

The Ninety-Nines, Inc.,<sup>®</sup> International Organization of Women Pilots<sup>®</sup>

# Aviation Adventure Guide

## Module 10 - Weather



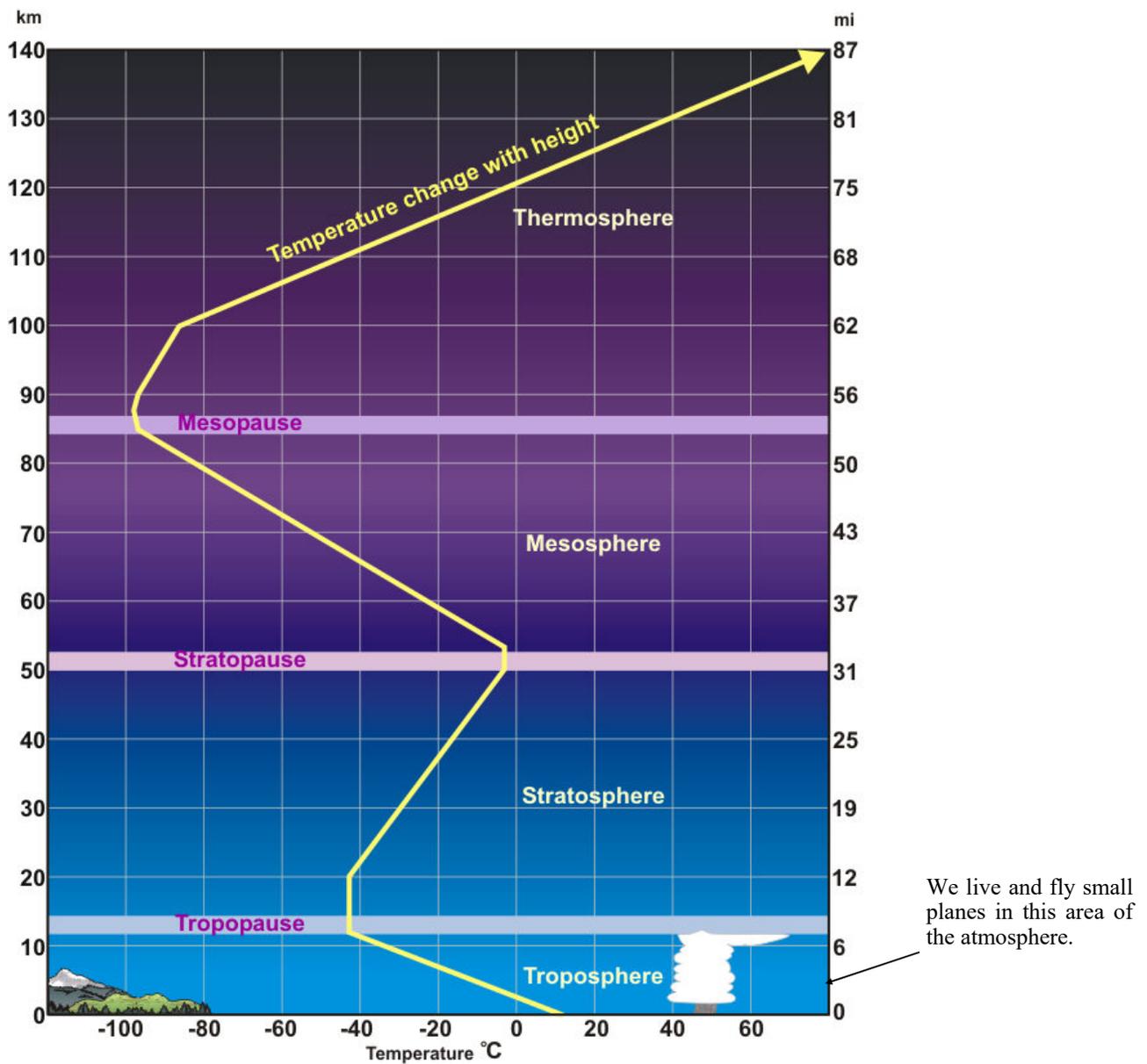
# Module 10

## Weather



**Weather:** What is weather? Weather is day to day changes in the atmospheric condition as described by the elements of temperature, air pressure, humidity, clouds, precipitation, visibility and wind. We care about weather as pilots because weather may present dangerous flying conditions that can be easily avoided if you understand how weather works.

