BASICS FOR AIR TRAFFIC CONTROL – FUNDAMENTALS OF WEATHER AND AVIATION WEATHER SERVICES

MODULE OVERVIEW

Purpose: The purpose of this module is to explain the basic principles of weather, different elements of the atmosphere, and the National Weather Service's (NWS) role in providing aviation weather services to the FAA.

MODULE OUTLINE

Lesson: Earth's Atmosphere

Purpose: The purpose of this lesson is to help you recognize characteristics associated with each layer of the Earth's atmosphere, and how they affect weather and aviation.

Objective:

- Identify characteristics and properties of the Earth's atmosphere

Topics:

- Earth's Atmosphere
  - Troposphere
  - Stratosphere
  - Standard Atmosphere
  - Jet Streams
  - Jet Stream Features
- Knowledge Check
- Review/Summary

Lesson: Atmospheric Moisture

Purpose: The purpose of this lesson is to explain the different characteristics of atmospheric moisture and the various forms of clouds.

Objectives:

- Describe characteristics of atmospheric moisture
- Define forms of clouds

Topics:

- Atmospheric Moisture
  - Water Vapor
  - Evaporation
  - Sublimation
  - Temperature
  - Dew Point
  - Condensation
  - Relative Humidity
  - Saturation
- Temperature/Dew Point Spread
- Knowledge Check

- Clouds
  - Cloud Formation and Dissipation
  - Cloud Forms
  - Cloud Prefixes and Suffixes
- Knowledge Check
- Review/Summary

Question and Answer Session – *Parking Lot*

Lesson: Wind, Air Masses, and Fronts

Purpose: The purpose of this lesson is to explain the details of air masses, mass modifications, and frontal types.

Objectives:

- Identify air masses and their characteristics
- Identify air mass modifications and their characteristics
- Identify frontal types and their characteristics

Topics:

- Wind
- High Weather Effects
- Low Weather Effects
- Knowledge Check
- Air Masses
- Air Mass Classification
  - Temperature
  - Moisture
- Air Mass Modification
- Knowledge Check
- Fronts
- Frontal Types
  - Cold Front
  - Warm Front
  - Stationary Front
  - Occluded Front
- Cold Front
- Warm Front
- Knowledge Check
- Review/Summary

Question and Answer Session – *Parking Lot*

Lesson: Precipitation

Purpose: The purpose of this lesson is to help you recognize the different ingredients and weather conditions that contribute to forms of precipitation. The lesson will also identify selected National Weather Service (NWS) offices and explain their duties and responsibilities.

Objectives:

- Identify ingredients required to form precipitation
- Identify types of precipitation
- Identify duties and responsibilities of selected National Weather Service (NWS) offices

Topics:

- Precipitation
- Ingredients for Precipitation Formation
  - Water Vapor
  - Lift
  - Growth Process
- Precipitation Types
  - Snow
  - Ice Pellets
  - Freezing Rain
  - Rain
- Knowledge Check
- National Weather Service (NWS)
  - United States NWS Offices
  - Center Weather Service Unit (CWSU)
  - Center Weather Coordinator (CWC)
- Knowledge Check
- Review/Summary

Activity – Atmospheric Aptitude

Question and Answer Session – *Parking Lot*

End-of-Module (EOM) Test

INTRODUCTION

LESSONS	■ Earth's Atmosphere ■ Atmospheric Moisture ■ Wind, Air Masses, and Fronts ■ Precipitation
TOTAL ESTIMATED RUN TIME	4 hr. 17 mins.
MODULE CONTENT	■ Module Overview ■ Lesson: Earth's Atmosphere ■ Lesson: Atmospheric Moisture ■ Q&A Session – Parking Lot ■ Lesson: Wind, Air Masses, and Fronts ■ Q&A Session – Parking Lot ■ Lesson: Precipitation ■ Activity – Atmospheric Aptitude ■ Q&A Session – Parking Lot ■ End-of-Module Test

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Instruct students to select ***Fundamentals of Weather and Aviation Weather Services*** module link within Blackboard ■ Instruct students to read the module introduction and then wait quietly for additional instructions	Blackboard
	EST. RUN TIME
	2 mins.

Weather plays an integral role for controllers. Controllers are required to be familiar with, and stay familiar with, current weather information needed to perform Air Traffic Control (ATC) duties.

What do you, as an air traffic controller, need to know about weather?

Despite the development of advanced technologies such as radar and Global Positioning Systems (GPSs), safety in flight is still subject to hazardous weather. Thus, you must have a fundamental knowledge of weather to help pilots avoid hazardous weather.

This module will help you understand basic principles of weather, different elements of the atmosphere, and the National Weather Service's (NWS) role in providing aviation weather services to the FAA.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Earth's Atmosphere*** and ***Atmospheric Moisture*** lessons in Blackboard ■ Instruct students to navigate to the ***Earth's Atmosphere*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of ***Earth's Atmosphere*** instruct students to navigate to the ***Atmospheric Moisture*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, students should review previously introduced content or wait quietly until other students have completed	Blackboard **EST. RUN TIME** 15 mins.

EARTH'S ATMOSPHERE

Purpose: This lesson will help you recognize characteristics associated with each layer of the Earth's atmosphere, and how they affect weather and aviation.

Objective:

- Identify characteristics and properties of the Earth's atmosphere

The references for this lesson are as follows:

- NWS: Jetstream: Online School for Weather
- FMH-1, Surface Weather Observations and Reports
- AC-00-6, Aviation Weather

Earth's Atmosphere

The atmosphere is a cloud of gas and suspended solids extending from the Earth's surface out thousands of miles. This gas grows thinner as the distance from the Earth increases.

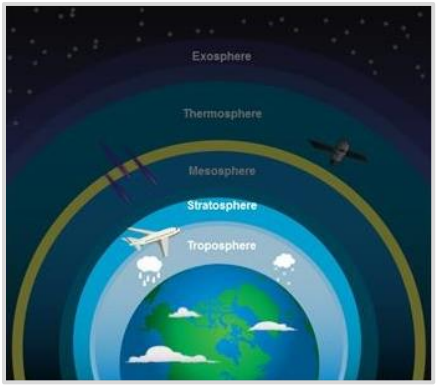
The atmosphere:

- Surrounds the Earth
- Is held in place by gravitational pull
- Holds the air we breathe
- Protects us from outer space
- Holds moisture, clouds, gases, and tiny particles

This protective bubble absorbs ultraviolet solar radiation, which warms the surface through heat retention and reduces temperature extremes.

Atmosphere

The atmosphere is subdivided into the five layers shown here. This lesson will emphasize the troposphere and lower stratosphere. This is where virtually all aircraft fly.



Troposphere

The troposphere is the lowest layer of the Earth's atmosphere and extends around 36,000 feet out from the Earth's surface.

The troposphere is where:

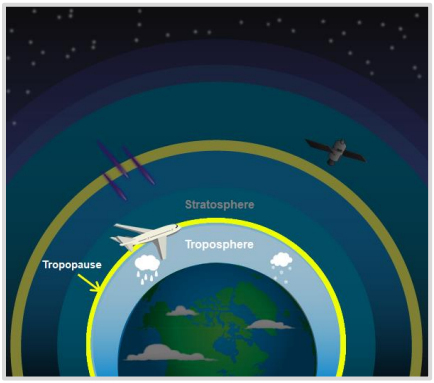
- Almost all clouds and precipitation occur
- Most weather takes place
- Air pressure and density decrease with altitude
- Temperature generally decreases with altitude

Note: *An increase in temperature with altitude is abnormal and is defined as an inversion.*

The vertical depth varies due to fluctuating temperature associated with latitude and season:

- At the equator, the depth is about 65,000'
- At 50°N and 50°S latitude, the depth is about 30,000'
- At the poles, the depth is about 20,000'

The transition boundary between the troposphere and the stratosphere is called the tropopause.



Stratosphere

The stratosphere extends from the tropopause up to 31 miles above the Earth's surface.

The stratosphere is where:

- Temperature increases with altitude, making it devoid of significant weather
- Thunderstorm tops reside, which commonly extend into the lower stratosphere
- The ozone layer resides

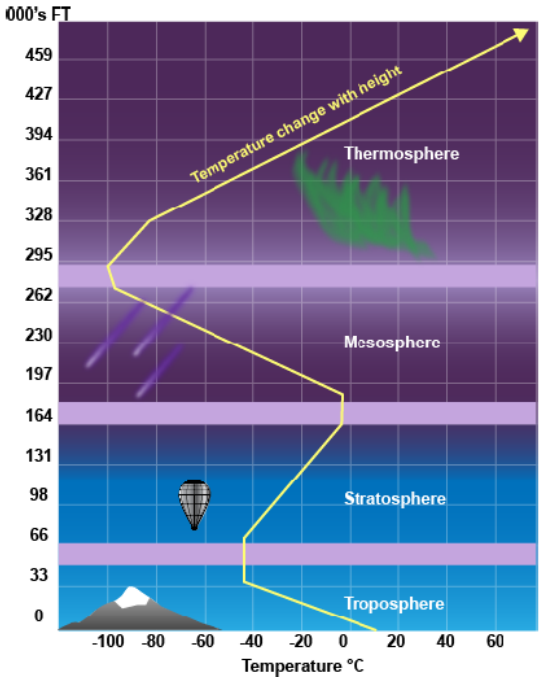
Standard Atmosphere

Standard Atmosphere is a hypothetical vertical distribution of the atmospheric temperature, pressure, and density, which, by international agreement, is considered to be representative of the atmosphere.

