Air Masses and Fronts

Session Time: Four, 50-minute session(s)

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Air forms masses of similar temperature and moisture content acquired from the area of origin, and circulates as a body.

Where air masses of different types come together, they form predictable patterns of inclement weather called fronts, which impacts flight safety.

ESSENTIAL QUESTIONS

1. Why do you sometimes find cold air in a normally hot climate or moist air in a desert?

LEARNING GOALS

Students Will Know

- The names and characteristics of different types of air masses
- Four types of weather fronts
- Interactions that occur between air masses creating different types of clouds and precipitation
- The kind of weather associated with each front

Students Will Be Able To

- *Identify* the types of precipitation and clouds that form with different frontal boundaries (DOK-L1)
- *Interpret* weather symbology (DOK-L2)
- *Analyze* weather scenarios to determine how fronts affect the flight experience (DOK-L4)
- *Analyze* how air masses change as they pass over various land and water surfaces (DOK-L4)

ASSESSMENT EVIDENCE

Warm-up
Students will fill in and assess their weather diary, first started in Unit 1, Section A, Lesson 1, and then assess the conditions to determine "Is it a good day to fly?"

Formative Assessment
Students will work in pairs to analyze three aviation-related scenarios to identify the weather associated with air masses and fronts, and then apply that analysis to make a risk-based decision about the proposed flight.

Summative Assessment
Students will divide into four groups with each group taking one major air mass type. The groups will determine the characteristics of their assigned air mass as well as how those characteristics change as the air masses move over other

land or water surface. Students will also use that information to hypothesize about the influence of those changing air masses on the typical weather patterns found in the continental United States.

LESSON PREPARATION

MATERIALS/RESOURCES

- Air Masses and Fronts Presentation
- Air Masses and Fronts Student Activity 1
- Air Masses and Fronts Student Activity 2
- Air Masses and Fronts Student Activity 3
- Air Masses and Fronts Student Activity 4
- Air Masses and Fronts Student Activity 5
- Air Masses and Fronts Teacher Notes 1
- Air Masses and Fronts Teacher Notes 2
- Air Masses and Fronts Teacher Notes 3
- Air Masses and Fronts Teacher Notes 4
- Air Masses and Fronts Teacher Notes 5
- Air Masses and Fronts Student Notes 1
- Student Daily Weather Diary

LESSON SUMMARY

Lesson 1: Makeup of the Atmosphere
Lesson 2: Atmospheric Circulation and Winds
Lesson 3: Clouds and Precipitation
Lesson 4: Air Masses and Fronts
Lesson 5: Thunderstorms

This four-session lesson will begin with a warm-up in which the students discuss their current local weather: how it changes, how stable the atmosphere is, and how that affects aviators. The students' responses to what causes the current weather and how it changes will segue into a discussion of the various types of air masses and their physical characteristics. Students will learn how air masses are formed, how they move around the earth and how they evolve as they travel across different types of terrain.

During the next part of the lesson, students will learn about the boundaries of intersecting air masses, known as fronts. They will learn about the four types of fronts and the different types of weather that accompany each before, during, and after frontal passage. This will solidify their understanding of fronts by completing a Frontal Weather chart. Using graphical depictions and METARs, they will analyze the weather along a proposed route of flight. They will also analyze videos showing satellite images of varying weather phenomena to determine what kinds of air masses and fronts they are seeing.

In the summative assessment, students will apply and visualize this information as they complete activities that analyze hypothetical flights and the way these air masses, fronts, and weather patterns would affect their flight planning and execution.

BACKGROUND

Large bodies of air can remain over geographic areas for several days or weeks, causing them to acquire the temperature and water vapor properties of the surface below. The air exchanges heat with the land or water, either warming or cooling, until its temperature closely matches that of the surface below it. The body of air also gains or loses moisture depending on the temperature and moisture content of the surface. A body of air that resembles the characteristics of the surface over which it forms is called an air mass.

Air masses form over areas of uniform temperature and humidity, called source regions. Air masses are categorized by these source regions and their humidity. For example, an air mass that forms over a warm, dry land source region is categorized as continental Tropical, or “cT.” Due to various global effects, these air masses move from one region to another. As they do, they bring their own weather characteristics (hot or cold, dry or moist) to the new region. When an air mass collides with an air mass of different characteristics, the boundary, called a front, can become a source of weather (a storm). Movement of air masses can cause weather patterns. Heat exchange and moisture are the primary actors in the weather patterns caused by these air masses and their movement.

