

Whither the Weather?
Five Lessons on Our Atmosphere and Weather

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I. Reasons for studying the atmosphere in a High School curriculum

The atmosphere surrounds us and yet remains invisible to us most of the time. Many people may talk about the weather, and some people try to do something about it, but few people really understand it. Most people today are introduced to their atmosphere in lessons taught in elementary and middle school on the weather which may include the water cycle and simple measurements made to determine temperature and relative humidity of the atmosphere. Often the lasting impression students receive from their teacher's efforts is the thrill of weather's storm activities and perhaps an appreciation of what the news stations offer in weather forecasting. However, much of atmospheric science is lost in the attempt to make appealing to young minds what is a rather complicated process.

The newest approach to teaching science in high schools is what is called "integrated science". This method of arranging the curriculum springs from the notion that science is used more as a tool to study natural phenomena than as an end in itself. Thus students integrate the various disciplines of physics, chemistry and biology in solving problems of a practical nature. This philosophy has of course its proponents and detractors within the academic community. Some hold that it is more important that students learn the concepts of each discipline separately and use them in context with natural phenomena which do not markedly overlap other areas of science. It is not my purpose to side with either view, however, I do find that a course such as I am developing here can be used very easily as an integrated science unit as the atmosphere and it's phenomena are global not only geographically but disciplinarily. I think there is a need for such curricula as is being written to be well developed so as to avoid the pitfall of expecting understandings which students will not have encountered yet. Therefore, I hope to offer a curriculum that is free of missing concepts and skills and that can be used either as a stand alone unit or

taken apart as it pertains to specific disciplines of science. I personally teach in a "separated curricula" school and have found that a unit on the atmosphere fits well in my environmental science and physical science classes. Certain of the lessons are also applicable to biology, chemistry and physics independently.

As adults we are asked to make political decisions based on understandings of weather and it's phenomena. Of recent concern we have the phenomena of Global Warming and Ozone Depletion, complex problems than can not be adequately addressed in the lower grades and which tend to be lumped together in the minds of most lay persons and become therefore thoroughly misunderstood. (My classes have done surveys to support these statements.) Considering the fact that millions of dollars are involved in the decisions about these two issues alone, I think it is incumbent on the high schools to teach the science necessary to understand issues such as these and many others which affect our daily lives. Such concerns as air pollution, hurricane devastation and flood control are also weather issues and involve a multitude of scientific concepts that may not have been taught on the high school level from which most of our voting public receives it's final formal education.

For these reasons therefore, I believe that a renewed emphasis should be made on teaching atmospheric science and weather phenomena on the high school level. I would expect a curriculum to include concepts of the various science disciplines involved as well as those of math, economics, politics and other related course work as needed. My curriculum will be a start on that task which I hope will be corrected and added to by other teachers who view my efforts on the internet. I will also be testing the lessons on students in my classes which will refine and enlarge on the effectiveness of the pedagogy.

II. Core concepts necessary for understanding the atmosphere

The density of air is related to its components. Air is composed primarily of Nitrogen, Oxygen, water vapor and trace amounts of Argon and other gasses. As you go up a mountain there is less of each of these gases, because the number of molecules becomes less per volume since the air pressure is lower. For example, a weather balloon is not filled up completely as it is released from the earth, but as it rises the gas in it expands and it forms a sphere. We can take in only a set amount of volume in our lungs when we breathe. Therefore, if there is less oxygen per volume, we get less oxygen and have to breathe in more often or may feel dizzy at higher elevations.

Temperature of air masses are also a factor in weather changes. A temperature increase lowers the density of air. Air at the equator higher temperature and therefore tends to become "puffed up". Cold air at the poles tends to be "squashed". Air pours off the equatorial "puff" and moves away from the equator toward the poles in the upper atmosphere cools and falls down to the earth and travels back toward the equator. This causes a great movement of air, which is available to become localized winds, winter storms, hurricanes and other phenomena of weather.

Nitrogen (N₂) has a mass of 28, Oxygen (O₂) a mass of 32 and Water (H₂O) a mass of only 18. Wet air is 76% Nitrogen and 20% oxygen and 4% water. Dry Air is 79% Nitrogen and 21% oxygen. When we calculate the mass of each component as to its percentage of the whole we see that wet air is less dense than dry air. Therefore there needs to be only a slight change in humidity and therefore a change in density for the air to rise. Most of these changes are due to the amount of water, which is dependent on the temperature. Houston air in the summer is about 2.5 % water but that little bit makes sufficient difference in the density of the air and thus in the turbulence of our weather.

To change a cubic centimeter of water to gas we need 540 calories of energy! When that water vapor turns back into liquid it releases that energy. Every time you turn water vapor into liquid or snow it releases heat energy. This energy is stored in the water vapor at the equator or over the Gulf of Mexico. The air over the oceans has a lot of water vapor (energy) stored in it. Air from the equator rises because it is less dense. This makes a low-pressure area. Cold air can't hold much water. When the cold dry air from Canada hits the warm moist air from the ocean, the warm air will go up over the cold. The boundary is called a front. As the cold air sinks below the warm air, the water in the warm moist air drops out in the form of rain or snow. The condensation of the vapor from gas to liquid or solid gives off the heat, which warms the rising air causing it to rise even more.

These are just two of the concepts that are necessary in order to understand the atmosphere and its weather. In the following ten lessons we will be investigating weather phenomena as a function of the composition of the atmosphere, its density and temperature.

III. Curriculum guide for sample lessons.

A LESSON 1 - WHAT IS AIR?

Our Atmosphere - Using available resources: 1.) List the layers of the atmosphere according to altitude away from the earth and give the distinguishing characteristics of each layer. 2.) How do matter cycles interact with the atmosphere? Be specific.

What are the components of air?

Air is composed of the following materials: Nitrogen, Oxygen, Water vapor, Argon and trace amounts of other gases. As you go up a mountain there is less of each of these, because the number of molecules is less per area since the air pressure is lower. Example: a weather balloon is not filled up completely but as it rises the gas in it expands and it forms a sphere. We can take in only a set amount of volume in our lungs. If there is less oxygen per volume, we get less oxygen and therefore have to breathe in more often or may feel dizzy if we don't get enough.

What is "air pressure" and how is it important?

Go to this website to learn about pressure and take the "test":

[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/prs.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/prs.rxml)

Pressure = (Mass/volume) a Gas constant X Temperature

Mass/volume = density

As you go up the temperature also decreases.

One atmospheric pressure = 1000 millibars at the surface of the earth.

Some airplanes travel at 700 millibars @ ten thousand feet.

