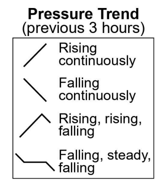
9. On the Surface Observations Map, find and label the dew point at any weather station.

As you know, the boundary between two air masses is called a front. As a result, fast moving cold fronts indicate a rapid change in the weather. Warm fronts also can have large changes in weather but the change is usually not as rapid as with a cold front. On a weather map, fronts are drawn where there are large changes in temperature, changes in wind direction and speed, and between areas where there are large changes in pressure.

1. Use the information provided by the station models around the low-pressure L on the map to draw a cold front, in blue, and a warm front, in red, on the Surface Observation map.

Hint: use the other four maps to help you. You are looking for an area where temperature changes quickly (shown by lines close together on the temperature map), where pressure is changing quickly (shown by loops close together on the changes in air pressure map), that passes through the Low pressure region. The fronts will be moving in the direction of the arrows from the air pressure map.

Check your work. Open the Drawing Conclusions Link , and look through the maps. Make sure your final map looks like the final map on the link. If it does not, retrace your steps to find and correct your mistake.



2. On the Surface Observations Map, find and label the direction of change in air pressure at any weather station. Compare the change in air pressure on each side of the cold front. What do you observe? Support your answer with evidence from the map and weather symbols key.

3. Examine the weather station data on the Surface Observation map. What do you notice about the cloud cover and precipitation under the areas around the cold and warm fronts?

6. Surface Observation Map of Winter Storm Jonas on 1/21/2016

Objective:
Now you will apply what you've learned to identify a progressing storm system on a real weather map.

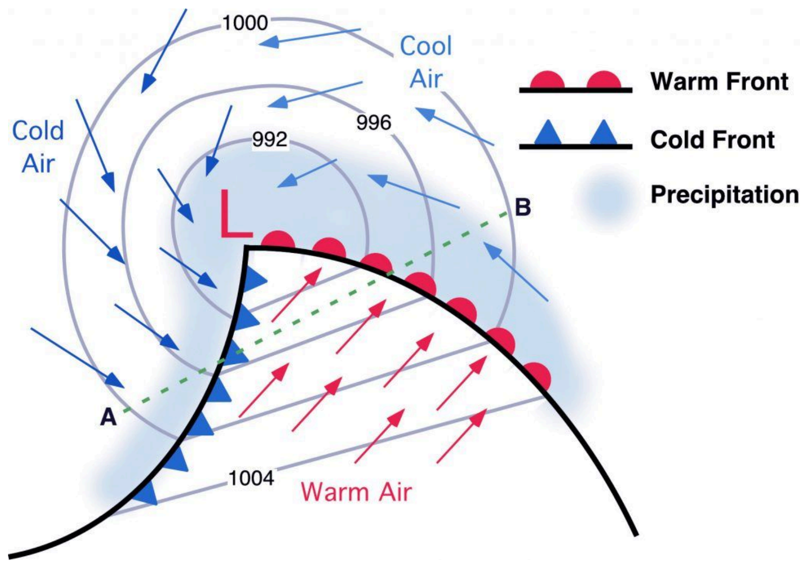
1. Look at the Winter Storm Jonas: Jan 21, 05 UTC - Surface Analysis Map
2. Using what you've learned about pressure systems, winds, and weather map keys, identify and mark at least one region where there is evidence that a low pressure storm is forming. In the space below, describe the characteristics of that location that helped you identify the region.

3. Check your work with your teacher. Were you able to identify a brewing storm? Why or why not?

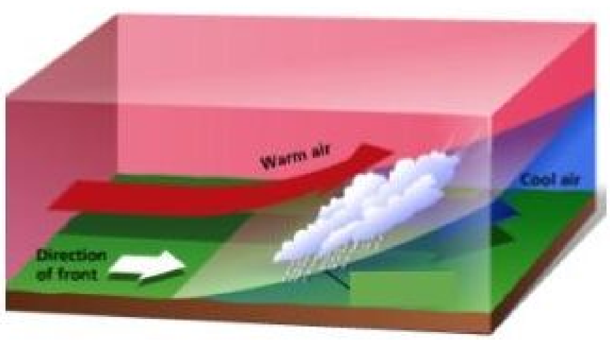
Part 2: Bringing it all together - How did precipitation and wind occur during Winter Storm Jonas?

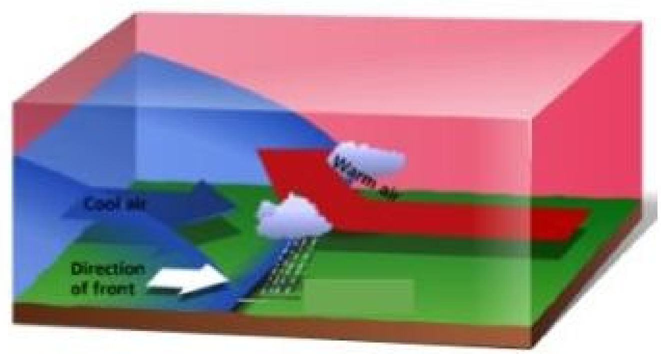
The diagram below provides a map representation of a mid-latitude cyclonic system. You will need to explain the existence and direction of wind, as well as why precipitation is happening at the areas shaded light blue.

Answer the questions below and annotate the diagram in order to provide an explanation that others can easily understand. Be sure to refer to what you have observed and learned from specific activities in class.



First, recall which diagram below shows a warm front, and which shows a cold front. Label each diagram with their symbol.





1. Why is wind occurring here? Be sure to discuss air pressure in your response.

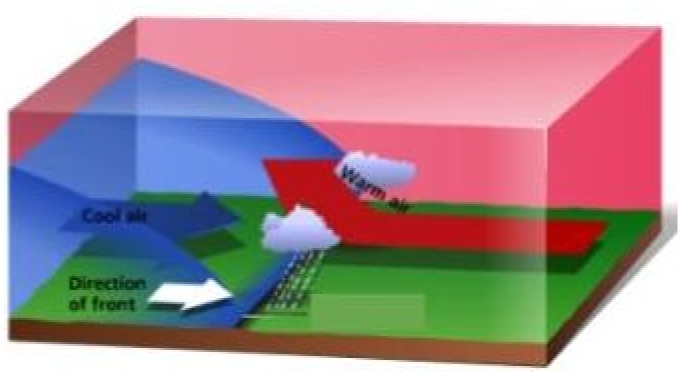
2. Why is the wind moving toward the low-pressure center in a counterclockwise motion as indicated by the diagram?

3. Why is precipitation occurring at the shaded areas?

On January 23rd of 2016, Winter Storm Jonas was at its worst. Use the data table to create a station model for a weather station in NYC during Winter Storm Jonas.

Inches of precipitation	26.60 in 6 hours
Wind speed and Wind Direction	25 mph North East
Temperature	26 F
Dew Point	21 F
Pressure	29.77 in of mercury
Cloud cover	100 %
Type of precipitation (present weather)	Snow
Visibility	.25 miles

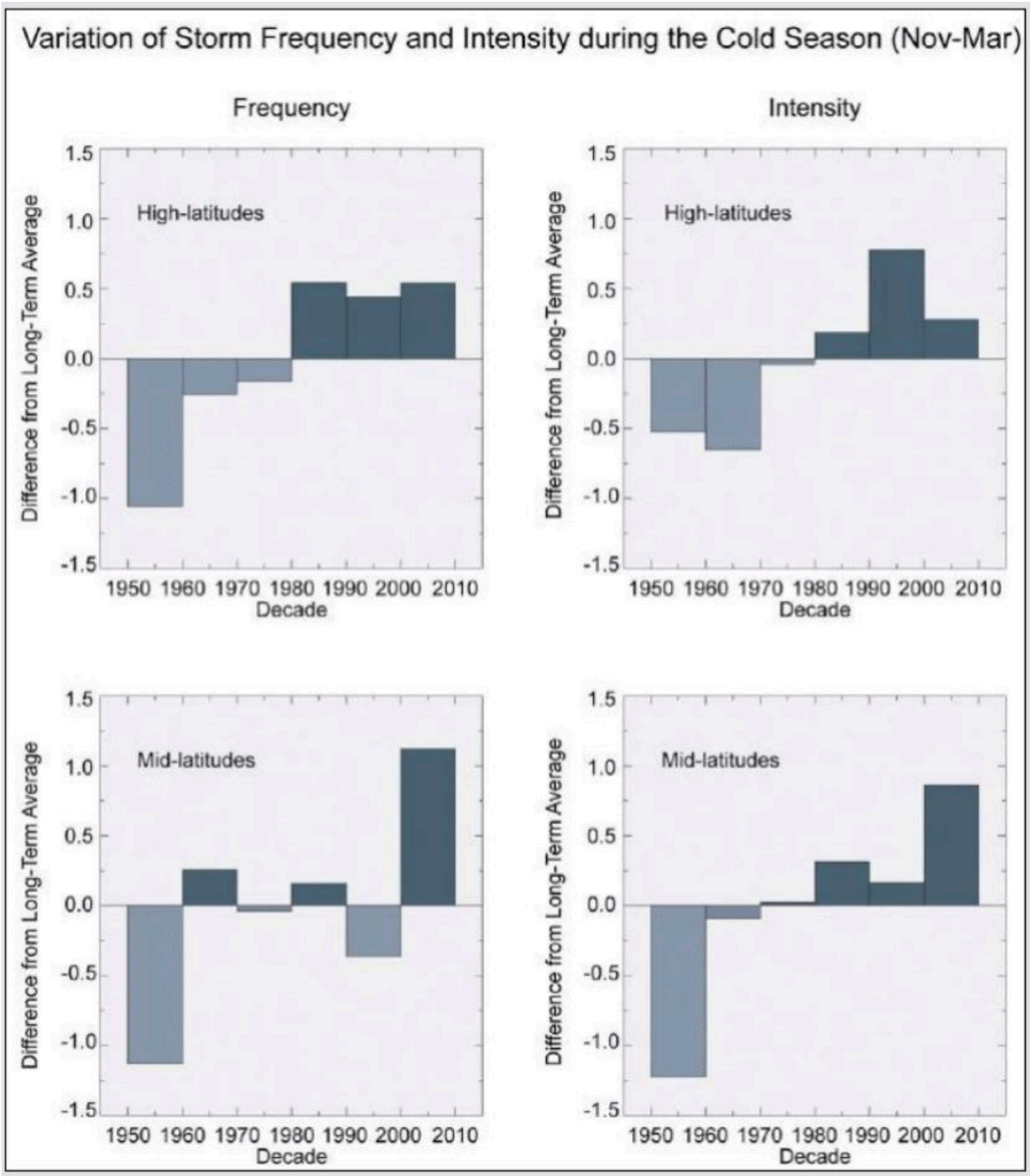
Below complete a station model for Winter Storm Jonas in NYC



What is the Future of Winter Storms?

Part 1: Are winter storms becoming more frequent and stronger?

The graphs below show the frequency of winter storms from Nov-March, between 1950 and 2010. Each bar shows how much less or more the frequency is compared to the average during the time period. Use them to answer the questions on the following page.



Questions:

1. Has the total number of winter storms increased, decreased, or stayed about the same? Is the trend the same for the mid-latitude and high-latitude regions?

2. Has the intensity of winter storms increased, decreased, or stayed about the same? Is the trend the same for the mid-latitude and high-latitude regions?

Part 2: Using Climate Models to Make Predictions About the Future

Now, apply what you have learned in this investigation to making predictions about blizzards in the future. You will do this by

- Reviewing what you know about blizzard formation,
- Analyzing data from a climate model,Evaluating the precision and accuracy of the model.

Reviewing what we know about blizzard formation:

Review the class's ideas from Explain 1 *Explaining Winds from Winter Storm Jonas* and Part 2 of the Explain 2 phase: *Where and When do Blizzards Occur?*

1. What are the two key elements of a winter storm?

2. What factors are required for those elements to occur and a blizzard to form?

3. Where and when do they usually form?

Analyzing Data from a Climate Model: What do global climate models tell us about conditions where blizzards form?

1. Click on this link to visit the IPCC WGI Interactive Atlas and explore future climate change projections in the regions and time of year where we know blizzards form.
2. Click on “season” on the right side of the top toolbar. Use the “customized season” option to select the months you want to view, like November to April
3. Click on the areas of the globe that you want to focus on at that time of year. You can select as many areas as you like.
4. Once you’ve selected at least one region, a line graph will appear in the bottom half of the window.
5. The interactive atlas shows temperature (listed under atmosphere as “mean temperature” in the drop-down list) by default, but you can choose other variables to explore. To do so, click on the “Variable” icon and select whatever other variables you’d like to see. That will change the variable shown on the globe and represented in the line graph.
6. Use what you observe to complete the See-Think-Wonder table below.

See	Think	Wonder
What do you notice about the average air surface temperatures where mid-latitude cyclones occur?	What does this make you think about how frequent and intense blizzards will be in the future?	What questions do you have?

Evaluating Precision and Accuracy of Models

Precision & Accuracy:
Precision refers to the degree of accuracy and consistency in something. In the context of models, precision asks whether the model offers very accurate and dependable results.

To illustrate precision, let's consider a straightforward example. Imagine a machine designed to measure the weight of apples. If this machine consistently displays the same weight for a specific apple (let's say it's expected to weigh 100 grams, and the machine consistently shows 100 grams), we can affirm that the machine is precise. In other words, the results it provides are remarkably similar each time you weigh an apple.

Precision in models can be enhanced when the model is based on a wide range of reliable data sets. When multiple data sets consistently support the model's predictions or calculations, it strengthens the precision of the model. This is akin to having several machines that all consistently measure the same weight for an apple, further ensuring the precision of the results.

1. Click on any of the regions in the map that allows you to pull up the graph for any variable. How many models, which are all based on different data sets, is the IPCC WGI Interactive Atlas based on?

2. How does the number of models the IPCC WGI Interactive Atlas is based on enhance its precision?

Blizzards 5E Arguing from Evidence Rubric

Component	Developing	Proficient
Claim & Evidence	Provides a claim and evidence that includes **some** of the elements below: • An appropriate claim is identified • At least 2 sources of relevant evidence are provided • Evidence supports the claim • If appropriate, evidence that refutes the claim is included and clearly indicated	Effectively and clearly provides a claim and evidence that includes **all** of the elements below: • An appropriate claim is identified • At least 2 sources of relevant evidence are provided - **including**: historical winter storm frequency data & relevant data from global climate models, such as projections of future temperatures • Evidence supports the claim • If appropriate, evidence that refutes the claim is included and clearly indicated
Scientific Reasoning & Logic	Effectively and clearly provides scientific reasoning and logic that includes **some** of the elements below: • An explanation of the conditions necessary for a winter storm to form is used to link the evidence to the claim. • Includes a logic statement that links the evidence to the claim (including words such as because and therefore) • If appropriate, an idea or concept is used to refute or question the claim	Effectively and clearly provides scientific reasoning and logic that includes **all** of the elements below: • An accurate explanation of the conditions necessary for a winter storm to form is used to link the evidence to the claim. • Includes a logic statement that links the evidence to the claim (including words such as because and therefore) • If appropriate, an idea or concept is used to refute or question the claim
Evaluation of claims, evidence, and reasoning	A lens is used to understand and/or evaluate the scientific concept and how it relates to the evidence and/or claim with **some** of the following components: • An explanation of how cause and effect and/or systems & system models is used to defend the strength of the claim, evidence, or how the scientific concept links the claim and the evidence.	A lens is used to understand and/or evaluate the scientific concept and how it relates to the evidence and/or claim with **all** of the following components: • An explanation of how cause and effect and/or systems & system models is used to defend the strength of the claim, evidence, or how the scientific concept links the claim and the evidence.

