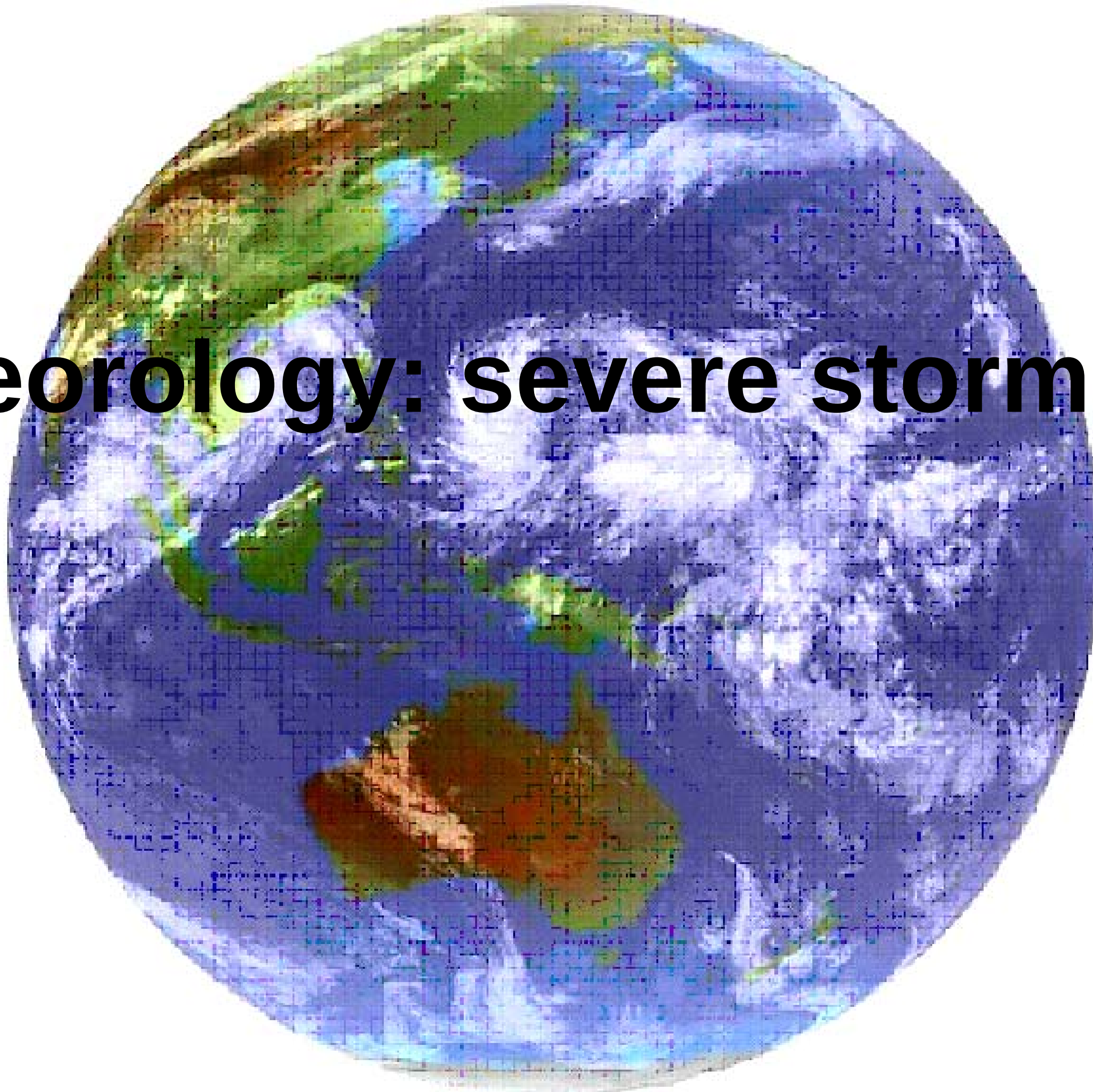


Meteorology: severe storms

Meteorology: Severe Storms

- **Severe Weather:** is the second topic in the B-Division Science Olympiad Meteorology Event.
- **Topics:** rotate annually so a middle school participant may receive a comprehensive course of instruction in meteorology during the three-year cycle.
- **Sequence:**

1. Everyday Weather (2010)
2. Severe Storms (2008)
3. Climate (2009)

topics to be covered

- General knowledge of basic weather including: the composition and structure of the atmosphere, air masses, fronts, highs and lows, cyclones, anticyclones, weather maps, weather stations, surface weather maps, meteograms, and isopleths.
- Modern weather technology: satellite imagery and doppler imagery.
- Global circulation patterns: easterlies, westerlies, polar front, etc.
- Thunderstorms: all types
- Tornados
- Mid-latitude Cyclones
- Hurricanes
- Saffir-simpson, Fujita & E-scales
- Lightning (including sprites and jets), hail and other associated storm hazards
- Common storm tracks across the continental United States

General knowledge – composition and structure of the atmosphere

- **ITS COMPOSITION**
- **There are permanent gasses (nitrogen and oxygen)**
- **There are variable gasses (carbon dioxide, methane, water vapor, ozone, particulates**
- **The composition of the atmosphere has not been constant but has changed through time.**
- **We used to be the stuff of stars (helium and hydrogen) but outgassing, comets, UV radiation and photosynthesis have changed us.**

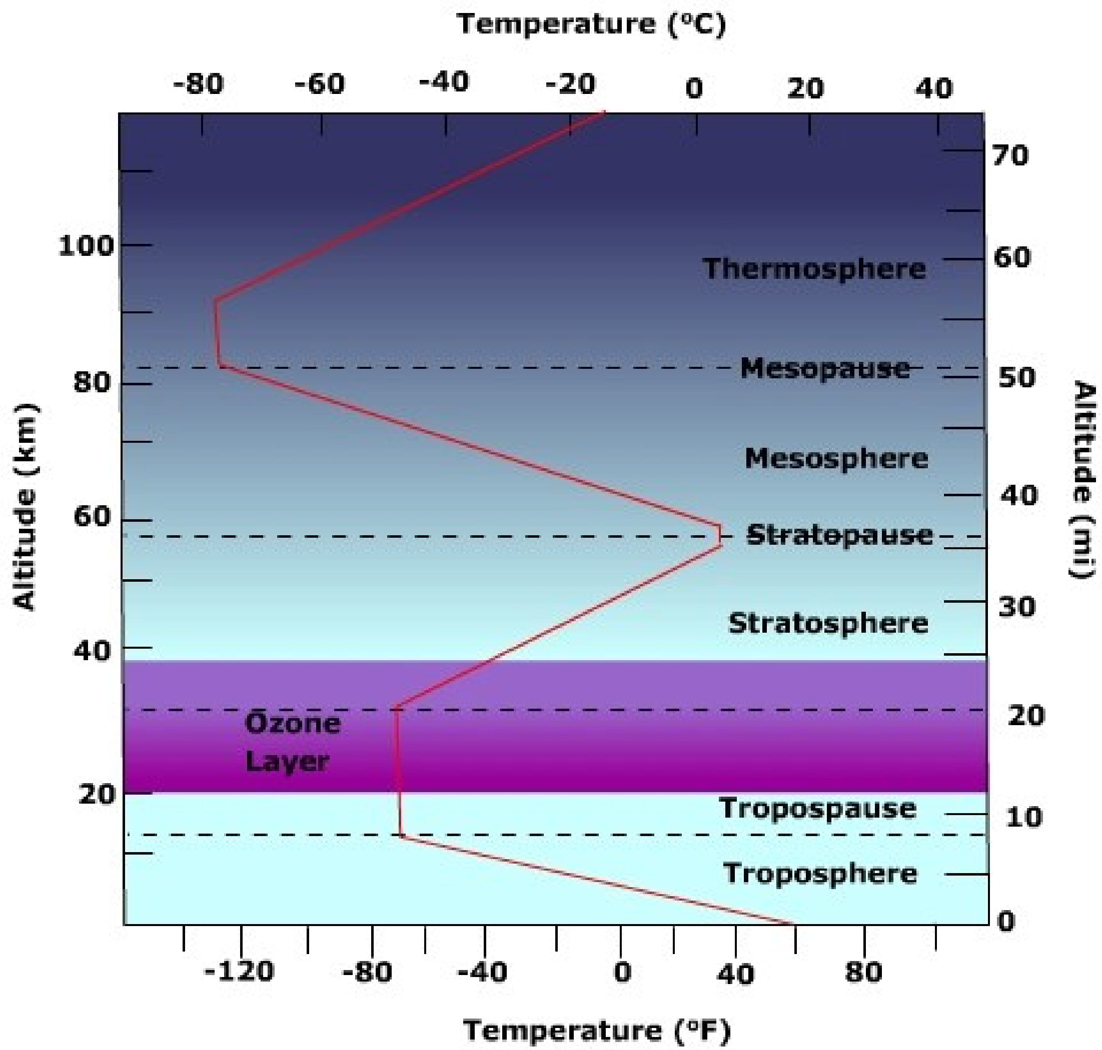
Constant components *(proportions remain the same over time and location)*	
Nitrogen (N_2)	78.08%
Oxygen (O_2)	20.95%
Argon (Ar)	0.93%
Neon, Helium, Krypton	0.0001%

Variable components *(amounts vary over time and location)*	
Carbon dioxide (CO_2)	0.0003%
Water vapor (H_20)	0-4%
Methane (CH_4)	*trace*
Sulfur dioxide (SO_2)	*trace*
Ozone (O_3)	*trace*
Nitrogen oxides (NO, NO_2)	*trace*

- http://www.uwsp.edu/gEo/faculty/ritter/geog101/textbook/atmosphere/atmospheric_structure.html
- http://www.physicalgeography.net/fundamentals/7a.html
- http://www.visionlearning.com/library/module_viewer.php?mid=107&l=&c3=
- http://www.globalchange.umich.edu/globalchange1/current/lectures/samson/evolution_atm/index.html#evolution

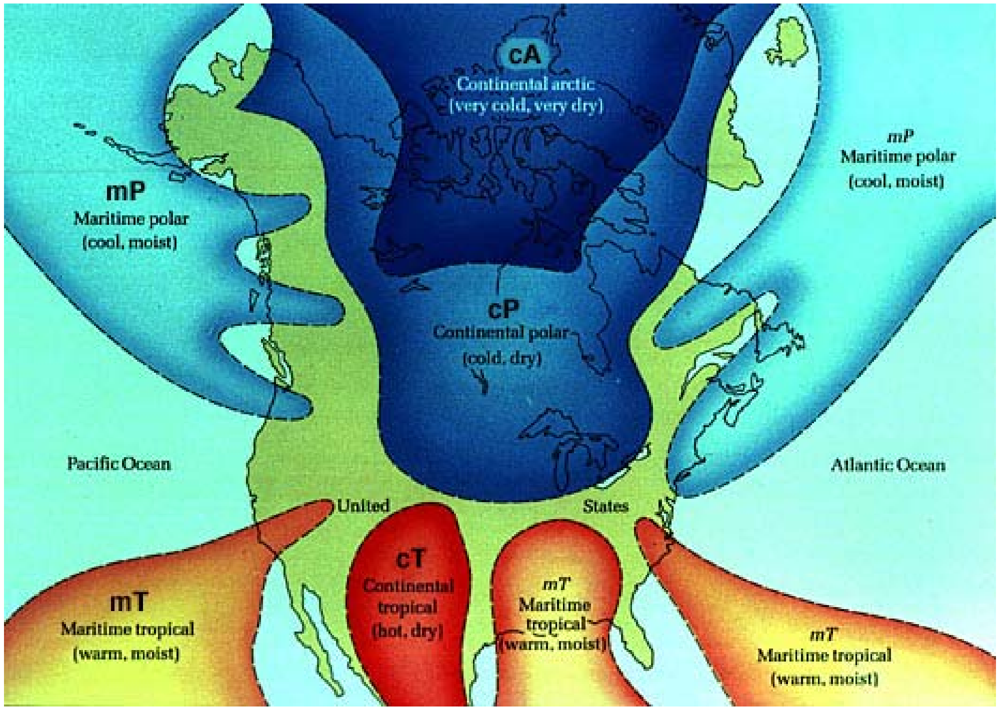
General knowledge – composition and structure of the atmosphere

- **IT'S STRUCTURE**
- **Layers are defined by temperature, altitude, and unique characteristics**
- **There are layers where temperature rises with altitude or falls with altitude (our natural instinct).**
- **Between these layers there are pauses where temperature is constant with altitude change.**
- **Each layer has unique characteristics like 90% of the ozone is in the stratosphere and gasses stratify by molecular weight in the thermosphere**
- **Thickness of these layers varies with latitude.**



- http://www.uwsp.edu/gEo/faculty/ritter/geog101/te phere/atmospheric_structure.html
- http://www.albany.edu/faculty/rgk/atm101/structur.htm

General knowledge – air masses



- Air masses tend to be homogeneous in nature. The two critical properties of any air mass are:
  - 1. Temperature
  - 2. Moisture
- The point of origin of an air mass will determine temperature and moisture content. Combined these properties produce the weather we experience daily.

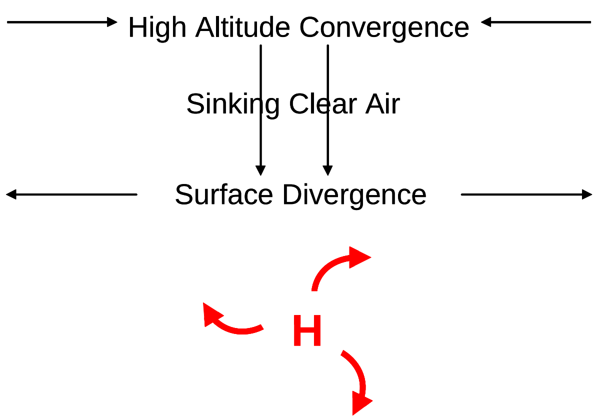
- http://www.ecn.ac.uk/Education/air_masses.htm
- http://okfirst.ocs.ou.edu/train/meteorology/AirMasses.html

General knowledge – air masses

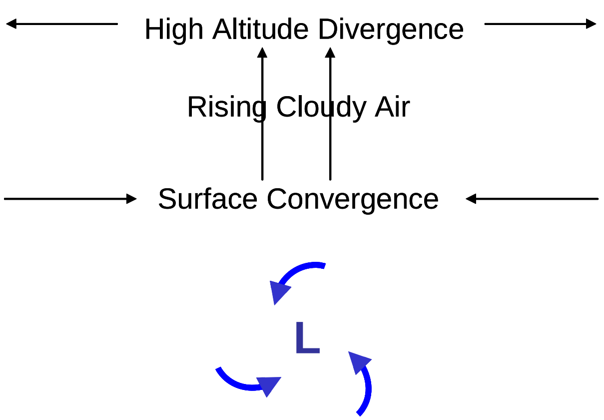
- An air mass is a huge volume of air that covers hundreds of thousands of square kilometers that is relatively uniform horizontally and vertically in both temperature and humidity
- The characteristics of an air mass are determined by the surface over which they form so they are either continental or maritime indicated with a lower case m or c
- Then they are classed as Arctic, Polar, Tropical or Equitorial (A, P, T, or E)
- And finally they have a lower case k or w at the end to indicate whether they are warmer or colder than the land over which they are moving.
- Note that arctic and polar are difficult to distinguish as are tropical and equatorial.
- Air masses are driven by the prevailing winds. Hot air originates near the equator and cold near the poles and the middle latitudes where we live is the mixing zone and we have spectacular weather as warm and cold air masses work their way across us.

General knowledge highs, lows, and fronts

- **High pressure system is an anticyclone**
- **Highs generally have good weather and when seen from above surface winds surrounding a high blow in a clockwise direction and outward from the high**
- **Lows and highs track with the prevailing winds from west to east across the US**



- **Low pressure system is a cyclone**
- **Lows tend to have cloudy bad weather and when seen from above surface winds surrounding a low blow in a counter clockwise direction and inward to the low.**
- **Lows and highs track with the prevailing winds from west to east across the US**

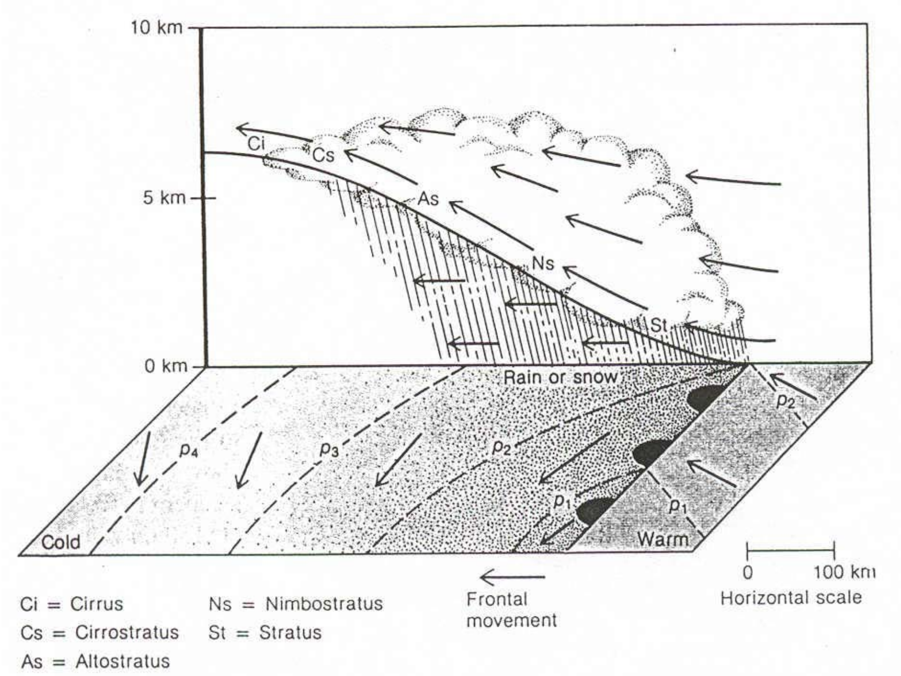


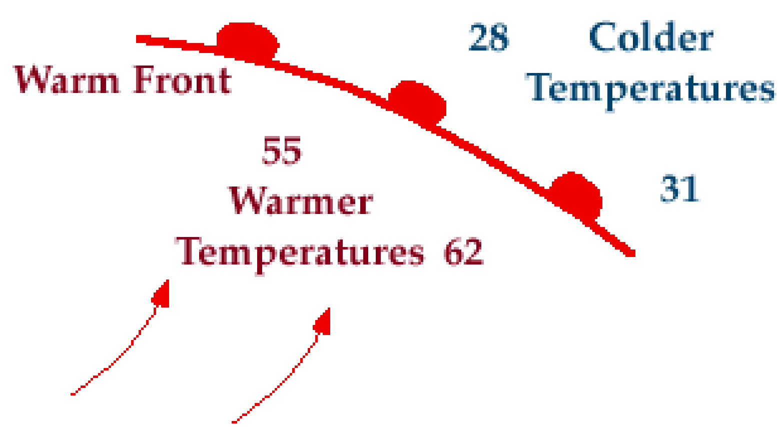
General knowledge highs, lows, and fronts

- **As air masses collide carrying their characteristic temperature and moisture they create fronts: warm, cold, stationary and occluded.**
- **Each type of front has unique vertical characteristics with characteristic weather patterns.**

General knowledge - warm fronts

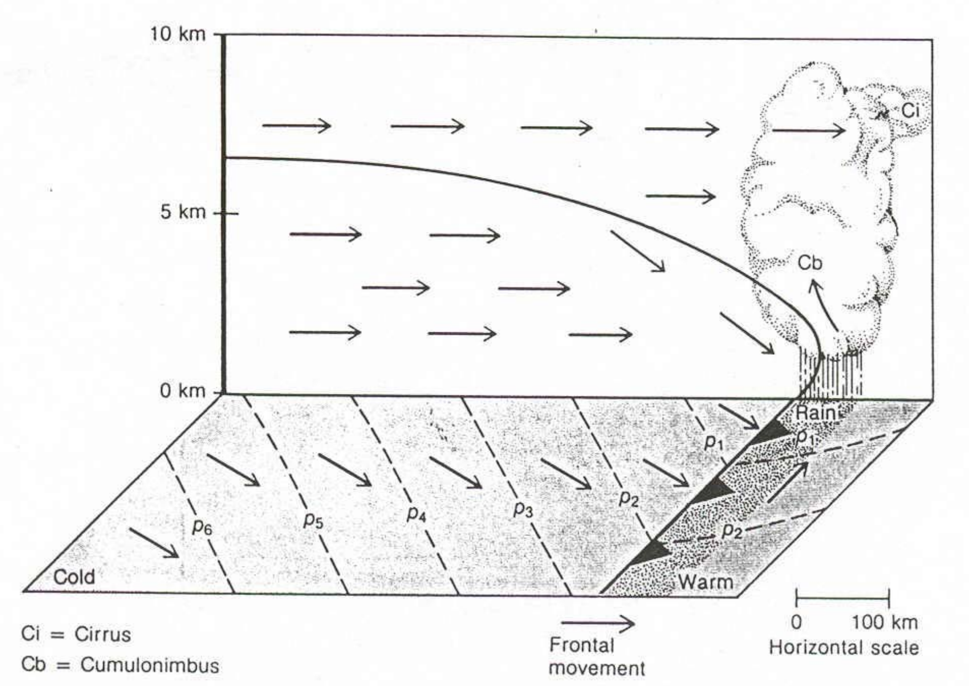
- Warm fronts tend to move slowly
- They carry broad bands of clouds that begin high and drop lower with time.
- They tend to be associated with light and prolonged rains and warming temperatures
- A warm front is defined as the transition zone where a warm air mass is replacing a cold air mass. Warm fronts generally move from southwest to northeast and the air behind a warm front is warmer and more moist than the air ahead of it. When a warm front passes through, the air becomes noticeably warmer and more humid than it was before.
- Symbolically, a warm front is represented by a solid line with semicircles pointing towards the colder air and in the direction of movement.

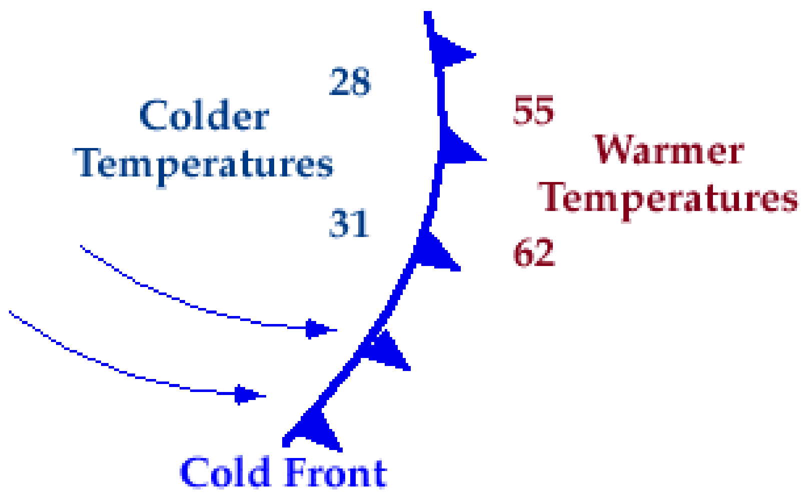




General knowledge - cold fronts

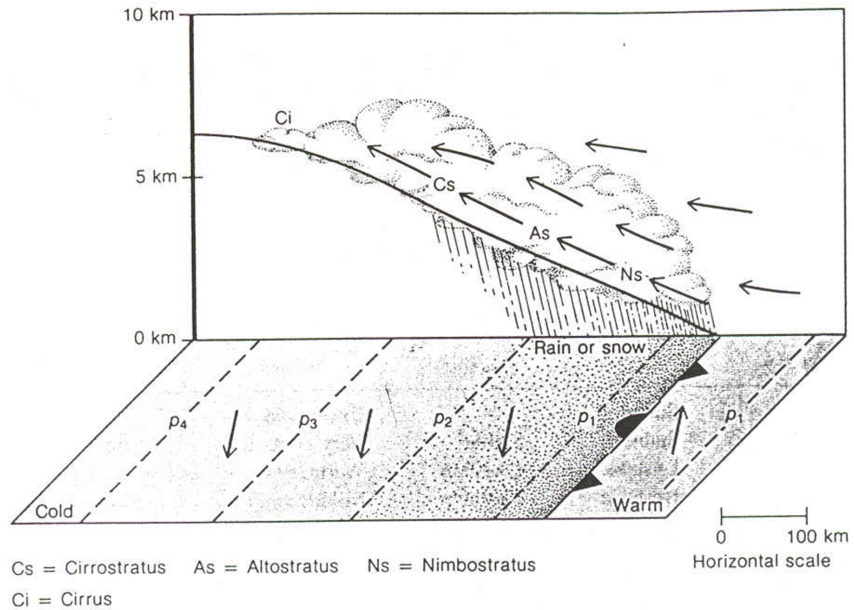
- A cold front is defined as the transition zone where a cold air mass is replacing a warmer air mass. Cold fronts generally move from northwest to southeast. The air behind a cold front is noticeably colder and drier than the air ahead of it. When a cold front passes through, temperatures can drop more than 15 degrees within the first hour.
- Cold fronts tend to be associated with vertical clouds and rains of short duration but often with intensity.
- There is typically a noticeable temperature change from one side of a cold front to the other. In the map of surface temperatures right, the station east of the front reported a temperature of 55 degrees Fahrenheit while a short distance behind the front, the temperature decreased to 38 degrees. An abrupt temperature change over a short distance is a good indicator that a front is located somewhere in between.
- Symbolically, a cold front is represented by a solid line with triangles along the front pointing towards the warmer air and in the direction of movement. On colored weather maps, a cold front is drawn with a solid blue line.