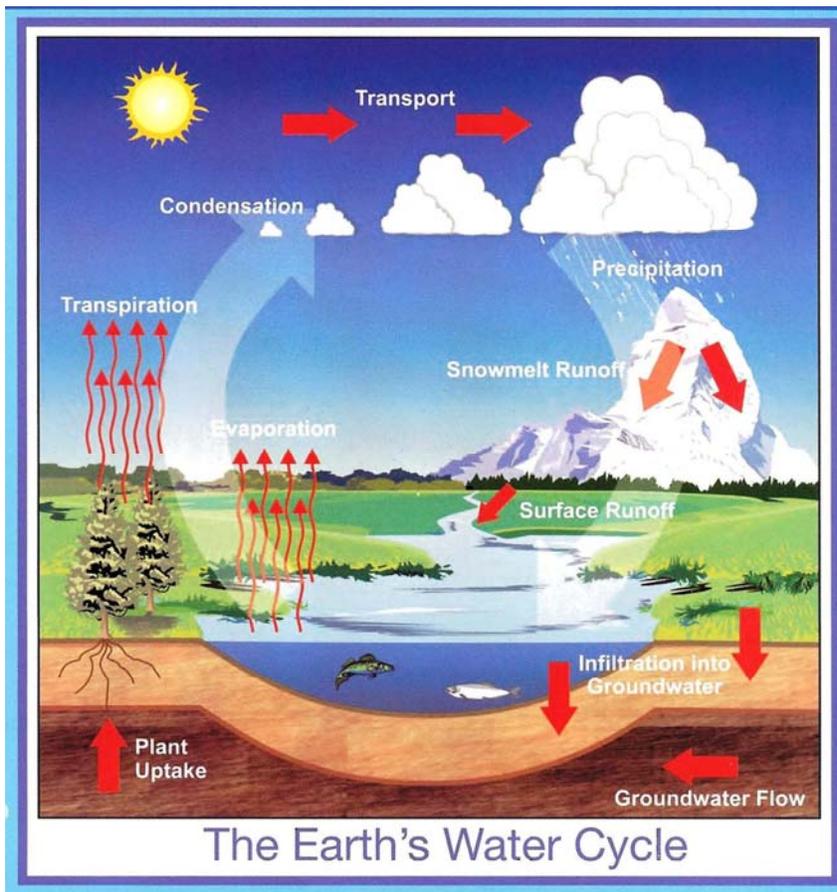
To understand weather, we have to start with an understanding of where we live in the atmosphere. We live in an area called the **TROPOSPHERE**, the atmospheric layer immediately above the earth's surface. The origin of that word is descriptive: "tropo" means to change; and "sphere" means a round layer. We live in an atmospheric layer of constant change. All of the other levels of the atmosphere have their own different characteristics.



**Heat & Water:** What makes our changing weather? The basic answer is heat and water. Both are in a constant state of change. It is the interaction of the changes in heat and water that create our weather.

In our weather, water exists in three forms: solid (ice, snow, hail), liquid (rain, lakes, dew, oceans) and gas (fog, clouds and invisible water vapor). Water changes from one form to the other in several ways.

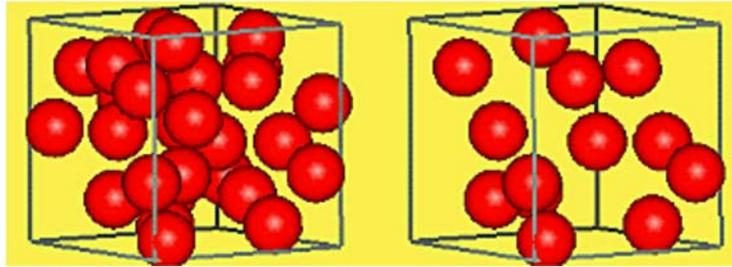
- **EVAPORATION** - liquid water molecules (the smallest piece of water) become a gas as the water gets into the air
- **SUBLIMATION** - solid water turns directly into the gas form or the gas form of water turns directly into a solid. The best example of this is frost that seems to magically appear on your car windows in the winter.
- **CONDENSATION** - water vapor in the air turns to liquid when it touches something cold. Get a cold glass of water on a hot day and watch the glass sweat. The water on the outside of the glass is water from the air that condensed onto the outside of the glass.
- **PRECIPITATION** - water vapor in the air that returns to earth as rain or snow.



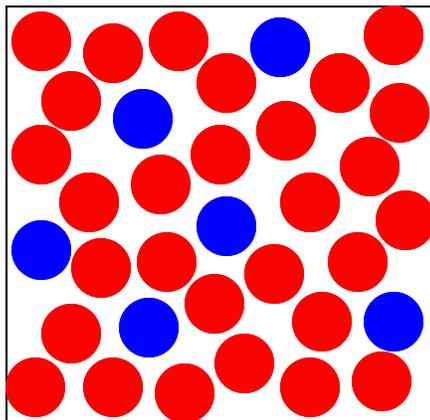
Note the changing forms of water in the diagram to the left. You can see how water moves from one form to the other.



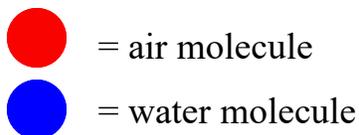
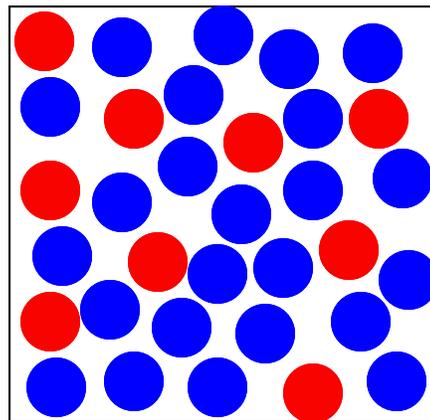
So how does water get into air? The smallest unit of air and water is a molecule. Air, like water, changes as molecules move. As altitude increases, pressure decreases. The two boxes below show how air changes. The box on the left has more pressure: the air molecules are closer together so the air is more dense. The box on the right has less pressure: the air molecules are fewer and farther apart so the air is less dense. **DENSITY** of the air also changes with temperature. Cold air is more dense as air molecules are packed together tightly (like the box on the left). Warm air is less dense so the air molecules are farther apart (like the box on the right).



**Cold Air**



**Warm Air**



Now, look at the two boxes above. The one with cold air has more air molecules and they are packed together so tightly that only a few water molecules have room to get in.

