WEATHERING THE STORM

Meteorology Curriculum

TEACHER GUIDES

Tulsa Regional STEM Alliance

CIWRO

COOPERATIVE INSTITUTE FOR SEVERE AND HIGH-IMPACT WEATHER RESEARCH AND OPERATIONS

WEATHERING THE STORM

Module 1 Storyline

Content Key

- Key Concept Development
- Environmental Hazards
- Phenomena in the Sky
- Community Impact & Safety
- Meet a Professional Spotlight

Activity Key

- Class Discussion
- Technology Use
- Outdoor Learning
- Laboratory Setup
- Group Activity

Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 0

Topic	Standards	Key Concepts	Student Artifacts
Weather and Meteorology	**Computer Science:** 6.IC.CU.01 6.IC.CU.02	• Weather is the state of the atmosphere at any given time. • The components of weather are temperature, atmospheric pressure, wind, humidity, precipitation and cloudiness. • Meteorology is the study of the atmosphere and its processes.	• Interest Survey of various careers in meteorology

Vocabulary: Weather, Meteorology

Lesson Navigating Question: What is weather?

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Module 1 Storyline

Lesson 1

Topic	Standards	Key Concepts	Student Artifacts
Temperature Vocabulary: Temperature, Fahrenheit, Celsius, Kelvin, Absolute zero	**Science:** 6.PS3.3 6.PS3.4 **Math:** 6.N.1.1 6.D.1.1 **Computer Science:** 6.DA.CVT.01 6.DA.IM.01	• Temperatures differ in the sun and shade. • Different substances absorb different amounts of energy from the sun. • Temperature can be measured in Celsius or Fahrenheit.	• Temperature readings of air, water, and soil in varying amounts of sunlight. • Initial models to explain why temperature differs in sun and shade. • Comparison of temperature readings in Celsius and Fahrenheit.

Lesson Navigating Question: How do we measure weather?

Lesson 2

Topic	Standards	Key Concepts	Student Artifacts
Heat Transfer Vocabulary: Radiation, Conduction, Convection, Convection current, Warm front, Cold front, Mirage	**Science:** 6.PS1.4 6.PS3.3 6.PS3.4 6.PS4.2	• Energy from the sun powers all weather - it heats the air, increasing the energy of the molecules which then increases the temperature of the air. • Heat is transferred through radiation, conduction, and convection. • Convection currents are caused by warm air rising and cool air sinking. • Convection currents create air masses that affect weather patterns. • A mirage is evidence of convection.	• Adaptation of initial temperature models to include modes of heat transfer. • Simulation of convection current.

Lesson Navigating Question: What happens after air heats up?

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Module 1 Storyline

Lesson 3

Topic	Standards	Key Concepts	Student Artifacts
Heat Index Vocabulary: Humidity, Water vapor, Relative humidity, Saturation, Heat index	**Science:** 6.PS3.4 6.ESS2.4 **Math:** 6.N.3.1 **Computer Science:** 6.DA.S.01 6.DA.CVT.01 6.DA.IM.01	• Relative humidity is another component of weather. • Humidity affects how the outside temperature may feel, but does not affect the actual temperature. • Heat Index is a measure of temperature combined with relative humidity.	• A variety of models and simulations that compare temperatures, relative humidity, and heat index in Oklahoma and Arizona.

Lesson Navigating Question: Why does hot weather in Oklahoma feel different than hot weather in Arizona?

Lesson 4

Topic	Standards	Key Concepts	Student Artifacts
Wind Chill Vocabulary: Wind chill	**Science:** 6.PS3.4 **Computer Science:** 6.DA.S.01 6.DA.CVT.01 6.DA.IM.01	• Wind chill is a measure of how air temperature feels to human skin due to wind. • Higher wind speeds increase heat loss from the skin, decreasing body temperature.	• Windchill forecasts based on temperature and wind speed data.

Lesson Navigating Question: Does heat index work the same in winter?

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Module 1 Storyline

Lesson 5

Topic	Standards	Key Concepts	Student Artifacts
Temperature Advisory Alerts	**Computer Science:** 6.DA.CVT.01 6.DA.IM.01 6.IC.CU.01 6.IC.CU.02 6.AP.PD.01	• High temperatures, humidity, and/or heat indexes can create unsafe conditions that put people at risk for heat exhaustion or stroke. • High wind speeds and low temperatures or wind chill can create unsafe conditions that put people at risk for hypothermia and frostbite.	• Creation of either summer or winter temperature alerts for the public.

Vocabulary: Excessive heat warning, Wind chill warning, Heat exhaustion, Heat stroke, Hypothermia

Lesson Navigating Question: How do we keep people safe in the extreme temperatures of summer and winter?

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Teacher Guide: Module 1 Lesson 0

Module Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 0 - Weather and Meteorology

Lesson Navigating Question: What is weather?

Grade Levels:
6-8

Time Required:
50 Minutes
1 Class period

STEM Content Areas:
Technology

Overview

Students will gain an understanding of what weather is and it is studied through the field of meteorology. Students will explore various career options in the field of meteorology.

Oklahoma Academic Standards

Computer Science Standards

- 6.IC.CU.01 - Explain how computing impacts people's everyday activities and careers.
- 6.IC.CU.02 - Identify and discuss the technology proficiencies needed in the classroom and the workplace, and how to meet the needs of different users.

Learning Objectives

1. Define weather.
2. List the components used to describe weather.
3. Define meteorology.
4. Name some examples of careers in the field of meteorology.

Vocabulary

Weather - the state of the atmosphere including temperature, pressure, wind, humidity, precipitation, and cloud cover
Meteorology - the study of the atmosphere and all its processes, especially phenomena related to weather.

Materials

- Computers with internet access
- Student Handouts: *How's the Weather?*

Preparation

On slide 7 (Experience), insert a weather forecast clip from your local TV station. Most news stations have short, up-to-date weather forecast clips available online.

Phase	Time	Slide	Description
Enroll	10 min.	3	1. Allow students to ponder the question, "What is weather?" Have students write some thoughts in their notebooks. What does it include? What does it not include? 2. Students turn and talk to share their ideas or may share ideas as class discussion. 3. Ask the class, "Does everywhere have the same weather?" • Allow class discussion. When a student makes a claim that weather is or isn't the same everywhere, ask for examples or evidence. Why do they think that? 4. Have students turn and talk with a partner to make a list of places that might have different weather than Oklahoma. Ask students, "Why might the weather be different in these places?" • Have students share their thoughts with the class. Make a list of student responses on the board. • Ask students if they notice any patterns with places that have different weather than Oklahoma. Accept all responses.
Experience	10 min.	4	5. Ask students to describe what the weather is like today. Allow students to think silently for a few minutes while they write a response on the What's the Weather? Handout. • Have students share their responses with a partner, then with the class. Accept all responses. 6. Next, ask students to describe what the weather was like yesterday and 3 months ago. • Have students share their responses with a partner or group. 7. Ask students to identify what their descriptions have in common. After giving groups some time to talk, ask students to share with the class the patterns that they noticed. What words or characteristics do we use to describe the weather? • Make a list of responses on the board. Accept all responses.

Phase	Time	Slide	Description
Label	2 min.	5	8. Define weather and the different characteristics or components that can be used to describe weather. Tell students that they will learn about each of the characteristics of weather as they learn about the science of meteorology.
Enroll	5 min.	6	9. Ask students what they think a meteorologist does. • Allow students to talk with a partner for a minute before sharing ideas with the class. • Students will likely say that a meteorologist is the person on TV that gives the weather report. 10. Ask students if they would like to learn how to create a weather forecast.
Experience	10 min.	7	11. Watch a clip of a local weather forecast. This can usually be found on your local weather station's website. 12. As students watch the clip, ask them to record what they notice and what they wonder. You may need to show the clip more than once. After giving students a chance to think silently, have them share with a partner before sharing with the class. • Accept all responses for what students notice, but focus discussion around the types of information that is included in the forecast. Use questioning such as, "Did anyone else notice what kind of weather information was included in the report?" • Ask students to share what they wondered. Accept all responses, but focus discussion around how the weather information was obtained or why it's important. **Teaching Tip:** There is no right or wrong way to notice and wonder. If this is students' first experience with notice and wonder, they may feel pressure to find a "correct" answer. You can help alleviate this pressure by responding positively to all ideas, even if they seem "off topic". Although there is a direction you hope the conversation will flow, allow students to share their thoughts and build off each other's ideas. If discussion is not moving in the direction you want, use questioning techniques to draw out certain topics.

Phase	Time	Slide	Description
Label	2 min.	8	13. Define meteorology as the study of the atmosphere and all its processes, especially phenomena related to weather.
Demonstrate	10 min.	9	14. Have students explore some example careers in meteorology. The following are useful web pages: • American Meteorological Society: All About Careers in Meteorology • indeed: 9 Jobs in Meteorology (Plus Salaries and Responsibilities) *Students should explore what they think they would be most interested in and what they find most surprising.*
Celebrate	1 min	10	15. Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 1 Lesson 1

Module Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 1 - Temperature

Lesson Navigating Question: How do we measure weather?

Grade Levels:
6-8

Time Required:
125 Minutes
2-3 Class periods

STEM Content Areas:
Science, Technology, Math

Overview

Students will learn that there are several components that can be used to describe the weather, one of which is temperature. Students will compare the Celsius and Fahrenheit temperature scales. Using a thermometer, students will collect temperature data in the sun and in the shade, constructing an explanation of how energy from the sun heats the surface of the Earth.

Oklahoma Academic Standards

Mathematics Standards

- **6.N.1.1** - Use manipulatives and models (e.g., number lines) to determine positive and negative numbers and their contexts, identify opposites, and explain the meaning of 0 (zero) in a variety of situations.
- **6.D.1.1** - Interpret the mean, median, and mode for a data set.

Science Standards

Disciplinary Core Ideas

- **6.PS3.3** - Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
  - Temperature is a measure of the average kinetic energy of particles of matter
- **6.PS3.4** - Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample
  - Temperature is a measure of the average kinetic energy of particles of matter
  - The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter present
  - The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment

Science and Engineering Practices

- Planning and Carrying Out Investigations - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data is needed to support a claim.

Crosscutting Concepts

- Energy and Matter - the transfer of energy can be tracked as energy flows through a designed or natural system.
- Scale, Proportion, and Quantity - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Computer Science Standards

- **6.DA.CVT.01** - Collect data using computational tools and transform the data to make it more useful.
- **6.DA.IM.01** - Use data to highlight or propose cause-and-effect relationships, predict outcomes, and communicate ideas.

Learning Objectives

1. Compare Celsius and Fahrenheit temperature scales.
2. Explain the meaning of zero in different contexts.
3. Collect temperature data using a thermometer.
4. Analyze data using measures of central tendency.
5. Produce graphical representations of temperature data.
6. Explain how different substances absorb different amounts of energy from the sun.

Vocabulary

- **Temperature** - a measure of the average kinetic energy of particles of matter
- **Fahrenheit** - a scale used to measure temperature in which the freezing point of water is 32 degrees and the boiling point is 212 degrees
- **Celsius** - a scale used to measure temperature in which the freezing point of water is 0 degrees and the boiling point is 100 degrees
- **Kelvin** - a scale used to measure temperature in which 0 is the lowest temperature possible (molecules have no kinetic energy)
- **Absolute zero** - the lowest temperature possible, in which molecules have zero kinetic energy

Materials

- 1-2 Glass Thermometers for each group of students - separate thermometers for Celsius and Fahrenheit, if possible
- 2 cups or beakers for each group of students
- Ice
- Water
- Sand or soil
- 12 plastic shoebox containers
- Masking tape
- 12 Ring stands (optional)
- 3 heat lamps (optional)
- Student Handouts: Taking Temperatures, What I Know, Heat Absorption, Developing Ideas

Preparation

1. Record the temperature of the room in both Celsius and Fahrenheit. Ensure that students cannot see the thermometer or thermostat settings.
2. For each group of students, prepare two cups or beakers of water that are at different temperatures, such as ice water and room temperature water.
3. Fill 2 plastic shoebox containers with sand or soil, 2 with water, and leave 2 empty.
4. Place one of each (water, empty, and sand/soil) somewhere sunny and somewhere in the shade.
5. Using tape or a ring stand, attach a thermometer to each container so that the bulb is just below the surface of the water and soil. For the empty container, place the bulb in approximately the same position as the other containers. Ensure the bulbs are not touching the side of the container or the ground. In the case of inclement weather or lack of sun, heat lamps may be used indoors.

Teaching Tip: Students can also set up the samples, which will add approximately 10-15 minutes to this step. Allow the thermometers to adjust for at least 5 minutes before recording data.

Module 1 Lesson 1.1

Phase	Time	Slide	Description
Enroll	5 min.	3-4	1. Show a weather forecast with some heat index temperatures listed. Ask students, “Are these temperatures safe for outdoor activities? How can we be sure?” 2. Show a weather forecast with colder weather and some wind chill temperatures. Ask students, “Are these temperatures safe for outdoor activities?” 3. Inform students that it is sometimes too hot or too cold to be working or playing outside. Ask if they would like to learn how to read a weather report to determine if outdoor activities are safe on a hot or cold day.

Phase	Time	Slide	Description
Experience	5 min.	5	4. Ask students how we measure temperature. Most students are likely familiar with the concept of a thermometer. 5. Next, ask students where we should measure temperature. Students will likely say, "outside." Have students think more deeply by asking where you should measure temperature outside. "Does it matter where we place a thermometer?" • Continue accepting responses until students identify that the shade usually feels cooler than in the sun. • If students are not making the connection to different areas outside feeling warmer or cooler, have students close their eyes and picture a nice warm area outside. Have them describe what it looks like, feels like, where they are, etc. • Next, ask them to picture a cool area outside and have them describe it in the same way. Responses will probably be somewhere sunny and somewhere shady. • Ask again, "Does it matter where we place a thermometer outside?"
Label	15 min.	6-9	6. Ask students what they think the temperature of the room is. Give two answer options and allow students to vote. One option should be in Celsius, and the other in Fahrenheit. Both options should be the actual temperature of the room. Do not provide the Celsius and Fahrenheit labels. For example, "Do you think the temperature in this room is 68 degrees, or 20 degrees?" **Teaching Tip**: Anonymous voting reduces risk for students and increases engagement from all learners.

Phase	Time	Slide	Description
Label (cont.)	15 min.	6-9	7. After students have submitted all of their votes, reveal the answer - both options are true! 8. Ask students, "How can the room be both [68 degrees] and [20 degrees]?" Have students turn and talk to come up with ideas. Have groups share their ideas with the class, or rotate to discuss with another group. **Teaching Tip**: Students that have lived in other countries are likely familiar with the Celsius temperature scale. By having the chance to discuss their ideas with other students, they get to be "the experts in the room." This expertise can be leveraged later, when students practice comparing the Celsius and Fahrenheit scales. 9. Introduce the Celsius and Fahrenheit temperature scales on a thermometer. 10. Explain that Celsius is used in science and in most countries around the world. 11. Show students an image of a thermometer and ask how it is similar to a number line. 12. Explain that a thermometer is like a vertical number line. Unlike number lines they may be familiar with, a thermometer also includes negative numbers, which are numbers below zero. 13. On the Celsius scale, zero represents the temperature at which water freezes, which is why Celsius is used for science. Negative temperatures are temperatures below freezing. (On the Fahrenheit scale, it is possible to have temperatures below freezing that are not negative.) 14. Some sciences work with extreme temperatures, so they instead use the Kelvin scale. Negative temperatures are not possible on the Kelvin scale, as 0 Kelvin is the lowest possible temperature, also known as absolute zero.
Demonstrate	15 min.	10-11	15. Handout the student handout titled *Taking Temperatures*. 16. Students will compare the two temperature scales and convert between them.

Phase	Time	Slide	Description
Demonstrate (cont.)	15 min.	10-11	**Teaching Tip:** If students are struggling to read the thermometer, explain that it works like a ruler. Students may need help determining the scale of each mark on the thermometer. 17. Students will take the temperature of two water samples in Celsius, such as ice water vs. room temperature water. If using hot water, ensure the water is not boiling for student safety. If possible, use a thermometer that only displays Celsius. **Teaching Tip**: Digital thermometers can be used, but glass thermometers will better support math concepts related to measurement, number lines, integers, and positive/negative numbers. 18. Students will now estimate the temperature of each sample in Fahrenheit. For a true estimation, ensure students are not able to measure the samples with a Fahrenheit thermometer. They may, however, use the thermometer image on their handout. 19. Have students discuss their estimates with a partner. 20. Now allow students to measure the temperature of the samples in Fahrenheit. This can also be accomplished by revealing what the Fahrenheit temperatures are.
Review	5 min.	12	21. Students reflect on their learning using the handout, *What I Know*.
Celebrate	5 min.	13	22. Celebrate students' efforts with high fives, team chants, a treat, awards, etc. Make sure every student's effort is celebrated.

Module 1 Lesson 1.2

Phase	Time	Slide	Description
Enroll	5 min.	15	1. On the handout Heat Absorption, students recall their thinking from Lesson 1.1 to predict how temperature will differ in the sun and in the shade. 2. Students will draw an initial model using words and pictures to explain their thinking.
Experience	40 min.	16-17	3. Take students outside to collect temperature data of 6 different samples that have been prepared in advance (water, soil, and air in both the sun and shade) 4. Have students enter their data into a spreadsheet such as Excel or Google Sheets. Students may need assistance if they have little experience with spreadsheets. See Resources for Google Sheets at the end of this document. 5. Students analyze their data and create graphs using the spreadsheet. **Teaching Tip**: Data analysis and graphing can be done on paper, but utilizing a spreadsheet supports computer science standards and digital literacy skills.
Label	10 min.	18-20	6. Explain that air, water, and soil absorb heat differently. Air heats up and cools down more quickly than soil, which heats up and cools down more quickly than water.
Demonstrate	5 min.	21	7. Revise initial models to explain temperature differences in the sun and in the shade.
Review	10 min.	22	8. Compare models with a partner. 9. Update *What I Know* handout
Celebrate	1 min	23	15. Celebrate every effort! High fives, team chants, toasts, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 1 Lesson 2

Module Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 2 - Heat Transfer

Lesson Navigating Question: What happens after air heats up?

Grade Levels:
6-8

Time Required:
265-280 Minutes
5-6 Class periods

STEM Content Areas:
Science

Overview

Students will continue developing their understanding of how the sun heats the earth by exploring the concepts of radiation, conduction, and convection. Students will investigate how heat is transferred through each of these modes. Students will demonstrate how convection currents are formed and will explain how convection creates weather fronts. Students will observe multiple mirage phenomena and explain how a mirage is evidence of heat transfer.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.PS1.4** - Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
  - Gasses and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
  - The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.
  - The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material.
  - Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.
- **6.PS3.3** - Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
  - Temperature is a measure of the average kinetic energy of particles of matter
  - The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
  - Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- **6.PS3.4** - Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample
  - Temperature is a measure of the average kinetic energy of particles of matter
  - The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter present
  - The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment

Oklahoma Academic Standards (cont.)

- **6.PS4.2** - Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
  - When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
  - The path that light can travel can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.

Science and Engineering Practices

- **Developing and Using Models** - Develop a model to predict and/or describe phenomena.
- **Analyzing and Interpreting Data** - Analyze data produced through a scientific investigation in order to derive meaning.
- **Constructing Explanations and Designing Solutions** - Construct theories to provide an explanation of natural phenomena.
- **Engaging in Scientific Argument from Evidence** - Engage in reasoning and argument based on evidence in order to identify explanations for natural phenomena.

Crosscutting Concepts

- **Cause and Effect** - Cause and effect relationships are routinely identified, tested, and used to explain change.
- **Energy and Matter** - The transfer of energy can be tracked as energy flows through a designed or natural system.
- **Structure and Function** - Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.
- **Systems and System Models** - Define the system under study and make an explicit model of that system to provide tools for understanding and testing ideas.

Learning Objectives

1. Identify that energy from the sun powers all weather.
2. Explain how heat is transferred through radiation, conduction, and convection.
3. Create models of convection currents that show warm air rising and cool air sinking.
4. Understand that convection currents create air masses that affect weather patterns.
5. Demonstrate that a mirage is evidence of convection.

Vocabulary

- **Radiation** - the transfer of energy across space in the form of waves
- **Conduction** - the transfer of heat from one object to another through direct contact
- **Convection** - the transfer of heat by the movement of fluids (liquids and gasses)
- **Convection current** - the pattern of warm fluids rising and cool fluids sinking
- **Warm front** - a large mass of warm air created by a convection current
- **Cold front** - a large mass of cold air created by a convection current
- **Mirage** - an optical illusion that causes us to see images that aren't really there

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Materials

For each group of 3-4 students:

- Heat lamp with clamp
- Ring stand
- Hot plate
- 2 glass beakers or 2 aluminum pans
- Stopwatch
- Stainless steel washers or hex nuts
- Medium clear plastic tub
- 2 small cups or beakers
- 2 disposable pipettes

Miscellaneous:

- Ice
- Food coloring
- Small paper or plastic cups
- Pony beads
- Computer and internet access
- Candle and lighter or matches
- 2 Large glass flask or beaker
- Student Handouts: *Heat Transfer, Make it Melt!, Make it Melt (Again)!, What I Know - Lesson 2, Simulating Air Movements, Notice & Wonder Chart, Are Invisibility Cloaks Real?, Putting It All Together*

Preparation - Module 2 Lesson 2.2

1. Obtain enough ice for 2-4 ice cubes per group of students. Cubed ice is preferable to crushed ice.
2. Obtain a small paper or plastic cup for each student in class.
3. Partially fill (about halfway) each cup with pony beads. Try to make sure each cup is evenly filled.
4. Draw a line on the outside of each cup to note the “fill level” of the pony beads. This can also be accomplished by using a ruler to measure to a certain height.
5. Transfer all pony beads to a larger container. Add some extra pony beads to the larger container to ensure there are enough for each student.

Preparation - Module 2 Lesson 2.3

1. Determine if any students have severe asthma or allergies that may be aggravated by a candle. Consider using an unscented candle to alleviate student sensitivity to smell.
2. Determine if open flame (even briefly) is allowed in your classroom.
3. Set up a hotplate with a large flask or beaker filled with water. Add enough red food coloring to the water so that it is visibly and completely red. Heat the water so that it is hot but not boiling or scalding.
4. Place another large flask or beaker into an ice bath and fill with water. Add enough blue food coloring to the water so that it is visibly and completely blue.

Module 1 Lesson 2.1 - 50 min.

Phase	Time	Slide	Description
Enroll	5 min.	3	1. Show sample images of a mirage effect. Ask students what they think is going on in the images. Discussion can be generated through a Turn & Talk or Think-Pair-Share activity. • Continue eliciting responses until students have identified the shimmering air above the fire and the false image of water in the desert. Students may or may not identify that these images represent forms of mirages. • Help students notice different parts of the image as needed until they name the shimmering/wavy air and fake water. 2. Ask students if they have ever seen something similar. Accept a few examples. 3. Ask students when we normally see this type of phenomenon. • Guide students to identify that it usually happens around hot things or places, such as the fire and desert.
Enroll	10 min.	4	4. Ask students what else they know about heat. Have students write their ideas in their notebook. • Give students 2-3 minutes to think individually. Then ask students to turn to a partner to share ideas. Students should place a star or dot next to each idea that both they and their partner had. • Have a few students share ideas that they and their partners had in common.
Experience	13 min.	5-6	5. Ask students why they can feel heat from a hot object when they're not touching it. Accept a few responses. Students may have some initial ideas about heat being transferred through the air. 6. Using the student handout *Heat Transfer*, students will work in groups to set up a heat lamp and test if they can feel heat coming from the lamp without touching it. This may also be setup as a demonstration with students taking turns at 1 lamp station. • Students will place their hands 12 inches from the heat lamp when it is both off and on.

Phase	Time	Slide	Description
Experience (cont.)	13 min.	5-6	• Students will then create an initial model to explain why they can feel heat from the lamp without directly touching it. **Safety First!** All other objects should be kept away from heat lamps, as it is possible for fires to start. The lamps and shades can get very hot and should not be touched. Students should not hold their hand or other objects closer than 12 inches in front of the bulb. This should allow them to feel warmth from the lamp without experiencing unsafe levels of heat. **Misconception Alert:** The heat from the lamp is not coming from the visible light itself. Heat and light radiation are different types of waves. While many objects emit both heat and light radiation (such as the sun or a candle), this is not always the case. A curling iron or oven emits heat radiation but not light.
Label	5 min.	7	7. Explain the concept of radiation as a method of heat transfer. **Teaching Tip:** Add the word and definition to a Word Wall. Instead of making the Word Wall yourself, have students make their own Word Wall posters to hang in the classroom.
Demonstrate	10 min.	8	8. Have students think about the investigation from Lesson 1 when they compared temperatures in the sun and in the shade. • Ask students how we're able to feel warmth from the sun if we're not actually touching it? Students should identify that we are feeling radiation from the sun. 9. Have students complete the "Putting It All Together" portion of their handout. **Assessment opportunity:** Students should be able to identify that the heat we feel from the sun is radiation. We feel more heat in the sun vs. in the shade because trees and other objects block the sun's radiation (rays).

Phase	Time	Slide	Description
Review	5 min.	9	10. Students propose other examples of radiation and discuss with a partner. • **Assessment opportunity:** Students should only name examples of heat transfer in which there is no direct contact with objects.
Celebrate	2 min.	10	11. Celebrate students' efforts with high fives, team chants, toasts, a treat, awards, etc. Make sure every student's effort is celebrated.

Module 1 Lesson 2.2 - 80-95 min.

Phase	Time	Slide	Description
Enroll	5 min.	13	1. Play the video of wax melting and ask students to write some observations in their notebooks. Play the video 2-3 times to give students adequate opportunity to observe. 2. Ask students if they can explain what is happening. • Students will likely say the wax is melting. • Ask why the wax is melting. What is heating the wax to make it melt? ◦ Students may or may not identify that the saucer is hot, but will likely say there is something inside the warmer that is heating it (such as a candle or bulb). • Tell students that they are going to investigate what causes the wax to melt.
Experience	15 min.	14	3. Students will investigate whether ice melts faster on a hotplate or on the table using the handout *Make It Melt!* **Teaching tip:** Glass beakers are best for this activity as it is more obvious that there is a barrier between the ice cube and the surface of the hotplate. Aluminum pans also get hotter than glass beakers, increasing the risk of burns if students touch the pan while hot.

Phase	Time	Slide	Description

Experience	10 min.
	(25 w/ ext.)
		15	4. Ask students why they think the ice on the hotplate is melting faster. Students will likely say the hotplate is heating it up.
			• Ask students, "Is the ice touching the heat source?"
			• Continue guiding discussion until students identify that the ice is not directly touching the hotplate. The glass/aluminum is touching the hotplate, and the ice is touching the glass/aluminum.
			• Ask students why the ice melts if it's not directly touching the hotplate.
			  ◦ Play the video of the wax melting again to show the wax is not directly touching the heat source.
			  ◦ Students may say that it's radiation, or that the hotplate is heating up the container, which then melts the ice.
			  ◦ If students think radiation is melting the ice, replay the wax video and point out where the wax is melting - it's only melting from the bottom, where it is touching the bowl. While there may be some radiation, the ice is mostly melting because it is touching
			
			Extension Activity:
			Demonstrates that air can conduct heat, but not as well as solid objects.
			• Ask students if the ice would melt as fast if the glass or aluminum were not directly touching the hotplate, with a thin layer of air between them.
			• Complete the activity *Make It Melt (Again)!*
			The ice suspended above the hotplate will melt slower than the container directly on the hotplate.

Phase	Time	Slide	Description
Label	10 min.	16-17	5. Explain the concept of conduction. **Teaching Tip:** Draw a class model of how conduction works to melt the ice cube. Ask students to share what they included in their own models from the *Make It Melt* activity. Include a zoomed in portion of what is happening to the molecules. A separate section can be included to show air also conducts heat.

Demonstrate	20 min.	18-19	6. Students will demonstrate their knowledge of how energy changes the movement of molecules and what happens when energy is transferred.
			• Give each student an empty cup with a pre-drawn line.
			• A gas will be demonstrated first. Tell students they can move anywhere in the classroom.
			• Demonstrate how students are able to move when they have little or no energy vs. when they have lots of energy.
			  ◦ Little or no energy might look like very slow steps, very small steps, or swaying back and forth.
			  ◦ Lots of energy might look like very quick steps or very large steps.
			• Have students keep their hand raised for a high-five until their cup is full to the line with beads. The activity will continue until all students' cups are full to the line.
			• Have students start moving. Pour some beads into a student's cup and say you are introducing a heat source. Start a timer when you do this.

Phase	Time	Slide	Description
Demonstrate (cont.)	20 min.	18-19	• That student should then start moving faster and transferring energy to other students. Keep introducing more beads until all beads are in circulation. • Stop the timer when all students put their hands down to show their cups are full. Write this time on the board. • Repeat the activity, this time with the class representing a solid. • Make a much smaller area for students to move. Students should be close together without a lot of space in between them. • Time the activity and write the new time on the board. • Ask students if solids or gasses are better at conducting heat. The times should show that heat is transferred faster through a solid than through a gas. This is because the molecules in a solid are much closer together and collide more frequently.
Review	15 min.	20	7. *What I Know* handout **Extension Activity:** Read the UCAR article on conduction. Have students do a GIST activity. • Read the article and highlight important points. • Summarize the highlighted points in 3-4 sentences. • Summarize the summary in no more than 30 words. • For students below level in reading: Have them highlight important points in the article. Then have them choose the 3 most important points they highlighted. • For advanced students, shorten their summaries to 2 sentences and no more than 20 words.

Phase	Time	Slide	Description
Review (cont.)	15 min.	20	**Extend the Extension:** Have students share summaries with a partner or a small group. Have the groups summarize their summaries in no more than 30 words.
Celebrate	5 min.	21	8. Celebrate students' efforts with high fives, team chants, toasts, a treat, awards, etc. Make sure every student's effort is celebrated. This lesson was a lot of work - make it a big celebration!

Module 1 Lesson 2.3 - 70 min.

Phase	Time	Slide	Description
Enroll	10 min.	22-24	1. Show students the video of heat shimmer in the desert. 2. Ask them to write in their journals what they observe and what they think is happening. 3. Have a few students share their ideas with the class. 4. Briefly review radiation and conduction. 5. Ask students what happens to air after it heats up. 6. Light a candle and let it burn for a few seconds, then blow it out. Have students observe what the smoke does. You may need to do this a few times for students to see what is happening. 7. Students should note that the smoke is rising. Ask students why they think that is happening. 8. Tell students they are going to investigate what happens to air when it heats up and cools down. **Teaching Tip:** If you have concerns about students with asthma or if candles are not allowed in your classroom, you can show a video clip of a candle being blown out with smoke rising.

Phase	Time	Slide	Description
Experience	20 min.	25	9. Students will use water to simulate air movement in the activity *Simulating Air Movements.* • Prepare the hot and cold water ahead of time. 10. Have students practice proper pipetting technique prior to doing the activity. 11. Because this activity uses food coloring, their clothes may be stained if they do not use the pipettes properly. Also, improper technique may result in mixing of the water, which will make the results less obvious. • Students should see the hot water rise to the surface and spread towards one end of the container. The cold water should sink to the bottom and spread to the other side of the container. • Students can add multiple pipettes-full of hot and cold water. • If they make a mistake while pipetting and the water all starts to mix together, they can easily dump their container and try again. **Teaching Tip:** Results are more dramatic the hotter and colder your water is. You may want to pour the hot water for students so they don't burn themselves. Proper Pipetting Technique: • Hold the pipette vertically, never horizontally when there is liquid in the pipette. The tip should be facing down. Liquid will not come out unless the bulb is squeezed. ◦ Students usually want to turn the pipette over so the tip is facing up. This will actually cause water to shoot out of the end of the pipette, making a mess and possibly staining clothing. If a hazardous substance were being used, injury could result. Emphasize that proper technique in a laboratory is important for safety. • Squeeze the pipette bulb before inserting the tip into the liquid, then release the bulb to suck liquid into the pipette. Squeezing the pipette should not create bubbles in the liquid.

Phase	Time	Slide	Description
Experience (cont.)	20 min.	25	◦ Bubbles can be a safety hazard if a harmful chemical is being used (because of possible splashing). • Hold the pipette upright while transferring liquid to another container. • When releasing the liquid from the pipette, make sure the tip is submerged before squeezing the bulb. • Steadily squeeze the bulb until the liquid is released. Again, try not to create bubbles. It is better to leave some liquid in the pipette than to create bubbles. The best way to avoid bubbles in this step is to squeeze slowly in a controlled manner and stop squeezing just before the air bubble in the pipette is released. This takes some practice. • With the bulb still squeezed, remove the tip from the liquid, then release the bulb. This will prevent liquid from being sucked back up into the pipette, which will create mixing.
Label	10 min.	26-28	12. Define convection and convection current. Ask students to explain how the results of the *Simulating Air Movements* activity is evidence of a convection current. 13. Have students recall what they know about molecule movement in a warm substance - molecules move faster. Explain that when the molecules move faster they spread out and the fluid becomes less dense. 14. Show the video of water boiling, where students can see warm water rising to the surface. 15. Using this knowledge, have students predict why cold fluids sink. Students should be able to explain the opposite process, that cold molecules move slower so they get closer together. The cold fluid becomes more dense and sinks. 16. Masses of rising warm air and sinking cold air are called fronts. This concept will be explained in more detail in subsequent modules.

Phase	Time	Slide	Description
Demonstrate	10 min.	29	17. Show the video of mixing warm and cold water. **Pause the video at 0:18.** Have students predict what will happen in the two systems (warm water on top of cold and cold water on top of warm). They should have time to record their thoughts individually before sharing with a partner or with the class. 18. Pause the video again at 0:25. Ask students to reflect on what just happened. Why did one system mix together but not the other? Give students time to record their thoughts individually before sharing with a partner or with the class.
Demonstrate (cont.)	10 min.	29	19. Ask students what will happen if the system that is still separated is flipped over, so that cold water is on top of warm water. 20. Play the remainder of the video. Ask students for evidence that convection happened. You may need to play the whole video more than once so students can see how the mixing occurs. **Extension Activity:** After showing the video, repeat the demonstration in class so that students can see the water moving up close.
Review	15 min.	30	21. Have students read the article from NOAA about heat transfer, then record what they've learned on their *What I Know* handout.
Celebrate	5 min.	31	22. Celebrate students' efforts with high fives, team chants, toasts, a treat, awards, etc. Make sure *every* student's effort is celebrated.

Module 1 Lesson 2.4 - 65 min.

Phase	Time	Slide	Description
Enroll	2 min	32-33	1. Revisit the heat shimmer video from Lesson 2.3. Ask students if they can explain what is happening. • Students should note that warm air is rising. 2. Ask students why we're able to see the warm air. Can they always see warm air rising? 3. Tell students we're going to find out why we can sometimes see warm air rising.
Experience	5 min.	34	4. Show the video of the carbon nanotube cloaking device. Have students record their observations on the *Notice & Wonder Chart* handout. You may need to show the video multiple times to give students plenty of time to make observations. Play the video with sound, as there is a faint click in the background. 5. Students should notice that the tubes become "invisible" and the water at the top is rippling. • Students may connect the rippling water to the video of water boiling or to the heat shimmer effect in the desert. It's not necessary that they make that connection at this time.
Label	30 min.	35	6. Have students read the Science Daily article about the carbon nanotube cloaking device and complete the handout *Are Invisibility Cloaks Real?* 7. After completing the handout, have students share with a group or with a whole class. Note that the "On the Page" and "Between the Lines" sections have correct answers, whereas the "Beyond the Lines" section will not have definitive answers that can be found in the article. In this section, how students justify their response is what matters most. **Teaching Tip:** Have students circle or underline words from the article that are new to them or that they are unsure about the meaning and create a class glossary as you discuss the meanings together.

Phase	Time	Slide	Description
Label	8 min.	36-37	8. Explain what a mirage is and how conduction is involved. 9. There are many types of mirages, including the appearance of water on the roadway, floating objects just above the horizon, reflected objects "below" the horizon, and heat shimmer.
Review	5 min.	38	10. Replay the video of the carbon nanotube (CNT) cloaking device. Ask students why it turns invisible. 11. Students should be able to explain that the CNT are heating the water, which causes light to be reflected and creating a mirage, making it appear as if the CNT are invisible.
Demonstrate	10 min.	39	12. Students complete a model of what happens after air heats up using the handout *Putting It All Together*. 13. This can be used as a summative assessment for this lesson.
Celebrate	5 min.	40	14. Celebrate students' efforts with high fives, team chants, a treat, awards, etc. Make sure *every* student's effort is celebrated.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 1 Lesson 3

Module Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 3 - Heat Index

Lesson Navigating Question: Why does hot weather in Oklahoma feel different than hot weather in Arizona?

Grade Levels:
6-8

Time Required:
310 - 365 Min
6-7 class periods

STEM Content Areas:
Science, Technology, Engineering, Math

Overview

Students will discover that there is a relationship between temperature and humidity, and will explore how changes in temperature affect relative humidity. Students will develop models to explain why relative humidity changes with temperature. Temperature and relative humidity will then be measured using a device that students design. These values will be used to determine the heat index for a given day.

Oklahoma Academic Standards

Mathematics Standards

- **6.N.1.3** - Explain that a percent represents parts "out of 100" and ratios "to 100."

Science Standards

Disciplinary Core Ideas

- **6.PS3.4** - Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample
  - Temperature is a measure of the average kinetic energy of particles of matter
  - The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter present
  - The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment
- **6.ESS2.4** - Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
  - Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, and crystallization, and precipitation, as well as downhill flows on land.

Science and Engineering Practices

- **Planning and Carrying Out Investigations** - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data is needed to support a claim.
- **Developing and Using Models** - Develop a model to describe unobservable mechanisms

Crosscutting Concepts

- **Energy and Matter** - Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
- **Scale, Proportion, and Quantity** - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Oklahoma Academic Standards (cont.)

Computer Science Standards

- **6.DA.S.01** - Create multiple representations of the same data.
- **6.DA.CVT.01** - Collect data using computational tools and transform the data to make it more useful.
- **6.DA.IM.01** - Use data to highlight or propose cause-and-effect relationships, predict outcomes, and communicate ideas.

Learning Objectives

1. Identify that relative humidity is an important component of weather forecasts.
2. Compare percent saturation and relative humidity.
3. Model the relationship between temperature and relative humidity.
4. Explain that humidity does not affect the outside temperature, but it can affect how humans perceive the temperature.
5. Use a heat index chart to determine heat index values when given temperature and relative humidity.

Vocabulary

- **Humidity** - the amount of water in the air; AKA absolute humidity
- **Water vapor** - water in gaseous form
- **Relative Humidity** - the amount of water vapor present compared to how much the air could hold at that temperature
- **Saturation** - when air holds as much water vapor as it can for a given temperature; 100% relative humidity
- **Heat Index** - a measure of what the temperature feels like to the human body when relative humidity is combined with the air temperature; AKA apparent temperature

Materials

Student Handouts: *It's Not The Heat..., ...It's The Humidity, Studying Saturation, Lesson 3 - What I Know, It's All Relative (Humidity), Think Like A Meteorologist*

Lesson 3.1 materials needed per lab group:

- Medium beaker
- Disposable pipette
- Dry sponge

Lesson 3.2 materials:

- Large beaker or graduated cylinder
- Small beaker or graduated cylinder

Lesson 3.2 materials needed per lab group:

- 2 analog thermometers
- Cardboard, plastic bottle, cup, or other sturdy material
- Cotton balls or gauze
- Strong twine or string
- Strong tape
- Rubber bands

Preparation - Lesson 3.1

1. Ensure sponges are completely dry.
2. If desired, set up a "Research and Development" station with multiple sponges, pipettes, and a beaker of water. These materials should be separate from the student sets of materials.

Preparation - Lesson 3.2

It's All Relative (Humidity)

1. Determine if the demonstration will be completed as a class demonstration or by student groups. Having students complete the demonstration is preferable but works best with access to multiple sinks, or in a location where spills don't matter (such as outside).
2. If students are completing the demonstration themselves, fill a large pitcher with water. You can streamline the activity by using this pitcher to add water to students' beakers at appropriate times in the activity.

Preparation - Lesson 3.2 (cont.)

Think Like A Meteorologist

1. Obtain a variety of sturdy materials such as cardboard, chipboard, 2 liter bottles, plastic cups, etc. Consider cutting the materials to appropriate sizes ahead of time, especially if using plastic bottles.
2. Test your string or twine to ensure it is strong enough to withstand swinging a weight without breaking.
3. When going outside to use the psychrometers, bring a container of water so students can wet their cotton.

Module 1 Lesson 3.1 - 165 to 220 minutes

Phase	Time	Slide	Description
Enroll	10 min.	3-4	1. Show the map of the U.S. with Arizona and Oklahoma highlighted. 2. Have students record what they know about both states on the handout, *It's Not The Heat...* • These are initial thoughts that students may have. It's okay if they don't know anything about either state, they can imagine what they think it might be like. • If you have students that have lived in AZ, they can share their experiences with the class if they are comfortable doing so. • Have students share some of their responses with the class. Keep eliciting responses until students have at least identified that Arizona contains desert and most of Oklahoma does not. • Students will likely identify that deserts are dry. If they don't, ask students which state they think would get more rain. It is important for students to identify that AZ is drier than OK. • Ask students which state they think would be more comfortable in the summer and in the winter. 3. Show the weather forecasts for Phoenix and for Tulsa.

Phase	Time	Slide	Description
Enroll (cont.)	10 min.	3-4	**Teaching Note:** The weather forecasts are fake. They are intended to be from the same day in summer. The graphs to the side are just background images and do not relate to the forecast. 4. Have students individually record what they notice and what they wonder. Then have students share some of their ideas with the class. • Students should notice that the humidity in Tulsa is higher and the "Feels like" temperature in Tulsa is higher. • Ask students why the temperature in Tulsa would be lower than in Phoenix, but it would feel hotter in Tulsa. ◦ Some students may describe Phoenix as being a "dry heat." ◦ Students may or may not identify that the humidity makes Tulsa feel hotter. If they don't, ask if there is any information in the weather forecasts that could possibly explain why it feels hotter in Tulsa. ◦ After students have identified humidity as an important factor, tell students that they are going to investigate how temperature and humidity are connected, but first they are going to explore the concept of humidity further.
Experience	10 min.	5-6	5. Have students visualize a time when they've taken a shower and the bathroom was very steamy afterwards, and a time it wasn't steamy afterwards (slides 5 and 6, respectively). 6. Have students discuss their experiences of what the air felt like, if they cooled off quickly, if they dried off quickly, etc. Give students time to discuss slides 5 and 6 separately. • After students have discussed both scenarios, ask students why the air would feel different if everything else is the same.

Phase	Time	Slide	Description
Experience (cont.)	10 min.	5-6	◦ Students may suggest that the bathroom stays warmer and more steamy in the summer and cooler in the winter. Point out that they have an air conditioner and heater in their home, which keeps it about the same temperature year round. Point out that the water temperature will also be about the same. Ask how summer and winter might affect the air inside their house if they have a thermostat to control the temperature. Allow multiple ideas to emerge. 7. At this point, students will probably not connect how the air in the bathroom feels to the weather conditions outside. That's okay. • Refer students back to the weather forecasts for Tulsa and Phoenix, where they noticed a higher humidity and higher "feels like" temperature for Tulsa. • Suggest that there may be some connection with temperature and humidity that we should investigate.
Label	30 min.	7	8. Define humidity, which is the amount of water vapor in the air. Explain why the word "moisture" is an inaccurate description for humidity. 9. Ask students to think about the states of matter. Pause the lecture at this point to have students write on their handout everything they know about the states of matter. This should be a familiar concept for students, but you may need to clarify that you are referring to solids, liquids, and gasses. Allow students to share their ideas with a partner before sharing as a class. Write their ideas on the board. • The most important idea to look for is that gasses can't be seen (some gasses actually do have color, but it is unlikely that students will know this). 10. Now ask students what state of matter water vapor would be. Refer students back to the list they just made and ask if water vapor matches the characteristics of gasses they just listed.

Phase	Time	Slide	Description

Label (cont.)	30 min.	7	• Students will likely name that water vapor can sometimes be visible in the form of clouds and steam.
			• Ask students to imagine if we could zoom in on air molecules to see them under a microscope. Have students draw a model on their handout of what they think water vapor (that they can't see) would look like compared to steam.
			  ◦ Have a hot plate with water boiling so that students can observe steam. Alternatively, show a video clip of steam rising.
			  ◦ Give students some time to work on their models, then ask them to include what happens to the water molecules after they can no longer see the steam.
			  ◦ Have students share ideas with a partner before sharing as a class. The main idea to look for is the molecules being closer together when the steam is visible.
			• Now ask students to reflect on their learning throughout the unit so far. Have they experienced other examples of molecules being closer together and farther apart?
			  ◦ Examples should include when they investigated conduction through a solid versus a gas. The molecules in a solid were very close together and the molecules in a gas were very far apart.
			  ◦ Now ask students to take another look at their models of steam. Do their models show the characteristics of a gas? Have students make a claim about the state of matter of the water in steam.
			  ▪ Students should say that it is liquid. Whatever their response, ask them to support their claim with evidence. They may still claim that steam is a gas at this point. As previously stated, this is a very complex concept that will be explored more later. It is okay if student ideas are not yet concrete or accurate at this point.
			  ▪ Allow students to share claims and evidence with the class. There are likely to be some conflicting ideas. The most important aspect of this discourse to focus on is the evidence that students use to support or refute their claims.

Phase	Time	Slide	Description
Label (cont.)	30 min.	7	11. Return to the lecture slide. Explain that water vapor is a gas and not a liquid. "Water" is simply the name of the substance, whether it is a solid, a liquid, or a gas. • It may be helpful to have liquid water and ice available as a reference point. You could also have an empty container to represent water vapor in the air, which can't be seen but is still present. 12. Now explain that when water vapor is visible, like in the case of the picture on the slide or steam, it is no longer a gas, but tiny droplets of liquid water. • Have a cold glass with condensation on it available as a reference point. • These concepts will be explored further in future units when the water cycle, cloud formation, and precipitation are covered. **Optional extension activity:** Give students a glass object and ask them to use their breath to fog the glass. Have students record observations. Ask students to fog the glass again and then wipe the fog with their finger. Does it feel wet? Have them wipe their fingers on glass without fog for comparison.
Experience	60-120 min.	8	13. Ask students if they have ever heard, "It's not the heat, it's the humidity." Ask students what they think that means. Accept all responses. 14. Next, ask students to recall what humidity means. (water vapor in the air) 15. Ask students if they think there is a limit to how humid the air can be. Ask students to justify or expand on their responses. Why do they think there is (or isn't) a limit? Is there any evidence or observations they can provide to support that idea? • Answers may involve things like clouds, fog, rain, or other times water vapor becomes visible. There are likely to be conflicting ideas. • Tell students that it sounds like we have some questions about water vapor in the air, so we should investigate further.

Phase	Time	Slide	Description
Experience (cont.)	60-120 min.	8	16. Give students the …It's the Humidity handout. Explain that in order to investigate how much water vapor the air can hold we will need to design a simulation since we can't see air. 17. Students will design this investigation. Designs can be different for each group or the whole class can decide to use the same design. Either way, most groups' designs will be very similar. • If students have little experience with designing an investigation, it might be best to decide on a procedure as a class. 18. Point out the Investigation Question and available materials. Point out that the question does not specifically say water vapor or air. Ask students why they think that is. • Continue probing students until they identify that "water" doesn't specify if it is solid, liquid, or gas, and/or that water vapor is still water. • Students should also identify that we use the word "substance" instead of "air" because we are not testing air in our investigation. ◦ Students may need support to reach this conclusion. Designing an investigation that addresses a question is a difficult concept that takes a lot of practice. ◦ Point out that air is a kind of substance, so we should be able to apply the results of this investigation to air. 19. Have students start by brainstorming some ideas for how to design their investigation. This should be done individually or with a partner. • Ideally, students will decide on the following uses for the materials: ◦ Water - represents water vapor in the air ◦ Sponge - represents the air ◦ Beaker - used to obtain water ◦ Pipette - drizzle water over the sponge

Phase	Time	Slide	Description
Experience (cont.)	60-120 min.	8	• Have each student or student pair share their brainstorming ideas with another pair. The group should decide on the best ideas they want to use for their investigation. ◦ If the whole class will use the same procedure, numbers 2-8 of the handout can be completed together as a class. Consider having students complete these steps as a think-pair-share before creating class procedures. ◦ If each group will be doing their own investigation, check in with each group to have them explain their procedure to you before they begin. ▪ Make sure students have a clear plan that details how they will be using materials, what they will be looking for, what data they will collect, how they will drizzle water over the sponge (will they cover the entire sponge or continue adding to the same place?), etc. Student investigations should be designed to directly answer the Investigation Question. ▪ If students are unable to explain their plans, seem confused, or appear to be randomly playing with supplies, have them consult with another group to get ideas. Check back in with them to see if they have a clearer picture of how they should proceed. **Teaching Tip:** Adopt a "look but don't touch" policy when students are brainstorming investigation designs. Students have a tendency to jump straight into tinkering without having a clear plan. Allow students to view the materials but not take them to their desk until their procedure receives teacher approval. Alternatively, allow students to have all materials except water at their desk. You can also create a Research & Design station with an extra set of materials that students can tinker with to get ideas during their brainstorming. Make sure students understand that R&D happens before collecting data, so they should not use the R&D station to conduct their investigation. It should only be used to see how the materials might be used together or to try out an idea to see if it works.

Phase	Time	Slide	Description
Experience (cont.)	60-120 min.	8	20. After students have completed their investigations and analyzed their results, have groups share their results with the class. • If groups have all completed the same experiment, average the class data for analysis. • If groups have completed slightly different experiments, ask students if their data can be compared with groups that did a different investigation. Are the results still useful if the investigations were different? ◦ In this case, data should not be averaged, but patterns can be identified. A possible extension is to repeat the experiment with each group using the same procedure. ◦ Possible differences in data include groups counting number of pipettes-full while others measured milliliters. These numbers wouldn't represent the same information and should not be averaged together. However, the pipettes have measurement indicators, so the number of pipettes-full could be converted to an equivalent measurement in milliliters. 21. Discuss what students observed in their investigation. What happened when the sponge was full of water? How do they know it was too much water? Ask students to provide specific evidence or data from their investigation. Possible Extension: Emphasize the importance of writing clear procedures by having groups trade investigation plans. Groups will use another group's procedures to attempt to replicate their investigation. Students should follow the instructions exactly as written. They should then share their results with the original group. Are their results significantly different, or were the original results replicated? It is unlikely that the results will be exactly the same, but is it close enough that their conclusions would be the same? Groups should also provide feedback on how the procedures were written. Was it clear and easy to follow? What are some suggestions for improvement?

Phase	Time	Slide	Description
Label	10 min.	9-10	22. Ask students to recall the results of their *…It's The Humidity* investigation. Ask students if we can apply those results to water vapor in the air to make a claim about whether there is a limit to how humid the air can be. Ask them to use data from their investigation as evidence to support their claim. • Students should identify that the results indicate there is a limit. 23. Ask students if they have any data that tells us how much water vapor the air can hold. • There may be some uncertainty here, but students should identify that they are not able to make any claims about how much water vapor the air holds. 24. Inform students that there is not a certain amount of water vapor that can be in the air, because it changes depending on the temperature of the air. • Explain that warm air can have more water vapor molecules than cold air. • Have students pause and reflect on why that statement might be true. Ask them to record their thoughts in their notebooks. Is there an analogy the statement makes them think of, have they personally experienced or observed something similar, etc. • Ask students to draw a model of warm and cold air in their notebooks. Do they see anything in their drawings that they think might explain the statement? • Allow students to discuss with a partner, and then share their thoughts with the class. ◦ They may not have clearly formed ideas at this point, but will likely involve how close the molecules are or how fast the molecules are moving. This is foundational knowledge for the concept of condensation, which will be explored more later. ◦ Accept all responses, but draw attention to responses that involve the closeness and/or speed of molecules. 25. Define relative humidity as the amount of water vapor compared to how much the air could hold at that temperature. 26. Define saturation as the maximum amount of water vapor the air can hold at a certain temperature, otherwise known as 100% humidity.

Phase	Time	Slide	Description
Demonstrate	30 min.	11	27. Give students the handout *Studying Saturation* and inform them that they will be analyzing the saturation of the sponge from the *…It's The Humidity* activity. 28. Begin by having students reflect on what it meant for the sponge to be saturated. They should recall their data from the previous investigation to include how much water it took to saturate the sponge. • Data is likely to vary from group to group. They should use the data that their group collected, not the class average or another group's data. • The "Setting the Stage" portion of the handout should be completed collaboratively in pairs or small groups so that students have the opportunity to discuss their ideas with others. • Have groups discuss their ideas with the class. **Teaching Tip**: Notice that the questions in "Setting the Stage" do not have a correct answer, even #2 in which students should say 100%. All of the questions offer the opportunity for disagreement and debate. For example, some students may say the sponge was fully saturated when it dripped water. Others may say it was fully saturated just before it dripped water, since dripping water indicates that it can't hold any more. Students should say 100% on #2, but may reason that 99% was the most the sponge could hold, because at 100% it couldn't hold more and began to drip water. In either case, it is how students justify their answers that matters, not necessarily the answer itself. Both of the sample responses above indicate that students understand the meaning of 100% saturation. You can encourage alternate explanations and out of the box thinking by asking students if there are any other plausible ways to interpret or explain their observations.

Phase	Time	Slide	Description
Demonstrate (cont.)	30 min.	11	29. Before moving to the next section of the handout, ask students if the saturation of the sponge remained constant throughout the investigation. Students should reason that it became more saturated as they continued adding more water. 30. Have students draw a model or chart of how they think the saturation of the sponge changed throughout the investigation, then have students share with each other and with the class. Call attention to any models that resemble a graph, but don't offer the word "graph" as a description. Ask students to explain what they've drawn and what it means. Look for graphical reasoning in non-graphical models, such as showing a sponge with a water level that is rising (similar reasoning of a bar graph). **Teaching Tip:** Graphing can be intimidating and confusing for students. They often fail to relate graphs to data sets or to infer meaning from a graph. Offering students the chance to produce a graph on their own and in context, without them realizing it is a "graph" can help alleviate some of their preconceived negative feelings about graphs. Ask questions such as, "What does this show?" "What does this mean?" "Why did you choose to draw it this way?" or "What does this part represent?" 31. In the "Let's Calculate" portion, it is important for students to understand not only how to calculate a percentage, but what it means. • You may want to have students complete #6 as a Think-Pair-Share before moving onto the next questions. • After students have determined the answer is 90%, ask them to explain what 90% means or represents. What is 90%? 90% of what? ◦ Students should express that 9 points is 90% of the total possible points. 32. Have students calculate the % Saturation for each time they added water to the sponge. They should track this information using a data table or spreadsheet. • A spreadsheet can be programmed with a formula to do the calculations automatically when data is entered. • Using a spreadsheet can reduce the emphasis on correctly copying data and instead put more emphasis on interpreting data.

Phase	Time	Slide	Description
Review	10 min.	12	33. Have students reflect on what they've learned so far using the *What I Know* handout for Lesson 3. • Students should be able to respond confidently through the first 5 targets. Use their responses to determine any points that need more instruction.
Celebrate	5 min.	13	34. Celebrate students' efforts with high fives, team chants, a treat, awards, etc. Make sure *every* student's effort is celebrated.

Module 1 Lesson 3.2 - 145 minutes

Phase	Time	Slide	Description
Enroll	5 min.	14	1. Start with the weather forecast images for Tulsa and Phoenix that were first introduced in Lesson 3.1. 2. Ask students if we have enough information to answer the question, "Why does hot weather in Oklahoma feel different than hot weather in Arizona?" • Students will likely say no. • Ask students to list some things they learned in the previous lesson that they think might be relevant. Students will likely say humidity. • Have students think about the % humidity listed on the weather forecasts. Ask students to imagine what 20% humidity would feel like compared to 67% percent humidity. Give students about a minute to imagine. • Ask students how they think the difference in humidity might affect the "feels like" temperature. • Allow students to think silently and write in their notebooks before they share ideas with a partner and with the class.

Phase	Time	Slide	Description
Experience	30	15	3. Begin the It's All Relative (Humidity) handout by reviewing the meaning of relative humidity. 4. Have students draw a picture that represents the meaning of relative humidity. • Allow students to share their pictures with each other and explain what they drew. Have a few students share with the class. 5. Go through the statements on #2 together. Have 2 measuring cups, beakers, or graduated cylinders (empty) on hand, one that is much larger than the other. Ask students which container they think would represent warm air and which would represent cooler air. The larger container represents warmer air, since it is able to hold more. 6. Have students consider the scenario in #3 and record their thinking. This is a difficult concept for students to grasp, so it is okay if their thinking is not correct at this stage. Encourage students to record their initial thoughts and reasoning and to draw what they're thinking with a model. • Allow students to discuss their models with a partner before sharing responses as a class. *The following steps may be done as a demonstration or students may manipulate the materials themselves. If students are manipulating the materials, follow the same procedure, directing students to do the water pouring instead of yourself.* 7. While students are working, fill the smaller container to the top measurement line with water. • After students have discussed their responses to #3, show students the smaller container that is full of water. Ask students what they think will happen if you pour the water into the larger container. If necessary, prompt students to think about the water level in each container. Accept all responses.

Phase	Time	Slide	Description
Experience (cont.)	30	15	8. Pour the water into the larger container. Ask students what they notice. • Students should identify that the container is not as full, or that the water level is lower. • Ask if it would be possible to pour more water into the container. Students should say yes. • Add more water, until the level reaches the top measurement line. Ask students what would happen if you poured this water back into the smaller container. Pour it back in, allowing the water to overflow. 9. When the smaller container is completely full, ask the students what the % saturation of the container would be. • Students should say 100%. • Now ask if the container were to represent air, what would the % relative humidity be? • Students should again say 100%. ◦ Point out that % saturation and % relative humidity are the same. 10. Pour the water in the smaller container back into the (now empty) larger container. Ask students if the % relative humidity would still be 100%. Students should say no, and may offer an estimated %. 11. Now refer students back to the models they drew on #3. • Pour water into the larger container to represent 45%. You can measure this exactly if desired. • Tell students the larger container represents 75 degrees with 45% humidity, and the smaller container represents 60 degrees. • Now pour the water into the smaller container. Ask students if the relative humidity is more or less than 45%. If desired, you can have students measure this exactly. It should be obvious to students that it is more than 45%. 12. Have students revise their initial models about relative humidity using this new information.

Phase	Time	Slide	Description

Experience	15 min.	16-18	13. Ask students to close their eyes and imagine playing outside in August in both Arizona and Oklahoma. Encourage them to think about how it feels outside.
			14. Tell students to imagine they've been playing for a while. Ask them if they would feel sweaty and hot in each place.
			• Students will likely say yes.
			• Ask students why we sweat. What does it do for us, what purpose does it serve?
			  ◦ Continue probing until students identify that it cools you off.
			• Refer students back to the weather forecasts for OK and AZ. The "feels like" temperature is not the actual temperature, but how hot it feels to our bodies. Ask students if OK feels hotter, is sweat cooling you off the same in both places?
			• Now return to the *It's All Relative (Humidity)* handout to have students think about why they could cool off easier in AZ than in OK.
			  ◦ Give students time to consider their models. Allow students to discuss with a partner before sharing with the class.
			  ◦ At this point, students should be starting to put together that higher humidity means there is less availability for more water vapor to enter the air. In other words, sweat will not evaporate as much.

Label	15 min.	19-20	15. Explain that sweat helps cool you off because it allows water to evaporate from your skin, carrying heat with it. • Because air becomes more saturated with water vapor as more water evaporates, sweat won't be able to evaporate as readily in high humidity. Therefore, it will not cool you off as much. • This causes the temperature to feel warmer, which is called the heat index. 16. Show students the heat index table. Explain that it uses temperature and relative humidity to determine the heat index. The table also indicates unsafe temperature and humidity conditions for being outside.

Phase	Time	Slide	Description
Demonstrate (cont.)	75 min.	21	17. Give students the handout *Think Like A Meteorologist*. Explain that students will be making a sling psychrometer, which is the same type of instrument a field meteorologist would use to collect weather data. More sophisticated digital instruments exist, but sling psychrometers are still widely used when working in the field. 18. Students should first look at the 2 sets of thermometers to predict which would have the higher relative humidity. This is a thinking space to get student ideas flowing. • Have students think-pair-share to explain their ideas. • Students may need help realizing that a larger difference between the dry and wet bulbs means more water evaporated, indicating the air is "drier" or has a lower relative humidity. When the dry and wet bulb temperatures are similar, it means there is a high humidity, so not as much cooling happens through evaporation. • If students are struggling to come to this idea themselves, have them think of the moistened cotton around the wet bulb as sweat. Is the thermometer's "sweat" doing a good job of cooling it off? Does sweat cool you off better when it is humid or when it is dry? **Teacher Tip:** This is a good opportunity for a quick check to make sure students remember how to read a thermometer, and to make sure they understand the math involved. When you talk about comparing the temperatures of the dry and wet bulbs, use mathematical language. Ask students what the *difference* in temperature is between the thermometers, or *how much warmer* the dry bulb is than the wet bulb. Have students explain what they did to figure out the temperature difference. This will make the calculations seem more intuitive later. 19. Students will design their own sling psychrometers. How they attach the thermometers doesn't really matter, as long as both bulbs are exposed to the air.

Phase	Time	Slide	Description
Demonstrate (cont.)	75 min.	21	• Ensure that students have a written plan or blueprint of what they will be building. #2 is intended to be a brainstorming space where they can draft a plan before building. Try adopting the same "Look but don't touch" policy for supplies that you have used in previous activities. • You can supply all materials for students, or you can have students scavenge their own materials (except the thermometers). 20. Allow students to practice with their designs before attaching the thermometers, or use shatter-proof thermometers. • Students should describe and draw any changes they make to their designs on #3. This step should not be skipped! Engineering Design is an iterative process, so it is highly unlikely that students will not change anything about their design. Even if they change the position of the tape or the length of the string, they should record their changes on this step. • Students' designs may go through multiple iterations. They should record all changes on this step. Recording changes and iterations does not come naturally to most students, so they may need help identifying where, when, and how their designs changed. 21. After designs have been tested to ensure the thermometers won't fly off, students should record data outside. Allow the thermometers to come to temperature for at least 5 minutes before applying the wet cotton or before slinging. It is important that both the wet and dry thermometers begin at the same temperature. Data collection should ideally be done in the shade. 22. To analyze results, students will subtract the wet bulb temperature from the dry bulb temperature. This result will be used with the Relative Humidity Table to determine the % Relative Humidity. • Notice that temperature readings are in intervals of 5. Students should round the temperature to the nearest multiple of 5 before using the chart.