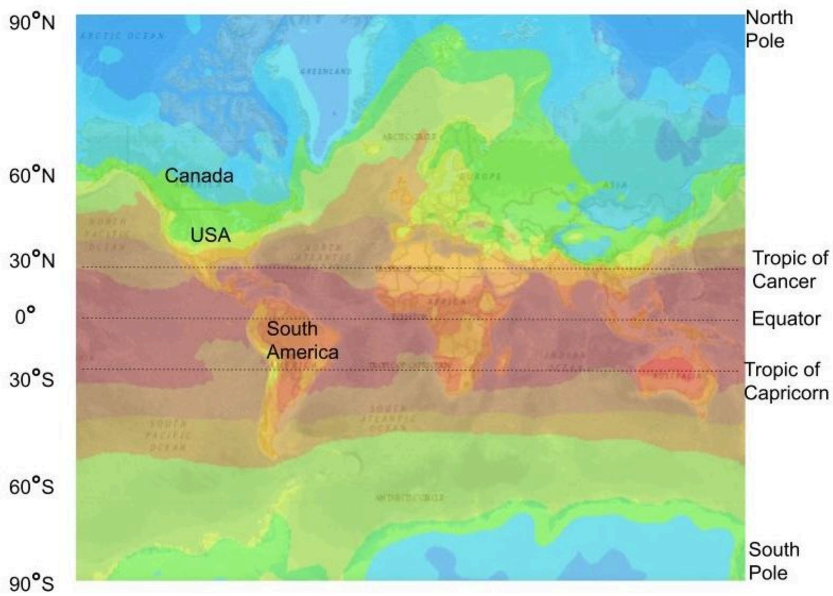
Student Self-Evaluation Circle one			**Teacher/Peer Evaluation** Circle one		
Evidence	Developing	Proficient	**Evidence**	Developing	Proficient
Reasoning	Developing	Proficient	**Reasoning**	Developing	Proficient
Evaluation	Developing	Proficient	**Evaluation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		

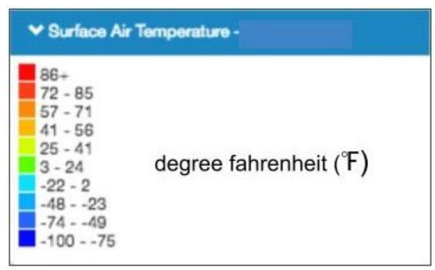
The Paths of Severe Storms 5E

Unit 5 More Hurricanes and Blizzards in NYC?	Earth and Space Science
Student Name:	

Air Masses Investigation

Global Average Surface Air Temperature Data
Examine the map of the world with different colors representing average temperatures across the globe in January. The legend below the map indicates a temperature range that corresponds to each color.





1. What patterns do you see in the temperature and latitude data?

How does energy received from the Sun vary on Earth?

1. Use the simulator Explore the Effect of the Angle of Incidence on Sun's Energy to investigate how the energy received from the Sun varies on Earth. For this activity, you can leave the 'select month' box on March. Record your observations in Table 1.

Table 1: Energy from Sun

Location	**Energy from the Sun** Watts per meter squared (W/m^2)	**Energy received on Earth** Watts per meter squared (W/m^2)
North Pole		
Tropic of Cancer		
Equator		
Tropic of Capricorn		
South Pole		

2. What patterns do you notice in the 'Energy from the Sun' data and the 'Energy on Earth' data?

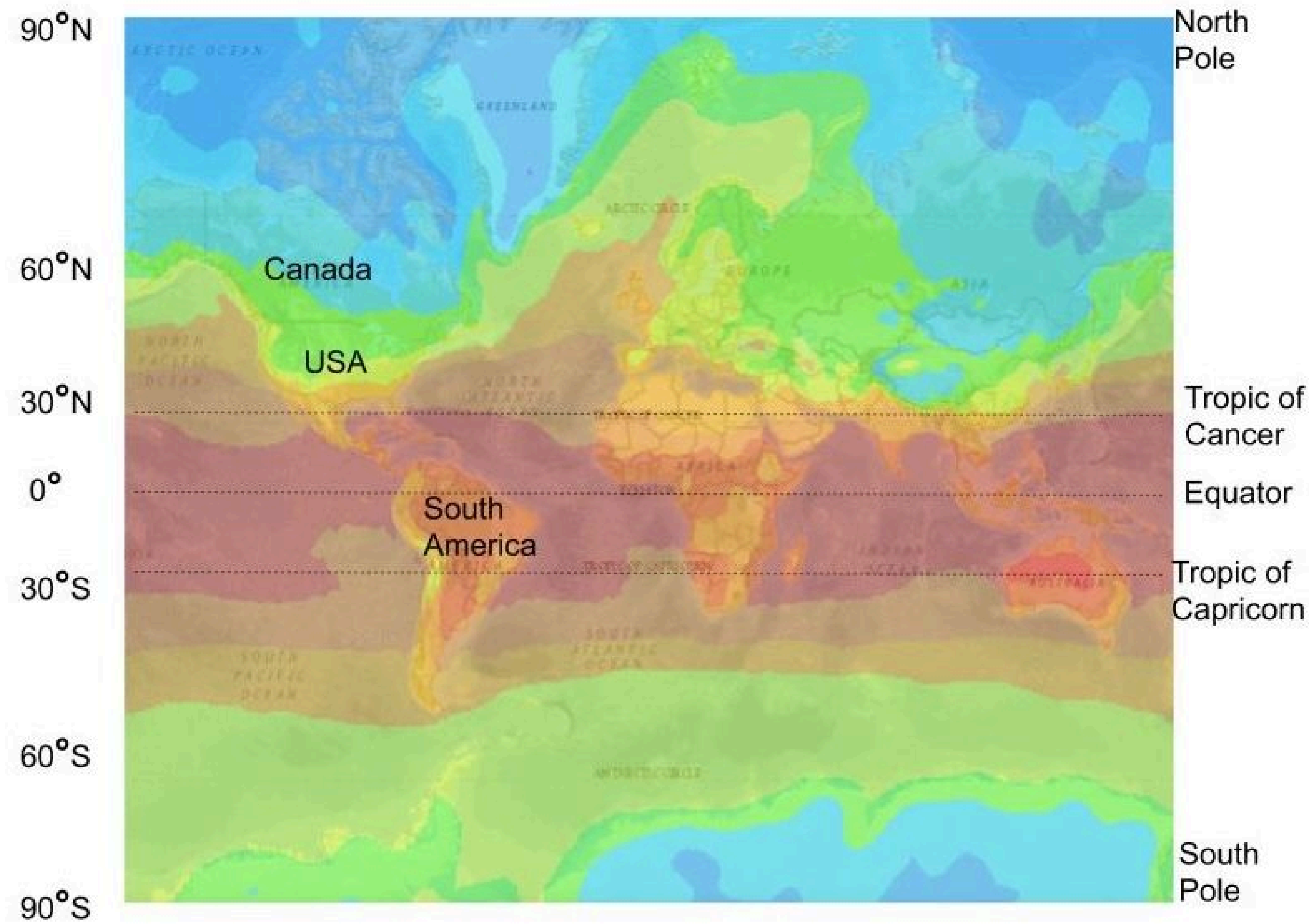
3. Continue to make observations of the way sunlight hits the Earth at different locations and pay close attention to the spread of sunlight. What patterns do you notice?

4. Do you see any connections between the patterns in spread of sunlight and the data that you recorded about Energy on Earth in the table above?

See-Think-Wonder

See **What did you observe?**	**Think** **What does each observation make you think?**	**Wonder** **What questions do you have about each observation?**
What pattern(s) did you notice in the global average temperature data?	What do you think explains the pattern(s)?	
What pattern(s) did you notice in the amount of energy received at different parts of the globe?	What do you think explains the pattern(s)?	
What pattern(s) did you notice in the spread of sunlight at different parts of the globe?	What do you think explains the pattern(s)?	

Part 1: What explains the surface air temperature patterns you observed?



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In Table 2 below, copy the Energy on Earth Data from the Explore phase and use the Global Average Temperature map to fill in the last column on the right.

Table 2

Location	**Energy received on Earth** Watts per meter squared (W/m^2)	**Average temperature range** degree fahrenheit (°F)
North Pole		
Tropic of Cancer		
Equator		
Tropic of Capricorn		

South Pole		

1. What is the relationship between energy received on Earth and Average temperature range?

2. What explains the differences in energy received on Earth and across the globe? Be sure to consider the way you observed the sunlight hitting the Earth. If it helps, feel free to revisit the interactive diagram you used during the Explore phase.

Part 2: What causes the characteristics of different air masses?

Defining Air Masses: Air masses are very large parcels of air that have the same temperature and moisture level throughout them. They develop in different regions around the world where the atmosphere is relatively stable, and they take on the moisture and temperature characteristics of that region. Below is a list of different types of air masses and what they are called.

Types of Air Masses
- Continental Tropical (dry and warm)
- Maritime Polar (moist and cold)
- Continental Polar(dry and cold)
- Maritime Tropical (moist and warm)

1. Summarize the key ideas about air masses in your own words:

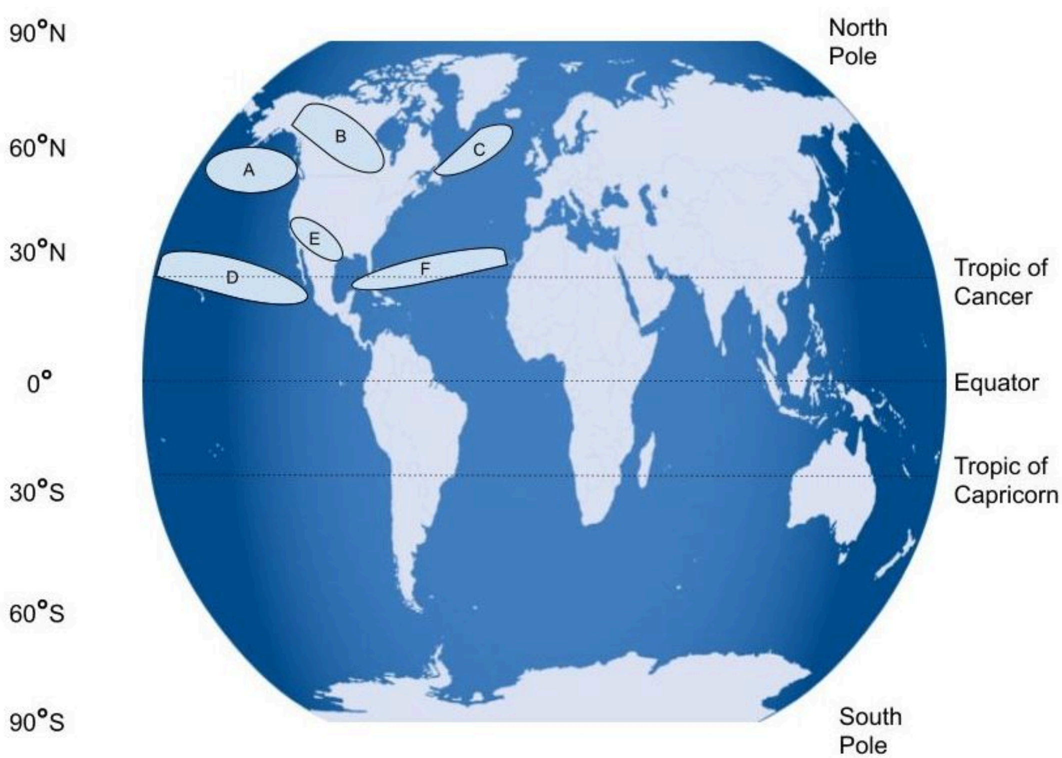
____

____

____

____

The map below shows regions where air masses that affect US weather the most develop. In the *Claims About the Origin of Air Masses* table on the following page, match each of the regions labeled A-F with the characteristics of air masses that you think would develop in that region. Your evidence should come from:
- patterns you noticed when observing the global temperature map
- patterns you noticed when observing the interactive diagram that shows the amount of energy received from solar insolation across the globe
- the map below

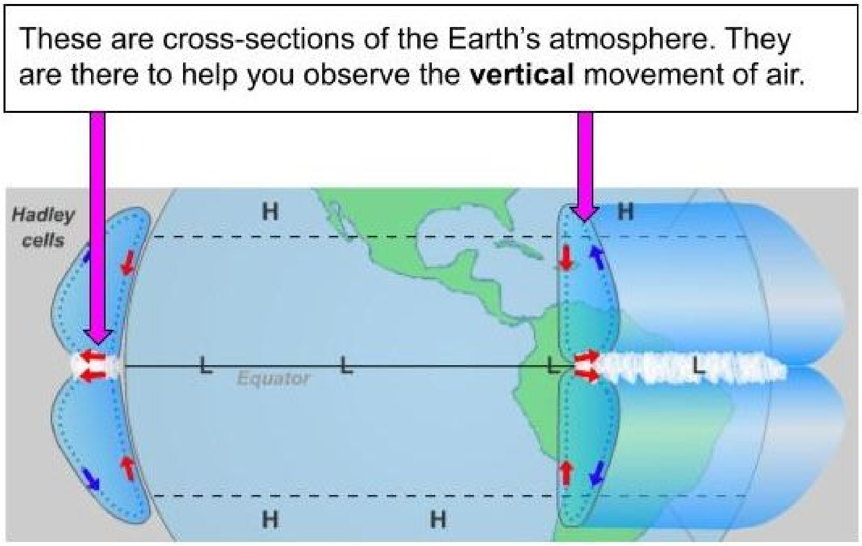


Claims About the Origin of Air Masses

Air Mass Characteristics	**Claim** *Which region(s) produces air masses with these characteristics?*	**Evidence** *What evidence do you have?*	**Reasoning** *What science concept connects the evidence to the claim?*
Continental Tropical (dry and warm)			
Maritime Polar (moist and cold)			
Continental Polar (dry and cold)			
Maritime Tropical (moist and warm)			

Explore 2: Global Movement of Air Investigation

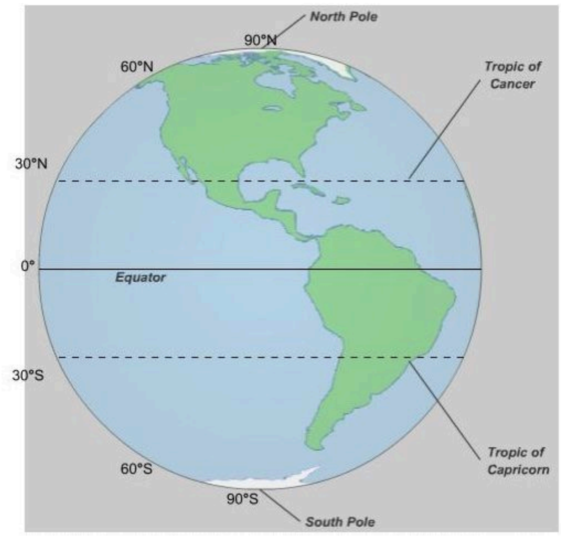
Part 1. What patterns of air flow do we see on a global scale?