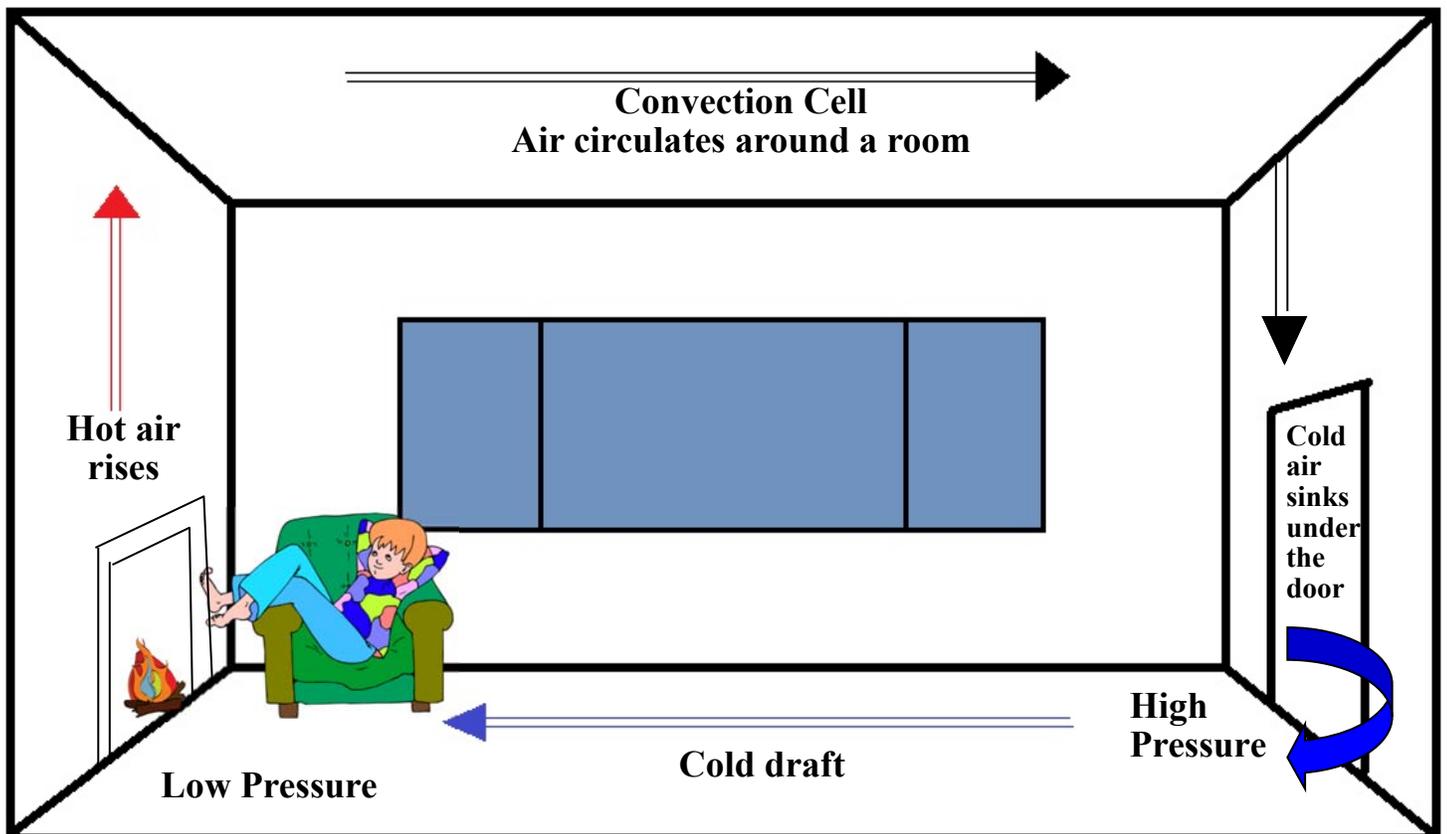
The warm air box has air molecules that are farther apart so more water can get in between the air molecules. As air heats up, it will hold more water; as air cools, it holds less water. This is why you see fog in the morning: the air that has been warmer during the day cools off to a point at which the air cannot hold as much water any more and dew or fog forms. This temperature where the air can hold no more water is called the **DEW POINT**.

The primary source of heat on the earth is the sun. However, the sun warms different areas at different rates. This variation is due to differences in distance from the sun and the angle of the sun's rays hitting the earth (**ANGLE OF INCIDENCE**).

There are four different ways to heat something:

- **CONDUCTION** - heating by direct contact like putting a spoon in a hot cup of water. The spoon will absorb the heat of the water by direct contact with the water.
- **CONVECTION** - vertical heating by the upward movement of hot air as in convection oven.
- **ADVECTION** - lateral or sideways movement that transfers heat. When warm air blows over an area of cold air, the area of cold air becomes warmer.
- **RADIATION** - transfer of heat from one thing to another without changing the temperature of the space in between. The sun heats the earth by radiation heat.

Heat, along with the rotation of the earth, helps to make air move. Hot air rises; cold air sinks. All of this creates air flow. Since airplanes fly in the air, pilots are very concerned about the air flow and all of the different characteristics of water and heat.



# Clouds:

Clouds are formed when water vapor condenses onto tiny pieces of dust that are floating around in the air. When billions of these water droplets get together, they form a cloud that we can see. There are several types of clouds that are categorized by their height and their looks.