See Figure 1

In the diagram above we can see two columns of air, one at the North Pole and one at the equator. Lines between these two columns indicate the barometric pressure of the air in millibars of mercury at different altitudes. The pressure gradient flow indicates the direction of air movement of warm air from the equator to the poles in the upper atmosphere and the corresponding circulation from the North Pole to the equator of cold air nearer the ground. Air at the equator is "puffed up" whereas air at the poles is "squashed". Air pours off the equator puff and toward the poles in the upper atmosphere and the cold air from the poles falls down to the earth and travels toward the equator. If an airplane were to travel from the equator to the poles at a constant altitude the pressure on it would change from 880mb to 750mb. Thus airplanes tend to change their altitude in order to minimize atmospheric pressure changes.

How is air temperature affected by water?

To change a cubic centimeter of water to gas we need 540 calories of energy!

When that water vapor turns back into liquid it releases that energy.

Every time you turn water vapor into liquid or snow it releases heat energy.

The energy is stored in the water vapor at the equator or the Gulf of Mexico. The air over the oceans has a lot of water vapor (energy) stored in it. Air flowing from the equator aloft sinks because it must converge because of the geometry of the earth's sphere. This converging and sinking air makes a high-pressure area. Over polar land areas this air cools and becomes more dense. When the cold air in Canada hits the warm moist air from the ocean, the warm will go up over the cold. The boundary is called a front. As the cold air sinks below the warm air, the water in the warm moist air drops out in the form of rain or snow.

See Figure 2

Why is wet air less dense than dry air?

Nitrogen = N_2 = 28 mass

Oxygen = O_2 = 32 mass

Water = H_2O = 18 mass

Wet air is 76% Nitrogen and 20% oxygen and 4% water. What is the mass of wet air?

Dry Air is 79% Nitrogen and 21% oxygen What is the mass of dry air?

Therefore there needs to be only a slight change in density for the air to rise. Most of these changes are due to the amount of water, which is dependent on the temperature. Houston air in the summer is about 2.5 % water.

Demonstration: The layers of air are denser at the poles than at the equator because it's colder. Show this by cutting 7 layers of cardboard into isosceles triangles and stacked on top of each other. Compress the tip which represents the dense compact air at the pole and let the broad end expand representing the warmer less dense air of the equator. High in the atmosphere at a given elevation, the pressure is less at the poles than at the equator so the air higher in the atmosphere flows to the poles from the equator. Use the triangle and say "If we had a line of cars at the equator what will happen when they drive to the pole? They will converge together crash. The air does the same. The air converges as it approaches the poles and must go down. We call the resulting air masses produced at the surface "Highs". They are found everywhere except at the equator. Since the air at the poles is denser, it tends to flow from the poles to the equator at the surface. Air at the equator starts out with a lot of water. As the air goes higher it gets cooler and loses its water. . . rain at the equator! Air that is coming back down in a high-pressure zone doesn't have much water in it so it is dry. No rain in a high pressure zone!

B. LESSON 2 - DENSITY MAKES THE WORLD GO ROUND

Things that are more dense go down, things that are less dense go up in both gases and liquids. In the atmosphere differences in density make winds; in oceans, currents. Density is determined by two factors: **temperature** and the **composition** of the air (i.e. the change in the percentage of water in the air). In the oceans density is regulated by the amount of dissolved salt and temperature, however, temperature has the greater effect. Pressure can change density but the pressure differences are related to temperature and changes in gas composition. Pressure and temperature change in gases are interrelated as described in the Gas Laws. $Pressure = Density \times Temperature \times Gas\ Constant$

Demonstration: The Relationship between temperature and density. A smoking match shows that warm air rises as the smoke rises. In this simple demonstration, air is rising. Heat is spreading the molecules out. Place dry ice in a cooler. CO_2 makes air much colder. You can pour the cold CO_2 out and as the cold hits the air it condenses the water in the air allowing you to see a descending cloud. The cold CO_2 gas has a greater

density than N_2 or O_2 gases in the air. These are two reasons why CO_2 -dry ice is denser than air.

Demonstration: Gases have different densities because of their masses. Balloon blown up with air falls and one with helium rises. He_2 has a mass of 4 whereas that of the mixture in air (Nitrogen (N_2) has a mass of 28, Oxygen (O_2) a mass of 32 and Water (H_2O) a mass of only 18.) is much more massive. So for the same volume of gas helium weighs less and is less dense and therefore buoyant in air composed of N_2 and O_2 .

Demonstration: Cooling increases the density. Blow up a balloon with air. Put it in dry ice. The balloon shrinks in volume and as it warms up the balloon expands. Note that when the volume decreases the density will increase since the same number of molecules are occupying a smaller volume. If we place a helium filled balloon in the dry ice the helium will not raise the balloon in the surrounding air? The density will be high enough that the rubber compensates for the mass of the gas and the balloon won't rise until it warms up. As it warms the balloon's contents expand and the density as it becomes less than the surrounding air causes the balloon to rise. **Caution: Handling "Dry Ice" is dangerous. Do not let it come in contact with skin or put in sealed container. Advise use by teacher only.**

Lightening decreases the density of the air suddenly because of intense heating and that sudden movement of air creates the thunder. When the balloon is expanding it makes a little noise. Thunder occurs between two thermal layers one of which is suddenly expanding due to the lightning's energy.

Demonstration: Differences in density of water Prepare two containers one of hot water and one of cold saturated salty water. Put blue dye in the cold salt water. When gradually poured at the edge of the beaker on top of the hot water, the high density cold salty water will spill down the side of the beaker to the bottom. This is a demonstration of a deep ocean circulation, When we have a real cold spell and then there is a fish kill in a lake. The cold water gets so dense that the top layer sinks and chills the fish and they die.

Demonstration: Cold water expands hot water contracts Two graduated cylinders. Put cold and hot water into cylinders at the same height. Later at the end of the class the water will not be at the same height as the cold water warms and the hot water cools. Put a cork in it tightly and you can see a reverse meniscus because of the creation of a vacuum.

Demonstration: The mirage effect Asphalt highway heated by the sun the asphalt will be hotter than the surrounding grass. Air rising on the highway creates the mirage effect making low density air right near the surface interact with air just above it to create an optical effect.

Demonstration: The water in the ocean bottom is created at the poles. Sea ice forms at the poles. Salt ions (Na⁺ and Cl⁻) don't fit into the crystal lattice of ice. As sea water makes ice the salt stays out of the ice making the water more salty and more dense and it sinks to the bottom of the ocean. Cold deep water is formed at the poles. It's all uniformly cold (2-5 °C). So even at the equator the water gets cold as you go down. Intermediate water, in part, comes from salty warm water formed in Mediterranean and Red Seas.

See the following film to review and add to what we've studied so far:

WEATHER

VC15347

26 min Color VHS Video 1991 S

By visiting a weather forecaster we learn why different weather occurs in different places and about the water cycle, take a trip in a hot air balloon, and make a simple version of a rain gauge. From the Wonder Why Series.

Try your skill at weather forecasting at:

[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/prjct/home.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/prjct/home.rxml)

“Trusting the Forecast” This project provides students with first hand experience in weather forecasting and all the issues a meteorologist must consider when issuing a forecast.