Many of these weather patterns are predictable over the long term. For example, people might recognize the stereotypical warm, humid Southeast or the dry, hot Southwest caused by air masses, or the severe thunderstorms that occur when certain air masses meet. For aviators, understanding how these factors influence the weather increases a pilot’s ability to manage risk and safely and effectively plan and complete flights.

MISCONCEPTIONS

Students may assume that weather always takes on the characteristics of the area where it is happening—in other words, they may think weather is always "local." For example, students may assume the weather in the desert is always hot and dry or coastal areas are always humid. However, as this lesson will demonstrate, local weather patterns can be substantially influenced by air moving from one source region to another. As air masses move, they bring with them the characteristics of the place where the air mass was formed. If an air mass from a dry source region moves over the coast, the normally humid coastal area could experience unusually low humidity. Similarly, when air masses from particularly high-moisture regions move over deserts, humidity may increase, or they may even bring heavy rains to the normally dry region. Weather is a function of both the temperature and humidity of the air mass over the region and the changes brought about by the air masses that move through the region.

DIFFERENTIATION

Consider having students complete Student Activity 1 in pairs or small groups in the **EXPLAIN** section of the lesson plan. This activity could also be turned into a jigsaw exercise in which groups of students gain expertise in one area, then disperse that knowledge through other groups by sharing what they’ve learned.

LEARNING PLAN

ENGAGE

Teacher Material: Air Masses and Fronts Presentation
Student Material: Student Daily Weather Diary

Session 1

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up**.

Warm-Up

Ask: Is this a good day to fly?

Discuss the day’s weather. Students should refer to the weather diary they started in Unit 1, Section A, Lesson 1.

Questions for discussion:

What is the weather like today? What is the ceiling? What are the winds? How has the weather changed since yesterday? What do you think has caused this change? What do you think the weather will look like tomorrow? How stable is the atmosphere likely to be today?

Answers will vary based on the actual weather conditions and student assessments of the weather.

How would the weather affect your plans if you went flying today?

Answers will vary based on the students' current understanding of the atmosphere.

[DOK-L2; *observe*]

Slide 5: Invite students, as a group, to define the displayed terms without looking them up. The following descriptions are some that students might suggest, though they are not necessarily specific to air masses and fronts:

- Equatorial: related to the equator, the region of the globe that receives the most direct sunlight
- Tropical: related to the tropics, the lower-latitude regions of the globe, closer to the equator
- Polar: related to the upper-latitude regions of the globe, closer to the poles
- Arctic/Antarctic: related to the northernmost and southernmost regions of the globe, surrounding the North and South Poles
- Continental: related to the major land masses of the earth
- Maritime: related to the seas and oceans

Teaching Tips

Different sources identify slightly different categories of air masses. Some list only four: polar, tropical, continental, and maritime; some include additional categories, such as Monsoon (M) and Superior (S). For the purposes of this course, the specific category names are less important than the understanding that air masses are classified by their source (e.g., the equator, the tropics, the polar regions, the Arctic) and their moisture content (e.g., continental or maritime).

Questions

What weather might you expect in each of the places described by these geographic terms? For example, would you expect "continental" weather to be hot, cold, moist, dry, or some combination of these? Would it be cloudy, foggy, sunny, rainy, etc.?

Possible responses: Answers may vary, and discussion should be encouraged to include personal experiences and understandings from multiple students. Summarize and record student responses on a board or display where they can be seen. The goal is not for a "book answer" to be on the board, but rather for students to see how their understanding changes throughout the lesson.

Because of the breadth of the terms, there is no single "correct" answer. Generally, tropical /equatorial weather is warm, polar/Arctic is cool, continental is dry, and maritime is humid.

However, the actual weather in a region will be influenced by a variety of factors. For example, weather conditions like fog, clouds, rain, etc. would be a function of current moisture levels, relative temperatures, and the changes that occur as the air masses move. These topics are the focus of this lesson and will be discussed in later slides.

EXPLORE

Teacher Material: Air Masses and Fronts Presentation

Slide 6: An air mass is a large body of air that takes on the moisture (humidity) and temperature characteristics of the area over which it forms. Due to pressure, gravity, and other forces, these air masses form over regions with uniform temperature and moisture characteristics and then move around the globe.