## Types of clouds:

**Cumulus** - piled up fluffy clouds



**Stratus** - flat and layered clouds



**Cirrus** - very high wispy and fibrous



**Nimbo or Nimbus** - rain or precipitation clouds

**Alto** - middle to high clouds (but NOT the highest clouds)

**Lenticular** - clouds resembling a contact lens that form over a mountain due to high winds

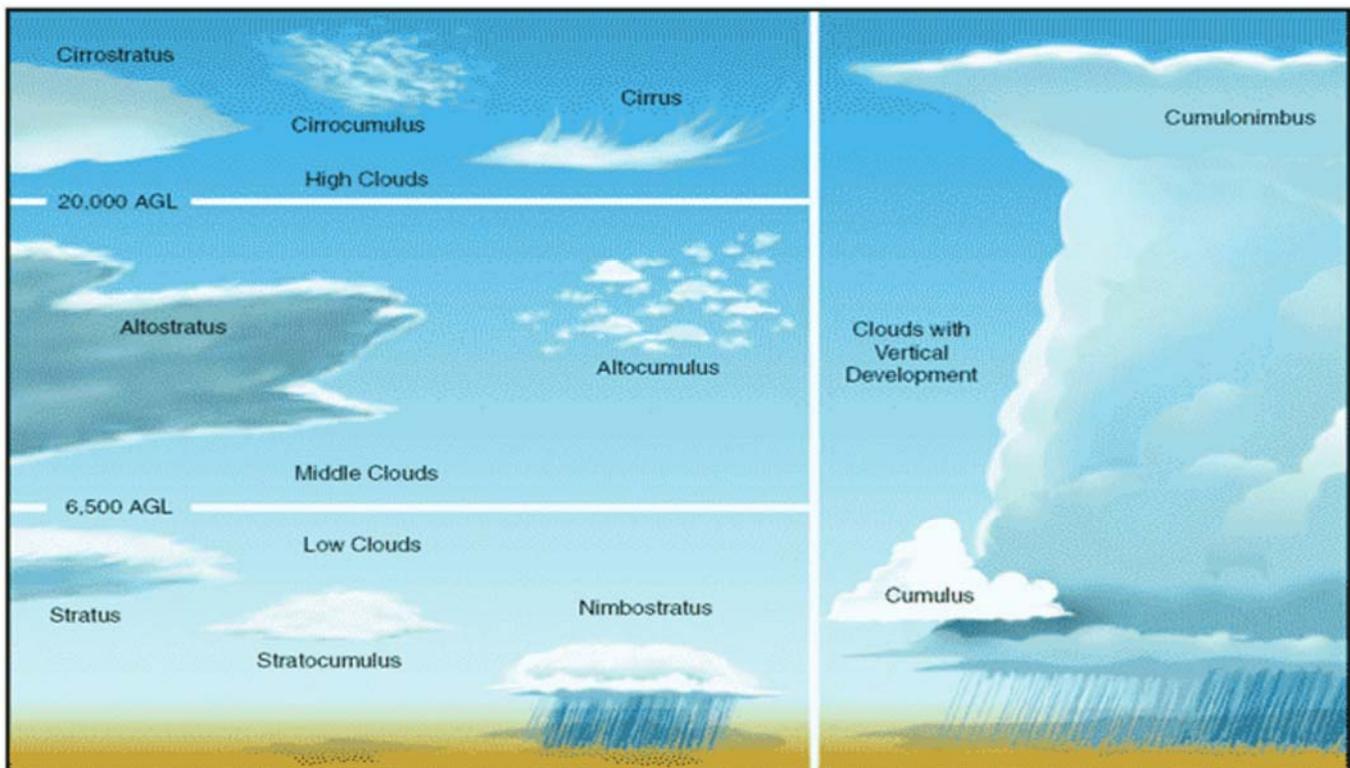
**Vertical clouds** - Fair weather cumulus clouds often resemble large cotton balls all clumped together. These clouds often appear to have flat bottoms. Cumulonimbus clouds can reach miles into the sky and are the thunderstorm clouds. These are some of the most dangerous clouds for pilots because of the up-drafts and down-drafts, hail, storms and tornadoes that they can produce.

## Clouds Heights:

**Low level clouds** - Stratus clouds, including fog, are low level (below 6,500'). They can cover the entire sky. Nimbo-stratus clouds are rain clouds covering the entire sky.

**Mid-level clouds** - These clouds form between 6,500' to 20,000'. Sometimes, if it is cold enough, they can be formed from ice droplets or crystals. Altocumulus clouds are gray, puffy clouds usually seen in the morning, indicating that a thunderstorm will follow later in the day. Altostratus clouds are made up of ice crystals and form before a rain storm. They can cover the whole sky.