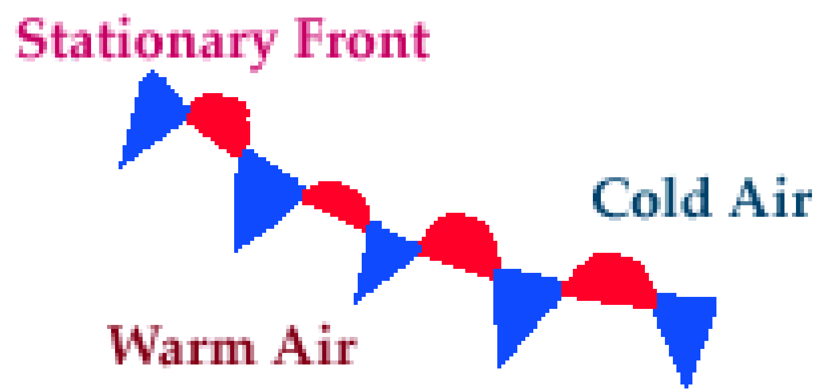




General knowledge - Stationary fronts

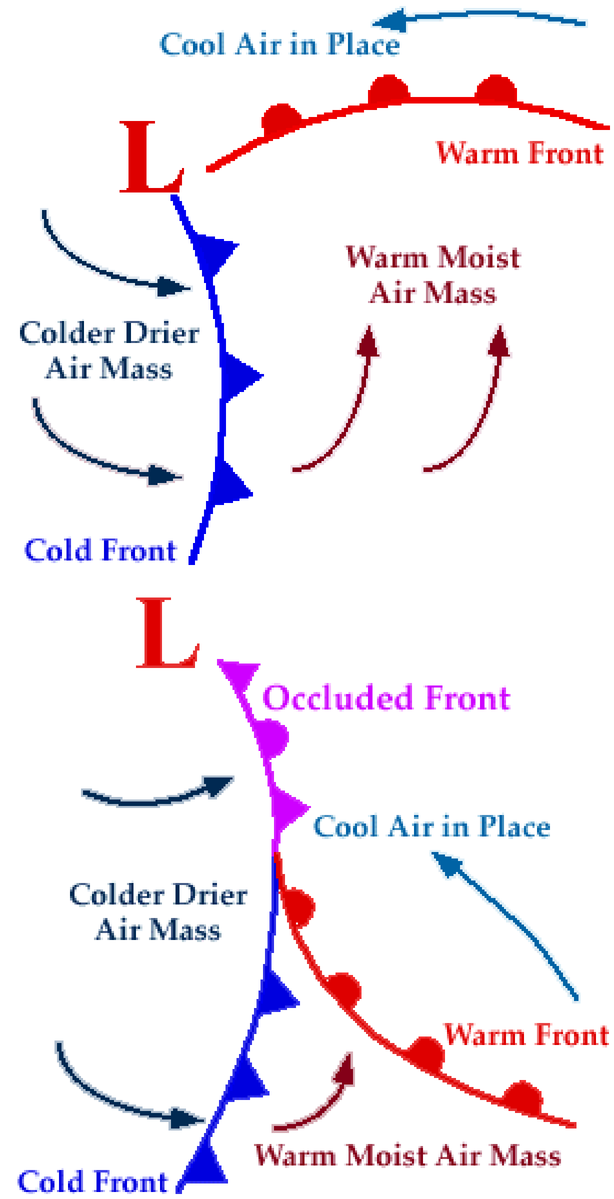
- When a warm or cold front stops moving, it becomes a stationary front. Once this boundary resumes its forward motion, it once again becomes a warm front or cold front. A stationary front is represented by alternating blue and red lines with blue triangles pointing towards the warmer air and red semicircles pointing towards the colder air.
- A noticeable temperature change and/or shift in wind direction is commonly observed when crossing from one side of a stationary front to the other.





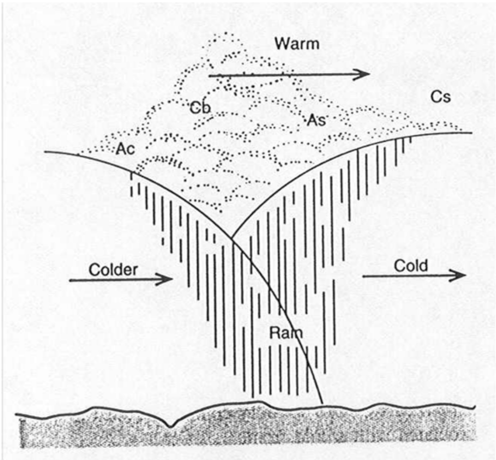
General Knowledge - Occluded fronts

- A developing cyclone typically has a preceding warm front (the leading edge of a warm moist air mass) and a faster moving cold front (the leading edge of a colder drier air mass wrapping around the storm). North of the warm front is a mass of cooler air that was in place before the storm even entered the region.
- As the storm intensifies, the cold front rotates around the storm and catches the warm front. This forms an occluded front, which is the boundary that separates the new cold air mass (to the west) from the older cool air mass already in place north of the warm front.
- Symbolically, an occluded front is represented by a solid line with alternating triangles and circles pointing the direction the front is moving. On colored weather maps, an occluded front is drawn with a solid purple line.
- Changes in temperature, dew point temperature, and wind direction can occur with the passage of an occluded front.
- A noticeable wind shift also occurred across the occluded front. East of the front, winds were reported from the east-southeast while behind the front, winds were from the west-southwest.

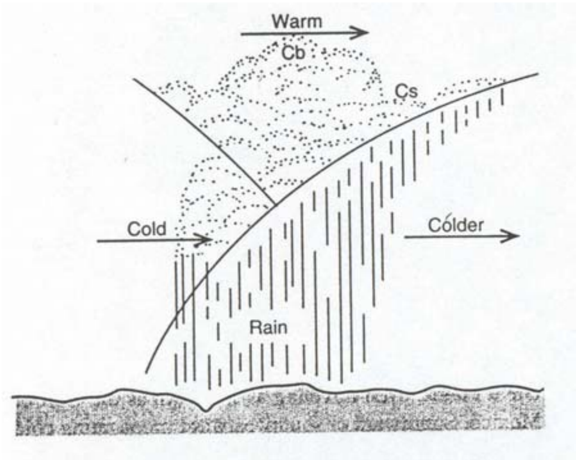


General knowledge - Warm or cold occluded fronts

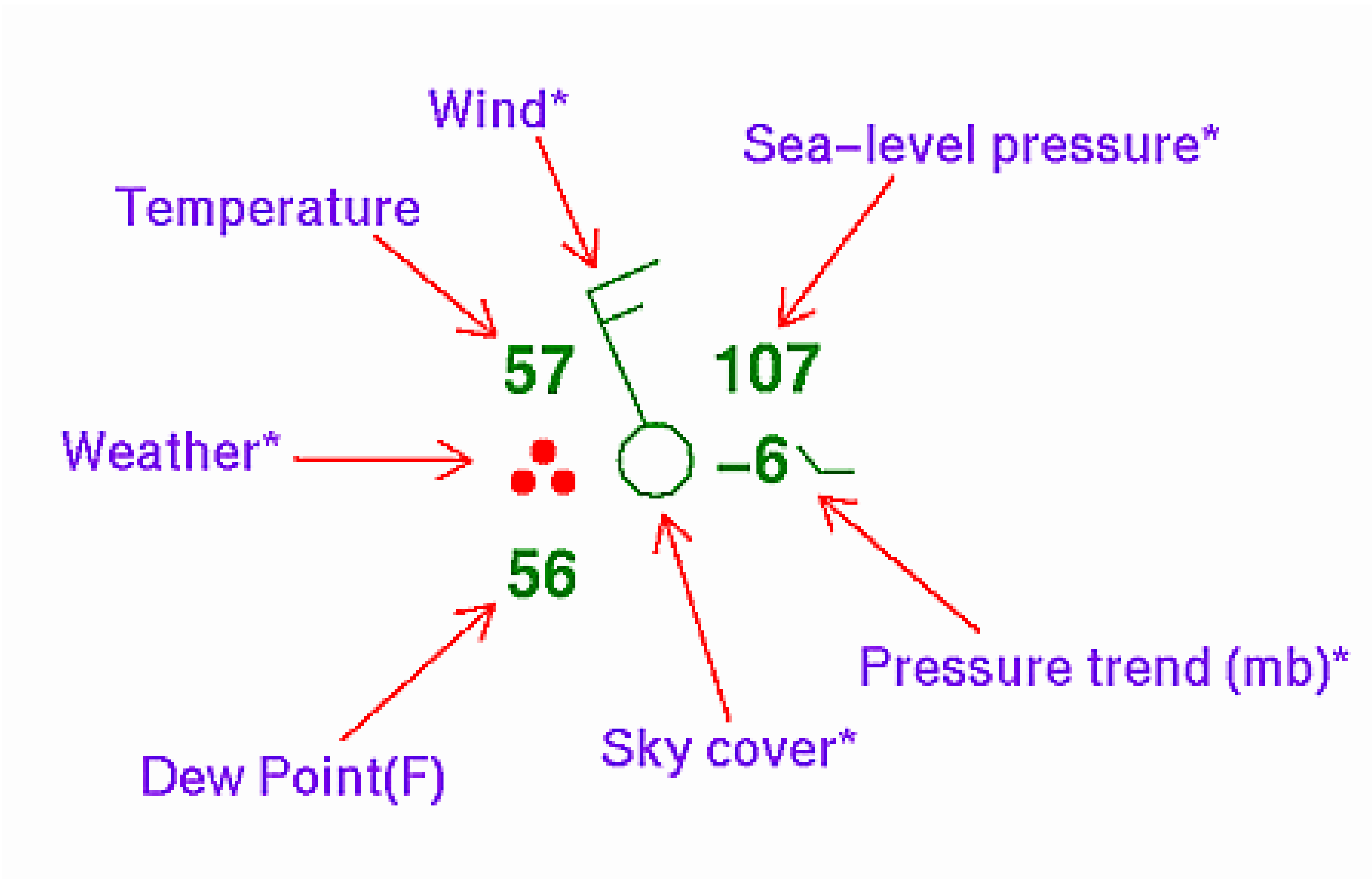
- Cold occlusion
- A colder air mass advances on a cold air mass and occludes warmer air.



- Warm occlusion
- A warmer air mass advances on a cold air mass and occludes warmer air.

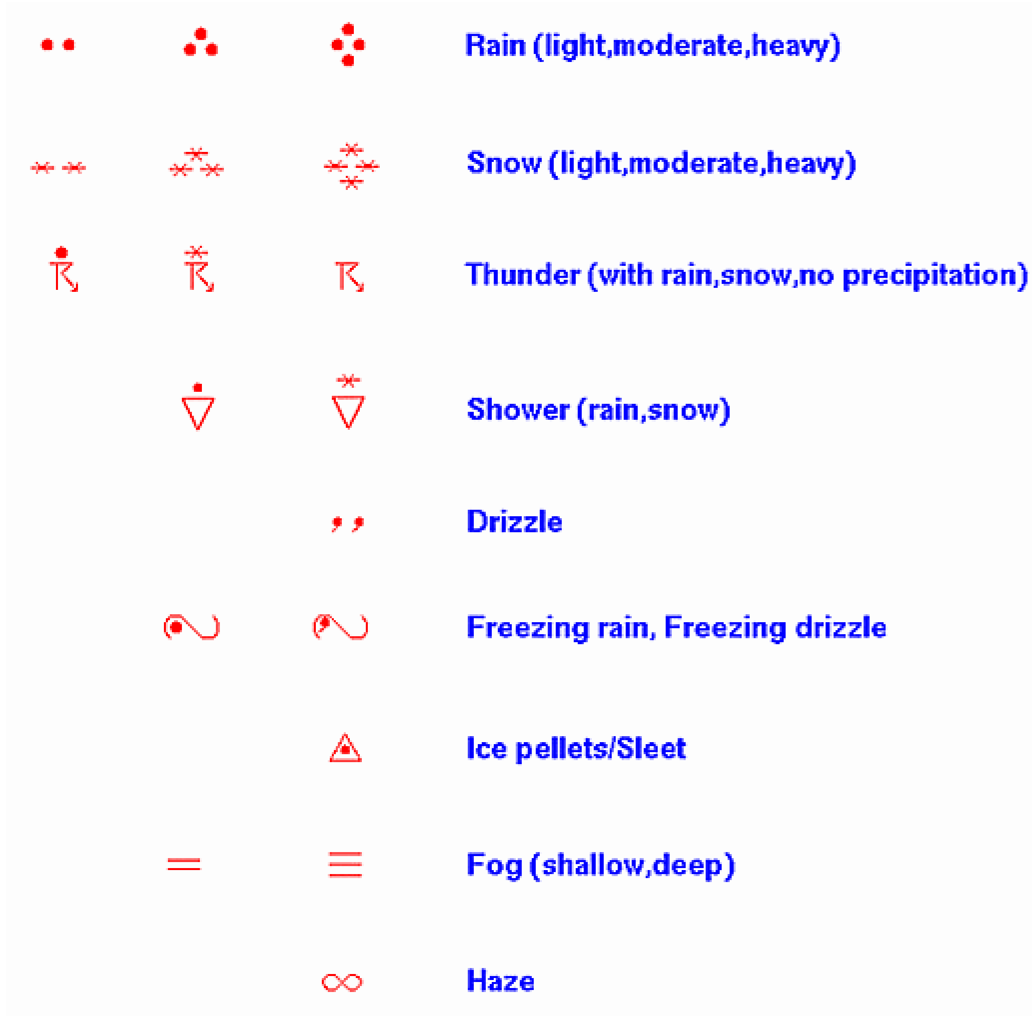


General knowledge - Surface weather stations



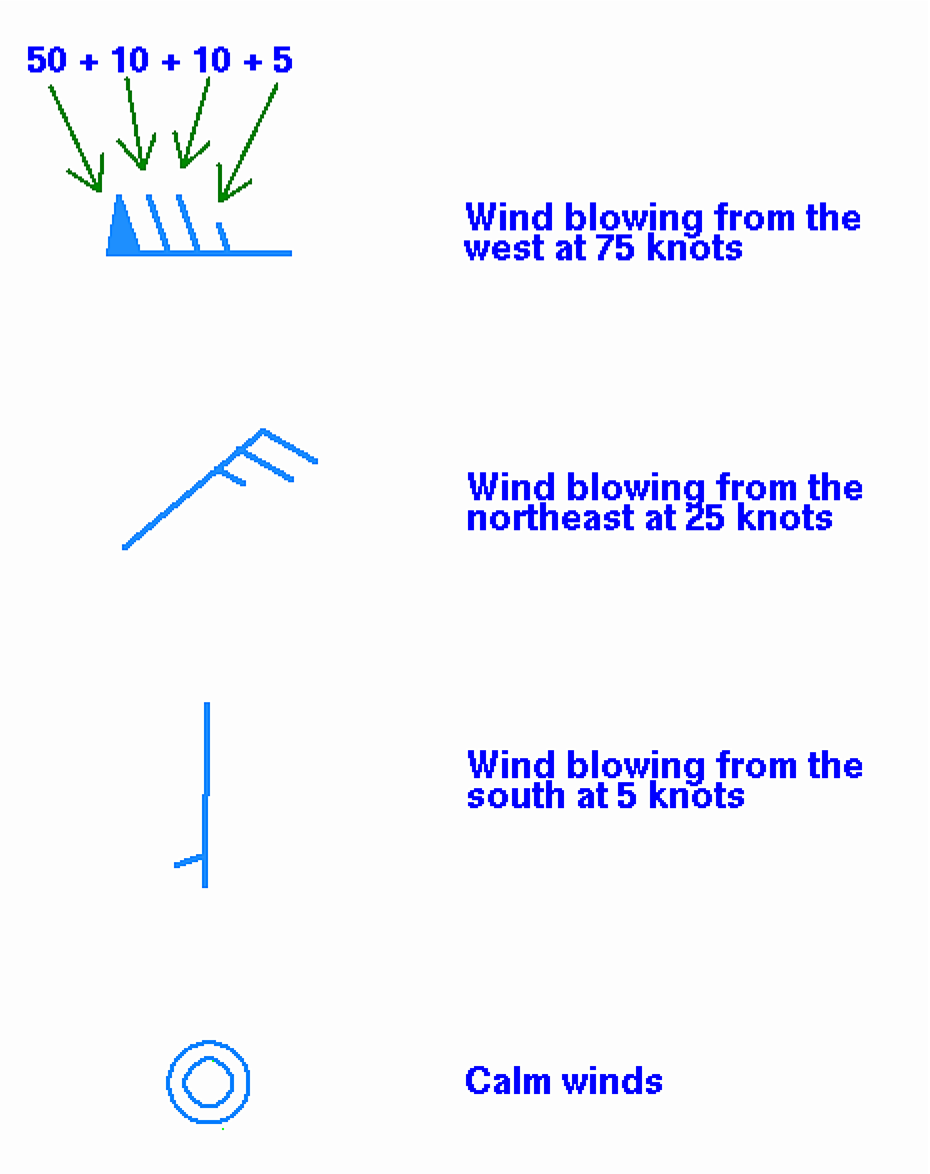
surface weather stations: current conditions

- **A weather symbol is plotted if at the time of observation, there is either precipitation occurring or a condition causing reduced visibility.**
  Below is a list of the most common weather symbols:



surface weather stations: wind speed and direction

- Wind is plotted in increments of 5 knots (kts), with the outer end of the symbol pointing toward the direction from which the wind is blowing.
- The wind speed is determined by adding up the total of flags, lines, and half-lines, each of which have the following individual values: flag: 50 kts, Line: 10 kts, Half-Line: 5 kts.
- Wind is always reported as the direction from which it is coming.
- If there is only a circle depicted over the station with no wind symbol present, the wind is calm. Below are some sample wind symbols:



surface weather stations: pressure and trend

- **PRESSURE**

  Sea-level pressure is plotted in tenths of millibars (mb), with the leading 10 or 9 omitted. For reference, 1013 mb is equivalent to 29.92 inches of mercury. Below are some sample conversions between plotted and complete sea-level pressure values. If the surface weather station number is <500 place a leading 10 if it is >500 place a leading 9; then divide by 10:

  410: 1041.0 mb
  103: 1010.3 mb
  987: 998.7 mb
  872: 987.2 mb

  http://www.csgnetwork.com/meteorologyconvtbl.html

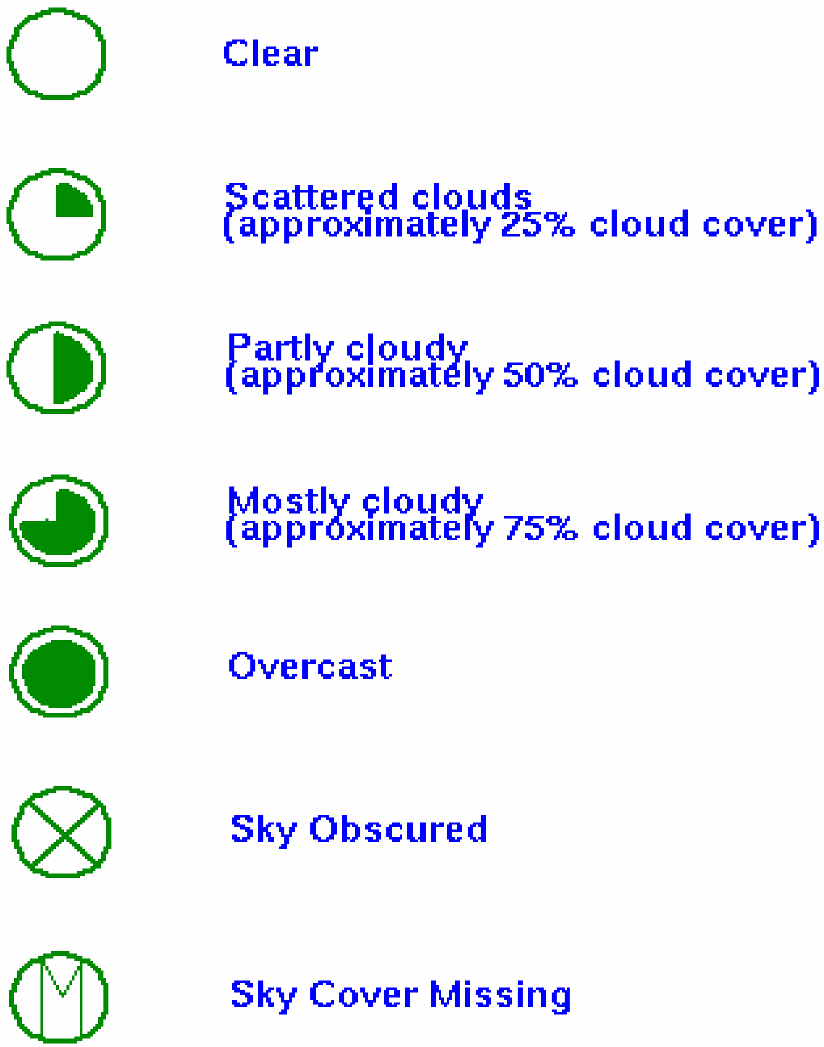
- http://ww2010.atmos.uiuc.edu/(Gh)/guides/maps/sfcobs/home.rxml

- **PRESSURE TREND**

  The pressure trend has two components, a number and symbol, to indicate how the sea-level pressure has changed during the past three hours. The number provides the 3-hour change in tenths of millibars, while the symbol provides a graphic illustration of how this change occurred. Below are the meanings of the pressure trend symbols:

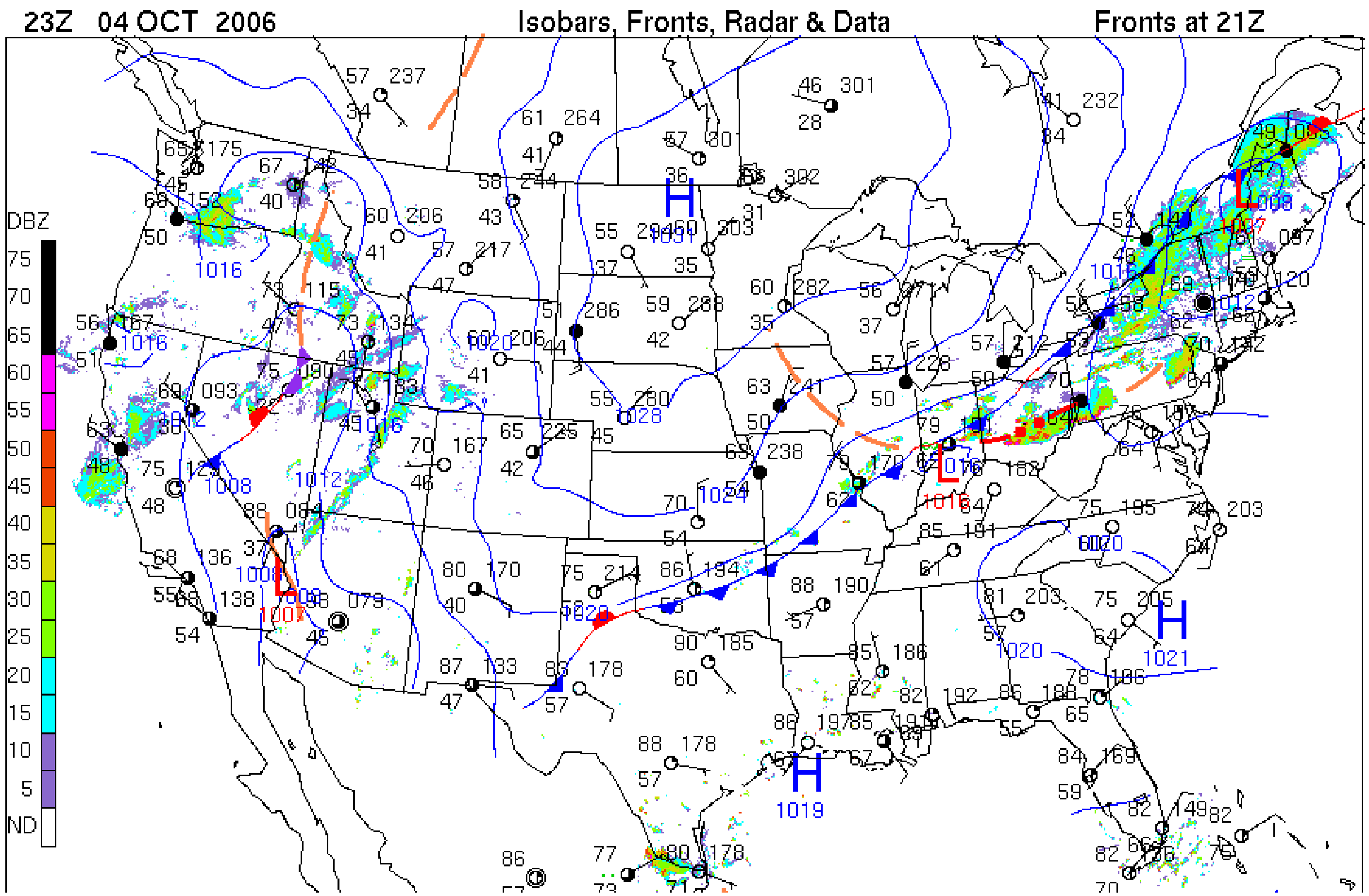
surface weather stations: sky cover

- The amount that the circle at the center of the station plot is filled in reflects the approximate amount that the sky is covered with clouds. To the right are the common cloud cover depictions