Phase	Time	Slide	Description
Demonstrate (cont.)	75 min.	21	23. Once students know the temperature and relative humidity, they can use the Heat Index Table to determine the heat index. • Note that the heat index may actually be cooler than the ambient temperature, depending on the humidity that day. **Optional Extension:** Have students use their sling psychrometers daily for an extended period of time to track how temperature, RH, and heat index vary over time. Their data can be recorded in a spreadsheet and graphed.
Review	10 min.	22	24. Ask students if they think they now have enough information to answer the question of why hot weather in OK feels different than hot weather in AZ. They should record their thoughts on the *What I Know* handout. • You can have students discuss ideas with each other. • Have students provide evidence from the data they've collected, charts they've analyzed, etc. You can make a list of evidence on the board.
Celebrate	5 min.	23	25. Celebrate students' efforts with high fives, team chants, toasts, a treat, awards, etc. Make sure *every* student's effort is celebrated.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 1 Lesson 4

Module Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 4 - Wind Chill

Lesson Navigating Question: Does heat index work the same in the winter?

Grade Levels:
6-8

Time Required:
95 Minutes
2 Class periods

STEM Content Areas:
Science, Technology

Overview

Students will investigate why heat index is not a value reported for temperatures below 76 degrees. Students will analyze data of various temperatures and relative humidities to identify patterns and construct an explanation of why heat index values have a lower limit. Students will use a standard chart to determine wind chill and will evaluate the safety of those weather conditions.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.PS3.4** - Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample
  - Temperature is a measure of the average kinetic energy of particles of matter.
  - The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter present.
  - The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.

Science and Engineering Practices

- **Planning and Carrying Out Investigations** - Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
- **Developing and Using Models** - Develop a model to describe unobservable mechanisms.
- **Analyzing and Interpreting Data** - Analyze and interpret data to determine similarities and differences in findings.
- **Mathematics and Computational Thinking** - Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
- **Constructing Explanations and Designing Solutions** - Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

Crosscutting Concepts

- **Patterns** - Graphs, charts, and images can be used to identify patterns in data.
- **Energy and Matter** - The transfer of energy can be tracked as energy flows through a designed or natural system.
- **System and System Models** - Models can be used to represent systems and their interactions - such as inputs, processes, and outputs - and energy, matter, and information flows within the systems.

Oklahoma Academic Standards (cont.)

Computer Science Standards

- **6.DA.S.01** - Create multiple representations of the same data.
- **6.DA.CVT.01** - Collect data using computational tools and transform the data to make it more useful.
- **6.DA.IM.01** - Use data to highlight or propose cause-and-effect relationships, predict outcomes, and communicate ideas.

Learning Objectives

1. Interpret temperature and relative humidity data to explain why heat index is not reported in cold weather.
2. Recognize that wind chill is a measure of how temperature feels to human skin due to wind.
3. Create a model to demonstrate how wind increases heat loss from the skin, causing the air to feel colder than the actual temperature.

Vocabulary

- **Wind Chill** - what the air temperature feels like to humans due to wind blowing on exposed skin

Materials

- Fan
- Hair dryer
- Computer access
- Student Handouts: *How Low Can You Go, Chilling with Wind Chill, Wind Chill Chart, Putting It All Together*

Preparation

1. Ensure students have access to computers and the internet.
2. Set up a fan and hair dryer station. If possible, allow each group of students to have both a fan and hair dryer.

Module 1 Lesson 4.1 - 95 minutes

Phase	Time	Slide	Description
Enroll	5 min.	3	1. Ask students to consider the lesson question, "Does heat index work the same in the winter?" Ask if we have any reason to think it wouldn't work the same based on what we've learned so far. • Have students talk with a partner or with a group before sharing ideas with the whole class.
Experience	40 min.	4	2. Have students examine the **Heat Index Table**, record what they notice, and wonder about the lower temperatures on the chart. Students should record their thoughts on the student handout *How Low Can You Go?* 3. Students will create an initial model that they think explains why lower temperatures are not included on the table. 4. Have students use a computer to access this **heat index calculator**. Students will use the calculator to investigate how heat index behaves with lower temperatures. • Students should first plan how they will investigate. They should decide what temperatures and what %RH they wish to enter into the calculator. The intention with this step is to help students experiment methodically and with reason instead of randomly entering numbers. This step can be completed individually or with a partner. • Have students record their results on a spreadsheet. • Check with individual students to determine what their investigation plan is. If students appear to have selected random numbers, suggest that it may be easier to see patterns in the results if they use a pattern to select what values to test.

Phase	Time	Slide	Description
Experience (cont.)	40 min.	4	5. After students have entered their results, they should use colors and/or graphs to analyze their data. Color coding can easily be accomplished with conditional formatting. 6. Students have likely chosen different values to test. Consider having students submit their data to a class data set. This will allow them to analyze a wider range of data. 7. Students should make a claim about why they think lower temperatures are not included in the heat index table. They should use evidence they have collected to support this claim. Have students share their claims and evidence with the class.
Label	5 min.	5	8. Explain that wind chill makes the air feel colder than it is because wind blows body heat away from our bodies. • Wind chills only affect animals like humans, which produce body heat. The temperature of inanimate objects will not change, no matter how strong the wind is. Inanimate objects will never be colder than the air temperature.
Demonstrate	30 min.	6	9. On the handout *Chilling with Wind Chill*, have students consider how wind might have a cooling effect against our skin. Have students share their models with a partner and/or with the class. 10. Set up at least one fan and hair dryer. Allow students to feel the air from both. Make sure the hair dryer is set for warm air. Students should notice that the fan feels cool but the hair dryer feels warm. 11. Ask students to create a model that explains how heat is being transferred. • Students may need a reminder of heat transfer, such as conduction and convection. • Students should identify that the warm air from the hair dryer is transferring heat to our skin so it feels warm. The air from the fan is cooler than our skin, so heat from our skin is transferred to the air, making us feel cooler.

Phase	Time	Slide	Description
Demonstrate (cont.)	30 min.	6	12. Have students share their models with a partner and with the class. • Students should identify that heat is always transferred from warmer objects to cooler objects. 13. Students will practice determining wind chill using a wind chill chart. • Students should create a color coding system to indicate the safety of outdoor activity in the given weather conditions. • Students should determine what information they want to convey, such as safe vs. unsafe, frostbite times, exposure threshold time, etc. Ideally, they will create their own color coding system instead of copying the one on the wind chill chart.
Review	10 min.	7	14. Have students reflect on what they've learned so far on the handout *Putting It All Together.* • Students should identify that: ◦ Humans can perceive the temperature to be hotter or colder than it actually is. ◦ When the humidity is high, heat from our bodies is not conducted as readily to the surrounding air because not as much sweat evaporates. This causes a heat index (perceived temperature) that is higher than the actual temperature. ◦ When temperatures are low and wind speeds are high, more heat from our bodies is conducted to the surrounding air, causing a wind chill (perceived temperature) that is lower than the actual temperature. ◦ Humidity is an important factor for heat index because our bodies sweat to cool us down, but it is not important for wind chill. **Teaching Tip:** This activity can be used as a summative assessment.
Celebrate	5 min.	8	15. Celebrate students' efforts with high fives, team chants, toasts, a treat, awards, etc. Make sure *every* student's effort is celebrated.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 1 Lesson 5

Module Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

Lesson 5 - Temperature Advisory Alerts

Lesson Navigating Question: How do we keep people safe in the extreme temperatures of summer and winter?

Grade Levels:
6-8

Time Required:
155 Minutes
2-3 Class periods

STEM Content Areas:
Technology

Overview

After examining the work of a meteorologist in Oklahoma, students create a temperature advisory alert for either extreme heat index or wind chill temperatures. Students will decide how the alert should be designed and disseminated for equitable access for all.

Oklahoma Academic Standards

Computer Science Standards

- **6.DA.CVT.01** - Collect data using computational tools and transform the data to make it more useful.
- **6.DA.IM.01** - Use data to highlight or propose cause-and-effect relationships, predict outcomes, and communicate ideas.
- **6.IC.CU.01** - Explain how computing impacts people's everyday activities and careers.
- **6.IC.CU.02** - Identify and discuss the technology proficiencies needed in the classroom and the workplace, and how to meet the needs of different users.

6.AP.PD.01 - Seek and incorporate feedback from team members to refine a solution to a problem.

Learning Objectives

1. Describe the health risks associated with extreme heat index and wind chill conditions.
2. Create an informational display to warn people of the effects of extreme temperatures

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Materials

- Computer and internet access
- Student Handouts: *Investigating Weather Warnings, Meet a Professional, Creating a Temperature Advisory Notice, Peer Evaluation Form*

Vocabulary

- **Excessive heat outlook** - excessive heat possible in the next 3-7 days
- **Excessive heat watch** - excessive heat is likely in the 24 to 72 hours
- **Heat advisory** - when the max heat index is 100°F or higher for at least 2 days
- **Excessive heat warning** - When the max heat index is 105°F or higher for at least 2 days
- **Wind chill watch** - there is potential for very cold air and strong winds to create dangerously low wind chill values
- **Wind chill advisory** - low wind chill temperatures are expected but will not reach local "warning" criteria
- **Wind chill warning** - very cold air and strong winds will create dangerously low wind chill values
- **Heat exhaustion** - a serious condition in which the body overheats
- **Heat stroke** - the body can no longer control its temperature and is unable to cool down
- **Hypothermia** - when the body loses heat faster than it can produce heat

Module 1 Lesson 5 - 155 minutes

Phase	Time	Slide	Description
Enroll	10 min.	3-4	1. Tell students that they have learned a lot about temperature and how humans experience temperature. Remind students of the module driving question. Now we want to know how we can use that information to keep people safe during the extreme temperatures of summer and winter. 2. As a Think-Pair-Share, have students discuss if they have seen the words watch, warning, or advisory on weather alerts. Have students discuss what they think those words mean. Have they seen an extreme temperature advisory alert? Where did they see it? When was the alert announced? How or where do they normally get information about extreme temperature warnings?

Phase	Time	Slide	Description
Enroll (cont.)	10 min.	3-4	• First, give students time to think quietly, and then have them talk with a partner. ◦ You may want to have them discuss each question separately. • Have some students share with the class. Make a list of responses on the board. Continue accepting all responses until all ideas have been listed. 3. Now ask students if there might be people who are unable to receive warnings in the ways they've listed. • Examples may include people without cell service, or don't have a TV, people who speak a language other than English, people who are vision impaired, etc. **Teaching Tip:** It is important not to approach step 3 with a deficit view. If people do not have access to weather safety information, it is not a fault of their own. The goal is to help students see that there is not equitable access to safety information, such as weather reports that are only offered in English. If there are limited ways to access safety information, some people will be left out. This is a problem that students will attempt to solve.

Experience	45 min.	5	4. Have students research temperature advisory alerts for either extreme heat or extreme cold. They should look for patterns, such as what kind of information is included, how the alerts are disseminated, terminology that is used, impact on humans, etc.
			• The Investigating Weather Warnings handout may be used to help guide students' research if desired.
			• Useful websites include:
			  ◦ **Heat Safety Tips and Resources** (weather.gov/safety/heat)
			  ◦ **Cold Weather Safety** (weather.gov/safety/cold)
			5. Have students share their findings. This could be in the form of class discussion or a short slideshow presentation.

Phase	Time	Slide	Description
Label	5 min.	6-8	6. Student research should identify the definition of advisories, watches, and warnings for both heat index and wind chill. If not, define with students what these mean. 7. Student research may also uncover heat exhaustion, heat stroke, and hypothermia. If not, define these with students as well.
Enroll	10 min.	8	8. Now that students have seen examples of watches, warnings, and advisories, ask if the difference between those words was obvious to them. 9. Have students think about past experiences that helped them understand these words. Have they seen those words used before? • Students who have lived in Oklahoma for a while are probably familiar with severe storm watches and warnings. 10. Now, have students consider whether they would have the same innate understanding of the words if they had not had those past experiences (for example, maybe they recently moved to Oklahoma and have not seen severe storm watches or warnings). • Students who have lived elsewhere and are not familiar with the terminology (or have seen it used in a different context) may be able to share how their past experiences have given them a different understanding of the words. • Students whose primary language is not English may explain that the difference in meaning between the words is unclear. **Teaching Tip:** If students have different understandings of the words watch, warning, and advisory (such as in the examples above), do not put them on the spot to explain their past experiences. This can accentuate a feeling of "otherness" or that their personal experience and knowledge is not "correct." Instead, aim to create a classroom culture of respect so that all students feel safe in sharing their experiences. Treat student knowledge, culture, and experience as a valuable resource that they may share if they feel comfortable doing so. This will be made more clear in the Meet a Professional Spotlight.

Phase	Time	Slide	Description
Experience	20 min.	9	11. In the Meet a Professional Spotlight, students are introduced to Joseph Trujillo Falcón, a meteorologist specializing in bilingual risk communication. Joseph lives and works in Oklahoma with the Cooperative Institute for Severe and High-Impact Weather Research and Operations (CIWRO) at the University of Oklahoma. • Watch MyRadar's interview with Joseph as he introduces his background and field of expertise, which involves removing barriers for Spanish speakers to access weather safety information. • Have students read an **article** about Joseph's work. On the handout *Meet a Professional*, students will consider how Joseph's work could be used to make temperature advisory alerts more accessible for all.
Demonstrate	60 min.	10	12. Students will create a temperature advisory for either heat index or wind chill. 13. Using the *Creating a Temperature Advisory Notice* handout, have students first plan out their advisory notice before constructing a prototype. Allow students to create whatever type of advisory they think will be most helpful to people. This could be one of the examples listed on the handout, or they could come up with their own solution to the problem, similar to how Joseph changed the Spanish alert system. 14. Ideally, students should make a digital version of their advisory. That could be a video, sound recording, or graphic display.
Review	10 min.	11	15. Have students evaluate the advisories of other students using the *Peer Evaluation* form. Every student can evaluate every advisory notice, or students could be assigned a few random evaluations. • The form is designed to be anonymous, but names can be included if desired. • Have students include specific information in the comments column explaining their scores. For example, if they give a 5, they could include a comment such as, "I like that you explained the difference between a warning and a watch. That should help people understand it better." 16. Peer evaluations should be returned to students so they can make any adjustments to their design.
Celebrate	5 min.	12	17. It's the final celebration! Celebrate students' efforts with high fives, team chants, toasts, a treat, awards, etc. Make sure *every* student's effort is celebrated.

WEATHERING THE STORM

MODULE 1: WEATHER

Driving Question: How do we keep people safe in the extreme temperatures of summer and winter?

WHAT IS WEATHER?

LESSON 0

LESSON 0 – ENROLL

1

What is weather?

2

Does everywhere have the same weather?

3

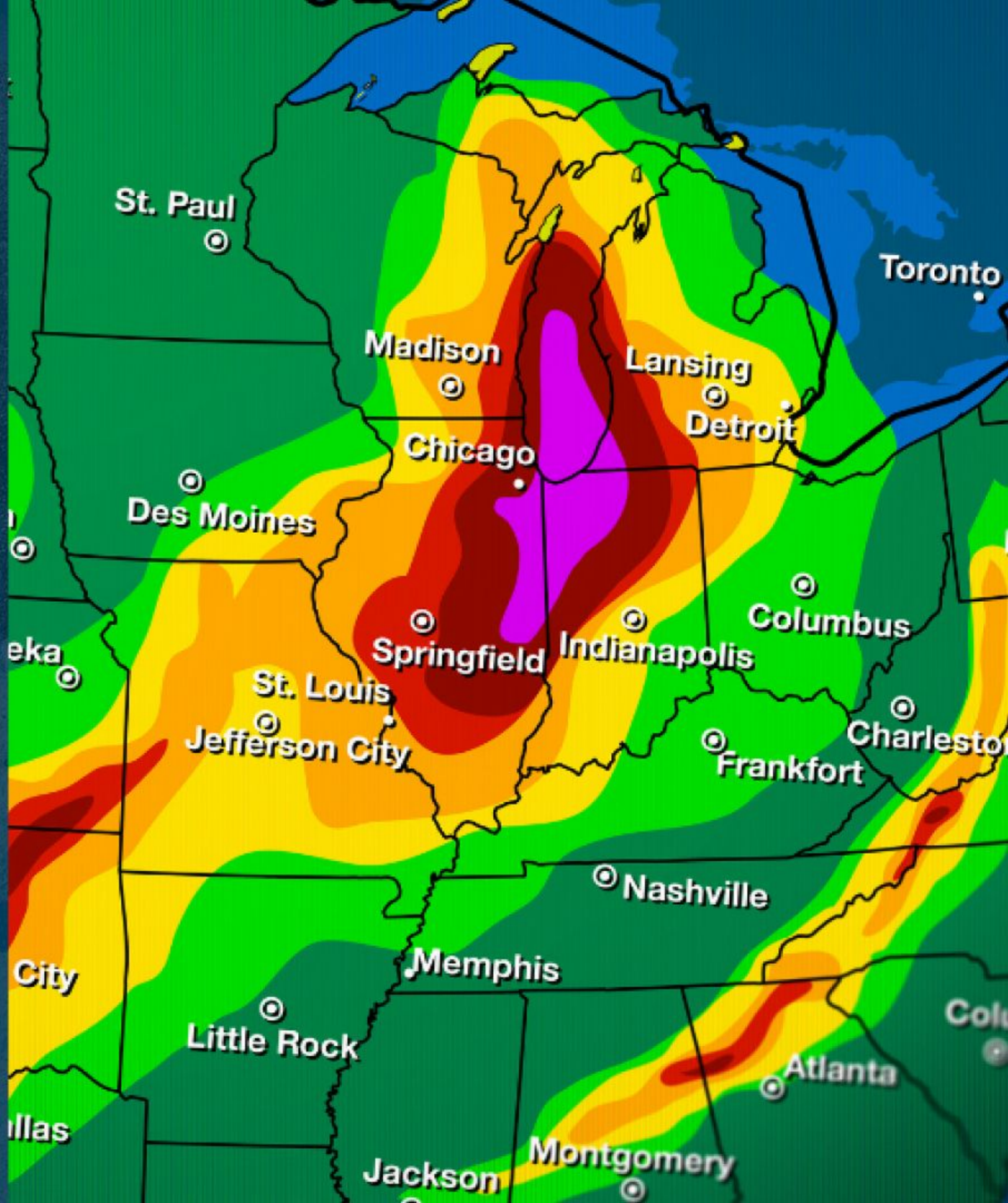
What kind of places might have different weather than Oklahoma?

LESSON 0 - EXPERIENCE

What is the weather like today?

What was the weather like yesterday?

What about 3 months ago?



LESSON 0 – LABEL

Weather is the state of the atmosphere including:

- **Temperature**
- **Pressure**
- **Wind**
- **Humidity**
- **Precipitation**
- **Cloud cover**

LESSON 0 – ENROLL

What does a meteorologist do?

Would you like to learn how to create a weather forecast?

LESSON 0 – EXPERIENCE

‹Insert your local weather clip›

EXAMPLE

LESSON 0 – LABEL

Meteorology is the study of the atmosphere and all its processes, especially phenomena related to weather.

There are many types of careers in meteorology, not just the people you see on TV.

LESSON 0 - DEMONSTRATE

Let’s explore some different careers in meteorology.

What do you find most interesting?

What is most surprising?

LESSON 0 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

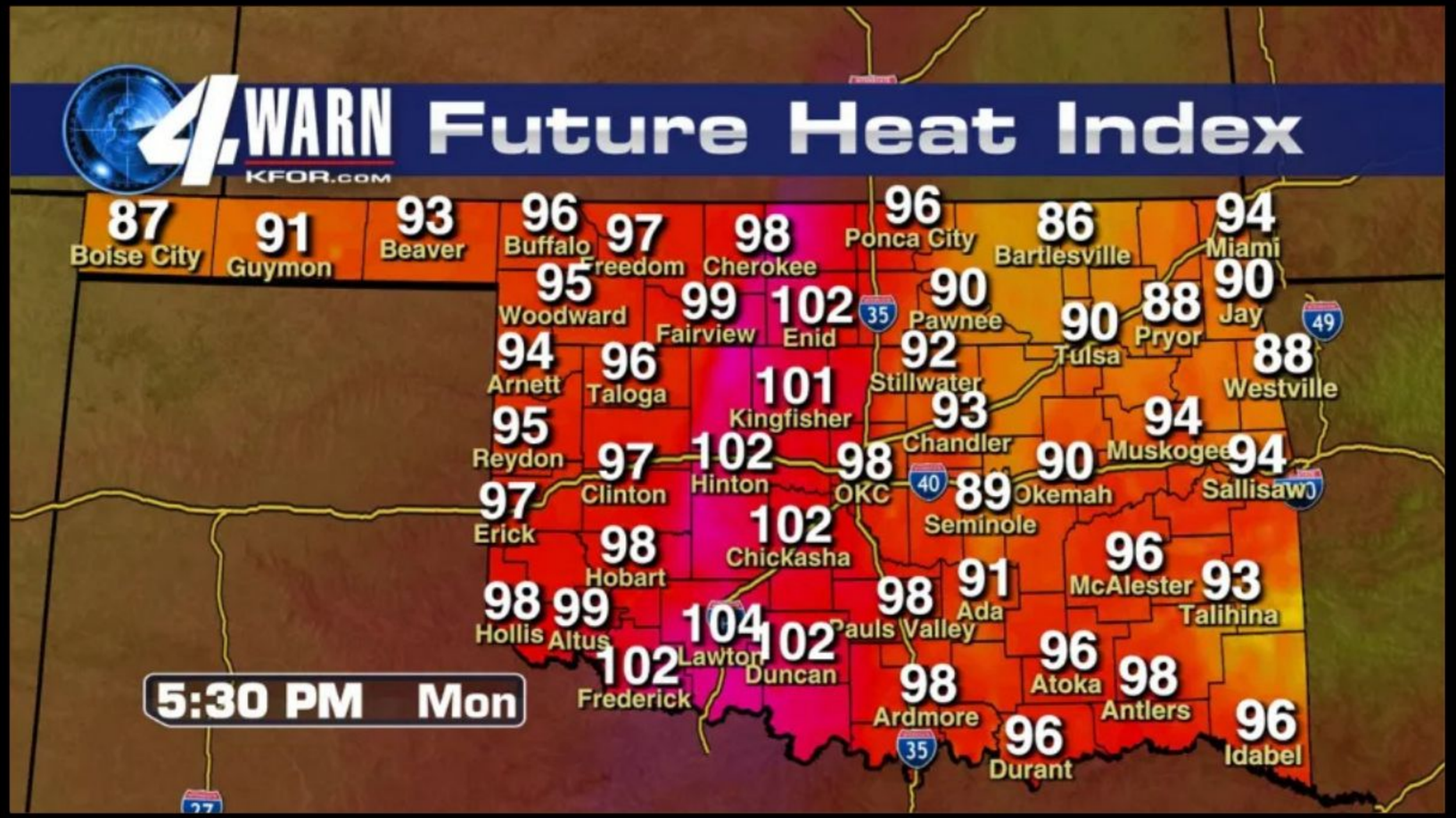
WEATHERING THE STORM

MODULE 1: WEATHER

Lesson 1 - Temperature

HOW DO WE MEASURE WEATHER?

LESSON 1.1


4 WARN
KFOR.com
Future Heat Index
87 Boise City
91 Guymon
93 Beaver
96 Buffalo
97 Freedom
98 Cherokee
96 Ponca City
86 Bartlesville
94 Miami
95 Woodward
99 Fairview
102 Enid
90 Pawnee
90 Tulsa
88 Pryor
90 Jay
94 Arnett
96 Taloga
101 Kingfisher
92 Stillwater
88 Westville
95 Reydon
97 Clinton
102 Hinton
98 OKC
93 Chandler
94 Muskogee
90 Okemah
94 Sallisaw
97 Erick
89 Seminole
98 Hobart
102 ChicKasha
96 McAlester
93 Talihina
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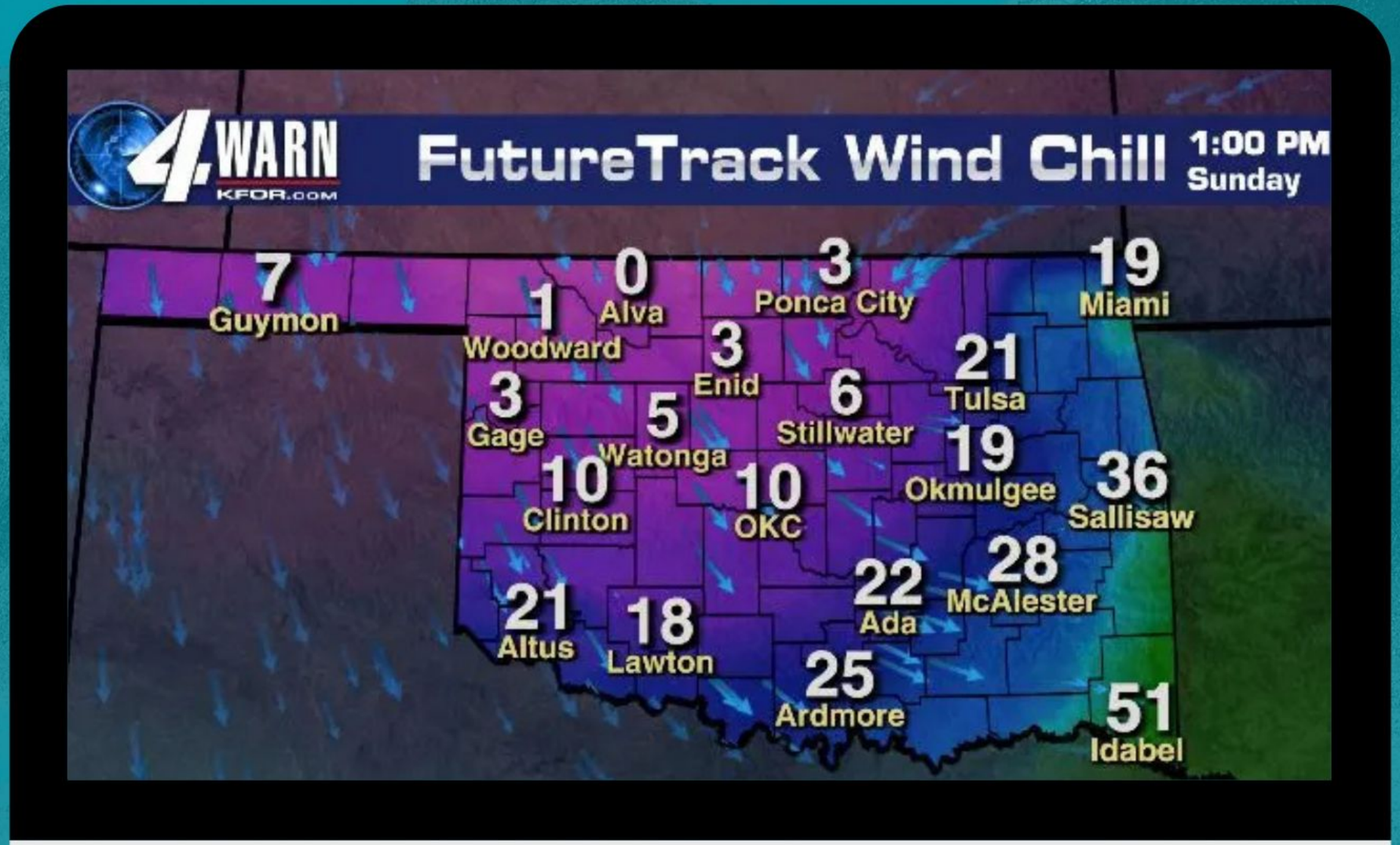
4 WARN
KFOR.com
FutureTrack Wind Chill
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7
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1
Woodward
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Alva
3
Ponca City
19
Miami
3
Enid
21
Tulsa
3
Gage
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Watonga
6
Stillwater
19
Okmulgee
36
Sallisaw
10
Clinton
10
OKC
28
McAlester
22
Ada
21
Altus
18
Lawton
25
Ardmore
51
Idabel

LESSON 1.1 - EXPERIENCE

How do we measure temperature?

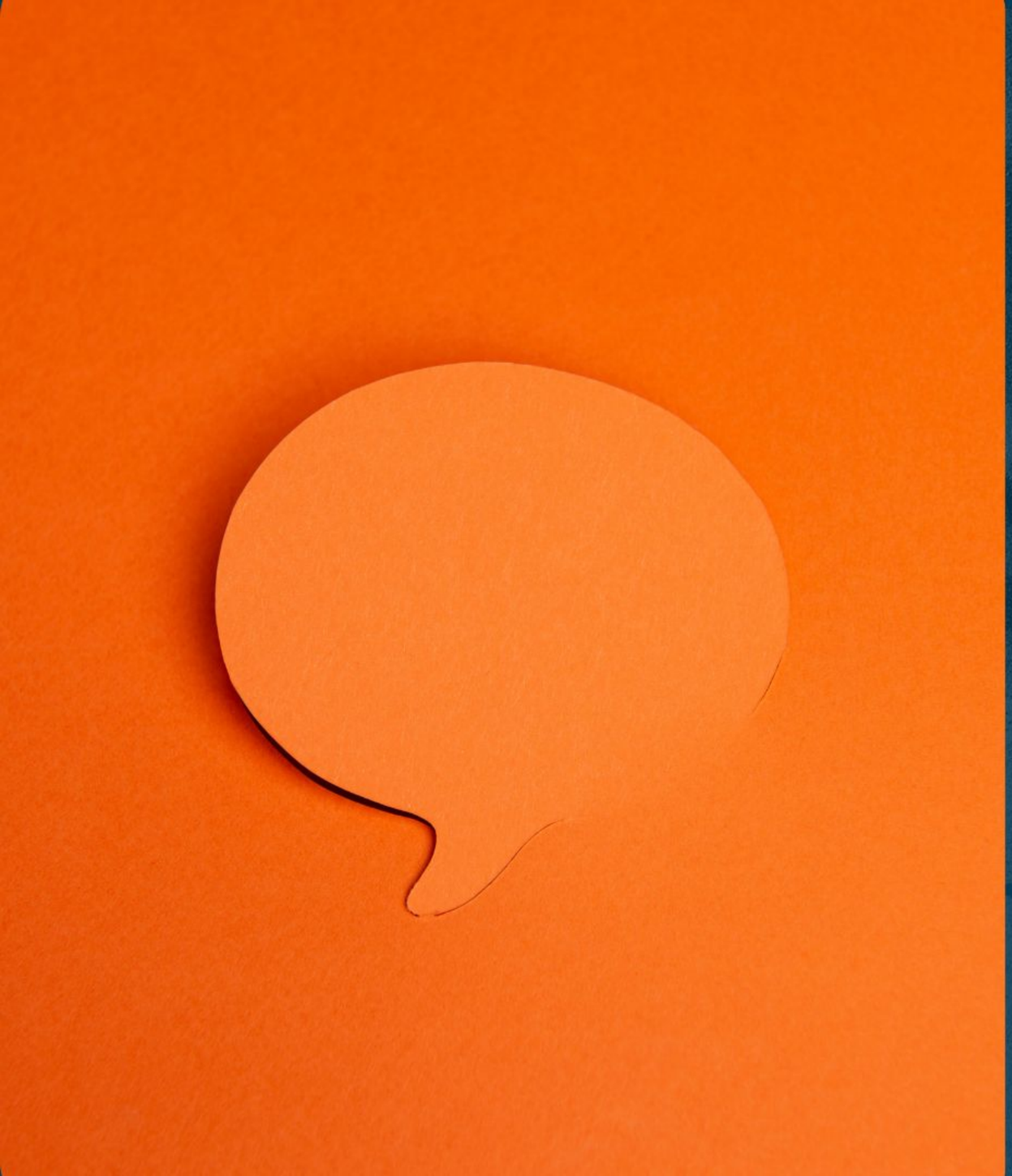
Where should we measure temperature?

LESSON 1.1 - LABEL

What is the temperature of this room?

‹temp in F°›

‹temp in C°›



LESSON 1.1 - LABEL

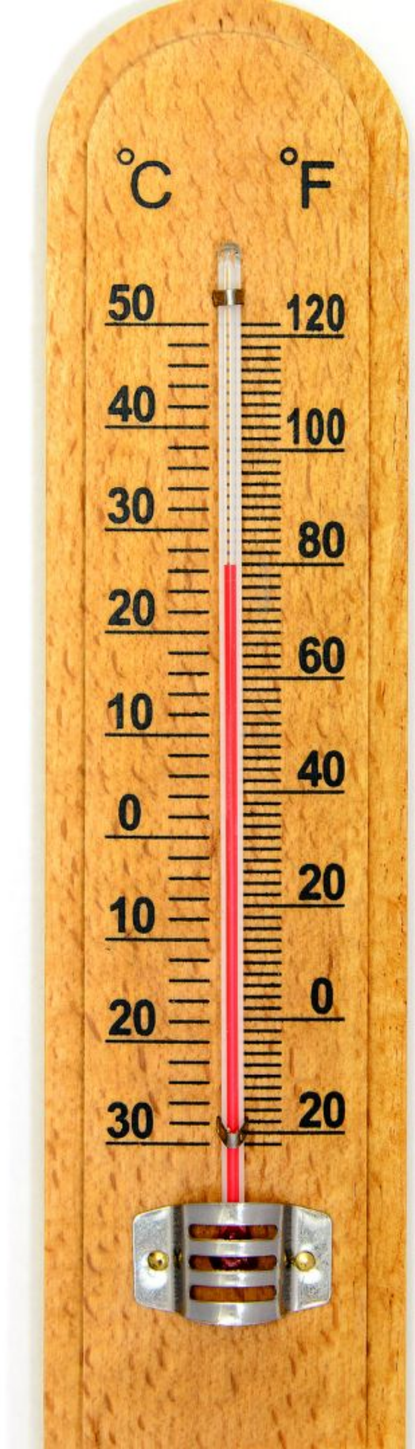
Turn and Talk!

- **How can the room be two different temperatures at the same time?**
- **Be prepared to share your ideas with the class.**

LESSON 1.1 - LABEL

Celsius and Fahrenheit use different scales

Celsius is used for scientific purposes and in most countries around the world



LESSON 1.1 - LABEL

How is this thermometer like a number line?

- Larger numbers on the thermometer represent higher temperatures
- Notice that zero is not at the bottom
  - 0°C is the temperature at which water freezes
  - In the Kelvin scale for temperature, zero (also known as absolute zero) is the lowest temperature possible
    - absolute zero (0K) has never been reached

LESSON 1.1 – DEMONSTRATE

Let’s practice reading a thermometer!

Complete page 1 of your *Taking Temperatures* handout.

LESSON 1.1 – DEMONSTRATE

Now that you're more familiar with Celsius and Fahrenheit temperatures, let's try collecting some data.

Complete page 2 of *Taking Temperatures*.

LESSON 1.1 – REVIEW

Now you know how to collect temperature data, just like a real meteorologist!

You'll get more practice later in this lesson. But for now, it's time to reflect on what you've learned. Record your ideas on your *What I Know* handout.

LESSON 1.1 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

HOW DO WE MEASURE WEATHER?

LESSON 1.2

LESSON 1.2 – ENROLL

Does it matter where we collect temperature data outdoors?

Think about how temperatures might be different in the sun and in the shade.

Create an initial model to explain how you think temperatures might be different.

LESSON 1.2 – EXPERIENCE

Time to collect some data!

Record the temperature of 6 different samples. Some will be in the sun, some will be in the shade.

Remember that scientists use Celsius!

LESSON 1.2 - EXPERIENCE

On your *Heat Absorption* handout, analyze your data to determine patterns and formulate an explanation.

THINK LIKE THE PROS!
Professionals use spreadsheets to analyze and graph their data. Practice your career-readiness skills by putting your data into Excel or Google Sheets.

LESSON 1.2 - LABEL

Air, water, and soil absorb heat differently - why?

- The molecules in solids, liquids, and gases are moving at different speeds because they have different amounts of energy.
- Temperature can be described as the average kinetic energy (energy of motion) of the molecules in a substance.

LESSON 1.2 - LABEL

Air, water, and soil absorb heat differently - why?

- As molecules of air, water, or soil heat up (absorb energy) they start to move faster (increase in temperature).
- Water and soil have more molecules than air does in the same amount of space, so it takes more energy to change the temperature of water or soil than air.

LESSON 1.2 - LABEL

Gases absorb energy most quickly, so air will heat up and cool down the fastest.

Soil will heat up and cool down slower than air, but faster than water.

Is this what your results showed?

LESSON 1.2 – DEMONSTRATE

Now that you've analyzed your data, **think back to the initial model you created about how temperatures might be different in the sun vs. in the shade.**

On your *Developing Ideas* handout, construct a new model to explain what you've learned.

LESSON 1.2 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 1: WEATHER

Lesson 2 - Heat Transfer

WHAT HAPPENS AFTER AIR HEATS UP?

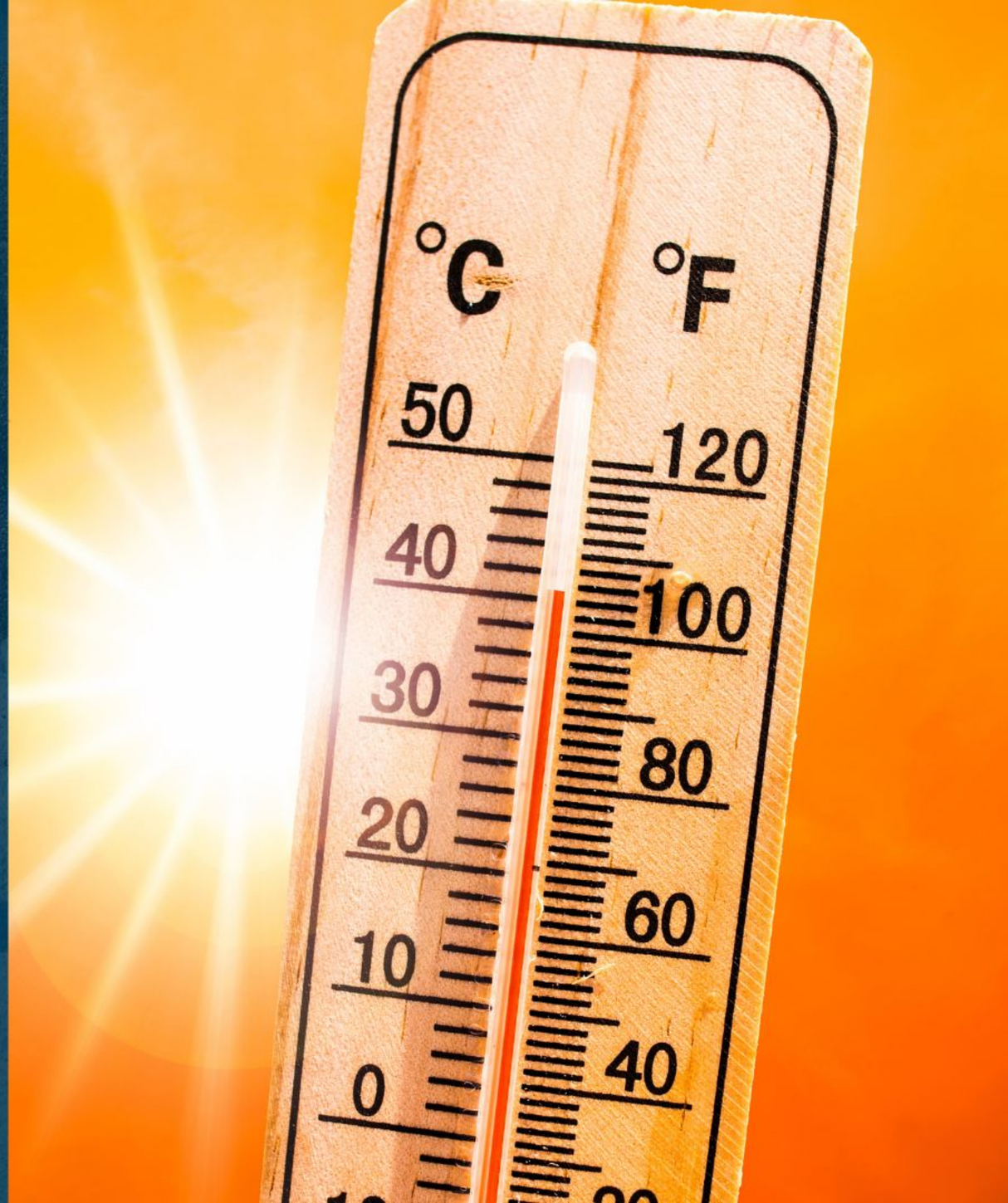
LESSON 2.1

WHAT IS GOING ON IN THESE IMAGES?

LESSON 2.1 - ENROLL

What else do we know about heat?

Think about things such as where heat comes from, how we know when something is hot, how objects heat up and cool down, etc.



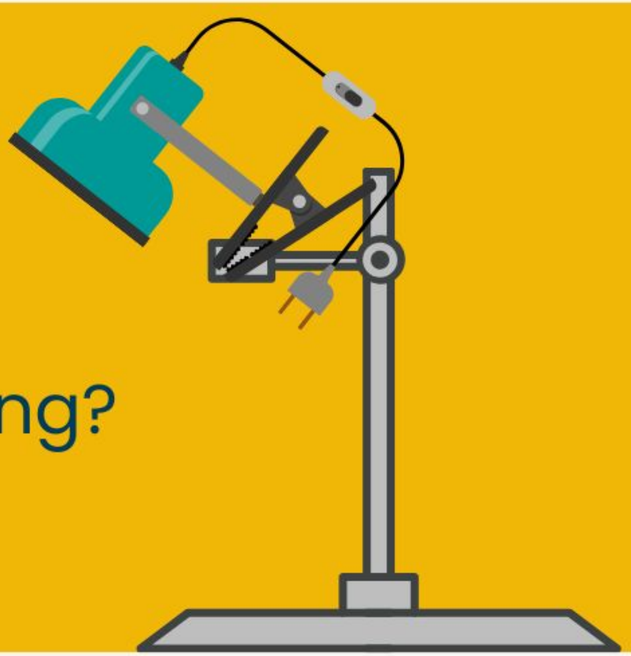
LESSON 2.1 – EXPERIENCE

Why can you feel heat when you're near a hot object if you're not touching it?

LESSON 2.1 – EXPERIENCE

Let’s try it!

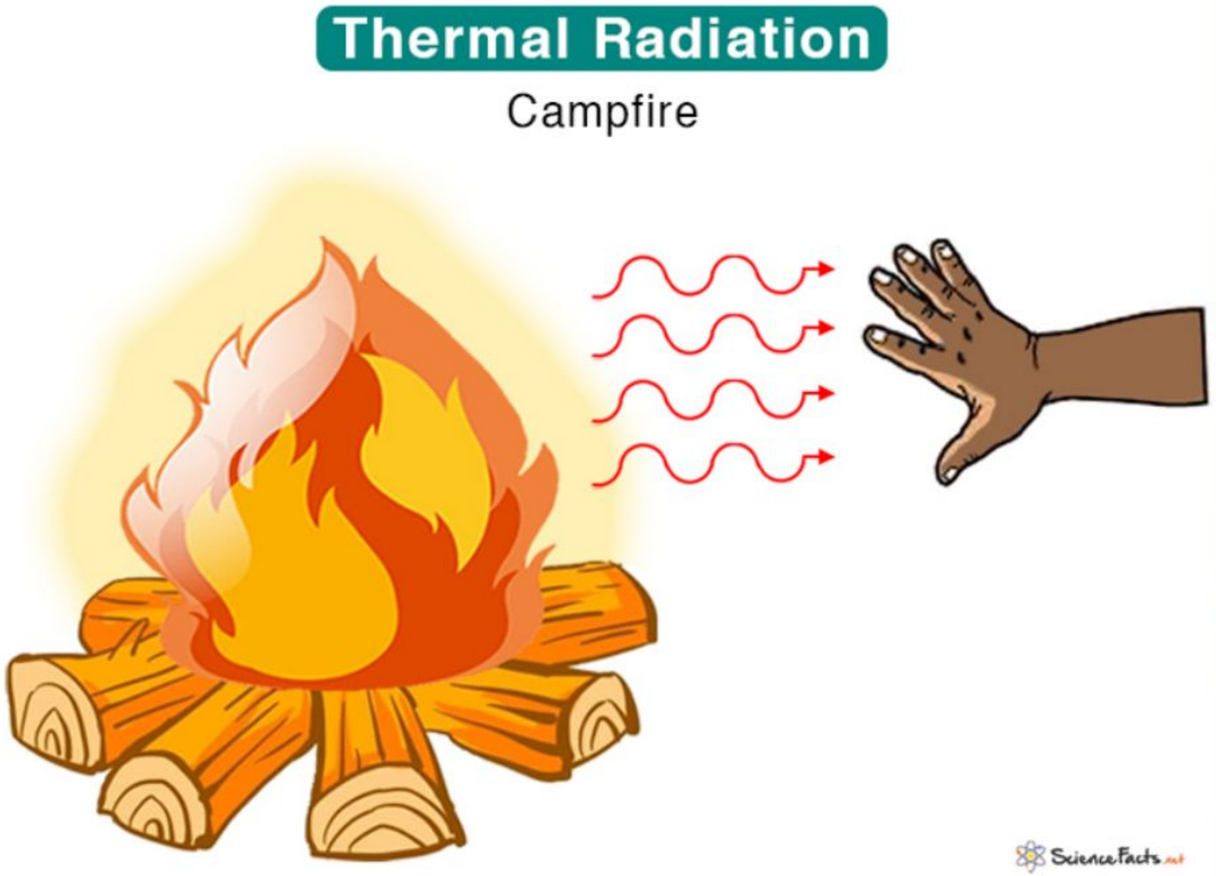
Can you explain what is happening?



LESSON 2.1 - LABEL

Could you feel heat from the lamp?

What is happening?



LESSON 2.1 – LABEL

Radiation is the transfer of energy across space in the form of waves.

You can see radiation (in the form of heat) by using a thermal or infrared camera.

LESSON 2.1 – DEMONSTRATE

Remember our investigation of temperatures in the sun and shade?

How can we feel heat from the sun? Answer on page 2 of your *Heat Transfer* handout.

LESSON 2.1 – REVIEW

What other examples of **radiation** can you think of?

LESSON 2.1 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WHAT HAPPENS AFTER AIR HEATS UP?

LESSON 2.2

LESSON 2.2 – ENROLL

What do you observe in this video?

Can you explain what is happening?

LESSON 2.2 - EXPERIENCE

Observe how ice melts when placed on a heat source compared to when it is left at room temperature.

Use your *Make it Melt* handout.

LESSON 2.2 - EXPERIENCE

Why does the ice on the hot plate melt faster?

What is the ice actually touching?

LESSON 2.2 – LABEL

Conduction is the transfer of heat from one object to another through direct contact.

Objects conducting heat can also radiate heat. More than one type of heat transfer often happens at the same time.

LESSON 2.2 – LABEL

How does conduction work?

- Molecules within a substance move faster or slower, depending on how much energy they have.
  - Solids have less energy and move slower, so the molecules are closer together
  - Gases have more energy and move faster, so the molecules are farther apart
- When heat is added, molecules move faster and bump into each other, transferring some energy to their neighbors
- As the hot plate heats up, it transfers energy to the molecules of the beaker, which then transfers energy to the molecules of the ice

LESSON 2.2 – DEMONSTRATE

Let’s demonstrate conduction!

We are going to compare how heat is transferred in a solid and in a gas.

Each of you represents a molecule in either a solid or a gas. Your cup represents the amount of energy you contain.

As energy is added to the solid/gas in the form of heat, the way you are able to move will also change.

LESSON 2.2 – DEMONSTRATE

The amount of beads in your cup represents how much energy you have. The more energy you have, the faster you're able to move.

Move around the space according to how much "energy" you have. When you are close enough to high-five another person, give them a high-five. If you have more energy than they do, transfer some of your energy to their cup.

Keep moving until everyone has about the same amount of energy (the line on your cup).

LESSON 2.2 – REVIEW

Read the article from the UCAR Center for Science Education.

- As you read, highlight important points of information
- Summarize what you highlighted in 3-4 sentences.

LESSON 2.2 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WHAT HAPPENS AFTER AIR HEATS UP?

LESSON 2.3

LESSON 2.3 – ENROLL

What is happening in this video?

LESSON 2.3 – ENROLL

Quick review!

- We can feel heat when we are near a hot object because of radiation.
- Air that is near a hot object heats up because of conduction.

What happens to that air after it heats up?

LESSON 2.3 - EXPERIENCE

We’re going to use water to simulate what happens when air heats up and cools down.

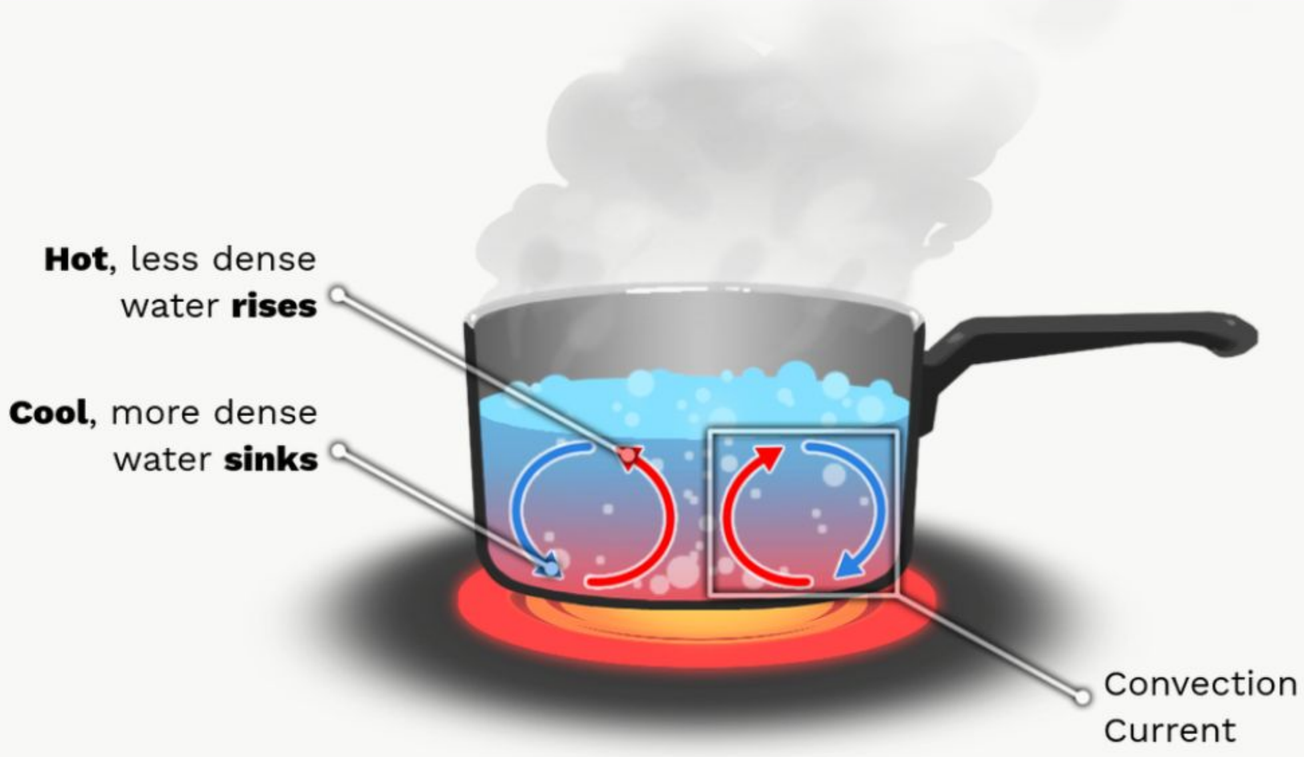
Why are we using water?

- Water is easier to see than air
- Both are fluids, so both behave in the same way.

LESSON 2.3 – LABEL

Convection is the transfer of heat by the movement of fluids (liquids and gases).

Warm fluids rise and cool fluids sink. This pattern creates a **convection current.**



LESSON 2.3 - LABEL

Why do warm fluids rise?

- Think about what happens to the molecules of a substance when it heats up.
  - They move faster!
  - As the molecules start to move faster, they spread out, making the warm fluid lighter (less dense) so it floats up (rises).

LESSON 2.3 – LABEL

Using what you know about warm fluids, why do you think cold fluids sink?

- When a substance is cool, its molecules move slower. Because the molecules are moving slower, they get closer together (condense).
- This makes the fluid heavier (more dense), causing the cold fluid to sink.

Convection currents in the air can create large masses of warm or cold air that we call **warm fronts** and **cold fronts**.

LESSON 2.3 – DEMONSTRATE

Can you predict what will happen in this video?

LESSON 2.3 – REVIEW

Read this article on heat transfer from NOAA.

Update your *What I Know* handout with what you've learned about heat transfer.

LESSON 2.3 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WHAT HAPPENS AFTER AIR HEATS UP?

LESSON 2.4

LESSON 2.4 – ENROLL

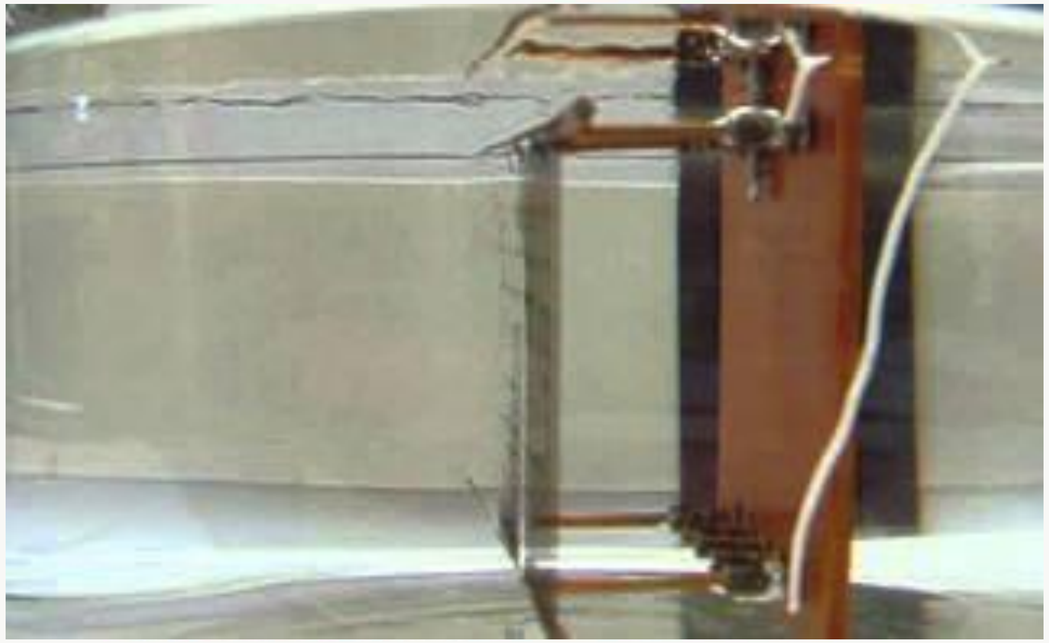
What is happening in this video?

LESSON 2.4 – EXPERIENCE

Watch the video and record your observations.

What do you notice? What do you wonder?

What do you think is happening?

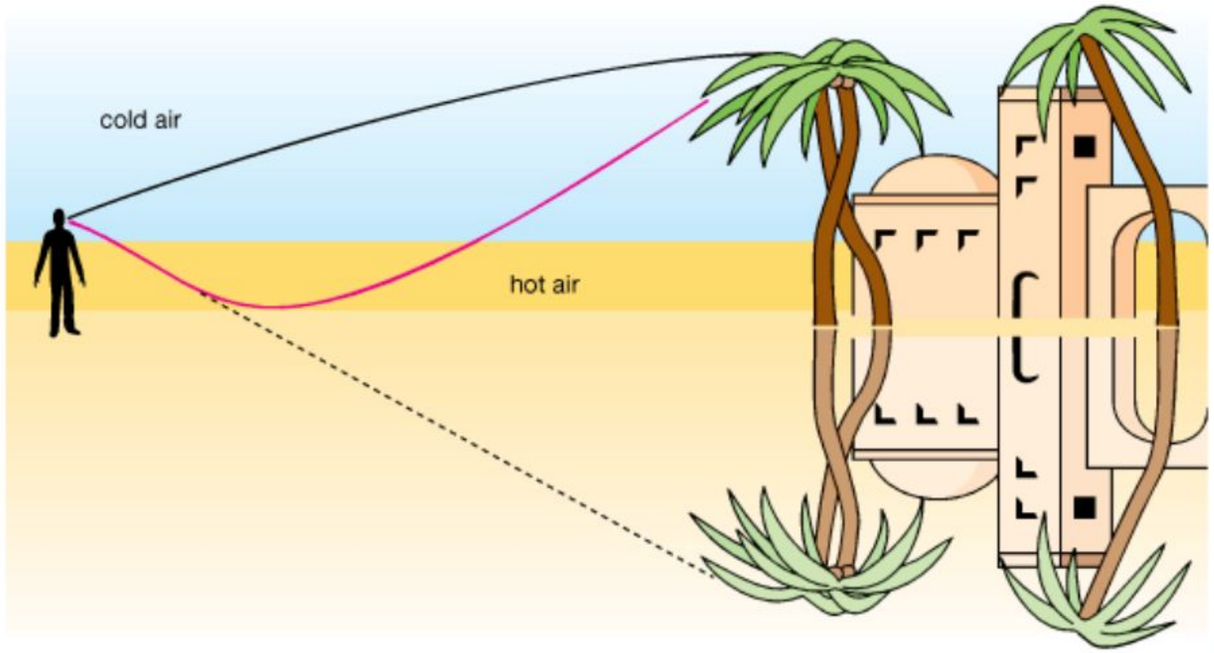


LESSON 2.4 – LABEL

Read this article about the device you just witnessed.

Update your *Are Invisibility Cloaks Real* handout.

Formation of an inferior image



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LESSON 2.4 – LABEL

A **mirage** is an optical illusion that causes us to see images that aren't really there.

A mirage happens when a very hot surface (such as a roadway) conducts a lot of heat to the air directly above the surface.

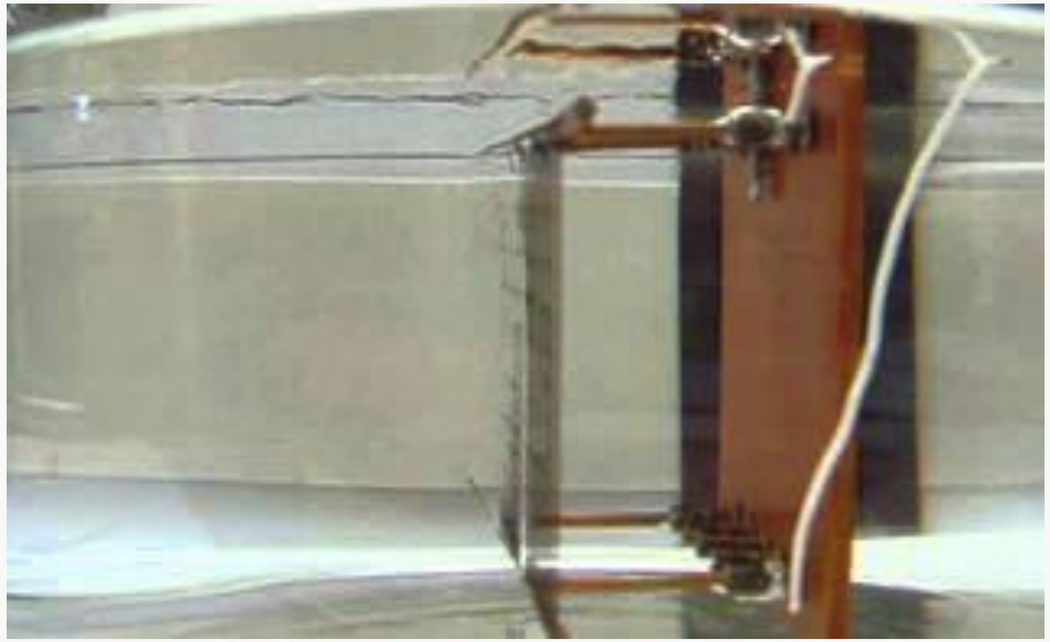
LESSON 2.4 - LABEL

- The air near the surface is much hotter than the air above it.
- Light moves differently through the two layers of drastically different air temperatures.
- This causes us to see reflections of images or the sky (when it looks there's water on the ground).
- A mirage can also hide part of the surface, making it appear is though things are floating in the air

Heat shimmer is a type of mirage.

LESSON 2.4 – REVIEW

Why does the device become invisible?



LESSON 2.4 – DEMONSTRATE

Use what you've learned to create a model that answers the question, "What happens after air heats up?"

Complete your *Putting It All Together* handout.

LESSON 2.4 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 1: WEATHER

Lesson 3 - Heat Index

WHY DOES HOT WEATHER IN OKLAHOMA FEEL DIFFERENT THAN HOT WEATHER IN ARIZONA?