Standard atmosphere is used for:

- Pressure altimeter calibrations
- Aircraft performance calculations
- Aircraft design
- Weather-related processes

Property	Units
Sea level pressure	29.92 inches of mercury
Sea level temperature	15°C / 59F°
Decrease of temperature with height (lapse rate) in the troposphere	2°C / 3.5°F / 1,000 feet
Pressure altitude of the tropopause	36,000 feet (FL 360)

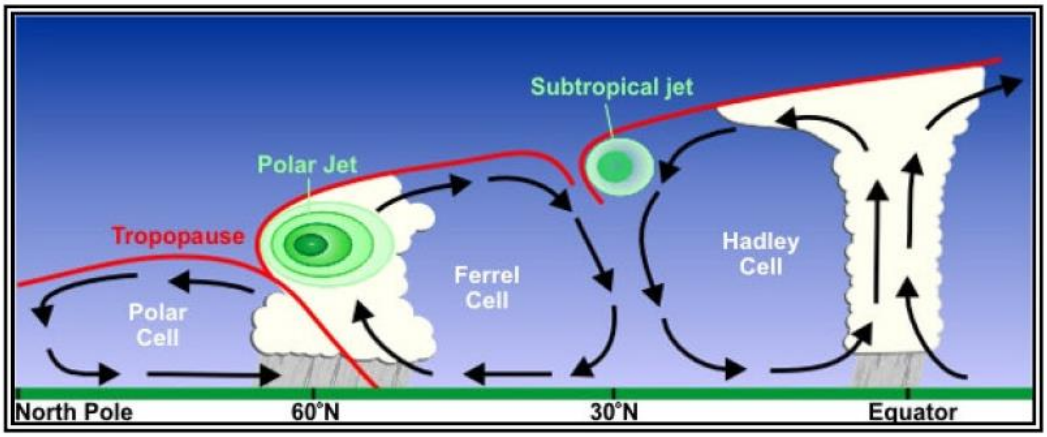


Jet Streams

Jet streams are migrating streams of high-speed winds present at high altitudes. Two jet streams that are commonly identified are the polar jet stream and the subtropical jet stream.

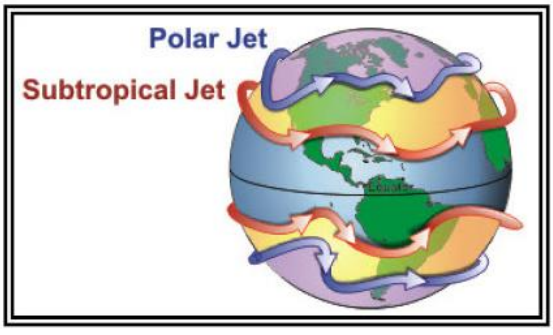
8.3.3 Location. In addition, with the three cell circulations mentioned previously, the regions around 30° N/S and 50°-60° N/S are areas where temperature changes are the greatest. As the difference in temperature between the two locations increases, the strength of the wind increases. Therefore, the regions around 30° N/S and 50°-60° N/S are also regions where the wind in the upper atmosphere is the strongest.

Figure 8-4. Three Cell Circulations and Jet Stream Location



The 50°-60° N/S region is where the polar jet is located with the subtropical jet located around 30° N. Jet streams vary in height of 4 to 8 miles and can reach speeds of more than 275 miles per hour (239 knots /442 kilometers per hour).

Figure 8-5. Polar and Subtropical Jet Streams



The actual appearance of jet streams results from the complex interaction between many variables, such as the location of high and low pressure systems, warm and cold air, and seasonal changes. They meander around the globe, dipping and rising in altitude/latitude, splitting at times and forming eddies, and even disappearing altogether to appear somewhere else.

FEATURE	FEATURE/CHARACTERISTIC
Flow	The jet stream flows from west to east, but the flow often shifts to the north and south due to weather systems and seasonal changes.
Nature	Jet streams naturally extend around the globe but are segmented, splitting at times and even disappearing altogether to appear somewhere else.
Boundaries	Jet streams are associated with the boundaries between hot and cold air. Since these boundaries are most pronounced during winter, that is when jet streams are strongest.
ATC Challenges	Jet streams make air traffic control (ATC) separation more difficult. They often produce Clear Air Turbulence (CAT) and cause aircraft to move at different ground speeds.

Knowledge Check A

REVIEW what you have learned so far about the Earth's atmosphere. ANSWER the questions listed below.

1. Which layer of the atmosphere contains almost all clouds and precipitation? *(Select the correct answer.)*
   - ❑ Stratosphere
   - ❑ **Troposphere**
   - ❑ Mesosphere

2. Which layer of the atmosphere is stable and generally devoid of significant weather? *(Select the correct answer.)*
   - ❑ **Stratosphere**
   - ❑ Troposphere
   - ❑ Mesosphere

3. What is the value of sea level pressure in the standard atmosphere? *(Select the correct answer.)*
   - ❑ **29.92 inches of mercury**
   - ❑ 29.92 hectopascals
   - ❑ 1013.2 inches of mercury

4. What is produced when a migrating stream of high-speed winds are present at high altitudes? *(Select the correct answer.)*
   - ❑ Vortices
   - ❑ **Jet streams**
   - ❑ Downwash

5. Which two jet streams are commonly identified? *(Select the correct answer.)*
   - ❑ Arctic and Tropical
   - ❑ Hot and Cold
   - ❑ **Polar and Subtropical**

Earth's Atmosphere Summary

The atmosphere is a bubble that surrounds Earth and protects the life within it. This lesson identified characteristics and properties of the Earth's atmosphere. Knowing how atmosphere can affect flight will allow you to provide better air traffic control services.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ ***Note*: *Atmospheric Moisture*** lesson should have already been enabled in Blackboard, if not ensure it is enabled ■ Instruct students to navigate to the ***Atmospheric Moisture*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, students should review previously introduced content or wait quietly until other students have completed	Blackboard **EST. RUN TIME** 20 mins.

ATMOSPHERIC MOISTURE

Purpose: This lesson explains the different characteristics of atmospheric moisture and the various forms of clouds.

Objectives:

- Describe characteristics of atmospheric moisture
- Define forms of clouds

The references for this lesson are as follows:

- AC-00-6, Aviation Weather
- NWS: Jetstream: Online School for Weather

Atmospheric Moisture

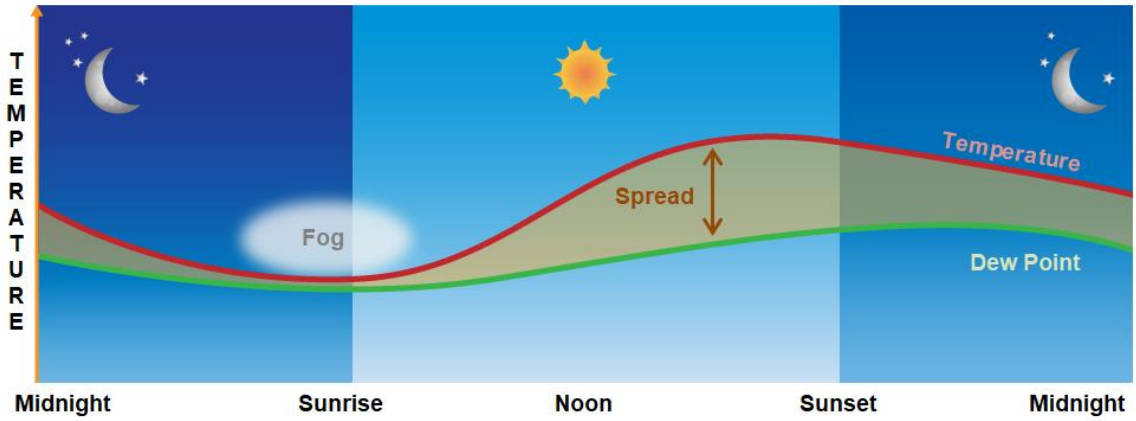
Atmospheric moisture defines the amount of water vapor in the atmosphere.

TYPES	DEFINITION
Water Vapor	The gaseous form of water.
Evaporation	The phase transition by which a liquid is changed to a vapor (gas).
Sublimation	The phase transition by which a solid is changed into vapor (a gas) without passing through the liquid phase.
Temperature	A numerical value representing the average kinetic energy of the atoms and molecules within matter. Temperature depends directly on the energy of molecular motion. The air's capacity to hold water is directly related to its temperature. Warm air can hold more water vapor than cold air.
Dew Point	The temperature an air parcel must be cooled at constant pressure and constant water vapor pressure to allow the water vapor in the parcel to condense into water (dew). Higher dew points at a location generally indicate higher quantities of water vapor.
Condensation	The phase transition by which vapor (a gas) is changed into a liquid.
Relative Humidity	The ratio, usually expressed as a percentage, of water vapor actually in the air parcel compared to the amount of water vapor the air could hold at a particular temperature and pressure.

Saturation	The maximum possible quantity of water vapor that a parcel of air can hold at any given temperature and pressure. "**Saturated**" means an air parcel contains all the water vapor it can hold. "**Unsaturated**" means it has the capacity to hold more.

