NAVAL AVIATION SCHOOLS COMMAND

NAS PENSACOLA, FLORIDA **NAVAVSCOLSCOM-SG-200**

PREFLIGHT COURSE (API) MODULE/UNIT 3:

AVIATION WEATHER

TRAINEE GUIDE

APRIL 2017

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OUTLINE SHEET 3-1-1

ATMOSPHERIC STRUCTURE

A. INTRODUCTION

The purpose of this lesson is to introduce the student to the general composition and structure of the atmosphere, the properties of temperature and atmospheric pressure, and their effect on aircraft altimeters.

B. ENABLING OBJECTIVES

2.199 DESCRIBE the characteristics of the troposphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.200 DESCRIBE the characteristics of the tropopause, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.201 DESCRIBE the characteristics of the stratosphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.202 DESCRIBE the flight conditions associated with the troposphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.203 DESCRIBE the flight conditions associated with the tropopause, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.204 DESCRIBE the flight conditions associated with the stratosphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.205 DEFINE a lapse rate, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.206 STATE the average lapse rate in degrees Celsius, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.207 DEFINE atmospheric pressure, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.208 STATE the standard units of pressure measurement, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.209 DEFINE the standard atmosphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.210 DIFFERENTIATE between sea level pressure and station pressure, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.211 DEFINE the types of altitudes, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.36 DEFINE indicated altitude, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.212 DESCRIBE the effects of pressure changes on aircraft altimeters, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.213 DESCRIBE the effects of temperature deviations from the standard lapse rate on aircraft altimeters, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. Atmosphere Overview
2. Atmospheric Layers
3. Atmospheric Pressure
4. Altitude Measurement
5. Altimeter Errors

INFORMATION SHEET 3-1-2

ATMOSPHERIC STRUCTURE

A. INTRODUCTION

The purpose of this lesson is to introduce the student to the general composition and structure of the atmosphere, the properties of temperature and atmospheric pressure, and their effect on aircraft altimeters.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. JPATS Aviation Weather Booklet, JX100
3. Flight Information Handbook

C. INFORMATION

THE ATMOSPHERE

The atmosphere is the gaseous covering of the Earth. This envelope of air rotates with the Earth but also has a continuous motion relative to the Earth's surface, called circulation. It is created primarily by the large temperature difference between the tropics and the polar regions, and is complicated by uneven heating of land and water areas by the Sun.

Atmospheric Layers

If the Earth were compared to a baseball, the gaseous covering would be about as thick as the baseball's cover.

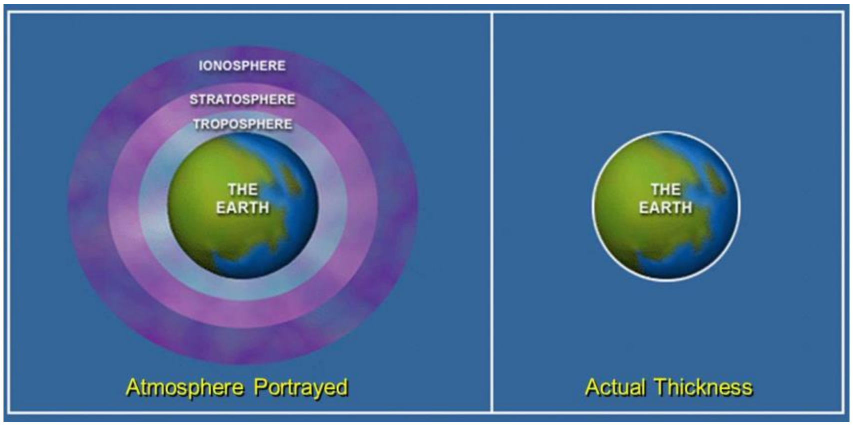


Figure 1-1 — Thickness of the Earth's Atmosphere

It is divided into layers that have certain properties and characteristics. The troposphere is the layer adjacent to the Earth's surface. It varies in height from an average 55,000 feet over the equator to 28,000 feet over the poles.

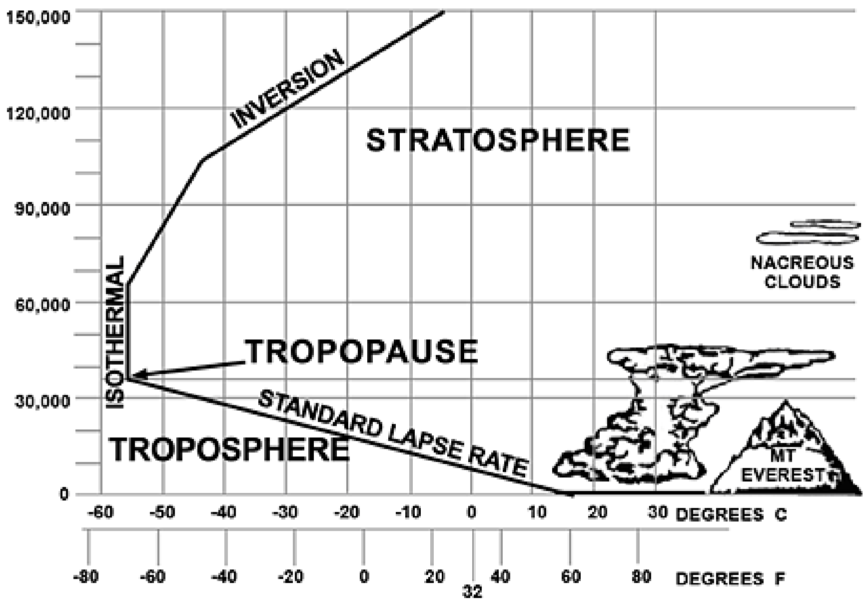


Figure 1-2 — Atmospheric Layers and Lapse Rates

The average height of the troposphere over the United States is 36,000 feet MSL, but pressure systems and seasonal differences cause a variance in the height. Due to heating, the troposphere extends to a greater height in summer than in winter. The atmosphere becomes less dense with altitude, and roughly 50% of it, by weight, lies below 18,000 feet and 90% within 53,000 feet. Within the troposphere, the temperature normally decreases with increasing altitude. Large amounts of moisture and condensation nuclei are found in the troposphere because of its closeness to the Earth’s surface, and nearly all weather occurs here. Winds are generally light near the Earth’s surface and increase with altitude. Wind speeds over 200 knots may occur near the top of the troposphere. An abrupt change in the rate of temperature decrease with increasing altitude marks the boundary, called the tropopause.

The tropopause is a transition zone between the troposphere and the stratosphere. The temperature in this layer is constant with altitude. The tropopause is important to aviators for several reasons. The strongest winds, those of the jet stream, occur just below the tropopause. Moderate to severe turbulence is sometimes associated with the wind shear caused by the jet stream. Contrails frequently form and persist near the tropopause since it is normally the coldest area within the lower atmosphere. While clouds and weather are generally confined to the troposphere, severe thunderstorm tops may penetrate the tropopause into the stratosphere. You can sometimes identify the tropopause while in-flight by the following characteristics: the average height of the tropopause over the US is 36,000 feet MSL, anvil tops of thunderstorms will spread out at the base of the tropopause, and a haze layer with a definite top frequently exists at the tropopause.

The stratosphere is characterized by increasing temperature with increasing altitude. This increase in temperature is due to the gas ozone, which plays a major part in heating the air at this altitude. Flying in the stratosphere is generally smooth with excellent visibility. The air is thin and offers very little resistance to the aircraft. The general lack of weather in this layer makes for outstanding flying.

Composition

Air is a mixture of gases having weight, elasticity, and compressibility. Pure, dry air contains 78% nitrogen, 21% oxygen, a 1% mixture of 10 other gases. The atmosphere also contains water vapor amounting to 0% to 5% by volume. Water vapor (for ordinary considerations) acts as an independent gas mixed with air.

The atmosphere appears clear, but it contains many nongaseous substances such as dust and salt particles, pollen, etc, which are referred to as condensation nuclei. When these particles are relatively numerous, they appear as haze and reduce visibility.

Lapse Rates

The decrease in atmospheric temperature with increasing altitude is called the temperature lapse rate. In order to determine how temperature changes with increasing altitude, meteorologists send up a weather balloon to take the temperature (among other readings) at different altitudes. The resulting temperature profile is known as the environmental lapse rate (a.k.a. the existing lapse rate, or ELR). The average or standard lapse rate is 2° Celsius (3.5° Fahrenheit) per 1000 feet. Even though this is the average lapse rate of the troposphere, close to the surface of the earth the ELR may indicate an increase, decrease, or a constant temperature when measured at increasing altitudes. These different ELRs give meteorologists a clue to the type of weather that exists, and there are names for these various types of ELRs, as well. The standard lapse rate is actually a shallow lapse rate (between 1.5 and 3.0° C/1000 ft). Any lapse rate greater than 3 °C/ 1,000 feet is called a steep lapse rate. An isothermal lapse rate indicates the temperature is the same at different altitudes, and an inversion is a lapse rate where the temperature increases with increasing altitude, such as occurs in the stratosphere. Inversions can be anywhere from a few hundred to a few thousand feet thick, and stable conditions are generally found within them.

There is also a pressure lapse rate, which indicates the decrease in atmospheric pressure with increasing altitude, to be discussed next. Notice that the values used for lapse rates assume that a decrease is normal, thus positive lapse rates actually indicate a decrease in the value measured, and a negative lapse rate (only temperature has this characteristic) would indicate an increase.

Atmospheric Pressure

Pressure is force per unit area. Atmospheric (barometric) pressure is the pressure exerted on a surface by the atmosphere due to the weight of the column of air directly above that surface. For example, the average weight of air on a square inch of the Earth's surface at sea level under standard conditions is 14.7 pounds. Pressure, unlike temperature, always decreases with altitude. In the lower layers of the atmosphere pressure decreases much more rapidly than it does at higher altitudes because density decreases as altitude increases.

Units of Measurement
In the U.S., two units are used to measure and report atmospheric pressure: inches of mercury (in-Hg) and millibars (mb). Inches of mercury is a measure of the height of a column of mercury that can be supported by atmospheric pressure. The millibar is a direct representation of pressure, which is defined as force per unit area. Normal sea level pressures in the atmosphere vary from as low as 28 in-Hg (about 960 mb) to as high as 31 in-Hg (about 1060 mb).

Some countries, particularly those using the metric system, use millibars for altimeter settings. However, in the United States and Canada altimeter settings are reported in inches of mercury.

The Standard Atmosphere
For a standard reference, a concept called a standard day is used. In aviation, everything is related to standard day conditions at sea level, which are 29.92 in-Hg (1013.2 mb) and 15° C (59° F). In the lower atmosphere, and thus for most aviation applications, a 1000 foot increase in altitude will result in a pressure decrease of approximately 1 in-Hg (34 mb) and a temperature decrease of 2° C (3.5° F). These values are the standard day pressure and temperature lapse rates.

Pressure Charts
The pressure at the Earth's surface changes for several reasons. The most noted reason for this change is the movements of high and low pressure systems. The temperature and moisture content of air also affect surface pressures.

Meteorologists track these different weather systems by noting the pressure each time a weather observation is made and then forwarding all observations to the national weather service (NWS). The NWS then plots the weather on various charts. The resulting horizontal distribution of pressure across the Earth's surface is depicted on weather charts by isobars, or lines of equal barometric pressure.

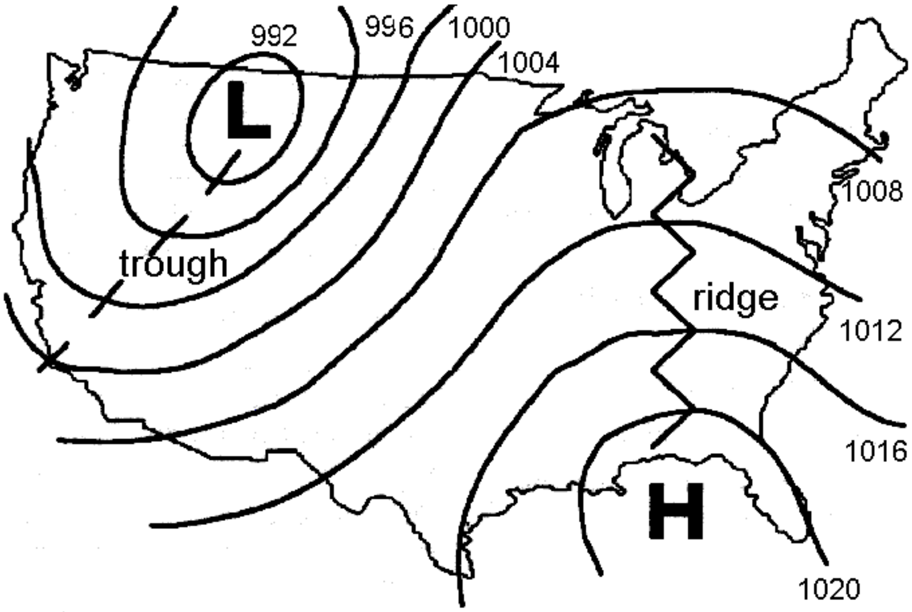


Figure 1-3 — Pressure Systems

There are several standard types of pressure distribution patterns found on weather charts. A high-pressure area (or high)–where the pressure in the center is higher than the surrounding areas–may be thought of as a mountain on a surface pressure chart. Similarly, a low pressure area–where the pressure in the center is lower than the surrounding areas–may be thought of as a basin or valley. A ridge is an extension of a high-pressure area, and a trough is an extension of a low-pressure area. There are certain characteristic winds and weather systems associated with these pressure systems. For example, poor weather such as found with fronts and squall lines are generally associated with troughs and lows, while good weather is associated with highs and ridges.

Station and Sea Level Pressure

Station pressure is the atmospheric pressure measured directly at an airfield or other weather station. Sea level pressure is the pressure that would be measured from the existing weather if the station were at mean sea level (MSL). This can be measured directly at sea level, or calculated if the station is not at sea level using the standard pressure lapse rate.

Surface analysis charts use MSL as the reference level for the depicted isobars (to provide a common reference), even though the pressure was first measured at a weather station. This is done so that daily pressure variations associated with weather systems can be tracked as they move across the country, as mentioned above. If, instead, station pressures were used, the pressure charts would depict the inverse of the land topography, reflecting the contour lines of a map. Mountain tops would always have lows over them, and valleys would have highs. In other words, high altitude stations such as Denver would always reflect lower pressure than surrounding stations at lower altitudes regardless of the day to day pressure variations that occur with passing weather systems. Thus, for pressure to be meaningful, all stations–even those far from the ocean–will report sea level pressure.

ALTITUDE MEASUREMENT
Altitude is defined as the height above a given reference. The instrument that displays altitude in the cockpit is called an altimeter. The barometric altimeter is an aneroid barometer that is calibrated to display altitude in feet, as opposed to pressure in inches of mercury.

Figure 1-4 — Barometric Altimeter

Since an altitude includes not only the height number, but also the reference, altimeters have a Kollsman window that shows the reference pressure, known as the altimeter setting. The altimeter setting is the value to which the scale of the pressure altimeter is set so the altimeter indicates true altitude at field elevation. It is very nearly equal to the station pressure corrected to mean sea level pressure (not exact, but close enough for instructional purposes). An adjustment knob allows the altimeter setting to be changed. If the local altimeter setting is dialed in to the Kollsman window, the altimeter will indicate the altitude in feet above mean sea level (ft MSL). If 29.92 is set, the altimeter will indicate the altitude above the standard datum plane. These are the two altitudes most often displayed on the altimeter, MSL and pressure altitudes, and both are discussed in the next section.

Altitudes
Indicated altitude is the altitude read directly from the altimeter. Since altimeters need no power (except for lighting–they operate by measuring the outside pressure), they will always indicate some value. For an indicated altitude to be useful, however, the altimeter needs to have the correct reference for the situation by dialing either the local altimeter setting or 29.92 in to the Kollsman window. This way, the indicated altitude will be equal to either the MSL or the pressure altitude, which will be discussed later.

To illustrate, if an aircraft is parked at Sherman Field with the local altimeter setting in the Kollsman window, the indicated altitude should be the same as the airfield elevation, and the indicated altitude will be an MSL altitude. Therefore, the altimeter should indicate approximately 30 feet MSL since Sherman Field is 30 feet above mean sea level.

Altimeters are subject to mechanical errors caused by installation, misalignment, and positioning of the static ports that measure the pressure. Collectively, these errors are referred to as instrument error. Instrument error is determined prior to takeoff by noting the difference between field elevation and indicated altitude. For example, an aircraft taking off from Sherman Field (elevation +30 ft MSL) with an indicated altitude of 70 ft would have an instrument error of +40 ft. If the instrument error is in excess of 75 ft, the aircraft is considered unsafe for instrument flight. Calibrated altitude is indicated altitude corrected for instrument error.

Mean Sea Level (MSL) or True altitude is the actual height above mean sea level (MSL). It is found by correcting calibrated altitude for temperature deviations from the standard atmosphere. On a standard day, MSL/true altitude is equal to calibrated altitude. If there is no instrument error, true altitude would also be equal to indicated altitude. Mean Sea Level/MSL altitude is very important since airfields, hazards, and terrain elevations are stated in feet above mean sea level.

AGL or absolute altitude is the aircraft's height above the terrain directly beneath the aircraft and is measured in feet above ground level (AGL). Absolute altitude is not normally displayed on an altimeter, but it can be calculated by subtracting the terrain elevation from the true altitude. Additionally, it can be displayed directly on a radar altimeter.

Pressure altitude is the height above the standard datum plane. The standard datum plane is the actual elevation above or below the earth's surface at which the barometric pressure is 29.92 in-Hg. Federal Aviation Rules (FAR) require that all aircraft operating above 18,000 feet MSL set 29.92 in to the altimeter to ensure consistent altitude separation. Since most mountains in the U.S. are well below 18,000 feet MSL, there is less concern with terrain avoidance than with aircraft separation above that altitude. Thus, a pilot flying a pressure altitude will have an altimeter setting of 29.92 instead of the local altimeter setting. In short, a pressure altitude is the height above the place in the atmosphere where the pressure is 29.92 in-Hg. Whether this place is above, below, or coincides with sea level is of little concern.

When aircraft fly pressure altitudes, they are assigned a flight level (FL) of three digits, representing hundreds of feet above 29.92. As an example, an aircraft assigned FL250 (pronounced "flight level two five zero") would be flying a pressure altitude, and the pilot would fly the aircraft so that the altimeter reads 25,000 feet with 29.92 in the Kollsman window.

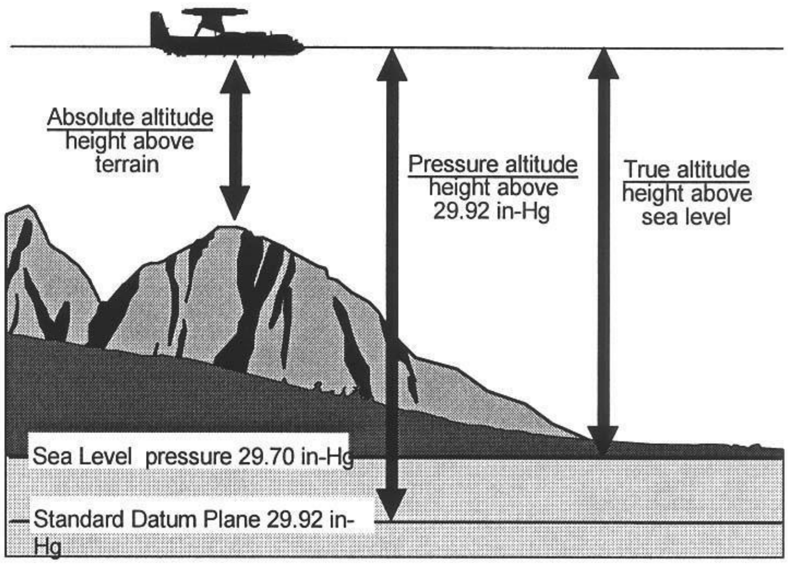


Figure 1-5 — Altitudes

Density altitude (DA) is pressure altitude corrected for nonstandard temperature deviations. On a hot day, air molecules are farther apart, decreasing the air density and increasing the density altitude. In this situation, the DA of an airfield would be higher than both the published field elevation and the pressure altitude. The opposite is true on a colder day: Increased air density causes a decreased density altitude and a DA lower than the published field elevation and the pressure altitude.

Density altitude is not a height reference; rather, it is an index to aircraft performance. It affects airfoil, engine, propeller, and rotor performance. Thrust is reduced because a jet engine has less mass (air) to compress. Lift is also reduced due to thinner air. Additionally, higher density altitudes result in longer takeoff and landing distances and a reduced rate of climb. Takeoff distances are longer since reduced thrust requires a longer distance to accelerate to takeoff speed. Landing distances are longer since a higher true airspeed is required to land at the same indicated airspeed. Climb rate is decreased because of reduced available thrust. At certain high density altitudes, takeoffs and/or single-engine flight (loss of one engine after becoming airborne) are not possible due to limitations of thrust, lift, and runway length. Moisture affects aircraft performance in the same manner as temperature, but to a much lesser degree.

HIGH TEMPERATURE OR MOISTURE	LOW TEMPERATURE OR MOISTURE
Lower Air Density	Higher Air Density
Higher Density Altitude	Lower Density Altitude
Decreased Thrust and Lift	Increased Thrust and Lift
Longer Takeoffs and Landings	Shorter Takeoffs and Landings

Table 1-1 — Density Altitude Effects on Aircraft Performance

Altimeter Errors

Pressure
When an aircraft flies from one place to another at a constant indicated altitude (by referencing the barometric altimeter), it is flying along a surface of constant pressure. Figure 1-6 shows the path of an aircraft as it follows such a constant pressure surface–done by flying a constant indicated altitude. As the sea level pressure on the surface decreases (all other conditions remaining the same), the whole column of air aloft is lowered, causing an aircraft flying at an assigned MSL altitude to descend to a lower AGL altitude. Only by updating the reference of the altimeter setting can this potential problem be eliminated, and a more constant AGL altitude can be maintained.

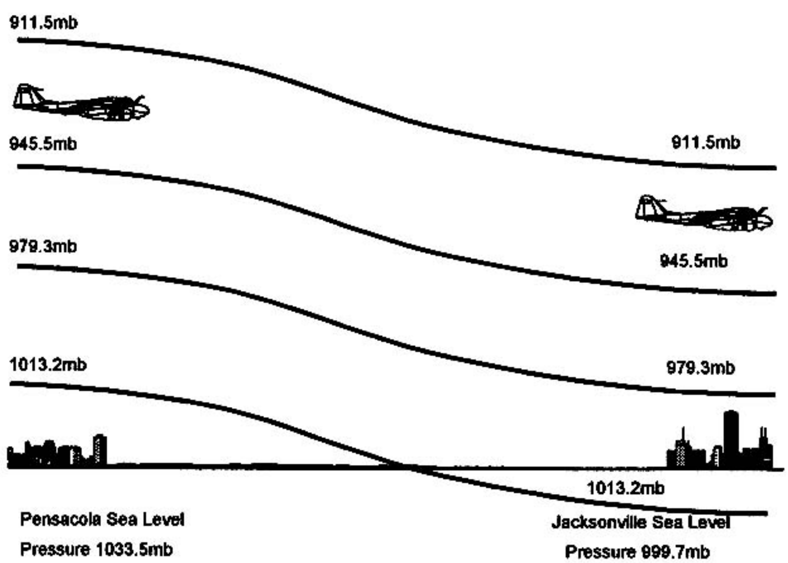


Figure 1-6 — Constant Indicated Altitude with Decreasing Surface Pressure

This updating is accomplished via radio throughout the flight. Usually, when switching to a different air traffic controller–about every 50-100 miles–an updated altimeter setting will also be passed to the aircrew. This ensures that all aircraft in a given area are flying at the correct altitudes (up to FL180). A change in pressure of 0.10 in-Hg will change the altimeter reading 100 feet. Therefore, it is imperative to receive a current altimeter setting at your destination prior to landing. If the altimeter is not adjusted and your flight path takes you into an area of lower MSL pressure the aircraft will be lower than the altimeter indicates. Conversely, if your flight path takes you into an area of higher MSL pressure, the aircraft will be higher than the altimeter indicates. These events are summarized by a set of rhymes.

Rule: High to Low, Look Out Below

The aircraft is lower than indicated, thus the indicated altitude is higher than the aircraft.

- Higher Pressure to Lower Pressure
    - MSL = Assigned Altitude (-) Altitude Error
    - AGL = MSL (-) Field Elevation
    - Indicated Altitude on Deck = Field Elevation (+) Altitude Error

Rule: Low to High, Plenty of Sky

The aircraft is higher than indicated, thus the indicated altitude is lower than the aircraft.

- Lower Pressure to Higher Pressure
    - MSL = Assigned Altitude (+) Altitude Error
    - AGL = MSL (-) Field Elevation
    - Indicated Altitude on Deck = Field Elevation (-) Altitude Error

PRESSURE CHANGE	ALTIMETER	ACTUAL MSL ALTITUDE
Flying toward lower MSL pressure	Indicates higher than actual	Lower than indicated by the altimeter
Flying toward higher MSL pressure	Indicates lower than actual	Higher than indicated by the altimeter

Table 1-2 — Pressure Change vs. Indicated and MSL Altitude

Temperature
Aircraft altimeters are calibrated for a standard lapse rate. An incorrect altitude indication will result if the temperature deviates from the standard. For every 11 °C that the temperature varies from the standard, the altimeter will be in error by 4%. If the air is colder than the standard atmosphere, the aircraft will be lower than the altimeter indicates. If the air is warmer than

standard, the aircraft will be higher than the altimeter indicates. You may notice that the rules presented in the pressure section, above, also apply to temperature deviations.

TEMPERATURE CHANGE	ALTIMETER	ACTUAL MSL ALTITUDE
Flying from standard temp. toward lower temp.	Indicates higher than actual	lower then indicated
Flying from standard temp. toward higher temp.	Indicates lower than actual	Higher than indicated

Table 1-3 — Temperature Deviation vs. Indicated and MSL Altitude

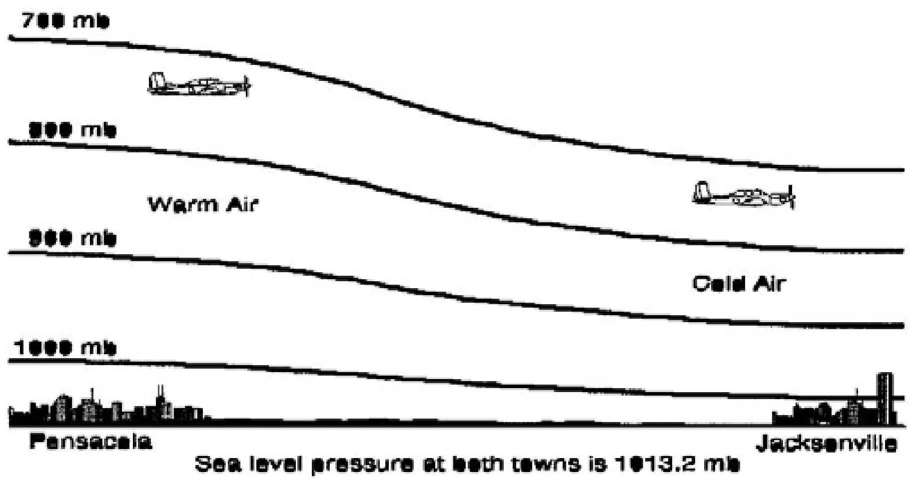


Figure 1-7 — Constant Indicated Altitude with Decreasing Temperature

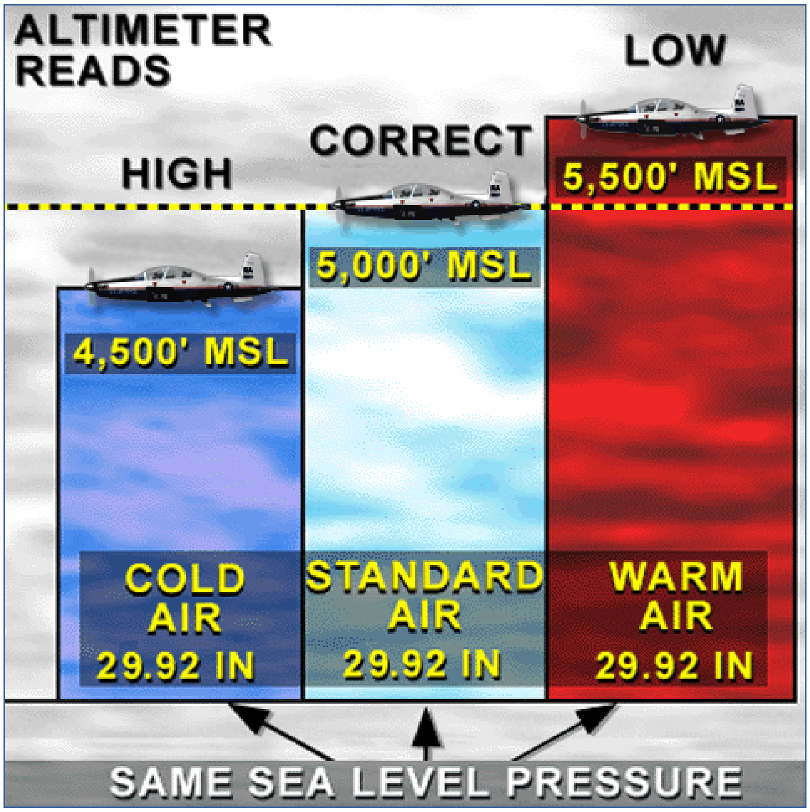


Figure 1-8 — Temperature Deviation vs. Indicated and MSL Altitude

As you fly from warm to cold air, an altimeter will read too high–
the aircraft is lower than the altimeter indicates. Over flat terrain, this lower true reading is no great problem; other aircraft in the vicinity are also flying indicated altitudes resulting from the same temperature and pressure conditions, and the altimeter readings are compatible because the errors result from the same conditions.

Since these deviations due to temperature are usually relatively small, these errors are often ignored in the early stages of flight training, and calibrated altitude is often treated directly as true altitude. However, toward the advanced stages, tactical accuracy becomes paramount, and temperature effects cannot be ignored. For example, when flying in cold weather over mountainous terrain, you must take this difference between indicated and true altitude into account by calculating a correction to the indicated altitude.

ASSIGNMENT SHEET 3-1-3

ATMOSPHERIC STRUCTURE REVIEW

A. INTRODUCTION

The purpose of this lesson is to introduce the student to the general composition and structure of the atmosphere, the properties of temperature and atmospheric pressure, and their effect on aircraft altimeters.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

1. Review JPATS Aviation Weather Booklet, JX100 Chapter JX101.
2. Read JPATS Aviation Weather Booklet, JX100 Chapter JX102.

D. STUDY QUESTIONS

1. At the top of the troposphere, there is a transition zone called the ______.
   a. tropopause
   b. ozone layer
   c. atmospheric layer
   d. stratosphere

2. The two lower layers of the atmosphere are the ______ and ______,
   a. tropopause; mesosphere
   b. troposphere; stratosphere
   c. tropopause; stratopause
   d. mesosphere; thermosphere

3. Which one of the following best describes the flight conditions found in the stratosphere?
   a. The strongest winds occur in the stratosphere.
   b. Contrails frequently form and persist in this part of the atmosphere.
   c. 50% of the atmosphere, by weight, is found in the stratosphere.
   d. Flying in the stratosphere is generally smooth with excellent visibility.

4. What is the standard temperature lapse rate of the atmosphere in °Celsius per 1000 feet?
   a. 1.5
   b. 2.0
   c. 3.0
   d. 3.5

5. Using the standard lapse rate, a pilot flying at 10,000 ft MSL and at a temperature of -8° C should do what to find an altitude at which the temperature is +4 °C?
   a. Descend to approximately 2000 feet MSL
   b. Descend to approximately 4000 feet MSL
   c. Descend to approximately 6000 feet MSL
   d. Climb to find an inversion

6. A condition where the air temperature aloft is higher than that of the lower atmosphere is generally referred to as ______,
   a. a low-pressure area
   b. turbulence
   c. a temperature inversion
   d. convection currents

7. Which one of the following best describes the change in atmospheric pressure with increasing altitude?
   a. Increases
   b. Decreases
   c. May increase or decrease, depending on weather conditions
   d. Remains constant

8. Which one of the following correctly lists the standard day conditions of sea level pressure, temperature, pressure lapse rate, and temperature lapse rate?
   a. 30.00 in-Hg, 15° C, 1.5 in-Hg/1000', 3.0° C/1000'
   b. 29.92 in-Hg, 59° C, 34 in-Hg/100', 5° C/100'
   c. 29.92 in-Hg, 15° C, 1 in-Hg/1000', 2° C/1000'
   d. 30.02 in-Hg, 20° C, 2 in-Hg/1000', 1° C/1000'

9. The horizontal distribution of pressure on the Earth's surface is depicted on weather charts by ______.
   a. isotherms
   b. isotachs
   c. isogonic lines
   d. isobars

10. The weight of the air mass over any point on the Earth's surface defines ______.
   a. density altitude
   b. atmospheric pressure
   c. pressure altitude
   d. true weight

11. The quantities 1013.2 mb and 29.92 in-Hg are two different expressions for the ______.
    a. atmospheric density at a standard air temperature of 15° C
    b. atmospheric pressure at sea level at an air temperature of 0° C
    c. standard atmospheric pressure at mean sea level and at a standard air temperature of 15° C
    d. weight of the atmosphere at the surface of the Earth

12. In the lower 5000 feet of the atmosphere, a decrease of one inch of mercury in atmospheric pressure would cause a change in an altimeter reading of approximately ________ feet (assuming constant elevation and altimeter setting).
    a. minus 100
    b. plus 100
    c. minus 1000
    d. plus 1000

13. Which one of the following correctly describes the meteorological feature of a trough?
    a. An elongated area of relatively low pressure
    b. An elongated area of relatively high pressure that extends from the center of a High pressure area.
    c. An area where the pressure in the center is higher than the surrounding areas
    d. A long shallow often V-shaped receptacle for the drinking water or feed of domestic animals

14. Which one of the following items would have a value closest to that used as a Kollsman window setting for an altimeter in the U.S. (assuming an airfield above sea level)?
    a. Station pressure
    b. Station temperature
    c. AGL pressure
    d. Sea level pressure

15. The height of an aircraft above the ground is known as ______.
    a. MSL/True altitude
    b. AGL/absolute altitude
    c. indicated altitude (IA)
    d. pressure altitude (PA)

16. Which one of the following types of altitudes would be assigned in the U.S. above 18,000 feet MSL?
    a. MSL/True altitude
    b. AGL/absolute altitude
    c. Indicated altitude (IA)
    d. Pressure altitude (PA)

17. Density altitude is ______.
    a. the same as an MSL/True altitude.
    b. pressure altitude corrected for nonstandard field elevations.
    c. an indicator of aircraft performance.
    d. the height above the standard datum plane.

SITUATION FOR ITEMS 18-20: The altimeter setting at Randolph AFB is 29.85 in-Hg, and at Vance AFB, the altimeter setting is 30.15 in-Hg. A pilot sets the altimeter correctly at Randolph and flies to Vance at an indicated altitude of 5000 feet without changing the altimeter setting.

18. Assuming a standard lapse rate, what is the MSL/true altitude when flying over Vance at the assigned indicated altitude?
    a. 4700 feet
    b. 5000 feet
    c. 5030 feet
    d. 5300 feet

19. If Vance’s elevation is 1307' MSL, what is the AGL/absolute altitude over Vance?
    a. 3393 feet
    b. 3693 feet
    c. 3723 feet
    d. 3993 feet

20. If the pilot lands successfully at Vance (elevation 1307' MSL) without resetting the altimeter, what altitude will the altimeter indicate?
    a. 0 feet
    b. 1007 feet
    c. 1307 feet
    d. 1607 feet

Answers:

1. A	11. C
2. B	12. D
3. D	13. A
4. B	14. D
5. B	15. B
6. C	16. D
7. B	17. C
8. C	18. D
9. D	19. D
10. B	20. B

Atmosphere Overview

Composition

Mixture of gases:

78% nitrogen

21% oxygen

1% mixture of 10 other gases

Water vapor as a separate gas 0% to 5% by volume

Earth gasses

Thin gaseous covering

Divided into layers

Troposphere

Layer adjacent to the earth's surface

Large amounts of moisture and condensation

Nearly all weather occurs there.

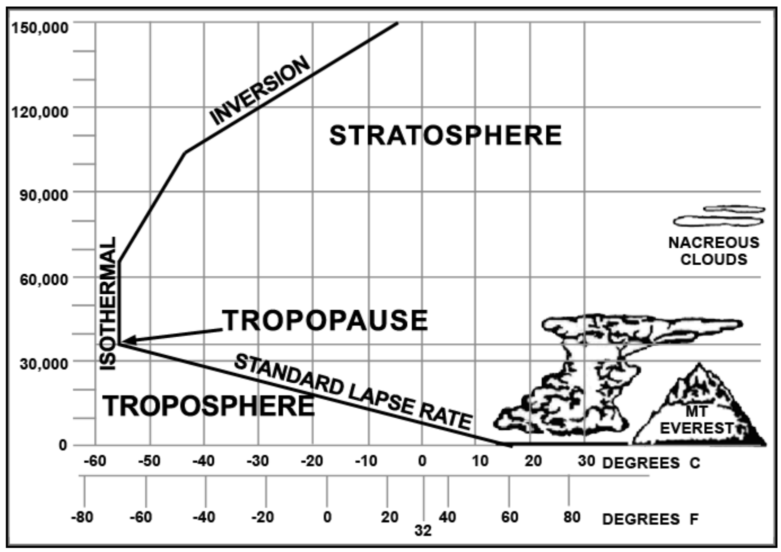
Height:

28,000 feet over poles

55,000 feet over equator

Temperature normally decreases with altitude (lapse rate).

Winds increase with altitude.



Tropopause

Boundary between troposphere and stratosphere.

Identified by abrupt change in lapse rate.

Frequently find turbulence, contrails, and haze.

Average height over USA 36,000 feet MSL.

Jet stream winds occur just below tropopause.

Stratosphere

Smooth flying conditions

Excellent visibility

Constant temperature to approximately 66,000 feet

Temperature slowly increases with altitude
(above 66,000 feet).

Few aircraft can fly in Stratosphere.

Average top height over USA 158,000 feet MSL

Atmospheric Temperature

Standard lapse rate (troposphere)

Decrease in temperature with increasing altitude.

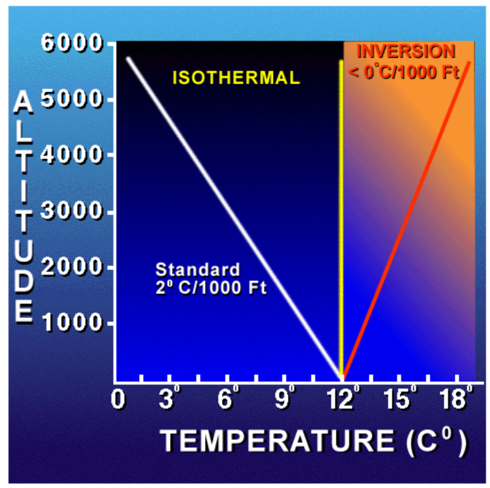
2° C per 1000 feet

Isothermal lapse rate (stratosphere)

Temperature constant with increasing altitude.

Inverted lapse rate (temperature inversion) (stratosphere)

Temperature increases with increasing altitude.



Atmospheric Pressure

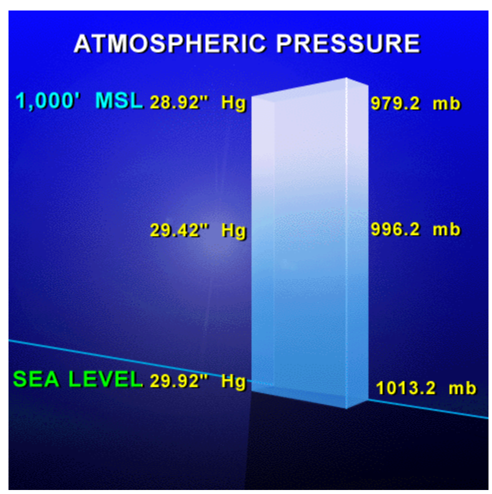
Pressure exerted on a surface by the atmosphere due to the weight of a column of air directly above that surface.

Always decreases with altitude.

Units of measurement

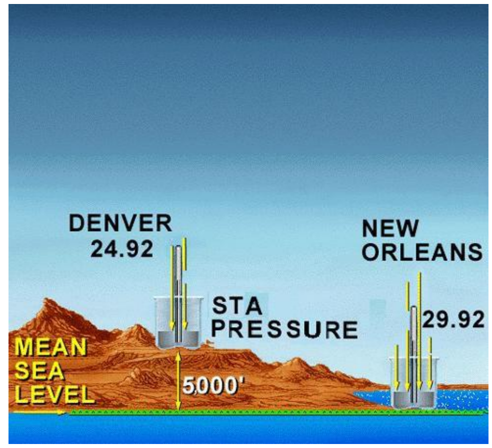
Inches of mercury

Millibars



Station Pressure

Atmospheric pressure at an airfield or station



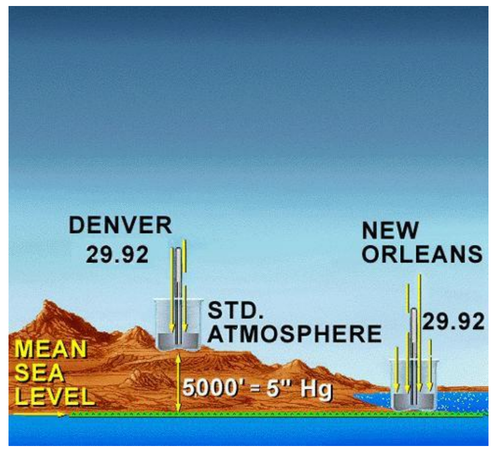
Sea Level Pressure (SLP)

Pressure at mean sea level (MSL)

Measured directly at sea level.

Calculated if the station is not at sea level.

Used for surface analysis charts.



Pressure Charts

High and low pressure systems move bringing weather patterns.

Horizontal distribution of pressure

Isobars or lines of equal (sea level) pressure

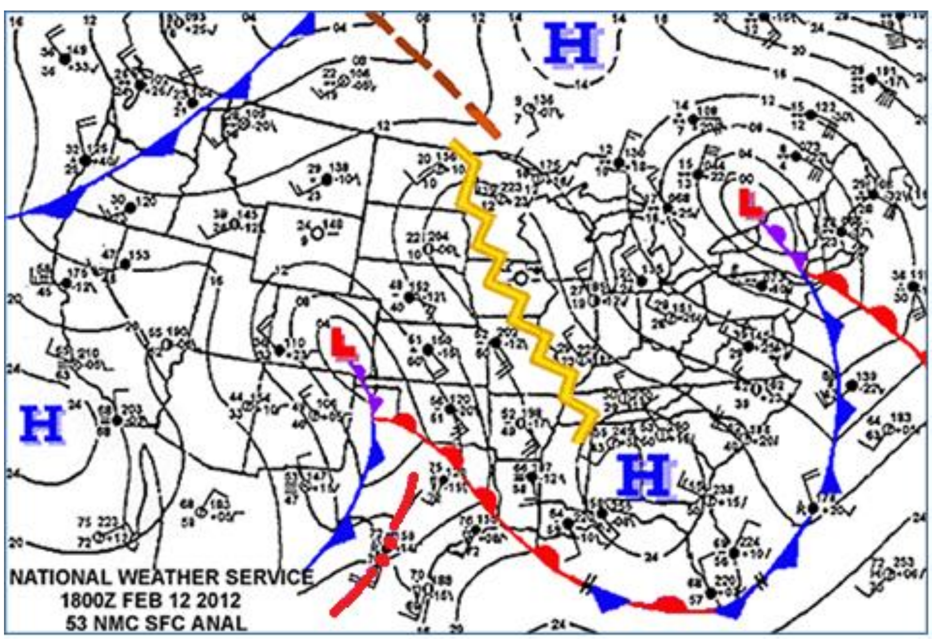
Symbology

High (blue H)

Low (red L)

Ridge (high pressure/ good weather)

Trough (low pressure/ poor weather)



Altitude Measurement

Altimeters

Barometric altimeter

Displays altitude in feet instead of pressure.

Altimeter setting

Corrected for mean sea level.

Sea level pressure equivalent to setting.

Increasing setting increases the altimeter readout.

Calibration

For a standard lapse rate

4% error for every 11° C temperature variation from standard.

Altimeter Error - Pressure

When flying from one locale to another a change in pressure of 1.0 in-Hg will change the altimeter reading 1000 feet.

Vital to update altimeter settings throughout the flight.

"High to Low Look Out Below"

- Higher Pressure to Lower Pressure
    - MSL = Assigned Altitude (-) Altitude Error
    - AGL = MSL (-) Field Elevation
    - Indicated Altitude on Deck = Field Elevation (+) Altitude Error

"Low to High Plenty of Sky"

- Lower Pressure to Higher Pressure
    - MSL = Assigned Altitude (+) Altitude Error
    - AGL = MSL (-) Field Elevation
    - Indicated Altitude on Deck = Field Elevation (-) Altitude Error

Altimeter Error - Temperature

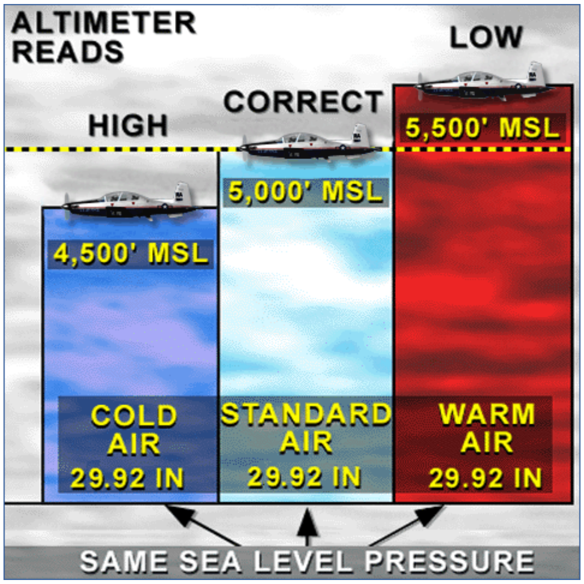
Colder than the standard atmosphere:

Aircraft will be lower

Warmer than standard atmosphere:

Aircraft will be higher

Flight Information Handbook contains altitude corrections for extreme cold temperatures (< 0° C).



Altitude Definitions

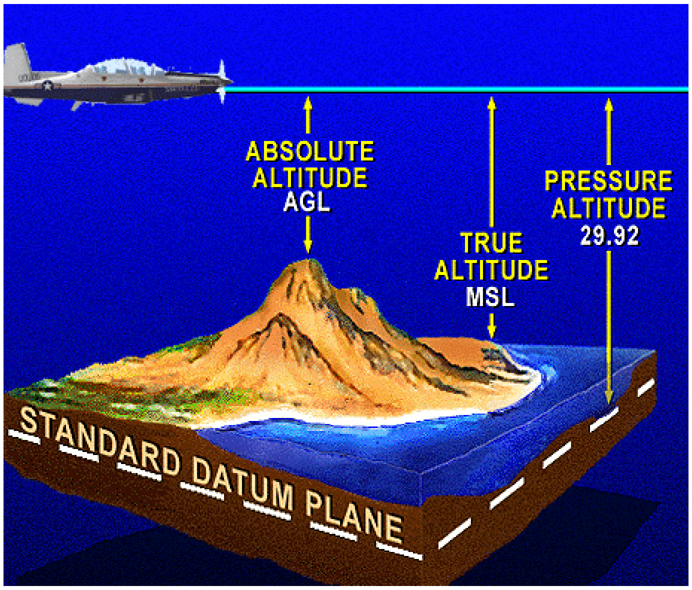
Indicated altitude: As read on altimeter

Absolute altitude: Above ground level (AGL)

True altitude: Above Mean Sea Level (MSL)

Pressure altitude: Above Standard Datum Plane

Density Altitude: Not a height reference



OUTLINE SHEET 3-2-1

ATMOSPHERIC MECHANICS

A. INTRODUCTION

The purpose of this lesson is to introduce the student to the general structure of the atmosphere and the properties of wind, clouds, atmospheric stability and their effect on flight operations.

B. ENABLING OBJECTIVES

2.214 EXPLAIN the term pressure gradient, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.215 EXPLAIN and identify gradient winds and Buys Ballot's Law with respect to the isobars around pressure systems in the Northern Hemisphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.216 EXPLAIN and identify the surface wind direction with respect to the gradient winds in a pressure system in the Northern Hemisphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.217 DESCRIBE the jet stream, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.218 DESCRIBE sea breezes, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.219 DESCRIBE land breezes, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.220 DESCRIBE mountain winds, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.221 DESCRIBE valley winds, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.222 DEFINE saturation, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.223 DEFINE dew point temperature, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.224 DEFINE dew point depression, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.225 DEFINE relative humidity, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.226 DESCRIBE the relationship between air temperature and dew point temperature with respect to saturation, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.227 DESCRIBE the three characteristics of precipitation, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.228 DESCRIBE the types of precipitation, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.229 DESCRIBE the four principal cloud groups, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.230 DESCRIBE the weather conditions associated with various clouds, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.231 DESCRIBE the types of atmospheric stability, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.232 DESCRIBE the four methods of lifting, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.233 DESCRIBE the flight conditions associated with a stable atmosphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.234 DESCRIBE the flight conditions associated with an unstable atmosphere, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. Winds
2. Large Scale Wind Patterns
3. Pressure Gradients and Jet Stream

4. Local Winds
5. Atmospheric Moisture
6. Clouds and Precipitation
7. Atmospheric Stability
8. Flight Conditions

INFORMATION SHEET 3-2-2

ATMOSPHERIC MECHANICS

A. INTRODUCTION

The purpose of this lesson is to introduce the student to the general structure of the atmosphere and the properties of wind, clouds, atmospheric stability and their effect on flight operations.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. JPATS Aviation Weather Booklet, JX100
3. Flight Information Handbook

C. INFORMATION

WINDS

Understanding the causes of wind and wind direction is essential to the safe operation of an aircraft. Takeoffs and landings are best performed into a headwind, whereas landing with a strong crosswind can be dangerous, to say the least. In addition, the circulation of air brings about changes in weather by transporting water vapor, and, therefore, wind plays an important role in the formation of fog, clouds, and precipitation.

So how does one determine the wind direction? Wind direction is always expressed in terms of the direction from which it is blowing. This convention holds throughout the world–civilian or military, weather or navigation, aviation or sailing–wind always blows from a particular direction. Thus, it would be best for a student to master this particular concept as early as possible in a career where wind is an everyday concern.

There are many different ways that weather phenomenon, such as wind, are annotated on charts or in print. One of these methods is the use of a station model. Since the basics of station models will be used throughout this course, they will be discussed in the next section. In Chapter 7,
when other chart features are explained, it will be assumed that station models are understood.

Station Models

Some weather charts display the information gathered from individual weather stations through the use of the station model, shown in Figure 2-1. This model begins with a circle (or a square for automated stations) at the center to represent the location of the station that issued the weather report. Around the station symbol, data describing wind, temperatures, weather, and pressures are displayed in a pictorial shorthand (Figure 2-2) to provide the maximum amount of data in a minimum of space.

Another noticeable feature of the station model is a line coming out of the circle indicating the wind direction. Since the station models are aligned for ease of reading, north is at the top of the page. Therefore, in Figure 2-1, the winds are from the northwest. At the end of this stick are any numbers of barbs, which come in three shapes, to indicate the wind speed. A long barb represents 10 knots, short barbs are 5 knots, and pennants are 50 knots.

The numbers to the left of the station symbol indicate the temperature (top left) and dew point (bottom left). In between the temperature and dew point, there may be a symbol from Figure 2-2 representing the present weather at the station. Additionally, the circle (or square) may be filled in to represent the amount of sky that is covered by clouds, in eighths. An empty circle would mean clear skies, while a fully darkened circle would indicate a completely overcast sky (also from Figure 2-2).

The right-hand side of the station model describes the pressure at the station. On the top right, there will be three digits to represent the sea level pressure (SLP) in millibars and tenths. Since SLP will always be somewhere around 1000 millibars, the hundreds digit (and thousands, if present) is dropped, and the decimal point is also omitted. Thus, depicted pressures beginning with large numbers (such as a 9) really start with a hidden “9”, and pressures beginning with small numbers (such as a 1) actually have a “10” in front of them. Below the current SLP is the pressure tendency over the last 3 hours, beginning with a (+) or (-) sign to denote an overall rise or fall, and then the value of that total pressure change. After this notation is a set of two connected line segments that graphically show the pressure change over those three hours, as indicated on the right-hand side of Figure 2-2.

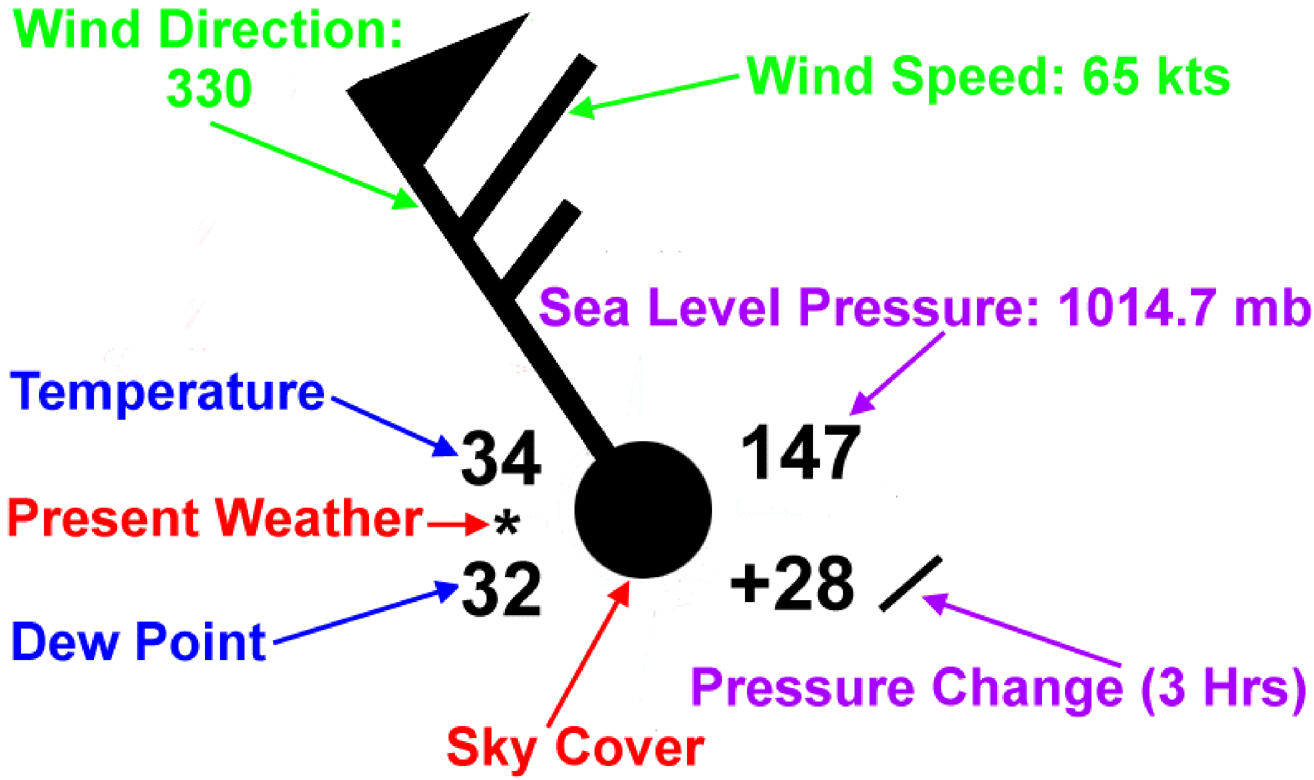


Figure 2-1 — Station Model

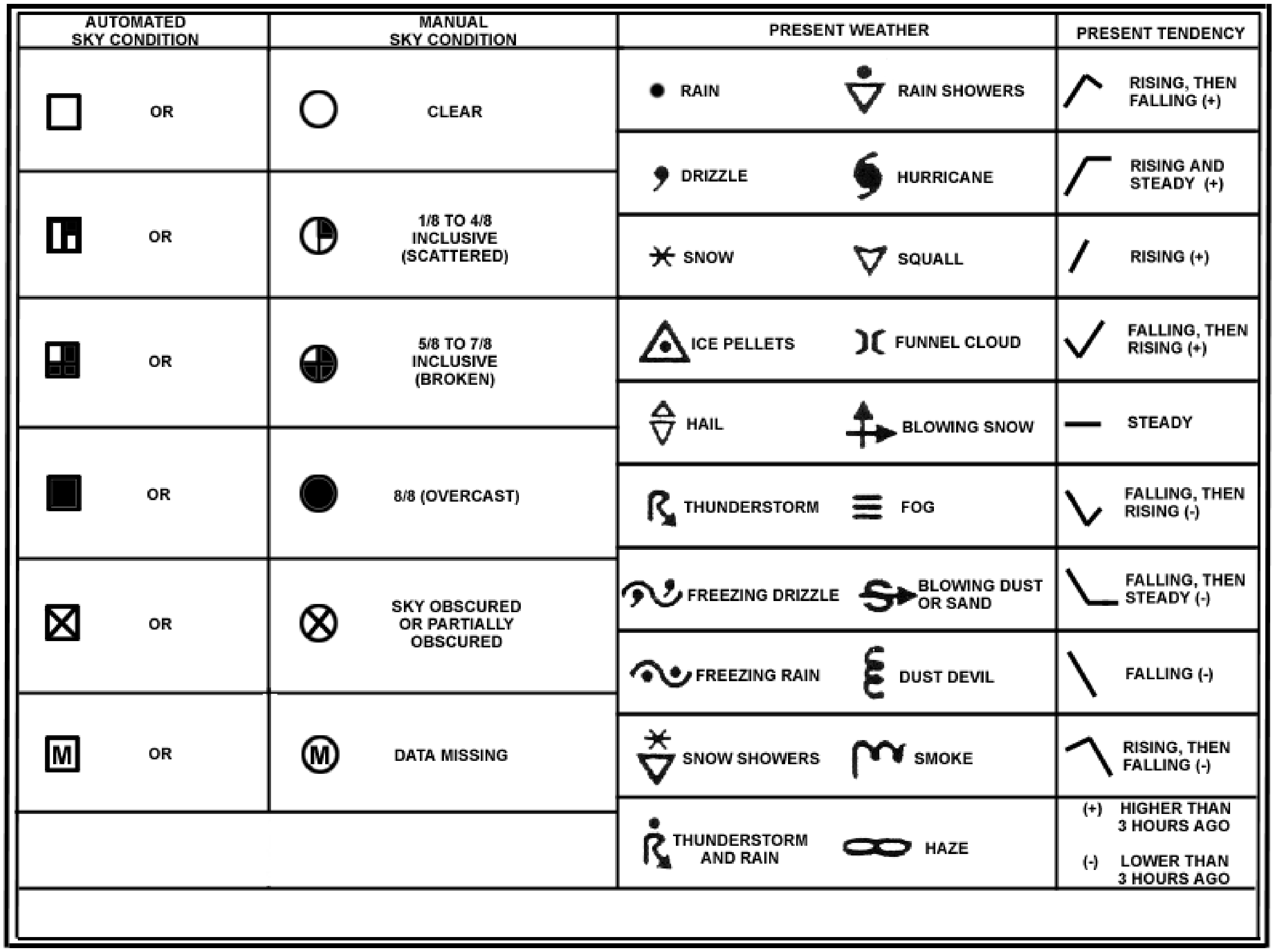


Figure 2-2 — Major Station Model Symbols

Large Scale Wind Patterns

Now that we have presented an understanding of station models, it may be easier to understand how pressure and wind fit together by imagining how a surface analysis chart is constructed, such as the one pictured in Figure 2-3. While most of these are built automatically by computer, picture a meteorologist at the National Weather Service starting with a U.S. map covered only with station models. The first thing she would do is to start playing “connect the dots” by finding stations with the same pressures, and drawing isobars between them (as discussed in Chapter 1). These isobars are drawn, as a standard, with 4 millibars of space between each line, and they are labeled accordingly. At this point, it would become clear where the low and high pressure systems are located, and she could draw either a big red “L” or a blue “H” to signify these locations. Finally, she could draw other symbols, such as fronts and troughs, as needed, depending on the chart type. However, we now have enough of a picture to move onward in the discussion of winds.

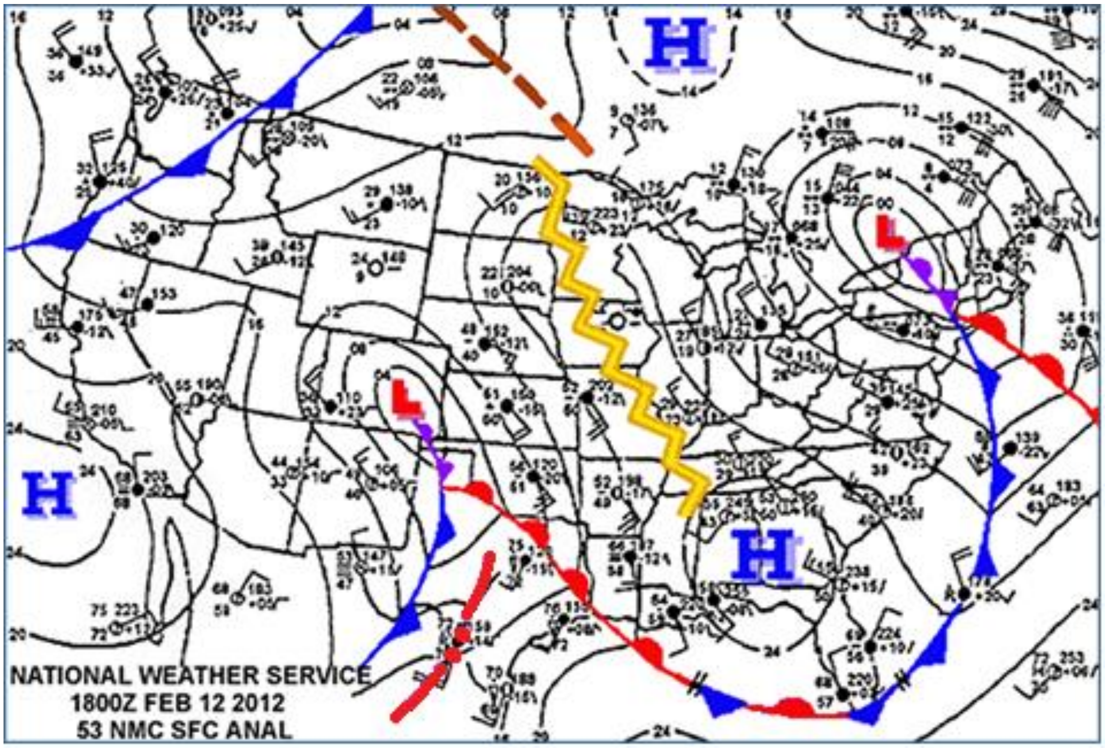


Figure 2-3 — Typical Surface Analysis Chart

Notice that the winds in Figure 2-3 are moving in generally the same direction in the areas between each of the pressure systems. If you look closely, you may even notice that the winds are moving almost parallel to the isobars, in most situations. After enough observation, you may also recognize a pattern of air circulation around high and low- pressure systems. In fact, each of these characteristics is a result of pressure differences causing the air to circulate in a consistent pattern: parallel (or almost parallel) to isobars, clockwise around high pressure, and counterclockwise around low pressure. Next, we will discuss why winds blow in this fashion.

Pressure Gradients

The spacing of isobars indicates the rate of pressure change over a horizontal distance. In Figure 2-4, the isobars are more closely spaced to the east than they are to the west, indicating that pressure changes more rapidly on the eastern side. The rate of pressure change in a direction perpendicular to the isobars (horizontal distance) is called the pressure gradient, and this isobar spacing represents the size of the pressure gradient force (PGF). The PGF is steep, or strong, when isobars are close together, and is shallow, or weak, when the isobars are far apart–the steeper the gradient, the stronger the winds. The PGF is the initiating force for all winds.

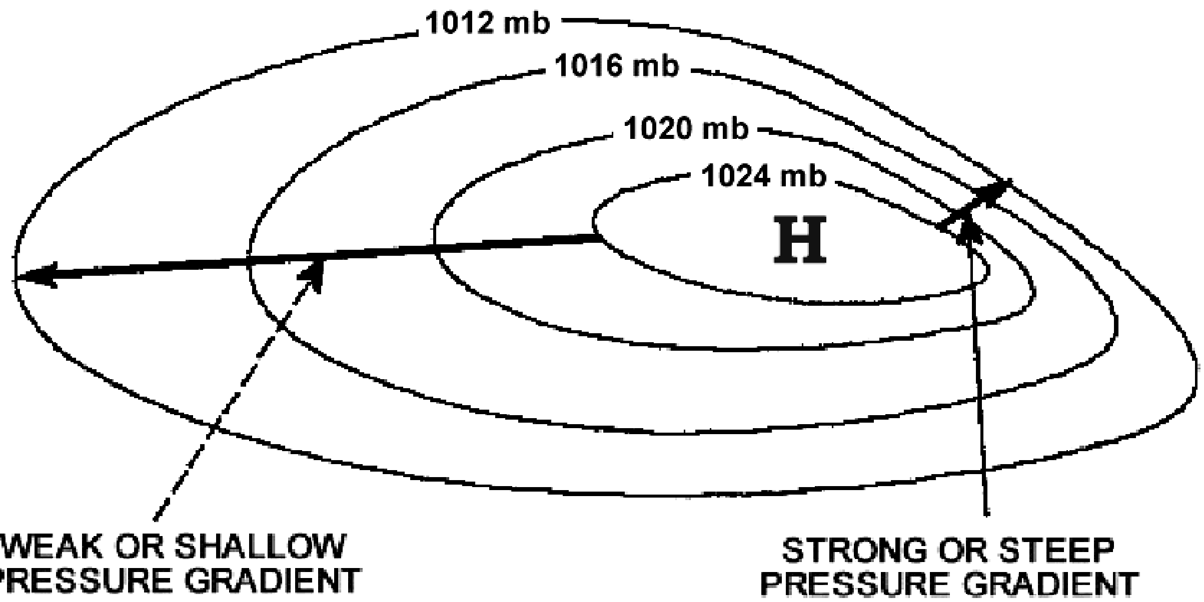


Figure 2-4 — Pressure Gradient Force

Atmospheric circulation moves air in mainly two ways: ascending and descending currents. When the air descends, the downward force against the Earth creates a high- pressure system on the surface. The air then can only spread out and diverge, moving across the surface of the earth, producing the horizontal flow of air known as wind. Likewise, air moving upward, away from the Earth results in a low at the surface, and air tries to converge toward the center of the low, also producing wind.

However, the wind cannot and does not blow straight out of a high and into a low. These motions are only the result of the pressure gradient force, pictured for each pressure system in Figure 2-5.

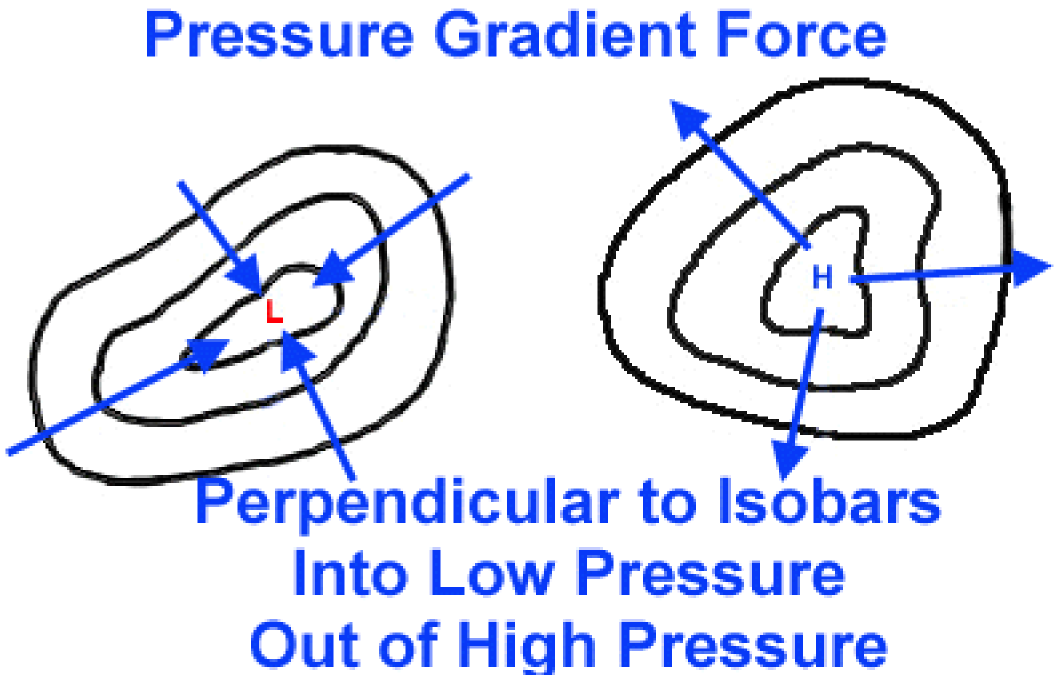


Figure 2-5 — Pressure Gradient Force

Gradient Winds
While the pressure gradient force causes air to flow from high pressure to low pressure across the isobar pattern, another force acts upon the wind to determine its direction. The Coriolis force, created by the Earth's rotation, diverts the air to the right–with respect to its initial direction of motion–regardless of whether the air is near a high or a low pressure system. The result of these two forces is the gradient winds, which flow perpendicular to the pressure gradient force. This also means that gradient winds flow parallel to the isobars (Figure 2-6), and the resulting circulation flows clockwise around highs, and counterclockwise around lows. Finally, gradient winds are found above 2000 feet AGL.