Slide 7: Each type of air mass is classified by its source region and its moisture content, and its physical properties change slightly based on the season. Air masses that form over land are designated "continental" air masses and are generally dryer, while those that form over a body of water are designated "maritime" air masses and are generally more humid. For example, in North America, continental Tropical (cT) air masses form over the southwestern United States and Mexico. During the winter, these air masses are warm and dry. During the summer, they are hot and dry. Variations in temperature and humidity will influence the weather associated with each air mass.

The slide contains a graphic that illustrates the varying air masses around the continental United States; these and other air masses will be discussed in later slides.

Slide 8: Different parts of the globe are affected by different types of air mass. As shown in the graphic, the United States is affected by four types of air masses, though there are others in other parts of the world. The arrows show the direction in which the air masses tend to move. Notice that each type identifies both the moisture content (the first term or letter) and the source region (the second term or letter) of the mass.

- Continental polar (cP)
- Continental tropical (cT)
- Maritime polar (mP)
- Maritime tropical (mT)

Air masses that affect other parts of the world include continental Arctic (cA), continental Equatorial (cE), and maritime Equatorial (mE). (There is technically no "maritime Arctic" because the water mass around the North Pole is frozen.)

The graphic also introduces the concept of a front, or the boundary between air masses, which will be discussed in future slides.

Slide 9: Air masses move about the globe in relatively predictable patterns, bringing different atmospheric conditions to the new region and acquiring characteristics of the region they've entered. If an air mass passes over a warmer surface, it tends to cause convection and lift, which causes instability and good visibility. Passing over cooler surfaces tends to cause atmospheric stability but poor visibility, low clouds, and fog. The movement of these air masses from other regions is why you sometimes find potentially unexpected weather patterns like cool, moist air in a desert environment: the air mass has come from another region and settled over the desert area.

Watch the following video on air masses, and encourage students to take notes to review the characteristics of air masses. (This video describes air masses that affect the United Kingdom, but they include the same categories that affect the United States.)

- "What are air masses?" (Length 4:36)
  https://video.link/w/HMcq

For teachers who are unable to access Safe YouTube links, this video is also available here: https://www.youtube.com/watch?v=kvk-hBFnBTI&t=92s

Slide 10: As these moving masses of air collide, they form a "front." An approaching front or air mass boundary means a change in the weather is coming, both at the front and after it passes.

There are four types of fronts:

1. Cold
2. Warm
3. Stationary
4. Occluded

Each of the first two fronts is named for the temperature of the air that is replacing the previous air mass. A **cold front**, for example, is a mass of cold air replacing a mass of warmer air; a **warm front** happens when warm air replaces cooler air.

As the name implies, a **stationary front** is a "stalled" front that doesn't move much. The weather at the front may take the form of either a cold or warm frontal system (or both) and may last for days over an area.

An **occluded** front occurs when a cold front overtakes a warm air mass, pushes it aloft, and contacts the cooler air mass on the other side of the warm air mass.

The slide contains a graphic that identifies the standardized graphical representation of the different kinds of fronts. Students may even recognize these from their local news weather forecasts.

EXPLAIN

Teacher Materials: Air Masses and Fronts Presentation, Air Masses and Fronts Teacher Notes 1, Air Masses and Fronts Teacher Notes 2
Student Materials: Air Masses and Fronts Student Activity 1, Air Masses and Fronts Student Activity 2

Session 2

Slide 11: Distribute copies of **Air Masses and Fronts Student Activity 1**, which consists of three charts. Students should fill in the charts as the class discusses the types of fronts over the next few slides. The complete correct responses can be found in **Air Masses and Fronts Teacher Notes 1**.

Slide 12: This slide contains a graphical representation of a cold air mass, on the left, moving to the right and encountering a warm air mass, with the resulting severe weather occurring at the frontal boundary.

A **cold front** occurs when a cold, dense, and stable air mass runs into and displaces a warmer air mass. A cold front moves faster than a warm front and, because it is more dense, stays closer to the ground and "plows under" the warmer air. This pushes the warmer air aloft to higher altitudes. When the warmer air rises and mixes with the colder air at altitude, severe weather can form.

