Welcome to the Elite Spotter Workshop!

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service – Paducah, KY

Todd Lindley

Requirements of this course

- Participants are required to be present for the entire course to receive credit.
- Participants are required to complete all exercises and pass an ***end of course exam*** with a minimum score of 70%.
- Participants *must* have attended Spotter Concepts 1 & 2 prior to attending this class.

NWS Partners

- Federal, state and local agencies
- Media
- Private Weather Companies
- Academia
- Public (storm spotters, weather observers)

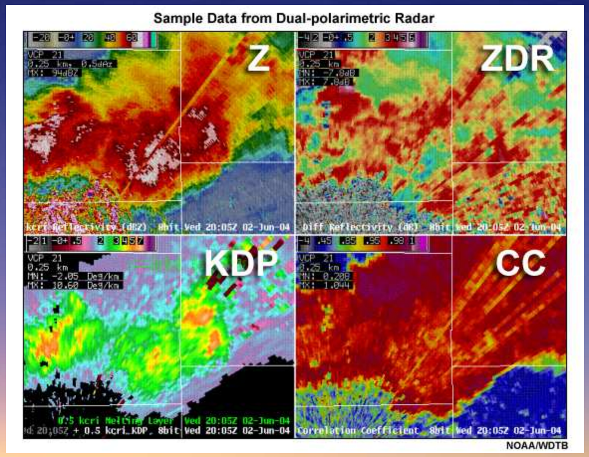
The importance of our Skywarn Spotter Volunteers:

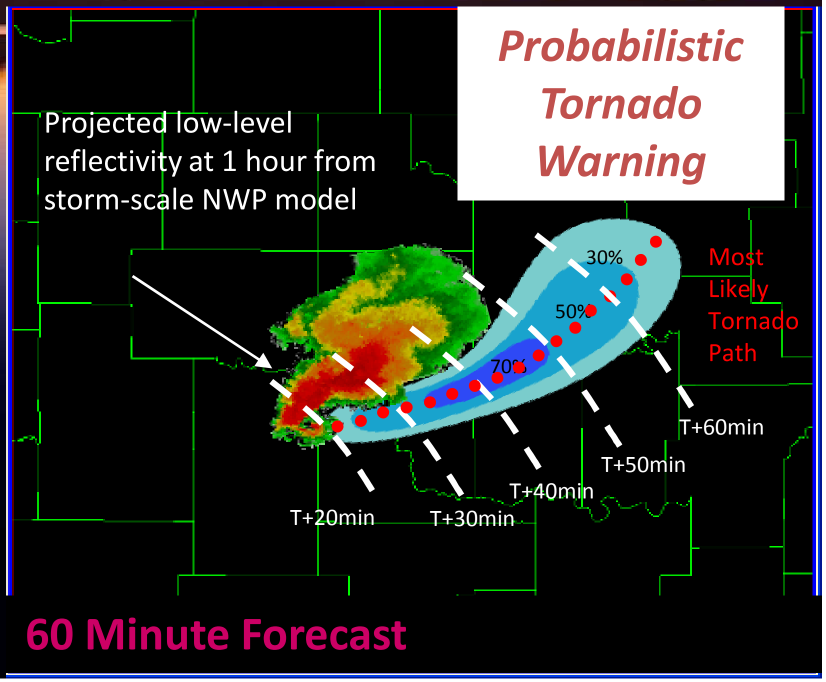
- They are the "ground-truth" to what is happening and can help the radar operator gauge other storms by what is reported on the current storm.
- Aid in warning decisions (extend, cancel, modify warnings).
- Helps save lives by reporting actual location of severe weather rather than where radar is estimating it is occurring
- Data sent to the Storm Prediction Center for use in historical data.
- Clearinghouse information to all TV stations, radio, Internet, and other counties.
- Data included in a national database used by researchers, insurance companies, attorneys, etc.
- <u>PRIORITY OF REPORTING:</u>
  - Spotter hotline 800-533-7189
  - E-Spotter
  - NWS Chat (EMs. Media, & govt only)
  - Amateur Radio
  - Twitter


The Muskegon Chronicle

So what does the future hold for the NWS? How are we keeping up with the times?

- AWIPS II
- Dual Polarization Radar – 2011?
- Multimedia briefings for large events
- NWS using communication avenues such as Facebook, Twitter, etc.
- Longer lead times for tornadoes and severe thunderstorms.
- Decreased warned areas and false alarms.
- Probabilistic warnings - 2020
- Weather model enhancements
- Phased Array Radar?






Basic Weather 101:
A brief overview of the elements of weather and what causes it.