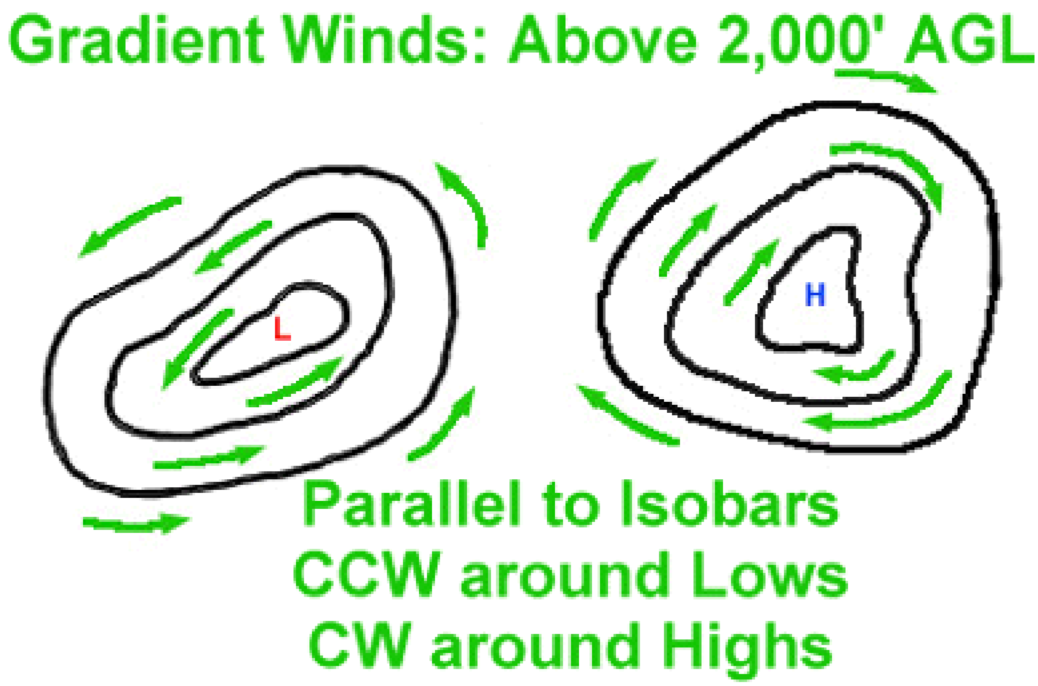
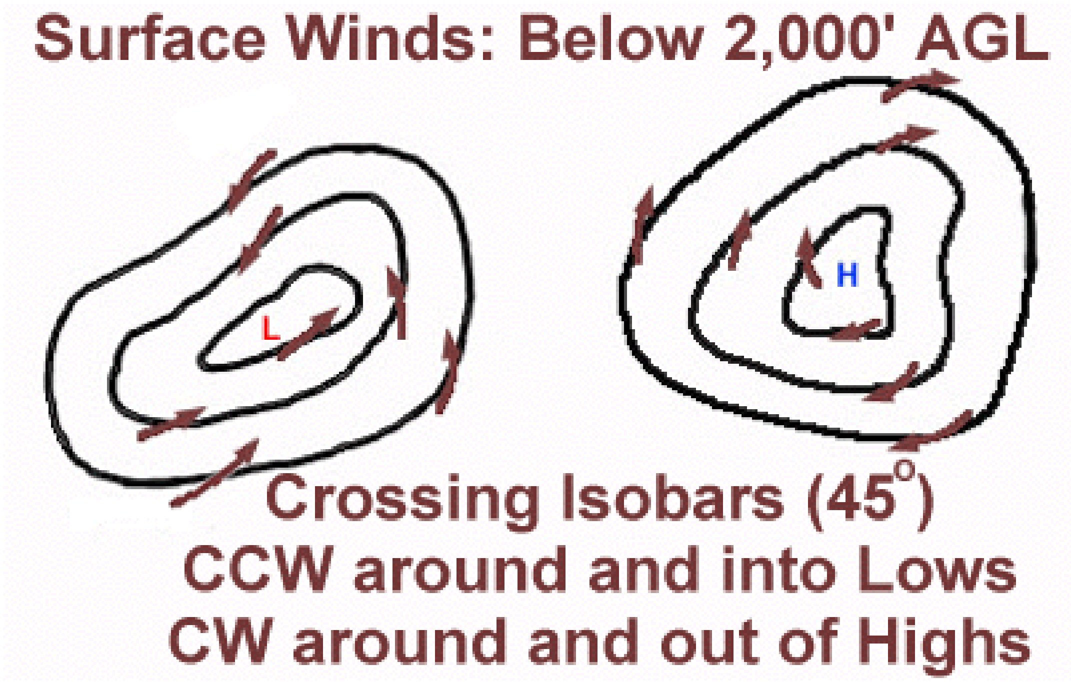


Figure 2-6 — Gradient Winds Flow Parallel to Isobars (Found Aloft)

Surface Winds

When we consider winds below 2000 feet AGL, we cannot ignore the role of surface friction in the analysis of wind direction. Surface friction reduces the speed of the wind, which causes a reduction in the Coriolis force. This results in a different set of forces that must be balanced: the PGF, Coriolis force, and friction. When the new balance of forces is reached, the air blows at an angle across the isobars from high pressure to low pressure. This angle varies as a result of the type of terrain, but for our purposes, we will assume a 45° angle (Figure 2-7). Another way to think of this effect is that the Coriolis force still tries to turn the wind to the right, from its initial intended direction of the PGF, but it does not turn to the right quite as much as with gradient winds. Thus, surface winds still move clockwise around highs, and counterclockwise around lows, but since they blow across the isobars at a 45° angle, they also have a component of motion that moves air out of the high pressure and into the low.



Gradient:	N	E	S	W
Surface:	NW	NE	SE	SW

Figure 2-7 — Surface Winds Are Deflected Across Isobars Toward Lower Pressure And Relate To The Gradient Winds Above It

Buys Ballot's Law, A Rule Of Thumb

A rule of thumb to help remember the direction of the wind in relation to a pressure system is Buys Ballot's Law. This law states that if the wind is at your back, the area of lower pressure will be to your left. When standing on the Earth's surface, the low will be slightly forward or directly left because the winds flow across the isobars.

Movement of Pressure Systems and Large Scale Wind Patterns

Weather in the Temperate Zone (which includes the U.S.) and farther north, changes almost constantly with the passage of highs and lows. These migrating systems move from west to east with the prevailing westerly winds. They are accompanied by wind shifts, and with some exceptions, large and rapid changes in temperature and broad areas of precipitation. These systems furnish the most significant means of heat transfer between high and low latitudes.

The Jet Stream
Wind speeds generally increase with height through the troposphere, reaching a maximum near the tropopause, and often culminating in the jet stream. The jet stream is a narrow band of strong winds of 50 knots or more that meanders vertically and horizontally around the hemisphere in wave-like patterns. The jet streams (polar and subtropical) have a profound influence on weather patterns.

These winds average about 100-150 knots but may reach speeds in excess of 250 knots (Figure 2-8). Since the jet stream is stronger in some places than in others, it rarely encircles the entire hemisphere as a continuous river of wind. More frequently, it is found in segments from 1000 to 3000 miles in length, 100 to 400 miles in width, and 3000 to 7000 feet in depth.

The average height of jet stream winds is about 30,000 feet MSL, but they can be above or below this level depending on the latitude and the season. During the winter, the position of the jet stream is further south, the core descends to lower altitudes, and its speed is faster than in the summer.

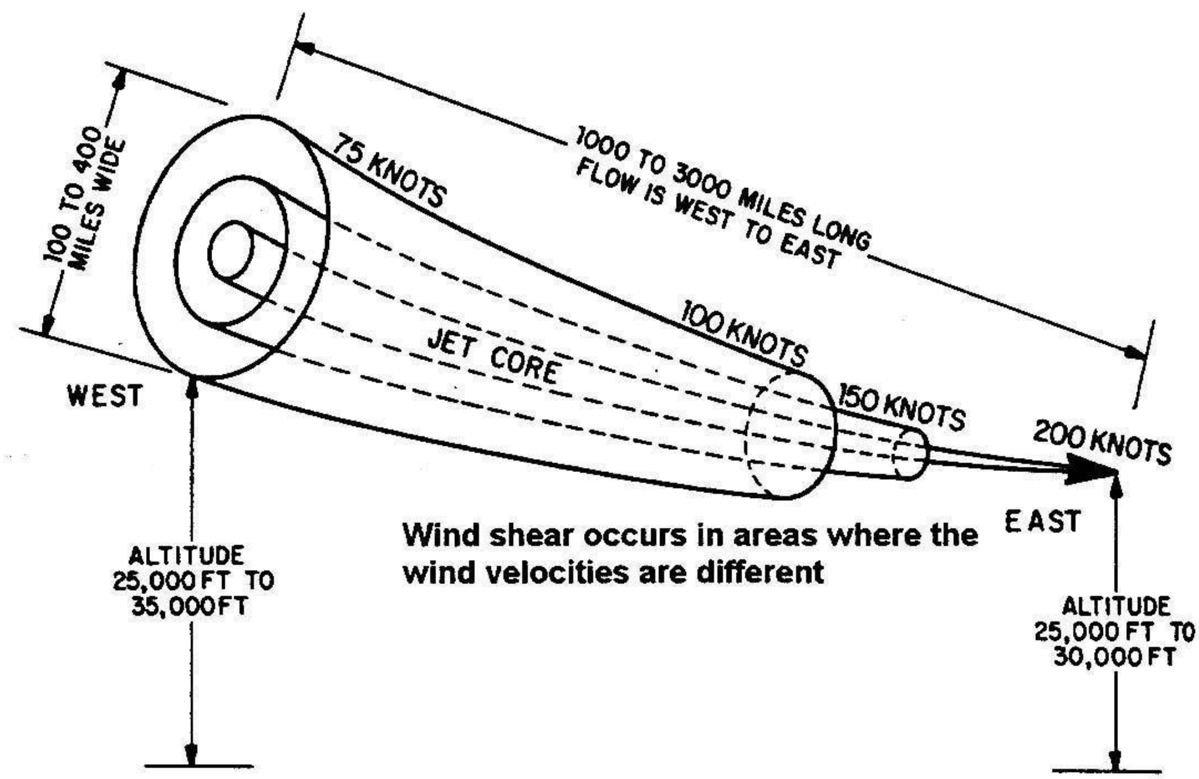


Figure 2-8 — Jet Stream

The existence of jet streams at operational altitudes requires additional aircrew flight planning consideration. The greater headwind component for westbound aircraft will increase fuel consumption and may require additional alternate landing fields along the route. Wind shear associated with the jet stream may also cause turbulence, forcing the aircrew to change altitude or course.

Local Winds

The term "local," in the case of wind systems, applies to areas whose sizes range from tens of miles across, to long, geographically thin areas. The local wind systems created by mountains, valleys, and water masses are superimposed on the general wind systems and may cause significant changes in the weather.

Sea and Land Breezes

The differences in the specific heat of land and water cause land surfaces to warm and cool more rapidly than water surfaces through insulation and terrestrial radiation. Therefore, land is normally warmer than the ocean during the day and colder at night. This difference in temperature is more noticeable during the summer and when there is little horizontal transport of air in the lower levels of the atmosphere. In coastal areas, this difference of temperature creates a tendency for the warmer, less dense air to rise, and the cooler, denser air to sink, which produces a pressure gradient. During the day, the pressure over the warm land becomes lower than that over the colder water. The cool air over the water moves toward the lower pressure, replacing the warm air over the land that moved upward. The resulting onshore wind, blowing from the sea, is called a sea breeze, with speeds sometimes reaching 15 to 20 knots (Figure 2-9).

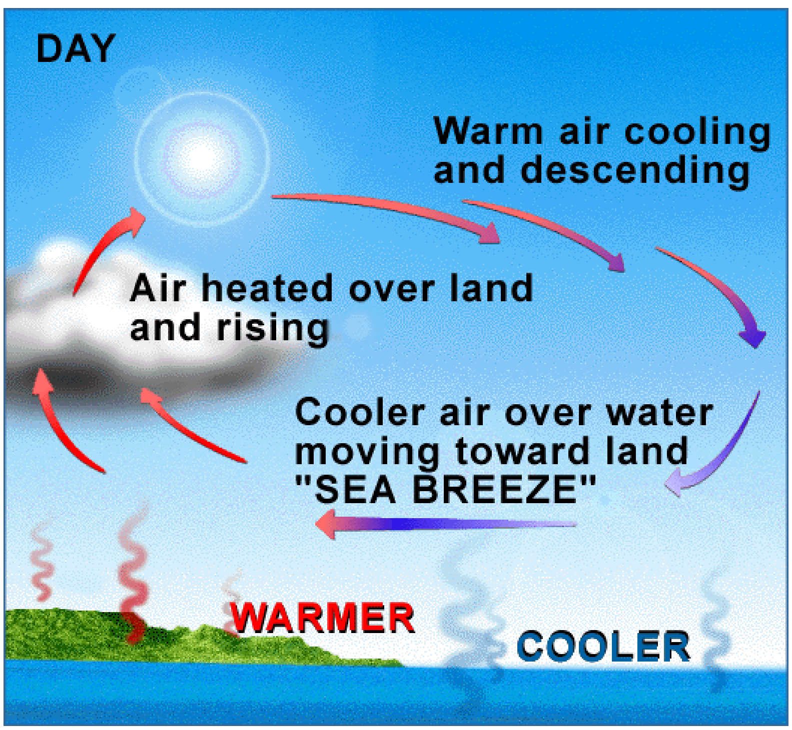


Figure 2-9 — Sea Breeze

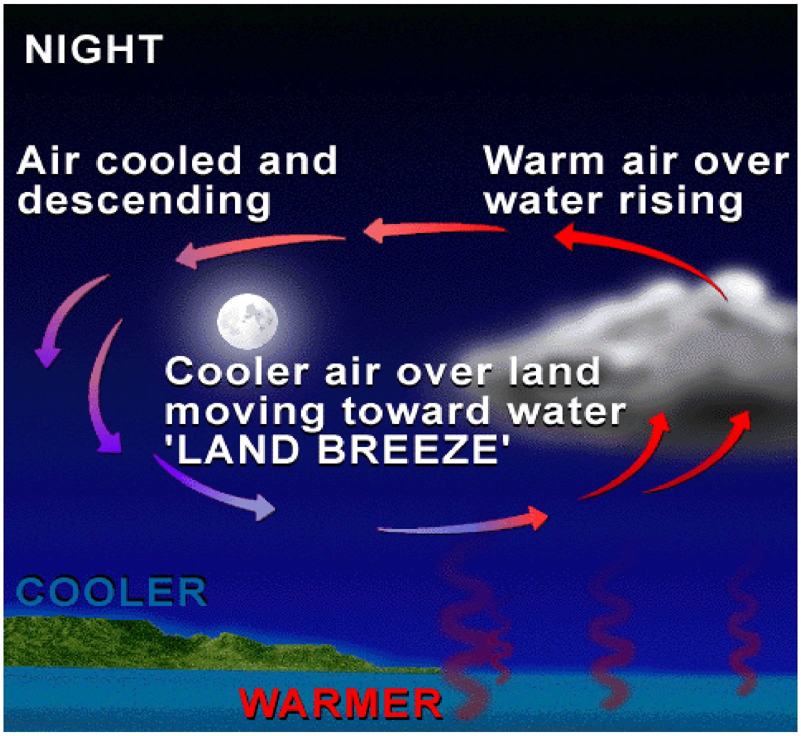


Figure 2-10 — Land Breeze

At night, the circulation is reversed so that the air movement is from land to sea, producing an offshore wind called the land breeze (Figure 2-10). The sea breezes are usually stronger than the land breezes, but they seldom penetrate far inland. Both land and sea breezes are shallow in depth, and their existence should be considered during takeoff and landing near large lakes and oceans.

Mountain and Valley Winds

In the daytime, mountain slopes are heated by the Sun's radiation, and in turn, they heat the adjacent air through conduction. This air usually becomes warmer than air farther away from the slope at the same altitude, and, since warmer air is less dense, it begins to rise (Figure 2-11). It cools while moving away from the warm ground, increasing its density. It then settles downward, towards the valley floor, completing a pattern of circulation (not shown in Figure 2-11). This downward motion forces the warmer air near the ground up the mountain, and since it is then flowing from the valley, it is called a valley wind.

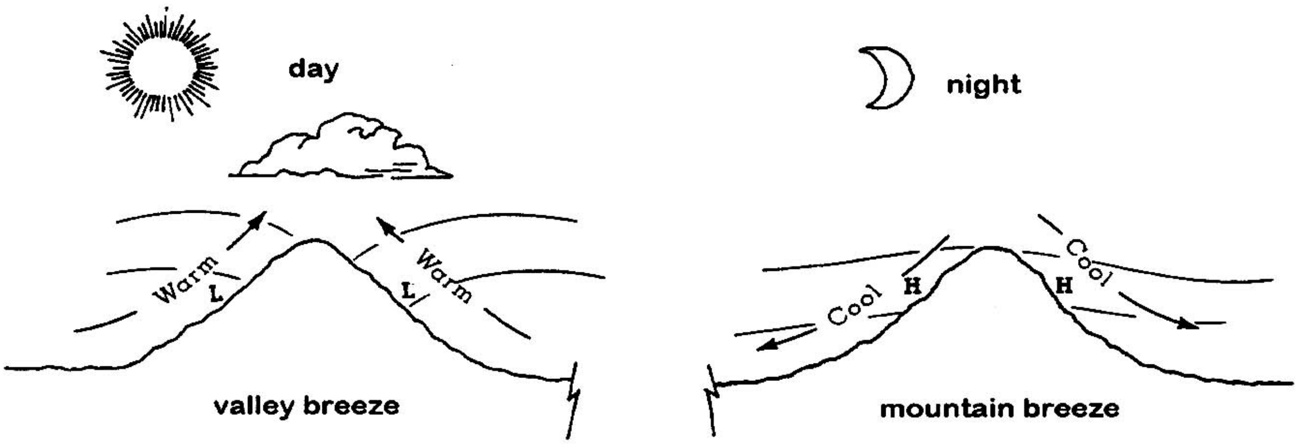


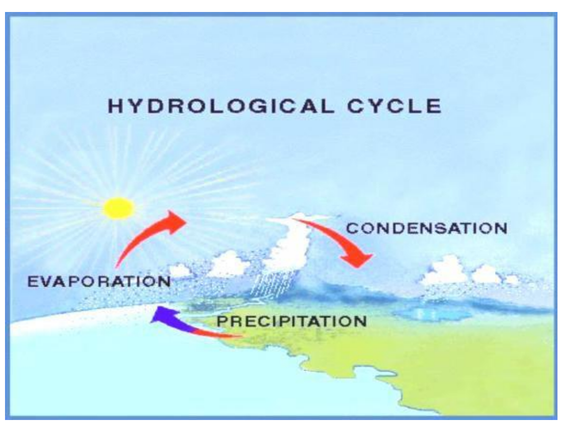
Figure 2-11 — Mountain and Valley Winds

At night, the air in contact with the mountain slope is cooled by outgoing terrestrial radiation and becomes denser than the surrounding air. As the denser air flows downhill, from the top of the mountain, it is called the mountain wind, and a circulation opposite to the daytime pattern forms.

These winds are of particular importance for light aircraft, helicopter, and low-level operations. In mountainous areas where the performance of some fixed-wing aircraft or helicopters is marginal, the location of mountain and valley winds can be critical.

ATMOSPHERIC MOISTURE

Moisture is water in any of its three states: solid, liquid, or gas. As water changes from one state to another, it releases (or absorbs) heat to (or from) the atmosphere. For example, when water in the atmosphere freezes, it releases heat into the air, and the air becomes warmer. Air can hold only a certain amount of water, however, depending on the air temperature. The higher the temperature, the more water vapor the air can hold (Figure 2-12). The air reaches saturation when it contains the maximum amount of water vapor it can hold for that temperature.



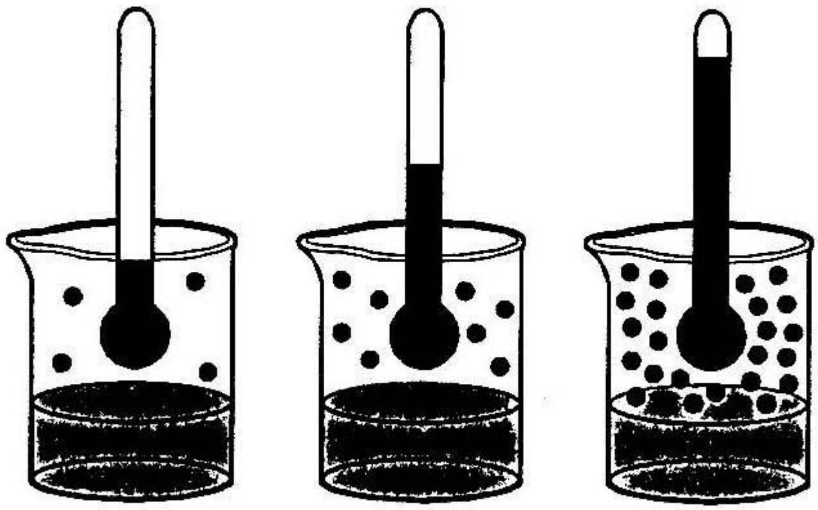


Figure 2-12 — Example of Increased Water Vapor Capacity of Warmer Air

The dew point temperature (T_D) is the temperature at which saturation occurs. The dew point is a direct indication of the amount of moisture present in the air. The higher the dew point, the greater chances for clouds, fog, or precipitation.

If there is a difference between the air temperature and the dew point temperature, this is known as the dew point depression, or dew point spread, and the dew point will always be the lower of the two. The dew point can never be higher than the air temperature: only equal to or less than. This spread provides a good indication of how close the atmosphere is to the point of saturation. When the dew point depression reaches about 4° F, the air is holding close to the maximum amount of water vapor possible. If this spread continues to decrease, moisture will begin to condense from the vapor state to the liquid (or solid) state, and become visible. This visible moisture can form dew or frost on exposed surfaces, fog near the ground, or clouds higher in the atmosphere.

Another measure of atmospheric moisture is the relative humidity (RH), which is the percent of saturation of the air. The air can become saturated (RH = 100%) by one of two ways. If the air is cooled, the falling air temperature decreases the dew point spread closer to zero, while the RH rises closer to 100%. If evaporation occurs, this adds moisture to the atmosphere, increasing the dew point, which again lowers the dew point spread and increases the RH. Once the dew point spread reaches 4° F, the RH will be 90%, and the water vapor will begin to condense into fog or clouds. Any further cooling or evaporation will produce precipitation, as there will be more water present in the air than it can hold.

Characteristics and Types of Precipitation

The characteristics and types of precipitation reveal information about various atmospheric processes. The nature of precipitation may give a clue about a cloud's vertical and horizontal structure, or indicate the presence of another cloud deck aloft. The three characteristics of precipitation are:

1. Showers **-** Characterized by a sudden beginning and ending, and abruptly changing intensity and/or sky conditions. Showers are associated with cumuliform clouds.
2. Continuous **-** Also known as steady (*not* showery). Intensity changes gradually, if at all. Continuous precipitation is associated with stratiform clouds.
3. Intermittent **-** Stops and restarts at least once during the hour. Intermittent precipitation may be showery or steady, and therefore may be associated with cumuliform or stratiform clouds.

Precipitation takes many forms. Only a few of the more common types of precipitation are mentioned here.

1. Drizzle **–** Very small droplets of water that appear to float in the atmosphere.
2. Freezing drizzle **–** Drizzle that freezes on impact with objects.
3. Rain **–** Precipitation in the form of water droplets that are larger than drizzle and fall to the ground.
4. Freezing rain **–** Rain that freezes on impact with objects.
5. Hail or graupel **–** A form of precipitation composed of irregular lumps of ice that develop in severe thunderstorms, consisting of alternate opaque and clear layers of ice in most cases. Water drops, which are carried upward by vertical currents, freeze into ice pellets, start falling, accumulate a coating of water, and are carried upward again, causing the water to freeze. A repetition of this process increases the size of the hailstone. It does not lead to the formation of structural ice, but it can cause structural damage to aircraft.
6. Ice pellets or sleet **–** Small translucent and irregularly shaped particles of ice. They form when rain falls through air with temperatures below freezing. They usually bounce when hitting hard ground and make a noise on impact. Ice pellets do not produce structural icing unless mixed with super-cooled water.
7. Snow **–** White or translucent ice crystals, usually of branched hexagonal or star-like form that connect to one another forming snowflakes. When condensation takes place at temperatures below freezing, water vapor changes directly into minute ice crystals. A number of these crystals unite to form a single snowflake. Partially melted, or "wet" snow, can lead to structural icing.
8. Snow grains **–** Very small white, opaque grains of ice. When the grains hit the ground, they do not bounce or shatter. They usually fall in small quantities from stratus-type clouds, never as showers.

Precipitation, depending on the type and intensity, affects aviation in many ways:

Visibility in light rain or drizzle is somewhat restricted. In heavy rain or drizzle, it may drop to a few hundred feet. Rain or drizzle streaming across a windscreen further restricts forward visibility. Snow can greatly reduce visibility and can lead to a total lack of forward vision.

Very heavy rain falling on a runway may cause hydroplaning. During hydroplaning, the tires are completely separated from the runway surface by a thin film of water. Tire traction becomes negligible, and the wheels may stop rotating. The tires now provide no braking capability and do not contribute to directional control of the aircraft. Loss of control may result.

If there is enough wet snow on the runway, it tends to pile up ahead of the tires during takeoff. This can create sufficient friction to keep the aircraft from reaching rotation speed and becoming airborne.

Heavy rain ingested into the engines of a jet or turboprop aircraft in flight can cause power loss or even flameout.
Hail can cause serious damage to any aircraft, but so can rain if it is penetrated at very high speed.

CLOUDS
Clouds may be defined as the visible manifestation of weather. With some knowledge of the weather conditions that cause clouds to develop, a pilot can get an excellent picture of the weather environment and can make a reasonable forecast of the weather conditions to follow. The most important element in the formation of clouds is water vapor.

General Theory of Clouds
Clouds are condensed water vapor, consisting of water droplets or ice crystals. They form when the air becomes saturated either by being cooled to the dew point or through the addition of moisture. Most clouds are the result of cooling from some lifting process, such as surface heating. The excess moisture condenses on minute particles in the atmosphere, thus forming droplets.

Condensation Nuclei
Water vapor requires a surface on which to condense. An abundance of microscopic solid particles, called condensation nuclei, are suspended in the air and provide condensation surfaces. Condensation nuclei consist of dust, salt crystals from the sea, acid salts from industrial waste, ash and soot from volcanoes and forest fires, rock particles from wind erosion, and organic matter from forests and grass lands. The most effective condensation nuclei are the various salts since they can induce condensation or sublimation even when air is almost, but not completely, saturated.

Types of Clouds
Clouds provide visible evidence of the atmosphere’s motions, water content, and degree of stability and are therefore weather signposts in the sky. They can be numerous or widespread, form at very low levels, or show extensive vertical development.

Knowledge of principal cloud types helps the aircrew member when being briefed to visualize expected weather conditions. Knowledge of cloud types will also help the pilot recognize potential weather hazards in flight. Clouds are classified according to their appearance, form, and altitude of their bases, and may be divided into four groups:

1. Low clouds, ranging from just above the surface to 6500 feet AGL.
2. Middle clouds with bases between 6500 and 20,000 feet AGL.
3. High clouds found above 20,000 feet AGL.
4. Special clouds with extensive vertical development.

The height of the cloud base, not the top, determines the classification. A cloud with a base at 5000 feet AGL and a top at 8000 feet AGL is classified as a low cloud. Each group is subdivided by appearance. There are two principal cloud forms:

1. Cumuliform – A lumpy, billowy cloud with a base showing a definite pattern or structure.
2. Stratiform – A cloud with a uniform base, formed in horizontal, sheet-like layers.

Low Clouds
Cloud bases in this category range from just above the surface to 6500 feet AGL (Figure 2-13). Low clouds are mainly composed of water droplets. The low clouds have no special prefix attached to their name. However, if the word nimbo or nimbus appears, beware that these clouds are producing violent, or heavy, precipitation.

Figure 2-13 — Stratus Clouds

Low clouds frequently present serious hazards to flying. The most serious hazard is the proximity of the cloud base to the surface of the Earth. Some of the low cloud types hide hills, making a collision with the terrain a very real danger, and visibility within low clouds is very poor. Low clouds may also hide thunderstorms. If the clouds are at or below freezing temperatures, icing may result. Icing accumulates faster in low clouds since they are generally denser than middle and high clouds. Turbulence varies from none at all to moderate turbulence. Expect turbulence in and below the clouds. Precipitation from low clouds is generally light rain or drizzle.

Middle Clouds
In this category, cloud bases form between 6500 and 20,000 feet AGL. The names of the middle clouds will contain the prefix alto**-** (Figure 2-14). They are composed of ice crystals, water droplets, or a mixture of the two.

Figure 2-14 — Altocumulus Clouds

Visibility in middle clouds varies depending on cloud density from ½ mile to a few feet. Turbulence may be encountered in middle clouds. Frequently these clouds are dark and turbulent enough to make formation flying difficult. Icing is common due to the presence of super-cooled water droplets. Rain, rain and snow mixed, or snow can be encountered in thick middle clouds.

Virga, which is rain or snow that evaporates before reaching the ground, may be encountered below these clouds.

High Clouds
In this category, cloud bases average 20,000 to 40,000 feet AGL. The names of the high clouds will contain the prefix cirro**-** or the word cirrus (Figure 2-15).

High clouds have little effect on flying except for moderate turbulence and limited visibility associated with dense jet stream cirrus. Since high clouds are composed mostly of ice crystals, they have no precipitation and do not constitute an icing hazard. Severe or extreme turbulence is often found in the anvil cirrus of thunderstorms.

Figure 2-15 — Cirrus Clouds

Special Clouds with Extensive Vertical Development
This category consists of towering cumulus and cumulonimbus clouds. The bases of these clouds are found at the low to middle cloud heights and their tops extend through the high cloud category. Figure 2 - 16 shows cumulonimbus clouds.

A special cloud, nimbostratus, produces continuous rain, snow, or ice pellets. The cloud base will extend down to about 1000 ft AGL, and fog is often present. Expect poor visibility and low ceilings with very slow clearing.

Figure 2-16 — Cumulonimbus Clouds

Towering cumulus are clouds nearing the thunderstorm stage. They can produce heavy rain showers and moderate turbulence in and near the cloud. Icing is common above the freezing level.

Cumulonimbus clouds are thunderstorm clouds. A cumulonimbus cloud is sometimes referred to as a "CB." Cumulonimbus is an exceedingly dangerous cloud, with numerous hazards to flight such as severe to extreme turbulence, hail, icing, lightning, and other hazards to be discussed in Chapter 4.

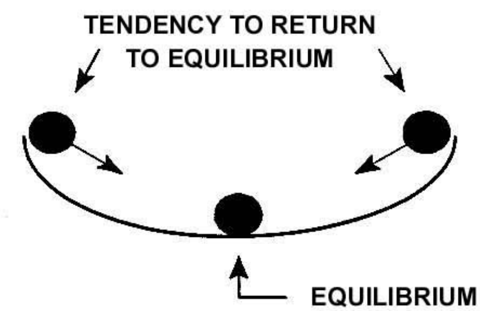
Cloud Groups				
	High Clouds	**Middle Clouds**	**Low Clouds**	**Clouds with Extensive Vertical Development**
Visibility	Good to Fair	½ mile to a few feet	A few feet	A few feet
Icing	None to Light	None to Moderate	None to Moderate	Severe
Turbulence	None to Light	None to Moderate	None to Moderate	Severe

Table 2-1 — Cloud Families

ATMOSPHERIC STABILITY

One of the most important meteorological considerations to a pilot is that of stability or instability. Atmospheric stability is one of the primary determinants of weather encountered in flight. In some cases, a pilot may be able to determine if stable or unstable conditions exist along the route of flight.

There are three conditions of stability: stable, neutral stable, and unstable. We will consider each of these individually by observing a ball inside a bowl. If the ball is displaced, and tends to return to its original position, the ball is said to be stable (Figure 2-17).



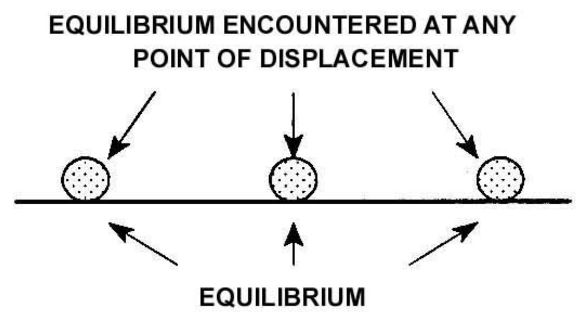


Figure 2-17 — Stable Equilibrium and Neutrally Stable Equilibrium

If a ball on a flat table is displaced, it will tend to remain in its new position and is said to be neutrally stable (Figure 2-17). It will not have a tendency to return to its original position, or move away from its final position.

Now, consider an inverted bowl with a ball balanced on top. Once the ball is displaced, it will tend to move away from its original position, never to return, and the ball is said to be in an unstable condition (Figure 2-18).

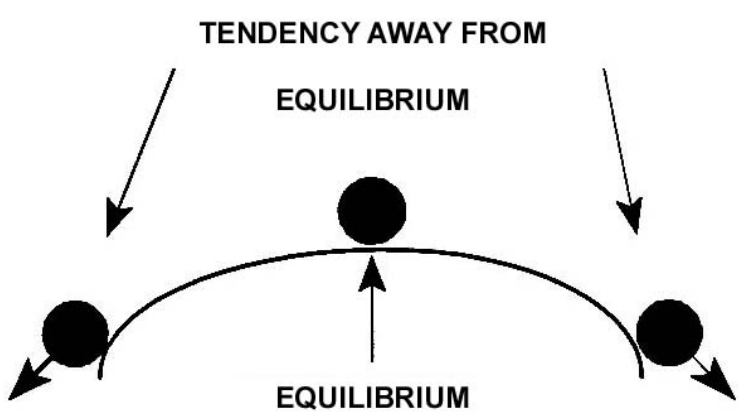


Figure 2-18 — Unstable

In weather, parts, or parcels, of an air mass become displaced through one of four methods of lifting. The stability of a quantity of air after it is lifted is determined by the temperature of the surrounding air. Lifted air that is colder than the surrounding air settles when the lifting action is removed, since it is denser. This indicates a stable condition. Lifted air that is warmer than the surrounding air continues to rise when the lifting action is removed because it is less dense indicates an unstable condition. This lifted air that continues to rise has reached the point of free convection, which occurs when the lifted air rises with no external lifting force, due only to the parcel's warmer temperature. Lifted air that has the same temperature as the surrounding air after it is lifted will simply remain at the point where the lifting action was removed. This is an example of a neutrally stable atmosphere. If the air behaves in one of these three ways, then we can say that the atmosphere has that same condition of stability (Figure 2-19).

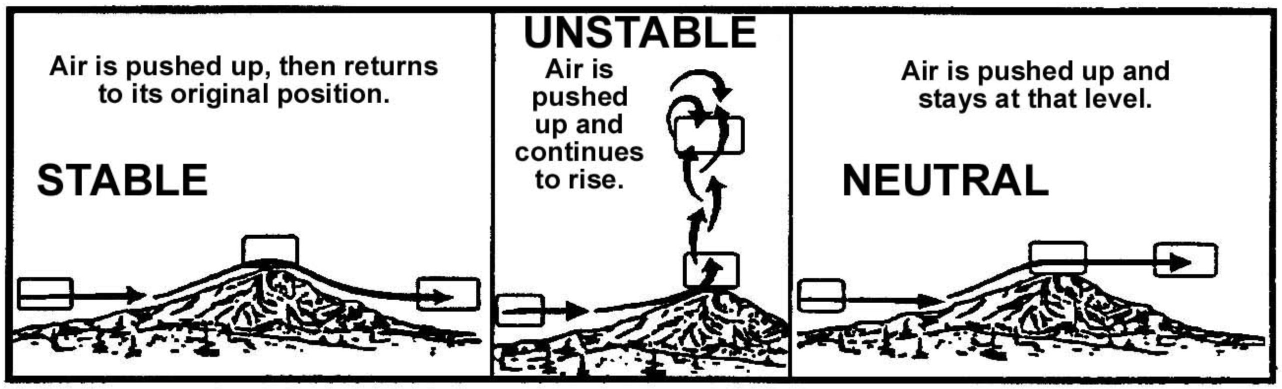


Figure 2-19 — Stable, Unstable, and Neutral Stability

Methods of Lifting

The four methods of lifting are convergence, frontal, orographic, and thermal (Figure 2-20). Convergence of two air masses, or parts of a single air mass, force the air upward because it has nowhere else to go. Because of the shape of cold fronts, as they move through an area, they will lift the air ahead of the cold air mass. Orographic lifting is a term indicating that the force of the wind against a mountainside pushes the air upward. Thermal lifting, also known as convective lifting, is caused when cool air is over a warm surface, and it is heightened by intense solar heating.

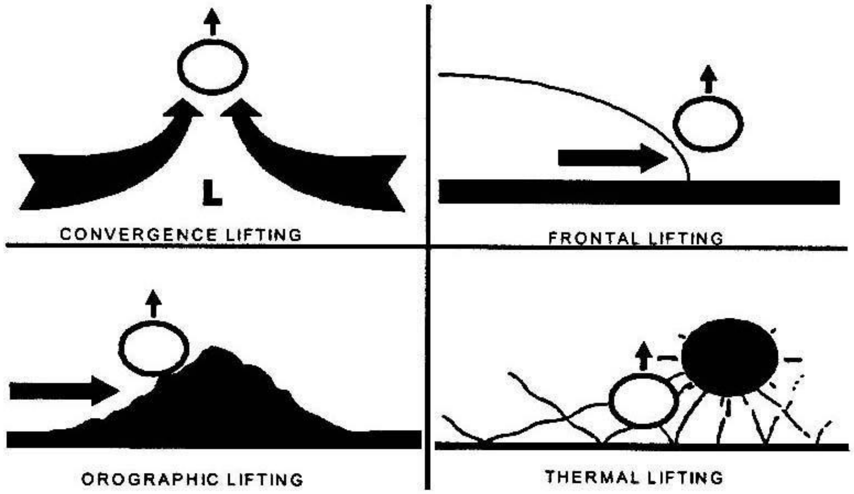


Figure 2-20 — The Four Lifting Methods

Stability and Flight Conditions
Cloud types are helpful in identifying conditions of stability or instability. Cumuliform clouds develop with unstable conditions and stratiform clouds develop with stable conditions (Figure 2-21), assuming sufficient moisture exists for cloud development.

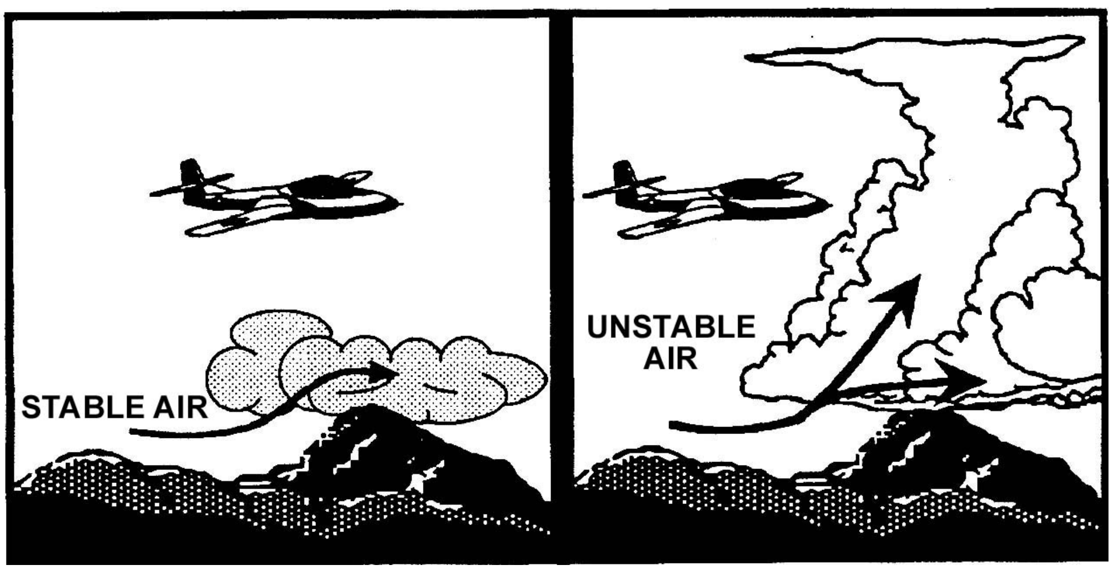


Figure 2-21 — Clouds in Stable and Unstable Air

There are a significant number of flight conditions associated with atmospheric stability, as depicted in Table 2-2. If one or more of these conditions is encountered, the stability of the atmosphere can be easily determined, and other flight conditions can be predicted. Thus, understanding the relationships among stability and flight conditions provides aircrew with a key that unlocks many of the mysteries of weather phenomena.

FLIGHT CONDITIONS	STABLE ATMOSPHERE	UNSTABLE ATMOSPHERE
FRONTS	WARM	COLD
AIRMASS	WARM	COLD
TURBULENCE	SMOOTH	ROUGH
VISIBILITY	POOR	GOOD, outside of clouds
ICING	RIME	CLEAR
PRECIPITATION	STEADY	SHOWERY
WINDS	STEADY	GUSTY
CLOUD TYPES	STRATUS	CUMULUS

Table 2-2 — Atmospheric Stability and Flight Conditions

Being able to recognize the stability of the air while flying will help prepare you for the various flight conditions you are experiencing. When encountering a change in weather conditions–apart from what was briefed–the relationships in Table 2-2 can also be a guide to understanding the different options available, and to making better decisions for avoiding weather hazards. Here are some additional “signs in the sky” that indicate stable air: temperature inversions, low fog and stratus, and rising air temperature while climbing. Thunderstorms, showers, towering clouds, dust devils, and rapidly decreasing air temperature while climbing all indicate unstable atmospheric conditions.

ASSIGNMENT SHEET 3-2-3

ATMOSPHERIC MECHANICS REVIEW

A. INTRODUCTION

The purpose of this lesson is to introduce the student to the general structure of the atmosphere and the properties of wind, clouds, atmospheric stability and their effect on flight operations.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

1. Review JPATS Aviation Weather Booklet, JX100 Chapter JX102.
2. Read JPATS Aviation Weather Booklet, JX100 Chapter JX103.

D. STUDY QUESTIONS

1. Which one of the following types of isobar spacing would indicate a weak pressure gradient force?
   a. Narrow
   b. Deep
   c. Wide
   d. Tight

2. Which one of the following types of pressure gradients would indicate the presence of strong winds?
   a. Steep
   b. Low pressure
   c. Weak
   d. Shallow

3. The initial movement of air toward a low-pressure area is caused by the ______.
   a. pressure gradient force
   b. Coriolis force
   c. centrifugal force
   d. force of friction

4. The forces that determine the wind direction in the atmosphere are weakened at the Earth's surface by the ______.
   a. pressure gradient force
   b. Coriolis force
   c. centrifugal force
   d. force of friction

5. Gradient winds move parallel to the isobars above 2000 feet AGL because they are NOT affected by the ______.
   a. pressure gradient force
   b. Coriolis force
   c. centrifugal force
   d. force of friction

6. The surface wind, when compared with the gradient wind is of ______.
   a. lesser speed and blows parallel to the isobars
   b. lesser speed and blows across the isobars toward low pressure
   c. greater speed and blows across the isobars toward high pressure
   d. greater speed and blows across the isobars toward low pressure

7. In the Northern Hemisphere, the wind blows ______.
   a. from low to high pressure
   b. clockwise around a low
   c. counterclockwise around a low
   d. perpendicular to the isobars

8. Gradient winds blow parallel to the isobars because of the ______.
   a. Coriolis force
   b. frictional force
   c. centrifugal force
   d. wind force

9. The sea breeze blows from the _______ to the _______ during the _______, and the land breeze blows from the _______ to the _______ during the _______.
   a. water, land, day; water, land, night
   b. land, water, day; land, water, night
   c. land, water, day; water, land, night
   d. water, land, day; land, water, night

10. ______ and water vapor must be present in the atmosphere for precipitation to occur.
    a. Carbon dioxide
    b. Condensation nuclei
    c. Wind
    d. Nitrogen

11. When air contains the maximum moisture possible for a given temperature, the air is ______.

12. The temperature to which air must be cooled to become saturated is called the ______.

13. Which one of the following conditions could produce fog, clouds, or precipitation?
    a. Dew point spread of 5° C
    b. Dew point greater than air temperature
    c. RH of 0%
    d. RH of 100%

14. Stratiform clouds are associated with ______ flight conditions.
    a. stable
    b. unstable

15. At which altitude could an altostratus cloud be found?
    a. 5000' MSL
    b. 5000'AGL
    c. 10,000' AGL
    d. 25,000' AGL

16. Cumulonimbus clouds typically produce which type of precipitation?
    a. Drizzle
    b. Light steady
    c. Heavy showers
    d. Fog

17. Nimbostratus clouds will produce ______ precipitation.
    a. heavy showery
    b. light showery
    c. heavy steady
    d. light steady

18. ______ defines air with the same temperature as the surrounding air.
    a. Unstable
    b. Neutrally stable
    c. Stable
    d. Displaced

19. Which one of the following correctly lists the four methods of lifting?
    a. Convergence; frontal; orographic; and thermal
    b. Convergence; subsidence; orographic; and thermal
    c. Convergence; convection; adiabatic; and katabatic
    d. Divergence; subsidence; frontal; and convective

20. If lifted air is warmer than the surrounding air, then ______ clouds will form resulting in ______ flight conditions.

21. If stratus clouds are present, which of the following flight conditions could be expected?
    a. Rough turbulence, good visibility, showery precipitation, and clear icing
    b. Smooth flight, good visibility, steady winds, and no precipitation
    c. Poor visibility, steady winds, continuous precipitation, and rime icing
    d. Smooth flight, turbulent flight, good visibility, and showery precipitation

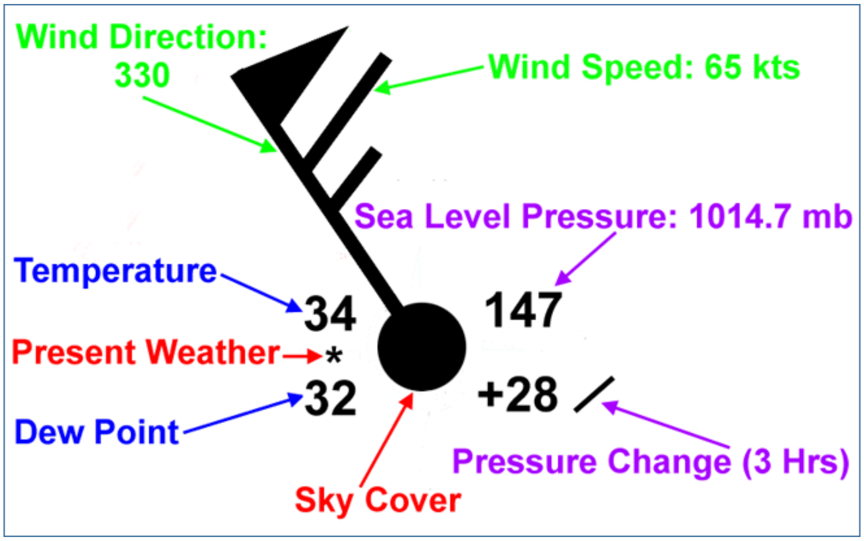
22. Which one of the following types of clouds could be produced by unstable conditions?
    a. Cirrus
    b. Cumulonimbus
    c. Stratus
    d. Nimbostratus

Answers

1. C	12.dew point temperature
2. A	13.D
3. A	14.A
4. D	15.C
5. D	16.C
6. B	17.C
7. C	18.B
8. A	19.A
9. D	20.cumuliform;unstable
10.B	21.C
11. saturated	22.B

Winds

Station Models



Wind direction and speed

Stick points to FROM wind direction

Barbs & pennant indicate wind speed

Single barb - 10 knots

Half barb - 5 knots

Pennant - 50 knots

Present weather and sky cover

Temperature

Present weather

Dew point

Sky cloud coverage

Pressure

Current pressure in mb

Pressure change (± in last three hours)

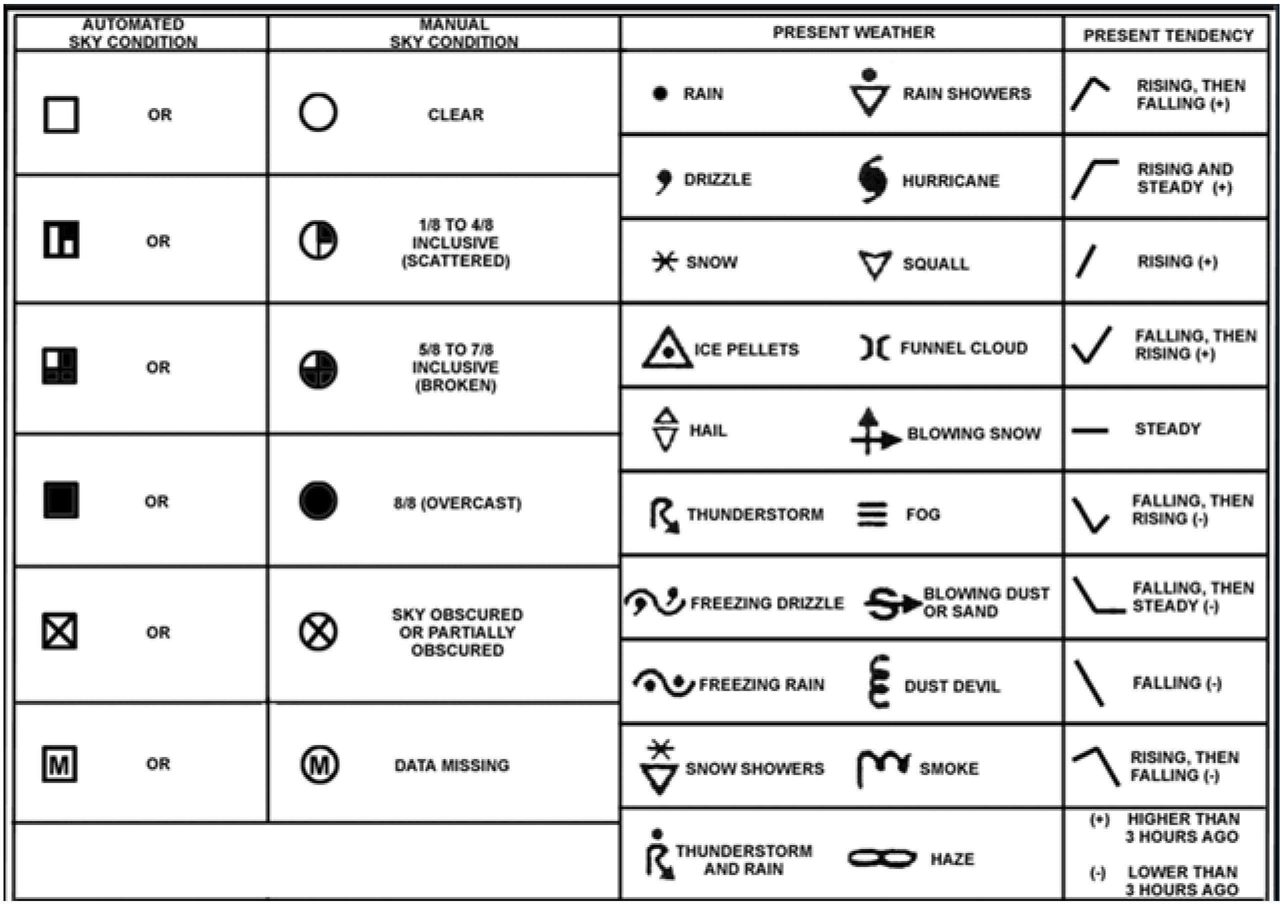
Major Station Model Symbols

Automated sky condition

Manual sky condition

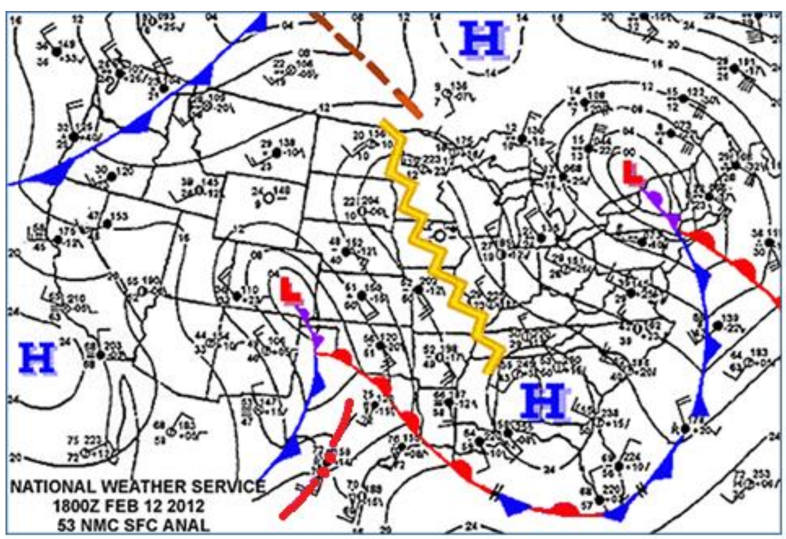
Present weather

Present tendency



Large Scale Wind Patterns

- Winds affect the flight of aircraft
- Brings about changes in weather
- Transports water vapor:
  - Fog Clouds
  - Precipitation
- Pressure distribution shown on surface charts by isobars
- Wind direction parallel to isobars
  - Clockwise around highs
  - Counterclockwise around lows



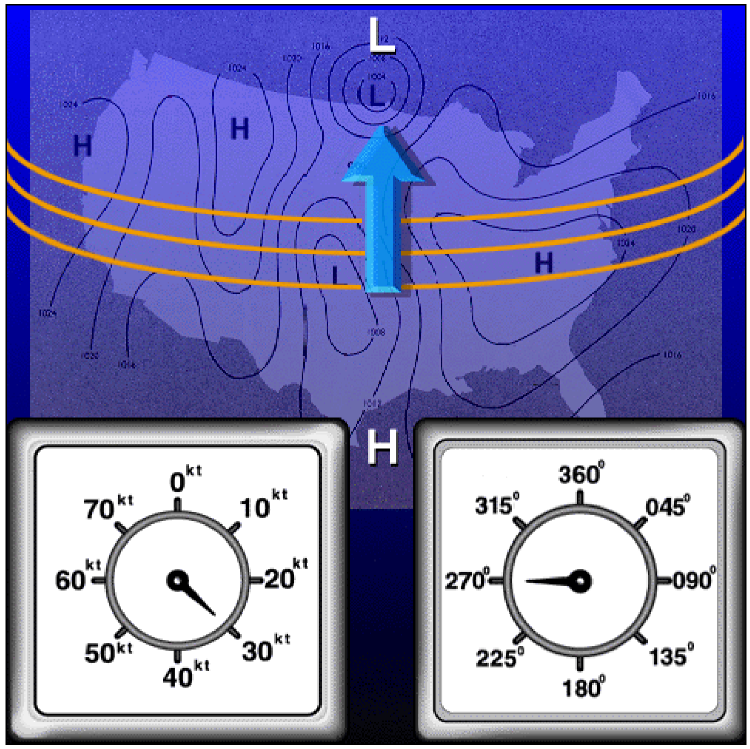
Pressure Gradient Force (PGF)

Rate of change in pressure in horizontal distance

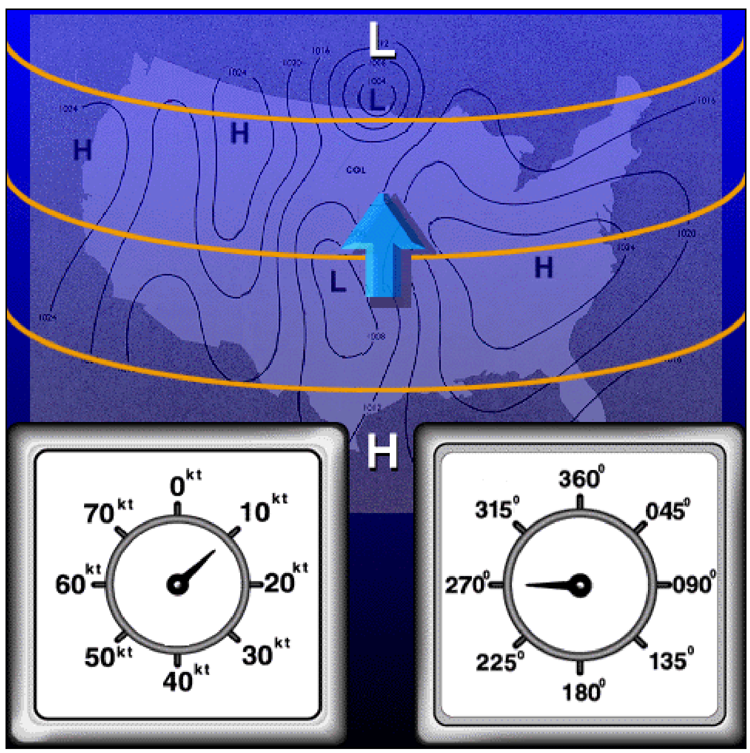
Perpendicular to isobars

Size of pressure gradient represented by isobar spacing

Tight spacing →
Steep pressure gradient →
Strong Pressure Gradient Force →
Faster wind speed

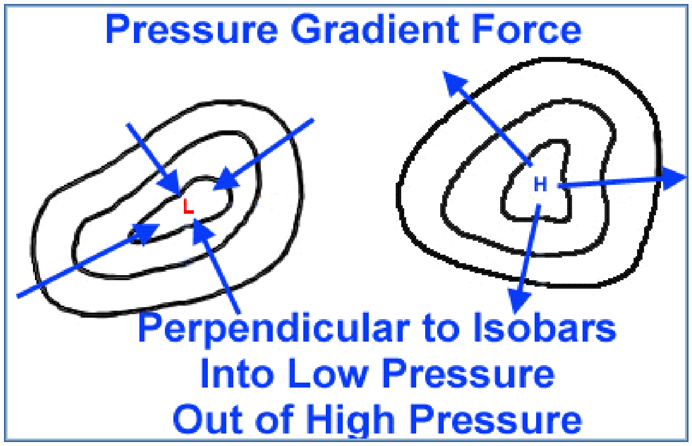


Wide spacing →
Shallow pressure gradient →
Weak Pressure Gradient Force →
Slower wind speed

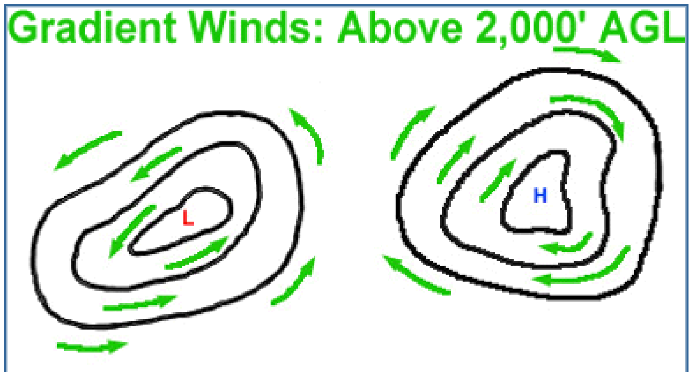


Gradient and Surface Winds

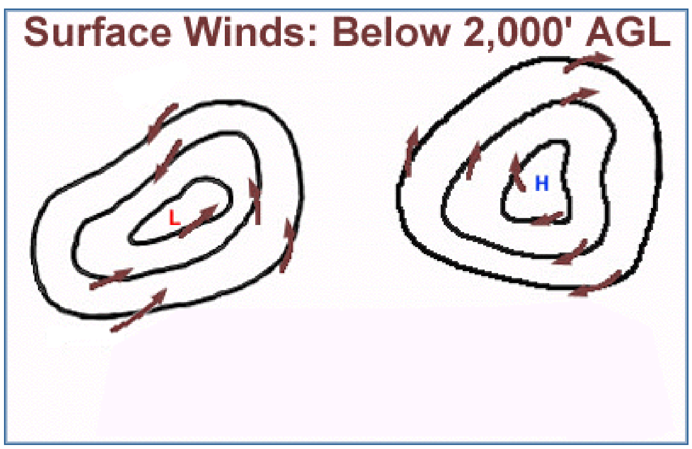
- High pressure results from descending air
  - Creates horizontal diverging force (PGF)
  - Shown via isobars -- out of Highs into Lows
- Low pressure results from ascending air
  - Creates horizontal converging force (PGF)
  - Into Lows from High



- Pressure Gradient force and Coriolis force balance to create flows
  - Parallel to isobars Clockwise
    - around Highs Counterclockwise
    - around Lows
  - Gradient winds
    - Found above 2000 feet AGL



- Surface winds (below 2000 feet) AGL
  - Friction reduces wind speed
  - Coriolis force shifts wind direction toward isobars
  - New balance of forces
    - Wind blowing across the isobars (45°)
    - CW around Highs
    - CCW around Lows
    - Out of High pressure into Low pressure



Jet Streams

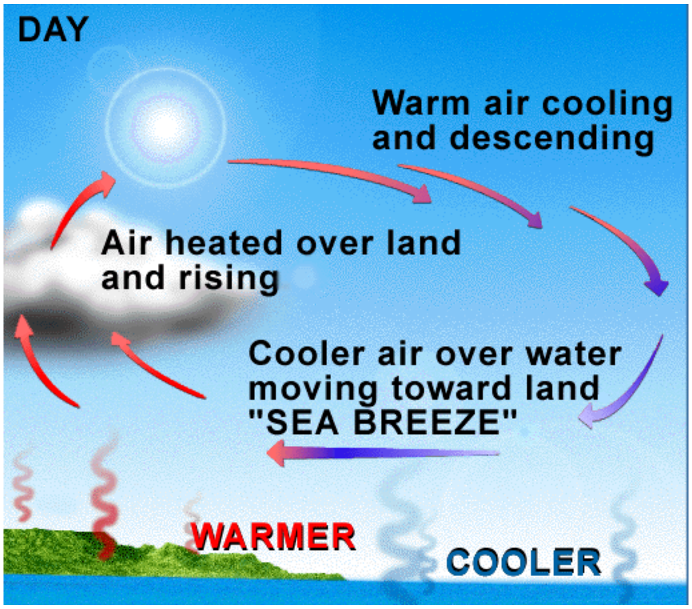
- Narrow band of strong winds found below the tropopause
- Average height: 30,000 feet MSL.
  - May be above or below depending on latitude and season
- Speed: 100 - 150 knots
  - May reach speed in excess of 250 knots
- Location
  - Position of jet stream changes daily
  - Changes weather patterns
- Aircrew considerations
  - Head/tail wind
  - Turbulence

Local Winds

- Created by:
  - Mountains
  - Valleys
  - Water masses
- Results:
  - General wind system development
  - Significant weather changes

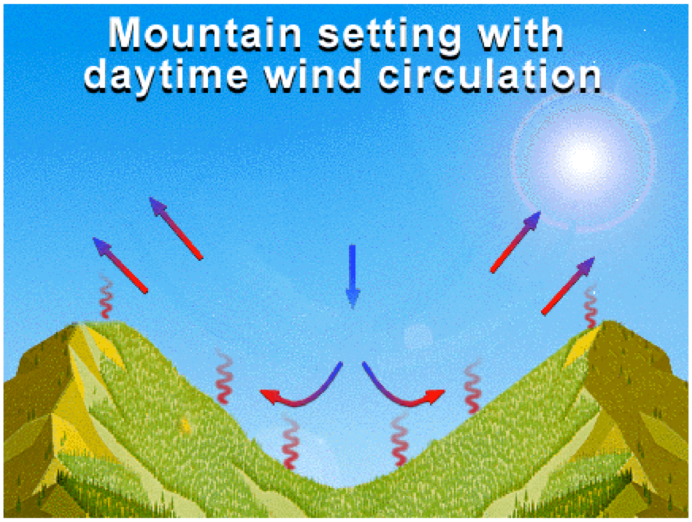
Land and Sea Breezes (land and water heating)

- Generally, land mass gains/loses heat quicker than water mass
- Sea breeze comes from sea during the day
- Land breeze comes from land at night



Valley winds

- Flow out of valley during day
- Air heats and rises
- Air cools and settles back in valley



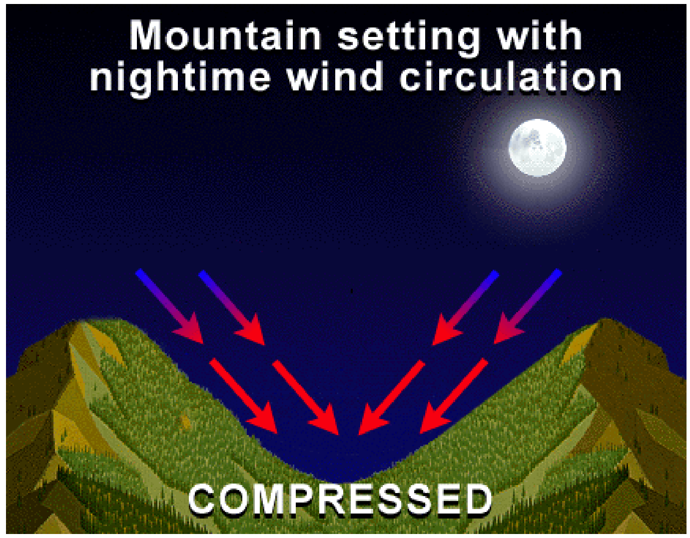
Mountain breeze

Flow down mountain slopes at night

Air is cooled by outgoing land radiation and becomes more dense than surrounding air

Denser air flows downhill

Rising air cools and creates a circulation



Clouds and Moisture

Atmospheric Moisture

Moisture in three states:

Solid

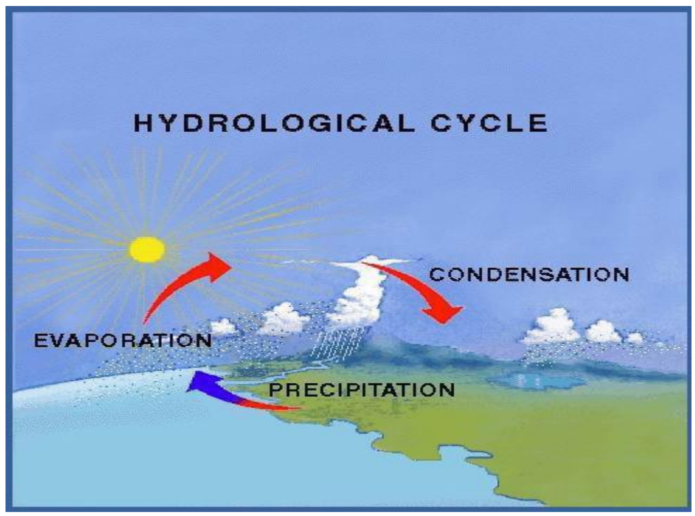
Liquid

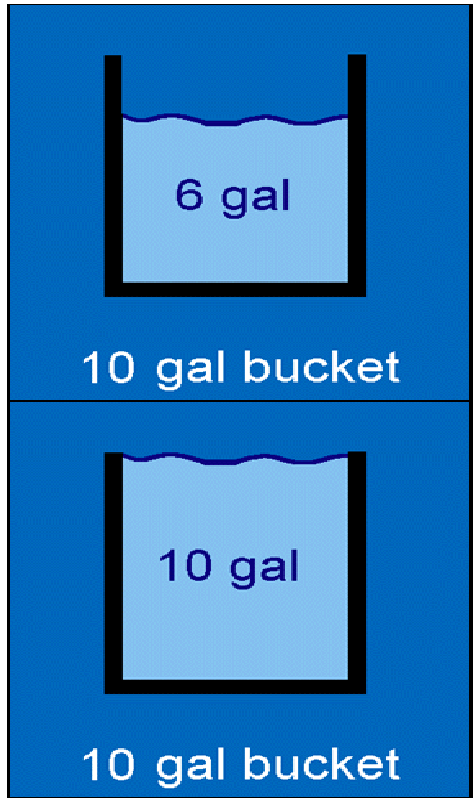
Gas

Atmosphere cycles

Evaporation and Condensation

Hydrological Cycle





Atmospheric Moisture and Saturation

Saturation

Air is holding the maximum water vapor for:

Temperature

Pressure

Dew point temperature (TD)

Temperature saturation occurs

Higher temperature = more moisture in the air

Dew point depression or spread

Degree difference between air temperature and TD

Relative humidity

Percentage of water vapor in air compared to the maximum amount the air could hold at that temperature

Characteristics and Types of Precipitation

Characteristics

Showers – starts, stops, changes intensity rapidly, associated with cumuliform clouds

Continuous – steady, changes intensity gradually, associated with stratiform clouds

Intermittent – stops, starts at least once during the hour, showers or steady, cumuliform or stratiform clouds

Precipitation forms

Drizzle - liquid and freezing

Rain - liquid and freezing

Frozen - hail, ice pellets, snow and snow grains

Cloud Formation

- Condensation nuclei required to provide surface that water vapor can condense
  - Dust
  - Ocean salt crystals
  - Acid salt
  - Ash and soot
  - Organic matter
- Condensed water vapor
  - Water droplets
  - Ice crystals
- Air becomes saturated by
  - Cooling to dew point
  - Evaporation adding moisture

Low Clouds

- Characteristics
  - Surface to 6500 feet AGL
  - Serious hazard due to cloud base proximity to terrain
- Types:
  - Stratus – steady precipitation
  - Cumulus – showery precipitation

Middle Clouds

Characteristics

Bases form between 6500 feet and 20,000 feet AGL

Usually light form of precipitation

Prefix “Alto”

Types:

Altostratus – light steady precipitation

Altocumulus – light showery precipitation

High Clouds

Characteristics

Base form above 20,000 feet AGL

Composed of ice crystals

Produce no icing or precipitation

Prefix “cirro”

Types:

Cirrocumulus

Cirrostratus

Cirrus

Special Clouds

Characteristics

Cumulonimbus clouds are towering thunderstorm clouds with extensive vertical development

Nimbostratus clouds build downward

Types

Cumulonimbus – heavy showers

Nimbostratus – violent/heavy steady precipitation

Atmospheric Stability

Conditions of stability

Stable - Tendency to return toward initial condition when disturbed

Neutrally stable - System has tendency to remain in its new state after being disturbed

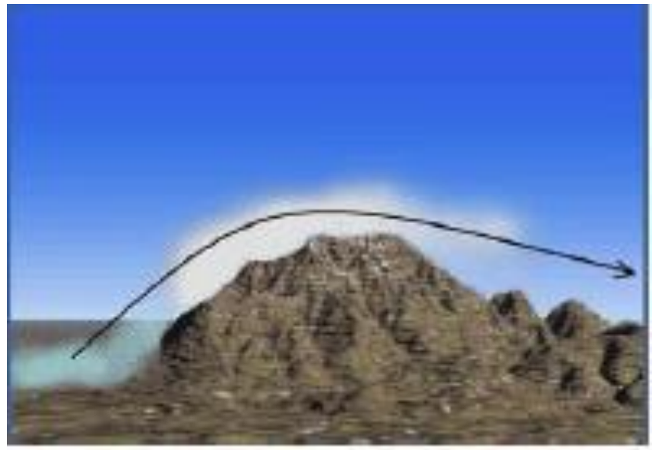
Unstable - System has tendency to move away from its initial condition when disturbed

Atmospheric Stability

Stable Air

Colder than the surrounding air after being lifted

Settles when lifting is removed



Stable Air Condition

Neutrally stable air

Same temperature of the surrounding air after being lifted

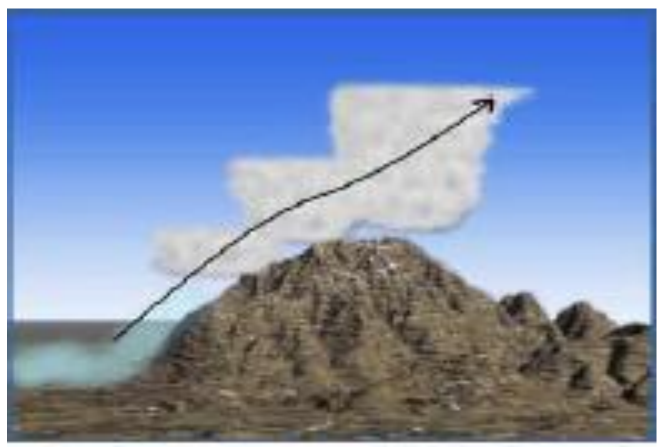
Remains at the same place until acted upon by something else

Rare but same results as stable

Unstable air

Warmer than the surrounding air after being lifted

Lifted air continues to rise after the lifting force is removed due only to the parcel's warmer temperature



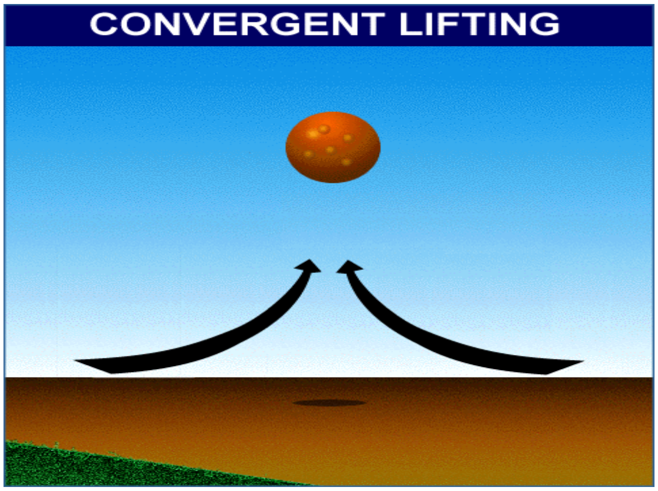
Unstable Air Condition

Methods of Lifting

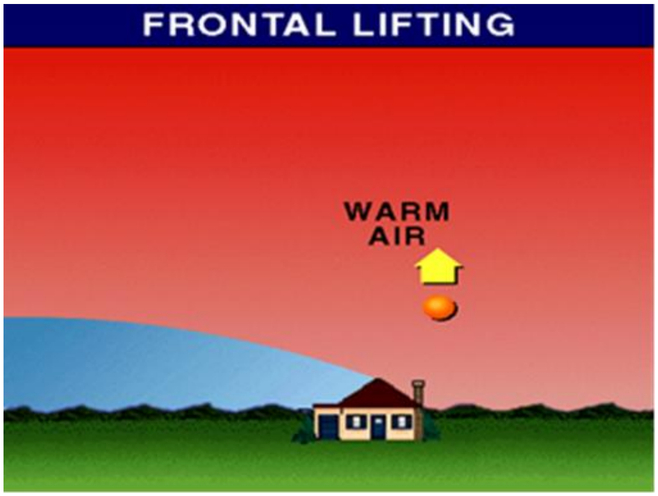
Providing initial disturbance necessary to create stability or instability in the atmosphere

Four methods

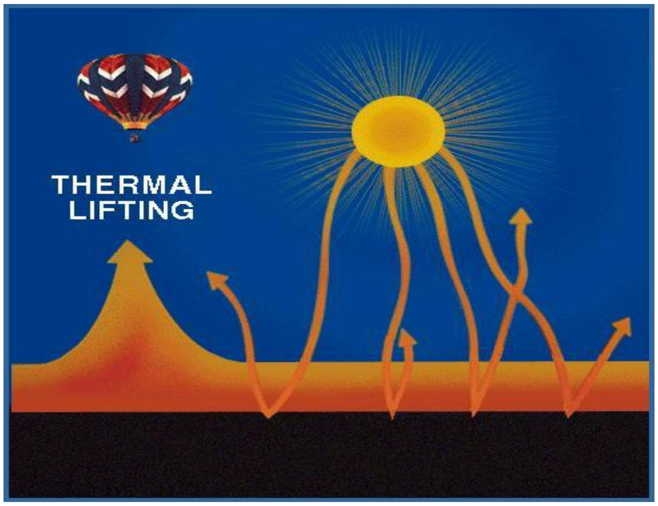
Convergence



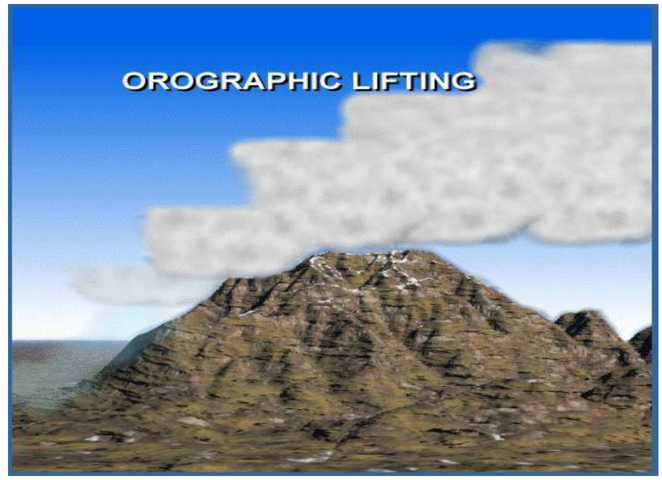
Frontal



Thermal



Orographic



Atmosphere Stability and Flight Conditions

FLIGHT CONDITIONS	STABLE ATMOSPHERE	UNSTABLE ATMOSPHERE
FRONTS	WARM	COLD
AIRMASS	WARM	COLD
TURBULENCE	SMOOTH	ROUGH
VISIBILITY	POOR	GOOD, outside of clouds
ICING	RIME	CLEAR
PRECIPITATION	STEADY	SHOWERY
WINDS	STEADY	GUSTY
CLOUD TYPES	STRATUS	CUMULUS

Clues to Flight Conditions

Stable

Temperature inversions

Wide spread fog or low clouds

Rising or slightly decreasing temperatures while climbing

Unstable

Thunderstorms

Towering cumulus clouds

Heavy showers

Dust devils

Rapidly decreasing temperature while climbing

OUTLINE SHEET 3-3-1

FRONTAL MECHANICS

A. INTRODUCTION

The purpose of this lesson is to provide the student with a general discussion of frontal systems, including their formation, flight conditions and associated weather patterns.

B. ENABLING OBJECTIVES

2.235 DEFINE the term air mass, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.236 DEFINE the term front, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.237 DESCRIBE the structure of a front, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.238 DESCRIBE the discontinuities used to locate and classify fronts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.239 DESCRIBE the factors that influence frontal weather, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.240 DESCRIBE the conditions associated with a cold front, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.241 DESCRIBE the characteristics of a squall line, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.242 DESCRIBE the characteristics of a warm front, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.243 DESCRIBE the conditions associated with a stationary front, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.244 DESCRIBE the conditions associated with occluded fronts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.245 DESCRIBE the conditions associated with an inactive front, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. Air Masses
2. Frontal Systems
3. Frontal Structure
4. Cold Fronts
5. Warm Fronts
6. Occluded Fronts

INFORMATION SHEET 3-3-2

FRONTAL MECHANICS

A. INTRODUCTION

The purpose of this lesson is to provide the student with a general discussion of frontal systems, including their formation, flight conditions and associated weather patterns.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. JPATS Aviation Weather Booklet, JX100

C. INFORMATION

AIR MASSES

The weather in the mid-latitude regions is a direct result of the continuous alternation of warm and cold air masses. Warm air masses predominate in the summer and cold air masses predominate in the winter. However, both cold and warm air may prevail almost anywhere in the temperate zone–the region between 30 and 40 degrees North latitude, which covers the continental United States–at any season.

An air mass is a large body of air that has essentially uniform temperature and moisture conditions in a horizontal plane, meaning that there are no abrupt temperature or dew point changes within the air mass at a given altitude. It may vary in size from several hundred to more than several thousand square miles (Figure 3-1).

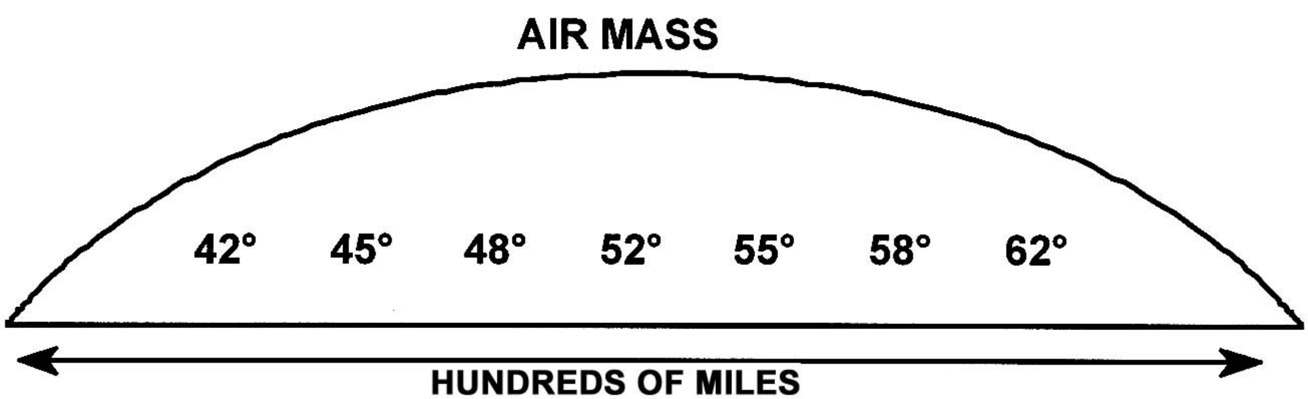


Figure 3-1 — Air Mass Profile

Air masses are named according to their location, moisture content, and temperature. The location of an air mass has a large influence over the other two properties. Naturally, moist air masses will have a greater potential for producing clouds and precipitation than dry air masses. Most importantly, though, its temperature indicates the stability of the air mass. Warm air masses bring stable conditions, while cold air masses are inherently unstable.

Named according to:

- Location
  - Tropical
  - Arctic
  - Polar
  - Equatorial
- Moisture content
  - Maritime
  - Continental
- Temperature
  - Warm
  - Cold

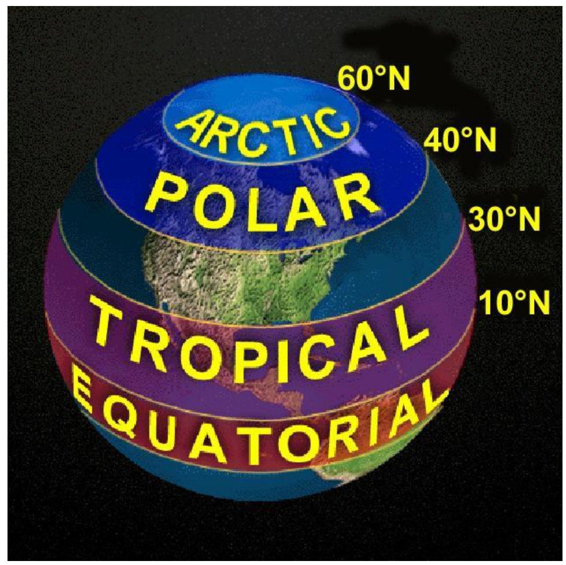


Figure 3-2 – Air Masses

Frontal Systems

A front is an area of discontinuity that forms between two contrasting air masses when they are adjacent to each other. A front can be thought of as a border, boundary, or line between the air masses. These air masses must have sufficiently different temperature and moisture properties– the defining characteristics of an air mass–otherwise there would be little reason to distinguish between them. Since air masses cover many thousands of square miles, the boundary between them can be hundreds of miles long. As air masses are three-dimensional, fronts are, as well. The point where a front comes in contact with the ground is called the surface front. The surface front is the line that is plotted on surface analysis charts with different colors and shapes representing each type of front, as pictured in Table 3-1.

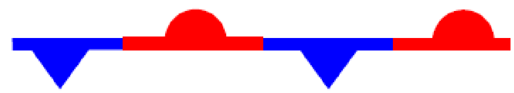
Type of Front	Color Scheme	Symbol
Cold front	Blue	
Warm front	Red	
Occluded front	Purple	
Stationary front	Blue and Red	
Trough	Brown or Black	
Ridge	Yellow or Black	
Squall line	Red	

Table 3-1 — Frontal Symbols

The frontal zone is that area that encompasses the weather located on either side of the front. The depth of this frontal zone depends on the properties of the two air masses. When the properties differ greatly, the resulting narrow frontal zone can include sudden and severe weather changes. It is often impossible to determine the exact outer boundaries of a frontal zone.

Most active weather is focused along and on either side of the surface front and frontal zone. Likewise, most aviation weather hazards are also found in the vicinity of fronts. In the mid latitudes, fronts usually form between the warmer, tropical air to the south and the cooler, polar air to the north.

When a pilot passes through a front, or a front moves past a station, the atmospheric conditions change from one air mass to those of the other. Abrupt changes indicate that the frontal zone is narrow, and in some cases, the zone can be less than a mile wide. On the other hand, gradual changes indicate the frontal zone is broad and diffuse, often over 200 miles in width. Abrupt changes will bring more severe weather than gradual changes.

Aviation weather hazards are not limited to the area of frontal zones. Some fronts do not produce clouds or precipitation. Additionally, weather associated with one section of a front is frequently different from the weather in other sections of the same front. Do not conclude that all adverse weather occurs along fronts. In some cases, very large areas of low ceilings and poor visibility occur in areas that are far removed from a front.

Air Masses and Fronts
Now that we have introduced the basics of both air masses and fronts, an analysis of a real-world situation can help show how these pieces fit together. Figure 3-3 shows the weather across the U.S. at the same time from three different points of view. From the frontal systems shown on the Current Surface chart, we can see that there are three major air masses over the nation: one over the West, one over the Midwest and the East, and one over the Deep South. For simplicity, we will compare only the two eastern air masses.

Looking at the Current Temperatures chart, the Midwest air mass (centered approximately on the "H" of the high pressure) has temperatures in the 50s, give or take a few degrees. So far, this shows a relatively uniform temperature across the air mass, matching with what we would expect from the discussion above. The southern air mass, on the other hand, has much warmer temperatures, generally in the 70s and 80s. Even so, these temperatures are still relatively uniform throughout the air mass.

The dew points are also different between the two air masses. Even though the Dew Point chart only indicates dew points above 50° F, it is clear that the southern air mass contains much more moisture than the air mass to its north. Thus, these charts indeed show two air masses over the eastern U.S., each with temperature and moisture properties different from the other. Accordingly, a front has been drawn between the two. From the "L" to just south of the "H," there is a warm front, and to the east of that position, all the way to the next "L" over New England, it is a cold front.

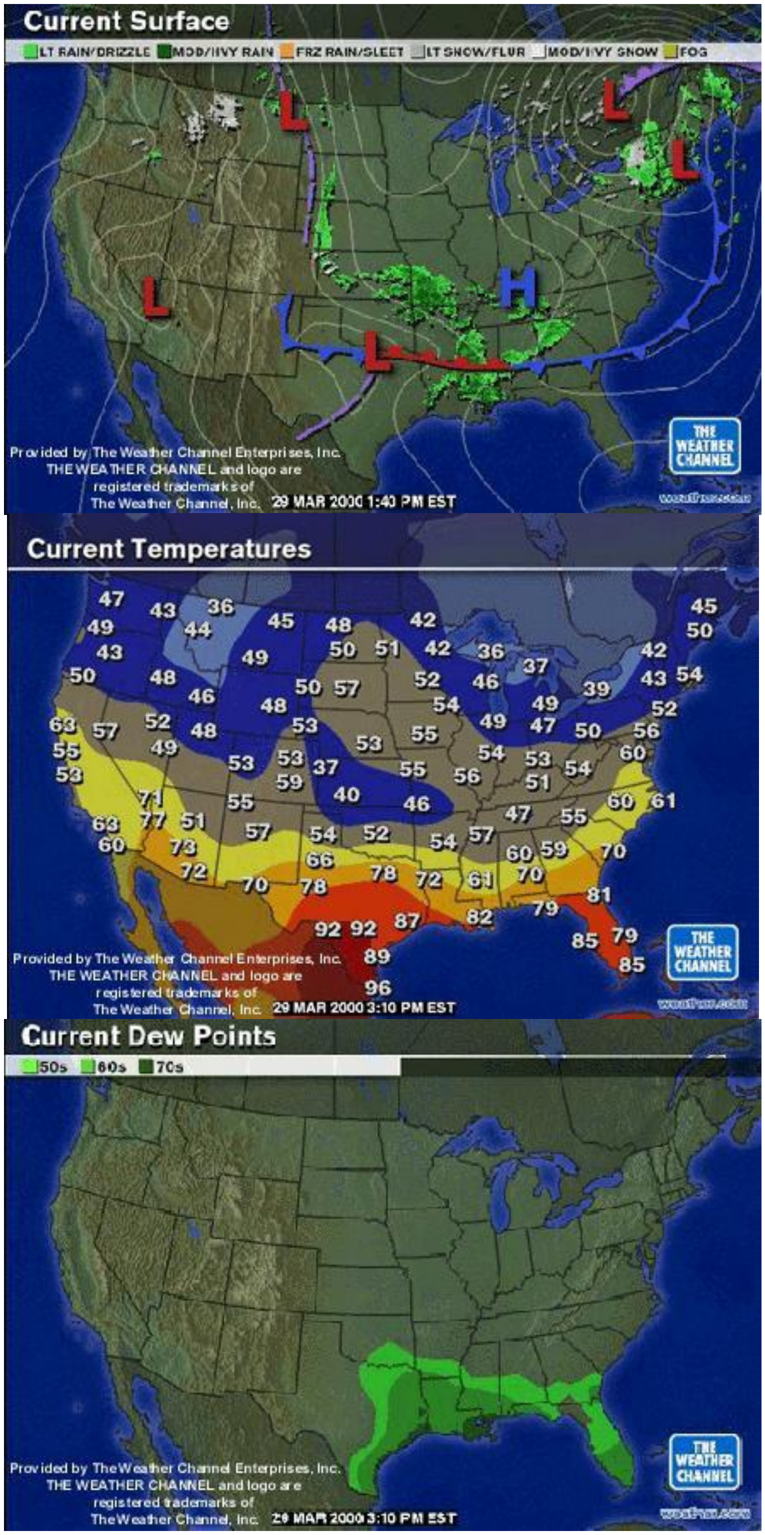


Figure 3-3 — Uniform Temperature and Moisture of Air Masses

General Frontal Structure

The characteristics of each air mass on either side of the front diminish with increasing altitude. At some level above the surface, usually above 15,000 to 20,000 feet, the differences between the two air masses forming the front become negligible, and the cloud and precipitation patterns in the upper frontal zone are not easily attributable to one frontal type or another (Figure 3-4). Therefore, the most significant frontal weather occurs in the lower layers of the atmosphere. However, the temperature contrast between the air masses can sometimes extend as high as the tropopause.

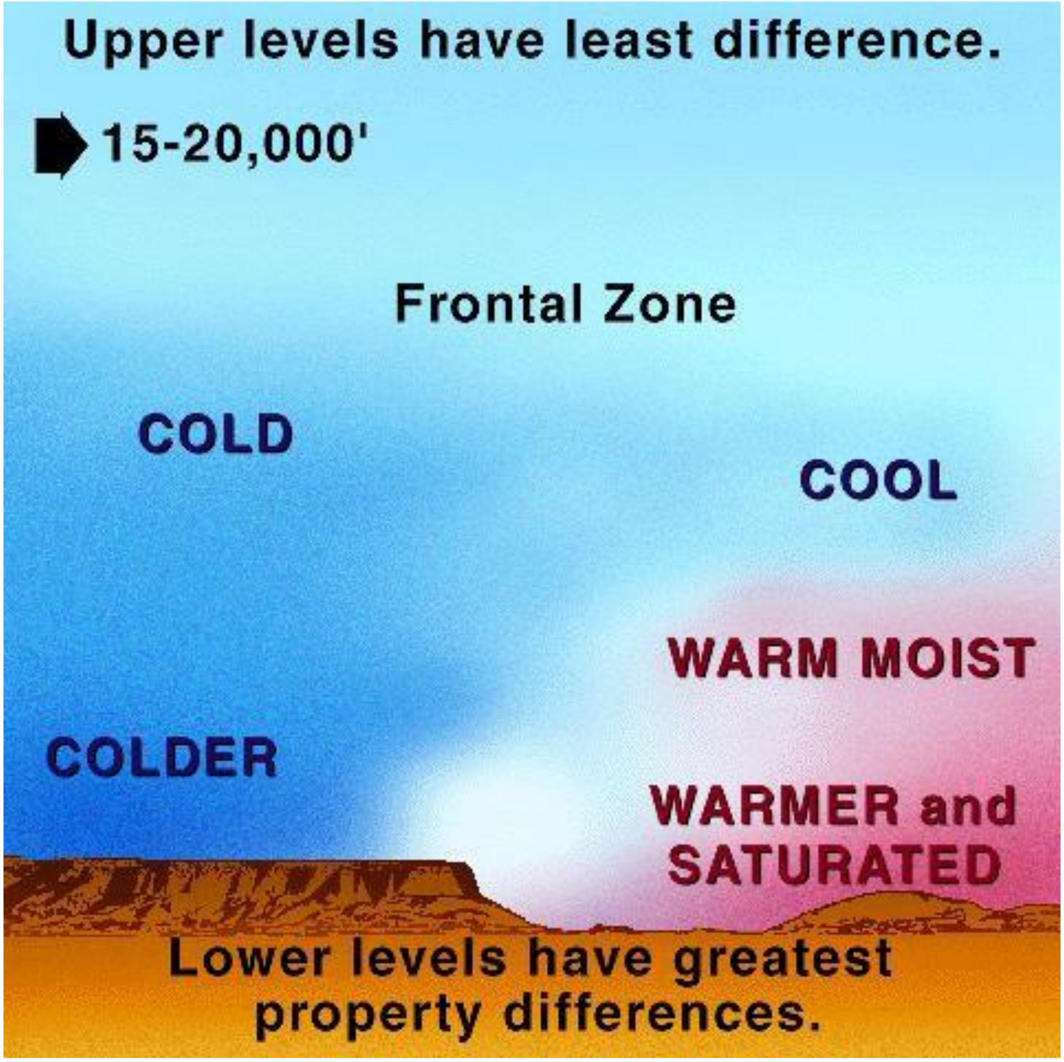


Figure 3-4 — Frontal Zone Structure

Most fronts, regardless of type, have some common characteristics. First, fronts are named according to the temperature change they bring. For example, if the temperature will become warmer after the front passes, it is named a warm front. Second, fronts move across the country with their attached low-pressure system and isobars, as the corresponding air masses move. As they move, we are only concerned with any movement perpendicular to the line representing the front; thus, fronts are considered to move perpendicular to the way they are drawn. Also, cold fronts move faster than warm fronts, in general. Next, we usually see a 90° wind shift from one side of the front to the other, with two exceptions that will be explained below. Finally, every front is located in a trough of low pressure.

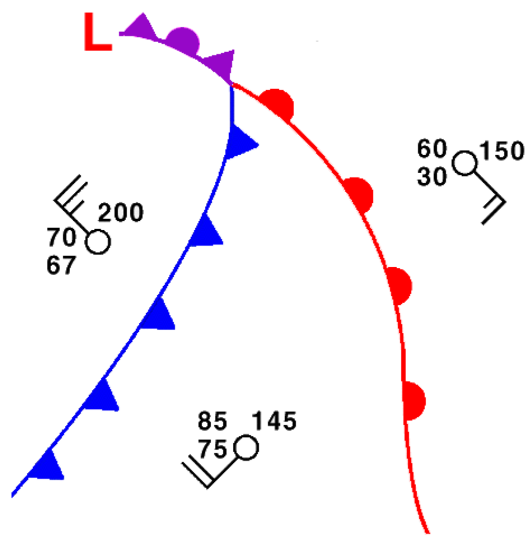


Figure 3-5 — General Model of a Frontal System

This course will use the general frontal model presented in Figure 3-5 to illustrate the different characteristics of the various fronts. Remembering the basics of this model can aid in the comprehension of how the various fronts usually move, as well as the characteristic changes in weather from one side of a front to the other. Once this model is understood, it can easily be modified to fit the appropriate real-world situation by rotating the system, by changing the angle between the fronts, or by considering a curvature to any of the frontal lines. As we discuss each frontal type, imagine zooming in on this model to study the particular characteristics of that front. These frontal characteristics will be discussed in depth for each type of front, and as a group in the next section, which explains how meteorologists determine where to place fronts on weather charts.

Frontal Discontinuities

Differences in the various properties of adjacent air masses–in particular, their temperature, moisture (indicated by the dew point), winds, and pressure–are used to locate and classify fronts. For example, when comparing two dissimilar air masses, one will be colder than the other. Because of this, the colder one will be denser and drier (it must have a lower dew point). Cloud types are also useful indicators of the type of front and will be discussed in connection with each individual front.

Temperatures

Temperature is one of the most easily recognizable differences across a front. In the lower layers of the atmosphere a greater temperature change will be noticed with frontal passage or when flying through a front. The amount and rate of change partially indicates the front's intensity. Strong and weak fronts are accompanied by abrupt and gradual changes in temperature, respectively.

Dew Points

The dew point temperatures reported from weather observing stations are helpful in locating the position of a front. The dew point temperature and the air temperature give an indication of the relative humidity of the air. Cold air masses will usually have lower dew point temperatures than warm air masses. Higher dew points indicate a greater amount of moisture available to produce clouds, fog, or precipitation.

Pressures

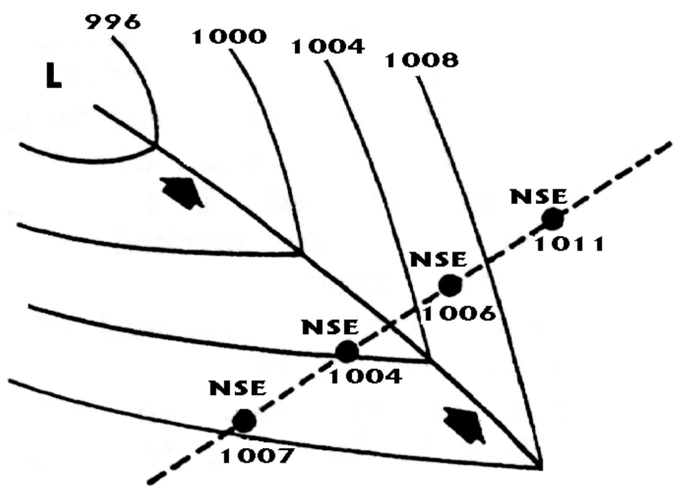


Figure 3-6 — Pressure Changes Across a Front

All fronts are located in troughs of low pressure. The arrows in Figure 3-6 indicate the trough (where low pressure extends outward from the center of the low), as well as the direction of movement of the low-pressure system. Therefore, when a front approaches a station, or a pilot flies toward a front, the pressure decreases. Pressure then rises immediately following frontal passage. Figure 3-5 illustrates this pressure fall and rise with the time-sequence of the weather at station NSE. The earliest time is pictured in the upper right, when the pressure is 1011 mb, and the last point in time is at the lower left, with a pressure of 1007 mb. Because of this pressure change, it is extremely important to obtain a new altimeter setting when flying in the vicinity of a front.

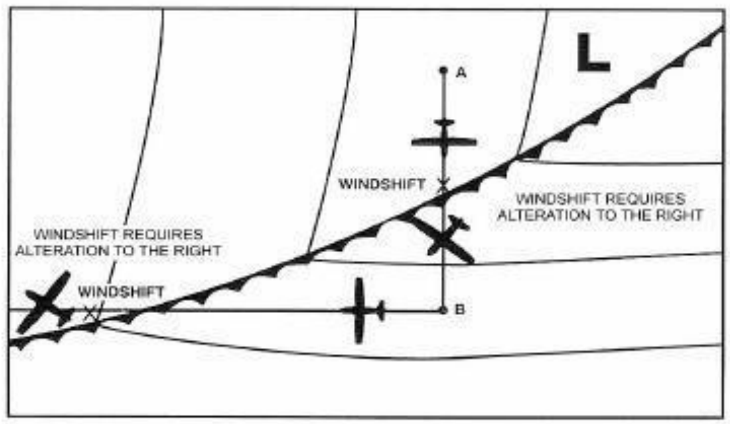


Figure 3-7 — Wind Shift Across a Cold Front

Winds

Near the Earth's surface, the wind changes direction across a front. In the Northern Hemisphere, as the front approaches and passes a station the wind changes direction in a clockwise rotation. When flying across a front, because of this wind shift you must adjust heading to the right to maintain your original ground track (Figure 3-7). This wind shift often creates a hazardous wind shear when departing or approaching an airfield. For example, winds at 220 degrees at 10 knots ahead of the front can rapidly change to 330 degrees at 20 knots gusting to 30 knots immediately after the front.

Factors Influencing Frontal Weather

The weather along fronts is not always severe. Flying conditions can vary from insignificant weather to situations that are extremely hazardous. The hazardous situations can include thunderstorms, turbulence, icing, low ceilings, and poor visibility. The severity of the clouds and precipitation occurring along a front are dependent on the following factors:

1. The amount of moisture available (shown by the dew point)
2. The degree of stability of the lifted air
3. The slope of the front
4. The speed of the frontal movement
5. The contrast in the amounts of temperature and moisture between the two air masses.

The amount of moisture available, as indicated by the dew point, greatly determines the amount of weather associated with a front. Often little or no significant weather is associated with a front or a portion of a front because of a lack of moisture, despite the presence of all other factors.

The degree of stability of the air that is lifted determines whether cloudiness will be predominantly stratiform or cumuliform. With stratiform clouds, there is usually steady precipitation and little or no turbulence. Precipitation from cumuliform clouds is showery and the clouds indicate turbulence.

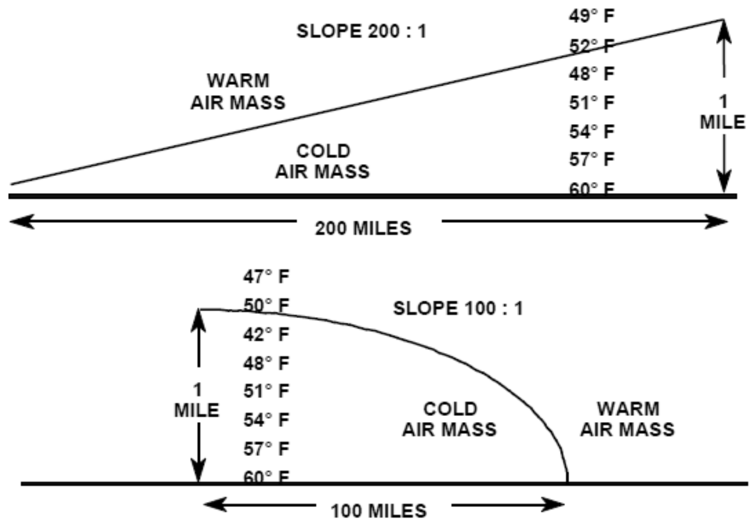


Figure 3-8 — Frontal Slope

The slope is the ratio of the vertical rise to horizontal distance. The slope of a warm front is generally shallow, while the slope of a cold front can be quite steep (Figure 3-8). Shallow frontal slopes tend to produce extensive cloudiness with large areas of steady precipitation, while steep frontal slopes tend to move rapidly producing narrow bands of cloudiness and showery precipitation. Steep frontal slopes normally separate air masses of vastly different properties, indicating the potential for more severe weather.

The speed of the frontal movement affects the weather associated with it. Faster moving fronts are generally accompanied by a narrow band of more severe weather. On the other hand, slower moving fronts have less severe weather, but the frontal zone is more extensive.

COLD FRONTS

The greater the contrast in temperature and moisture between the colliding air masses, the greater the possibility of weather associated with a front, particularly severe weather. For example, most tornadoes occur in the spring due to very cold, dry air from Canada colliding with very warm, moist air from the Gulf of Mexico.

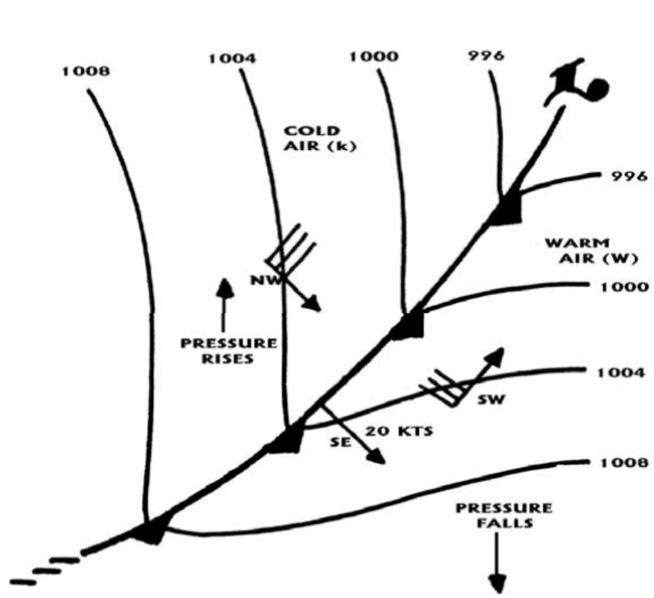


Figure 3-9 — Cold Front

A cold front is the leading edge of an advancing cold air mass. In this case, the colder (denser) air mass is overtaking and wedging underneath a relatively warmer (less dense) air mass. As the cold air pushes the warm air upward, this motion sometimes produces very violent and unstable conditions, to include strong thunderstorms (cumulonimbus clouds) and severe turbulence. Figure 3-9 shows the manner in which a cold front is depicted on a surface weather chart. Cold fronts move toward the SE at 20kts, on average, and the wind shift is from the SW to the NW.

Cold front weather can vary greatly depending on the speed of the front and the characteristics of the air masses. Usually, though, as the cold front approaches, the southwesterly winds in the warm air mass ahead of the front begin to increase in speed. Meanwhile, the barometric pressure decreases, and altocumulus clouds appear on the horizon. Next, the cloud bases lower, and rain or snow showers begin as the cumulonimbus clouds move into the area. The precipitation increases in intensity and may persist as the front nears the station. As the front passes, the pressure rises sharply and the wind shifts approximately 90° from SW to NW. The postfrontal weather includes rapidly clearing skies, fair weather cumulus clouds, and decreasing temperature and dew point. The extent of postfrontal cloudiness depends on the degree of stability and moisture content of the cold air mass. In some cases, the sequence of events described here may be considerably different, depending on the specific atmospheric conditions (Figure 3-10).

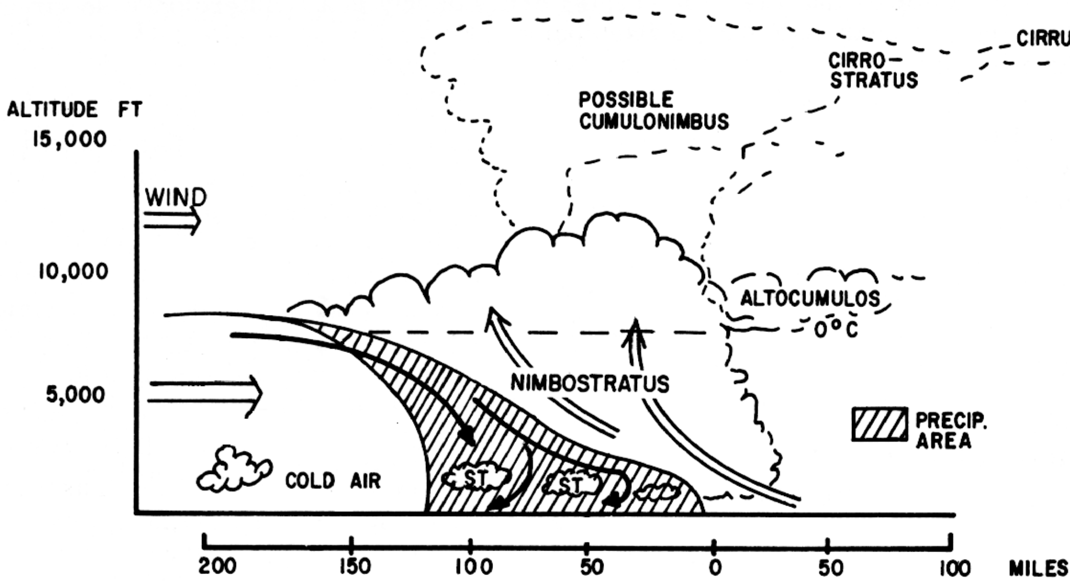


Figure 3-10 — Cold Front Cloud Formation

Weather with fast-moving cold fronts occurs in a narrow band, is usually severe, and clears rapidly behind the front. Cumuliform clouds, showers, or thunderstorms may form near the front position. Lines of fast-moving thunderstorms, or squall lines, can form well ahead of the front. Weather with slow-moving cold fronts (usually from late fall through early spring) occurs over a large area, is less severe, but may persist for hours, even after the front is past.

Recognizing Cold Fronts During Flights

During a flight over flat terrain, you may see a long line of cumuliform clouds on the horizon. These clouds may indicate you are flying toward an approaching active cold front. When flying above an altocumulus layer extending ahead of the front, the lower frontal clouds are often hidden. Stratus or stratocumulus decks extending many miles ahead of a front may conceal the main clouds from a low flying aircraft.

Cold Fronts Flight Problems

Wind shifts — Expect an abrupt wind shift when passing through a frontal zone, especially when flying at lower altitudes. Turbulence is often associated with the wind shift. The wind generally shifts from SW to NW with greater speeds behind the front.

Ceiling and visibility — If an active cold front moves at a moderate or rapid speed (15-30 knots), its weather zone is generally less than 50 miles wide. If the front moves slower, its weather zone may be broad enough to seriously affect flight operations for many hours. Ceilings and visibilities are generally visual meteorological conditions (VMC), but isolated instrument meteorological conditions (IMC) exist in heavy precipitation and near thunderstorms. Wider areas of IMC conditions can exist in winter due to snow showers.

Turbulence — Many active cold fronts have turbulent cloud systems associated with them, but thunderstorms may not always be present. Even when there are no clouds, turbulence may still be a problem. As a rule, expect a rough flight in the vicinity of an active cold front, even when flying at a considerable altitude.

Precipitation and icing conditions — Active cold fronts usually have a relatively narrow belt of precipitation, especially if the precipitation is showery. Icing may be severe in cumuliform clouds. Slow-moving cold fronts may have a broader area of precipitation and a greater threat of remaining in icing conditions for a longer period.

Thunderstorms and squall lines — Severe weather is implied to exist in areas of reported thunderstorms. Chapter 4 will detail the hazards associated with thunderstorms.

Squall Lines

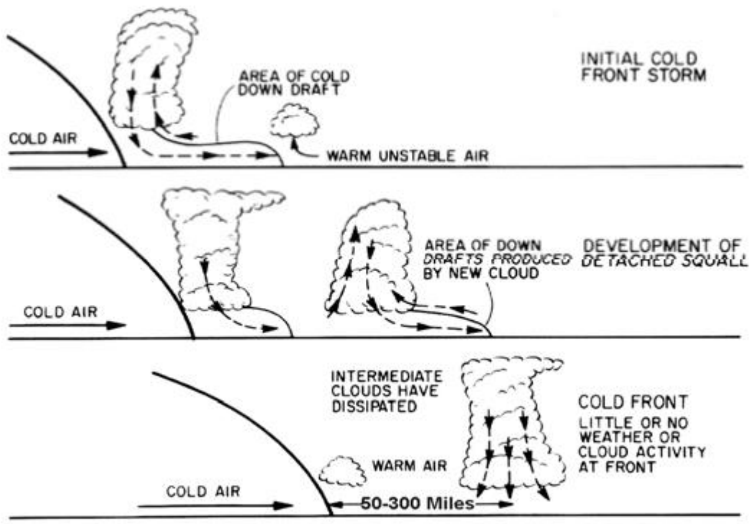


Figure 3-11 — Squall Line Formation

A squall line is a line of violent thunderstorms. They are indicated on surface charts by a dashed, double-dotted red line. They develop 50 to 300 miles ahead of the cold front and roughly parallel to it. They form when cold air downdrafts flowing ahead of a cold front lift additional warm, unstable air. The uplifted air develops its own updrafts and downdrafts and starts the thunderstorm development cycle (Figure 3-11). Sometimes, however, squall lines can be located nowhere near a cold front, possibly from the convergence of air flows at one location. Squall lines are usually the most intense during the late afternoon and early evening hours, just after maximum daytime heating.

It is often impossible to fly through squall lines, even with radar, since the storms are extremely close to one another. Similar to cold fronts, Squall lines will also have a 90° wind shift from the SW to the NW.

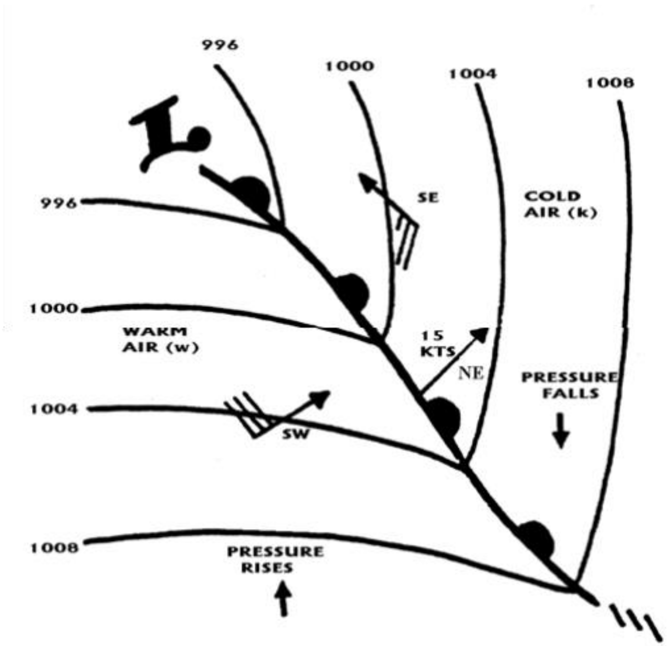


Figure 3-12 — Warm Front

WARM FRONTS
A warm front is the boundary of the advancing warm air mass that is overtaking and replacing a colder air mass. To do so, the warmer, less dense air must ride up and over the top of the cold air mass. Figure 3-12 shows the manner in which a warm front is depicted on a surface weather chart. The warm air mass gradually moves up over the frontal surface creating a broad area of cloudiness. This cloud system extends from the front's surface position to about 500 to 700 miles in advance of it (Figure 3-13).

A warm front typically moves at a slower speed than a cold front–15 knots on average–and produces a more gradual frontal slope, as well as sloping forward, ahead of the surface front. Because of this slower speed and gradual slope, warm fronts are not as well defined as cold fronts. The winds shift across a warm front from the SE to the SW.

Recognizing Warm Fronts During Flight
The most common cloud found along a warm front is the stratiform cloud. If one were to approach the front from the east, the sequence of clouds would be cirrus, cirrostratus, altostratus, nimbostratus, and stratus, rain and fog (Figure 3-13). Steady precipitation gradually increases with the approach of this type of warm front and usually continues until the front passes.

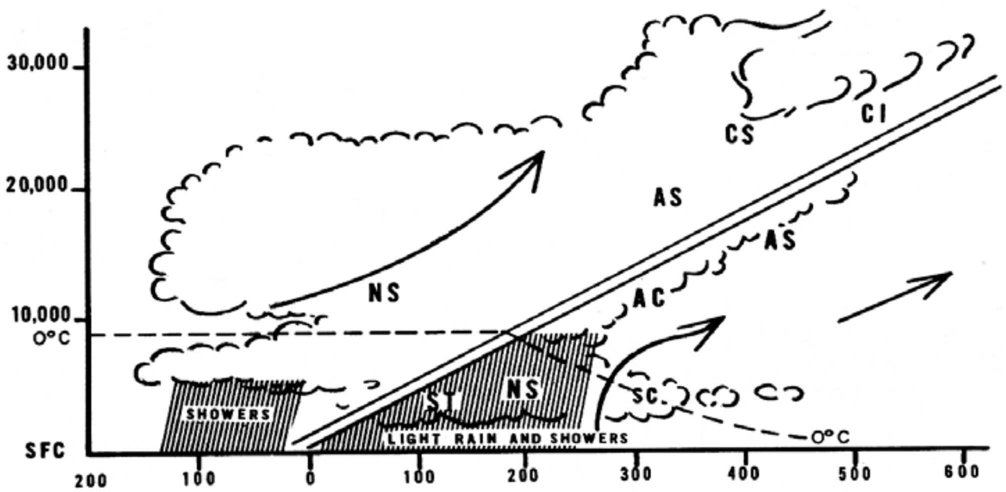


Figure 3-13 — Warm Front Cloud Formation

Warm Front Flight Problems

Wind Shift — Warm front wind shifts are not as sudden as those of a cold front, and therefore, turbulence isn't likely. The wind generally shifts from SE to SW.

Ceiling and Visibility — The widespread precipitation ahead of a warm front is often accompanied by low stratus and fog. In this case, the precipitation raises the moisture content of the cold air until saturation is reached. This produces low ceilings and poor visibility covering thousands of square miles. Ceilings are often in the 300 to 900-foot range during steady, warm frontal rain situations. Just before the warm front passes the station, ceilings and visibilities can drop to zero with drizzle and fog. The worst conditions often occur in the winter when the ground is cold and the air is warm; the best scenario for dense fog and low ceilings.

Turbulence and Thunderstorms — If the advancing warm air is moist an unstable, altocumulus and cumulonimbus clouds can be embedded in the cloud masses normally accompanying the warm front. These embedded thunderstorms are quite dangerous, because their presence is often unknown to aircrews until encountered. Even with airborne radar, it can be difficult to distinguish between the widespread areas of precipitation normally found with a warm front and the severe showers from the embedded thunderstorms. The only turbulence along a warm front would be found in such embedded thunderstorms. Otherwise, little to no turbulence exists in warm front systems.

Precipitation and Icing — Approaching an active warm front from the cold air side (from the east), precipitation will begin where the middle cloud deck is from 8000 to 12,000 feet AGL. Often, this precipitation will not reach the ground–a phenomenon called virga. As you near the front, precipitation gradually increases in intensity and becomes steadier. Occasional heavy showers in the cold air beneath the frontal surface indicate that thunderstorms exist in the warm air aloft. Drizzle, freezing drizzle, rain, freezing rain, ice pellets (sleet), and snow are all possible in a warm front, depending on the temperature. The shallow slope and widespread thick stratiform clouds lead to large areas of icing. It may take a long time to climb out of the icing area, and you may need to descend into warmer air to avoid the icing.

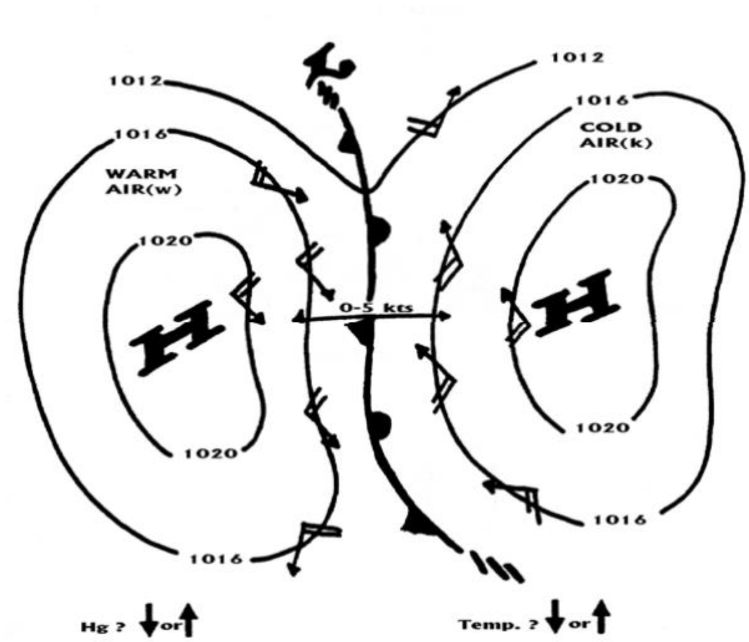


Figure 3-14 — Stationary Front

Stationary Fronts
Sometimes the frontal border between the air masses shows little or no movement. Since neither air mass is replacing the other, the front is called a stationary front (Figure 3-14). Stationary fronts are indicated on surface charts by an alternating warm and cold front symbols, retaining their original red and blue colors, but pointing in opposite directions. Even though the front may not be moving, winds can still be blowing. Surface winds tend to blow parallel on both sides of the front rather than against and or away from it. Therefore, a stationary front has a 180° wind shift. The wind shift may be from any one direction to the opposite direction, as stationary fronts are less likely to be aligned in any one particular direction.

The weather conditions occurring with a stationary front are similar to those found with the warm front, but are usually less intense. The weather pattern of a stationary front may persist in one area for several days, until other, stronger weather systems are able to push the stationary front weather along its way.

OCCLUDED FRONTS
Occluded fronts form when a faster moving cold front overtakes a slower moving warm front. There are two types of occluded fronts, cold and warm. The type of occlusion that forms depends on which front remains in contact with the ground. For example, if the cold front remains in contact with the ground, then it is named a cold front occlusion.

Occlusions are shown on surface charts with both cold and warm frontal symbols pointing in the same direction, but colored purple. Both types of occlusions tend to be aligned from NW to SE, and hence move toward the NE at the speed of the front that remains on the ground. The wind shift across either type of occlusion will be a 180° shift, as there are actually two fronts in the same location. Therefore, ahead of the occlusion, the winds will be the same as those ahead of the warm front, and behind the occlusion, the wind will be from the same direction as behind the cold front: the wind shift is SE to NW. Because the occluded front is the result of the meeting of both a cold front and a warm front, the weather associated with the occlusion will be a combination of both types of frontal weather.

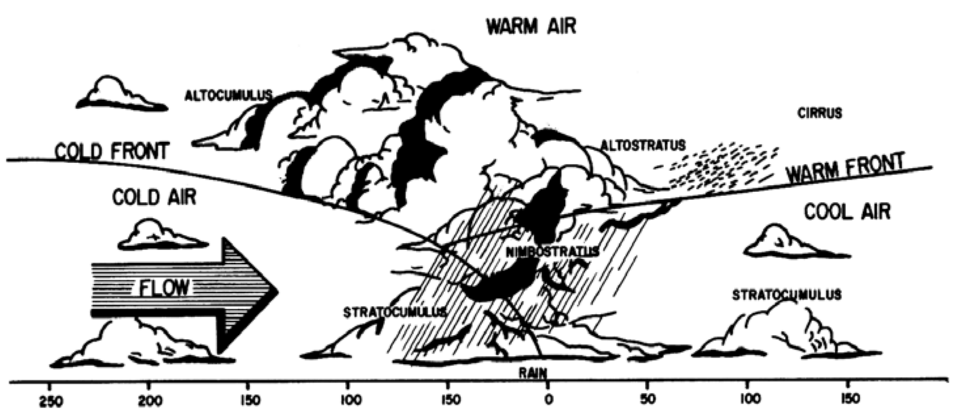


Figure 3-15 — Occluded Front

Figure 3-15 depicts a profile of an occluded front. If either type of occlusion is approached from the east, you would first encounter warm front type weather which may extend for several hundred miles to the east of the surface front. On the other hand, if it were approached from the west you would first encounter cold front type weather. The location of the occluded front is significant to aircrews because the most severe weather, including ceilings and visibilities, is generally located in an area 100 NM south to 300 NM north of the frontal intersection. Figure 3-16 illustrates the stages of development of an occlusion.

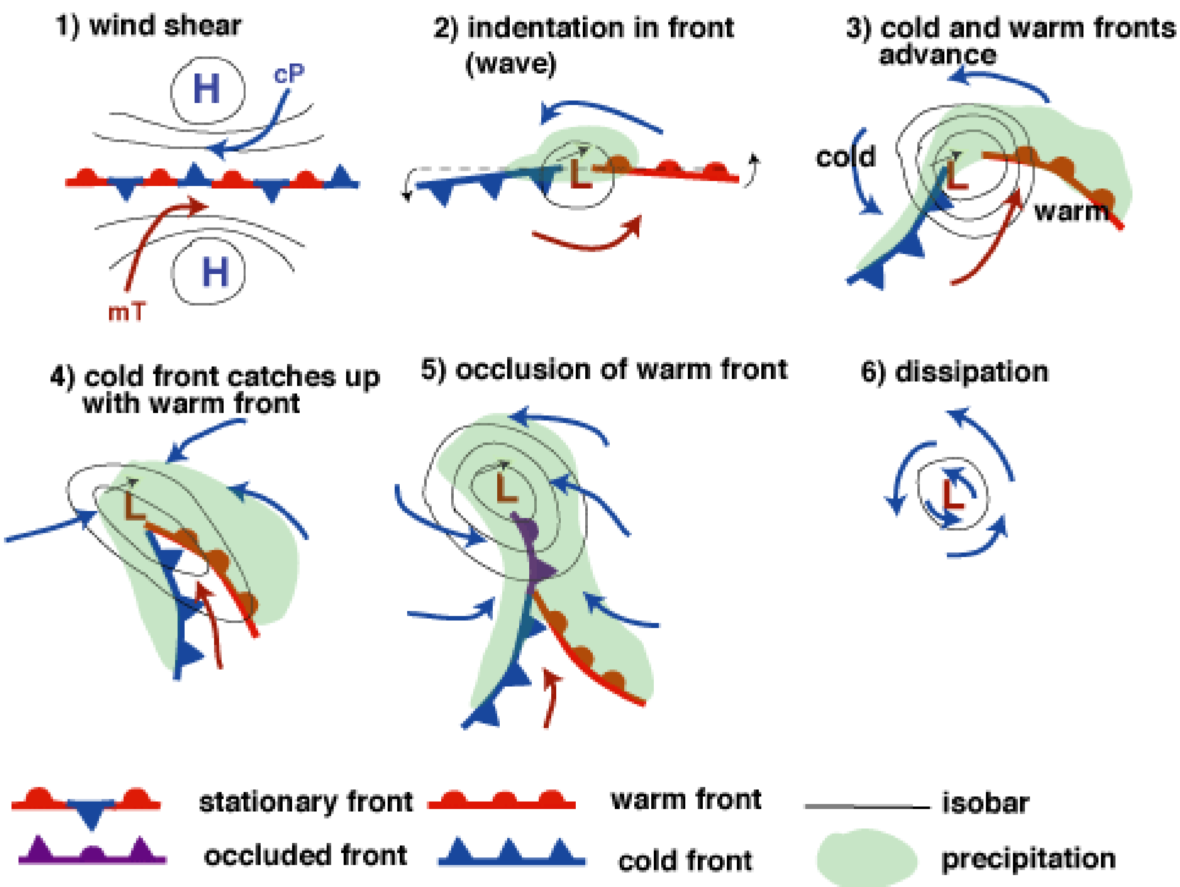


Figure 3-16 — Occluded Wave Formation

Inactive Fronts
Clouds and precipitation do not accompany inactive fronts. Sometimes the warm air mass is too dry for clouds to form even after the air is lifted and cooled. Inactive fronts may also be referred to as dry fronts.

The reason for showing an inactive front on the weather chart is to indicate the boundary of the opposing air masses. Additionally, it displays the location of potentially unfavorable flying weather. The warm air mass may gradually become moister and lead to the formation of clouds and precipitation in the frontal zone. In many cases the inactive front only has a shift in the wind direction and a change in the temperature and pressure.

ASSIGNMENT SHEET 3-3-3

FRONTAL MECHANICS REVIEW

A. INTRODUCTION

The purpose of this lesson is to provide the student with a general discussion of frontal systems, including their formation, flight conditions and associated weather patterns.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

1. Review JPATS Aviation Weather Booklet, JX100 Chapter JX103.
2. Read JPATS Aviation Weather Booklet, JX100 Chapter JX104.

D. STUDY QUESTIONS

1. Which one of the following parameters of an air mass are generally uniform when measured across any horizontal direction?
   a. Pressure and stability
   b. Pressure and moisture
   c. Temperature and pressure
   d. Temperature and moisture

2. Which one of the following correctly indicates the four air mass properties used to locate and classify fronts?
   a. Pressure, wind, stability, and slope
   b. Pressure, temperature, dew point, and wind
   c. Pressure, temperature, dew point and slope
   d. Pressure, wind, dew point, and stability

3. Which one of the following lists two of the five factors that influence frontal weather?
   a. Slope and stability
   b. Slope and pressure change
   c. Stability and winds
   d. Stability and pressure change

4. With frontal passage, the winds of a cold front will shift from the ______to the ______, and the winds of a warm front will shift from the ______ to the ______.
   a. southeast to the northwest, southeast to the northwest
   b. southeast to the southwest, southwest to the northwest
   c. southwest to the northwest, southeast to the southwest
   d. northwest to the southwest, southwest to the southeast

5. In one respect, embedded warm-front thunderstorms present a greater flying hazard than cold-front thunderstorms because the warm-front cumulonimbus clouds ______.
   a. may be hidden in stratus type clouds.
   b. generally contain a great amount of cloud-to-ground lightning.
   c. have lower bases and lie closer to the earth’s surface.
   d. are much more violent and turbulent.

6. Which one of the following would indicate that a cold front has passed?
   a. Wind shifts
   b. Pressure falls
   c. Humidity increases
   d. Temperature rises

7. If you are flying from east to west and you encounter cirrus, cirrostratus, alto-stratus, nimbostratus and then stratus clouds, you are most likely approaching a ______.
   a. stationary front c. Either a or b
   b. warm front d. Neither a nor b

In each cell of the table, circle the correct characteristics of each of the types of fronts. This is similar to a multiple-choice question, where the question is formed by matching a column heading with a row heading, and the alternatives are listed in the intersecting cell.

Type of Front	Wind Shift	Temper-ature Change	Pressure Change	Direction of Movement	Speed of Movement (kts)	Cloud Types	Turbulence Conditions	Color Code
Warm Front	SE to SW SW to NW SE to NW 180°	Warmer Colder Either	Rises then Falls Falls then Rises	SE NE NW None	0 to 5 15 20 25	Stratiform Cumuliform Combination	Smooth Rough Combination	Red Blue Purple R & B
Cold Front	SE to SW SW to NW SE to NW 180°	Warmer Colder Either	Rises then Falls Falls then rises	SE NE NW None	0 to 5 15 20 25	Stratiform Cumuliform Combination	Smooth Rough Combination	Red Blue Purple R & B
Warm Front Occlusion	SE to SW SW to NW SE to NW 180°	Warmer Colder Either	Rises then Falls Falls then rises	SE NE NW None	0 to 5 15 20 25	Stratiform Cumuliform Combination	Smooth Rough Combination	Red Blue Purple R & B
Cold Front Occlusion	SE to SW SW to NW SE to NW 180°	Warmer Colder Either	Rises then Falls Falls then rises	SE NE NW None	0 to 5 15 20 25	Stratiform Cumuliform Combination	Smooth Rough Combination	Red Blue Purple R & B
Stationary Front	SE to SW SW to NW SE to NW 180°	Warmer Colder Either	Rises then Falls Falls then rises	SE NE NW None	0 to 5 15 20 25	Stratiform Cumuliform Combination	Smooth Rough Combination	Red Blue Purple R & B

Answers:

1. D	5. A
2. B	6. A
3. A	7. C
4. C	

8.

Type of Front	Wind Shift	Temperature Change	Pressure Change	Direction of Movement	Speed of Movement (kts)	Cloud Types	Turbulence Conditions	Color Code
Warm Front	SE to SW	Warmer	Falls then rises	NE	15	Stratiform	Smooth	Red
Cold Front	SW to NW	Colder	Falls then rises	SE	20	Cumuliform	Rough	Blue
Warm Front Occlusion	SE to NW	Warmer	Falls then rises	NE	15	Combination	Combination	Purple
Cold Front Occlusion	SE to NW	Colder	Falls then rises	NE	20	Combination	Combination	Purple
Stationary Front	180°	Either	Falls then rises	None	0 to 5	Stratiform	Smooth	R & B

Air Masses

Air Masses

An air mass is a large body of air that has essentially uniform temperature and moisture conditions in a horizontal plane.

Air Mass Naming

Named according to:

Location

Tropical

Arctic

Polar

Equatorial

Moisture content

Maritime

Continental

Temperature

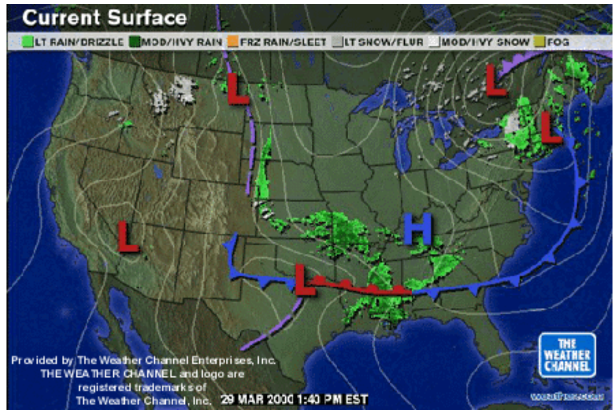
Warm

Cold

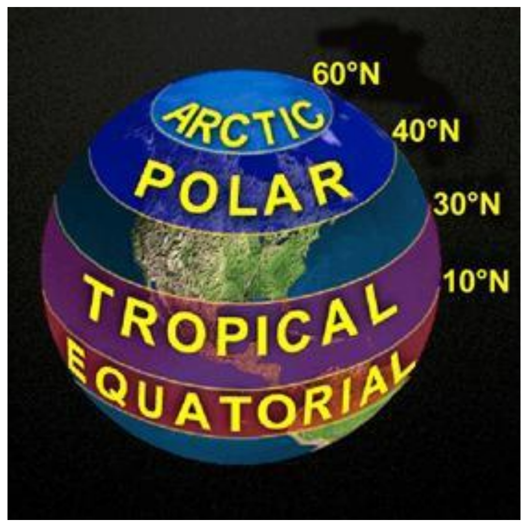
Temperature indicates stability

Warm equals stable

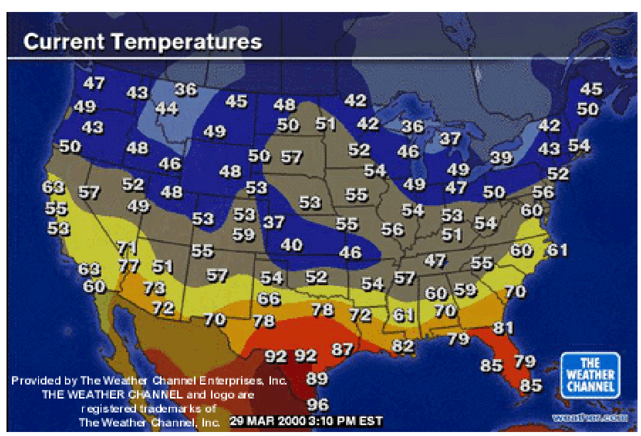
Cold equals unstable



Air Masses



Location



Current Temperatures

Fronts

A front is a boundary between two contrasting air masses.

Named according to the temperature change.

Winds usually shift 90°.

Parallel ahead and perpendicular behind

Fronts are located in troughs of low pressure.

Pressure falls then rises as front passes.

Fronts move perpendicular to their depicted line.

Cold fronts move faster than warm fronts.

Greatest contrast between air masses exists at the surface.

Frontal Discontinuities

Discontinuities between air masses used to locate and classify fronts:

Temperature

Front is named after temperature change.

Dew point

Used to determine air mass boundary.