Slide 13: Before the cold front passes, cirriform or towering cumulus clouds may be present, and cumulonimbus clouds may develop. Rain showers may also develop due to the rapid development of clouds that are created with the rising warm air. A high dew point and falling barometric pressure are indicative of imminent cold front passage. The pressure falls because of the rising warm air.

Side 14: During the cold front passage, towering cumulus or cumulonimbus clouds continue. Heavy rain showers may form and be accompanied by lightning, thunder, and/or hail. Intense cold fronts are capable of creating storms that may produce tornadoes. The visibility is poor with winds variable and gusty, and the temperature and dew point drop rapidly as the cold air mass rapidly replaces the warmer air. The barometric pressure rapidly falls and bottoms out during the frontal passage, which is when the warmer air is forced upward at its greatest point, then begins a gradual increase.

Slide 15: After the front passes, the clouds and weather begin to clear. A cumulus layer may remain. The visibility improves. In the United States, winds are from the west-northwest. With the steady presence of the colder air mass, the temperatures are cooler and the pressure continues its rise due to the stabilization of the rising warm air.

Slide 16: This slide contains the answer key for the cold fronts portion of **Air Masses and Fronts Student Activity 1**.

Teaching Tips

Consider focusing the discussion on the characteristics of a cold front while on Slides 12-15, and moving to Slide 16 to fill in any specifics that may have been missed. A more detailed set of answers is available in **Air Masses and Fronts Teacher Notes 1**.

Slide 17: A **fast-moving cold front** is pushed by an intense pressure system that is actually well behind the front itself. The speed of the air mass combined with the friction with the ground causes a very steep frontal surface. The steep face causes a narrow band of severe frontal weather. If the warmer air mass is stable, the weather behind the front may be overcast and rainy. If it is unstable, there may be scattered thunderstorms. Along the front a continuous line of severe, unpredictable thunderstorms may form, known as a “squall line.” After the front passes, the weather clears and the cold air mass results in gusty winds and cold temperatures.

Slide 18: This slide contains a graphical representation of a warm air mass, on the left, moving to the right and encountering a cold air mass, with the resulting weather occurring at the frontal boundary.

A **warm front** occurs when a warm air mass overtakes and displaces a colder air mass. Warm fronts move more slowly than cold fronts, typically 10 to 25 mph. Because it is warmer and less dense, the slope of the advancing front slides over the top of the cooler air and gradually pushes it out of the area. (Contrast this with a cold front, which wedges itself under the displaced air mass.) Warm fronts contain warm air that often has high humidity. As the warm air is lifted over the cold air mass, it cools and forms clouds and rain.

Slide 19: Generally, prior to the passage of a warm front, cirriform or stratiform clouds, along with fog, can be expected to form along the frontal boundary. In the summer months, cumulonimbus clouds (thunderstorms) are more likely to develop. Light to moderate precipitation is likely (rain, sleet, snow) with poor visibility. The wind blows from the south-southeast, and the temperature is cool or cold because the cold air mass is still present. The dew point rises and the barometric pressure falls.

Slide 20: During the passage of a warm front, there are stratiform clouds and drizzle. The visibility is normally poor but improving, and the winds are variable. The temperature rises steadily due to the arrival of the warm air mass. The dew point is constant and the pressure stabilizes.

Slide 21: After the passage of a warm front, stratocumulus clouds predominate and rain showers are possible. The visibility improves but is still hazy for a short period. The wind blows from the south-southwest. With warming temperatures, the dew point rises and then levels off. There is generally a slight rise in barometric pressure, followed by a decrease of barometric pressure.

Slide 22: This slide contains the answer key for the warm front portion of **Air Masses and Fronts Student Activity 1**.

Teaching Tips

Consider focusing the discussion on the characteristics of a warm front while on Slides 18-21, and moving to Slide 22 to fill in any specifics that may have been missed. A more detailed set of answers is available in **Air Masses and Fronts Teacher Notes 1**.

Slide 23: A stationary front is a line between two air masses that "stalls." A stationary front occurs when two air masses push against each other with approximately equal strength, so that neither is strong enough to move the other. A stationary front may remain in one place for a period of days.

This slide contains a graphical representation of a cold air mass, on the left, moving to the right and encountering a warm air mass, in the center, overtaking it and catching up to the preceding cold air mass, with the resulting weather occurring at the frontal boundary.