Temperature/Dew Point Spread

The difference between air parcel's temperature and its dew point temperature is the dew point depression, or commonly referred to as the spread. During a typical 24-hour period over land, the surface air temperature increases during the day and decreases at night, while the dew point changes more slowly.



Knowledge Check B

REVIEW what you have learned so far about the atmospheric moisture. ANSWER the questions listed below.

1. What is the name of the process in which a solid is changed into vapor without passing through the liquid phase? *(Select the correct answer.)*
   - ❑ Evaporation
   - ❑ **Sublimation**
   - ❑ Condensation

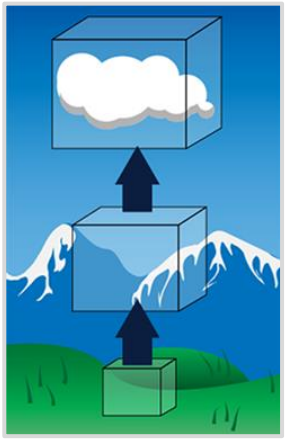
2. What is the ratio of water vapor actually in the air parcel, compared to the amount of water vapor the air could hold at a particular temperature and pressure? *(Select the correct answer.)*
   - ❑ **Relative humidity**
   - ❑ Condensation
   - ❑ Sublimation

3. The maximum possible quantity of water vapor that a parcel of air can hold at any given temperature and pressure is called _____. *(Select the correct answer.)*
   - ❑ Sublimation
   - ❑ Dew point
   - ❑ **Saturation**

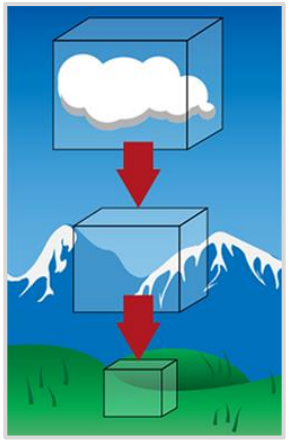
Clouds

A cloud is a visible aggregate of minute water droplets and/or ice particles in the atmosphere above the Earth's surface. Clouds form when air is cooled to its dew point and becomes saturated. The most common way is via condensation of water vapor in rising air currents.

Cloud Formation

	6,000 feet Temperature 8ºC Dew Point 8ºC Spread 0ºC *(Saturated)* 3,000 feet Temperature 15ºC Dew Point 12.5ºC Spread 2.5ºC *(Unsaturated)* Surface Temperature 24ºC Dew Point 14ºC Spread 10ºC *(Unsaturated)*	A parcel of rising air expands and cools as pressure decreases with altitude. As temperature/dew point spread **decreases**, a cloud will form, given sufficient lift to achieve saturation.

Cloud Dissipation

	6,000 feet Temperature 8ºC Dew Point 8ºC Spread 0ºC *(Saturated)* 3,000 feet Temperature 17ºC Dew Point 9.5ºC Spread 7.5ºC *(Unsaturated)* Surface Temperature 26ºC Dew Point 11ºC Spread 15ºC *(Unsaturated)*	A parcel of sinking air warms as it encounters increasing pressure and is compressed. As temperature/dew point spread **increases,** a cloud will quickly dissipate due to sinking air.

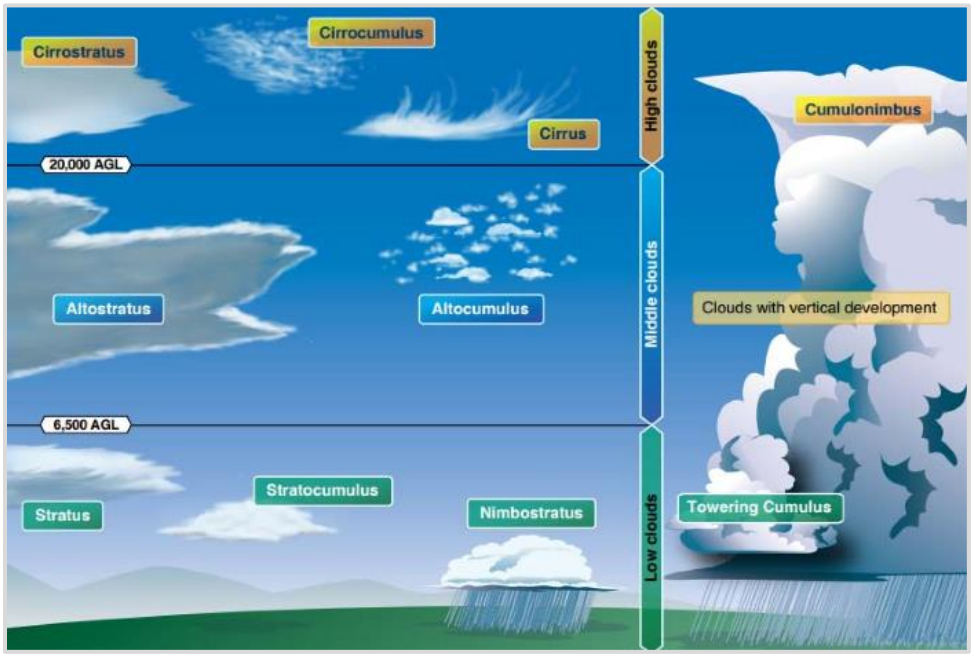
Cloud Forms

There are three forms of clouds: cirriform, cumuliform, and stratiform. The details are shown below.

 Cirriform		• High-level clouds which form above 20,000 feet • Usually composed of ice crystals • Typically thin and white in appearance • Contains no significant icing
 Cumuliform		• Resembles white fluffy cotton balls or heaps • Indicates upward vertical motion or thermal uplift of air • Tops can reach over 60,000 feet • May produce icing, turbulence, and other hazards
 Stratiform		• "Stratus" is Latin for “layer” or “blanket” • Consists of a featureless low layer that can cover sky • Often produces widespread Instrument Flight Rules (IFR) weather • Little or no turbulence but can produce icing

Cloud Prefixes and Suffixes

The prefix ***nimbo-*** or the suffix ***-nimbus*** means “raincloud.” Stratiform clouds from which rain is falling are ***nimbostratus***, and cumuliform clouds which produce precipitation are ***cumulonimbus***.



Knowledge Check C

REVIEW what you have learned so far about the clouds. ANSWER the questions listed below.

1. A parcel of _____ air expands and cools as pressure decreases with height. *(Select the correct answer.)*
   - ❑ **Rising**
   - ❑ Sinking
   - ❑ Stationary

2. Which cloud form indicates upward vertical motion or thermal uplift of air? *(Select the correct answer.)*
   - ❑ Cirriform
   - ❑ Stratiform
   - ❑ **Cumuliform**

3. Which cloud form often produces widespread IFR weather? *(Select the correct answer.)*
   - ❑ Cirriform
   - ❑ **Stratiform**
   - ❑ Cumuliform

4. Which type of cloud formations are rainclouds? *(Select all correct answers that apply.)*
   - ❑ Cirrinimbus
   - ❑ **Cumulonimbus**
   - ❑ **Nimbostratus**
   - ❑ Stratonimbus

Atmospheric Moisture Summary

The atmosphere, by nature, contains moisture which will affect flight in many different ways. This lesson explained the different characteristics of atmospheric moisture and the various forms of clouds. Knowing the details of atmospheric moisture and clouds will give you a better handle on what the pilots are dealing with and how you can help guide them.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Review content presented in ***Earth's Atmosphere*** and ***Atmospheric Moisture*** lessons ■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content	Facilitated Discussion **EST. RUN TIME** 30 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Wind, Air Masses, and Fronts*** lesson in Blackboard ■ Instruct students to navigate to the ***Wind, Air Masses, and Fronts*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, students should review previously introduced content or wait quietly until other students have completed	Blackboard **EST. RUN TIME** 25 mins.

WIND, AIR MASSES, AND FRONTS

Purpose: This lesson explains the details of air masses, mass modifications, and frontal types.

Objectives:

- Identify air masses and their characteristics
- Identify air mass modifications and their characteristics
- Identify frontal types and their characteristics

The references for this lesson are as follows:

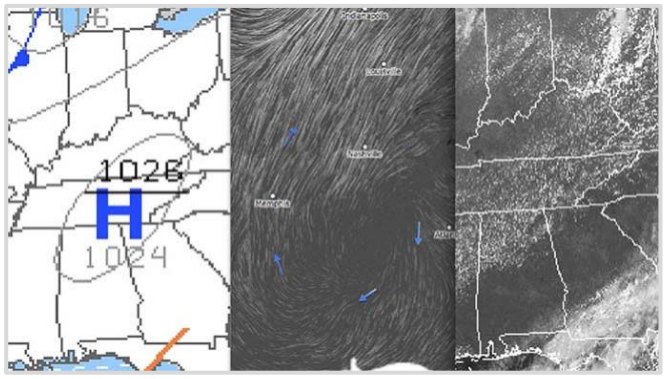
- AC-00-6, Aviation Weather
- NWS: Jetstream: Online School for Weather

Wind

Wind is the air in motion relative to the surface of the Earth. The vertical component of the wind is typically very small compared to the horizontal component. However, it is very important in the formation and dissipation of clouds and precipitation.