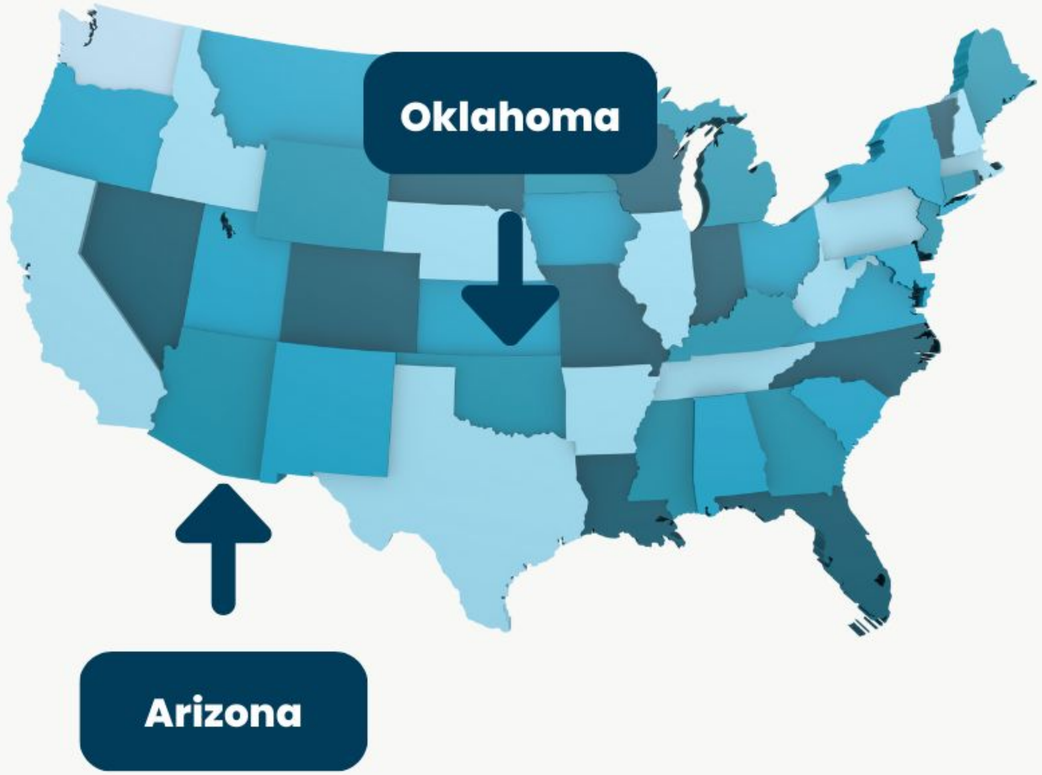
LESSON 3.1

LESSON 3.1 – ENROLL

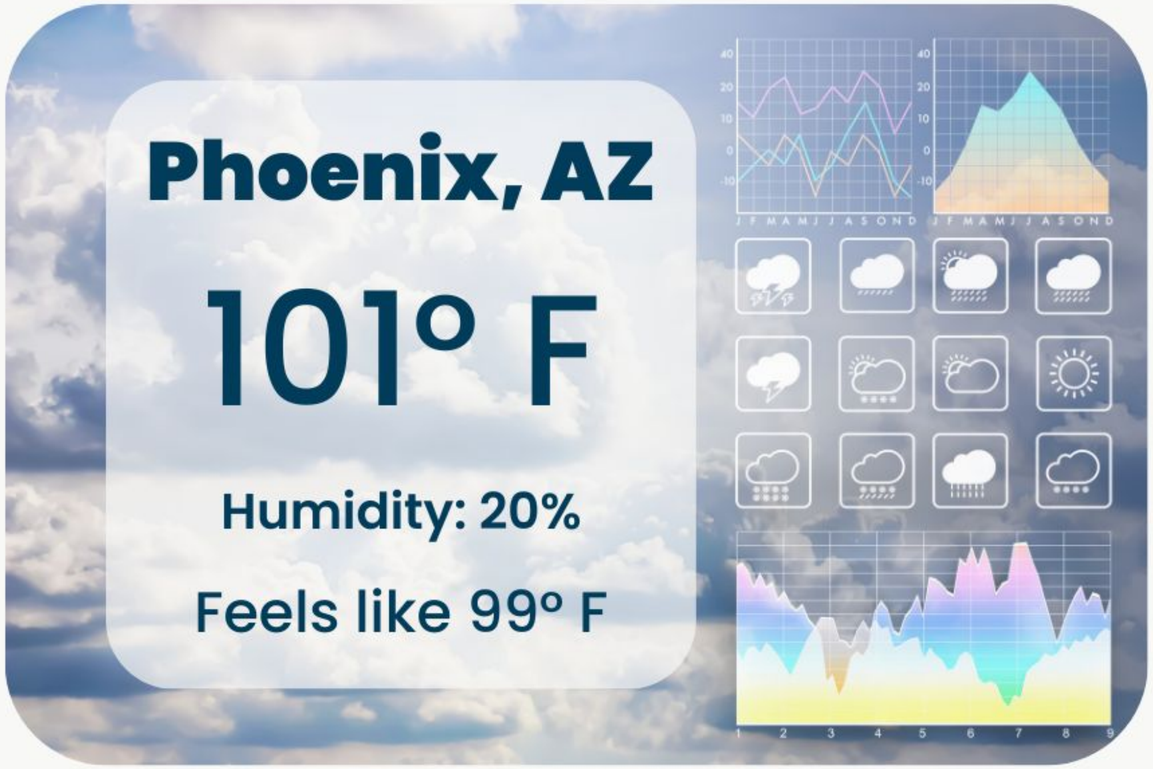
What do you know about Arizona and Oklahoma?

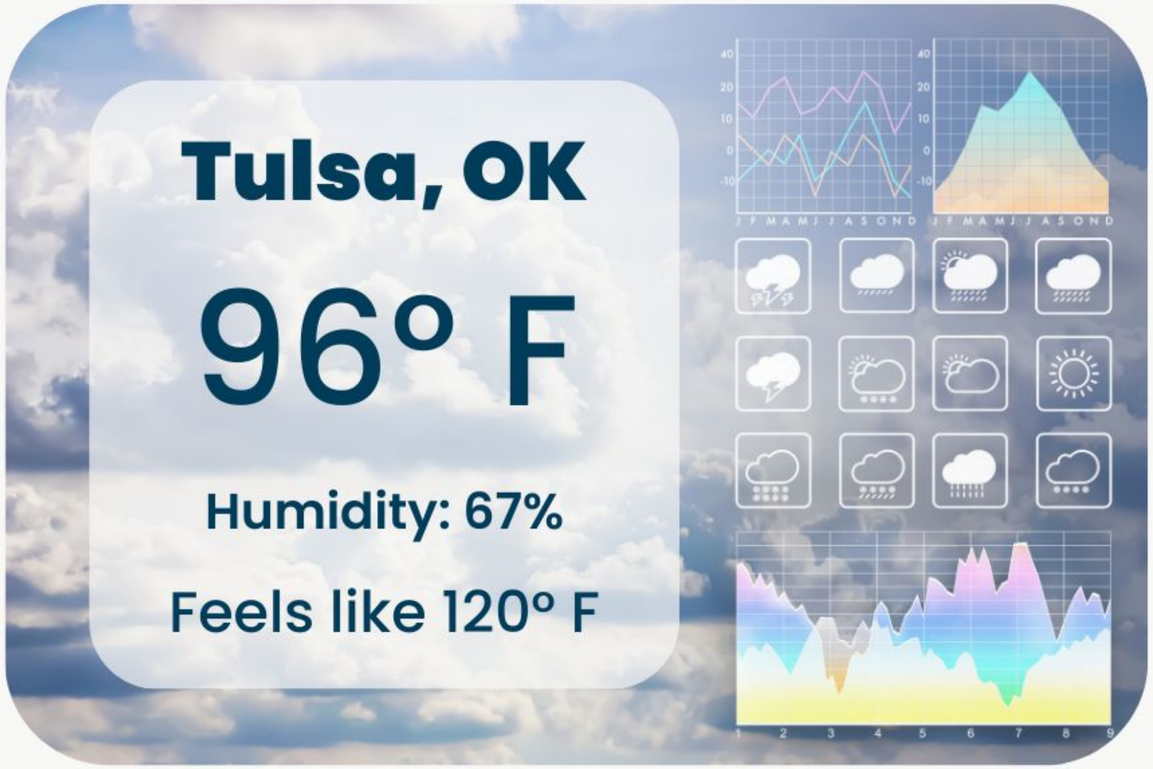
Have you ever been there?

What do you think it is like there?



WHY DOES HOT WEATHER IN OKLAHOMA FEEL DIFFERENT THAN HOT WEATHER IN ARIZONA?





LESSON 3.1 - EXPERIENCE

Think about a time when you've taken a shower and the bathroom had a lot of steam afterwards.

- Could you see the steam?
- Was the mirror or other surfaces foggy and damp?
- How did the air feel?
- Did you cool off quickly?
- Was it easy to dry off?

LESSON 3.1 - EXPERIENCE

Think about a time when you've taken a shower and the bathroom wasn't steamy afterwards, and the mirror and other surfaces weren't foggy or damp.

- How does it compare to the steamy bathroom?
- How did the air feel?
- Did you cool off quickly?
- Was it easy to dry off?
- Why would the air feel different if everything else is the same?

LESSON 3.1 – LABEL

Humidity is the amount of water in the air. (AKA absolute humidity)

- This is often referred to as “moisture” in the air, but this is a misleading description
- Remember the states of matter?
- What state of matter would ***water vapor*** be?
- Water in the air is not liquid, it’s a gas!
- Water is still water whether it’s solid (ice), liquid, or a gas

Water vapor in the air can’t be seen, no matter how much is present.

When you see condensation like this, it is not water vapor, it’s liquid (in the form of tiny droplets).

LESSON 3.1 – EXPERIENCE

Have you ever heard the phrase, “It’s not the heat, it’s the humidity”?

Is there a limit to how humid the air can be?

Let’s investigate! Use your *…It’s the Humidity* handout.

LESSON 3.1 – LABEL

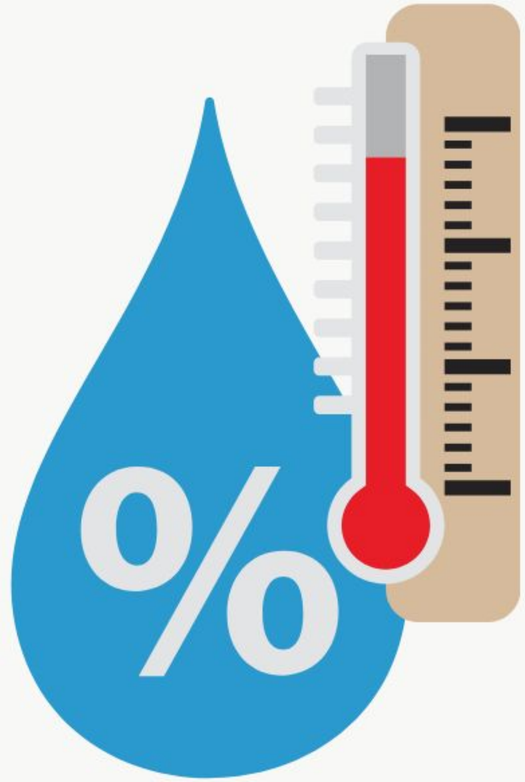
Is there a limit to how humid the air can be?

- It depends on temperature
  - Warm air can have more water vapor molecules than cold air
  - The amount of water vapor present compared to how much could be present at that temperature is called relative humidity.
    - This is expressed as a percent
    - For example, 70% humidity means the air contains 70% of the total water vapor that could be present at that temperature

LESSON 3.1 – LABEL

When 100% humidity is reached, the air is completely **saturated.**

- This does not mean that it will rain
- Fully saturated air may result in fog or clouds if some of the water vapor collect together to form tiny liquid droplets
- In order for complete saturation to cause rain, the air would first need to cool
  - A lower temperature means not as much water vapor can be present



LESSON 3.1 – DEMONSTRATE

Let’s analyze how % saturation can change with the presence of more or less water.

Use your *Studying Saturation* handout.

LESSON 3.1 – REVIEW

Let’s take a moment to review what you’ve learned so far.

Use your *Module 1 – What I Know* handout.

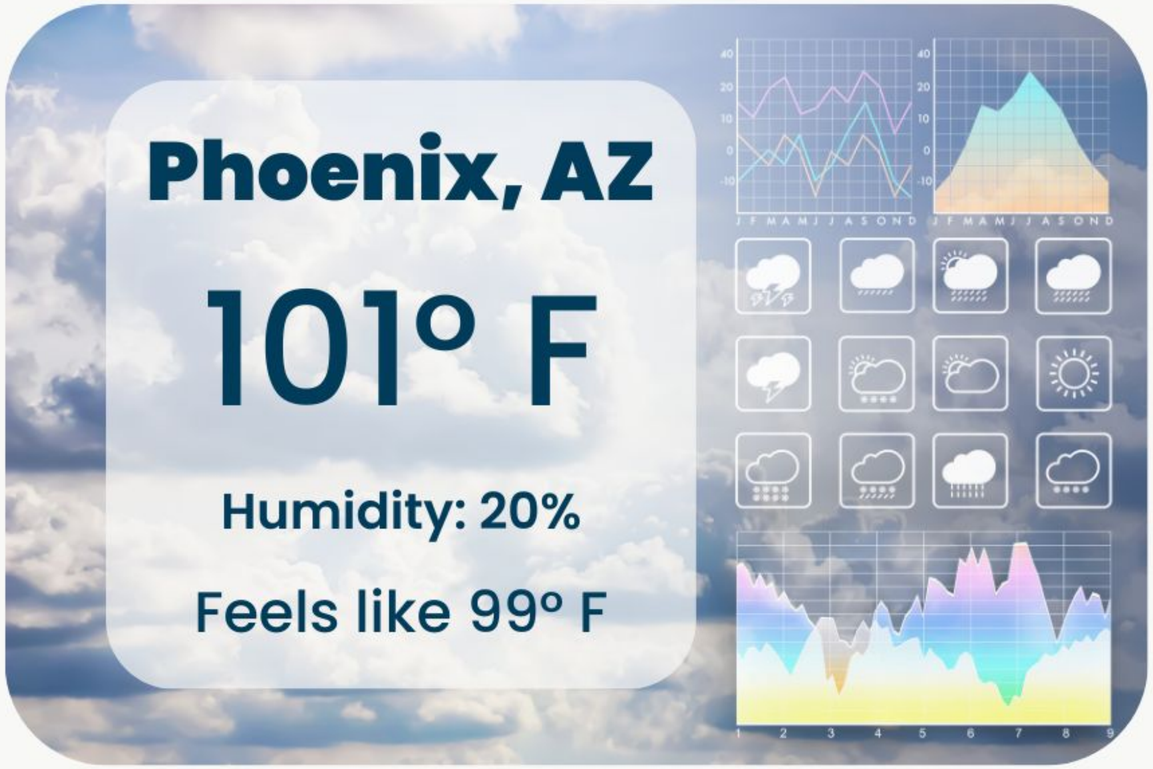
LESSON 3.1 - CELEBRATE

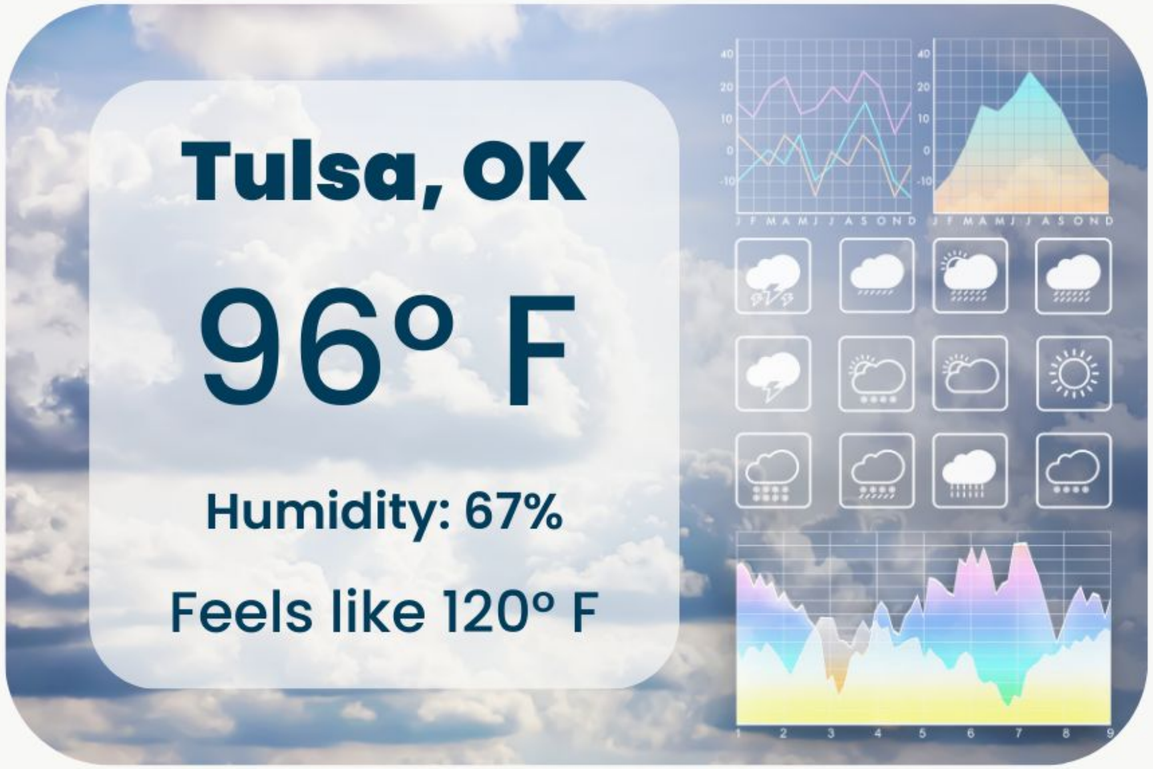
Celebrate every effort! High fives, team chants, have a treat, etc.

WHY DOES HOT WEATHER IN OKLAHOMA FEEL DIFFERENT THAN HOT WEATHER IN ARIZONA?

LESSON 3.2

WHY DOES HOT WEATHER IN OKLAHOMA FEEL DIFFERENT THAN HOT WEATHER IN ARIZONA?





LESSON 3.2 – EXPERIENCE

Let’s take a closer look at the relationship between temperature and relative humidity.

Use your *It’s All Relative (Humidity)* handout.

LESSON 3.2 – EXPERIENCE

Humidity doesn’t affect the temperature outside, but temperature does affect the relative humidity.

Why does it feel hotter when it’s more humid?

LESSON 3.2 - EXPERIENCE

Imagine you are playing outside in Arizona in August. Think about what your surroundings look like.

- What does it feel like outside?
- Is there a breeze?
- Is it hot?
- How does the air feel?
- Is it raining, sunny, cloudy?

LESSON 3.2 - EXPERIENCE

Now imagine you are playing outside in Oklahoma in August. Think about what your surroundings look like.

- What does it feel like outside?
- Is there a breeze?
- Is it hot?
- How does the air feel?
- Is it raining, sunny, cloudy?

LESSON 3.2 – EXPERIENCE

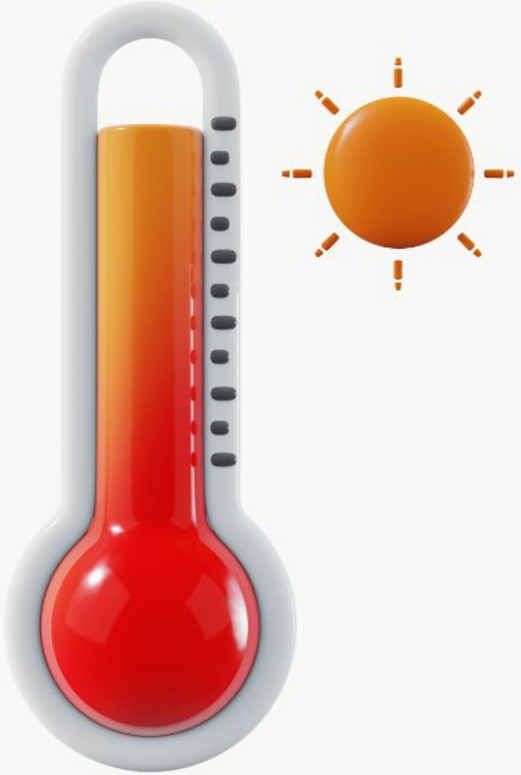
Let’s say you’ve been outside playing soccer for a while. Would you be sweating if you were in Arizona? What about in Oklahoma?

- What does sweat do for your body?
- If Oklahoma feels hotter than Arizona, is sweat cooling you off the same in both places?
- Why do you cool off easier in Arizona than in Oklahoma?

LESSON 3.2 – LABEL

- As sweat evaporates from your body, it helps cool you off.
- When the humidity is high, this evaporation doesn't happen as easily.
  - When humidity is high, the air is more saturated with water vapor, which means less water vapor is able to enter the air.
- Since your body can't cool as well, you perceive the air as being hotter than it actually is.

This is called the **Heat Index**.



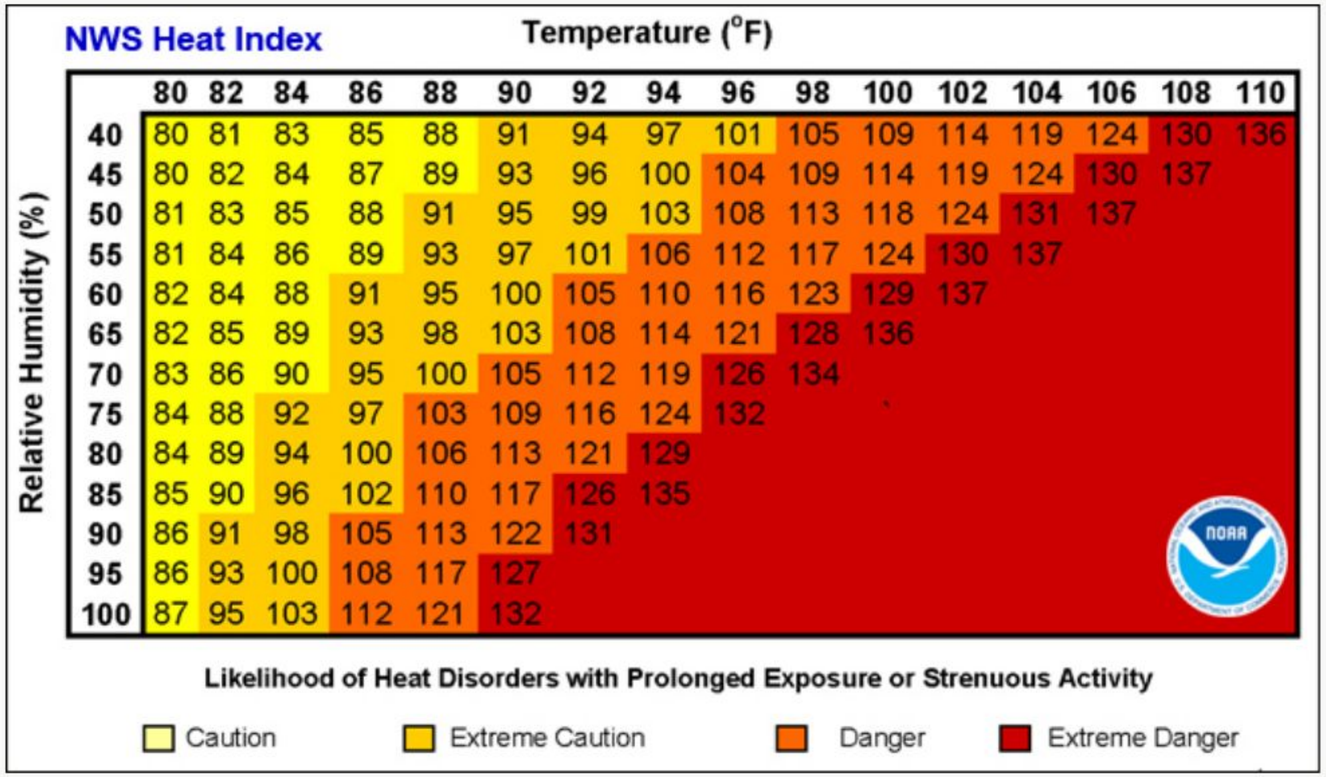
LESSON 3.2 – LABEL

Heat Index is calculated by comparing the relative humidity with air temperature in the shade.

The chart on the following slide is then used to determine the **heat index**.

Heat index can be used to determine outdoor safety during hot weather.

LESSON 3.2 – LABEL



As you read a heat index chart, notice that it sometimes it feels cooler outside than the actual air temperature.

LESSON 3.2 – DEMONSTRATE

Let's find out what the heat index is today using your *Think Like a Meteorologist* handout.

We will first need to measure the temperature and relative humidity.

Field meteorologists that collect weather data use a device called a sling psychrometer to measure relative humidity. These can easily be made at home.

LESSON 3.2 – REVIEW

Do we now have enough information to answer the question, “Why does hot weather in Oklahoma feel different than hot weather in Arizona?”

Consider all the data you have collected, models you have drawn, charts you have analyzed, etc.

LESSON 3.2 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 1: WEATHER

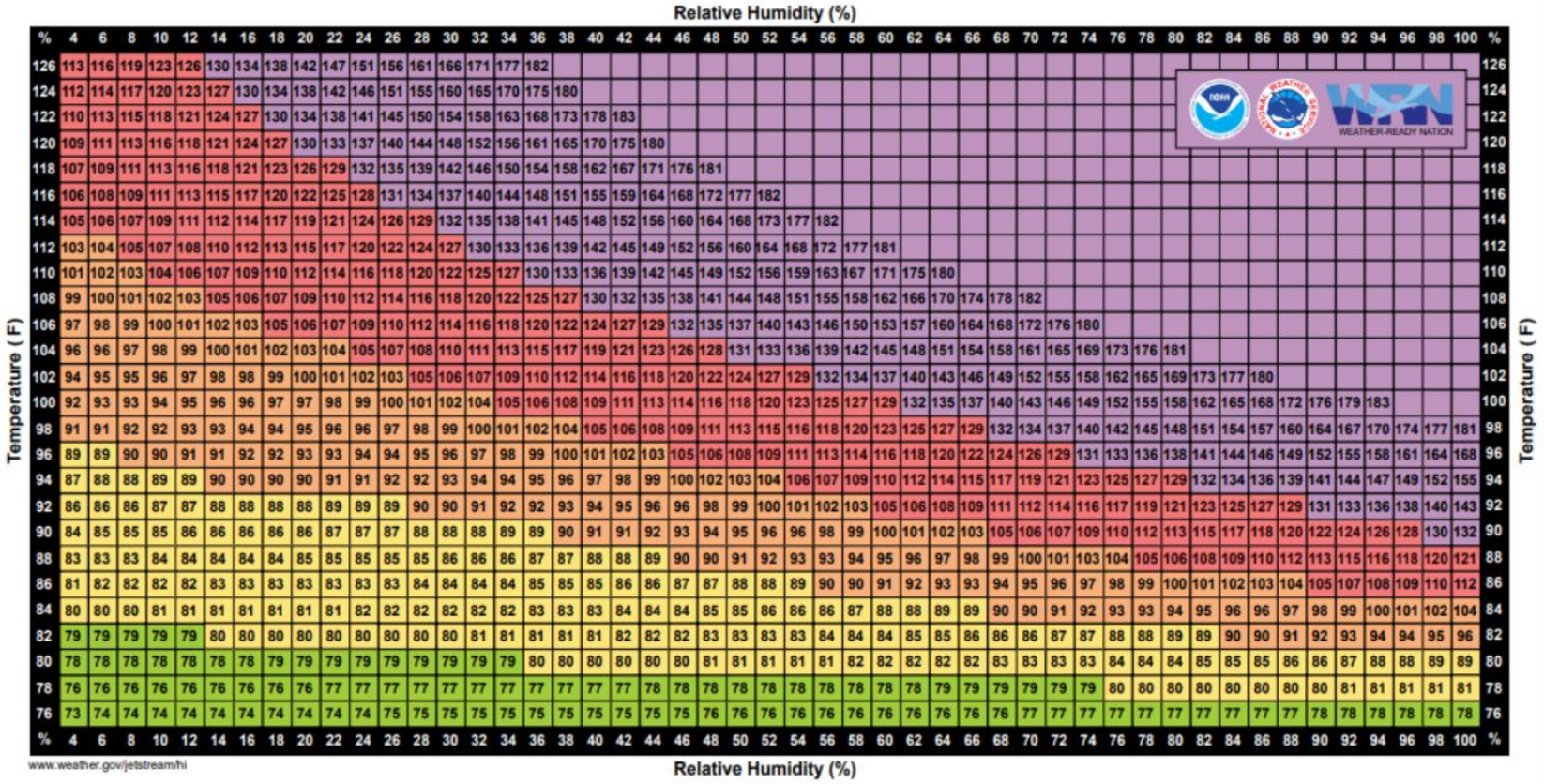
Lesson 4 - Wind Chill

DOES HEAT INDEX WORK THE SAME IN THE WINTER?

LESSON 4

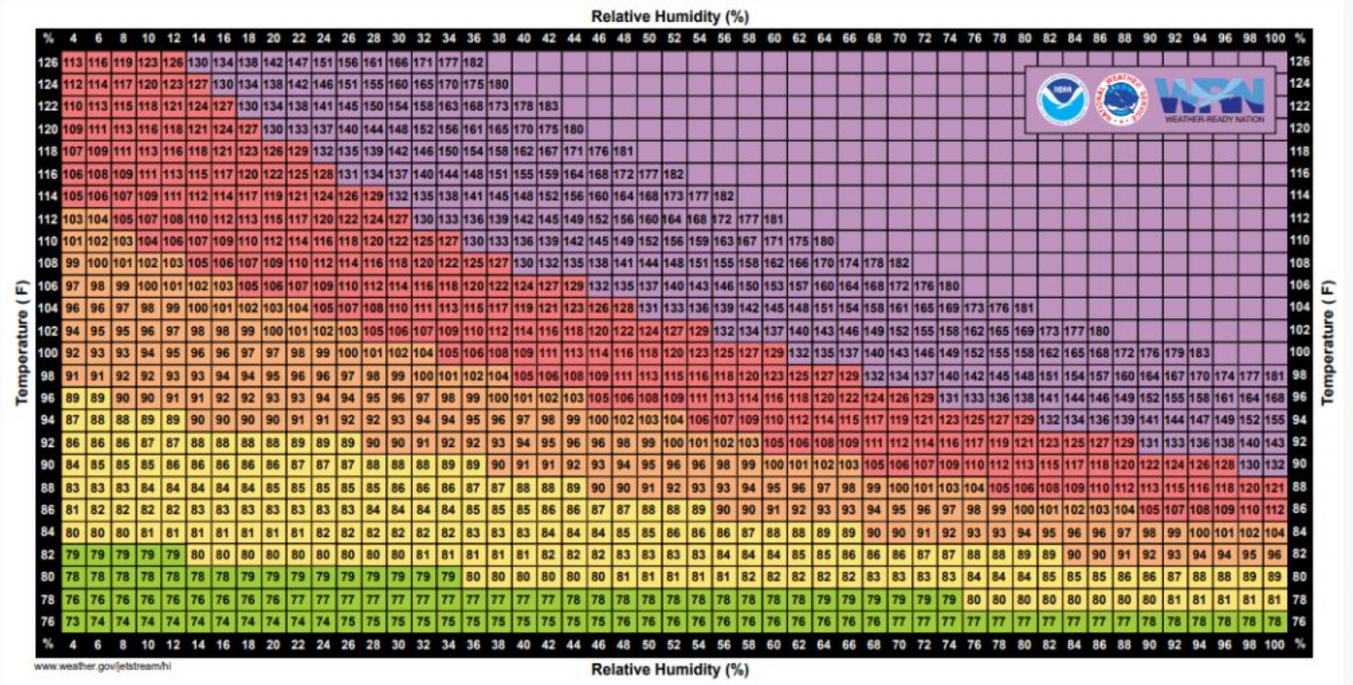
LESSON 4 – ENROLL

Does heat index work the same in winter?



LESSON 4 – EXPERIENCE

- Have you ever seen a weather report for a cold day that included a heat index?
- Why do you think that is?
- Look at the heat index table. Why do you think there aren't any temperatures listed below 76° F?
- Let's figure it out!



LESSON 4 - Label

At cooler temperatures, humidity no longer causes the air to feel warmer than it really is, because evaporation of sweat is no longer an issue.

However, our bodies may still lose heat due to other atmospheric conditions like wind.

- Wind blows our body heat away, making us feel colder.

Wind chill is what the air feels like to humans due to wind blowing on exposed skin.

- The higher the wind speeds, the colder it will feel
- Wind chill does not affect things that are not alive

LESSON 4 – DEMONSTRATE

How does wind make it feel colder than it really is?

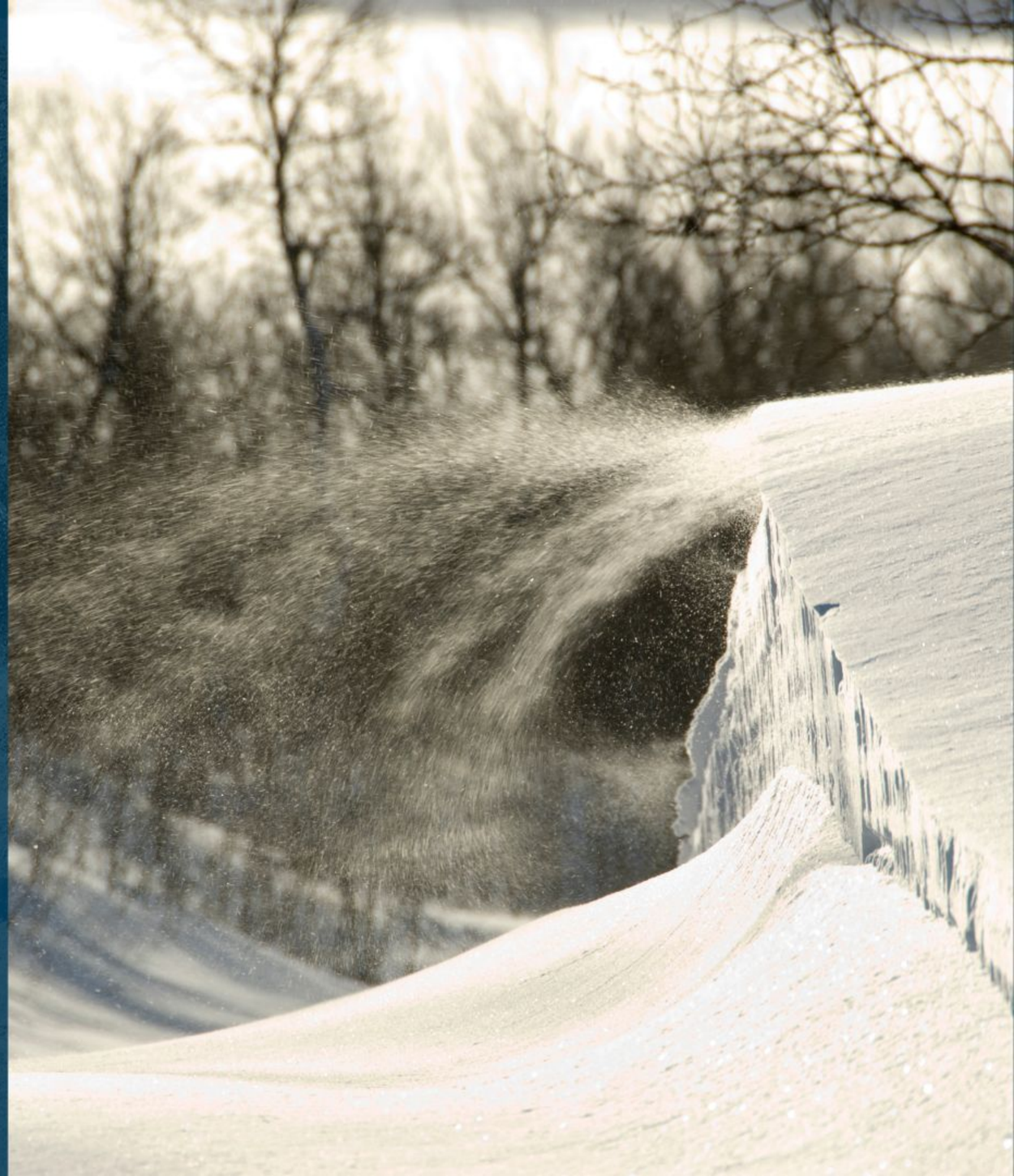
How much can wind affect the temperature?

Fill out your *Chilling with Wind Chill* handout.

LESSON 4 - REVIEW

- You've learned a lot about temperature, heat transfer, and how our bodies perceive temperature.

- Use your *Putting It All Together* handout to explain why we sometimes perceive the temperature to be hotter or colder than it really is.



LESSON 4 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 1: WEATHER

Lesson 5 - Temperature Advisory Alerts

HOW DO WE KEEP PEOPLE SAFE IN THE EXTREME TEMPERATURES OF SUMMER AND WINTER?

LESSON 5

LESSON 5 – ENROLL

- Have you seen the words *watch, warning, or advisory* on weather alerts?
- Have you ever seen a temperature advisory alert?
- Where or when have you seen one?
- How do you usually receive a warning about extreme temperatures?

LESSON 5 - EXPERIENCE

What do temperature advisory warnings have in common?

When and how are they issued?

Search the internet to find some examples of temperature advisory warnings and share your discoveries with others.

Complete your *Investigating Weather Warnings* handout.

LESSON 5 - LABEL

- Issued in advance for those who need extra time to prepare for extreme conditions:
  - **Excessive Heat Outlook** - excessive heat possible in the next 3-7 days
  - **Excessive Heat Watch** - excessive heat is likely in the next 24 to 72 hours

- Issued within 12 hours of the onset of extremely dangerous heat conditions:
  - **Heat Advisory** -When max heat index is 100° or higher for at least 2 days
  - **Excessive Heat Warning** - When max heat index is 105° or higher for at least 2 days

LESSON 5 – LABEL

Wind Chill Watch

there is potential for very cold air and strong winds to create dangerously low wind chill values

Wind Chill Advisory

low wind chill temperatures are expected but will not reach local “warning” criteria

Wind Chill Warning*

very cold air and strong winds will create dangerously low wind chill values

**These levels will result in frostbite and hypothermia if precautions are not taken*

LESSON 5 – LABEL

Heat Exhaustion

a serious condition in which the body overheats

Can lead to heat stroke if untreated

Heat Stroke

the body can no longer control its temperature and is unable to cool down

Can result in brain damage, organ failure, coma, and death

Hypothermia

when the body loses heat faster than it can produce heat

Can cause organ failure and death

LESSON 5 – ENROLL

Is the difference between these words obvious to you?

- Watch
- Warning
- Advisory

What past experience helps you understand these words?

If you didn’t have that past experience, do you think the words would have the same meaning for you?

If your primary language was a language other than English, do you think the words would have the same meaning for you?

MEET A PROFESSIONAL

Joseph Trujillo Falcón

Meteorologist - Bilingual Risk Communication

Watch Joseph's interview with MyRadar Weather Radar.

LESSON 5 - DEMONSTRATE

How can we keep people safe?

Choose either extreme heat or extreme cold and make a temperature advisory that will help keep people safe.

Use your *Creating a Temperature Advisory Notice* handout.

LESSON 5 – REVIEW

Use the *Peer Evaluation Form* to review the advisory notices of other students and provide them with feedback.

What suggestions do you have for how they can improve their design?

LESSON 5 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

STUDENT HANDOUTS

Tulsa Regional **STEM** Alliance

COOPERATIVE INSTITUTE FOR SEVERE AND HIGH-IMPACT WEATHER RESEARCH AND OPERATIONS

CIWRO

Name _____ Date_____

How's the Weather?

1. What is the weather like today? Imagine you are describing today's weather to someone who doesn't live here. Be as descriptive as possible. You don't have to look anything up, just describe it in your own way.

_____

_____

2. What was the weather like yesterday?

_____

_____

3. What about 3 months ago?

_____

_____

4. Share your descriptions with a partner or group. What do your descriptions have in common? What patterns do you notice in how you describe the weather?

_____

_____

_____

_____

What do meteorologists do?

5. Watch a clip of your local weather forecast. What do you notice about the weather report? What do you wonder?

I Notice...	I Wonder...

Careers in Meteorology

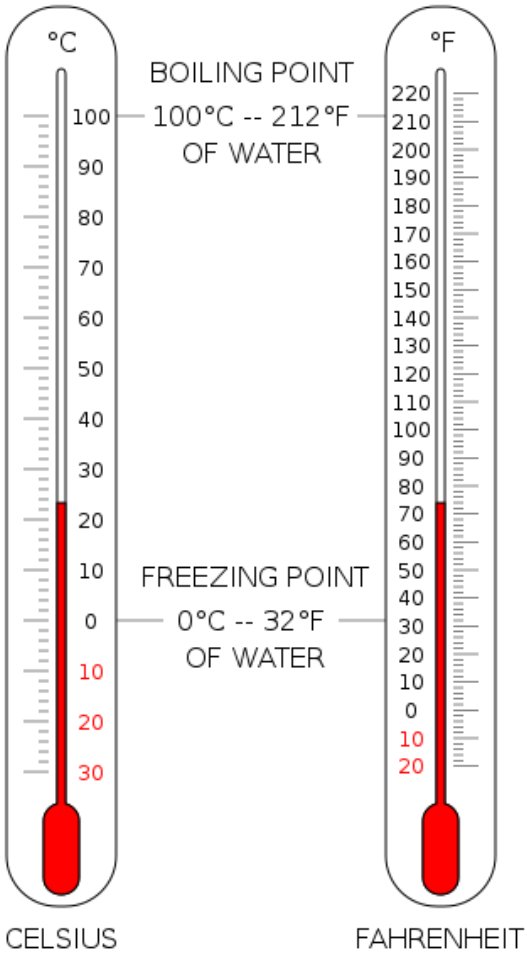
6. There are many types of careers in meteorology. Explore the following websites to discover different careers in meteorology. What careers are the most interesting to you?
    - https://www.indeed.com/career-advice/finding-a-job/jobs-in-meteorology
    - https://www.ametsoc.org/index.cfm/ams/education-careers/careers/career-guides-tools/meteorology-fields/

7. What do you find most surprising about the different types of careers?

Name _____ Date_____

Taking Temperatures

1. Compare the Celsius temperature scale with the Fahrenheit temperature scale. What do you notice?



2. How does "zero" differ on the two scales?

3. Choose 3 different temperatures in Fahrenheit and determine what the equivalent temperature would be in Celsius.
   - _____°F = _____°C
   - _____°F = _____°C
   - _____°F = _____°C

4. Which scale do you feel would be easier to use? Why?

Let's Try It!

5. Your teacher has set up two different water samples for you to measure. Practice using a thermometer by recording the temperature of each sample in Celsius.
    - Sample 1: _____°C
    - Sample 2: _____°C
6. Use your measurements in Celsius to estimate the temperature of each sample in Fahrenheit.
    - Sample 1: _____°F
    - Sample 2: _____°F
7. Compare your estimates with a partner. Now measure the actual temperature in Fahrenheit. Who estimated closest to the actual temperature?

	My Estimated Temp in °F	My Partner's Estimated Temp in °F	Actual Temp in °F	Who is closest?
Sample 1				
Sample 2				

Name _____ Date_____

Module 1 - What I Know

Lesson 1

- ☐ What weather is
- ☐ Components that can be used to describe weather
- ☐ How to use a thermometer
- ☐ How temperature is different in the sun and in the shade
- ☐ How different substances absorb heat differently

What I Know	How I Know, I Know It

Name _____ Date_____

Heat Absorption

1. Predict what will happen if we measure temperatures of the same substances in the sun and in the shade. Use words and/or pictures to explain what you think will happen and why.

In the sun	**In the shade**

Data Collection

2. Collect temperature readings of the substances indicated by your teacher. You should record temperatures for the same substances in the sun and in the shade. Record temperatures in degrees Celsius.

Substance	°C in the Sun	°C in the Shade

Data Analysis

3. Input your data in a spreadsheet such as Excel or Google Sheets. Remember to label the columns and rows.

4. How does the temperature of each substance compare in the sun and in the shade? Use the formula functions in the spreadsheet to calculate the difference between the sun and shade in degrees Celsius. You may want to add a column to the table in your spreadsheet.

5. Use the formula functions to calculate the mean (average) temperature difference between the sun and shade.

6. Use the graphing functions in the spreadsheet to produce a graph of the temperature difference between each substance in the sun and in the shade.

7. Analyze the mean temperature difference and the graph of your data. What do these things tell us about energy transfer in the sun versus in the shade? (Remember that energy can be in the form of heat.)

8. Based on your data, make a claim about the differences in how air, water, and soil absorb heat from the sun.

Name _____ Date_____

Developing Ideas

1. Review your initial model about temperature. Revise your initial thinking to explain why temperatures in the sun and shade are different for different substances. Why do you think air, soil, and water would absorb heat differently? Consider how the molecules are arranged and move in a solid, liquid, and gas. Use words and/or pictures to explain your ideas.

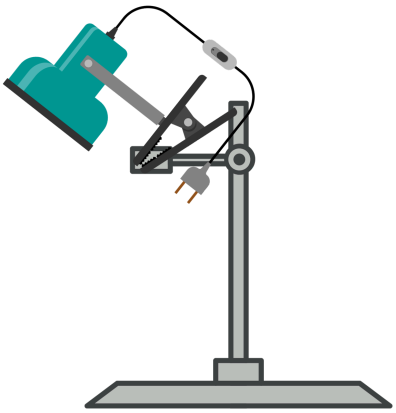
In the sun	**In the shade**

2. Discuss your model with a partner. Did you have similar ideas? Make any necessary adjustments to your model based on your conversation with your partner.

Name _____ Date_____

Heat Transfer

1. Set up a heat station by attaching a heat lamp to the top of a ring stand.



Caution! Heat lamps get HOT! Be sure not to touch the bulb or lamp shade while in use. Keep all other objects clear from the lamp, as they may catch fire!

2. Before turning on your lamp, place your hand about 12 inches in front of the bulb. Do you feel any heat?

_____

_____

3. Turn on the lamp and place your hand in the same position, 12 inches in front of the bulb. Does it feel different?
Do not move your hand closer than 12 inches to the bulb. Remember that heat lamps get hot!

_____

_____

4. Turn off the lamp and allow it to cool completely before disassembling the ring stand.

5. Draw a model that explains why you can feel heat if you're not touching the lamp. Where is the heat coming from? Use words and pictures to show what you think is happening. Remember to include labels.

Putting It All Together

6. Revisit your model from Lesson 1 about why temperatures might be different in the sun and in the shade. Draw a new model that explains how shade might affect how we feel the radiation from the sun. Be sure to include the term radiation and label all parts of your model.

In the Sun	**In the Shade**

7. What other examples of radiation can you think of?

_____

_____

8. Share your list with a partner. What ideas did they come up with?

_____

_____

Name _____ Date_____

Make it Melt!

Investigate how and why some objects melt by setting up a heat station.

Materials:

- Hot plate
- 2 aluminum foil pans or 2 glass beakers
- Ice
- Stopwatch

Procedure:

1. Place an aluminum foil pan or glass beaker on top of the hotplate.
2. Place the second foil pan or glass beaker on the table top next to the hotplate.
3. Add one ice cube to both containers. Make sure the ice cubes are about the same size.
4. Turn on the hotplate to medium-high temperature
5. Start the stopwatch and wait for the ice to melt.
6. Record the time at which each ice cube is fully melted.
7. Turn off the hotplate when the ice has melted.

Caution! Hotplates get HOT! **Do not touch** the surface of the hotplate. Objects placed on top of the hotplate will also be hot! Allow the foil pans or beakers to **cool completely** before touching them. Keep all flammable objects like paper clear, as they may catch fire!

1. Predict which ice cube will melt first. Why do you think so?

_____

_____

2. Record your data and observations below.

	On Hotplate	**On Table**
Time to fully melt (min : sec)		
Observations		

3. Which ice cube melted faster? Why do you think that is?

_____

_____

4. What is causing one ice cube to melt faster than the other? Use words and pictures to create a model that explains what is happening. Remember to include labels.

Name _____ Date_____

Make it Melt (Again)!

Investigate how and why some objects melt by setting up a heat station.

Materials:

- Hot plate
- 1 aluminum foil pan or glass beaker
- Several stainless steel washers or hex nuts
- Ice
- Stopwatch

Procedure:

1. Use 3-4 stainless steel hex nuts or several stainless steel washers stacked on top of each other to create a platform on top of the hotplate.
2. Place an aluminum foil pan or glass beaker on top of the hex nuts so that there is about 0.5-1 cm of air between the hotplate surface and the container.
3. Add an ice cube to the container.
4. Turn on the hotplate to medium-high temperature
5. Start the stopwatch and wait for the ice to melt.
6. Record the time at which the ice cube is fully melted.
7. Turn off the hotplate when the ice has melted.

Caution! Hotplates get HOT! **Do not touch** the surface of the hotplate. Objects placed on top of the hotplate will also be hot! Allow the foil pans, beakers, and hex nuts to **cool completely** before touching them. Keep all flammable objects like paper clear, as they may catch fire!

1. Do you think the ice cube with air beneath it will melt faster or slower than when its container was placed directly on the hotplate in the previous activity? Why do you think so?

_____

_____

2. Record your data and observations below. Compare these results to the results of the previous activity.

	Hovering Above Hotplate	**Directly on Hotplate**	**On Table**
Time to fully melt (min : sec)			
Observations			

3. Which ice cube melted faster? Why do you think that is?

_____

_____

4. Why is the ice cube that is hovering above the hotplate still able to melt? Use words and pictures to create a model that explains what is happening. Remember to include labels.

Name _____ Date_____

Module 1 - What I Know

Lesson 2

- ☐ What radiation is
- ☐ What conduction is
- ☐ What convection is
- ☐ How radiation, conduction, and convection result in heat transfer between Earth's surface and the atmosphere
- ☐ How mirages are formed

What I Know	How I Know, I Know It

Name _____ Date_____

Simulating Air Movements

We will be using water to simulate how air moves when it heats up and cools down.

Materials

- Colored hot water
- Colored cold water
- Room temperature water
- 1 Large container
- 2 Small cups or beakers
- 2 Pipettes

Predictions

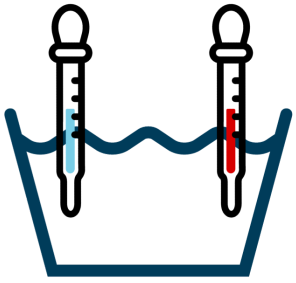
Predict what you think will happen to both hot water and cold water when it is added to room temperature water.

_____

_____

Procedure

1. Fill the large container with room temperature water and place it on the table where it will not be disturbed.
2. Fill one small cup with colored hot water and one with colored cold water. *Remember that hot water is **hot**! Use caution when handling hot water!*
3. Fill one pipette with hot water while someone else fills the other pipette with the cold water. Remember to use proper pipetting technique.
4. Insert both pipette tips into the large container of room temperature water. The pipettes should be on opposite sides of the container.
5. When the pipette tip is about midway to the bottom of the container, slowly squeeze the bulb to release the colored water. Be sure not to create bubbles or to suck water back up into the pipette! This will create mixing which may make results difficult to see.



6. Slowly pull the pipette back out of the container, being careful not to mix the water.

7. Observe how the hot and cold water move within the container. Record your observations.

Observations

1. Use words and pictures to record your observations about how the colored water moved.

Hot Water	Cold Water

2. How do your results compare to your predictions?

Name _____ Date_____

Notice & Wonder Chart

1. Watch the video of carbon nanotubes and record your observations. Use words and/or pictures to record your observations of what you see and hear. What questions do you have?

I Notice...	I Wonder...

2. What do you think might be happening in this video?

_____

_____

3. How is this carbon nanotube phenomenon similar or different from the heat shimmer effect in the desert?

_____

_____

Name _____ Date_____

Are Invisibility Cloaks Real?

Read the following Science Daily article. As you read, decide if you agree or disagree with the statements below. Provide evidence from the article to support your stance or explain your reasoning.

'Mirage Effect' Helps Researchers Hide Objects

On the Page - *Think of these as true or false statements that can be found in the article.*

Agree Disagree

_____ _____ 1. Mirages are most likely seen in hot areas.

_____ _____ 2. Mirages occur because of a layer of hot air that is above a layer of cool air.

_____ _____ 3. Mirages occur because of how light travels through air at different temperatures.

Between the Lines - *These statements are alluded to in the article, but aren't directly stated. You will need to "read between the lines" to decide if you agree or disagree.*

Agree Disagree

_____ _____ 4. A mirage is evidence of heat transfer.

_____ _____ 5. There is only one type of mirage phenomenon.

Beyond the Lines - *These statements are not necessarily referenced in the article at all. You will need to form an opinion based on what you've read.*

Agree Disagree

_____ _____ 7. The "mirage effect" produced by the cloaking device would work better for a submarine than an airplane.

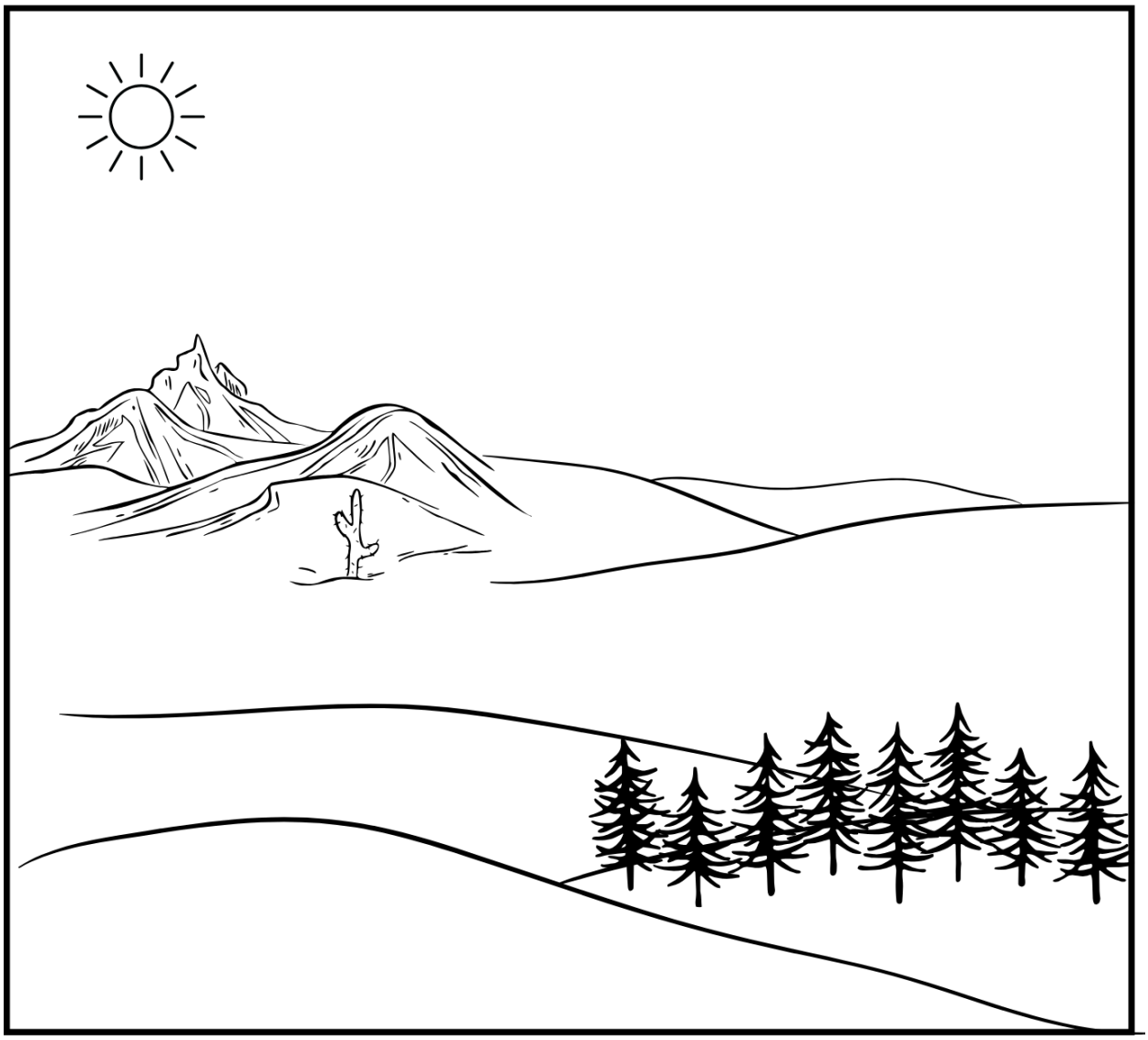
_____ _____ 8. A mirage can't occur in low-light conditions.

Name _____ Date_____

Putting It All Together

Can we answer the question, "What happens after air heats up?"

Use what you've learned about heat transfer to create a model that explains how the sun is responsible for the events and phenomena we've explored in this lesson. Start with what causes air to heat up, then include everything that happens after it heats up, such as how the air behaves or where the heat goes. Be sure to include the terms *radiation, conduction, convection, convection current, warm front, cold front, less dense, more dense, and mirage*. Feel free to add components to the landscape to illustrate your ideas.



Name _____ Date_____

It's Not The Heat...

1. What do you know about Arizona and Oklahoma? Use words and/or pictures to record your thoughts about what it might be like to live there, what the weather is like, what you might see, what kinds of plants or animals live there, etc.

Arizona	Oklahoma

2. Look at the weather forecasts for Phoenix and for Tulsa. Use words and/or pictures to record what you see and what questions you have.

I Notice...	I Wonder...

3. Can you explain what might be going on to make Tulsa feel different than Phoenix?

_____

_____

What is “moisture”?

4. What do you know about the states of matter? Use words and pictures to record everything you know about the 3 states of matter. This may be something you have seen or experienced yourself, something you’ve learned previously, an analogy, or even a question you have or something you’re not sure about.

State of Matter:			
My Ideas:			

5. Draw a model of water vapor in the air compared to steam. Imagine you can zoom in on the molecules using a microscope. How might air and steam look different?

Water Vapor in the Air	**Steam**

6. Make a claim about the state of water in steam. What evidence supports this claim?

Name _____ Date_____

...It's The Humidity

We want to investigate how much water vapor can be in the air. There's only one problem - we can't see air or water vapor! Let's use other materials that we *can* see to simulate water vapor entering the air. Use the provided materials to design an investigation. Your design should provide data that allows you to answer the Investigation Question.

Materials

- Beaker
- Pipette
- Water
- Dry sponge

Investigation Question

We wish to investigate the question, "Is there a limit to how much water can be added to a substance?"

Brainstorming Space

1. Let's brainstorm some ideas for how we can design our investigation. What can we use to represent the air? What can we use to represent water vapor in the air? How can we measure how much water is held by our air-substitute? How do we know when there's too much water? Draw or describe your ideas below.

Investigation Design

2. After sharing your ideas with classmates, decide on a design for your investigation.
3. Describe how you will use the provided materials (What is the purpose of each?):
    a. Beaker

    b. Pipette

    c. Water

    d. Dry sponge

4. Keeping the purpose of our investigation in mind, what data will you collect to help you answer the investigation question?

    _____

    _____

5. When will you stop collecting data? In other words, how will you know if you have reached the limit to how much water can be added to the object/substance?

    _____

    _____

6. How will you represent the data? Will you use a chart, a table, a graph, etc.?

    _____

    _____

7. How will you share your results with classmates?

    _____

    _____

8. Now think about your procedures. What steps will you follow during your investigation? Outline your procedure below. The procedure should be specific enough that anyone could follow your directions and do exactly what you did. You may include a materials list and diagrams if you wish.

    You can assume other scientists will know they should first gather their materials before using them, so do not include, "Gather your materials" as one of the steps. However, consider including directions for using specific materials such as size of beaker, temperature of water, type of sponge, etc.

Results

9. Conduct your investigation. Record your data and observations using the format you determined in number 6. You may choose to record your data, observations, and analysis digitally for a more professional presentation.

10. Analyze your results. Use data you collected to answer the Investigation Question. Use the template below as a guide to help you explain your results. Feel free to expand upon the template below.

    We investigated if _____. *Our*

    results showed that _____.

    Additionally, we observed _____.

    Therefore, we conclude that _____.

Name _____ Date_____

Studying Saturation

Let's practice calculating percent saturation using the data from our *...It's The Humidity* investigation.

Setting the Stage

1. At what point was the sponge fully saturated? What does it mean for the sponge to be saturated? What did you observe? Include how much water or how many pipettes of water it took to saturate the sponge.

   _____

   _____

2. When the sponge was fully saturated, what was the % saturation? _____%

3. Why do you say it was that % saturated? What does that mean to you?

   _____

   _____

4. What is the highest possible % saturation? Why do you think so?

   _____

   _____

Let's Calculate!

5. Draw a model or chart of how you believe the saturation of the sponge changed throughout the investigation.

6. We can calculate the % saturation of the sponge each time you added another pipette of water. This is the same process as calculating your grade percentage on an assignment or test. Let's say you scored a 9 out of 10 on an assignment. Describe how you would calculate your grade percentage. Use words to explain the process, then write a sample calculation.

7. Let's track how the % saturation of the sponge changed as you added more water. Calculate the % saturation for each time you added another pipette of water to the sponge. If you previously used number of pipettes for your data, use that unit of measurement here. If you previously used total milliliters, use that unit of measurement. Start with recording the total amount of water you added to reach 100% saturation.

   100% saturation = _____(pipettes or mL)

   Remember that to calculate % saturation, you will use the amount of water added at each step divided by the total amount of water added, times 100.

$$\frac{\text{Amount of water added}}{\text{Total amount of water added}} \times 100 = \%\ \text{Saturation}$$

   For example: $\frac{6\ \text{Pipettes}}{15\ \text{Pipettes}} \times 100 = 40\%\ \text{Saturation}$

   Create a table to track how the % saturation changes each time you added water to the sponge. This may be done on paper or using a spreadsheet.

8. Create a graph to represent how the % saturation changed over time. This may be done on paper or using the chart functions in a spreadsheet.
9. Compare your data and graph with that of another group. You may have had a different amount of water that you added to the sponge, but did the % saturation change in a similar way? How do your graphs compare?

Name _____ Date_____

Module 1 - What I Know

Lesson 3

- ☐ What humidity is
- ☐ How water vapor is similar to and different from other forms of water
- ☐ What relative humidity is and how it is different than absolute humidity
- ☐ What saturation is
- ☐ The relationship between relative humidity and saturation
- ☐ What heat index is
- ☐ Why hot weather may feel different in different places

What I Know	How I Know, I Know It

Name _____ Date_____

It's All Relative (Humidity)

Recall that relative humidity is the amount of water vapor present in the air compared to how much could be present at that temperature.