Slide 24: An **occluded front** occurs when a cold front, which is already wedging itself under a warm air mass, moves so fast that it pushes the entire warm air mass aloft and contacts the cold air mass that had been on the far side of the warm air mass. Because there is a warm air mass aloft, as an occluded front approaches, the front still has the weather characteristics of a warm front. However, the weather quickly changes to cold front weather.

There are two types of occluded fronts that can occur, which depend on the relative temperatures of the two cold air masses:

- If the cold air mass wedging itself under the warm air mass is colder than the cold air mass on the other side of the warm front, it is a *cold front occlusion.* As with any front, the colder air then pushes the cool air aloft, just as it would if it had been a warm air mass. As a result, the weather associated with a cold front occlusion can be a mix of both cold and warm front weather.

- If the cold air mass wedging itself under the warm air mass is warmer than the cold air mass on the other side of the warm front, it is a *warm front occlusion*. As with any front, the warmer air slides over the colder air mass. This could contribute to instability in the atmosphere, so warm front occlusions often have more severe weather.

Slide 25: An occluded front is normally associated with high clouds (cirriform and stratiform), precipitation, poor visibility, and falling pressure—in other words weather consistent with a warm front. As the front passes, the clouds become nimbostratus and cumulonimbus, with the possibility for thunderstorms and towering cumulonimbus, and the pressure levels off. After the front has passed, the weather takes on the more typical cold front characteristics with mid-level clouds remaining (nimbo and altostratus), decreased precipitation, and improved visibility.

Slide 26: This slide contains the answer key for the occluded front portion of **Air Masses and Fronts Student Activity 1**.

Teaching Tips

Consider focusing the discussion on the characteristics of an occluded front while on Slides 24-25, and moving to Slide 26 to fill in any specifics that may have been missed. A more detailed set of answers is available in **Air Masses and Fronts Teacher Notes 1**.

Slide 27: Complete the **Formative Assessment**.

Formative Assessment

Provide students with **Air Masses and Fronts Student Activity 2** worksheet. Students will analyze three scenarios to identify the weather associated with air masses and fronts, and then make a risk-based decision about the proposed flight. Have the students work in pairs to answer the questions. Allow them to use the tables they completed as part of Student Activity 1. Sample student responses can be found in **Air Masses and Fronts Teacher Notes 2**.

[DOK-L2; *identify,* DOK-L4; *analyze, apply*]

EXTEND

Teacher Materials: Air Masses and Fronts Presentation, Air Masses and Fronts Teacher Notes 3, Air Masses and Fronts Teacher Notes 4
Student Materials: Air Masses and Fronts Student Notes 1, Air Masses and Fronts Student Activity 3, Air Masses and Fronts Student Activity 4

Session 3

Slide 28: Show students the following video, which was taken from an aircraft as it flew along a cold front. Then ask students the questions below.

- "Flying along a cold front, time lapse from FL390" (Length 0:31)
  https://video.link/w/Mezp

For teachers who are unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=W5zZVTop_D8

Questions

Describe what is happening with the weather in the video. What weather phenomena do you see? What is causing this weather?

The aircraft is at flight level 390, or approximately 39,000 feet. At approximately 0:05, you can see the tower of cumulonimbus clouds building. This may be the result of the cold front wedging itself under the warm air mass, which pushes the warm air higher into the atmosphere. When the warm air rises, it cools and condenses into clouds and storms. At 0:08, you can see where the clouds appear to have leveled out and flattened, which may be an indication of the beginning of the troposphere. The plane is near the top of the troposphere, so some of the cloud layers appear to be capped by the atmosphere, while others have pushed higher, possibly due to the strength of the front pushing the warm air higher as the frontal boundary interacts.

Next, provide students with the resource document **Air Masses and Fronts Student Notes 1**. The resource document contains graphics that will be used as a legend to interpret the weather depictions on future slides.

Teaching Tips

The Weather Service provides a decoder for virtually all possible METAR codes at https://www.weather.gov/media/wrh/mesowest/metar_decode_key.pdf. Note that students will need to be able to decode METARs for FAA knowledge tests.

Slide 29: The graphic depicts how a cold air mass, moving from west to east (left to right, from St. Louis to Pittsburgh), would create a cold front as it overtook and displaced the warm air mass on the right. (The pictorial graphic is consistent with the tables filled in during **Air Masses and Fronts Student Activity 1**.) The cold air mass plows under the warm air mass and pushes it to the east. The high-altitude warm air cools, and the water vapor condenses, forming clouds and eventually rain and storms.