1. Click the Global Winds Animation to open a video of an animation of air flow on a global scale. As you watch the video, draw your observations in the diagram below and fill in the see-think-wonder table.

2. Observe as the video shows the 'Idealized Hadley Cell Circulation.' Record your observations in the diagram and table.
3. Watch as the video clicks the buttons 'Develop Tropical and Midlatitude Components' and 'Develop High Latitude Components' on the left. Draw your observations on Diagram 1 on the previous page, then fill out the See-Think-Wonder organizer below.

Diagram (Model) 1



See What are your observations?	**Think** What inferences can you make based on your observations?	**Wonder** What questions do you want to investigate further?
What patterns do you see in the movement of air when the video shows the idealized Hadley Cell Circulation?	What do you think explains these patterns?	
What patterns do you see in the movement of air when the video shows the midlatitude and high latitude components?	What do you think explains these patterns?	

4. Complete Table 3 based on your observations from the video and the *Cross Section Model of Earth's Lower Atmosphere* below . You may need to refer to the video again to complete the table.

Cross Section Model of Earth's Lower Atmosphere

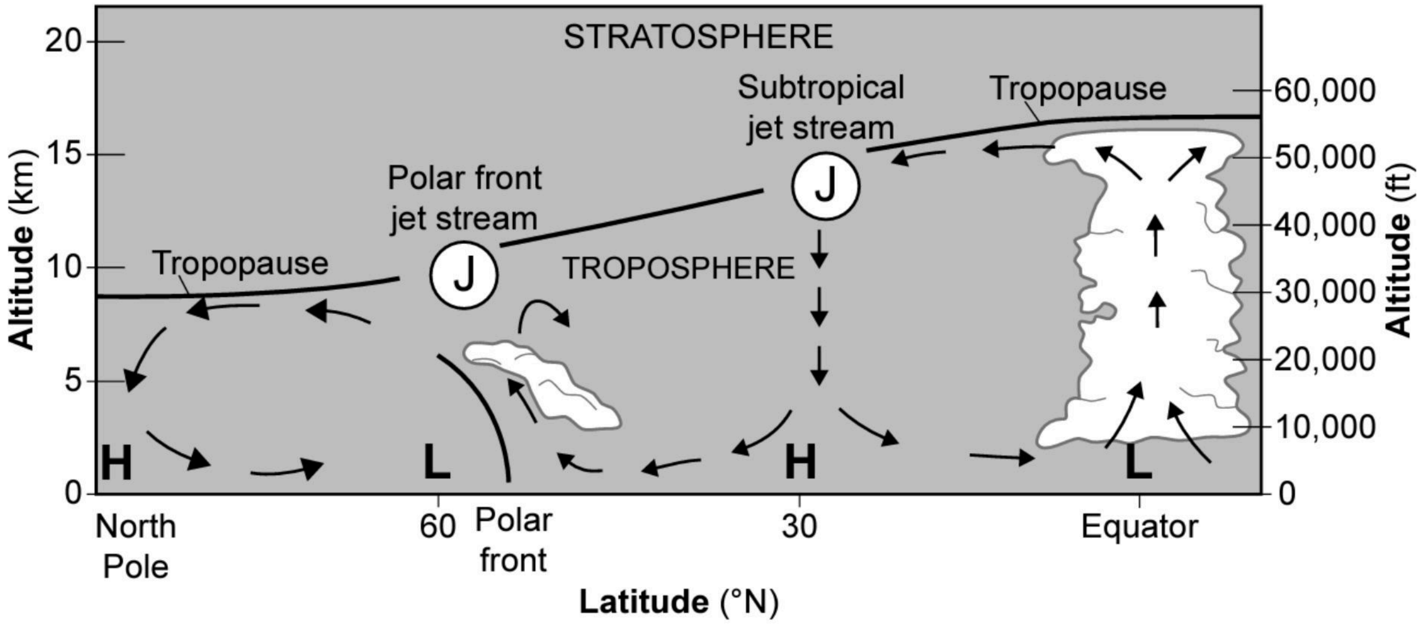


Table 3: Global Winds

Latitude	**Winds** Does the air on Earth's surface collide or move apart here?	**Vertical Movement** Is the air rising or sinking?	**Pressure** High or Low?	**Precipitation** Wet or Dry?
North Pole				
60° N				
30° N				
Equator				
30° S				
60° S				
South Pole				

5. Fill out the See-think-Wonder organizer below Table 3.

See What are your observations?	**Think** What inferences can you make based on your observations?	**Wonder** What questions do you want to investigate further?
What patterns do you see in relationships between variables in the table?	What do you think explains these patterns?	

Part 2.
Why does air curve as it travels north and south?
Using a model to explain why global winds bend

Materials (per each student pair)
1 Balloon (round)
3 Permanent Markers (different colors; visible when applied to balloons)

Procedure

1. Blow up a balloon.
2. With a marker, draw the equator on the balloon midway between the knot and the top of the balloon. Label the top North Pole and the knot South Pole.
3. Hold the balloon at eye level, by the knot, and rotate it left to right, simulating the rotation of the earth.
4. While 1 partner rotates the earth balloon, the other examines the movement of the earth from the North Pole perspective and from the South Pole perspective. Answer questions 1 and 2.
5. While 1 partner continues to rotate the balloon steadily from left to right, the other slowly tries to draw a line straight from the North Pole, south to the equator, using a second marker. While the earth continues to rotate, 1 partner tries to draw a straight line from the South Pole, north to the equator. Answer questions 3 and 4.

Analysis of Observations Questions

1. As you look from the North Pole toward the equator, is the balloon spinning clockwise or counterclockwise?

2. As you look from the South Pole toward the equator, is the balloon spinning clockwise or counterclockwise?

3. What happened when you tried to draw a straight line from the North Pole to the equator?

4. Which direction did the line bend towards?

5. What happened when you tried to draw a straight line from the South Pole to the equator?

6. Which direction did the line bend towards?

7. Predict what would happen if you again drew lines in the northern and southern hemispheres but with the earth rotating in the opposite direction.

8. How does what you observed in the model explain why wind bends the way you observed in the video?

Reliability of the Model Questions

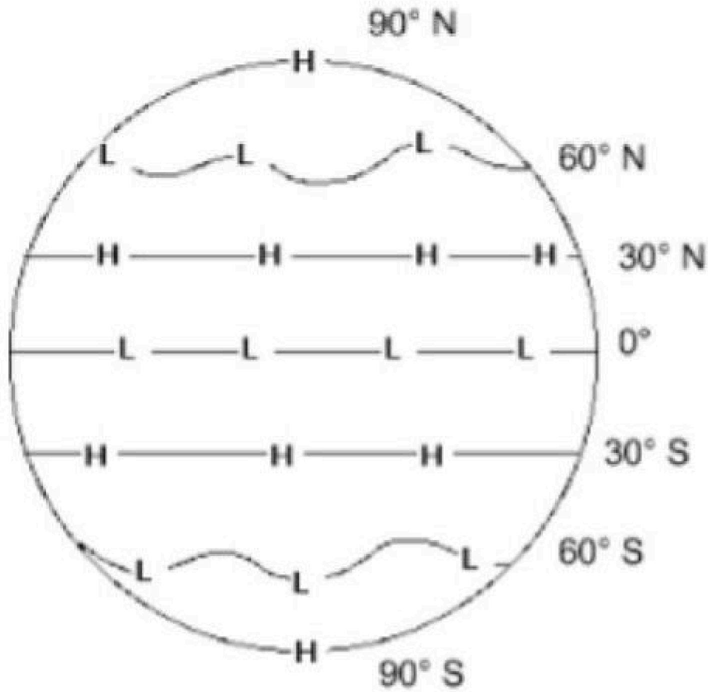
1. The model uses a balloon in place of the Earth. What differences are there between the surface of the balloon and the surface of the Earth?

2. You were using the balloon model to explain why wind bends in different directions during global circulation. Do you think the balloon model works well enough for that purpose? Explain your thinking?

3. What assumption do you have to make in order to be confident that the balloon is a reliable model for the purpose of determining why tropical cyclones spin in different directions? Explain your thinking.

Explaining Global Wind Patterns

Part 1: Explaining High and Low Pressure Bands at Earth's Surface on a Global Scale
The diagram to the right shows the high and low pressure bands at Earth's surface that you should have observed during the Explore phase.



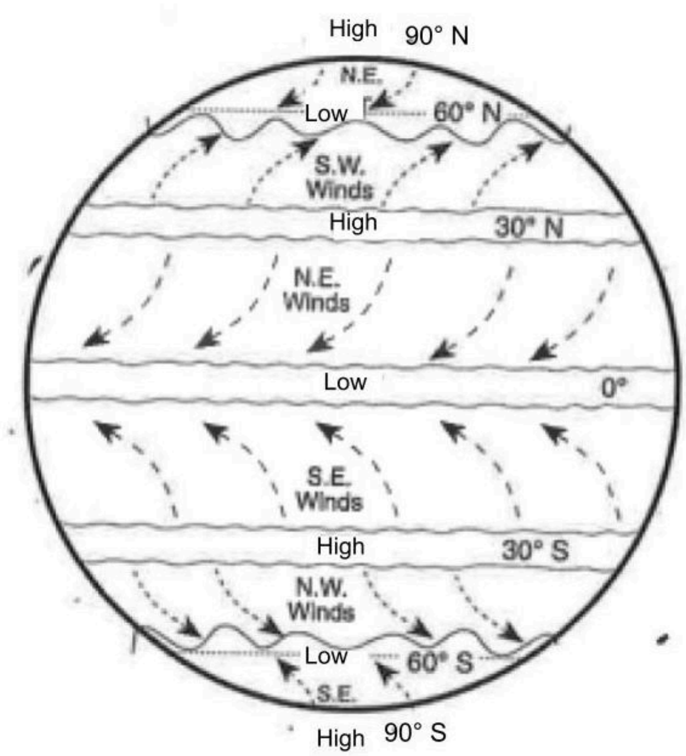
1. Why is the air pressure low at the surface of 0°, 60°N, and 60°S? Provide your claim, evidence, and scientific reasoning in the table below.

Claim	Evidence	Reasoning
	What pattern from Table 3 is evidence that supports your claim?	What are the science concepts you have learned that link your evidence to your claim?

2. Why is the air pressure high at the surface of 30°N, 30°S, 90°N and 90°S? Provide your claim, evidence, and scientific reasoning in the table below.

Claim	Evidence	Reasoning

Part 2: Explaining the General Direction of Wind at Earth's Surface on a Global Scale
The diagram below shows the general direction of wind at Earth's surface, which you should have observed during the Explore phase.



1. Why does the wind at Earth's surface tend to move in the north/south directions indicated in the diagram? Provide your claim, evidence, and scientific reasoning in the table below. You can annotate the diagram to make your thinking more visible.

Claim	Evidence	Reasoning

	What pattern from Table 3 is evidence that supports your claim?	What are the science concepts you have learned that link your evidence to your claim?

2. Why does the wind at Earth's surface tend to move in the east/west directions indicated in the diagram? Provide your claim, evidence, and scientific reasoning in the table below. You can annotate the diagram to make your thinking more visible.

Claim	Evidence	Reasoning
	What pattern from Explore 2 is evidence that supports your claim?	What are the science concepts you have learned that link your evidence to your claim?

Part 3. Explaining Winds In Local Storm Systems

As we discussed, the tendency of wind to appear to bend in specific directions is due to the coriolis effect. Not only does this impact global winds, but this bending phenomenon also has impacts on winds in local low pressure storm systems. Follow the steps below to visualize the movement of winds during a storm.

1. Review the directional bends to wind:

In the northern hemisphere, wind appears to bend towards the

____

In the southern hemisphere, wind appears to bend towards the

____

2. On the right, there is an L representing a low pressure area.

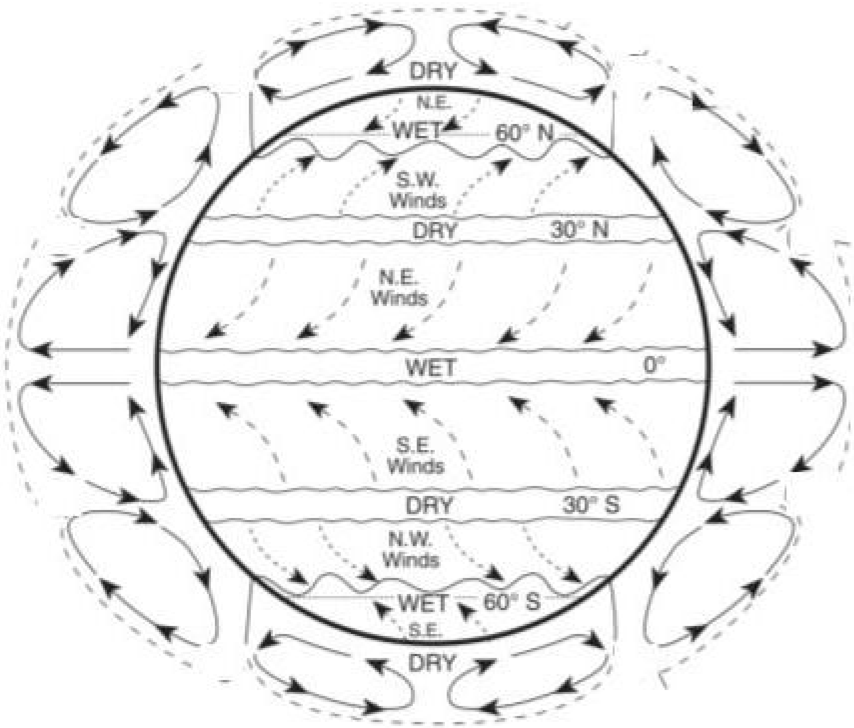
L

3. Does wind move towards or away from low pressure zones?
4. Draw at least 5 arrows all around the low pressure zones, moving in that direction.
5. At the end of each arrow point, draw another arrow in the direction that wind bends towards in the Northern hemisphere
6. What overall shape do the arrows create?