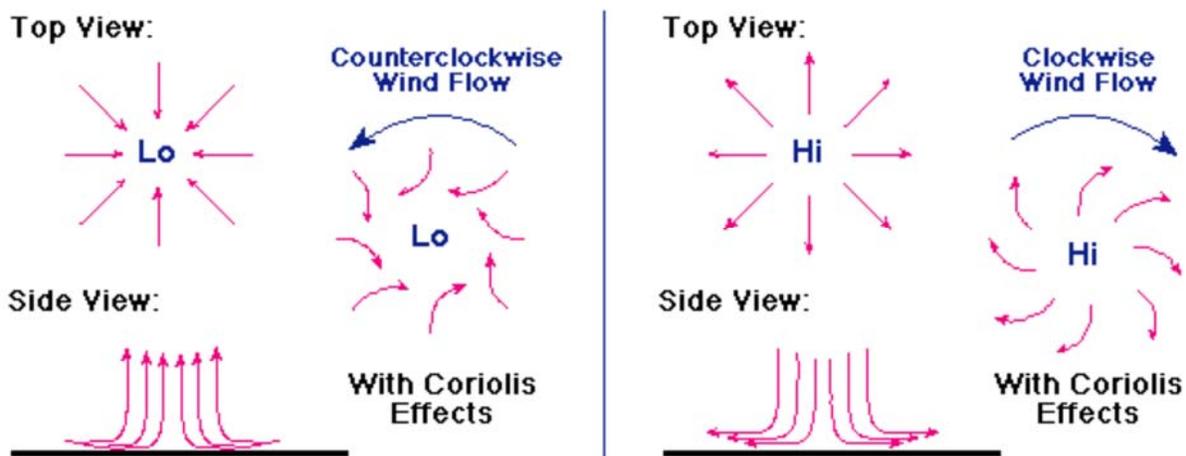
**High-level clouds** - These clouds form above 20,000'. They are made from ice crystals because it is so cold at that altitude. Cirrostratus clouds are thin sheet clouds that cover large portions of the sky. Cirrocumulus clouds are high, small round puffs that can resemble fish scales.



**Weather - Pressure Systems, Air Masses and Fronts:** When you listen to the Meteorologists talk about forecasting the weather they often talk about pressure systems, air masses and fronts: what are those?

A **PRESSURE SYSTEM** is a whirling mass of air. Pressure systems are either high pressure or low pressure. (See diagram below.)

- **HIGH PRESSURE** generally has light winds, good weather and poor visibility (hazy). The winds circulate around the high pressure center clockwise, down and out from the center. The symbol on a weather chart is **H**.
- **LOW PRESSURE** generally has strong wind and stormy weather but good visibility. The winds circulate in a counter-clockwise direction and flow in and up from the center. The symbol on a weather chart is **L**.

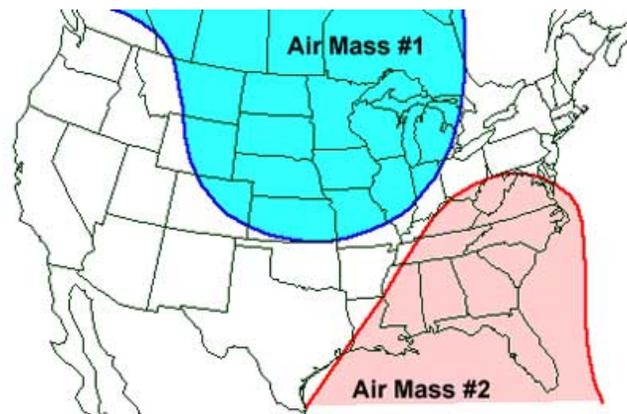


An **AIR MASS** is a large body of air that is relatively uniform in its characteristics. Air masses are named for their characteristics and for where they come from.

- **POLAR AIR MASSES** come from the north and south polar regions (north of 60° latitude above the equator and south of 60° latitude below the equator) and are cold.
- **TROPICAL AIR MASSES** come from the equator region (between 25° north latitude and 25° south latitude) and they are warm.
- **CONTINENTAL AIR MASSES** come from over the land and they are relatively dry.
- **MARITIME AIR MASSES** come from over the water and they are relatively wet.

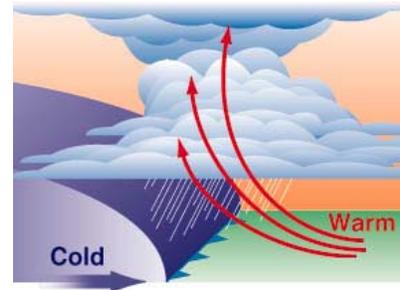
Air Mass # 1 would be a Continental Polar air mass.

Air Mass # 2 would be a Tropical Maritime air mass.

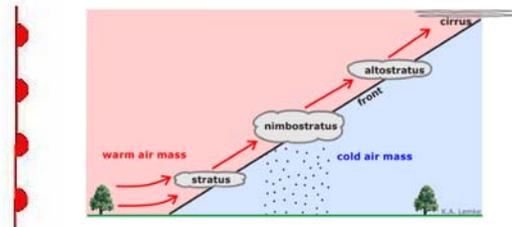


**FRONTS** are boundaries between air masses. You can recognize a front because there is a sharp change in the temperature, a wind shift, changes in the precipitation and cloud patterns and a pressure change. There are several kinds of fronts.

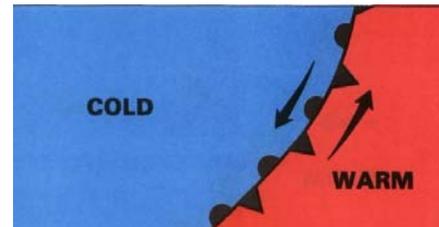
- **COLD FRONT** is a mass of cold air advancing to take the place of warmer air. The air pressure will tend to drop as the front approaches. The winds will be out of the west to northwest. There will be precipitation and the cirrus and stratus clouds will give way to varieties of cumulus clouds. You can think of a cold front coming in like a snow plow, pushing the warm air up and over the cold air. Cold fronts are usually fast moving. The weather symbol on a map is a blue line with triangles (think cold blue icicles).



- **WARM FRONT** is a mass of warmer air catching up to and replacing cooler air. The air will generally be out of the south and southwest as the front moves through, and there might be some light drizzle. Mostly stratus type of clouds will be present. Warm fronts are usually slower moving. The weather symbol is a red line with half circles (think red hot half-suns).