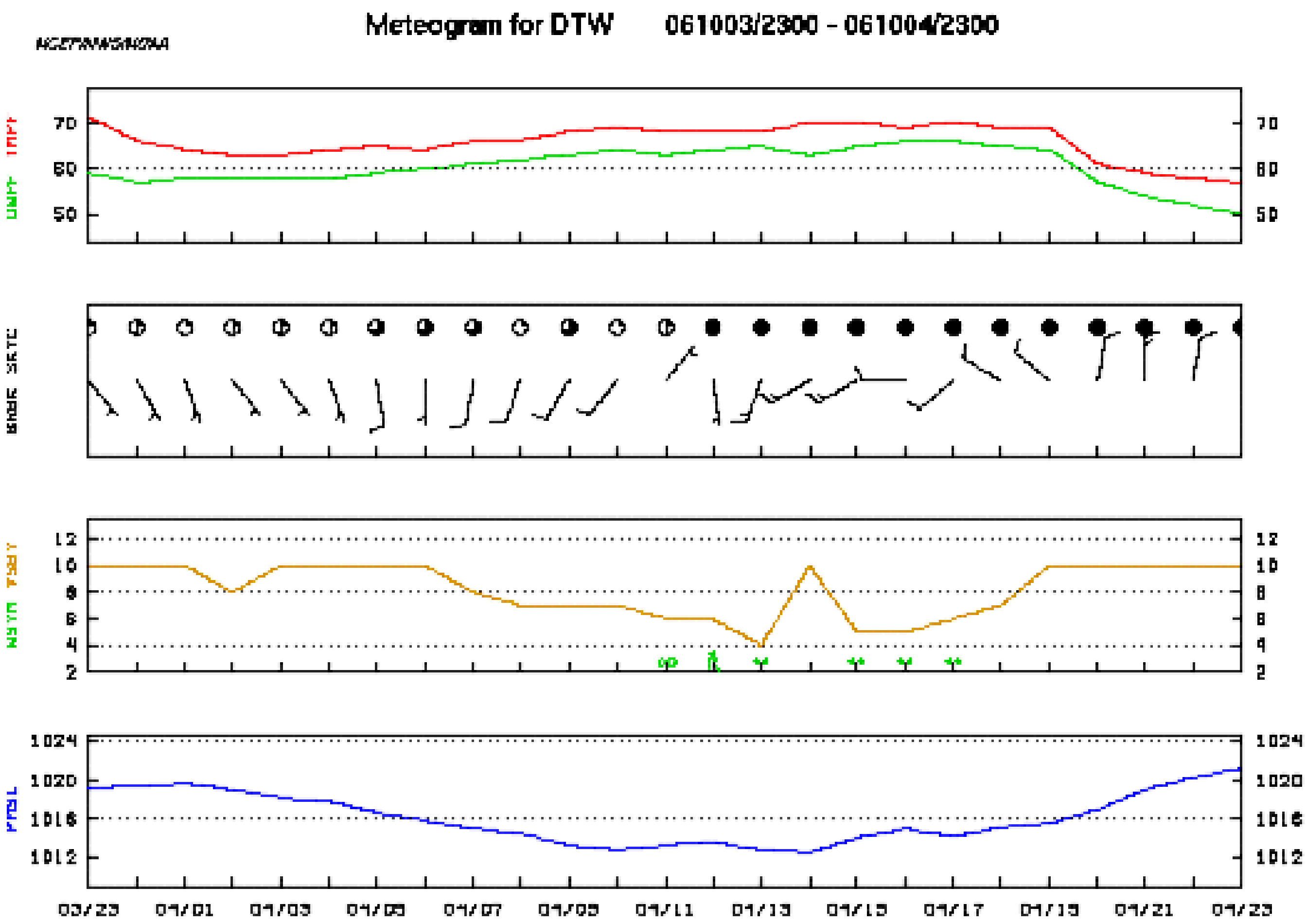
General knowledge - weather maps radar, fronts, isopleths and data

- **There is a tremendous amount of information on maps like these and they make excellent material for test questions. For instance, what type of front is about to enter the state of Arkansas? What is the current wind direction and speed for the surface weather station in central New Mexico? Students need to know their state maps!**



General knowledge - meteograms

- Meteograms give vast amounts of information about a given areas weather over a 24 hour period. Great thinking questions can be drawn from this material

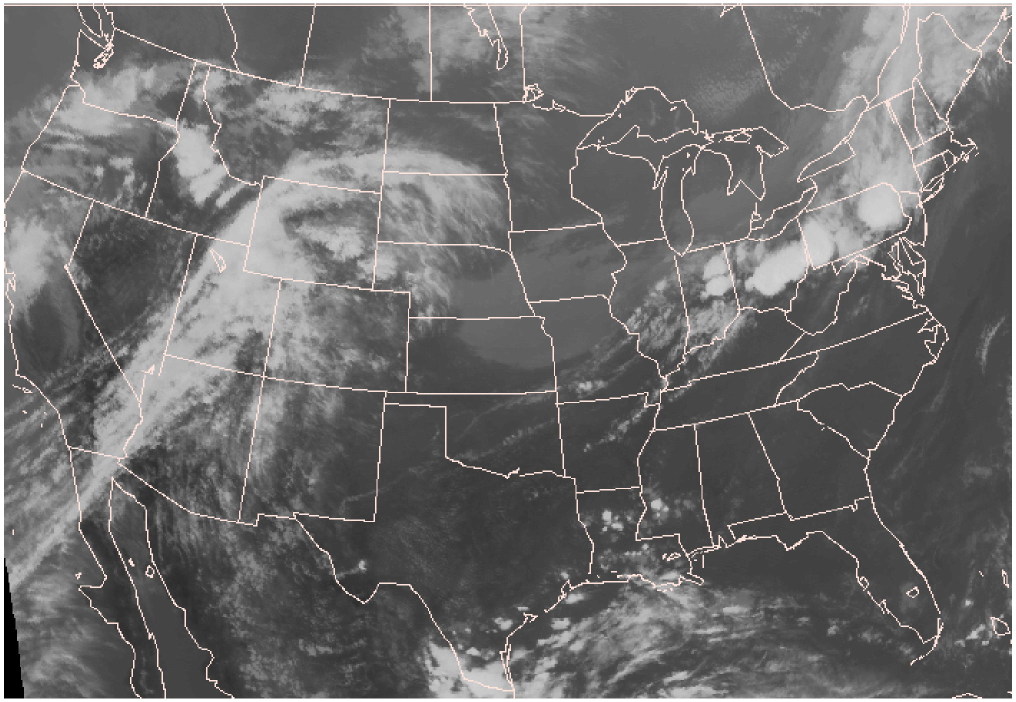


modern weather technology
satellites and radar imagery

- With the advent of satellites and radar vast amounts of weather data may be observed . . . It is learning what it all means and what it can do for us that is important.
- Lets look at some of the types of data collected by these satellites.
- These types of images are great ways to view severe storms

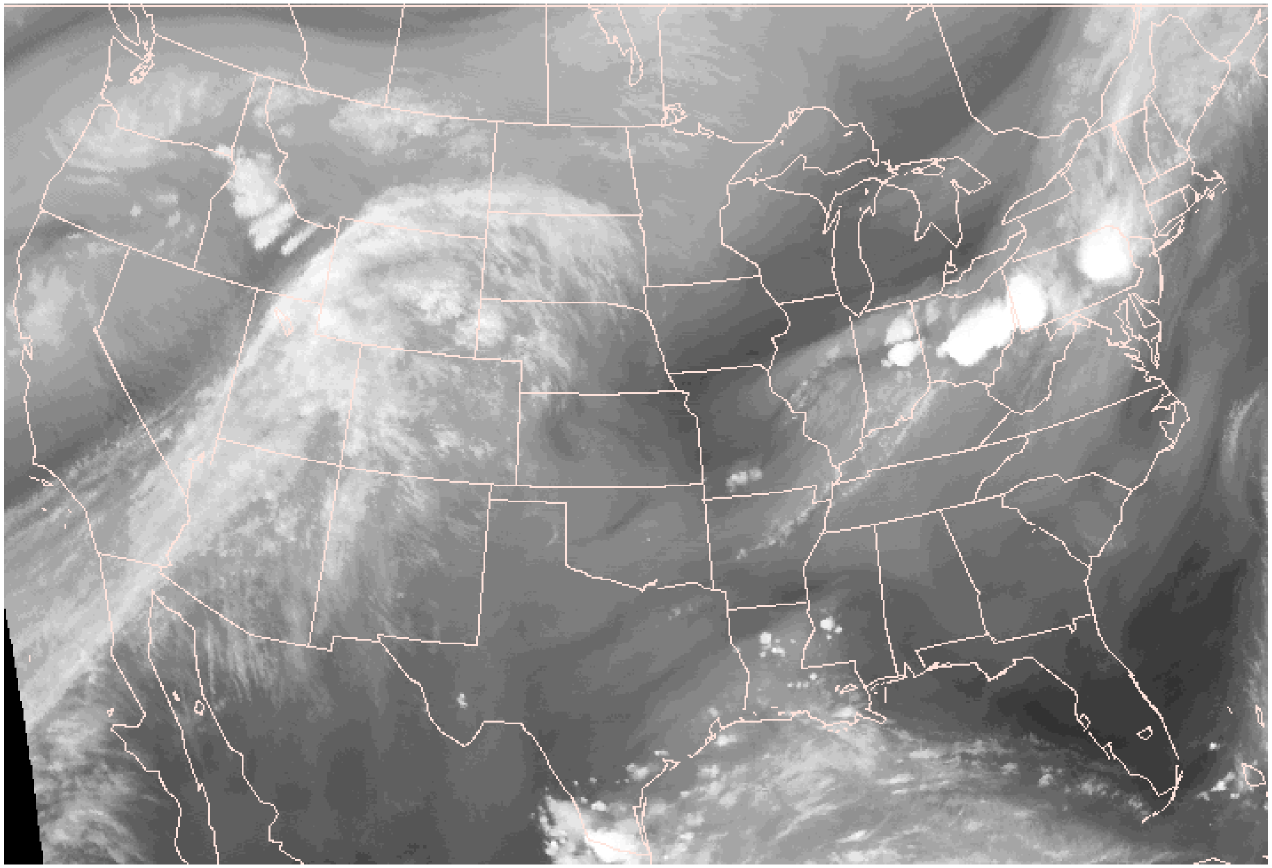
weather technology: infrared imagery

- These images come from satellites which remain above a fixed point on the Earth (i.e. they are "geostationary"). The infrared image shows the invisible infrared radiation emitted directly by cloud tops and land or ocean surfaces. The warmer an object is, the more intensely it emits radiation, thus allowing us to determine its temperature. These intensities can be converted into grayscale tones, with cooler temperatures showing as lighter tones and warmer as darker.
- Lighter areas of cloud show where the cloud tops are cooler and therefore where weather features like fronts and shower clouds are. The advantage of infrared images is that they can be recorded 24 hours a day. However low clouds, having similar temperatures to the underlying surface, are less easily discernable. Coast-lines and lines of latitude and longitude have been added to the images and they have been altered to northern polar stereographic projection.
- The infrared images are updated every hour. It usually takes about 20 minutes for these images to be processed and be updated on the website. The time shown on the image is in UTC.



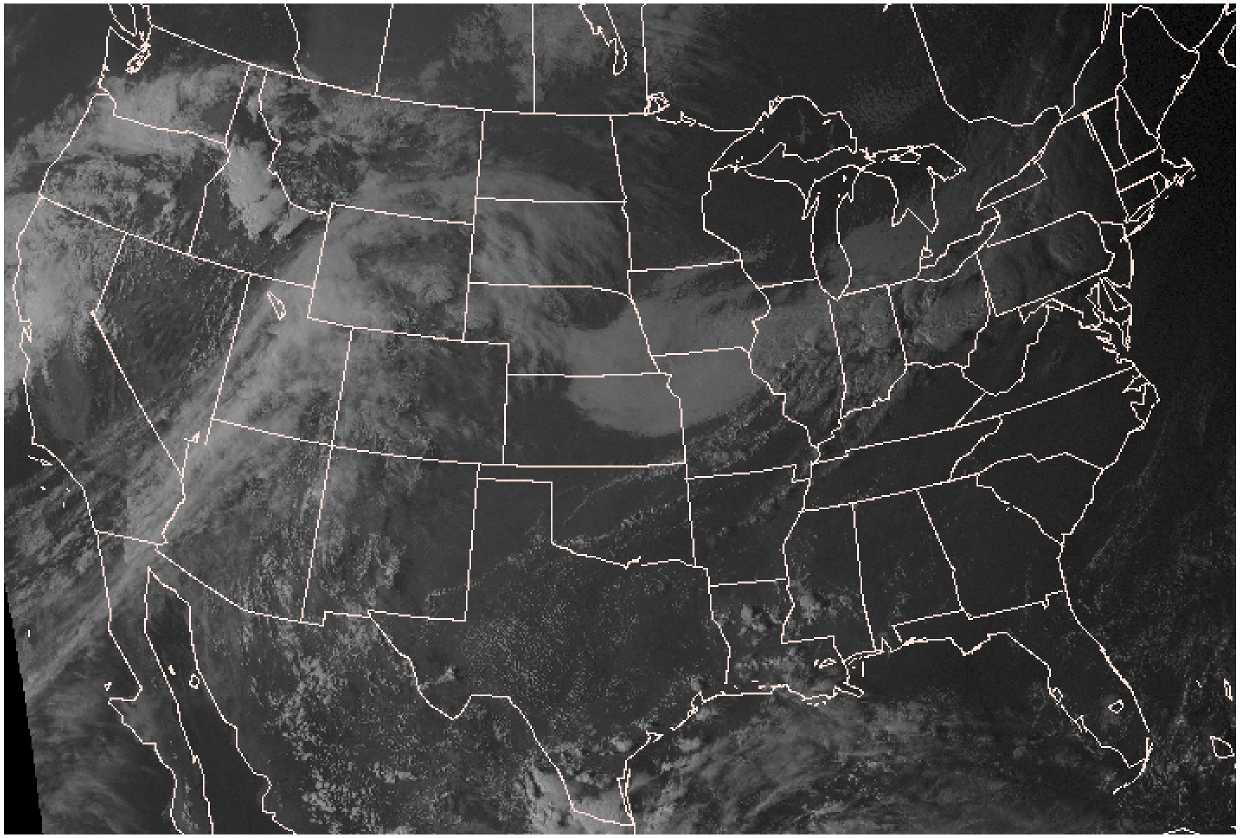
modern weather technology
water vapor imagery

- These images come from satellites which remain above a fixed point on the Earth (geostationary). The image shows the water vapor in the atmosphere and is quite different from the visible or the infrared image.
- The are updated every hour.

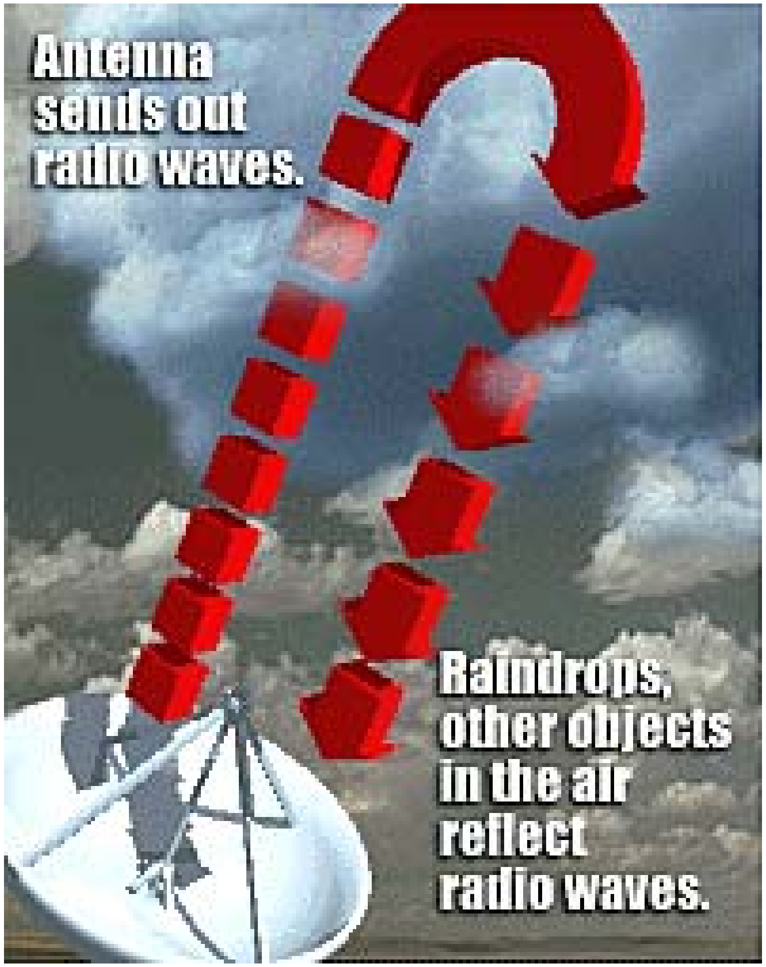


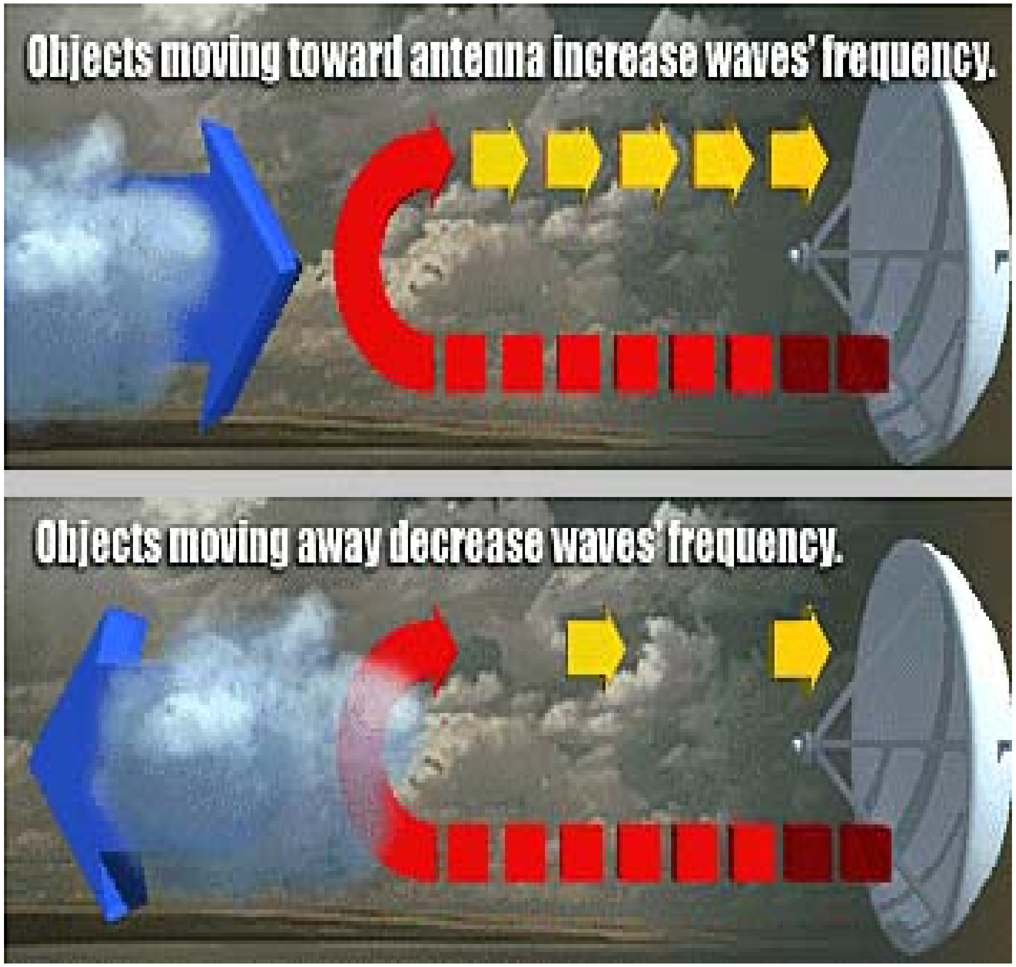
modern weather technology
visible light imagery

- These images come from satellites which remain above a fixed point on the Earth (geostationary). The visible image record visible light from the sun reflected back to the satellite by cloud tops and land and sea surfaces. They are equivalent to a black and white photograph from space. They are better able to show low cloud than infrared images. However, visible pictures can only be made during daylight hours. The visible images are updated hourly and the time shown on the image is in UTC.



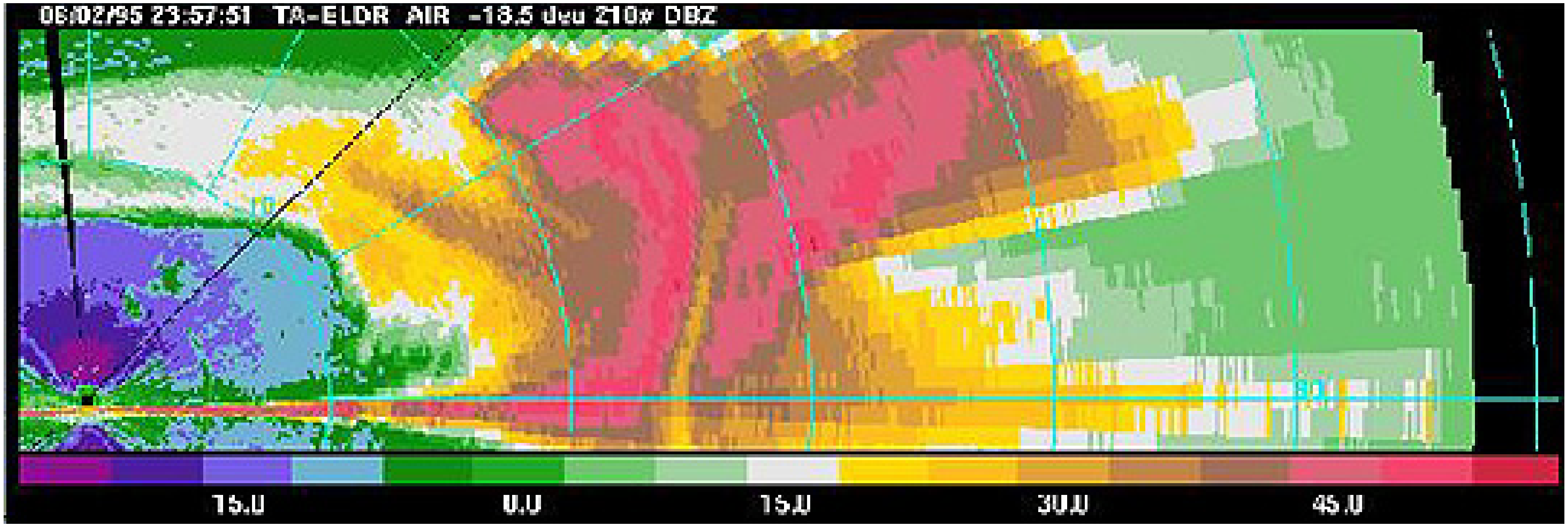
Doppler weather radar – how it works





Doppler weather radar – what it shows

- All weather radars send out radio waves from an antenna. Objects in the air, such as raindrops, snow crystals, hailstones or even insects and dust, scatter or reflect some of the radio waves back to the antenna. All weather radars, including Doppler, electronically convert the reflected radio waves into pictures showing the location and intensity of precipitation.
- Doppler radars also measure the frequency change in returning radio waves.
- Waves reflected by something moving away from the antenna change to a lower frequency, while waves from an object moving toward the antenna change to a higher frequency.
- The computer that's a part of a Doppler radar uses the frequency changes to show directions and speeds of the winds blowing around the raindrops, insects and other objects that reflected the radio waves.
- Scientists and forecasters have learned how to use these pictures of wind motions in storms, or even in clear air, to more clearly understand what's happening now and what's likely to happen in the next hour or two.