7. Summarize: based on what you've seen here, explain why tropical cyclones appear to form counterclockwise spirals in the Northern hemisphere.

Predict: how do you think tropical cyclones would behave differently in the Southern hemisphere, and why?

Part 4: Explaining Patterns of Precipitation on a Global Level
The diagram below shows 'Wet' bands where a lot of precipitation falls and 'Dry' bands at Earth's surface.



1. Why do the 'Wet' latitudes tend to experience a great deal of precipitation? Provide your claim, evidence, and scientific reasoning in the table below. You can annotate the diagram to make your thinking more visible.

Claim	Evidence	Reasoning
	What pattern from Table 3 is evidence that supports your claim?	What are the science concepts you have learned that link your evidence to your claim?

2. Why do the 'Dry' latitudes tend to experience very little precipitation? Provide your claim, evidence, and scientific reasoning in the table below. You can annotate the diagram to make your thinking more visible.

Claim	Evidence	Reasoning

1. What limitations are there in the models we have looked at so far? How are these models different from the real globe? What are they ignoring?

2. How do you think winds might behave differently on Earth than they do in the model? Explain your reasoning.

Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following question, based on what we discussed today:

1. In the models the class developed, what science concepts were most useful in explaining what causes global wind and precipitation patterns?

2. How will you consider your response to the previous question when developing models for other phenomena?

Elaborate Part 1: Explaining Patterns of Storm Origin and Trajectories

Use the storm trajectory maps and the global wind map below to respond to the following two questions..

1. Use what you have learned about how winter storms form, the origin of different types of air masses, and global wind patterns at different latitudes to explain why so many winter storms form over the US.

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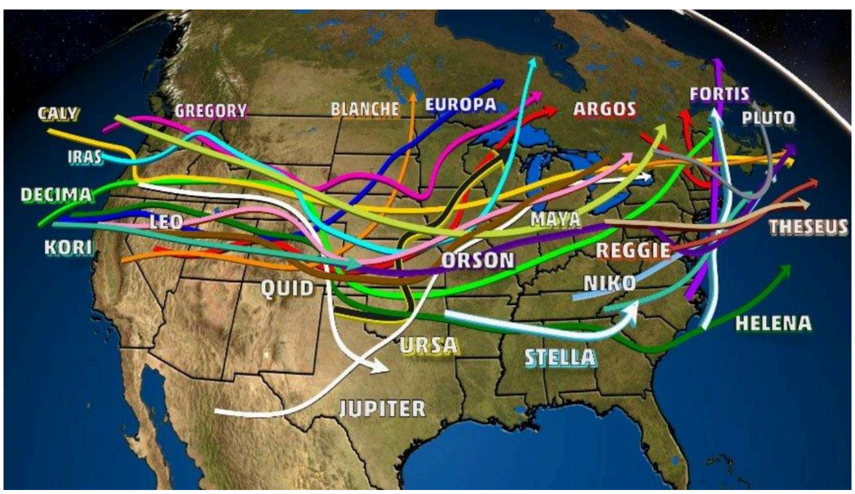
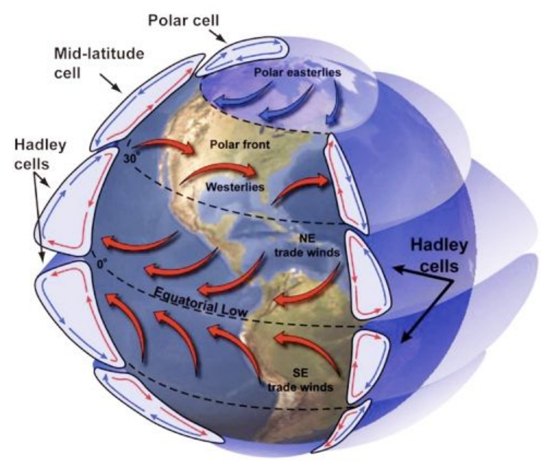
2. Use what you have learned about global wind patterns at different latitudes and the images below to explain the path of blizzards over the US.

2016-2017 US Winter Storms



Global Winds



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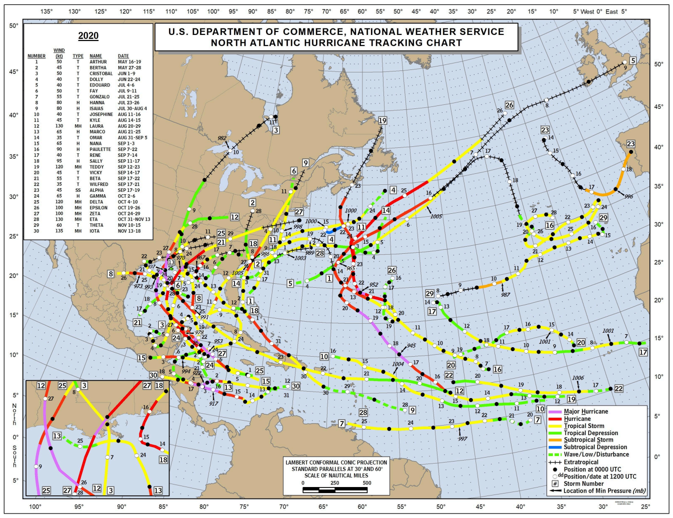
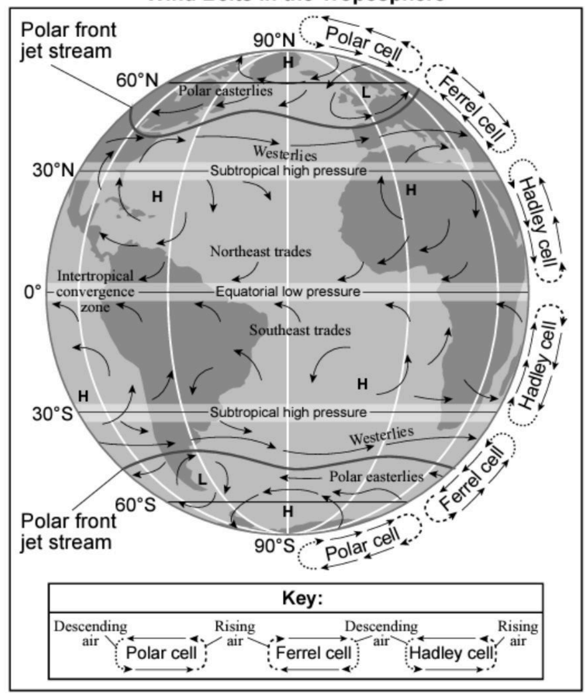
3. Use what you have learned about global wind patterns at different latitudes and the images below to explain the path of hurricanes in the North Atlantic and Eastern US.

2020 Atlantic Tropical Storms



Model of Generalized Planetary Wind Belts in the Troposphere



Elaborate Part 2: Making Predictions about the Trajectory of Winter Storm Jonas

What is Your Two Day Forecast for the Movement of Winter Storm Jonas?
Revisit the weather map you analyzed to identify Winter Storm Jonas during the Evaluate phase of the last 5E plan.

1. Use what you have learned about surface wind patterns on a global scale to predict where you think Winter Storm Jonas was located 2 days later.
2. Mark the location you predict on your map.
3. Ask your teacher to provide you with a weather map of the US at 3 UTC on Jan 23, 2016 and check your prediction. How close was your prediction?

What is Your Forecast for the Movement of Winter Storm Jonas Over the Next Several Hours?

1. Look at the location of Winter Storm Jonas at 3 UTC (Coordinated Universal Time) on Jan 23, 2016. Examine the direction and strength of wind along its cold front. Based on the direction and strength of wind around the cold front, make a prediction about where on the map Winter Storm Jonas will be located 6 hours later (9 UTC on Jan 23, 2016).
2. Mark the location you predict on your map.
3. Ask your teacher to provide you with a weather map of the US at 9 UTC on Jan 23, 2016 and check your prediction. How close was your prediction?

4. Look at the location of Winter Storm Jonas at 9 UTC on Jan 23, 2016. Examine the direction and strength of wind along its cold front. Based on the direction and strength of wind around the cold front, make a prediction about where on the map Winter Storm Jonas will be located 6 hours later (15 UTC on Jan 23, 2016).
5. Mark the location you predict on your map.
6. Ask your teacher to provide you with a weather map of the US at 15 UTC on Jan 23, 2016 and check your prediction. How close was your prediction?

Reliability of Our Predictions

1. How close were your predictions overall?

2. Which predictions were easier to make? Why?

How will global wind patterns be affected by rising global temperatures?

Apply what you have learned in this investigation to making predictions about blizzards and hurricanes in the future. You will do this by analyzing a climate model, and then evaluating how confident you are about the reliability of the model.

As you read the research article on the following page, consider the following questions:

- What is the claim researchers are making about global wind and precipitation patterns in the future?
- What is the model they are basing their claims on?
- What assumptions are the researchers making in order to use that model to make their claim?
- Based on the diagram in the article, how many degrees might the westerlies move, if they followed the historic pattern?

CLIMATE, EARTH SCIENCES, PRESS RELEASE

Will Global Warming Bring a Change in the Winds? Dust from the Deep Sea Provides a Clue.

BY MARIE DENOIA ARONSOHN |JANUARY 6, 2021

From the Columbia Climate School, State of the Planet

The westerlies—or westerly winds—play an important role in weather and climate both locally and on a global scale, by influencing precipitation patterns, impacting ocean circulation and steering tropical cyclones. So, finding a way to assess how they will change as the climate warms is crucial.

Typically, the westerlies blow from west to east across the planet's middle latitudes. But scientists have noticed that over the last several decades, these winds are changing, migrating poleward. Research suggests this is because of climate change. But, scientists have been debating whether the poleward movement of the westerlies will continue as temperatures and atmospheric carbon dioxide (CO2) increase further under future warming scenarios. It's been difficult to resolve this scientific question because our knowledge of the westerlies in past warm climates has until now been limited.

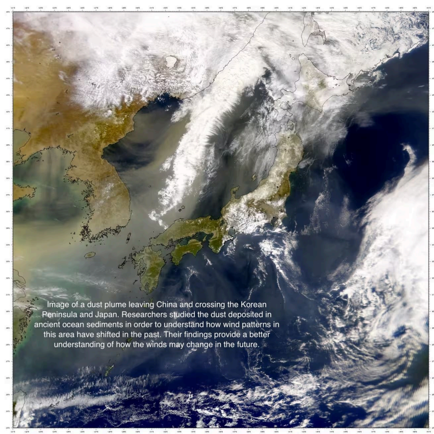


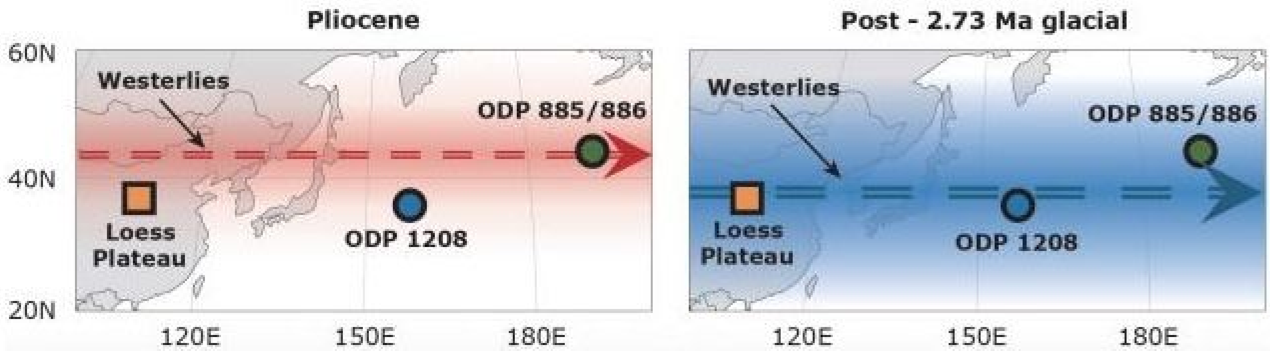
Image of a dust plume leaving China and crossing the Korean Peninsula and Japan. Researchers studied the dust deposited in ancient ocean sediments in order to understand how wind patterns in this area have shifted in the past. Their findings provide a better understanding of how the winds may change in the future.

In a paper published January 6 in *Nature*, climate researchers from Columbia University's Lamont-Doherty Earth Observatory describe a new method of tracking the ancient history of the westerly winds—a proxy for what we may experience in a future warming world. The lead author, Lamont graduate student Jordan Abell and his advisor, Gisela Winckler, developed a way to apply paleoclimatology—the study of past climate—to the question of the behavior of the westerly winds, and found evidence suggesting that atmospheric circulation patterns will change with climate warming.

The finding represents a breakthrough in our understanding of how the winds changed in the past, and how they may continue to change in the future.

By using dust in ancient, deep sea sediments as an indirect tracer of wind, the researchers were able to reconstruct wind patterns that occurred three to five million years ago. Knowing that winds—in this case the westerlies—transport dust from desert regions to faraway locations, the authors examined cores from the North Pacific Ocean. This area is

downwind from Eastern Asia, one of the largest dust sources today and a known dust-generating region for the past several million years. By measuring the dust in cores from two different sites thousands of kilometers apart, the researchers were able to map changes in dust, and in turn the westerly winds.
"We could immediately see the patterns. The data is so clear. Our work is consistent with modern observations, and suggests that wind patterns will change with climate warming," said Abell.
They found that during the warm parts of the Pliocene (a period three to five million years ago, when the Earth was about two to four degrees Celsius warmer than today but had approximately the same concentration of CO_2 in the air as we do now), the westerlies, globally, were located closer towards the poles than during the colder intervals afterwards.



The researchers found that during the warm parts of the Pliocene (3-5 million years ago), the westerlies were located closer to the poles. The image on the right shows how the westerlies moved toward the equator during colder intervals afterward. Recent observations indicate that as the planet warms due to climate change, the westerlies are once again shifting poleward. Credit: Abell et al., 2021

"By using the Pliocene as an analogue (model) for modern global warming, it seems likely that the movement of the westerlies towards the poles observed in the modern era will continue with further human-induced warming," explained Winckler.
The movement of these winds have huge implications for storm systems and precipitation patterns. And while this research does not indicate exactly where it will rain more or less, it confirms that the wind and precipitation patterns will change with climate warming.
"In the Earth history record, tracking down movements of wind and how they've changed, that's been elusive because we didn't have a tracer for it," said Winckler. "Now we do."
Robert Anderson from Columbia University's Lamont-Doherty Earth Observatory and Brown University's Timothy Herbert were co-authors on this study.