C. LESSON 3 - THE EARTH IS CLOSEST TO THE SUN IN JANUARY. SO WHY ISN'T IT WARMER THEN?

Demonstration: Convection, conduction, radiation - how heat is circulated. The sun looks yellow because the blue light is scattered, in the evening or morning the sun is going through a thicker amount of atmosphere and the sun appears orange.

Demonstration: More radiation takes more energy. Energy from the sun is more intense than that which radiates back off the earth. Using a rope held between two people, shake the rope up and down to demonstrate the following: Sun's radiation (shake vigorously) producing higher energy and more waves thus demonstrating the ratio $E=h\nu$ where energy is equal to a constant (Plank's constant) times ν , the frequency. Earth's radiation back toward the sun (shake less vigorously) produces fewer weaker waves having longer wavelengths.

Demonstration: The Seasons. More radiation is coming in at the equator than at the poles. At equinoxes the amount of heating is greatest at the equator but same energy is spread out over a larger surface area. Demonstrate with 100-watt lightbulb and pieces of black poster board. Place the lightbulb the same distance from two poster boards, one of which the light shines directly on and the other which receives the light at an angle.

Measure the temperatures of both boards after a period of time to see if the one under direct light is hotter.

Using a globe and flashlight show the maximum zone of heating through the seasons going from the north to the south and being maximum at the equator at the equinoxes. Hold the lightbulb in the center of the room and have a student revolve around it holding the globe at the proper angle while keeping one's eyes on a distant object so that you won't "steer" the globe.

In the tropics rain follows the maximum zone of heating of the sun. So the rainy season in the tropics tended to come in March and September. In India the summer monsoon is caused by the maximum zone being over India. Mexico also has a monsoon in the summer as well but it's not as pronounced because the landmass of India is larger and better situated.

Demonstration: Richmond, Virginia and San Francisco get the same amount of heat. So why aren't they the same temperature? If you put heat into land and into water there is a difference. Take the two small beakers of sand and water of equal weights and put them on a hot plate for 30 sec. each. You will have to mix the sand as it is on the hotplate. The sand will be hotter. Water has a specific heat of 1 cal/gm/oC land has a specific heat of .2 cal/gm/oC . So the same amount of heat heats the sand more. Heat is transferred in sand by conduction which is a slow process. In water, the heat can be distributed by convection, conduction and radiation. Land heats up faster but it cools off faster than the water. Water temperature varies less, So San Francisco's temperature remains more consistent than Richmond Virginia because the prevailing wind blows off the ocean.

To sum up and preface what we have and are going to learn, view the following film:

WATER AND WEATHER, VOL. II

VT14399

30 min Color VHS Video 1987 S M E

Questions such as: Why do we have seasons? What is a rainbow? Why does thunder follow lightning? How does a hurricane differ from a tornado? And many more are answered. From the Tell Me Why Series. From the Tell Me Why Series.

D. LESSON 4 - WHAT MAKES THE WIND BLOW?

Demonstration: How to determine the weight of a volume of air. Weigh a container. Pump out the air and weigh it again. How much does a kilogram of air weigh. 2.4 g wt. per 2 liters of air. 1 liter is 10cm^3 one kilogram of air at one atmosphere pressure is about one cubic meter in volume. Density equals 1.2 grams per liter. Therefore 1m^3 of air equals 1.2 kg or $1000 \times 1.2\text{grams}$

Demonstration: The Coriolis Effect Show the pattern of the air due to the Coriolis effect by having a student draw a straight line down a spinning globe. This causes a trace on the globe that shows the winds to blow from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere. (rotate the globe counter clockwise looking at the North Pole) The Coriolis effect is zero at the equator and at it's maximum at the poles. The heating at the equator creates the circulation described before and the Coriolis force causes the curved pathway.

Demonstration: Highs vs. Lows The air in a high pressure zone is also getting warmer as it approaches the surface because it is compressing as it sinks. You can demonstrate this by pumping up a tire with a bicycle pump and noting that the pump gets hotter with the increased pressure. High-pressure areas over the ocean take on water, but air sinking over the land stays dry and if it's over Canada the ground is cold and it gets colder. Thus a high-pressure area over the Gulf will bring warm humid air to Houston. The dry air from Canada will be dense because it is cold and has little water as well. Over the ocean the high-pressure area has warm moist air which is less dense. When the dry cold high meets the wet warm high you get a storm or low pressure center as the wet warm rises and the high cold air slides under the warm moist air. And water from the warm wet air falls as rain. Raining lowers the pressure because water molecules are removed from the air. Big thunder clouds form. Because of the Coriolis effect the low spins. A storm is the interaction between two highs and has a front separating them. The part of the front where cold air is pushing the warm air is called a cold front. The part of the front where warm air is pushing the cold air is called a warm front. The cold air side of the warm front has "igloo" shapes on it, the warm air side of the cold front has "teepees" on it.

See Figure 3

As the front develops the cold air is pushed faster than the warm air because of its greater density. This causes the wave to kink and the low to form at the peak of that kink (see the picture above). Rain forms in a wide band ahead of the warm front and along the cold front. Energy for the storm comes from air masses trying to attain equilibrium. Warm air rises, cold air sinks and this transforms potential energy into kinetic. Condensation causing rain releases latent heat which supplies additional energy to the system. And wind speeds increase as the surface air flows into the low center at the tip of the kink. The cold front and warm front spin counterclockwise because of the Coriolis effect and because the cold front travels faster than the warm front. Eventually the two fronts converge and form another global boundary called an "occlusion.

Go to: [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/fpr.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/fpr.rxml) to learn about precipitation along fronts.

Then go to: [http://ww2010.atmos.uiuc.edu/\(Gh\)/wwhlpr/cyclone_ani.rxml?hret=/guides/crclm/act/cyc.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/wwhlpr/cyclone_ani.rxml?hret=/guides/crclm/act/cyc.rxml) to study cyclones and their formation. For a detailed account of a series of

thunderstorms that crossed Michigan on the 2nd of July, 1997 go to <http://www.osf.noaa.gov/otb/tngmat/pds/jul02case/torcase.htm>

Demonstration: Mapping the Weather Using cardboard slices students can make a contour map of the millibar differences using an upper air contour map from over North America. Where the lines are closest together the winds are the highest speed. The highest velocities are the jet stream. (Go to www.weather.unisys.com to find upper level maps. There are maps at 850, 700, 500, 300 and 200.) These pressures are found with weather balloons that carries an aneroid barometer and reports back pressure at various heights as it rises. This is how we get the heights of the pressure surfaces which we can contour.

To learn more about how weather maps are made and what the symbols mean, go to: [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crlm/act/sfcobs.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crlm/act/sfcobs.rxml) and do the activity. [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crlm/act/wx.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crlm/act/wx.rxml) will show you other weather symbols and their meanings.