1. Draw a diagram or picture that helps you understand what relative humidity means.

2. Finish these sentences:
   - Warm air can contain_____water vapor than cold air.
   - As the temperature outside increases,_____water vapor is able to enter the air.
3. Let's say the temperature outside is 75 degrees with a relative humidity of 45%. The temperature then cools off to 60 degrees, but the amount of water vapor in the air stays the same. Would the new relative humidity be more or less than 45%? Why do you think so?

   _____

   _____

   Draw a model that describes your thinking. How do the statements from #2 show up in your model?

75 degrees, 45% humidity	**60 degrees, ? % humidity**

4. Now that you've seen an example of how relative humidity can change with temperature, create a new model to revise your thinking. How easy would it be for more water vapor to enter the air at each temperature? Use words and pictures to express your reasoning.

75 degrees, 45% humidity	**60 degrees, <u>?</u> % humidity**

5. Why do you think sweat isn't as effective at cooling you off in Oklahoma? Think about the weather forecasts for each location. What might be preventing sweat from cooling you off? Look back at the model you drew in #4 for more inspiration. Use words and pictures to express your thinking.

Phoenix, Arizona **Temp = 101°F** **Humidity 20%** **Feels like = 99°F**	**Tulsa, Oklahoma** **Temp = 96°F** **Humidity 67%** **Feels like = 120°F**

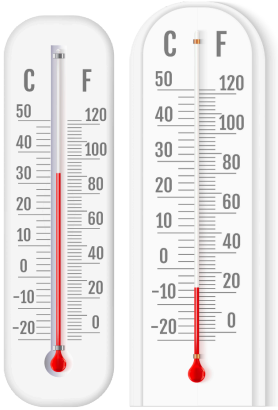
Name _____ Date_____

Think Like A Meteorologist

Heat index is how hot it feels outside when temperature and relative humidity are combined. If relative humidity and temperature are known, heat index can be determined using a standardized chart or heat index calculator.

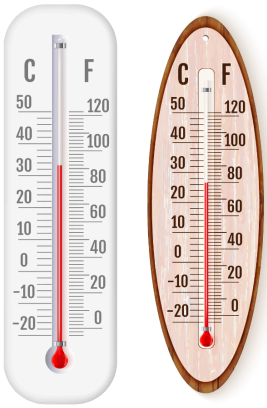
Let's measure the heat index outside! We can use a regular thermometer to determine the temperature, but we will need to use a special tool called a sling psychrometer to measure the relative humidity. A sling psychrometer uses two thermometers to measure how much the temperature can be lowered through evaporation. One thermometer will measure the air temperature, while the other will measure the temperature when water is evaporating from its surface. These two values can be used to determine how much water vapor is already present in the surrounding air.

1. Look at the following sets of temperature readings from a psychrometer. Which one do you think represents higher humidity? Why do you think so? Use words and/or pictures to explain your reasoning.



Dry-Bulb Wet-Bulb

Set 1



Dry-Bulb Wet-Bulb

Set 2

_____

_____

_____

Making The Psychrometer

Materials

- 2 thermometers
- Cardboard, plastic bottle, cup, or other sturdy material
- Cotton balls or gauze
- Strong twine
- Strong tape
- Rubber bands

Plan Your Design

Your sling psychrometer will need to have 2 thermometers firmly attached to a sturdy surface while still being able to read the thermometer. The bulbs of the thermometers will need to be completely exposed to air. One thermometer will be the dry-bulb that will measure actual air temperature while the other will be the wet-bulb that will measure temperature after evaporation. The wet-bulb thermometer needs to have wet cotton or gauze firmly wrapped around the bulb (this should not be added until you are outside). A long length of strong twine will need to be attached to the entire construction. This device is called a sling psychrometer because you are going to swing it around in the air. It is therefore very important that all parts of your device are securely attached!

2. Plan how you will design your sling psychrometer. Use words and pictures to describe your design below:

3. Try your design to make sure it works by using a pencil or marker in place of the thermometer (we don't want to break the thermometers). After testing it out, describe any changes you'd like to make to your design.

4. After you are happy with your design, take your psychrometer outside:
    - Allow your thermometers to rest outside for at least 5 minutes before adding the wet cotton or gauze to your wet-bulb thermometer. Check the temperature of both thermometers to ensure they are the same. Now add the wet cotton or gauze.
    - Twirl the psychrometer in the air like a lasso for at least 2 minutes. Pause every 30 seconds to observe the temperatures of both thermometers.
    - Keep swinging your psychrometer until the wet-bulb thermometer seems to no longer be changing temperature.
    - Record the temperature of both thermometers.
        - Dry-bulb= _____°F Wet-bulb=_____°F

Analyze Your Results

5. To analyze your results, you will first need to determine the difference in temperature between the dry-bulb and wet-bulb thermometers. Subtract the wet-bulb temperature from the dry-bulb temperature and record it below:
   Dry temp - wet temp = _____°F
6. Use the Relative Humidity (%) table to determine the relative humidity by comparing the actual air temperature with the dry temp - wet temp you calculated in #5.
   Relative humidity = _____%
7. Use the Heat Index table to determine the heat index outside.
   Actual temperature= _____°F Heat Index=_____°F
8. Do you think it is safe to spend much time outside today?

   _____

Name _____ Date_____

How Low Can You Go?

1. Look at the heat index table. There aren't any temperatures listed below 76°F. Let's see if we can figure out why. What do you notice about the cooler temperatures compared with the warmer temperatures? Are there any patterns? What questions do you have?

I Notice...	I Wonder...

2. Is there anything going on in the air or with our bodies that might explain why temperatures below 76°F aren't included on the heat index table? Create a model using words and pictures that explains your ideas.

Above 76°F	Below 76°F

Let's Investigate

3. Use a heat index calculator to investigate heat index values for temperatures below 76°F. Use a spreadsheet to track what data you put into the calculator and what the results are. Try at least 10 different temperature values with at least 5 different relative humidity percentages. First decide what values you will try. Why do you think those are good values to test?
   Temperatures and % Relative Humidity I will try:

   Why I think I should test those values:

4. Enter your chosen temperature and % relative humidity values in the calculator and record the results.
5. Try using a color coding system and/or graphs to help you make sense of the data. What patterns do you notice?

6. Make a claim about why heat index values for temperatures below 76°F are not included on the table. What evidence do you have that supports this claim? Gather additional evidence from other groups if needed.

Name _____ Date_____

Chilling with Wind Chill

1. Why does wind chill make you feel colder? What is it about wind blowing against your skin that cools you down? Use words and pictures to create an initial model that might explain why wind can make the air feel colder.

2. Let's test out some different types of wind to see if they have the same cooling effect. Stand in front of a fan, then in front of a hair dryer. Describe what you observe. Do both types of "wind" feel the same?

Fan	Hair Dryer

3. Think about the heat transfer that is happening when the fan and hair dryer are blowing on you. Why do they feel different? Create a model that explains the difference in how heat is being transferred.

Fan	Hair Dryer

Forecasting Wind Chill

4. Use a Wind Chill Chart to determine the wind chill values for the following weather conditions. Create a color coding system to indicate the safety of outdoor activity in those conditions. Be sure to include a key below the chart.

Temperature	Wind Speed	Wind Chill
35°F	40 mph	
10°F	5 mph	
6°F	30 mph	
-5°F	15 mph	
-10°F	25 mph	
-15°F	50 mph	

Key:

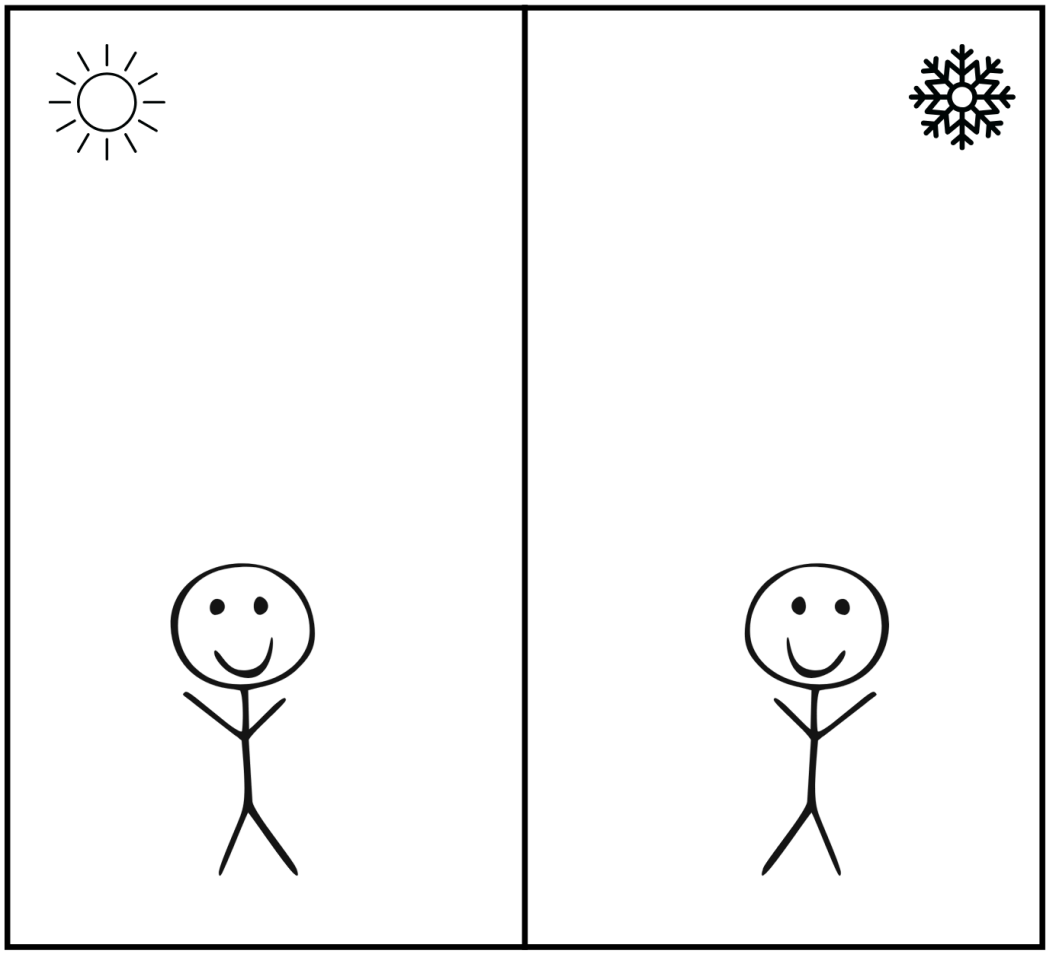
Name _____ Date_____

Putting It All Together

Think about what you've learned about temperature, air movement, heat transfer, relative humidity, heat index, and wind chill. Create a model using words and pictures to explain why summer and winter weather conditions cause us to feel hotter or colder than the actual air temperature.

Include in your model:

- Air temperature vs. what humans perceive
- Methods of heat transfer (such as radiation, conduction, convection)
    - How these are involved in the heat index and the wind chill
- Movement of air molecules
- Our bodies' responses to heat and cold (such as sweating)
- Causes and process of the heat index
- Causes and process of wind chill



Name _____ Date_____

Investigating Weather Warnings

What do temperature advisory warnings have in common? Search the internet to find some examples of temperature advisory warnings and share your discoveries with others.

1. Search for heat index or wind chill temperature advisories. These might be graphics, pictures, news clips, app updates, etc. What do you notice about what the advisory warnings have in common?

2. Is there any terminology or vocabulary used that might be confusing for people?

3. What else do you notice about these warnings? Think about how the warnings are accessed by people, what information is included, etc.

Name _____ Date_____

Meet a Professional

Have you ever tried learning another language? If so, you may have noticed that words or phrases don't always have a direct translation. For example, a heat watch and heat warning don't have separate meanings in every language. People whose primary language is something other than English may miss important weather safety information because of this.

Joseph Trujillo Falcón is a meteorologist in Oklahoma who is working to increase access to weather information for Spanish speakers. Read about his work here: https://ciwro.ou.edu/news-article-template?article_id=217&previous=1

1. How is Joseph's research working to reduce barriers for Spanish speakers?

2. How can we use Joseph's work to make sure weather forecasts are more accessible for all?

3. If you could solve one problem relating to weather safety, what would it be?

Name _____ Date_____

Creating a Temperature Advisory Notice

What can we do to help make sure people are prepared and protected during extreme temperatures of summer and winter?

1. Decide if you would like to make a heat index or wind chill temperature advisory.

Make a Plan

2. What weather information do you want to include in your advisory notice?

3. What safety information do you want to include?

4. What kind of format will you use (how will people access it)? For example, will it be a radio announcement, a TV commercial, an app notification, etc.

5. How will you make sure it is accessible for all people? Who is the audience you are trying to reach?

Make a Prototype

6. Use the space below to sketch your plans. How do you want the advisory to look or sound? What will the design be? Do you need a script?

7. Make a prototype of your temperature advisory. This could be a video for a TV spot, a radio recording, a graphic for an app, etc.

Peer Evaluation Form

Content	Score	Comments
How well do you understand the advisory notice?	I'm confused 1 2 3 4 5 It's totally clear	
How well do you think the public would understand the advisory notice?	Not well 1 2 3 4 5 Really well	
How helpful is the information in the advisory?	Not very helpful 1 2 3 4 5 Really helpful	
Is the advisory accessible for all people?	No 1 2 Somewhat 3 4 5 Yes	
What suggestions do you have for how to improve the advisory notice?		

WEATHERING THE STORM

Meteorology Curriculum

TEACHER GUIDES

Tulsa Regional STEM Alliance

CIWRO

COOPERATIVE INSTITUTE FOR SEVERE AND HIGH-IMPACT WEATHER RESEARCH AND OPERATIONS

WEATHERING THE STORM

Module 2 Storyline

Content Key

- Key Concept Development
- Environmental Hazards
- Phenomena in the Sky
- Community Impact & Safety
- Meet a Professional Spotlight

Activity Key

- Class Discussion
- Technology Use
- Outdoor Learning
- Laboratory Setup
- Group Activity

Driving Question: Why is it so windy in Oklahoma?

Lesson 1

Topic	Standards	Key Concepts	Student Artifacts
Air Pressure and Wind	**Science:** 6.ESS2.5, 6.ESS2.6 **Computer Science:** 6.DAIM.01	• Wind speed and direction can be determined based on weather graphs. • Changes in atmospheric pressure are responsible for wind patterns. • Wind is the result of a pressure gradient.	• Predictions of wind direction and air pressure based on weather maps.

Vocabulary: Surface Pressure, Sea Level Pressure, Isobar, Wind, Pressure Gradient

Lesson Navigating Question: What makes wind?

WEATHERING THE STORM

Module 2 Storyline

Lesson 2

Topic	Standards	Key Concepts	Student Artifacts
Measuring Air Pressure Vocabulary: Barometer, Isobars, Millibars, Standard Atmospheres, Millimeters/Inches of Mercury	**Science:** 6.ESS2.5 **Math:** 6.N.3.3 6.N.4.3 6.N.4.4 6.GM.2.1 **Computer Science:** 6.IC.SI.01 6.IC.SLE.01	• Gravity causes air to exert pressure on Earth's surface. • Air pressure changes with altitude. • Air pressure can be measured with barometers and radiosondes. • There are multiple units that may be used to express air pressure measurements. • We can convert between these units of measurement using mathematical procedures.	• Data that shows how air pressure affects objects on the surface. • Research presentation on air pressure measurement.

Lesson Navigating Question: How is atmospheric pressure measured?

Lesson 3

Topic	Standards	Key Concepts	Student Artifacts
Measuring Wind Vocabulary: Wind speed, Wind direction, Anemometer, Wind vane, Windsock	**Science:** ETS-1 **Math:** 6.N.3.2 6.N.4.2 6.A.1.1 6.D.1.2 7.GM.3.3	• Measuring wind speed and direction helps us understand current air quality, safety, and helps predict precipitation and temperature changes. • Wind speed is measured with a tool called an anemometer. • Wind direction is measured with a tool called a wind sock or wind vane.	• Engineered device to measure wind speed and direction. • Calculation of wind speed.

Lesson Navigating Question: How and why is wind measured?

WEATHERING THE STORM

Module 2 Storyline

Lesson 4

Topic	Standards	Key Concepts	Student Artifacts
Global Wind Patterns	**Science:** 6.ESS2.5 6.ESS2.6	• Prevailing winds follow predictable patterns across the globe. • Prevailing wind patterns are based on uneven heating of Earth's surface, differences in air pressure, convection currents, and the Coriolis Effect.	• Investigation of the cause of wind patterns. • Claims supported by evidence about the cause of wind patterns. • Models of the relationship between air pressure, temperature, Earth's rotation, and wind patterns.

Vocabulary: Prevailing Winds, Trade Winds, Westerlies, Jet Stream, Coriolis Effect

Lesson Navigating Question: Is wind the same everywhere?

Lesson 5

Topic	Standards	Key Concepts	Student Artifacts
Local Wind Patterns	**Science:** 6.ESS2.5 6.ESS2.6	• Grasslands and mountain ranges can experience high wind speeds. • Forests usually experience low wind speeds. • Friction on the surface can affect wind speed. • Mountains cause air to rise and can create unpredictable wind patterns.	• Investigation to explore how wind is affected by land formations. • Construct a scientific argument based on evidence. • Final model to explain factors that affect wind in Oklahoma.

Vocabulary: Windward, Leeward, Turbulence, Friction, Rotor Clouds

Lesson Navigating Question: What else affects how windy it is where I live?

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 2 Lesson 1

Module Driving Question: Why is it so windy in Oklahoma?

Lesson 1 - Under Pressure

Lesson Navigating Question: What makes wind?

Grade Levels:
6-8

Time Required:
200-230 Minutes
4-5 Class periods

STEM Content Areas:
Science, Computer Science

Overview

Students will analyze wind and air pressure maps of Oklahoma to develop hypotheses about their relationship. They will examine various representations of these measures to gather evidence supporting their claims and predict wind or pressure based on given map observations.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.ESS2.5** - Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- **6.ESS2.6** - Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Science and Engineering Practices

- **Developing and Using Models** - Develop a model to predict and/or describe phenomena.
- **Constructing Explanations and Designing Solutions** - Construct theories to provide an explanation of natural phenomena.

Crosscutting Concepts

- **Cause and Effect** - Cause and effect relationships are routinely identified, tested, and used to explain change.
- **Systems and System Models** - Define the system under study and make an explicit model of that system to provide tools for understanding and testing ideas.

Computer Science Standards

- **6.DA.IM.01** - Use data to highlight or propose cause-and-effect relationships, predict outcomes, and communicate ideas.

Learning Objectives

1. Observe patterns in wind speed and direction on a weather graph.
2. Connect wind patterns to patterns in atmospheric pressure.
3. Explain wind as the result of a pressure gradient.
4. Predict wind behavior based on observed pressure differences.

Vocabulary

- **Surface pressure -** (also called atmospheric or barometric pressure) the pressure exerted by the atmosphere due to gravity at any given location on Earth's surface
- **Sea level pressure** - the air pressure at sea level
- **Isobar** - lines on a weather observation map that connect areas of equal surface pressure
- **Wind** - air in motion relative to the Earth's surface
- **Pressure gradient** - the rate of pressure decrease per unit of horizontal difference

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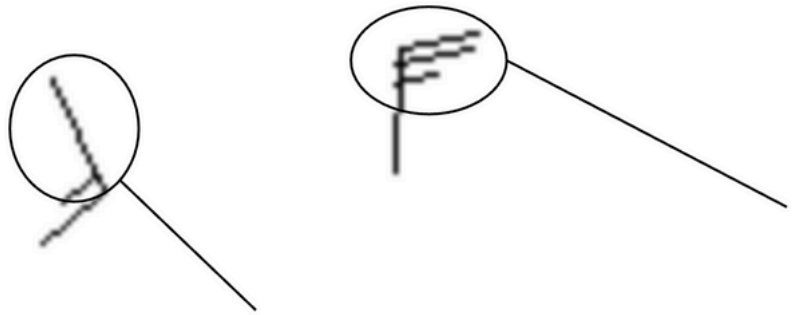
Materials

- Feathers or other light objects such as tissue paper
- Fan or hair dryer
- Highlighters
- Colored pencils
- Student Handouts: *Birds of a Feather, Weather Maps, Where's the Wind?, Think Like a Meteorologist, Module 2 - What I Know (Lesson 1)*

Preparation

1. Reading a wind barb:



The wind is flowing in the direction of the indicator from the “barb” end toward the point. So in this case we’d call this a southeast wind because it’s blowing from the SE. Sometimes these are shown as angle measures in degrees.

The “barbs” at the end of these wind indicators show how fast the wind is blowing. A long barb represents 10 knots and a short one represents 5 knots. Long and short barbs are used in combinations up to 50 knots, which is represented by a triangular shape called a pennant.

The whole shape together is called a “wind barb” and it shows the direction and speed of the wind measured in the place it’s anchored on the map.

Module 2 Lesson 1

Phase	Time	Slide	Description
Enroll	30 min.	1-7	1. Introduce students to the module's driving question, "Why is it so windy in Oklahoma?" 2. Show the video clip of the song *Oklahoma* from the Rodgers and Hammerstein musical. Encourage students to sing along! 3. Ask students to share their initial ideas about why it might be windy in Oklahoma. These could be things they've experienced, stories they've heard, prior science knowledge, or possible explanations. 4. **Optional:** Take students outside to observe the wind. Have students point out what they notice. How do they know that the wind is or is not blowing? 5. Using the handout *Birds of a Feather*, have students throw a feather in the air and observe what happens. (Alternatively, students can hold the feather to feel how air is pushing against it.) Other light objects can be used instead of feathers, such as a coffee filter or tissue paper. • Next, have students throw a feather in the air directly in front of a fan. Does the feather behave differently? • Then have students move 5-10 feet away from the fan and throw the feather in the air again. How does the feather behave? 6. Ask students to brainstorm some ideas about where real wind comes from. Give students 2-3 minutes to free write on their handout *Birds of a Feather*. • Have students turn and talk before sharing as a class. Accept all ideas. Keep the list to return to later. ◦ Students may or may not connect wind with air masses at this point. The goal at this point is simply to gather their initial ideas and assess their current knowledge.

Phase	Time	Slide	Description
Experience	20 min.	8-10	7. Recall the components of weather from Module 1. Students should now have a good understanding of how temperature and humidity impact weather. 8. Review that temperature affects humidity, but humidity does not cause the temperature to change. It does affect how temperature feels to us (heat index). Students should recall that wind can also affect how we perceive temperature, such as with wind chill. What other relationships exist between wind and other components of weather? **Teaching Tip:** Try an interactive word wall to help students keep track of what they've learned. To learn more: **Interactive Word Walls Create a tool to increase science vocabulary in five easy steps.** 9. Tell students that today they are going to investigate patterns between some kinds of weather observations to better understand wind. 10. Using the *Weather Maps* handout: • Allow students time to examine the weather maps and make some observations. After students brainstorm what the numbers might mean, pause for class discussion. • Ask some students to share what they noticed. Students should only share observations at this time, not explanations. Look for ideas such as: ◦ *some numbers have H or L above them; the numbers with H are larger than the numbers with L* ◦ *there are lines that seem to separate different numbers; the lines occur in different patterns* ◦ *some arrows are big and some are small; the arrows move in different directions; large areas of arrows move in the same direction; the arrows sometimes change near a line; arrows are in a circle around some lines that are a circle*

Phase	Time	Slide	Description

Experience (cont.)	20 min.	8-10	• Students may not have noticed at this point that arrows are generally pointing away from the areas with H and towards the areas with L. That's fine, they should discover this eventually.
			• Ask students what they think these numbers and symbols might represent.
			  ◦ Allow class discussion to flow if there are any debates about what the numbers mean. Accept all ideas, but ask for students' reasoning.
			  ◦ If students don't notice the upper left corner, point out where it says "surface wind vectors" and "sea level pressure." Ask students if they think these terms might relate to what they've observed.
			11. Students should stop when they reach the "Pause for Class Discussion" symbol. They will complete the backside after the next section.

Label	25 min.	11-14	12. Define surface pressure, or air pressure. Note that the map we have examined includes measures of sea level air pressure.
			• Ask students why we might use sea level pressure for areas that aren't at sea level. What is the difference between surface pressure and sea level pressure?
			  ◦ Prompt students to think about high elevations, like mountains. Students may recognize that the air is "thinner" on top of a mountain. How does this relate to air pressure?
			• Air pressure is due to air molecules bumping into the ground, or "pressing down" on the ground due to gravity. Have students demonstrate this by pressing their hand on the table. Their hand is putting pressure on the table.
			  ◦ Ask a student volunteer to come up to the class and hold out their hands. Place a book in their hands and ask if it feels heavy. Add pressure to their hands by placing another book on top of the first. Is it heavier? Ask how heavy it would be if you place 10 books in their hands. The student can sit down now.

Phase	Time	Slide	Description
Label (cont.)	25 min.	11-14	▪ Relate this to air pressure and elevation. Higher elevation has less atmosphere above you, therefore the air isn't as "heavy" so the pressure is lower. Sea level is considered the average or "normal" thickness of atmosphere, which is why pressure is often described as sea level pressure. Sea level pressure takes altitude or elevation into account, but surface level pressure does not. That is why it is sometimes easier to compare the air pressure of different regions by using sea level pressure. 13. Define Isobars as the lines observed on the map. These lines connect areas of equal air pressure. In other words, the lines divide areas of different air pressure. • The numbers they see are the sea level pressure. • Some numbers have H or L above them to note that these areas are higher or lower pressure than the areas around them. • Connect back to Module 1 when students learned about convection currents and warm fronts/cold fronts. The "front" is the boundary at the leading edge of the air mass. The air mass as a whole is called a pressure system. 14. Define wind as air in motion. Wind is represented by the arrows on the map called wind vectors. 15. Have students return to their *Weather Maps* handout to create an initial model of why Oklahoma might be more windy than other areas.
Experience	30 min.	15	16. On the handout *Where's the Wind?* students return the previous map they studied. Note that the map includes sea level pressure with H and L indicators, and the lines on the map are isobars. Students may have already figured out that the size of the arrows indicates wind speed and the arrows point in the direction wind is blowing. If they have not made these connections, guide class discussion to help them notice this.

Phase	Time	Slide	Description

Experience (cont.)	30 min.	15	• Have students consider how the air pressure readings and wind vectors together create patterns. A Think-Pair-Share is recommended for this step.
			  ◦ What students should notice by the end of this handout:
			  ▪ Wind generally moves from areas of high pressure towards areas of low pressure.
			  ▪ Wind is stronger when the difference in pressure is greater.
			  ◦ Students may notice:
			  ▪ High pressure often (but not always) occurs in mountainous areas like Colorado and New Mexico.
			  ▪ Low pressure often (but not always) occurs in warm areas like Mexico.
			  ▪ Wind tends to move counterclockwise around Low pressure zones and clockwise around High pressure zones.
			17. After sharing out some patterns they notice, have students examine the next couple of maps to see if the patterns continue, or if they notice any new patterns. Students should write a short paragraph to describe their observations, along with any diagrams or annotations on the maps. This step should be completed in groups of 2-4.
			
			Teaching Tip: Have students use highlighters or colored pencils to trace patterns on the map. For students that need additional support, have them shade the large areas within each isobar a different color to indicate different pressure zones. Then have them use a marker or darker color to follow the direction of the arrows.

Label	20-50 min.	16-21	18. Explain that wind is created by differences in surface pressure. This difference is called a pressure gradient.

Phase	Time	Slide	Description
Label (cont.)	20-50 min.	16-21	• The maps we examined showed drastic changes in pressure between the isobars, but actually pressure changes more gradually. The maps were just simplified to make them easier to read, but we could add more frequent measurements to the map. • Air molecules are moving around in the atmosphere and they tend to move into available space. In areas of high pressure, the molecules are very close together. In areas of low pressure, they're more spread out. Therefore, the molecules tend to move from higher pressure to lower pressure to "fill in" the available space. The pressure gradient is the measure of this difference. ◦ The same type of thing occurs in the flow of heat energy from higher temperatures to lower temperatures. 19. Introduce students to Elizabeth Leitman, a meteorologist from Norman, OK. Liz works with surface analysis maps like the students have been examining. Meteorologists usually make these maps by hand because they are more accurate than computer simulations. • Included is a picture of a map drawn by Liz. • She is the first woman to issue a thunderstorm watch. Included is a video interview with her and some articles about her work and what first interested her in meteorology. • **Optional**: have students read the interviews and discuss what they found interesting.
Demonstrate	25 min.	22	20. On the handout *Think Like a Meteorologist*, have students draw in the missing observation on the four maps. Students can compare their ideas with others. This activity works well as a collaborative effort.

Phase	Time	Slide	Description
Demonstrate (cont.)	25 min.	22	• Students will likely not have the exact correct answer. It takes years of experience and training to be able to create maps like these. Instead, focus on making connections between high and low pressure and wind direction/speed. Students should be able to identify: ◦ Zones of high pressure and low pressure ◦ Approximate areas where pressure might change ◦ Wind moving from high pressure towards low pressure • There are "answer" slides at the end of the slide deck if you'd like to go over the maps with students. **Accommodations**: Give students maps with isobars and pressure readings, but remove the H and L. Have students add H and L to the maps in addition to wind arrows. This focuses their attention on the difference between high and low pressure while making the maps easier to read for those with processing disorders. Additional maps can be generated at **Plymouth State Weather Center**.
Label	5 min.	23	21. Explain that meteorologists use wind barbs to note the direction and speed of wind. Wind barbs can be thought of as an arrow that is missing the point. The flags on the end are like the feathers of an arrow. The wind barb points in the direction that wind is moving. The flags indicate the speed of the wind. More information can be found at **National Weather Service: Information about wind barbs** and **wikiHow: How to Read Wind Barbs**
Demonstrate	25 min.	24	22. **Optional:** Have students practice reading wind barbs on a map. On the handout *Where the Wind Blows*, students are given maps with isobars and wind barbs and are asked to draw arrows indicating the direction of wind movement. At the end of the slides are the "answers" with arrows filled in.

Phase	Time	Slide	Description
Review	15 min.	25	23. Have students review what they've learned using the *Module 2 - What I Know* handout for Lesson 1. Students should use words and/or pictures to reflect on what they've learned. Note: *This is a good formative assessment tool.*
Celebrate	1 min.	26	24. Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 2 Lesson 2

Module Driving Question: Why is it so windy in Oklahoma?

Lesson 2 - Measuring Pressure

Lesson Navigating Question: How is atmospheric pressure measured?

Grade Levels:
6-8

Time Required:
225 - 285 Minutes
4-6 Class periods

STEM Content Areas:
Science, Mathematics, Computer Science

Overview

Students will discover instruments and units for measuring atmospheric pressure. Students will calculate the air pressure in the classroom exerted on different objects related to their surface area.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.ESS2.5** - Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Science and Engineering Practices

- **Planning and Carrying Out Investigations** - Plan an investigation individually and collaboratively, and in the design: identify what tools are needed to do the gathering and how measurements will be recorded.
  - Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of the investigation.
  - Collect data to serve as the basis for evidence to answer scientific questions.
- **Analyzing and Interpreting Data** - Analyze and interpret data to provide evidence for phenomena.
- **Mathematics and Computational Thinking** - Use mathematical representations to describe or support scientific conclusions.
  - Apply mathematical concepts and processes to scientific questions and problems.
- **Obtaining, Evaluating, and Communicating Information** - Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each.
  - Critically read scientific texts adapted for classroom use to determine the central ideas and obtain scientific information to describe evidence about the natural and designed world(s).
  - Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

Crosscutting Concepts

- **Cause and Effect -** Cause and effect relationships are routinely identified, tested, and used to explain change.
- **System and System Models** - Models can be used to represent systems and their interactions - such as inputs, processes, and outputs - and energy, matter, and information flows within the systems.
  - Models are limited in that they only represent certain aspects of the system under study.
- **Stability and Change** - Small changes in one part of a system might cause large changes in another part.

Oklahoma Academic Standards (cont.)

Mathematics Standards

- **6.N.3.3** - Apply the relationship between ratios, equivalent fractions, unit rates, and percents to solve problems in various contexts.
- **6.N.4.3** - Multiply and divide fractions and decimals using efficient and generalizable procedures.
- **6.N.4.4** - Use mathematical modeling to solve and interpret problems using money, measurement, geometry, and data requiring arithmetic with decimals, fractions, and mixed numbers.
- **6.GM.2.1** - Develop and use formulas for the area of squares and parallelograms using a variety of methods including but not limited to the standard algorithms and finding unknown measures.

Computer Science Standards

- **6.IC.SI.01** - Describe and use safe, appropriate, and responsible practices (i.e., netiquette) when participating in online communities.
- **6.IC.SLE.01** - Differentiate between appropriate and inappropriate content on the Internet, and identify the characteristics of unethical and illegal online behavior.

Learning Objectives

1. Explain gravity's role in air pressure measurements.
2. Collect and interpret data that shows how air pressure affects objects.
3. Calculate an estimate for the force exerted from air pressure on different objects in the classroom related to their surface area.
4. Use safe and responsible practices for internet research to obtain and communicate information about instruments and units for measuring atmospheric pressure.
5. Use mathematical procedures to convert between different units of measurement for atmospheric pressure.

Vocabulary

- **Area** - the number of square units an object takes up
- **Surface Area** - the area of all surfaces of an object
- **Barometer** - (pronounced bar-AH-met-er) the instrument used to measure surface pressure; there are two types: the mercury barometer and the aneroid barometer
- **Radiosonde** - an instrument carried by balloon or other means to various levels of the atmosphere and transmits measurements by radio.
- **Millibars (mb)** - a pressure unit of 1000 dynes per square centimeter; this unit does not fit into any commonly used system of physical units, but has been used to describe surface pressure since 1929 in meteorology
- **Pascal (Pa)** - named for Blaise Pascal, this is the scientific unit of pressure; 1 Pa = 0.01 mb
- **Standard atmospheres (atm)** - a standard unit of atmospheric pressure recommended for meteorological use; 1 atm = 760 mm Hg = 29.92 in Hg = 1013.2 mb
- **Millimeters/Inches of Mercury (mmHg, in Hg)** - refers to the height of mercury in a mercury barometer measured in millimeters (mm Hg) or hundredths of inches (in Hg); note that Hg is the periodic table abbreviation for the element mercury

Materials

For each group of 2-3 students:

- 1 plastic bag
- 1 sheet of printer paper
- 1 sheet of newspaper (or tissue paper)
- Ruler or paint stir-stick
- Small ball (such as rubber, ping-pong, or foam)
- Calculator
- Colored pencils or markers
- Colored sticky notes
- Poster paper (optional)
- Computer or tablet with internet access

Student Handouts:

- *Pick A Paper*
- *Under Pressure*
- *Internet Safety*
- *Tools and Units*
- *Careful Conversion (Optional)*

Preparation

1. Collect materials for the *Pick A Paper* and *Under Pressure* activities.
2. Try the experiment yourself to make sure the materials you have will work properly.

Module 2 Lesson 2.1 - 135 minutes

Phase	Time	Slide	Description

Enroll	10 min.	1-4	1. Give students a plastic shopping bag or zip top bag. Ensure the bags do not have holes. Have them open the top of the bag and shake it out so the bag can fill with air. Then have students close the bag to trap air inside.
			2. Now have students try to squish or pop the bag. Is it difficult?
			• Ask students why an empty bag might be hard to pop.
			  ◦ Students should suggest that air in the bag is making it hard to pop.
			  ◦ If students need additional prompting, ask what they are feeling when they squish the bag. Is it the bag that feels squishy or is it something else?
			3. Have students consider how the bag changes shape when it's closed with air inside and then compressed. Once the bag is closed, we're not adding more air, so why does it bulge or get more firm when we compress it?
			• Accept all ideas at this point, but ensure students understand that the amount of air inside the bag is not changing.
			
			Accessibility Note: If you have students with sensory issues, do not encourage attempting to pop the bags. Students can squish the bags to feel the pressure caused by the air.

Phase	Time	Slide	Description
Experience	60 min.	5-7	4. Explain that when the bag is compressed, we add pressure to the bag. This increases the air pressure inside the bag. Because the air pressure is higher, more air molecules are colliding with the bag, which causes it to bulge. The bag pops when the pressure inside is greater than the strength of the bag. 5. Have students consider air that is not contained, such as outside. How would we know air is exerting pressure on an object? • Accept all ideas. 6. Tell students that we are going to perform an experiment to see if we can determine whether or not air is exerting pressure on an object. 7. Have students complete the experiments in Phases 1 and 2 on the handout *Pick A Paper*. • After completing Phase Two, students are asked to develop a model to explain why the system behaves the way it does when paper is used to cover the ruler. • It is ok if they have partial or incomplete ideas at this point. • While completing the experiments, students will usually identify that the paper is the key piece of the puzzle and will often begin tinkering with different ways to change the paper. ◦ This tinkering provides crucial evidence that helps students reach the correct conclusion, that surface area of the paper is at the root of the phenomenon. (See the misconception alert below.) ◦ Tinkering can either be allowed to flow naturally and informally, or can be structured by inviting students to change one aspect of the paper at a time. The provided activity does not include structured tinkering time. ▪ If structured investigation is desired, consider having each group investigate a different way to change the paper.

Phase	Time	Slide	Description
Experience (cont.)	60 min.	5-7	8. After students complete Phase Two, they should pause for class discussion. 9. Have students share their ideas about why the paper reduced movement of the ruler by using the prompt, "We think it has something to do with…" • Students will likely suggest air pressure or the surface area of the paper. • Since the "answer" is implied with the leadup to the experiment, ask students to explain their reasoning or provide evidence to support their claims. 10. If students suggest air pressure is involved, it is unlikely that they will be able to offer many supporting details at this point. Use these ideas as a springboard for the next part of the investigation. • Acknowledge that all students' ideas are valued and worthy of further exploration, but since many ideas involve the paper, that is the direction we will take the next step of our investigation. 11. Move to Phase 3 of the handout, in which students will repeat the experiment with a newspaper. Note that when the newspaper is spread out, it is much larger than the regular paper. Students may also note that the newspaper is a different texture and thickness. • If desired, you can have some groups investigate paper thickness as the primary factor in the phenomenon. • Students should notice that there is less movement of the ruler and paper when a newspaper is used. You can invite students to tap the ruler with their hand to feel the difference between the force on regular paper and newspaper. ◦ Pressing on the ruler slowly or very forcefully is the only way to move either type of paper. ◦ **Be advised** that a piece of newspaper can withstand enough force to break the ruler. You may consider having students use craft sticks or paint sticks instead of rulers, or encourage students to feel the effects of the paper types by tapping on the ruler instead of forcefully slapping.

Phase	Time	Slide	Description
Experience (cont.)	60 min.	5-7	**Misconception Alert:** The reason the ruler does not fall is not because of the weight of the paper itself. The force of the air pressure across the surface of the paper is what keeps the ruler on the desk. Students can discover this by repeating the experiment with the same piece of paper folded or crumpled. That is why allowing students to tinker with the setup of the system is recommended.

Label	10-15 min.	8-13	12. Review the idea of surface pressure with students.
			• Gravity pulls air in the atmosphere towards the surface. Every object has *all* of the air above it pressing down upon it.
			• Ask students to share their experiences or knowledge of different elevations.
			  ◦ Students may have experienced being on a mountain and finding it harder to breathe, or they may know that mountain climbers need to carry oxygen.
			  ◦ Students may be familiar with sports at different altitudes and how "thinner" air can affect a football, for example.
			  ◦ Students may know that a car's tires may change pressure after changing elevation.
			  ◦ Students may also recognize that sometimes their ears pop when changing elevation.
			  ◦ While we don't really feel less air pressing on us, we do notice some of the effects of more or less air around us.
			13. This is why we usually use sea level pressure, to account for how elevation affects air pressure.
			• Air pressure at sea level is 14.7 pounds per square inch.
			• Objects with more surface area will therefore experience more air pressure.
			• Air pressure is a downwards force, so the surface of an object that is pointed towards the sky will have the greatest air pressure exerted upon it.

Phase	Time	Slide	Description

Demonstrate	40 min.	14-16	14. On the handout *Under Pressure,* students will calculate the amount of air pressure exerted on the papers in the ruler experiment.
			• Students begin by reviewing what they already know and some of the evidence they have already collected.
			• They then brainstorm how to use math to compare the air pressure exerted on paper vs. newspaper.
			  ◦ Students should know how to calculate area, which is the same calculation for surface area of paper. See the misconception alert below.
			• Students will also determine what materials they need to complete this activity.
			  ◦ Students should recognize that they need a paper and newspaper, as well as a ruler and calculator.
			
			Teaching Tip: Because this is written as a "student designed" activity, it is not recommended to encourage students to have a specific answer to the questions in the "What do we know?" section. However, you can support students' success by having them discuss with another group before moving to the back of the handout. You can also check off their materials list and plan before they begin their investigation. If time allows, you can let students complete the entire handout before comparing answers and approaches with other groups, then refine their methods and try again.
			
			Misconception Alert: Surface area is not always calculated exactly like area. Normally it would include all surfaces of a 3D object. Since paper has a depth that is nearly impossible to measure and we are only concerned with the part that is facing up, we will use the exact same calculation as area. If the object were an irregular shape, the calculation would be a little more complicated.

Phase	Time	Slide	Description
Review	10 min.	17	15. On the handout *What I Know,* have students reflect on what they have learned so far.
Celebrate	1 min.	18	16. Celebrate every effort! High fives, team chants, have a treat, etc.

Module 2 Lesson 2.2 - 90 minutes

Phase	Time	Slide	Description
Enroll	3 min.	19-20	1. Bring student focus to the fact that the maps used before didn't use pounds per square inch (psi) to measure surface pressure. 2. Ask students what unit the maps did use? • All maps observed in this Module have used "mb" which stands for millibars 3. Have students consider why a different unit of measurement would be used for a large area of land. • Students should suggest that calculating the surface area of an entire state would be very difficult and result in a very large number. 4. Ask students if this creates any questions for them, and allow a few to share. • Some questions might be: what are millibars? How are millibars related to pounds per square inch? Are there other units used to measure surface pressure? What tool is used to measure surface pressure? Why does air pressure change if the size of the state doesn't change?

Phase	Time	Slide	Description
Enroll (cont.)	3 min.	20	**Teaching Tip:** If you receive the last question listed above, take a moment to have students explore what the results of the *Under Pressure* activity tells them. They didn't *measure* the pressure of the atmosphere. They *calculated* the equivalent *pounds* of pressure placed on the papers. To do this, they first had to *assume* that the pressure of the atmosphere was 14.7 psi. If we want to know the pressure of the atmosphere outside, we have to *measure* it. Before we can perform a calculation, we have to find out what number to plug into the equation: ***Area x air pressure = pounds of pressure*** In the activity, we already had the air pressure measurement. We calculated pounds of pressure, not pounds per square inch (psi).
Experience	45 min.	21-22	5. Students will use the internet to research other ways we measure air pressure. There are several units used to measure air pressure, and most of them are described online as the "standard" way of measuring air pressure. Students will see different units used in different scenarios, so it is important that they are able to recognize and understand all of them. 6. This activity works best as a jigsaw, with each group researching a different topic and then sharing their knowledge with the class. 7. Before researching, co-create a set of guidelines with students. • Some sample questions and considerations are listed. • A template for the class guidelines is included in the handout *Internet Safety*. 8. Have groups research the measurement units and tools listed in the slides. • Students will orally present their findings to the class. ◦ Oral presentations do not have to take place in front of the entire class. Consider having a round of presentations that occurs in smaller sections of the class. This can be less stressful for students, resulting in better sharing of information. For example:

Phase	Time	Slide	Description
Experience (cont.)	45 min.	21-22	◦ Groups 1, 2, and 3 present to each other. Groups 4, 5, 6 present to each other. ◦ One group from each presentation set pairs up to share the information from their presentation sets. For example, Group 1 pairs with Group 4. Group 1 shares information from Groups 1, 2, and 3 while Group 4 shares information from Groups 4, 5, and 6. **Teaching Tip:**Students are often more willing to abide by research boundaries and norms if they have some ownership of them being created. **Note:** AI can be a powerful tool to generate and summarize information that is then used or applied. It is becoming more important to help students navigate the ethics of using this type of tool and how to do so without plagiarizing. For example, AI pulls from many sources. The summary may include direct quotations from an article. Copy/pasting an AI generated paragraph may lead to direct plagiarism. AI will also sometimes create false sources. The information may be correct, but that does not mean the article listed really exists. A useful prompt for students using AI is, "Rewrite this text with a 6th grade reading level." A section of an article can then be copy and pasted into the AI tool for a version with less complex language. However, key terms or information may be removed so students should still view the AI as a tool to help them understand the content, not their primary source of research.
Demonstrate	30 min.	23	9. Students present the results of their research. 10. During presentations, other students should record relevant information. **Assessment Opportunity:** students should be describing tools and units appropriately in their presentations.

Phase	Time	Slide	Description
Review	10 min.	24	11. Return to the list of topics that students researched. Co-create definitions for each using input from students. 12. If skipping Lesson 2.3, include the Review section for 2.3 here.
Celebrate	1 min.	25	13. Celebrate every effort! High fives, team chants, have a treat, etc.

Module 2 Lesson 2.3 - 60 minutes (Optional Math Connection)

Phase	Time	Slide	Description
Enroll	5 min.	26-28	1. Review what students have learned about air pressure. 2. Have students consider how we can compare air pressure readings that are in different units of measurement.
Label	15-20 min.	29-31	3. Remind students of standard air pressure at sea level for each of the units we studied. 4. Explain that these are not completely different measurements, but rather different ways of representing the same amount, just like 12 inches and 1 foot. 5. We can use ratios to convert between the different units of measurement. • There are many different ways that unit conversion is taught in schools, but this curriculum recommends using the format shown in the slides if this is a new concept for students.

Phase	Time	Slide	Description
Label	15-20 min.	29-31	• Students often get confused by "rules" of math or tricks and shortcuts that don't allow them to reason about the math. However, allow students to use whichever method or "rule" makes the most sense to them. • The method presented here doesn't involve any memorization and offers the opportunity for reasoning skills. The only thing students will need to remember is that the units on both sides of the equal sign need to match. So if mb is in the numerator on one side, it should be in the numerator on the other side. If students forget this, they can use reasoning skills to figure it out. **Teaching Tip:** Solving for a variable may be an unfamiliar skill for students at this time. Try using a question mark or an empty box instead of a letter variable. Remind students to always include the units during their calculations. Units can help students make sense of the problems and evaluate the reasonableness of their answers.
Demonstrate	20 min.	32	6. Have students practice converting air pressure measurements on the handout *Careful Conversion*.
Review	10-15 min.	33	7. Have students return to the models they made in Lesson 1 on the handout *Weather Maps*. They should annotate their model using the key or prompt provided on the slide rather than erasing their previous work.
Celebrate	1 min.	34	8. Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 2 Lesson 3

Module Driving Question: Why is it so windy in Oklahoma?

Lesson 3 - Measuring Wind

Lesson Navigating Question: How is wind measured?

Grade Levels:
6-8

Time Required:
165-230 Minutes
3-5 Class periods

STEM Content Areas:
Science, Mathematics, Engineering

Overview

Students will create an instrument with which to collect wind data and place it in a location suitable for collecting that data. Students will compare the data they collected using their engineered instruments with that from standardized instruments. Students will also be introduced to two research scientists who work on improving weather data collection.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.ETS1.A –** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.
  - The more precisely a design task's criteria and constraints can be defined, the more likely it is that the design solution will be successful.
  - Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.
- **6.ETS1.B** - A solution needs to be tested and then modified on the basis of the test results in order to improve it.
- **7.ETS1.C** - The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Science and Engineering Practices

- **Asking Questions and Defining Problems** - Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
- **Engaging in Scientific Argument from Evidence** - Compare and critique arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
  - Respectfully provide and receive critiques about one's explanations and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
- **Analyzing and Interpreting Data** - Analyze and interpret data to determine similarities and differences in findings.
  - Analyze concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.
  - Consider limitations of data analysis (e.g., measurement error, sample selection) and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

Oklahoma Academic Standards (cont.)

- **Constructing Explanations and Designing Solutions** - Apply scientific ideas or principles to design, construct, and test a design of an object or tool.
  - Undertake a design project, engaging in the design cycle to construct and implement a solution that meets specific design criteria and constraints.
  - Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.

Crosscutting Concepts

- **Patterns** - Graphs, charts, and images can be used to identify patterns in data.
- **Scale, Proportion, and Quantity** - Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
  - Scientific relationships can be represented through the use of algebraic expressions and equations.

Mathematics Standards

- **6.N.3.2** - Determine the unit rate for ratios.
- **6.N.4.2** - Illustrate multiplication and division of fractions and decimals to show connections to fractions, whole number multiplication, and inverse relationships.
- **6.A.1.1** - Plot integer- and rational-valued (limited to halves and fourths) ordered-pairs as coordinates in all four quadrants and recognize the reflective relationships among coordinates that differ only by their signs.
- **6.D.1.2 –** Explain and justify which measure of center (mean, median, or mode) would provide the most descriptive information for a given set of data
- **7.GM.3.3** - Calculate the circumference and area of circles to solve problems in various contexts, in terms of pi (π) and using approximation for pi (π).

Learning Objectives

1. Engineer an instrument to measure wind speed and direction.
2. Collect and compare data from wind instruments.
3. Describe the effects that location may have on the data an instrument collects.

Vocabulary

- **Wind speed** - the measure of the force exerted by the wind and expressed as a rate
- **Wind direction** - describes the cardinal direction from which the wind is blowing
- **Anemometer** - a tool used to measure the force exerted by the wind; there are many types but a rotational anemometer is very recognizable.
- **Wind vane** - a tool used to determine wind direction
- **Windsock (also called wind cone or wind sleeve)** - a tool which can be used to determine wind speed and direction; often used at airports, ports, etc

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Materials

<u>To build the Wind Measurement Tool:</u>

- Straws
- Popsicle sticks
- Variety of cardboard materials (i.e. cereal boxes, empty roll tubes, etc)
- Glue sticks and/or hot glue
- Paperclips
- String or yarn
- Paper cups
- Other materials that students request or that seem helpful

<u>For Wind Data Collection:</u>

- Clipboards
- Stopwatches
- Tablets or devices with video recording capability
- Fans (for testing the tools inside)

<u>Student Handouts:</u>

- *Think Like a Meteorologist*
- *What I Know (Module 2, Lesson 3)*

Preparation

1. Determine if students will be collecting data outside or indoors.
2. Clear the placement of wind measurement tools outside of the school with your administration. It may be necessary to determine safe and accessible areas ahead of time for the students.
3. More information about weather measurement can be found at **Oklahoma Mesonet: Instruments**. They share detailed information about the tools used at their stations for collecting wind data across Oklahoma.

Module 2 Lesson 3 - 165-230 minutes

Phase	Time	Slide	Description
Enroll	15 min.	1-6	1. Review with the class what they have learned about the different components of weather. • In Lesson 1 we reviewed how temperature, wind, and humidity are related. • Review with students that Air pressure generates wind. • We know how air pressure is measured, now we want to know how wind is measured. 2. Have students discuss with a partner what they've learned about wind so far, as well as any experiences they've had with wind that help them understand something about it. 3. Ask students to share an idea they discussed that they think is the most important thing to know about wind. Allow each pair or group of students to name something and make a list on the board. 4. Facilitate class discussion to narrow the list down to 3 ideas that students believe are most important for understanding wind. • Ask students to justify their reasoning.

Phase	Time	Slide	Description
Enroll (cont.)	15 min.	1-6	**Teaching Tip:** This discussion should not be a simple vote. The purpose is to have students engage in scientific argument. They should be able to identify what statements are similar enough to be combined, any contradictory statements, and if they have collected enough evidence to support each statement. In narrowing the list, students should offer suggestions for how to refine the statements. Conversations should proceed respectfully and civilly.
Experience	10 min.	7-8	5. Ask students why we would want to measure wind. How does knowing about wind forecasts help us? • Accept all responses. 6. Present the video clip on slide 7. Ask students what they think the weather would feel like in the picture. • Ask if it would feel different if there was more or less wind. • Ask students how they would describe the wind in this video. • Now ask students if it would be safe to go hiking or other outdoor activities in this area. 7. Present the video on slide 8. Ask students how they would describe the wind in this video. • Ask students if they would want to do outdoor activities in this area. • Would it be safe to drive a car?
Label	10 min.	9-12	8. There are two components to wind data: direction and speed (or magnitude). Wind speed is provided as a rate; direction can be provided as a degree measure or a cardinal direction. 9. Discuss briefly the different kinds of tools for measuring wind: anemometers generally measure the force exerted by the wind (its speed) and wind vanes or windsocks are used to determine the direction of the wind.

Phase	Time	Slide	Description
Label (cont.)	10 min.	9-12	• We will discuss the math associated with anemometers later, but for now students need to understand that we will measure how far the arms of the anemometer move in a certain amount of time.
Experience	60-80 min.	13-14	10. Students will have the chance to act as engineers by designing an anemometer. 11. Using the handout *Think Like A Meteorologist*, students will use the engineering design process to develop a tool that incorporates both an anemometer and wind vane or wind sock. 12. If desired, have students select a role. The purpose of these roles is to simulate a career environment where people with different specialties collaborate on a project. This should not be thought of as, "the writer, the builder, the person that cleans up but does nothing else," etc. The idea is that each member of the team is responsible for the success of the project by utilizing their strengths and collaborating with each other. Real engineering projects aren't completed by a single person. It takes a team! 13. After students have built their devices, the class should pause for discussion about data collection. **Teaching Tip:** Consider evaluating each student based on how they performed in their role, rather than giving each member of the group the same grade based on the overall project. This can give students more ownership of and investment in their role, and is more realistic of a career environment. A sample rubric is included at the end of this guide. If the project takes more than one class period, have the Project Manager give you a daily update about their group's progress and their goals for the next day.

Phase	Time	Slide	Description
Label	15 min.	15-18	14. Discuss how to turn data from their anemometers into wind speed data. 15. Students will first need to calculate the circumference of their anemometer arms to know the distance each arm travels. 16. They will then need to time how long it takes one arm to complete a full revolution. • If the arms are spinning very quickly, it may be easier to count the number of revolutions in a certain amount of time, such as 30 sec. The math will be the same either way. ◦ If needed, prompt students to think about how they will know that one arm of their anemometer has completed a full revolution. Should one piece look different? 17. Discuss how to read wind direction. Wind direction is named as the direction the wind is blowing *from*, so a "south wind" blows from the south. **Misconception Alert:** It is tricky to name the direction of the wind correctly. Ensure that students take care when naming wind direction especially when they are using tools like windsocks, as the wind direction is the opposite of where the windsock is pointing.
Experience	20 min.	19	18. Have students take their device outside to measure wind speed and direction. Alternatively, use a fan indoors to test their devices. 19. If testing outdoors, have students record the time at which they took their measurements. This may help in identifying outliers in their data later (wind might vary). 20. While students are testing, evaluate the success criteria of: • easily portable • measures both wind speed and direction **Optional:** Have students place their measurement devices in a location that is not optimal and recollect data. Compare the data from each location. Have students construct an explanation for how objects like buildings and trees can obstruct wind.

Phase	Time	Slide	Description
Demonstrate	15-20 min.	20	21. Have students share their wind speed and direction data. 22. Construct a scatter plot or other type of graph to compare data. You can have students place their data on the graph with a dot sticker. 23. Analyze the data for outliers. Ask students if they see any data points that don't match the rest of the class. 24. Discuss reasons for any data that is considered an outlier. 25. Have students calculate the mean wind speed and mode wind direction. • Discuss why mean and mode are the most appropriate measures of central tendency in this case. ◦ Mean - the class's wind speed data represents multiple tests or samples taken at the same time, so we would want the average of all data ◦ Mode - words can't be averaged, so we will take the most common result 26. If you have a digital anemometer, compare students' data to the actual wind speed and direction and assess for accuracy.
Review	20-60 min.	21 - 24	27. Introduce students to Drs. Segalés and Bell. Both have careers that are not what students might typically think of when they think of meteorology. • Their work demonstrates how meteorology integrates STEM components like math, technology, and engineering. • Their work also shows how meteorology can be a good career for those that enjoy building, tinkering, travel, aviation, and working outdoors. 28. This is a good time to remind students that understanding more about wind can help us develop better technology that saves lives. 29. Have students reflect on their learning using the *What I Know* handout.
Celebrate	1 min.	25	Celebrate every effort! High fives, team chants, have a treat, etc.

Think Like A Meteorologist Rubric

The design of the rubric for this activity is called a single-point rubric, where the only description given is for what meets expectations. Feedback is then added for students who exceed expectations or have room for improvement. Separate rubrics are provided for each job description.

Suggestions for assigning scores

Weighted Percentages

- Assign scores for the device, the student handout, and individual job descriptions.
- The rubrics included for job descriptions are scored based on behavior during the activity.
- Each group member receives the same score for the device and handout, but individual scores for their job descriptions.

Standards-Based Grading

- The "Meets Expectations" category is considered the minimum acceptable score.
- Students that achieve Meets Expectations have met the standard.
- Translating these scores to an A-F scale would mean that Meets Expectations would be a B or C, with Exceeds Expectations scoring above that and Room For Improvement scoring below.

Straight Points

- Like a more traditional rubric, the three scoring categories are assigned point values.
- Meets Expectations would be full credit.
- Exceeds Expectations would be extra credit.
- Room For Improvement would be partial or no credit.

Think Like A Meteorologist Rubric

Criteria	Room For Improvement	Meets Expectations	Exceeds Expectations
Project Manager:			
Success of Project		Project overall is successful and meets all requirements.	
Leadership		Project is completed on time, with all deadlines met. Team roles and assignments are managed effectively. Interacts with team members respectfully.	
Communication		Student communicates appropriate information with the teacher. Updates and questions are communicated effectively and timely.	
Collaboration		Team members work together effectively. Manages workload fairly across team members.	

Think Like A Meteorologist Rubric

Criteria	Room For Improvement	Meets Expectations	Exceeds Expectations
Resource Manager:			
Resources		All resources are accounted for and in good condition (including paperwork and construction materials).	
Progress		Construction progress is updated in project documents in a timely manner. All project documents are complete.	
Documentation		Project documents include a detailed and thorough account of work completed at all steps of the design process.	
Professionalism		Project documents are neat and orderly. Documents are presented in a professional manner and reflect the work of all team members.	

Think Like A Meteorologist Rubric

Criteria	Room For Improvement	Meets Expectations	Exceeds Expectations
Lead Engineer:			
Construction Plan		Construction plan is complete and detailed. Plan could easily be replicated by another group to produce the same design.	
Design Goals / Success Criteria		Success criteria and constraints are thoroughly described and reflect thoughtful application of engineering principles.	
Leadership		Effectively leads team members through the construction process.	
Product		Final construction meets design goals. Construction is completed timely and successfully.	

Think Like A Meteorologist Rubric

Criteria	Room For Improvement	Meets Expectations	Exceeds Expectations
Quality Analyst:			
Effectiveness of Design		Design is effective and works as expected. Data collection method is planned in advance and is appropriate for the situation.	
Accuracy		Device is able to collect accurate data that closely matches with that of other groups.	
Data Analysis		Data analysis is complete and calculations are correct. Data is displayed or communicated in an appropriate manner.	
Collaboration		Effectively manages teamwork during data collection and analysis. Effectively works with team members to ensure mutual understanding of goals and data analysis.	

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 2 Lesson 4

Module Driving Question: Why is it so windy in Oklahoma?

Lesson 4 - Global Wind Patterns

Lesson Navigating Question: Is wind the same everywere?

Grade Levels:
6-8

Time Required:
100 - 130 Minutes
2-3 Class periods

STEM Content Areas:
Science

Overview

Students investigate patterns of prevailing winds and jet streams by conducting small-scale experiments in order to determine the cause of global wind patterns. Students discover that the movement of prevailing winds is determined by a combination of the Coriolis Effect, convection, and air pressure.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.ESS2.5** - Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions..
  - The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- **6.ESS2.6** - Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Science and Engineering Practices

- **Asking Questions and Defining Problems** - Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- **Planning and Carrying Out Investigations** - Collect data to serve as the basis for evidence to answer scientific questions.
- **Constructing Explanations and Designing Solutions** - Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

Crosscutting Concepts

- **Patterns** - Graphs, charts, and images can be used to identify patterns in data.
  - Patterns can be used to identify cause and effect relationships.
- **Cause and Effect -** Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- **Systems and System Models** - Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

Learning Objectives

1. Identify global patterns of air movement.
2. Conduct investigations to determine the cause of global patterns of air movement.
3. Make a claim based on evidence about why some prevailing winds blow from east to west and some blow from west to east.
4. Construct a model that explains the role that air pressure, temperature, and Earth's rotation play in global wind patterns.

Vocabulary

- **Prevailing winds** - winds that blow consistently in a certain direction over large regions
- **Trade winds** - blow from east to west near the equator
- **Westerlies** - blow from west to east at higher latitudes
- **Jet Stream -** narrow, fast moving bands of wind that occur higher in the atmosphere (around 30,000 ft) at boundaries between warm and cool air
- **Coriolis Effect** - force that causes air masses moving over Earth's surface to curve instead of moving in a straight line

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Materials

<u>Earth and its Wind:</u>

- Access to computers or other internet devices

Materials (cont.)

Where the Wind Blows:

Earth's Rotation Activity (groups of 2-4 students)

- Lazy susan or turntable
- Pie plate (foil works fine) or bowl
- Water
- Food coloring
- Puppy pads (optional)

Prevailing Winds Activity (groups of 2-3 students)

- Balloon
- Permanent markers (at least 2 different colors)
- Balloon stick (optional)

Miscellaneous:

- Colored pencils, markers, or highlighters
- Sticky notes

Student Handouts:

- *Earth and its Wind*
- *Where the Wind Blows*

Preparation

1. Determine if students will research additional videos for *Earth and its Wind* on their own or if you will show videos as a class.
   - If students will be doing their own investigation, ensure they have devices with internet and can access the **Plymouth State Weather Center: Archived Satellite Images and Loops** webpage.
   - If you will show videos as a class, pre-select a few videos that include both Atlantic and Pacific locations, as well as a few different times throughout the year.
2. Obtain pitchers of water for *Where the Wind Blows* and designate an area for students to dump their used water.
   - Place puppy pads on student work surfaces to reduce cleanup from spills.
   - Test your pie plates or bowls ahead of time to make sure they work well with the turntables so that students can see water movement.