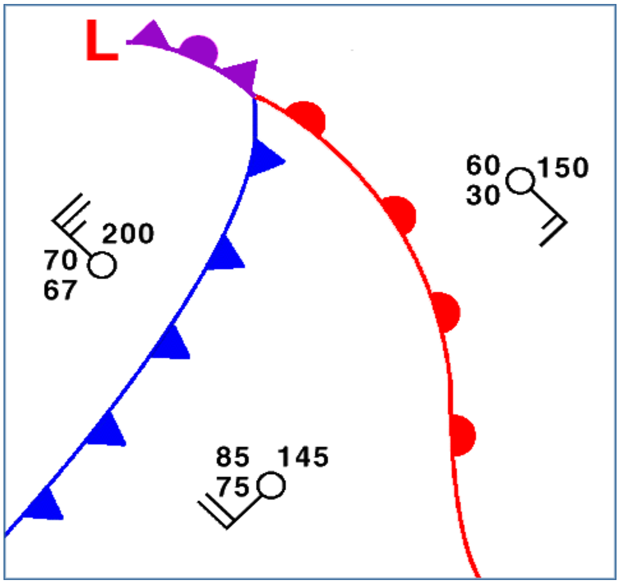
Larger contrast produces more severe weather.

Pressure

Falls ahead and rises after frontal passage.

Wind

90° clockwise shift after frontal passage.



Factors Influencing Frontal Weather

The amount of moisture available.

The degree of stability of the lifted air.

The slope of the front.

The speed of frontal movement.

The contrast in the amounts of temperature and moisture between the two air masses.

Cold Fronts

Cold Fronts

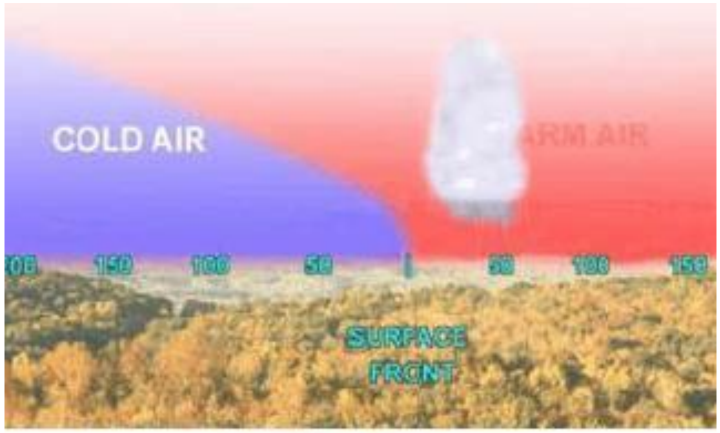
Overtaking cold air is denser than warm air.

Frontal lifting creates unstable conditions.

Cooler temperatures and clearing skies after frontal passage.

Narrow frontal zone

Normally moves southeasterly at 20 kts.



Cold Front

Squall Lines

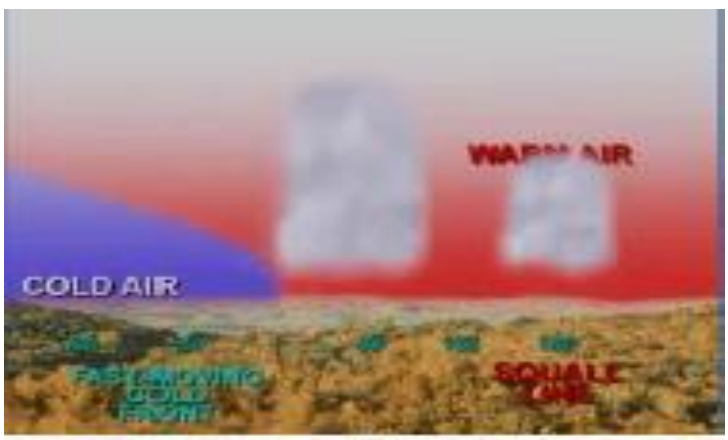
Line of severe thunderstorms.

Exact cause is unknown.

Forms 50-300 miles ahead of cold front.

Sometimes forms without a cold front.

Contains severe hazards to aviation.



Squall Line

Warm Fronts

Warm Fronts

Warm air advances over dense cold air.

Extensive forward slope

Weather occurs ahead of surface front.

Steady precipitation and reduced visibility ahead of frontal passage.

Winds shift from southeasterly to southwesterly with frontal passage.

Warm Front

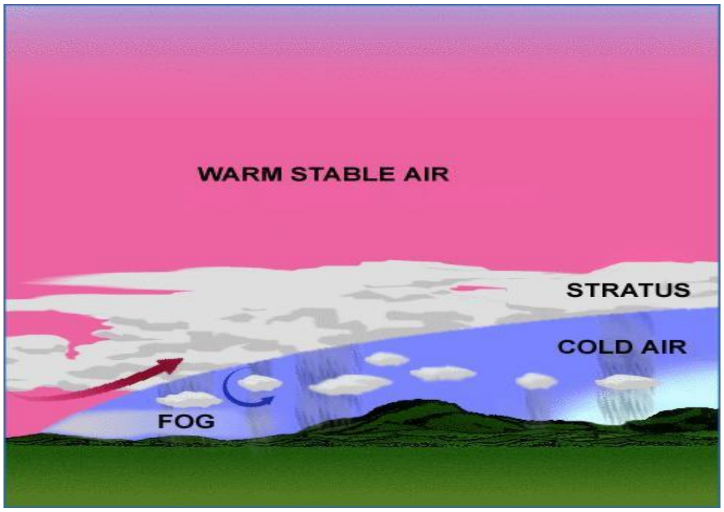
Stationary Fronts

Alternating cold and warm front symbols

Weather similar to warm front

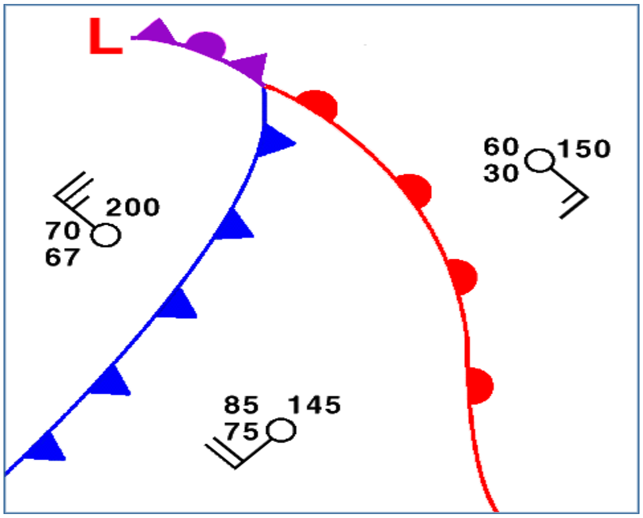
Align in any direction.

180 degree wind shift across the frontal boundary.



Occluded Fronts

Occluded Front



Formed when cold front overtakes a warm front.

Warm front occlusion - warm front touches

ground.

Cold front occlusion - cold front touches ground

Purple warm and cold front symbols

Pressure falls then rises

Wind shifts from southeasterly to northwesterly with frontal passage

Occluded Front

Occluded Front on Ground

Inactive Fronts

Also known as dry fronts.

No clouds or precipitation.

Wind shift and temperature change still occurs.

Marks area of potentially unfavorable flying conditions.

OUTLINE SHEET 3-4-1

WEATHER HAZARDS

A. INTRODUCTION

The purpose of this lesson is to provide the student with a background knowledge of aviation weather to include the hazards associated with turbulence, icing, ceiling and visibility, fog, and ash clouds.

B. ENABLING OBJECTIVES

2.246 LIST the classifications of turbulence used in Pilot Reports (PIREPs), in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.247 LIST the intensities of turbulence used in Pilot Reports (PIREPs), in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.248 DEFINE the terms used to report turbulence with respect to time, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.249 DESCRIBE how thermal turbulence develops, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.250 DESCRIBE how mechanical turbulence develops, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.251 DESCRIBE the cloud formations associated with mountain wave turbulence, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.252 DESCRIBE techniques for flight in the vicinity of mountain waves, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.253 DESCRIBE how frontal lifting creates turbulence, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.254 DESCRIBE how temperature inversions are examples of wind shear turbulence, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.255 DESCRIBE how jet streams are examples of wind shear turbulence, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.256 DESCRIBE the recommended procedures for flying through turbulence, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.257 DESCRIBE structural icing, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.258 STATE the requirements for the formation of structural icing, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.259 STATE the temperature range most conducive to structural icing, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.260 DESCRIBE icing conditions associated with fronts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.261 IDENTIFY the hazards of aircraft icing, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.262 DESCRIBE the types of engine icing, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

5.1 DESCRIBE ground icing hazards, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.263 IDENTIFY the procedures to minimize or avoid the effects of icing, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.264 LIST the intensities of icing used in Pilot Reports (PIREPs), in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.265 LIST the types of icing used in Pilot Reports (PIREPs), in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.266 DEFINE the types of visibility, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.267 DEFINE obscuring phenomena, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.268 DESCRIBE the sky coverage terms that define a ceiling, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.269 DESCRIBE the parameters that define fog, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.270 STATE the requirements for fog formation, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.271 DESCRIBE the two main types of fog, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.272 DESCRIBE the aviation hazards of ash clouds, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. Intensity of Turbulence
2. Classifications of Turbulence
3. Wind Shear
4. Aircraft Icing
5. Engine Icing
6. Avoiding Icing
7. Minimizing Icing
8. Visibility
9. Sky Coverage and Ceilings
10. Fog
11. Volcanic Ash Clouds

INFORMATION SHEET 3-4-2

WEATHER HAZARDS

A. INTRODUCTION

The purpose of this lesson is to provide the student with a background knowledge of aviation weather to include the hazards associated with turbulence, icing, ceiling and visibility, fog, and ash clouds.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. JPATS Aviation Weather Booklet, JX100
3. DoD Flight Information Publication (FLIP) General Planning, GP-1 Flight Information Handbook (FIH)

C. INFORMATION

OVERVIEW
This chapter will cover the causes of turbulence, classification of the various categories of turbulence, conditions under which turbulence exists, and will recommend flying procedures to be used when turbulence is encountered. This chapter will also cover the requirements for icing formation, types of icing, and their effects on aircraft flight and aircraft components, including techniques that should be following for safe flight. Finally, this chapter will introduce the student to ceilings and visibility, sky coverage terminology, and the requirements for fog formation and dissipation, plus a synopsis of the aviation hazards of volcanic ash clouds.

Turbulence is one of the most unexpected aviation hazards to fly through and is also one of the most difficult hazards to forecast. Severe and extreme turbulence has been known to cause extensive structural damage to military aircraft, with lesser intensities resulting in compressor stalls, flameouts, and injury to crewmembers and passengers. From minor bumps to severe mountain wave turbulence, turbulence comes in many forms and is usually worst during the winter months. It is estimated that turbulence causes $30 million in damage annually to aviation assets.

Aircraft icing is another aviation weather hazard. Many aircraft accidents and incidents have been attributed to aircraft icing. In fact, many icing-related mishaps have occurred when the aircraft was not deiced before attempting takeoff. Most of the time, ground deicing and anti-icing procedures will adequately handle icing formation. However, there are times when pilots may be caught unaware of dangerous ice buildup.

Historically, low ceilings and poor visibilities have contributed to many aircraft accidents. Fog, heavy snow, heavy rain, blowing sand, and blowing dust all restrict visibility and can also result in low ceilings. Adverse weather conditions causing widespread low ceilings and visibilities can restrict flying operations for days. Since ceiling and visibility is so important to operational flying, it is imperative that a pilot understands the strict meanings of the two terms. There are many different kinds of “visibility,” but pilots are usually more concerned with “prevailing visibility.”

Ash clouds from volcanic eruptions present a unique hazard to aviation. Though most prudent aviators would choose to keep well clear of any active volcano, certain situations such as evacuations may require the military to operate in close proximity to ash clouds. The corresponding causes of aircraft damage are discussed in the last portion of the chapter.

TURBULENCE DEFINED AND CLASSIFIED

Turbulence is any irregular or disturbed flow in the atmosphere producing gusts and or eddies. Occurrences of turbulence are local in extent and transient in character. Although general forecasts of turbulence are quite good, forecasting precise locations is difficult.
Turbulence intensity is classified using a subjective scale. Table 4-1 contains the four intensity levels and the three time descriptors used by aircrew when giving a Pilot Report (PIREP), which details the in-flight weather. You can see how individual crewmembers of the same aircraft might not agree on the degree of turbulence that they encountered. Realize that moderate turbulence for a B-52 could be severe or extreme for a T-6.

Intensity	Aircraft Reaction	Reaction Inside Aircraft
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as Light Turbulence; [1] or Turbulence that causes slight, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as Light Chop.	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate	Turbulence that is similar to Light Turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as Moderate Turbulence; [1] or Turbulence that is similar to Light Chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Report as Moderate Chop.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as Severe Turbulence; [1]	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.
Extreme	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as Extreme Turbulence.	
[1]High level turbulence (normally above 15,000 feet MSL) not associated with cumuliform cloudiness, including thunderstorms, should be reported as CAT (clear air turbulence) preceded by the appropriate intensity, or light or moderate chop. NOTE: Reporting Term — Definition **Occasional** — Less than 1/3 of the time **Intermittent** — 1/3 to 2/3 of the time **Continuous** — More than 2/3 of the time		

Table 4-1 — PIREP Turbulence Reporting Table

The different types of turbulence can be divided according to their causative factors: thermal, mechanical, frontal, and large-scale wind shear.

Two or more of these causative factors often work together. Any of the four types of turbulence may occur without the visual warning associated with clouds. Turbulence in the absence of or outside of clouds is referred to as clear-air turbulence (CAT).

Clear Air Turbulence
CAT normally occurs outside of clouds and usually occurs at altitudes above 15,000 feet MSL, due to strong wind shears in the jet stream. CAT is not limited to jet streams–in fact CAT can be found in each of the four categories of turbulence–but the most severe CAT is associated with jet streams. You may also notice that the Wind Shear category of turbulence is only CAT.

Thermal Turbulence
Thermal (or convective) turbulence is caused by localized vertical convective currents resulting from surface heating or cold air moving over warmer ground. Strong solar heating of the Earth's surface can result in localized vertical air movements, both ascending and descending. For every rising current, there is a compensating downward current that is usually slower in speed since it covers a broader area. Such vertical air movements can also result from cooler air being heated through contact with a warm surface. The turbulence that forms as a result of heating from below is called thermal, or convective, turbulence.

The strength of convective currents depends in part on the extent to which the earth's surface has been heated, which in turn, depends upon the nature of the surface (Figure 4-1). Notice in the illustration that dry, barren surfaces such as sandy or rocky wasteland and plowed fields absorb heat more readily than surfaces covered with grass or other vegetation, which tend to contain more moisture. Thus, barren surfaces generally cause stronger convective currents. In comparison, water surfaces are heated more slowly. The difference in surface heating between land and water masses is responsible for the turbulence experienced by aircrews when crossing shorelines on hot summer days.

When air is very dry, convective currents may be present even though convective-type clouds (cumulus) are absent. The upper limits of the convective currents are often marked by haze lines or by the tops of cumulus clouds that form when the air is moist. Varying surfaces often affect the amount of turbulence experienced in the landing pattern and on final approach.

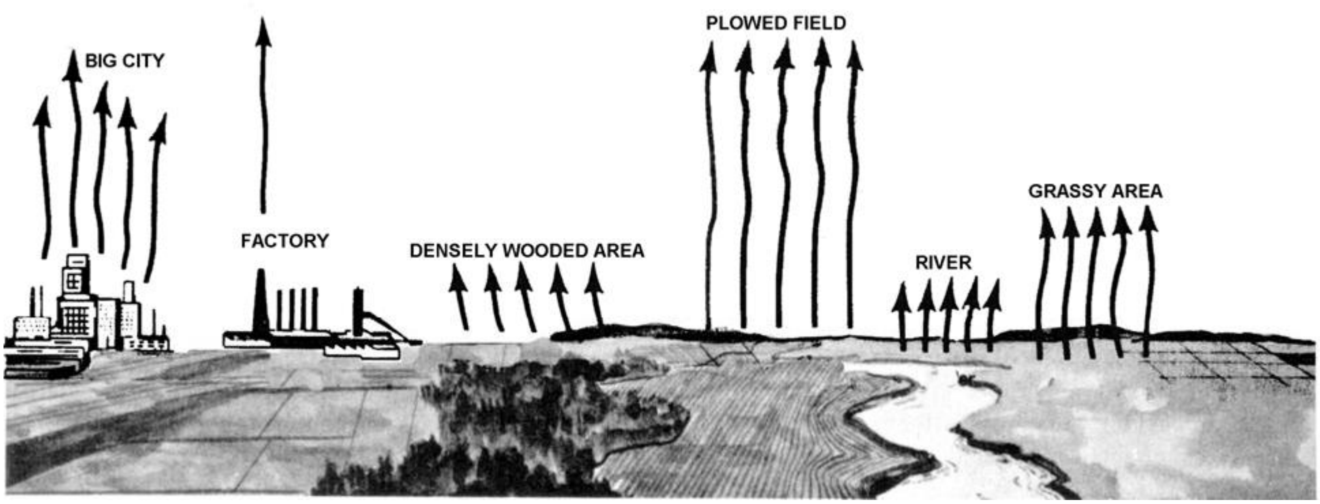


Figure 4-1 — Strength of Convective Currents Vary With Composition of Surface

Mechanical Turbulence

Mechanical turbulence results from wind flowing over or around irregular terrain or other obstructions. When the air near the surface of the Earth flows over obstructions, such as bluffs, hills, mountains, or buildings, the normal horizontal wind flow is disturbed and transformed into a complicated pattern of eddies and other irregular air movements (Figure 4-2). An eddy current is a current of air (or water) moving contrary to the main current, forming swirls or whirlpools. One example of mechanical turbulence may result from the buildings or other obstructions near an airfield.

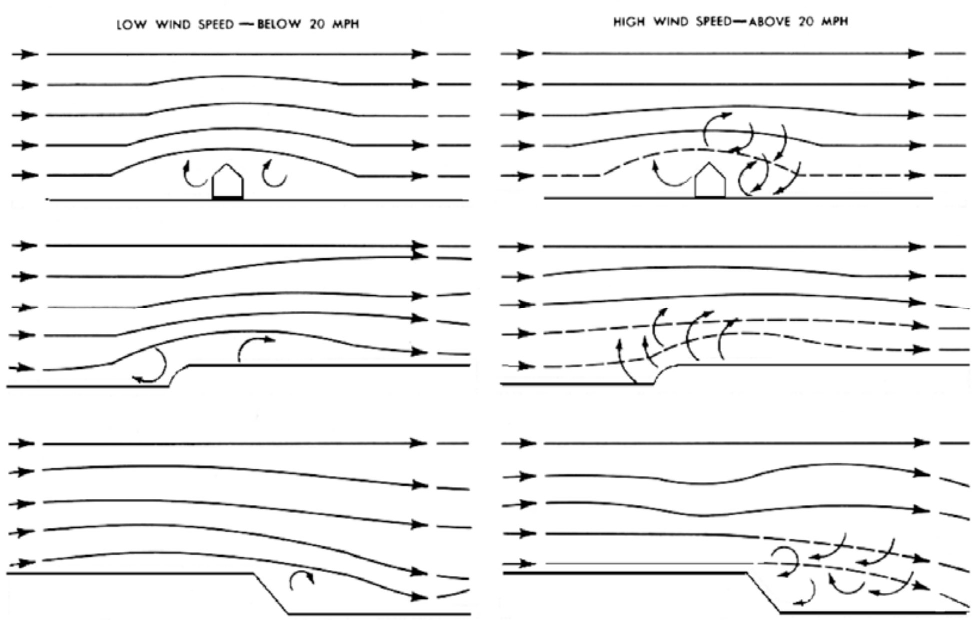


Figure 4-2 — Airflow Over Irregular Terrain

The strength and magnitude of mechanical turbulence depends on the speed of the wind, the roughness of the terrain (or nature of the obstruction), and the stability of the air. Stability seems to be the most important factor in determining the strength and vertical extent of the mechanical turbulence. When a light wind blows over irregular terrain, the resulting mechanical turbulence has only minor significance. When the wind blows faster and the obstructions are larger, the turbulence intensity increases and it extends to higher levels.

Mountain Wave Turbulence

When strong winds blow approximately perpendicular to a mountain range, the resulting turbulence can be severe. Associated areas of steady updrafts and downdrafts may extend to heights from 2 to 20 times the height of the mountain peaks. When the air is stable, large waves tend to form on the lee side of the mountains and extend up to the lower stratosphere for a distance of up to 300 miles or more downwind. These are referred to as standing waves or mountain waves, and may or may not be accompanied by turbulence (Figure 4-3). Pilots, especially glider pilots, have reported that the flow in these waves is often remarkably smooth. Others have reported severe turbulence.

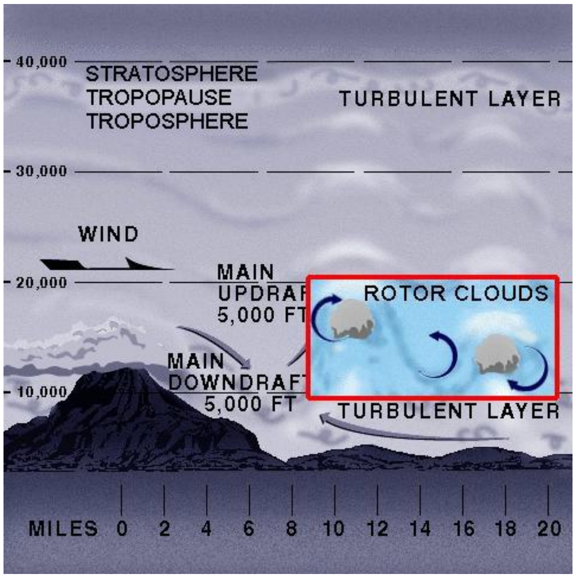


Figure 4-3 — Mountain Wave Turbulence

Even though mountain wave turbulence may be present, when the airflow begins to move up the windward side of the mountain, is usually fairly smooth as the orographic lifting imparts the vertical component to the motion of the air. The wind speed gradually increases, reaching a maximum near the peak of the mountain. Past the peak, the air naturally flows down the leeward side, completing one cycle of oscillation and setting up the standing wave pattern of the mountain wave turbulence. Downwind, perhaps 5 to 10 miles from the peak, the airflow begins to ascend again, where the rotor or lenticular clouds may appear. Additional waves, generally less intense than the primary wave, may form farther downwind. Note in Figures 4-3 and 4-4 that the mountains are on the left and the wind is flowing from left to right.

Figure 4-4 — Lenticular Clouds

While clouds are usually present to warn aircrews of mountain wave activity, it is possible for wave action to take place when the air is too dry to form clouds, producing CAT. Still, cloud forms particular to wave action provide the best means of identifying possible turbulence, aside from weather forecasts and PIREPs. Although the lenticular clouds in Figure 4-4 are smooth in contour, they may be quite ragged when the airflow at that level is turbulent. These clouds may occur singularly or in layers at heights usually above 20,000 feet. The rotor cloud forms at a lower level and is generally found at about the same height as the mountain ridge. The cap cloud usually obscures both sides of the mountain peak. The lenticular clouds (Figure 4-4), like the rotor and cap clouds, are stationary in position, even though the wind flows through them.

The pilot is concerned, for the most part, with the first wave because of its more intense activity and proximity to the high mountainous terrain. Extreme turbulence is usually found at low levels on the leeward side of the mountain in or near the rotor and cap clouds when the winds are 50 knots or greater at the mountaintop. With these wind conditions, severe turbulence can frequently be found to exist from the surface to the tropopause and 150 miles downwind. Moderate turbulence can be experienced often as far as 300 miles downwind under those same conditions. When the winds are less than 50 knots at mountain peak level, a lesser degree of turbulence may be experienced.

Mountain wave turbulence is dangerous in the vicinity of the rotor clouds and to the leeward side of the mountain peaks. The cap cloud must always be avoided in flight because of the turbulence and the concealed mountain peaks.

The following techniques should be applied when mountain wave turbulence has been forecast:
1. Avoid the turbulence if possible by flying around the areas where wave conditions exist. If

this is not feasible, fly at a level that is at least 50% higher than the height of the highest mountain range along your flight path. This procedure will not keep the aircraft out of turbulence, but provides a margin of safety if a strong downdraft is encountered.
2. Avoid the rotor, lenticular, and the cap clouds since they contain intense turbulence and strong updrafts and downdrafts.
3. Approach the mountain range at a 45° angle, so that a quick turn can be made away from the ridge if a severe downdraft is encountered.
4. Avoid the leeward side of mountain ranges, where strong downdrafts may exist, until certain turbulence is not a factor.
5. Do not place too much confidence in pressure altimeter readings near mountain peaks. They may indicate altitudes more than 2500 feet higher than the true altitude.
6. Penetrate turbulent areas at air speeds recommended for your aircraft.

Frontal Turbulence

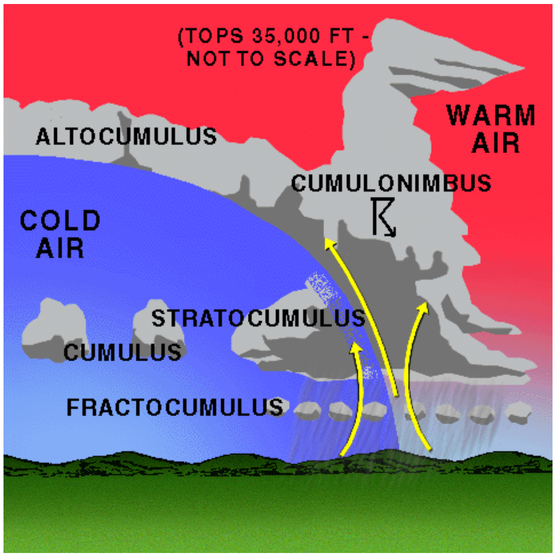


Figure 4-5 — Frontal Turbulence

Frontal turbulence is caused by lifting of warm air by a frontal surface leading to instability, or by the abrupt wind shift between the warm and cold air masses. The vertical currents in the warm air are the strongest when the warm air is moist and unstable. The most severe cases of frontal turbulence are generally associated with fast moving cold fronts. In these cases, mixing between the two air masses, as well as the differences in wind speed and or direction (wind shear), add to the intensity of the turbulence.

Ignoring the turbulence resulting from any thunderstorm along the front, Figure 4-5 illustrates the wind shift that contributes to the formation of turbulence across a typical cold front. The wind speeds are normally greater in the cold air mass.

Wind Shear Turbulence
Large-scale wind shear turbulence results from a relatively steep gradient in wind velocity or direction producing eddy currents that result in turbulence. Wind shear is defined as a sudden change in wind speed or direction over a short distance in the atmosphere. The greater the change in wind speed and/or direction in a given area, the more severe the turbulence will be. These turbulent wind shear flight conditions are frequently encountered in the vicinity of the jet stream, where large shears in both the horizontal and vertical planes are found, as well as in association with land and sea breezes, fronts, inversions, and thunderstorms. Strong wind shear can abruptly distort the smooth flow of wind, creating rapid changes in aircraft performance.

Jet Stream Turbulence

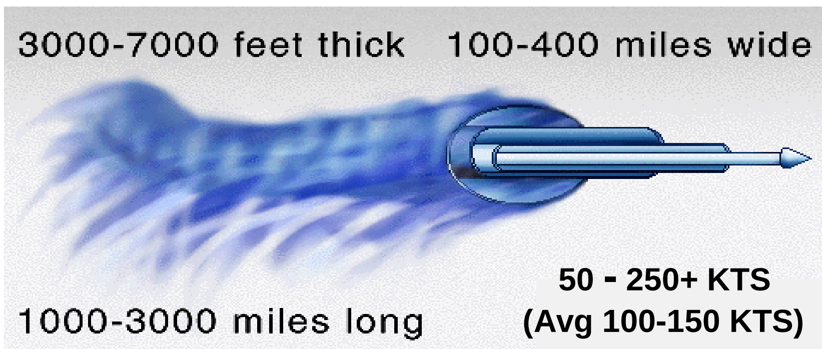


Figure 4-6 — Jet Stream Diagram

As described in Chapter 2, one of the major sources of wind shear turbulence is the jet stream, which can sometime reach speeds of over 250 knots (Figure 4-6). The highest wind speeds and probable associated turbulence is found about 5000 feet below the tropical tropopause, and closer to the tropopause in the polar regions. The rapid change of wind speed within a short distance of the jet core is particularly significant. The vertical shear is generally close to the same intensity both above and below the core, and it may be many times stronger than the horizontal shear. The horizontal shear on the cold air side of the core is stronger than on the warm air side. Thus, if it is desired to exit jet stream turbulence, a turn to the south should result in smoother air. Also, a climb or descent to a different flight level should also help, as jet stream turbulence often occurs in patches averaging 2000 feet deep, 20 miles wide, and 50 miles long. If changing altitude, watch the outside air temperature for a minute or two to determine the best way to exit the CAT quickly. If the temperature is rising, climb; if the temperature is falling, descend. This maneuver will prevent following the sloping tropopause or frontal surface and thereby staying in the turbulent area. If the temperature remains the same, either climb or descend.

Temperature Inversions
Recall from Chapter 1 the lapse rate where temperature increases with altitude, the temperature inversion. Even though this produces a stable atmosphere, inversions can cause turbulence at the boundary between the inversion layer and the surrounding atmosphere. The resulting turbulence can often cause a loss of lift and airspeed near the ground, such as when a headwind becomes a

Tailwind. This can create a wind shear that decreases aircraft performance. It is important to know how to recognize and anticipate an inversion in flight so you can prepare and take precautions to minimize the effects. If you are caught unaware, the loss of lift can be catastrophic because of your proximity to the ground. Inversions often develop near the ground on clear, cool nights when the winds are light and the air is stable. If the winds just above the inversion grow relatively strong, wind shear turbulence can result.

Figure 4-7 shows a wind shear zone and the turbulence that developed between the calm air and stronger winds above the inversion. When taking off or landing in near-calm surface winds under clear skies within a few hours of sunrise, watch for a temperature inversion near the surface. If the wind at 2000 to 4000 feet AGL is 25 knots or more, expect a shear zone at the inversion. To prepare yourself, allow a margin of airspeed above normal climb or approach speed if turbulence or a sudden change in wind speed occurs in order to counteract the effects of a diminished headwind or increased tailwind at and below the inversion.

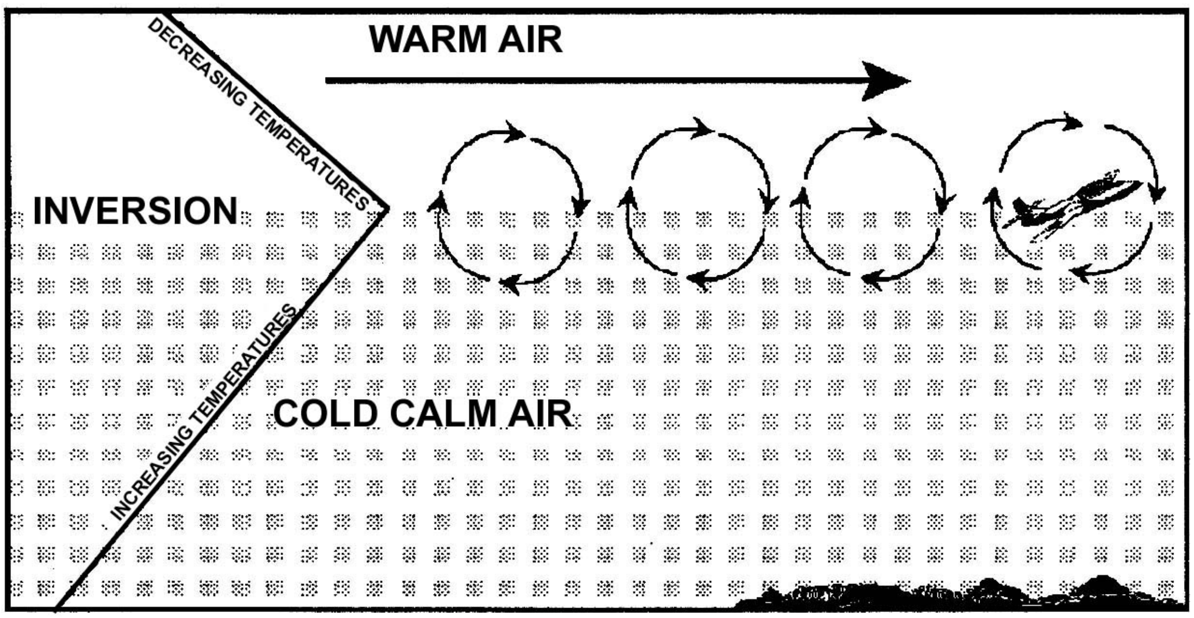


Figure 4-7 — Wind Shear Associated With a Temperature Inversion

Turbulence Associated with Thunderstorms
The strongest turbulence within cumulonimbus clouds occurs with the shear between the updrafts and downdrafts. Outside the clouds, wind shear turbulence has been encountered several thousand feet above and 20 miles laterally from a severe storm. Severe turbulence can be encountered in the anvil 15 to 30 miles downwind. The storm cloud is only the visible portion of a turbulent system whose updrafts and downdrafts often extend outside the storm.

Flight Techniques for Turbulence
The following are recommended procedures if you can't avoid flying in turbulence:
1. Establish and maintain thrust settings consistent with turbulent air penetration airspeed and

aircraft attitude. Severe turbulence may cause large and rapid variations in indicated airspeed. Don't chase airspeed.
2. Trim the aircraft for level flight at the recommended turbulent air penetration airspeed. Don't change trim after the proper attitude has been established.
3. The key to flying through turbulence is proper attitude control. Both pitch and bank should be controlled by reference to the attitude gyro indicator. Extreme gusts may cause large changes in pitch or bank. To avoid overstressing the aircraft, don't make abrupt control inputs. Use moderate control inputs to reestablish the desired attitude.
4. Severe vertical gusts may cause appreciable altitude deviations. Allow altitude to vary. Sacrifice altitude to maintain desired attitude. Don't chase the altimeter.

AIRCRAFT ICING

Summary of Air Florida Mishap On January 13, 1982, Air Florida Flight 90, a Boeing 727-222 (N62AF), was a scheduled flight to Fort Lauderdale, Florida, from Washington National Airport, Washington D.C. There were 74 passengers, including 3 infants, and 5 crewmembers on board. The flight's scheduled departure time was delayed about 1 hour 45 minutes because of moderate to heavy snowfall, which necessitated the temporary closing of the airport. Following takeoff from runway 36, which was made with snow and/or ice adhering to the aircraft, the aircraft at 1:31 EST crashed into the barrier wall of the northbound span of the 14th Street Bridge, which connects the District of Columbia with Arlington County, Virginia, and plunged into the ice-covered Potomac River. It came to rest on the west side of the bridge 0.75 nm from the departure end of runway 36. Four passengers and one crewmember survived the crash. When the aircraft hit the bridge, it struck seven occupied vehicles and then tore away a section of the bridge barrier wall and bridge railing. Four persons in the vehicles were killed; four were injured. The National Transportation Safety Board determined that the probable cause of this accident was the flight crew's failure to use engine anti-ice during ground operation and takeoff, their decision to take off with snow/ice on the airfoil surfaces of the aircraft, and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings. Contributing to the accident were the prolonged ground delay between deicing and the receipt of ATC takeoff clearance during which the airplane was exposed to continual precipitation, the known inherent pitch up characteristics of the B-727 aircraft when the leading edge is contaminated with even small amounts of snow or ice, and the limited experience of the flight crew in jet transport winter operations.

Table 4-2 — Air Florida Mishap Abstract

As graphically demonstrated by Table 4-2, icing poses a serious threat to aviation. No matter which part of the world home base is located, icing can become a hazard to any phase of flight, not just the takeoff or landing phase.

Aircraft icing is classified into two main groups: structural and engine icing.

Structural icing is icing that forms on the external structure of an aircraft. Structural ice forms on the wings, fuselage, antennas, pitot tubes, rotor blades, and propellers. Significant structural icing on an aircraft can cause control problems and dangerous performance degradation. The types of structural icing are clear, rime, mixed, and frost.

Engine icing occurs when ice forms on the induction or compressor sections of an engine, reducing its performance.

Icing Requirements

There are two requirements for the formation of aircraft icing. First, the atmosphere must have super-cooled visible water droplets. Second, the free air temperature (measured by the aircraft's outside air temperature gauge) and the aircraft's surface temperature must be below freezing.

Clouds are the most common form of visible liquid water, and super-cooled water is liquid water found at air temperatures below freezing. When super-cooled droplets strike an exposed object, such as a wing, the impact induces freezing and results in aircraft icing. Therefore, when penetrating a cloud at subzero temperatures, icing should be expected.

Super-cooled water forms because, unlike bulk water, water droplets in the free air do not freeze at 0° C. Instead, their freezing temperature varies from –10 to –40° C: the smaller the droplets, the lower the freezing point. As a general rule, serious icing is rare in clouds with temperatures below –20° C since these clouds are almost completely composed of ice crystals. However, be aware that icing is possible in any cloud when the temperature is 0° C or below.

Structural Icing Conditions

Clear icing normally occurs at temperatures between 0° C and –10° C, where water droplets are large because of unstable air, such as in cumulus clouds and in areas of freezing rain or drizzle. Instead of freezing instantly upon contact with the aircraft's surface, these large water droplets move along with the airflow, freeze gradually, and form a solid layer of ice. This layer of clear ice can cover a large portion of the wing surface and is difficult to break off. Clear icing is extremely hazardous because it builds up fast, can freeze the flight controls, and disrupts airflow over the wings.

Rime icing is milky white in appearance and is most likely to occur at temperatures of –10 to –20° C. It is denser and harder than frost, but lighter, softer, and less transparent than clear ice. Rime ice occurs in stable conditions–clouds where the water droplets are small and freeze instantaneously, such as stratiform clouds and the upper portions of cumulus clouds. It is brittle and fairly easy to break off. Rime ice does not normally spread over an aircraft surface, but protrudes forward into the air stream along the leading edges of airfoils.

Mixed icing is a combination of clear ice and rime ice, occurring where both large and small water droplets are present, normally at temperatures of –8 to –15° C. Because mixed icing is a combination of large and small water droplets, it takes on the appearance of both rime and clear icing. It is lumpy, like rime ice, but also hard and dense, like clear ice. The most frequent type of icing encountered is usually a form of mixed icing.

Frost is a thin layer of crystalline ice that forms on exposed surfaces. It normally occurs on clear, calm winter nights on aircraft surfaces just as it does on automobiles. Frost also forms in flight when a cold aircraft descends from a zone of freezing temperatures into high relative humidity. The moist air is chilled suddenly to below freezing temperatures by contact with the cold surfaces of the aircraft, and deposition occurs. Frost, like other forms of icing, disrupts the smooth boundary layer flow over airfoils, and thus increases drag, causes a loss of lift, and increases stall speed. Though it is unlikely to add considerable weight to an aircraft, any amount of frost is hazardous and must be removed prior to takeoff.

Aircrews should anticipate and plan for some type of icing on every flight conducted in below freezing temperatures and should be familiar with the icing generally associated with different atmospheric conditions, as discussed in the next section.

Frontal Icing Conditions
Cold fronts and squall lines generally have a narrow band of both weather and icing. The associated clouds will be cumuliform. The icing zone will be about 10,000 feet thick, 100 miles wide, and the icing will be predominantly clear, accumulating rapidly.

Warm fronts and stationary fronts generally have a much wider band of weather and icing, reflecting the size of the warm frontal zone. The icing will be found mainly inside stratiform clouds, accumulating at a relatively low rate, due to the smaller size of the super-cooled water droplets. The vertical depth of the icing zone will generally be about 3000 to 4000 feet thick, possibly up to 10,000 feet. The type of icing will be predominantly rime, but may also contain mixed icing.

The most critical freezing precipitation (rain or drizzle) area is where water is falling from warm air above to a flight level temperature that is below freezing. In this case, severe clear ice would be encountered below the cloud layer and the evasive action is to climb to an altitude where the temperature is above freezing.

Occluded fronts often produce icing covering a very widespread area, containing both stratiform and cumuliform-type clouds. The depth of the icing zone will often be 20,000 feet–approximately double the depth of icing zones with other type fronts. The types of icing will be clear, mixed, and rime, with a very rapid and heavy rate of accumulation.

EFFECTS AND HAZARDS OF STRUCTURAL ICING

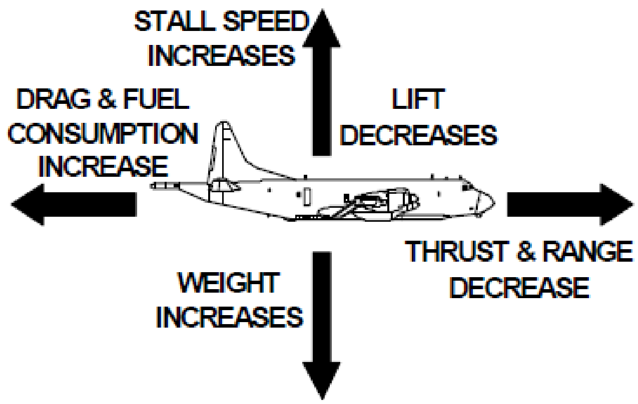


Figure 4-8 — Cumulative Effects of Icing

The most hazardous aspect of structural icing is its aerodynamic effects. The presence of ice on an aircraft decreases lift, thrust, and range, and increases drag, weight, fuel consumption, and stall speed. The added weight with reduced lift and thrust can be a dangerous combination (Figure 4-8). Ice can alter the shape of an airfoil, changing the angle of attack at which the aircraft stalls therefore increasing the stall speed. Ice reduces lift and increases drag on an airfoil. Ice thickness is not the only factor determining the effect of icing. Location, roughness, and shape are important, too. For example, a half-inch high ridge of ice on the upper surface of the airfoil at 4% chord reduces maximum lift by over 50%. Yet, the same ridge of ice at 50% chord decreases maximum lift by only 15%. On another airfoil, a distributed sandpaper-like roughness on the leading edge of the wing may decrease lift by 35%. Along with this decrease in lift, it is obvious that parasite drag will significantly increase. The buildup of ice on various structural parts of the aircraft can result in vibration, causing added stress to those parts. This is especially true in the case of propellers and rotors, which are delicately balanced. Even a small amount of ice, if not distributed evenly, can cause great stress on the propeller and engine mounts.

Icing is not restricted to airfoils and other external structure. Engines, fuel, and instruments may also be affected by ice formation.

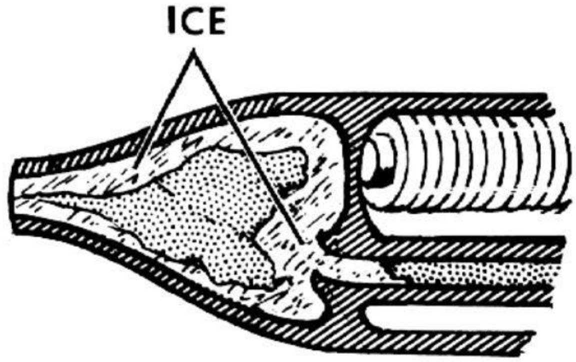


Figure 4-9 — Pitot Tube Icing

Ice associated with freezing rain or drizzle can accumulate beyond the limits of an ice protection system. If you encounter any type of freezing rain or drizzle, the best course of action is to leave the area.

Structural icing can block the pitot tube (Figure 4-9) and static ports. This can cause a pilot to either lose or receive erroneous indications from various instruments such as the airspeed indicator, VSI, and altimeter. For example, if the pitot tube becomes blocked with ice, the “total pressure” input to the system remains constant. Therefore, during a descent, as the “static pressure” input to the system increases, the airspeed indicator gives an erroneous indication of decreasing airspeed. The opposite would be true during a climb.

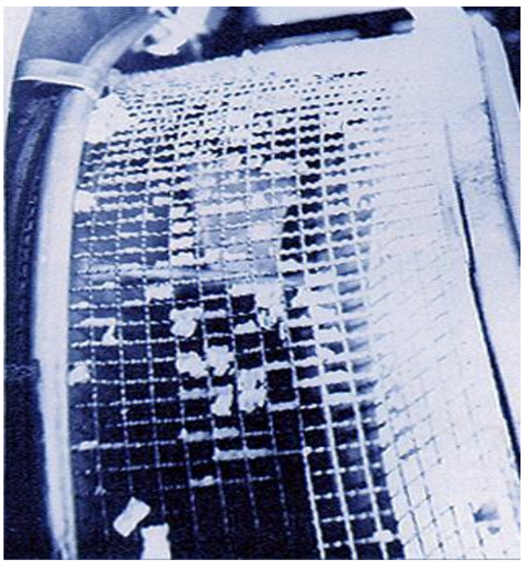
During flight, it can be difficult to detect ice on areas such as the empennage that may be impossible to see. Some cues which signal the potential for icing include the following: (1) ice on windshield wiper arms or projections such as engine drain tubes, pitot tubes, engine inlet lips, or propeller spinners, (2) decreasing airspeed with constant power and altitude, and (3) ice detector annunciation.

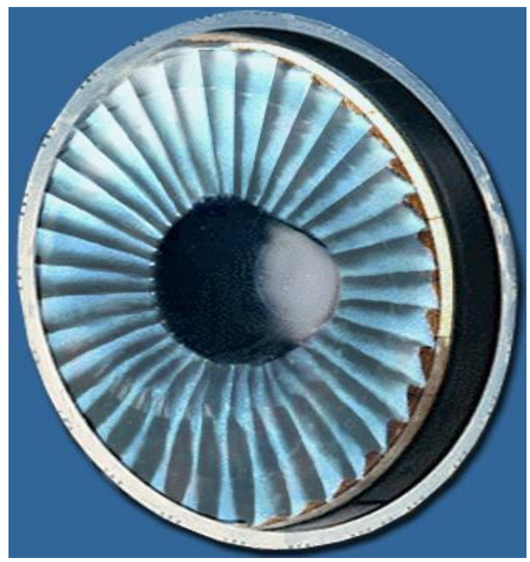
Icing on rotary wing aircraft is related to those involving wings and propellers. Ice formation on the helicopter main rotor system or anti-torque rotor system may produce serious vibration, loss of efficiency or control, and can significantly deteriorate the available RPM to a level where safe landing cannot be assured. In fact, a 3/16-inch (4.8-mm) coating of ice is sufficient to prevent some helicopters from maintaining flight in a hover.

OTHER TYPES OF AIRCRAFT ICING

Induction icing – In flights through clouds that contain super-cooled water droplets, air intake duct icing is similar to wing icing. However, the ducts may ice when skies are clear and temperatures are above freezing. The reduced pressure that exists at the intake lowers the temperature to the point that condensation and or deposition take place, resulting in the formation of ice. The degree of temperature decrease varies considerably with different types of engines. However, if the free air temperature is 10° C or less (especially near the freezing point), and the relative humidity is high, the possibility of induction icing exists. Ingestion of ice shed ahead of the compressor inlet may cause severe foreign object damage (FOD) to the engine.

Compressor icing – Ice forming on compressor inlet screens and compressor inlet guide vanes will restrict the flow of inlet air, eventually causing engine flameout. The reduction in airflow is noticeable through a loss of thrust and a rapid rise in exhaust gas temperature. As the airflow decreases, the fuel-air ratio increases, which in turn raises the temperature of the gases going to the turbine. The fuel control attempts to correct any loss in engine RPM by adding more fuel, which merely aggravates the condition. Ice build-up on inlet screens sufficient to cause turbine failure can occur in less than 1 minute under severe conditions.





Ground icing hazards – We have already stressed the importance of removing all icing and frost from an aircraft prior to takeoff. De-icing itself, however, can also be a hazard. De-icing fluids (discussed in the next section) are highly corrosive to internal aircraft and engine parts. Thus, it is imperative that de-icing crews understand the particular requirements for your type of aircraft. Additionally, taxiing through mud, water or slush on ramps and runways can create a covering of ice that can hamper the movement of flaps, control surfaces, and the landing gear mechanism. Ice and snow on runways are conditions that affect braking action of aircraft. Braking action varies widely with aircraft type and weight. Therefore, pilots must be aware of the limits to their aircraft's braking capabilities.

MINIMIZING OR AVOIDING ICING HAZARDS
Flight Path Options

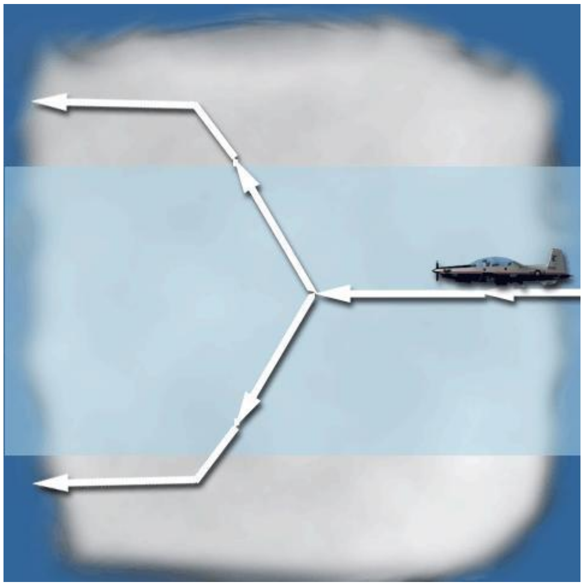


Figure 4-10 — Options to Escape Icing

In coping with an icing hazard in flight, a pilot usually has two alternatives. First, the pilot can climb to the colder temperatures where the precipitation will be frozen and therefore not an icing hazard. Second, the pilot can descend to an altitude where the air temperatures are well above freezing (Figure 4-10). However, if encountering clear icing in the freezing precipitation below the clouds of a warm front, the aircraft is most likely in the cold air ahead of the warm front. In this case, the best alternative may be to climb to warmer temperatures, across the frontal boundary, as the freezing precipitation may extend all the way to ground level.

Anti-Icing and De-Icing Equipment
Deicing equipment eliminates or removes ice that has already accumulated on the aircraft. Anti-icing equipment prevents the accumulation of ice on specific aircraft surfaces. Most military aircraft are equipped with anti-icing and or deicing equipment. There are three common methods for preventing and or eliminating ice buildup: mechanical, fluids, and heat.

The mechanical method uses deicing boots, which are rubber bladders installed on the leading edges of lift producing surfaces. Compressed air cycles through these rubber boots causing them to alternately inflate and deflate, thus cracking accumulated ice and allowing the air stream to peel it away.

Anti-icing fluids are freezing point depressants and are pumped through small holes in the wing's leading edge. This fluid coats the wing, preventing ice from forming on the wing's surface. Deicing fluids are also used by ground crews to remove and prevent ice buildup before takeoff.

Heat application capability to wings, props, tail surfaces, or engine intakes is installed in most aircraft. Systems of this nature can be designed for either anti-icing or de-icing purposes. Critical areas can be heated electrically or by hot air that is bled from the engine’s compressor section.

Recommended Precautions:
Keep these precautions in mind when flying in the vicinity of icing conditions.
1. Don’t fly into areas of known or forecast icing conditions.
2. Avoid flying in clouds with temperatures from 0° C to –20° C.
3. Don’t fly through rain showers or wet snow with temperatures near freezing.
4. Avoid low clouds above mountain ridges or crests. Expect the heaviest icing in clouds around 5000 feet above the mountaintops.
5. Do not make steep turns with ice on the airplane due to increased stall speeds.
6. Avoid high angles of attack when ice has formed on the aircraft since the aircraft is closer to stall speed in these maneuvers.
7. Under icing conditions, increased drag and additional power required increases fuel consumption.
8. Change altitude to temperatures above freezing or colder than -20° C. An altitude change also may take you out of clouds.
9. In freezing rain, climb to temperatures above freezing, since it will always be warmer at some higher altitude. Don’t delay your climb since ice can accumulate quickly. If you are going to descend, you must know the temperature and terrain below.
10. Do not fly parallel to a front while encountering icing conditions.
11. Avoid icing conditions as much as possible in the terminal phase of flight due to reduced airspeeds.
12. Expect to use more power on final approach when experiencing structural icing.
13. Always remove ice or frost from airfoils before attempting takeoff.

Icing Intensities and PIREPs
Weather personnel cannot generally observe icing; they must rely on PIREPs. When flying during icing conditions, pilots should report these conditions as indicated in Table 4-3. However, forecasters attempt to forecast the maximum intensity of icing that may be encountered during a flight, not necessarily the intensity of icing that will be encountered by a particular aircraft. It becomes the pilot’s responsibility to make certain that a complete weather briefing is obtained, to include the information for safe completion of the flight.

<table>
<tr><th>Intensity</th><th>Airframe Ice Accumulation</th><th>Pilot Report</th></tr>
<tr><td>Trace</td><td>Ice becomes perceptible. Rate of accumulation slightly greater than rate of sublimation. It is not hazardous even though deicing/anti-icing equipment is not used, unless encountered for an extended period of time--over one hour.</td><td rowspan="4">Aircraft identification, location, time (GMT), altitude (MSL), type aircraft, sky cover, visibility & weather, temperature, wind, turbulence, icing, remarks.

Example of PIREP transmission:

"Pensacola METRO, Rocket 501, holding 20 miles south of Navy Pensacola, at 2100Z and one-six thousand feet, single T-39 Sabreliner, we're IFR in stratus clouds, temperature –15° C, winds 330 at 25, no turbulence, Light Rime Icing, flying 200 knots indicated.</td></tr>
<tr><td>Light</td><td>The rate of accumulation may create a problem if flight is prolonged in this environment (over one hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/anti-icing equipment is used.</td></tr>
<tr><td>Moderate</td><td>The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or diversion is necessary.</td></tr>
<tr><td>Severe</td><td>The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary.</td></tr>
<tr><td colspan="3">Icing may be rime, clear, or mixed:

Rime ice – Rough milky opaque ice formed by the instantaneous freezing of small super-cooled water droplets.

Clear ice – A glossy, clear or translucent ice formed by the relatively slow freezing of large super-cooled water droplets.

Mixed ice – A combination of rime and clear ice.</td></tr>
</table>

Table 4-3 — Icing Reporting Criteria

VISIBILITY DEFINITIONS

Visibility is important to all aviators since it plays an essential role in takeoffs, approaches, and landings. Visibility is defined as the ability to see and identify prominent unlighted objects by day and prominent lighted objects at night, and is expressed in statute miles, hundreds of feet, or meters. There are several particular methods of reporting visibility, some of which are defined below.

Flight Visibility – The average forward horizontal distance, measured in statute miles from the cockpit of an aircraft in flight, at which a pilot can see and identify prominent unlighted objects by day and prominent lighted objects at night.

Prevailing Visibility – The greatest horizontal visibility, measured in statute miles, equaled or exceeded throughout at least half the horizon circle, which need not be continuous. Figure 4-11 illustrates how prevailing visibility is determined. The center of the circles depict the observation point, and the edge of the circles represent a distance of 3 miles, the furthest that prominent objects may be seen and identified. In the left depiction, the maximum visibility common to half or more of the horizon circle is 3 miles, so the prevailing visibility is 3 miles. If a bank of fog were to roll in to the airfield, as in the right depiction, visibility toward the east would be reduced. However, the observer can still see 3 miles throughout at least 180° of view, so the prevailing visibility is still 3 miles. Look at the visibility for each of the runways, and notice how the actual visibility may vary significantly from the prevailing visibility.

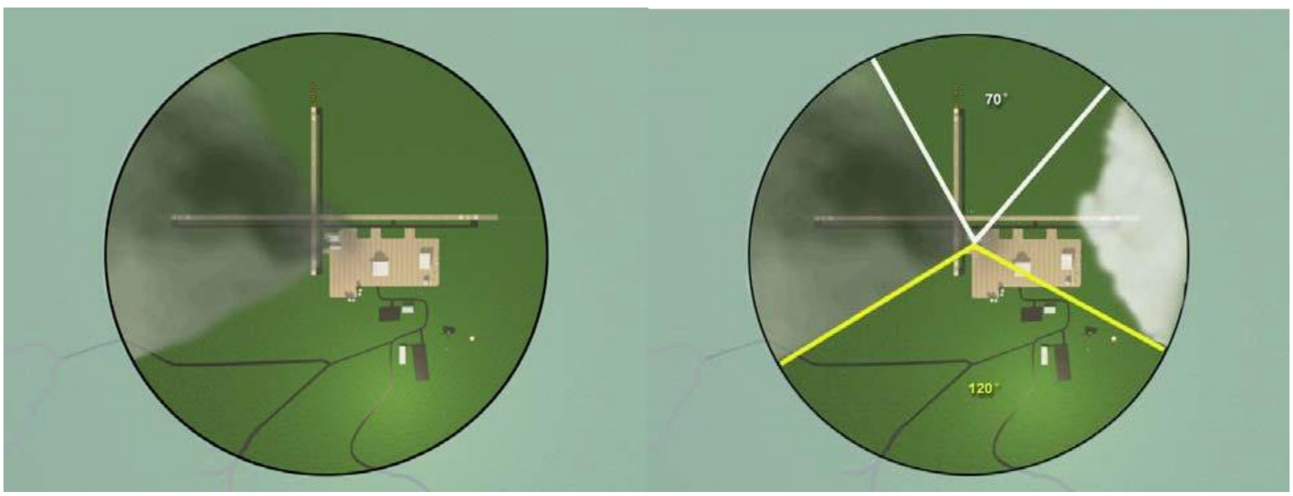


Figure 4-11 — Prevailing Visibility Determination

Slant Range Visibility – The distance on final approach when the runway environment is insight. This is probably the most vital weather information needed during a final approach in questionable weather. Unfortunately, slant rage visibility is not often provided because of great difficulty in estimating or measuring it from the ground. RVR provides the best indication of the slant range visibility. However, other weather information such as precipitation and prevailing visibility help indicate slant range visibility.

Runway Visual Range (RVR) – The horizontal distance, expressed in hundreds of feet or meters, a pilot will see by looking down the runway from the approach end. For takeoff and landing under IFR, prevailing visibility is not as important as the visibility within the runway environment.

Surface vs Flight Visibility
RVR and prevailing visibility are horizontal visibilities near the Earth's surface. They may be quite different from the vertical visibility when looking down at the ground from an aircraft in

flight. For example, surface visibility may be seriously reduced by fog or blowing snow, yet only a slight reduction in visibility is apparent when viewed from above the field. In Figure 4-12, the airfield may be seen relatively clearly from above the fog. When descending to the level of the fog, however, the airfield may disappear from sight. In another situation, flying into the setting sun on a hazy day may reduce flight visibility to values less than the surface visibility. When given the surface visibility, learn to anticipate what your flight visibility is likely to be. It may vary, depending on other weather conditions present.

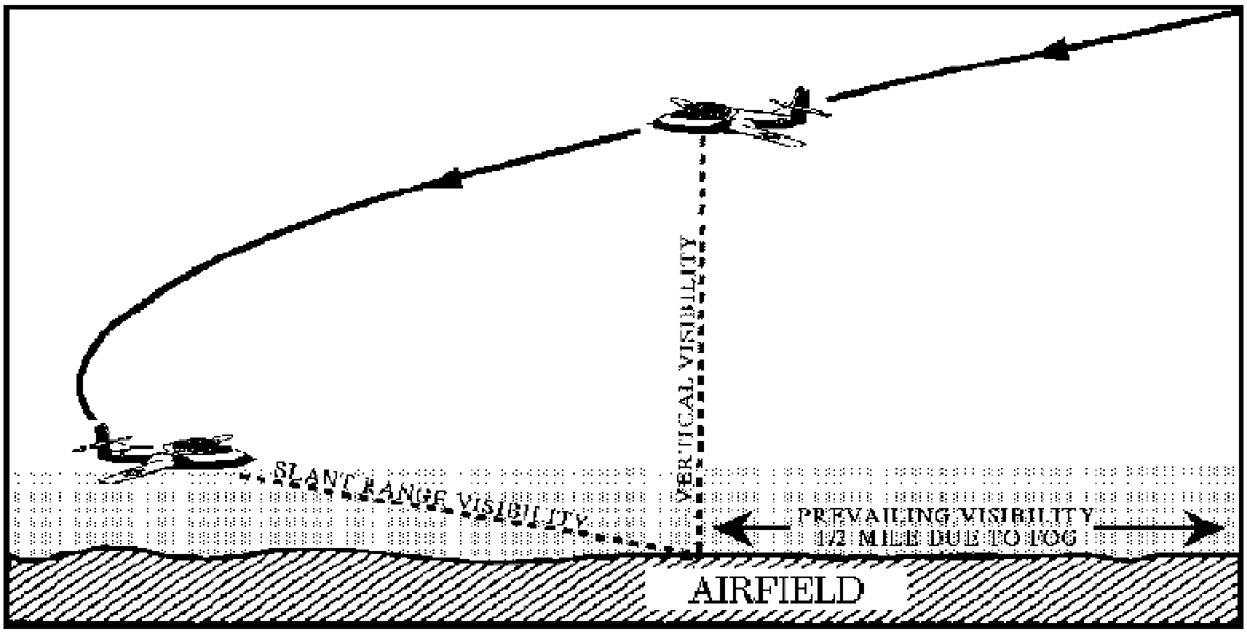


Figure 4-12 — Surface vs. Flight Visibility

Obscuring Phenomena

Obscuring phenomena are any collection of particles that reduce horizontal visibility to less than six miles. They may be either surface based or aloft. Examples include fog, haze, smoke, volcanic ash, and blowing spray, to name a few.

Haze produces a bluish color when viewed against the ground. Although haze may occur at any level in the troposphere, it is more common in the lower few thousand feet. Haze is associated with a stable atmosphere. The top of a haze layer, which is usually confined by a low-level inversion, has the appearance of a horizon when viewed from above the layer. In this case, the haze may completely obscure the ground in all directions except the vertical. Dense haze may reduce visibility to less than 3 miles, with slant range visibility generally less than surface visibility. Visibility in haze is lower when looking toward the Sun than away from it.

Smoke causes the sunrise and sunset to appear very red. Smoke reduces visibility in a manner similar to haze. Smoke from forest fires is often concentrated in layers aloft with good visibility beneath. Smoke may be a major concern near industrial areas. Smoke from forest fires has been carried great distances at high altitudes. Aircrews flying at these altitudes may encounter dense smoke, although the lower altitudes are clear.

Rain and Drizzle – Precipitation in its liquid form can, on its own, reduce visibility. Precipitation also reduces visibility as it streams across a windshield or canopy. Drizzle is a feature of stable air, and fog or smog are also likely to be present. Therefore, drizzle may result in extremely poor visibility. Approaches and the ensuing transition to visual flight can be very hazardous since moderate to heavy rain conditions can seriously affect the recognition of visual cues. Night approaches in these conditions can be even more critical as you may be distracted by the aircraft's flashing strobes or sequenced flashing runway lights.

Snow —Snow affects visibility much more than rain or drizzle and can easily reduce visibility to less than 1 mile. It is often difficult to see snow falling ahead of you; you may enter the snow unexpectedly.

Blowing Snow – Fine, dry snow can be easily lifted by the wind up to 300 feet AGL, depending on wind strength and air stability. During or after a fresh snowfall with brisk winds, surface visibility may be reduced to less than ½ mile. Blowing snow is accompanied by many of the same hazards as rain, such as turbulence (creating difficulties in reading flight instruments) and obscured visual cues (a lack of visual cues for runway identification during the visual portion of the approach). The approach and runway lights will provide some identification of the runway environment; however, runway markings may be lost in the whiteness. Therefore, depth perception will be difficult, requiring more emphasis on instruments.

Dust and Sand form when strong winds combined with unstable air and loose, dry soil can blow dust or sand into the air. Dust is finer than sand, and strong winds may lift the dust to considerable heights. Sand will usually be limited in altitude to 50 or 100 feet. In severe conditions, visibility can be near zero. Blowing dust is common behind cold fronts moving rapidly across prairies in early spring before a cover of vegetation has appeared. This effect may cause blowing dust conditions and reduced visibilities over a wide area.

SKY COVERAGE AND CEILINGS

For determining the amount of sky covered by clouds, the celestial dome is divided into 8ths. The terms contained in Table 4-4 are used to report the percentage of sky coverage as well as any obstructions to visibility. These coverages apply to a given altitude; therefore, more than one is normally reported. For example, the sky may be reported as follows: SCT at 2000 ft., BKN at 5000 ft., OVC at 10,000 ft., where the altitudes refer to the bases of the cloud layers in feet AGL.

Reportable Contractions	Meaning	Amount of Sky Cover
SKC or CLR[1]	Sky Clear	0/8
FEW[2]	Few	> 0/8 - 2/8
SCT	Scattered	3/8 - 4/8
BKN	Broken	5/8 - 7/8
OVC	Overcast	8/8
VV	Obscured[3]	8/8 (surface based)

1. The abbreviation CLR is used at automated stations when no clouds at or below 12,000 feet are reported; the abbreviation SKC is used at manual stations when no clouds are reported.

2. Any amount less than 1/8 is reported as FEW.

3. The last 3 digits report the height of the vertical visibility into an indefinite ceiling.

Table 4-4 — Sky Coverage Contractions

A ceiling is the height above the ground (AGL) ascribed to the lowest broken or overcast layer; or the vertical visibility into an obscuring phenomenon (total obscuration).

Vertical visibility is the distance that can be seen directly upward from the ground into a surface based obscuring phenomenon. This term is used when the celestial dome is totally hidden from view (8/8s) by some surface based obscuration, and the reported ceiling is determined by measuring the vertical visibility upward as seen from the ground. In this type of situation, the base of the obscuration is less well defined, but it may still be possible to see upwards into the moisture (or other obstruction) for a short distance. While this does constitute a ceiling, it is sometimes referred to as an “indefinite” ceiling, and the distance that can be seen upward into the phenomenon is then given as the vertical visibility. For example, if the sky were totally hidden by fog which touched the ground, but a ground observer could see a weather balloon ascend upward into the fog for 200 feet, she would report a vertical visibility of 200 feet.

It is important to realize that the vertical visibility of 200 feet in the foregoing example is very different from a cloud ceiling of 200 feet. With a low cloud ceiling, a pilot normally can expect to see the ground and the runway once the aircraft descends below the cloud base. However, in the case of vertical visibility, the obscuring phenomenon also reduces the slant range visibility. Therefore, a pilot will have difficulty seeing the runway or approach lights clearly even after descending below the level of the reported vertical visibility.

If the weather observer on the ground is able to see part of the celestial dome or some clouds through an obscuring phenomenon (a partial obscuration) it is reported as few, scattered, or broken as appropriate, and assigned a height of 000 to indicate it is a surface based phenomenon. If clouds are present, their bases and amount or coverage are also reported.

Surface based obscuring phenomena classified as few, scattered, or broken also present a slant range visibility problem for pilots on approach for a landing but normally to a lesser degree that when the celestial dome is completely hidden. Thus, partial obscurations are *not* considered ceilings.

Fog vs Stratus
Fog related low ceilings and reduced visibility are among the most common and persistent weather hazards encountered in aviation. Since fog occurs at the surface, it is primarily a hazard during takeoff and landing.

Fog is a visible aggregate of minute water droplets that is based at or within 50 feet of the surface, is greater than 20 feet in depth, and reduces the prevailing visibility to less than ⅝ of a statute mile. Fog reduces horizontal and vertical visibility and may extend over a large area.

Fog that extends no more than 200 feet in height is considered shallow fog and is normally reported as a partial obscuration. Since the fog may be patchy, it is possible that visibility will vary considerably during the approach and rollout. RVR may not be representative of actual conditions in this situation if the measuring equipment is located in an area of good visibility.

One of the most serious problems with shallow fog stems from the abundance of cues available at the start of the approach. You may see the approach lighting system and possibly even some of the runway during the early stages of the approach. However, as the fog level is entered, loss of visual cues may cause confusion or disorientation. In these conditions, you should not rely entirely on visual cues for guidance. Bring visual cues into your instrument cross-check to confirm position, but maintain instrument flight until visual cues can provide sufficient references for landing.

Dense fog normally causes a total obscuration. You will not normally see visual cues during the early portion of an approach. Strobe lights and landing lights may cause a blinding effect at night. Transitioning to land in a total obscuration involves the integration of visual cues with the instrument cross-check during the latter portion of the approach.

A layer of low clouds forming a ceiling is usually formed from stratus clouds. Stratus, like fog, is composed of extremely small water droplets or ice crystals suspended in the air. The main distinction between fog and stratus is that a stratus layer is not surface based. It is above the ground (greater than 50 feet AGL) and does not reduce the horizontal visibility at the surface. An observer on a mountain enveloped in the layer would call it fog, while one farther down the slope would call it stratus. In fact, the requirements for formation of fog contain many of the same items listed in the requirements for cloud formation.

Fog Formation
The formation of fog or cloudiness of any type is dependent on the air becoming temporarily supersaturated (contains more moisture than the air can hold at that temperature). Once the air

reaches a supersaturated state, the excess moisture in the air condenses out of solution into minute water droplets that are light enough to remain suspended in the air. If the condensed water particles form in sufficient amount near the surface, the resulting condition is fog. For fog to form, three conditions must be satisfied: (1) condensation nuclei must be present in the air, (2) the air must have a high water content (a low dew point spread), (3) and light surface winds must be present.