Doppler weather radar – what it shows

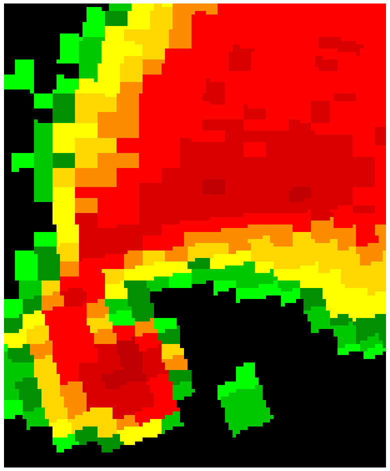
- **Precipitation Intensity levels**

- **Radar images are color-coded to indicate precipitation intensity. The scale below is used on radar mages. The light blue color is the lightest precipitation and the purple and white are the heaviest. Sometimes radar images indicate virga, or precipitation that isn't reaching the ground.**

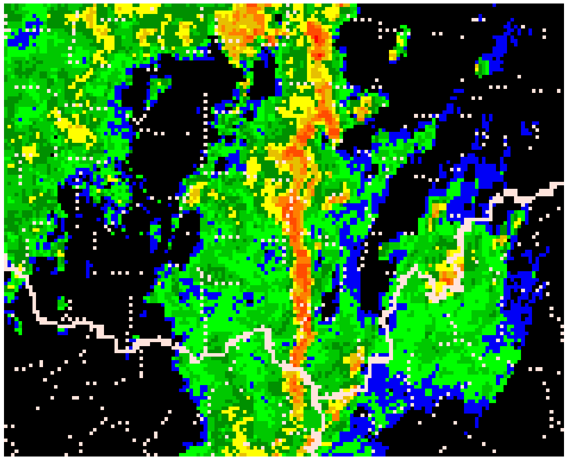
- **Precipitation type**

- **Reflectivity not only depends on precipitation intensity, but also the type of precipitation. Hail and sleet are made of ice and their surfaces easily reflect radio energy. This can cause light sleet to appear heavy. Snow, on the other hand, can scatter the beam, causing moderate to heavy snow to appear light.**

Doppler weather radar – what it shows

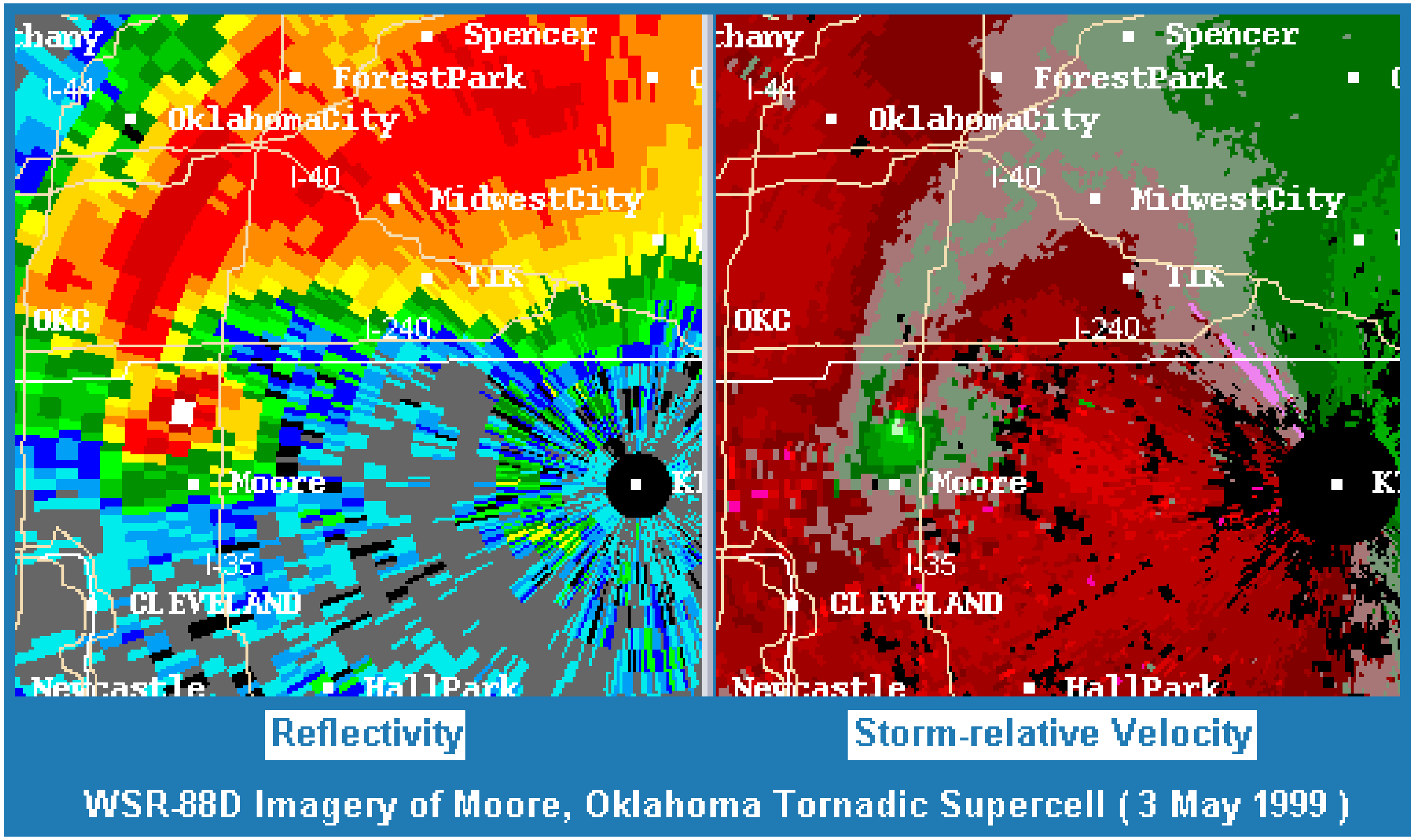


- **Hook echo**
- **These are commonly found in a single thunderstorm, in which the reflectivity image resembles a hook. When this occurs, the thunderstorm is producing a circulation and possibly a tornado. The rain gets wrapped around this circulation in the shape of a hook. In this image, a thunderstorm with a hook echo moves across central Oklahoma May 3, 1999.**



- **Squall line thunderstorms**
- **An organized line of thunderstorms is known as squall line. These are common during the spring and are usually triggered along cold fronts. In this picture, a squall line slices across southern Ohio ahead of a cold front.**

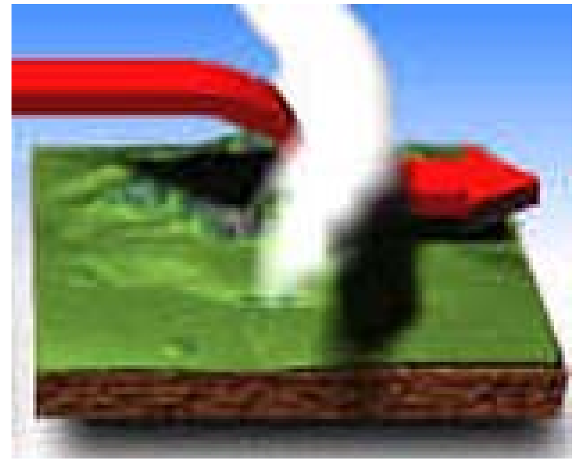
Doppler weather radar – what it shows

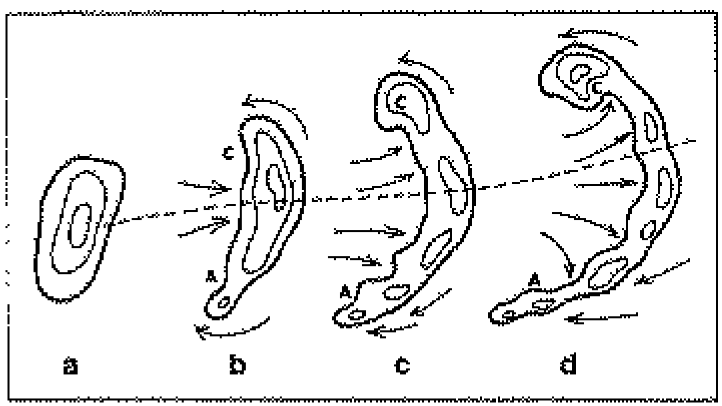


- **Tornado vortex signature**
- **Doppler radar can tell when a thunderstorm has Tornado Vortex Signature (TVS). This indicates where wind directions are changing — known as shear —- within a small area and there is rotation. There is also a strong possibility that a tornado will form in that area. A National Weather Service forecaster could issue a tornado warning based on this radar signature.**

Doppler weather radar – what it shows

- **Bow echoes**
- **Bow echoes are clusters of thunderstorms that resemble a bow, where the center of the line extends past the two ends of the line. This bow shape is a result of strong winds in the upper levels of the atmosphere that often mix down to the surface.**





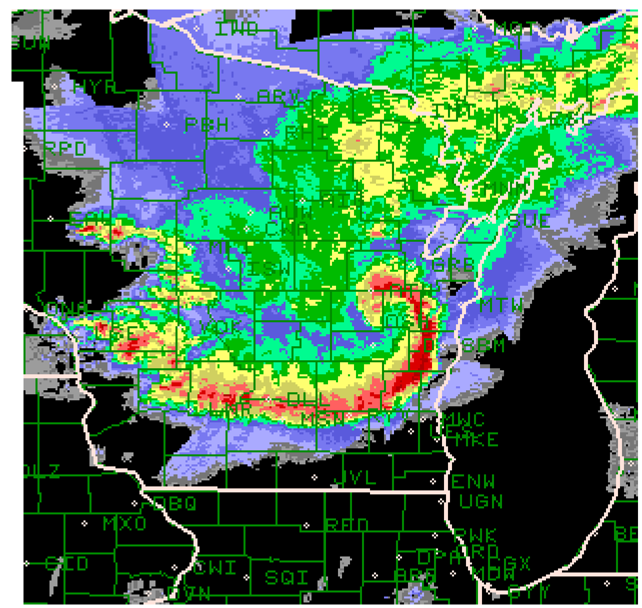
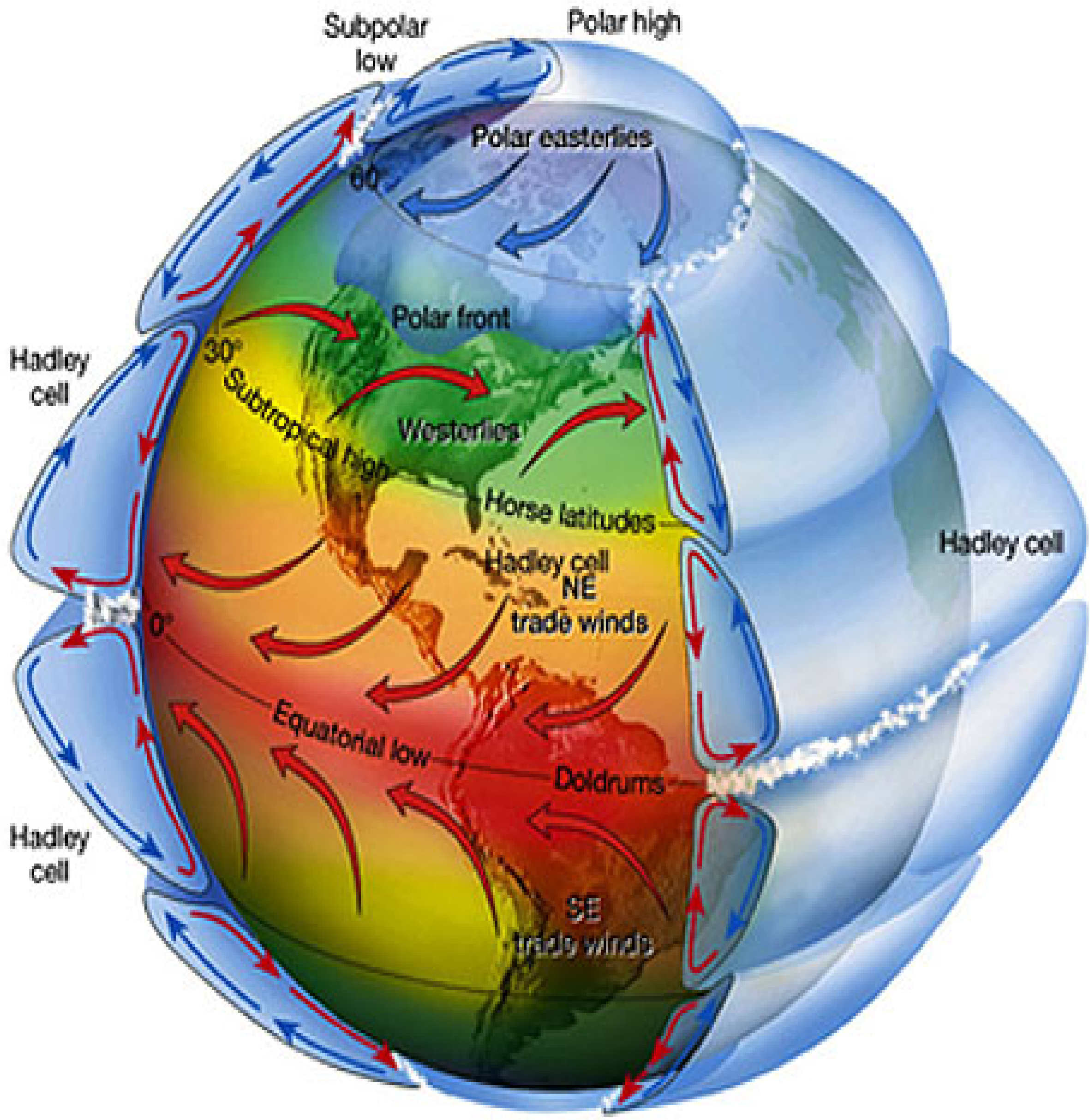


Fig. 1. Bow echo. Typical evolution of a thunderstorm radar echo (a) into a bow echo (b, c) and into a comma echo (d). Dashed line indicates axis of greatest potential for downbursts. Arrows indicate wind flow relative to the storm. Note regions of cyclonic rotation (C) and anticyclonic rotation (a); both regions, especially C, are capable of supporting tornado development in some cases.

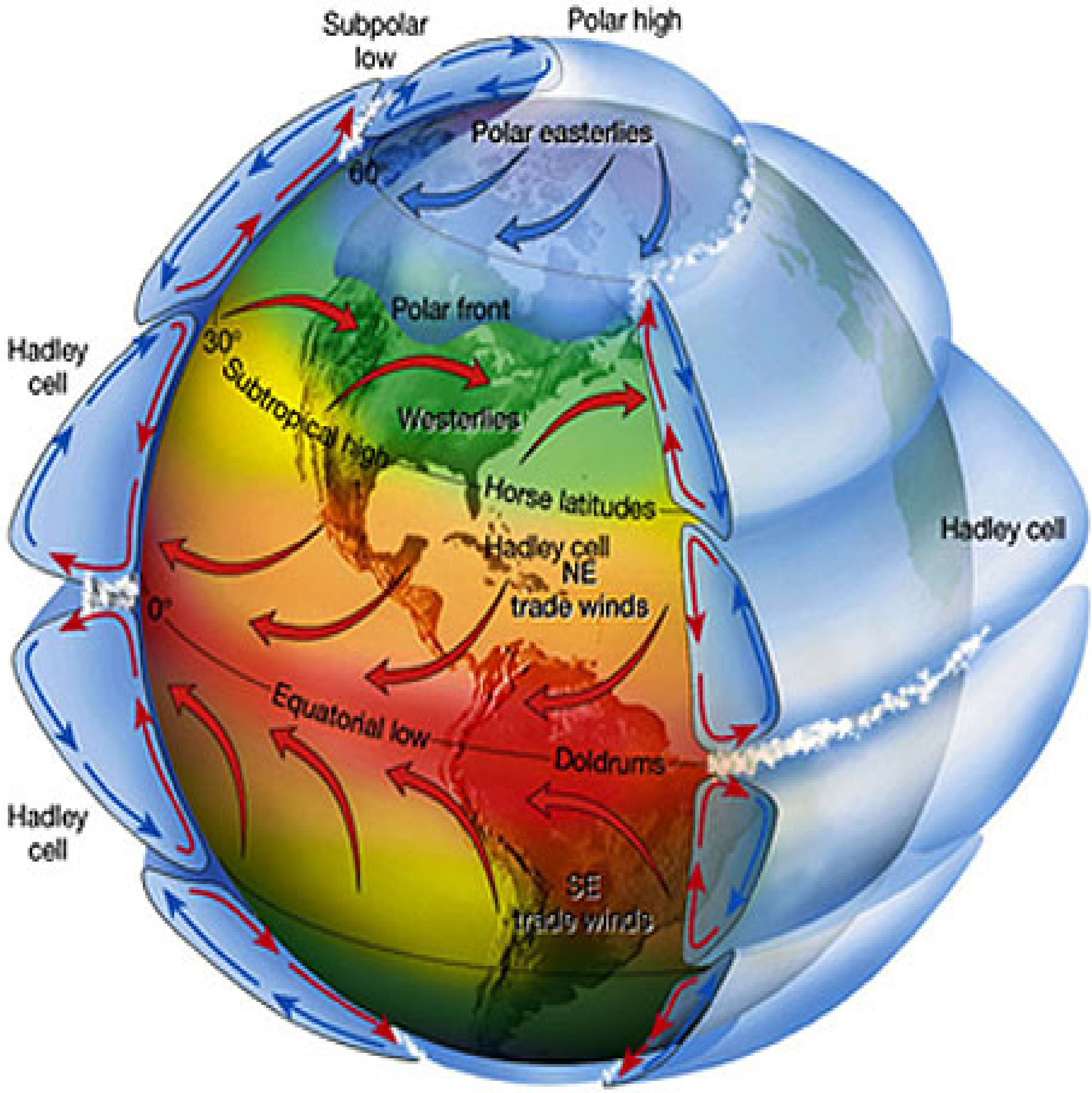
GLOBAL ATMOSPHERIC CIRCULATION: PLANETARY WINDS AND CORIOLIS

- In the three cell model, the equator is the warmest location on the Earth and acts as a zone of thermal lows known as the intertropical convergence zone (**ITCZ**).
- The ITCZ draws in surface air from the subtropics and as it reaches the equator, it rises into the upper atmosphere by convergence and convection. It attains a maximum vertical altitude of about 14 kilometers (top of the troposphere), then begins flowing horizontally to the North and South Poles.
- Coriolis force causes the deflection of this moving air, and by about 30° of latitude the air begins to flow zonally from west to east.



GLOBAL ATMOSPHERIC CIRCULATION: PLANETARY WINDS AND CORIOLIS

- This zonal flow is known as the subtropical. The zonal flow also causes the accumulation of air in the upper atmosphere as it is no longer flowing meridionally.
- To compensate for this accumulation, some of the air in the upper atmosphere sinks back to the surface creating the subtropical high pressure zone.
- From this zone, the surface air travels in two directions. A portion of the air moves back toward the equator completing the circulation system known as the Hadley cell. This moving air is also deflected by the Coriolis effect to create the Northeast Trades (right deflection) and Southeast Trades (left deflection).



ATMOSPHERIC CIRCULATION: PLANETARY WINDS AND CORIOLIS

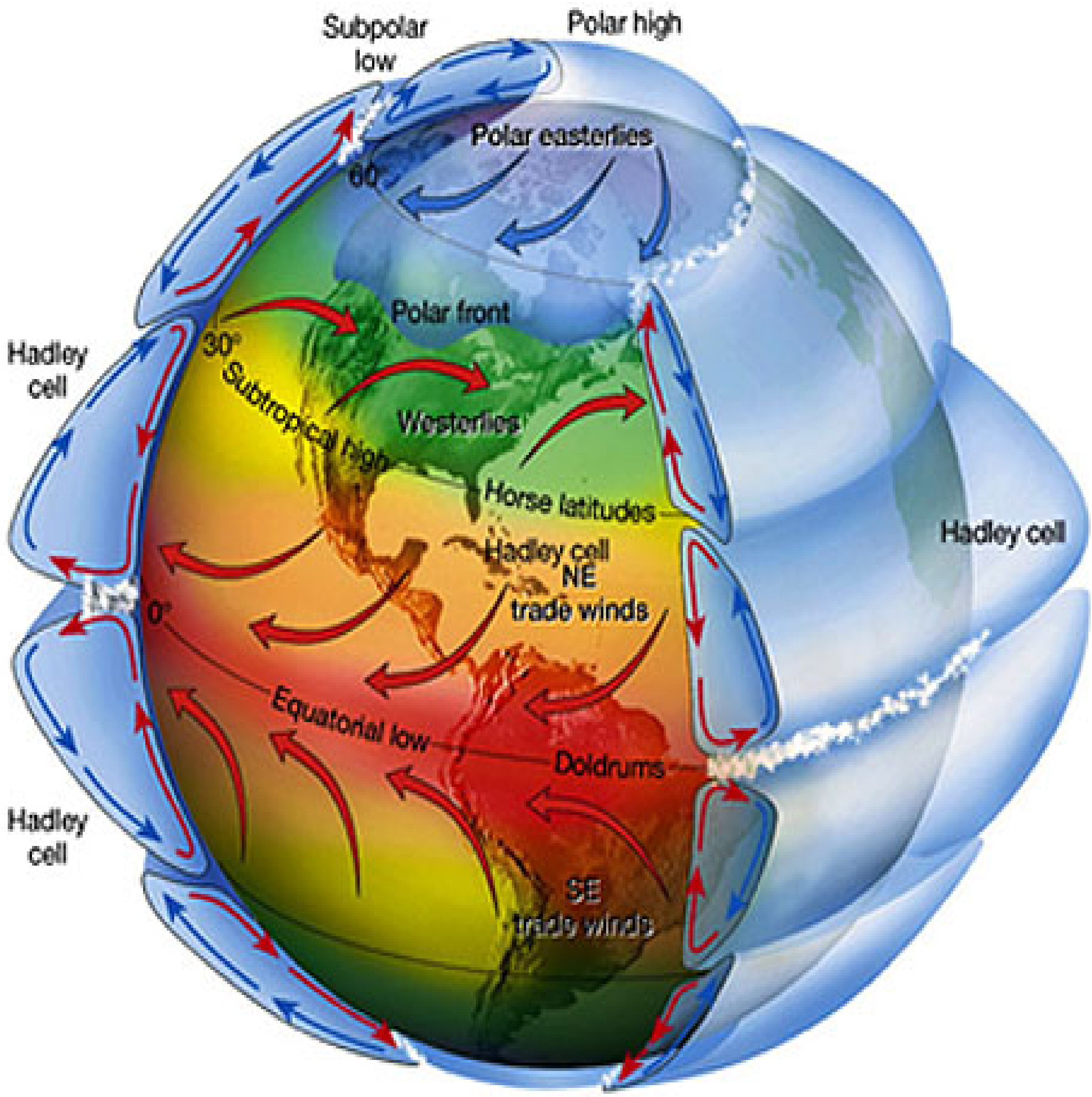
- The surface air moving towards the poles from the subtropical high zone is also deflected by Coriolis acceleration producing the Westerlies.

- Between the latitudes of 30 to 60° North and South, upper air winds blow generally towards the poles. Once again, Coriolis force deflects this wind to cause it to flow west to east forming the polar jet stream at roughly 60° North and South.

- On the Earth's surface at 60° North and South latitude, the subtropical Westerlies collide with cold air traveling from the poles. This collision results in frontal uplift and the creation of the subpolar lows or mid latitude cyclones.

- A small portion of this lifted air is sent back into the Ferrel Cell after it reaches the top of the troposphere. Most of this lifted air is directed to the polar vortex where it moves downward to create the polar high.

- http://www.physicalgeography.net/fundamentals/7p.html



THUNDERSTORMS

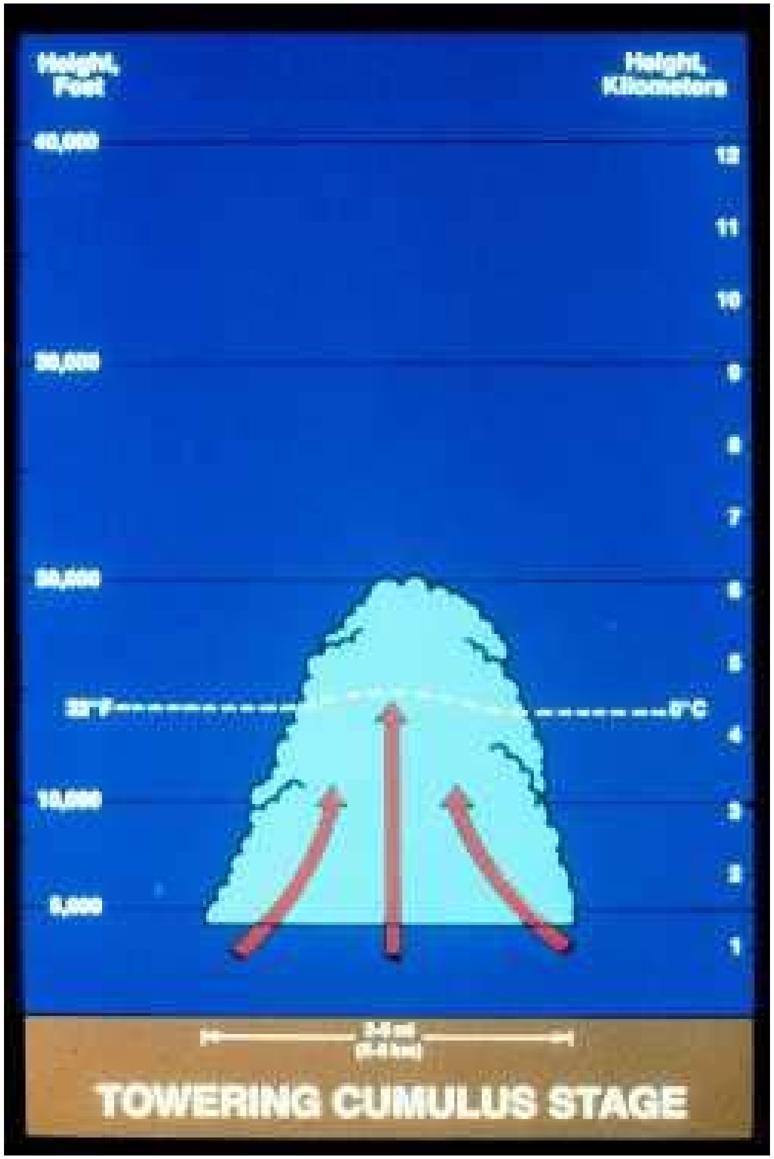
http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/tstorm.html

- It is late afternoon. The white puffy clouds that have been growing all day are replaced by a greenish sky. A distant rumble is heard...then another. It starts to rain. A flash of light streaks the sky, followed by a huge BOOM. Welcome to a thunderstorm.

- Thunderstorms are one of the most thrilling and dangerous of weather phenomena. Over 40,000 thunderstorms occur throughout the world *each day*.

- Thunderstorms have several distinguishing characteristics that can cause large amounts of damage to humans and their property. Straight-line winds and tornadoes can uproot trees and demolish buildings. Hail can damage cars and crops. Heavy rains can create flash floods. Lightning can spark a forest fire or hurt you. safety during a thunderstorm is really important.