To sum up what you have learned view the following films:

WEATHER WISE: AN OCEAN OF AIR

10 min Color VHS Video 1990 S M E

Covers air pressure, movement, temperature, and humidity. Teaches what types of winds are dangerous, why summer days are longer. Shows a barometer and other weather measuring instruments. From the Weather Wise Series.

From NASA the following films are available:

THE WEATHER WATCHERS, 15:00 min., Grade 7-11, Cat. #Bb1

Dramatically explains the use and importance of severe storms, meteorological information obtained from NASA satellites. This tape contains unusual footage of the formation of a tornado as well as actual shots of its awesome force.

HURRICANE, 28:00 min., Grade 7-10, Cat. #Bb2

Tracks an actual hurricane from its tame beginning in the Atlantic to its violent and deadly landfall at Galveston, Texas in August 1983. Using the sights and sounds from Alicia, this documentary reports the horror of a hurricane from the people who forecast them, working to minimize loss, and aid in the recovery.

THE CLIMATE FACTOR, 25:05 min., Grade 7-11, Cat. #Bb3

The climate factor affects all of us, everyday. This film takes a close look at the climate factor and many scientists studying climate's impact on man, and man's impact on climate. Subjects covered include agricultural architecture, fuel supply demands, and the greenhouse effect, and more. (Obtained from National Oceanic and Atmospheric Administration)

TERRIBLE TUESDAY, 23:30 min., Grade 7-10, Cat. #Bb4

Takes us to Wichita Falls, Texas to hear compelling stories of survivors from one of history's worse tornado outbreaks. They teach an invaluable lesson—tornadoes are nature's most violent storms, but taking the proper safety precautions can minimize the danger. A CINE Golden Eagle Award Winner. (Obtained from National Oceanic and Atmospheric Administration)

E. LESSON 5 - THE STRUCTURES OF STORMS

Figuring the cloud base: Assume the pressure at 1000 mb for sea level. Using that horizontal line as the base of your thermodynamic diagram graph, (**Figure 4**) find the dew point on the temperature axis and find the temperature on the same axis. Follow the lines parallel to the degrees Kelvin lines. Where the two lines intersect that is where the temperature and dew point is the same, which is also the location of the cloud base.

Reading a Sounding: Look at the sounding graph (**Figure 5**) that is created by a hot air balloon that is sent up twice a day to register the temperature and the dew point at various heights. Flag points into the wind. lines indicate 5 and 10 knots and the triangles =50 knots. Note that temperature lines are skewed to the right.

A pilot reading the sample sounding would see that on takeoff the wind would be out of the southeast

Stability, Air Masses and The Jet Stream:

Stability: For every cc of water you change to vapor 540 calories are absorbed. Called latent heat or heat of vaporization. It is this latent heat that powers storms. This water content and changing states of water in separate bodies of air cause movement of the air and thus unstable conditions.

Air Masses: MT(Maritime Tropical- warm moist) air over the oceans. CP(Continental Polar-cold dry) air is over the continents. MP (cold moist air over cold water) can be formed when CP air goes over cold oceans and picks up water.

Go to [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/arms.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/arms.rxml) to learn more about air masses.

Jet Stream: (See Figure 6) Storms tend to form where the jet stream turns. After the air goes around the turn and reaches point A it slows down and sinks causing a high-pressure area. After it goes around the next turn and reaches point B it spreads up and sucks air from below. On the far side of the turn the air is lifted back into the jet stream and this causes a low-pressure area.(freeway analogy). As the air enters the narrow part of the jet stream it's velocity speeds up and as it goes into wider areas of the jet stream it slows down. Where the water is moving fast it erodes the stream bed and goes down as the river widens the water rises again and deposits it's load. (river analogy)

How a storm develops: The vertical structure of a storm

Looking at the drawing of the vertical structure of a cyclone and anticyclone we can see that there is a cold air behind the cold front both aloft and at the surface. The surface low tends to be located to the east of the upper level low. (note the dotted arrows) Directly above the surface low the air can spread out and diverge as shown by the contour lines. This allows the converging surface air to rise and flow upward. When upper level divergence is stronger than surface convergence (more air is taken out at the top than is brought in at the bottom) surface pressure drops and the low intensifies. This vertical movement of air causes clouds to rise high in the sky and condensation to form rain.

Tornadoes: This description comes from the following website:
<http://www.txdirect.net/~msattler/tform.htm>

See Figure 7

Tornadoes: This description comes from the following website:
<http://www.txdirect.net/~msattler/tform.htm>

There are four main stages in a tornado's life. These are the organization stage, the mature stage, the shrinking stage, and the decaying stage. In the organization stage, a funnel appears and touches down. The tornado is at its largest in the mature stage. The funnel then decreases to a thin column in the shrinking stage, and becomes fragmented and very disorganized in the decaying stage, although it is still a destructive funnel.

Tornadoes require an almost perfect atmosphere to form. Warm moist air must collide with cooler, drier air to form massive storms known as super cells. Despite all the necessities needed, tornadoes form in great numbers across a stretch of the United States known as Tornado Alley. In this area, warm, moist Gulf air meets with cool, dry Canadian air during the spring and early summer months. This results in a large number of storms during this part of the year.

When the warm air meets the cooler air, the warm air rises, and then condenses to form clouds. When an area of warm air rises very quickly, it is known as an updraft. Updrafts cause the cloud tops to grow higher and higher, sometimes as high as ten miles. High winds in the upper atmosphere sometimes cause the tops of the storm to be blown to the northeast. This is known as the anvil of the storm. The clouds underneath this anvil are generally free of rain. The rain falls to the northeast of the anvil.

Super cells form along an area of instability known as a squall line. A squall line is an area of cooler air out in front of a cold front. This cooler air meets with the warmer air first, sometimes forming very destructive storms. A super cell is a very characteristic storm. It is named "super" because of its extreme organization. Whereas most storms

have several updrafts and downdrafts, which interfere with each other, a super cell has one updraft and downdraft. This allows the storm to feed off itself, giving it a long, and intense life. These storms often produce very gusty winds, heavy rain, large hail, and even tornadoes.

Wind shear, which is composed of winds blowing from different directions at different altitudes and speeds, causes the air around it to begin rotating horizontally. When this horizontal column of air meets one of the strong updrafts, it can become twisted and bent upward. This mass of rotating air is known as the mesocyclone. The tornado will usually form within this area of rotating air. The funnel usually appears at the southwest edge of the storm and southwest of an updraft, close to its adjacent downdraft. A wall cloud, or a lowering of the cloud base in a specific area is usually seen prior to tornado development.