Recall from Chapter 2 that when the air temperature is equal or nearly equal to the dew point temperature, there is a low dew point spread, and the air is close to saturation. Once saturation is achieved–either through the cooling of the air or through the evaporation of water into the atmosphere–water will condense from the vapor state into water droplets or ice crystal.

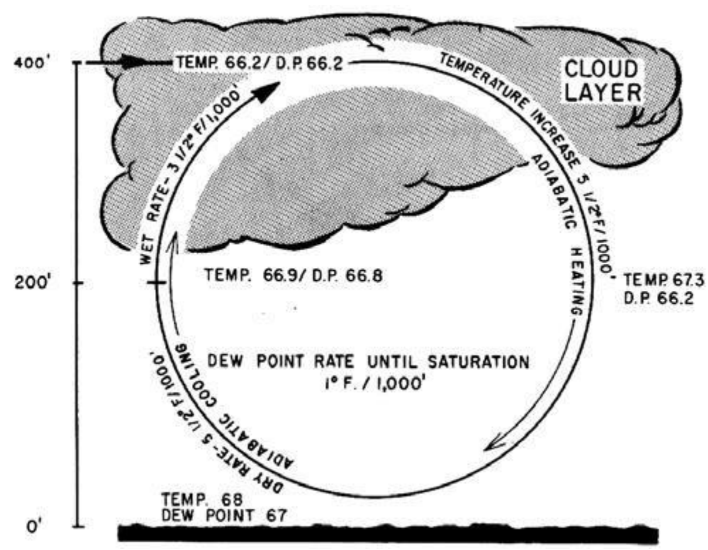


Figure 4-13 — Wind Causing Eddy Currents, Cooling Air to Saturation

Wind velocity is an important consideration in the formation of fog. As will be discussed shortly, the radiational cooling of the Earth's surface is one of the main causes of fog formation. When light surface winds are present, on the order of 1 to 10 knots, the speed differential resulting from friction slowing the air directly next to the surface causes the air to tumble in a mild eddy current (Figure 4-13). This brings more air in contact with the surface, enabling more air to be cooled, producing a thicker layer of condensed moisture. If the winds become too fast, however, this layer lifts away from the ground, lifting the bases higher with increasing speeds.

Types of Fog

The two main types of fog are radiation fog and advection fog.

Radiation Fog

Figure 4-14 — Radiation Fog

Radiation fog (Figure 4-14) occurs due to nocturnal cooling, usually on clear nights, when the Earth releases relatively large amounts of radiation into the atmosphere, cooling the surface. (Cloudy nights, on the other hand, reflect most terrestrial radiation back to the Earth, reducing the amount of cooling through a “blanket” effect.) Radiation cooling actually begins after the maximum daily temperature is reached, usually between 1530 and 1600 local time. Cooling continues until sunrise or shortly after sunrise, and it effects only the lower limits of the atmosphere. If nocturnal cooling reduces the air temperature to the dew point temperature, fog or low ceiling clouds will develop in the area. Winds play an important factor in fog formation. Winds less than 5 knots usually results in shallow fog. Winds of 5 to 10 knots will usually cause dense fog. Winds of greater than 10 knots will usually dissipate the fog and cause low stratus or stratocumulus clouds to form. The other way radiation fog can dissipate is through solar heating.

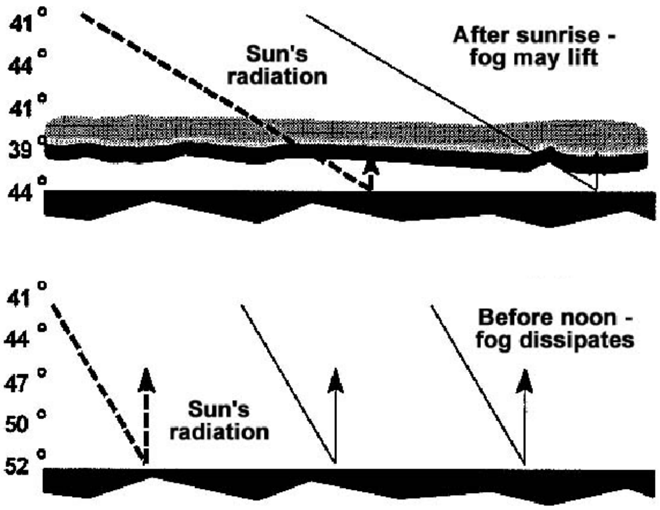


Figure 4-15 — Dissipation of Radiation Fog

In considering the dissipation of fog and low clouds, consideration should be given to the rate at which the ground temperature can increase after sunrise. Vertically thick fog or multiple cloud layers in the area will slow down the morning heating of the ground. Only the heating of the ground can increase the temperature of the air overlying the ground. Once the surface air temperature rises, the ability of the air to hold more water vapor increases, and the fog particles tend to evaporate (Figure 4-15).

Advection Fog

Advection fog occurs when warm, moist air moves over a cold surface and the air is cooled to the dew point. Common in coastal areas, it is often referred to as sea fog when observed to come from the sea. Fog of this type becomes thicker and denser as the wind speed increases, up to about 15 knots. Winds much stronger than this lift the fog into a layer of low stratus. However, in some oceanic areas, sea fog has been known to persist with winds as high as 40 knots. Advection fog can stay over the water for weeks, moving over the land late in the day and moving back over the water the next morning.

Figure 4-16 — Advection Fog

The west coast of the United States is quite vulnerable to sea fog (Figure 4-16). This frequently occurring fog forms offshore–largely as a result of very cold water from the ocean depths rising to the surface, cooling the moist air above it–and is carried inland by the wind. Advection fog over the southeastern United States and along the Gulf Coast results from moist tropical air moving over cold ground. It is, therefore, more frequent in winter than in summer.

Advection fog dissipates only with a wind shift, blowing the fog away, usually back out over the sea. Incoming solar radiation will seldom cause the dissipation of advection fog because its thickness generally prevents enough radiation to warm the Earth sufficiently. The high specific heat of water and the resulting stable temperature also prevents any solar heating from causing the dissipation of sea fog. Only a change in wind direction that moves the air from a colder surface to a warmer surface, reversing the saturation process, can cause advection fog to dissipate.

VOLCANIC ASH CLOUDS

Volcanic eruptions are rare, but the severe effects ash clouds have on an aircraft make it important to understand the hazards in order to minimize or avoid them.

Volcanic ash clouds create an extreme hazard to aircraft operating near (especially downwind) of active volcanoes. Aircraft flying through volcanic ash clouds have experienced a significant loss of engine thrust and/or multiple engine flameouts along with wing leading edges and windshields being sandblasted.

Flight into an area of known volcanic activity must be avoided. Avoiding volcanic ash clouds is particularly difficult during hours of darkness or in daytime instrument meteorological conditions when the volcanic ash cloud may not be detected by the flight crew. Volcanic ash clouds are not displayed on airborne or Air Traffic Control (ATC) radar, as the radar reflectivity of volcanic ash is roughly a million times less than that of a cumuliform cloud.

A volcanic ash cloud is not necessarily visible, either. Aircrews have reported smelling an acrid odor similar to electrical smoke and smoke or dust appearing in the aircraft, but not seeing the ash cloud. Expect minor eye irritation if odors become noticeable (i.e., eyes watering). Remove contact lenses if this occurs. Consider using oxygen when odors or eye irritation occurs.

If volcanic activity is reported, the planned flight should remain at least 20 NM from the area and, if possible, stay on the upwind side of the volcano even when flying outside of the 20 NM limitation. Volcanic ash clouds may extend downwind for several hundred miles and thousands of feet in altitude. Volcanic ash can cause rapid erosion and damage to the internal components of engines with loss of thrust within 50 seconds.

Since airborne radar cannot detect volcanic ash clouds, weather forecasts are occasionally wrong, and ash clouds may be hidden by other clouds, inadvertent flight through an ash cloud may occur. It may be difficult to determine if you are in an ash cloud when flying through other clouds or at night. The following conditions may indicate you have inadvertently flown into an ash cloud:

1. Airspeed indications may fluctuate greatly or appear unusually high or low due to volcanic dust blocking the pitot-static system. Establish the proper pitch and power settings required by the Dash One or the NATOPS Flight Manual for flying with an unreliable airspeed indicator.
2. An acrid odor similar to electrical smoke may be present.
3. A rise in oil temperature could indicate dust-plugged oil cooler(s).
4. Torching (flames) from the engine tailpipe(s) may occur.
5. Volcanic ash/dust may be blown into the cockpit through the aircraft air conditioning system.
6. Windshields become pitted so severely that they are translucent. In addition, the abrasive cloud particles will sandblast the aircraft’s leading edges.
7. At night, St. Elmo’s fire and static discharges around the windshield are often visible. A bright orange glow in engine inlets frequently occurs.
8. At night, or in dark clouds, landing lights cast dark distinct shadows in ash clouds (unlike the fuzzy, indistinct shadows that are cast against moisture clouds).
9. Multiple engine malfunctions such as power surges, loss of thrust, high EGT, or compressor stalls. These result from ash buildup and blockage of the high-pressure turbine guide vanes and high-pressure turbine cooling ports.
10. More than one or all engines may flameout, since all engines are exposed to the same ash cloud.

If you encounter volcanic ash in flight, the best procedure is to perform a 180 degree turn immediately and leave the area. Consider also a reduction in altitude, as hot ash has most likely ascended in convective currents before forming the cloud. Reduce thrust to the minimum practical and monitor your engine instruments for indications of a possible flameout. If engines flameout, continue attempting restart procedures, as exiting the ash cloud may improve the probability of light off. Declare an in-flight emergency as soon as practicable, and land at the nearest suitable airfield. Transmit PIREPs to military weather stations to report the location of the volcanic ash cloud (to warn other aircrews). As soon as safely possible, record the altitude, location, duration of exposure, and any related malfunctions observed, since special aircraft cleanup procedures are required after flight through volcanic ash.

ASSIGNMENT SHEET 3-4-3

WEATHER HAZARDS REVIEW

A. INTRODUCTION

The purpose of this lesson is to provide the student with a background knowledge of aviation weather to include the hazards associated with turbulence, icing, ceiling and visibility, fog, and ash clouds.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

1. Review JPATS Aviation Weather Booklet, JX100 Chapter JX104
2. Read JPATS Aviation Weather Booklet, JX100 Chapter JX105

D. STUDY QUESTIONS

1. Which one of the following is NOT one of the classifications used to describe turbulence?
   a. Trace
   b. Light
   c. Moderate
   d. Extreme

2. Which one of the following may cause mechanical turbulence when air is flowing over it?
   a. Irregular terrain
   b. Buildings
   c. Mountains
   d. All of the above

3. Which one of the following is not one of the cloud formations associated with mountain wave turbulence?
   a. Lenticular cloud
   b. Roll cloud
   c. Rotor cloud
   d. Cap cloud

4. Frontal turbulence would be the most severe when associated with a ______.
   a. fast moving warm front
   b. fast moving cold front
   c. slow moving warm front
   d. slow moving cold front

5. Which one of the following is not one of the recommended procedures for flying through turbulence?
   a. Establish and maintain thrust settings consistent with cruise airspeeds
   b. Control attitude by referencing the attitude gyro indicator
   c. To avoid overstressing the aircraft, don’t make abrupt control inputs
   d. Allow airspeed and altitude to vary; don’t chase the altimeter

6. What conditions are necessary for the formation of ice on aircraft?
   a. Freezing temperatures, invisible moisture, and rain
   b. Freezing temperatures, visible moisture, and aircraft skin temperature below freezing
   c. Freezing temperatures, humidity above 75 percent, and aircraft skin temperature below freezing
   d. Freezing temperatures, strong head winds, and clear skies

7. An aviation hazard associated with structural icing is that it results in ______.
   a. a reduction of lift by changing the airfoil characteristics
   b. a decrease in airspeed
   c. a decrease in drag
   d. both a and c are correct

8. Clear icing will generally be encountered between a temperature ranges of______.
   a. –2° C to –10° C
   b. 0° C to –10° C
   c. 0° C to –20° C
   d. +2° C to –20° C

In questions 9 through 12, match the types of structural ice in column B with the correct descriptions in column A.

A	B
9. Formed from small super-cooled water droplets in stratiform clouds of stable air	a. Clear icing
10. Consists of ice crystals formed by deposition.	b. Rime icing
11. Formed by large individual water droplets freezing as they strike the aircraft surface	c. Mixed icing
12. Considered to be the most frequently encountered type of icing	d. Frost

13. What happens to stall speed when ice forms on the wings of an aircraft?
    a. It will increase
    b. It will decrease
    c. It will remain the same
    d. All of the above

14. Engine failure due to icing conditions encountered by a jet aircraft is generally the result of ______.
    a. carburetor icing
    b. a rapid drop in exhaust gas temperature
    c. a decrease in the fuel-air ratio
    d. induction icing

15. Ice in the pitot tube or static ports could affect instruments, depending on the type of aircraft and its system hookup.
    a. True
    b. False

16. Which one of the following would be correct if an aircraft attempted to take off without removing frost that has formed during the night?
    a. Increase in the stall speed
    b. Lift and drag/ratios will be affected
    c. Extensive weight increase
    d. All of the above are correct
    e. Only a and b are correct

17. Which one of the following types of clouds would you most likely be flying through if encountering clear icing?
    a. Nimbostratus
    b. Cumulus
    c. Cirrocumulus
    d. Both b and c are correct

18. Which one of the following is NOT one of the classifications used to describe icing?
    a. Light
    b. Moderate
    c. Severe
    d. Extreme

19. Which one of the following conditions would most likely result in frost on an aircraft?
    a. Cloudy nights, 5 knots of wind, dew point 28° F
    b. Clear nights, no wind, dew point of 28° F
    c. Clear nights, 5 knots of wind, dew point of 32° F
    d. Cloudy nights, no wind, dew point of 37° F

20. Which one of the following describes a basic type of fog classification?
    a. Air mass
    b. Advection
    c. Adiabatic
    d. All of the above are correct

21. Which one of the following will result in the saturation of an air mass?
    a. Rising dew point
    b. Lowering humidity
    c. Lowering dew point
    d. Rising temperature

22. A layer of condensed water vapor is considered to be fog if its base is at or below 20 feet above terrain elevation and greater than 50 feet in thickness.
    a. True
    b. False

23. Radiation fog could be expected in areas characterized by ______.
    a. low wind speed, and clear skies
    b. low wind speed, and cloudy skies
    c. high wind speed, and cloudy skies
    d. high wind speed, and clear skies

24. What phenomenon would your aircraft be flying through if experiencing a rise in oil temperatures, acrid odor (possibly from an electrical fire), airspeed fluctuations, pitted windscreens, and a bright orange glow around the engine inlets?
    a. Advection fog
    b. Microburst
    c. Volcanic ash cloud
    d. Mountain wave turbulence

Answers:

1. A	14.D
2. D	15.A
3. B	16.E
4. B	17.B
5. A	18.D
6. B	19.B
7. A	20.B
8. B	21.A
9. B	22.B
10.D	23.A
11.A	24.C
12.C	
13.A	

Turbulence

Turbulence Definition

Irregular or disturbed atmospheric flow producing gusts and/or eddies.

Intensity classification

Light

Moderate

Severe

Extreme

Light Turbulence

Momentary slightly erratic changes

Altitude

Attitude

Pitch

Roll

Yaw

Slight strain against seat belts and shoulder straps.

Unsecured objects displaced slightly.

Moderate Turbulence

Larger changes in altitude and/or attitude.

Variations in indicated airspeed.

Definite strain against seat belts and shoulder straps.

Unsecured objects dislodged.

Severe Turbulence

Large abrupt changes in altitude and/or attitude.

Large variations in indicated airspeed.

Unsecured objects tossed about.

Aircraft may be momentarily out of control.

Extreme Turbulence

Aircraft violently tossed about.

Control difficult or impossible.

Possible structural damage.

Declare Emergency.

Exit area ASAP

Duration of Turbulence

Occasional - Less than ⅓ of the time

Intermittent - ⅓ to ⅔ of the time

Continuous - More than ⅔ of the time

Classification and Types

Turbulence Classifications

Turbulence classified by causative factors.

Thermal

Mechanical

Frontal

Wind Shear

Clear Air Turbulence (CAT)

Not associated with clouds or convective activity.

Usually in Jet Stream.

Most severe there

Any of four classifications can be CAT.

Wind shear almost always CAT.

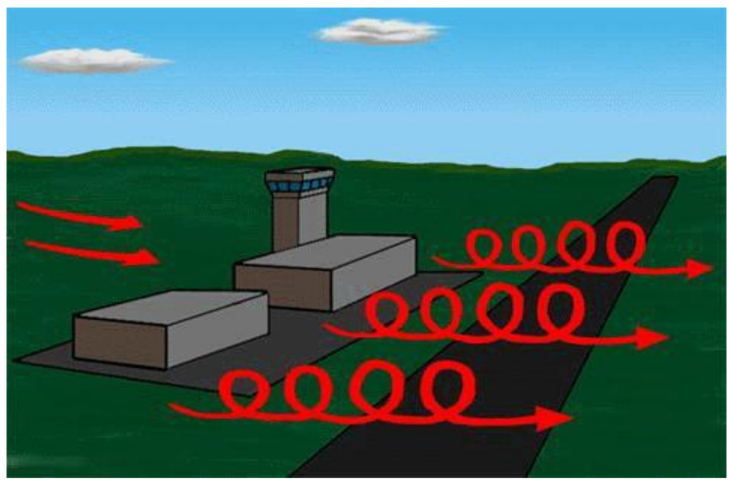
Thermal Turbulence

- Also called Convective Turbulence.
- Vertical air movement
  - Result of heating from below.
  - Solar heating
  - Cold air moving over warmer surface.
  - Strength depends on type of surface.

Thermal Turbulence

Mechanical Turbulence

- Caused by passage of wind over obstructions.
  - Buildings
  - Irregular terrain/ mountains
- Strength and magnitude dependent on
  - Wind speed
  - Roughness of terrain
  - Stability of the air



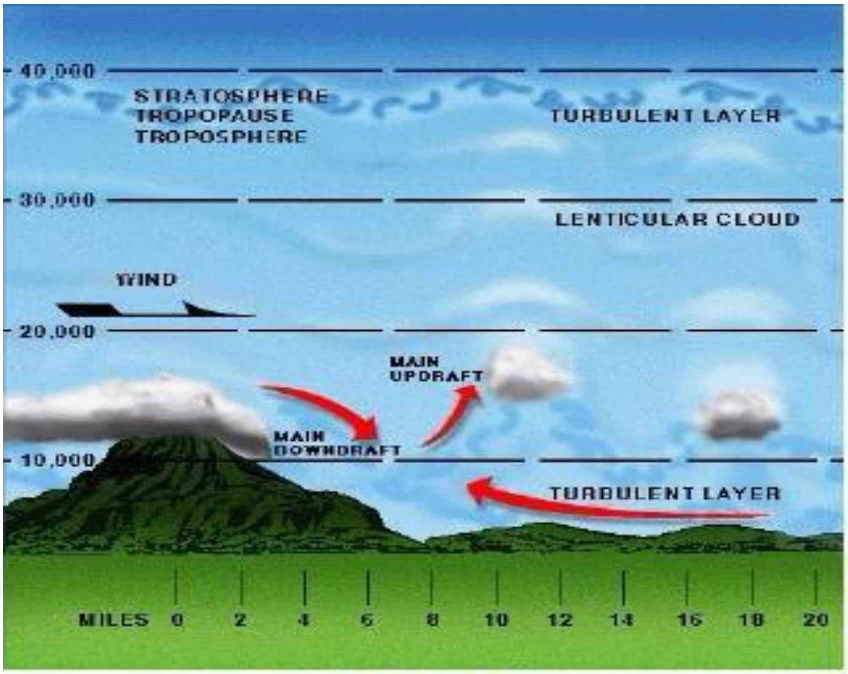
Mountain Wave

Strong winds blowing perpendicular to a mountain range.

Form standing waves

Turbulence can be in clear air as well as in clouds.

Clouds best way to determine if turbulence present.



Mountain Wave

Rotor Cloud

Form downwind from and parallel to mountain range.

Cylindrical shape

Downward flow has been known to reach the ground.

Cap Clouds

Cover top of mountain

Remain stationary

Lenticular Clouds

Form on leeward side of mountain from standing waves.

Local Intensities

Rule of thumb for turbulence proximity/intensity

With 50 knots wind at altitude of peak - EXTREME

Up to 150 miles downwind - SEVERE

Up to 300 miles downwind - MODERATE

Avoiding Mountain Wave Turbulence

Circumnavigate if possible.

Fly 50% higher than peak.

Avoid rotor, cap, and lenticular clouds.

Approach mountain range at a 45° angle.

Avoid strong downdrafts on leeward side of mountain.

Pressure changes affect pitot-static instruments.

Fly recommended turbulent air penetration speed.

Frontal Turbulence

Caused by warm air lifted by cold front.

Most severe in fast-moving front.

No turbulence in warm front due to little or no lifting.

Wind Shear Turbulence

Sudden change in wind speed or direction over short distance, vertically or horizontally.

Generally occurs in clear air.

Greater the change more severe the turbulence.

Three types

Jet stream Gusty winds

Temperature inversion

Land and sea breezes, mountain winds, thunderstorms also produce wind shears.

Wind Shear - Jet Stream

Rapid change of wind speed short distance from core.

Vertical shear more significant than horizontal.

Exit by turning south or changing altitude.

Wind Shear - Gusty Winds

Gusty winds at low levels can create problem during approach and landing or takeoff.

Wind Shear - Temperature Inversion

Extreme wind shear turbulence may be formed when strong inversion exists near ground.

Stable conditions near ground

If strong winds exist in upper warmer air

Wind shear produced at layer boundary

Sudden change in wind direction/velocity causes loss of airspeed, lift.

Can be catastrophic if not compensated.

Closer inversion to ground, less time to react.

Can be unexpected in clear air.

Compensate with added airspeed.

Anticipate higher descent rates.

Turbulence Procedures

Maintain PCL setting consistent with desired turbulent air penetration airspeed.

Trim aircraft for level flight.

Do not chase airspeed deviations with power corrections.

Severe turbulence causes large rapid variations.

Allow altitude to vary; do not chase altimeter.

Vertical gusts cause significant altitude deviations.

Maintain pitch and bank by reference to attitude indicator.

Aircraft Icing

Icing Classification

Aircraft icing classified into two main groups.

Structural icing

Engine icing

Icing Categories

Structural icing

Forms on external surfaces of aircraft.

Icing types:

Clear

Rime

Mixed

Frost

Engine icing

Affects engine areas

Compressor icing

Induction icing

Icing Requirements

Visible moisture

Super-cooled water droplets

Liquid water at air temperatures below freezing

Clouds most common form

Free air temperature and aircraft’s surface temperature below freezing.

Clear Icing

Found at temperatures between 0° and -10° C.

Large water droplets freeze slowly, spreading out and assuming shape of airfoil.

Found in cumulus clouds; unstable conditions.

Rime Icing

Found at temperatures between -10° and -20° C.

Small water droplets freeze instantaneously, retaining shape.

Air bubbles do not escape, causing opaque (milky white) color and brittleness.

Found in stratiform clouds; stable conditions.

Mixed Icing

Combination of clear and rime.

Most common type.

Found at temperatures between -8° and -15° C.

Lumpy (like rime) but hard and dense (like clear).

Frost

Occurs on clear, calm nights.

Lack of clouds promotes radiational cooling.

Little or no wind allows moisture to deposit as ice crystals (deposition).

May also form in flight when descending from below freezing temperatures into high humidity.

Does not add weight, but still disrupts boundary layer air flow over wings, increasing stall speed.

Frontal Icing - Warm Front

Stratiform clouds

Rime icing

Low rate of accumulation

Widespread area of icing

Frontal Icing - Cold Front

Cumuliform clouds

Clear Icing

High rate of accumulation

Limited area of icing

Frontal Icing - Occluded Front

Mixed clouds

Stratus and cumulus

Mixed icing

Rime, clear, and mixed

Rapid and heavy accumulation

Very widespread area of icing

Effects and Hazards

Aerodynamic Effects

Most hazardous aspect of structural icing.

Alters shape of airfoil changing the stall angle of attack.

Performance Effects

Decreases

Lift

Thrust

Range

Increases

Drag

Weight

Fuel consumption

Stall speed

Effects on stall speed can be fatal if not predicted.

All others provide time to take appropriate action (except lift, during takeoff).

Other Effects

Pitot-static system - faulty instrument indications

Inhibits control surface movement and antenna transmission.

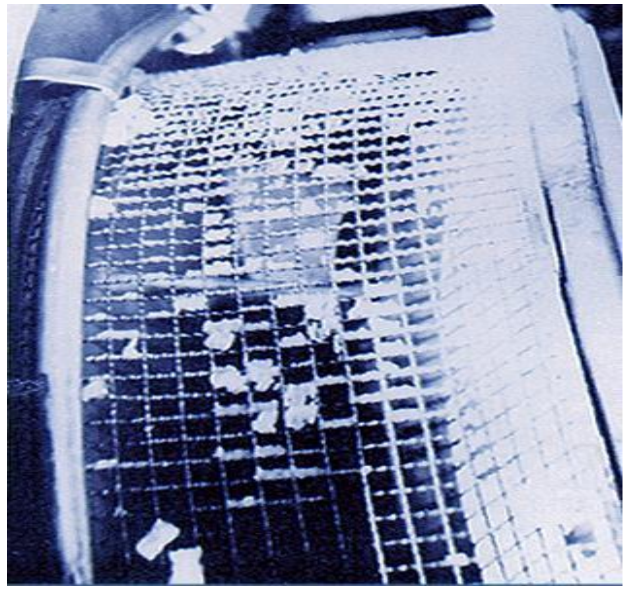
Other Types of Icing

Engine Icing

Two types of engine icing

Induction icing

Compressor icing



Induction Icing

Also known as inlet icing.

Clear skies and above freezing temperatures.

Taxi and departure

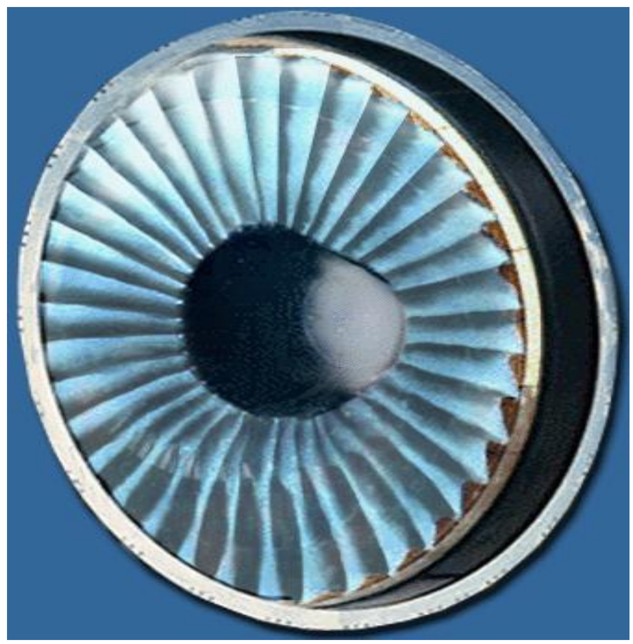
Reduced pressures in intake system.

Lowers temperature

Condensation

Ice formation

High probability with air temperatures +10° C or less and high relative humidity.



Compressor Icing

Forms on compressor inlet guide vanes.

Both induction and compressor icing restrict airflow and could FOD engine.

Ground Icing Hazards

Frost usually found first thing in morning.

Remove prior to flight.

De-icing fluids highly corrosive.

Should not be sprayed down intakes or other openings.

Other Ground Hazards

Taxiing through mud, slush, or water.

Splashed on aircraft surfaces.

Can freeze later at higher altitudes and colder temperatures.

Runway braking conditions

Hazardous to control during braking of aircraft.

Avoiding Icing Hazards

Avoiding Icing

Icing conditions

Visible moisture

0° to -20° C

At low altitude or mountainous terrain

Two options when encountered

Climb

Out of visible moisture

To colder temperature

Frozen moisture not an icing hazard.

To warmer temperature

If below warm front or temperature inversion.

Descend

Out of visible moisture

Below freezing level

If visible moisture or freezing level on surface, descending not an option.

Anti-Ice/De-Ice

Anti-Ice

Prevents icing

De-Ice

Removes existing ice

Three types of anti-ice/de-ice equipment

Fluid

Lowers freezing point of water.

Ground fluids sprayed on aircraft.

Prevent or remove icing.

In-flight fluids

Pumped onto aircraft surfaces to prevent icing.

Mechanical

Rubber bladders on leading edge of airfoils.

Expand and contract

Prevent ice buildup

Most common on thick-winged aircraft.

Heat

Increases aircraft surface temperature.

Anti-icing or de-icing

Electrically

Hot air bled off engine

Minimizing Icing Effects

Avoid areas of known or forecast icing.

Avoid clouds and precipitation at temperatures between 0° and -20° C.

Especially at low altitudes over mountainous terrain

Minimize bank angle and high AOA

Increased stall speed

Climbing may alleviate icing conditions associated with warm fronts.

Do not fly parallel to a front in icing conditions.

Maximizes exposure time to icing.

Remove ice or frost prior to takeoff.

USE COMMON SENSE!

Icing Intensities

Icing reported in PIREPs by type (clear, rime, mixed) and intensity.

TRACE

Ice becomes perceptible.

Rate of accumulation slightly greater than sublimation.

De-icing/anti-icing not used unless encountered for extended time.

LIGHT

Rate of accumulation can be a problem over extended time (over one hour).

Occasional use of de-ice/anti-ice equipment prevents accumulation.

Not a problem if equipment used.

MODERATE

Rate of accumulation potentially hazardous.

Even for short encounters

De-ice/anti-ice equipment or diversion necessary.

SEVERE

Rate of accumulation extreme.

De-ice/anti-ice equipment fails to reduce or control.

Immediate diversion necessary.

Visibility

Visibility

Ability to see and identify.

Prominent unlighted objects by day

Prominent lighted objects at night

Expressed in

Statute miles

Hundreds of feet

Meters

Flight Visibility

Average forward horizontal distance from cockpit.

See and identify.

Prominent unlighted objects by day

Prominent lighted objects at night

Measured in statute miles

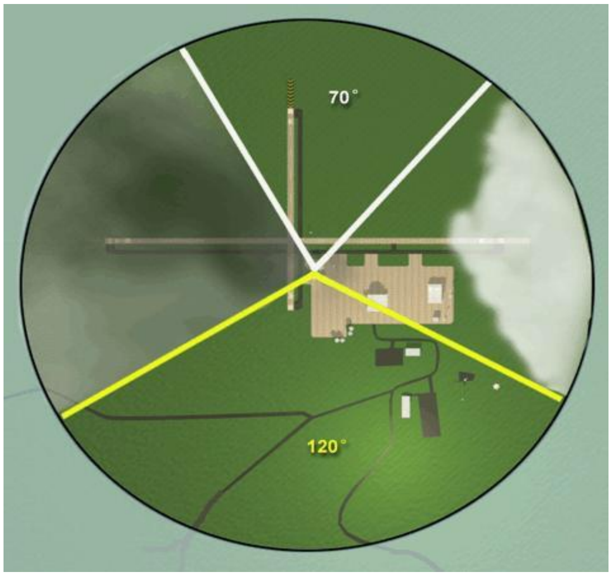
Prevailing Visibility

Greatest horizontal visibility

Equaled or exceeded throughout over half horizon circle.

Measured in statute miles.

Need not be continuous.



Slant Range Visibility

Distance on final approach at which runway environment in sight.

May be reported by PIREP.

Can be estimated by meteorologists.

Runway Visual Range (RVR)

Horizontal distance seen by looking down runway from approach end.

Reported in meters or hundreds of feet.

Obscuring Phenomena

Visibility reported obscured

When reduced less than 6 miles.

Cause reported

Depending on phenomenon, visibilities can differ greatly in same location with different points of view.

Types of phenomena:

Fog

Haze

Smoke

Rain and drizzle

Snow

Blowing snow, dust, or sand

Sky Coverage and Ceilings

Sky Coverage

Reported in eighths

Height of cloud bases given in hundreds of feet AGL.

Ceiling

Height above ground (AGL)

Lowest broken or overcast layer

Vertical visibility (VV) into an obscuring phenomenon.

Reportable Contractions	Meaning	Amount of Sky Cover
SKC or CLR[1]	Sky Clear	0
FEW[2]	Few	> 0/8 - 2/8
SCT	Scattered	3/8 - 4/8
BKN	Broken	5/8 - 7/8
OVC	Overcast	8/8
VV	Obscured[3]	8/8 (surface based)

1. The abbreviation CLR is used at automated stations when no clouds at or below 12,000 feet are reported; the abbreviation SKC is used at manual stations when no clouds are reported.
2. Any amount less than 1/8 is reported as FEW.
3. The last 3 digits report the height of the vertical visibility into an indefinite ceiling.

Obscurations

Vertical visibility (VV) is distance seen directly upward from the ground into a total obscuration.

Used when sky is totally hidden.

Base within 50 feet of surface.

Hazardous

Reduces slant range visibility

Referred to as indefinite ceiling.

Fog

Fog Definition

Visible layer of condensed moisture.

Base at or within 50 feet of surface.

Greater than 20 feet thick.

Reduces visibility to less than ⅝ mile.

Must meet all three conditions to be fog.

Two types of fog

Radiation

Advection

Requirements

Conditions required for formation of fog.

Condensation nuclei

High moisture content

Small temperature/dew point spread

Near equal (saturation)

Light surface winds

1 - 10 knots

Radiation Fog

Caused by nocturnal radiation cooling.

Rate depends on

Surface composition

Vegetation

Cloud coverage

Ceiling

Light winds

Dissipation begins as sun warms surface.

Advection Fog

Warm moist air moves over cool surface.

At or near saturation

Cool surface reduces temp/dew point spread.

Usually forms over water.

Brought inland by winds.

Winds can be stronger.

Very thick layer

Only wind shift can dissipate.

Persistent

Volcanic Ash Clouds

Volcanic Ash Clouds Overview

Severe effects on aircraft and ability to remain airborne.

Must avoid areas of known volcanic activity.

Eruption at night or near your time of flight.

Presence unknown until entering ash cloud.

Radar detection unlikely

Small size of particles

Volcanic Ash Cloud

- Flight in volcanic ash indicated by
  - Torching (flames) from engine tailpipe
  - St. Elmo's Fire like effect
  - Bright glow in engine inlets
- Hazards
  - Multiple engine malfunctions
    - Flameout
    - All engines affected on multi-engine aircraft.
  - Pitted windscreens
    - Affecting cockpit visibility
  - Sandblasting of external surfaces
- Avoidance
  - Avoid flying in areas of known volcanic activity.
  - If encountering ash cloud
    - Do not proceed or try to fly over or under.
    - Hundreds of miles long
    - Thousands of feet thick
    - 180° turn to escape
    - Notify nearest ATC and transmit PIREP.

OUTLINE SHEET 3-5-1

THUNDERSTORMS

A. INTRODUCTION

The purpose of this lesson is to provide the student with a general discussion of thunderstorms, including their associated hazards, microbursts and their hazards, and techniques to avoid them.

B. ENABLING OBJECTIVES

2.273 DESCRIBE the hazards associated with thunderstorms, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.274 DESCRIBE the signs and hazards associated with microbursts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.275 EXPLAIN how radar can aid a pilot when flying in the vicinity of thunderstorms, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.276 DESCRIBE the recommended techniques for avoiding thunderstorm hazards, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. Thunderstorm Development
2. Tornadoes
3. Microbursts
4. Icing
5. Radar Thunderstorm Information
6. Avoiding
7. Penetration

INFORMATION SHEET 3-5-2

THUNDERSTORMS

A. INTRODUCTION

The purpose of this lesson is to provide the student with a general discussion of thunderstorms, including their associated hazards, microbursts and their hazards, and techniques to avoid them.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. JPATS Aviation Weather Booklet, JX100
3. Flight Information Handbook

C. INFORMATION

OVERVIEW

Thunderstorms contain many of the most severe weather hazards. They are often accompanied by strong wind gusts, severe turbulence, lightning, heavy rain showers, severe icing, and possibly hail and tornadoes. As a result, thunderstorms should be avoided if possible.

About 44,000 thunderstorms occur daily over the earth and pilots can expect to encounter one occasionally. In some tropical regions, thunderstorms occur year-round. In the mid-latitudes, they develop most frequently in spring, summer, and fall. This chapter presents hazards a pilot must consider when flying in the vicinity of, or actually entering, a thunderstorm. Being familiar with these factors will help you better understand what is going on both inside and outside the cockpit. Knowledge of thunderstorm characteristics and the application of tested procedures will help aircrews operate more safely near thunderstorms.

THUNDERSTORM DEVELOPMENT

The basic requirements for thunderstorm formation are moisture, unstable air, some type of lifting action, and building up through the freezing layer. Lifted air does not always result in thunderstorm activity. Air may be lifted to a point where the moisture condenses and clouds form, but these clouds may not grow significantly unless the air parcel reaches a point where it will continue to rise freely. This point is more easily reached when the moisture content is high. One of the four lifting methods (from Chapter 2) is necessary to force warmer air from its lower level to the point of free convection, which is the trigger to starting the cumulus cloud through the thunderstorm life cycle. Once moist air is lifted in an unstable environment, the rapidly rising unstable air quickly forms towering cumulus and eventual cumulonimbus clouds. The degree of vertical cloud growth often indicates the potential severity of the thunderstorm.

THE LIFE CYCLE OF A THUNDERSTORM CELL

Thunderstorm cells progress through three stages during their life cycle: the cumulus, mature, and dissipating stages. A thunderstorm cell is simply an individual cumulonimbus cloud. It is virtually impossible to visually detect the transition from one stage to another. A thunderstorm often consists of a cluster of cells in different stages. The life cycle of each thunderstorm cell ranges from 20 minutes to 1½ hours with a few lasting up to three hours. The life span of a line of thunderstorms depends on the number of cells contained in the line and their stage of development.

Life Cycle of a T-Storm

1. Cumulus- Updrafts
2. Mature- Updrafts, Downdrafts and Hazards
3. Dissipating- Downdrafts and Hazards

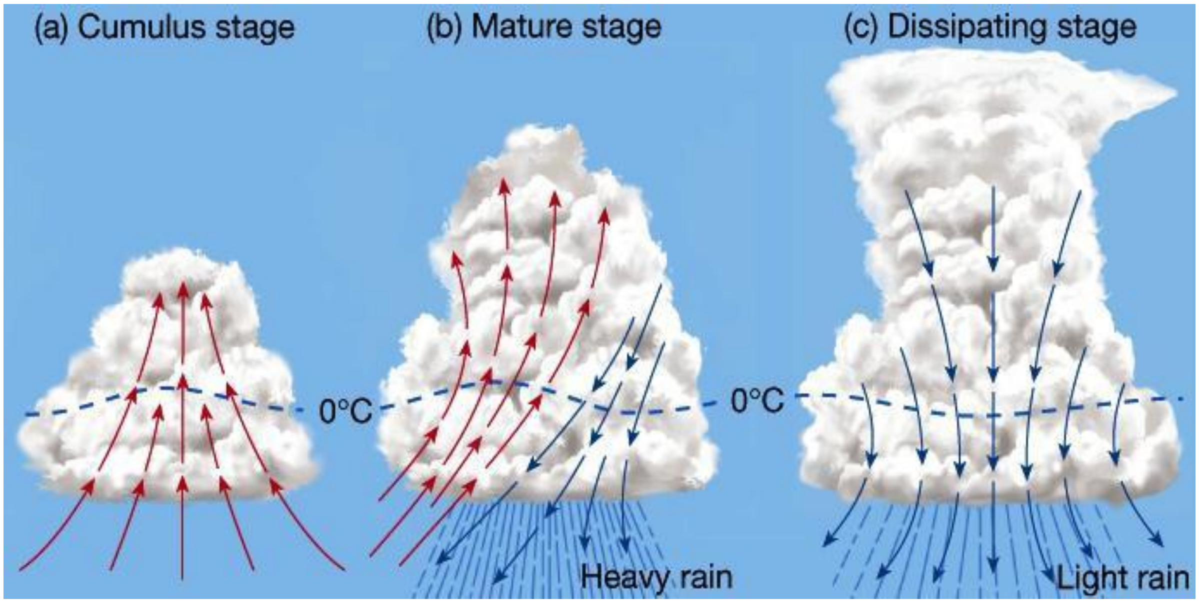


Figure 5-1 – Thunderstorm Life Cycle

Cumulus Stage

Most cumulus clouds do not become thunderstorms. However, the initial stage of a thunderstorm is always a cumulus cloud. The main feature of the cumulus stage is the updraft which may extend from near the Earth's surface to several thousand feet above the visible cloud top. The strongest updrafts occur at higher altitudes late in the stage and may be greater than 3000 feet per minute. No precipitation is associated with this stage, however significant turbulence exists.

Mature Stage
The mature stage is reached when the raindrops and ice particles in the cloud have grown too large to be supported by the updrafts and begin to fall. Rain and/or hail falling from the cloud base indicates a downdraft has developed and the cell has entered the mature stages. The average cell grows to a height of 25,000 feet during this stage. At higher latitudes, tops may be as low as 12,000 feet.

Dissipating Stage
Downdrafts continue to develop while the updrafts continue to weaken during the mature stage. As a result, the entire thunderstorm cell becomes an area of downdrafts with precipitation in the dissipating stage (Figure 5-2). Thunderstorms begin to dissipate when the updrafts, which are necessary to produce condensation and the resulting release of heat, are no longer present. During this stage the strong winds aloft may carry the upper section of the cloud into the familiar anvil form. However, the appearance of an anvil does not indicate the thunderstorm is free of hazards. Severe weather is present in many storms with a well-developed anvil.

	Updrafts	Downdrafts	Hazards
Cumulus	√		
Mature	√	√	√
Dissipating		√	√

Figure 5-2 Summary of Thunderstorm Stage Characteristics

THUNDERSTORM WEATHER HAZARDS
Thunderstorms are accompanied by some or all of the following hazards: extreme turbulence, hail, microbursts, severe icing, lightning, and tornadoes.

Extreme Turbulence
Extreme turbulence is the most severe hazard associated with thunderstorms. One of the major characteristics of every thunderstorm is updrafts and downdrafts that can occur near each other creating strong, vertical shear and turbulence. This turbulence can extend over 5000 feet above the cloud tops and down to the ground beneath the cloud base. It can damage an airframe and cause serious injury to passengers and crew.

The first gust or gust front of an approaching thunderstorm is another form of turbulence that can cause a rapid and drastic change in the surface wind (Figure 5-1). An attempt to take off or land with an approaching thunderstorm nearby could have disastrous results. Gust fronts can travel 5 to 20 miles from the thunderstorm.

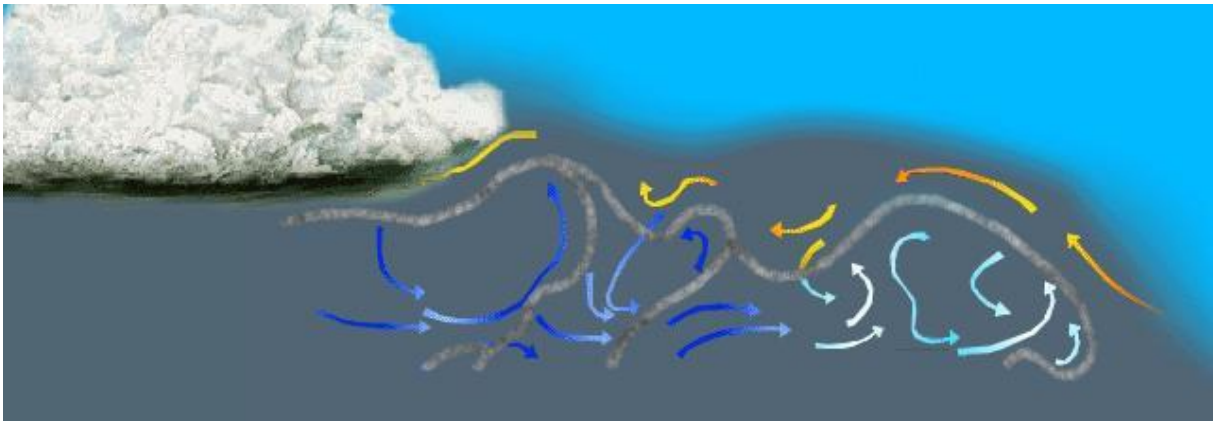


Figure 5-1 — Gust Front

A roll cloud on the lower leading edge of a cumulonimbus cloud marks an area of strong eddy currents and identifies the location of wind shear and severe turbulence occurring with the onset of the gust front (Figure 5-3).

Figure 5-3 — Roll Cloud

Large pressure changes can accompany thunderstorm formation due to the turbulence of updrafts and downdrafts. Therefore, if the altimeter setting is not updated, the indicated altitude might be in error by over 200 feet. The pressure variations associated with thunderstorms follow a common pattern:

1. A rapid fall in pressure as the storm approaches
2. An abrupt rise in pressure with the onset of the first gust and arrival of rain showers
3. A gradual return to normal pressure as the storm passes and the rain ceases

Hail
As a rule, the larger the storm, the more likely it is to produce hail. Hail has been encountered as high as 45,000 feet in completely clear air and may be carried 10 to 20 miles downwind from the storm core. Aircrews should anticipate possible hail with any thunderstorm, especially beneath the anvil of a large thunderstorm. Hailstones larger than ½ to ¾ of an inch (Figure 5-4) can cause significant aircraft damage in only a few seconds. Give yourself a clearance of at least 20 miles around a thunderstorm.

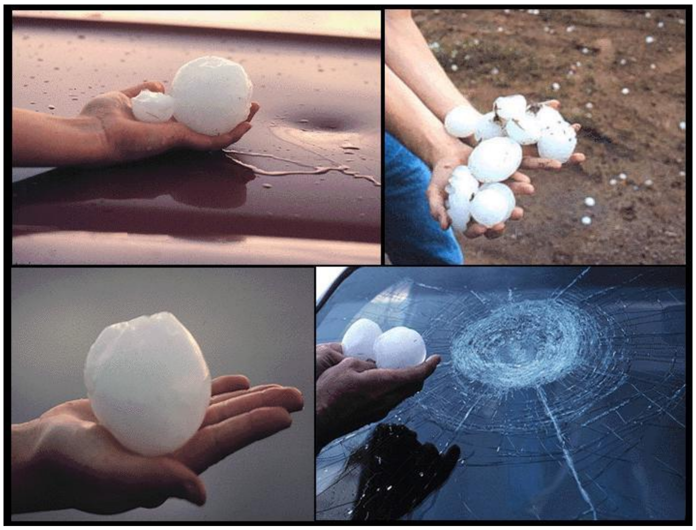


Figure 5-4 — Hailstones

Lightning and Electrostatic Discharge
Lightning occurs at all levels in a thunderstorm. The majority of lightning bolts never strike the ground, but occur between clouds or within the same cloud. Lightning also occurs in the clear air around the tops, sides, and bottoms of storms. Aircrews flying several miles from a thunderstorm can still be struck by the proverbial “bolt out of the blue.” Lightning strikes can also occur in the anvil of a well-developed or dissipated thunderstorm. Additionally, lightning strikes in the anvil have occurred up to 3 hours after the thunderstorm has dissipated.
An electrostatic discharge (ESD) is similar to a lightning strike, but it is caused by the aircraft itself. The larger and faster the aircraft, the more particles it impacts, generating a greater static electricity charge on the airframe. The electrical field of the aircraft may interact with the cloud and an electrostatic discharge may then occur. Aircraft have reported damage from electrostatic discharges occurring in cirrus clouds downwind of previous thunderstorm activity, in cumulus clouds around a thunderstorm’s periphery, and even in stratiform clouds and light rain or showers. This release of static electricity is frequently called Saint Elmo’s fire.

Aircraft Lightning or ESD Encounters
Lightning strikes and electrostatic discharges are the most reported weather related aviation incidents. All types of aircraft are susceptible to lightning strikes and electrostatic discharges. Aircraft have been struck by lightning or experienced electrostatic discharges at altitudes ranging

from the surface to at least 43,000 feet.

Most lightning strikes occur when aircraft are operating in one or more of the following conditions:

1. Within 8° C of the freezing level
2. Within approximately 5000 feet of the freezing level
3. In precipitation, including snow
4. In clouds
5. In some turbulence

It should be noted that not all these conditions need to occur for a lightning strike or an electrostatic discharge to take place.

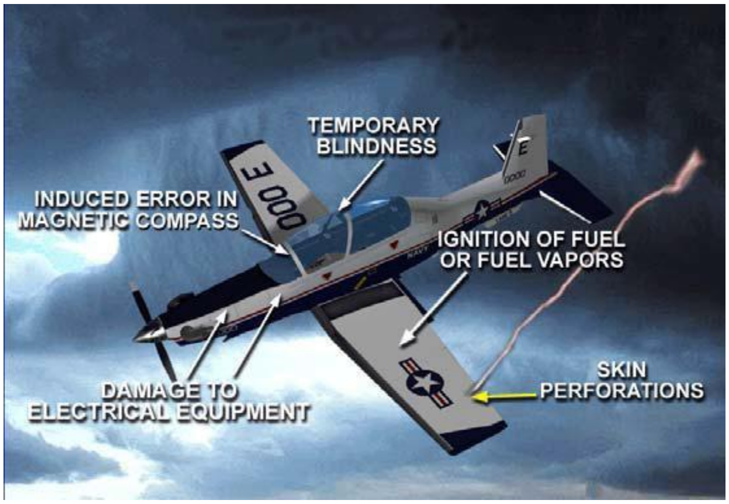


Figure 5-5 — Lightning Hazards

Lightning strikes have varied effects on aircraft and aircrews (Figure 5-5). Usually the structural damage is minor, but it has the potential to be severe. Normally, it will only interrupt electrical circuits, causing damage to aircraft electrical systems, instruments, avionics, or radar.

Catastrophic fuel ignition can occur under certain conditions. In non-pressurized fuel tanks, a mixture of vaporized fuel and air fills the space above the liquid fuel. The proper ratio of fuel vapor to air can form a highly explosive mixture. For this reason, as well as for battle survivability, most military aircraft fuel tanks are pressurized.

Pilots are not immune to the effects of lightning strikes, either. Temporary night vision degradation can occur due to flash blinding, but this effect can be minimized by turning cockpit lighting to maximum intensity. Some pilots have also experienced mild electric shock and minor burns.

Tornadoes
A tornado is a violent, intense, rotating column of air that descends from cumulonimbus clouds in funnel-like or tube-like shapes. If the circulation does not reach the surface, it is called a funnel cloud. If it touches down over the water, it is called a waterspout. A tornado vortex is normally several hundred yards wide, but some have been measured up to 2½ miles wide. Within the tornado's funnel-shaped circulation, winds have been measured at speeds over 300 miles per hour, while the forward speed of tornadoes averages 30-40 knots.

Observed as appendages of the main cloud, tornadoes often form in groups or families of funnel clouds, some as far as 20 miles from the lightning and precipitation areas. Innocent looking cumulus clouds trailing a thunderstorm may mask tornadic activity, and the vortex may not be visible to warn unwary aircrews. The invisible vortices may be revealed only by swirls in the cloud base or dust whirls boiling along the ground, but may be strong enough to cause severe damage to aircraft.

Tornadoes form only with severe thunderstorms. The hazards they present have been chronicled often by news reports and television documentaries. To avoid tornadoes, avoid areas of severe thunderstorm activity.

MICROBURSTS
A microburst is an intense, highly localized downward atmospheric flow with velocities of 2000 to over 6000 feet per minute. This downward flow diverges outward, producing a vortex ring of wind that can produce differential velocities ranging from 20 to 200 knots in an area only ¼ to 2½ miles in diameter (Figures 5-6 and 5-7). Microbursts may emanate from any convective cloud, not just cumulonimbus clouds. Another unique aspect of a microburst is its short life span–usually only 5 to 10 minutes after reaching the ground–which makes the study, and hence the prediction, of microbursts a difficult task.

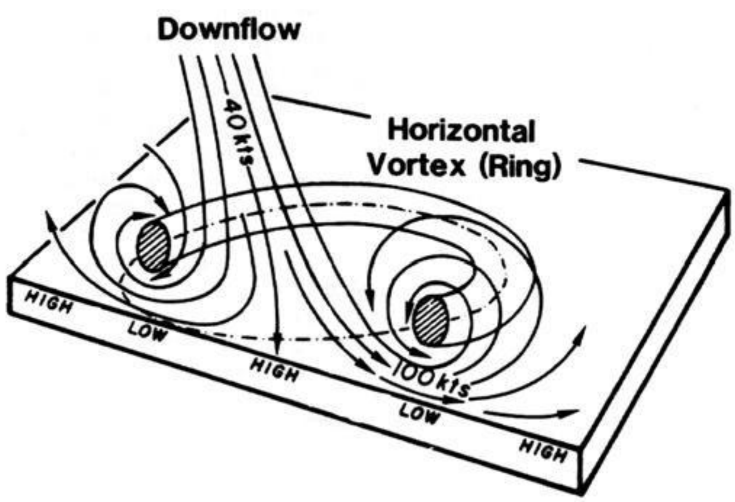


Figure 5-6 — Vortex Ring of a Microburst

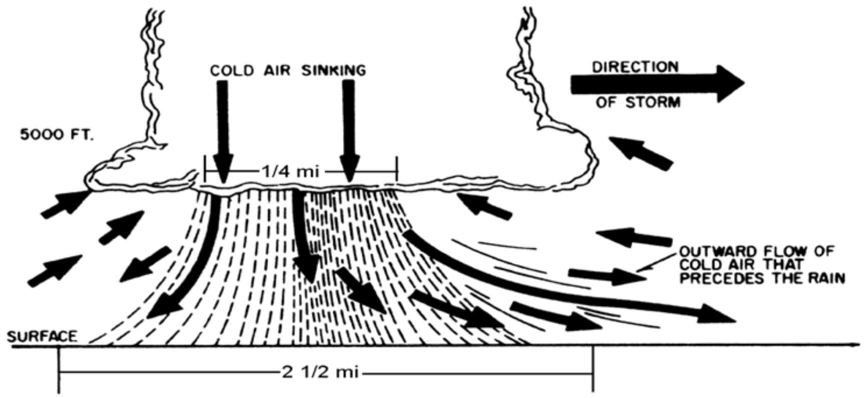


Figure 5-7 — Cross Section of a Microburst

The wind shear created by microbursts is extremely dangerous to aircraft during the takeoff, approach, and go-around phases of flight. Not all microbursts are associated with thunderstorms. Microbursts are possible with any rain shower, even if the rain isn't reaching the ground (virga).

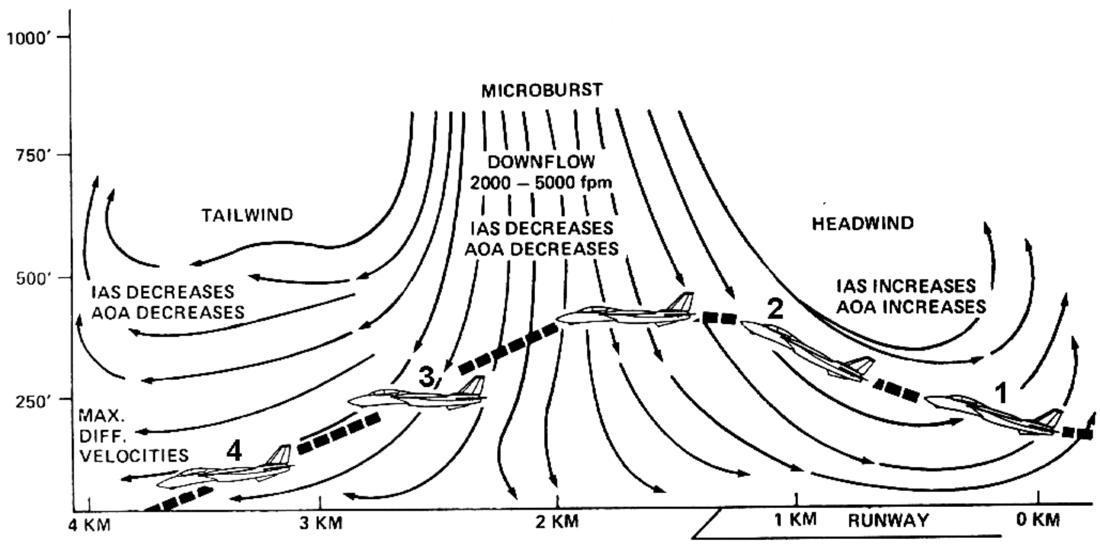


Figure 5-8 — Attitude Changes with Microburst Penetration

In Figure 5-8, the aircraft at position 1 has entered a microburst. At this point, the crew may notice an increased angle of attack as the aircraft enters the upward flow of the vortex ring. Once inside the microburst, the aircraft will experience a strong increase in headwind, with a resulting increase in indicated airspeed and lift, which will cause the aircraft to pitch up (position 2). A natural reaction of the pilot would be to reduce power and apply nose down stick force. This would correct the situation if the aircraft was not in a microburst, and would appear to work here until the reaching position 3. At this point, the aircraft will be in a severe downdraft, and a transition from a strong headwind to a strong tailwind will occur (position 4). The resulting loss of indicated airspeed and lift will cause the aircraft to pitch down and lose altitude. At this point (or earlier), the correct reaction would be to add maximum power and establish a climbing attitude on the vertical gyro. Chances of successful recovery depend on reaction time, aircraft performance capabilities, and the altitude of the aircraft.

If you encounter a microburst on final approach or on takeoff, the results could be disastrous. The best course of action is to avoid microbursts at all costs. This point cannot be over emphasized. You must always be alert for the warning signs of a microburst. Remember–avoid, avoid, avoid. You may only get one chance to make a life or death decision.

Methods of Microburst Detection
Because microbursts are such a dangerous phenomenon, early detection is vital to mishap prevention. In most microburst accidents there have been warning signs that were ignored, misinterpreted, or misunderstood. You must evaluate the warning signs and make a decision quickly and decisively. Here are some very important clues that indicate the presence of microburst.

Ground-based Doppler radar now has the capability to accurately detect hazards that can take the form of microbursts, tornadoes, and other low-level wind shear activity. Therefore, when weather observations or recordings mention low-level wind shear, or call for gusty winds, heavy rain, or severe thunderstorms, be aware that the potential for microburst activity exists.

Visual cues are also very important in detecting microbursts. In fact, in many fatal wind shear mishaps the pilot continued the approach or takeoff in visible and known thunderstorm conditions. Visual cues include virga, localized blowing dust (especially in circular or elliptical patterns), rain shafts with rain diverging away from the core of the cell, roll clouds, and, of course, experiencing vivid lightning or tornado-like activity.

If you suspect the potential for wind shear conditions prior to takeoff or landing, get additional information from the tower or base weather station to include the latest radar report and pilot reports (PIREPs). Some airfields even have a wind shear warning system to help you. These sources will not identify every microburst situation, so if in doubt, wait it out! If you do encounter a wind shear condition, you must make a PIREP to warn fellow aviators about the dangerous situation. Your PIREP should include the location where the activity was encountered, an estimate of its magnitude and, most importantly, a description of what was experienced, such as turbulence, airspeed gain or loss, glidepath problems, etc.

Icing
Expect severe icing in thunderstorms where the free-air temperature is at or below freezing. Since heavy rainfall and turbulence most frequently occur at the freezing level, this particular altitude appears to be the most hazardous. Most of the icing, however, occurs in the top ⅔ of the thunderstorm cell. Note that the actual altitude of the freezing level will fluctuate with the up and down drafts, and it will be lower in the area of downdrafts. Due to the heavy amounts of moisture and large water droplets, the icing in thunderstorms is mostly clear icing, accumulating rapidly on the airfoils and other aircraft surfaces. Other aspects of icing were covered in more

detail in Chapter 4.

RADAR THUNDERSTORM INFORMATION

Ground-based weather radar is the most accurate means of tracking thunderstorms. In addition to the locating and tracking of cumulonimbus cells, their intensities can also be determined. The large drops of water and hail, if present, within thunderstorms yield the strongest return signals. Smaller droplets result in dimmer areas on the scope and snow produces the faintest echo. Detection and warnings are more accurate with the modern NEXRAD Doppler radar systems (Figure 5-9). This is particularly true for microbursts and wind shear alerts.

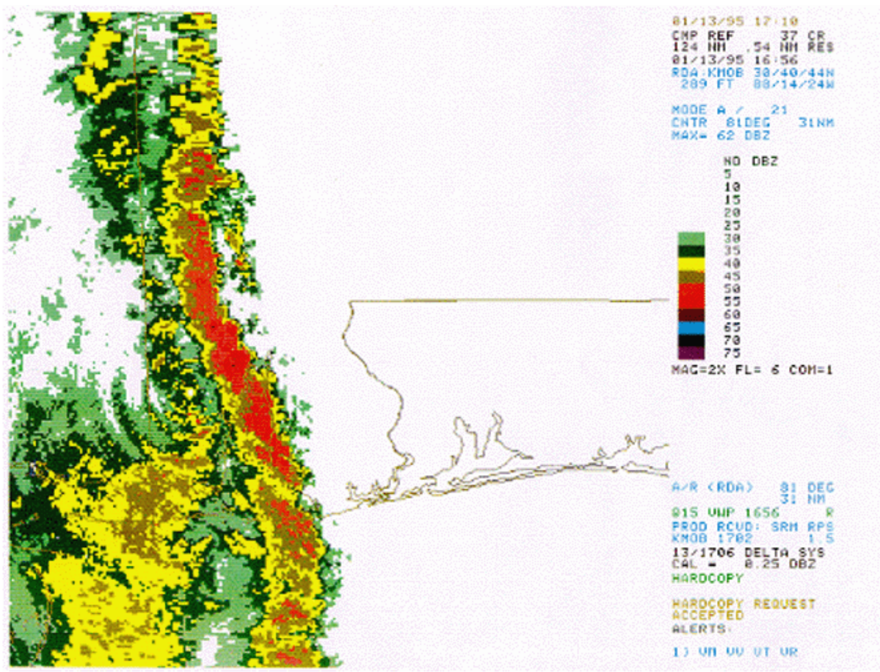


Figure 5-9 — NEXRAD Doppler Radar Composite

A direct relationship exists among the strength of the radar echoes, the presence of aircraft icing, and the intensity of turbulence. Stronger radar echoes are associated with more severe thunderstorms.

The following weather radar information is of particular interest to pilots:

1. A thunderstorm with radar echo tops indicated above 35,000 feet often contains extreme turbulence and hail.
2. Hazardous weather associated with scattered echoes can usually be circumnavigated. However, if the lines or areas are reported as broken or solid and are of moderate to strong intensity, hazardous weather can be avoided only if the aircraft is radar equipped.
3. Severe clear air turbulence and hail may be experienced between thunderstorms if the separation between echoes is less than 30 miles.

Ground-based weather radar is the most valuable to a pilot when there are numerous thunderstorms that are obscured by multiple cloud layers. However, echoes can change shape, character, and intensity in a matter of minutes when updrafts reach velocities of over 6000 feet per minute. Therefore, radar information received before takeoff may be worthless by the time thunderstorms are encountered.

A pilot with airborne weather radar should remember that radar does not eliminate the hazards of the thunderstorm. It merely helps to locate the most severe conditions. Since the radarscope indicates only precipitation areas within thunderstorms, hazards can be encountered even in soft spots. Thunderstorms having frequent, vivid lightning discharges are especially dangerous.

Airborne weather radar should be used as an avoidance rather than penetration tool. The pilot should take time to properly evaluate scope indications and watch for trends in order to avoid the most intense echo patterns. The pilot without airborne weather radar should make no attempt to find soft spots on the basis of any radar information that is not current up-to-the-minute.

FLIGHT TECHNIQUES IN THE VICINITY OF THUNDERSTORMS
Since thunderstorms have so many potential hazards, it is appropriate to list some recommended practices for pilots who must cope with these “uninvited guests.” As far as flying is concerned, there is no such thing as a small thunderstorm, so some common sense recommendations are provided below:

1. If at all possible, avoid thunderstorms.
2. Do not venture closer than 20 miles to any storm cloud with overhanging anvils because of the possibility of encountering hail.
3. Do not attempt to fly under thunderstorms in mountainous regions even if the area on the other side of the mountains can be seen. Winds that are strong enough to provide the lifting action to produce the thunderstorms can also create extreme turbulence between mountain peaks.
4. If at all possible, avoid flying under thunderstorms because updrafts and downdrafts can exceed the performance of the aircraft.
5. Do not take off or land if a thunderstorm is approaching. Sudden wind shifts or microbursts can cause control problems.
6. Do not fly into a cloud mass containing scattered embedded thunderstorm without airborne radar. Radar is necessary to “see” storms in the cloud mass. Scattered thunderstorms can be circumnavigated visually unless they are embedded.
7. To avoid lightning do not penetrate a thunderstorm or fly through the cirrus anvil of a well-developed or dissipated thunderstorm. Aircraft should also avoid clouds downwind of thunderstorms.
8. The brighter and more frequent the lightning, the more severe the thunderstorm.
9. Regard any thunderstorm with tops 35,000 feet or higher as severe.

Thunderstorms should be avoided if at all possible using the following recommendations, listed in order of priority of choice:
1. Fly around (circumnavigate) the storm.

2. Fly over the top of the storm.
3. Fly under the storm.
If it is not possible to avoid the storm(s) then,
4. Fly through the lower ⅓ of the storm.

When thunderstorms are isolated, they are easily circumnavigated provided the surrounding area is clear of masking clouds. If lines of thunderstorms are present or if masking clouds obscure the area around the storm, other techniques must be employed.

Circumnavigation

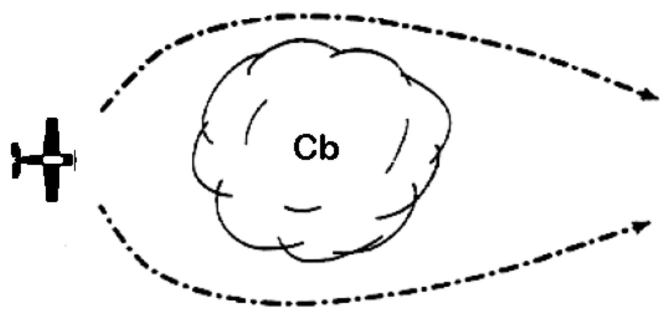


Figure 5-10 — Around a Thunderstorm

Circumnavigation presents no special flight problems. When the aircrew determines that circumnavigation is possible, they merely alter course to take them around the storm (Figure 5-10). Since most individual thunderstorm cells are about five to ten miles in diameter, detouring to one side or another would not appreciably add to either the time or distance of the flight. In case of a line of thunderstorms, it is sometimes possible to circumnavigate them by flying through thin spots of precipitation between the storms. Care should be exercised in this procedure because another thunderstorm may lie on the other side of a thin spot.

Over the Top

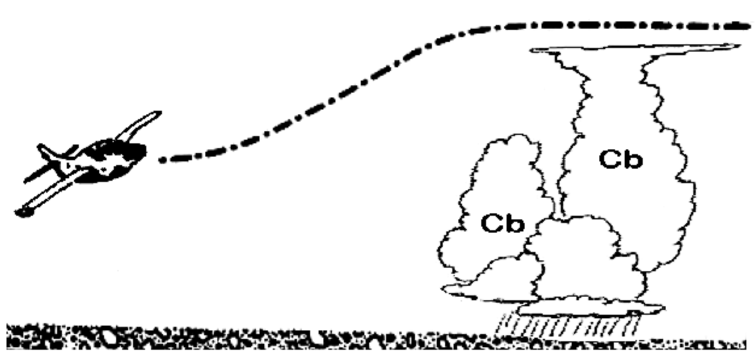


Figure 5-11 — Over the Top

When circumnavigation of thunderstorms is not possible, the next best course of action is to go over the top (Figure 5-11). Realize that thunderstorms build to great heights, and that this procedure is restricted to aircraft with the capability and fuel to climb to these altitudes. Some turbulence may be encountered in the clear air above the cloud. In addition, hail can be thrown out the top of the cumulonimbus cloud. Thus, allow a margin of safety by choosing an altitude separation from the top of the thunderstorm of 1000 feet for every 10 knots of wind speed at the altitude of the tops. Oftentimes, aircraft cannot climb over the top of the cloud, but it will still be possible to fly over the saddlebacks between the build-ups.