THUNDERSTORMS – FORMATION



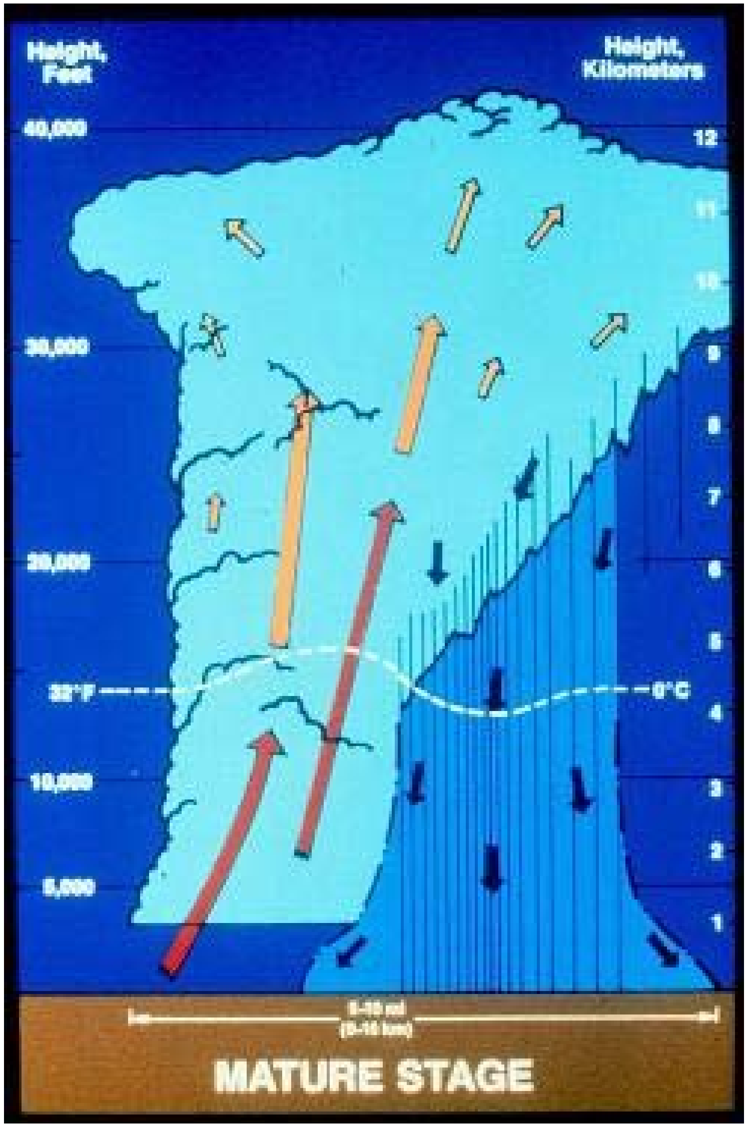
- The initial stage of development is called the ***cumulus stage***. During this stage warm, moist, and unstable air is lifted from the surface. In the case of an air mass thunderstorm, the uplift mechanism is convection. As the air ascends, it cools and upon reaching its dew point temperature begins to condense into a cumulus cloud. Near the end of this stage precipitation forms.

- http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/weather_systems/severe_weather_thunderstorms.html

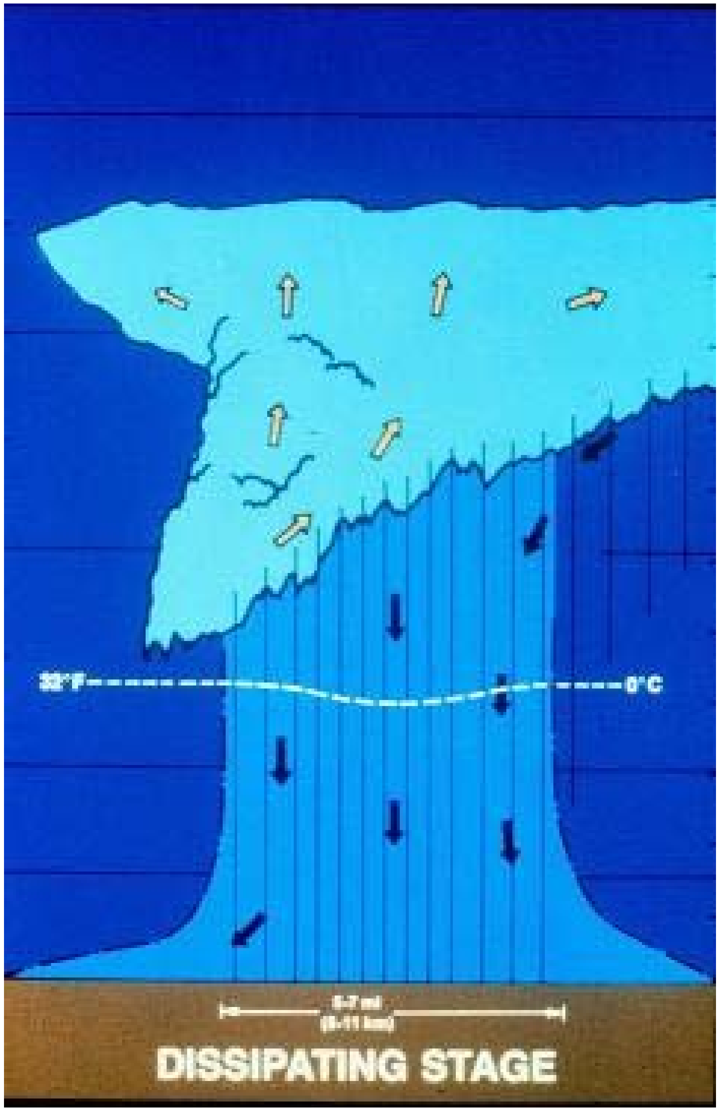
THUNDERSTORMS – FORMATION

- The second stage is the ***mature stage*** of development. During the mature stage warm, moist updrafts continue to feed the thunderstorm while cold downdrafts begin to form. The downdrafts are a product of the entrainment of cool, dry air into the cloud by the falling rain. As rain falls through the air it drags the cool, dry air that surrounds the cloud into it. As dry air comes in contact with cloud and rain droplets they evaporate cooling the cloud. The falling rain drags this cool air to the surface as a cold downdraft. In severe thunderstorms the region of cold downdrafts is separate from that of warm updrafts feeding the storm. As the downdraft hits the surface it pushes out ahead of the storm. Sometimes you can feel the downdraft shortly before the thunderstorm reaches your location as a cool blast of air.

- http://www.nssl.noaa.gov/primer/tstorm/tst_basics.html



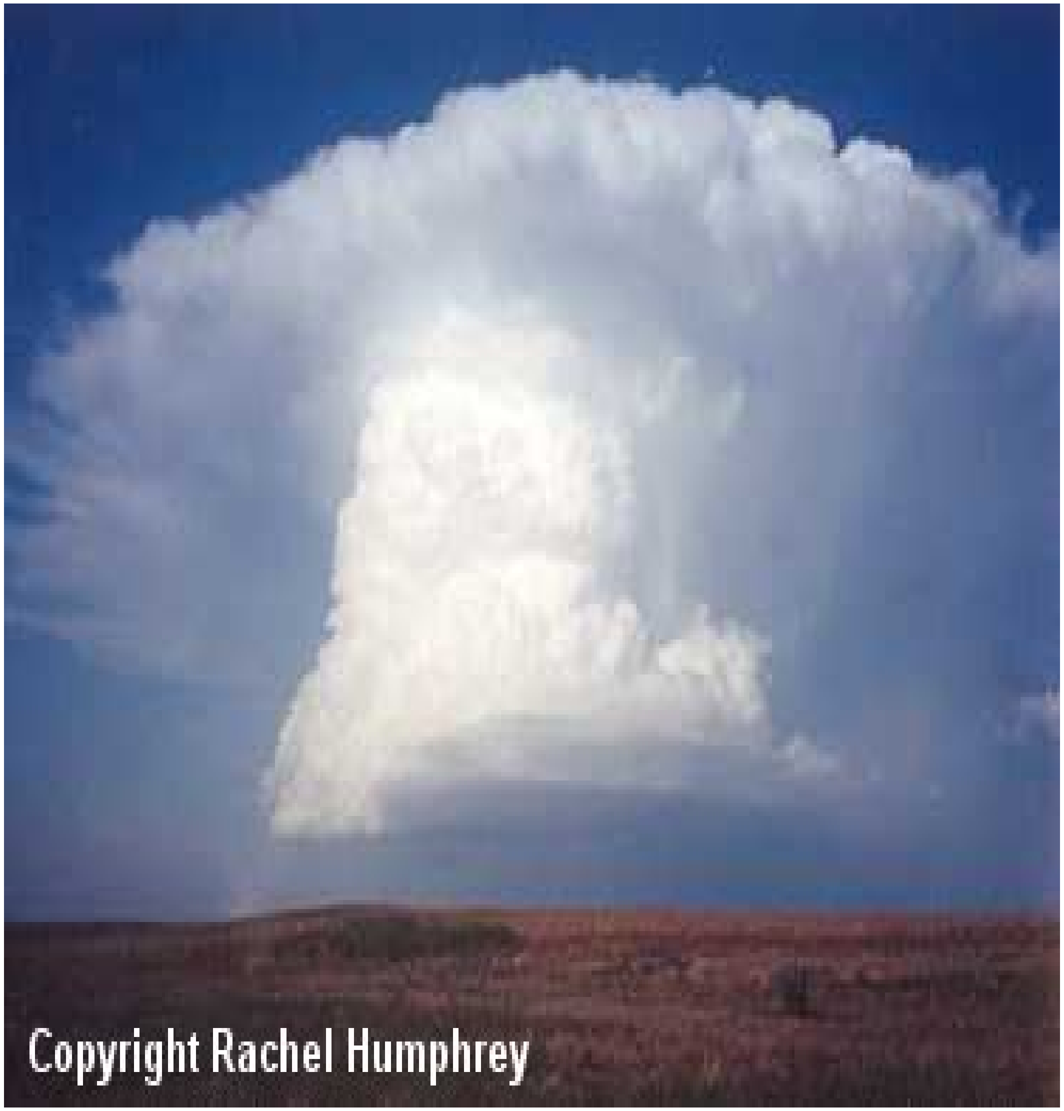
THUNDERSTORMS - FORMATION



- The final stage is the ***dissipating stage*** when the thunderstorm dissolves away. By this point, the entrainment of cool air into the cloud helps stabilize the air. In the case of the air mass thunderstorm, the surface no longer provides enough convective uplift to continue fueling the storm. As a result, the warm updrafts have ceased and only the cool downdrafts are present. The downdrafts end as the rain ceases and soon the thunderstorm dissipates.

http://www.nssl.noaa.gov/primer/tstorm/tst_climatology.html

THE SINGLE CELL STORM – air mass thunder storm



Single cell thunderstorms usually last between 20-30 minutes. A true single cell storm is actually quite rare because often the gust front of one cell triggers the growth of another.

Most single cell storms are not usually severe. However, it is possible for a single cell storm to produce a brief severe weather event. When this happens, it is called a pulse severe storm. Their updrafts and downdrafts are slightly stronger, and typically produce hail that barely reaches severe limits and/or brief microbursts (a strong downdraft of air that hits the ground and spreads out). Brief heavy rainfall and occasionally a weak tornado are possible. Though pulse severe storms tend to form in more unstable environments than a non-severe single cell storm, they are usually poorly organized and seem to occur at random times and locations, making them difficult to forecast.

THE MULTI-CELL CLUSTER STORM

- The multicell cluster is the most common type of thunderstorm. The multicell cluster consists of a group of cells, moving along as one unit, with each cell in a different phase of the thunderstorm life cycle. Mature cells are usually found at the center of the cluster with dissipating cells at the downwind edge of the cluster.
- Multicell Cluster storms can produce moderate size hail, flash floods and weak tornadoes.
- Each cell in a multicell cluster lasts only about 20 minutes; the multicell cluster itself may persist for several hours. This type of storm is usually more intense than a single cell storm, but is much weaker than a supercell storm.
- http://www.mcwar.org/articles/types/tstorm_types.html

THE MULTI-CELL CLUSTER STORM

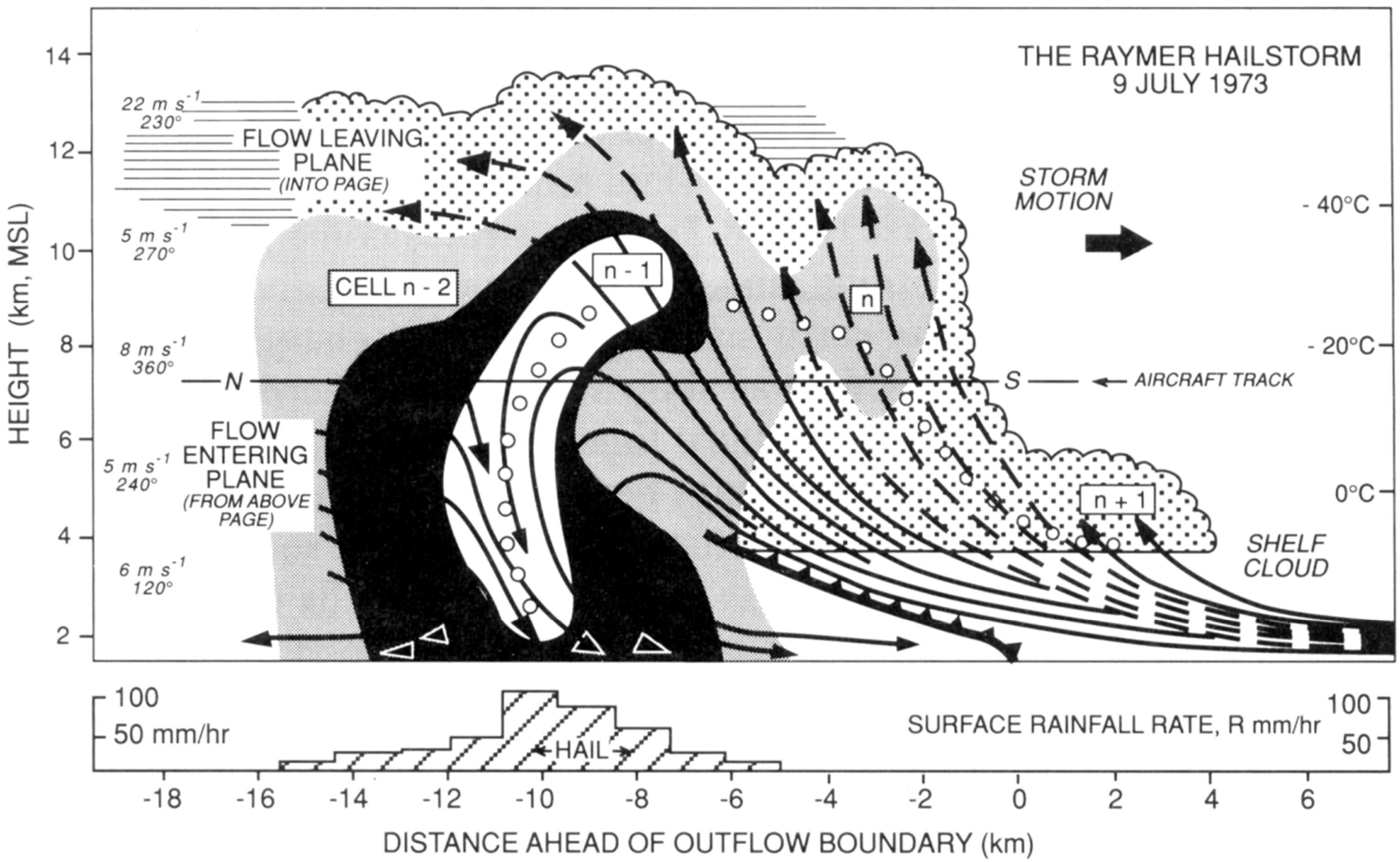


FIG. 3 Schematic diagram of a multicell cluster observed near Raymer, CO (from Houze, 1993).

THE MULTI-CELL CLUSTER STORM

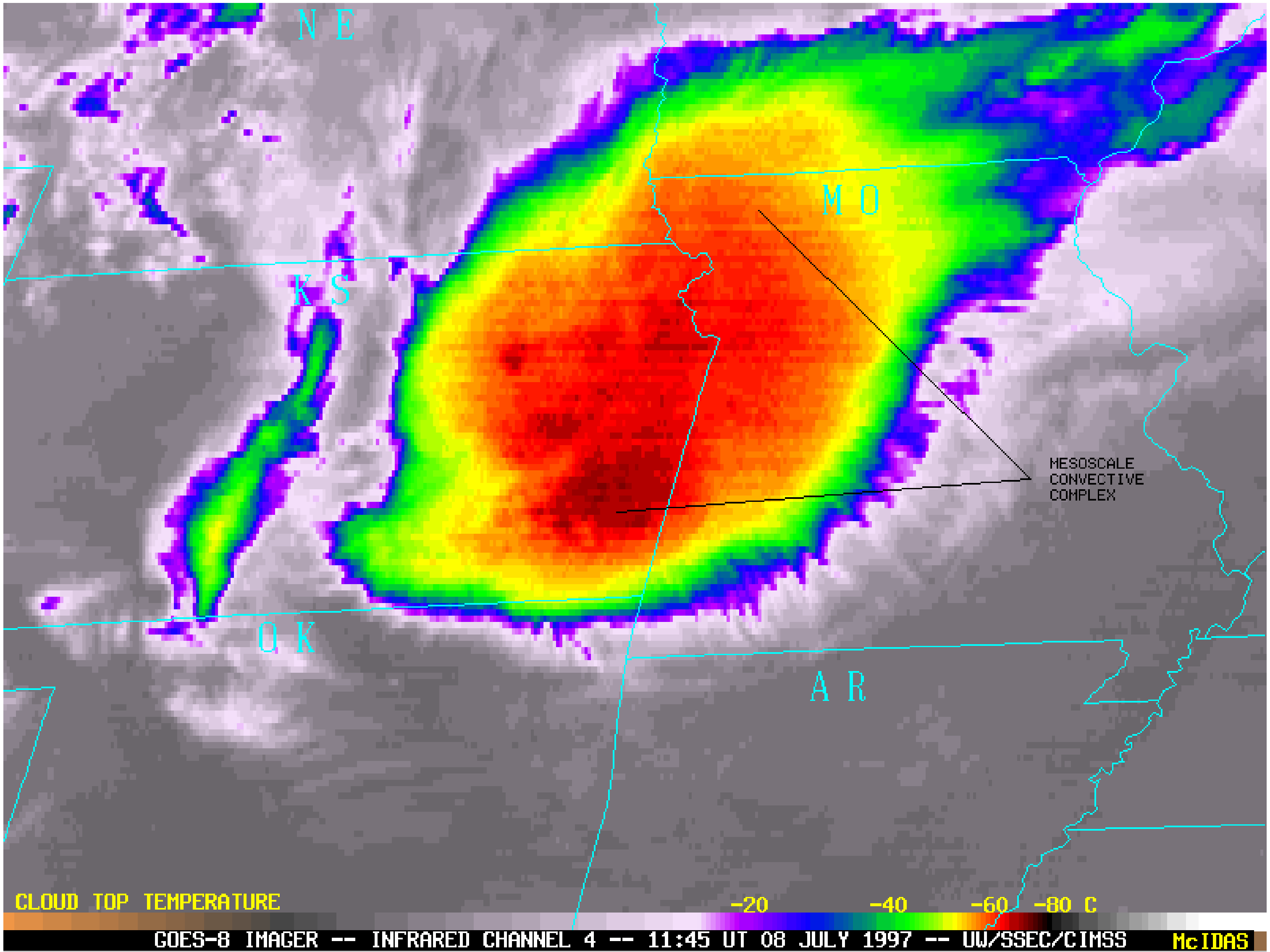


FIG. 2 GOES-8 infrared image of an MCC over KS /MO (from CIMMS, 1997).

MULTICELL LINE STORM - SQUALL LINE

- The multicell line storm, or squall line, consists of a long line of storms with a continuous well-developed gust front at the leading edge of the line. The line of storms can be solid, or there can be gaps and breaks in the line.
- Squall lines can produce hail up to golf-ball size, heavy rainfall, and weak tornadoes, but they are best known as the producers of strong downdrafts. Occasionally, a strong downburst will accelerate a portion of the squall line ahead of the rest of the line. This produces what is called a bow echo. Bow echoes can develop with isolated cells as well as squall lines. Bow echoes are easily detected on radar but are difficult to observe visually.

MULTICELL LINE STORM - SQUALL LINE

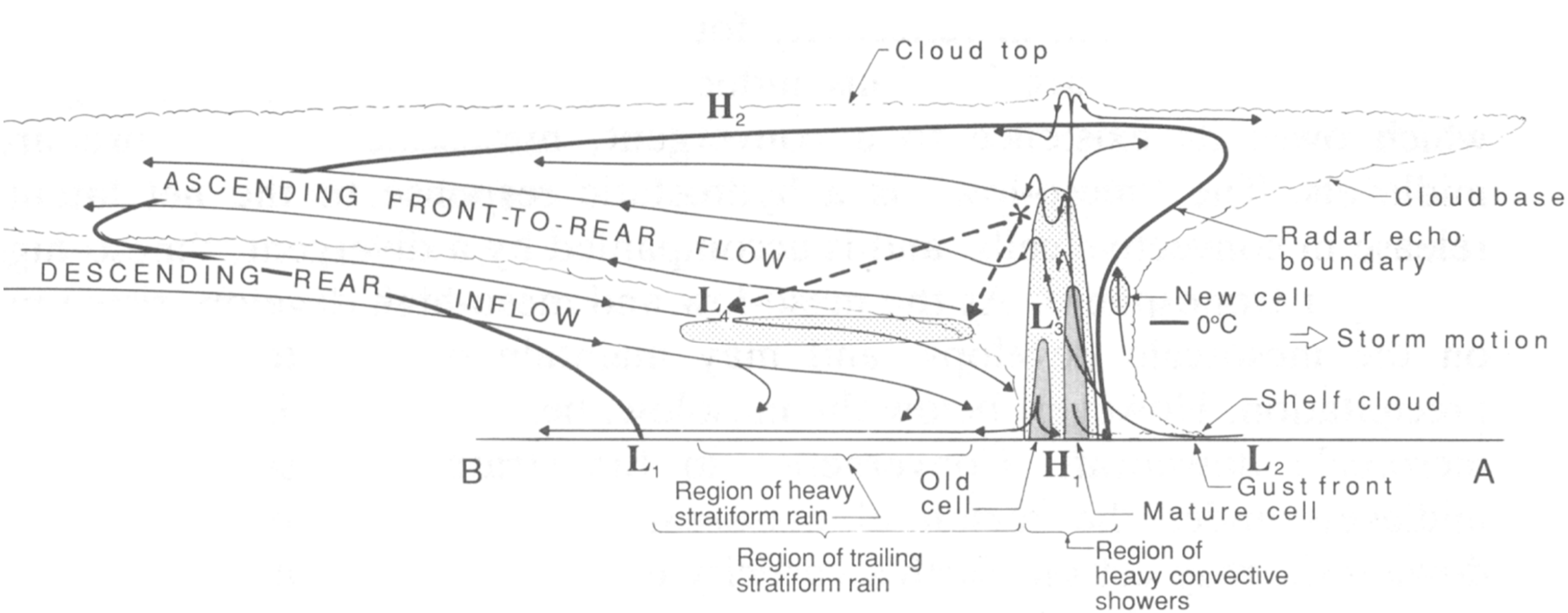


FIG. 4 Schematic diagram of an ideal multicell line or squall line (from Bluestein, 1993).

THE SUPERCELL STORM

- The supercell is a highly organized thunderstorm. Supercells are rare, but pose a high threat to life and property. A supercell is similar to the single-cell storm because they both have one main updraft. The difference in the updraft of a supercell is that the updraft is extremely strong, reaching estimated speeds of 150-175 miles per hour. The main characteristic which sets the supercell apart from the other thunderstorm types is the presence of rotation. The rotating updraft of a supercell (called a mesocyclone when visible on radar) helps the supercell to produce extreme severe weather events, such as giant hail (more than 2 inches in diameter, strong downbursts of 80 miles an hour or more, and strong to violent tornadoes.

- The surrounding environment is a big factor in the organization of a supercell. Winds are coming from different directions to cause the rotation. And, as precipitation is produced in the updraft, the strong upper-level winds blow the precipitation downwind. Hardly any precipitation falls back down through the updraft, so the storm can survive for long periods of time.

- The leading edge of the precipitation from a supercell is usually light rain. Heavier rain falls closer to the updraft with torrential rain and/or large hail immediately north and east of the main updraft. The area near the main updraft (typically towards the rear of the storm) is the preferred area for severe weather formation.