High Weather Effects

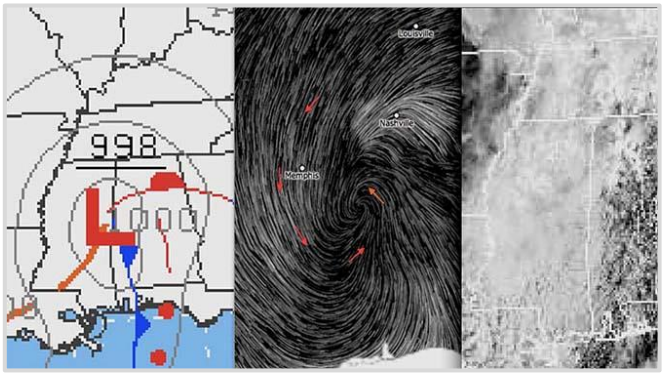
A high occurs when a maximum of atmospheric pressure in two dimensions (closed isobars) on a surface chart, or a maximum of height (closed contours) on a constant pressure chart; also known as an anti-cyclone. Air flow around a high diverges in a clockwise motion and sinks.



- Sinking air compresses and warms
- Warming air can hold more water vapor so clouds tend to evaporate

Low Weather Effects

Low occurs when there is a minimum of atmospheric pressure in two dimensions (closed isobars) on a surface chart, or a minimum of height (closed contours) on a constant pressure chart; also known as a cyclone. Air flow around a low converges in a counterclockwise motion and rises.



- Rising air expands and cools
- Cooling air can hold less water vapor so some of the invisible vapor may eventually condense into clouds and precipitation

Knowledge Check D

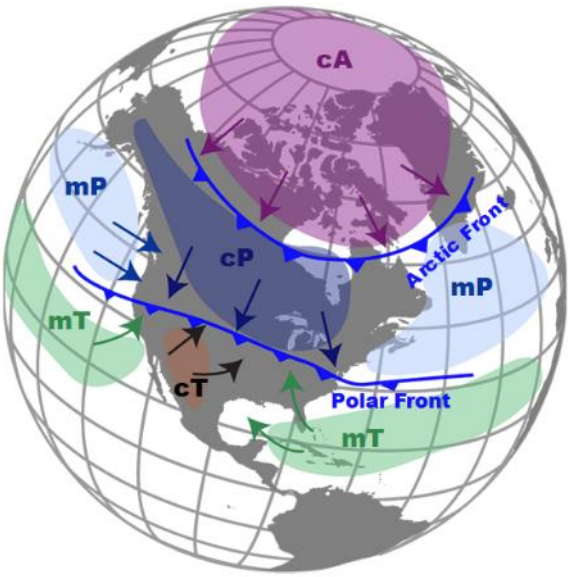
REVIEW what you have learned so far about wind. ANSWER the questions listed below.

1. Which type of weather effect occurs when there is a minimum amount of atmospheric pressure on Earth's surface? *(Select the correct answer.)*
   - ❑ High
   - ❑ **Low**
   - ❑ Wind

2. Which type of weather effect occurs when there is a maximum amount of atmospheric pressure on Earth's surface? *(Select the correct answer.)*
   - ❑ **High**
   - ❑ Low
   - ❑ Wind

Air Masses

An **air mass** is a large body of air with generally uniform temperature and humidity. An **air mass source region** is a region where air masses originate and acquire their properties of temperature and moisture. These properties are acquired by prolonged contact (days to weeks) with the underlying surface. Air masses are classified according to the temperature and moisture properties of their source regions.



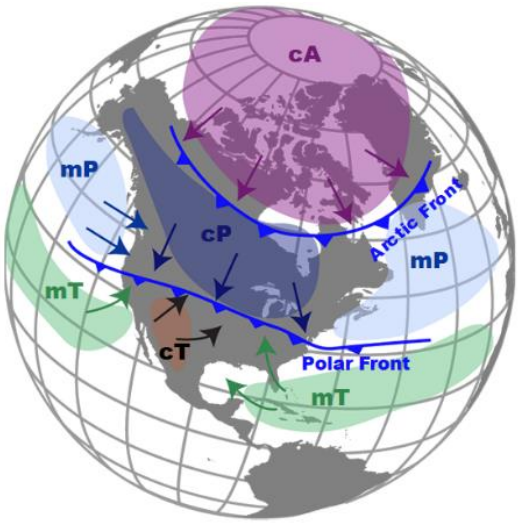
Air Mass Classification

Air masses are classified according to the temperature and moisture properties of their source regions.

TEMPERATURE	MOISTURE
Temperature properties ■ Arctic (A) – An extremely deep, cold air mass which develops mostly in winter over arctic surfaces of ice and snow ■ Polar (P) – A relatively shallow, cool-to-cold air mass which develops over high latitudes ■ Tropical (T) – A warm-to-hot air mass which develops over low latitudes	Moisture properties ■ Continental (c) – A dry air mass which develops over land ■ Maritime (m) – A moist air mass which develops over water

When this classification scheme is applied, the five air masses shown in the chart below may be identified.

Source Region	Continental (c)	Maritime (m)
Arctic (A)	Continental Arctic (cA) *(Cold, dry)*	*Not Applicable*
Polar (P)	Continental Polar (cP) *(Cold, dry)*	Maritime Polar (mP) *(Cool, moist)*
Tropical (T)	Continental Tropic (cT) *(Hot, dry)*	Maritime Tropical (mT) *(Warm, moist)*

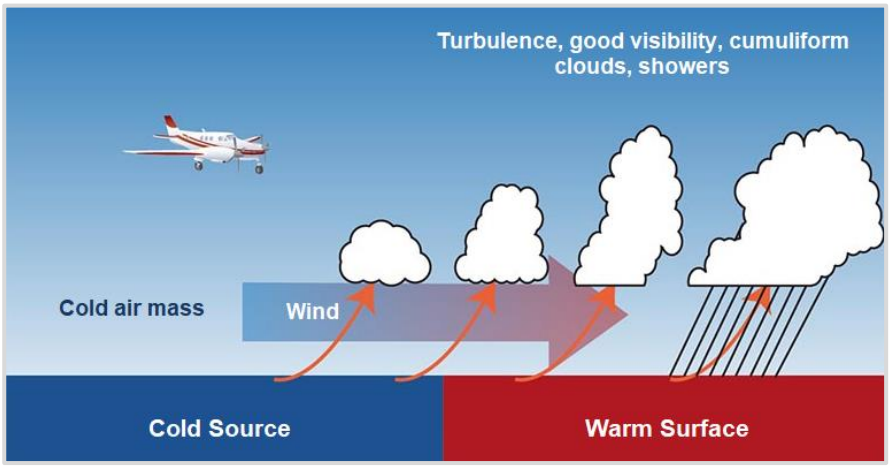


Note: *Maritime Arctic (mA) is not listed since it seldom, if ever, forms due to the Arctic Ocean being frozen most of the time.*

Air Mass Modification

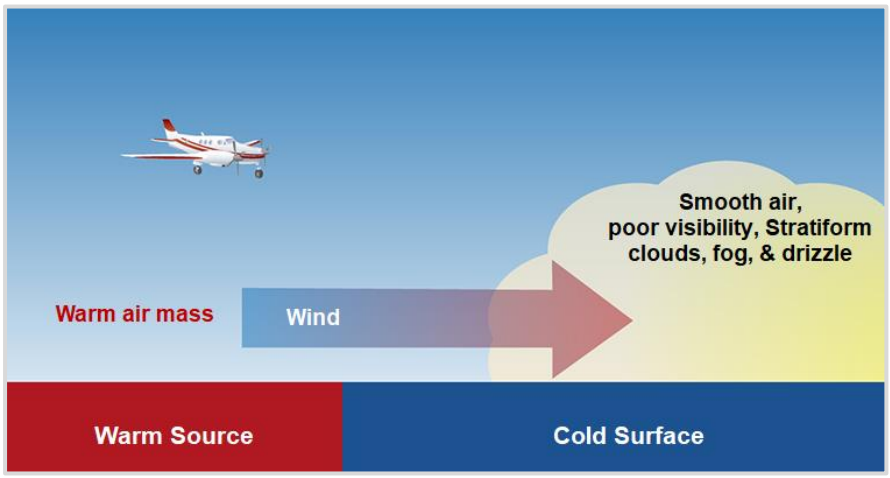
As an air mass is blown away from its source region, it is modified by its underlying surface. Cold air mass moving over a warm surface often produces unstable air associated with:

- Turbulence
- Good visibility (outside of clouds)
- Cumuliform clouds and showers



A warm air mass moving over a cold surface often produces stable air associated with:

- Smooth air
- Poor visibility
- Stratiform clouds, fog, and drizzle



Knowledge Check E

REVIEW what you have learned so far about air masses. ANSWER the questions listed below.