Slide 30: The graphic is an overhead view of a surface weather depiction, showing St. Louis on the left and Pittsburgh on the right. Each blue line is a change in atmospheric pressure (in millibars), which shows that the pressure decreases as the front approaches. The Station Plots graphically depict the weather at each airport along the route (consistent with the legend provided in **Air Masses and Fronts Student Notes 1**). The current conditions at each airport are shown in text in the METARs and can be further interpreted with the information provided in **Air Masses and Fronts Student Notes 1**.

Have the students use their copy of **Air Masses and Fronts Student Activity 1** and **Air Masses and Fronts Student Notes 1** to highlight and discuss weather conditions in the area as depicted on the weather chart and METARs.

For example, the skies are mostly clear in Pittsburgh, with a light wind from the southwest, while in Indianapolis it is overcast with winds from the southwest. Note that Pittsburgh is showing 3 statute miles (SM) visibility, which increases to 6SM at Columbus, before falling to 3SM at the front at Indianapolis, and finally 10SM at St. Louis on the other side of the front. This is consistent with visibility decreasing as a warm front approaches.

Slide 31: The graphic on the slide depicts how a warm air mass, moving from west to east (left to right, from St. Louis to Pittsburgh), would create a warm front as it overtook and displaced the cold air mass on the right. (The pictorial graphic is consistent with the tables filled in during **Air Masses and Fronts Student Activity 1**.) The warm air mass gradually slopes over the cold air mass and pushes it to the east. The high-altitude warm air cools and the water vapor condenses, forming clouds and eventually rain and storms.

Slide 32: The graphic is an overhead view of a surface weather depiction, showing St. Louis on the left and Pittsburgh on the right. Each blue line is a change in atmospheric pressure (in millibars), which shows that the pressure decreases as the warm front approaches. The Station Plots graphically depict the weather at each airport along the route (consistent with the legend provided in **Air Masses and Fronts Student Notes 1**). The current conditions at each airport are shown in text in the METARs on the graphic and can be further interpreted with the information provided in **Air Masses and Fronts Student Notes 1**.

Have the students use their copy of **Air Masses and Fronts Student Activity 1** and **Air Masses and Fronts Student Notes 1** to highlight and discuss weather conditions in the area as depicted on the weather chart and METARs.

For example, the skies are mostly clear in Pittsburgh, with a light wind from the southeast, while in St. Louis it is overcast with winds from the southwest. Note that Pittsburgh is showing 10 statute miles (SM) visibility, which decreases to 6SM at Columbus, 3SM at Indianapolis, and finally 1SM at St. Louis. This is consistent with visibility decreasing as a warm front approaches.

Slide 33: The graphic on the slide depicts how a cold air mass, moving from west to east (left to right, from St. Louis to Pittsburgh), would create an occluded front as it overtook and displaced a warm air mass and then caught up with another cold air mass on the right. The pictorial graphic of the resulting weather is consistent with the tables filled in during **Air Masses and Fronts Student Activity 1**. Note the gradual slope of the warm front being replaced by the steep gradient of the cold front behind it, which causes strong weather. The cold air mass to the west pushes the warm air to higher altitude rapidly, causing strong storms at the front passage.

Slide 34: The graphic is an overhead view of a surface weather depiction, showing St. Louis on the left and Pittsburgh on the right. Each blue line is a change in atmospheric pressure (in millibars), which shows the decreasing pressure on the warm side of the front and the increase in pressure on the back side of the front. The Station Plots graphically depict the weather at each airport along the route (consistent with the legend provided in **Air Masses and Fronts Student Notes 1**). The current conditions at each airport are shown in text in the METARs and can be further interpreted with the information provided in **Air Masses and Fronts Student Notes 1**.

Have the students use their copy of **Air Masses and Fronts Student Activity 1** and **Air Masses and Fronts Student Notes 1** to highlight and discuss weather conditions in the area as depicted on the weather chart and METARs.

For example, the skies are mostly covered at Pittsburgh, are overcast at Columbus and Indianapolis, but are mostly clear at St. Louis on the other side of the occluded front. Note that the winds at Pittsburgh are 12 knots from 130 degrees (southeast), while in Indianapolis they are 28 knots gusting to 45 knots from the west (at the occluded front).