THE SUPERCELL STORM

THE SUPERCELL STORM

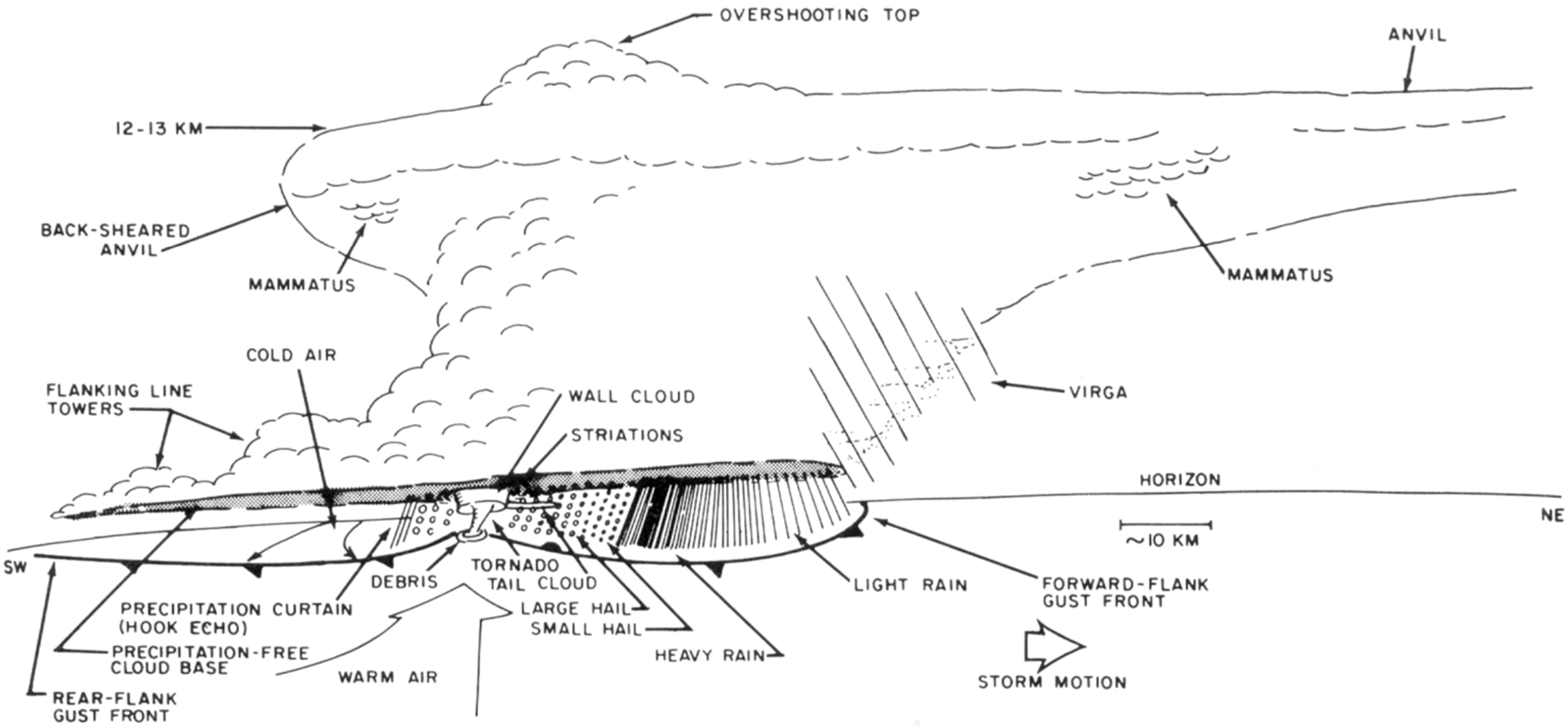
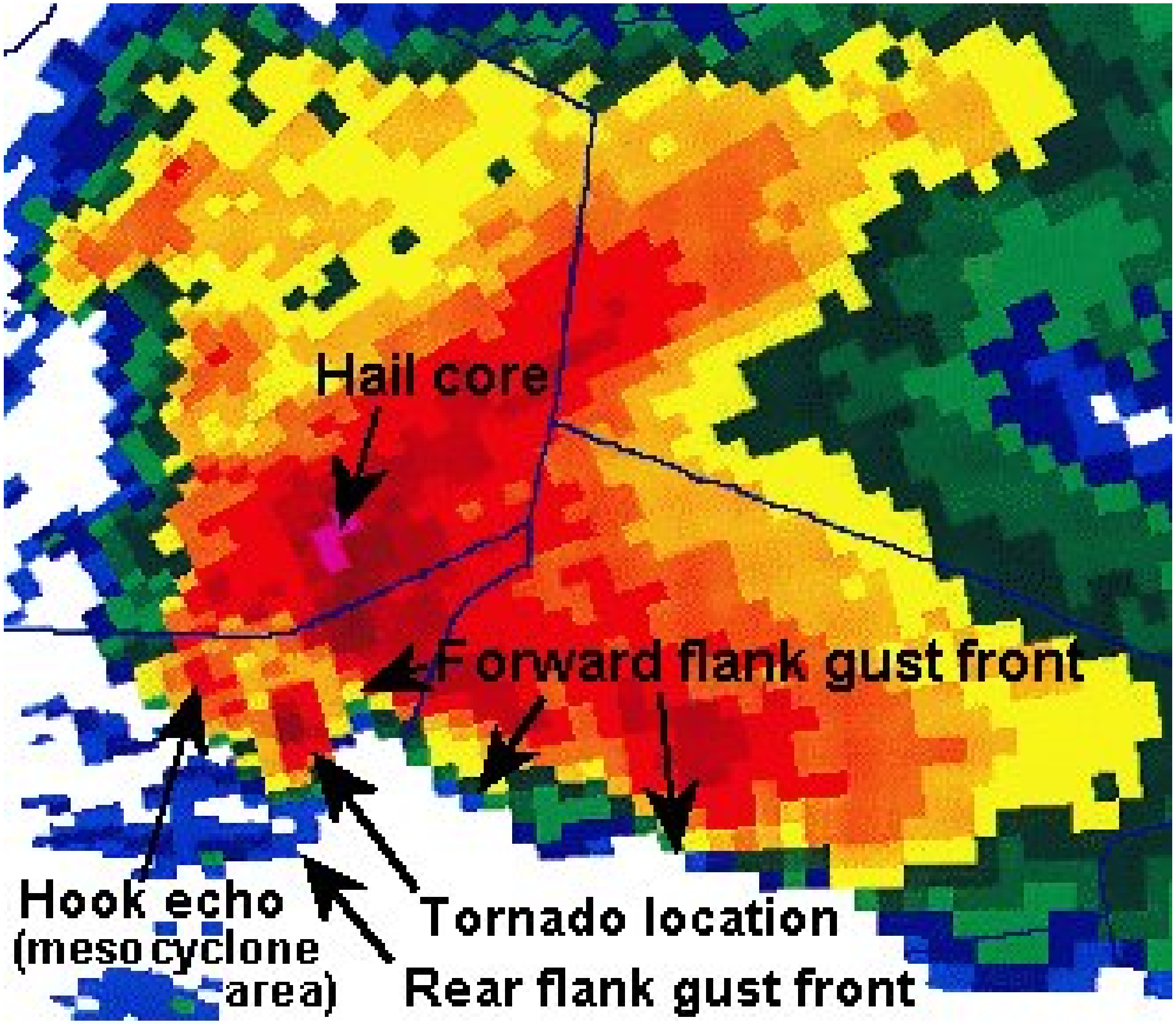
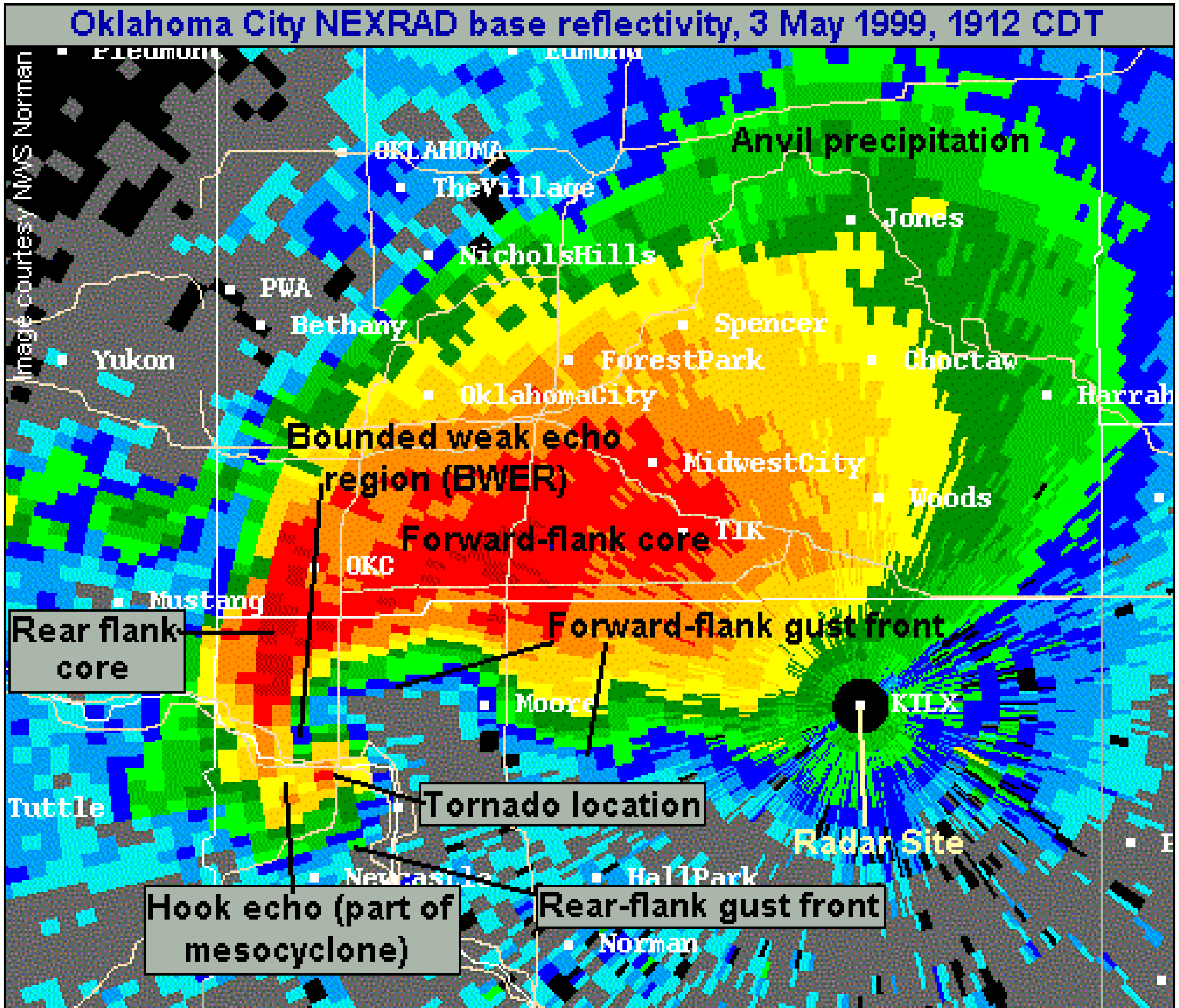


FIG. 5 Schematic diagram of an ideal supercell (from Houze, 1993).

THE SUPERCELL STORM and TORNADOS



THE SUPERCELL STORM and TORNADOS



RADAR DEPICTION OF A CLASSIC SUPERCELL CONTAINING A VIOLENT TORNADO

Lightning

http://thunder.msfc.nasa.gov/primer/

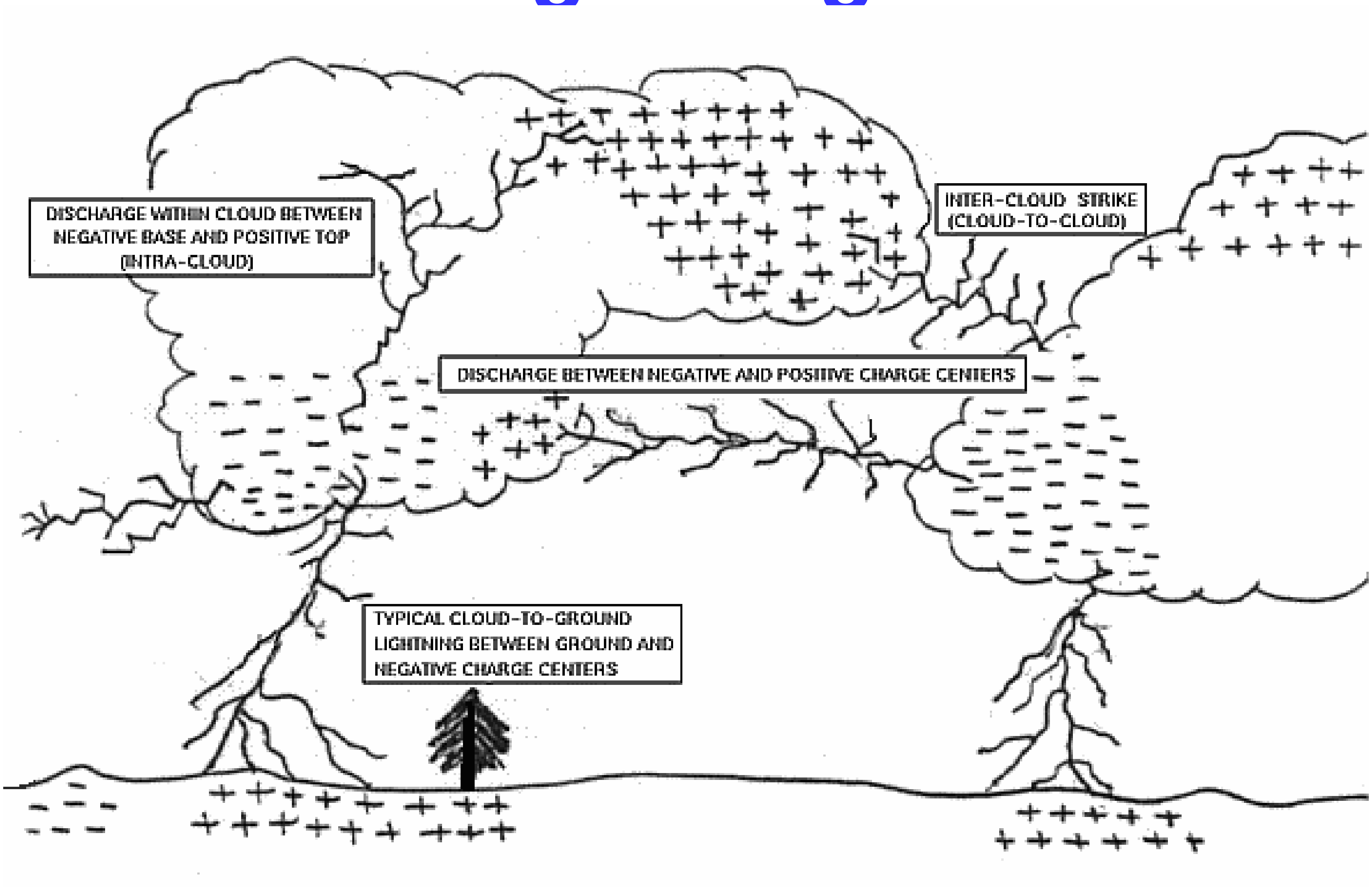
http://science.howstuffworks.com/lightning.htm

- Lightning is one of the most beautiful displays in nature. It is also one of the most deadly natural phenomena known to man. With bolt temperatures hotter than the surface of the sun and shockwaves beaming out in all directions, lightning is a lesson in physical science and humility.

Lightning

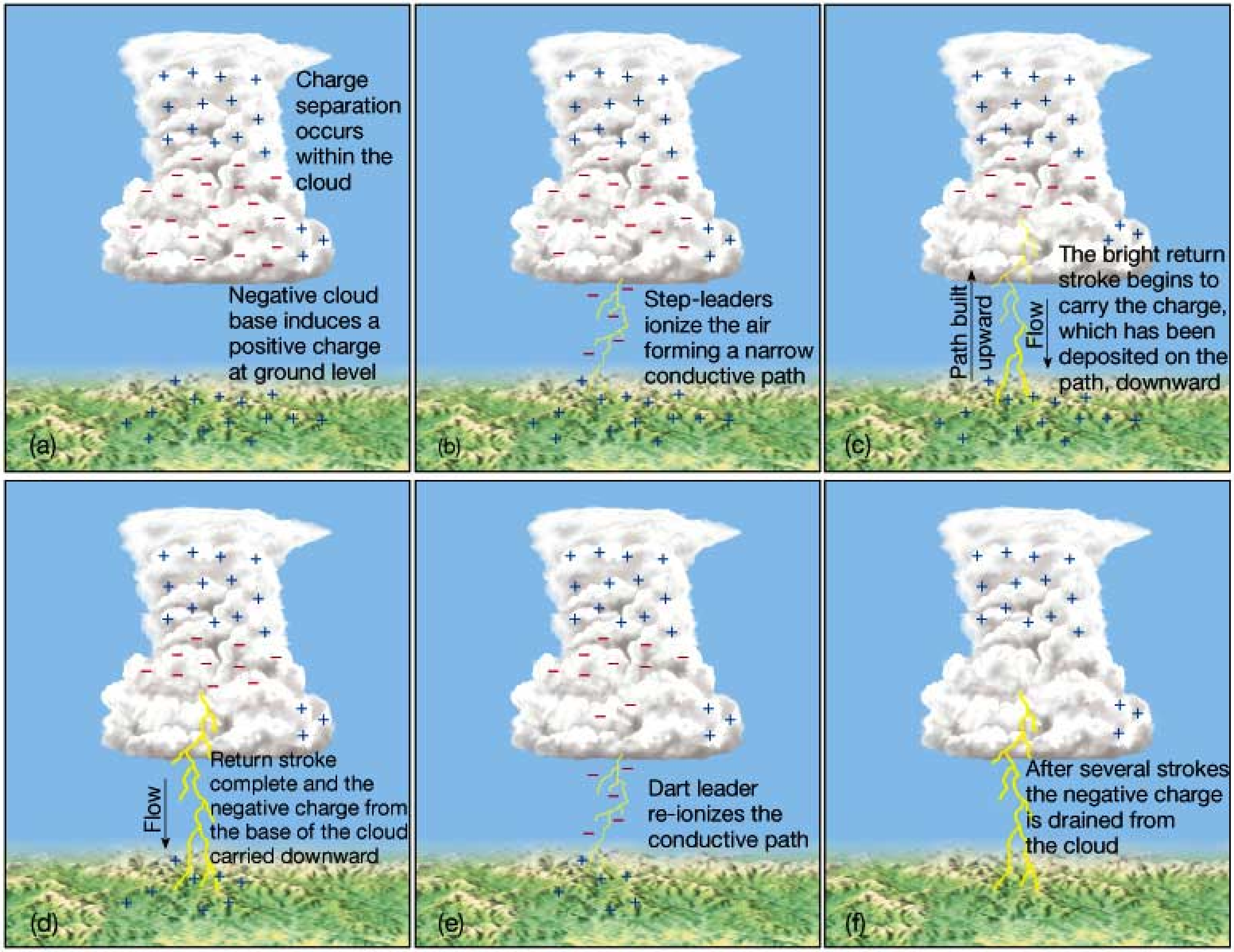
- In an electrical storm, the **storm clouds are charged** like giant capacitors in the sky. The upper portion of the cloud is positive and the lower portion is negative. How the cloud acquires this charge is still not agreed upon within the scientific community.

Lightning


DISCHARGE WITHIN CLOUD BETWEEN
NEGATIVE BASE AND POSITIVE TOP
(INTRA-CLOUD)
INTER-CLOUD STRIKE
(CLOUD-TO-CLOUD)
DISCHARGE BETWEEN NEGATIVE AND POSITIVE CHARGE CENTERS
TYPICAL CLOUD-TO-GROUND
LIGHTNING BETWEEN GROUND AND
NEGATIVE CHARGE CENTERS

Lightning - mechanism

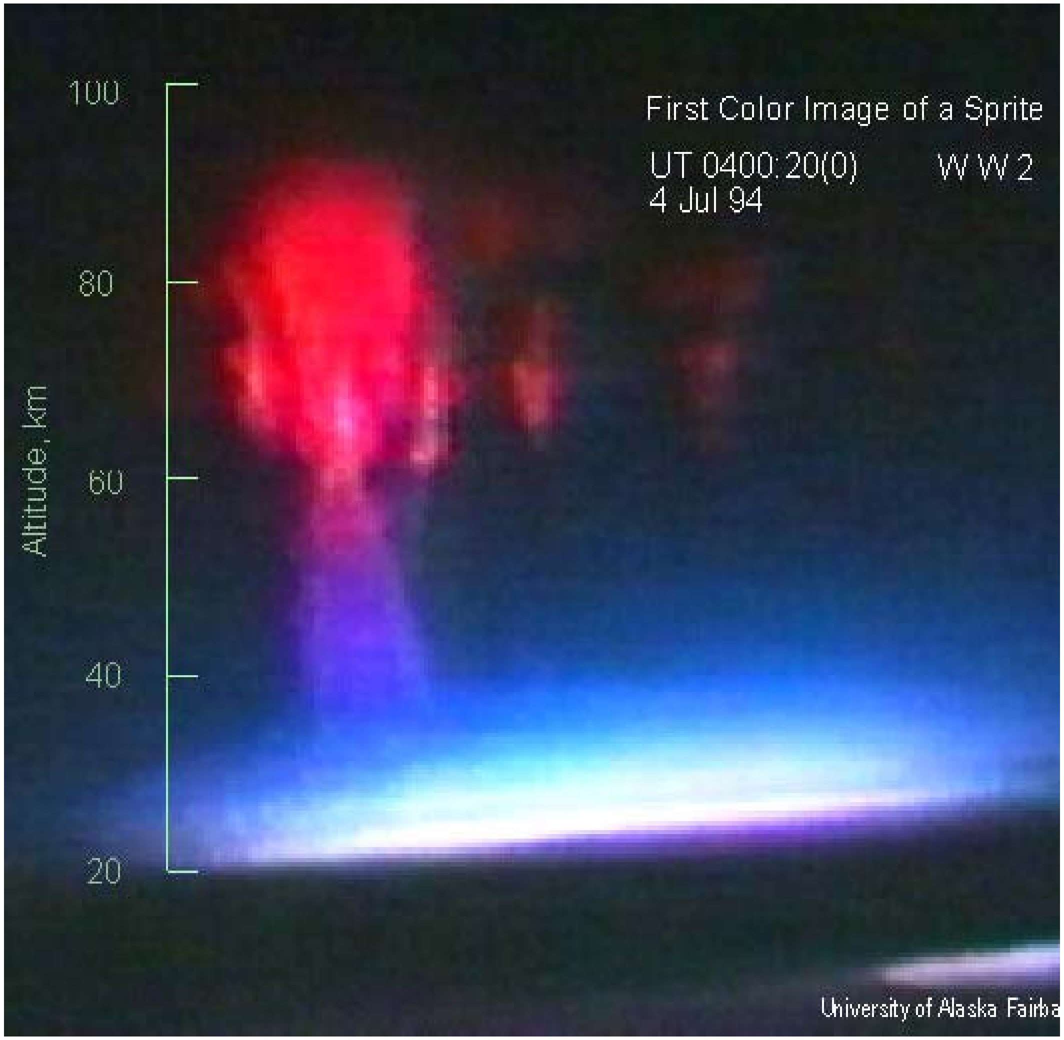
http://home.earthlink.net/~jimlux/lfacts.htm
http://www.ux1.eiu.edu/~jpstimac/1400/shockinglecture.html



Lightning – types

http://www.uh.edu/research/spg/Sprites99.html

- **Types of Lightning**
- **Normal lightning - Discussed previously cloud to ground, ground to cloud and cloud to cloud**
- **Sheet lightning - Normal lightning that is reflected in the clouds**
- **Heat lightning - Normal lightning near the horizon that is reflected by high clouds**
- **Ball lightning - A phenomenon where lightning forms a slow, moving ball that can burn objects in its path before exploding or burning out**
- **Red sprite - A red burst reported to occur above storm clouds and reaching a few miles in length (toward the stratosphere)**
- **Blue jet - A blue, cone-shaped burst that occurs above the center of a storm cloud and moves upward (toward the stratosphere) at a high rate of speed**



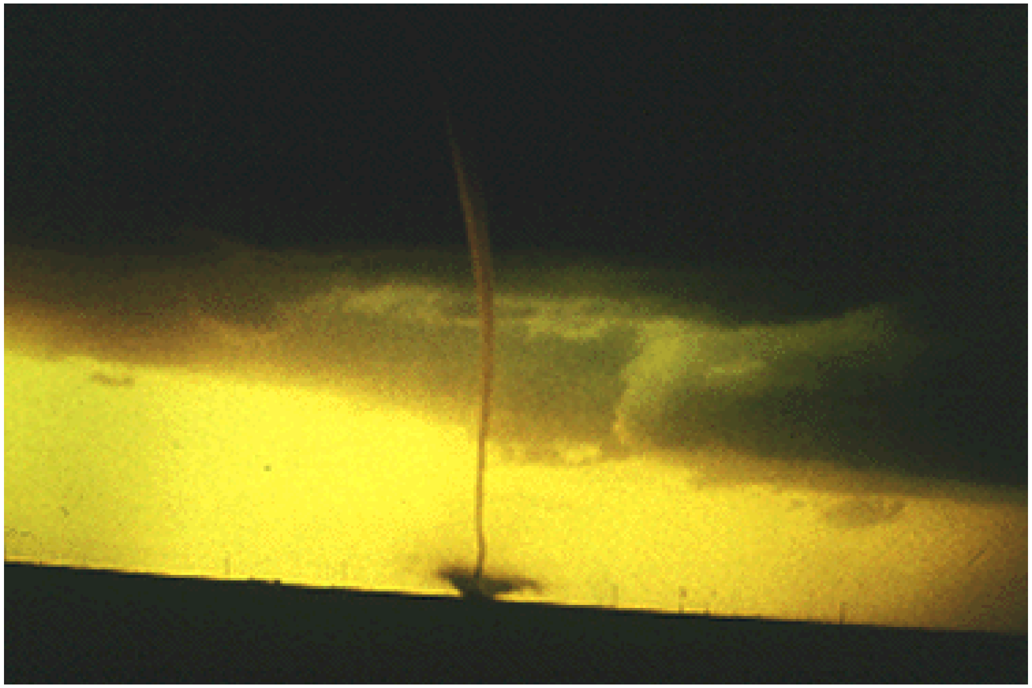
tornadoes

- Tornadoes are one of nature's most violent storms. In an average year, 800 tornadoes are reported across the United States, resulting in 80 deaths and over 1,500 injuries. A tornado is as a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph or more. Damage paths can be in excess of one mile wide and 50 miles long.
- Tornadoes come in all shapes and sizes and can occur anywhere in the U.S at any time of the year. In the southern states, peak tornado season is March through May, while peak months in the northern states are during the summer.