Use what you have learned from the article to respond to the guiding questions.

1. What is the claim researchers are making about global wind patterns in the future?

2. What is the model they are basing their claims on?

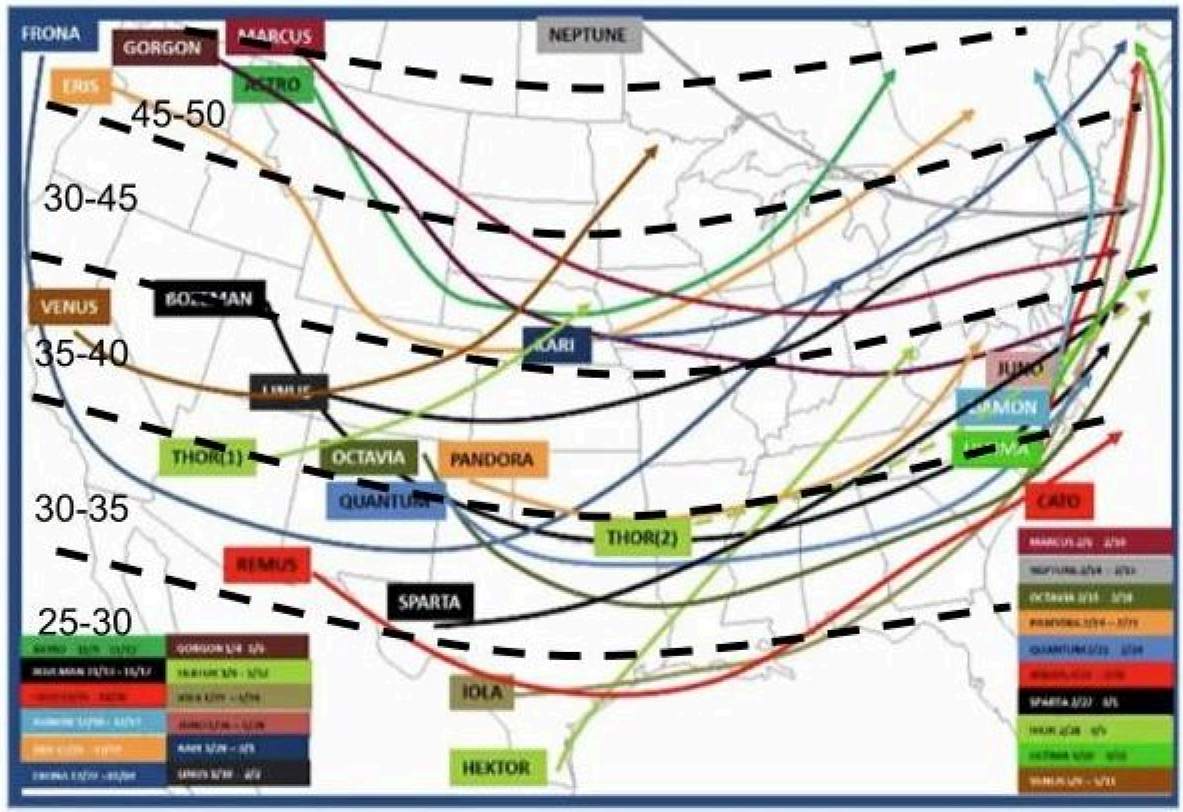
3. What assumptions are the researchers making in order to use that model to make their claim?

4. Based on the diagram in the article, how many degrees might the westerlies move, if they followed the historic pattern?

After looking at the maps below, answer the questions that follow in order to estimate the impact of moving westerlies on the quantity of storms reaching your state.

1. Observe the four maps below. Each map shows the winter storms for a specific year. The maps are labeled with approximate latitude lines.
2. For each map, rank the latitude bands from most to fewest storms
3. Then, imagine that the westerlies shift 5 degrees upwards, moving the storms with them. To do so, imagine that each stripe of storm bands has moved upwards one position.
4. Now rank the bands from most to fewest storms again.

2014-2015



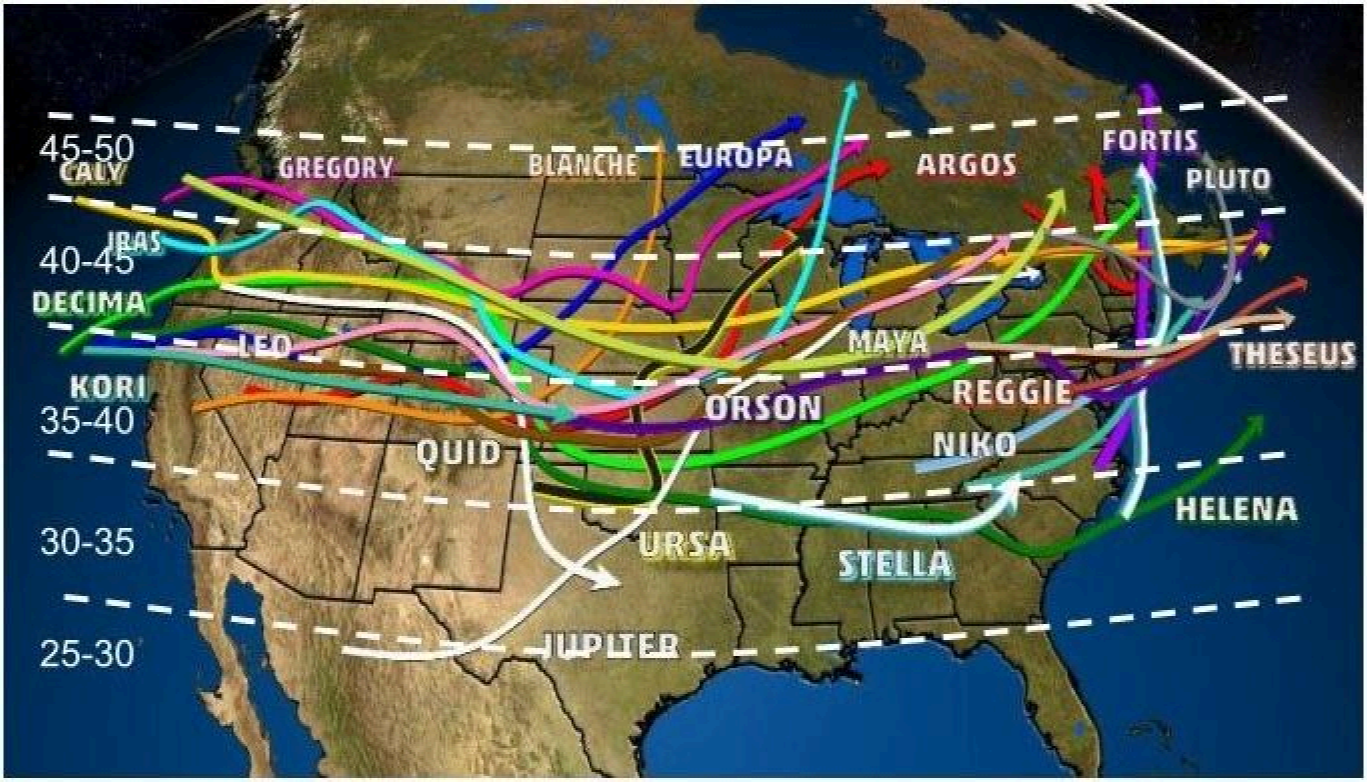
1. Looking at where the storms appear on the map, rank the latitude bands from most storms to least storms.

Most	Second Most	Middle	Second Least	Least

2. Imagine that the storms all move one latitude band north. Where would there be the most storms now? Re-rank the latitude bands from most to least storms.

Most	Second Most	Middle	Second Least	Least

2016-2017



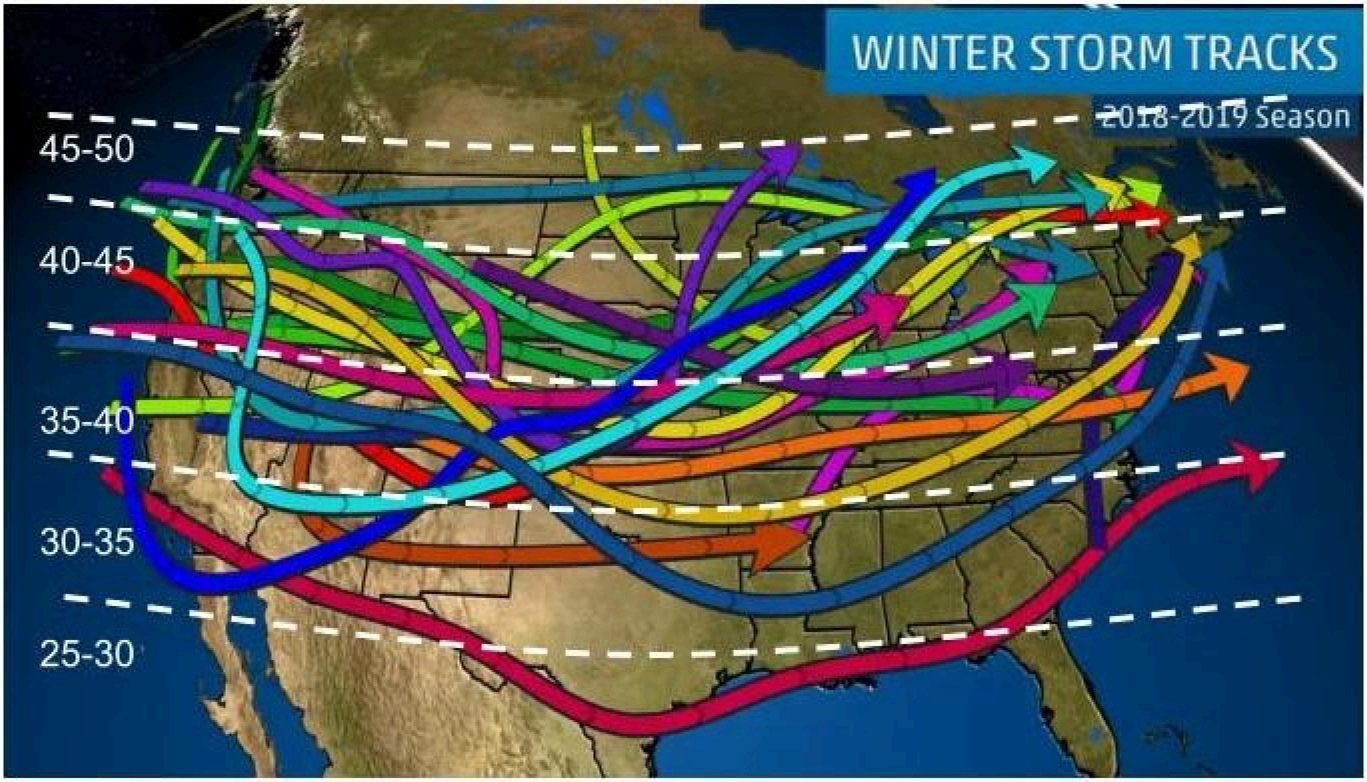
1. Looking at where the storms appear on the map, rank the latitude bands from most storms to least storms.

Most	Second Most	Middle	Second Least	Least

2. Imagine that the storms all move one latitude band north. Where would there be the most storms now? Re-rank the latitude bands from most to least storms.

Most	Second Most	Middle	Second Least	Least

2018-2019

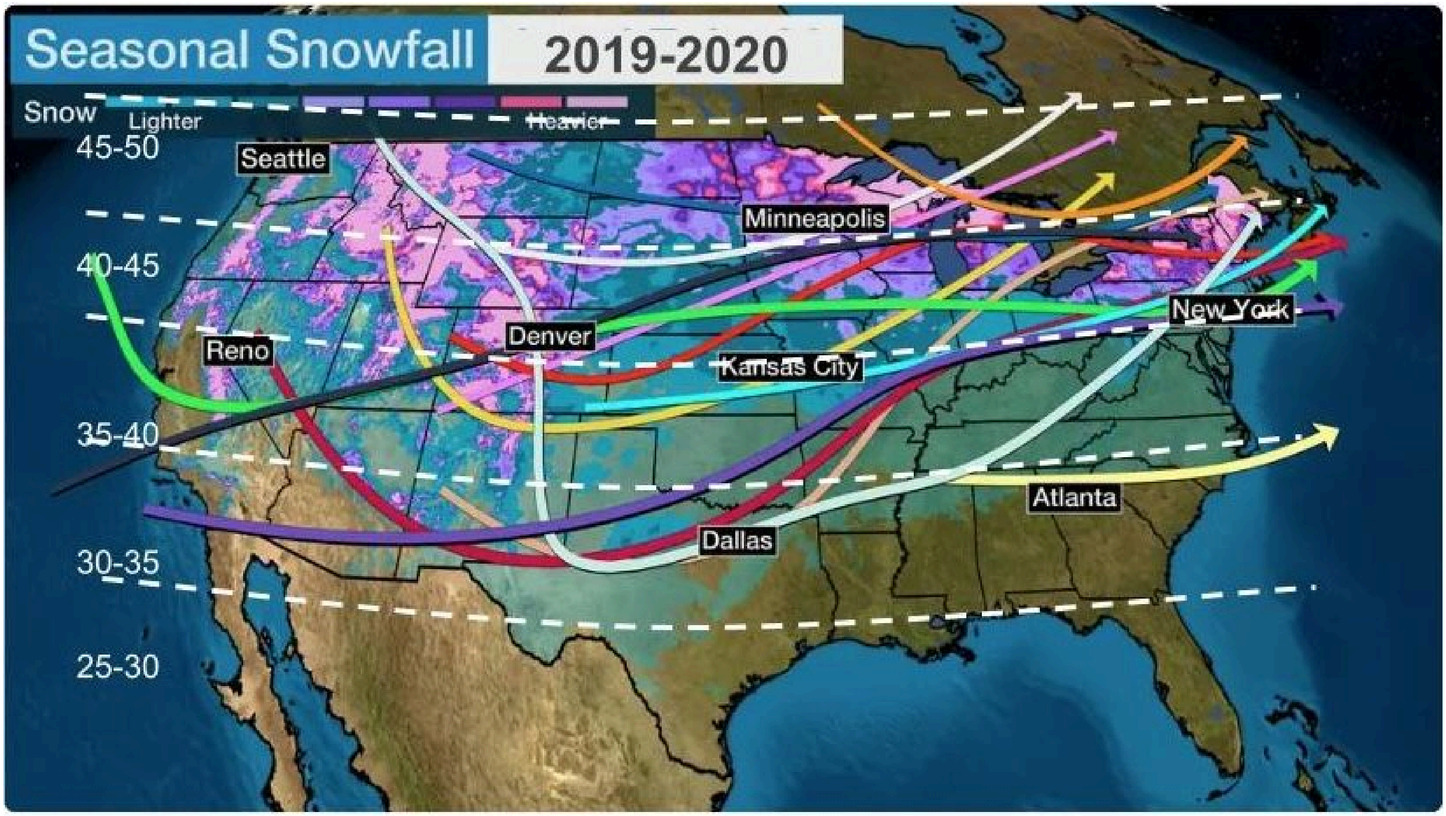


1. Looking at where the storms appear on the map, rank the latitude bands from most storms to least storms.

Most	Second Most	Middle	Second Least	Least

2. Imagine that the storms all move one latitude band north. Where would there be the most storms now? Re-rank the latitude bands from most to least storms.