Slide 35: Divide the class into two groups. Provide one group with A**ir Masses and Fronts Student Activity 3**, and the other with **Air Masses and Fronts Student Activity 4**. For each activity, the students should answer the questions as a group and then come back together as a class to brief the *other* group on their thoughts and decisions. Potential responses can be found in **Air Masses and Fronts Teacher Notes 3** and **4**.

The slide contains a copy of the graphics from the warm and occluded fronts slides, which represent the two weather systems the students are assessing.

Session 4

Slide 36: Watch the following video, which was taken by a National Oceanic and Atmospheric Administration (NOAA) satellite during a nor'easter in 2018. Have students point out the weather features they've learned during this lesson. (You may need to play this several times.)

- "Lightning Associated with March 7, 2018 Nor'easter" (Length 0:43)
  https://video.link/w/SnLp

For teachers who are unable to access Safe YouTube links, the video can also be found here: https://www.youtube.com/watch?v=j_vxcJwcFes

The video shows a real-world example of how air masses interact and how the fronts between them cause weather (as observed from space). From the start of the video until 0:06, you can see a high-pressure and low-pressure system enter from the west. The high pressure system is on the south side of the screen and rotates clockwise; the low pressure system is on the north side and rotates counterclockwise. There is a band of clouds and weather between the systems that includes a lightning storm. The high-pressure system soon moves offshore, while the low-pressure system stalls over the eastern seaboard; the counterclockwise rotation brings moisture from the ocean back to the coast, where it mixes with the cold air from the north and causes an event of immense, continuous snowfall and high winds known as a "nor'easter." The low-pressure system does not move offshore until approximately 16 hours later, at 0:17. At 0:26, another cold front enters the video from the west, with a strong line of storms and lightning, with the large, counterclockwise-rotating, low-pressure system behind it.

Slide 37: Watch the following video, which was taken by a NOAA satellite over the span of the 2017 hurricane season. Focus on the air masses along the Rocky Mountains in the western United States, observe the hurricanes that form in the Atlantic Ocean, and note the cloud formations along the bottom edge of the screen, near the equator. Consider pausing the video at key points (noted in the next paragraph) or replaying the video after students identify key points of interest.

- "2017 Hurricane Season - Captured by NOAA GOES-East Satellite" (Length 4:31)
  https://video.link/w/tBKp

For teachers who are unable to access Safe YouTube links, the video can also be found here: https://www.youtube.com/watch?v=xHm7oh0Yn60&t=31s

At approximately 0:29, note the clouds that push in from the north over the continental United States. A cold air mass from Canada pushed into the United States, forming a cold front that proceeded east across the United States, forming a line of clouds and distinct frontal boundary along the East Coast. The cycle repeats several times. Note that low pressure systems in the Northern Hemisphere rotate counterclockwise, while high pressure systems rotate clockwise. Observing the continental United States, periods of clearing are sometimes marked by a clockwise flow (high pressure), while increasing clouds and storms are associated with a counterclockwise flow (low pressure). For example, at approximately 3:03, there is a high-pressure system over most of the eastern United States, marked by the large clear area with some clockwise flow noted at its edges. The front associated with this high-pressure system also acted on Hurricane Maria during this time, causing it to turn toward the northeast rather than make landfall in the United States.

At approximately 2:08, note the formation of Tropical Storm Harvey, just southeast of Haiti, and watch its path as it crosses the Gulf of Mexico and impacts Texas (2:22). (A tropical storm is an intense low-pressure system, so it rotates counterclockwise.) As it made landfall, Harvey interacted with the air masses in the central United States, which appear to be pushing down from Canada. This stalled the remains of Harvey over Texas (until about 2:30) before another frontal system swept it to the east. This stall over Texas resulted in immense rainfall from an otherwise weak storm, causing substantial flooding and making Harvey one of the costliest tropical cyclones to ever strike the United States. At 3:49, another distinct frontal boundary forms just east of the Rockies and proceeds across the United States. Finally, note the relatively stagnant clouds along the southern edge of the screen. This is a result of the air masses from the Southern Hemisphere and Northern Hemisphere interacting along the equator. This region is known as the Inter-Tropical Convergence Zone, or ITCZ (pronounced "itch"); it is responsible for the wet and dry seasons of the tropics.