1. A Maritime Tropical (mT) air mass is _____ and _____. *(Select the correct answer.)*
   - ❑ **Warm, moist**
   - ❑ Warm, dry
   - ❑ Cold, dry

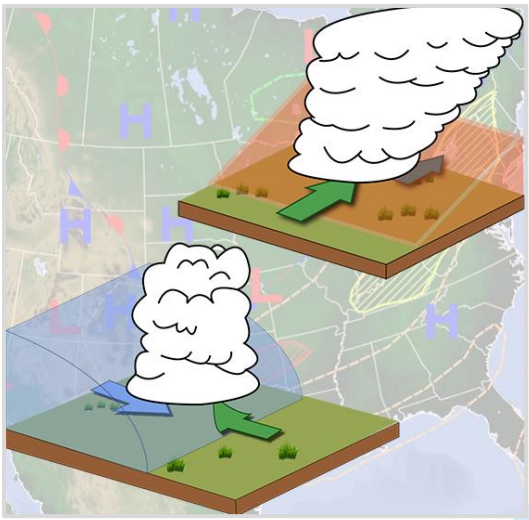
2. Cold air mass moving over a warm surface often produces unstable air associated with_____. *(Select the correct answer.)*
   - ❑ Smooth air
   - ❑ Poor visibility
   - ❑ **Turbulence**

Fronts

A front is a boundary or transition zone between two air masses of different density and usually different temperatures. Fronts are normally detectable at the surface when:

- There are significant temperature differences along frontal zones
- Winds come together at the fronts
- Pressure decreases as a front approaches and increases after it passes

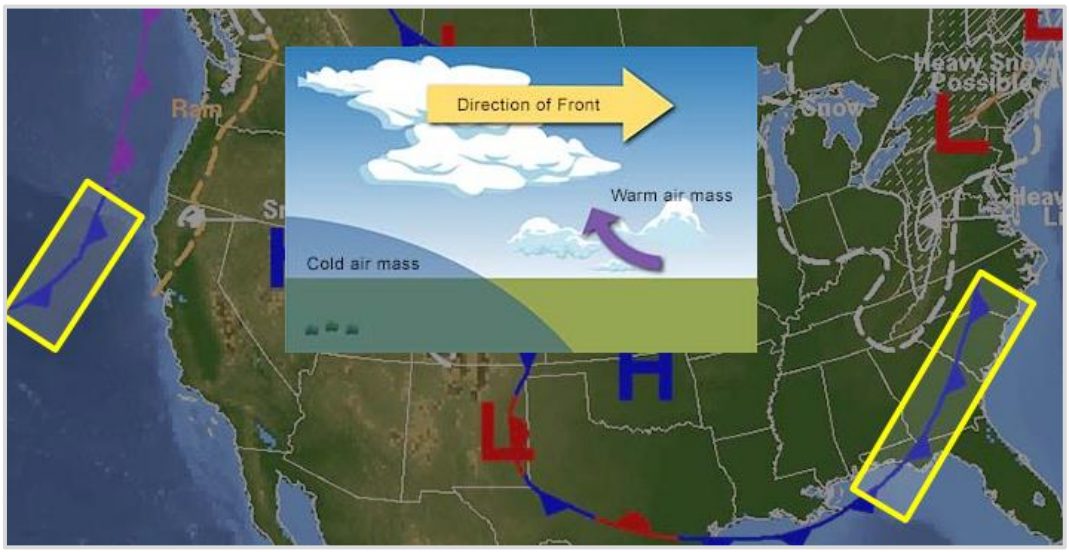
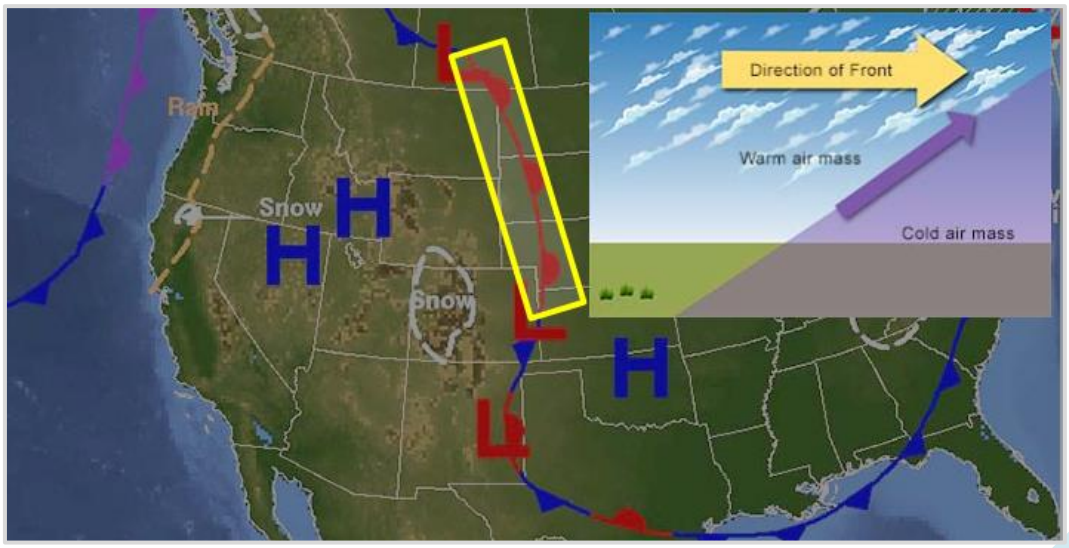
Fronts exist at the surface of the Earth and have a vertical structure in which the front slopes over the colder, denser air mass.

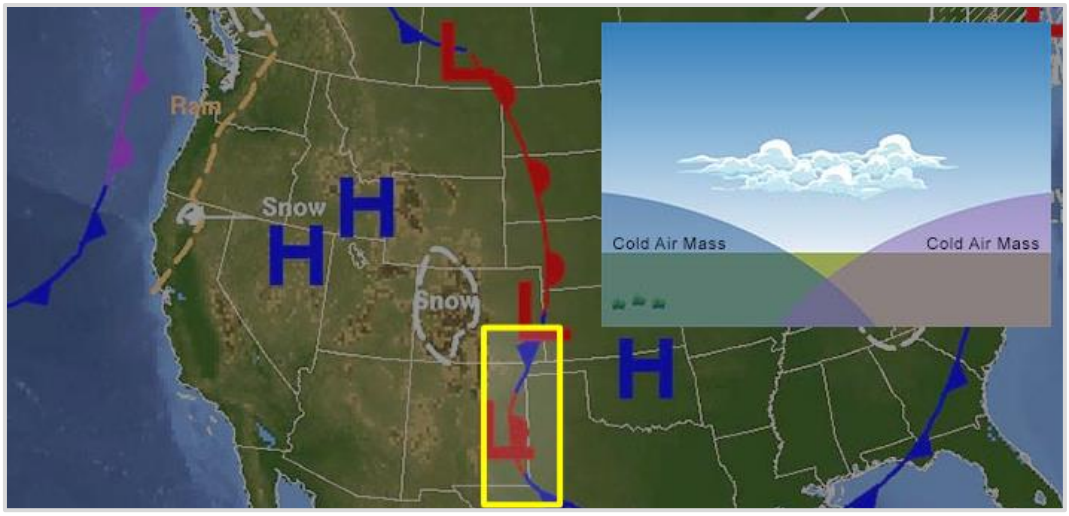
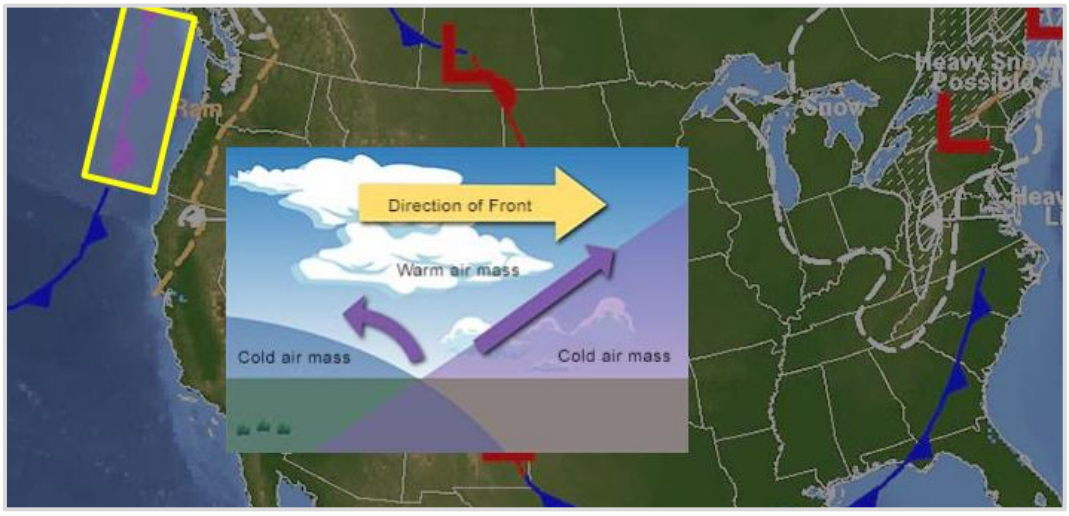


There are four different types of fronts:

- Cold
- Warm
- Stationary
- Occluded

Frontal Types

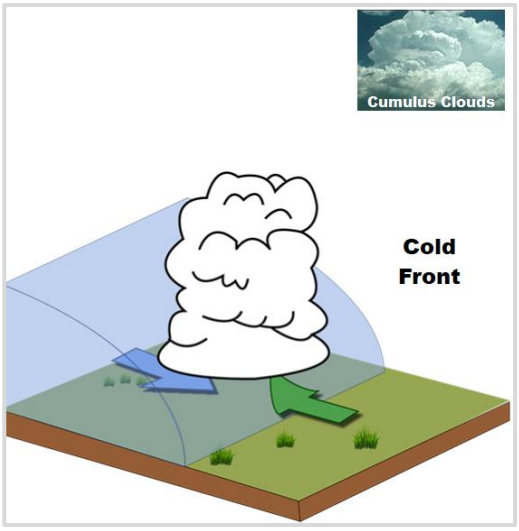
TYPE OF FRONT	FEATURES/CHARACTERISTICS
Cold 	Cold fronts typically move faster than warm fronts, so in time they "catch up" to warm fronts. When this occurs, colder air replaces warmer air. 
Warm 	A front that moves in such a way that warmer air replaces colder air. 