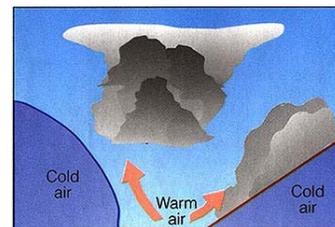


- **STATIONARY FRONT** is a mix of weather that basically does not move, although it might wobble back and forth a bit. This can be weather that includes characteristics of warm fronts and cold fronts. The weather symbol is a red and blue line with both triangles and half circles (think cannot make up its mind so it has both)

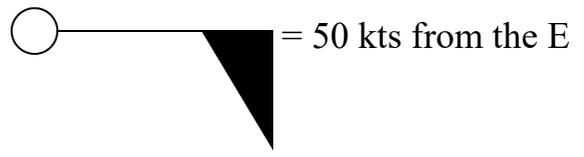
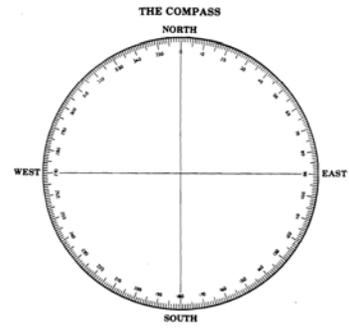
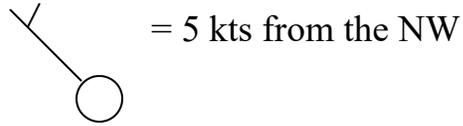
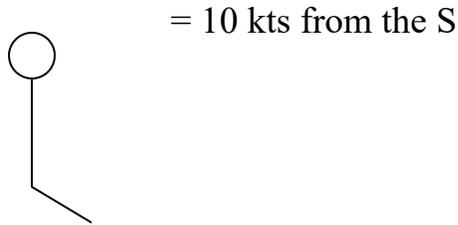


Source: *Aviation Weather*, US FAA & US Department of Commerce, 1965

- **OCCLUDED FRONT** is where a faster cold front caught up with and overtook a warm front. The most severe storms happen where the cold air and warm air collide. The weather symbol is purple triangles and half circles (think blue + red = purple).

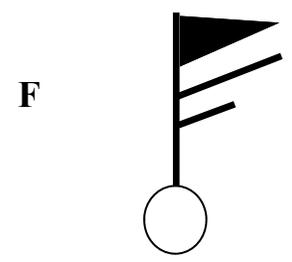
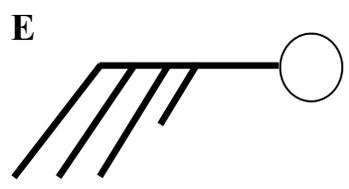
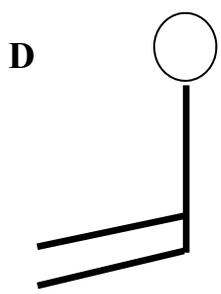
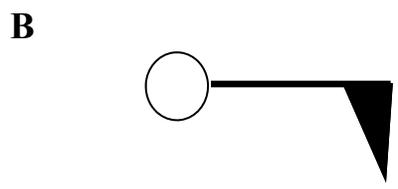
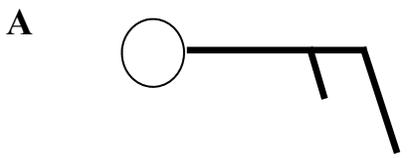


**Wind Barbs:** As pilots, we are very concerned about the wind and always want to know its direction and velocity. Weather charts use special **WIND BARBS** so pilots can read the wind information very quickly. The wind barbs are a key, just like other keys we have seen on maps and charts. If you understand the key, you can read all wind barbs! The direction of the wind is always stated in terms of where the wind is blowing FROM. The wind shown by the barbs and by the flags blows toward the dot. Each side line represents 10 knots (kts) of wind. One half of a side line represents 5 kts of wind. Each full flag represents 50 kts of wind.