Module 2 Lesson 4 - 100-130 minutes

Phase	Time	Slide	Description
Enroll	10 min.	1-4	1. Show the GIF of clouds moving across the U.S. and Atlantic Ocean. Note the timestamp in the upper right corner, indicating that the time-lapse is about 48 hours. Remind students that the movement of clouds is evidence of wind. 2. Allow the GIF to play for a couple minutes while students record what they notice about the cloud movement using the handout *Earth and its Wind*. If needed, prompt students to look at different areas of the map. 3. Have students turn and talk to compare observations. • Ask groups to share something they noticed, and record their observations on the board. • Accept all responses until no new noticings emerge. • Key observations to look for: ◦ *A line of clouds forms along the east coast* ◦ *Clouds move over most of the U.S. from west to east* ◦ *Circular motion occurs over the Atlantic* ◦ *Some clouds seem to move fast and some seem to move slow* ◦ *Less clouds are present over Central and South America (closer to the equator)* ◦ *Some clouds (especially around Central and South America) move east to west* 4. As a think-pair-share, ask students to list some questions or wonderings they have about the cloud movement GIF. • Key questions to look for: ◦ *Do the clouds always follow the same pattern?* ◦ *Why don't they all move in the same direction?* ◦ *Why are some bigger than others?*

Phase	Time	Slide	Description
Experience	20-25 min.	5-6	5. Give students time to process their ideas and come up with suggestions of other things to investigate. 6. Have students either investigate on their own or share their ideas with the class to investigate together. 7. Using the **Plymouth State Weather Center: Archived Satellite Images and Loops** webpage, you can see similar GIFs of other regions, dates, times, etc. • Clouds don't move in the same direction everywhere, so students should view both the Atlantic and Pacific, and multiple days in order to determine patterns. • **This page*** offers zoomed in images of the current date. • **This page*** offers a global map of the current date. 8. After students have collected more information about global wind patterns, have them construct an initial model to explain why they think those patterns exist. **Note that these links include copyrighted images and are therefore not published for view in this curriculum. User discretion is advised.*
Label	10-15 min.	7-10	9. Winds tend to follow the same major patterns across the globe. These are called prevailing winds. • **CLEAN: Earth - An animated map of global wind and weather** has an animation of current global wind. It can be helpful in showing prevailing winds and sometimes the jet stream, but it does depend on current conditions. 10. Wind also occurs higher in the atmosphere, called jet streams. Oklahoma is right in the path of the major jet stream in the U.S. • While airplanes often fly in jet streams, that is not how they received their name. "Jet stream" is a translation from the name given to them by a German scientist.

Phase	Time	Slide	Description
Label (cont.)	10-15 min.	7-10	11. Students should be familiar with convection by now, but this is a good time to help them put the pieces together. The sun heats the air at the equator, which then rises and cools before it falls back to the surface. These large convection currents are responsible for warm and cool air masses and for global wind patterns. • Hadley cell is the name for the convection currents that occur near the equator. • Remember that L and H on weather maps indicate low and high pressure, not temperature. • Low pressure is associated with higher temperatures and high pressure is associated with lower temperatures (because of the density of the air).
Demonstrate	40-60 min.	11	12. Students will investigate how the rotation of the earth affects global wind patterns. The handout *Where the Wind Blows* includes two activities to help students make sense of this relationship. 13. Students will place a bowl or pie plate of water on a turntable and spin the turntable. They will then drop food coloring into the water and observe what happens. • Students should notice that the water in the center of the bowl does not move as fast as the water on the edge of the bowl. • They should also notice that the water swirls in the direction the bowl is spinning. 14. Have students stop the turntable and observe what happens. • Students should notice that the water continues to spin even though the bowl is no longer moving. 15. This demonstrates how the rotation of the earth causes air in the atmosphere to rotate as well. However, the atmosphere and the surface are separate entities and therefore do not move exactly the same. 16. The second activity demonstrates why some prevailing winds move east-west and some move west-east.

Phase	Time	Slide	Description
Demonstrate (cont.)	40-60 min.	11	17. Students will use a balloon to simulate rotation of the earth. • As they use the marker to draw a line up towards the pole, they should notice that the line curves towards the east. • As they draw a line down towards the equator, they should notice that the line curves to the west. • Students should identify that the rotation is what causes the lines to curve. 18. Students should be able to explain that this activity provides evidence that the rotation of the earth, combined with convection current patterns, causes the east-west and west-east patterns we see in prevailing winds. **Teacher Tip:** If students struggle with spinning the balloon in the second activity, try using balloon stick holders. Alternatively, you can use a foam ball on a stick.
Label	5 min.	12	19. Explain the Coriolis Effect. • It is most noticeable on large scales, such as with prevailing winds and hurricanes. • Hurricanes rotate counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. This is because the center of a hurricane creates a low pressure area. Students will learn more about this in a later module. • For more information about the Coriolis Effect, visit **SciJinks: What is the Coriolis Effect?** **Misconception alert:** There is a popular misconception that the Coriolis Effect causes water to drain down a toilet or sink in opposite directions in the Northern and Southern hemispheres, but this is not caused by the rotation of the Earth. The force related to the Coriolis Effect is only noticeable on very large scales. Any directional differences in draining between the hemispheres is a difference only in plumbing or design.

Phase	Time	Slide	Description
Review	15 min.	13	20. Have students return to the initial model they made on the handout *Earth and Its Wind*. Ask students to revise their initial models using the color key on slide 13. They should not erase anything they previously wrote. Being able to read our initial thoughts lets us see what we've learned and helps spark new ideas. • These revisions can be done by adding colored sticky notes or by using highlighters, markers, or colored pens/pencils. 21. **Crash Course Geography: Where Does Wind Come From?** is a good summary of some of the concepts that students have learned so far
Celebrate	1 min.	14	Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

Teacher Guide: Module 2 Lesson 5

Module Driving Question: Why is it so windy in Oklahoma?

Lesson 5 - Living with the Wind

Lesson Navigating Question: What else affects how windy it is where I live?

Grade Levels:
6-8

Time Required:
190 Minutes
3-4 Class periods

STEM Content Areas:
Science

Overview

Students will examine wind phenomena and design an investigation to explore how surface land features can influence local wind patterns.

Oklahoma Academic Standards

Science Standards

Disciplinary Core Ideas

- **6.ESS2.5** - Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions..
  - The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- **6.ESS2.6** - Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Science and Engineering Practices

- **Planning and Carrying Out Investigations** - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- **Analyzing and Interpreting Data** - Consider limitations of data analysis (e.g., measurement error, sample selection) and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- **Constructing Explanations and Designing Solutions** - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) that describe the natural world.
- **Engaging in Scientific Argument from Evidence** - Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
  - Construct, use and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.

Oklahoma Academic Standards (cont.)

Crosscutting Concepts

- **Cause and Effect –** Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
- **Scale, Proportion, and Quantity** - Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- **Systems and System Models** - Models can be used to represent systems and their interactions - such as inputs, processes, and outputs - and energy, matter, and information flows within the systems.

Learning Objectives

1. Plan and conduct an investigation to explore how wind is affected by different types of land formations or environments.
2. Identify independent and dependent variables and constants.
3. Construct a scientific argument based on evidence collected during an investigation.
4. Develop a model that explains how multiple complex factors combine to create the wind environment experienced in Oklahoma.

Vocabulary

- **Windward –** towards the wind
- **Leeward** - away from the wind
- **Turbulence** - chaotic and unpredictable swirls of air
- **Friction** - resistance that one object encounters when moving over another
- **Rotor Clouds** - turbulent clouds that form on the leeward side of a mountain range where high-speed winds pass over the mountain

Materials

- Aluminum foil
- Paper
- Small cardboard boxes
- Wooden blocks
- Small fans
- Sticky notes
- Cardboard tubes
- Cardstock
- Tape
- Plastic bottles
- Digital anemometer

Student Handouts:

- *Wind at the Surface*
- *Putting the Pieces Together*

Preparation

1. Collect a variety of materials that students can use to design their wind experiment.
2. If using plastic bottles, partially fill the bottles with water or sand to make them heavy enough not to blow over.
3. If you are short on time, divide the types of environments between groups so that each group tests one environment type.
   - Be sure to discuss variables and constants as a class so that experiments are similar enough to share results.

Module 2 Lesson 5 - 190 minutes

Phase	Time	Slide	Description
Enroll	10 min.	1-4	1. Show the image loop of clouds moving from the Pacific Ocean towards the U.S. Ask students what they notice about the clouds' movement when they hit land.

Phase	Time	Slide	Description

Enroll (cont.)	10 min.	1-4	• Students should notice that the clouds appear to slow down and change direction.
			• Ask students what they think might be the cause.
			  ◦ If necessary, suggest that there could be something on the land that is altering the wind.
			2. Show students pictures of different types of land formations and land cover and ask which they think would experience the strongest winds.
			• Students may be unsure about grasslands and mountains, but should identify that a forest would have the weakest wind.
			  ◦ Both grasslands and mountains can experience very high wind speeds.

Experience	100 min.	5	3. On the handout *Wind at the Surface*, students will simulate different environments and measure the wind speed in each to determine how local land formations can impact wind. • A digital anemometer will give the most accurate results, but students could also use the anemometers they previously created in this module. 4. Students will create three different environments - mountains, grasslands, and forests. • Provide students with a variety of materials to replicate the different environments. Here are a few suggestions: ◦ Crumpled foil or paper to replicate mountains. The materials should be shaped to represent large mountain tops and valleys. This works best with multiple mountain peaks so that students can measure the difference between wind at the top of a mountain, behind it, and in valleys. This can be done by shaping a mountain range out of foil or cardstock, or piling crumpled paper and other items together.

Phase	Time	Slide	Description
Experience (cont.)	100 min.	5	◦ Replicate grasslands by creating a "field" of sticky notes. Stick the note to the table and then fold it so the note is standing upwards. ◦ Replicate forests by arranging tall items close together, such as cardboard tubes, water bottles, wooden blocks, or small boxes. ▪ Make sure the grasslands are shorter than the forests. • Students will then use a small fan or hair dryer to produce wind over their simulated environments. They will measure wind speed behind the objects and compare. ◦ Be sure the objects are secured to the table or are heavy enough not to be blown over. 5. After students conduct their experiments, have groups share their conclusions with the class. Ask for groups to share any evidence they collected that confirms or refutes their classmates' conclusions. • Depending on how students design their tests, they may conclude: ◦ *Grasslands have high wind speeds.* ◦ *Short grass has higher wind speeds than tall grass.* ◦ *Mountain tops and valleys have high wind speeds.* ◦ *Forests have low wind speeds.* ◦ *Wind speed above a forest is higher than at the surface.* **Misconception Alert:** Both mountains and grasslands can experience high wind speeds, but it depends on where you are at in the mountains. The peaks and mountain passes generally have very high winds, but the arrangement of surrounding mountains can block the wind. The same is true for valleys. Valleys are often sheltered from wind, but can experience strong winds depending on topography. The goal of this investigation is for students to identify that something in the path of the wind will alter the speed. They do not need to have consensus on whether mountains or grasslands have higher wind speeds. They should, however, agree that forests have the lowest wind speeds.

Phase	Time	Slide	Description
Label	10 min.	6-9	6. Students will have observed in their experiments that different landscapes can affect how wind flows. 7. When wind moves over a mountain, it is forced upward. The Leeward side of the mountain can experience very unpredictable wind patterns and turbulence. 8. Forests also create turbulence as wind encounters the trees and flow is interrupted. 9. Grasslands like in Oklahoma have little to impede wind movement. • As wind moves over any surface, there is friction between the surface and the wind. The more friction at the surface (more stuff in the way), the more the wind will be altered. • Grasslands provide very little friction and can therefore experience high speed winds.
Demonstrate	25 min.	10-11	10. At this point, students should have enough information to answer the driving question, "Why is it so windy in Oklahoma?" 11. Have students complete the model on the handout *Putting the Pieces Together*. They should be able to incorporate all of the concepts they have learned throughout the module. **Assessment Opportunity:** This final model is a great summative assessment that can be used to replace a traditional test. Students should identify that Oklahoma is largely grasslands, is in the middle of high and low pressures from the Rocky Mountains and Gulf of Mexico, and is influenced by trade winds and the Jet Stream

Phase	Time	Slide	Description
Review	45 min.	12-19	12. Now that students can explain why Oklahoma is more windy than other places, ask why it is important to learn about wind. 13. Remind students that wind data can help us better understand other weather conditions, improving our forecasting abilities and keeping people safe. 14. Wind can produce some pretty wild phenomena! 15. Wind is important for pilots to understand so they can avoid unsafe turbulence. Wind and air pressure can even cause their altimeter to stop working correctly. 16. Wind can increase the risk of wildfires. Fires even create their own wind that can cause small tornadoes made of fire. 17. Severe wind is very hard to predict, which is why it is important for researchers to continue learning more about it. 18. Explore the radar readings with students. **NSSL NOAA: Realtime CAM Data** shows data for the current day. • First show students the Synoptic map at 2-m Temperature. You can slide the bar at the top to different temperatures. Ask students what they notice. • Next show students the Synoptic map at 250mb (altitude) Upper Air. How is it different? • You can show students the Synoptic maps at other altitudes as well. • Ask students why it would be important to have data at different altitudes? Here is additional information that may provide helpful context: ◦ 2-m is about 6.5 feet ◦ The jet stream is at about 300mb, or 30,000 feet ◦ The top of the lower atmosphere is at about 700mb, or 9,000 feet ◦ Clouds typically form at less than 45,000 feet, but can extend much higher 19. Students will learn more about clouds and storms in future modules, so it is ok if they have more questions at this point.
Celebrate	1 min.	20	Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 2: WIND

Driving Question: Why is it so windy in Oklahoma?

RFH
OKLAHOMA!

WHY DO WE EXPECT IT TO BE WINDY IN OKLAHOMA?

What do you know about Oklahoma and wind?

What makes Oklahoma different from areas that aren’t as windy?

Let’s make a list of our initial ideas.

WHAT MAKES WIND?

LESSON 1

LESSON 1 - ENROLL

How do you know if it's windy outside?

What would you look for?

What would you expect to see?

LESSON 1 - ENROLL

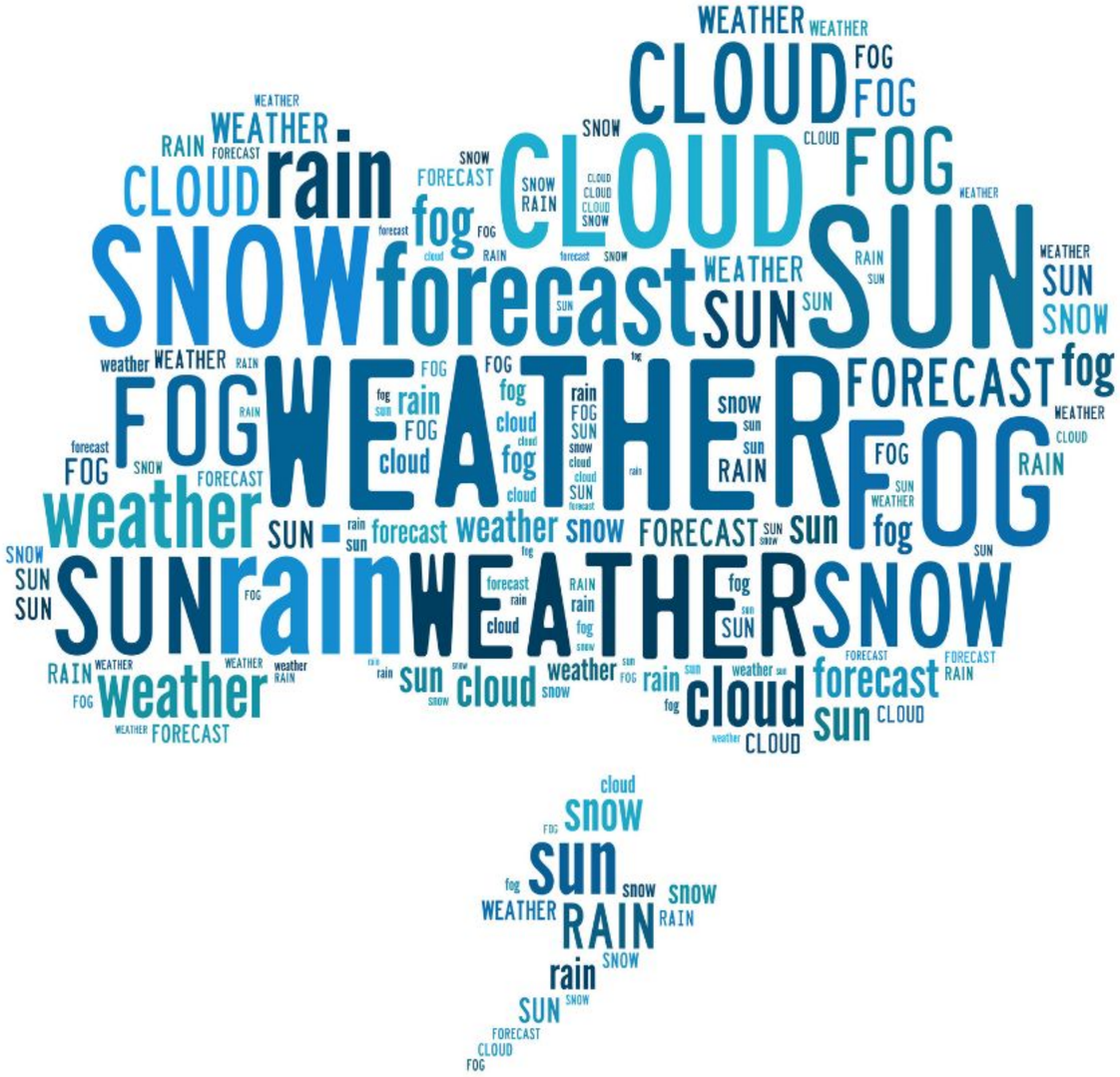
What happens to an object in the wind?

Let’s find out! Use your *Birds of a Feather* handout.

LESSON 1 - ENROLL

We created wind using a fan, but where does real wind come from?

Use the “Let’s Brainstorm” section of your handout.


WEATHER
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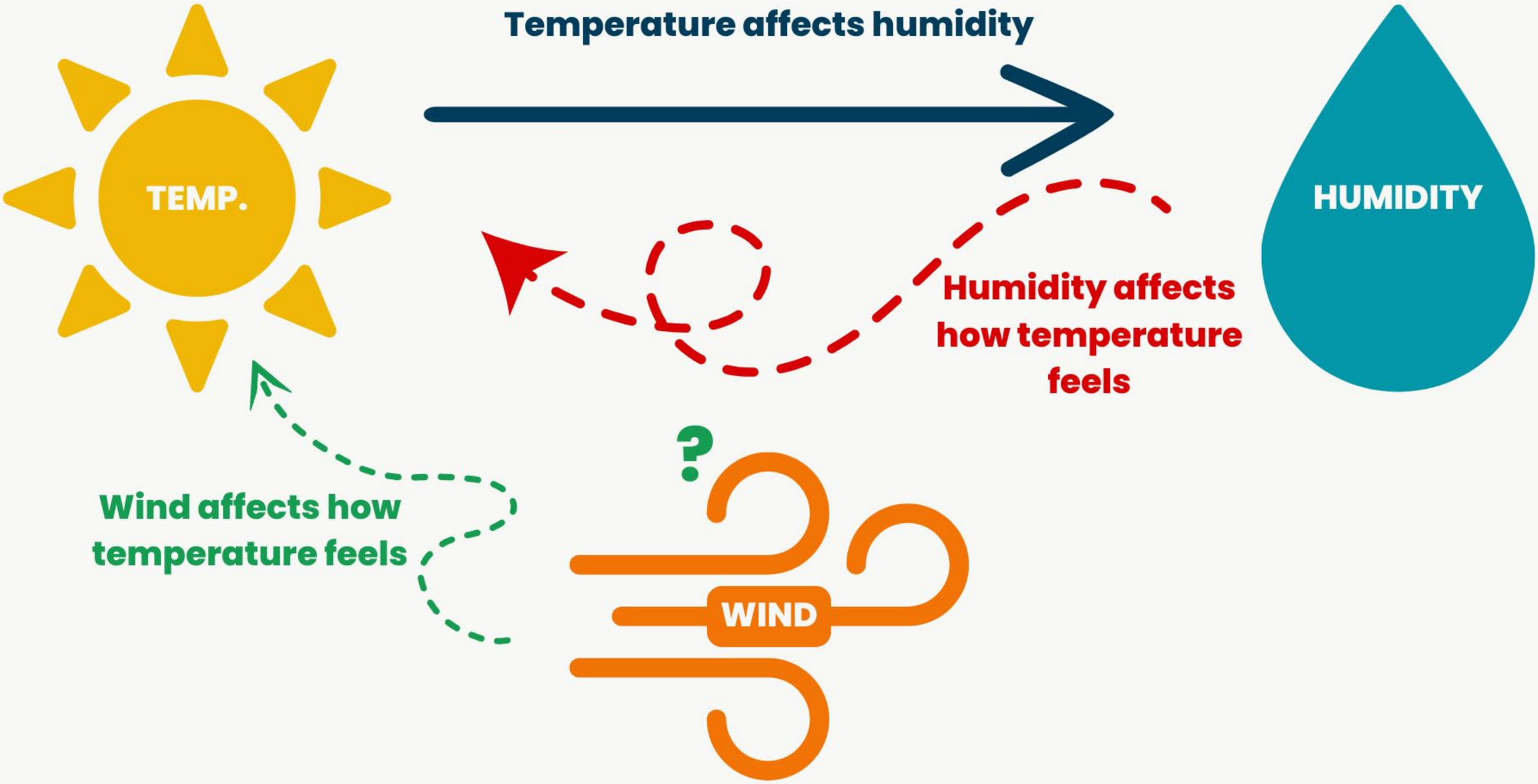
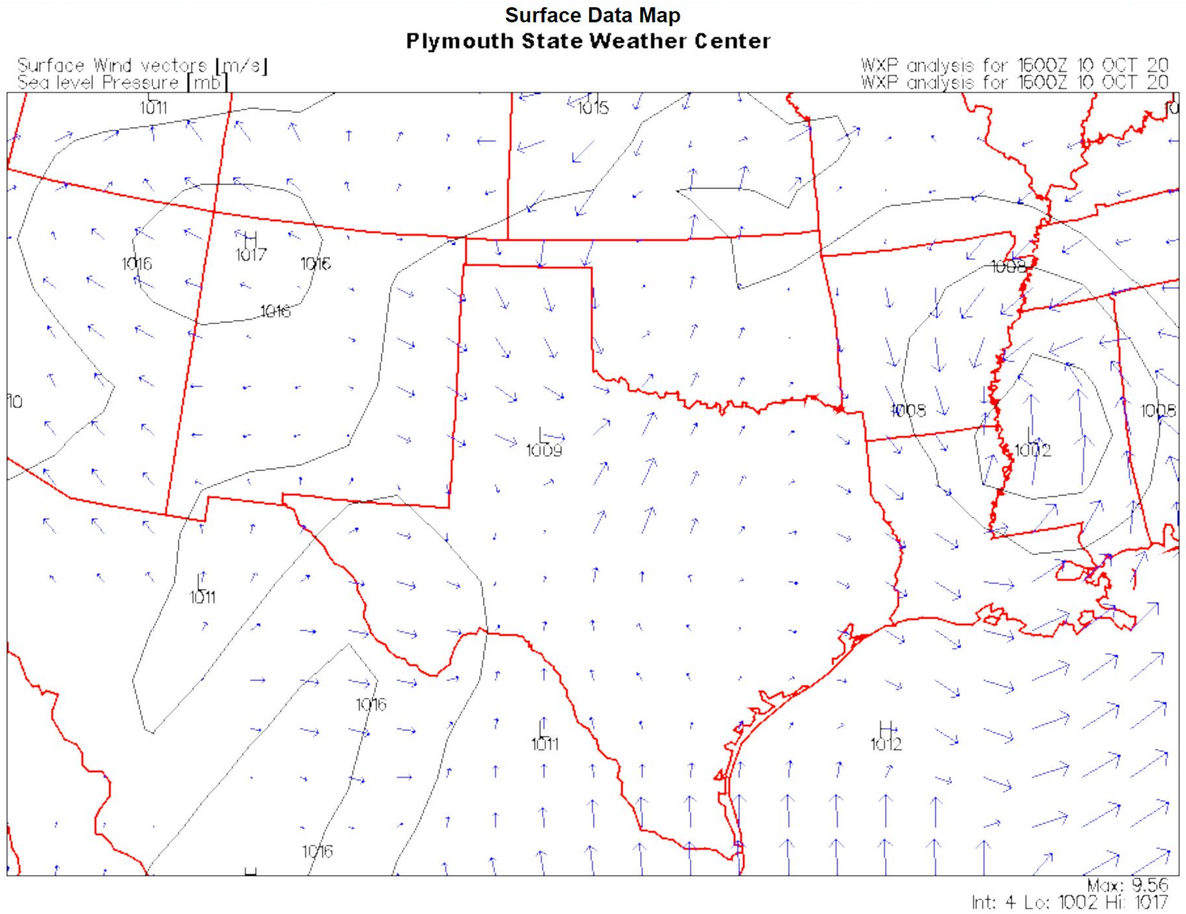

Temperature affects humidity
TEMP.
HUMIDITY
Humidity affects how temperature feels
Wind affects how temperature feels
?
WIND



LESSON 1 - EXPERIENCE

What do you notice about this map?

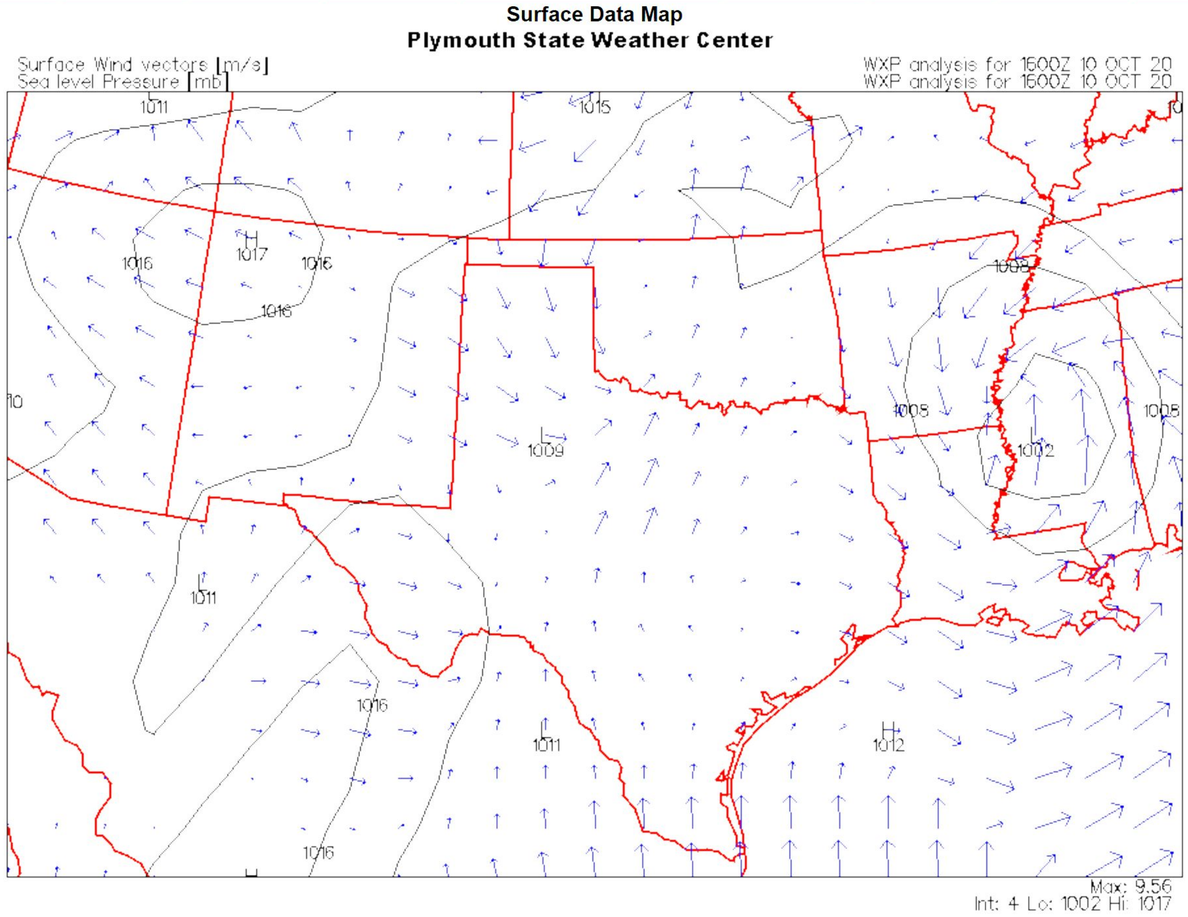
What do you think the numbers and symbols mean?

LESSON 1 - LABEL

Surface Pressure (AKA Air Pressure) is the pressure exerted by the atmosphere due to gravity at any given location on Earth's surface.

This is often measured as **Sea Level Pressure**, which is the air pressure at sea level.

Why would we use sea level pressure for areas that aren't at sea level (like on a mountain)?



LESSON 1 - LABEL

Isobars are lines that connect areas of equal surface pressure

- These areas are often label as High (H) or Low (L)
- High and Low pressure are relative - air pressure is considered “low” if it is lower than the other pressure zones near it.

LESSON 1 - LABEL

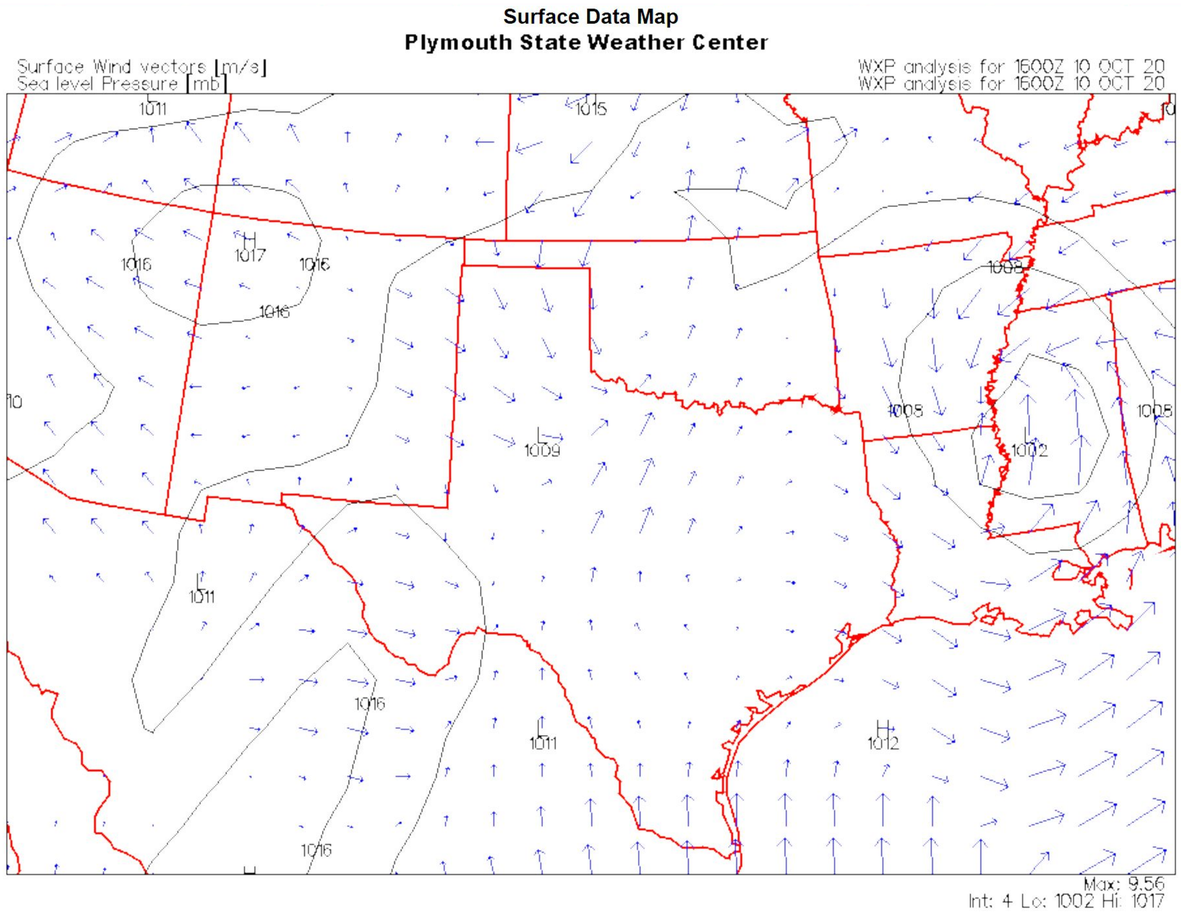
Remember when we learned about cold fronts and warm fronts?

- A front is the boundary or leading edge of a pressure system, or large mass of air.
- High pressure systems are associated with cooler air and low pressure systems are associated with warmer air.

LESSON 1 - LABEL

Wind is air in motion relative to the Earth's surface.

But what causes air to move?



LESSON 1 - EXPERIENCE

Let’s take another look at this map.

What patterns do you notice?

LESSON 1 – LABEL

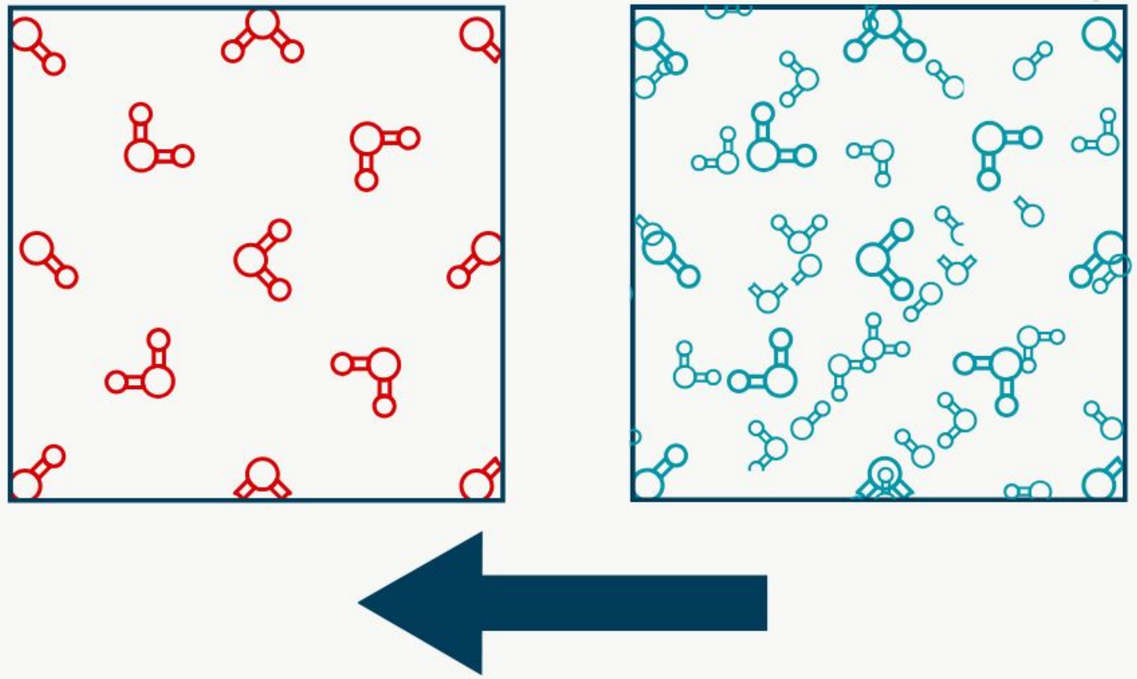
Wind is created by differences in **surface pressure** called a *pressure gradient*.

- High air pressure means the air molecules are closer together.
- Air molecules are moving very quickly and will move into areas with more available space (lower pressure).
- We feel this movement as wind.

LESSON 1 – LABEL

What do you remember about warmer air and cooler air?

- Warmer air is **less dense** and cooler air is **more dense**.
- How do you think this relates to air pressure?



MEET A PROFESSIONAL

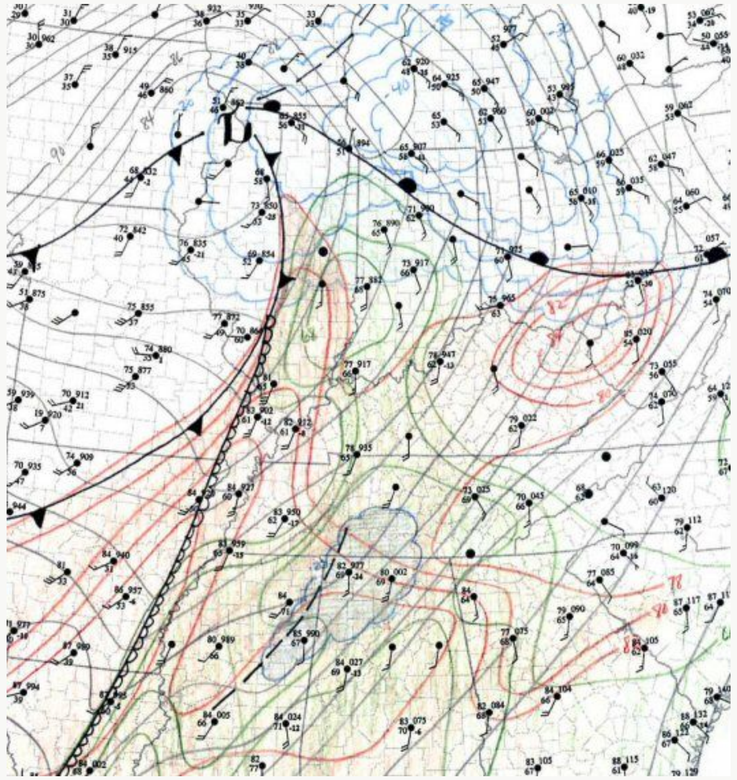
Liz Leitman
Storm Prediction Center -
Norman, OK

LESSON 1 - LABEL

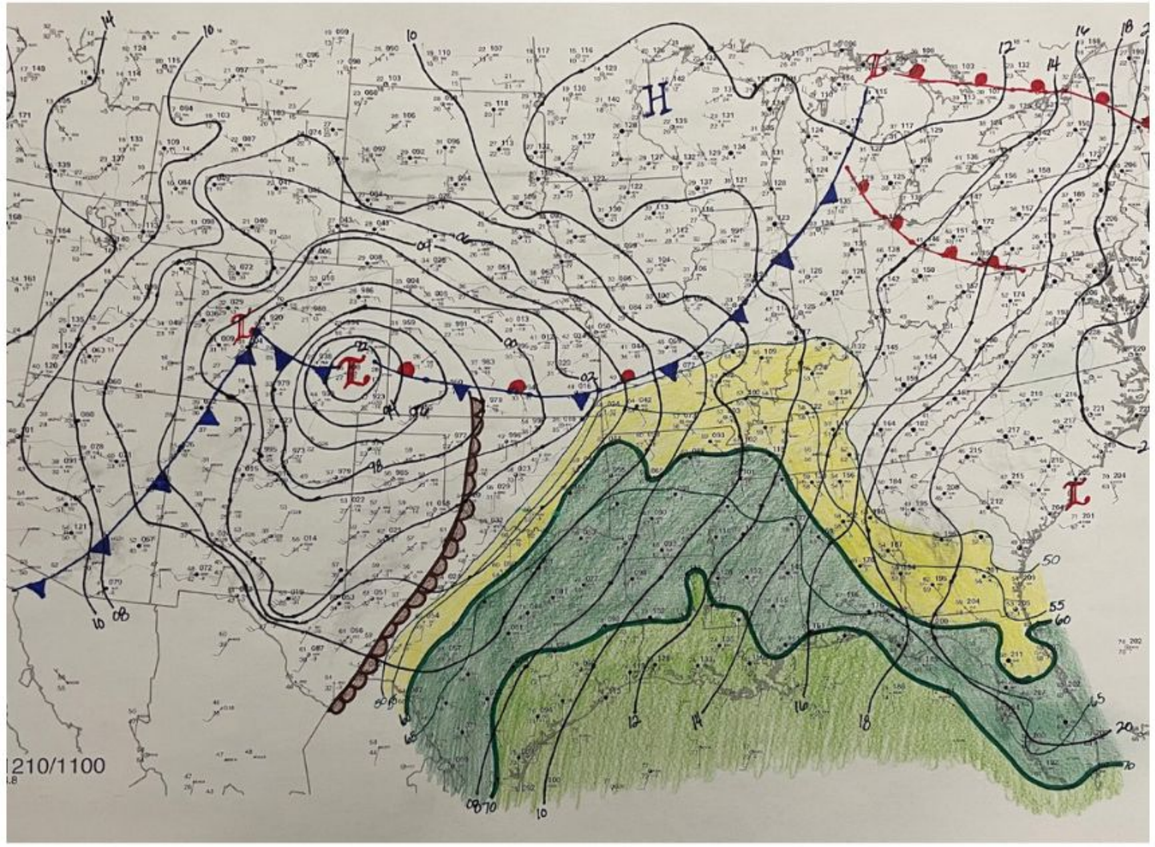
Did you know that meteorologists make hand drawn maps of wind and surface pressure?

These hand drawn maps are considered the most accurate way to understand local weather conditions.

Meteorologists like Liz draw these maps many times per day.



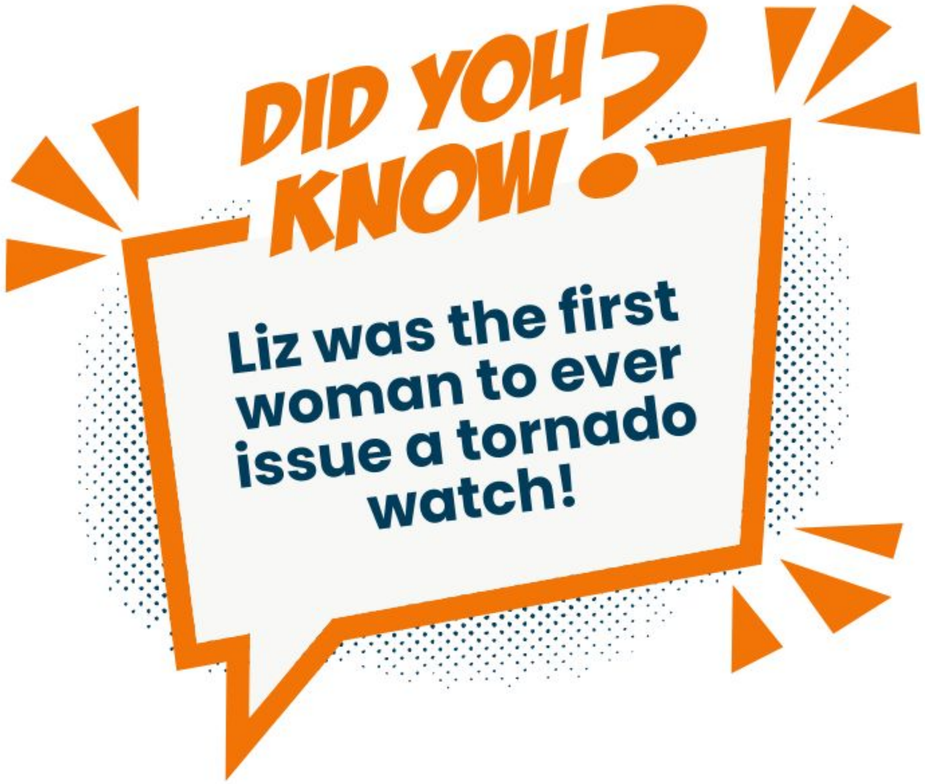
A HAND-DRAWN SURFACE ANALYSIS MAP BY METEOROLOGIST LIZ LEITMAN AT THE STORM PREDICTION CENTER IN NORMAN, OK.



LIZ LEITMAN BECOMES FIRST WOMAN TO ISSUE A THUNDERSTORM WATCH.

Watch this interview with Liz about her historic prediction in 2023 and the future of women in meteorology.

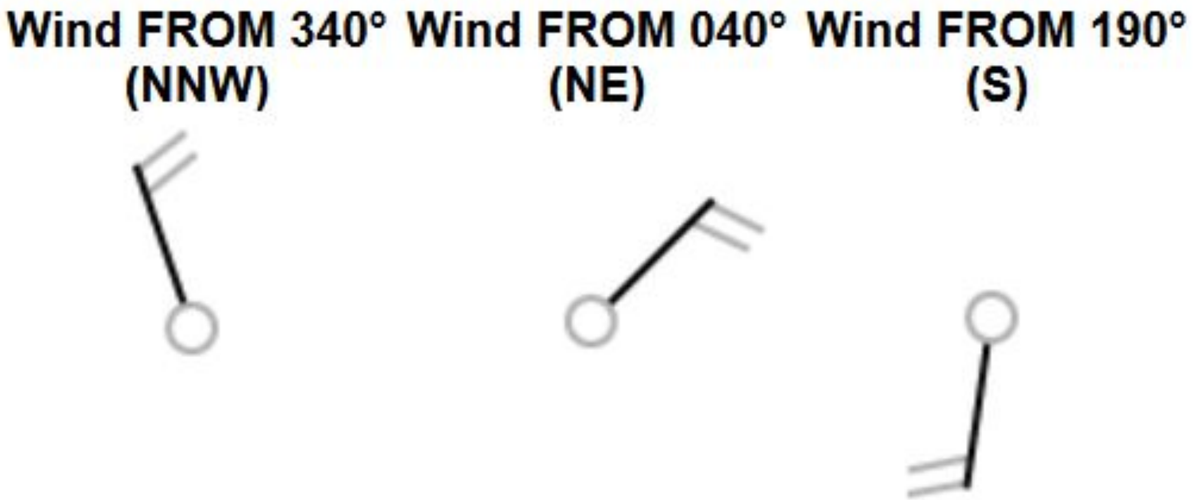
You can read additional interviews with her from KOSU News and the National Weather Service.

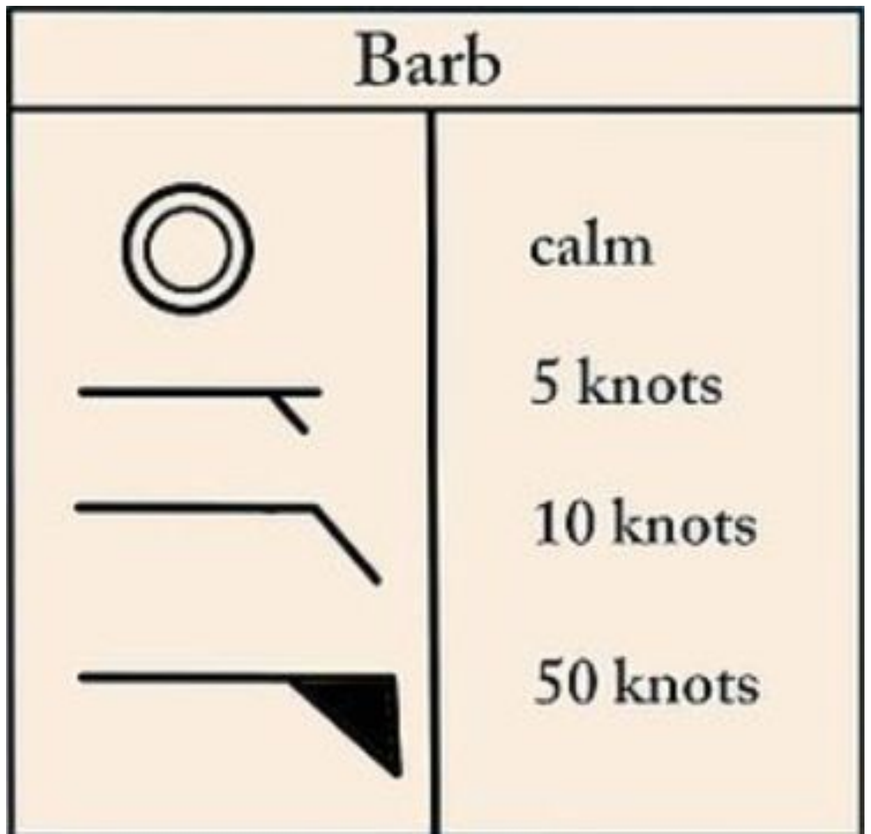


LESSON 1 – DEMONSTRATE

You've learned a lot about what causes wind. Now let's put your skills to the test as you think like a meteorologist and make your own surface analysis maps. Use the *Think Like a Meteorologist* handout.

This skill takes years of experience to master, so don't worry if your predictions aren't exactly right. With enough practice, you can become as talented as Liz!





LESSON 1 – LABEL

You may have noticed that Liz's hand drawn surface analysis map didn't have any arrows.

Meteorologists use symbols called **wind barbs** to note wind direction and speed.

LESSON 1 – DEMONSTRATE

Let’s take another look at some surface maps. This time the maps have isobars and wind barbs. Can you interpret the direction of the wind? Refer to the *Where the Wind Blows* handout for guidance.

LESSON 1 - REVIEW

Let’s review what you’ve learned so far.

Use your *Module 2 - What I Know* handout.

LESSON 1 - CELEBRATE

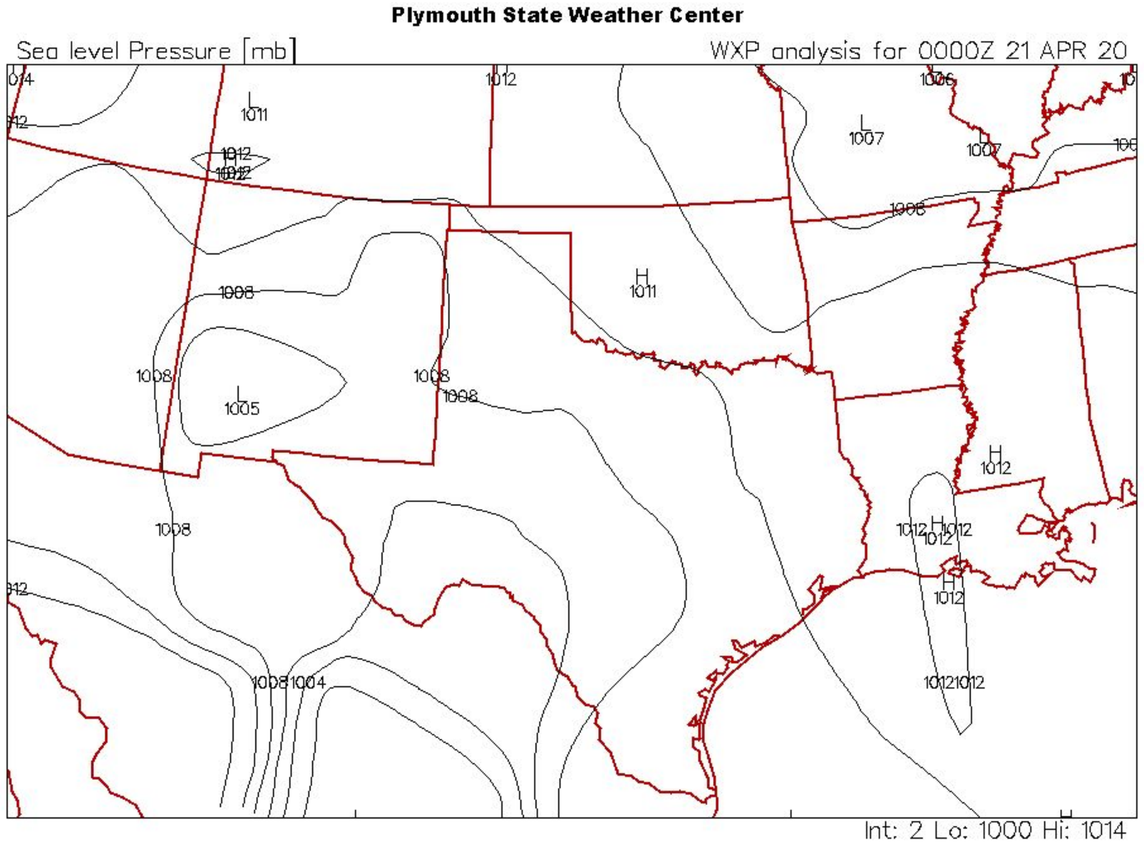
Celebrate every effort! High fives, team chants, have a treat, etc.

THINK LIKE A METEOROLOGIST KEY

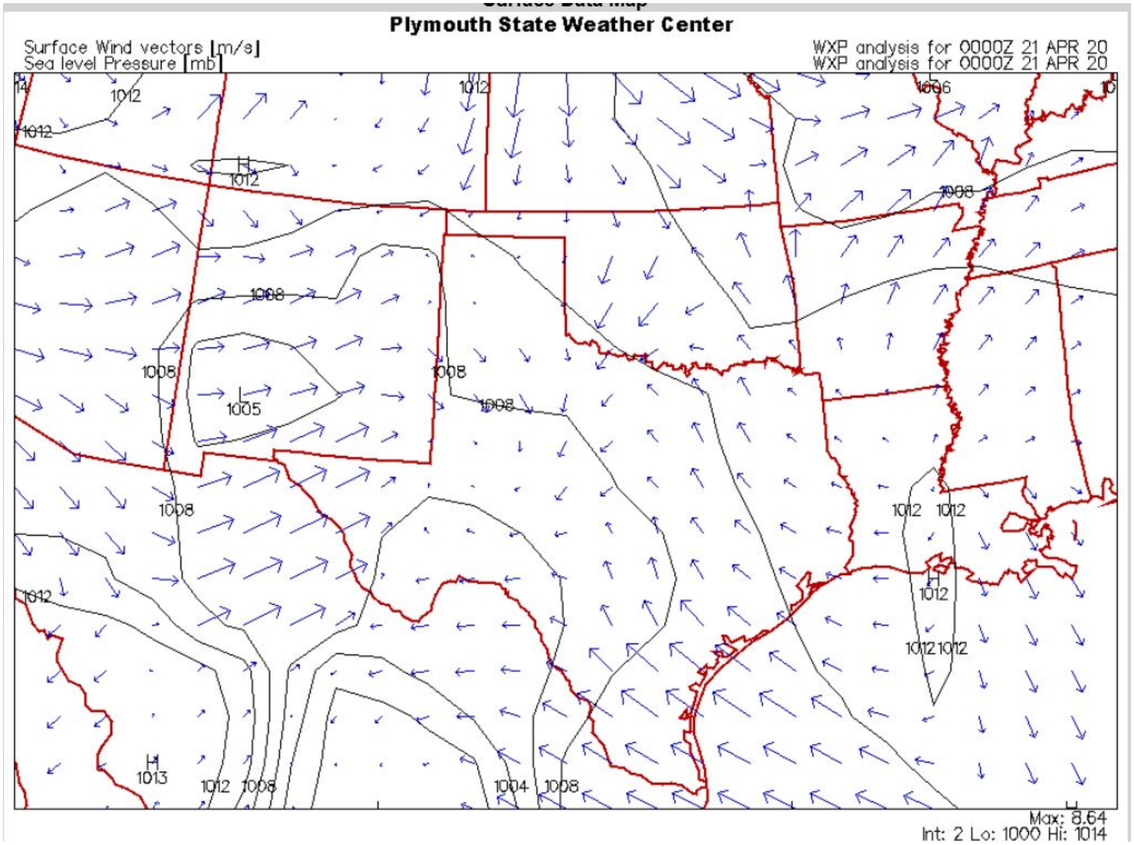
On the next few slides you will see a sequence of surface observations.