EVALUATE

Teacher Materials: **Air Masses and Fronts Presentation**, **Air Masses and Fronts Teacher Notes 5**
Student Material: **Air Masses and Fronts Student Activity 5**

Slides 38-43: Quiz students on the Private Pilot Knowledge Test Questions.

Slide 44: Conduct the **Summative Assessment**.

Show the following video:

- "Air Masses Video" (Length 3:13)
  https://video.link/w/KvLp

For teachers who are unable to access Safe YouTube links, the video can also be found here: https://www.youtube.com/watch?v=66MC2iPfoJU

Summative Assessment

In this summative assessment, students will break into four groups and, as a group, describe the characteristics of air masses and analyze how those air masses change as they move across new regions. The groups will include:

1. mT
2. cT
3. cP
4. mP

Groups will hypothesize about the origins of common weather patterns in the continental United States. Provide each student with a copy of **Air Masses and Fronts Student Activity 5**.

Sample answers are provided in **Air Masses and Fronts Teacher Notes 5**.

[DOK-L2; *describe, cause and effect*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Responses show evidence of one or more of the following:
    - Correct understanding of the moisture and temperature characteristics of their assigned air mass at its source region
    - Correct understanding of how the air mass moving from land to water (or vice versa) influences their assigned air mass
    - Correct understanding of how the air mass moving to areas of higher/lower humidity /temperature affects their assigned air mass
    - Reasonable proposition of how these characteristics affect weather patterns within the continental United States
- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points **Performance Levels**

9-10 Correctly lists all or almost all characteristics of the air mass at its source region, changes due to moving over land/water/temperature/humidity, and provides a reasonable proposition of a weather pattern caused by these characteristics within the United States.
7-8 Correctly lists all or almost all characteristics at source region; lists most but not all correct changes due to regional changes in land/water/temperature/humidity, and provides a reasonable proposition of a weather pattern caused by these characteristics within the United States.
5-6 Correctly lists one characteristic at source region but lists others incorrectly; lists a few correct changes due to regional changes in land/water/temperature/humidity but several incorrect, and provides a reasonable proposition of a weather pattern caused by these characteristics within the United States.
0-4 Lists few, if any, correct characteristics at source region or in changed region; does not provide a reasonable proposition of a weather pattern caused by these characteristics within the United States.

STANDARDS ALIGNMENT

COMMON CORE STATE STANDARDS

- **RST.9-10.2** - Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **RST.9-10.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.

FAA AIRMAN CERTIFICATION STANDARDS

PRIVATE PILOT - AIRPLANE

- **PA.I.C.K3** Meteorology applicable to the departure, en route, alternate, and destination under VFR in Visual Meteorological Conditions (VMC) to include expected climate and hazardous conditions such as:
    - **PA.I.C.K3a** a. Atmospheric composition and stability
    - **PA.I.C.K3b** b. Wind (e.g., crosswind, tailwind, wind shear, mountain wave, etc.)
    - **PA.I.C.K3c** c. Temperature
    - **PA.I.C.K3d** d. Moisture/precipitation
    - **PA.I.C.K3e** e. Weather system formation, including air masses and fronts
    - **PA.I.C.K3f** f. Clouds
    - **PA.I.C.K3g** g. Turbulence
    - **PA.I.C.K3h** h. Thunderstorms and microbursts
    - **PA.I.C.K3i** i. Icing and freezing level information
    - **PA.I.C.K3j** j. Fog
    - **PA.I.C.K3k** k. Frost
- **PA.I.C.R1** Factors involved in making the go/no-go and continue/divert decisions, to include:
    - **PA.I.C.R1a** a. Circumstances that would make diversion prudent
    - **PA.I.C.R1c** c. Hazardous weather conditions to include known or forecast icing or turbulence aloft
    - **PA.I.C.R2b** b. Aviation weather reports and forecasts
- **PA.I.C.S1** Use available aviation weather resources, obtain an adequate weather briefing, and correlate weather information to make a competent go/no-go decision.

- **PA.I.C.S2** Discuss the implications of at least three of the conditions listed in K3a through K3k above, using actual weather or weather conditions in a scenario provided by the evaluator.

REFERENCES

Station Plot data: https://www.wpc.ncep.noaa.gov/html/stationplot.shtml

METAR Decoder: https://www.weather.gov/media/wrh/mesowest/metar_decode_key.pdf