Hurricanes: The following description and graphics come from <http://abcnews.go.com/sections/science/DailyNews/hurricanebirth.html> for additional information and student activities go to <http://www.abcclassroom.com/newsconnect/09-10-99/>

The circumstances in which hurricanes form are simple and typical; moist air over a warm ocean. But the processes by which the sea actually creates a hurricane are complex. Here is a basic outline of the forces at work:

See Figure 8

1. Humid air flows over warm ocean currents. The air, warmed by the ocean, begins to rise.
2. As the air reaches higher altitude, the humidity it carries begins condensing into rain. The condensation generates heat.
3. The upper air grows warmer, creating a high-pressure area aloft which begins pushing air away from it, dropping the pressure at the sea surface. This low-pressure area draws more moist air from the outside into the center where it is lifted up once again, and the cycle repeats itself.

See Figure 9

The storm intensifies as this process, called convection, feeds on itself. The storm system eventually begins to swirl in a counter clockwise direction and smaller convection zones known as rain bands form in the spiral arms.

See Figure 10

When sustained wind speeds reach 74 mph the storm is officially classified a hurricane. Weak winds aloft are needed for a hurricane. Slow winds are common aloft at low latitudes near the equator because the air is uniformly low in density. Hurricanes do

not form right on the equator because there is no Coriolis Force to cause rotation. It has to get it hot and moist enough at the surface and aloft it needs to be relatively cool and winds weak. If the ocean level air gets hot enough and wet enough the air will rise and there will form thunderstorms. Waves of these thunderstorms come off the continent of Africa.

A column of air in the ocean with weak winds aloft and warm moist air at the surface; these form thunderstorms. The rain in the mid levels of that column releases heat and the air flows out of the column at the midlevel and this loss of air in the midlevels causes the air at the surface to rise into the vacuum lowering the surface pressure. This causes more warm moist air and more thunderstorms and more vacuums and more winds moving into this vacuum. The eye of the hurricane is the air coming up from below and down from above to fill the vacuum.

If high-speed winds (jet streams) come, they carry away all that midlevel heat and break the vacuum. Or, when the hurricane goes on land there is no warm moist air to feed it and the engine dies. Another way to kill a hurricane engine is to cool the ocean current. The California current (cool current) kills hurricanes going toward Hawaii.

For a long-term project, consider [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/prjct/strm93/home.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/prjct/strm93/home.rxml) where you can become involved in the case study "SuperStorm93". This project investigates key weather processes and phenomena associated with a potent winter storm.

IV. INTERNET RESOURCES AND BIBLIOGRAPHY

The following are some references that can be used as student resources and that may be utilized in lessons within this unit:

Books:

- Clark, Camp. Planet Earth, Flood, Time-Life Books, 1982.
Hecht, Jeff. Shifting Shores, Charles Scribner Sons 1990.
Kals, W.S. The Riddle of the Winds, Doubleday, 1977.
Lee, Albert. Weather Wisdom, Dolphin Books, 1977.
Polking, Kirk. Oceans of the World, Philomel Books, 1983.
Ruffner, James The Weather Almanac, Gale Research Co. 1974.
Thompson, Philip D. Weather, Time life Books 1965.
Watson, Benjamin, Acts of God, Random House, 1993.
Whipple, A.B.C. Planet Earth, Storm, Time-Life Books, 1982.
Williams, Jack. The Weather Book 2nd Edition, Vintage Books, 1997.

Cited References:

- The Plain English Guide to the Clean Air Act, U.S. EPA; What You Can Do to Reduce Air Pollution, U.S. EPA
Meteorology Today 4th ed. C. Donald Ahrens West Publ. New York, 1991.

Internet Links for use in this curriculum:

- [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/prs.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/prs.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/prjct/home.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/prjct/home.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/fpr.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/fpr.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/wwhlpr/cyclone_ani.rxml?hret=/guides/crclm/act/cyc.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/wwhlpr/cyclone_ani.rxml?hret=/guides/crclm/act/cyc.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/sfcobs.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/sfcobs.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/wx.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/wx.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/act/fprcp.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/act/fprcp.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crclm/prjct/strm93/home.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/prjct/strm93/home.rxml)
[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/mtr/cld/dvlp/wtr.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/dvlp/wtr.rxml)
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<http://www.weatherwatchers.org/photos/IMG0004.html>
<http://www.mania.com.au/~robo/cloud.html>
http://www.gorp.com/gorp/publishers/menasha/how_weat.htm
<http://www.tnrcc.state.tx.us/water/quantity/flood/weather.html>
<http://216.122.100.206/training/wx/wx2/>
<http://teachers.net/lessons/posts//491.html>
<http://www.osf.noaa.gov/otb/tngmat/pds/jul02case/torcse.htm>
<http://www.weatherwatchers.org/photos/IMG0004.html>
<http://vortex.plymouth.edu/home.html>
<http://members.tripod.com/Lomitas/weather/cloudlsn.htm>