Examine the pressure and wind measurements. Are they what you predicted

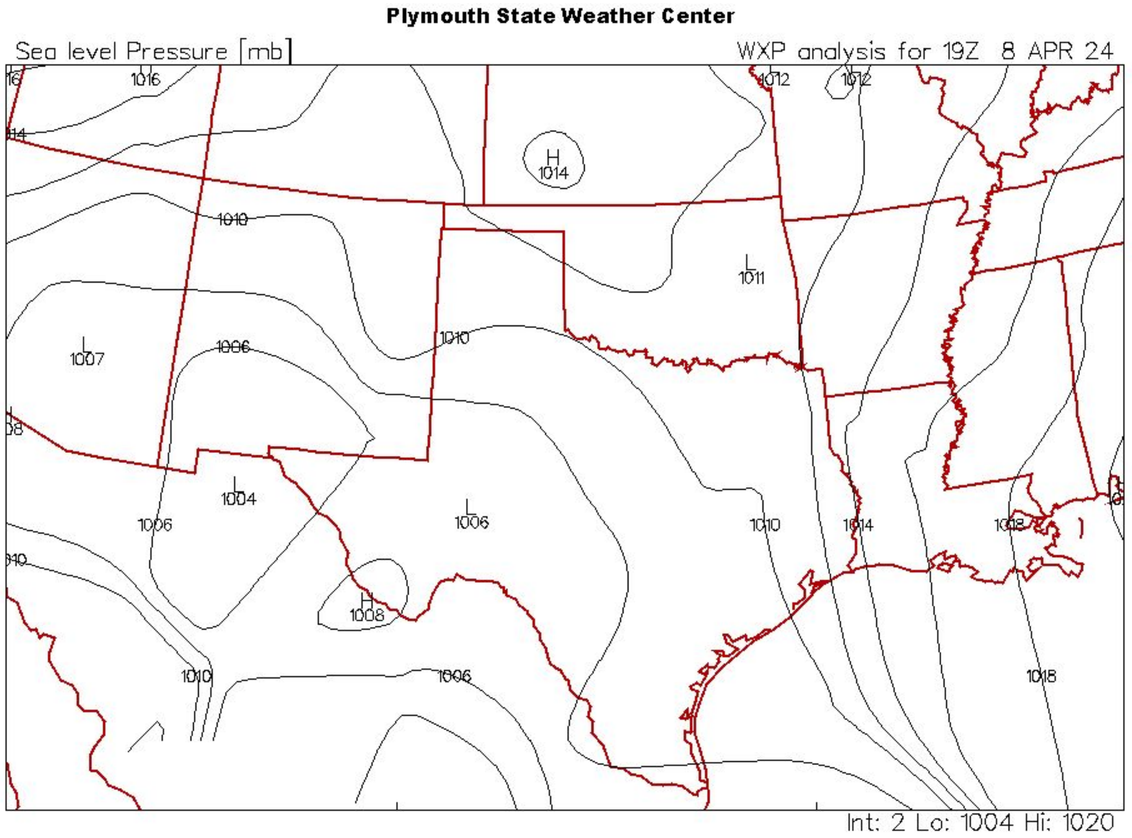
EXAMPLE #1


Plymouth State Weather Center
Sea level Pressure [mb]
WXP analysis for 0000Z 21 APR 20
1011
1012
1007
1008
1005
1004
Int: 2 Lo: 1000 Hi: 1014

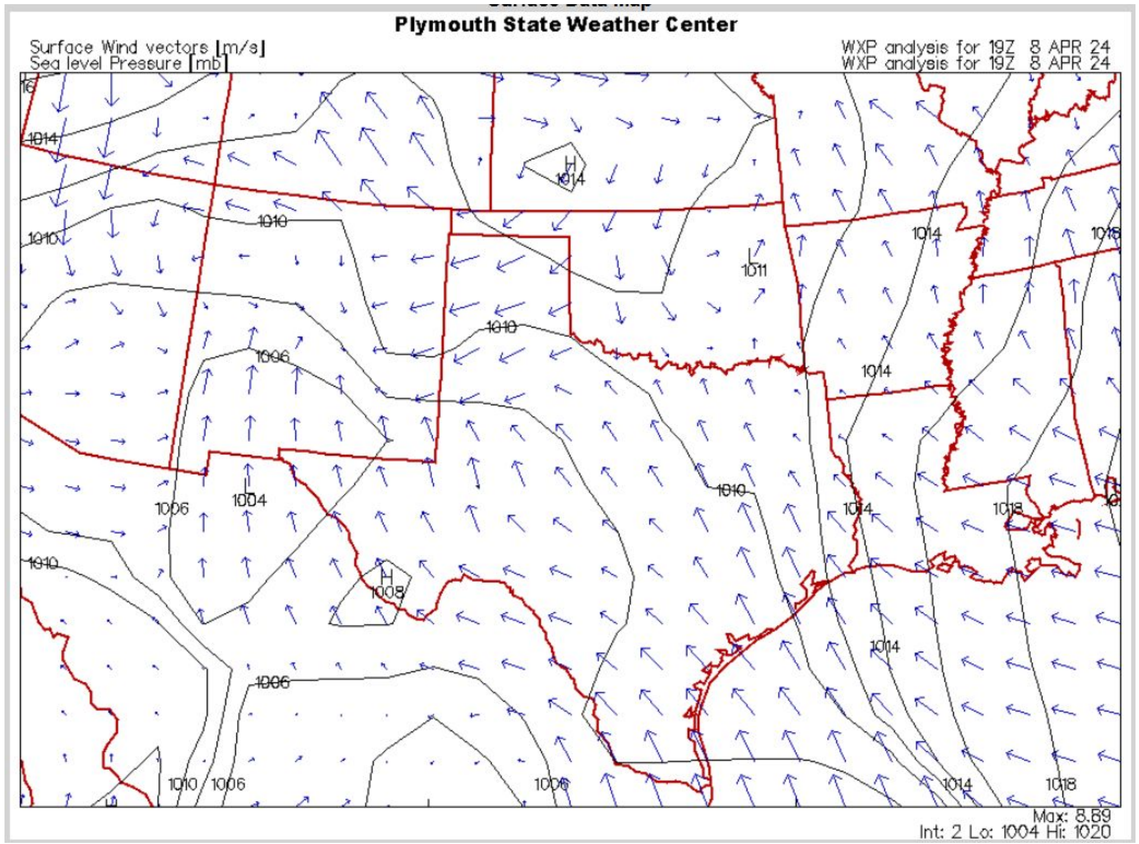
EXAMPLE #1 WITH WIND



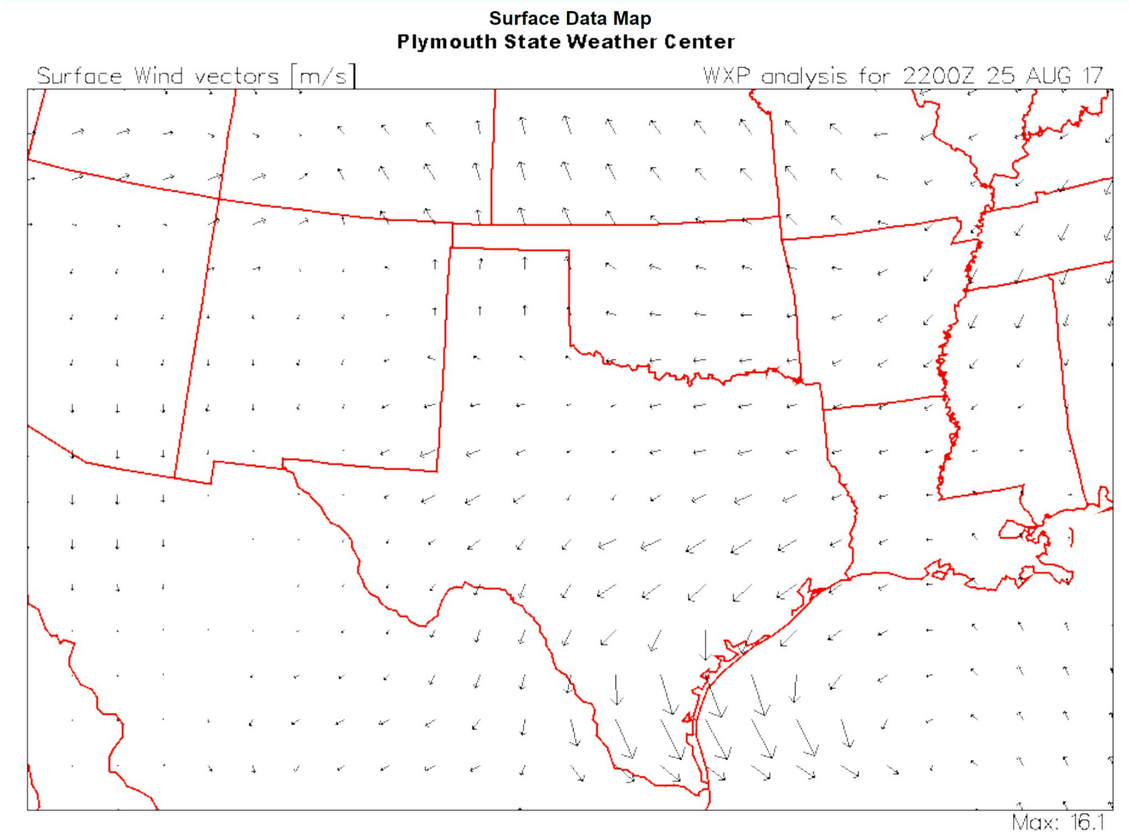
EXAMPLE #2


Plymouth State Weather Center
Sea level Pressure [mb]
WXP analysis for 19Z 8 APR 24
1016
1012
1012
H
1014
1010
L
1011
1010
L
1007
1006
1004
1006
L
1006
1010
1014
1008
H
1008
1010
1006
1018
Int: 2 Lo: 1004 Hi: 1020

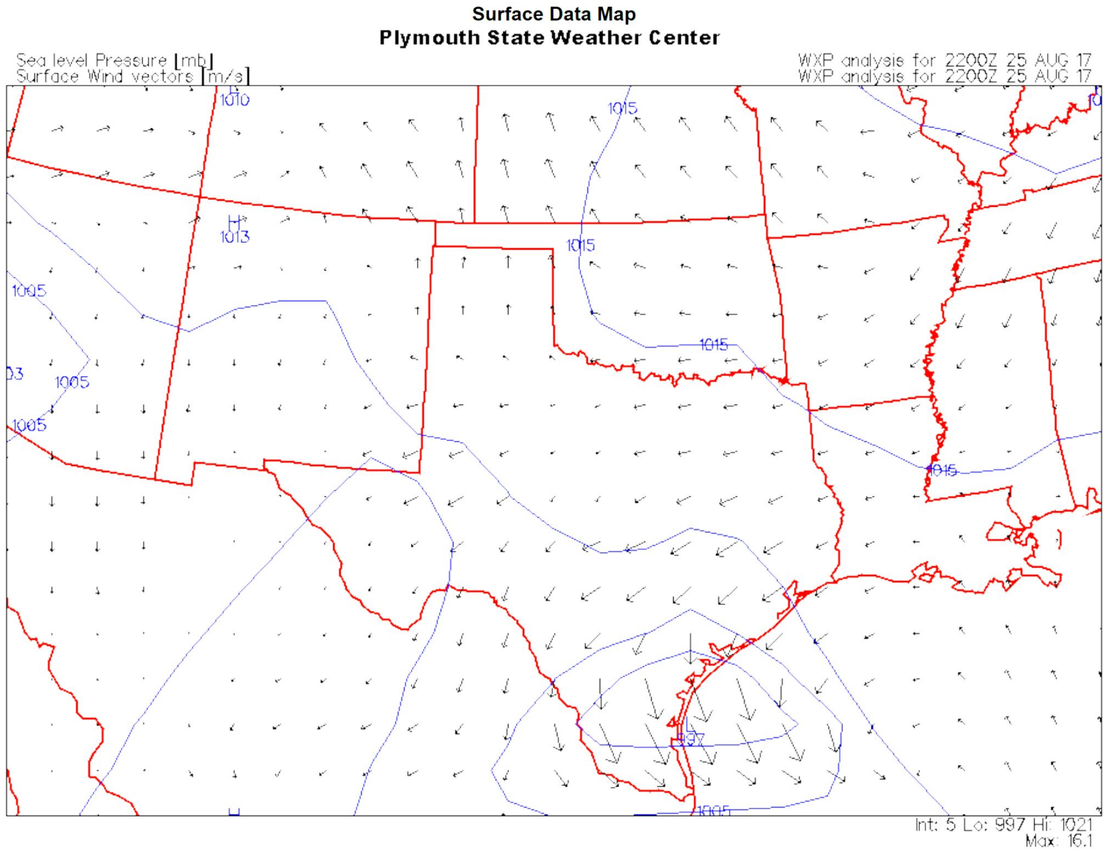
EXAMPLE #2 WITH WIND



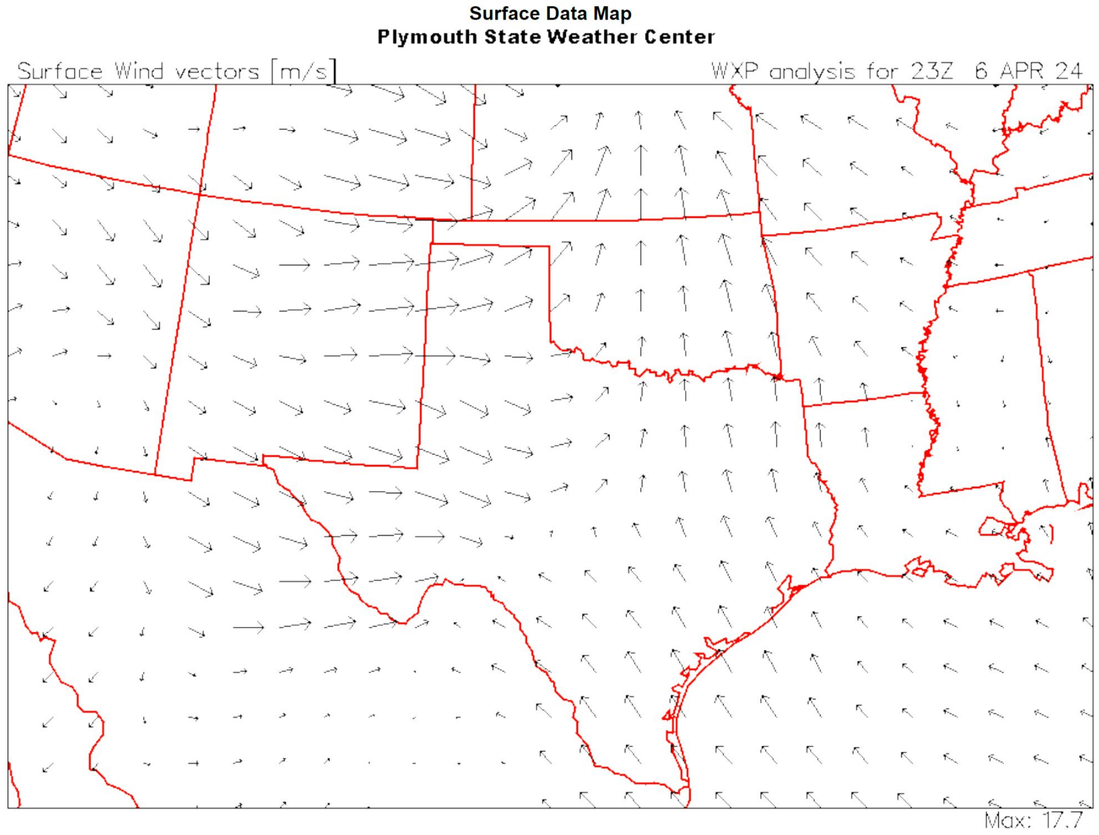
EXAMPLE #3


Surface Data Map
Plymouth State Weather Center
Surface Wind vectors [m/s]
WXP analysis for 2200Z 25 AUG 17
Max: 16.1

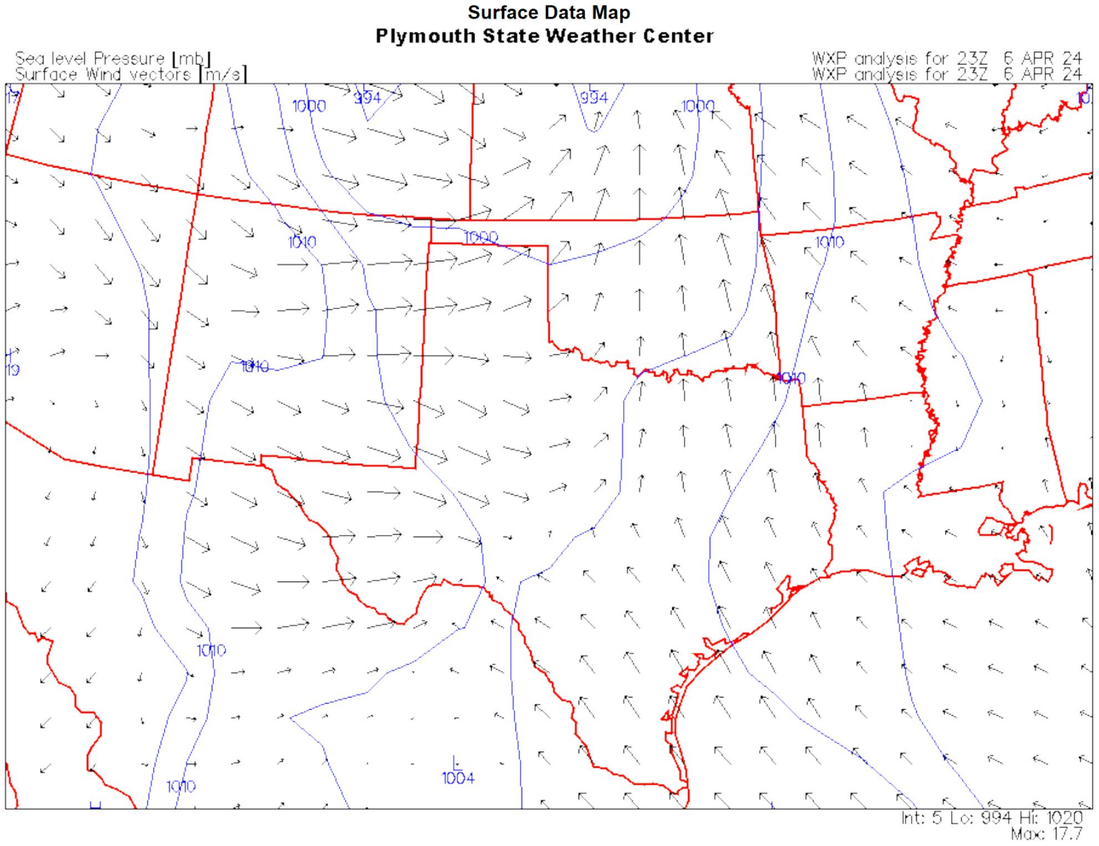
EXAMPLE #3 WITH PRESSURE



EXAMPLE #4


Surface Data Map
Plymouth State Weather Center
Surface Wind vectors [m/s]
WXP analysis for 23Z 6 APR 24
Max: 17.7

EXAMPLE #4 WITH PRESSURE

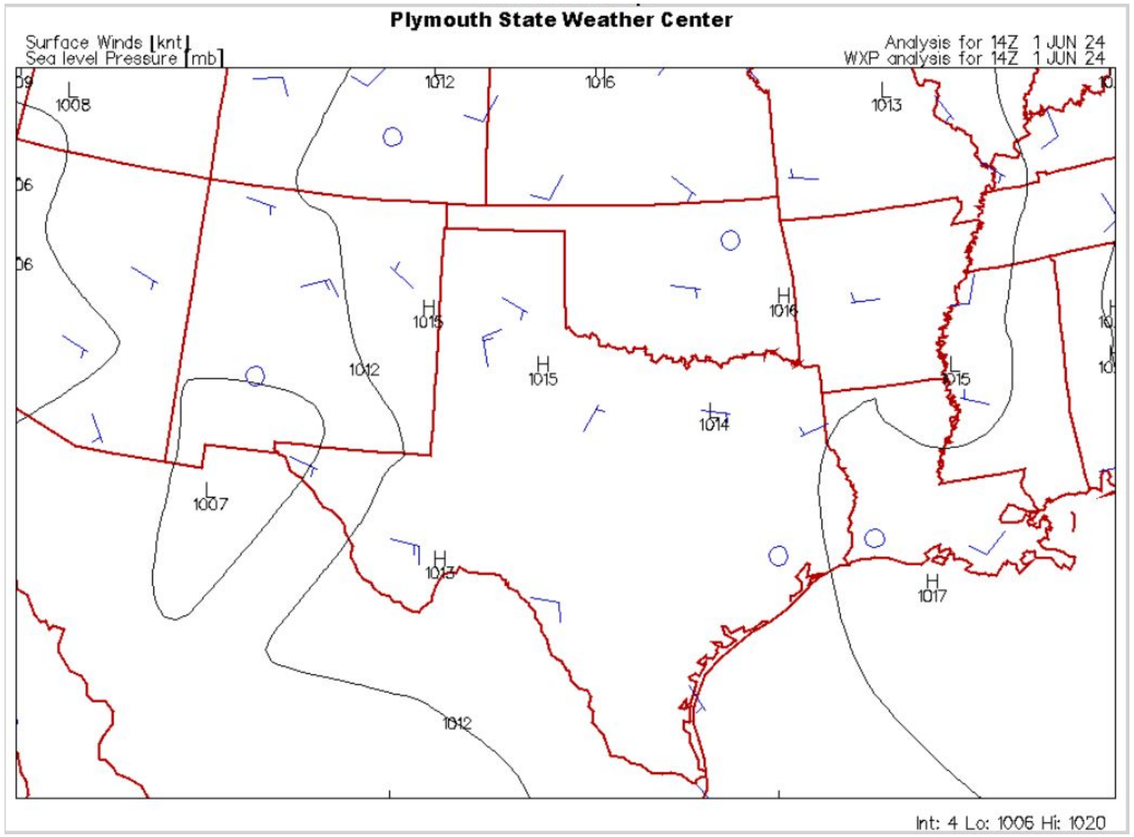


WHERE THE WIND BLOWS KEY

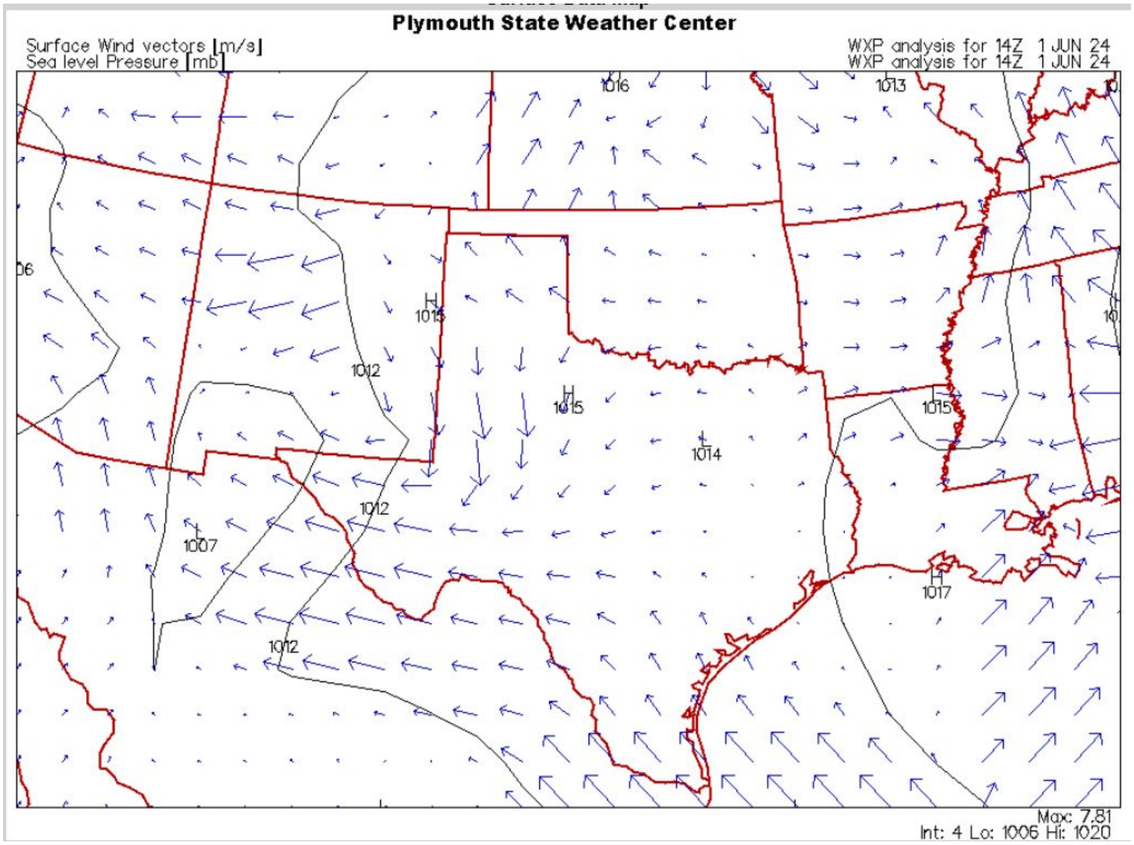
On the next few slides you will see a sequence of surface observations.

Examine the pressure and wind measurements. Are they what you predicted?

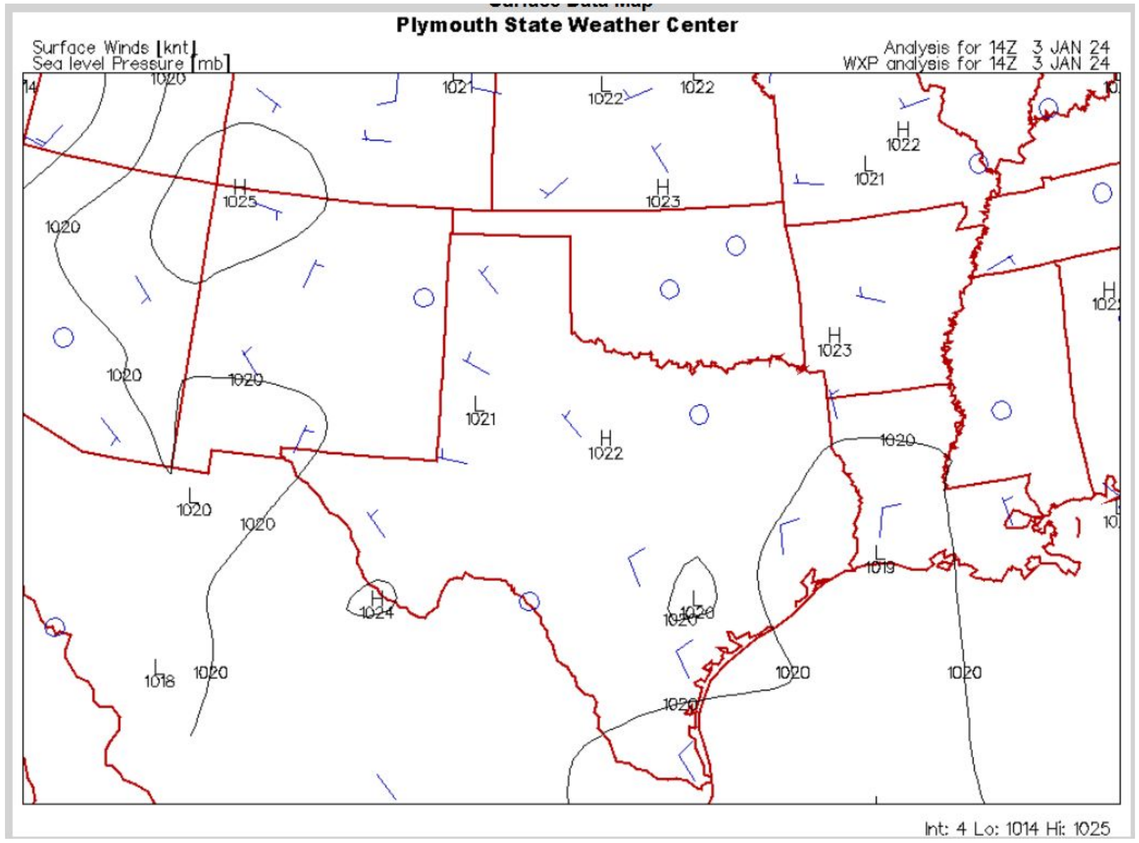
EXAMPLE #1


Plymouth State Weather Center
Surface Winds [knt]
Sea level Pressure [mb]
Analysis for 14Z 1 JUN 24
WXP analysis for 14Z 1 JUN 24
1008
1012
1016
1013
1015
1016
1012
1015
1014
1007
1013
1017
1012
Int: 4 Lo: 1006 Hi: 1020

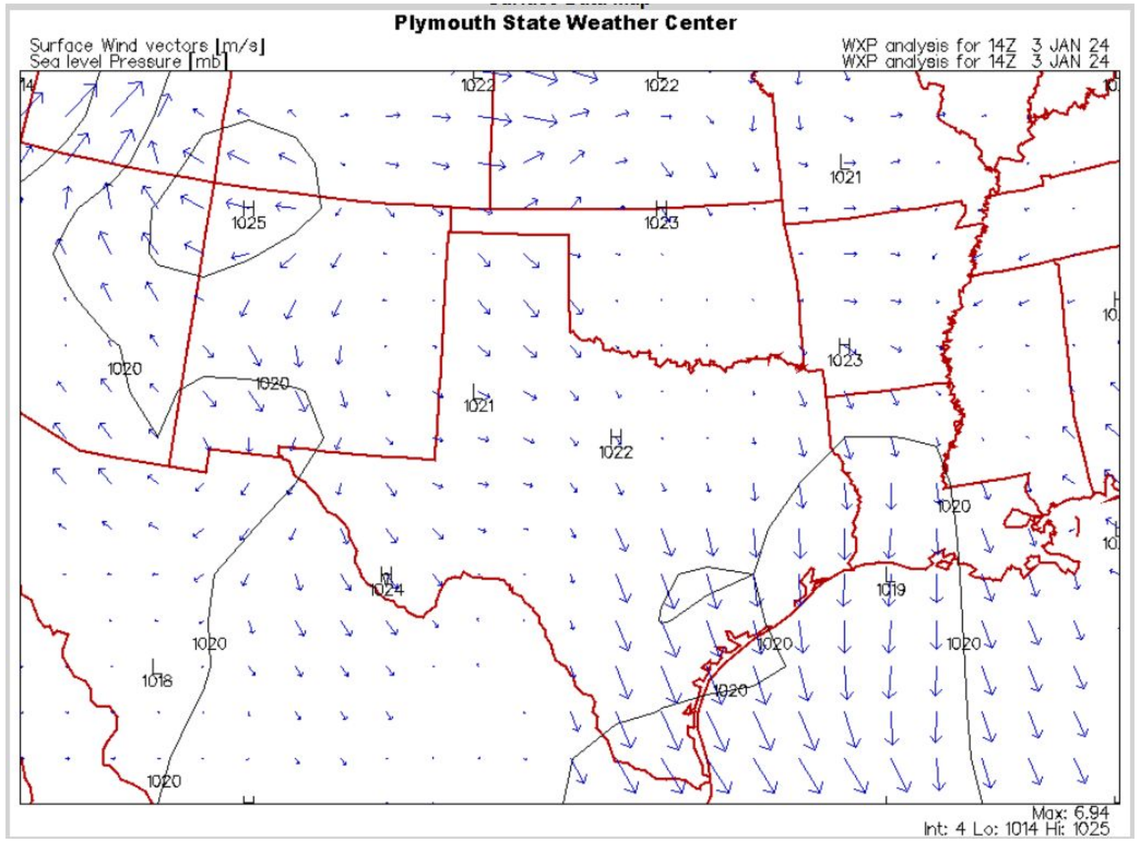
EXAMPLE #1 WITH ARROWS



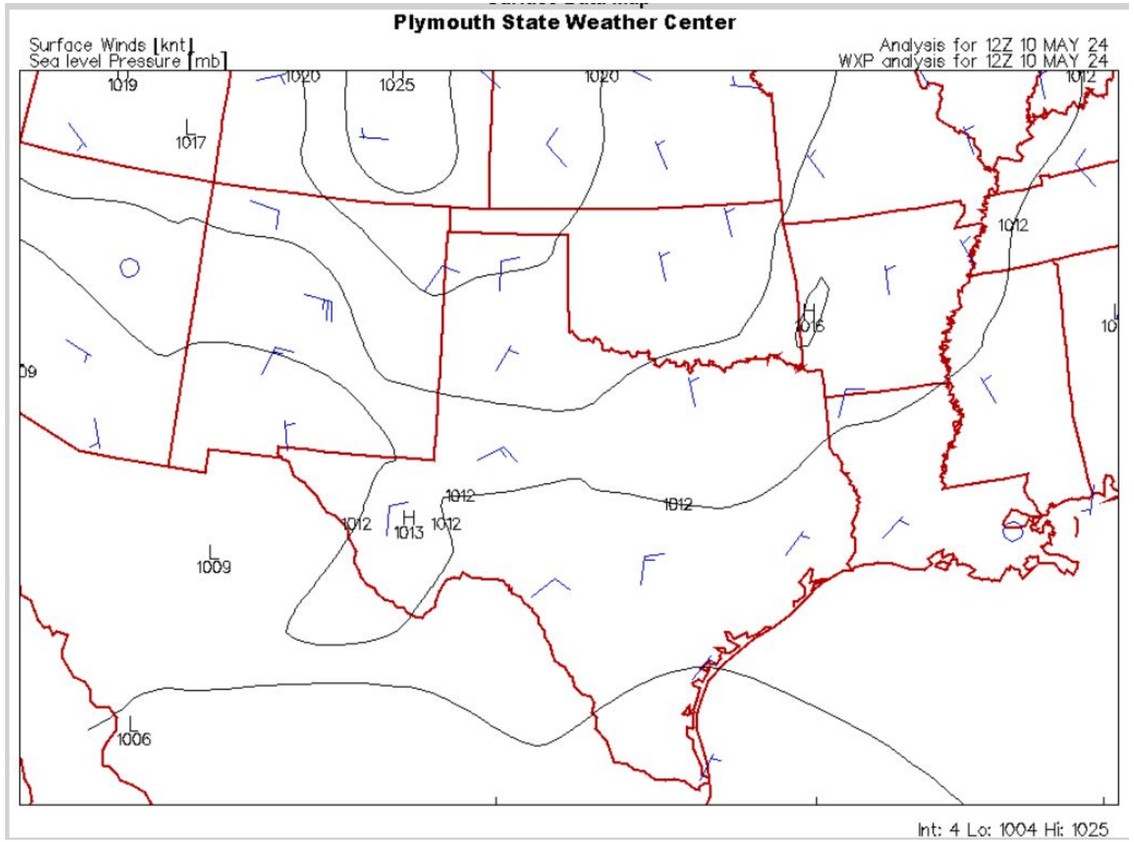
EXAMPLE #2


Plymouth State Weather Center
Surface Winds [knt]
Sea level Pressure [mb]
Analysis for 14Z 3 JAN 24
WXP analysis for 14Z 3 JAN 24
Int: 4 Lo: 1014 Hi: 1025

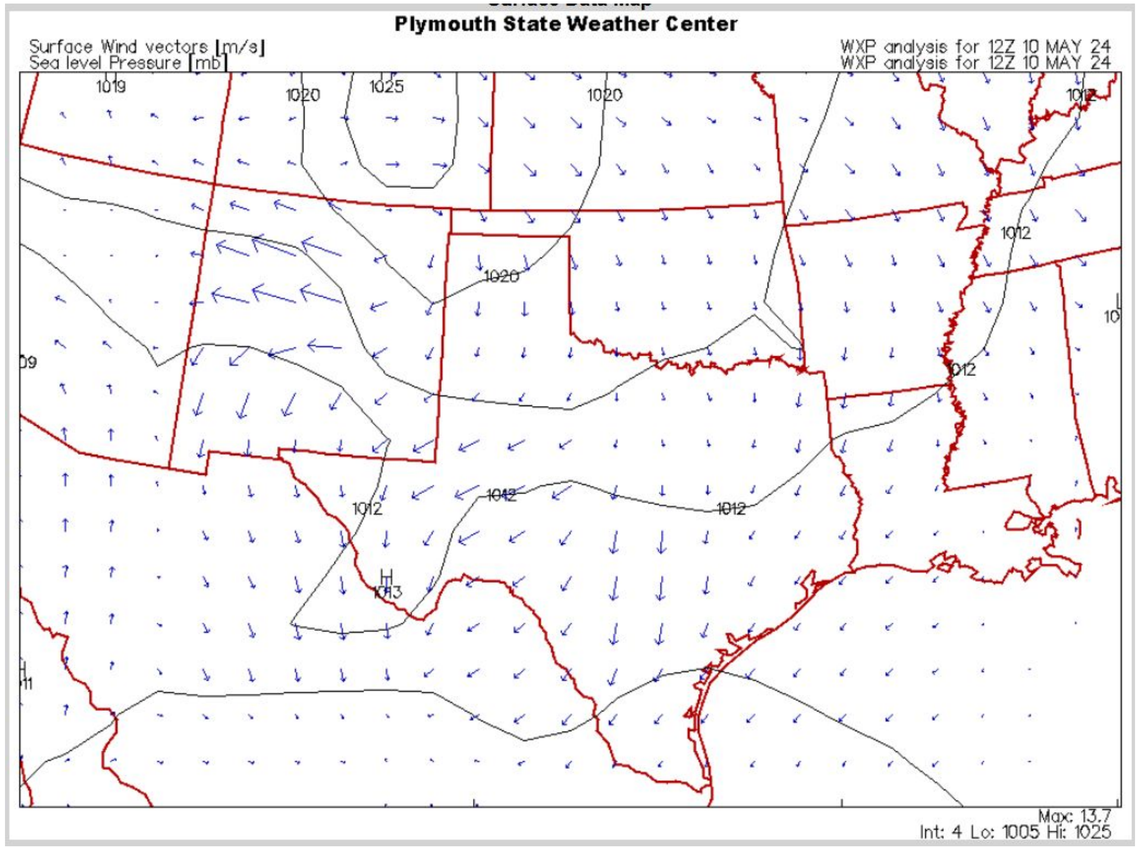
EXAMPLE #2 WITH ARROWS



EXAMPLE #3


Plymouth State Weather Center
Surface Winds [knt]
Sea level Pressure [mb]
Analysis for 12Z 10 MAY 24
WXP analysis for 12Z 10 MAY 24
L 1019
1020
L 1025
1020
1012
L 1017
1012
H 1016
1012
1012
1012
H 1013
1012
L 1009
L 1006
Int: 4 Lo: 1004 Hi: 1025

EXAMPLE #3 WITH ARROWS



WEATHERING THE STORM

MODULE 2: WIND

Driving Question: Why is it so windy in Oklahoma?

HOW IS ATMOSPHERIC PRESSURE MEASURED?

LESSON 2.1

LESSON 2.1 - ENROLL

Can you pop an empty bag?

If the bag is empty, why does it take effort to pop it?

LESSON 2.1 – ENROLL

Is air really that powerful?

If the amount of air in the bag doesn’t change, why does the bag bulge when we compress it?

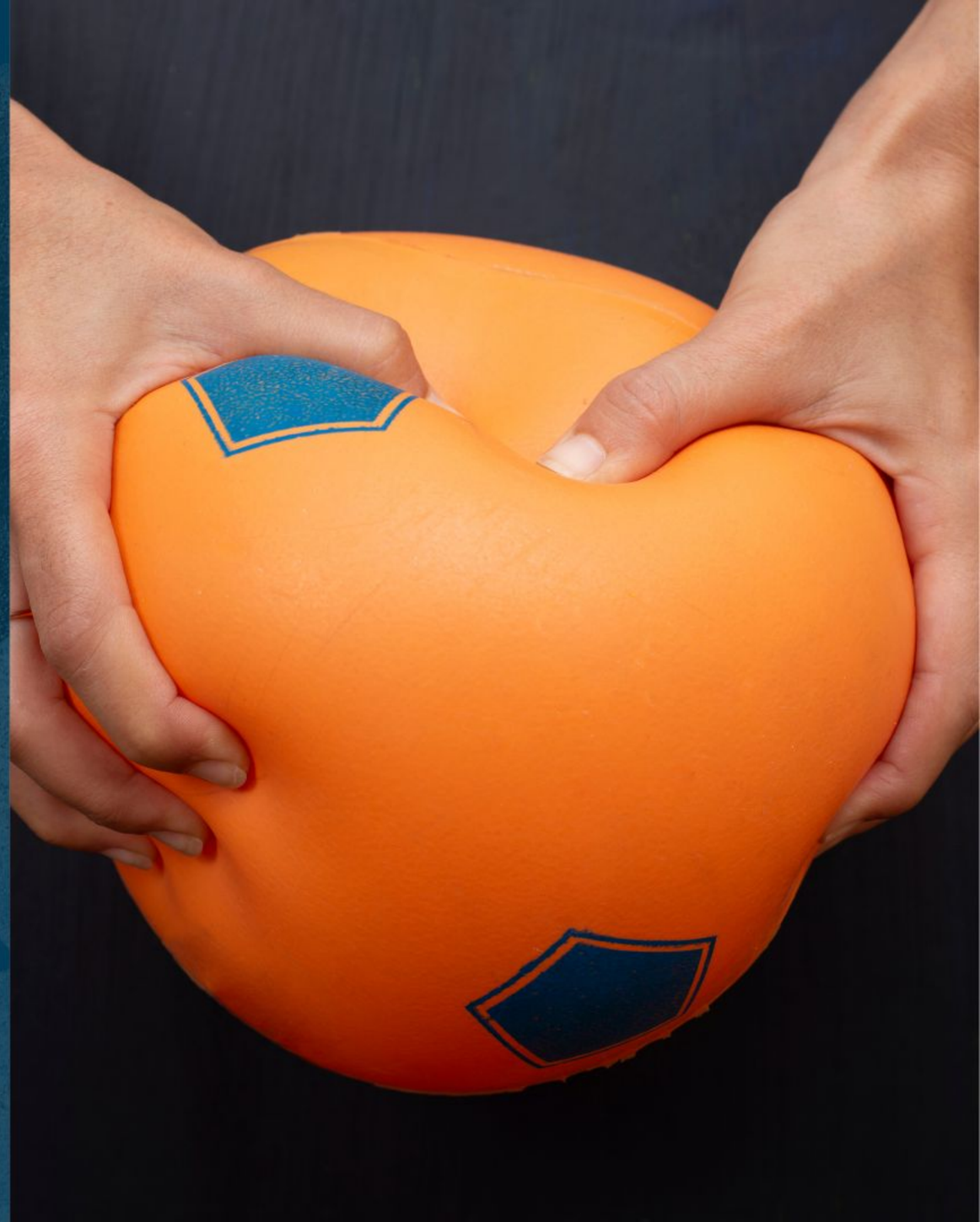
How can air make it difficult to pop an empty bag or balloon?

LESSON 2.1 - EXPERIENCE

When we squish the bag, we add *pressure*.

Now that the air pressure inside the bag is higher, more air molecules will be bumping into the plastic, causing it to bulge or even pop.

What about when the air isn't contained by a bag? How do we know air is exerting pressure?



LESSON 2.1 – EXPERIENCE

Let’s do an experiment to determine when and if air exerts pressure on objects.

Use your *Pick a Paper* handout.

LESSON 2.1 – EXPERIENCE

Why did the paper reduce movement of the ruler?

Share your ideas with the class.

“We think it has something to do with…”

LESSON 2.1 – LABEL

What happened when we used a larger piece of paper?

How can paper prevent the ruler from falling?

LESSON 2.1 – LABEL

How is air holding the ruler in place?

We know that **surface pressure** is the pressure exerted by the atmosphere due to gravity at any given location on Earth's surface.

- Remember when we squeezed the bag of air and the air pressed on the sides of the bag?
- Gravity has a similar effect by pulling air in the atmosphere towards the surface

LESSON 2.1 - LABEL

Why does air pressure affect the larger newspaper more than the smaller paper?

- Because there's more air above it!
- Every object has all of the air above it pressing down towards it

Why don't we feel the air pressing down on us?

- We're used to it!
- We can feel the effects if we move to a different elevation.
  - Death Valley is below sea level, so there is more air above you
  - Mountains are higher above sea level, so there is less air above you

LESSON 2.1 - LABEL

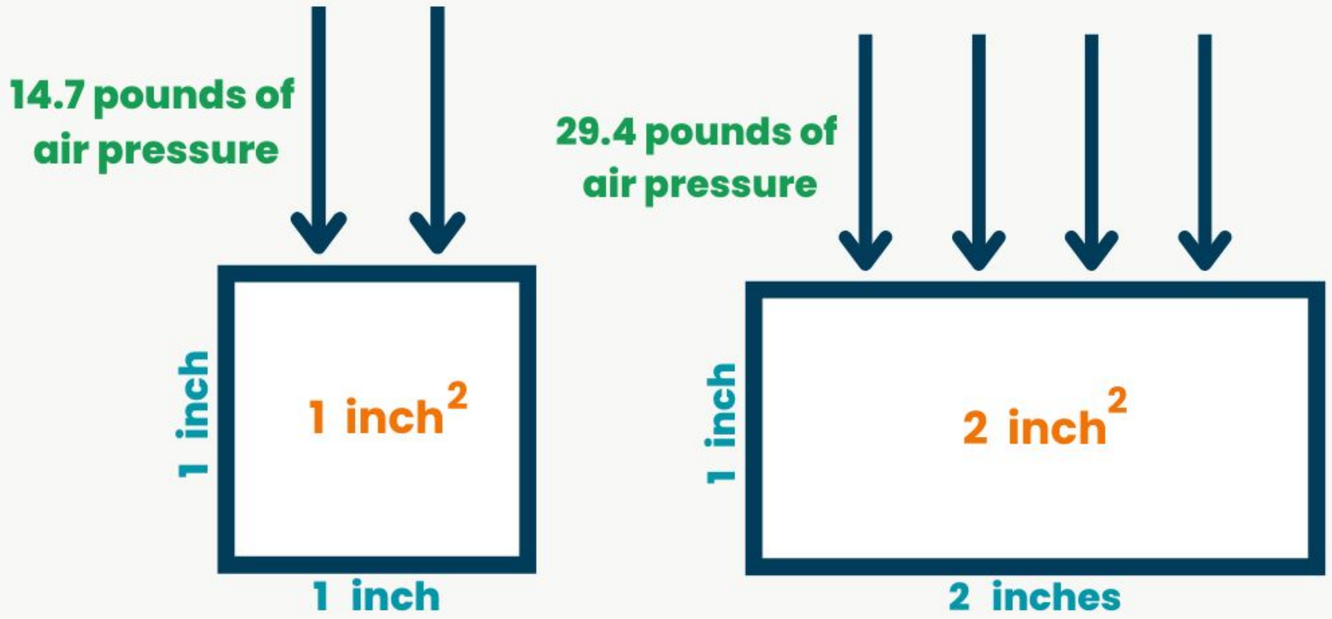
If air pressure changes with elevation, how do we know how to measure it?

We usually use **sea level pressure**, which is the air pressure at sea level. This accounts for the differences because of elevation.

At exactly sea level, air pressure is measured at around **14.7 pounds per square inch (psi)**.

LESSON 2.1 – LABEL

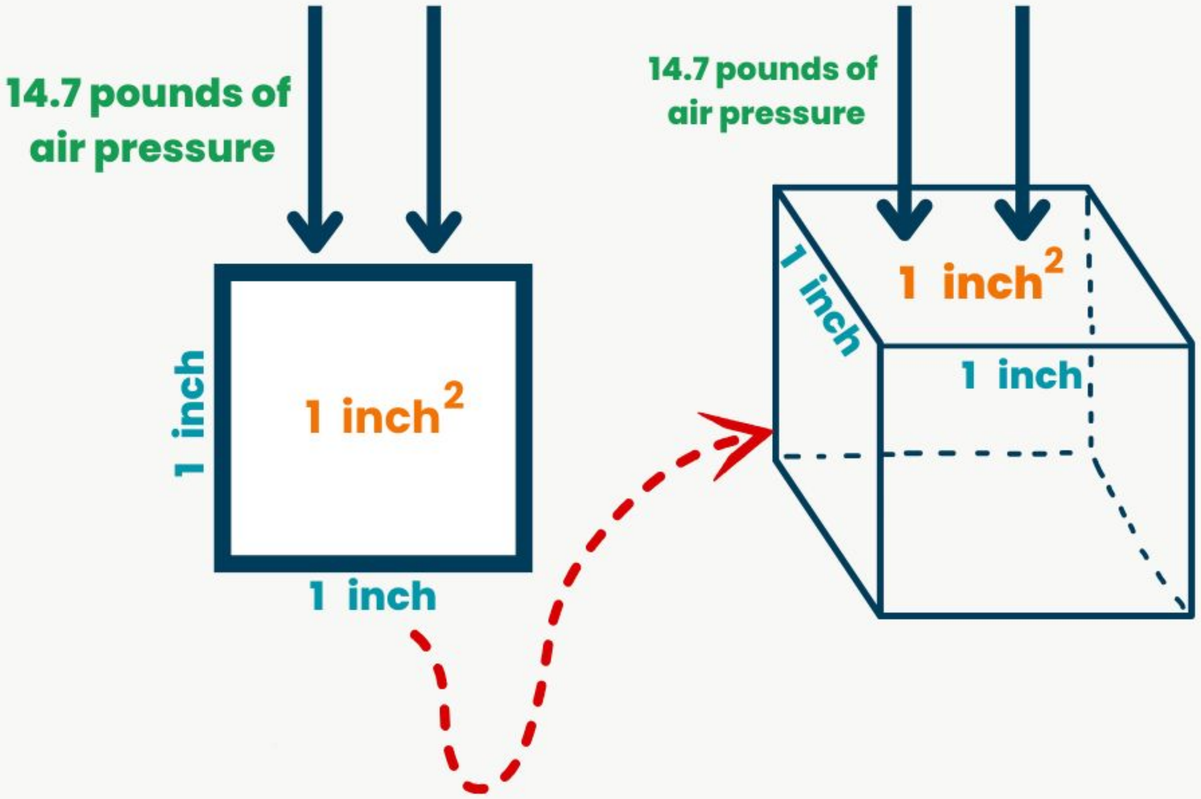
Objects with more **surface area** experience more air pressure.



LESSON 2.1 – LABEL

Area and **surface area** are similar, but not quite the same.

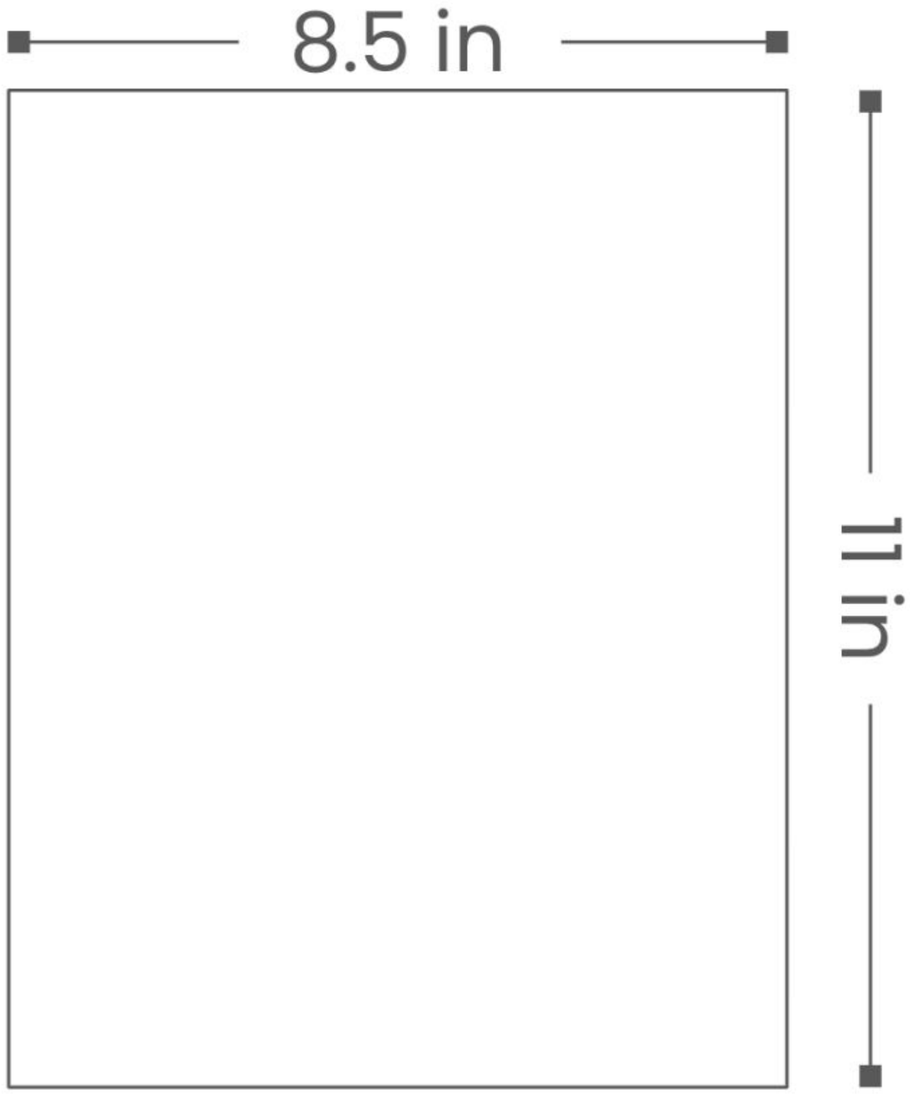
Area only relates to 2-dimensional objects, whereas **surface area** relates to the exposed surface of a 3-dimensional object.



LESSON 2.1 – DEMONSTRATE

If the atmosphere exerts a force of 14.7 pounds per square inch on an object, how much force is exerted on the:

1. Piece of regular paper?
2. Piece of newspaper?



FORCE ON THE PRINTER PAPER

How many square inches make up this paper?

Area = length x width

= 8.5 x 11 = 93.5 sq. in.

For every square inch, there is 14.7 pounds exerted on the paper.

Force = 14.7 x 93.5 = 1,374.45 pounds of pressure!

FORCE ON THE NEWSPAPER

Most newspapers are folded to be 12 inches by 22.75 inches. What are the dimensions of an unfolded sheet?

How much force is exerted by the atmosphere on the unfolded sheet of newspaper?

LESSON 2.1 - REVIEW

Let’s review what you’ve learned so far.

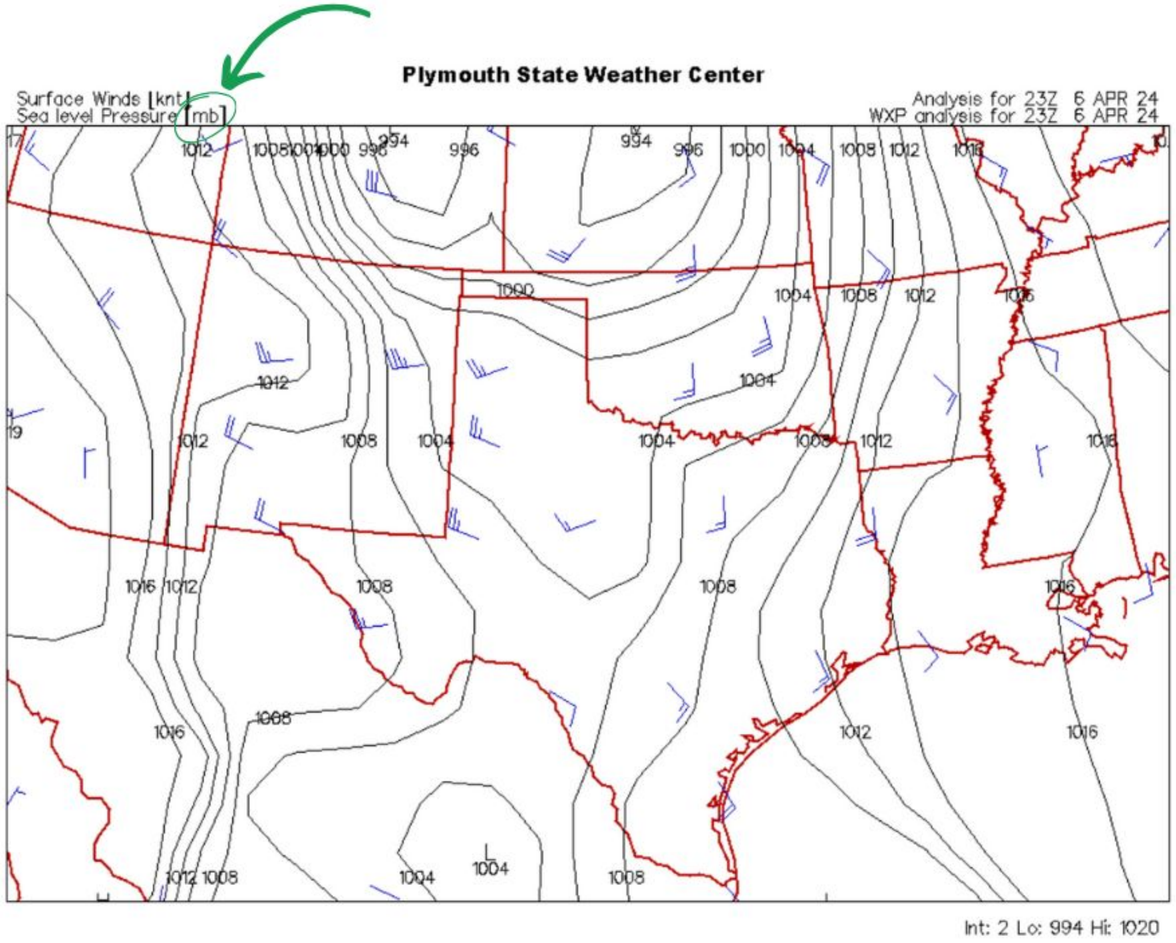
Use your *Module 2 - What I Know* Handout

LESSON 2.1 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

HOW IS ATMOSPHERIC PRESSURE MEASURED?

LESSON 2.2



LESSON 2.2 ENROLL

Wait a minute...

The maps we saw before didn't have surface pressure measured in pounds per square inch...

Why might we want to use a different unit of measurement for this map?

LESSON 2.2 - EXPERIENCE

You will research the tools and units used to measure surface pressure.

How do we use the Internet ethically and legally?

- Where do we find information?
- How do we know the information is reliable?
- How many sources should we have?
- How do we summarize the information?
- When or how do we reference our sources?
- Is it wrong to use AI?

LESSON 2.2 - EXPERIENCE

Barometer:

Radiosonde:

Millibars (mb):

Pascal (Pa):

Standard atmosphere (atm):

Millimeters or inches of Mercury (mmHg, in Hg):

LESSON 2.2 DEMONSTRATE

What did you learn about the tools and units of surface pressure?

LESSON 2.2 – REVIEW

Barometer:

Radiosonde:

Millibars (mb):

Pascal (Pa):

Standard atmosphere (atm):

Millimeters or inches of Mercury (mmHg, in Hg):

LESSON 2.2 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

HOW IS ATMOSPHERIC PRESSURE MEASURED?

LESSON 2.3

LESSON 2.3 – ENROLL

We know that the atmosphere presses down on the earth because of gravity.

We also know that air molecules move, bump into things, transfer energy, and can have an observable effect on objects.

We learned that pressure from the air can be measured using a barometer or radiosonde, and that there are several units we can use to describe air pressure.

LESSON 2.3 ENROLL

What do we do if we have an air pressure reading in one unit, but need the measurement to be in a different unit?

Can we convert the measurement from one unit to another?

LESSON 2.3 – LABEL

What do we know about air pressure measurements at sea level?

PSI = 14.7 psi
Millibars = 1013.25 mb
Pascal = 101,325 Pa
Standard atmosphere = 1 atm
Mercury = 760 mmHg or 29.92 inHg

These numbers may look very different, but they all represent the same air pressure.

12 inches and 1 foot are different numbers with different units, but they're the same length!

Just like we can convert between inches and feet, we can convert air pressure measurements.

LESSON 2.3 – LABEL

If we have an air pressure of 1008 mb, what the pressure be in mmHg?

- We can use ratios to help us solve this problem.
- We know that these quantities are equivalent: (standard measurements at sea level)
  - 1013.25 mb = 760 mmHg
- We can create a ratio to represent the relationship between these units of measurement
  - $\frac{1013.25 \text{ mb}}{760 \text{ mmHg}}$ or $\frac{760 \text{ mmHg}}{1013.25 \text{ mb}}$
- There are 1013.25 mb per every 760 mmHg and vice versa

LESSON 2.3 – LABEL

If our air pressure reading is 1008 mb, which ratio should we use?

Which unit should go in the numerator and which should go in the denominator?

It doesn't matter, as long as your units match!

$$\frac{1008\ \text{mb}}{y\ \text{mmHg}} = \frac{1013.25\ \text{mb}}{760\ \text{mmHg}} \quad \text{OR} \quad \frac{y\ \text{mmHg}}{1008\ \text{mb}} = \frac{760\ \text{mmHg}}{1013.25\ \text{mb}}$$

We can now solve for *y* to determine the equivalent measurement in mmHg.

LESSON 2.3 – DEMONSTRATE

Let’s practice converting between different units of air pressure.

LESSON 2.3 – REVIEW

Let’s return to our initial models about why Oklahoma might be more windy than other areas. Revise your model by adding sticky notes, attaching notecards, or adding annotations in colored pencils. Don’t erase what you had before! Your initial ideas can help you identify what you’ve learned.

Add: We think [evidence from activity or reading] supports PART of our model, but we want to add ____ to make it more accurate.

Remove: We think [evidence from activity or reading] contradicts ___ in our model, and we want to remove it or find out more about it.

Revise: We think [evidence from activity or reading] supports PART of our model, but we want to change ____ to make it more accurate.

Questions: We still have questions about ___.

LESSON 2.3 - CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

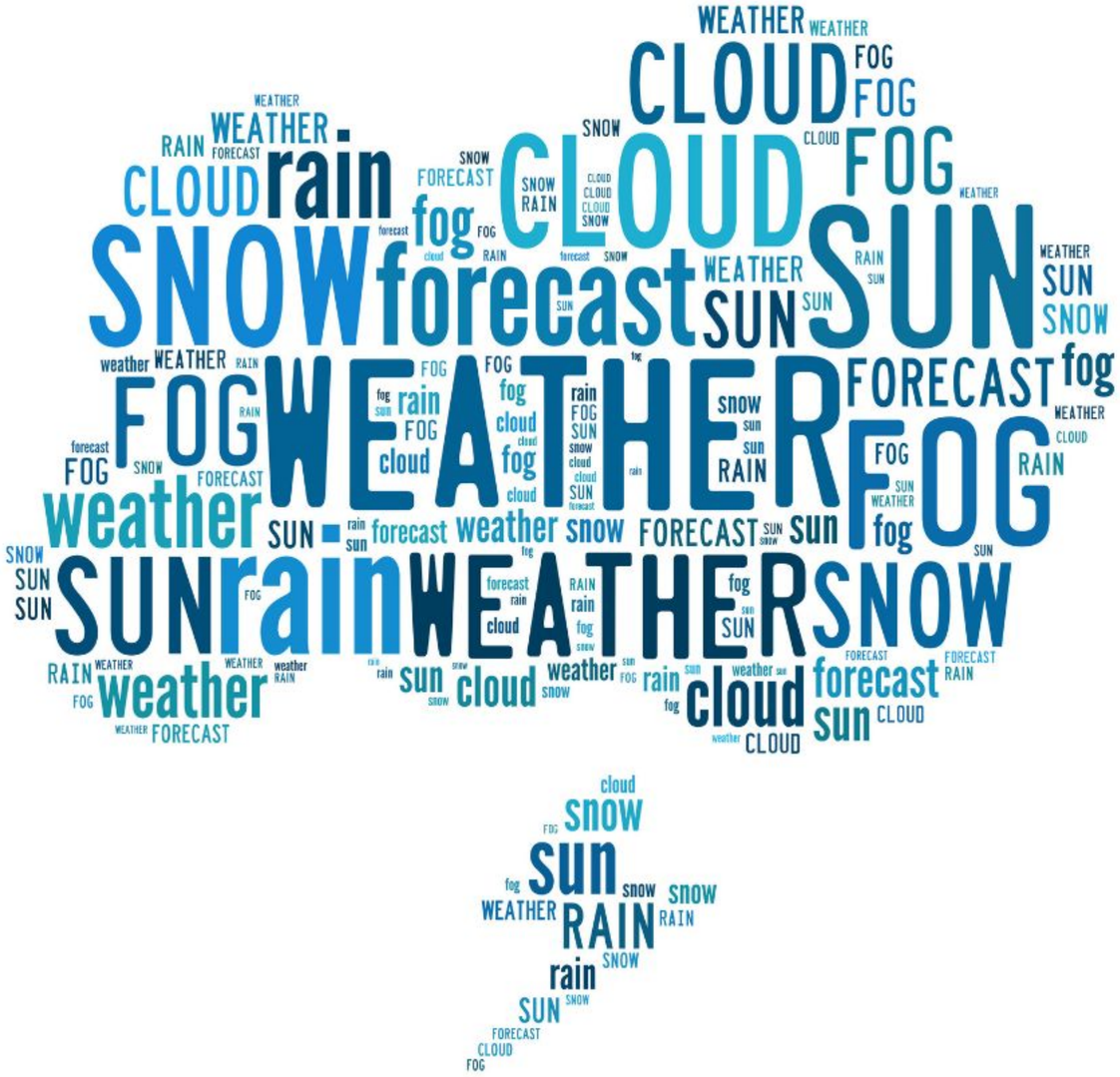
WEATHERING THE STORM

MODULE 2: WIND

Driving Question: Why is it so windy in Oklahoma?

HOW AND WHY IS WIND MEASURED?

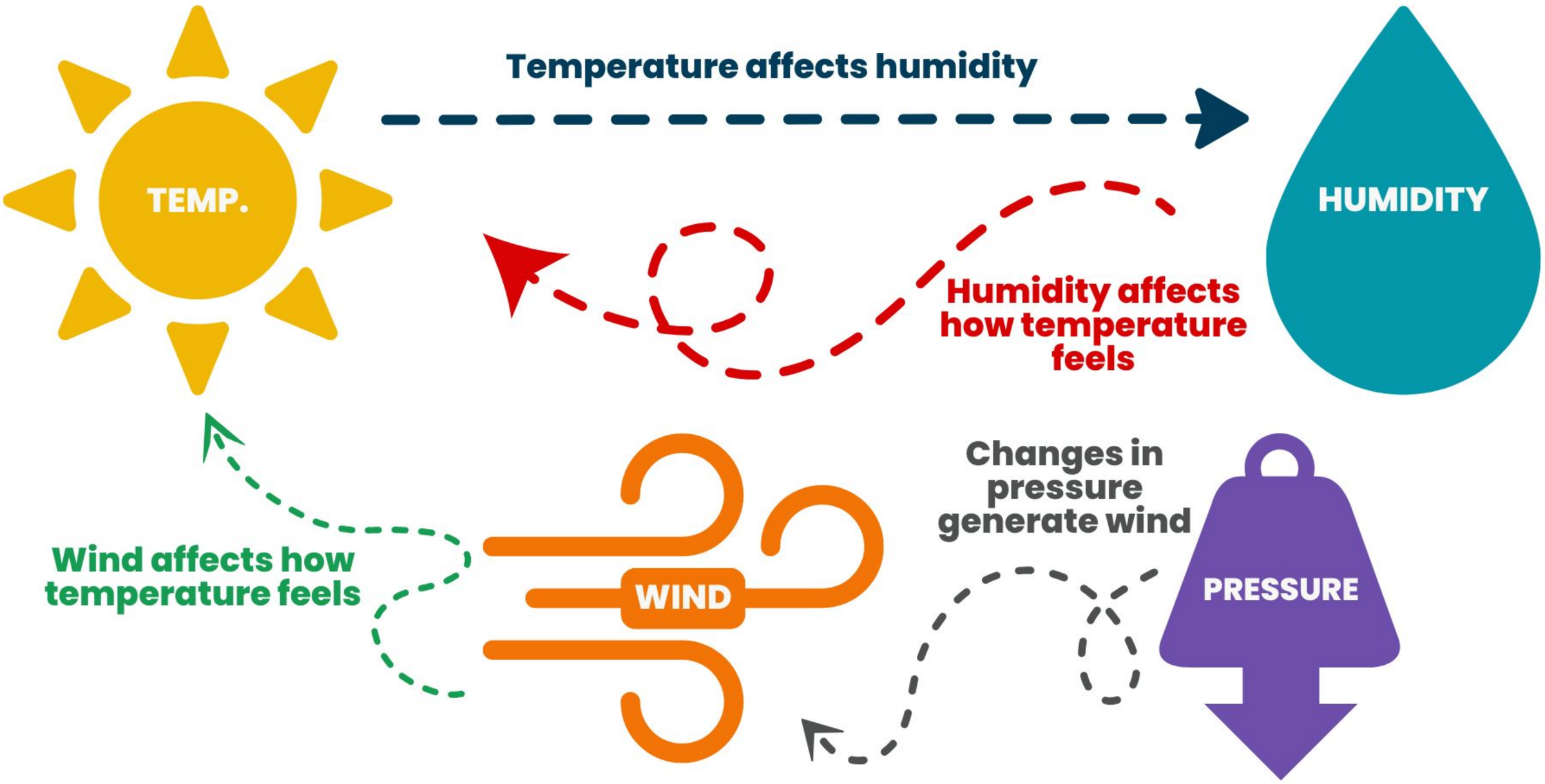
LESSON 3



COMPONENTS OF WEATHER

What have we learned so far?