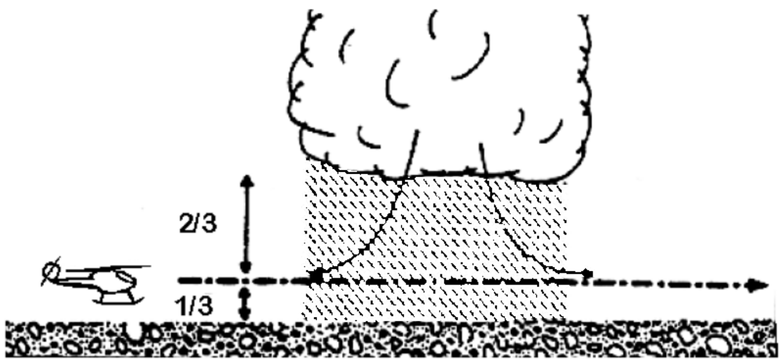


Figure 5-12 — Under the Thunderstorm

Underneath

If you are unable to circumnavigate the thunder-storms in your area and the ceiling capabilities of your aircraft will not permit an over-the-top flight, you should consider flying below the base of the cloud. The speed of downdrafts usually decreases closer to the surface (Unless a microburst is present!). Therefore, an altitude should be selected which will keep you as far away from the cloud base as possible and still enable you to maintain adequate terrain clearance. Here you can use the ⅓ rule which specifies selecting an altitude ⅓ the distance from the surface to the base of the cloud (Figure 5-12). This procedure is not recommended for areas of mountainous terrain. Below the storm, expect a low ceiling, poor visibility, and moderate turbulence. Perhaps the most dangerous threat to flight below a thunderstorm is the downburst, or microburst, which can be deadly to the unsuspecting pilot.

Penetration

Mission urgency or fuel state dictates whether thunderstorm penetration is required when avoidance is not possible. The lower in the storm the penetration is made, the less the chance of encountering hail, structural icing, or being struck by lightning. Therefore, another version of the ⅓ rule applies: penetrate through the lower ⅓ of the storm, since most hazards are more severe in top ⅔ of the cell (Figure 5-13). However, with the strong updrafts and downdrafts, adequate terrain clearance should also be considered in the selection of a penetration level. When crossing a line of thunderstorms (a squall line for example), attempt to determine the orientation of the line and penetrate the line at right angles (Figure 5-14). During the penetration of a thunderstorm, do not attempt to turn back once you are inside the storm. Remember that single cell thunderstorms are only about one to five miles in diameter, and turning around will only increase your time in the storm. Turning around can also result in a pilot becoming disoriented and flying in the storm for a considerably longer period of time than continuing directly through the storm in the first place. With no other information to make a decision, a penetration altitude between 4000 and 6000 feet AGL should be adequate.

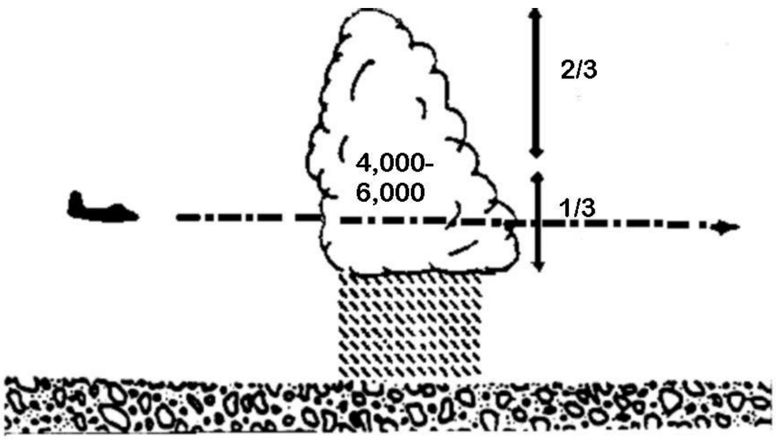


Figure 5-13 — Through the Thunderstorm

Penetration Procedures

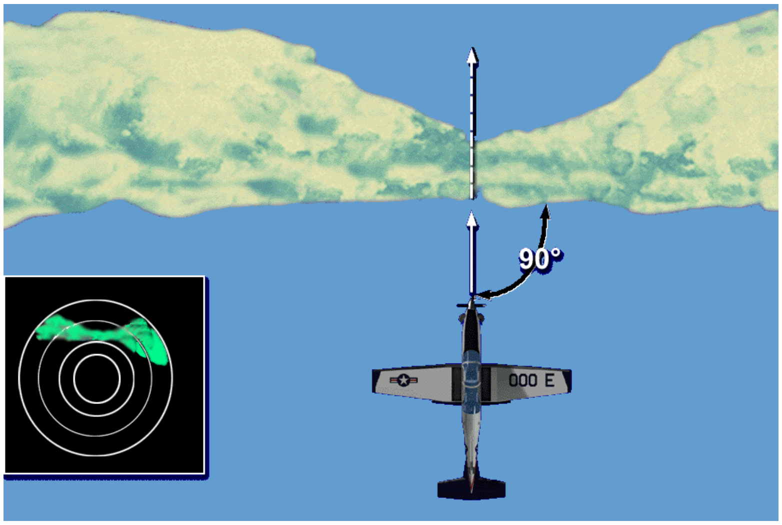


Figure 5-14 — Thunderstorm Penetration

The faster a plane is going when it strikes an updraft or downdraft, the greater the shock. Refer to your flight manual for the recommended turbulent air penetration speed.

Once inside the storm, the pilot should let the plane ride out the updrafts and downdrafts and concentrate on maintaining a level attitude. With power set to maintain the proper airspeed, maintaining the same attitude will result in only minor airspeed variations. However, the aircraft's altitude may vary by thousands of feet. The rapidly changing pressure conditions within the storm will result in unreliable indications and erratic variations in altitude, airspeed, and rate of climb instruments. Since the attitude gyro is independent of the pitot-static system, its indications should be considered reliable.

If thunderstorm penetration is unavoidable or you inadvertently fly into a thunderstorm, follow these procedures:

1. Secure all loose objects, tighten your lap belt and lock your shoulder harness. Turn cockpit lights up to highest intensity.
2. Turn on pitot heat. (Also turn on engine anti-ice, if the aircraft is so equipped. Neither the T-34 nor the T-6 has engine anti-ice.)
3. If able, plan your course to take you through the storm in minimum time, penetrating below the freezing level or above -20° C to avoid the most critical icing areas.
4. Establish the recommended turbulent air penetration speed and disengage the autopilot to minimize control inputs that could increase structural stresses.
5. Don't chase the airspeed and minimize power changes. Expect significant deviations in attitude and altitude. Keep your eyes on your instruments.
6. Don't turn back once in the thunderstorm.

Experience in severe weather flying is gained by necessity more often than by design and planning. Your first flight experience near a severe thunderstorm will make the dangers listed in this chapter all too real. No pilot should knowingly fly into severe weather if the mission does not demand it. In making a "go/no-go" decision, consider that it is better to arrive at the destination late than not at all.

ASSIGNMENT SHEET 3-5-3

THUNDERSTORMS REVIEW

A. INTRODUCTION

The purpose of this lesson is to provide the student with a general discussion of thunderstorms, including their associated hazards, microbursts and their hazards, and techniques to avoid them.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

1. Review JPATS Aviation Weather Booklet, JX100 Chapter JX105.
2. Read JPATS Aviation Weather Booklet, JX100 Chapter JX106.

D. STUDY QUESTIONS

1. The atmospheric conditions necessary for the formation of a thunderstorm include a combination of ______.
   a. stable air or relatively low humidity and some type of lifting action
   b. stable air of relatively high humidity and some type of subsiding action
   c. unstable air of relatively low humidity and some type of subsiding action
   d. unstable air of relatively high humidity and some type of lifting action.

2. Which one of the following hazards to flight are associated with thunderstorms?
   a. Hail, turbulence, and lightning
   b. Hail, icing, and microbursts
   c. Hail, turbulence, and icing
   d. All of the above are correct

3. Which one of the following is an indication of turbulence found in thunderstorms?
   a. Rotor clouds
   b. The gust front
   c. Orographic lifting
   d. Severe icing

4. Which one of the following type clouds could indicate the possibility of microburst activity?
   a. Convective only
   b. Cumulonimbus only
   c. Both a and b
   d. Nimbostratus

5. Which one of the following telltale signs in the vicinity of thunderstorms should alert you to the possibility of microburst activity?
   a. Roll clouds
   b. Blowing dust
   c. Gusty conditions
   d. All of the above

6. Which one of the following is/are correct concerning thunderstorm recommended flight techniques?
   a. Penetration of a thunderstorm should be at an altitude of 4000 to 6000 feet AGL.
   b. When flying under a thunderstorm, select an altitude 1/3 the distance from the surface to the base of the cloud
   c. Both a and b above are correct
   d. Neither a or b above are correct

7. When flying through a thunderstorm a pilot should concentrate on maintaining a level attitude.
   a. True
   b. False

Answers:

1.D	5.D
2.D	6.C
3.B	7.A
4.C	

Thunderstorm Hazards

Thunderstorm Development

Four requirements for thunderstorm development are:

Moisture

Unstable air

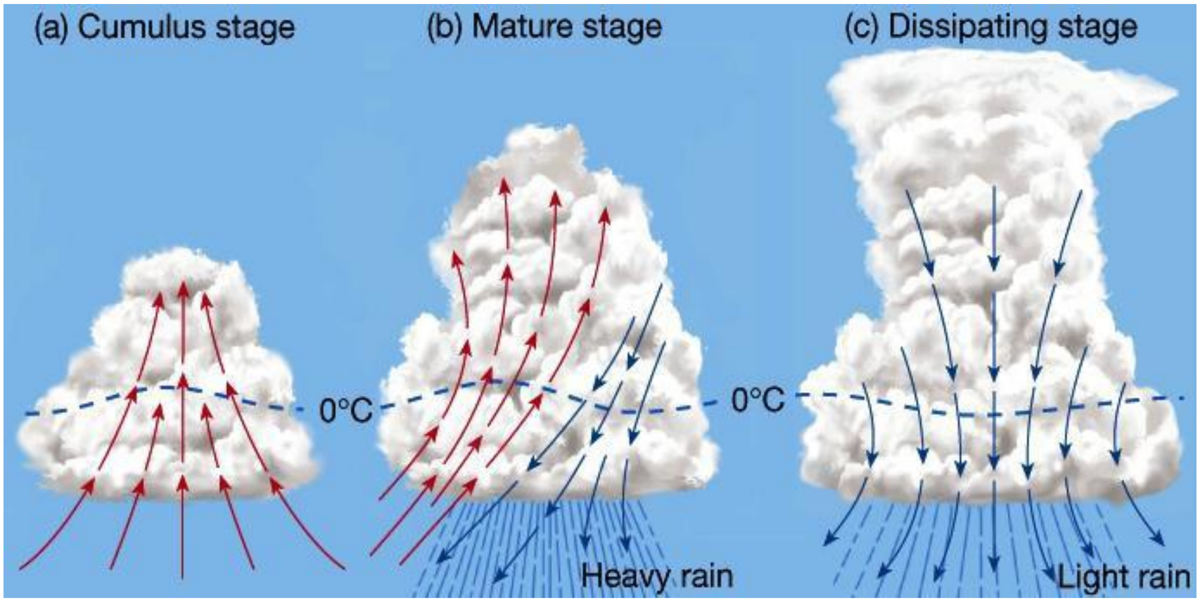
Lifting action

Building through the freezing layer

Once lifted air has reached the point where it will continue to rise freely, the cumulus cloud can grow rapidly and form cumulonimbus clouds.

Lifecycle of a T-Storm

1. Cumulus- Updrafts
2. Mature- Updrafts, Downdrafts and Hazards
3. Dissipating- Downdrafts and Hazards



Extreme Turbulence

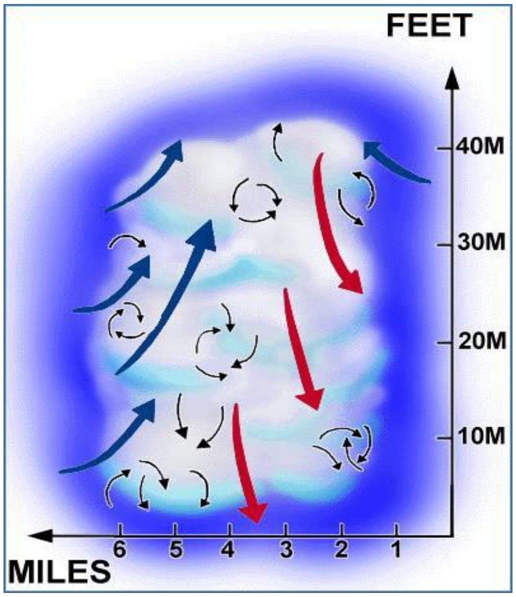
Can cause changes in altitude.

Can cause structural damage.

Extra stress on the airframe.

Effect depends on severity of turbulence and aircraft speed.

Extreme turbulence is the most severe hazard associated with thunderstorms.



Gust Front

Forms on the surface at the leading edge of an advancing thunderstorm.

Roll and Wall Clouds

Roll clouds and wall clouds occur in severe and fast moving thunderstorms.

Indicate the presence of low level wind shear and extreme turbulence.

Hail

Circulate in updrafts and downdrafts.

Hailstones larger than one-half to three-quarters of an inch can cause significant damage to aircraft in a few seconds.

Hail has been encountered:

As high as 45,000 feet in clear air

Carried 10 to 20 miles downwind.

Lightning and Electrostatic Discharge

Results from separation of positive and negative charge, from water and ice passing in up and down drafts.

Lightning Hazards

Static charge builds up in the aircraft while in the clouds.

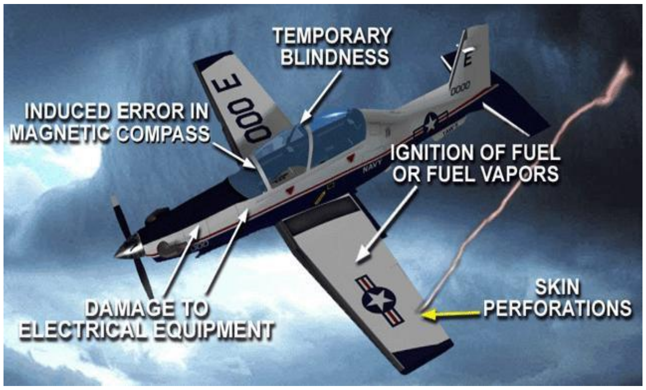
Can strike aircraft flying in the clear.

Structural damage is possible.

Catastrophic fuel ignition possible.

Pilots can experience flash blindness.

Static buildup sometimes released through St. Elmo's fire.



Tornado

Violent destructive whirling wind accompanied by a funnel shaped cloud.

Damage and effects documented in television and news reports.

Cloud types:

Tornado touches ground.

Funnel cloud - not touching surface.

Waterspout - touches water surface.

Microbursts and Their Hazards

Microbursts

An intense, highly localized downward atmospheric flow with velocities of 2000 to over 6000 feet per minute.

Outflow produces wind shears of 20 to 200 knots.

Area only ¼ to 2 ½ miles wide

Lasts only 5-10 minutes

Emanates from cumuliform cloud not a thunderstorm.

Microburst Sequence 1

Normally occur mid-afternoon during summer months.

Large vortex ring of air flows outward from center of the downburst.

Shaft of rain makes flow visible.

Microburst Sequence 2

May also form dry microbursts.

Forms when there’s a large temperature (dew point) spread at the surface.

Rain evaporates as it descends (virga), which cools the air.

Colder air accelerates as it descends.

Microburst Damage

Strong winds destructive to ground objects.

Many aircraft mishaps have been attributed to microbursts.

Takeoff During Microburst

When first entering a microburst, edge of vortex ring produces wind blowing upward from ground.

Increase in headwind causes IAS to jump upward rapidly.

In center of downdraft, aircraft will begin to descend, but soon enter other side of outflow.

Headwind will shift to tailwind, IAS drops rapidly, probably causing aircraft to stall.

Landing During Microburst

Natural reaction is to first reduce power and attempt to re-establish descent.

Removes power from engine, and wastes valuable time to get aircraft away from ground before entering outflow.

Methods of Microburst Detection 1

- Visual cues
  - Virga (precipitation that evaporates before reaching the ground)
  - Localized blowing dust
  - Shaft of rain which diverges closer to the ground.
  - Severe thunderstorms
  - Heavy rain
  - Low or no visibility
  - Gusty winds
  - Frequent lightning
  - Tornado activity

Methods of Microburst Detection 2

- Ground-based Doppler radar
  - Detects
  - Microbursts
  - Tornados
  - Low-level wind shear
  - Real time hazard reporting
- Low level shear alert systems
  - Measures wind speed and direction at ground locations.
  - Compares readings to central sensor.
  - Not real time - after the fact identity

Methods of Microburst Detection 3

- Pilot Weather Reports (PIREPs)
  - Encountered unusual and unforecast weather conditions.
  - Wind shear encountered on departure or arrival.
  - Definitive information not real time
- Departure or arrival weather reports
  - Gusty winds
  - Heavy rains or thunderstorms

Techniques For Avoiding Thunderstorm Hazards

Radar Detection

NEXRAD (Next Generation Radar)

Most accurate means of tracking thunderstorms.

Scale indicates wind intensity or speed.

Television shows Doppler composite.

Direct relationship exists between:

Strength of radar echoes

Presence of aircraft icing

Intensity of turbulence

Height of tops of CBs indicate thunderstorm severity.

Airborne Radar

Used to circumnavigate and avoid scattered thunderstorms.

Not for thunderstorm penetration

Severe clear air turbulence and hail can be experienced between thunderstorms.

Thunderstorm Hazard Avoidance

Circumnavigate isolated thunderstorms.

Over the top

Avoids most hazards.

Altitude margin for turbulence and hail (at least 1000 feet higher for every 10 knots of wind speed at cloud top level)

Underneath

Not in the worst of hazards

Altitude margin - ⅓ distance from ground to cloud base

Penetrate lower ⅓ of storm.

Thunderstorm Common Sense

Don’t takeoff or land if a thunderstorm is approaching.

Don’t fly into a cloud mass containing embedded thunderstorms without airborne radar.

Avoid flying under a thunderstorm, even if you can see through to the other side.

Thunderstorm Penetration Procedures

Penetrate perpendicular to minimize time in storm.

Penetrate the storm below the freezing level or above the -20° C level.

Minimum altitude should be 4000 to 6000 feet AGL above the highest terrain.

Establish recommended turbulent air penetration airspeed.

Expect significant deviations in attitude and altitude.

Disengage the autopilot.

Avoid abrupt control inputs to prevent pilot-induced structural damage.

Secure all loose objects.

Tighten lap belt and lock shoulder harness.

Turn cockpit lights up to highest intensity to lessen dangers of temporary blindness from lightning.

Turn on pitot heat.

OUTLINE SHEET 3-6-1

METARS AND TAFS

A. INTRODUCTION

This lesson is an introduction to basic aviation weather reports (METARs) and Terminal Aerodrome Forecasts (TAFs). It provides a knowledge base for the reading and understanding of up-to-date weather information as provided by various aviation weather forecasting and reporting services.

B. ENABLING OBJECTIVES

4.18 DESCRIBE the use of METARs in flight planning in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.19 INTERPRET weather conditions from a METAR, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.20 DESCRIBE the use of TAFs in flight planning, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.21 DESCRIBE differences in U.S. civil, military, and international TAFs, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.22 INTERPRET forecast weather conditions from a TAF, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. METARS in Flight Planning
2. Weather Conditions represented in a METAR
3. TAFs in Flight Planning
4. Differences in U.S., Civil, Military, and International TAFs
5. Forecast Weather Conditions represented in a TAF

INFORMATION SHEET 3-6-2

METARS AND TAFS

A. INTRODUCTION

This lesson is an introduction to basic aviation weather reports (METARs) and Terminal Aerodrome Forecasts (TAFs). It provides a knowledge base for the reading and understanding of up-to-date weather information as provided by various aviation weather forecasting and reporting services.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. DoD Flight Information Publication (FLIP), FIH (Flight Information Handbook), C-15
3. JPATS Aviation Weather Booklet, JX100
4. Flight Information Handbook

C. INFORMATION

INTRODUCTION

The Aviation Routine Weather Report (METAR) and the Terminal Aerodrome Forecast (TAF) are the most widely used methods of disseminating weather observations and forecasts (respectively) to aircrew. They are also the quickest means, as well, because they contain only letters and numbers. Years ago, when Teletype was the quickest means of information dissemination, METARs and TAFs were distributed across the country and overseas by this method, as well. Today, even though electronic communication is an important part of the existing military and civilian weather networks, the same basic character set is used, and these reports are still often called "teletype" products.

The METAR and TAF formats have not changed greatly over recent years, except to conform better to international standards. Thus, these formats contain certain codes, which–while they may be cumbersome at first–provide users with precise weather information because of their clear and exact nature.

Once the interpretation of a METAR has been discussed, the TAF format should then be easier to understand, since they use similar data groups. The TAF, however, is usually longer since it is a forecast covering a greater period of time. As such, the TAF format has additional rules that must be understood before an aviator can apply the forecast information to a particular situation. Following the discussion of these topics, this chapter will point out the major differences between the military TAF and its civilian and international counterparts. Finally, this chapter will demonstrate how to apply this knowledge to various flight planning situations.

THE AVIATION ROUTINE WEATHER REPORT (METAR)

Aviation Routine Weather Reports (METAR) provide a rapid and efficient means of transmitting the latest observed weather information for various stations throughout the world. These reports are transmitted over available computer/teletype circuits.

A METAR example is shown in Figure 6-1.

SAU55 KAWN 151800

METAR KALO 151756Z 14015KT 6SM BLDU OVC015 09/07 A3024 RMK SLP240 RADAT 80052

METAR KBAL 151758Z 35012KT 1 1/2SM R10/6000FT RA BR HZ BKN005 OVC010 08/06 A2978 RMK SLP085

METAR KRDR 151756Z 09009KT 15SM SCT050 BKN090 OVC200 M15/M18 A2997 RMK PSR09P SLP149

METAR KHAR 151757Z 05015G22KT 1 1/2SM RA BR BKN011 OVC015 07/05 A2986 RMK PK WND 05025/32 SLP112

METAR KNKX 151758Z 08012KT 8SM BKN007 OVC040 09/07 A2984 RMK BINOVC BKN TOPS 020 SLP105

METAR KCBM 151755Z 00000KT 10SM SCT012 BKN029 OVC120 M06/M07 A2998 RMK IR18 SLP156

METAR KPAM 151757Z 17015G22 5SM HZ SCT007 BKN040 OVC050 22/21 A2990 RMK SCT007VBKN SLP125

METAR KPHX 151756Z 33007KT 20SM SKC M14/M24 A3021 RMK SLP230

METAR KVPS 151758Z 18009KT 7SM OVC006 19/17 A2994 RMK CIG005V007 SLP139

METAR KOZR 151755Z 22012G16 15SM OVC017 23/17 A2987 RMK OVC TOPS 045/054 SLP115

METAR KBNA 151759Z 27003KT 1 1/2SM DZ BR SCT000 SCT017 OVC025 19/16 A2977 RMK VIS 1V2 CIG 023V027 BR SCT000 TOPS OVC 066

Figure 6-1 — Sample METAR Printout

METARs are used to communicate the latest observed weather to meteorologists and aircrew so they can determine the existing weather at the destination or alternate, and whether a field is operating under conditions of instrument flight rules (IFR) or visual flight rules (VFR). These users can also use METARs to determine weather trends by checking the last several hours of reports to see if they indicate improving or deteriorating conditions. Additionally, METARs can provide a comparison between the observed and forecast weather, to determine if conditions are actually developing as originally forecast.

METAR Format

A METAR example is shown below in Figure 6-2 with each coded group underlined and labeled for reference during the following discussion. METARs have two sections: the body of the report and the remarks section.

Group 1: Type of Report
The first word of the report line, either “METAR” or “SPECI,” will indicate which of these two main types of observations was reported (Figure 6-3).

METAR — An hourly routine scheduled observation–containing wind, visibility, runway visual range, present weather, sky condition, temperature/dew point, and altimeter setting–constitutes the body of the report. Additional coded data or plain language information that elaborates on the report may be included in the “Remarks” section.

SPECI — A SPECIal, unscheduled observation containing all the data elements found in a METAR whenever critical data have changed from the previous observation (reasons are too numerous to cover in this course). All SPECI are made as soon as possible after the element criteria are observed.

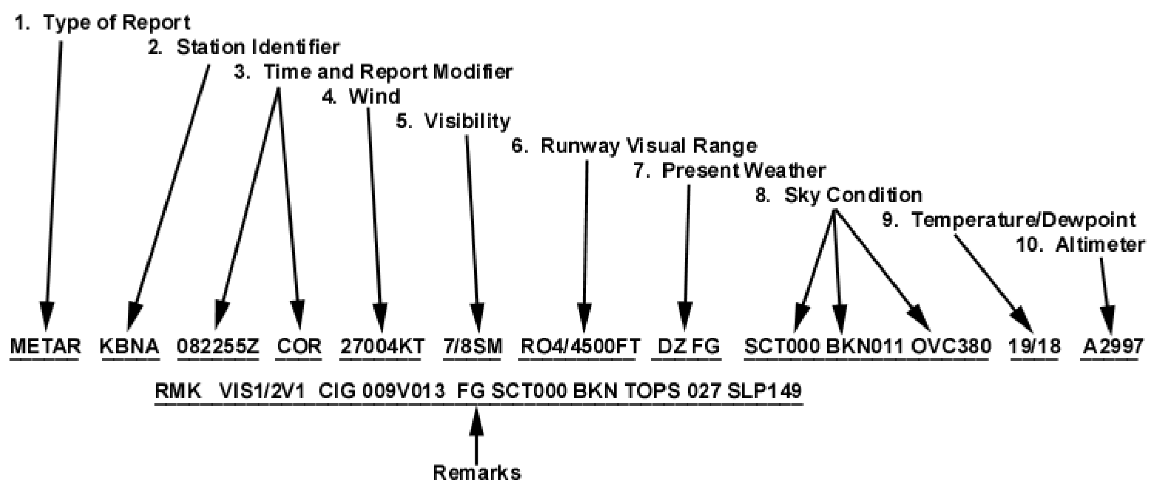


Figure 6-2 — METAR Code Groups

METAR KNPA 082255Z 27004KT 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

SPECI KNPA 082317Z 31020G30KT 3/8SM R04/2500FT VCTS SCT000 BKN006 OVC380 17/17 A2993 RMK VIS1/8V1 CIG004V008 FG SCT000 BKN TOPS 350 SLP136

Figure 6-3 — Type of Report: METAR or SPECI

Group 2: Station Identifiers
The METAR code format uses a 4-letter ICAO (International Civil Aviation Organization) identifier. In the continental U. S., all 3-letter identifiers are prefixed with a “K,” e.g., KLAX for Los Angeles, and KBOS for Boston (Figure 6-4). Elsewhere, the first two letters of the ICAO identifier indicate what region of the world (e.g. K=USA, C=Canada, P=Pacific, E=Europe) and country the station is located. For example, PAFA is Fairbanks, Alaska, PHNA is Barber’s Point,

Hawaii, and CYUL is Montreal, Canada. Also, EG indicates a station in England, and LI indicates a station in Italy. For a complete worldwide listing of all the identifiers, one must refer to the ICAO Document 7910 Location Identifiers.

METAR **KNPA** 082255Z 27004KT 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-4 — Station Identifier in METAR

Group 3: Date Time Group and Report Modifier
The time of observation will be included in all reports, using the standard date time group (DTG) format. Times are always given in Universal Coordinated Time (UTC) and therefore will end in “Z,” indicating Zulu, or UTC, time. The first two numbers are the date, and the second four are the time of the report (Figure 6-5).

METAR KNPA **082255Z** 27004KT 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-5 — DTG in METAR

Manual METAR observations are required to be started no earlier than 15 minutes prior to the reporting time, which is a window between 55 and 59 minutes past the hour. Additionally, elements having the greatest rate of change are evaluated last. At automated stations, evaluations are based on sensor data taken within 10 minutes of the report time (although sky cover data is gathered over the preceding 30 minutes). Therefore, as an aviator, you can be assured you have the most up-to-date information available, assuming you’re checking the weather at the top of the hour.

Of course, report times given for SPECI observations are the time at which the event requiring the SPECI report occurred.

Reports may also contain one of two modifiers, “COR,” or “AUTO,” which will appear after the DTG:

COR — Indicates a CORrected report, which is transmitted as soon as possible whenever an error is detected in a METAR or SPECI report. In this case, the DTG will be the same time used in the report being corrected.

AUTO — Indicates a routine scheduled observation was sent from a fully AUTOmated station with no human intervention. In the remarks section, either “AO1” or “AO2” will be present indicating the type of automatic precipitation measuring equipment. Sometimes, manual observations are reported using data gathered from automatic devices, in which case an “AO1” or “AO2” will be present in the remarks without an “AUTO” following the DTG.

Group 4: Wind

Winds are a 2-minute average speed and direction report in knots and degrees true from which direction the wind is blowing. The wind direction is first and will be in tens of degrees, using three digits. Directions less than 100 degrees are preceded by a zero to supply three digits. Speed is in whole knots, using two or three digits after the direction, without spaces, and speeds of less than 10 knots are preceded with a zero. The wind group will always end with the letters “KT” to indicate knots. Other countries may use different units of measurement, such as KM (kilometers), MPH (miles per hour), or MPS (meters per second) (Figure 6-6).

METAR KNPA 082255Z **27004KT** 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-6 — Wind Direction and Speed in METAR

Examples:
09008KT — Wind from 090 degrees at 08 knots.
270112KT — Wind from 270 degrees at 112 knots.

GUSTS — The letter “G” immediately following the average wind speed indicates the presence of gusts, which are rapid fluctuations in speeds of peaks and lulls of 10 knots or more. Wind speed for the most recent 10 minutes is used to determine gusts, and the maximum peak is reported using two or three digits.

Examples:
14015G28KT — Wind from 140 degrees at 15 knots with gusts to 28 knots.
33065G105KT — Wind from 330 degrees at 65 knots with gusts to 105 knots.

VARIABLE WINDS — If “VRB” is present in place of the wind direction, the direction cannot be determined (used with wind speeds of 6 knots or less). If the wind direction is variable with speeds greater than 6 knots, a special group will immediately follow the wind group using the letter “V” between two directions (listed clockwise).

Example:
22015KT 180V250 — Winds from 220 degrees at 15 knots with direction varying from 180 degrees to 250 degrees.

CALM WINDS — Calm winds are reported as 00000KT.

Notes:
1. Peak winds and wind shifts will be reported in the RMK section of the METAR/SPECI. (See remarks section later in this chapter.)
2. A sudden increase in wind speed of at least 16 knots and sustained at 22 knots or more for at least 1 minute requires that Squalls (SQ) be reported in the present weather section of the report.

Group 5: Visibility
METAR uses the prevailing visibility, reported in statute miles (SM) in the United States and in meters at overseas stations (Figure 6-7). Any of the values in Table 6-1 may be used. Automated stations may use “M” to indicate less than ¼ statute mile when reporting visibility (think of “Minus”). If visibility is less than 7 statute miles, then the weather/obstruction to vision will also be reported (using the abbreviations discussed later in the Present Weather section and shown in Table 6-2).

METAR KNPA 082255Z 27004KT **7/8SM** R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-7 — Visibility in METAR

Examples:
1 ⅛ SM — Visibility one and one-eighth statute miles.
5SM — Visibility five statute miles.
M1/4 — Visibility from an automated station less than one-quarter statute mile.

NOTE: Other types of visibility are reported in the RMK portion of the METAR/SPECI (see the remarks section later in this chapter). At military stations tower visibility will be reported when either surface or tower visibility is 4 miles or less. This visibility will be a remark with the surface visibility remaining in the body of the report.

Source of Visibility Report							
Automated			**Manual**				
M1/4	2	9	0	5/8	1 5/8	4	12
1/4	2 1/2	10	1/16	¾	1 3/4	5	13
1/2	3		1/8	7/8	1 7/8	6	14
3/4	4		3/16	1	2	7	15
1	5		1/4	1 1/8	2 1/4	8	20
1 1/4	6		5/16	1 1/4	2 1/2	9	25
1 1/2	7		3/8	1 3/8	2 3/4	10	30
1 3/4	8		1/2	1 1/2	3	11	35[a]
a. Further values in increments of 5 statute miles may be reported (i.e., 40, 45, 50, etc.)							

Table 6-1 — Visibility Values Reportable in METAR

Group 6: Runway Visual Range
The runway visual range (RVR), defined in Chapter 5, is a measure of the horizontal visibility as determined from instruments (transmissometers) located alongside and about 14 feet higher than runway centerline. They are calibrated with reference to the sighting of either high-intensity

runway lights or the visual contrasts of other targets, whichever yields the greater visual range. Only activities with operational equipment are allowed to report RVR.

RVR is reported whenever the prevailing visibility is 1 statute mile or less and/or the RVR for the designated instrument runway is 6000 feet or less. RVR is measured in increments of 200 feet through 3000 feet and in 500-foot increments above 3000 feet (Figure 6-8).

METAR KNPA 082255Z 27004KT 7/8SM **R04/4500FT** DZ FG SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-8 — RVR in METAR

RVR is encoded with an "R" indicating runway, followed by a 2-digit group denoting runway number, and may be followed by an "R," "L," or "C," denoting right, left, or center runway. Next is a forward slash followed by the constant reportable value in four digits and ending with the letters "FT" for feet.

If RVR is varying, the coding will be the same as above, except the two reportable values will be separated by a "V." If RVR is less than its lowest reportable value, the 4-digit value will be preceded with an "M" (for Minus), and if greater than the highest reportable value, it is preceded with a "P" (for Plus).

Examples:
R33/1800FT — Runway 33 visual range 1800 feet.
R17R/3500FT — Runway 17 Right visual range 3500 feet.
R09/1000V4000FT — Runway 09 visual range 1000 feet variable to 4,000 feet.
R28L/P6000FT — Runway 28 Left visual range greater than 6000 feet.
R02/M0800FT — Runway 02 visual range less than 800 feet.

NOTE: Runway visual range is not reported from USN/USMC stations. It will, however, be disseminated locally to arriving and departing aircraft.

Group 7: Present Weather
Present weather includes precipitation, well-developed dust or sand swirls, squalls, tornadic activity, sandstorms, and dust storms. It may be evaluated instrumentally, manually, or through a combination of methods. The codes used for present weather as seen below in Figure 6-9 and Table 6-2 are used throughout meteorology.

METAR KNPA 082255Z 27004KT 7/8SM R04/4500FT **DZ FG** SCT000 BKN011 OVC380 19/18 A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-9 — Present Weather in METAR

In addition to the notes of Table 6-2, the following are a few of the conventions used to report present weather conditions in METAR/SPECI observations.

A. Present weather given in the body of the report occurs at the point of observation or within 5 miles from the station. If the letters “VC” are used, the weather is in the vicinity of 5-10 miles. Any reported weather occurring beyond 10 miles of the point of observation will be included in the remarks portion of the METAR.
B. Intensity refers to the precipitation, not its descriptor (TS or SH).
C. TS may be coded by itself, or it may be coded with RA, SN, PL, GS, or GR.

QUALIFIER		**WEATHER PHENOMENA**[1]		
INTENSITY OR PROXIMITY 1	**DESCRIPTOR 2**	**PRECIPITATION 3**	**OBSCURATION 4**	**OTHER 5**
– **Light**	MI Shallow	**DZ Drizzle**	**BR Mist**	PO Well-Developed Dust/ Sand Whirls
Moderate[2]	PR Partial	**RA Rain**	**FG Fog**	**SQ Squalls**
+ **Heavy**	BC Patches	**SN Snow**	**FU Smoke**	**FC Funnel Cloud(s) (Tornado or Waterspout)**[3]
VC In the Vicinity	**DR Low Drifting**	SG Snow Grains	VA Volcanic Ash	**SS Sandstorm**
	BL Blowing	**IC Ice Crystals**[2]	**DU Widespread Dust**	**DS Duststorm**
	SH Shower(s)	**PL Ice Pellets**	**SA Sand**	
	TS Thunder-storm	**GR Hail**[2]	**HZ Haze**	
	FZ Freezing	**GS Small Hail and/or Snow Pellets**	**PY Spray**	
		UP Unknown Precipitation		

1. Weather groups are constructed by considering columns 1 to 5 above in sequence, i.e., intensity, followed by description, followed by weather phenomena (e.g., heavy rain shower(s) is coded as +SHRA).

2. No symbol denotes moderate intensity. No intensity is assigned to Hail (GR) or Icing (IC).

3. Tornadoes and waterspouts in contact with the surface are coded +FC.

Table 6-2 — Present Weather Codes Reportable in METAR

Group 8: Sky Condition

METAR KNPA 082255Z 27004KT 7/8SM R04/4500FT DZ FG **SCT000 BKN011 OVC380**

19/18 A2997 RMK VIS1/2V1 **CIG009V01**3 FG **SCT000 BKN TOPS 027** SLP149

Figure 6-10 — Sky Condition in METAR

The sky condition group (Figure 6-10) gives a description of the appearance of the sky including the type of clouds, cloud layers, amount of sky coverage, height of their bases, and any obscuring phenomena. Cloud layer amounts for each layer indicate eighths of the sky that is covered, according to the abbreviations in Table 6-3, which is the same as Table 5-3.

Reportable Contractions	Meaning	Amount of Sky Cover
SKC or CLR[1]	Sky Clear	0/8
FEW[2]	Few	> 0/8 - 2/8
SCT	Scattered	3/8 - 4/8
BKN	Broken	5/8 - 7/8
OVC	Overcast	8/8
VV	Obscured[3]	8/8 (surface based)
1. The abbreviation CLR is used at automated stations when no clouds at or below 12,000 feet are reported; the abbreviation SKC is used at manual stations when no clouds are reported.		
2. Any amount less than ⅛ is reported as FEW.		
3. The last 3 digits report the height of the vertical visibility into an indefinite ceiling.		

Table 6-3 — Sky Coverage

In addition to the notes of Table 6-3, the following are some of the cloud reporting rules that are used in METAR/SPECI.

A. All sky cover heights are reported in feet above the ground level (AGL).
B. Sky condition is annotated by a 6-digit group, the first 3 digits (letters) describing the amount of sky cover (from Table 6-3), and the second 3 digits (numbers) the height of that layer in hundreds of feet. Layers will be reported in ascending order up to the first overcast. If the cloud layer is below the station (for mountain stations), the height will be coded as ///.
C. When the sky is totally obscured by a surface-based obscuration the only group in the sky condition section will be a 5-digit group, the first 2 digits VV (Vertical Visibility) and the last 3 digits the height of the vertical visibility into the indefinite ceiling. Most always this height will be 000, as any surface-based phenomenon is (by definition of “surface-based”) within 50 feet of the surface, and will be rounded down to the nearest hundred feet (i.e., zero).
D. When the sky is partially obscured by a surface-based obscuration, the amount of the sky cover hidden by the weather phenomena will be reported as FEW000, SCT000, or BKN000. A remark will then also be given to describe these details (see Remarks section).

E. At manual stations CB (cumulonimbus) or TCU (towering cumulus) will be appended to the layer if it can be determined.

Examples:
BKN000 — Partial obscuration of ⅝ to ⅞ (surface-based).
VV008 — Sky obscured, indefinite ceiling, vertical visibility 800 feet AGL.
SCT020CB — Scattered clouds (3/8 to 4/8 of the sky) at 2000 feet AGL composed of cumulonimbus clouds.
FEW011 BKN040 OVC120 — Few clouds (1/8 to 2/8) at 1100 feet AGL, broken clouds (5/8 to 7/8) at 4000 AGL, overcast clouds (8/8) at 12,000 feet AGL.

Group 9: Temperature/Dew Point
Temperature and dew point are reported as two 2-digit groups, rounded to the nearest whole degree Celsius, and separated with a (/) (Figure 6-11). Sub-zero temperatures or dew points will be prefixed with the letter "M" (for Minus). If the temperature and dew point are not available, the entire group is omitted. If only dew point is unavailable, then only temperature is coded, followed by the (/).

METAR KNPA 082255Z 27004KT 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 **19/18** A2997 RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-11 — Temperature and Dew Point in METAR

If necessary, convert between Fahrenheit and Celsius using the following formulas:

$F = (C * 9/5) +32$ $C = (F - 32) * 5/9$ $(9/5 = 1.8)$

or by using the conversion scale on the CR-2 circular slide rule.

Group 10: Altimeter Setting
The altimeter setting will be included in all reports. The altimeter group always starts with the letter "A", and will be followed with a 4-digit group using the tens, units, tenths, and hundredths of inches of mercury. For example, A2992 indicates an altimeter setting of 29.92 inches of Hg (Figure 6-12).

METAR KNPA 082255Z 27004KT 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 **A2997** RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149

Figure 6-12 — Altimeter Setting in METAR

Remarks Section
Remarks will be included in all METAR/SPECI reports if deemed appropriate. They will be separated from the body of the report by a space and the abbreviation RMK. If there are no remarks, then "RMK" is omitted (Figure 6-13). The remarks fall into three major categories, (1) Manual and Automated remarks, (2) Plain language remarks, and (3) Additive data and

Maintenance remarks. Only the first two will be discussed in this chapter, as the last is of very little importance to an aviator.

METAR KNPA 082255Z 27004KT 7/8SM R04/4500FT DZ FG SCT000 BKN011 OVC380 19/18 A2997 **RMK VIS1/2V1 CIG009V013 FG SCT000 BKN TOPS 027 SLP149**

Figure 6-13 — Remarks Section of METAR

Remarks are made in accordance with the following conventions.

A. Where plain language is called for, authorized abbreviations and symbols are used to conserve time and space.
B. Time entries will be in minutes past the hour if occurrence is during the same hour the observation is taken. If not, then hours and minutes will be used.
C. Present weather in the body of the report using VC (vicinity) may be further described, if known. DSNT (distant) indicates weather that is beyond 10 miles of the point of observation, and it will be followed by the direction.
D. Movement of clouds and weather indicates the direction toward which it is moving (remember wind is always from).
E. Directions use the eight points of the compass.
F. Insofar as possible, remarks are entered in the order they are presented in the following examples:

TORNADO B13 6 NE	Tornado began 13 minutes past the hour, 6 statute miles northeast of the station
AO2A	Automated station with precipitation measuring equipment, augmented by observer
PK WND 28045/15	Peak wind of 45 knots from 280 degrees occurred at 15 minutes past the hour
WSHFT 30 FROPA	Wind shift 30 minutes after the hour with frontal passage
TWR VIS 1 ½	Tower visibility one and one-half statute miles
VIS ½V2	Visibility varying between 1/2 and 2 statute miles
VIS 2 ½ RY11	Visibility at second sensor located on runway 11 is two and one-half statute miles
DVR/R11L/1000V5000FT	Dispatch visual range varying between 1000 and 5000 feet on runway 11 left (automated stations only)
DVR/P6000FT	Dispatch visual range not associated with a specific runway is greater than 6000 feet (automated stations only)
OCNL LTG	Occasional lightning
FRQ LTGCGIC	Frequent lightning cloud to ground in vicinity
LTG DSNT W	Lightning distant west (beyond 10 miles but less than 30 miles)
RAB05E30SNB20E55	Rain began 5 minutes past the hour and ended 30 minutes past the hour, snow began 20 minutes past the hour and ended 55 minutes past the hour
TSB0159E30	Thunderstorm began at 0159 and ended at 0230
CIG 005V010	Ceiling varying between 500 feet and 1000 feet
CIG 002 RY11	Ceiling at second location on runway 11 is at least broken at 200 feet
PRESRR	Pressure rising rapidly
PRESFR	Pressure falling rapidly
SLP982	Sea Level Pressure is 998.2 millibars

SLPNO	Sea Level Pressure not available
VIS NE 2 ½	Visibility northeast two and one-half statute miles
TS SE MOV NE	Thunderstorm southeast moving northeast
GR 1 1/4	Hailstones one and one-quarter inch
VIRGA SW	Precipitation southwest not reaching the ground
FG SCT000	Fog partially obscures 3/8 to 4/8 of the sky
BKN014 V OVC	Broken clouds at 1400 feet are variable to overcast
CB W MOV E	Cumulonimbus clouds west moving east
CBMAM E MOV S	Cumulonimbus mammatus clouds east moving south
TCU W	Towering cumulus clouds west
TOP OVC050	Tops of overcast are 5000 feet MSL.
ACC NW	Altocumulus castellanus northwest (indicates turbulence)
ACSL SW-W	Altocumulus standing lenticular clouds southwest through west (indicates mountain wave turbulence)
APRNT ROTOR CLD NE	Apparent rotor cloud northeast (also indicates mountain wave turbulence)
CCL S	Cirrocumulus standing lenticularis south
FU BKN020	Smoke layer broken at 2000 feet
ACRFT MSHP	Aircraft mishap

Special Remarks That May be Appended to the Remarks Section
Runway Condition Reporting (RSC & RCR) — Runway condition, when reported, will include two parts, the RSC (runway surface condition), and the RCR (runway condition reading) as determined by the airfield manager or operations officer. The following RSCs describe the runway condition:

METAR Code	Runway Surface Condition
WR	Wet Runway
SLR	Slush On Runway
LSR	Loose Snow On Runway
PSR	Packed Snow On Runway
IR	Ice On Runway
RCRNR	Not Reported

The RCR is a 2-digit number giving an average decelerometer reading from 02 to 25 (Table 6-4). Two slants (//) will be entered when the runway is wet, slush-covered, or when no decelerometer reading is available.

Runway Braking Action Reading	Equivalent Terminology	% Increase in Landing Roll
02 to 05	NIL	100% or more
06 to 12	POOR	99% to 46%
13 to 18	FAIR (MEDIUM)	45% to 16%
19 to 25	GOOD	15% to 0%

Table 6-4 — RCR Values and Corresponding Braking Action

The following will be added to the report when applicable:

"P" is appended to the RCR when there are patches of ice, snow, or slush on the runway.
"SANDED" is appended when runways have been treated with sand or other friction enhancing materials.
"P WET" or "P DRY" is appended whenever the rest of the runway is either wet or dry.
ICAO braking action remarks (such as BA GOOD, BA NIL) may be reported at airfields not equipped with decelerometers when required.

Examples:

PSR15	Packed snow on runway, RCR value 15
IR//	Ice on runway, no RCR value available
LSR08P DRY	Loose snow on runway, RCR value 08 patchy, rest of runway dry
WR//	Wet runway
RCRNR	Base Operations closed
PSR12 HFS IR08	Packed snow on runway, RCR value 12 on touchdown, on rollout portion of a high friction surface with ice on runway, RCR value 08

PSR// SANDED BA MEDIUM Packed snow on runway, no RCR available, runway treated with friction enhancer, braking action medium

Freezing Level Data (RADATS) — Information beginning with the contraction RADAT gives freezing level data. (Think of RAdiosonde DATa. A radiosonde is a weather balloon.) RADAT is followed by the relative humidity (RH) at the freezing level and the height of the freezing level in hundreds of feet MSL. When multiple crossings are reported, the order will be the lowest crossing first, followed by the intermediate crossing with the highest RH, then the highest crossing. A letter "L" or "H" after the RH value will indicate to which altitude the RH corresponds. A single slash after these altitudes indicates that more than three crossings occur, and the number of additional crossings is noted after the slash. When a "00" appears for the RH, this indicates an RH of 100%. If “20” is coded, this indicates that the RH is the lowest that can be obtained. Two slashes, “//”, indicate RH data is missing.

Examples:

RADAT 63017	Freezing level at 1700 feet MSL with 63% RH
RADAT 91L028039061	Freezing levels at 2800, 3900, and 6100 feet MSL with 91%RH at 2800 feet
RADAT 84H008025085/1	Freezing levels at 800, 2500, and 8500 feet MSL with 84% RH at 8500 feet, and one additional crossing
RADAT ZERO	Freezing level at the surface
RADAT MISG	Unable to obtain, high winds, or equipment failure
RAICG 89MSL	Balloon iced up at 8900 feet MSL

THE TERMINAL AERODROME FORECAST (TAF)

TAF Use For Flight Planning

Any aviator planning a flight should know both the destination's existing and forecasted weather. Previously we learned the Aviation Routine Weather Report (METAR) provides existing weather. Now, we will discuss the surface forecasted weather conditions by learning how to read Terminal Aerodrome Forecasts (TAFs). This teletype information will also aid you in planning for the type of flight (IFR/VFR), type of approach you require, determining if an alternate is required, and selection of the best alternate.

Although there are many differences in TAF reporting between the military and civilian weather offices, as well as throughout the world, we will focus this discussion on the U.S. military TAF since the bulk of your training flights will commence from military bases. Once this has been accomplished, it will be much easier to point out differences existing among the TAFs of the U.S. military, civilian, and international communities.

TAF Sequence

It will become readily apparent that each line of the TAF forecast will follow the same basic sequence: message heading or change group, time, wind, visibility, weather and obstructions to vision, clouds, altimeter, and remarks. The only deviation that occurs is the addition of wind shear, temperature, icing, and turbulence groups when applicable. Figure 6-14 shows an example of a single line forecast with a breakdown of each group. Figure 6-15 shows an actual forecast for Navy Whiting Field.

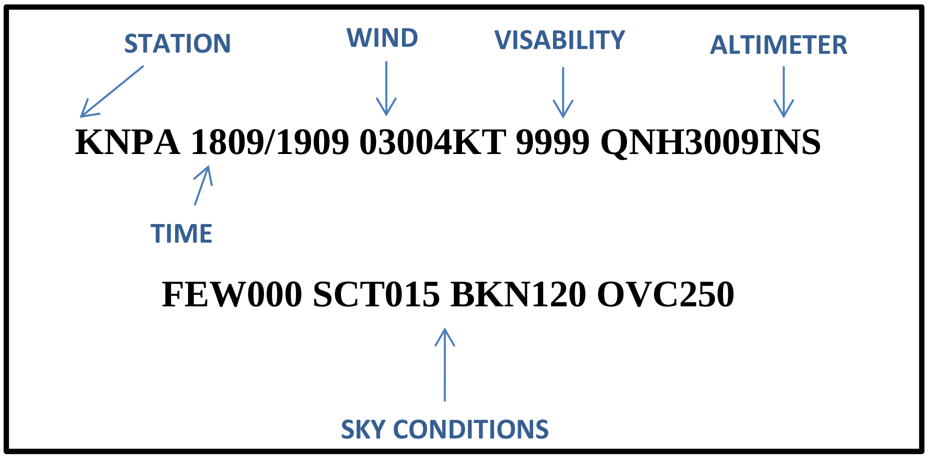


Figure 6-14 — TAF Groups

KNSE TAF 2609/2709 28004KT 9000 HZ SCT020 SCT200 QNH2998INS

FM261200 26007KT 9000 HZ SCT025 SCT080 BKN250 QNH2996INS

VCSHRA

BECMG 2614/2616 9999 SCT025CB SCT250

BECMG 2617/2618 23015G25KT 530004

TEMPO 2619/2702 8000 TSSHRA SCT010 BKN025CB

FM 270200 27010KT 9999 SCT030 BKN080 BKN250 QNH3001INS 20/09Z

KMOB 262046Z 2621/2721 00000KT 3200 BR VV004 QNH3012INS

BECMG 2706/2707 14012 9999 SCT004 SCT025 QNH3016INS

Figure 6-15 — TAF Example

Message Heading
The message heading begins with the 4-letter ICAO location identifier (e.g., KNSE for NAS Whiting Field) as shown in Figure 6-16. Next comes the letters “TAF” and any modifiers such as AMD, COR, or RTD, which stand for AMenDed, CORrected, or RouTine Delayed, unless the station is USN/USMC, in which case a remark will be appended to the last line of the forecast.

KNSE TAF 2609 / 2709 28004KT 9000 HZ SCT020 SCT200 QNH2998INS

Figure 6-16 — TAF Heading

Forecast Times

The two 4-digit number blocks following the message heading indicate the forecast period of the entire TAF, which is usually 24 hours (Figure 6-17). In each number block the first two digits indicate the date and the following two digits indicate the time. The first block is the start date and time of the TAF and the second block indicates the expiration date and time of the TAF. For example, 2609 / 2709 means that the forecast begins on the 26th at 0900Z and covers the 24-hour period up to but not including the 27th at 0900Z. U.S. civil stations include date and time of transmission prior to the forecast period (i.e., 091720Z 0918 / 1018).

KNSE TAF **2609 / 2709** 28004KT 9000 HZ SCT020 SCT200 QNH2998INS

Figure 6-17 — TAF Time Group

Whenever the forecast is an AMD, COR, or RTD, the times may not be for a 24-hour period and will be indicated accordingly. When USN/USMC stations amend, correct, or have a routine delayed forecast, a remark will be appended to the last line of the forecast with the appropriate time (e.g., AMD2218).

Winds

Wind direction is forecasted to the nearest 10 degrees true, in the direction from which the wind will be blowing (Figure 6-18). If wind direction is expected to vary by 60 degrees or more, the limits of variability will be noted as a remark, e.g., WND 270V350. The contraction VRB can only be used to replace direction when forecasted wind speed is 6 knots or less, or in more rare cases when it is impossible to forecast a single wind direction, such as for thunderstorms.

KNSE TAF 2609 / 2709 **28004KT** 9000 HZ SCT020 SCT200 QNH2998INS

Figure 6-18 — TAF Winds

Forecasted wind speeds and gust data are given in whole knots; if the wind speed is over 100 knots, then 3 digits are used. Calm winds are represented by “00000” for the wind group. “G” will be included to indicate gusts when the peak wind exceeds the average wind by 10 knots or more. Presently all U.S. winds are in knots and the contraction KT will end these wind groups. Some overseas stations use KPH (kilometers per hour) or MPS (meters per second).

Visibility, Weather, and Obstructions to Vision

For TAFs, forecasted prevailing visibility is reported in meters and rounded down to the nearest reportable value (Figure 6-19). U.S. civil stations, however, will report visibility in

KNSE TAF 2609 / 2709 28004KT **9000 HZ** SCT020 SCT200 QNH2998INS

Figure 6-19 — TAF Visibility Group

statute miles (Table 6-5). Whenever the prevailing visibility is forecasted to be 9000 meters or less (6 miles or less) the weather or obstructions to vision causing the reduced visibility will be included using the same notation as the METAR present weather group, described above in Table 6-2. A visibility code of "9999" indicates 7 miles visibility or greater is forecast, i.e.unlimited visibility. When appropriate, RVRs will follow immediately after the prevailing visibility.

VISIBILITY CONVERSION TABLE - STATUE MILES TO METERS					
Statute Miles	Meters	Statue Miles	Meters	Statute Miles	Meters
0	0	3/4	1200	1 7/8	3000
1/16	100	7/8	1400	2	3200
1/8	200	1	1600	2 1/4	3600
3/16	300	1 1/8	1800	2 1/2	4000
1/4	400	1 1/4	2000	3	4800
5/16	500	1 3/8	2200	4	6000[a]
3/8	600	1 1/2	2400	5	8000
1/2	800	1 5/8	2600	6	9000[b]
5/8	1000	1 3/4	2800	7	9999
Notes: [a] Rounded down from 6400m; [b] Rounded down from 9600m.					

Table 6-5 — Reportable Visibility Values for TAFs

If any significant weather or an obstruction to vision is forecast (rain, snow, sleet, hail, blowing dust, etc.), it will be included after visibility, using the codes in Table 6-2. If there is no significant weather, this group will be omitted.

Sky Condition Group
This group(s) will be included as often as necessary to indicate all forecast cloud layers–up to the first overcast layer (8/8ths)–in ascending order of cloud bases, with lowest layer first (Figure 6-20).

KNSE TAF 2609 / 2709 28004KT 9000 HZ **SCT020 SCT200** QNH2998INS

Figure 6-20 — TAF Sky Condition Group

As with METARs, TAF sky conditions will consist of five or six characters. The first two or three letters indicate the amount of sky coverage, from Table 6-3, above, and the last three digits indicate the height of the cloud bases in hundreds of feet AGL.

The types of clouds will not be forecast with the exception of cumulonimbus (CB), which will always be given as a separate layer (e.g., SCT005CB). In the event of a partial obscuration, it will be considered the first cloud layer and will be reported as FEW000, SCT000, or BKN000.

Special Wind Shear Group

An entry such as “WS020/22030KT” indicates the presence of wind shear. The three digits before the slash indicate the altitude (AGL), and the characters following the slash indicate wind direction and speed. North American stations will insert this special non-convective wind shear group immediately after the cloud group when it is forecast for altitudes 2000 feet AGL and below. However, if it cannot be forecast with accuracy, a less specific format of “WSCONDS” (wind shear conditions) may be used, and no further numeric data will be given. If no wind shear is forecast, then this group is omitted.

Icing Group

This group consists of six numbers only and begins with a “6.” It is used to forecast non-thunderstorm icing (the presence of thunderstorms implies moderate or greater icing), and is repeated as often as necessary to indicate multiple icing layers. The group is omitted if no icing is forecasted. The following example illustrates the decoding of the icing group:

641104

The “6” indicates that icing is forecasted. The next digit, “4,” is the type of forecasted icing from Table 6-6 (moderate icing). If more than one type of icing is forecast within the same stratum of air, the highest code Figure–the most severe–will be used. The next three digits, “110,” indicate the height of the base of the icing stratum in hundreds of feet AGL, which is 11,000' AGL in this case. If the numbers “000” are used, this would indicate icing occurring at or below 100 feet AGL. The last digit, “4,” is the thickness of the icing layer in thousands of feet (4000' here) using numbers 1 through 9. If layer is thicker than 9000 feet, the icing group is repeated so that the base of the repeated group coincides with the top of the first encoded icing group. If multiple layers are forecasted that are not related to each other, the layers are encoded in an ascending order.

Ic	TYPE OF ICING	B	TYPE OF TURBULENCE
Code	Description	Code	Description
0	No icing	0	None
1	Light icing	1	Light turbulence
2	Light icing in cloud	2	Moderate turbulence in clear air, occasional
3	Light icing in precipitation	3	Moderate turbulence in clear air, frequent
4	Moderate icing	4	Moderate turbulence in cloud, occasional
5	Moderate icing in cloud	5	Moderate turbulence in cloud, frequent
6	Moderate icing in precipitation	6	Severe turbulence in clear air, occasional
7	Severe icing	7	Severe turbulence in clear air, frequent
8	Severe icing in cloud	8	Severe turbulence in cloud, occasional
9	Severe icing in precipitation	9	Severe turbulence in cloud, frequent
		X	Extreme turbulence

Table 6-6 — TAF Icing and Turbulence Codes

Turbulence Group
This group is similar to the icing group because it is consists of six characters and follows the same format. The turbulence group, however, begins with a "5," and the second digit represents the turbulence intensity, also from Table 6-6. The turbulence group is used to forecast non-thunderstorm turbulence (the presence of thunderstorms implies moderate or greater turbulence) and is also repeated as often as necessary to indicate multiple turbulence layers. The group is omitted if no turbulence is forecasted. The example below illustrates the decoding of the turbulence group:

510302

Following the same rules as the icing group, above, one would expect light turbulence from 3000 feet AGL to 5000 feet AGL.

Altimeter Group
This group forecasts the lowest expected altimeter setting in inches of Hg (Mercury) during the initial forecast period and each subsequent BECMG and FM group (to be discussed shortly) that follows. TEMPO groups (also to be discussed shortly) do not forecast the QNH group. This minimum altimeter setting becomes quite valuable when aircraft lose radio communications in IMC conditions and need a useful altimeter setting for the destination airfield (Figure 6-21).

KNSE TAF 2609 / 2709 28004KT 9000 HZ SCT020 SCT200 **QNH2998INS**

Figure 6-21 — TAF Altimeter Group

The “QNH” indicates that sea level pressure is being given. The next four digits indicate the lowest forecast altimeter setting in inches of Hg (and hundredths), without the decimal. “INS” simply indicates the unit of measurement is inches. Other standards, such as QNE and QFE, are also used in different circumstances. QNE is the standard datum plane, 29.92 in-Hg, and some countries use QFE, the actual station pressure not corrected to sea level. If QFE is set, the altimeter indicates actual elevation above the field, but does not ensure terrain clearance. Aircrews must exercise extreme caution if conducting operations at a location using QFE.

International stations report the altimeter in millibars (a.k.a. hectopascals, hPa) and use the letter “Q” for indicator. For example, “Q1013” indicates a forecast altimeter setting of 1013 millibars. U.S. civil stations generally will not forecast an altimeter setting.

Remarks

Various remarks may be appended to the end of the initial forecast period and subsequent change groups. The contractions listed in Table 6-2 are used for weather and obstructions to vision, while the FAA General Use Contractions will be used for other abbreviations.

The abbreviation “VC,” also from Table 6-2, will only be used for air mass weather that is expected to occur within the forecast area. For example, “VCSHRA W” would indicate that rain showers are in the vicinity to the west. However, “VC” will not be used for weather expected to occur within a 5-mile radius of the runway complex, since that is considered to be “at the station.”

Temperature Group

This is an optional group; however, its usage is highly encouraged and should be included to meet the requirements of local operations, especially for helicopter and VSTOL aircraft, which require density altitude. The forecast maximum or minimum temperature, depending on the time of the day, is given in two digits Celsius, using “M” for minus temperatures. This is followed by the 2-digit hour during which the maximum or minimum is expected to occur. It will be on the last line of the TAF, unless the forecast was amended.

Change Group Terminology

The change groups of “FM,” “BECMG,” and “TEMPO” will be used whenever a change in some or all of the elements forecasted are expected to occur at some intermediate time during the 24-hour TAF period. A new line of forecasted text is started for each change group. More than one change group may be used to properly identify the forecast conditions (Figure 6-22).

FM (From) and BECMG (Becoming) are indicators of expected speed of change. FM is used when the change is expected to be quick, and BECMG is used when the change is expected to occur over a longer period of time. FM indicates that a permanent, dramatic or relatively dramatic, change to a weather pattern is forecast to occur in a short period. All elements of the forecast conditions will be listed on that TAF line. BECMG indicates that some forecast elements are going to change permanently, or possibly that all of the forecast elements are to change. TEMPO (Temporary) means just that: a temporary or non-permanent change to the to the overall weather pattern.

KNSE TAF 2609 / 2709 28004KT 9000 HZ SCT020 SCT200 QNH2998INS
FM261200 26007KT 9000 HZ SCT025 SCT080 BKN250 QNH2996INS VCSHRA
BECMG 2614 / 2616 9999 SCT025CB SCT250
BECMG 2617 / 2618 23015G25KT 530004
TEMPO 2619 2702 8000 TSSHRA SCT010 BKN025CB
FM270200 27010KT 9999 SCT030 BKN080 BKN250 QNH3001INS 20/09Z

Figure 6-22 — TAF Change Groups

FM Group
The heading “FM” is immediately followed by a date then time (hours and minutes) indicates that the forecast weather is expected to change rapidly to the conditions on that line. In other words, the time indicates the beginning of a significant and permanent change in the whole weather pattern, and all previously forecast conditions are superseded by the conditions forecasted on this line. Additionally, the “FM” line includes all elements of a normal forecast as discussed above.

Using Figure 6-22 as an example, the change group “FM261200” starts the change line, and this indicates a change is forecasted to occur on the 26th at 1200Z. All elements on that line will be in effect from 1200Z to the end of the original 24-hour period (0900Z in this example), unless changed later in the forecast by another change group (as is the case here).

BECMG Group
A line beginning with the heading “BECMG” indicates a change to forecast conditions is expected to occur slowly within the period designated in the time group immediately following the heading. The heading “BECMG” is followed immediately by two 4-digit number blocks (i.e., BECMG 2617 / 2618). The first 2 digits of each number block indicate the applicable date and the following two digits indicate a time. The time indicated by the first number block indicates the beginning hour in which the change will take place. The time indicated in the second number block indicates the ending hour. The duration of this change is normally about 2 hours, 4 hours at most and is how long the weather depicted within the BECMG line will take to fully develop.

The elements included in the BECMG line will supersede *some* of the previous TAF groups, but it is possible that all the groups may change. Any group omitted in the BECMG line will be the same during the BECMG period as indicated in the main TAF line. These new conditions are expected to exist until the end of the TAF forecast time period (unless changed later in the forecast by another change group).

KNSE TAF 2609 /2709 28004KT 9000 HZ SCT020 SCT200 QNH2998INS
FM261200 26007KT 9000 HZ SCT025 SCT080 BKN250 QNH2996INS VCSHRA

BECMG 2614 /2616 9999 SCT025CB SCT250
BECMG 2617 / 2618 23015G25KT 530004
TEMPO 2619 / 2702 8000 TSSHRA SCT010 BKN025CB
FM270200 27010KT 9999 SCT030 BKN080 BKN250 QNH3001INS 20/09Z

Figure 6-23 — TAF BECMG Group

From Figure 6-23, some aspects of the weather will begin to change slowly sometime between 1700 and 1800Z, specifically the winds and turbulence. These forecast winds of 230° at 15 kts, gusting to 25 kts, and the frequent, moderate CAT can be expected to last until superseded by the FM group at 0200Z.

TEMPO Group
The heading "TEMPO" is followed immediately by two 4-digit number blocks (i.e., TEMPO 2619 / 2702). The first 2 digits of each number block indicate the applicable date and the following two digits indicate a time. The time indicated by the first block indicates the beginning time of the weather occurrence. The weather indicated by the TEMPO line will continue until the time indicated in the second block. This does not represent a permanent change only that the weather will occur briefly. Rather, there will be a short-lived overlay to the base forecast occurring only between the beginning and ending hours specified by the time group. For example, the change group "TEMPO 2619 / 2702" indicates that the forecasted weather will occur from 1900Z on the 26th until 0200Z on the 27th. Furthermore, only the elements listed are forecast to be affected.

For example, in Figure 6-24, the temporary occurrence of thunderstorms and rain showers are forecast to exist only from 1900 up to, but not including, 0200. After this time, the conditions listed in the TEMPO line will be replaced by the forecast from other lines.

KNSE TAF 2609 / 2709 28004KT 9000 HZ SCT020 SCT200 QNH2998INS
FM261200 26007KT 9000 HZ SCT025 SCT080 BKN250 QNH2996INS VCSHRA
BECMG 2614 / 2616 9999 SCT025CB SCT250
BECMG 2617 / 2618 23015G25KT 530004
TEMPO 2619 / 2702 8000 TSSHRA SCT010 BKN025CB
FM270200 27010KT 9999 SCT030 BKN080 BKN250 QNH3001INS 20/09Z

Figure 6-24 — TAF TEMPO Group

PROB Group
Civilian stations will sometimes forecast the probability of occurrence of thunderstorms or other precipitation events. Such a line begins with "PROB," followed by a 2-digit percentage and the corresponding weather, as this example illustrates:

PROB40 1/2SM +TSRA OVC005CB

This station forecasts a 40% chance of heavy rain from thunderstorms, producing an overcast ceiling of cumulonimbus clouds at 500 feet, with visibility ½ mile. This group may also be followed by a 4-digit time period group giving the beginning and ending time for the occurrence. USN/USMC stations will not use this change group.

Change Groups and Times (FROM/TO)
In order to use a TAF effectively, one must know how long a given pattern of weather will last, as well as what that pattern will be. To do this, establish the FROM and TO times of that pattern. (Note: in this text, TO will mean up TO, but not including that time.)

- The times on the first line of code, after the location, are the FROM and TO date and times for the entire forecast, and the beginning (FROM) time of the first forecast line.
- The time listed immediately after a FM can be a beginning time of a new pattern of weather as well as a TO time of a previously defined pattern, depending upon where it falls in the forecast.
- The time indicated by the second two digits of the 4-digit group following BECMG will be the beginning time of the new forecast elements, and the time indicated by the second two digits of the second 4-digit group are the ending time of the previous line of code and indicate that the BECMG line of code is fully developed.
- The time indicated by the second two digits of the 4-digit group after a TEMPO are the beginning (FROM) time, and the time indicated by the second two digits of the second 4-digit group are the ending (TO) time for that TAF line.

```
KNSE 2009 / 2109 00000KT 0800 FG VV001 620106 QNH3000INS
TEMPO 2009 / 2012 00000KT 2400 BR SCT000 SCT005 SCT080 SCT250
FM201400 20005KT 6000 HZ SCT025 SCT080 SCT250 QNH3004INS
BECMG 2016 / 2017 9999 QNH3002INS
BECMG 2020 / 2022 23010KT 9999 SCT025 SCT080 BKN250 WSCONDS 531006
QNH2996INS VCTSSH
TEMPO 2023 / 2103 VRB15G30KT 1600 TSSH OVC010CB
```

Figure 6-25 — From/To Example

Using the example in Figure 6-25, the first forecast line (KNSE 2009 / 2109) begins FROM 0900Z on the 20th and is good up TO the 20th at 1400Z on the third line. (the 20th at 0900Z to the 21st at 0900Z is the 24 hour forecast period.) The second forecast line (TEMPO 2009 / 2012) begins FROM the 20th 0900Z and is forecast to occur up TO the 20th at1200Z. The third forecast line (FM201400) begins FROM the 20th at 1400Z and is good up TO the 20th at1700Z, with some of these conditions changing by 1700Z, as indicated by the fourth line. The fourth forecast line (BECMG 2016 / 2017) begins FROM the 20th at1600Z and is good up TO the 20th at 2200Z, with some of these conditions changing by 2000Z, as indicated by the fifth line. The fifth forecast line (BECMG 2020 / 2022) begins FROM the 20th at 2000Z and is forecast to occur up TO at least 0900Z, the end of the forecast period, with some temporary conditions changing between 2300Z and 0300Z, as indicated by the sixth line. The sixth line (TEMPO 2023 / 2103) begins FROM 2300Z on the 20th and is forecast to occur up TO 0300Z on the 21st.