Figure 2

AMOUNT OF WATER THE AIR CAN HOLD AT VARIOUS TEMPERATURES

Actual Data Compared to Exponential Curve

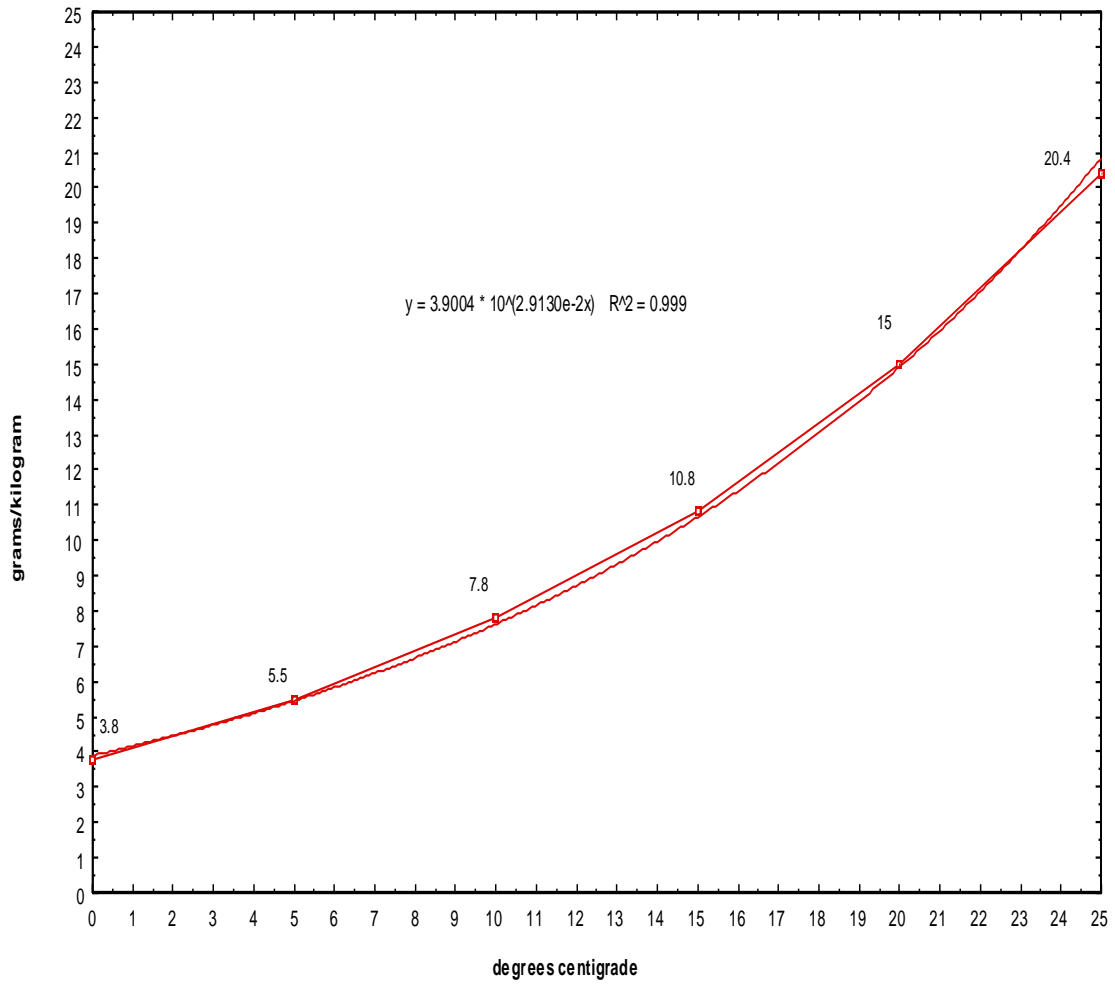
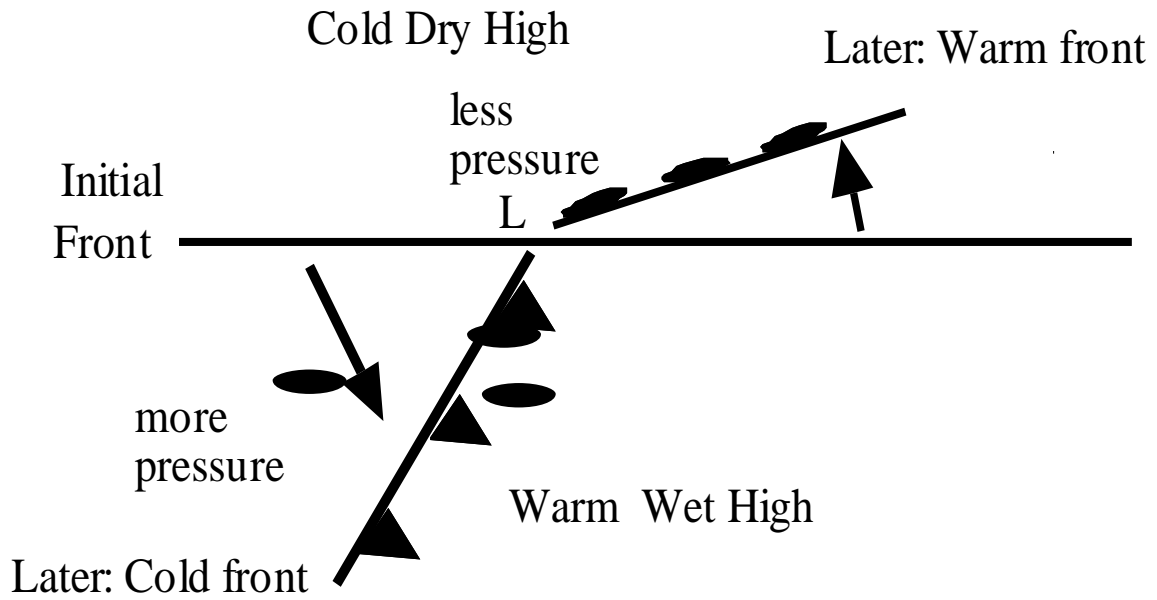


Figure 3



Cyclonic winds tend to be counter clockwise in the northern hemisphere.

Figure 4
Thermodynamic Diagram

Figure 5
 Skew T Sounding Graph example:

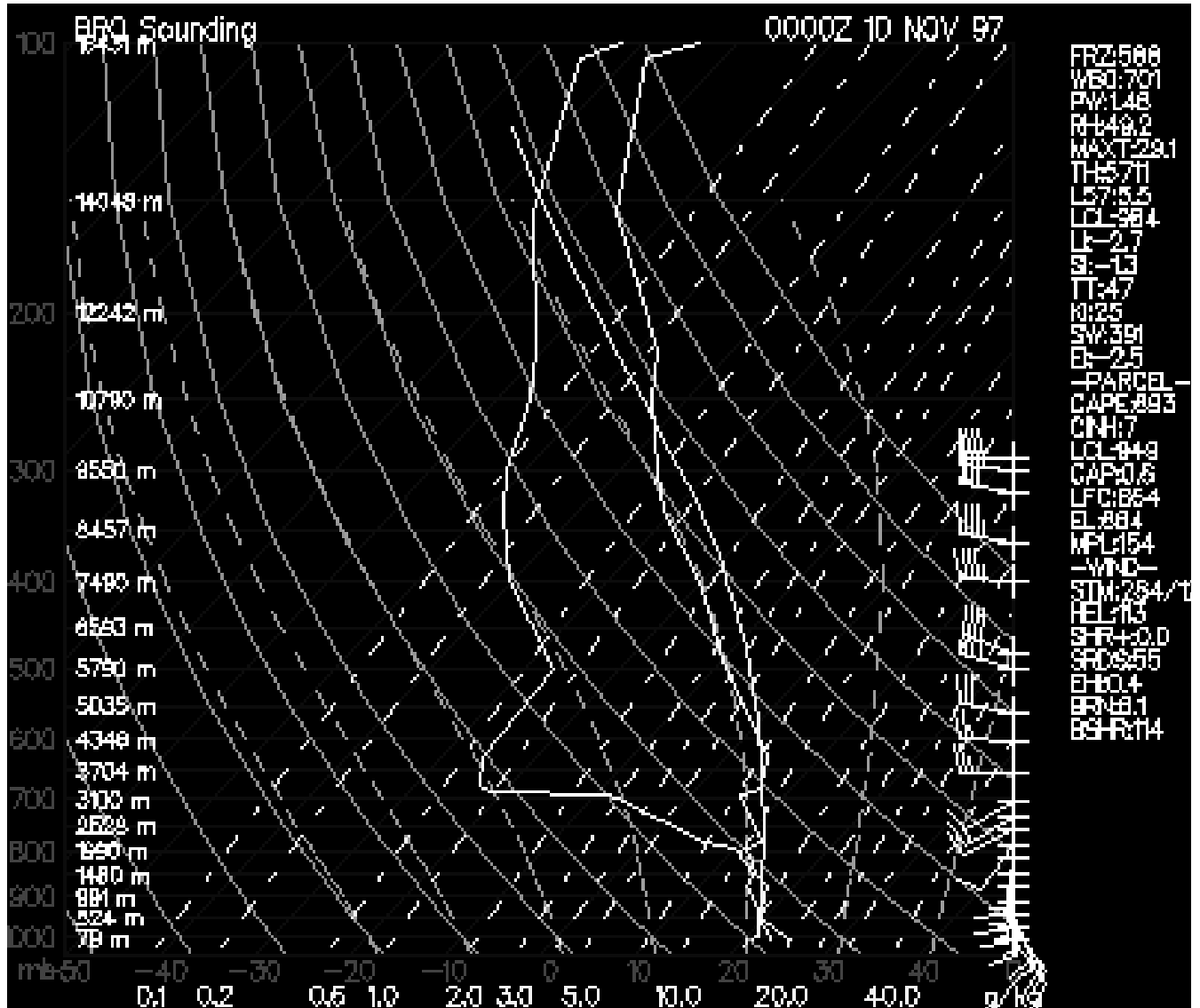


Figure 6

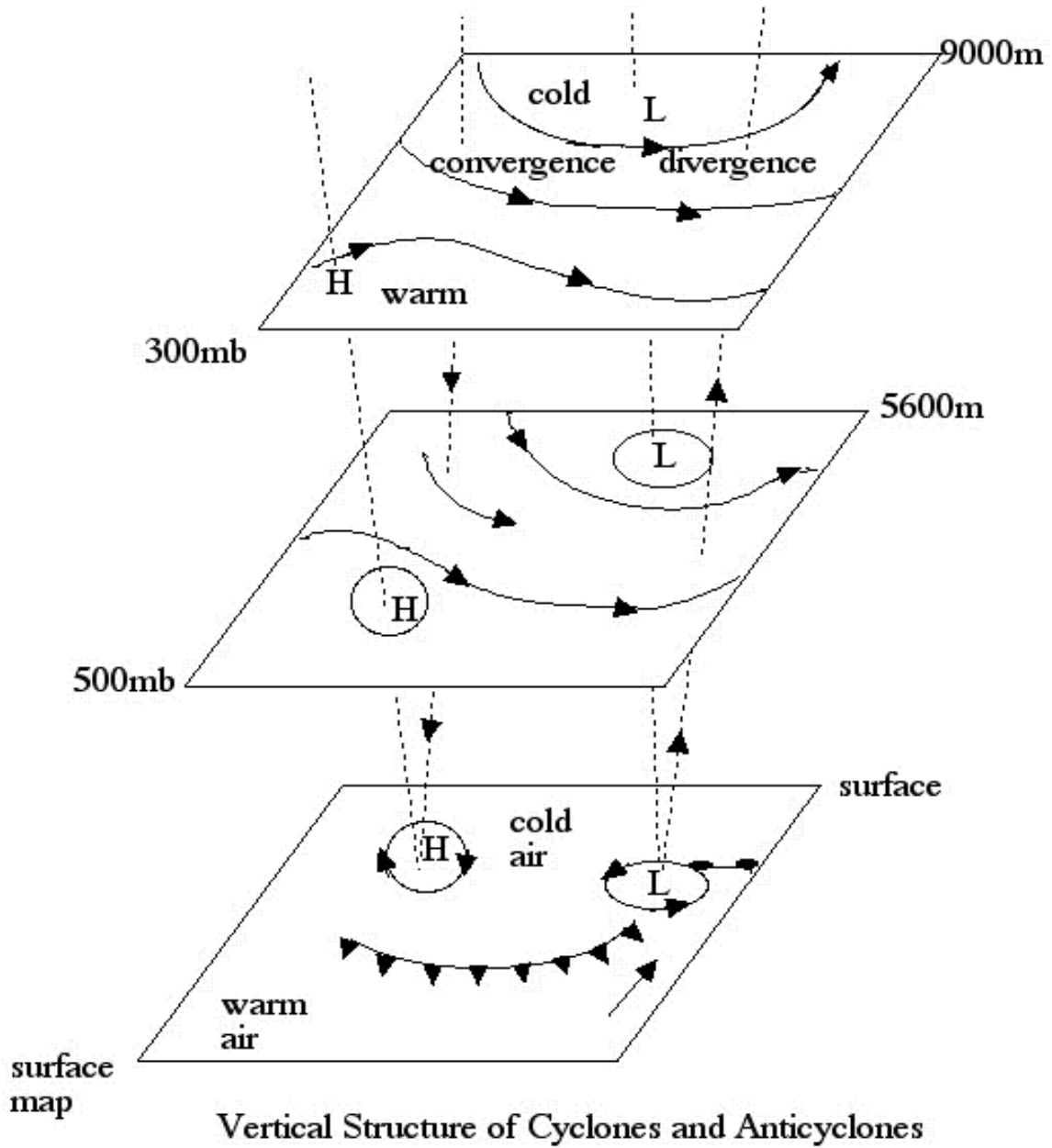


Figure 7

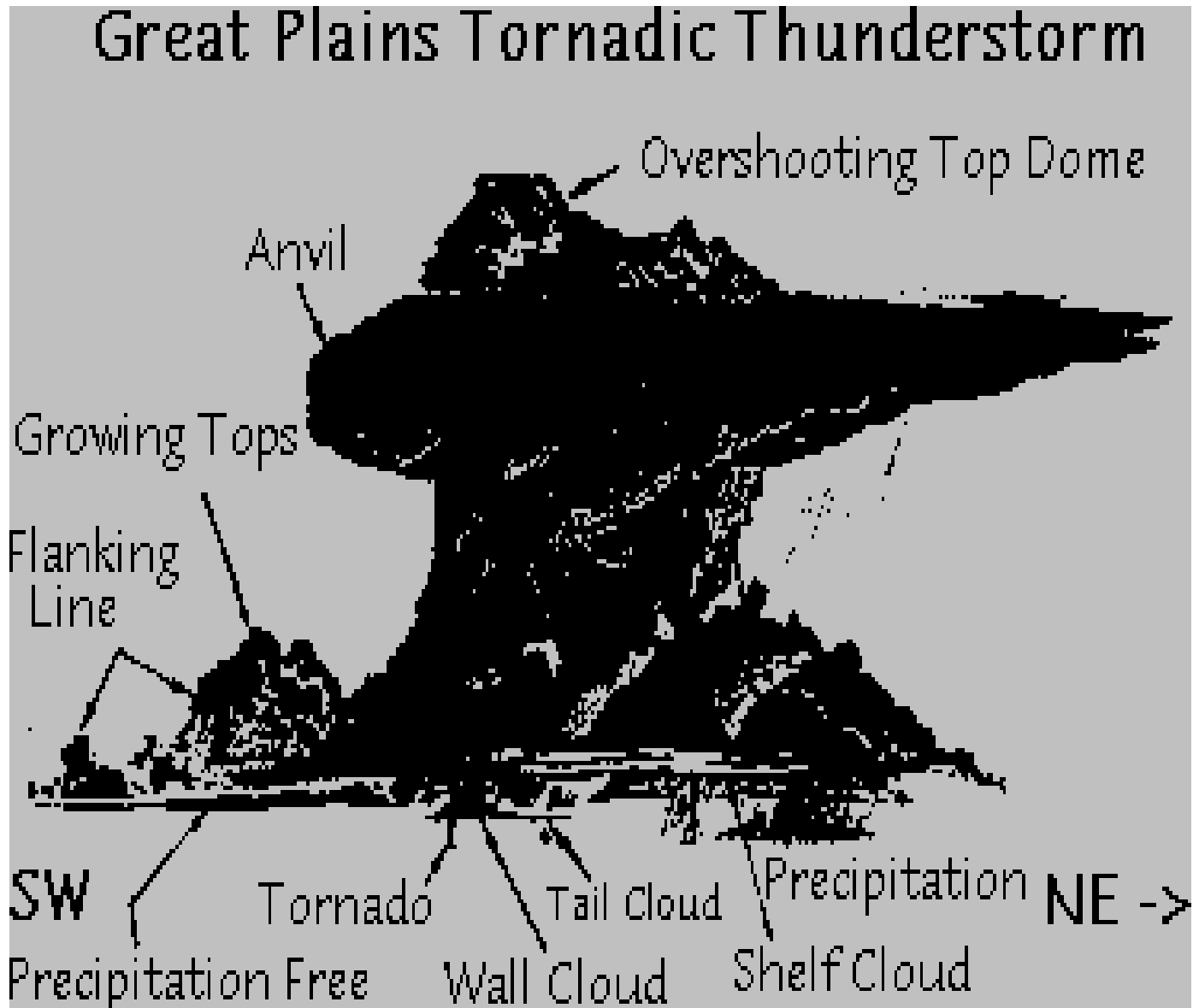