- [x] Temperature
- [x] Atmospheric pressure
- [ ] Wind
- [x] Humidity
- [ ] Precipitation
- [ ] Cloudiness


Temperature affects humidity
TEMP.
HUMIDITY
Humidity affects how temperature feels
Changes in pressure generate wind
Wind affects how temperature feels
WIND
PRESSURE

LESSON 3 - ENROLL

What else do you know about wind?

Use your *What I Know* handouts and any other resources to discuss what you've learned so far with a partner.

Discuss any experiences you've had with wind.

LESSON 3 – ENROLL

What are the 3 most important things we know about wind?

1

Insert text here

2

Insert text here

3

Insert text here

euro news.
Norway: Walking in the wind

LESSON 3 – LABEL

We know that **wind** is air in motion relative to the Earth's surface, but what does "in motion" tell us?

For a more useful forecast of wind we need to measure two things: **speed** and **direction**.

This can help us better understand current air quality, safety, and help us predict precipitation and temperature changes.

LESSON 3 – LABEL

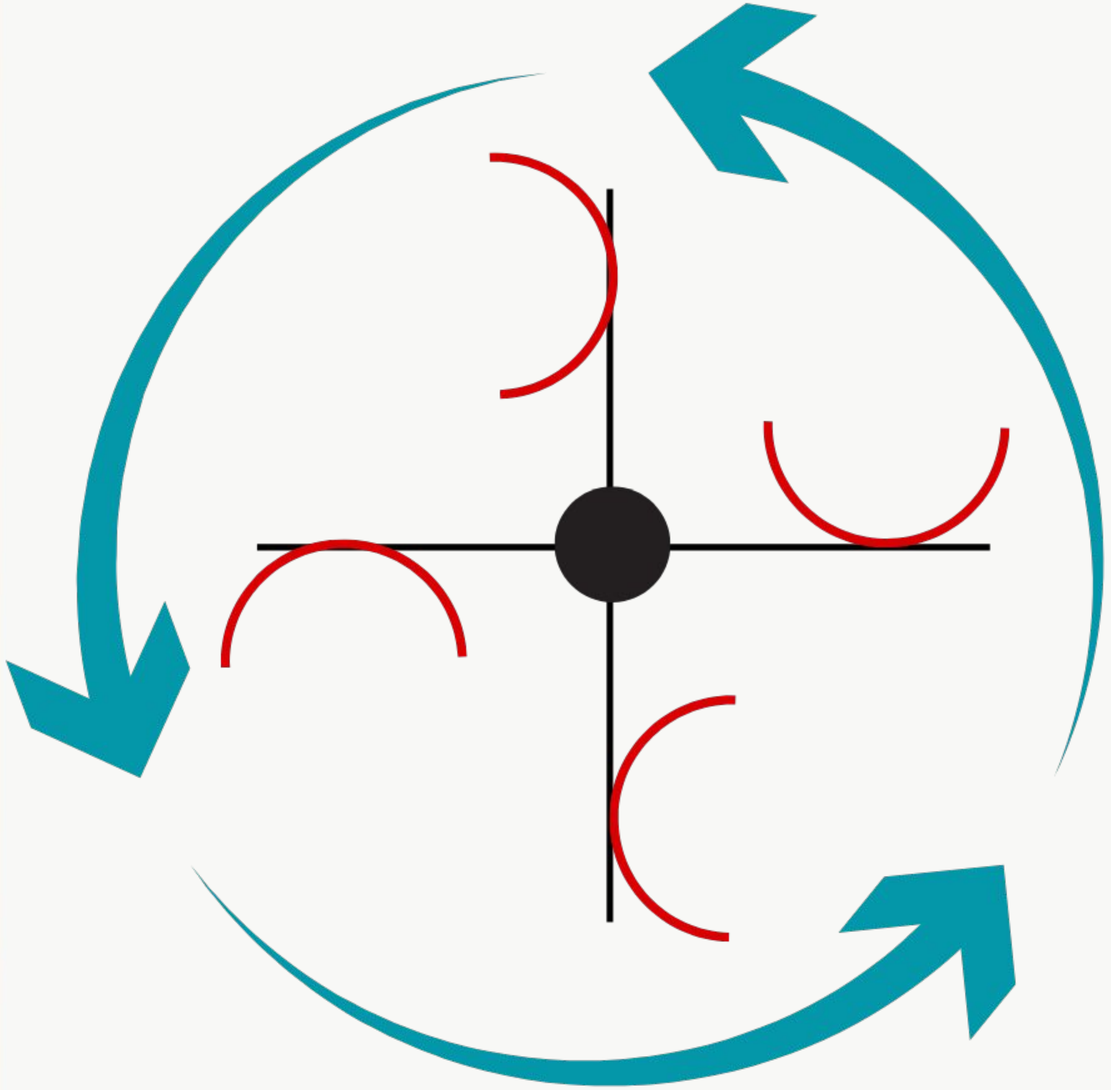
A tool called an **anemometer** is used to measure **wind speed**. There are several different kinds of anemometer, but the rotation anemometer is the easiest to recognize and uses a circular design to measure the force of the wind.

LESSON 3 - LABEL

How does it work?

As the anemometer rotates, we know the distance that it travels; it’s the circumference of the circle it follows around (and around, and around).

We can measure how far it travels in a certain amount of time, which will allow us to calculate the speed.



LESSON 3 – LABEL

The **direction** of the wind is measured with a different tool such as a **wind vane** or **wind sock**.

Wind socks are often used at airports and at sea ports.

LESSON 3 – EXPERIENCE

Let’s practice meteorology!

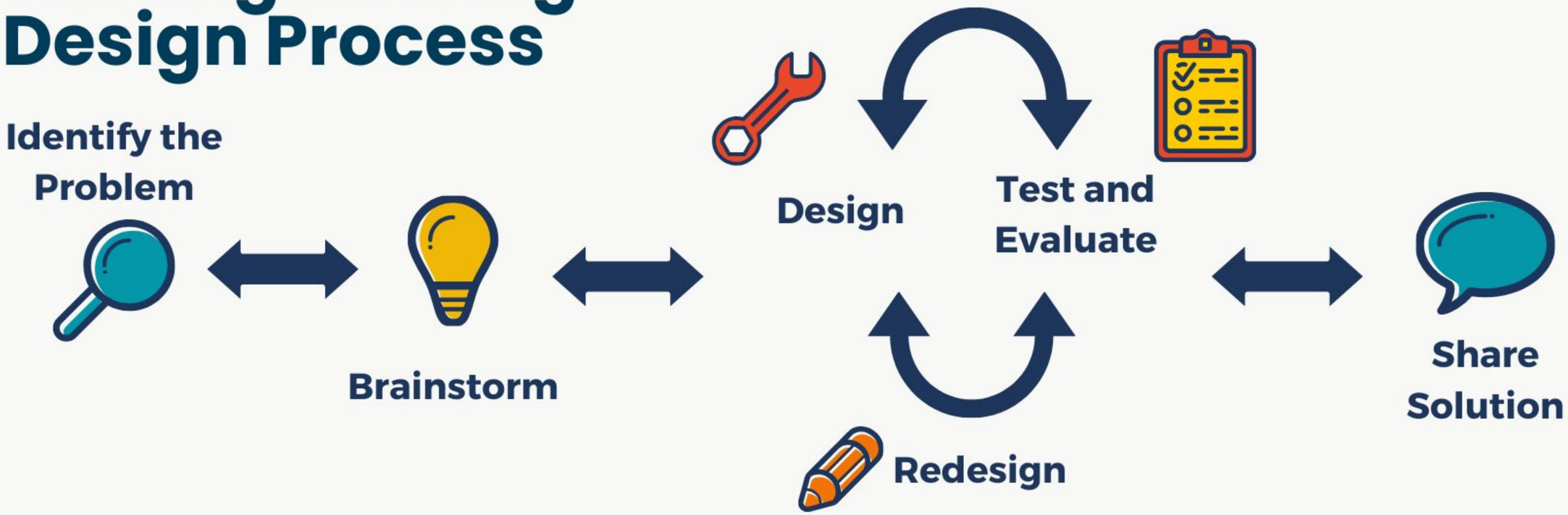
Meteorologists don’t just study nature or appear on the news, some of them are also engineers.

Imagine you and your group are field meteorologists and you need to develop a device to collect wind data.

What will you engineer?

LESSON 3 – EXPERIENCE

The Engineering Design Process



LESSON 3 – COLLECTING WIND DATA

How do we use data from our engineering designs to calculate wind speed?

If we know the diameter of your anemometer, we can calculate the circumference:

$C = \pi \times \text{diameter}$

So for this anemometer which is 10 inches across, the distance one arm travels around as it moves is:

$C = 3.14 \times 10 = 31.4 \text{ inches} = 2.6 \text{ feet}$

How can we find the speed of the wind now?

LESSON 3 – COLLECTING WIND DATA

We need to know how long it takes one arm of the anemometer to travel around the full circle.

For the 10 inch anemometer, a group observed that it took 15 seconds for one arm to travel the full circle. How fast did it go?

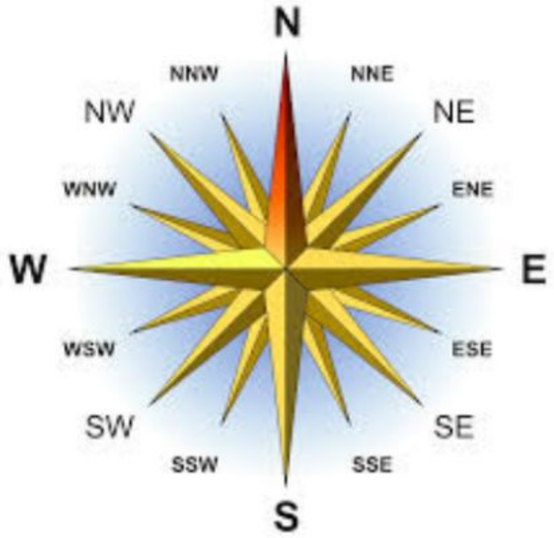
We know it traveled 2.6 feet in 2 seconds:

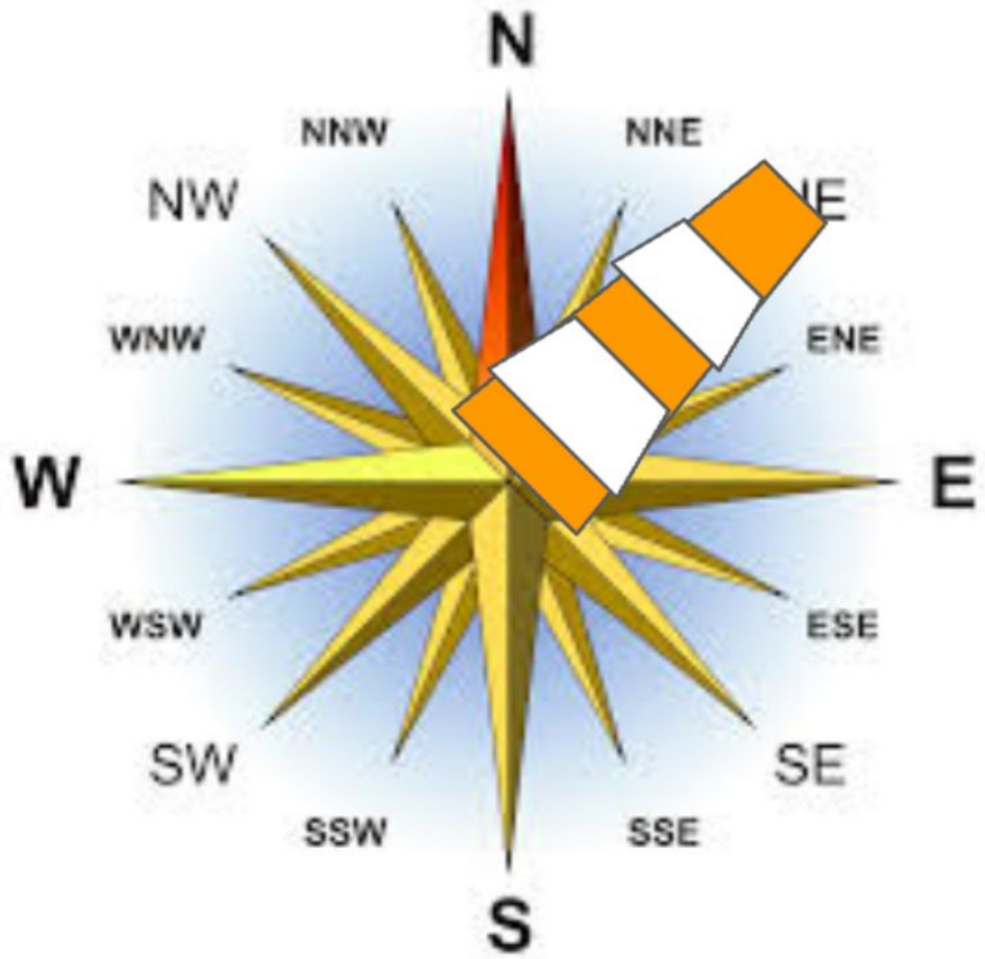
$$\text{Speed} = \frac{\text{distance}}{\text{time}} = \frac{2.6 \text{ feet}}{2 \text{ sec}} = 1.3 \text{ feet per second}$$

Is that fast?

LESSON 3 – NAMING THE WIND'S DIRECTION

If the TV meteorologist says to expect a "southerly wind" today, which direction will the wind be blowing?





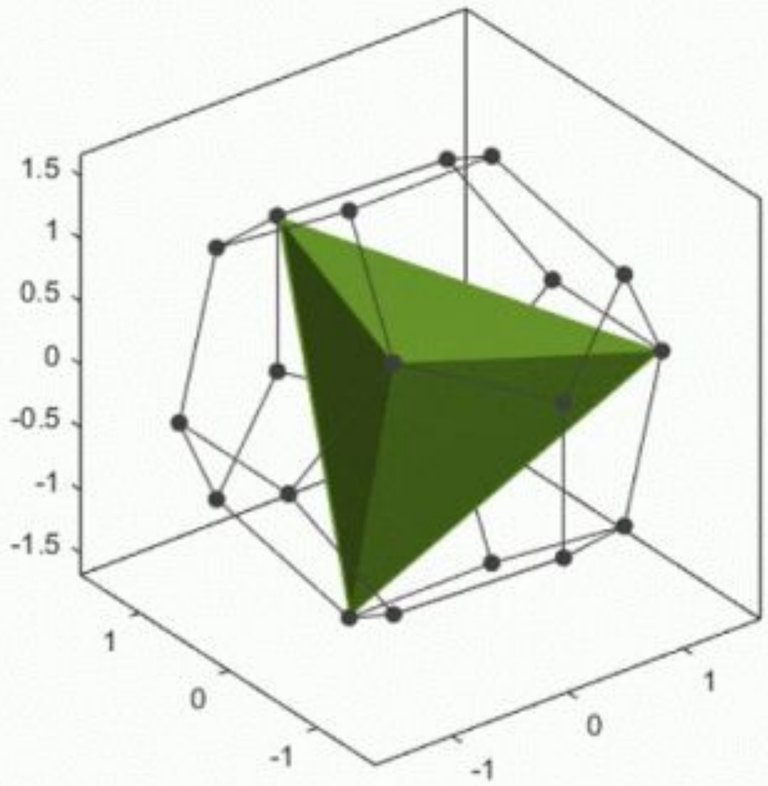
LESSON 3 - NAMING THE WIND'S DIRECTION

Wind directions are named for the direction from which the wind is blowing. So a "southerly wind" is coming from the south.

This makes reading the direction from a windsock a little tricky, since it's being blown by the wind. If the sock is pointing north east, the wind is coming from the opposite direction! What would we call the wind direction?

LESSON 3 – EXPERIENCE

Use your tool to collect wind data. Consider where you should place your device and what factors might affect your results.



LESSON 3 – DEMONSTRATE

Analyze your data and share your results with the class.

Are your results accurate?

How do you know?

MEET A PROFESSIONAL

Dr. Antonio Segalés
Weather Drone Engineer

DR. ANTONIO SEGALÉS
Weather Drone Engineer

- Research scientists and electrical engineer with the National Weather Center at the University of Oklahoma
- Developed the groundbreaking **CopterSonde**, a drone that is used to measure weather data
- The CopterSonde allows temperature, humidity, and wind speed data to be collected at higher altitudes, helping improve the accuracy of weather forecasts.

Read **this article** about how the CopterSonde is helping us understand severe storms.

Read more about the development of the CopterSonde in **this article** by Dr. Segalés from Bliss Science.

MEET A PROFESSIONAL

Dr. Tyler Bell
Research Tool Developer

DR. TYLER BELL
Research Tool Developer

- Research scientist and field meteorologist with the NOAA National Severe Storms Laboratory at the University of Oklahoma
- Assisted in developing the CopterSonde and Collaborative Lower Atmospheric Mobile Profiling System (CLAMPS)
- CLAMPS is a mobile laboratory that may allow forecasters to receive real-time data, significantly improving their ability to issue public safety warnings.

Watch **this video** to learn more about how CLAMPS works.

Read more about this innovative research tool **here**.

Did you notice the OU logo? Oklahoma is the national leader in severe weather research!

LESSON 3 – REVIEW

Reflect on what you've learned about wind.

Would you like to be a research scientist?

Photo Credit: Oklahoma Mesonet Instagram

LESSON 3 – CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 2: WIND

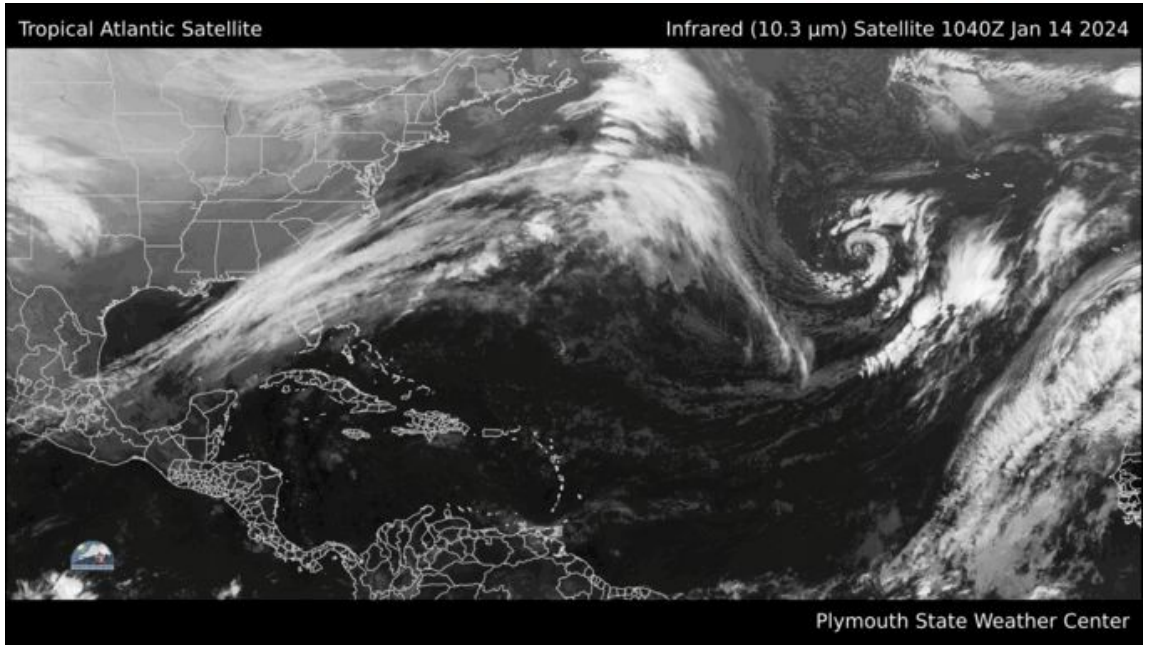
Driving Question: Why is it so windy in Oklahoma?

IS WIND THE SAME EVERYWHERE?

LESSON 4

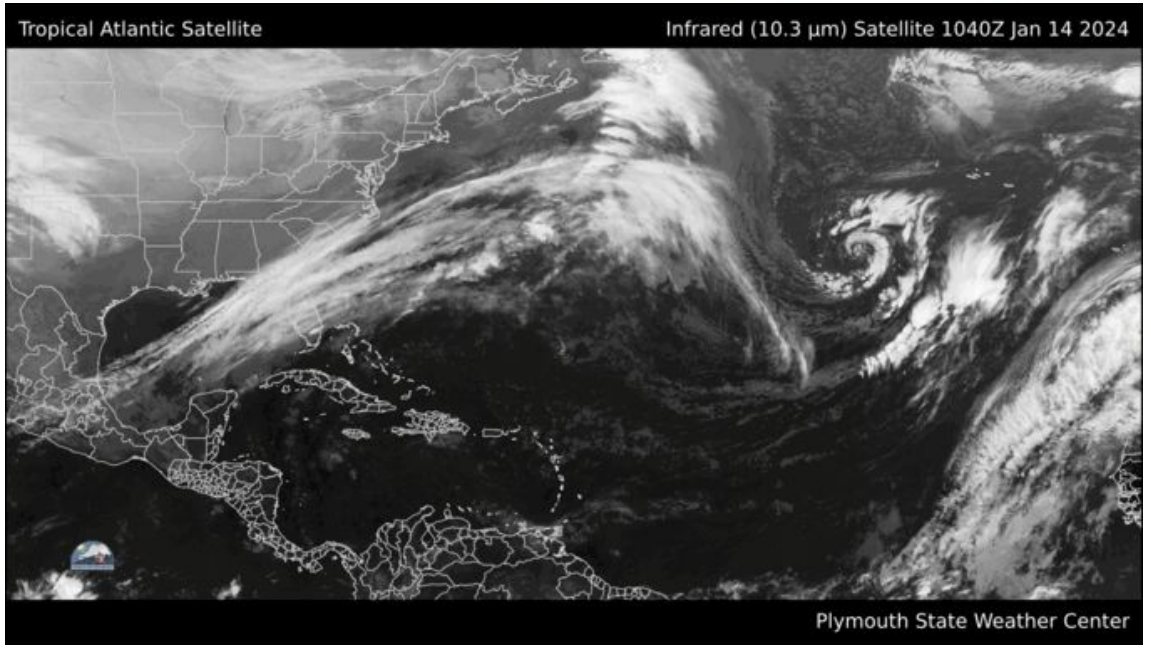
LESSON 4 – ENROLL

What do you notice as you watch the clouds moving?



LESSON 4 – ENROLL

What questions do you have about how the clouds are moving?



LESSON 4 – EXPERIENCE

- We know that wind is the result of changes in air pressure.
- We've just seen a timelapse video showing clouds moving in about the same patterns over 48 hours.
- We also know that some places like Oklahoma experience more wind than others.
- We have some ideas about how wind might be different depending on where you live, but we'd like to investigate more. What should we explore?

LESSON 4 – EXPERIENCE

What else do you know about wind?

Use your *What I Know* handouts and any other resources to discuss what you've learned so far with a partner.

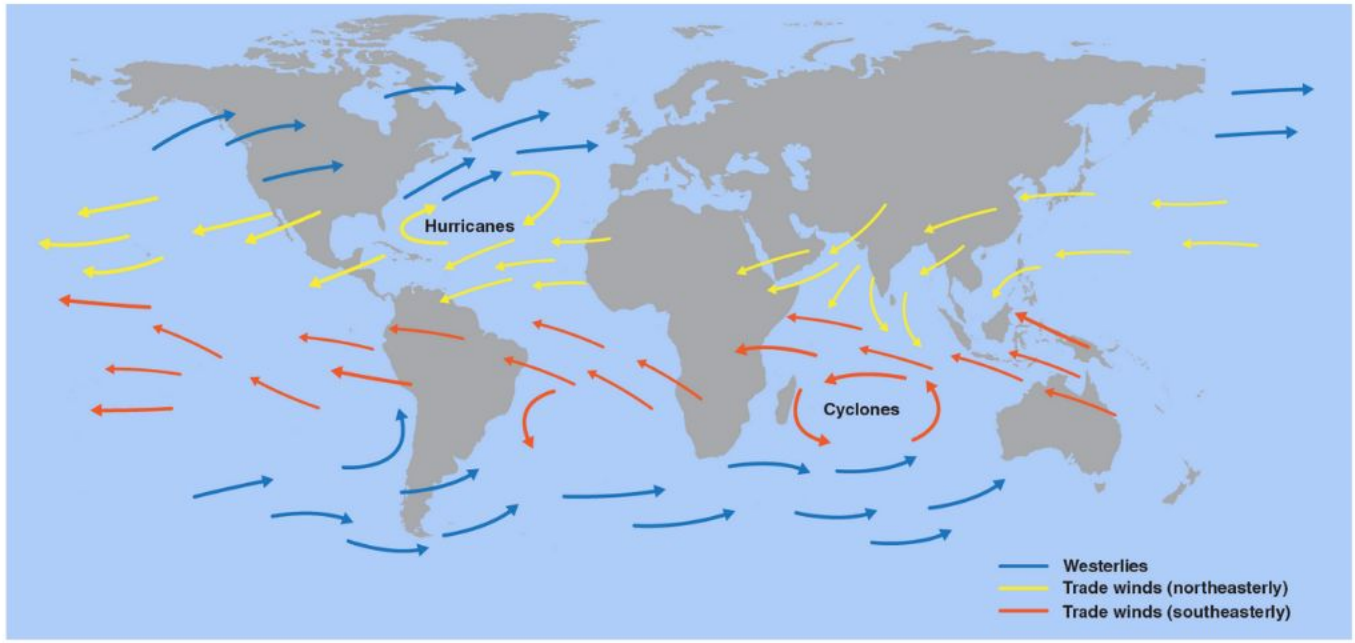
Discuss any experiences you've had with wind.

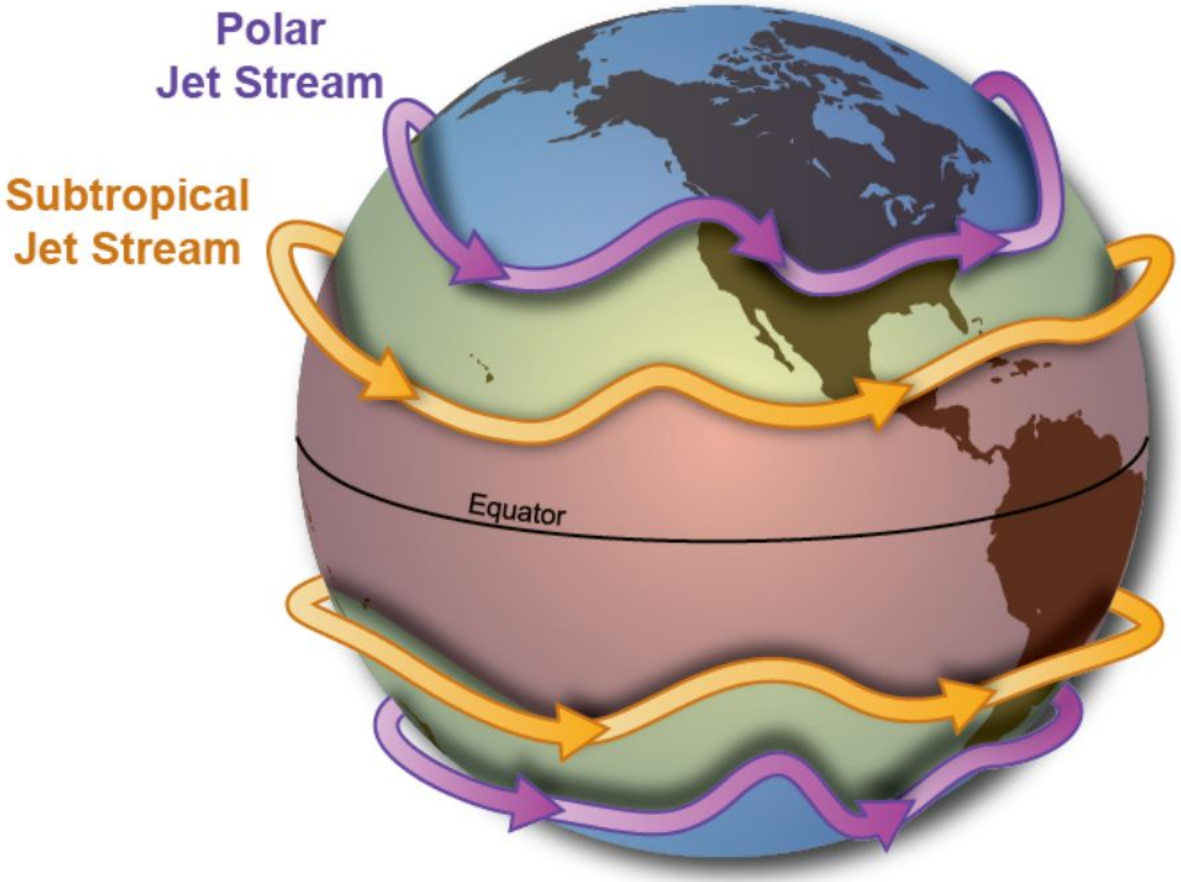
LESSON 4 – LABEL

Prevailing winds - winds that blow consistently in a certain direction over large regions.

- **Trade winds** - blow from east to west near the equator
- **Westerlies** - blow from west to east at higher latitudes

Did you notice these patterns during your investigation of wind?



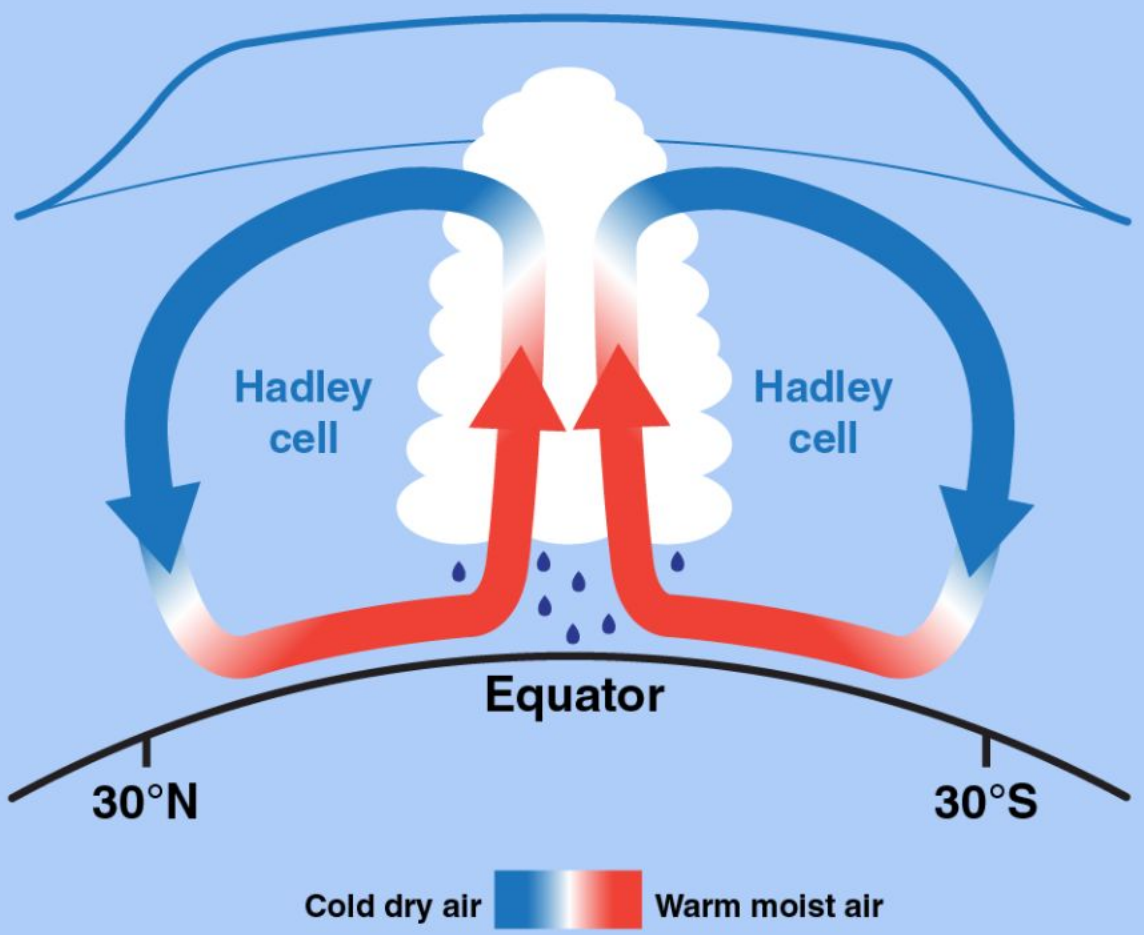


LESSON 4 – LABEL

- Wind doesn't just occur on the surface, but also occurs higher in the atmosphere (around 30,000 ft).
- These wind patterns are called jet streams.
- Jet streams blow from west to east and occur at boundaries between warm and cool air.
- Airplanes often fly in jet streams to help save fuel.

LESSON 4 – LABEL

- Why do these wind patterns occur?
  - The simple answer is *the sun*.
- What part of Earth receives the most sunlight?
  - *The equator*!
- What happens to warm air and cool air?
  - Warm air rises and cool air sinks, creating a *convection current*

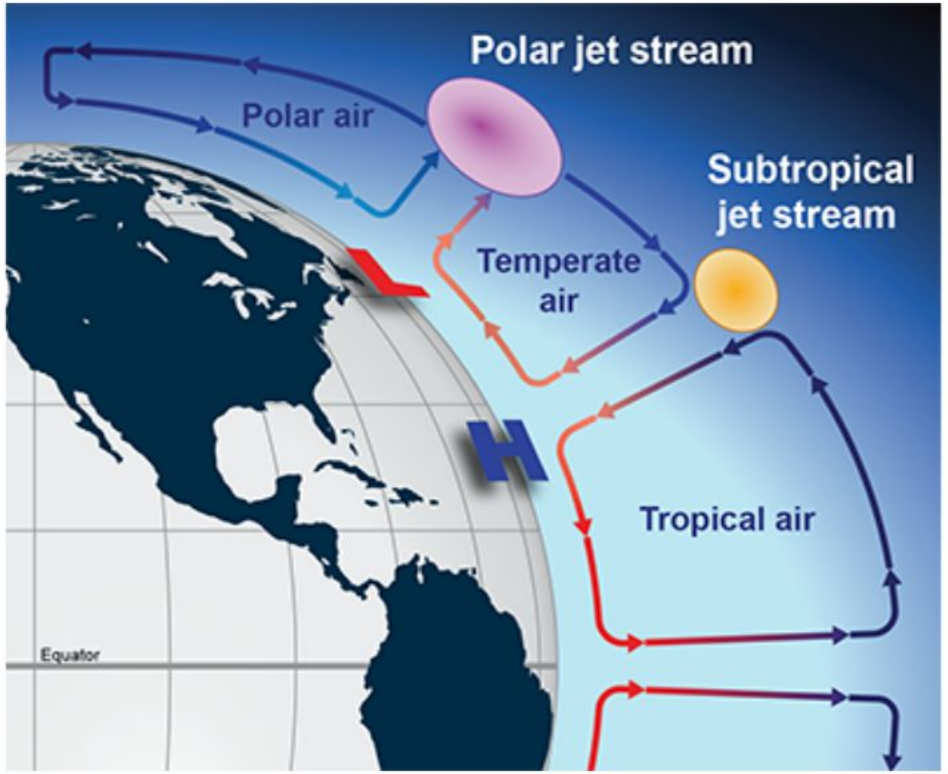


LESSON 4 – LABEL

These large convection currents are responsible for the global wind patterns we observe.

These are also the reason that warm fronts normally come from the south and cold fronts normally from the north (in the northern hemisphere).

Now we know what causes warm and cold winds, but why do prevailing winds blow east-west and west-east?



LESSON 4 – DEMONSTRATE

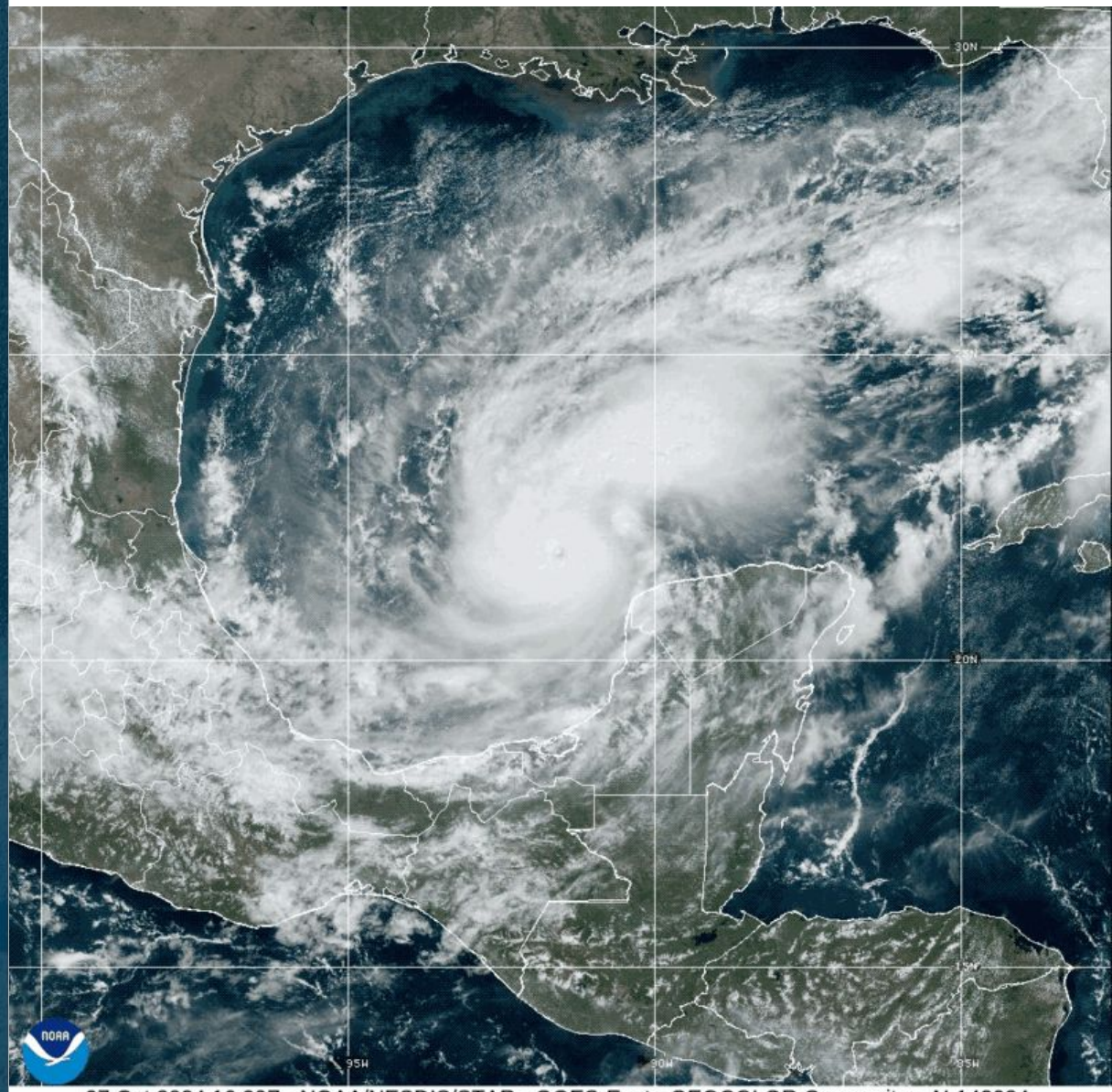
Could global wind patterns have to do with Earth's rotation?

LESSON 4 – LABEL

The **Coriolis Effect** is the force that causes air masses moving over Earth's surface to curve instead of moving in a straight line.

This is why prevailing winds don't move straight north or south.

The Coriolis Effect also causes hurricanes to rotate in different directions in the northern and southern hemispheres.



07 Oct 2024 16:20Z - NOAA/NESDIS/STAR - GOES-East - GEOCOLOR Composite - AL142024

LESSON 4 – REVIEW

Revise your initial models about wind movement using the key below. Remember not to erase any of your previous work!

Add: We think [evidence from activity or reading] supports PART of our model, but we want to add ____ to make it more accurate.

Remove: We think [evidence from activity or reading] contradicts ___ in our model, and we want to remove it or find out more about it.

Revise: We think [evidence from activity or reading] supports PART of our model, but we want to change ____ to make it more accurate.

Questions: We still have questions about ___.

LESSON 4 – CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

MODULE 2: WIND

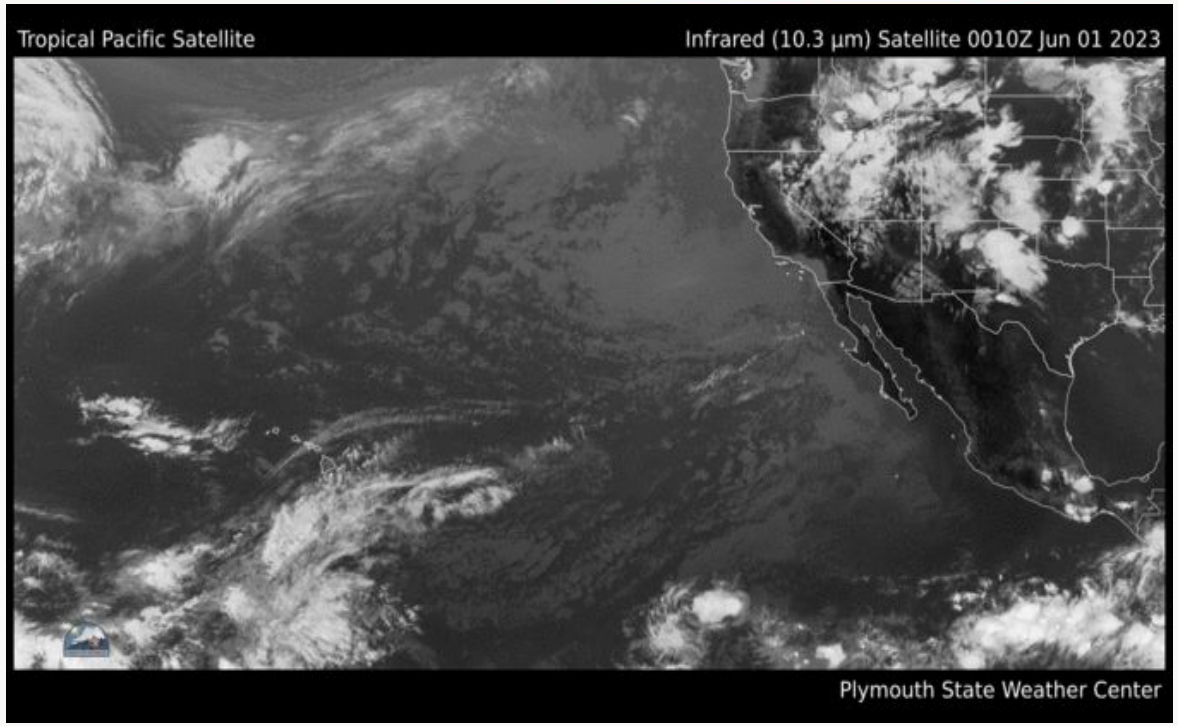
Driving Question: Why is it so windy in Oklahoma?

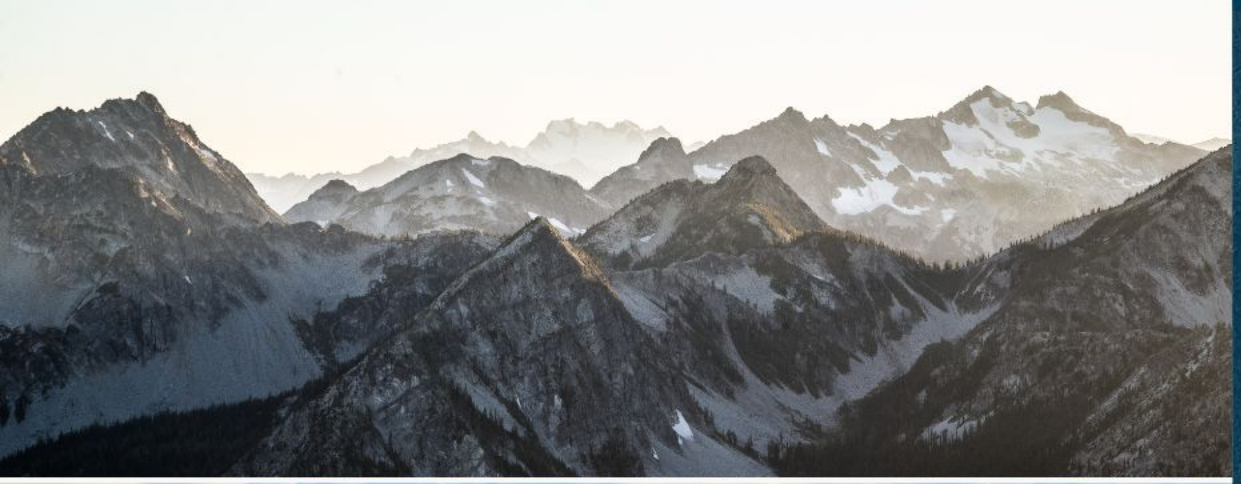
WHAT ELSE AFFECTS HOW WINDY IT IS WHERE I LIVE?

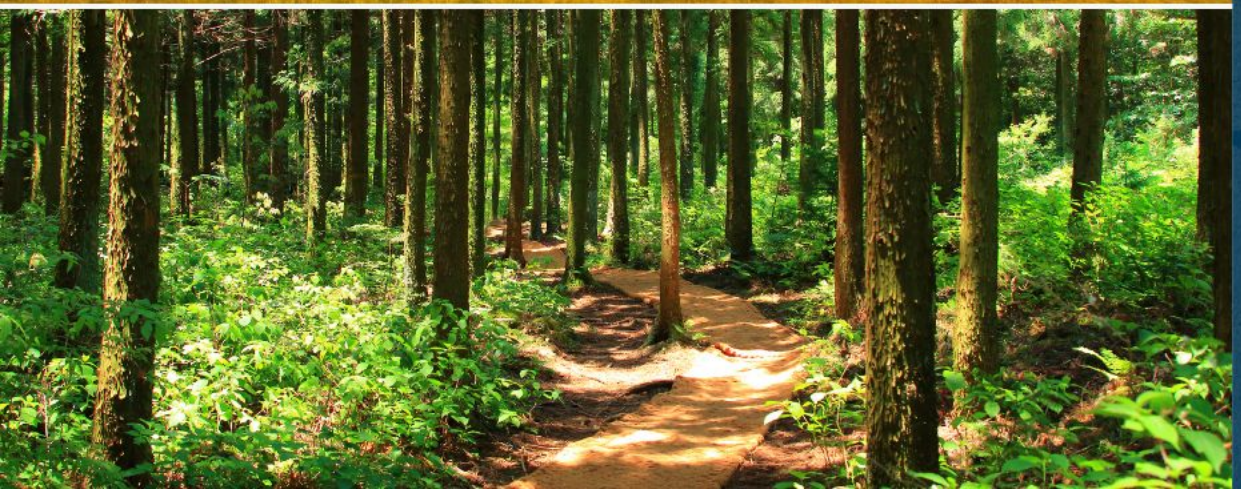
LESSON 5

LESSON 5 – ENROLL

In this image loop we see the jet streams of the northern hemisphere moving clouds towards the U.S. What happens when those clouds reach the land? How does their movement change?

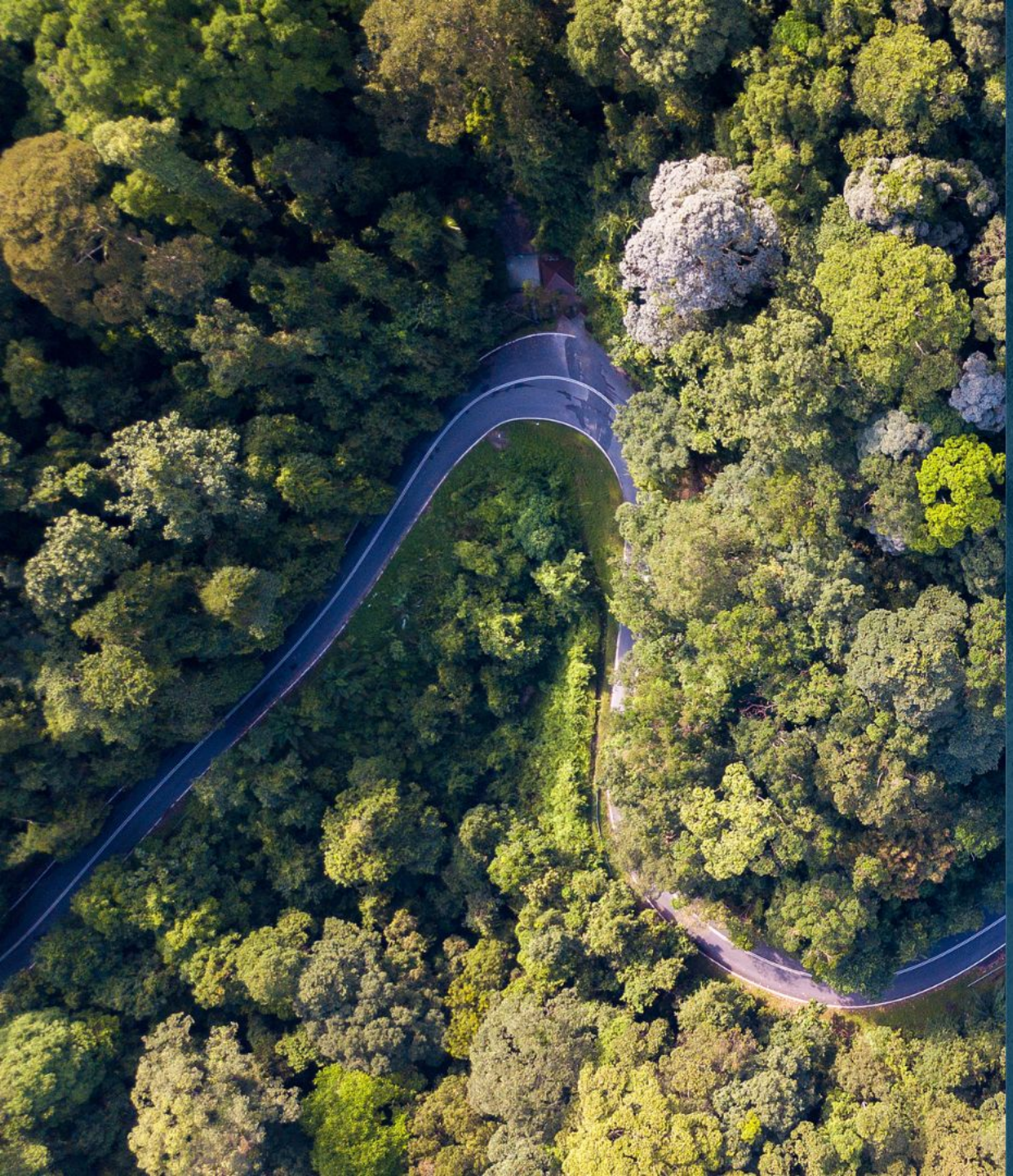






LESSON 5 – ENROLL

Which picture do you think would have the strongest winds? *Why?*



LESSON 5 – EXPERIENCE

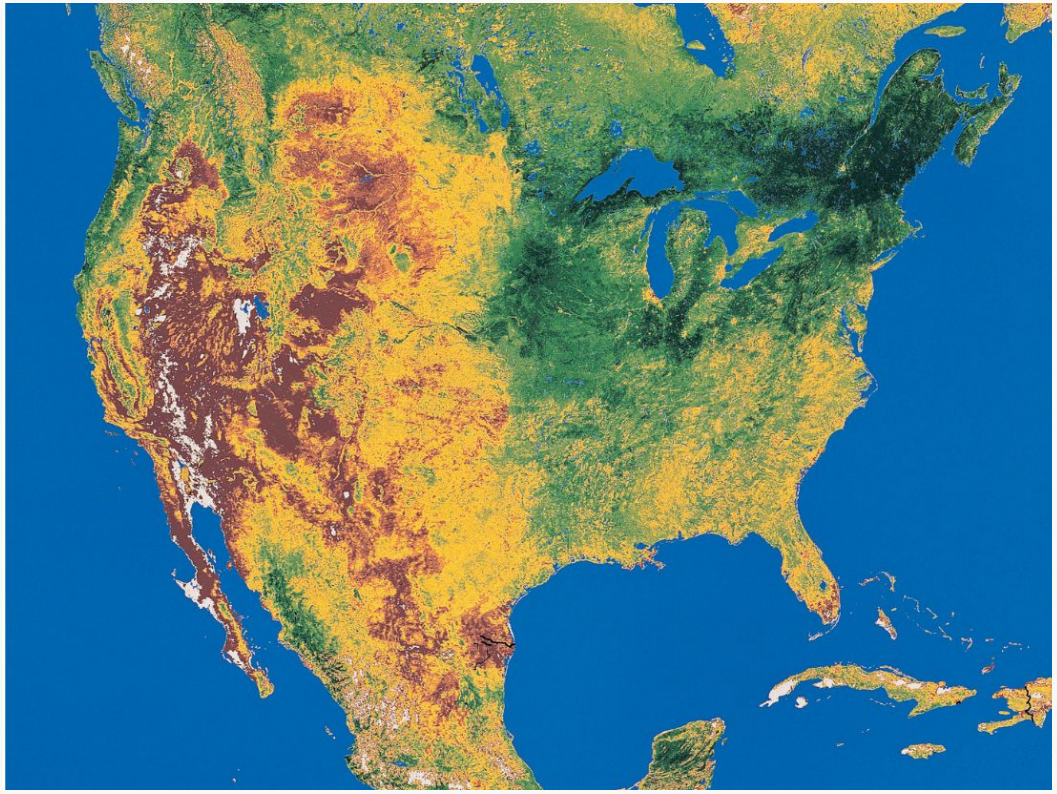
Let’s investigate how different environments can affect wind.

LESSON 5 – LABEL

Geographic features can have an effect on how wind flows.

When the surface is relatively smooth, there is less stuff to block the wind.

When there's stuff in the way, the wind will either be forced in a different direction or will dissipate.



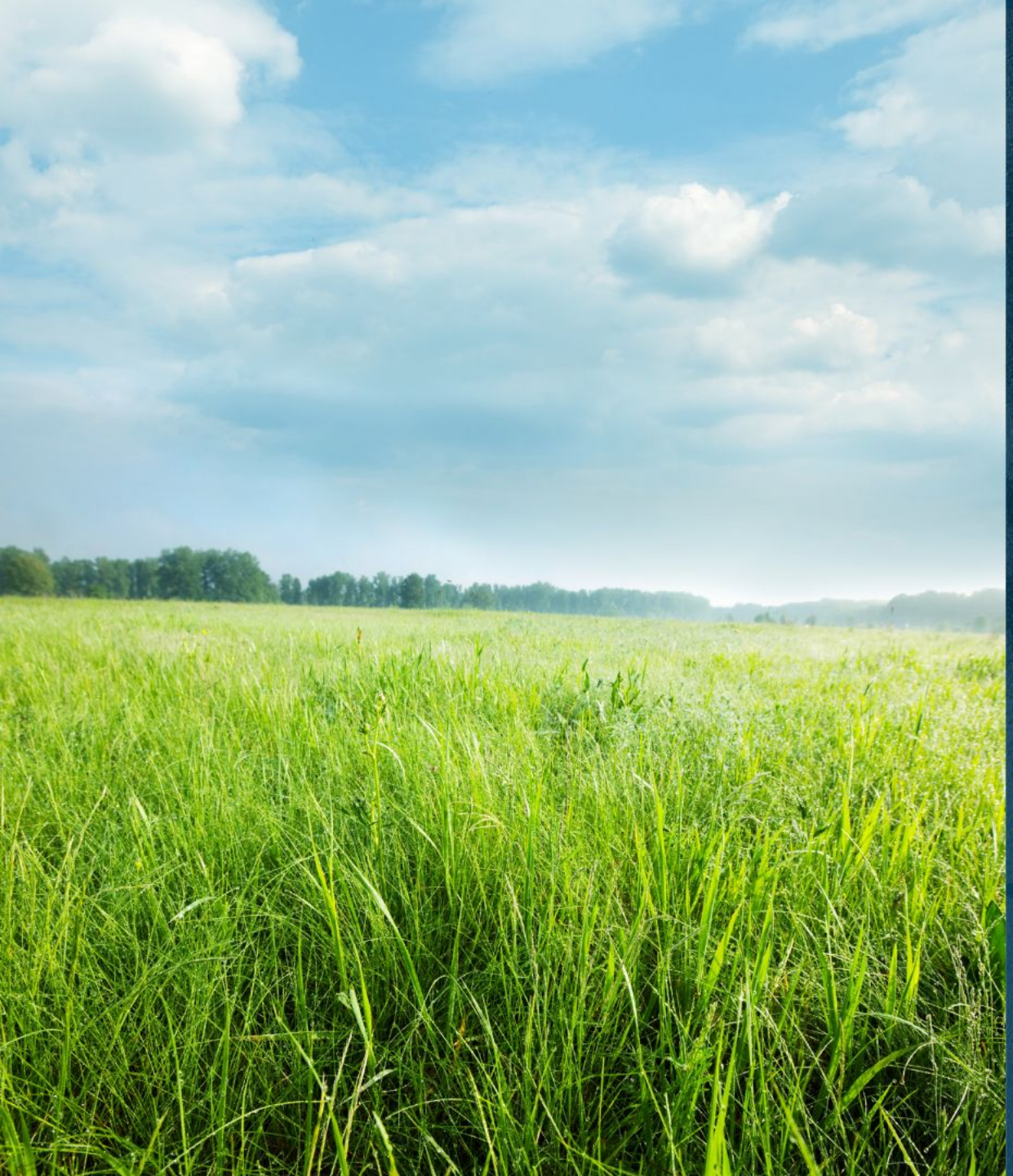
LESSON 5 – LABEL

When wind encounters mountains, it is usually forced upwards and over. The topography of mountain ranges can create unpredictable wind patterns and turbulence on the leeward side.

LESSON 5 – LABEL

A similar type of turbulence occurs as wind moves through forests.

The more dense a forest is, the more plants there are to interfere with the flow of the wind.



LESSON 5 – LABEL

Grasslands don’t have many large objects to interfere with the movement of wind.

Taller grasses can have some impact on wind due to more friction as wind moves over and through the grasses, but even tall grasslands generally have high wind speeds.

WHY IS IT SO WINDY IN OKLAHOMA?

LESSON 5 – DEMONSTRATE

Weather in any location is the combination of a lot of complex processes. Just the creation of wind includes many different factors!

What factors influence the wind in Oklahoma?

Let’s revise our initial models about what makes Oklahoma a windy place to live.

WHY IS IT IMPORTANT TO LEARN ABOUT WIND?

LESSON 5 – REVIEW

Learning about wind can help meteorologists keep people safe.