Most	Second Most	Middle	Second Least	Least



1. Looking at where the storms appear on the map, rank the latitude bands from most storms to least storms.

Most	Second Most	Middle	Second Least	Least

2. Imagine that the storms all move one latitude band north. Where would there be the most storms now? Re-rank the latitude bands from most to least storms.

Most	Second Most	Middle	Second Least	Least

Analyze the data:

1. Overall, what pattern do you see in which latitudes will receive more storms and which will receive less?

2. Look up the latitude of your school or home. How will your area be impacted if the westerlies move northwards 5 degrees, bringing the storms with them?

Evaluate: The Paths of Severe Storms 5E Arguing from Evidence Rubric

Component	Developing	Proficient
Claim & Evidence	Provides a claim and evidence that includes **some** of the elements below: • An appropriate claim is identified • At least 2 sources of relevant evidence are provided • Evidence supports the claim • If appropriate, evidence that refutes the claim is included and clearly indicated	Effectively and clearly provides a claim and evidence that includes **all** of the elements below: • An appropriate claim is identified • At least 2 sources of relevant evidence are provided - **including**: historical winter storm frequency data & relevant data from global climate models, such as projections of future temperatures • Evidence supports the claim • If appropriate, evidence that refutes the claim is included and clearly indicated
Scientific Reasoning & Logic	Effectively and clearly provides scientific reasoning and logic that includes **some** of the elements below: • An explanation of the conditions necessary for a winter storm to form is used to link the evidence to the claim. • Includes a logic statement that links the evidence to the claim (including words such as because and therefore) • If appropriate, an idea or concept is used to refute or question the claim	Effectively and clearly provides scientific reasoning and logic that includes **all** of the elements below: • An accurate explanation of the conditions necessary for a winter storm to form is used to link the evidence to the claim. • Includes a logic statement that links the evidence to the claim (including words such as because and therefore) • If appropriate, an idea or concept is used to refute or question the claim
Evaluation of claims, evidence, and reasoning	A lens is used to understand and/or evaluate the scientific concept and how it relates to the evidence and/or claim with **some** of the following components: • An explanation of how cause and effect and/or systems & system models is used to defend the strength of the claim, evidence, or how the scientific concept links the claim and the evidence.	A lens is used to understand and/or evaluate the scientific concept and how it relates to the evidence and/or claim with **all** of the following components: • An explanation of how cause and effect and/or systems & system models is used to defend the strength of the claim, evidence, or how the scientific concept links the claim and the evidence.

Student Self-Evaluation Circle one			**Teacher/Peer Evaluation** Circle one		
Evidence	Developing	Proficient	**Evidence**	Developing	Proficient
Reasoning	Developing	Proficient	**Reasoning**	Developing	Proficient
Evaluation	Developing	Proficient	**Evaluation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		

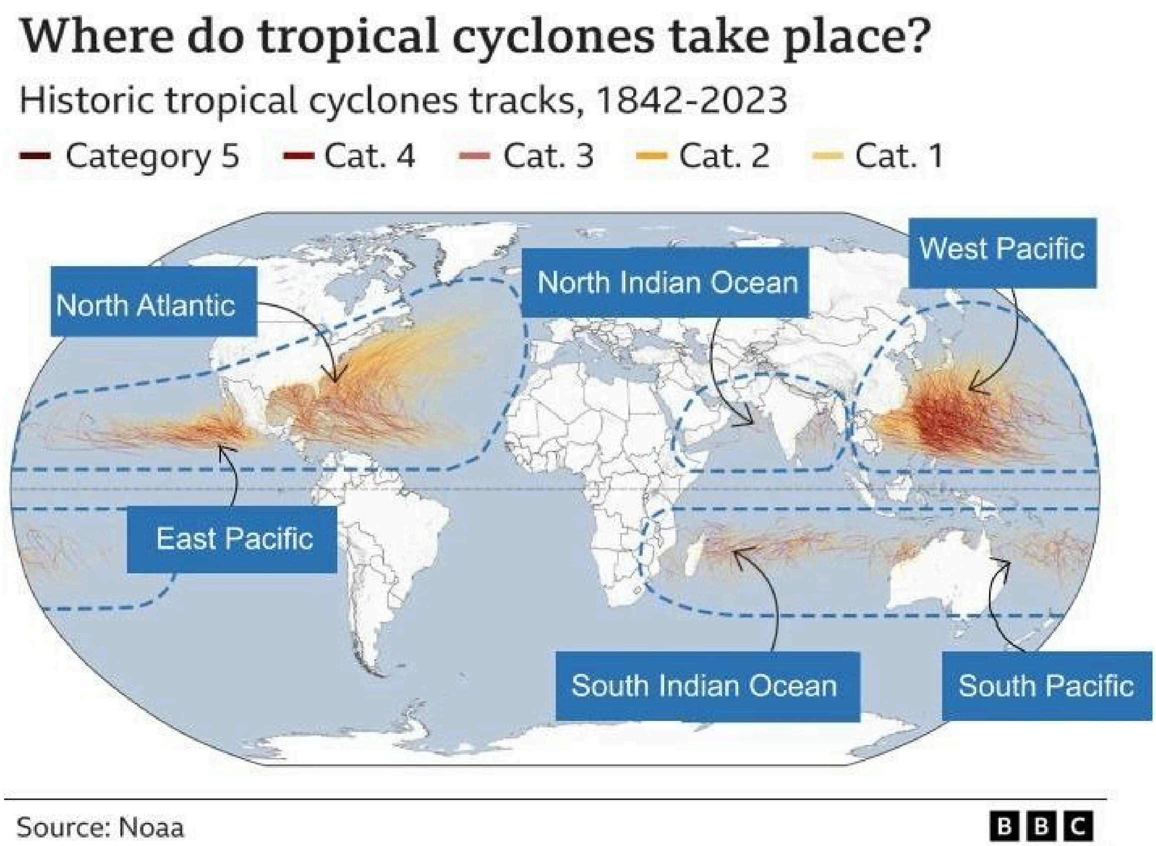
Hurricanes 5E

Unit 5 More Hurricanes and Blizzards in NYC?	Earth and Space Science
Student Name:	

What Patterns Do We See in Global Occurrence of Hurricanes?

Where do hurricanes happen?

There are six regions of the world where hurricanes (tropical cyclones) are likely to occur. These regions are labeled on the map below called "Where do Tropical Cyclones Take Place?"



See	Think	Wonder
What patterns do you notice about where these storms are taking place?	What do you think causes that pattern?	

How many hurricanes happen?

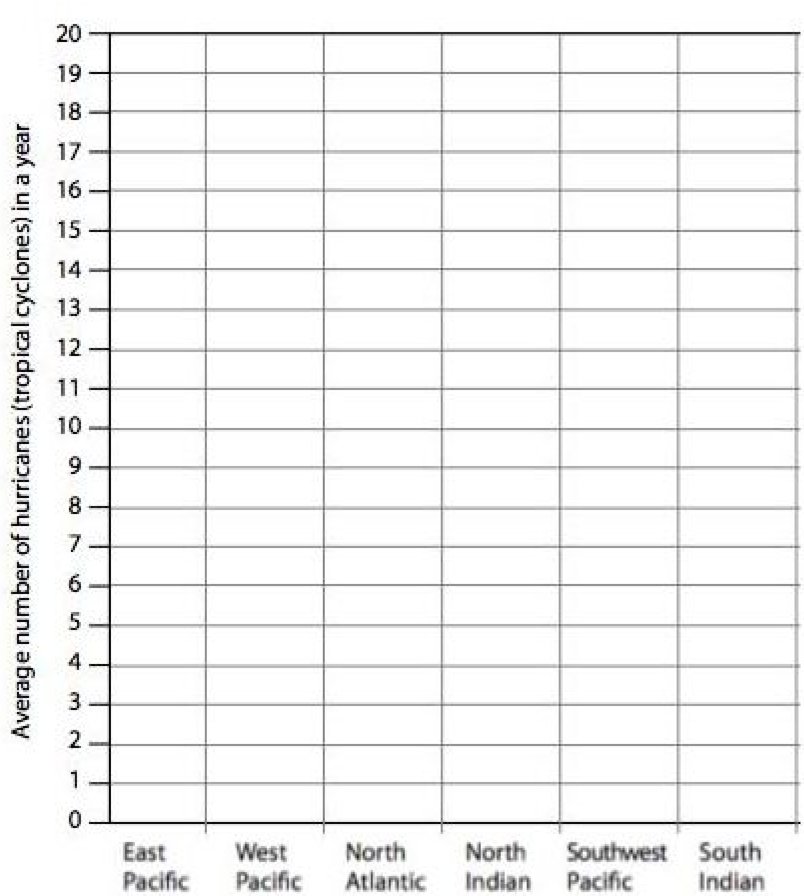
The number of hurricanes (strong tropical cyclones) that happen varies a bit from year to year. But the average number can tell you how many are likely. Take a look at the data table below. This shows the time of hurricane season and the average number of hurricanes in each region. What do you think? Do regions get the same number of hurricanes?

Hurricane Region	Hurricane Season	Number of Hurricanes per Year (average)

East Pacific Ocean	May-November	9
West Pacific Ocean	April-January	16
North Atlantic	June-November	7
Southwestern Pacific	October-May	4
North Indian Ocean	April-December	2
South Indian Ocean	October-May	6

Source: NOAA

Make a bar graph! A bar graph is a great way to show relative differences in numbers. Each bar is the amount of hurricanes for each region.



When do hurricanes happen?

Hurricane season is the time of year when hurricanes will most likely happen. But hurricane season is not at the same time in all places.

	January	February	March	April	May	June	July	August	September	October	November	December
East Pacific Ocean												
West Pacific Ocean												
North Atlantic												
North Indian Ocean												
Southwest Pacific												
South Indian Ocean												

1. Which regions have hurricane season at about the same time of year? Can you see how regions fall into two groups based on the timing of hurricane season? Which regions have similar timing?

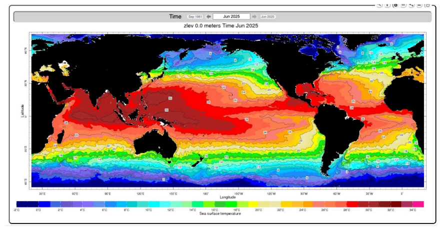
2. Look at where these regions are located on your map. In terms of their location, what do regions with similar hurricane seasons have in common? (Hint: look for the Equator!)

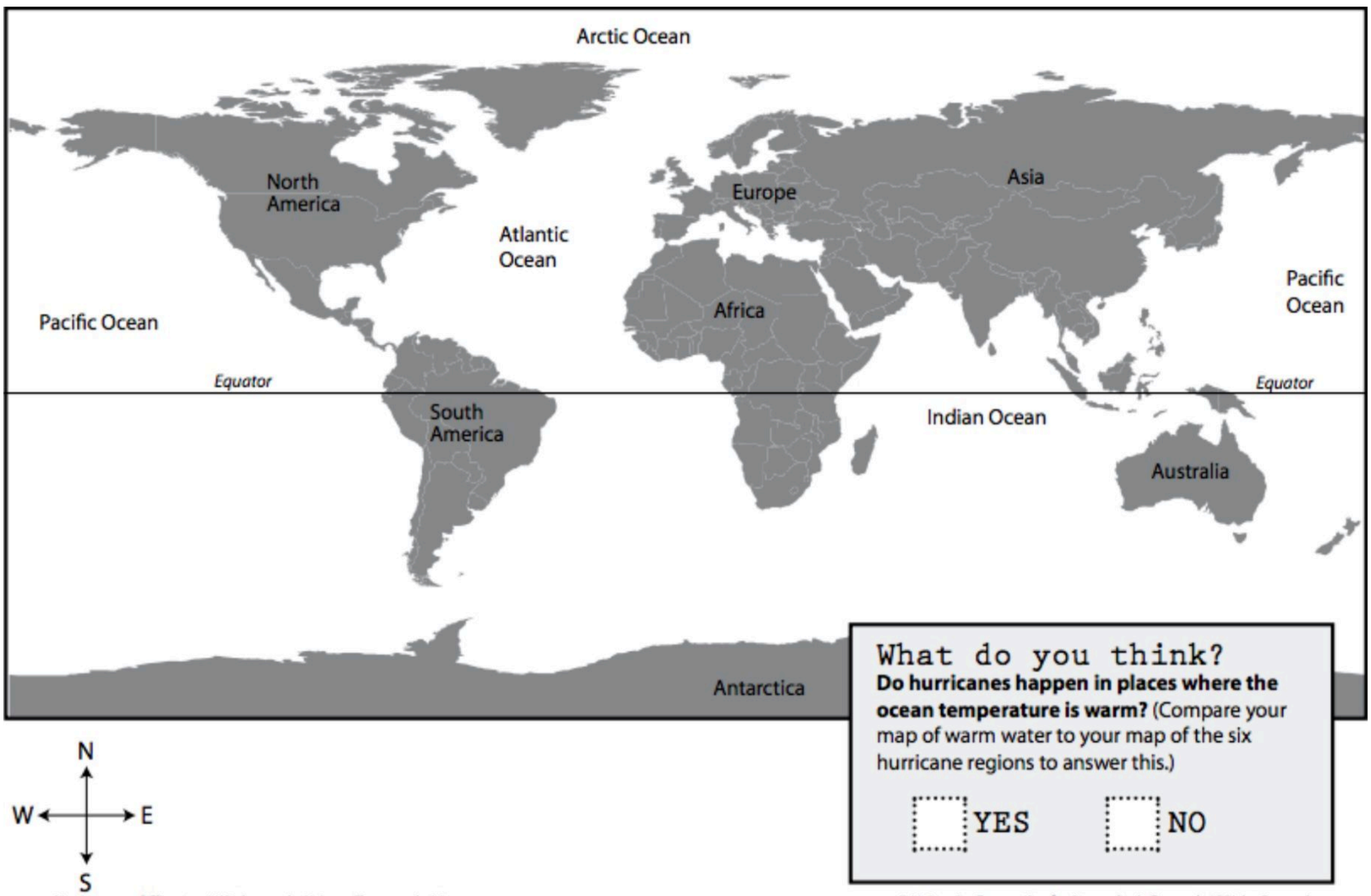
3. In which seasons are hurricanes most common? (Remember, seasons are opposite in the Northern and Southern Hemispheres.)