Stationary 	A front which is a boundary between two different air masses. Neither air mass is strong enough to replace the other, which renders it stationary or nearly so. A wide variety of weather can be found along a stationary front, but usually, clouds and prolonged precipitation occurs here. 
Occluded 	A composite of two fronts as a cold front overtakes a warm front or stationary front. The cold air undercuts the retreating cold air mass associated with the warm front, further lifting the already rising warm air. Clouds and precipitation can occur both ahead of and in the areas of frontal lift of an occluded front. 

Cold Front

Cold fronts have a steep slope and air is forced upward abruptly.

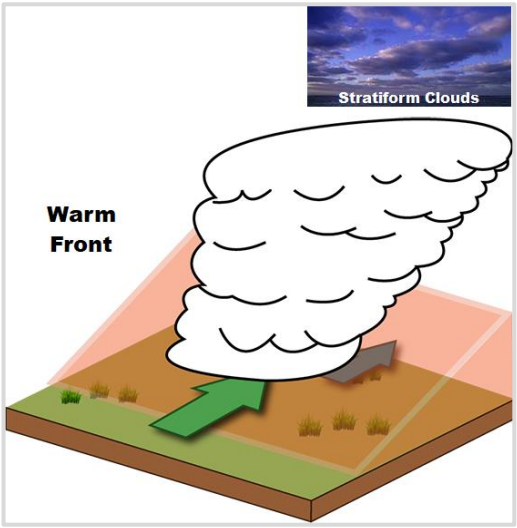
- This often leads to a narrow band of cumulus clouds, showers, and thunderstorms along or just ahead of the front if the rising air is unstable
- Good visibility and turbulence are associated with cold fronts



Warm Front

Warm fronts typically have a gentle slope so the air rising along the frontal surface is gradual.

- This favors the development of widespread layered or stratiform cloudiness and precipitation along and ahead of the front if the rising air is stable
- Poor visibility, smooth air, and steady precipitation are associated with warm fronts



Knowledge Check F

REVIEW what you have learned so far about fronts. ANSWER the questions listed below.

1. A cold air mass moving over a warm surface often produces which type of air? *(Select the correct answer.)*
   - ❑ Polluted
   - ❑ Stable
   - ❑ **Unstable**

2. Which front moves in such a way that warmer air replaces colder air? *(Select the correct answer.)*
   - ❑ Cold front
   - ❑ Stationary front
   - ❑ **Warm front**

3. What type of front has a steep slope which often leads to a narrow band of showers and thunderstorms if the rising air is unstable? *(Select the correct answer.)*
   - ❑ **Cold front**
   - ❑ Warm front
   - ❑ Cool front

Wind, Air Masses, and Fronts Summary

Why is weather today clear and cold over Oklahoma while it is warm and moist over Alabama? Air masses and fronts provide the answer. This lesson explained the details of air masses, mass modifications, and frontal types. You can better manage the safety and economy of air traffic when you can evaluate the expected effects of air masses and fronts.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Review content presented in ***Wind, Air Masses, and Fronts*** lesson ■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content	Facilitated Discussion **EST. RUN TIME** 30 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Precipitation*** lesson in Blackboard and ***Atmospheric Aptitude*** activity in ***Exercises and Activities*** folder in Blackboard ■ Instruct students to navigate to the ***Precipitation*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, instruct students to proceed to ***Atmospheric Aptitude*** activity in the ***Exercises and Activities*** folder in Blackboard ■ The activity may be performed individually ■ Instruct students to answer each question ■ At the end of the exercise, the activity will evaluate the students' performance ■ Suggest allowing opportunities to repeat the activity during periods of down time	Blackboard and Activity **EST. RUN TIME** 15 mins.

PRECIPITATION

Purpose: This lesson will help you recognize the different ingredients and weather conditions that contribute to forms of precipitation. The lesson will also identify selected National Weather Service offices and explain their duties and responsibilities.

Objectives:

- Identify ingredients to form precipitation
- Identify types of precipitation
- Identify duties and responsibilities of selected National Weather Service (NWS) offices

The references for this lesson are as follows:

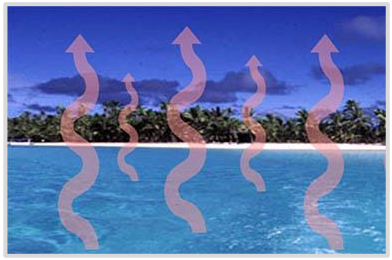
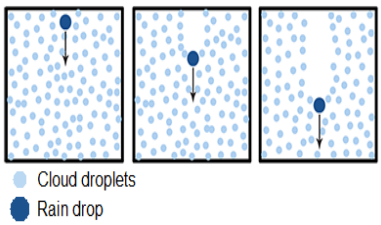
- FAA Order JO 7110.10, Flight Services
- American Meteorology Society (AMS), Glossary of Meteorology
- AC-00-45, Aviation Weather Services
- NWS: Jetstream: Online School for Weather

Precipitation

Precipitation is any of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground.

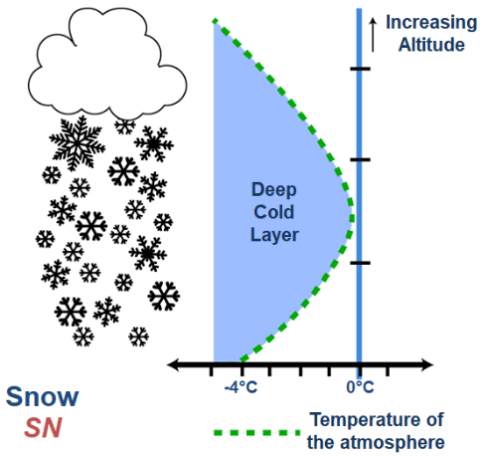
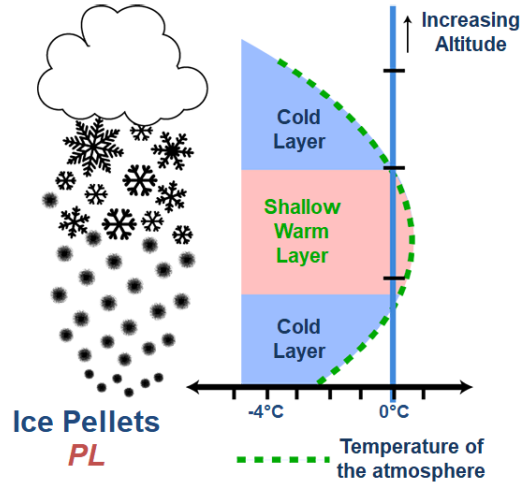
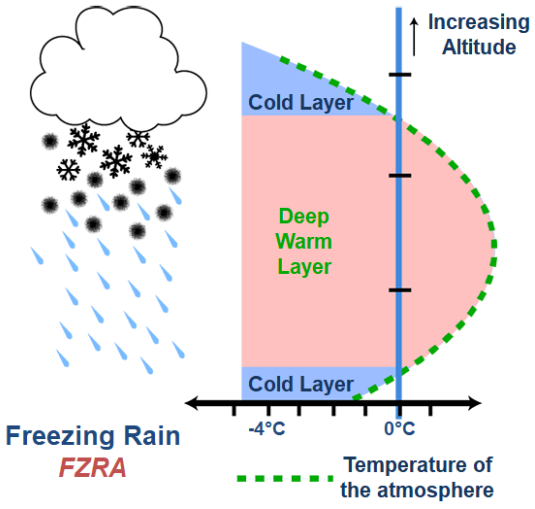
Ingredients for Precipitation Formation

Precipitation formation requires three ingredients: water vapor, lift, and growth process.

	**Water Vapor** The primary sources in the United States are: ■ Atlantic and Pacific Oceans ■ Gulf of Mexico ■ Great Lakes Winds transport this water vapor inland.
	**Lift** Sufficient **lift** to condense the water vapor into clouds ■ Converging winds around surface lows ■ Fronts
	**Growth Process** A **growth process** that allows water particles to grow large and heavy enough to fall as precipitation.

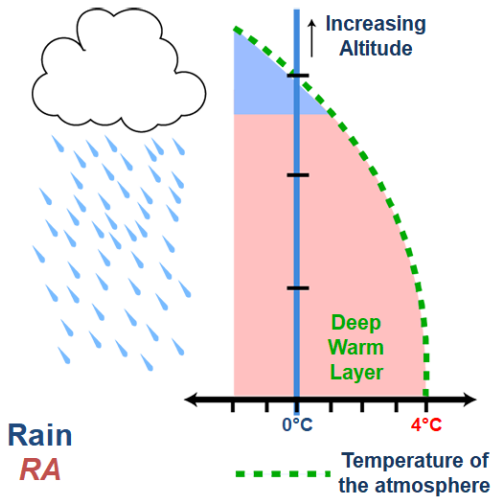
Precipitation Types

The vertical distribution of temperature will often determine the type of precipitation that occurs at the surface.