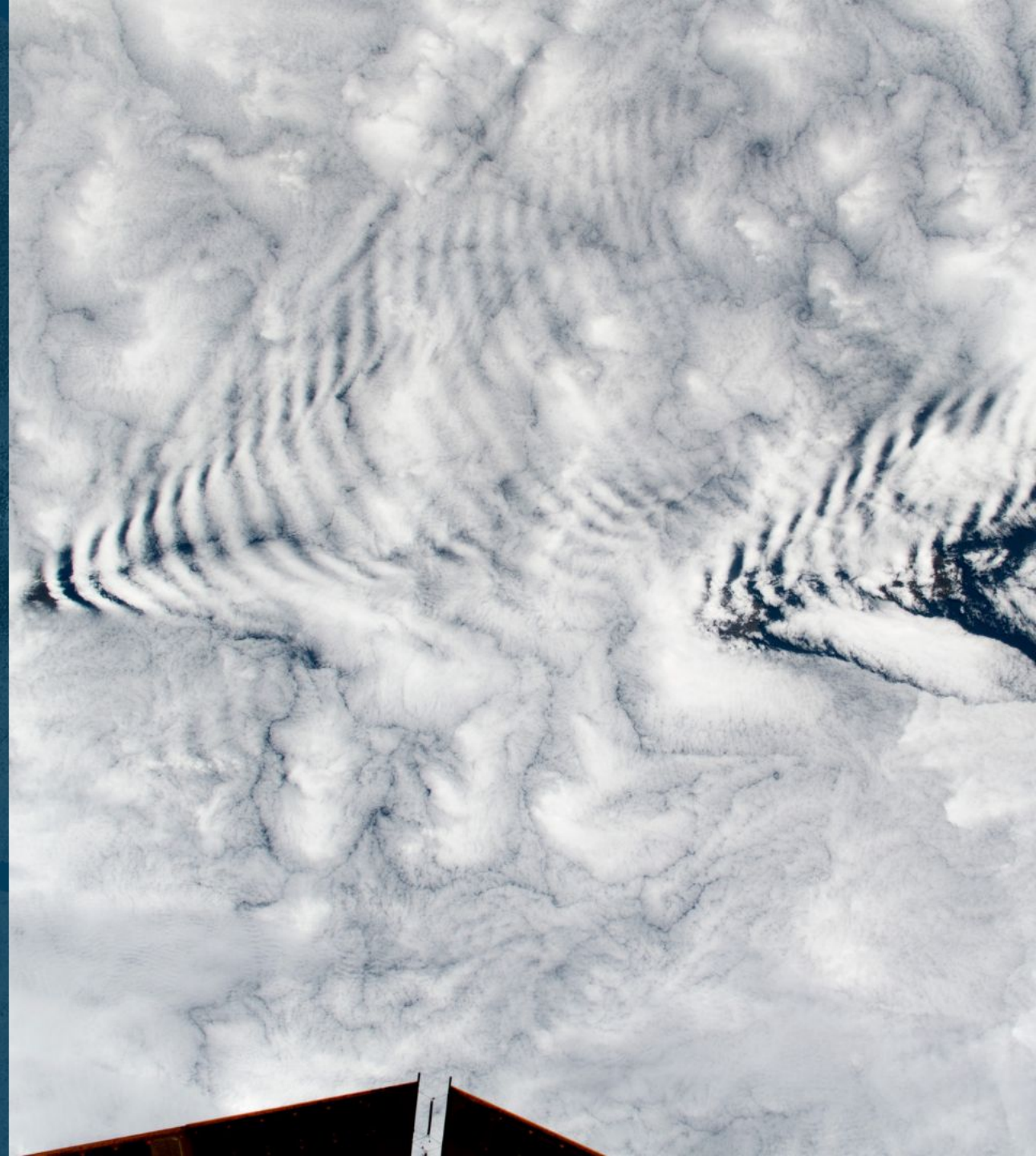
Who needs to know about wind safety? Here are a few examples:

- Homeowners
- Pilots
- Outdoor enthusiasts
- Drivers
- Farmers
- Anyone living in areas prone to thunderstorms
- Anyone living in coastal areas
- Anyone living in mountainous areas
- Anyone living in areas prone to fire

LESSON 5 – PHENOMENA IN THE SKY

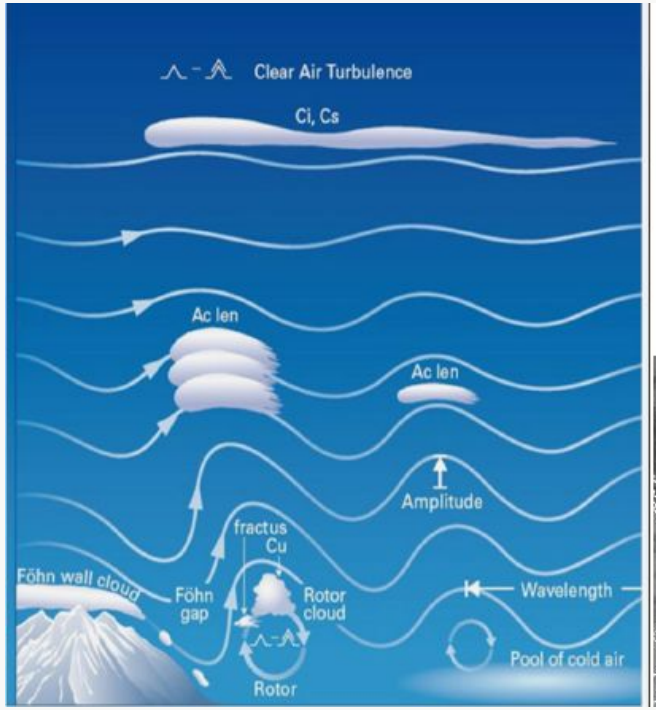
Have you ever seen clouds that make ripples like this?
These are called rotor clouds or wave clouds and they are very dangerous for pilots!

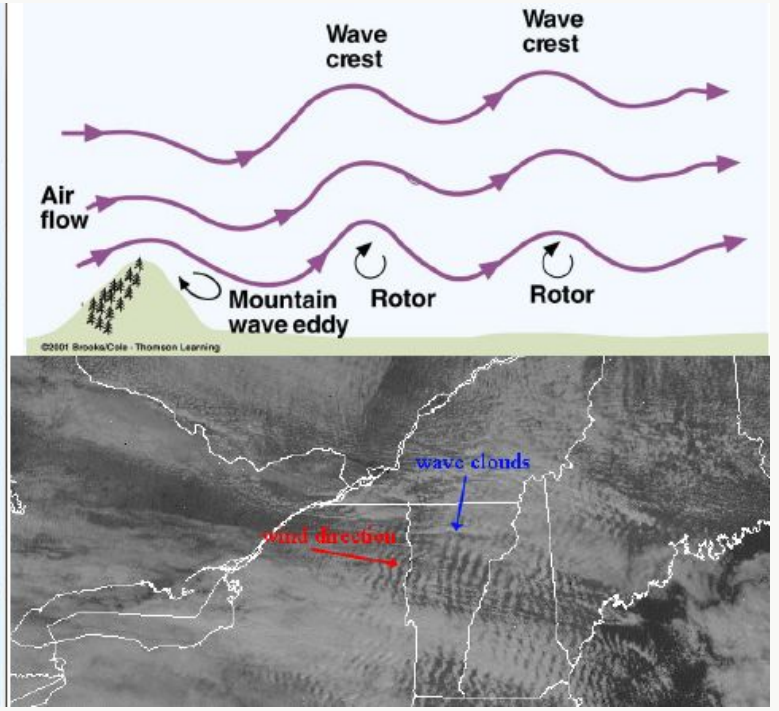
- Extreme turbulence
- Icing
- Altimeter error



LESSON 5 – PHENOMENA IN THE SKY

Rotor clouds usually form over mountains where the peaks cause interruptions in airflow.





LESSON 5 – PHENOMENA IN THE SKY

Is that a fire tornado?

The intense heat from wildfires can create their own windy environments.

While it might seem like wind would put out a fire, wind can actually increase the spread of wildfires!

Check out **this article** about how researchers at the University of Oklahoma are working to improve fire weather forecasting.

LESSON 5 – PHENOMENA IN THE SKY

Strong winds can cause damage to homes and property and can create other unsafe conditions.

LESSON 5 – REVIEW

Can we predict unsafe wind conditions?

Because the create of wind is very complex, it can be difficult to predict severe wind events.

Meteorologists use different kinds of radar such as Doppler to scan the surface and higher regions of the atmosphere.

These clues can help them predict changes in wind's behavior but there is still much to learn!

LESSON 5 – REVIEW

You can explore some different radar readings **here**.

Given what you know about factors that affect wind, why do you think it's important to measure wind at different altitudes?

LESSON 5 – CELEBRATE

Celebrate every effort! High fives, team chants, have a treat, etc.

WEATHERING THE STORM

Meteorology Curriculum

STUDENT HANDOUTS

Tulsa Regional **STEM** Alliance

COOPERATIVE INSTITUTE FOR SEVERE AND HIGH-IMPACT WEATHER RESEARCH AND OPERATIONS

CIWRO

Name _____ Date_____

Birds of a Feather

Record observations of how a light object like a feather behaves when there is a little, a lot, or no air movement. What do you see? What do you feel? Use words and/or pictures to describe your observations.

No Fan (no air movement)	Close To The Fan (a lot of air movement)	Far From The Fan (a little air movement)

Let's Brainstorm!

We have a fan to create wind in the classroom, but what about in nature? Where do you think wind comes from? Let's brainstorm some ideas. If you get stuck, consider the following questions:

> *Have you been to any places that aren't very windy? How are they different from Oklahoma? Have you been to any places that are really windy? How do they compare to Oklahoma?*

Record your thoughts below.

_____

_____

_____

_____

Name _____ Date_____

Weather Maps

This map shows some weather data collected across our region.

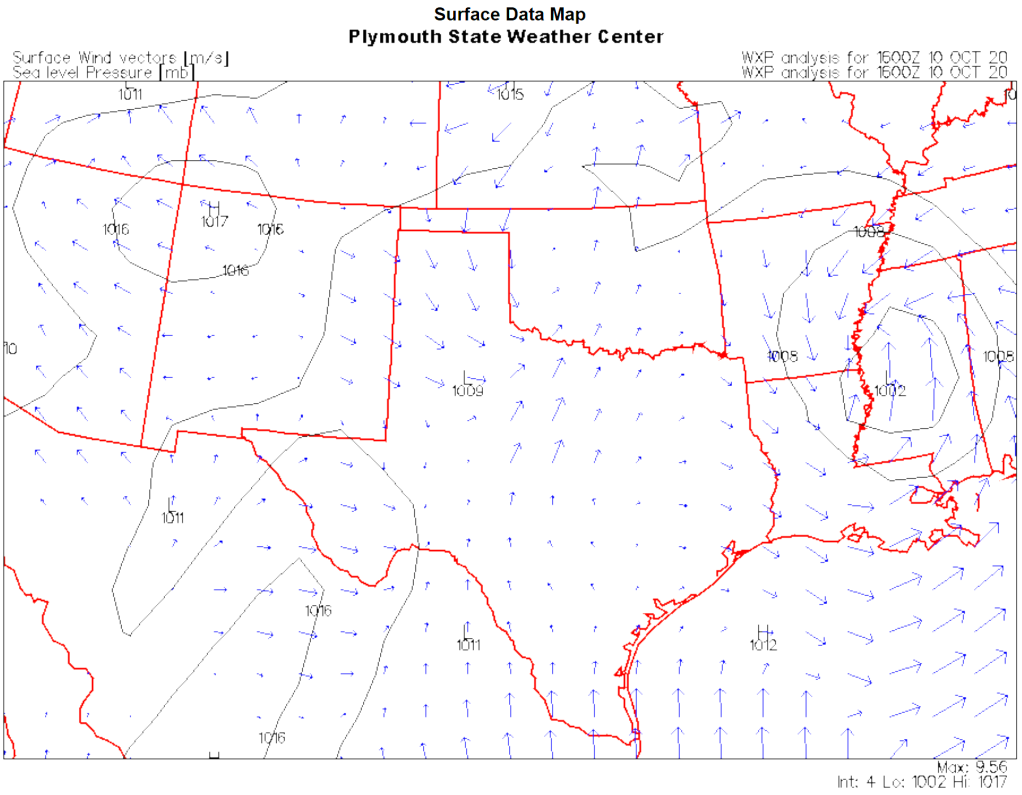


Photo Credit: https://vortex.plymouth.edu/wxp

1. What do you notice about this map?

_____

_____

2. What do you think the numbers and/or symbols might mean? Why do you think so? Is there anything on the map that supports your ideas?

_____

_____

Pause for class discussion

What causes wind?

Use words and pictures to create an initial model that describes the connection between air pressure and wind. Include why you think Oklahoma might be more windy than some other areas. Remember that this is an initial model that represents your current thoughts and ideas. These models will change as we learn more about wind.

Include in your model:

- High and low air pressure
- Wind direction
- Geography or land features that might influence wind in different locations
- Zoom in to show what air molecules are doing

Name _____ Date_____

Where's the Wind?

Let's take another look at the map we studied previously. Now we know that the numbers indicate the **sea level pressure**, and some pressure readings have H or L above them to indicate higher or lower pressure than the surrounding areas. We also know that the lines are **isobars** that are drawn around areas of equal pressure. The arrows represent wind direction and velocity (speed).

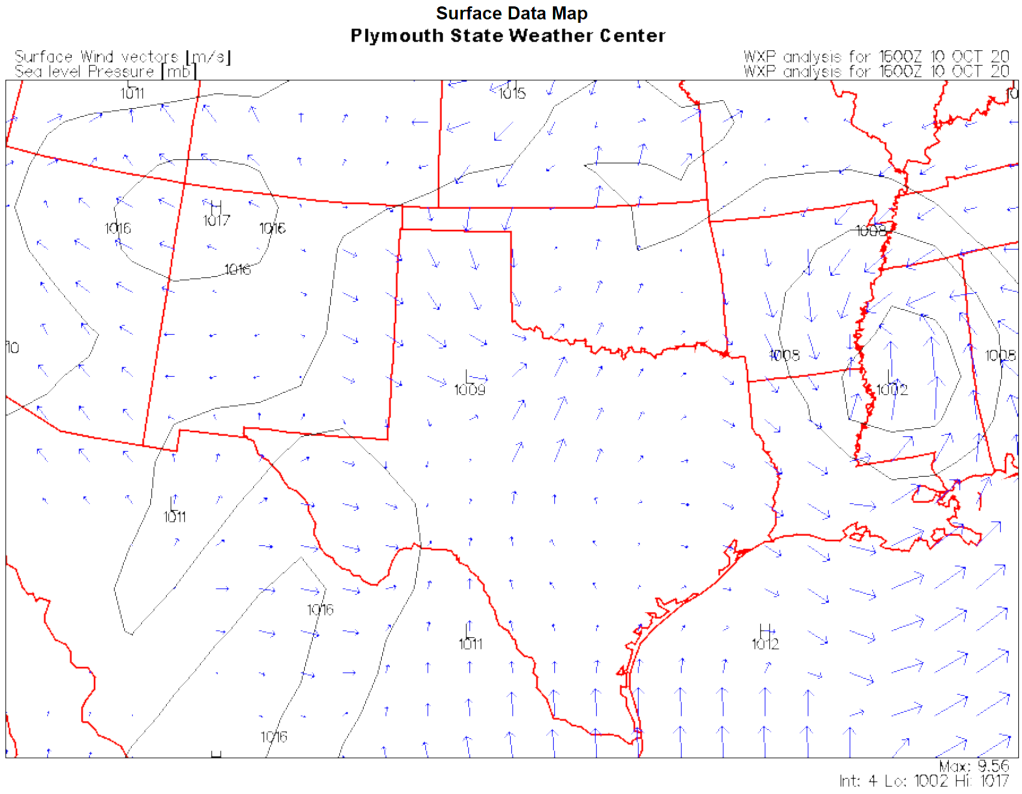


Photo Credit: https://vortex.plymouth.edu/wxp

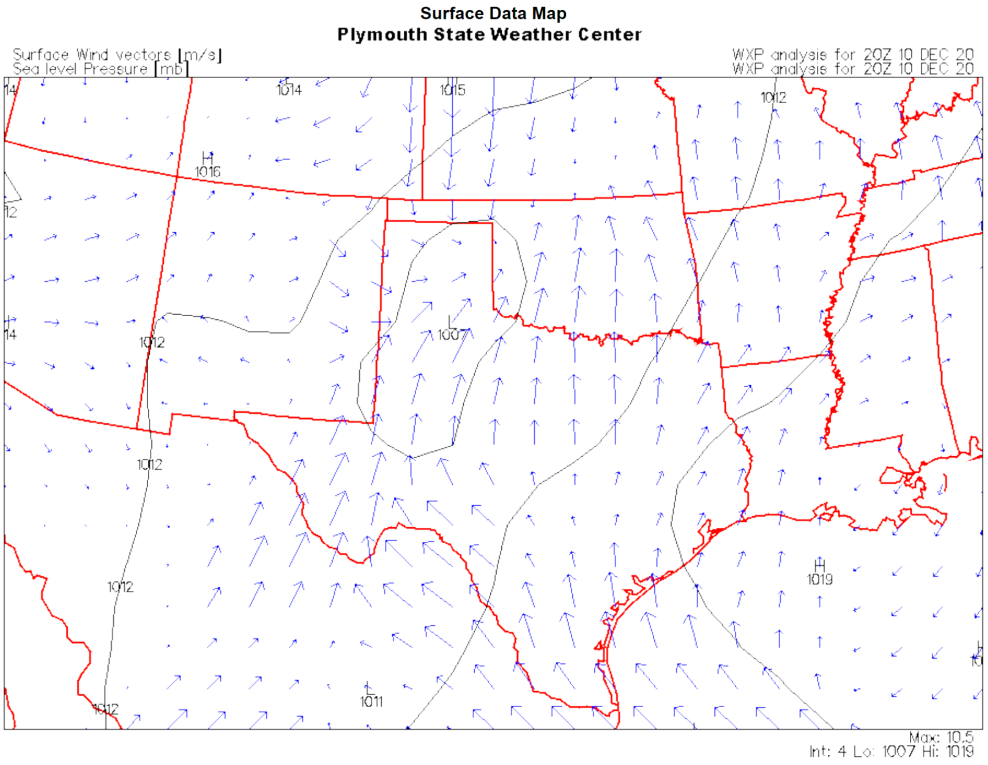
1. Consider the air pressure readings and wind vectors together. What patterns do you notice? You can also use a highlighter or other colored writing tool to indicate your observations on the map.

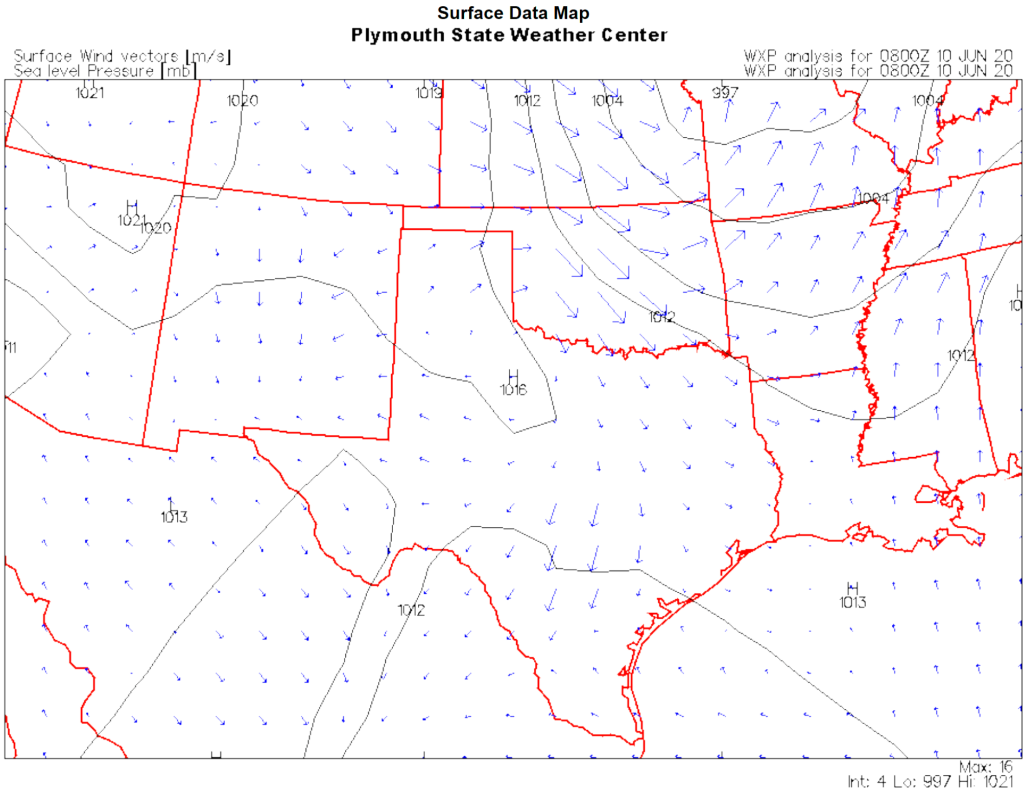
_____

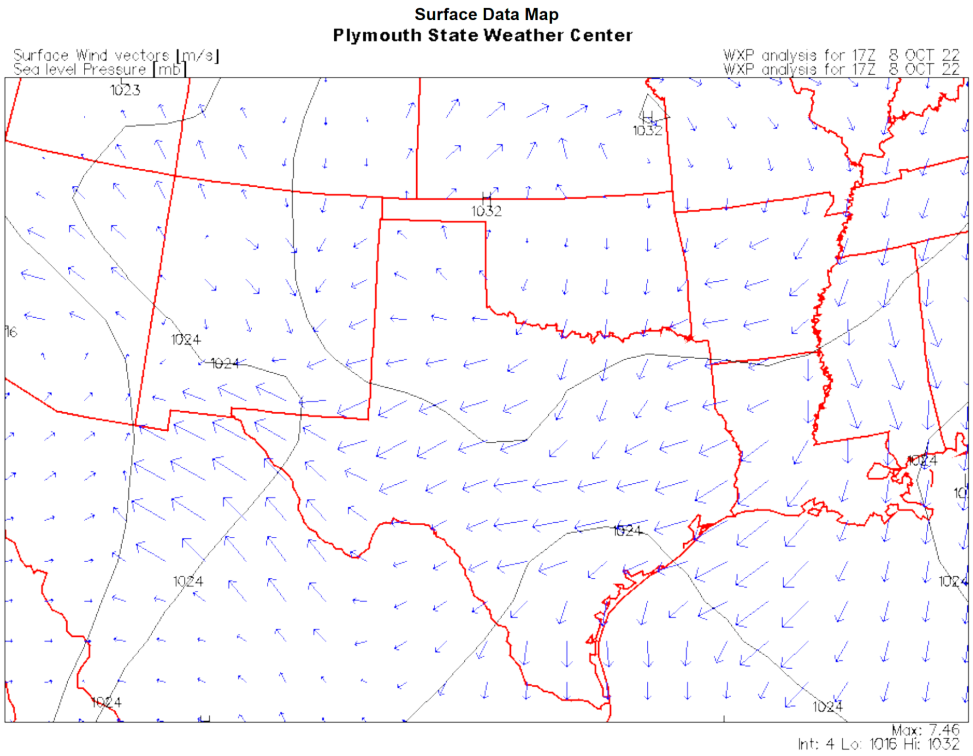
_____

Now, examine a couple more maps from different days and times.

Photo Credit for all maps: https://vortex.plymouth.edu/wxp







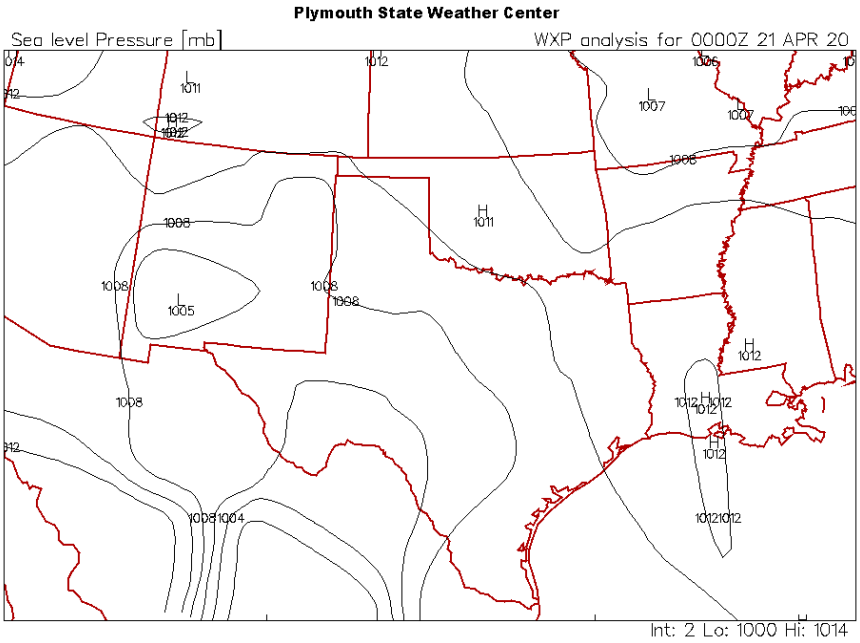
3. What patterns did you see in all of the maps? Consider things such as where wind comes from and where it moves to, why the wind is sometimes stronger, how wind moves in relation to High and Low pressure areas. You can also use a highlighter to note any patterns you see on the maps.

Name _____ Date_____

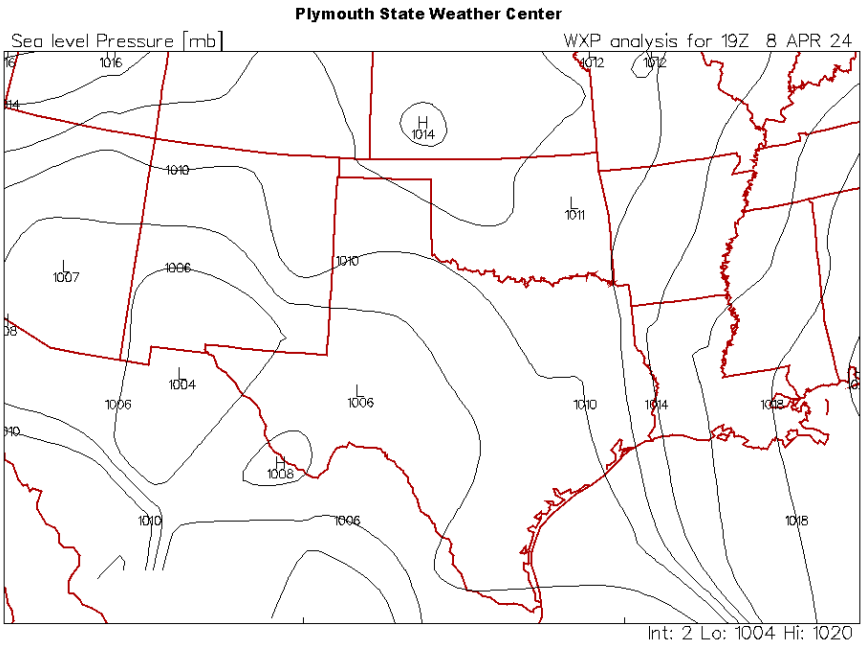
Think Like a Meteorologist

Now that you've determined the relationship between atmospheric pressure and wind, let's put it to the test! On these next few maps, you'll see either the pressure readings *or* the wind observations. Draw in the one that's missing.

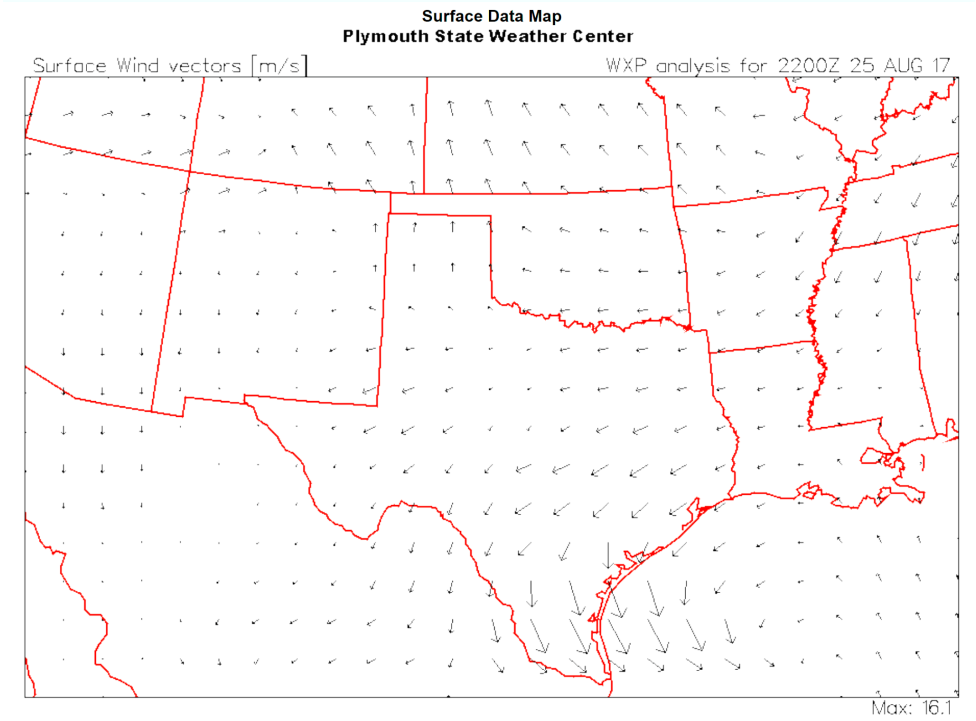
1.



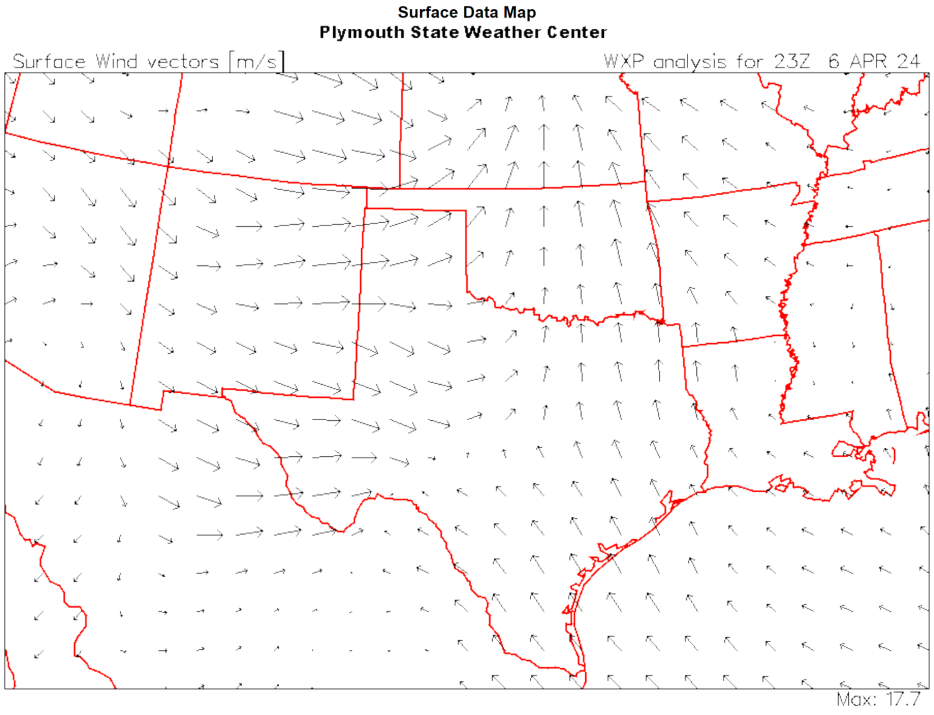
2.



3. For these maps, you do not need to add the pressure readings, just draw the isobars and indicate High or Low.



4.

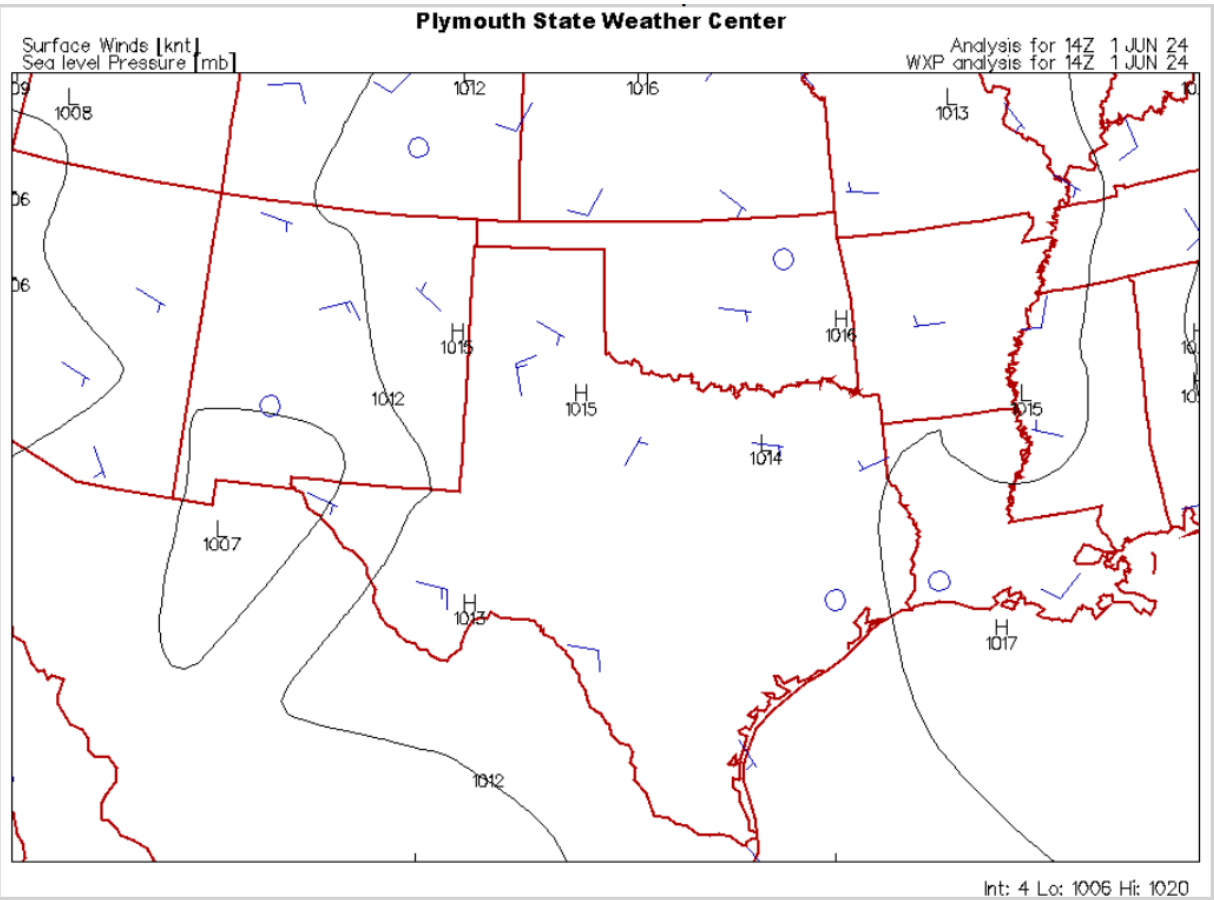


Name _____ Date_____

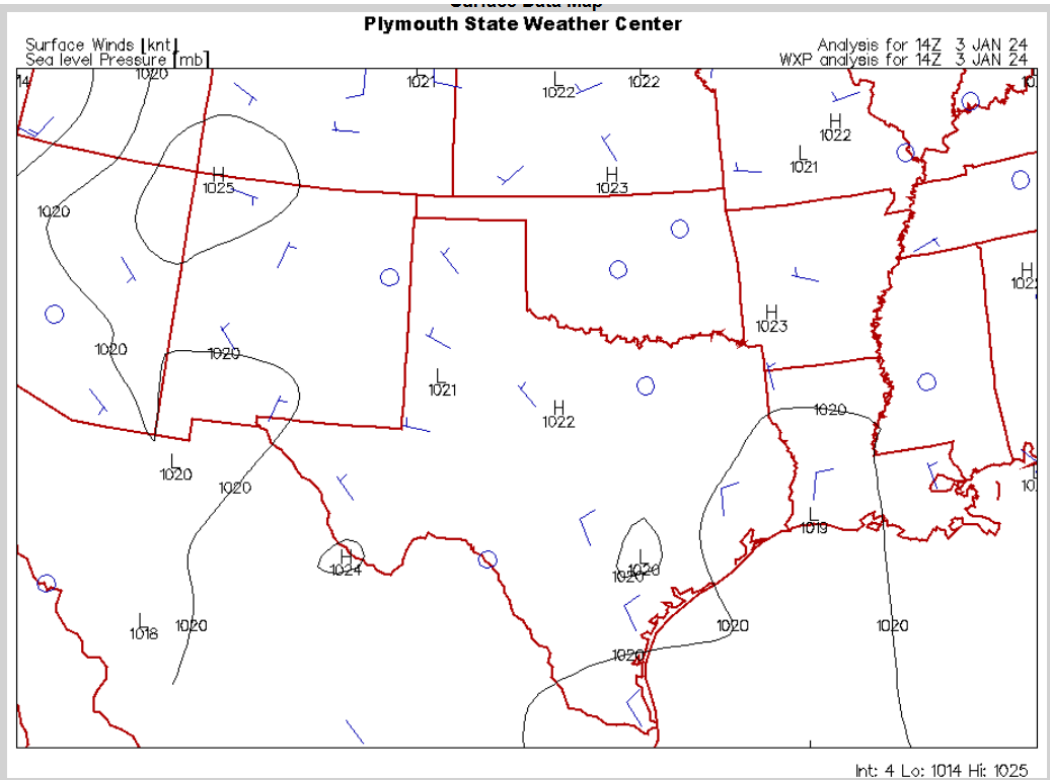
Where the Wind Blows

Now that you know a little more about how meteorologists predict windy weather, it's your turn to give it a try. The maps below have the sea level pressure indicated by isobars and the wind direction and speed indicated by wind barbs. Can you draw some arrows to show how the wind is moving? Indicate the direction of the wind plus the speed by making your arrows larger or smaller.
All maps are from https://vortex.plymouth.edu/myowxp/sfc/ovrmap-a.html

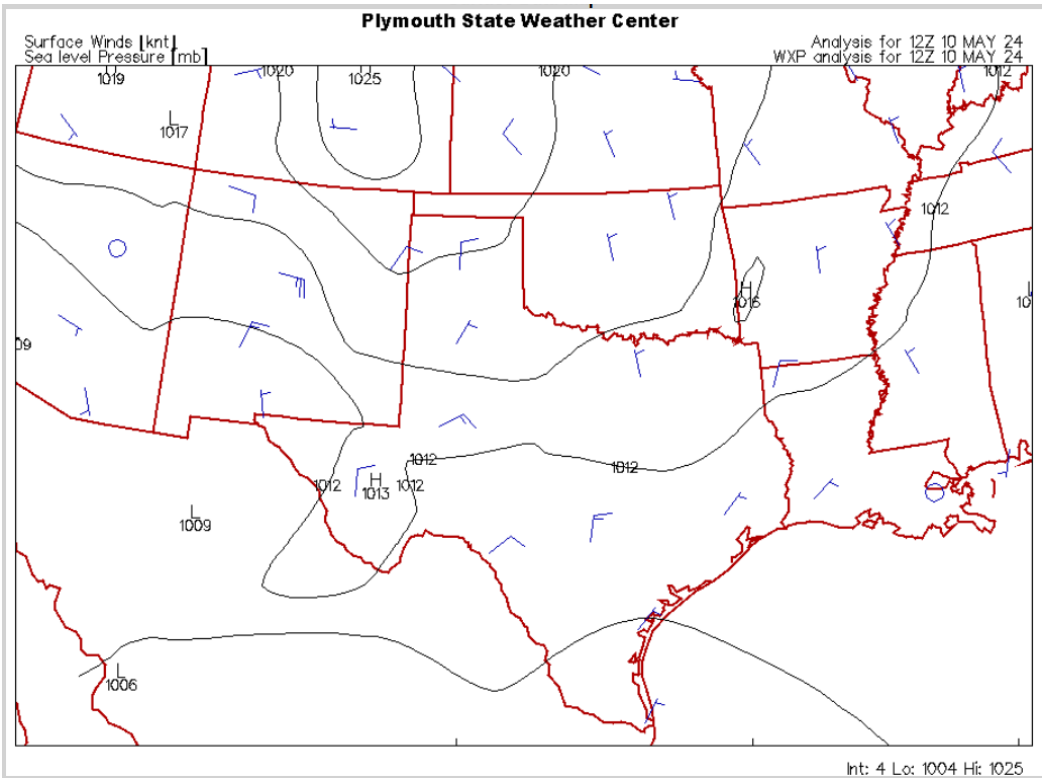
1.



2.


Plymouth State Weather Center
Surface Winds [knt]
Sea level Pressure [mb]
Analysis for 14Z 3 JAN 24
WXP analysis for 14Z 3 JAN 24
Int: 4 Lo: 1014 Hi: 1025

3.


Plymouth State Weather Center
Surface Winds [knt]
Sea level Pressure [mb]
Analysis for 12Z 10 MAY 24
WXP analysis for 12Z 10 MAY 24
Int: 4 Lo: 1004 Hi: 1025

Name _____ Date_____

Module 2 - What I Know

Lesson 1

- ☐ What atmospheric (air) pressure is
- ☐ Why surface pressure and sea level pressure might be different for the same location
- ☐ What causes high pressure
- ☐ What causes low pressure
- ☐ What isobars are and how they're used
- ☐ What causes wind
- ☐ How temperature and air pressure are related

What I Know	How I Know, I Know It

Name _____ Date_____

Pick A Paper

Materials

- 1 piece of plain paper
- 1 sheet of newspaper
- 1 ball
- 1 ruler or paint stir stick

Experiment Phase One

1. Place the ruler or stir stick perpendicular to the edge of the desk. Part of the ruler should be on the desk and part of it should hang off the edge.
2. Predict what will happen if you drop the ball on the end of the ruler that is hanging off the table.

_____

_____

3. Drop the ball on the part of the ruler hanging off the desk. Choose a height to drop the ball from that is comfortable and repeatable; you will need to drop from this height multiple times.
4. Describe what happened. Consider how each part of the system behaved.

_____

_____

_____

_____

5. You can repeat this phase a few times to check your results. Note any differences between trials below.

6. How do the results compare to your predictions?

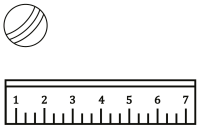
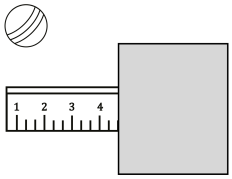
Experiment Phase Two

7. Place the ruler on the desk again as you did in Phase One.
8. Cover the part of the ruler on your desk with a sheet of paper.
9. Predict what will happen if you drop the ball on the end of the ruler that is hanging off the table. Consider what might happen to the ball, the ruler, and to the paper.

10. Drop the ball on the part of the ruler hanging off the desk from the same height used in Phase One.
11. Describe what happened. Consider how each part of the system behaved.

12. How do the results compare to your predictions?

13. Why do you think this happened? Develop a model to explain why the ruler system behaves the way it does with no paper vs. with paper. Include things you can't see, such as air molecules. Indicate movement of objects by using blue arrows. Use red arrows to indicate any forces at work.

No paper	With Paper
	

Pause for class discussion

Experiment Phase Three

14. Place the ruler again as you did in Phases One and Two.

15. Cover the part of the ruler on your desk with the sheet of newspaper. Unfold the newspaper so that it is fully spread out. Try to flatten creases as much as possible.

16. Predict what will happen if you drop the ball on the end of the ruler that is hanging off the table. Consider what might happen to the ball, the ruler, and

to the newspaper. Will the system behave the same or differently than the regular paper?

17. Drop the ball on the part of the ruler hanging off the desk from the same height used in the other Phases.
18. Describe what happened. Consider how each part of the system behaved.
19. How do the results compare to your predictions?
20. Do these results support or contradict your previous ideas? Can you provide evidence to support this claim?

Name _____ Date_____

Under Pressure

What do we know?

We saw that when we placed a larger paper over the ruler, the ruler moved less than when we used a smaller paper.

1. We know this was not due to the weight of the paper because:

_____

_____

2. We have some evidence that air pressure makes the ruler harder to move when a paper is covering it:

_____

_____

We can apply math to provide even more evidence that there is greater air pressure acting on a larger paper.

3. We know the average air pressure at sea level is _____.
4. To find the amount of air pressure acting upon a regular sheet of paper versus a newspaper, we first need to find the _____of each paper.
5. We can do that by:

_____

_____

6. We will need the following materials:

-
-
-
-

Let's calculate!

Object	Length (in)	Width (in)	Surface Area (in^2)	Pounds of Pressure (lbs)

Show your work for all calculations

7. What if we folded or wadded the newspaper into a size smaller than the regular paper? Which one would have a greater stabilizing effect on the ruler? Provide some mathematical evidence to support your claim.

Name _____ Date_____

Internet Safety

Reliable Sources

Sources that are off limits	
Recommended sources	
We'll know a source is reliable if...	

Ethical Use

We can avoid plagiarism by...	
We should cite a source when...	
We can use AI to...	
We do not use AI to...	

Legal Use

Things that should be cited include...	
Things that don't have to be cited...	

Name _____ Date_____

Tools and Units

Measurement Tools

Barometer	What it is: How it's used: How it works: Other important information: Peers I can go to if I have more questions:
Radiosonde	What it is: How it's used: How it works: Other important information: Peers I can go to if I have more questions:

Measurement Units

Millibars	Abbreviation: What it is: How it's measured: What it means: Information that will help me understand it: Peers I can go to if I have more questions:
Pascal	Abbreviation: What it is: How it's measured: What it means: Information that will help me understand it: Peers I can go to if I have more questions:

Standard Atmosphere	Abbreviation: What it is: How it's measured: What it means: Information that will help me understand it: Peers I can go to if I have more questions:
Millimeters or Inches of Mercury	Abbreviation: What it is: How it's measured: What it means: Information that will help me understand it: Peers I can go to if I have more questions:

Name _____ Date_____

Careful Conversion

We can use what we know about standard seal level pressure to convert between the different units of measurement.

1. What is standard sea level pressure for each of the following units?

Millibars (mb)	Pascals (Pa)	Standard Atmospheres (atm)	Pounds per Square Inch (PSI)	Millimeters or Inches of Mercury (mmHg or inHg)

2. Suppose we measured the air pressure outside today at 31 inHg. What would be the pressure in millibars?

3. Determine if the following expressions are true or false. Provide evidence for each.
   a. 14.9 psi > 101340 Pa
      True/False
      Evidence:

   b. 1140 mmHg > 1.5 atm
      True/False
      Evidence:

   c. 1015.3 mb > 29.45 inHg
      True/False
      Evidence:

4. Choose any pressure reading from this map and convert the air pressure to each unit of measurement we've learned about.

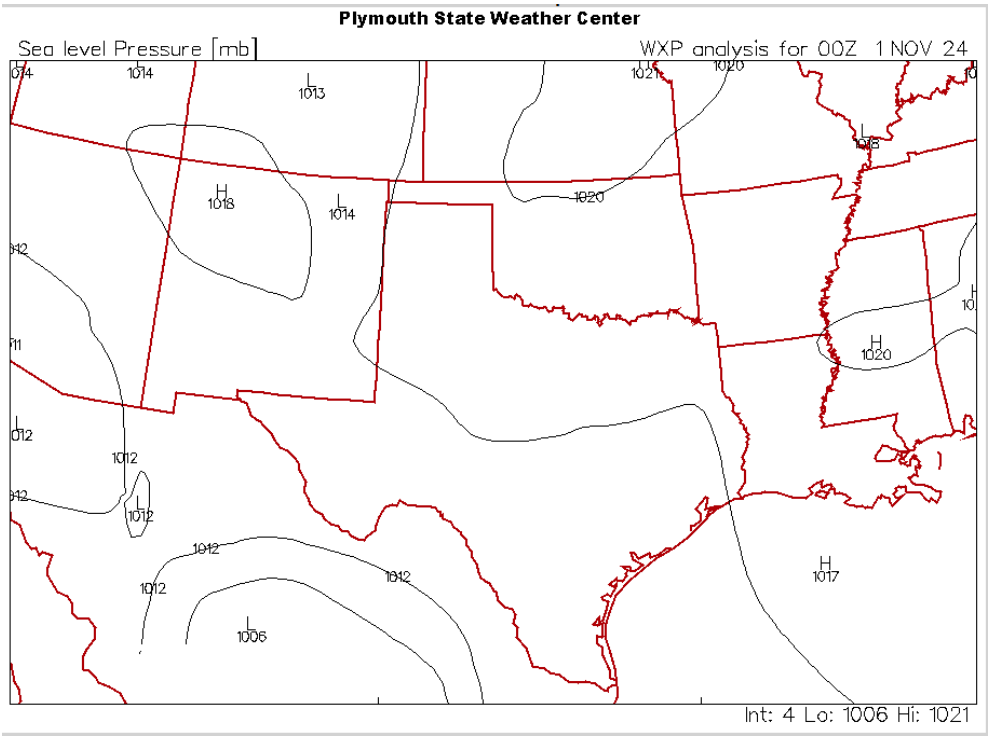


Photo credit: https://vortex.plymouth.edu/wxp

Millibars (mb)	Pascals (Pa)	Standard Atmospheres (atm)	Pounds per Square Inch (PSI)	Millimeters or Inches of Mercury (mmHg or inHg)

Name _____ Date_____

Module 2 - What I Know

Lesson 2

- ☐ How air can affect solid objects
- ☐ Air molecules in high pressure vs low pressure
- ☐ The relationship between elevation/altitude and air pressure
- ☐ Tools that are used to measure air pressure
- ☐ Units that are used to measure air pressure

What I Know	How I Know, I Know It

Name _____ Date_____

Think Like A Meteorologist

You and your group are field meteorologists who are collecting weather data across Oklahoma. You need a way to measure wind. Engineer a device that is easily portable, doesn't need any type of power, and can measure both wind speed and direction. Give each member of your team a role and record your names at the bottom of the table below.

Project Manager	**Resource Manager**	**Lead Engineer**	**Quality Analyst**
• Responsible for success of project • Ensures project is completed on time • Communicates progress to the CEO (your teacher) • Ensures effective communication among team members • Reasigns roles as needed	• Responsible for maintaining project resources • Ensures progress is updated • Documents work completed • Ensures documents are neat and professional	• Responsible for construction plan • Ensures all design goals are met • Delegates construction responsibilities as needed	• Responsible for effectiveness of design and data collection plan • Ensures accuracy of device and of data collected • Supervises data analysis • Delegates data collection and analysis duties as needed
This person should have: • Strong leadership skills • Good time management • Ability to work with and inspire others	This person should have: • Strong organizational skills • Attention to detail • Good written communication	This person should have: • Strong design skills • Creativity and big-picture thinking • Good verbal communication	This person should have: • Strong math skills • Analytical thinking • Ability to communicate data

Identify the need or problem

1. When engineers design something, they first determine the criteria for success. The success criteria is how they know they've met their design goals. What does your wind measurement device need in order to meet our design goals?

2. How will you know if your design is successful?

3. What are the constraints of this design problem? (Design constraints are limitations or restrictions that impact the design process and the final product.)

4. How will you collect and record data?

Brainstorm

5. Think about what you would like to build and how the parts will work together. Draw a sketch of your product below. Label the parts and briefly describe the function of each. Give your device a name!

What is your device called?

Design, Test, Redesign

As you build your device, you will probably want to make sure each part works how you want it to. As you test and redesign or refine different aspects of your device, make sure you record what you've already tried. You might find that you

want to undo some of the changes you make. If you've kept detailed engineering notes, you can easily return to the design that worked best.

Test and redesign your device as much as you want during the allotted time. Just be sure to record what you changed! Attach additional paper if needed.

Design 1

What we tried:

How it worked:

What we'd like to change:

Design 2

What we tried:

How it worked:

What we'd like to change:

Design 3

What we tried:

How it worked:

What we'd like to change:

Design 4

What we tried:

How it worked:

What we'd like to change:

Design 5

What we tried:

How it worked:

What we'd like to change:

⏸ Pause For Class Discussion

Data Collection

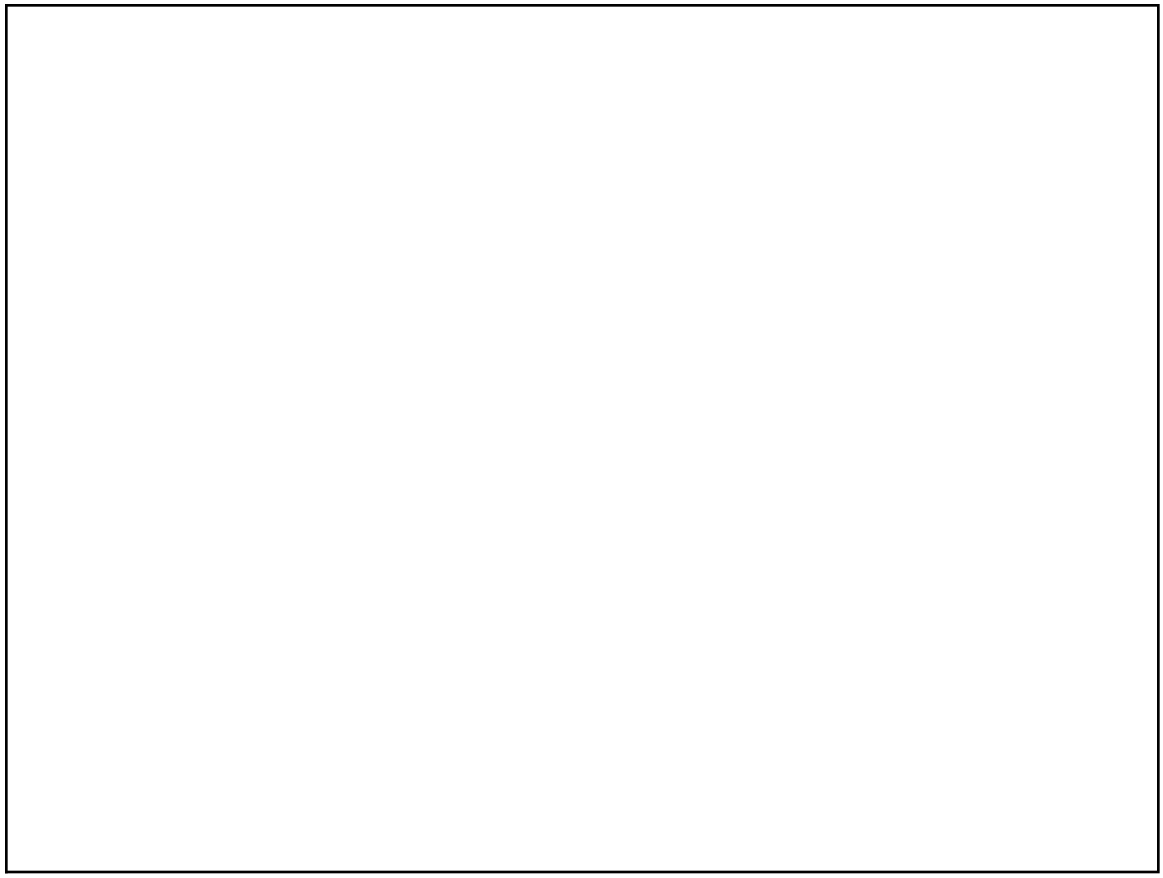
6. Decide how you will collect data. How many times will you measure? How will you measure? Where will you place your device? What factors might interfere with your data collection?

7. Describe where you decide to place your device and why.

_____

_____

8. Sketch the area outside. Indicate where you decide to place your device. Shade in red any object that might interfere with your data collection. Draw arrows to indicate movement of wind and how that movement might be affected by objects in your location.



9. Place your tool and observe it for a few minutes. If you find that this location does not work for any reason, discuss with your teacher to consider a new location.

10. Record your data below. Use the box to produce a table, graph, or other method of recording your data.

11. Analyze your data. Use your measurements to calculate wind speed. Record this data in an appropriate place of your choosing. Use the box below however you see fit.

Name _____ Date_____

Module 2 - What I Know

Lesson 3

- ☐ Why it's important to measure wind data
- ☐ How an anemometer works
- ☐ How a wind vane works
- ☐ How to calculate wind speed
- ☐ Possible careers related to collection of weather data

What I Know	How I Know, I Know It

Name _____ Date_____

Earth and its Wind

1. Watch the time lapse video of clouds moving over North America and the Atlantic Ocean. What do you notice?

_____

_____

_____

_____

2. After hearing from your classmates, add some of their ideas to your list. Did they notice some of the same things you did? Place a * next to those ideas.

_____

_____

3. What questions do you have about how the clouds are moving, what you observed, or why it looks the way it does?

_____

_____

_____

_____

Ideas for Investigation

4. What are your initial thoughts on how or why the clouds are moving the way they are?
   I think it has something to do with:

   _____

   _____

5. What other videos, information, or data would you like to see to confirm or revise your initial ideas? Some helpful sentence starters might be:
   I wonder if…, What happens in…, Does it always…, How does it compare to…, If we look at _____ we might see…

   _____

   _____

   _____

   _____

Initial Model

6. Now that you have seen how wind behaves in different areas, create a model to explain why you think certain patterns exist. Remember that this is an initial model, so you don't have to know all the answers right now. Your thoughts and ideas will change as you learn more. Consider the following:
    - Where clouds seem to form and the direction they move
    - How warm and cool air masses result in cloud and wind formation
    - Where warm and cool air masses come from
    - What role air pressure might play in wind formation

Name _____ Date_____

Where the Wind Blows

Earth's Rotation

We know that global wind patterns exist that cause winds to blow in the same direction. We also know that these patterns are due to how the earth is heated unequally by the sun - the equator receives more heat than the poles. This difference in heating creates large convection currents. But why do prevailing winds and jet streams blow side to side instead of straight north and south?

We know that Earth isn't stationary, it spins on its axis in an eastward direction. Let's investigate what happens to the atmosphere as Earth rotates.

Materials	Why
• Pie plate or bowl	➔ Earth substitute
• Water	➔ Air substitute
• Lazy Susan or turntable	➔ Rotation simulation
• Food coloring	➔ Makes movement visible

Procedure

1. Place the pie plate on the turntable and fill it with water. What do you think will happen to the water when you spin the turntable? Why do you think that will happen?

2. Spin the turntable. While it is spinning, drop one or two drops of food coloring into the water. What do you observe? Try stopping the turntable. Now what do you observe? Does all of the water appear to move at the same speed? Record your observations using words and/or pictures.

3. How does the movement of the water compare to the movement of air above Earth's surface?

4. Does this tell us why prevailing winds blow east-west and west-east? Do we have enough data to make a claim about what causes these patterns? If so, explain below. If not, what do we need to know more about?

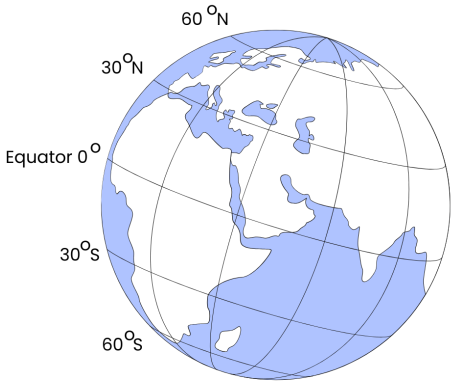
Prevailing Winds

We saw from the previous simulation that the air above Earth and Earth's surface don't spin in exactly the same way. The air above the surface behaves like the water in the pie pan. It moves because of the motion of Earth, but a fluid doesn't move the same way a solid does.

Let's take a closer look at why trade winds and westerlies follow a specific pattern of curving to the east or west.

Materials	Why
• Balloon	➔ Earth substitute
• Permanent markers	➔ Air substitute

Procedure



1. Blow up the balloon and tie off the end. Draw a line or dotted line around the equator of the balloon using black marker. If you'd like, draw a line or dotted line halfway between the equator mark and top/bottom of the balloon. These lines show where 30 degrees north and south of the equator would be.
2. Remember the large convection currents of rising warm air and sinking cold air? These convection currents occur between the equator and 30 degrees north/south, and between 30 and 60 degrees north/south.
3. The sun warms air at the equator, which causes the air to _____. As the air reaches higher levels of the atmosphere it cools, which causes the air to _____ and flow towards the equator.
4. To model this air movement, have one partner hold the balloon by the top and bottom. Spin the balloon as fast as possible, making sure it is spinning to the right (counterclockwise).

a. The second partner will hold a permanent marker and draw a line from 30 degrees north down towards the equator. What do you think the line will look like?

---

5. As air is sinking at 30 degrees latitude, some air is forced towards the poles. When this mass of air meets cold polar air that is moving towards the equator, the air is forced upwards, higher into the atmosphere.

    a. Model this movement by having one partner spin the balloon to the right (counterclockwise) while the other partner draws a line with a permanent marker from 30 degrees north up towards the pole. What do you think this line will look like?

---

6. How did your predictions compare to the results?

---

7. Does this tell us why prevailing winds blow east-west and west-east? Do we have enough data to make a claim about what causes these patterns? If so, explain below. If not, what do we need to know more about?

Name _____ Date_____

Wind at the Surface

We've noticed that wind doesn't always move the same over land, and we think it might have something to do with what's on the land. We're going to design an investigation to see if we can determine how different types of land cover might affect wind speed.

Planning

1. You have a variety of materials available to simulate three different environments. Make a plan for how you will use the materials. Remember that your simulated land covers need to be secured to the table or heavy enough that they won't blow over.

Environment	Requirements	Materials
• Mountain range	☐ Mountain peaks ☐ Valleys ☐ No isolated mountains	➔
• Forest	☐ Tall, strong trees ☐ Thick coverage	➔
• Grassland	☐ Shorter, thinner grass blades ☐ Thick coverage	➔

2. How will you design each of your environments? Sketch your plans below.

Mountain Range	Forest	Grassland

3. Remember that for the most accurate results in any experiment, you want to limit changes to only one independent variable. The more things you can keep the same, the more accurate your results will be. Describe your variables and constants below.
    a. The *independent variable* that you are manipulating is:
    Wind Speed Environment Type Materials

    b. The *dependent variable* that you will measure is:
    Wind Speed Environment Type Materials

    c. Here are some constants to consider:
        i. Speed setting on the fan: _____.
        ii. Distance from the fan to the anemometer: _____.
        iii. Area covered by a simulated environment: _____.
        iv. Position of the anemometer: _____.
        v. Any other constants you can think of?

_____

_____

4. Decide how you will collect data. Consider things such as where you will measure wind, how you will ensure you measure it the same way every time, how many measurements you will take for each simulated environment, etc. Describe your procedures below. Edit the constants you listed above if necessary.
    a. We will measure wind speed _____time(s) for each environment.
    b. We will measure wind speed at _____ height(s) for each environment.
        i. What height(s) will you be measuring at? (Such as on the surface of the table, 6 inches above the table, etc.)

_____

_____

c. Will you place the anemometer in a different position behind the environments or the same position for each measurement? By doing so, what are you hoping to learn from the data?

d. How will you record your data? Use the box below to create a table or chart to record your data. Be sure to include labels.

Test

5. Which environment do you think will have the greatest wind speeds? Why?

6. Complete your testing and record all data in the table you created above.

Analyze

7. Are there any calculations you need to perform with your data, such as mean, median, or mode? Perform those calculations and record them below.

8. Describe the outcome of your experiment. Does the data support your prediction? Write a paragraph to describe your results. You may use the following prompts:
   We predicted that…. Our results showed… The data (supports or does not support) our prediction because… We think this happened because… Based on the results of our experiment, we can conclude that (mountains, grasslands, or forests) would likely experience the highest wind speeds.

Name _____ Date_____.

Putting the Pieces Together

You've learned a lot about what causes wind. Let's put it all together into a final model that describes why Oklahoma might be more windy than some other places. Use words and pictures to help you.

Include in your model:

- How high and low air pressure affect wind
- Impact of temperature on air pressure
- Draw isobars to indicate pressure and label with H and/or L
- Use arrows (vectors) or wind barbs to indicate speed and direction
- Altitude, land features, or environments that might influence wind
- Global wind patterns that might influence local wind
- Zoom in to show what air molecules are doing