Where's the warm water?

The temperature of the ocean surface is not the same everywhere and it has an impact on hurricanes. We will use a computational model developed by Lamont-Doherty Earth Observatory from Columbia University in New York City to analyze sea surface temperatures across the globe. Follow these instructions to view where warm water is at different times of year and illustrate those areas on the map below:

1. Open the model called Monthly Sea Surface Temperature
2. Hover over the date stamp on the map, and arrows will appear
3. Use the arrows to move backwards in time, and observe the changes in ocean temperature as the months change
4. Use a red or orange pencil to color the parts of the ocean where the water is the warmest from June-August. Then use the same colored pencil to color the parts of the ocean where the water is the warmest from December-February.





Hurricanes and Climate - *A Windows to the Universe Classroom Activity*
www.windows.ucar.edu

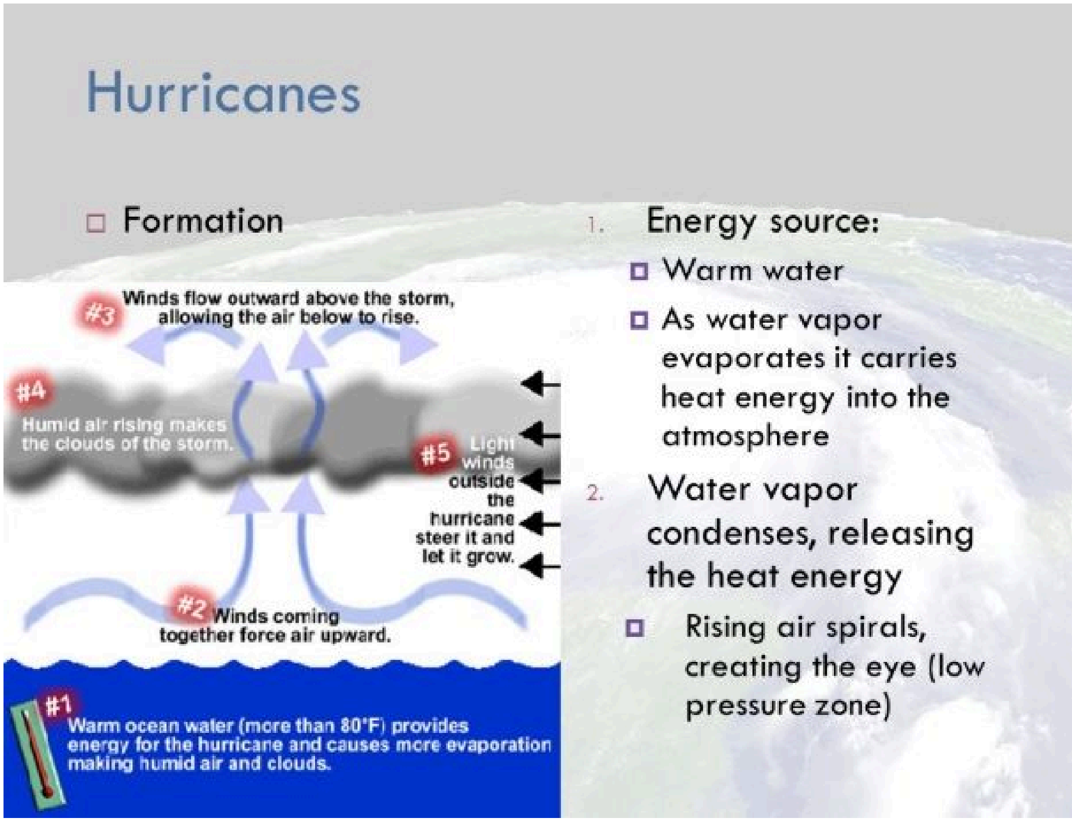
How does the warm water during the Northern Hemisphere's summer and winter relate to the times of year that hurricanes occur most frequently in different regions?

See-Think-Wonder

See **What did you observe?**	**Think** **What does each observation make you think?**	**Wonder** **What questions do you have about each observation?**
What patterns do you see in the location of tropical cyclones?		
What patterns do you see in the time of year that tropical cyclones occur?		
What patterns do you see in sea surface temperature throughout any given year?		

What Explains Patterns of Hurricane Occurrence?

Part 1: Analyze the model of hurricane formation. Then revise the diagram below to show what is happening to the ocean water on a molecular scale. In other words, illustrate what is causing the water to rise up and form clouds.



Hurricane Model Illustrating What is Happening to Water Molecules

Part 2: What Explains the Patterns from the 2005 Hurricane Season?

Question *What causes hurricane occurrence near the equator between June 1-Nov 30?*

Construct a Scientific Explanation

Using the information in the boxes you have completed, write a scientific explanation that includes:

- The scientific question
- Your claim
- Relevant evidence that supports your claim
- Science concepts that are connected to the evidence
- Scientific reasoning that links the evidence and science concepts to the claim

Scientific Explanation

Now use your model to construct a causal relationship that could make predictions about future storms.

1. Identify the dependent variable in the explanation you just wrote in response to the prompt: *What causes hurricane occurrence near the equator between June 1-Nov 30?*

Write the dependent variable below.

Dependent variable:

---

2. What is the independent variable in the model you developed?

Write the independent variable below.

Independent variable(s):

---

3. State the relationship between these two variables.

Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. When deciding on what computational model to use for any investigation, what information would you like to know about the data in order to feel confident about its accuracy?

2. How have we used *mechanisms at a molecular scale* to figure out what causes hurricane occurrence near the equator between June 1-Nov 30?

3. What were some of the main ideas you got out of analyzing the diagram of hurricane formation? How were they helpful in explaining the patterns in the location and time of year of hurricane occurrence?

4. Making claims about the relationship between independent and dependent variables.

    a. How did you identify the independent and dependent variable in your claim?

    b. Go back and review what you identified as the independent and dependent variables in your claim. In your own words, how did you decide which variable was the independent vs the dependent variable?

What is happening to precipitation as global temperatures rise?

Hurricane Helene's destructive path tore across several states, causing the ocean surge on the Florida coast and cutting off power supplies in Georgia. But the heaviest rainfall, and some of the worst damage, was hundreds of miles from where the storm made landfall.

In the area around Asheville, N.C., rain swelled streams and tributaries in the almost 1,000-square-mile watershed above the city. More than 15 inches of rain fell in the area, running off mountainous terrain that was already saturated from recent storms. The swollen French Broad River crumbled interstate highways, flooded homes with mud, and cut off the drinking water supply. The flooding has killed dozens of people so far.

The catastrophic damage is a sign of what climate scientists have been warning about: as the Earth heats up, rainfall is becoming increasingly extreme and deadly. And torrential rain can occur anywhere, including far from coastlines.

The heaviest storms in the southeastern U.S. today are already dropping 37% more rain since 1958, according to a recent study. As the climate keeps changing, that could increase by 20% or more.

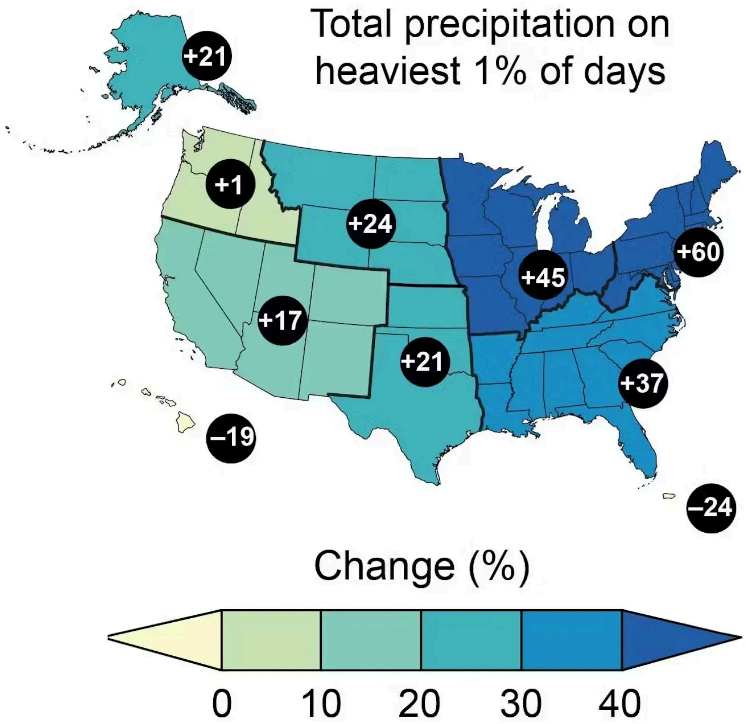
"We've had these shocking amounts of rain," says Bill Hunt, a professor at NC State University who works on stormwater infrastructure. "It's hard to imagine where you're safe."

As Hurricane Helene approached the U.S. coast, forecasters sent out alerts that it had reached a Category 4 storm. That's the rating system for a hurricane's severity, which is based entirely on wind speed.

But that masks the hidden danger hurricanes bring: rainfall. In 2018, Hurricane Florence hit North Carolina as only a Category 1, but the slow-moving storm dropped up to 30 inches of rain, causing severe flooding. Just in mid-September this year, a storm dropped 20 inches of rain on Wilmington, N.C., causing flooding there.

Text modified from NPR

This map shows the change in precipitation amounts during the heaviest storms from 1958-2021.



1. According to the article, how has rainfall changed during recent hurricanes?

2. According to the text, why doesn't "hurricane intensity" (the Category of the storm) describe the full risk from hurricanes?

3. How have states been impacted by changing rain levels?

4. Using what you know about temperature, energy, and precipitation, explain the relationship between global surface temperatures and amount of precipitation in a tropical storm event.

What is the Future of Tropical Cyclones?

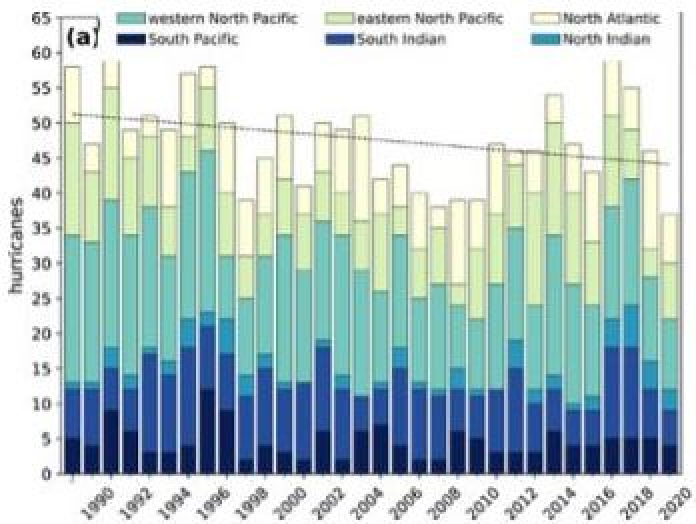
Your final task for this investigation will be to write an argument about whether hurricanes will become more frequent and / or intense as global temperatures rise in the future. You will now have an opportunity to collect data that you can use as for your argument?

Part 1: What are the trends in tropical cyclone and winter storm occurrences over the last several decades?

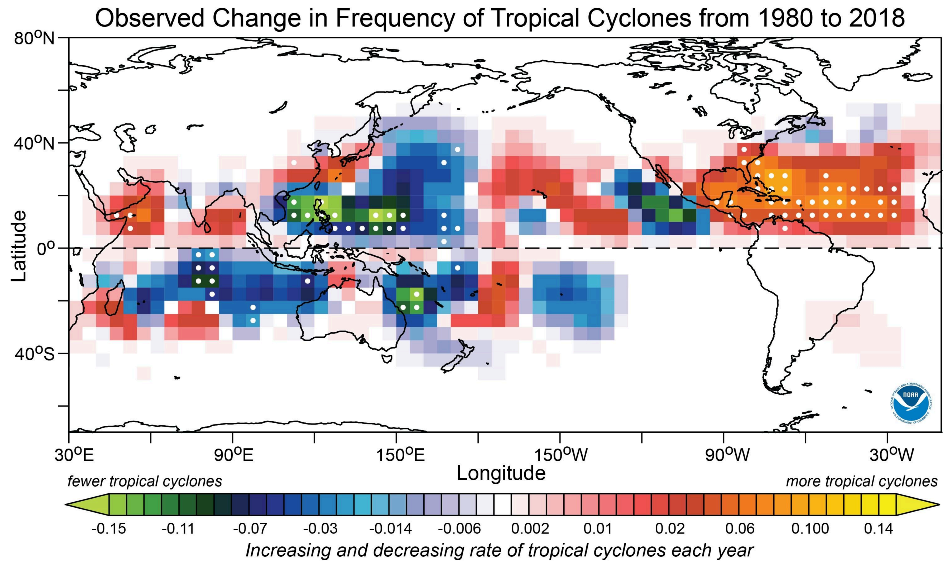
Is global warming affecting hurricanes?

We know that hurricanes form above warm ocean water. And it's thought that warmer water can lead to stronger hurricanes. The Earth warmed one degree Fahrenheit over the 20th Century. Warming is causing sea surface temperatures to climb. Has global warming had an impact on hurricanes? This is an area of active research. One way that scientists are trying to answer this question is by looking at the history of hurricanes.

Take a look at the graphs and tables below, then answer the questions that follow.

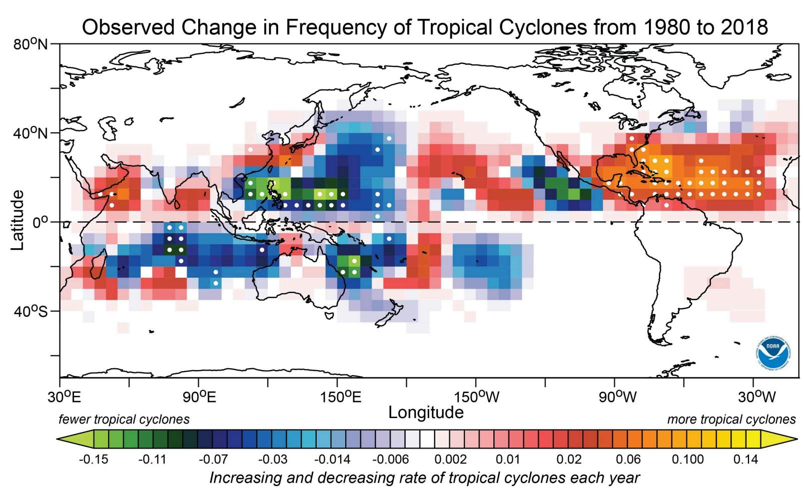


Total number of hurricanes in different regions from 1990-2020



This graphic depicts the global pattern of where the frequency of tropical cyclones has increased and where it has decreased around the world from 1980 to 2018. New NOAA research shows that while the global annual average number of tropical cyclones has remained at 86, climate change has influenced the location of where tropical cyclones have become more frequent, or less frequent.