TYPE OF PRECIPITATION	ILLUSTRATION
Snow (SN) – Precipitation of snow crystals, mostly branched in the form of six-pointed stars. ■ Snow occurs when the temperature remains below-freezing throughout the entire depth of the atmosphere ***Note:*** *This graphic depicts an inversion; an inversion is not necessary for the development of snow.*	
Ice Pellets (PL) – Precipitation of transparent or translucent pellets of ice, which are round or irregular, rarely conical, and have a diameter of 0.2 inch (5 mm) or less. Sometimes called "sleet." ■ Ice pellets occur when there is a shallow layer aloft with above-freezing temperatures, with a deep layer of below-freezing air based at the surface ■ As snow falls into the shallow warm layer, the snowflakes partially melt. ■ As the precipitation re-enters air that is below freezing, it re-freezes into ice pellets	
Freezing Rain (FZRA) – Rain that freezes on contact with the ground or exposed objects. Freezing rain: ■ Occurs when there is a deep layer aloft with above-freezing temperatures, with a shallow layer of below-freezing air at the surface ■ Can begin as either rain or snow but becomes all rain in the warm layer ■ Rain falls back into below freezing air, but since the depth is shallow, it does not have time to freeze into ice pellets ■ Drops freeze on contact with ground or exposed objects	

Rain (RA) – Precipitation, either in the form of drops larger than 0.02 inch (0.5 mm), or smaller drops that, in contrast to drizzle, are widely separated.

- Rain occurs when there is a deep layer of above-freezing air based at the surface



Knowledge Check G

REVIEW what you have learned so far about precipitation. ANSWER the questions listed below.

1. What ingredients are needed for precipitation formation? *(Select all correct answers that apply.)*
   - ❑ **Water vapor**
   - ❑ Unstable air
   - ❑ **Lift**
   - ❑ **Growth process**

2. Which precipitation type occurs when there is a deep layer aloft with above-freezing temperatures, with a shallow layer of below-freezing air at the surface? *(Select the correct answer.)*
   - ❑ Snow
   - ❑ Ice pellets
   - ❑ **Freezing rain**
   - ❑ Rain

3. Which of the following conditions must be present for precipitation to occur as snow? *(Select the correct answer.)*
   - ❑ A deep layer of above-freezing air based at the surface.
   - ❑ A shallow layer aloft with above-freezing temperatures, with a deep layer of below-freezing air based at the surface
   - ❑ A deep layer aloft with above-freezing temperatures, with a shallow layer of below-freezing air at the surface
   - ❑ **The temperature remains below freezing throughout the entire depth of the atmosphere**

National Weather Service (NWS)

The National Weather Service (NWS):

- Is a federal agency under the Department of Commerce's (DOC) National Oceanic and Atmospheric Administration (NOAA)
- Provides weather, hydrologic, and climate forecasts and warnings for the protection of life and property and the enhancement of the national economy

United States NWS Offices

- Meteorological Watch Offices (MWOs)
- Weather Forecast Offices (WFOs)

National Weather Service produces the following aviation weather products:

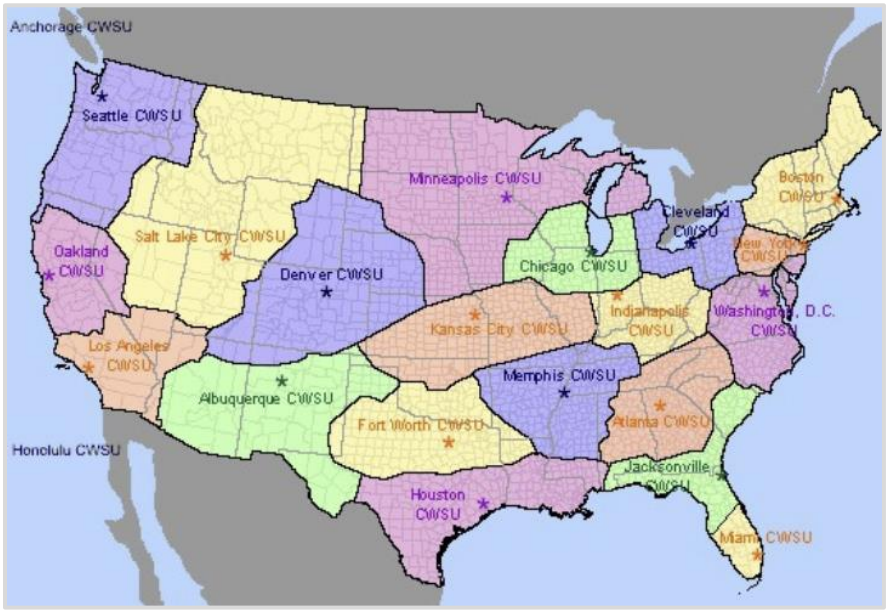
- Airmen's Meteorological Information (AIRMETs)
- Significant Meteorological Information (SIGMETs)
- Convective SIGMETs
- Terminal Aerodrome Forecasts (TAFs)

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHEREIC ADMINISTRATION

Center Weather Service Unit (CWSU)

Center Weather Service Units (CWSUs) are NWS offices located in every **Air Route Traffic Control Center (ARTCC)**, providing meteorological consultation, forecasts, and advice to ARTCCs and other FAA facilities regarding weather impact on their:

- Missions
- Equipment outages and repairs
- Staffing



The **Center Weather Coordinator (CWC)** is staffed by controllers and is the designated interface between CWSU meteorologists and:

- ARTCC controllers
- FAA facilities within the ARTCC area of responsibility

Knowledge Check H

REVIEW what you have learned so far about National Weather Service. ANSWER the questions listed below.

1. What NWS entity provides consultation, forecast, and advice to ARTCCs regarding weather impacts? *(Select the correct answer.)*
   - ❑ Meteorological Watch Office (MWO)
   - ❑ Weather Forecast Office (WFO)
   - ❑ **Center Weather Service Unit (CWSU)**

2. The CWSU provides information to ARTCCs and other FAA facilities regarding weather impact for which of the following areas? *(Select all correct answers that apply.)*
   - ❑ **Equipment outages and repairs**
   - ❑ **Missions**
   - ❑ Runway status
   - ❑ **Staffing**

3. Which organization is responsible for coordination between the CWSU meteorologists and ARTCC controllers and facilities? *(Select the correct answer.)*
   - ❑ MWO
   - ❑ CWSU
   - ❑ ARTCC
   - ❑ **CWC**

Precipitation Summary

Different types of precipitation can affect how an aircraft functions, which can be detrimental to the safety of pilots, passengers, and crew on an aircraft. As an air traffic controller, you must be advised of all current weather conditions that affect or could potentially affect your location.

You are responsible for obtaining updated and accurate forecasts or advisories from reliable resources. Being advised of weather conditions is a vital resource to controllers, as they strive to maintain the safety of those who rely on their guidance and direction.

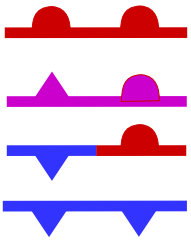
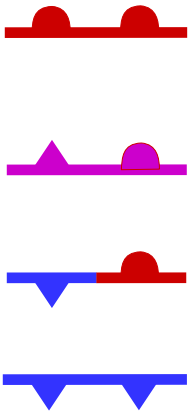
FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ ***Note: Atmospheric Aptitude*** activity should already have been enabled in Blackboard, if not ensure it is enabled ■ Instruct students to navigate to the ***Exercises and Activities*** folder in Blackboard ■ Instruct students to locate student activity ***Atmospheric Aptitude*** ■ The activity may be performed individually ■ Instruct students to answer each question ■ At the end of the exercise, the activity will evaluate the students' performance ■ Suggest allowing opportunities to repeat the activity during periods of down time	Activity **EST. RUN TIME** 20 mins.

