Weather Analysis and Forecasting

National Weather Service Shreveport

Slide 1: Introduction

Slide 2: An air mass is a large body of air with generally uniform temperature and humidity. The area from which an air mass originates is called a "source region."

Air mass source regions range from extensive snow covered polar areas to deserts to tropical oceans. The United States is not a favorable source region because of the relatively frequent passage of weather disturbances that disrupt any opportunity for an air mass to stagnate and take on the properties of the underlying region. The longer the air mass stays over its source region, the more likely it will acquire the properties of the surface below.

The four principal air mass classifications that influence the continental United States according to their source region are:

1. Polar latitudes - Located poleward of 60° north and south.
2. Continental - Located over large land masses between 25°N/S and 60°N/S.
3. Maritime - Located over the oceans between 25°N/S and 60°N/S
4. Tropical latitudes - Located within about 25° of the equator.

As these air masses move around the earth they can begin to acquire additional attributes. For example, in winter an arctic air mass (very cold and dry air) can move over the ocean, picking up some warmth and moisture from the warmer ocean and becoming a maritime polar air mass (mP) - one that is still fairly cold but contains moisture. If that same polar air mass moves south from Canada into the southern U.S. it will pick up some of the warmth of the ground, but due to lack of moisture it remains very dry. This is called a continental polar air mass (cP).

The Gulf Coast states and the eastern third of the country commonly experience the tropical air mass in the summer. Continental tropical (cT) air is dry air pumped north, off of the Mexican Plateau. If it becomes stagnant over the Midwest, a drought may result. Maritime tropical (mT) air is air from the tropics which has moved north over cooler water.

Air masses can control the weather for a relatively long time period: from a period of days, to months. Most weather occurs along the periphery of these air masses at boundaries called fronts.

Slide 3: Synoptic meteorology is primarily concerned with large-scale weather systems, such as extratropical cyclones and their associated fronts and jet streams but not as large as the global scale in the previous section. In this section, we will acquaint the student with the behavior of the atmosphere.

Synoptic means "view together" or "view at a common point". The forecast weather map is for a common point in time, and each of the many different elements that create our weather (e.g. the high and low pressure systems, fronts, and precipitation areas) can be viewed together.

Purpose: While we will not be able to go through the complete meteorology in this class, it is our hope that you will understand some basic fundamentals involved in this topic, and be able to apply them to your life/surroundings.

Slide 4: High Pressure is depicted by the blue “H” on a weather map, and denotes fair weather over a given location, as the air sinks. This system, or the airflow around it, will rotate clockwise.

Low Pressure is depicted by the red “L” on a weather map, and denotes poor weather over a given location, as the air will rise, giving way to cloud formation, and possibly precipitation. This system, or the airflow around it, will rotate counterclockwise.

We connect these areas or equal pressure with a line. Everywhere along each line is constant pressure. The closer the isobars are packed together the stronger the pressure gradient is. Pressure gradient is the *difference* in pressure between high and low pressure areas. Wind speed is *directly proportional* to the pressure gradient. This means the strongest winds are in the areas where the pressure gradient is the greatest.

Slide 5: There are three forces that cause the wind to move as it does. All three forces work together at the same time.

P**ressure Gradient Force** (Pgf): The force that tries to equalize pressure differences. This is the force that causes high pressure to push air toward low pressure. Thus air would flow from high to low pressure if the pressure gradient force was the only force acting on it.

Coriolis force: Because of the earth's rotation, there is second force, the **Coriolis force** that affects the direction of wind flow. This force is what causes objects in the northern hemisphere to turn to the right and objects in the southern hemisphere to turn to the left.

When viewed from space, wind travels in a straight line. However, when view from the Earth, air (as well as other things in flight such as planes and birds) is deflected to the right in the northern hemisphere (red arrow on image). The combination of the two forces would cause the wind to blow parallel to straight isobars with high pressure on the right.

Friction: The other force which is the final component to determining the flow of wind. The surface of the earth is rough and it not only slows the wind down but it also causes the diverging winds from highs and converging winds near lows. This is the last of the forces that causes air to spiral out from highs and into lows.

Slide 6: Density represents how molecules behave with one another in a substance or object. If the molecules move slowly, they will become tightly packed, resulting in a higher density. If the molecules move very fast, they will become more and more spaced apart from each other, resulting in a lower density.