1. Has the total number of hurricanes increased, decreased, or stayed about the same? Is the trend the same for all regions?



This graphic depicts the global pattern of where the frequency of tropical cyclones has increased and where it has decreased around the world from 1980 to 2018. New NOAA research shows that while the global annual average number of tropical cyclones has remained at 86, climate change has influenced the location of where tropical cyclones have become more frequent, or less frequent.

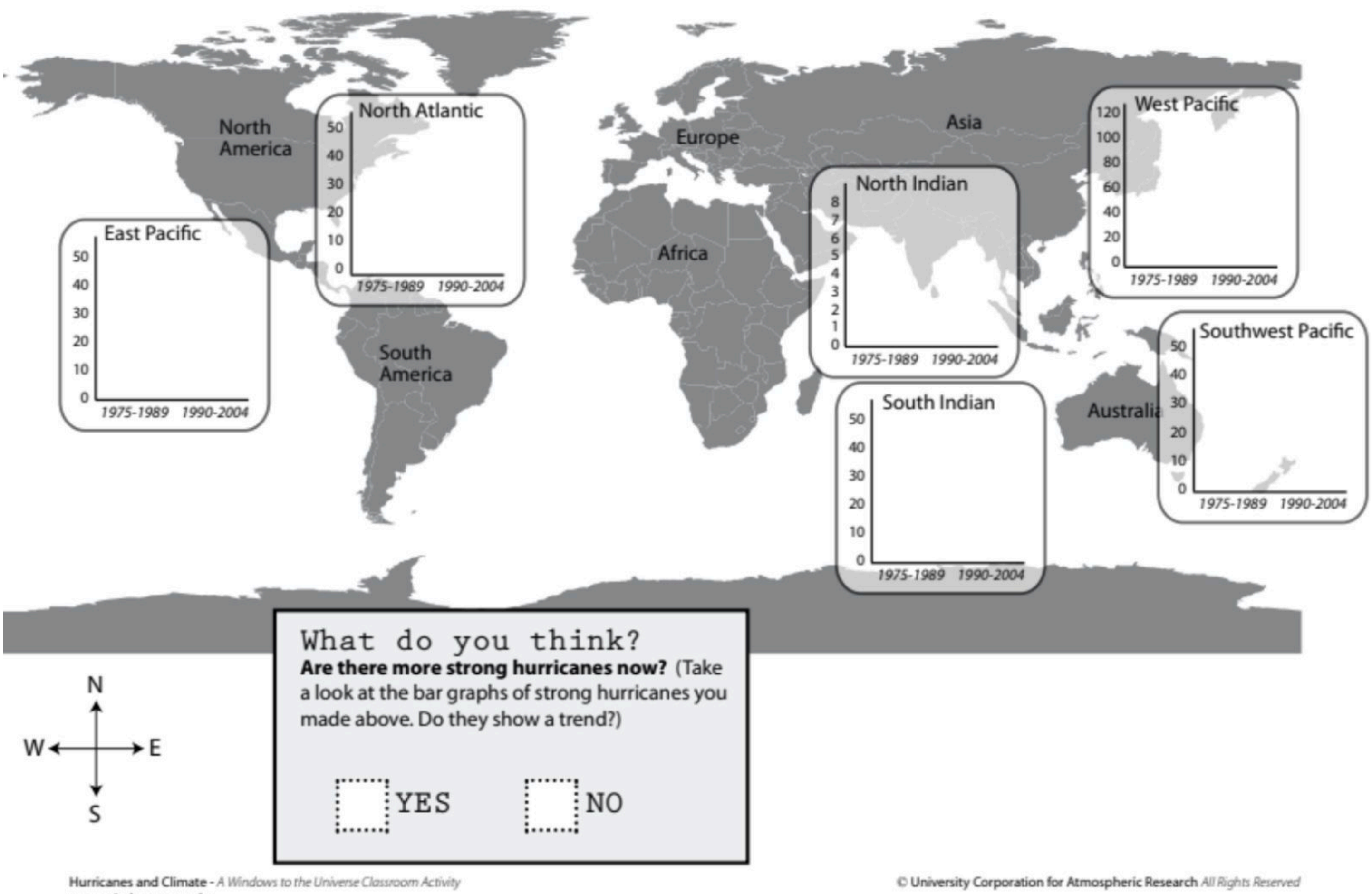
2. Has the number of strong (category 4 and 5) storms increased, decreased, or stayed about the same? Is the trend the same for all regions.

Hurricane Region	1975-1989	1990-2004
East Pacific Ocean	36	49
West Pacific Ocean	85	116
North Atlantic	16	25
Southwestern Pacific	10	22
North Indian Ocean	1	7
South Indian Ocean	23	50

Number of Hurricanes Reaching Categories 4 and 5

Are hurricanes getting stronger?

How many strong hurricanes were there a few decades ago? How many are there today? Make small bar graphs on the map below using the data on the previous page to show whether there has been a change in the number of strong hurricanes in the six regions of the world where tropical cyclones occur.



Part 2: Using Climate Models to Make Predictions About the Future

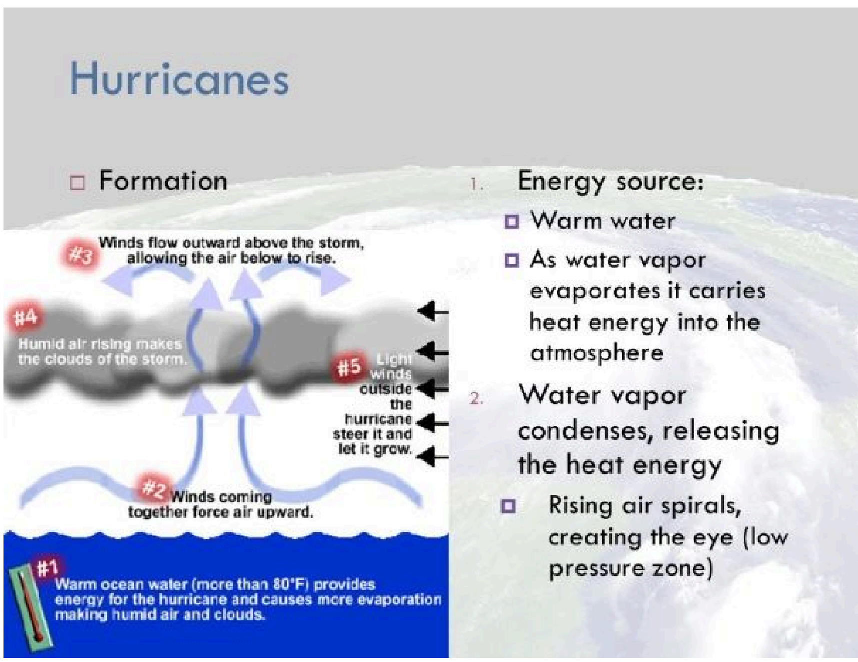
Apply what you have learned in this investigation to making predictions about hurricanes in the future. You will do this by reviewing some ideas about blizzard formation, analyzing data from a climate model, and then evaluating how confident you are about the reliability of the model.

Reviewing what we know about hurricane formation:

Review and analyze the diagram that depicts how a hurricane forms.

1. What is required for a hurricane to form?

2. How does a hurricane gain more energy?



What do global climate models tell us about sea surface temperature where hurricanes form?

1. Click on this link to visit the IPCC WGI Interactive Atlas and explore future climate change projections in the regions and time of year where we know hurricanes form.

2. Click on "season" on the right side of the top toolbar. Use the "customized season" option to select the months you want to view.
3. Click on the areas of the globe that you want to focus on at that time of year. You can select as many areas as you like.

4. Once you've selected at least one region, a line graph will appear in the bottom half of the window.

5. The interactive atlas shows temperature (listed under atmosphere as "mean temperature" in the drop-down list) by default, but you can choose other variables to explore. To do so, click on the icon and select whatever other variables you'd like to see. Consider variables like total one day rainfall or precipitation. That will change the variable shown on the globe and represented in the line graph.

6. Use what you observe to complete the See-Think-Wonder table below.

See	Think	Wonder
What do you notice about the average sea surface temperature?	What does this make you think about how frequent and intense hurricanes will be in the future?	What questions do you have?

Reliability of Models Based on Assumptions
Here you will have the opportunity to consider the reliability of the models you used to make predictions about hurricanes. Review the idea of precision and accuracy, then read about the concepts of reliability and assumptions.

Precision & Accuracy:
Precision refers to the degree of accuracy and consistency in something. In the context of models, precision asks whether the model offers very accurate and dependable results.

To illustrate precision, let's consider a straightforward example. Imagine a machine designed to measure the weight of apples. If this machine consistently displays the same weight for a specific apple (let's say it's expected to weigh 100 grams, and the machine consistently shows 100 grams), we can affirm that the machine is precise. In other words, the results it provides are remarkably similar each time you weigh an apple.

Reliability:
Reliability is about our confidence in something's consistent performance over time. When we discuss the reliability of models, we're essentially asking whether we can have faith in the model to deliver accurate results, even as circumstances evolve.

Drawing from our apple weight machine example, reliability can be likened to the machine's ability to provide accurate measurements not only for a short period but also as time goes on and when apples come in various sizes. A reliable machine is one you can depend on to perform well in different situations, even when the circumstances change.

In the context of models and assumptions, reliability relies on the accuracy of the underlying assumptions. If a model is constructed upon assumptions that accurately represent the real-world conditions, it's more likely to be reliable. This means you can trust the model to provide accurate predictions not only in the present but also in the future and under different conditions. A reliable model endures the test of time and changing circumstances, just as an accurate machine consistently measures apples' weights despite variations in the fruit.

Assumptions:
Assumptions are the ideas or beliefs that a model is built upon. Models are like tools, and they're based on certain assumptions about how things work. The precision and reliability of a model can depend on the accuracy of these assumptions.

If the assumptions of a model are very accurate and match the real world closely, it's more likely to be precise and reliable because it's built on solid foundations. However, if the assumptions are flawed or don't quite match reality, the model might not be very precise or reliable because it's starting with the wrong information. Choose 2-3 of the assumptions made for developing the IPCC WGI Interactive Atlas, then answer the question that follows.

Read the assumptions that the IPCC WGI Interactive Atlas based on below, then answer the questions that follow.
IPCC WGI Interactive Atlas Assumptions
The IPCC (Intergovernmental Panel on Climate Change) warming scenarios of 1.5, 2, 3, and 4 degrees celsius by the year 2100, are based on a range of assumptions and factors related to greenhouse gas emissions, human activities, and climate systems. The primary factors on which IPCC warming scenarios are based include:

- **Greenhouse Gas Emissions:** The most critical factor is future greenhouse gas emissions. The scenarios are based on assumptions about how much greenhouse gases will be released into the atmosphere over time. Different scenarios represent various emission trajectories, from high to low.

- **Economic and Population Growth:** The scenarios also consider future economic and population growth. These factors influence energy consumption, land use, and other activities that produce greenhouse gas emissions. Scenarios assume different levels of economic and population growth.
- **Technological Changes:** Assumptions about future technological developments and their impact on emissions play a role in the scenarios. This includes the adoption of renewable energy sources, energy efficiency improvements, and changes in land use practices.
- **Policy and Mitigation Measures:** Some scenarios take into account the implementation of climate policies and mitigation measures. These can include carbon pricing, regulations, and international agreements aimed at reducing emissions.
- **Land Use Changes:** Land use changes, such as deforestation and afforestation, also influence the amount of carbon in the atmosphere. Scenarios consider how land use patterns might evolve in the future.
- **Climate Feedbacks:** The scenarios incorporate feedback mechanisms, such as the effects of temperature increase on the release of greenhouse gases from permafrost or changes in cloud cover, which can either amplify or mitigate warming.
- **Socioeconomic Assumptions:** Different scenarios involve varying assumptions about societal values, development pathways, and preferences, which affect choices related to emissions and adaptation strategies.

1. How much variability do you think there can be in the assumptions you read about? Explain your thinking.

2. Based on your answer above, why do you think the IPCC WGI Interactive Atlas includes the different warming scenarios of 1.5, 2, 3, and 4 degrees celsius by the year 2100?

Unit Closing

Unit 5 More Hurricanes and Blizzards in NYC?	Earth and Space Science

Student Name:

Final Argument Rubric

Component	Not Evident	Level 1: Beginning	Level 2: Developing	Level 3: Advancing	Level 4: Proficient
Claim/ Counterclaim	Does not make a claim or counterclaim	A claim is provided, but does not address the problem.	A claim is provided that addresses the problem.	Claim addresses the problem, and a counterclaim is provided, but one or both is inaccurate, inappropriate, or incomplete.	Claim and counterclaim(s) address the problem, are accurate, appropriate, and complete.
Evidence	Does not provide evidence	Only provides inappropriate evidence (evidence does not support the claim)	Provides appropriate, but insufficient evidence to support the claim. May include some inappropriate evidence	Provides appropriate and sufficient evidence to support the claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support the claim

Note: Appropriate evidence is observations or data collected during an investigation, use of a simulation or model, or secondary data sets from a reputable source.Scientific ideas or concepts related to the claim are not considered evidence for a claim. To demonstrate sufficient evidence, students should have at least two examples of evidence for each claim discussed. Students are not expected to provide specific examples of evidence for the counterclaim (although it could be included as appropriate).

Reasoning: Science Concepts	Does not include reasoning	Restates evidence and does not include explanation of science concepts	Includes explanation of science concepts but all are inappropriate concepts that do not link evidence to claim	Includes explanation of some science concepts that link evidence to the claim, but are insufficient (one or more concepts that should have been included are not included) or some are inappropriate	Includes explanation of science concepts that link evidence to the claim (concepts are appropriate), and they are sufficient (no omission of key science concepts) and are clearly stated and accurate.

Reasoning: Logic	Does not include reasoning	Restates evidence or claim and does not include a logic statement that links the evidence to the claim	Attempts to include a logic statement that links the evidence to the claim but does not adequately link the evidence to the claim.	Includes a logic statement that attempts to link the evidence with the claim but needs to be more clearly stated to demonstrate logical reasoning	Includes a logic statement that links the evidence to the claim (including words such as *because* and *therefore*) that clearly demonstrates logical reasoning
Evaluation	Does not include an evaluation	Does not attempt to critique the argument or does not attempt to discuss the use of cause and effect or systems & system models in developing the argument	Attempts a critique of the argument and a discussion of the use of cause and effect or systems & system models in developing the argument but both are incomplete.	Includes an incomplete critique of the argument (missing strengths, weaknesses, or additional evidence/concepts needed) **or** an incomplete discussion of the use of cause and effect or systems & system models in developing the argument	Includes a complete critique of the argument (including strengths and weaknesses) and suggestions for additional evidence or scientific reasoning and clearly articulates the use of cause and effect or systems & system models in developing the argument