**Activity - Wind Barbs:** What is the direction and velocity of each of the wind barbs.

- A: \_\_\_\_\_ B: \_\_\_\_\_  
 C: \_\_\_\_\_ D: \_\_\_\_\_  
 E: \_\_\_\_\_ F: \_\_\_\_\_



**Activity - Weather Fronts:** Identify the symbols in the diagram

A: \_\_\_\_\_

B: \_\_\_\_\_

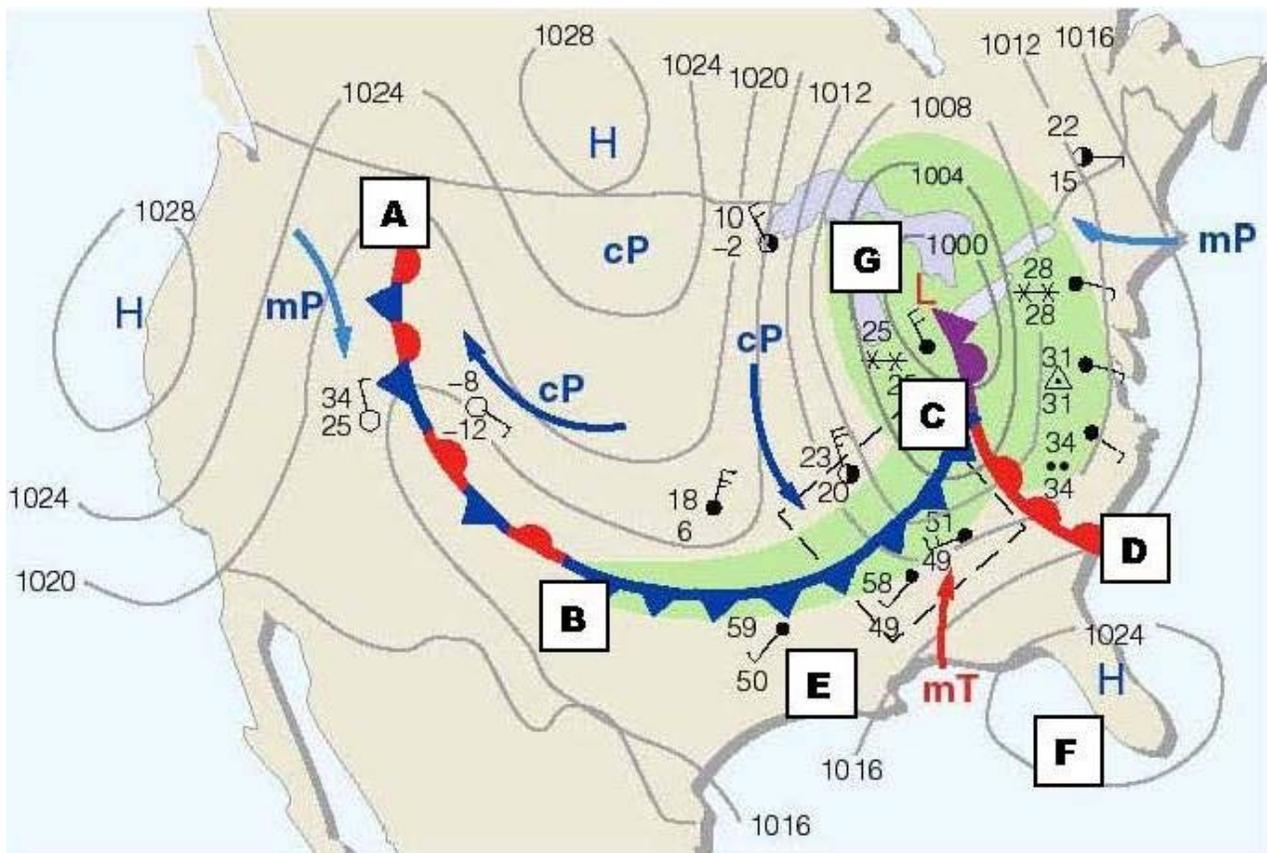
C: \_\_\_\_\_

D: \_\_\_\_\_

E: The wind is out of the \_\_\_\_\_ at \_\_\_\_\_ kts.

F: Over Florida the **H** is a \_\_\_\_\_.

G: In the Great Lakes Region the **L** is a \_\_\_\_\_.



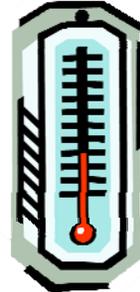
**Weather Instruments:** When you listen to the weather reports, the **METEOROLOGIST** will describe wind, weather, temperature, humidity and give measurements for each: how much, how fast, etc. She uses various instruments to make these measurements, instruments you see below.

**THERMOMETER** is the instrument that measures temperature. It has a small bulb of mercury in the bottom that heats and rises on a calibrated scale to show how hot or cold it is. Temperature can be measured in degrees Fahrenheit (° F), degrees Celsius (° C) or by other scales which we typically do not use in every day life.

**FUN FACT:** To convert ° F to ° C and vice versa:

$$^{\circ}\text{C} \times 9 \div 5 + 32 = ^{\circ}\text{F}$$

$$^{\circ}\text{F} - 32 \times 5 \div 9 = ^{\circ}\text{C}$$



**WIND VANE** tells the direction from which the wind is blowing. Wind is always labeled from the direction it is blowing. For example, a north wind blows out of the north to the south.



**RAIN GAUGE** measures the amount of rain that has fallen.



**HYGROMETER** is an instrument used to measure humidity in the atmosphere.



**BAROMETER** is used to measure atmospheric pressure. Changes in air pressure, higher or lower, indicate expected changes in weather.

**ANEMOMETER** is used to measure the wind velocity. The wind blows and the cups spin faster or slower. This moves the gauge at the bottom to show the speed.



Photo: Daniel FR

**Activity - Weather Instruments:** Match the name of the weather instrument with its function.

- |                |                                      |
|----------------|--------------------------------------|
| 1. Thermometer | A. Measures humidity in the air      |
| 2. Hygrometer  | B. Measures the air pressure         |
| 3. Anemometer  | C. Measures temperature              |
| 4. Barometer   | D. Measures how much rain has fallen |
| 5. Wind Vane   | E. Measures the wind direction       |
| 6. Rain Gauge  | F. Measures wind speed               |

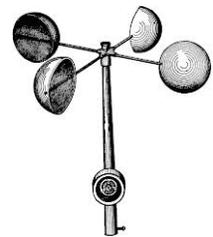
**BONUS:** What instrument is pictured to the right and how does it work?

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**Activity** - Complete the weather crossword puzzle on the next page. Three word clues are below.