Water and air behave very similarly…thus water can be used as a great example of how air parcels, or bubbles of air, can move when heated or cooled. When the air/water is heated, tiny bubbles will form and rise, because they have a lower density that the surrounding air/water. This can be viewed best when performing a "density" experiment. Here are the supplies you will need:

1.) 4 glass bottles
2.) Food coloring
3.) A portable boiler, or hot plate
4.) Paper towels
5.) Cookie sheet (optional)

Start by boiling several cups of water in the portable boiler/hot plate. Next, fill 2 glass bottles about ¾ full with tap water, while filling the remaining 2 bottles ¾ full with the hot water. **BE CAREFUL, AS THE GLASS BOTTLES CONTAINING THE HOT WATER WILL BE VERY HOT!!!** Add a few drops of food coloring to one of the cool water bottles, and also to one hot water bottle. Stand one hot water bottle atop one cold water bottle, until they balance, and also stand the remaining cold water bottle atop the last hot water bottle. (If the table you are using is uneven, you may use a cookie sheet for stability. In addition, the cookie sheet will catch any water that may spill out of the bottles.) Observe the motion of the food coloring.

From this experiment, you will be able to see that the food coloring will remain suspended in the hot water bottle that is atop the cold water bottle, while the food coloring in the adjacent bottle setup will fall into the hot water bottle, as the cold water bottle rests overhead. Why is this??? The density of the cold water is pushing the food coloring to the lower hot water bottle, while the fast molecular motion associated with the hot water bottle is suspending the food coloring in this bottle atop the cold water bottle. Also notice the bubbles rapidly rising in the hot water bottle; These bubbles can represent air parcels, emphasizing that the warmer air/water will be allowed to rise, because it is less dense than the colder air/water. What should happen to the food coloring when two of these bottles cool to the same temperature??? The food coloring will become evenly distributed, resulting in the same color to both bottles!!!

Slide 7: In order for clouds to form, a lifting mechanism, moisture (water droplets), and condensation nuclei are needed. The density experiment proved that indeed, warm air/water is less dense than cold air/water. Warm air can also serve as a good lifting mechanism needed to produce clouds. As the warm air rises, the air temperature will cool to the dewpoint temperature, the temperature that is needed to reach saturation. Water droplets form, and will bond onto the condensation nuclei, which will allow other water droplets/condensation nuclei to collide and coalesce. This collision and coalescence process will make the droplet larger and will eventually form a cloud.

Slide 8: Air can reach saturation in a number of ways. The most common way is through lifting. As a bubble or parcel of air rises it moves into an area of lower pressure (pressure decreases with height). As this occurs the parcel expands. This requires energy, or work, which takes heat away from the parcel. So as air rises it cools. This is called an adiabatic process.

Since cold air can hold less water vapor than warm air, some of the vapor will condense onto tiny clay and salt particles called condensation nuclei. The reverse is also true. As a parcel of air sinks it encounters increasing pressure so it is squeezed inward. This adds heat to the parcel so it warms as it sinks. Warm air can hold more water vapor than cold air, so clouds tend to evaporate as air sinks.

Slides 9: Stratus clouds consist of a feature-less low layer that can cover the entire sky like a blanket, bringing generally gray and dull weather. The cloud bases are usually only a few hundred feet above the ground. Over hills and mountains they can reach ground level when they may be called fog. Also, as fog "lifts" off the ground due to daytime heating, the fog forms a layer of low stratus clouds.

Cumulus clouds are of small vertical development with flat bases and rounded tops. These types of clouds indicate fair weather.

Slide 10: Mid-level clouds typically form between 7,000 and 15,000 feet and bring steady precipitation. As the clouds thicken and precipitation begins to fall, the bases of the clouds tend to lower toward the ground.

Slide 11: High-level clouds which form above 20,000 feet and are usually composed of ice crystals. High-level clouds are typically thin and white in appearance, but can create an array of colors when the sun is low on the horizon. Cirrus generally occur in fair weather and point in the direction of air movement at their elevation.

Slide 12: In order for precipitation to form, particularly over a large area, several ingredients are necessary. First there must be a source of moisture. The primary moisture sources in the U.S. are the Atlantic and Pacific Oceans as well as the Gulf of Mexico. Winds around high and low pressure systems (a subject of another lesson) transport this moisture inland.