Summary Of U.S. Civil/Military TAF Differences
Civilian weather stations are required to adhere to slightly different formats than military stations, as has been discussed in the corresponding sections above. For reference, these differences are summarized below. An example follows in Figure 6-26.

1. U.S. civil stations will use statute miles instead of meters.
2. U.S. civil stations include date time group of transmission prior to the forecast period (e.g., 091720Z 0818 / 0918).
3. When U.S. military stations amend, correct, or have a routine delayed forecast, a remark will be appended to the last line of the forecast with the appropriate time (e.g., AMD2218).
4. U.S. civil stations may include probability of precipitation occurrence.

```
KLCH TAF 032240Z 0323 / 0423 01012G22KT 5SM HZ OVC006
BECMG 0400 / 0402 01015G25KT 2SM -DZ BR OVC004 PROB40 0004 VRB25G35KT 2SM TSRA
VV002
FM040400 01012G20KT 2SM BR OVC004
BECMG 0415 / 0416 01015G25KT 4SM HZ OVC008
FM041700 01010KT 5SM HZ OVC009

KSHV TAF 032240Z 0323 / 0423 36010KT 4SM BR OVC004 WS005/27050KT
TEMPO 0423 / 0416 35015KT 2SM -FZDZ PL OVC020
FM041700 04008KT P6SM BKN025
```

Figure 6-26 — Civilian TAF Examples

Additionally, there are some differences between military TAFs and International TAFs, which are summarized in Table 6-7.

TAF Differences			
U.S. Military TAF		International TAF	
Forecast Period	24 Hours	Forecast Period	Variable
Wind Speed	Knots	Wind Speed	Knots-, or Meters- or Kilometers-per-hour
CAVOK not used		CAVOK used	

Table 6-7 — Differences Between Military and International TAFs

The term CAVOK is similar to the term sometimes used among aviators, CAVU, which stands for "Clear Air, Visibility Unlimited." The term CAVOK stands for "Clear Air, Visibility O.K." and is not used in U.S. Military TAF reporting.

Determination of Ceiling in METARs and TAFs

In Chapter 5 we first introduced the concept of cloud layers and ceilings. As you may recall, the definition of a ceiling is the height above the ground (AGL) ascribed to the lowest broken or overcast layer; or the vertical visibility into an obscuring phenomenon (total obscuration). Remember that partial obscurations, such as FEW000, or SCT000, do not constitute a ceiling.

Ceilings may be easy to determine in METAR, but more difficult in TAFs, since they usually have more than one line. Therefore, it is important to carefully evaluate the ceiling by using the appropriate time period, as will be discussed below in "Using TAFs for Flight Planning." Once the ceiling (and other cloud layers) has been determined, then one can move onward to determining the type of flight plan (IFR or VFR) as well as whether an alternate landing airfield is required.

Example of Military TAF with Description of Elements

KNSE TAF 2609 / 2709 28004KT 9000 HZ SCT020 SCT200 QNH2998INS
FM261200 26007KT 9000 HZ SCT025 SCT080 BKN250 QNH2996INS VCSHRA
BECMG 2614 / 2616 9999 SCT025CB SCT250
BECMG 2617 / 2618 23015G25KT 530004
TEMPO 2619 / 2702 8000 TSSHRA SCT010 BKN025CB
FM270200 27010KT 9999 SCT030 BKN080 BKN250 QNH3001INS 20/09Z

Figure 6-27 — Military TAF Example

1st line — Forecast for NAS Whiting field (KNSE) beginning on the 26th at 0900Z (2609) and valid up to but not including the 26th at 1200Z on the second line (FM261200), winds from 280 degrees and speed 4 knots (28004KT), visibility 6 miles (9000 meters), in haze (HZ), scattered clouds at 2,000 feet AGL (SCT020), scattered clouds at 20,000 feet AGL (SCT200), altimeter setting 29.98 inches (QNH2998INS).

2nd Line — From the 26th at 1200Z (FM261200), up to but not including the 26th at 1600Z (BECMG 2616), winds from 260 degrees at 7 knots (26007KT), visibility 6 miles (9000 meters), in haze (HZ), scattered clouds at 2500 feet AGL (SCT025), scattered clouds at 8000 feet AGL (SCT080), broken clouds at 25,000 feet AGL (BKN250), altimeter setting of 29.96 inches (QNH2996INS), and rain showers in the vicinity (VCSHRA), ceiling at 25,000 feet.

3rd Line — From the 26th at1400Z (BECMG 2614), up to but not including the 26th at1800Z (BECMG 2618), winds the same as 2nd line (26007KT), visibility greater than 7 miles (9999), scattered cumulonimbus clouds at 2500 feet AGL (SCT025CB), and scattered clouds at 25,000 feet AGL (SCT250), altimeter setting same as 2nd line (QNH2996INS); remarks same as 2nd line.

4th Line — From the 26th at 1700Z (BECMG 2617) up to but not including the 27th at 0200Z (FM270200), winds from 230 degrees at 15 knots with gusts to 25 knots (23015G25KT), visibility same as 3rd line (9999), clouds same as 3rd line (SCT025CB, SCT250), moderate turbulence in clear air from surface up to 4000 feet (530004), altimeter setting same as 2nd line, 29.96 inches (QNH2996INS). Remarks same as 2nd line.

5th Line — Temporarily between the 26th at 1900Z and the 27th at 0200Z (TEMPO 2619 / 2702), winds same as 4th line (23015G25KT), visibility 5 miles (8000 meters), with thunderstorms and rain showers (TSSHRA), scattered clouds at 1000 feet AGL (SCT010) and broken cumulonimbus clouds at 2500 feet AGL (BKN025CB), turbulence same as 4th line (530004), altimeter same as 2nd line (QNH2996INS), with ceiling at 2500 feet.

6th line — From the 27th at 0200Z (FM270200) up to but not including the 27th at 0900Z (end of TAF), winds from 270 degrees at 10 knots (27010KT), visibility greater than 6 miles (9999), scattered clouds at 3000 feet AGL (SCT030), broken clouds at 8000 feet AGL (BKN080), broken clouds at 25,000 feet AGL (BKN250), altimeter setting 30.01 inches (QNH3001INS), ceiling at 8000 feet AGL, minimum temperature forecasted for the day is 20° C (68° F) at 0900Z.

Using TAFs For Flight Planning

For flight planning purposes, an aviator must consider the worst weather conditions that fall within the period of 1 hour prior to the planned estimated time of arrival (ETA) up to but not including 1 hour after ETA, for a total of a 2-hour window. As an example, assume an ETA of
1620Z at NAS Whiting, use the TAF in Figure 6-27, and follow these simple steps:

1. Determine the arrival window, which would be 1520 – 1720Z in this case.
2. Evaluate the whole TAF to determine the forecast time period to which each line applies. If any part of the 2-hour ETA window falls within the time period of that line, then the information in that line will be applicable. In this case, lines 2, 3, and 4 each cover part of the 1520 – 1720Z window.
3. Finally, mix and match the weather from each line for use in flight planning, building a set of the worst-case scenario for each group: strongest winds, lowest visibility, worst weather, lowest ceiling, and lowest altimeter.

Using this technique, they would look for the worst weather among each of these lines and plan for:

- Winds 230 degrees at 15 knots gusting to 25 knots (23015G25)
- Visibility 6 miles in haze (9000 HZ)
- Scattered cumulonimbus at 2500' AGL, scattered clouds at 8000' AGL, and broken clouds at 25,000' AGL, with ceiling at 25,000' (SCT025CB, SCT080, BKN250)
- Altimeter setting 29.96 inches (QNH2996INS)
- Frequent moderate clear air turbulence from the surface up to 4000 feet (530004)
- Rain showers in the vicinity (VCSHRA)

ASSIGNMENT SHEET 3-6-3

METARS AND TAFS REVIEW

A. INTRODUCTION

This lesson is an introduction to basic aviation weather reports (METARs) and Terminal Aerodrome Forecasts (TAFs). It provides a knowledge base for the reading and understanding of up-to-date weather information as provided by various aviation weather forecasting and reporting services.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

1. Review JPATS Aviation Weather Booklet, JX100 Chapter JX106.

D. STUDY QUESTIONS

Use Figure 6-29 for questions 1-6, as well as any tables needed from the chapter.

KLEX 0359Z 19004KT 7SM BKN250 22/20 A3020 RMK SLP220

KPAH 0358Z 09008KT 15SM-RA BKN011 OVC060 22/20 A3007 RMK CB OVHD MOVG E SLP178

KAND 0357Z 09005KT 060V140 12SM SCT050 BKN250 30/22 A3015 RMK SLP204

KCAE 0356Z 0000KT 10SM FEW000 FEW050 SCT300 25/20 A3013 RMK CB N LTGIC SLP201

KAVL 0458Z 12004KT 2SM BR HZ SCT000 SCT060 BKN080 21/20 A3028 RMK FG HZ SCT000 PRESFR SLP226

KRDU 0456Z 13008KT 2SM HZ SCT000 24/22 A3017 RMK HZ SCT000 SLP208

Figure 6-29 — METAR for Questions 1-6

1. The report for Anderson (AND) indicates ______.
   a. broken clouds at 25,000 feet
   b. that the altimeter setting is 29.05 inches of mercury
   c. that the wind is 200° at 40 miles per hour
   d. broken clouds at 5000 feet

2. The report for Lexington (LEX) indicates ______.
   a. that the ceiling is reported at 25,000 feet
   b. that the wind is from the south at 40 miles per hour
   c. no ceiling
   d. that the station pressure reduced to sea level is 922.0 mb

3. The report for Paducah (PAH) indicates ______,
   a. the ceiling is 6000 feet
   b. the overcast is measured at 1100 feet
   c. the altimeter setting is 30.07 inches of mercury
   d. that it is snowing

4. The report for Columbia (CAE) indicates ______.
   a. over 15 statute miles visibility
   b. that there is no ceiling
   c. a mistake in the dew point
   d. a pilot would prefer to approach this station from the north

5. The report for Asheville (AVL) indicates ______.
   a. 20 statute miles visibility
   b. that the wind was 210° at 4 miles per hour
   c. that the visibility was restricted because of mist and haze
   d. that the wind was 040° at 12 knots

6. The report for Raleigh (RDU) indicates ______.
   a. that there was no ceiling
   b. that the altimeter setting was 20.17 inches of mercury
   c. a partial obscuration
   d. that A and C are correct

Use Figure 6-30 for questions 7-12, as well as any tables needed from the chapter.

KTLH 0455Z 04012KT 6SM-RA DZ BKN015 OVC018 22/21 A2995 RMK-RA OCNLY RA SLP144

KAQQ 0456Z 22010KT 3SM R04/P6000FT SCT000 BKN008 BKN080 OVC250 19/18 A2994 RMK FG SCT000 CIG 006V010 SLP142

KSUU 2157Z 16009KT 10SM BKN027 BKN200 30/26 A2999 RMK SLP190

KNGP 2158Z 18012KT 12M SKC 20/12 A2964 RMK VSBY E 1 1/2FU SLP037

KTIK 2158Z 18015G25KT 7SM BKN012 OVC090 26/14 A2966 RMK CIG LWR N SLP044

KBAD 2057Z 19007KT 15SM SCTO55 BKN180 26/15 A2996 RMK VSBY SE 3 FU SLP146

Figure 6-30 — METAR for Questions 7-12

7. The report for Tallahassee (TLH) indicates ______.
   a. that the light rain is occasionally heavy
   b. the ceiling is estimated to be 1800 feet AGL
   c. the present weather is light rain and drizzle
   d. the sea-level pressure is 1014.2 inches

8. The report for Apalachicola (AQQ) indicates ______.
   a. that there are two ceilings
   b. that on RWY 04, the visual range is greater than 6000 feet
   c. the ceiling varies between 6000 and 10,000 feet MSL
   d. fog obscures five-eighths of the sky

9. The report for Travis AFB (SUU) indicates that ______.
   a. the wind is 160° at 9 miles per hour
   b. there was a ceiling
   c. the visibility is 10 nautical miles
   d. the altimeter setting is 29.99 mb

10. The report for NAS Corpus Christi (NGP) indicates that ______.
    a. there is no ceiling
    b. the wind is 12 knots from the south
    c. the visibility in the area is restricted
    d. A and B are correct

11. The report for Tinker AFB (TIK) indicates that ______.
    a. the ceiling is 900 feet and is overcast
    b. a pilot flying at 10,000 feet would be above all clouds
    c. the ceiling on an approach from the north may be lower
    d. there are squalls

12. The report for Barksdale AFB (BAD) indicates ______.
    a. the magnetic wind is 190° at 07 knots
    b. the visibility is 15 statute miles in all directions
    c. the temperature-dew point spread is 12° C
    d. none of the above

Use Figure 6-31 for questions 13-19, as well as any tables needed from the chapter.

KNQA SPECI 2056Z 36007KT 3/4SM FG VV004 22/21 A2976 RMK SLP078

KBWG 1357Z 13004KT 10SM TSRA PL SCT025CB SCT035 SCT100 BKN250 28/26 A2990 RMK TSSH ALQDS SLP125

KMEM 1356Z 04010KT 010V070 30SM BKN120 BKN250 30/17 A2995 RMK SLP142

KPAH 1358Z 17023G30KT 12SM SKC 34/24 A2990 RMK FEW CI SLP111

KSDF SPECI 1357Z 00000KT 1SM-RA FG BKN006 19/18 A2976 RMK SLP078

KTRI 1356Z 00000KT 20SM BKN065 A3010 RMK LSR08P DRY SLP193

Figure 6-31 — METAR for Questions 13-19

13. The report of NAS Memphis (NQA) at 2100Z indicates ______.
    a. an overcast at 400 feet
    b. that the visibility is 3 statute miles
    c. that the ceiling was due to an obscuration
    d. that the lowest cloud layer is at 300 feet

14. The 2100Z report from NAS Memphis (NQA) indicates ______.
    a. that this was a special weather observation
    b. that the visibility is unrestricted
    c. that the wind information is missing
    d. no clouds

15. The report for Memphis (MEM) indicates that ______.
    a. the wind is steady from 040° magnetic at 10 knots
    b. the ceiling is 12,000 feet
    c. there is another ceiling at 25,000 feet
    d. the altimeter setting is 29.95 hectopascals

16. The report for Bristol (TRI) indicates ______.
    a. the temperature and dew point are minus values
    b. that the wind information is missing
    c. that the temperature is missing
    d. two layers of clouds

17. The report for Bowling Green (BWG) indicates ______.
    a. that the ceiling is 2500 feet
    b. that ice pellets were falling at the time of the observation
    c. that the wind is 130° at 4 miles per hour
    d. broken clouds at 10,000 feet

18. The report for Paducah (PAH) indicates ______.
    a. gusty winds
    b. that the wind speed reached 30 miles per hour
    c. that there are no clouds
    d. that the barometric pressure is 911.1 mb

19. The report for Louisville (SDF) indicates ______.
    a. light rain and fog
    b. that the wind is calm
    c. the height of the ceiling was 600 feet
    d. that all are correct

Use Figure 6-32 for questions 20-25, as well as any tables needed from the chapter.

KADM SPECI 0958Z 32014 KT 7SM SKC 21/18 A2970 RMK SLP057 RADAT 79100

KOKC 1008Z 108014KT 15SM SCT010 BKN025 28/23 A3006 RMK DSNT TSSH SLP219

KPWM 1055Z 30018KY 2SM R30/P6000FT –SN SCT000 OVC008 M01/M02 A2991 RMK SN SCT000 DRFTG SN PSR20 SLP118

KLUF 1356Z 18005KT 45SM SCT025 SCT050 BKN240 04/M06 A3017 RMK SHSN OBSCG MTNS N SLP217

KNFB SPECI 0123Z 01023G35 1/2SM R36R/1200FT –BLSN SCT000 OVC005 RMK VIS 3/8V5/8 BLSN SCT000 CIG 004V006

KNXX 0058Z COR 13008G15KT 100V170 8SM SCT005 BKN008 OVC012 06/M01 A2945 RMK BKN TOPS 070 SLP985

Figure 6-32 — METAR for Questions 20-25

20. The report for Ardmore (ADM) indicates that ______.
    a. the freezing level was observed to be at 10,000 feet MSL
    b. the time of the RADAT observation was 1008Z
    c. the freezing level was forecast to be at 10,000 feet MSL
    d. the freezing level was forecast to be at 10,000 feet AGL

21. The report for Oklahoma City (OKC) indicates ______.
    a. it is raining in sight of the field
    b. the temperature-dew point spread was 9° C
    c. Oklahoma City was still able to transmit the report at the assigned time slot
    d. that A and C are correct

22. The report for Portland (PWM) indicates that ______.
    a. the sky is partially obscured by snow
    b. the runway visual range is greater than 6000 feet
    c. the ceiling was 800 feet
    d. all above are correct

23. Luke AFB (LUF) reported ______.
    a. a visibility of 45 statute miles
    b. no weather in the vicinity of the station
    c. an unlimited ceiling
    d. all of the above

24. The report for NAS Grosse Isle (NFB) ______.
    a. indicates a partial obscuration due to blowing snow
    b. is in error, since RVR does not coincide with prevailing visibility
    c. indicates a possible ceiling at 400 feet
    d. indicates the conditions stated in A and C

25. NAS Willow Grove (NXX) reported ______.
    a. base of the overcast at 1200' AGL, top of the overcast at 7000' AGL
    b. conditions which would point up the wisdom of monitoring reports for further weather developments at Willow Grove while en route to that terminal
    c. VFR conditions over the field
    d. wind steady from 310° at 8 knots with gusts at 15 knots

Terminal Aerodrome Forecasts (TAFs)
Refer to the following figure (6-33) for questions 26-50, as well as any tables needed from the chapter.

KNPA 2012 / 2112 360005KT 0800 DZ FG VV002 QNH3001INS
FM201500 02011KT 8000 HZ BKN007 BKN020 BKN140 BKN300 641403 540209 QNH2995INS
TEMPO 2018 / 2022 16008KT 4800 SHRA SCT008 BKN020

KNTU 2012 / 2112 02008KT 1600 RA BR OVC004 QNH300INS
TEMPO 2012 / 2016 VRB05KT 0800 FG VV001
FM201600 02011KT 6000 HZ BKN007 BKN020 OVC300 670708 QNH2993INS
TEMPO 2018/2022 19006KT 4800 SHRA SCT009 BKN020

KDOV 2012 / 2112 36007KT 0800 DZ FG VV002 QNH3001INS
FM201500 02011KT 8000 HZ BKN007 BKN020 BKN150 OVC300 621403 540209 QNH2995INS
TEMPO 2018 / 2122 16008KT 4800 SHRA SCT008 BKN020

KNBE 2012 / 2112 VRB05KT 0800 DZ FG VV001 QNH3004INS
FM201300 12006KT 1600 BR OVC005 QNH3001INS VCRA
FM201700 17010KT 8000 HZ SCT007 BKN020 OVC300 650106 540209 QNH2991INS VCSHRA
TEMPO 2018 / 2023 18015KT 4800 SHRA BKN020
BECMG 2101 / 2102 VRB05KT 3200 BR BKN005 OVC020 QNH 3000INS

Figure 6-33 — TAF for Questions 26-50

KTIK 2012 / 2112 VRB05KT 1600 DZ BR OVC004 QNH2999INS
FM201500 15010KT 0800 DZ FG OVC006 QNH3001INS
BECMG 2021 / 2122 17010KT 2400 DZ BKN014 OVC025 QNH3005INS
FM210000 22012KT 9999 SCT030 OVC050 QNH3002INS
BECMG 2106 / 2108 24012KT SKC QNH3004INS

KSPS 2012 / 2112 17010KT 4800 BR BKN008 OVC015 QNH2987INS
FM201500 17015KT 9999 OVC015 QNH2989INS
FM202000 19012KT 9999 BKN030 QNH2990INS
BECMG 2002 / 2104 19010KT SKC QNH2993INS

KNQA 2015 / 2115 18008KT 9999 SKC QNH3012INS
FM201800 17012G20KT 9999 BKN025 611109 521103 QNH3008INS
FM210400 17015G22KT 9999 BKN020 BKN100 WSCONDS QNH3008INS
TEMPO 2104 / 2108 20025G35KT 1600 TSSHRA OVC008CB

KNBG 2015 / 2115 13008KT 9999 SCT025 SCT100 651309 521303 QNH3025INS
TEMPO 2015 / 2100 13012KT 9999 BKN025 BKN100
FM210900 VRB04KT 2400 BR SCT015 QNH3021INS
TEMPO 2109 / 2113 00000KT 0800 FG OVC015
FM211300 17010KT 9999 SCT030 QNH3020INS

KNMM 2015 / 2115 14005KT 8000 BR SCT025 QNH3028INS
FM201900 16005KT 8000 HZ SCT025 BKN080 651109 561203 QNH3024INS
TEMPO 2019 / 2102 18010KT 6000 HZ BKN025 OVC080
FM210200 00000KT 9999 SKC 562005 QNH3020INS
BECMG 2108 / 2109 1600 BR SCT000 QNH3018INS

Figure 6-33 — TAF for Questions 26-50

26. What is the forecast period for the first line of code on the NAS Pensacola (NPA) forecast?
    a. 1200Z up to, but not including 1200Z
    b. 1200Z up to, but not including 2200Z
    c. 1200Z up to, but not including 1800Z
    d. 1200Z up to, but not including 1500Z

27. An aircraft with an ETA into NPA of 1715Z would expect a ceiling of no less than ______.
    a. 2000 feet MSL
    b. 2000 feet AGL
    c. 700 feet AGL
    d. 700 feet MSL

28. What is the highest visibility forecast throughout the forecast period at NPA?
    a. 3 SM
    b. 5 SM
    c. ½ SM
    d. >6 SM

29. Would a pilot flying over NPA during the hours of 1600Z to 2000Z expect icing?
    a. Yes
    b. No

30. Which lines of the forecast for NAS Oceana (NTU) would it be necessary to look at to formulate the worst case scenario for an ETA of 1615Z?
    a. Line 3 only
    b. Lines 2 and 3 only
    c. All lines would be used.
    d. Lines 1 thru 3

31. What minimum visibility would be expected at NTU for an ETA of 1300Z?
    a. 1 SM
    b. ½ SM
    c. 4 SM
    d. >6 SM

32. What type of turbulence is forecast over NTU at 2000Z?
    a. Severe turbulence in clear, frequent
    b. Severe turbulence in cloud, infrequent
    c. Severe turbulence in clear, infrequent
    d. None forecast at that time

33. What is the temporary forecast sky cover between 1200Z and 1600Z at NTU?
    a. 800 foot ceiling
    b. Nine-tenths cloud coverage
    c. Partial obscuration
    d. Total obscuration

34. What is the forecast period for the second line of code for Dover AFB (DOV)?
    a. 1500Z up to, but not including 1200Z
    b. 1200Z up to, but not including 1500Z
    c. 1500Z up to, but not including 2200Z
    d. 1500Z up to, but not including 1800Z

35. Between which altitudes would icing be expected at DOV, at any time, if at all?
    a. 14,000 - 17,000 feet
    b. 14,000 - 14,300 feet
    c. 2000 - 11,000 feet
    d. None is forecast for DOV

36. What are the maximum forecast winds at DOV throughout the forecast period?
    a. 020° MAG at 11 mph
    b. 150° True at 16 knots
    c. 020° True at 11 knots
    d. 180° MAG at 22 knots

37. How many, if any, different types of weather are forecast throughout the forecast period at DOV?
    a. 2
    b. 3
    c. 4
    d. 5

38. What is the forecast period for the TEMPO line on the NAS Dallas (NBE) forecast?
    a. 1800Z up to, but not including 0200Z
    b. 1800Z up to, but not including 1200Z
    c. 1800Z up to, but not including 0100Z
    d. 1800Z up to, but not including 2300Z

39. The minimum expected ceiling throughout the forecast period for NBE is ______.
    a. 1000 feet AGL
    b. 100 meters MSL
    c. 100 feet AGL
    d. 500 feet MSL

40. What are the forecast winds for NBE for an ETA of 0315Z?
    a. 170/10
    b. Variable at 5 kts
    c. 180/15
    d. Calm

41. Was Millington Regional (NQA) was expecting wind shear at any time during the forecast period?
    a. Yes
    b. No

For questions 42-46, provide the minimum ceilings and visibilities for the location and ETA listed.

42. **NTU** ETA 1300Z: ___/___; ETA 1900Z: ___/___; ETA 0900Z: ___/
(CIG) / (VSBY)

43. **DOV** ETA 1400Z: ___/___; ETA 1800Z: ___/___; ETA 0100Z: ___/

44. **NBE** ETA 1415Z: ___/___; ETA 1920Z: ___/___; ETA 0130Z: ___/

45. **TIK** ETA 1300Z: ___/___; ETA 1545Z: ___/___; ETA 0300Z: ___/

46. **SPS** ETA 1310Z: ___/___; ETA 1730Z: ___/___; ETA 2300Z: ___/

47. Fill in the forecast elements for the following Table:

	NQA/ETA0700Z	**NBG**/ETA1600Z	**NMM**/ETA0730Z
2 HOUR WINDOW	________	________	________
CEILING (MIN)	________	________	________
VISIBILITY (MIN)/WEATHER(S)	____/____	____/____	____/____
ALTIMETER (LOWEST)	________	________	________
WINDS (MAX)	________	________	________
ICING (TYPE/ALTITUDES)	____/____	____/____	____/____
TURB (TYPE/ALTITUDES)	____/____	____/____	____/____

Answers:

1. A	22.D
2. A	23.A
3. C	24.D
4. B	25.A
5. C	26.A
6. D	27.C
7. C	28.B
8. B	29.A
9. B	30.D
10.D	31.B
11.C	32.D
12.D	33.D
13.C	34.A
14.A	35.A
15.B	36.C
16.C	37.C
17.B	38.D
18.A	39.C
19.D	40.B
20.A	41.Yes
21.A	

42. **NTU** ETA 1300Z: 100 / 1/2; ETA 1900Z: 2000/3; ETA 0900Z: 700/4 (CIG) / (VSBY)

43. **DOV** ETA 1400Z: 200 / 1/2; ETA 1800Z: BKN2000/3; ETA 0100Z: 700/5

44. **NBE** ETA 1415Z: 500 / 1; ETA 1920Z: 2000/3; ETA 0130Z: 500/2

45. **TIK** ETA 1300Z: 400 / 1; ETA 1545Z: 600 / ½; ETA 0300Z: 5000/≥ 7

46. **SPS** ETA 1310Z: 800/3; ETA 1730Z: 1500/≥ 7; ETA 2300Z: 3000/≥ 7

47.

	NQA/ETA0700Z	**NBG**/ETA1600Z	**NMM**/ETA0730Z
2 HOUR WINDOW	06-08Z	15-17Z	0630-0830Z
CEILING (MIN)	800	2500	NONE
VISIBILITY (MIN)/WEATHER(S)	1 / TSHRA	≥ 7 / None	1 / BR
ALTIMETER (LOWEST)	30.08	30.25	30.18
WINDS (MAX)	200/25G35	130/12	CALM
ICING	NONE	651309	NONE
TURBULENCE	NONE	521303	562005

METARs

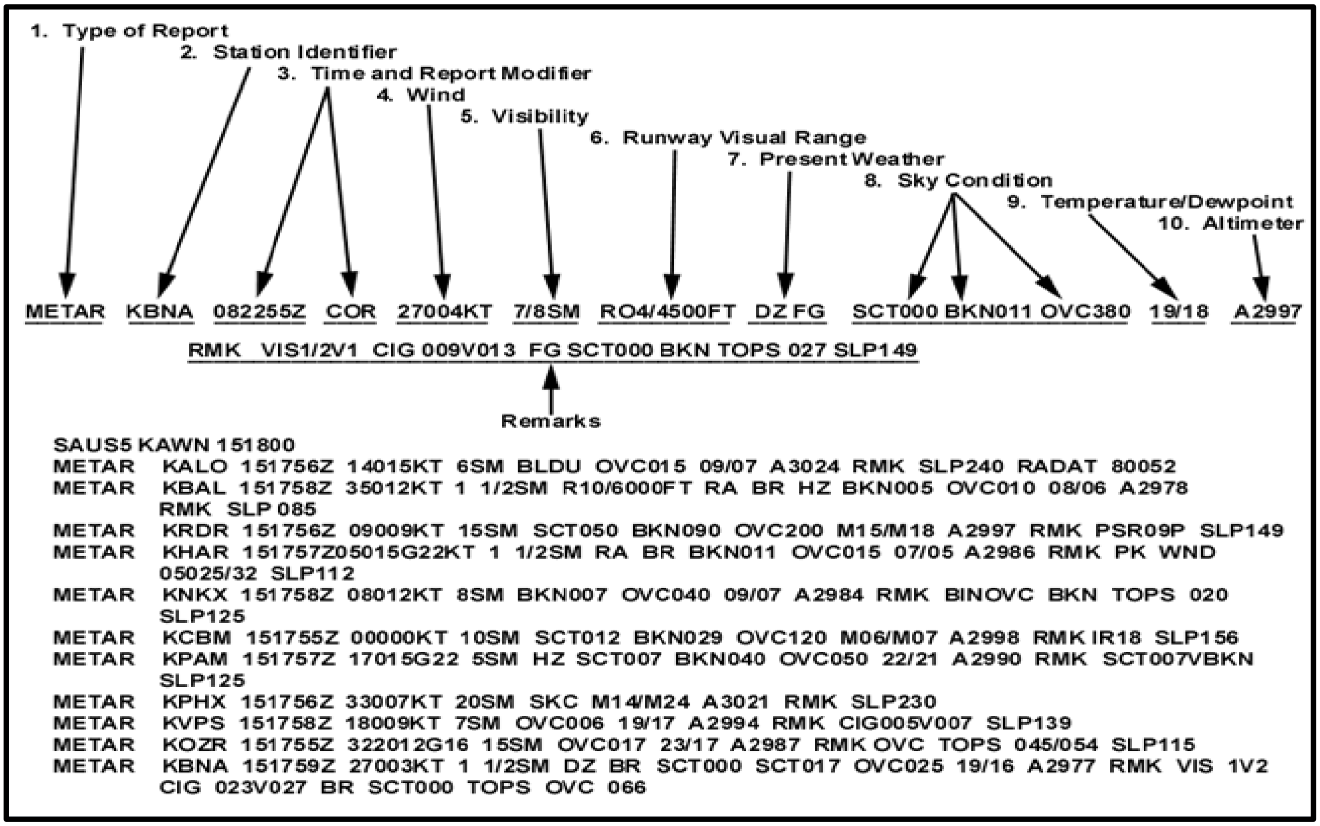
Aviation Routine Weather Reports (METARs)

Provide rapid and efficient means of transmitting latest observed weather to meteorologists and aircrews

Can determine weather at a primary or alternate destination

Can determine whether an airfield is under IFR or VFR operation

Can help determine trends in weather, to see if weather is developing as forecast



Type of Report

METAR

Routine hourly weather report

Specific format coded for brevity and clarity

SPECI

Special unscheduled observation

Issued when critical elements change

- Station Identifier
  - 4-letter ICAO identifier
    - “K” indicates United States
  - If 3-letter identifier
    - First letter “N” indicates USN

- Date Time Group and Report Modifier
  - DTG in Standard Message Format
    - 2-digit date
    - 4-digit “Z” time
    - “Z”
    - Reporting time between 55 and 59 minutes past hour
  - Modifier corrected report
    - COR -
    - AUTO - report from automated station
    - No Modifier - manual report by an individual

- Wind
  - First three digits direction
    - Rounded to nearest 10°
    - VRB undetermined
    - “V” between two headings
    - Variable between headings
    - Clockwise order
  - Wind speed
    - 2 or 3 digits for speed
    - Gusts “G” followed by speed
    - 00000KT calm winds

Visibility

Prevailing Visibility

Greatest vis over 50% of horizon

Statute miles

Meters at overseas locations

Vis < 7 SM includes obstruction to visibility

“M” indicates less than reported visibility

Variable visibility in Remarks section

Variable range separated by “V”

Runway Visual Range (RVR)

Included when prevailing visibility ≤1 SM or RVR ≤6000 ft

First two digits applicable runway

Runway visibility in feet

“V” between two values if RVR variable

Not included in USN/USMC METAR

Present Weather

Precipitation and/or obstructions to visibility are indicated on this chart

Absence of weather or obstruction indicates neither exists at time of observation

Weather Reporting Notations[1]

QUALIFIER		WEATHER PHENOMENA		
INTENSITY OR PROXIMITY 1	DESCRIPTOR 2	PRECIPITATION 3	OBSCURATION 4	OTHER 5
- LIGHT	MI - Shallow	DZ - Drizzle	BR - Mist	PO - Well-developed Dust and/or Sand Whirls
MODERATE [2]	PR - Partial	RA - Rain	FG - Fog	SQ - Squalls
+ HEAVY	BC - Patches	SN - Snow	FU - Smoke	FC - Funnel Cloud(s): (Tornado or Waterspout)[3]
VC - in the vicinity	DR - Low Drifting	SG - Snow Grains	VA - Volcanic Ash	SS - Sandstorm
	BL - Blowing	IC - Ice Crystals	DU - Widespread Dust	DS - Dust Storm
	SH - Shower(s)	PL - Ice Pellets	SA - Sand	
	TS - Thunderstorm	GR - Hail	HZ - Haze	
	FZ - Freezing	GS - Small hail and/or snow pellets	PY - Spray	
		UP - Unknown Precipitation		

1. The weather groups shall be constructed by considering columns 1 to 5 in the table above in sequence, (i.e., intensity, followed by description, followed by weather phenomena), (e.g., heavy rain shower(s), is coded as + SHRA).
2. To denote moderate intensity no entry or symbol is used. No intensity is assigned to Hail (GR) or Ice Crystals (IC). (UP not use in forecasts).
3. Tornado(es) and waterspout(s) shall be coded + FC.

Sky Condition

Reported in eighths for coverage

SKC Sky clear (manual report)

CLRNo clouds below 12,000 feet (automated report)

FEW Trace – 2/8

SCT 3/8 – 4/8

BKN *5/8 – 7/8

OVC *8/8

*Denotes ceiling

TCU Towering cumulus

CB Cumulonimbus/ Thunderstorm

VV Vertical visibility (indefinite ceiling)

Reported in hundreds of feet AGL for height

Temperature/Dew Point

Reported in degrees Celsius

Separated by slash

"M" for minus value

If dew point unavailable, no digits after slash

Altimeter Setting

In inches of mercury

Begins with "A"

No decimal

Remarks

Other supplemental data

SLP is sea level pressure in millibars

Place "9" before reported value (if over 600)

"10" if reported value is 600 or less

RADAT

Freezing level data

First two digits relative humidity

Last three digits altitude of freezing level

Runway Condition Reporting

Special remarks appended to Remarks section

Runway Surface Condition

METAR Code	Runway Surface Condition
WR	Wet Runway
SLR	Slush On Runway
LSR	Loose Snow On Runway
PSR	Packed Snow On Runway
IR	Ice On Runway
RCRNR	Not Reported

TAFs

Terminal Aerodrome Forecasts (TAF)

Airport forecast for specific period (usually 24 hours)

Used to determine VFR or IFR flight plan requirements

TAF contains forecasts of:

Wind

Forecast visibility

Weather/obstructions

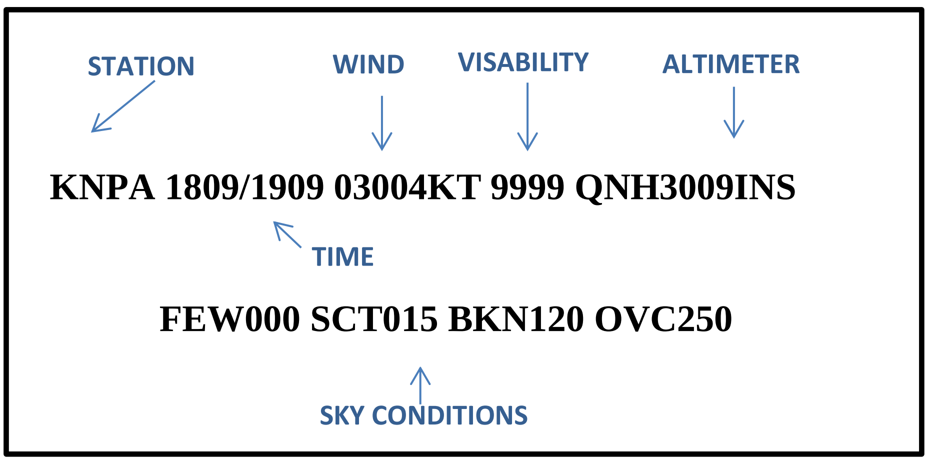
Sky coverage

Icing

Turbulence

Minimum altimeter setting

Pertinent remarks



Forecast Date And Valid Times

CIVILIAN

Date/Time prepared

First two digits date

Z time of issuance

Forecast valid times

Second two digits refer to valid time period of forecast

MILITARY

Preparation date (time omitted)

Valid time of forecast

TAF Winds

Following valid time group

First three digits direction

True direction

Nearest 10 degrees

Last two digits sustained wind speed

Knots (U.S.)

Kilometers per hour or meters per second (International)

Gusts depicted by “G”

VRB variable winds

TAF Visibility

Military and overseas

Visibility in meters

Maximum value 9999

Indicates > 9000 m

Overseas may use CAVOK No

significant weather

Visibility 10 km or greater

Ceilings > than 5000 feet

Civilian CONUS TAFs use statute miles

Forecast Weather

Group following visibility

Absence indicates no significant weather expected during forecast period

Examples:

HZ is haze

-RA is light rain

NSW (no significant weather)

Weather in previous group no longer expected

Does NOT indicate absence of clouds or weather hazards

Sky Coverage

Group following weather/obstructions

Forecast cloud coverage

Coverage in eighths

Height in hundreds of feet AGL

Must be 5/8 (BKN) or greater for ceiling

Total obscuration is a ceiling

Icing and Turbulence

KNGP 1815 / 1915 12005KT 6000 BR BKN250 651206 520403 QNH3000INS

Icing code preceded by “6” following cloud group

Turbulence code preceded by “5” following cloud or icing group

Next digit indicates intensity

Next three digits indicate base of layer in hundreds of feet

Last digit indicates thickness of layer in thousands of feet

1C	TYPE OF ICING	B	TYPE OF TURBULENCE
Code	Description	Code	Description
0	No icing	0	None
1	Light icing	1	Light turbulence
2	Light icing in cloud	2	Moderate turbulence in clear air, occasional
3	Light icing in precipitation	3	Moderate turbulence in clear air, frequent
4	Moderate icing	4	Moderate turbulence in cloud, occasional
5	Moderate icing in cloud	5	Moderate turbulence in cloud, frequent
6	Moderate icing in precipitation	6	Severe turbulence in clear air, occasional
7	Severe icing	7	Severe turbulence in clear air, frequent
8	Severe icing in cloud	8	Severe turbulence in cloud, occasional
9	Severe icing in precipitation	9	Severe turbulence in cloud, frequent
		X	Extreme turbulence

Altimeter Setting

Forecast minimum altimeter setting

Only in military forecasts

Begins with QNH (minimum)

Ends with INS (inches of mercury)

Provides lowest altimeter setting expected for period

Remarks

Other forecast items may be appended to TAF

Wind shear

Temperature

Pilot reports (PIREPs)

Change Groups

Establishing FROM and TO times indicates which TAF lines are applicable

Indicate change in some or all elements

Valid until forecast end time or subsequent change

Conditions in change line supersede applicable previous conditions

Change Groups

FM

Indicates rapid change

FM 201200 read “from the 20th at 1200Z ”

To end of previous forecast period

BECMG

Gradual change in predominant conditions by end time listed

BECMG 2014 / 2016 read “Becoming from the 20th 1400Z to the 20th at 1600Z” To end of previous forecast period

TEMPO

Temporary condition

Expires end of period listed

Reverts to previous line

Or when superseded by subsequent line

TEMPO 2019 / 2102 read “Temporary condition between the 20th at 1900Z and the 21st at 0200Z

TAF Differences

U.S. civil stations

Statute miles instead of meters

Include DTG of transmission prior to forecast period

May include probability of precipitation

When U.S. military stations amend, correct, or have routine delayed forecast, appropriate time appended to last line of forecast

TAF Differences			
U.S. Military TAF		International TAF	
Forecast Period	24 Hours	Forecast Period	Variable
Wind Speed	Knots	Wind Speed	Knots, Meter-per hour, or Kilometers-per-hour
CAVOK not used		CAVOK used	

OUTLINE SHEET 3-7-1

WATCHES, ADVISORIES AND CHARTS

A. INTRODUCTION

This lesson addresses data presented in various weather charts, watches, advisories, and the DD Form 175-1. It also covers the use and requirements for submitting a Pilot Report (PIREP) to meteorology offices while in flight.

B. ENABLING OBJECTIVES

4.23 DESCRIBE the use of Surface Analysis Charts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.24 INTERPRET Surface Analysis Charts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.25 DESCRIBE the use of Low Level Significant Weather Prognostic Charts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.26 DESCRIBE displayed data METARs, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.27 DESCRIBE weather data on NEXRAD, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.28 DESCRIBE weather data on satellite imagery, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.29 DESCRIBE the use of Winds-Aloft Prognostic Charts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.30 DESCRIBE the use of Winds-Aloft Forecasts, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.31 DESCRIBE the use of Severe Weather Watch messages, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.277 DESCRIBE the use of In-Flight Weather Advisories, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.278 STATE the letter identifiers of each of the In-Flight Weather Advisories, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

2.279 DESCRIBE the use of Pilot Weather Reports (PIREPs), in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

4.32 DESCRIBE the weather data entered on a DD Form 175-1, in a classroom, in accordance with Naval Aviation Fundamentals, NAVAVSCOLSCOM-SG-200

C. TOPIC OUTLINE

1. Prognostic and Surface Analysis Charts
2. METARs
3. NEXRAD and Satellite Imagery
4. Winds-Aloft Prognostic and Temperature-Aloft Charts
5. Winds-Aloft and Temperature-Aloft Textual Presentation
6. Aviation Secure Weather Watch Bulletins
7. In-Flight Weather Advisories
8. PIREPS
9. DD Form 175-1

INFORMATION SHEET 3-7-2

WATCHES, ADVISORIES AND CHARTS

A. INTRODUCTION

This lesson addresses data presented in various weather charts, watches, advisories, and the DD Form 175-1. It also covers the use and requirements for submitting a Pilot Report (PIREP) to meteorology offices while in flight.

B. REFERENCES

1. Weather for Aircrews, AFH 11-203
2. T-6 Joint Primary Pilot Training, AETC / CNATRA Syllabus P-V4A-J T-6B Courseware and SG
3. Flight Information Handbook

C. INFORMATION

Charts and Imagery

Chart Introduction

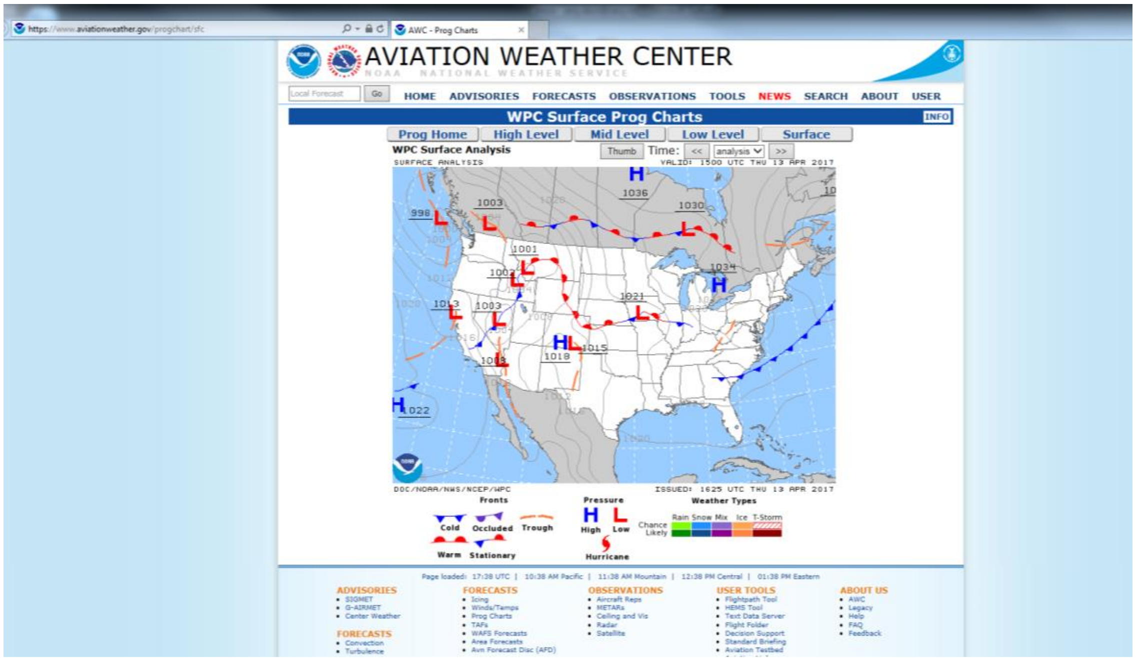
When pilots begin their flight planning routine, checking for any severe weather should be the very first step. Changes to missions are a commonplace occurrence due to quickly changing weather conditions, and new pilots will soon appreciate the ability to plan around the weather, when able.

The following topics will introduce the various charts, graphics, and textual products which will assist the pilot in effective mission planning.

Prognostic Charts

Prognostic Charts are available on the Prog Charts tab of the NOAA Aviation Digital Data Service (ADDS) site.

These charts include the latest surface analysis along with 12, 24, 36, and 48 hour forecasts.

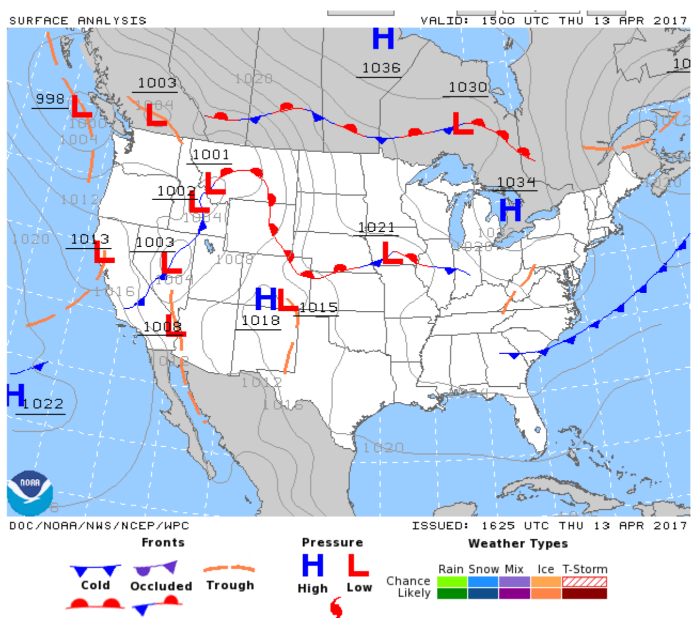


Prognostic Charts

Surface Analysis

The Surface Analysis Chart depicts pressure centers, fronts, and barometric pressure lines.

The information displayed on the Surface Analysis Chart is observed weather, meaning that the chart represents past history, and is not a forecast. The valid time (VT) of the chart is the observation time of the information that was gathered to compile the chart and is given in Coordinated Universal Time (UTC) at the top right.



Surface Analysis Chart

Chart Pressure Systems

Barometric pressure lines (isobars) are drawn at 4-millibar intervals.

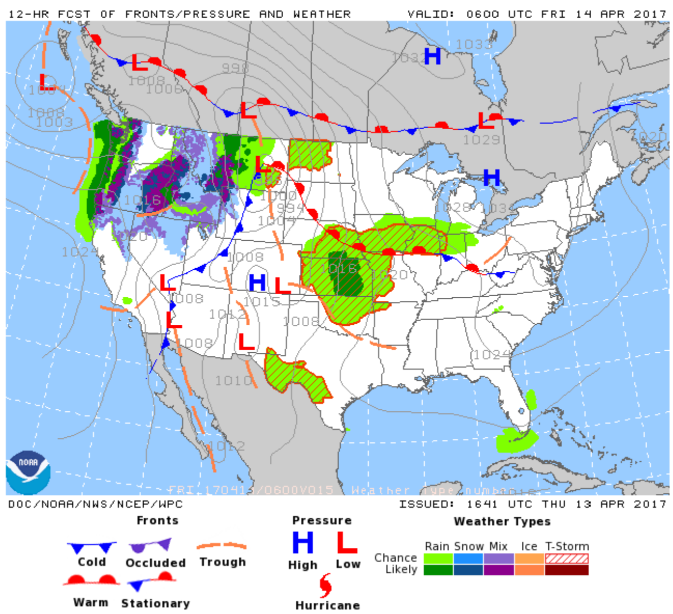
The observed barometric pressure at pressure centers is also shown.

Forecast Prog Charts

Forecast charts depict predicted positions of fronts and pressure centers, as well as forecast weather across the country.

Prog Chart Symbols

Definitions of symbols depicted on the Prog Charts are available in Chapter 2 of AFH 11-203, Vol. 2.

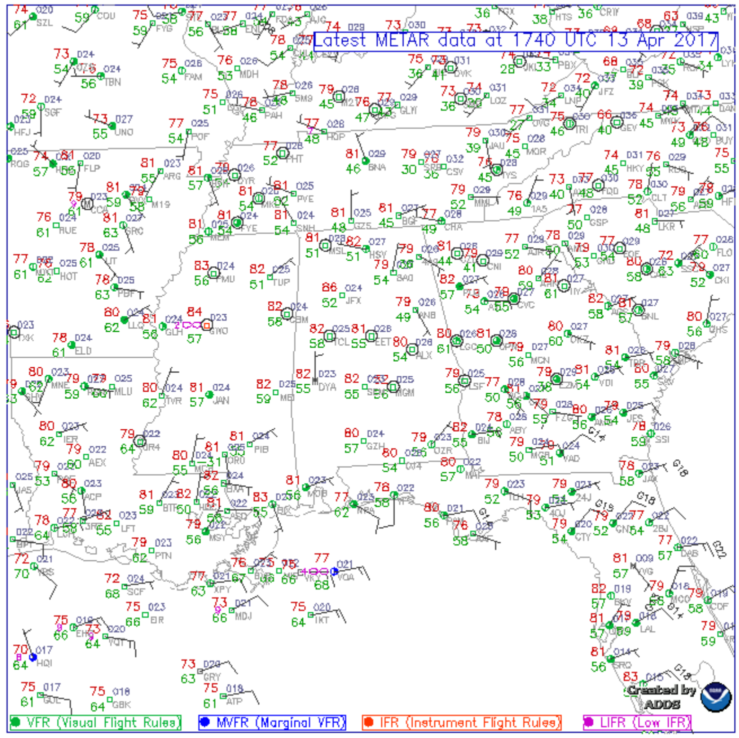


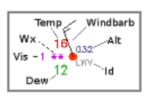
12-Hour Prognostic Chart

METARs

METARs, found on the METARs tab on the ADDS website, are scheduled observations taken between 55-59 minutes past the hour and used in flight planning to determine areas of IFR/VFR and to determine the minimum ceilings in route.

METARs are available in both graphic and textual form. To view the graphic presentation, you would click on the desired region on the U.S. map. Reporting stations are depicted on the chart using station models discussed in earlier lessons.





METARs Text

METARs are also available in text form. To obtain the report for a particular station, enter the station identifier in the box, check the “Raw” and “METARs” checkboxes, and click the Submit button.

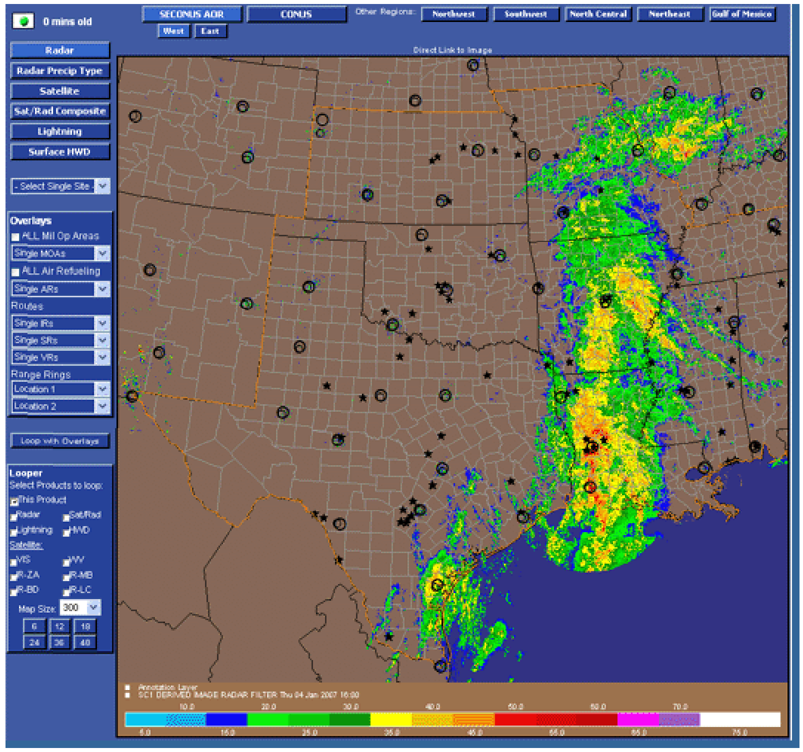
The translated option is **NOT** recommended because there is an opportunity for the translation to contain errors and omit portions of the Raw METAR.

NEXRAD and Satellite Imagery

NEXRAD

Radar data is available from the 26th OWS web site by clicking on the “Radar SCNTRL” link in the Weather Preview section.

Next Generation Radar (NEXRAD) images provide an excellent source of weather information for pilots. The computer monitor image seen in a weather office is a computer-generated compilation of radar data transmitted from a radar site.



NEXRAD Precip Display 1

NEXRAD presentations show precipitation levels in the area scanned by the radar system. The NEXRAD does not measure the rate of precipitation directly; rather, it measures the energy return from the precipitation particles. The image seen on the screen is actually a computer-generated compilation of returned energy shown in varying colors. This display is referred to as the reflectivity presentation.

NEXRAD Precip

Display 2

The intensity of precipitation can be determined by using the graduated scale shown in the legend area of the screen.

The maximum radar return strength at the time of the presentation is listed above the scale. This is measured in “dbz,” or strength in decibels, of the energy received by the radar. Through use of this scale, precipitation strength can quickly be deciphered for a given area by comparing the color of the area to the color-coded legend. Higher precipitation levels are farther down the color scale.

During flight planning, a pilot should carefully analyze the higher intensity areas in relation to the planned route of flight or operating area.

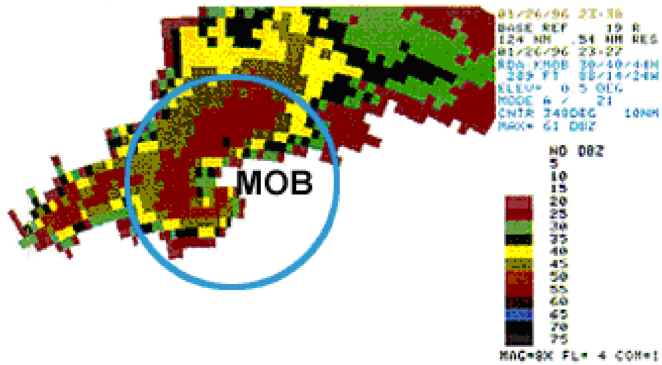
Other NEXRAD Features

Other unique features of the NEXRAD provide the capability to display areas of tornadoes, hail, wind shear, and microbursts. This type of information is particularly useful in planning a flight around known areas of potentially dangerous weather conditions.

NEXRAD Tornado Display

The NEXRAD system does not directly observe tornadic circulation; however, the system can display what is referred to as a "hook echo" that is considered indicative of a tornado.

In this graphic, a dark shaded hook echo is evident just west-southwest of MOB. This echo actually resulted in a tornado that caused severe property damage and injuries to personnel. A pilot looking at a NEXRAD display should plan around areas of red on the color-coded scale, as these are generally considered danger areas and should be avoided.



Hook Echo

NEXRAD Hail Display

The structure of a storm can provide clues to the potential for hail. Hailstorms have intense cores, generally between 2 and 5 NM in diameter, and usually begin developing at higher altitudes and descend toward the base of a storm. Very high reflectivity values (over 55 dbz) may also indicate that the precipitation is in the form of hail. Thunderstorms with strong updrafts, extensive vertical height, high liquid water content, and large cloud drop sizes are favorable conditions for the formation of hail.

NEXRAD Wind Shear Display

A major hazard to aviation is the presence of low-level wind shear and frontline wind shear. Although wind shear can occur at any altitude, it is particularly hazardous when it develops over a short period of time within 2000 feet of the ground. The primary concern for aircraft at low altitudes is a rapid change in wind direction that could affect the aircraft's handling characteristics. There are several display and data analysis options available to indicate possible wind shear.

NEXRAD Microburst Display

Microbursts are detectable by NEXRAD because of the density gradient of the descending air, the particulate matter contained therein, or both. However, because of the shallow vertical extent of the outflow from a microburst, the phenomenon will usually not be detected beyond a range of 20 NM from the radar site.

Satellite Imagery

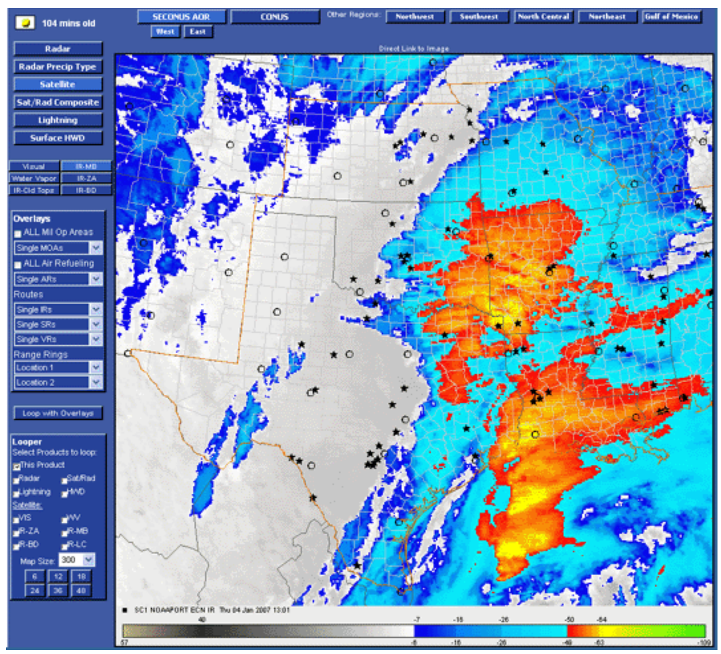
Satellite images are also available from the 26th OWS web site by clicking on the “Satellite SCNTRL” link in the Weather Preview section.

For general-purpose use, there are two types of satellite imagery available. When combined they provide a great deal of information about clouds to a pilot. Through interpretation, one can determine the type and height of clouds as well as the temperature and the thickness of cloud layers. From this information, the pilot can get a good idea of possible associated weather along the planned route of flight.

Infrared Imagery

One type of imagery is the infrared (IR) satellite.

The IR picture records heat radiation being emitted by the clouds and earth. The images show temperature differences between cloud tops and the ground, as well as temperature gradations of cloud tops over the surface of the Earth.



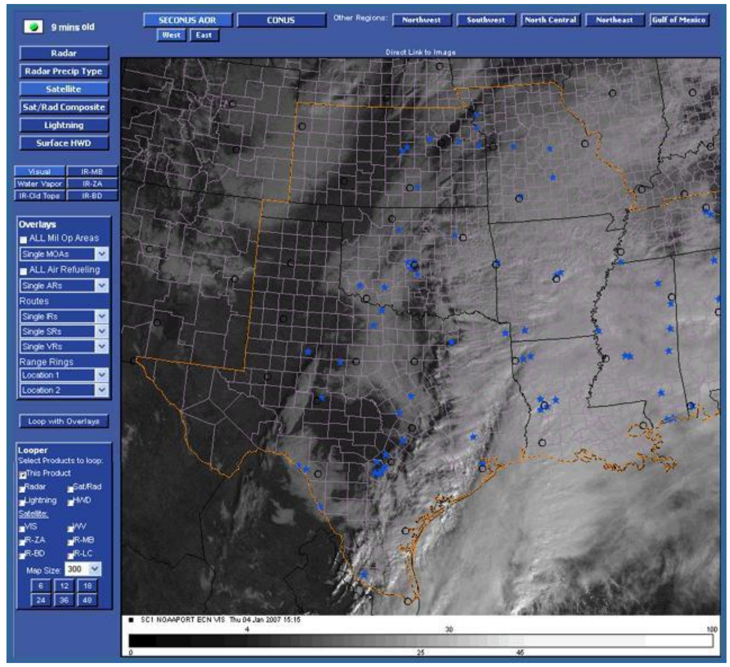
Infrared Imagery

Visible Imagery

The other type of imagery is the visible satellite which displays clouds and the Earth reflecting sunlight back to the satellite sensors.

The greater the reflected sunlight reaching the sensors, the brighter white the object is on the picture. The amount of reflectivity reaching the sensors depends upon the height, thickness, and ability of the object to reflect sunlight.

Since clouds are much more reflective than most of the earth, clouds will usually show up white on the picture, especially thick clouds. Thus, the visible picture is primarily used to determine the presence of clouds and the type of clouds from shape and texture.



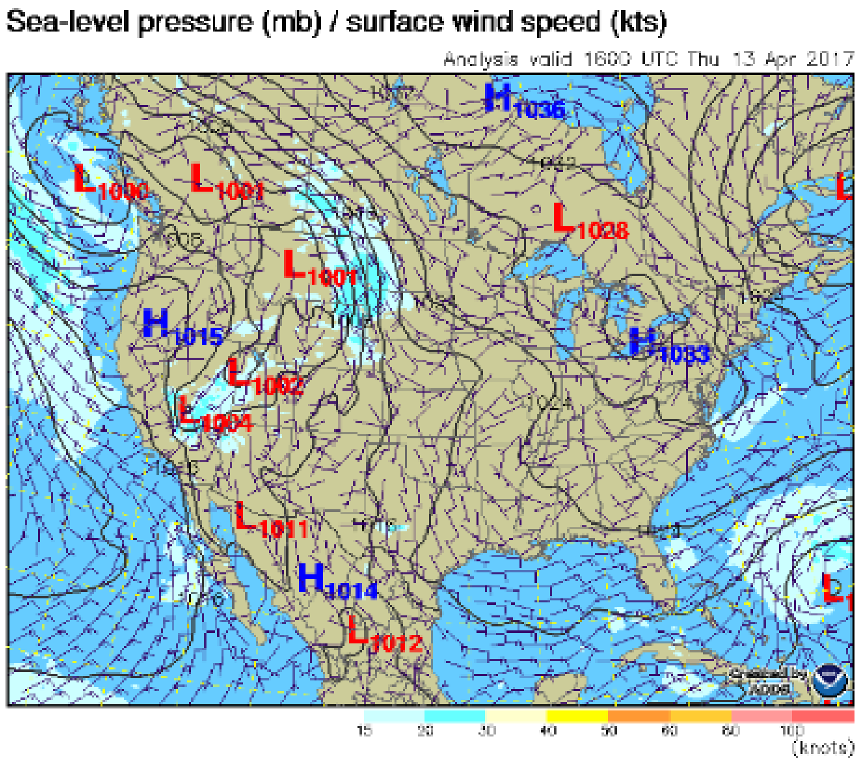
Visible Satellite

Winds Aloft

Winds Aloft Prog Charts

Winds-Aloft Prognostic Charts are available at the Winds/Temps tab on the ADDS website.

These charts present the observed and average forecast flight level winds aloft.



Winds Aloft Prognostic Chart

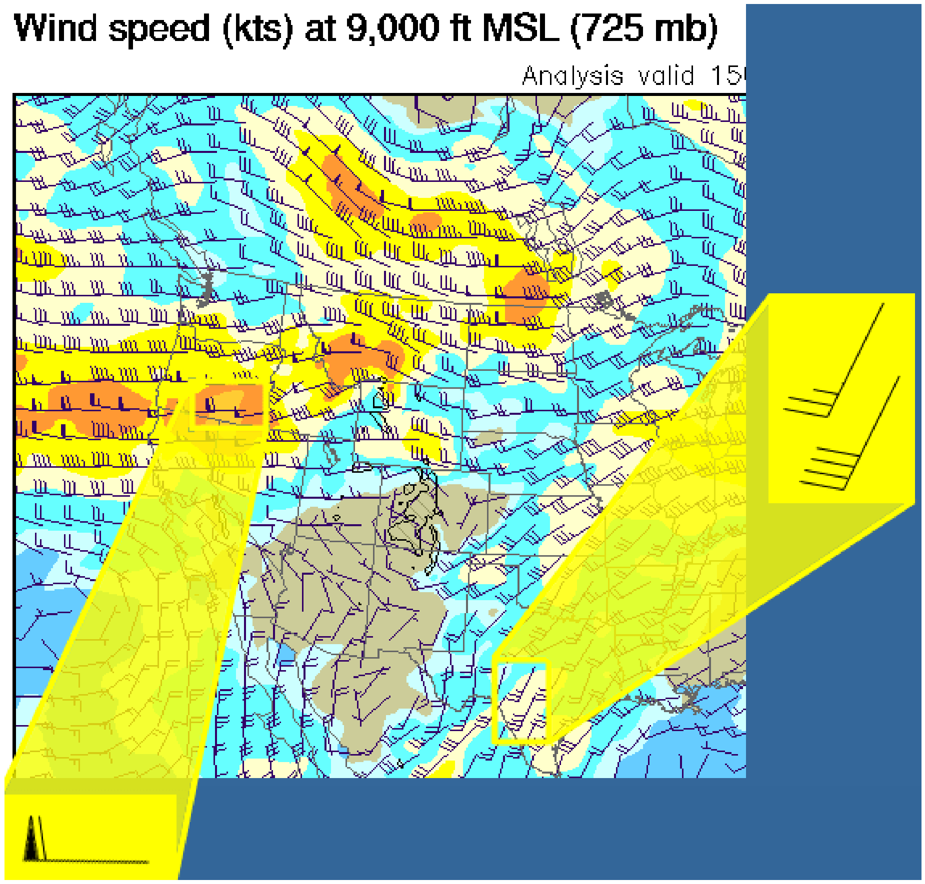
Winds Aloft Altitudes and Times

The charts are constructed and selectable for a range of altitudes within the continental United States.

You may also select either the current winds or those forecast over the next three days.

Wind Direction and Speed

Wind speed and direction are shown by flags on the chart. The shaft points in the direction of the wind, while barbs provide wind speed. Full barbs represent 10 knots, half barbs 5 knots, and a flag indicates 50 knots.



Wind Direction and Speed

Temps Aloft

Temperatures aloft charts are also available at the same window, with the same altitude and time options.

Winds Aloft Text

Textual presentations of winds and temperatures aloft are available by clicking the link at the top of the graphic presentation.

To reach the chart for the desired area, roll your mouse over the region to highlight it, then click.

Wind Coding/Decoding Rules 1

These charts present wind information similar to that found in Winds-Aloft Prognostic Charts in an organized series of four- or six-digit groups. The left column lists the reporting station, and the top row lists the corresponding altitudes for which wind and temperature data are given, referenced to feet MSL.