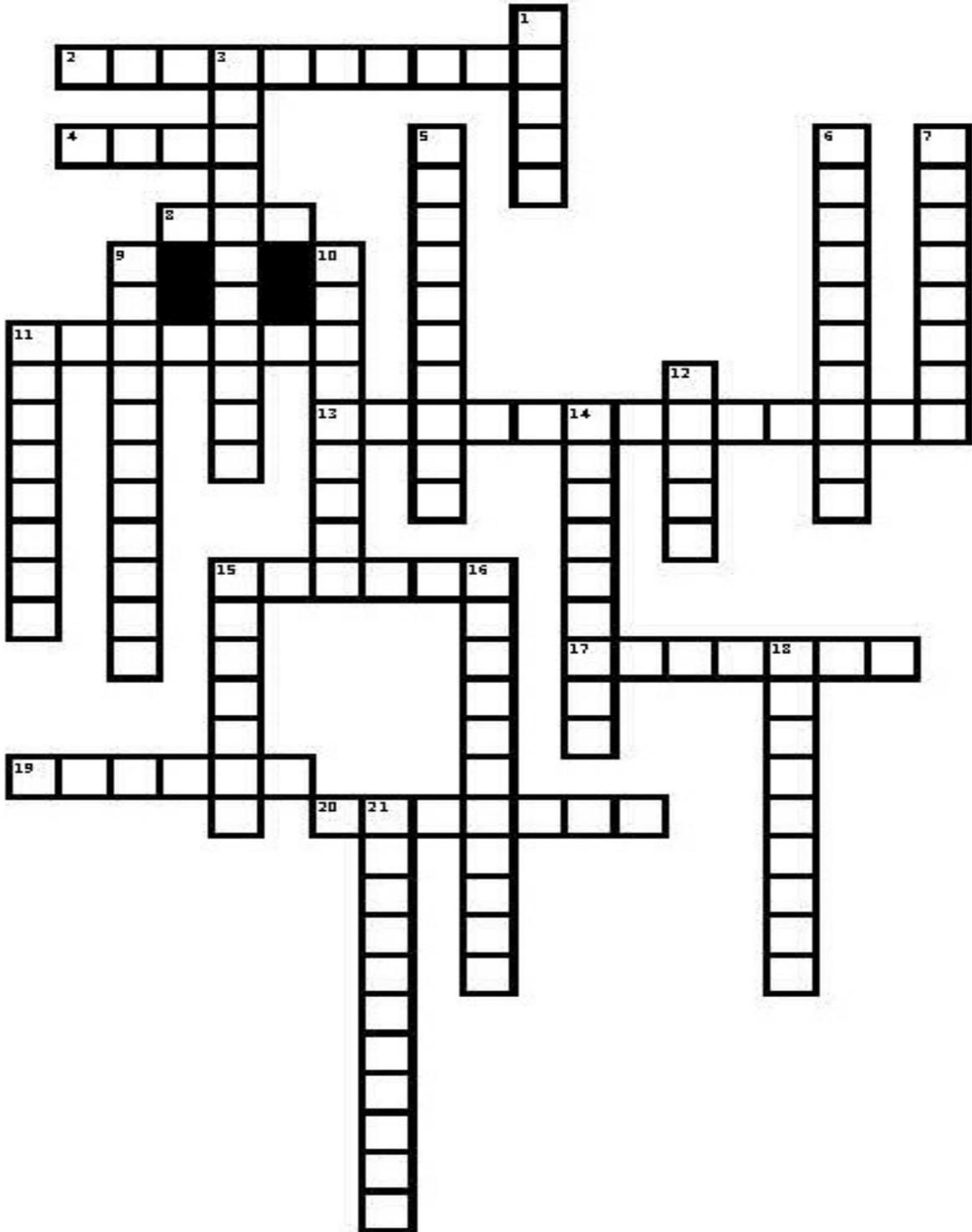
**ACROSS**

- 2 - Clouds resembling a contact lens that form over a mountain
- 4 - Middle level clouds
- 8 - Cloud that is very low or touches the ground
- 11 - Day to day changes in atmospheric condition
- 13 - Person who collects analyzes and interprets weather to create a forecast
- 15 - Wispy high level clouds made from ice crystals
- 17- Large body of air that is relatively uniform in its characteristics
- 19 - Rain clouds
- 20 - Flat and layered clouds.

**DOWN**

- 1 - Boundary between air masses
- 3 - Atmospheric layer just above the Earth's surface where we live
- 5 - Instrument that measures the wind
- 6 - Heating by direct contact
- 7 - Temperature where air can hold no more water
- 9 - Liquid water molecules becoming gas
- 10 - Instrument that measures the air pressure
- 11 - A symbol on a weather chart showing the velocity and direction of the wind.
- 12 - Billions of droplets of water vapor getting together
- 14 - Instrument that measures how much rain has fallen
- 15 - Low level fluffy clouds
- 16 - Solid water turning directly into vapor or gas form of water, or water that turn directly to a solid
- 18 - Lateral or sideways movement of air that transfers heat
- 21 - Instrument that measures the temperature

# WEATHER KNOWLEDGE CROSSWORD



**Activity - My Weather:** Think about the weather in the area where you live. Are there any patterns that you notice? What kinds of clouds do you see? Is the weather different in different seasons? What makes it that way? Describe your weather:

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**Activity: Weather record:** Each day for a week go outside and record your observations of the weather and fill in the chart below. You can copy this chart and record the weather for different months and different seasons. How do your observations change with the changing of seasons?

DATE							
PRECIPITATION							
AIR TEMPERATURE							
AIR PRESSURE							
RELATIVE HUMIDITY							
WIND DIRECTION							
WIND SPEED							
SKY CONDITION							
TYPES OF CLOUDS							