Once the moisture is in place, clouds still need to form. The most effective way to do this is by lifting the air. This can be accomplished by forcing the air up and over mountains or, more commonly, by forcing air to rise near fronts and low pressure areas.

Cloud droplets and/or ice crystals are too small and too light to fall to the ground as precipitation. So there must be a process(es) for the cloud water, or ice, to grow large enough to fall as precipitation. One process is called the collision and coalescence or warm rain process. In this process, collisions occur between cloud droplets of varying size, with their different fall speeds, sticking together or coalescing, forming larger drops Finally the drops become too large to be suspended in the air and they fall to the ground as rain.

Slide 13: Fronts are a dividing line that separates two different air masses. There are three different types of fronts: 1.) cold fronts 2.) warm fronts 3.) stationary fronts.

Slide 14: Typically, bad weather (thunderstorms) is associated with cold fronts. This threat peaks especially when cold fronts intersect warm fronts near low pressure systems.

Slide 15: Because cold air is denser than warm air, it can be best referred to as a deep dome of air, capable of easily lifting the warmer, less dense air, forming showers and thunderstorms through the collision and coalescence process.

Slide 16: Warm Front: A transition zone where warm, moist air replaces cold, dry air. Typically, warm fronts only travel at half the speed than that of cold fronts (because of the density principle). These fronts are depicted as the red line with semicircles pointing towards the direction of movement.

Slide 17: Since warm air is less dense than cold air, this air mass can be best referred to as a shallow wedge of air, which struggles to lift the heavier/denser cold air. A good analogy can be a weightlifter trying to push a large dump truck…this individual will have trouble pushing the vehicle. Warm fronts do not slope in the vertical as much as cold fronts do. The result will be the warm air gently overriding the cooler, less dense air, thus only light to moderate showers will form at best.

Slide 18: Stationary Front - A boundary that has essentially no movement, but separates warm, moist air from cold, dry air. It is depicted by an alternating red and blue line containing blue triangles and red semicircles. The triangles point towards the warmer air, while the semicircles point towards the cooler air.

Here, showers and thunderstorms can be more widespread/numerous on both sides of this front, as this precipitation continues to move parallel to this boundary over the same areas. This scenario can result in extensive flooding given the right conditions.

Slide 19: Draw and analyze a surface weather map for pressure and temperature, and draw the fronts that are indicated by these two variables. Discuss the results.

MAPPING EXRICISE

Slide 20: This exercise will allow the students to plot and analyze a weather map pertaining to pressure. The pressure map shows the sea level pressures for various locations over the contigous U.S. The values are in whole millibars.

Materials Needed:

1.) colored pencils
2.) copies of the unplotted temperature and pressure maps

Objective: Using a black colored pencil, lightly draw lines connecting identical values of sea level pressure. Remember, these lines, called isobars, do not cross each other. Isobars are usually drawn for every four millibars, using 1000 millibars as the starting point. Therefore, these lines will have values of 1000, 1004, 1008, 1012, 1016, 1020, 1024, etc., or 996, 992, 988, 984, 980, etc.

Procedure: Begin drawing from the 1024 millibars station pressure over Salt Lake City, Utah (highlighted in blue). Draw a line to the next 1024 value located to the northeast (upper right). Without lifting your pencil, draw a line to the next 1024 value located to the south, then to the one located southwest, finally returning to the Salt Lake City value. Remember, isobars are smooth lines with few, if any, kinks.

The result is an elongated circle, centered approximately over Eastern Utah. The line that was drawn represents the 1024 millibars line and you can expect the pressure to be 1024 millibars everywhere along that line. Repeat the procedure with the next isobar value. Remember, the values between isobars is 4. Since there are no 1028 millibars values on the map, then your next line will follow the 1020 millibars reports. Then continue with the remaining values until you have all the reports connected with an isobar.

Analysis: Isobars can be used to identify "Highs" and "Lows". The pressure in a high is *greater* than the surrounding air. The pressure in a low is *lower* than the surrounding air.

- Label the center of the high pressure area with a large blue "H".
- Label the center of the high pressure area with a large red "L".

High pressure regions are usually associated with dry weather because as the air sinks it warms and the moisture evaporates. Low pressure regions usually bring precipitation because when the air rises it cools and the water vapor condenses.

- Shade, in green, the state(s) would you expect to see rain or snow.
- Shade, in yellow, the state(s) would you expect to see clear skies.