- http://www.outlook.noaa.gov/tornadoes/

tornadoes

- A tornado is defined as a violently rotating column of air in contact with the ground and pendent from a cumulonimbus cloud.
- They can be categorized as "weak", "strong", and "violent"; with weak tornadoes often having a thin, rope-like appearance, as exhibited by this tornado near Dawn, Texas. About 7 in 10 tornadoes are weak, with rotating wind speeds no greater than about 110 MPH. (looking west from about 1 mile.)



tornadoes

The typical strong tornado often has what is popularly considered a more "classic" funnel-shaped cloud associated with the whirling updraft. Rotating wind speeds vary from 110 to 200 MPH.

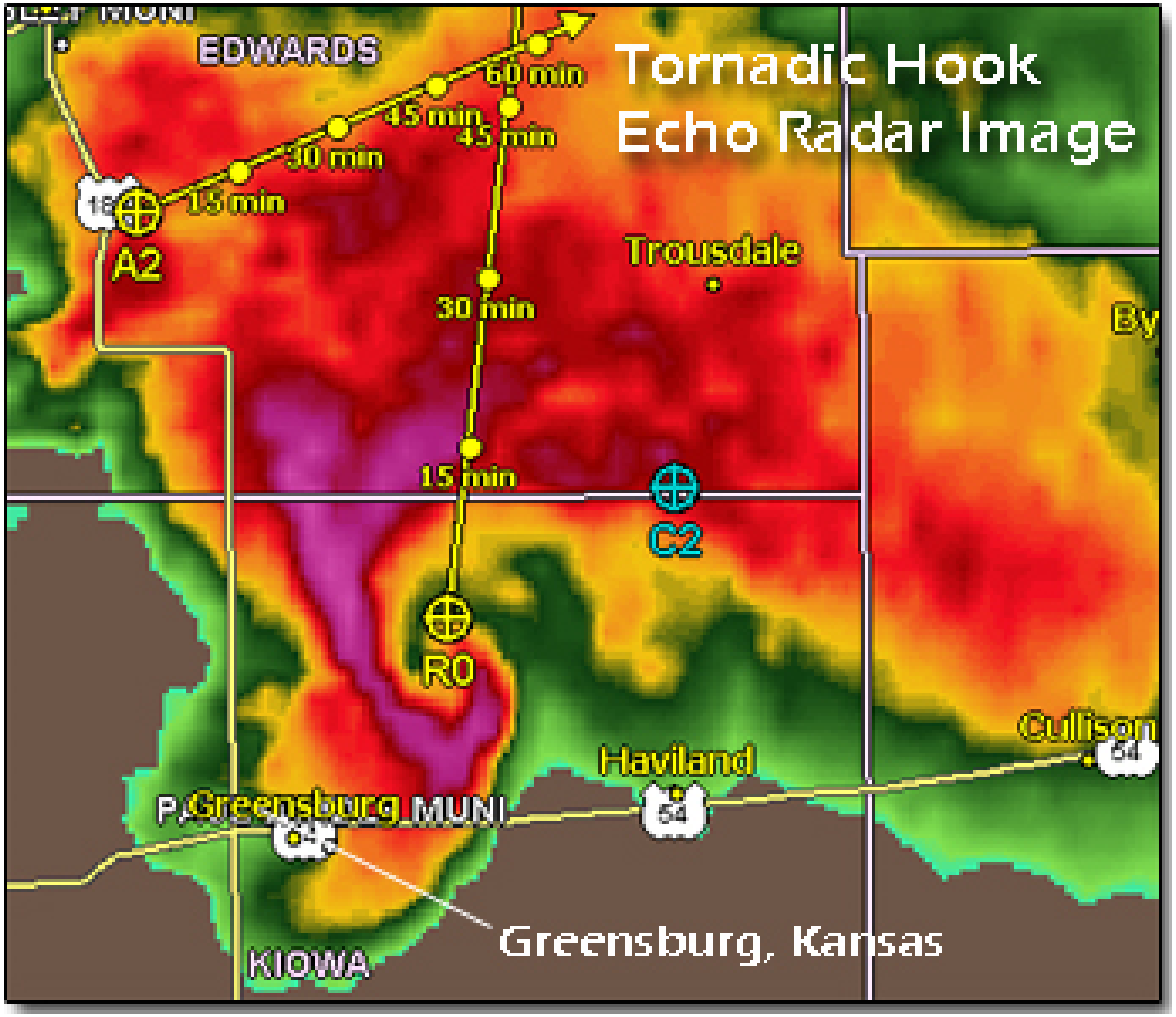
Nearly 3 in 10 tornadoes are strong, such as this twister on the plains of North Dakota. Looking northeast (from about 2 miles), note the spiraling inflow cloud, probably a tail cloud, feeding into the tornado. An important safety consideration is that weak and strong tornadoes by definition do not level well-built homes. Thus, a secure home will offer shelter from almost 100 percent of all direct tornado strikes.

tornadoes

- Only violent tornadoes are capable of leveling a well-anchored, solidly constructed home. Fortunately, less than 2 percent of all tornadoes reach the 200+ MPH violent category. Furthermore, most violent tornadoes only produce home-leveling damage within a very small portion of their overall damage swath. Less than 5 percent of the 5,000 affected homes in Wichita Falls, Texas were leveled by this massive 1979 tornado. (Looking south from 5 miles).

- Note the huge, circular wall cloud above the tornado. This feature is probably close both in size and location to the parent rotating updraft (called a mesocyclone) which has spawned the violent tornado. Strong and violent tornadoes usually form in association with mesocyclones, which tend to occur with the most intense events in the thunderstorm spectrum.

tornadoes



EDWARDS
Tornadic Hook
Echo Radar Image
60 min
45 min
45 min
30 min
15 min
A2
Trousdale
30 min
By
15 min
C2
R0
Cullison
Haviland
Greensburg
MUNI
KIOWA
Greensburg, Kansas

tornadoes

- **Fujita Tornado Damage Scale**
- **Developed in 1971 by T. Theodore Fujita of the University of Chicago**
- **IMPORTANT NOTE ABOUT F-SCALE WINDS:** Do not use F-scale winds literally. These precise wind speed numbers are actually guesses and have never been scientifically verified. Different wind speeds may cause similar-looking damage from place to place -- even from building to building. *Without a thorough engineering analysis of tornado damage in any event, the actual wind speeds needed to cause that damage are unknown.*
- The Enhanced F-scale (EF Scale) will be implemented February 2007.

Tornadoes – Fujita Scale

http://en.wikipedia.org/wiki/Fujita_scale

F 0	<73 mph	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.	
F 1	73-112 mph	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.	
F 2	113-157 mph	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.	
F 3	158-206 mph	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.	
F 4	207-260 mph	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.	
F 5	261-318 mph	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur.	

Tornadoes – E Fujita Scale

- **Enhanced Fujita Scale - an update to the original F-Scale by a team of meteorologists and wind engineers, to be implemented in the U.S. on 1 February 2007.**

- ***The Enhanced F-scale still is a set of wind estimates (not measurements) based on damage.* Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to 28 indicators. These estimates vary with height and exposure.**

- **Important: The 3 second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured, "one minute mile" speed.**

- **http://www.spc.noaa.gov/faq/tornado/ef-scale.html**

Tornadoes – Cloud formations

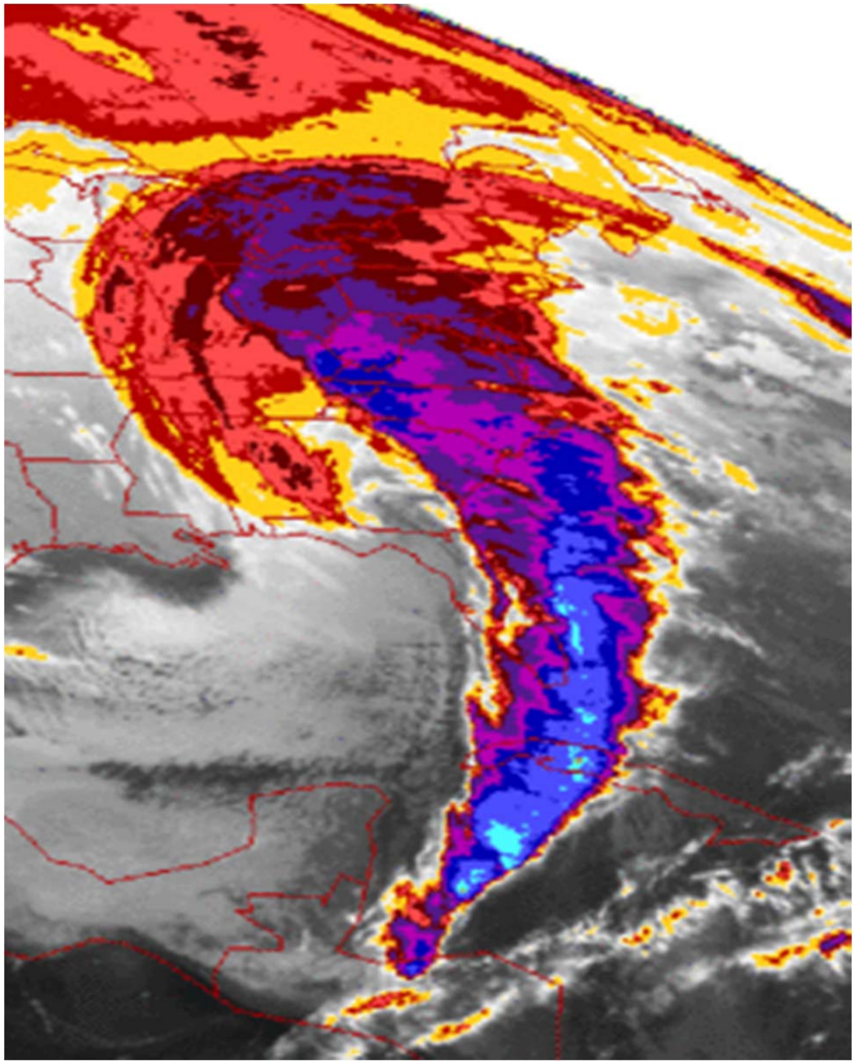
Tornadoes – Cloud formations

http://www.ems.psu.edu/~lno/Meteo437/atlas.html

Mid latitude cyclones

http://www.physicalgeography.net/fundamentals/7s.htm
http://www.aos.wisc.edu/~aalopez/aos101/wk13.html

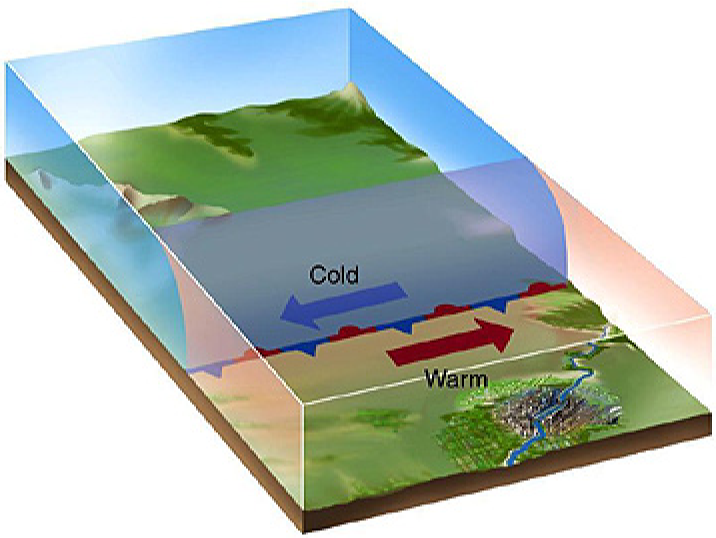
- **Mid-latitude or frontal cyclones** are large traveling atmospheric cyclonic storms up to 2000 kilometers in diameter with centers of low atmospheric pressure.
- An intense mid-latitude cyclone may have a surface pressure as low as 970 millibars, compared to an average sea-level pressure of 1013 millibars. Normally, individual frontal cyclones exist for about 3 to 10 days moving in a generally west to east direction.
- Frontal cyclones are the dominant weather event of the Earth's mid-latitudes forming along the polar front.



Mid latitude cyclones – cyclogenesis

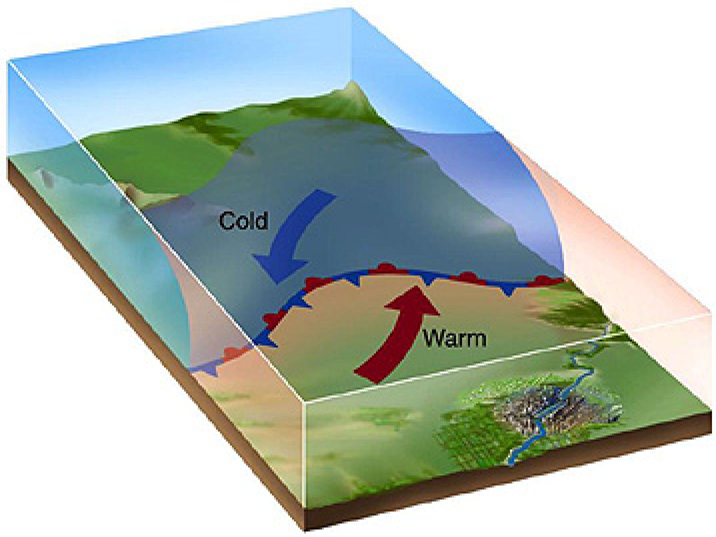
http://henry.pha.jhu.edu/ssip/asat_int/cyclogen.html

http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/weather_systems/cyclogenesis.html

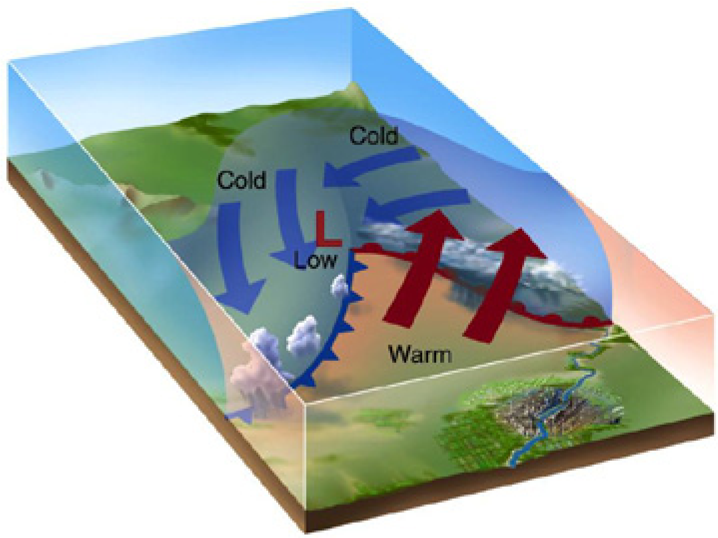


- Cold and warm air masses meet at a front and move parallel to it.

- A wave forms and warm air starts to move pole-ward while cold air begins to move equator-ward.

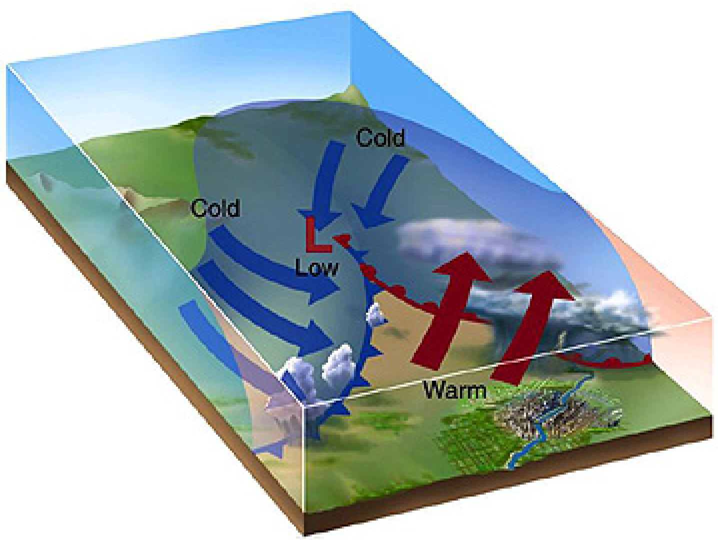


Mid latitude cyclones – cyclogenesis



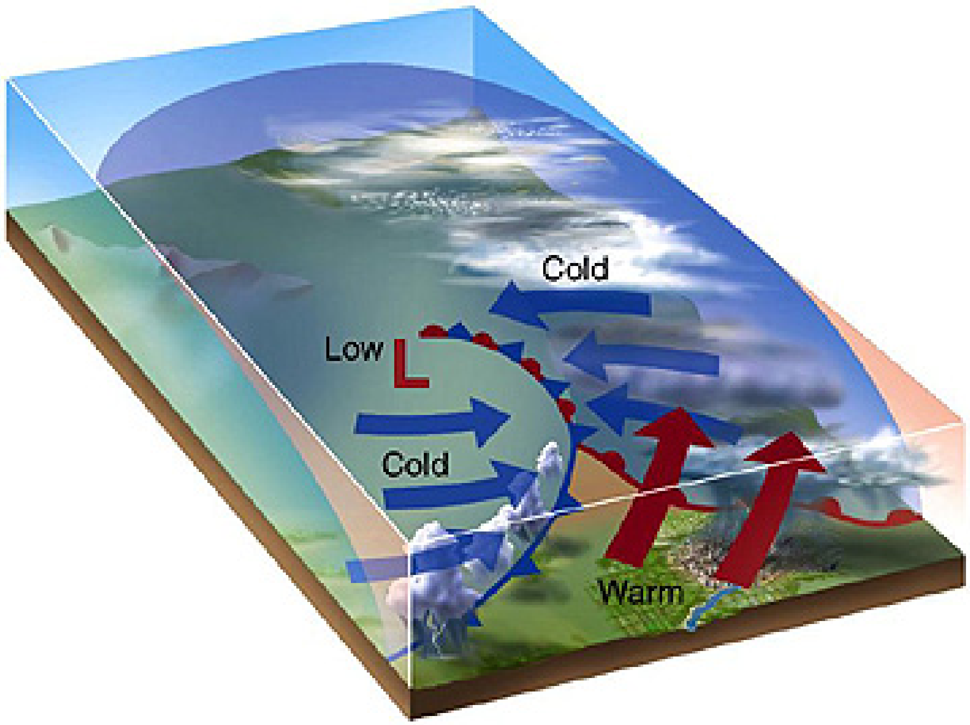
- Cyclonic circulation (ccw) develops with general surface convergence and uplifting.

- Cold front moves faster than the warm front and starts to overtake it – end of the mature stage.

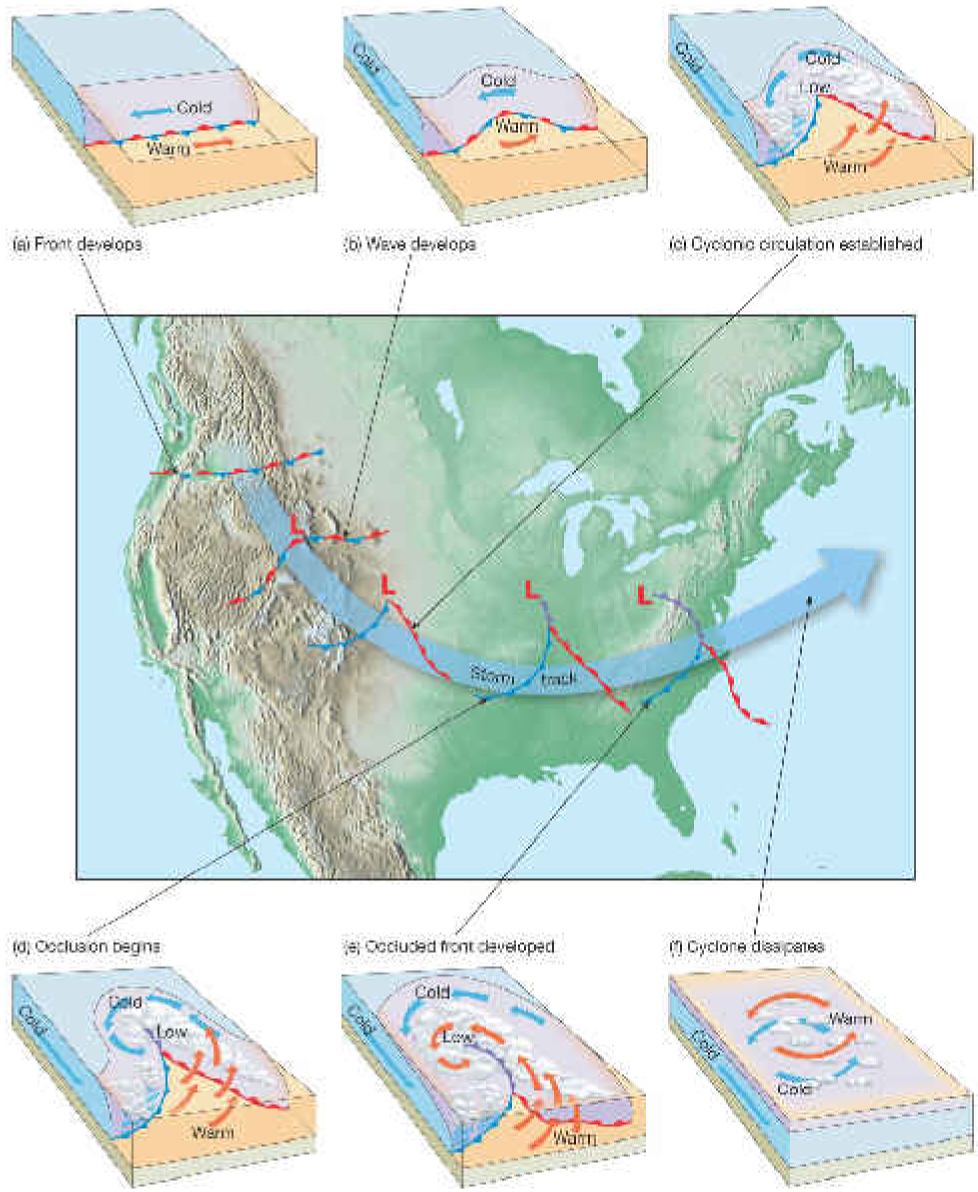


Mid latitude cyclones – cyclogenesis

- Full development of an occluded front with maximum intensity of the wave cyclone
- http://www.google.com/search?q=cyclogenesis+comma&hl=en&rlz=1T4ADBF_enUS234US235&start=20&sa=N
- http://www.google.com/search?q=cyclogenesis+comma&hl=en&rlz=1T4ADBF_enUS234US235&start=40&sa=N

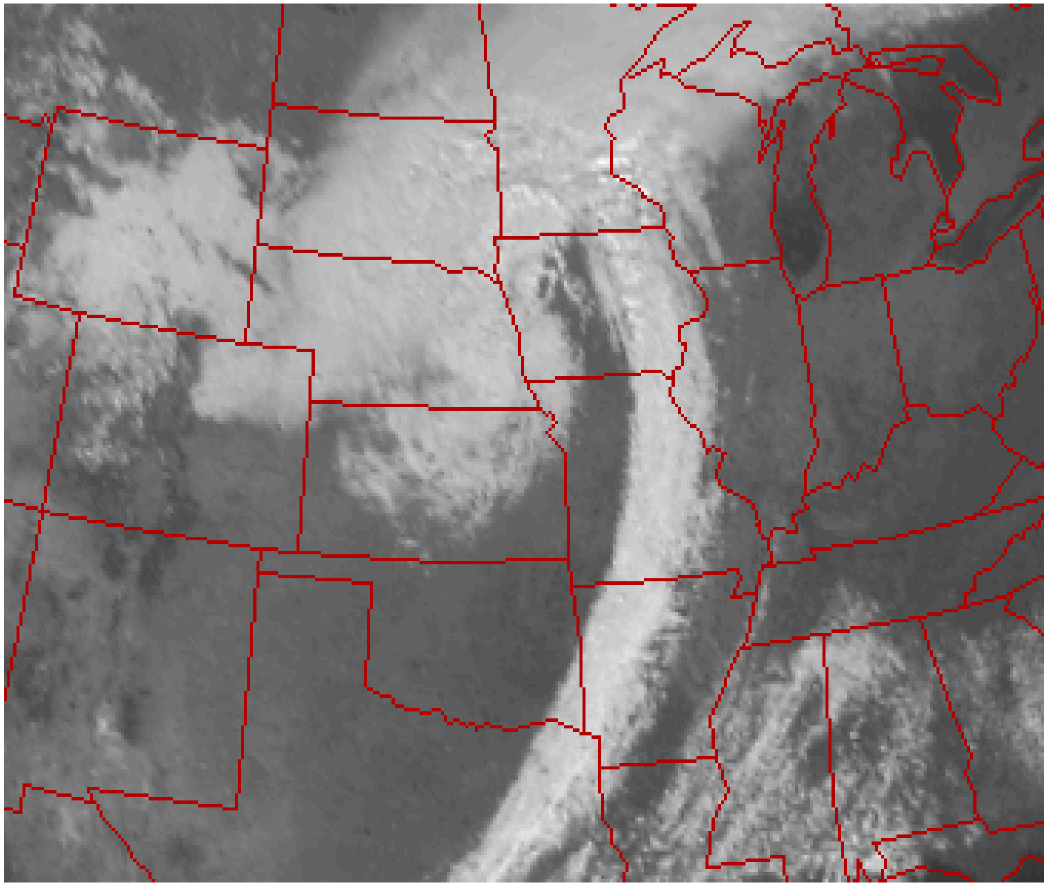


the life cycle of a mid latitude cyclone



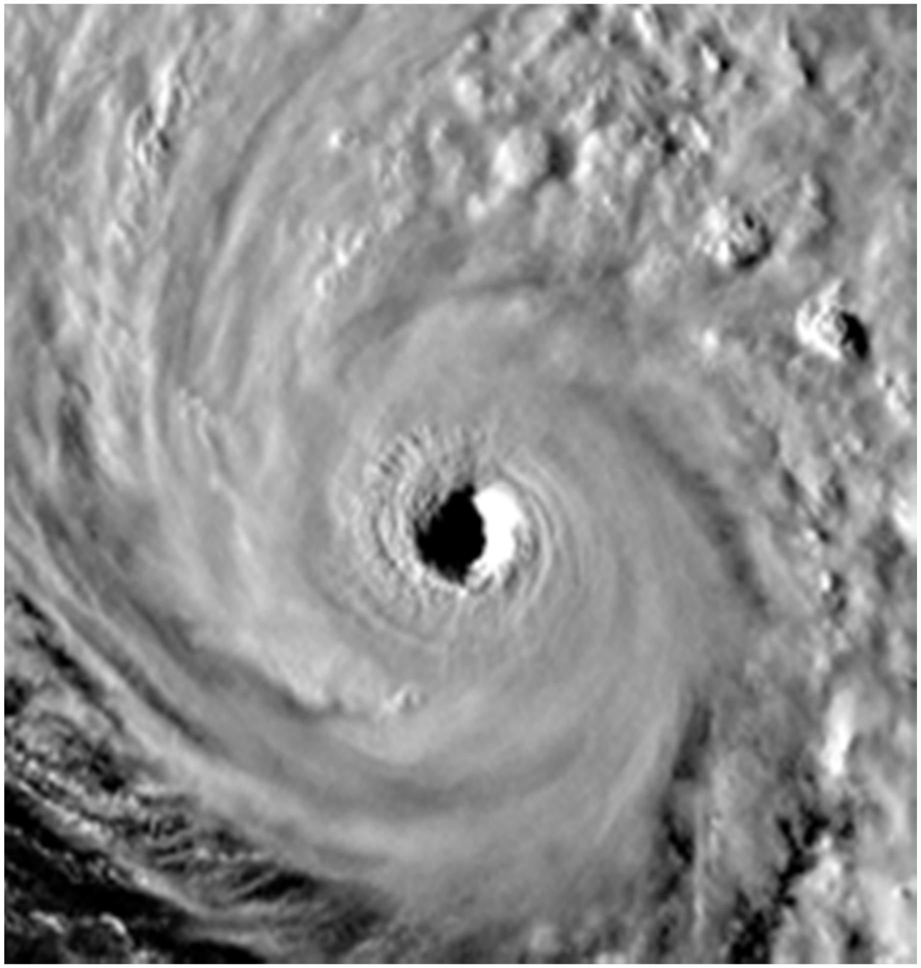
Mid latitude cyclones

- The Mid latitude cyclone or extra-tropical cyclone, is often identified by a comma shaped cloud mass on satellite imagery.