ACTIVITY: ATMOSPHERIC APTITUDE (ANSWER KEY)

Note: *The questions in the key and their distractors may appear in a different order than displayed here due to activity question randomization.*

Question	Answer
1. In which layer of the Earth's atmosphere do almost all clouds and precipitation and weather take place?	**Troposphere** Thermosphere Stratosphere Mesosphere
2. Identify the three upper layers of the Earth's atmosphere	**Mesophere;** **Stratosphere;** **Troposphere**
3. Which of the following is **NOT** a characteristic of the stratosphere?	**Temperature generally decreases with altitude** Contains the ozone layer Stable layer, generally lacks significant weather Temperature increases with altitude
4. Which of the following are characteristics of the troposphere?	**Air pressure and density decrease with altitude;** **Contains almost all clouds and precipitation;** **Layer where most of Earth's weather takes place** Stable layer, generally lacks significant weather
5. Identify the three forms of clouds	**Stratiform;** **Cirriform;** **Cumuliform**
6. Which of the following are characteristics of stratiform clouds?	**Often produces widespread IFR weather;** **Little or no turbulence but can produce icing** Tops can reach over 60,000 feet Typically thin and white in appearance
7. Which of the following are characteristics of cirriform clouds?	**Contains no significant icing;** **High-level clouds which form above 20,000 feet** Tops can reach over 60,000 feet Consists of a featureless low layer that can cover sky
8. Which of the following are characteristics of cumuliform clouds?	**Indicates upward vertical motion or thermal uplift of air;** **May produce icing, turbulence, and other hazards** Usually composed of ice crystals Often produces widespread IFR weather

Question	Answer
9. Match the description of atmospheric moisture to the term it describes.	**Evaporation: <u>The phase transition by which a liquid is changed to a vapor (gas).</u>** **Relative humidity: <u>The ratio, usually expressed as a percentage, of water vapor actually in the air parcel compared to the amount of water vapor the air could hold at a particular temperature and pressure.</u>** **Sublimation: <u>The phase transition by which a solid is changed into vapor (a gas) without passing through the liquid phase.</u>** **Condensation: <u>The phase transition by which vapor (a gas) is changed into a liquid.</u>** **Saturation: <u>The maximum possible quantity of water vapor that a parcel of air can hold at any given temperature and pressure.</u>** **Dew point: <u>The temperature an air parcel must be cooled at constant pressure and constant water vapor pressure to allow the water vapor in the parcel to condense into water (dew).</u>**
10. Identify the highlighted air mass.	**cP:** **<u>Cold and dry</u>** Warm and moist Hot and dry Cool and moist
11. Identify the highlighted air mass.	**mP:** **<u>Cool and moist</u>** Warm and moist Cold and dry Hot and dry
12. Identify the highlighted air mass.	**cA:** **<u>Cold and dry</u>** Warm and moist Hot and dry Cool and moist
13. Identify the highlighted air mass.	**mT:** **<u>Warm and moist</u>** Cold and dry Hot and dry Cool and moist

Question	Answer
14. Identify the highlighted air mass.	**cT:** **Hot and dry** Warm and moist Cold and dry Cool and moist
15. Identify the chart symbol that represents each type of front.	 **Warm** **Occluded** **Stationary** **Cold**
16. Identify the characteristics for each type of front.	 **Front that moves in such a way that warmer air replaces colder air** **Composite of two fronts as a cold front overtakes a warm front or stationary front** **Front which is stationary or nearly so** **Front that moves in such a way that colder air replaces warmer air**
17. Identify the precipitation symbols.	(Answers as shown in location on screen) **SN** **RA** **PL** **FZRA**
18. Match the definition to the precipitation symbols.	**PL: Transparent precipitation which is round or irregular, rarely conical, and which has a diameter of 0.2 inch (5 mm) or less** **FZRA: Precipitation that freezes on contact with the ground or exposed objects** **RA: Precipitation, either in the form of drops larger than 0.02 inch (0.5 mm) or smaller drops, which, in contrast to drizzle, are widely separated** **SN: Precipitation crystals, mostly branched in the form of six-pointed stars**
19. Who is designated to interface between CWSU meteorologists, ARTCC controllers, and FAA facilities within the ARTCC area of responsibility?	**CWC** DOC CWSU NOAA

Question	Answer
20. Which NWS office provides advice to ARTCCs and other FAA facilities regarding weather impact on their missions, equipment outages and repairs, and staffing?	**CWSU** DOC NOAA CWC
21. Which federal agency provides weather, hydrologic, and climate forecasts and warnings for the protection of life and property?	**NWS** DOC NOAA ARTCC

SUMMARY

The purpose of this module was to explain the basic principles of weather, different elements of the atmosphere, and the National Weather Service's (NWS) role in providing aviation weather services to the FAA.

In accordance with FAA Order JO 7110.10, Flight Services; NWS: Jetstream: Online School for Weather; FMH-1, Surface Weather Observations and Reports; AC-00-6, Aviation Weather; AC-00-45, Aviation Weather; and the American Meteorology Society (AMS), Glossary of Meteorology, you should now be able to:

- Identify characteristics and properties of the Earth's atmosphere
- Describe characteristics of atmospheric moisture
- Define forms of clouds
- Identify air masses and their characteristics
- Identify air mass modifications and their characteristics
- Identify frontal types and their characteristics
- Identify ingredients required to form precipitation
- Identify types of precipitation
- Identify duties and responsibilities of selected National Weather Service (NWS) Offices

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content ■ Instruct students to prepare for the End-of-Module test by putting away their Student Guides	Facilitated Discussion **EST. RUN TIME** 30 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD

■ **ENABLE *Fundamentals of Weather and Aviation Services End-of-Module Test*** link in Blackboard
■ Instruct students:
  ○ Clear desks
  ○ Do not write anything during or after the test
  ○ Navigate to the ***Fundamentals of Weather and Aviation Services End-of-Module Test*** link in Blackboard
  ○ Once they are satisfied with their responses, click “Save and Submit;” do not click “OK” to review results until directed to do so
  ○ Choose “Cancel” if they receive a warning message that the test has unanswered questions; choosing OK will submit the test and not allow them to go back and answer the questions
  ○ Leave the room after submitting the test and return at the “Be Back” time
■ ***Note:*** *This test is scored but not graded*
■ During test, monitor students to ensure a secure testing environment
■ Identify the most commonly missed questions by reviewing student statistics in Blackboard
■ Instruct students to click “View Results” when ready to review commonly missed questions
■ Review commonly missed questions with students
	Blackboard Assessment
	EST. RUN TIME
	30 mins.

END-OF-MODULE TEST (ANSWER KEY)

Note: *Test questions in Blackboard are presented to the students in random order. Please be aware the test key question order will not match the student version.*

1. Which of the following is **NOT** a characteristic of the stratosphere? *(Select the correct answer.)*
   - ❑ **It is a very unstable layer of the atmosphere**
   - ❑ Temperature increases with altitude
   - ❑ Generally devoid of significant weather
   - ❑ The tropopause lies directly beneath it

   Reference(s): NWS Jetstream Online School for Weather

2. Virtually all aircraft fly in which two layers of the atmosphere? *(Select the correct answer.)*
   - ❑ **Troposphere and stratosphere**
   - ❑ Thermosphere and stratosphere
   - ❑ Troposphere and mesosphere
   - ❑ Mesosphere and stratosphere

   Reference(s): NWS Jetstream Online School for Weather

3. A hazard associated with the jet stream is _____. *(Select the correct answer.)*
   - ❑ **Clear air turbulence**
   - ❑ Rime icing
   - ❑ Low-level wind shear
   - ❑ Temperature inversions

   Reference(s): NWS Jetstream Online School for Weather

4. The ratio of water vapor in the air compared to the amount of water vapor the air can hold at a particular temperature and pressure is the definition of _____. *(Select the correct answer.)*
   - ❑ **Relative humidity**
   - ❑ Barometric surface pressure
   - ❑ Dew point
   - ❑ Saturated air

   Reference(s): AC 00-6, Aviation Weather

5. What cloud type is usually composed of ice crystals, is typically thin and white in appearance, contains no significant icing, and is a high-level cloud forming above 20,000 feet? *(Select the correct answer.)*
   - ❑ **Cirriform**
   - ❑ Cumuliform
   - ❑ Stratiform
   - ❑ Nimboform

   Reference(s): NWS Jetstream Online School for Weather

6. What type of clouds look like fluffy cotton balls or heaps, indicate upward vertical motion or thermal uplift of air, and can produce severe turbulence, icing, and other hazards? *(Select the correct answer.)*
   - ❑ **Cumuliform**
   - ❑ Cirriform
   - ❑ Nimboform
   - ❑ Stratiform

   Reference(s): NWS Jetstream Online School for Weather

7. Air masses are classified according to the temperature and moisture properties of their source regions. Which of the following is **NOT** a temperature property? *(Select the correct answer.)*
   - ❑ **Equatorial**
   - ❑ Arctic
   - ❑ Polar
   - ❑ Tropical

   Reference(s): NWS Jetstream Online School for Weather

8. What type of air mass produces stable air that is associated with smooth air, poor visibility, and stratiform clouds? *(Select the correct answer.)*
   - ❑ **A warm air mass moving over a cold surface**
   - ❑ A cold air mass moving over a warm surface
   - ❑ Any warm air mass
   - ❑ Any cold air mass

   Reference(s): NWS Jetstream Online School for Weather

9. Which of the following is **NOT** considered a front? *(Select the correct answer.)*
   - ❑ **Maritime Polar**
   - ❑ Stationary
   - ❑ Occluded
   - ❑ Warm

   Reference(s): NWS Jetstream Online School for Weather

10. Precipitation formation requires water vapor, lift and _____. *(Select the correct answer.)*
    - ❑ **A growth process**
    - ❑ Frontal pressure
    - ❑ A stable temperature
    - ❑ A steep pressure gradient

    Reference(s): AC 00-45, Aviation Weather Services

11. What type of precipitation occurs when there is a shallow layer aloft with above-freezing temperatures, with a deep layer of below-freezing air based at the surface? *(Select the correct answer.)*
    - ❑ **Ice pellets**
    - ❑ Rain
    - ❑ Snow
    - ❑ Freezing rain

    Reference(s): AC 00-45, Aviation Weather Services

12. The National Weather Service produces which of the following weather products? *(Select the correct answer.)*
    - ❑ **All the answers**
    - ❑ AIRMETs
    - ❑ SIGMETs
    - ❑ TAFs

    Reference(s): NWS Jetstream Online School for Weather; AC 00-45 Section 1, Aviation Weather Services; JO 7110.10, Pilot Controller Glossary