In the northern hemisphere the wind blows clockwise around centers of high pressure. The wind blows counterclockwise around lows.

- Draw arrows around the "H" on your map to indicate the wind direction.
- Draw arrows around the "L" on your map to indicate the wind direction.

Lastly, draw the cold and warm frontal systems associated with the area of low pressure. Remember that low pressure rotates counterclockwise, and that high pressure rotates clockwise (in the Northern Hemisphere). Also remember the source region of cold and warm air: The coldest air will be found across the Arctic region and Canada, while the warmest air will be found over the Gulf of Mexico and Western Atlantic. Here is another hint: Look for the kinks in the pressure plot. Frontal systems can often be found in these kinks.

Slide 21: This next mapping exercise will have the students plot a **Temperature Map**. This map shows the air temperature for various locations over the coterminous U.S. The values are in °F.

Objective: Using a blue colored pencil, lightly draw lines connecting equal values of temperatures, every 10°F. Remember, like isobars, these lines (called isotherms) are smooth and do not cross each other.

Procedure: You will draw lines connecting the temperatures, much like you did with the **sea-level pressure map.** However, you will also need to *interpolate* between values. Interpolation involves estimating values between stations which will enable you to properly analyze a map.

We will begin drawing from the 40°F temperature in Seattle, Washington (top left value). Since we want to connect all the 40°F temperatures together, the nearest 40°F value is located in Reno, Nevada, (southeast of Seattle). However, in order to get there you must draw a line **between** a 50°F temperature along the Oregon coast and a 30°F temperature in Idaho. Since 40°F is halfway between the two locations, your line from Seattle should pass halfway between the 50°F and 30°F temperatures.

Place a light dot halfway between the 50°F and 30°F temperatures. This is your interpolated 40°F location.

Next connect the Seattle 40°F temperature with the Reno 40°F temperature ensuring your line moves through your interpolated 40°F temperature. Continue connecting the 40°F temperatures until you get to Texas.

Now your line will pass between two values, 60°F and 30°F. Like the last time, you should make a mark between the 60°F and 30°F but this time a 50°F is also to be interpolated in addition to the 40°F. Between the 60°F and 30°F temperatures, place a small dot about 1/3 the distance from the 30°F and another small dot about 2/3 the distance from the 30°F. These dots become your interpolated 40°F and 50°F temperatures. Finish drawing your 40°F isotherm passing through your interpolated 40°F value. Repeat the above procedures with the other isotherms drawn at 10°F intervals. Label your isotherms.

Analysis: Isotherms are used to identify warm and cold air masses.

- Shade, in blue, the region with the lowest temperatures.
- Shade, in red, the region with the warmest air.

Note: Temperatures themselves are neither "cold" nor "hot". The air temperature is the *measure of energy in the atmosphere*. Often, television meteorologists will erroneously say "cold temperatures are moving in" or "we have hot temperatures in such and such place". What they should say is "cold air is moving in" or "the weather is hot" in describing the air mass as indicated by the temperatures.

Lastly, draw the cold and warm frontal systems after analyzing the temperature chart. Here is a hint: Find the area where your isotherms (lines of constant temperature) are bunched up together. Also remember the source region of air, as well as how the low and high pressure systems rotate, as this analysis was taken at the same time as the pressure chart you plotted/analyzed earlier.

Slide 22: Results - Compare your pressure plot with the answer key. You will learn that based on the plots, a cold front extended southwest of the low pressure system from Central Tennessee southwest into Southcentral Arkansas, Northwest Louisiana, into Southeast and Southcentral Texas. Meanwhile, a warm front also extended east of the surface low pressure system from Eastern Kentucky, into Northern North Carolina and Southern Virginia.

Slide 23: Compare your temperature plot with the answer key. You will learn that based on the plots, a cold front extended southwest of the low pressure system from Central Tennessee southwest into Southcentral Arkansas, Northwest Louisiana, into Southeast and Southcentral Texas. Meanwhile, a warm front also extended east of the surface low pressure system from Eastern Kentucky, into Northern North Carolina and Southern Virginia.

You will find much cooler temperatures behind (north) of the cold front, while much warmer temperatures exist behind (south) of the warm front.

Slide 24: Blank observation map to analyze.

Slide 25: Answer key to slide 23.

Slide 26: Acknowledgements