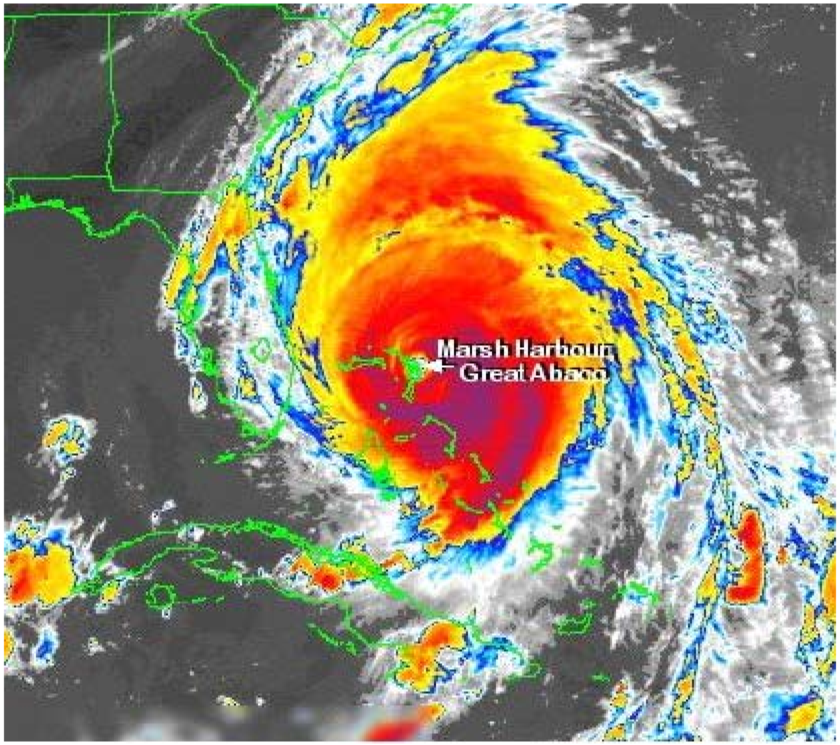
Hurricanes – tropical cyclones

- Hurricanes are tropical cyclones with winds that exceed 64 knots (74 mi/hr) and circulate counter-clockwise about their centers in the Northern Hemisphere (clockwise in the Southern Hemisphere).



Hurricanes – tropical cyclones

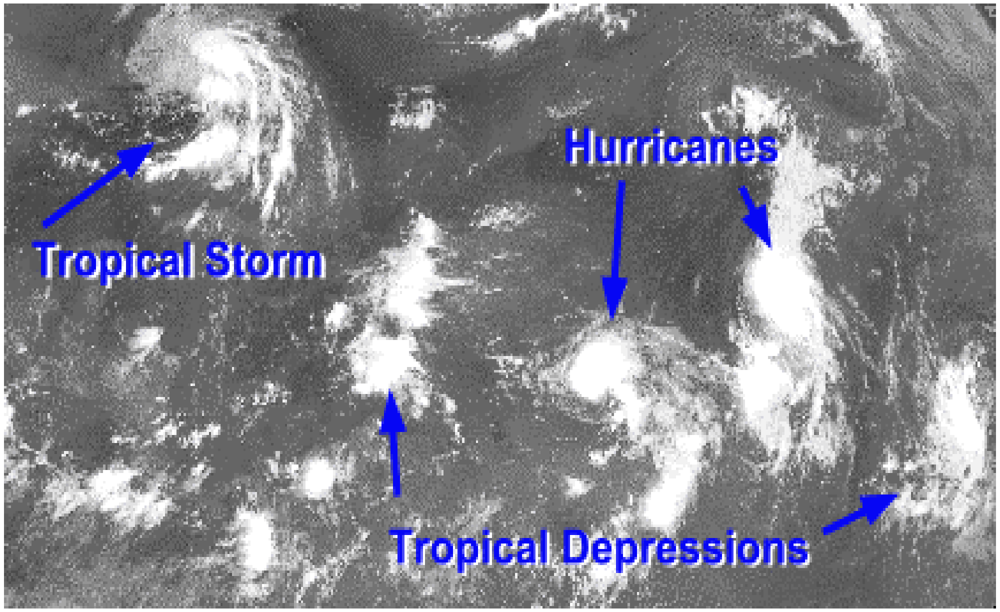
- Hurricanes are formed from simple complexes of thunderstorms. However, these thunderstorms can only grow to hurricane strength with cooperation from both the ocean and the atmosphere. First of all, the ocean water itself must be warmer than 26.5 degrees Celsius (81°F). The heat and moisture from this warm water is ultimately the source of energy for hurricanes. Hurricanes will weaken rapidly when they travel over land or colder ocean waters -- locations with insufficient heat and/or moisture.



Hurricanes – tropical cyclones – stages of development

- Hurricanes evolve through a life cycle of stages from birth to death. A tropical disturbance in time can grow to a more intense stage by attaining a specified sustained wind speed. The progression of tropical disturbances can be seen in the three images below.

- Hurricanes can often live for a long period of time -- as much as two to three weeks. They may initiate as a **cluster of thunderstorms** over the tropical ocean waters. Once a disturbance has become a **tropical depression**, the amount of time it takes to achieve the next stage, **tropical storm**, can take as little as half a day to as much as a couple of days. It may not happen at all. The same may occur for the amount of time a tropical storm needs to intensify into a **hurricane**. Atmospheric and oceanic conditions play major roles in determining these events.



HURRICANES

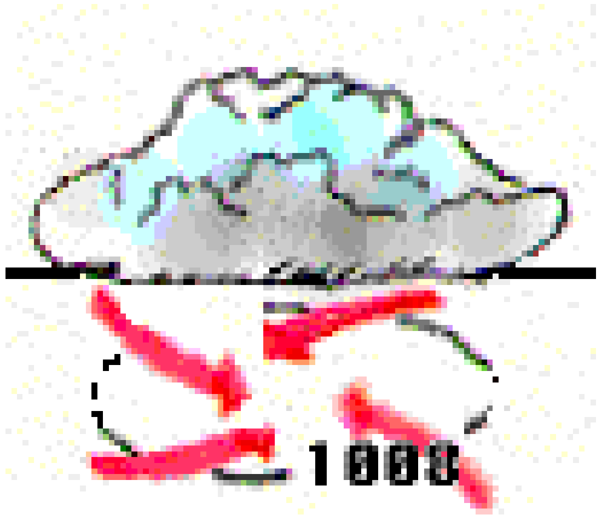
evolve through a life cycle of stages from birth to death. A tropical disturbance in time can grow to a more intense stage by attaining a specified sustained wind speed. The progression of tropical disturbances can be seen in the three images below.

HURRICANES – TROPICAL DEPRESSION

- Once a group of thunderstorms has come together under the right atmospheric conditions for a long enough time, they may organize into a tropical depression. Winds near the center are constantly between 20 and 34 knots (23 - 39 mph).

- A tropical depression is designated when the first appearance of a lowered pressure and organized circulation in the center of the thunderstorm complex occurs. A surface pressure chart will reveal at least one closed isobar to reflect this lowering.

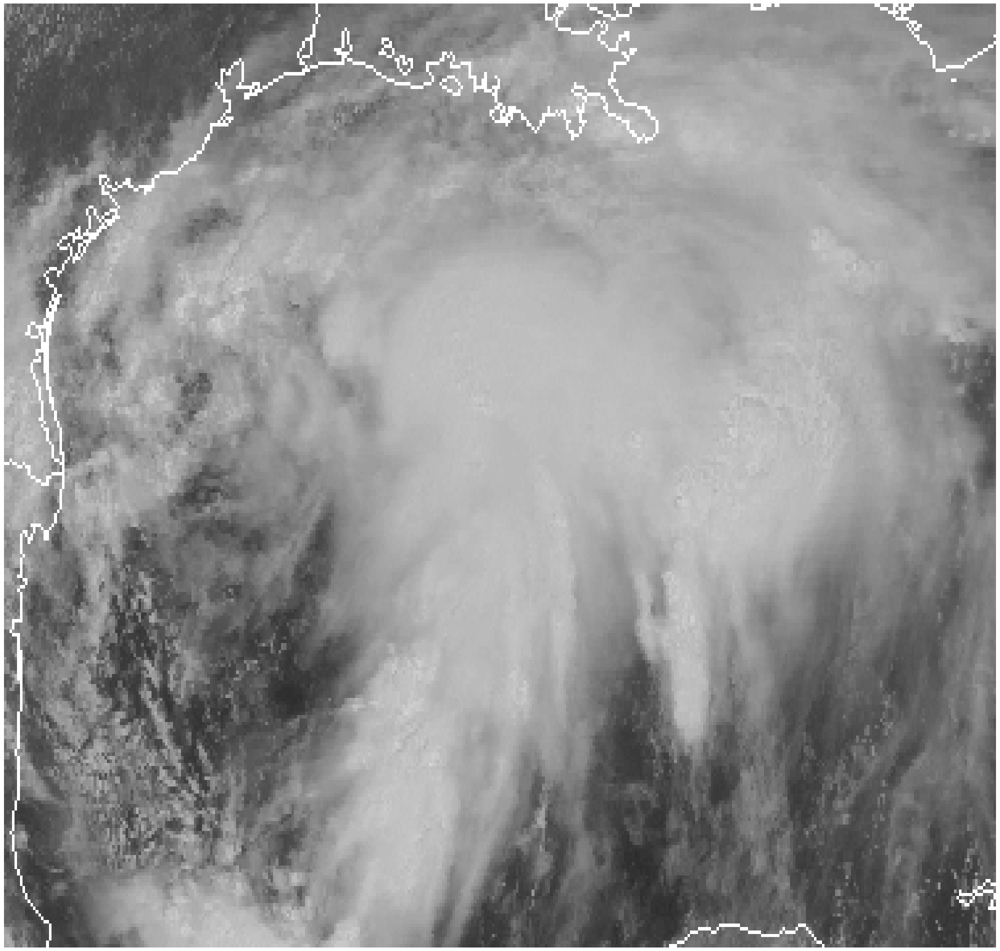
Depression



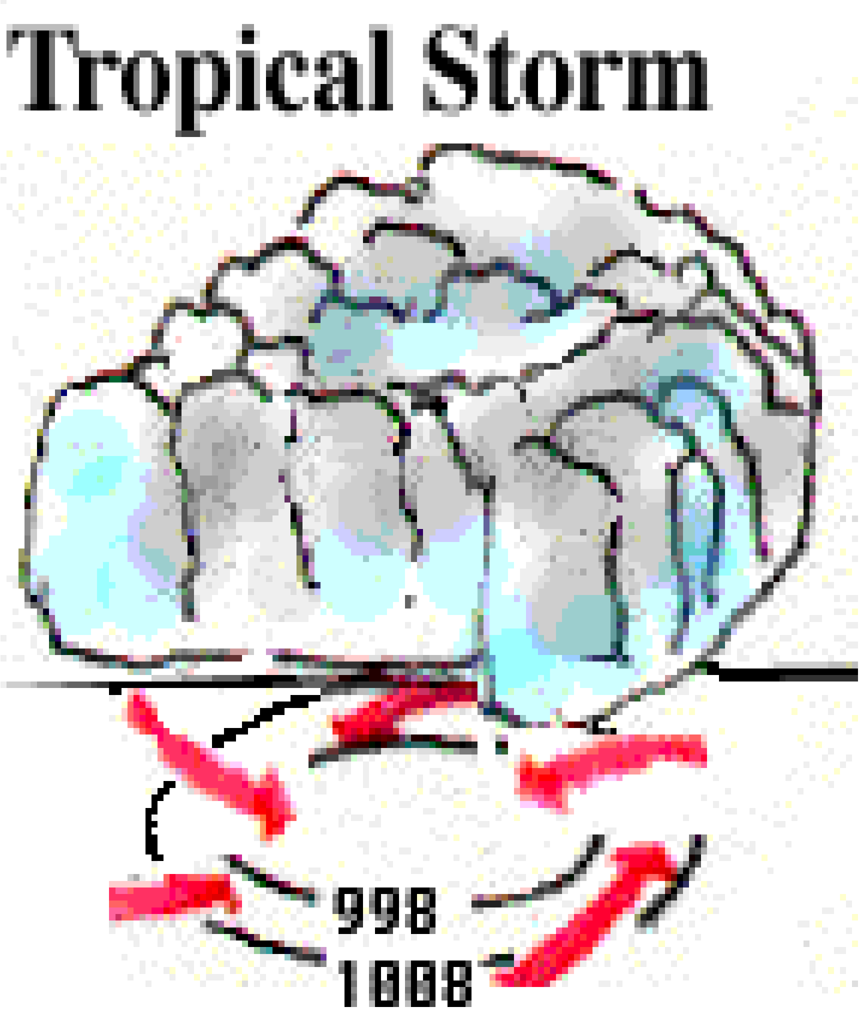
HURRICANES – TROPICAL DEPRESSION

- When viewed from a satellite, tropical depressions appear to have little organization. However, the slightest amount of rotation can usually be perceived when looking at a series of satellite images.

- Instead of a round appearance similar to hurricanes, tropical depressions look like individual thunderstorms that are grouped together. One such tropical depression is shown here.



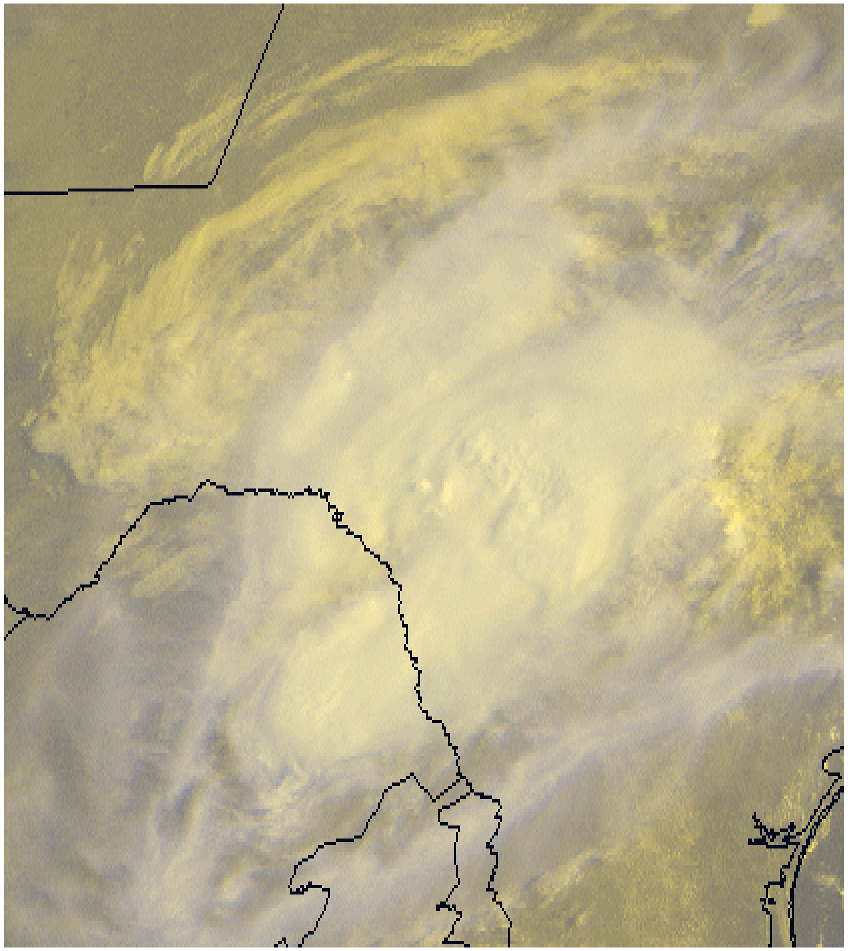
HURRICANES – TROPICAL STORMS



- Once a tropical depression has intensified to the point where its maximum sustained winds are between 35-64 knots (39-73 mph), it becomes a tropical storm. It is at this time that it is assigned a name. During this time, the storm itself becomes more organized and begins to become more circular in shape -- resembling a hurricane.
- The rotation of a tropical storm is more recognizable than for a tropical depression. Tropical storms can cause a lot of problems even without becoming a hurricane. However, most of the problems a tropical storm cause stem from heavy rainfall.

HURRICANES – TROPICAL STORMS

- The satellite image is of tropical storm Charlie (1998). Many cities in southern Texas reported heavy rainfall between 5-10 inches. Included in these was Del Rio, where more than 17 inches fell in just one day, forcing people from their homes and killing half a dozen.

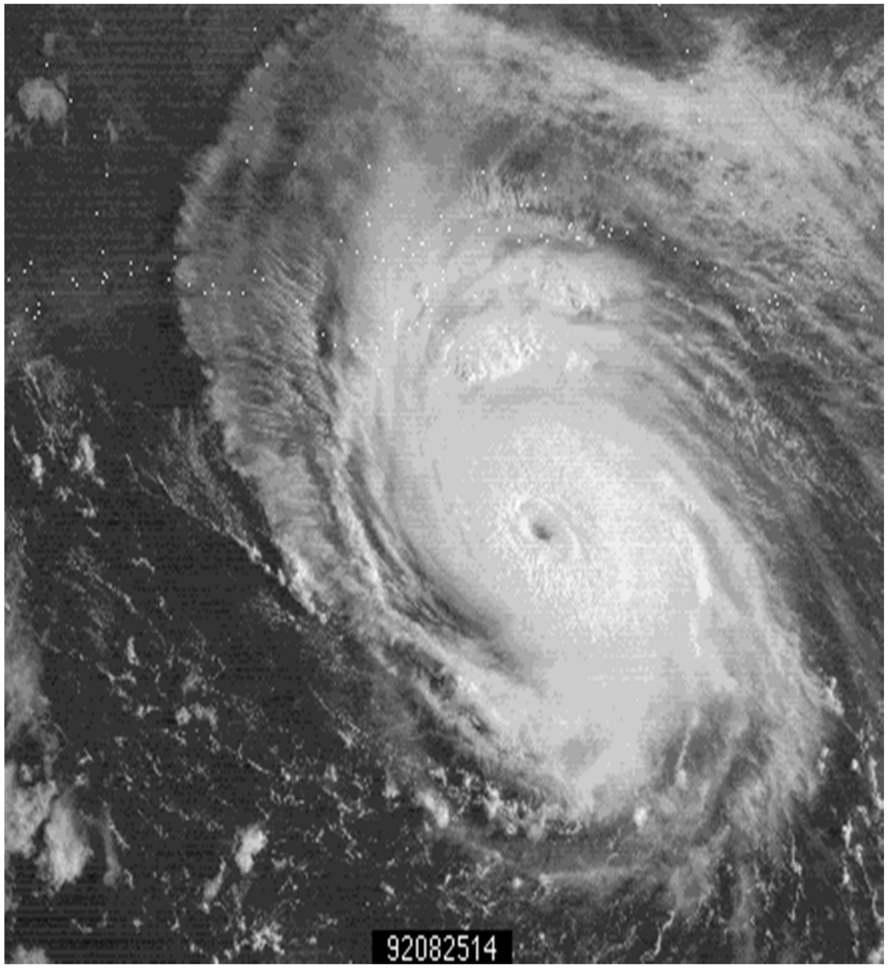


HURRICANES

- As surface pressures continue to drop, a tropical storm becomes a hurricane when sustained wind speeds reach 64 knots (74 mph). A pronounced rotation develops around the central core.

HURRICANES

- Hurricanes are Earth's strongest tropical cyclones. A distinctive feature seen on many hurricanes and are unique to them is the dark spot found in the middle of the hurricane. This is called the eye. Surrounding the eye is the region of most intense winds and rainfall called the eye wall. Large bands of clouds and precipitation spiral from the eye wall and are thusly called spiral rain bands.



HURRICANES – these things are huge!

- Hurricanes are easily spotted from the previous features as well as a pronounced rotation around the eye in satellite or radar animations. Hurricanes are also rated according to their wind speed on the Saffir-Simpson scale. This scale ranges from categories 1 to 5, with 5 being the most devastating. Under the right atmospheric conditions, hurricanes can sustain themselves for as long as a couple of weeks. Upon reaching cooler water or land, hurricanes rapidly lose intensity.

HURRICANES – Saffir-Simpson Scale

1	65 to 83 knots 74 to 95 mph 119 to 153 kph > 980 mb	Storm surge generally 4-5 ft above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage. Hurricanes Allison of 1995 and Danny of 1997 were Category One hurricanes at peak intensity.
2	84 to 95 knots 96 to 110 mph 154 to 177 kph 980 - 965 mb	Storm surge generally 6-8 feet above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings. Hurricane Bertha of 1996 was a Category Two hurricane when it hit the North Carolina coast, while Hurricane Marilyn of 1995 was a Category Two Hurricane when it passed through the Virgin Islands.
3	96 to 113 knots 111 to 130 mph 178 to 209 kph 964 - 945 mb	Storm surge generally 9-12 ft above normal. Some structural damage to small residences and utility buildings with a minor amount of curtain wall failures. Damage to shrubbery and trees with foliage blown off trees and large tress blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the hurricane center. Flooding near the coast destroys smaller structures with larger structures damaged by battering of floating debris. Terrain continuously lower than 5 ft above mean sea level may be flooded inland 8 miles (13 km) or more. Evacuation of low-lying residences with several blocks of the shoreline may be required. Hurricanes Roxanne of 1995 and Fran of 1996 were Category Three hurricanes at landfall on the Yucatan Peninsula of Mexico and in North Carolina, respectively.
4	114 to 134 knots 131 to 155 mph 210 to 249 kph 944- 920 mb	Storm surge generally 13-18 ft above normal. More extensive curtain wall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the hurricane center. Major damage to lower floors of structures near the shore. Terrain lower than 10 ft above sea level may be flooded requiring massive evacuation of residential areas as far inland as 6 miles (10 km). Hurricane Luis of 1995 was a Category Four hurricane while moving over the Leeward Islands. Hurricanes Felix and Opal of 1995 also reached Category Four status at peak intensity.
5	135+ knots 155+ mph 249+ kph < 920 mb	Storm surge generally greater than 18 ft above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the hurricane center. Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be required. There were no Category Five hurricanes in 1995, 1996, or 1997. Hurricane Gilbert of 1988 was a Category Five hurricane at peak intensity and is the strongest Atlantic tropical cyclone of record.

Severe storms are the weather where we live in the middle latitudes – watch, enjoy, and learn about them.

glossary

- This is the link to some of the best glossaries on the internet as far as science is concerned and almost all weather materials are covered.
- Use it often and well for all your Science Olympiad needs!
- http://www.physicalgeography.net/glossary.html
- http://www.uwsp.edu/geo/faculty/ritter/glossary/index.html
- http://www.paulpoteet.com/glossary/glossary1.shtml