Wind information on the Winds-Aloft Forecast is given with a series of four digits. The first two represent the true wind direction to the nearest ten degrees true, and the last two digits represent the speed in knots. For example, 1733 indicates a wind from 170 °T at 33 knots.

```
FD1US1
DATA BASED ON 031200Z
VALID 031800Z   FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000  30000  34000  39000
BHM 1612 2212+11 2313+06 2310+00 2618-13 2633-26 255243 266853 269162
HSV 1714 2014+11 2114+06 2313+00 2618-13 2636-26 265743 266654 268362
MGM 1708 2309+13 2315+06 2314+00 2518-12 2631-25 254442 277751 269561
MOB 9900 2705+12 2312+05 2710+00 2415-12 2630-24 266240 258449 269460
FSM 2216 2327+07 2229+04 2433+00 2442-15 2450-28 246845 258654 247461
LIT 2407 2524+09 2425+06 2328+01 2435-14 2435-28 245844 257553 257361
LCH 2110 2012+11 2518+06 2322+01 2119-13 2351-24 236940 248549 740658
MSY 2407 9900+12 3010+06 2819+01 2418-11 2530-26 247039 258348 269959
SHV 2205 2321+09 2330+05 2518+02 2328-14 2441-27 235643 247553 248060
JAN 2209 2516+10 2727+05 2516+01 2323-13 2533-25 255742 257851 259261
GAG      2335+07 2431+03 2430-01 2437-16 2442-29 253645 272952 272158
OKC 2325 2329+04 2334+04 2343-01 2448-16 2364-29 248545 258554 245658
TUL 2320 2229+06 2136+03 2341-02 2350-15 2460-29 248445 259154 246059
BNA 2018 1820+10 2119+05 2221-01 2625-15 2636-28 265944 276754 267363
MEM 2016 2224+09 2422+06 2424+02 2531-14 2531-28 255844 266954 257362
TRI      1909+10 2312+04 2417-01 2729-16 2842-29 286845 287655 288063
```

Winds-Aloft Text

Wind Coding/Decoding Rules 2

For most altitudes, the temperature follows the wind information in a set of two digits that may or may not include a sign for positive or negative. For example, 2123+04 indicates the wind will be 210° T at 23 knots with a temperature of +4° Celsius.

Notice that all temperatures are negative above 24,000 feet as indicated in the heading information by the phrase "TEMPS NEG ABV 24000." At these altitudes, all the digits are run together, eliminating the redundant minus sign between the wind and the temperature. For example, 251744 forecasts a wind from 250° T at 17 knots with a temperature of -44° Celsius.

Special Circumstances 1

The above procedures are used for all "normal" wind information. However, there are exceptions for unusual wind conditions.

A direction of "99" indicates a variable wind direction. When forecast wind speeds are less than 5 knots, direction is difficult to determine, and the winds are called "light and variable," and the code "9900" will be listed.

Special Circumstances 2

When a wind speed of 100 knots or greater is forecast, the simple four-digit wind code no longer works satisfactorily and an additional set of rules is used. For example, if the winds are forecast to be 230 at 145 knots, the normal code would require five digits, requiring a change to the format of the entire Winds-Aloft Forecast.

Special Circumstances 3

Therefore, if you see a direction that would translate to be greater than 360° T, it was not a mistake, it is this extra rule. The wind was encoded by adding 500° to the direction and subtracting 100 knots from the speed, thus requiring a total of only four digits again. To decode such winds, then, one must subtract 500 from “unrealistic” direction codes and add 100 to the indicated speed. For example, a code of 7409 would forecast winds of 240° T at 109 knots.

If winds are forecasted to be 200 knots or greater, the wind group is coded as 199 knots. For example, 8299 would be decoded as 320° T at 199 knots or greater.

Special Circumstances 4

Additionally, it is sometimes impractical to forecast the temperature and wind. This is particularly true for conditions near the surface, where the temperature is more likely to deviate from the standard lapse rate, and where the winds are more likely to be gusty and variable due to thermal or mechanical turbulence. So, for the following conditions, wind and temperature are omitted from the

Winds-Aloft Forecast:

Wind information is never forecast for altitudes within 1500 feet of the surface.

Temperature information is never forecast within 2500 feet of the surface.

Temperature information is never forecast for the 3000-foot level.

Flight Altitude Selection

Pilots planning a flight can use winds-aloft information to their advantage.

When the wind appears to be a tailwind component, they should generally try to take advantage of the situation by filing for an altitude with the fastest wind speed. When the wind would be a headwind component, they should generally try to minimize the disadvantage by filing for an altitude with the least wind speed.

However, they must keep in mind several other factors and potential hazards that may influence the selection of an altitude such as: clouds at flight level, visibility at flight level, icing and the minimum freezing level, thunderstorms, turbulence, and precipitation.

Head and Tail Winds

Flight Planning

For general planning purposes, Winds-Aloft Prognostic Charts are the most useful, as they give a pictorial representation of the winds. They can quickly narrow the search for generally favorable winds, or provide a fast solution to finding an alternate route that avoids unfavorable winds.

The textual charts may also be consulted as additional information in selecting the best particular altitude for which to file the flight plan, or when the Winds-aloft Prognostic Charts are not available. Often, the wind information will not be forecast for the exact altitude for which a pilot may wish to file. In this case, one must interpolate to find the desired information.

Watches

Severe Weather Watch Bulletins

Aviation Severe Weather Watch Bulletins are presentations that are identified by the letters "WW" in the heading. They originate from the National Storm Prediction Center, and are sometimes referred to as Severe Weather Forecasts.

The bulletins are not issued on a scheduled basis, but rather as required by the progress and development of severe weather. The forecast period is also variable, again depending on the particular weather.

All times are given in local time, as indicated in the warning itself. When possible, the area of coverage is limited in size to 10,000 square miles to provide increased accuracy.

```
WWUS 9 KMKC 181845
MKC WW 181845

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WATCH NUMBER 29
NATIONAL WEATHER SERVICE KANSAS CITY MO
1245 PM CST THUR FEB 18 20XX

A . . . THE STORM PREDICTION CENTER HAS ISSUED A SEVERE THUNDERSTORM WATCH FOR

                    SOUTH CENTRAL KANSAS
                    CENTRAL OKLAHOMA
                    NORTH CENTRAL TEXAS
                    EAST TEXAS

EFFECTIVE FROM 1 PM CST UNTIL 6 PM CST THIS THURSDAY AFTERNOON

LARGE HAIL . . . DANGEROUS LIGHTNING...AND DAMAGING THUNDERSTORM WINDS ARE
POSSIBLE IN THESE AREAS.

THE SEVERE THUNDERSTORM WATCH AREA IS ALONG AND 70 STATUTE MILES EITHER SIDE
OF A LINE FROM 70 MILES WEST OF AUSTIN TEXAS TO 35 MILES WEST OF WICHITA KANSAS.

REMEMBER . . . A SEVERE THUNDERSTORM WATCH MEANS CONDITIONS ARE FAVORABLE FOR
SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE AREAS
SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND LISTEN FOR
LATER STATEMENTS AND POSSIBLE WARNINGS.

B . . . OTHER WATCH INFORMATION...THIS SEVERE THUNDERSTORM WATCH REPLACES SEVERE
THUNDERSTORM WATCH NUMBER 28. WATCH NUMBER 28 WILL NOT BE IN EFFECT AFTER 1 PM
CST.

C . . . A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 2 IN. EXTRM TURBC AND SFC WND
GUSTS TO 70 KT. SCTD CBS WITH MAX TOPS TO 500 PSBL. MEAN WIND VECTOR 22040KT.

D . . . WITH CLD FNT MOVG SEWD FM WRN KS N CNTRL TX AND DVLPG LOW OK PANHANDLE
MOVG EWD STG CNVRGNC SHLD DVLP ALG CLD FNT AND NR INTERSECTION WITH WRM FNT.
CONTD STG INFLOW OF UNSTABLE AMS.
```

Severe Weather Watch Bulletin

WW Issuing Requirements

Aviation Severe Weather Watch Bulletins are issued for two types of expected severe weather conditions:

Funnel clouds or tornadoes

Severe thunderstorms, defined by one or more of the following:

50 knots of wind or greater

3/4 inch diameter hail or larger

WW Heading

The heading of the Aviation Severe Weather Watch Bulletins consists of a few lines of information including the station identifier of the message originator (KMKC), the message identifier (WW), the date-time group of issue (181845), the bulletin number (29), and the time of issue (1245 PM CST).

WW Body

The bulletin is arranged in several paragraphs giving such information as the area of coverage, the effective time of the watch, the expected type of severe weather, the mean wind vector, and any amplifying remarks deemed necessary.

WW Abbreviations

Whenever possible, wording in teletype presentations is shortened by abbreviating words or phrases according to the FAA Contractions Manual. Words or phrases are usually shortened by omitting the vowels.

Severe Weather Forecast Alert

Pilots may also encounter a Severe Weather Forecast Alert Message (AWW), which is a preliminary message issued to alert users that a WW is being issued.

These messages are unscheduled and are issued as required. Normally, pilots will have access to WWs during preflight planning, and thus will not need to reference AWWs.

```
MKC AWW 655 WW 279 SEVERE TSTM NY PA NJ 1630Z-1700Z.
70 STATUTE MILES EITHER SIED OF LINE 10W KMSS TO 20E KABE.
AVIATION COORDS 60 NM EITHER SIDE OF 160 NW KSLK -
35 W KEWR.  HAIL SURFACE AND ALOFT.  SURFACE WIND GUSTS
65 KNOTS.  MAX TOPS TO 540.  MEAN WIND VECTOR 19020.
REPLACES WW 278.  OH PA NY
```

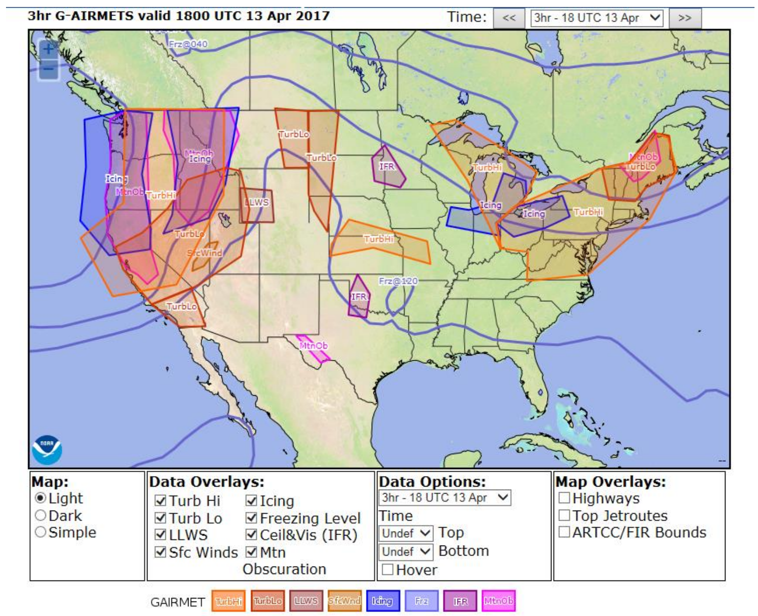
Severe Weather Forecast Alert

Advisories

AIR/SIGMETs

AIRMETs and SIGMETs are available on the ADDS website and provide information on potentially hazardous weather phenomena.

The reports may be displayed in either graphic or textual formats.



G-AIRMETS

SIGMETs

SIGMETs (WS) advise of SIGnificant METeorological information other than convective activity that is potentially hazardous to all aircraft. WSs are issued for the conterminous US by NAWAU and are valid for up to 4 hours when any of the following weather phenomena occur or are forecast over an area of at least 3000 square miles:

Severe or extreme non-convective turbulence, or CAT not associated with thunderstorms

Severe icing not associated with thunderstorms

Widespread dust storms or sand-storms lowering surface and/or flight visibilities to less than 3 miles

Volcanic eruption and ash clouds

SIGMETs ID

The first issuance of any non-convective SIGMET will always be identified as an Urgent SIGMET (UWS). Any subsequent issuance will be identified as WS unless the forecaster feels the situation warrants using UWS to trigger more expeditious communications handling.

SIGMETs Header

Each SIGMET is assigned a unique header to ensure computer systems can distribute and replace the proper messages as required.

Only the phonetic alphabet designators November, Oscar, Papa, Quebec, Romeo, Uniform, Victor, Whiskey, X-ray, and Yankee are used for non- convective SIGMETs (excludes those designators reserved for scheduled AIRMETs (Sierra, Tango, and Zulu)). These designators will follow the area designator (SFO, SLC, CHI, DFW, BOS, and MIA), which is used for distribution. It does not denote the office issuing the forecast; it denotes the geographical area affected.

```
WSUS04 KKCI 041845
DFWY WS 041845
SIGMET YANKEE 5 VALID UNTIL 042245
SIGMET
OK TX KS
FROM HLC TO 40W MKC TO 30S LFK TO JCT TO HLC
OCNL SEV TURB BTN FL270 AND FL360. RPRTD BY ACFT. CONDS CONTG BYD
2245Z.
WDH
```

SIGMET

SIGMETs Designators 1

The first time a SIGMET is issued for a phenomenon associated with a particular weather system, it is given the next alphabetic designator in the series and is numbered as the first for that designator (e.g., PAPA 1).

Subsequent messages are numbered consecutively, using the same designator (e.g., PAPA 2, PAPA 3, etc.) until the phenomenon ends or no longer meets SIGMET criteria.

SIGMETs Designators 2

In the conterminous US, this means that a phenomenon that is assigned an alphabetic designator in one area will retain that designator even if it moves into another area.

For example, the first issuance for a SIGMET that has moved into the DFW area from the SLC area might be SIGMET PAPA 4. While this is indeed the first SIGMET issued for this phenomenon in the DFW area, it is actually the fourth issuance for the phenomenon since it met SIGMET criteria, and the previous three issuances occurred in the SLC area.

SIGMETs Times

While SIGMETs may be issued up to 2 hours before the onset of any condition forecast to meet a criterion, note that the time in line 1 is the issuance time, not the onset time. The time indicated in the VALID UNTIL 042245 statement is the SIGMET expiration time. The difference between the two will not exceed 4 hours.

If it is expected to persist beyond 4 hours, a statement to this effect will be included in the remarks of the text. If the conditions do persist beyond the forecast period, then the SIGMET will be updated and reissued. However, if conditions end, a SIGMET cancellation will be transmitted.

Convective SIGMETs

Convective SIGMETs (WST) are issued only for thunderstorms and related convective phenomena over the conterminous US.

```
WSUS32 KKCI 041755
SIGC
CONVECTIVE SIGMET 42C
VALID UNTIL 1955Z
TX AND CSTL WTRS
FROM 40ENE PSX-100ESE PSX-80ENE BRO-50WNW BRO-10S CRP-40ENE PSX
AREA EMBD TS MOV FROM 22025KT. TOPS TO FL370.
REF INTL SIGMET FOXTROT SERIES.

OUTLOOK VALID 041955-042355
FROM ARG-VUZ-170S CEW-120SSW LCH-80E BRO-80SSE LRD-TXK-ARG
WST ISSUANCES EXPD. REFER TO THE MOST RECENT ACUS01 KWNS FROM THE
STORM PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS.
```

Convective SIGMET

Convective SIGMET Outlook

Appended to each WST is an outlook valid for up to 4 hours beyond the end of the WST. They are not scheduled, but rather issued as needed, when any of the following occurs and/or is forecast to occur for more than 30 minutes of the valid period regardless of the size of the area affected:

Tornadoes

Lines of thunderstorms

Embedded thunderstorms

Thunderstorm areas greater than or equal to thunderstorm intensity (VIP level) of four or greater with an area of coverage of 40% or more

Hail greater than or equal to 3/4 inch in diameter or greater and/or wind gusts to 50 knots or greater

Thunderstorms

For WSTs, a line of thunderstorms is defined as being at least 60 miles long with thunderstorms affecting at least 40 percent of its length.

Embedded thunderstorms, for the purpose of WSTs, are defined as occurring within and obscured by haze, stratiform clouds, or precipitation from stratiform clouds. WSTs for embedded thunderstorms are intended to alert pilots that avoidance by visual or radar detection of the thunderstorm could be difficult or impossible.

Note that the presence of thunderstorms implies the associated occurrence of severe or greater turbulence, severe icing, and low-level wind shear.

Convective SIGMETs Areas

Each of these three bulletins is transmitted hourly (at +55 minutes) and is valid for up to 2 hours. If there are no conditions within a region meeting Convective SIGMET criteria at the time of issuance, then a negative bulletin is sent.

AIRMETs

AIRMETs (WA) also advise of significant weather phenomena other than convective activity but indicate conditions at intensities lower than those that trigger SIGMETs. Both are intended for dissemination to all pilots in the enroute phase of flight to enhance safety, and are available for preflight planning, as well.

```
WAUS1 KDFW 210745
DFWS WA 210745
AIRMET SIERRA FOR IFR AND MTN OBSCN VALID UNTIL 211400

AIRMET IFR. . .TN KY
FROM 30E TRI TO 20S CHA TO 40SW ABY TO MOB TO IGB TO MEM TO DYR TO 30E TRI
OCNL CIG BLW010/VIS BLW 3SM -RA/BR. CONDS SPRDG EWD AND CONTG BYD 14Z AND IMPVG
EXC ERN TN BY 20Z

AIRMET MTN OBSCN. . .TN KY
FROM HNN TO 30E TRI TO 30E CHA TO CHA TO HNN
MTNS OCNL OBSCD IN CLDS/PCPN/FG. CONDS CONTG BYD 14A THRU 20Z.

DFWT WA 210745
AIRMET TANGO FOR TURB VALID UNTIL 211400

AIRMET TURB. . .AR OK TX TN MS LA AND CSTL WTRS
FROM 40S ICT TO ARG TO 20S BWG TO 80S LCH TO LRD TO 40S ICT
LGT OCNL MDT TURB FL140-FL350 ASSOCD WTH STG WNDSHR. CONDS CONTG BYD 14Z IMPVG
BY 20Z.

ELSW. . .NO SGFNT TURB EXC VC CNVTV ACT

DFWZ WA 210745
AIRMET ZULU FOR ICE AND FRZLVL VALID UNTIL 211400

AIRMET ICE. . .TN MS OK
OCNL LGT ISOLD MDT RIME ICGICIP FRZLVL TO ARND 120 MS AL AND TN. CONDS CONTG
BYD 14Z IMPVG BY 20Z.
```

AIRMET

AIRMETs Types

There are three types of AIRMET messages that may be issued within a WA. An AIRMET is issued when one or more of the following listed conditions occurs (or is expected to occur) and affects an area of at least 3000 square miles:

AIRMET Sierra - For widespread IFR conditions (ceilings less than 1000 feet and/or visibility less than 3 miles) affecting over 50% of the area or for extensive mountain obscuration

AIRMET Tango - For moderate turbulence or for sustained surface winds of 30 knots or more

AIRMET Zulu - For moderate icing or for freezing level data

AIRMETs Areas

Even though these AIRMET items are issued for widespread phenomena - at least 3000 square miles at any one time – if the total area to be affected during the forecast period is very large, it could be that only a small portion of this total area would be affected at any one time.

AIRMETs Headings

As with SIGMETs, the AIRMETs have unique headings that contain the bulletin type letter following the area designator. For example, when an AIRMET for turbulence is issued, the communications header might read “DFWT WA 210745,” where “T” indicated it is an AIRMET Tango bulletin.

AIRMETs Times

Also in the heading is the valid period expiration time, which is 6 hours after the scheduled “valid beginning” time, or 6 hours and 15 minutes after the scheduled issuance time.

AIRMETs Areas Affected

Each section begins with a text description of the type of AIRMET and a list of states and/or geographical areas affected. As a minimum, each bulletin may indicate that no significant weather of that type is expected, and AIRMET Zulu always contains a freezing level line.

AIRMETs Rules

There are a few specific rules that meteorologists follow when producing WAs that may be helpful for understanding what weather is and is not forecast.

Whenever a SIGMET is in effect, the AIRMET bulletins for the same phenomena (in the same area) will contain a reference to the appropriate SIGMET series. For example, “SEE SIGMET XRAY SERIES FOR SEV TURB AREA.”

Additionally, when non-convective low-level wind shear (LLWS-wind shear below 2000’ AGL) is affecting or expected to affect an area of at least 3000 square miles, the AIRMET Tango includes an LLWS potential statement as a separate line.

Pilot Weather Reports 1

Pilot Weather Reports (PIREPs) are a valuable source of information used to supplement ground station weather observations.

Pilot Weather Reports 2

Air traffic facilities are required to solicit PIREPs whenever the following conditions are reported or forecasted: ceilings at or below 5000 feet, visibility at or below 5 miles, thunderstorms and related phenomena, icing of a light degree or greater, turbulence of moderate degree or greater, and wind shear.

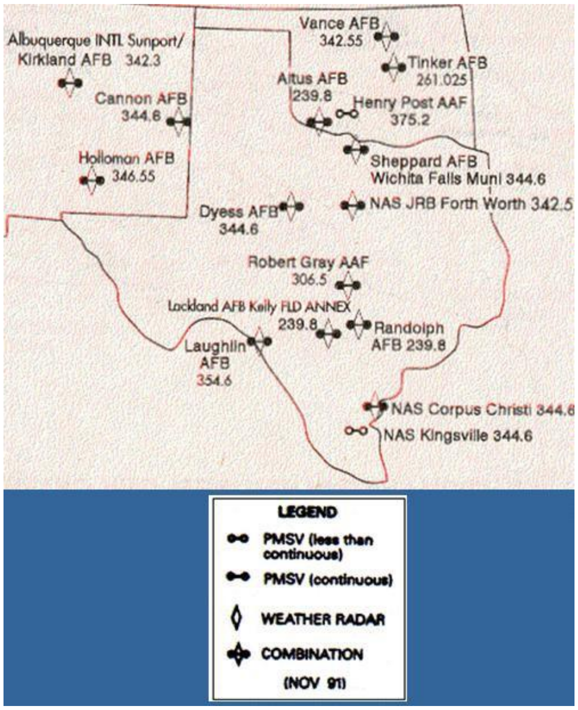
Pilot Weather Reports 3

All pilots are urged to cooperate and promptly volunteer reports on these conditions, and any other conditions pertinent to aviation, such as: cloud bases, tops, and layers; flight visibility; precipitation; visibility restrictions; winds at altitude; and temperatures aloft.

PIREP Conditions

Pilots are required to submit a PIREP under the following conditions:

- In-flight when requested
- When unusual or unforecast weather conditions are encountered
- When weather conditions on an IFR approach differ from the latest observation
- When a missed approach is executed due to weather
- When a wind shear is encountered on departure or arrival



PMSV

PIREP Recipients

Your observed PIREPs should be given to any ground facility with which you have established communication (e.g., FSS, ARTCC, EFAS En route Flight Advisory Service, etc.). After passing the immediately pertinent information, you should follow up with a radio call to a Meteorology Office (METRO) to ensure rapid dissemination to other using agencies.

If you are not able to report while in the air, you should make a report to the nearest FSS or Weather Service Office upon landing, especially if weather encountered was different than forecast.

"Pensacola METRO, Rocket 501, a single engine T-39 Sabreliner at one-six thousand feet, 200 knots indicated, holding 20 miles south of Navy Pensacola, at 2100Z experiencing IFR in stratus clouds, temperature -15°C, winds 330 at 25, no turbulence, light rime icing."

PIREP

PIREP Format

When airborne, you would consult the Flight Information Handbook for the proper format, which includes aircraft identification, location, time (UTC), altitude (MSL), type aircraft, sky cover, visibility & weather, temperature, wind, turbulence, icing, and remarks.

Even though your pilot report should be as complete and accurate as possible, do not be overly concerned with strict format and phraseology. The important thing is that your PIREP is relayed so others may benefit from your report.

PIREP FORMAT:

(a) Location of phenomena (station identifier, radial/DME and route segment

(b) Time (UTC)

(c) Altitude (MSL)

(d) Type Aircraft

(e) Skycover (bases, tops and amount)

(f) Flight Visibility and Weather

(g) Air Temperature

(h) Wind

(i) Turbulence (see tables below)

(j) Icing (see tables below)

(k) Remarks

DD Form 175-1

DD175-1 Intro

The DD Form 175-1, Flight Weather Briefing, is prepared and used by the local weather office to brief pilots on weather conditions both locally and along a planned route of flight.

The form may be faxed to you by the weather office if a verbal briefing is not desired. Keep in mind the some of the blocks on the form may not be completed, or extra data may be included as an attachment.

The following screens will outline the information contained in the form.

FLIGHT WEATHER BRIEFING

PART I - TAKEOFF DATA

1. DATE	2. ACFT TYPE/NO.	3. DEP PT/ETD	4. RWY TEMP	5. DEWPOINT	6. TEMP DEV	7. PRES ALT	8. DENSITY ALT
5 JAN 2007	T-6A / Texan 21	KRND / 1500Z	65 F/C	49 F/C	+10	+ 909 FT	—— FT

9. SFC WIND (M/T)	10. CLIMB WINDS	11. LOCAL WEATHER WATCH/WARNING/ADVISORY	12. RSC/RCR
21005	25030	N/A	N/A

13. REMARKS/TAKEOFF ALTN FCST: VFR

PART II - ENROUTE & MISSION DATA

14. FLT LEVEL/WINDS/TEMP ☐ SEE ATTACHED: 280/70 -27

15. SPACE WEATHER

	NO IMPACT	MARGINAL	SEVERE
FREQ	X		
GPS	X		
RAD	X		

16. SOLAR/LUNAR — LOCATION: KRND

BMNT Z			
SR Z	MR Z		
SS Z	MS Z		
EENT Z	ILLUM %		

17. CLOUDS AT FLT LEVEL: ☐ YES ☐ NO [X] IN AND OUT

18. OBSCURATIONS AT FLT LEVEL RESTRICTING VISIBILITY: ☐ YES ☐ NO TYPE

19. MINIMUM CEILING - LOCATION	20. MAXIMUM CLOUD TOPS - LOCATION	21. MINIMUM FREEZING LVL - LOCATION
NE TX 005 FT AGL	ENRTE 270 FT MSL	ENRTE 120 FT MSL

22. THUNDERSTORMS	23. TURBULENCE	24. ICING	25. PRECIPITATION
CHART OWS 05 / 12-18Z	CHART OWS 05 / 12-18Z	CHART OWS 05 / 12-18Z	CHART FCST
X NONE / AREA / LINE	NONE / IN CLEAR / IN CLOUD	X NONE / RIME / MIXED / CLEAR	X NONE / DRIZZLE / RAIN / SNOW / PELLET
ISOLATED 1 - 2%	LIGHT	TRACE	LIGHT
FEW 3 - 15%	MODERATE X	LIGHT	MODERATE
SCATTERED 16 - 45%	SEVERE	MODERATE	HEAVY
NUMEROUS - MORE THAN 45%	EXTREME	SEVERE	SHOWERS
HAIL, SEVERE TURBULENCE & ICING, HEAVY PRECIPITATION, LIGHTNING & WIND SHEAR EXPECTED IN AND NEAR THUNDERSTORMS.	LEVELS 180 - 300	LEVELS ——	FREEZING
LOCATION ——	LOCATION OK	LOCATION ——	LOCATION ——

PART III - AERODROME FORECASTS

26. DEST/ALTN	27. VALID TIME	28. SFC WIND	29. VSBY/WEA	30. CLOUD LAYERS	31. ALTIMETER	RWY TEMP	PRES ALT
KRND	1700Z to 1900Z	21006	7	SKC	2974 INS	75 F/C	+927 FT
KSKF	1700Z to 1900Z	22006	7	SKC	2972 INS	74 F/C	—— FT
KGRK	1700Z to 1900Z	19009	7	SCT015 SCT 030	2972 INS	55 F/C	—— FT
KNFW	1700Z to 1900Z	16007	7	OVC015	2968 INS	51 F/C	—— FT
KSPS	1700Z to 1900Z	18010	7	SCT030 SCT250	2961 INS	64 F/C	—— FT
KTIK	1700Z to 1900Z	20007	7	SKC	2964 INS	69 F/C	—— FT
KEND	1700Z to 1900Z	18010	7	BKN020	2973 INS	62 F/C	—— FT
DEST/ALTN	Z TO Z	M/T			INS	F/C	INS

PART IV - COMMENTS/REMARKS

32. BRIEFED RSC/RCR: ☐ YES [X] NOT AVAILABLE — 33. PMSV: 241.3 — 34. ATTACHMENTS: ☐ YES [X] NO

35. REMARKS: No changes

PART V - BRIEFING RECORD

36. WX BRIEFED TIME	37. FLIMSY BRIEFING NO.	38. FORECASTER'S INITIALS	39. NAME OF PERSON RECEIVING BRIEFING
E 1225 E1500 Z		CM	

40. VOID TIME	41. EXTENDED TO/INITIALS	42. WX REBRIEF TIME/INITIALS	43. WX DEBRIEF TIME/INITIALS
Z	Z	Z	Z

DD FORM 175-1, OCT 2002 PREVIOUS EDITION MAY BE USED.

DD Form 175-1

Part 1 Data

Part 1 of the form breaks down as follows:

Item 1 is the date.

Item 2 is the aircraft type and identification, such as radio call sign, mission number or last three digits of the tail number.

Item 3 is the departure ICAO designator and estimated time of departure.

Items 4 and 5 are the runway temperature and dew point, marked either °F or °C.

Item 6 is the temperature deviation in °C from the standard lapse rate.

Items 7 and 8 are the pressure and density altitudes.

Item 9 gives the surface winds in magnetic direction for local, and true direction for remote locations.

Item 10 is climb winds in true direction.

Item 11 provides weather warnings or advisories valid for the ETD ± 1 hour.

Item 12 is the latest RSC (Runway Surface Condition) or RCR (Runway Conditions Reading) for departure.

Item 13 shows any remarks on weather affecting takeoff and climb, such as inversions, icing, and turbulence.

Part 2 Data

Part 2:

Item 14 shows flight level winds and temperature.

Items 15 and 16 will depict any effects of space weather or solar/lunar phenomena.

Items 17 and 18 indicate if there are clouds or visibility restrictions at the desired flight level.

Items 19, 20, and 21 give the location and altitude of minimum ceiling, maximum cloud tops, and minimum freezing level.

Items 22 to 25 provide amount and levels of any thunderstorms, turbulence, icing, or precipitation.

Part 3 Data

Part 3:

Item 26 shows airfield ICAO identifiers.

Item 27 provides valid time for the forecast, through ± 1 hour of ETA.

Item 28 gives surface winds, again magnetic for local and true direction for off-station.

Item 29 shows visibility and any weather.

Item 30 lists cloud layers in hundreds of feet.

Item 31 is the altimeter setting for the airfield, followed by the runway temperature and pressure altitude.

Part 4 Data

Part 4:

Item 32 indicates if the RSC and/or RCR were briefed.

Item 33 provides the PMSV frequency for PIREPs.

Item 34 indicates if there are any attachments to the 175-1.

Item 35 shows any remarks.

Part 5 Data

Part 5:

Items 36 to 43 allow entry of forecaster, briefer, and pilot names and/or initials and weather briefing times.

ASSIGNMENT SHEET 3-7-3

WATCHES, ADVISORIES AND CHARTS REVIEW

A. INTRODUCTION

This lesson addresses data presented in various weather charts, watches, advisories, and the DD Form 175-1. It also covers the use and requirements for submitting a Pilot Report (PIREP) to meteorology offices while in flight.

B. ENABLING OBJECTIVES

C. STUDY ASSIGNMENT

D. STUDY QUESTIONS

1. The information displayed on the Surface Analysis Chart is observed weather, meaning that the chart represents past history, and is not a forecast.

   a. True
   b. False

2. Barometric pressure lines (isobars) are drawn at ______-millibar intervals.

   a. 2 c. 10
   b. 4 d. 50

3. The valid time of a Surface Analysis chart is given in local time at the top right.

   a. True
   b. False

4. METARs are scheduled observations taken between ______ minutes past the hour

   a. 10–15 c. 40–45
   b. 25–30 d. 55–59

5. NEXRAD displays what is referred to as a "hook echo" that is considered indicative of a ______.

   a. tornado
   b. hurricane
   c. lightning strike
   d. microburst

6. ______ satellite imagery displays clouds and the Earth reflecting sunlight back to the satellite sensors.

   a. Infrared
   b. Radar
   c. NEXRAD
   d. Visible

7. A flag on a barb on a Winds-Aloft Prognostic Chart represents ______ knots of wind.

   a. 10
   b. 25
   c. 50
   d. 100

8. On Winds-Aloft Prognostic Charts, all temperatures are negative above ______ feet

   a. 10,000
   b. 18,000
   c. 24,000
   d. 36,000

9. A direction of ______ in a Winds-Aloft Forecast indicates a variable wind direction.

   a. 00
   b. 99
   c. 900
   d. 999

10. Which one of the following lists the conditions for issuing a WW?

   a. Turbulence and hail
   b. Hail and lightning
   c. Tornadoes and severe thunderstorms
   d. Icing and gusty surface winds

11. Which one of the following would be the best altitude to enable flight above the cloud tops in this WW?

WWUS 9 KMKC 181845
MKC WW 181845

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WATCH NUMBER 29
NATIONAL WEATHER SERVICE KANSAS CITY MO
1245 PM CST THUR FEB 18 20XX

A . . . THE STORM PREDICTION CENTER HAS ISSUED A SEVERE THUNDERSTORM WATCH FOR

SOUTH CENTRAL KANSAS
CENTRAL OKLAHOMA
NORTH CENTRAL TEXAS
EAST TEXAS

EFFECTIVE FROM 1 PM CST UNTIL 6 PM CST THIS THURSDAY AFTERNOON

LARGE HAIL . . . DANGEROUS LIGHTNING...AND DAMAGING THUNDERSTORM WINDS ARE POSSIBLE IN THESE AREAS.

THE SEVERE THUNDERSTORM WATCH AREA IS ALONG AND 70 STATUTE MILES EITHER SIDE OF A LINE FROM 70 MILES WEST OF AUSTIN TEXAS TO 35 MILES WEST OF WICHITA KANSAS.

REMEMBER . . . A SEVERE THUNDERSTORM WATCH MEANS CONDITIONS ARE FAVORABLE FOR SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS AND POSSIBLE WARNINGS.

B . . . OTHER WATCH INFORMATION...THIS SEVERE THUNDERSTORM WATCH REPLACES SEVERE THUNDERSTORM WATCH NUMBER 28. WATCH NUMBER 28 WILL NOT BE IN EFFECT AFTER 1 PM CST.

C . . . A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 2 IN. EXTRM TURBC AND SFC WND GUSTS TO 70 KT. SCTD CBS WITH MAX TOPS TO 500 PSBL. MEAN WIND VECTOR 22040KT.

D . . . WITH CLD FNT MOVG SEWD FM WRN KS N CNTRL TX AND DVLPG LOW OK PANHANDLE MOVG EWD STG CNVRGNC SHLD DVLP ALG CLD FNT AND NR INTERSECTION WITH WRM FNT. CONTD STG INFLOW OF UNSTABLE AMS.

a. FL 280 c. FL 510
b. FL 350 d. FL 700

12. The first issuance of any non-convective SIGMET will always be identified as an ______.

a. Urgent SIGMET (UWS) c. Initial SIGMET (IWS)
b. Priority SIGMET (PWS) d. Leading SIGMET (LWS)

13. For Convective SIGMETs, a line of thunderstorms is defined as being at least ______ miles long with thunderstorms affecting at least ______ percent of its length.

a. 50, 50 c. 70, 30
b. 60, 40 d. 100, 75

14. An AIRMET ______ is issued for widespread IFR conditions (ceilings less than 1000 feet and/or visibility less than 3 miles) affecting over 50% of the area or for extensive mountain obscuration.

    a. Tango c. Sierra
    b. Zulu d. Bravo

15. Air traffic facilities are required to solicit PIREPs whenever ceilings are at or below ______ feet and visibility is at or below ______ mile(s).

    a. 1000, 1 c. 5000, 5
    b. 3000, 3 d. 10,000, 10

16. According to this portion of DD Form 175-1, Vance AFB (KEND) is reporting broken clouds at ______ feet.

PART III - AERODROME FORECASTS							
26.	27. VALID TIME	28. SFC WIND	29. VSBY/WEA	30. CLOUD LAYERS	31. ALTIMETER	RWY TEMP	PRES ALT
DEST/ALTN KRND	Z TO Z 1700Z to 1900Z	21006 M T	7	SKC	2974 INS	75 °F C	+927 FT
~~DEST~~/ALTN KSKF	Z TO Z 1700Z to 1900Z	22006 M T	7	SKC	2972 INS	74 °F C	— FT
~~DEST~~/ALTN KGRK	Z TO Z 1700Z to 1900Z	19009 M T	7	SCT015 SCT 030	2972 INS	55 °F C	— FT
~~DEST~~/ALTN KNFW	Z TO Z 1700Z to 1900Z	16007 M T	7	OVC015	2968 INS	51 °F C	— FT
~~DEST~~/ALTN KSPS	Z TO Z 1700Z to 1900Z	18010 M T	7	SCT030 SCT250	2961 INS	64 °F C	— FT
~~DEST~~/ALTN KTIK	Z TO Z 1700Z to 1900Z	20007 M T	7	SKC	2964 INS	69 °F C	— FT
DEST/~~ALTN~~ KEND	Z TO Z 1700Z to 1900Z	18010 M T	7	BKN020	2973 INS	62 °F C	— FT

    a. 200 c. 7000
    b. 2000 d. 20,000

17. NEXRAD is capable of displaying areas of ______.

    a. tornadoes c. wind shear
    b. hail d. all of the above

18. In a textual Winds-Aloft chart, if winds are called “light and variable,” the code ______ will be listed.

    a. “C” c. “L”
    b. “9900” d. “00”

19. Convective SIGMETs (WST) are issued only for thunderstorms and related convective phenomena over the conterminous US.

    a. True
    b. False

20. Clouds will usually show up white on a visible satellite image since clouds are much ______ than most of the earth.

    a. more dense
    b. more reflective
    c. warmer
    d. lighter

21. Wind information is never forecast for altitudes within ______ feet of the surface.

    a. 500
    b. 1500
    c. 5000
    d. 10,000

22. On a Surface Analysis Chart, the pressure systems mentioned are outlined by isobars drawn at ______-millibar intervals

    a. 2
    b. 4
    c. 8
    d. 10

23. On a Winds-Aloft forecast, temperature information is never forecast within ______ feet of the surface.

    a. 1000
    b. 2500
    c. 5000
    d. 10,000

24. Aviation Severe Weather Watch Bulletins can be issued for severe thunderstorms, defined by frequent lightning and ______ knots of wind or greater or ______ diameter hail or larger.

    a. 30, 1/2
    b. 50, 3/4
    c. 50, 1
    d. 75, 1/2

25. An AIRMET valid period expiration time is ______ hours after the scheduled “valid beginning” time.

    a. 2
    b. 6
    c. 12
    d. 24

Answers:

1. A
2. B
3. B
4. D
5. A
6. D
7. C
8. C
9. B
10. C
11. C
12. A
13. B
14. C
15. C
16. B
17. D
18. B
19. A
20. B
21. B
22. B
23. B
24. B
25. B

APPENDIX A

GLOSSARY OF SELECTED METEOROLOGICAL TERMS

ACTUAL TIME OF OBSERVATION – For METAR reports, it is the time the last element of the report is observed or evaluated. For SPECI reports, it is the time that the criteria for a SPECI were met or noted.

ADIABATIC – The word applied in the science of thermodynamics to a process during which no heat is communicated to or withdrawn from the body or system concerned. Adiabatic changes of atmospheric temperatures are those that occur only in consequence of compression or expansion accompanying an increase or a decrease of atmospheric pressure.

AIRCRAFT MISHAP – An inclusive term to denote the occurrence of an aircraft accident or incident.

ALTIMETER SETTING – Pressure of the reporting station converted in order to produce a reading on altimeters of field elevation at 10 feet above the runway (normal installation height of the altimeter). Altimeter settings are given in inches of mercury and represent sea level pressure.

ATMOSPHERIC PRESSURE – The force exerted by the weight of the atmosphere from the level of measurement to its outer limits.

AUGMENTED REPORT – A meteorological report prepared by an automated surface weather observing system for transmission with certified weather observers signed on to the system to add information to the report.

AUTOMATED REPORT – A meteorological report prepared by an automated surface weather observing system for transmission, and with no certified weather observers signed on to the system.

BLOWING DUST – Dust raised by the wind to moderate heights above the ground and restricting horizontal visibility to less than 7 miles. If visibility reduced to between 5/8 and 5/16 then a Dust storm; if less than 5/16, a severe Dust storm.

BLOWING SAND – Sand raised by the wind to moderate heights above the ground and restricting horizontal visibility to less than 7 miles. If visibility reduced to between 5/8 and 5/16 then a Sandstorm; if less than 5/16, a severe Sandstorm.

BLOWING SNOW – Snow particles raised and stirred violently by the wind to moderate or great heights. Visibility is poor (6 miles or less) and the sky may become obscured when the particles are raised to great heights.

BLOWING SPRAY – Spray raised in such quantities as to reduce the visibility at eye level (6 feet on shore, 33 feet at sea) to 6 miles or less.

BROKEN LAYER – A cloud layer covering whose summation amount of sky cover is 5/8 through 7/8.

CALM – A condition when no motion of the air is detected.

CEILING – The height above the earth's surface (field elevation or ground elevation) of the lowest non-surface based layer that is reported as broken or overcast, or the vertical visibility into an indefinite ceiling.

CEILOMETER – A device used to evaluate the height of clouds or the vertical visibility into a surface-based obscuration.

CELSIUS – The ninth General Conference of Weights and Measures, held in October 1948,

adopted the name Celsius in place of centigrade in honor of its originator, Anders Celsius (1704-1744), a Swedish astronomer who devised the scale.
CLEAR-AIR TURBULENCE (CAT) – Turbulence encountered when flying through air devoid of clouds, produced primarily by thermals and wind shear, including proximity to the jet stream.
CLEAR SKY (SKC) – The state of the sky when it is cloudless.
CLOUD-AIR LIGHTNING (CA) – Streaks of lightning which pass from a cloud to the air, but do not strike the ground.
CLOUD-CLOUD LIGHTNING (CC) – Streaks of lightning reaching from one cloud to another.
CLOUD-GROUND LIGHTNING (CG) – Lightning occurring between cloud and ground.
CLOUD HEIGHT – The height of the base of a cloud or cloud layer above the surface of the Earth.
CONTOUR LINE – A line connecting points of equal (constant) height on a Constant-Pressure Chart.
COORDINATED UNIVERSAL TIME (UTC) – The time in the zero meridian time zone.
CUMULUS – A principal cloud type in the form of individual, detached elements that are generally dense and possess sharp non-fibrous outlines.
CUMULONIMBUS – An exceptionally dense and vertically developed cloud, occurring either isolated or as a line or wall of clouds with separated upper portions. These clouds appear as mountains or huge towers, at least a part of the upper portions of which are usually smooth, fibrous, or striated, and almost flattened.
DESIGNATED RVR RUNWAY – A runway at civilian airports designated by the FAA for reporting RVR in long-line transmissions.
DEW POINT – The temperature to which a given parcel of air must be cooled at constant pressure and constant water-vapor content in order for saturation to occur.
DISPATCH VISUAL RANGE – A visual range value derived from an automated visibility sensor.
DRIZZLE – Fairly uniform precipitation composed exclusively of fine drops (diameter less than 0.02 inch or 0.5 mm) very close together. Drizzle appears to float while following air current, although unlike fog droplets, it falls to the ground.
DRY ADIABATIC LAPSE RATE – The rate of decrease of temperature with height, approximately equal to 3° C. per 1000 feet. This is close to the rate at which an ascending body of unsaturated air will cool by adiabatic expansion.
DUST STORM – An unusual, frequently severe weather condition characterized by strong winds and dust-filled air over an extensive area.
FEW – A layer whose summation amount of sky cover is 1/8 through 2/8.
FIELD ELEVATION – The elevation above sea level of the highest point on any of the runways of the airport.
FOG – A visible aggregate of minute water particles (droplets) which are based at the Earth's surface and reduce horizontal visibility to less than 5/8 statute mile and, unlike drizzle, it does not fall to the ground.
FREEZING – A descriptor, FZ, used to describe drizzle and/or rain that freezes on contact with the ground or exposed objects, and used also to describe fog that is composed of minute ice

crystals.
FREEZING DRIZZLE – Drizzle that freezes upon impact with the ground, or other exposed objects.
FREEZING FOG – A suspension of numerous minute ice crystals in the air, or water droplets at temperatures below 0° Celsius, based at the Earth's surface, which reduces horizontal visibility; also called ice fog.
FREEZING PRECIPITATION – Any form of precipitation that freezes upon impact and forms a glaze on the ground or exposed objects.
FREEZING RAIN – Rain that freezes upon impact and forms a glaze on the ground or exposed objects.
FROZEN PRECIPITATION – Any form of precipitation that reaches the ground in solid form (snow, small hail and/or snow pellets, snow grains, hail, ice pellets, and ice crystals).
FUNNEL CLOUD – A violent, rotating column of air which does not touch the ground, usually appended to a cumulonimbus cloud (see tornado and waterspout).
GLAZE – Ice formed by freezing precipitation covering the ground or exposed objects.
GRAUPEL – Granular snow pellets, also called soft hail.
GUST – Rapid fluctuations in wind speed with a variation of 10 knots or more between peaks and lulls.
HAIL – Precipitation in the form of small balls or other pieces of ice falling separately or frozen together in irregular lumps.
HAZE – A suspension in the air of extremely small, dry particles invisible to the naked eye and sufficiently numerous to give the air an opalescent appearance.
HECTOPASCAL – A unit of measure of atmospheric pressure equal to 100 newtons per square meter, abbreviated hPa.
ICE CRYSTALS (DIAMOND DUST) – A fall of unbranched (snow crystals are branched ice crystals in the form of needles, columns, or plates.
ICE PELLETS (PL) – Precipitation of transparent or translucent pellets of ice, which are round or irregular, rarely conical, and which have a diameter of 0.2 inch (5 mm), or less. There are two main types:
a. Hard grains of ice consisting of frozen raindrops, or largely melted and refrozen snowflakes.
b. Pellets of snow encased in a thin layer of ice which have formed from the freezing of either droplets intercepted by the pellets or of water resulting from the partial melting of the pellets.
IN-CLOUD LIGHTNING (IC) – Lightning which takes place within the thunder cloud.
INDEFINITE CEILING – The ceiling classification applied when the reported ceiling value represents the vertical visibility upward into surface-based obscuration.
INSOLATION – INcoming SOLar radiATION. The total amount of energy radiated by the Sun that reaches the Earth’s surface. Insolation is the primary source for all weather phenomena on the Earth.
INTENSITY QUALIFIER – Intensity qualifiers are used to describe whether a phenomena is light (–), moderate (no symbol used), or heavy (+).
ISOBAR – A line on a chart or diagram drawn through places or points having the same barometric pressure. (Isobars are customarily drawn on weather charts to show the horizontal

distribution of atmospheric pressure reduced to sea level or the pressure at some specified altitude.)

ISOTACH – A line joining points of equal wind speed.

ISOTHERM – A line on a chart or diagram drawn through places or points having equal temperature.

LOW DRIFTING – A descriptor, DR, used to describe snow, sand, or dust raised to a height of less than 6 feet above the ground.

LOW DRIFTING DUST – Dust that is raised by the wind to less than 6 feet above the ground; visibility is not reduced below 7 statute miles at eye level, although objects below this level may be veiled or hidden by the particles moving nearly horizontal to the ground.

LOW DRIFTING SAND – Sand that is raised by the wind to less than 6 feet above the ground; visibility is not reduced below 7 statute miles at eye level, although objects below this level may be veiled or hidden by the particles moving nearly horizontal to the ground.

LOW DRIFTING SNOW – Snow that is raised by the wind to less than 6 feet above the ground; visibility is not reduced below 7 statute miles at eye level, although objects below this level may be veiled or hidden by the particles moving nearly horizontal to the ground.

MANUAL STATION – A station, with or without an automated surface weather observing system, where the certified observers are totally responsible for all meteorological reports that are transmitted.

METAR/SPECI – An evaluation of select weather elements from a point or points on or near the ground according to a set of procedures. It may include type of report, station identifier, date and time of report, a report modifier, wind, visibility, runway visual range, weather and obstructions to vision, sky condition, temperature and dew point, altimeter setting, and Remarks.

MILLIBAR – (Bar – a unit of pressure equal to 1,000,000 dynes per square centimeter.) A millibar is equal to 1/1000 of a bar.

MIST – A hydrometer consisting of an aggregate of microscopic and more-or-less hygroscopic water droplets or ice crystals suspended in the atmosphere that reduces visibility to less than 6 statute miles but greater than or equal to ⅝ statute mile.

MOIST ADIABATIC LAPSE RATE – See Saturated Adiabatic Lapse Rate.

NON-UNIFORM SKY CONDITION – A localized sky condition which varies from that reported in the body of the report.

NON-UNIFORM VISIBILITY – A localized visibility which varies from that reported in the body of the report.

OBSCURED SKY – The condition when the entire sky is hidden by a surface-based obscuration.

OBSCURATION – Any aggregate of particles in contact with the earth's surface that is dense enough to be detected from the surface of the earth. Also, any phenomenon in the atmosphere, other than precipitation, that reduces the horizontal visibility.

OVERCAST – A layer of clouds whose summation amount of sky cover is 8/8.

PARTIAL – A descriptor, PR, used only to report fog that covers part of the airport.

PARTIAL FOG – Fog covering part of the station and which extends to at least 6 feet above the ground and apparent visibility in the fog is less than ⅝ SM. Visibility over parts of the station is less than or equal to ⅝ SM.

PARTIAL OBSCURATION – The portion of the sky cover (including higher clouds, the

moon, or stars) hidden by weather phenomena in contact with the surface.
PATCHES – A descriptor, BC, used only to report fog that occurs in patches at the airport.
PATCHES (OF) FOG – Fog covering part of the station which extends to at least 6 feet above the ground and the apparent visibility in the fog patch or bank is less than ⅝ SM. Visibility in parts of the observing area is greater than or equal to ⅝ SM, when the fog is close to the point of observation, the minimum visibility reported will be less than ⅝SM.
PEAK WIND SPEED – The maximum instantaneous wind speed since the last METAR that exceeded 25 knots.
PRECIPITATION DISCRIMINATOR – A sensor, or array of sensors, that differentiates between different types of precipitation (liquid, freezing, frozen).
PRESSURE FALLING RAPIDLY – A decrease in station pressure at a rate of 0.06 inch of mercury or more per hour which totals 0.02 inch or more.
PRESSURE RISING RAPIDLY – An increase in station pressure at a rate of 0.06 inch of mercury or more per hour which totals 0.02 inch or more.
RADIOSONDE – A balloon-borne instrument used to measure the temperature, pressure and humidity aloft.
RAIN – Precipitation of liquid water particles, either in the form of drops larger than .02 inch (0.5 mm) or smaller drops which, in contrast to drizzle, are widely separated.
PREVAILING VISIBILITY – The visibility that is considered representative of conditions at the station; the greatest distance that can be seen throughout at least half the horizon circle, not necessarily continuous.
ROTOR CLOUD – A turbulent cloud formation found in the lee of some large mountain barriers. The air in the cloud rotates around an axis parallel to the mountain range.
RUNWAY VISUAL RANGE (RVR) – An instrumentally-derived value, based on standard calibrations, that represents the horizontal distance a pilot may see down the runway from the approach end.
SANDSTORM – Particles of sand ranging in diameter from 0.008 to 1 mm that are carried aloft by a strong wind. The sand particles are mostly confined to the lowest ten feet, and rarely rise more than fifty feet above the ground.
SATURATED ADIABATIC LAPSE RATE – A rate of decrease of temperature with height equal to the rate at which an ascending body of saturated air will cool during adiabatic expansion. This value will vary, but is considered to average about 1.5° C. per 1000 feet.
SCATTERED – A layer whose summation amount of sky cover is ⅜ through 4/8.
SCHEDULED TIME OF REPORT – The time a schedule report is required to be available for transmission.
SEA-LEVEL PRESSURE – The pressure value obtained by the theoretical reduction or increase of barometric pressure to sea-level; measured in hectopascals (millibars).
SECTOR VISIBILITY – The visibility in a specified direction that represents at least a 45-degree arc of the horizon circle.
SHALLOW – A descriptor, MI, used only to describe fog when the visibility at 6 feet above the ground is ⅝ statute mile or more and the apparent visibility in the fog layer is less than 5/8 statute mile.
SHALLOW FOG – Fog in which the visibility at 6 feet above ground level is ⅝ statute mile or more and the apparent visibility in the fog layer is less than ⅝ statute mile.

SHOWER(S) – A descriptor, SH, used to qualify precipitation characterized by the suddenness with which they start and stop, by the rapid changes of intensity, and usually by rapid changes in the appearance of the sky.
SIGNIFICANT CLOUDS – Cumulonimbus, cumulonimbus mammatus, towering cumulus, altocumulus castellanus, and standing lenticular or rotor clouds.
SKY CONDITION – The state of the sky in terms of such parameters as sky cover, layers and associated heights, ceiling, and cloud types.
SKY COVER – The amount of the sky which is covered by clouds or partial obscurations in contact with the surface.
SMOKE – A suspension in the air of small particles produced by combustion. A transition to haze may occur when smoke particles have traveled great distances (25 to 100 statute miles or more) and when the larger particles have settled out and the remaining particles have become widely scattered through the atmosphere.
SNOW – Precipitation of snow crystals, mostly branched in the form of six-pointed starts; for automated stations, any form of frozen precipitation other than hail.
SNOW GRAINS – Precipitation of very small, white opaque grains of ice; the solid equivalent of drizzle.
SNOW PELLETS – Precipitation of white, opaque grains of ice. The grains are round or sometimes conical. Diameters range from about 0.08 to 0.2 inch (2 to 5 mm).
SPRAY – An ensemble of water droplets torn by the wind from an extensive body of water, generally from the crests of waves, and carried up into the air in such quantities that it reduces the horizontal visibility.
SPECI – A surface weather report taken to record a change in weather conditions that meets specified criteria or is otherwise considered to be significant.
SQUALL – A strong wind characterized by a sudden onset in which wind speeds increase to at least 16 knots and are sustained at 22 knots or more for at least one minute. **STANDARD ATMOSPHERE** – A hypothetical vertical distribution of the atmospheric temperature, pressure, and density, which by international agreement is considered to be representative of the atmosphere for pressure-altimeter calibrations and other purposes (29.92 in- Hg or 1013 Pa).
STANDING LENTICULAR CLOUD – A more or less isolated cloud with sharp outlines that is generally in the form of a smooth lens or almond. These clouds often form on the lee side of and generally parallel to mountain ranges. Depending on their height above the surface, they may be reported as stratocumulus standing lenticular cloud (SCSL); altocumulus standing lenticular (ACSL); or cirrocumulus standing lenticular cloud (CCSL).
STATION ELEVATION – The officially designated height above sea-level to which station pressure pertains. It is generally the same as field elevation at an airport station.
STATION IDENTIFIER – A 4-alphabetic-character code group used to identify the observing location.
STATION PRESSURE – Atmospheric pressure computed for the level of the station elevation.
SUMMATION LAYER AMOUNT – a categorization of the amount of sky cover at and below each reported layer of cloud.
SUMMATION PRINCIPLE – This principle states that the sky cover at any level is equal to the summation of the sky cover of the lowest layer, plus the additional sky cover present at all

successively higher layers up to and including the layer being considered.
SURFACE VISIBILITY – The prevailing visibility determined from the usual point of observation.
SYNOPTIC CHART – A chart, such as the ordinary weather map, which shows the distribution of meteorological conditions over an area at a given moment.
THUNDERSTORM – A descriptor, TS, used to qualify precipitation produced by a cumulonimbus cloud that is accompanied by lightning and thunder, or for automated systems, a storm detected by lightning detection systems.
TIME OF OCCURRENCE – A report of the time weather begins and ends.
TORNADIC ACTIVITY – The occurrence or disappearance of tornadoes, funnel clouds, or waterspouts.
TORNADO – A violent, rotating column of air touching the ground; funnel cloud that touches the ground (see funnel cloud and water spout).
TOWER VISIBILITY – The prevailing visibility determined from the airport traffic control tower when the surface visibility is determined from another location.
TOWERING CUMULUS – A descriptive term for a cloud with generally sharp outlines and with moderate to great vertical development, characterized by its cauliflower or tower appearance.
UNKNOWN PRECIPITATION – Precipitation type that is reported if the automated station detects the occurrence of light precipitation but the precipitation discriminator cannot recognize the type.
VARIABLE CEILING – A ceiling of less than 3000 feet which rapidly increases or decreases in height by established criteria during the period of observation.
VARIABLE LAYER AMOUNTS – A condition when the reportable amount of a layer varies by one or more reportable values during the period it is being evaluated (variable sky condition).
VARIABLE PREVAILING VISIBILITY – A condition when the prevailing visibility is less than 3 statute miles and rapidly increases and decreases by ½ mile or more during the period of observation.
VARIABLE WIND DIRECTION – A condition when (1) the wind direction fluctuates by 60 degrees or more during the 2-minute evaluation period and the wind speed is greater than 6 knots; or (2) the direction is variable and the wind speed is 6 knots or less.
VERTICAL VISIBILITY – A subjective or instrumental evaluation of the vertical distance into a surface-based obscuration that an observer would be able to see.
VICINITY – A proximity qualifier, VC, used to indicate weather phenomena observed between 5 and 10 statute miles of the usual point of observation but not at the station.
VIRGA – Visible wisps or strands of precipitation falling from clouds that evaporate before reaching the surface.
VISIBILITY – The greatest horizontal distance at which selected objects can be seen and identified or its equivalent derived from instrumental measurements.
VOLCANIC ASH – Fine particles of rock powder that originate blown out from a volcano and that may remain suspended in the atmosphere for long periods. The ash is a potential hazard to aircraft operations and may be an obscuration.
VOLCANIC ERUPTION – An explosion caused by the intense heating of subterranean rock which expels lava, steam, ashes, etc., through vents in the earth's crust.

WATERSPOUT – A violent, rotating column of air that forms over a body of water, and touches the water surface; tornado or funnel cloud that touches a body of water (see funnel cloud and tornado).

WELL-DEVELOPED DUST/SAND WHIRL – An ensemble of particles of dust or sand, sometimes accompanied by small litter, raised from the ground in the form of a whirling column of varying height with a small diameter and an approximately vertical axis.

WIDESPREAD DUST – Fine particles of earth or other matter raised or suspended in the air by the wind that may have occurred at or far away from the station.

WIND SHIFT – A change in the wind direction of 45 degrees or more in less than 15 minutes with sustained wind speeds of 10 knots or more throughout the wind shift.

APPENDIX B

COMMON WEATHER CONTRACTIONS

A
ABT about
ABV above
AC altocumulus
ACS across
ACFT aircraft
ACRS across
ACTVTY/ACT activity
ADJ adjacent
ADVY advisory
AFT after
AGL above ground level
AHD ahead
ALF aloft
ALG along
ALQDS all quadrants
AMS air mass
AOB at or below
APRNT apparent
AR Arkansas
ARPT airport
ATLC Atlantic
AUTO automated weather report
B
B began
BA breaking action
BC patches BCM
become BECMG
becoming BGNG
beginning BHND
behind
BINOVC breaks in overcast
BKN broken BL
blowing BLDPS
buildups
BLO/BLW below
BNDRY boundary
BR mist
BRFLY briefly
BTWN between
BYD beyond
C
C ceiling
CA clear above
CAT clear air turbulence
CBS/CB cumulonimbus
CDFNT/CFP cold front
CDT Central Daylight Time
CHC chance
CI cirrus CIG
ceiling CIGS
ceilings CLD
cold CLDS
clouds
CLR clear (used at automated stations)
CLSD closed
CNCL cancel
CNTRD/CNTR centered
CNTRL/CTRL central
CNSDBLY considerably
CNVGNC convergence
CNVTV convective
CO Colorado
CONDS conditions
CON/CONTD continue
CONS continuous
CONTG continuing
COR correction
CST Central Standard Time
CSTL coastal
CTC contact
CU cumulus
CUFA cumulofractus
D
D dust
DCRG decreasing
DEP depth
DMSHG diminishing
DR dropping rapidly
DR low drifting

DRFTG drifting DS
dust storm DSIPTG
dissipating DSNT
distant
DU (widespread) dust
DURG during
DURCG during climb
DURGD during descent
DVLP/DVLPG develop/developing
DVR dispatch visual range
DZ drizzle
E
E ended/east
EBND eastbound
ELSW elsewhere
ELY easterly
EMBDD embedded
ERN eastern
EST estimated
EWD eastward
EXCP/EXC except
EXPCD/EXPCTD/EXPTD/EXP expected
EXTM/EXTRM extreme
EXTDS extends
F
FAP final approach
FEW few clouds
FC funnel cloud(s)
FCST forecast
FG fog
FIBI filed but impractical to transmit
FL flight level/Florida
FLT flight
FM from
FNT front
FNTL frontal FRQ
frequent FQTLY
frequently FRMG
forming
FROPA frontal passage
FRTHR further
FRZLVL freezing level
FT feet
FU smoke
FXD fixed
FVRBL favorable
FZ freezing
FZRNO freezing rain sensor not available
G
G gust/gusting
GA Georgia
GND ground
GR hail (graupel)
GRT/GTR greater
GS small hail/snow pellets
GULFMEX/GLF Gulf of Mexico
H
H/HZ haze
HALF haze aloft
HGTS heights
HI high
HLSTO/GR/GS hailstone
HZ haze
I
IA Iowa
IC icing/ice crystals
ICGIC icing in clouds
ICGICIP icing in clouds & in precipitation
ID Idaho
IFR Instrument Flight Rules
IL Illinois
IMPVG/IPVG improving
INC in clouds
IN inch
IN Indiana
INCRG increasing
INTMT intermittent
INTSFYG intensifying
INSTBY instability
INVOF in vicinity of
ISLTD/ISOLD isolated
J
JSTR jet stream
K
K/FU smoke
KALF smoke aloft
KOCTY smoke over city
KS Kansas

KT knot
KTS knots
L
LCL local
LCLY locally
LE Lake Erie
LGT light
LI lifted index
LLWS low level wind shear
LN line
LOC location identifier
LO low LRG
large LTG
lightning
LTGCA lightning cloud to air
LTGCCCG lightning cloud to cloud
and cloud to ground
LTGCG lightning cloud to ground
LTGIC lightning in cloud
LTL little
LTLCHG little change
LVL level LWR
lower LWRG
lowering
LYR/LYRD layer/layered
M
M minus; less than
MALSR medium intensity
approach lighting system
MAX maximum
MDT/MOD moderate
MEGG merging
METAR aviation routine weather report
MI Michigan
MI miles MI
shallow MO
Missouri
MOGR moderate or greater
MOV move MOVD
moved MOVG\MVG
moving MS
Mississippi
MSL mean sea level
MST most
MSTLY mostly
MSTR moisture
MT mountains/Montana
MTN/MTNS mountain/mountains
MULTILYRD multi layered
MVFR Marginal Visual Flight Rules
MXD mixed
N
N north
ND North Dakota
NE Nebraska or northeast
NEG negative
NEWD northeastward
NJ New Jersey
NMRS numerous
NNEWD north-northeastward
NR near NRLY
nearly NRN
northern NW
northwest NWD
northward
NWLY northwesterly
O
OBSCD obscured
OBSCG obscuring
OBSCN obscuration
OCNL occasional
OCNLY occasionally
OMTS over mountains
OR Oregon
OTLK outlook
OTRW otherwise
OTS out of service
OVC overcast
OVHD overhead
OVR over
P
P plus; greater than
PCPN precipitation
PE ice pellets
PNHDL panhandle
PK peak
PK WND peak wind
PO well-developed dust/sand whirls

PR partial
PRCTN precautions
PRD period
PRES pressure
PRESFR pressure falling rapidly
PRESRR pressure rising rapidly
PSBL/POSS possible
PTN/PTNS portion/portions
PY spray
R
R runway
RA rain
RDG reading
REPTD/RPRTD/RPTD reported
RGD ragged
RMN remain
RMNDR remainder
RQR require
RTD routine delayed observation
RVR runway visual range
RVRNO RVR not available
RWU rain shower intensity unknown
RWY/RY runway
S
S south
SA sand
SCSL stratocumulus standing lenticular cloud
SCT scattered
SD South Dakota
SE southeast
SECS sections
SERN southeastern
SEWD southeastward
SEV/SVR severe
SFC surface
SG snow grains
SGFNT/SIG significant
SH shower(s)
SHD/SHLD should
SHFTG shifting
SHLW shallow
SHWRS showers
SIG CLD significant cloud
SKC sky clear
SLD solid
SLGT slight
SLP sea level pressure
SLPG sloping
SLPNO sea level pressure not available
SLY southerly
SM statute miles
SMTH smooth
SN snow
SPECI a special observation
SPRDG spreading
SQ squalls
SQLN squall line
SRN southern
SS sand storm
ST stratus
STFRA stratofractus
STG strong STN
station STNRY
stationary SVRL
several
SWD/SWRD/SWWD southwestward
SW snow showers or southwest
SYNS synopsis
T
TAF terminal aerodrome forecast
TCU towering cumulus
TE thunder ended
TEMPS temperatures
THN thin
THRU through
THSD thousand
TIL until
TS/TSTMS thunderstorms
TURB turbulence
TWR tower
U
UP unknown precipitation
UPR upper
UTC Coordinated Universal Time
UDDF updrafts and downdrafts
UNK/UNKN unknown
UNSTBL unstable

UP unknown precipitation
V
V variable
VA volcanic ash
VC/VCNTY vicinity
VFR Visual Flight Rules
VIS visibility
VLYS valleys
VOR Very high frequency
Omni-directional Range
VR visual range
VRB/VRBL variable
VRY very
VSBYDR visibility decreasing rapidly
VV vertical visibility
W
W west
WA Washington
WBND westbound
WDLY widely
WL will WM
warm WND
wind WRN
western WS
wind shear
WSCONDS wind shear conditions
WSHFT wind shift
WTRS waters
WX weather
X
XCP/XCPT except
XTNDG extending
Z
Z Zulu Time (UTC)

WIND DIRECTIONS (8 POINTS)
N – NORTH –000° or 360°
NE – NORTHEAST – 045°
E – EAST – 090°
SE – SOUTHEAST – 135°
S – SOUTH – 180°
SW – SOUTHWEST –225°
W – WEST – 270°
NW – NORTHWEST –315°

For additional contractions, acronyms, and locations not found in this Appendix, consult Section 14 of the AC 00-45E, Aviation Weather Services, available at the following location: http://www.faa.gov/avr/afs/afs400

APPENDIX C

STATE ABBREVIATIONS

Alabama AL
Alaska AK
Arizona AZ
Arkansas AR
American Samoa AS
California CA
Colorado CO
Connecticut CT
Delaware DE
District of Columbia DC

Florida FL
Georgia GA
Guam GU
Hawaii HI
Idaho ID
Illinois IL
Indiana IN
Iowa IA
Kansas KS
Kentucky KY

Louisiana LA
Maine ME
Maryland MD
Massachusetts
MA Michigan
MI Minnesota
MN
Mississippi
MS Missouri
MO Montana
MT Nebraska
NE Nevada
NV
New Hampshire
NH New Jersey
NJ
New Mexico
NM New York
NY North
Carolina NC
North Dakota
ND
Northern Mariana Island
CM Ohio OH

Oklahoma OK
Oregon OR
Pennsylvania PA
Puerto Rico PR
Rhode Island RI
South Carolina SC
South Dakota SD
Tennessee TN
Trust Territory TT
Texas TX
Utah UT
Vermont VT
Virginia VA
Virgin Islands VI
Washington WA
West Virginia WV
Wisconsin WI
Wyoming WY

APPENDIX D

SELECTED WEATHER INFORMATION RESOURCES

Current as of April 2017

Aviation Weather Center
Homepage:
http://www.aviationweather.gov
Frequently Asked Questions
http://www.aviationweather.gov/static/FAQ

Direct User Access Terminal Service – Free access to GTE DUATS is available to U.S. pilots and student pilots who hold current medical certificates, flight instructors without current medicals, aviation ground instructors, glider/balloon pilots, and other approved users in the U.S. aviation community.
http://www.duats.com/

Landings.com Aviation Weather Information
http://www.landings.com/_landings/pages/wthr/av_weather.html

National Hurricane Center/Tropical Prediction Center
http://www.nhc.noaa.gov

National Oceanographic and Atmospheric Administration – Home Page
http://www.noaa.gov/

National Weather Service
Home Page
http://www.nws.noaa.gov/
Links to Current Weather Products
http://www.weather.gov/html
METAR/TAF Information
http://adds.aviationweather.gov/metars

Naval Atlantic Meteorology and Oceanography Center home page – includes links to aviation weather and hurricane (tropical cyclone) data
http://www.nlmoc.navy.mil/

Storm Prediction Center
http://www.spc.noaa.gov/

The Weather Channel – Home Page
http://www.weather.com