Figure 8

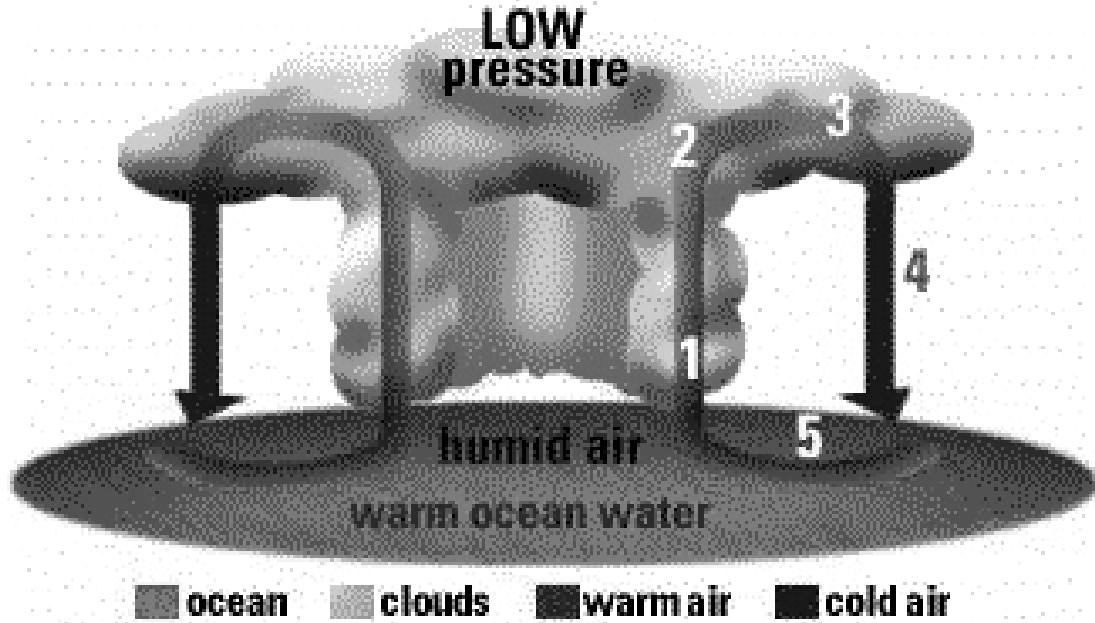


Figure 9

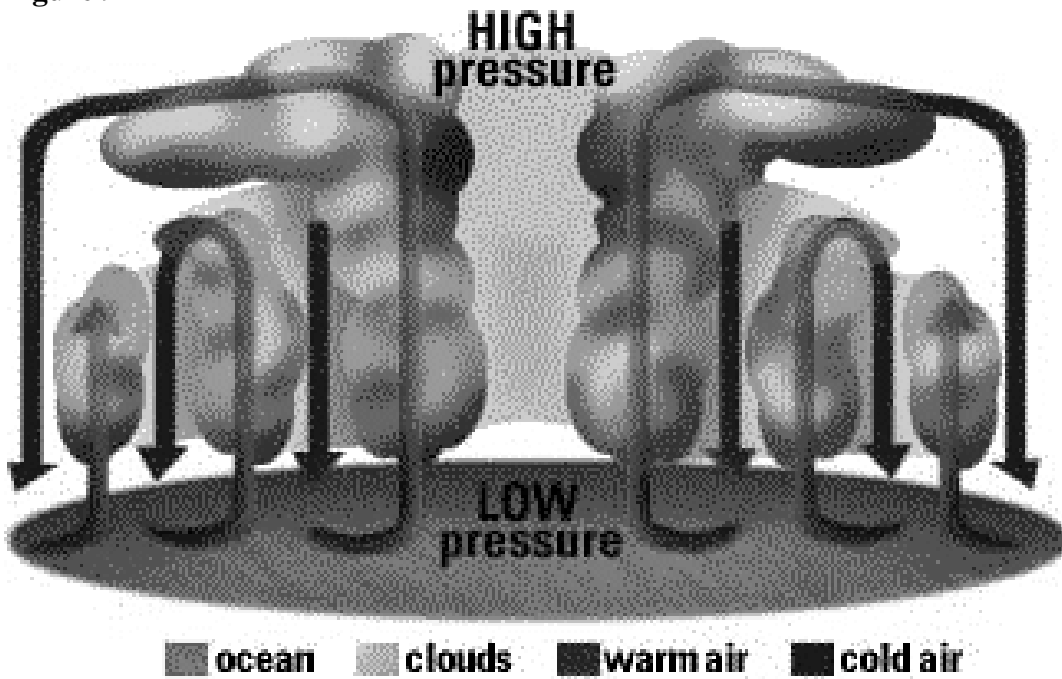


Figure 10