Elements of Weather

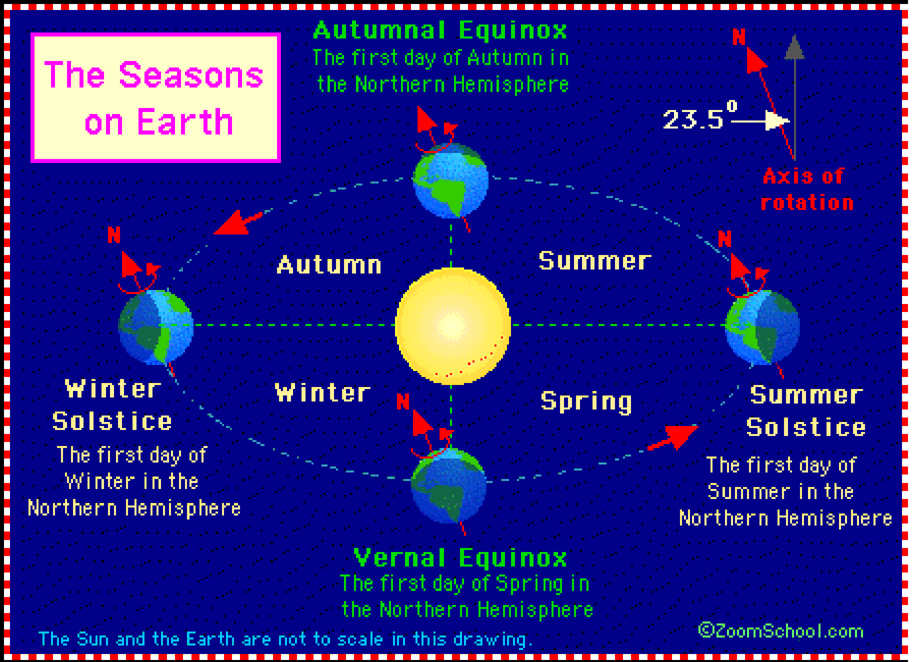
1) Temperature
2) Pressure
3) Wind
4) Moisture



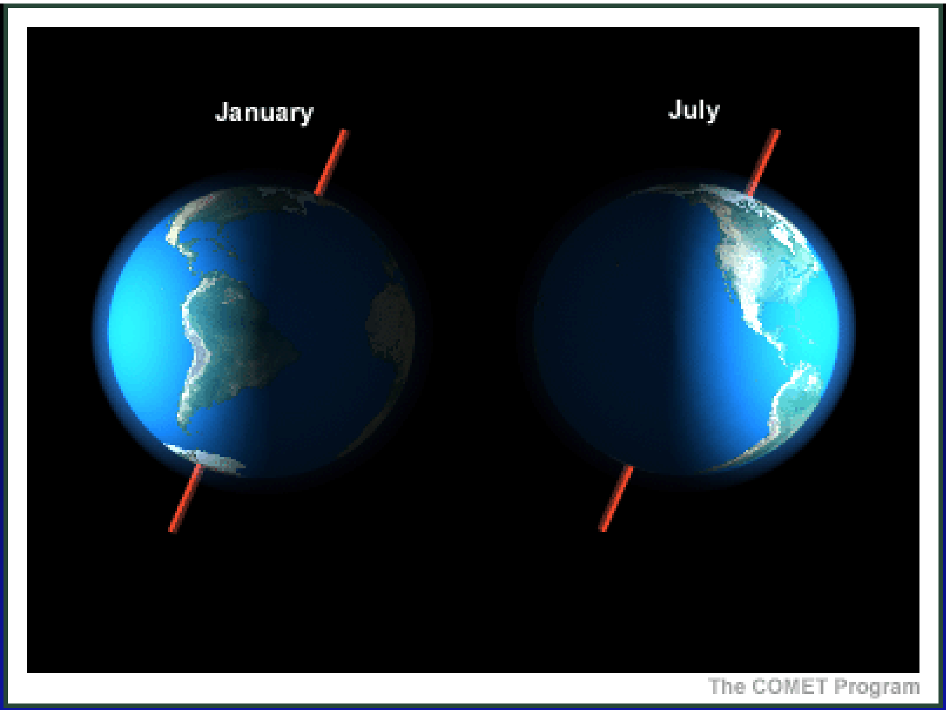

Our Seasons

Weather on our planet is created by sun heating areas of the planet unequally. This occurs because:

1. The sun's radiation reaches only half the planet at any one time (Earth rotates).
2. The amount of radiation reaching the surface varies at different places (Tilt of the earth).
3. The planet tilts as it revolves around the sun.



Seasons



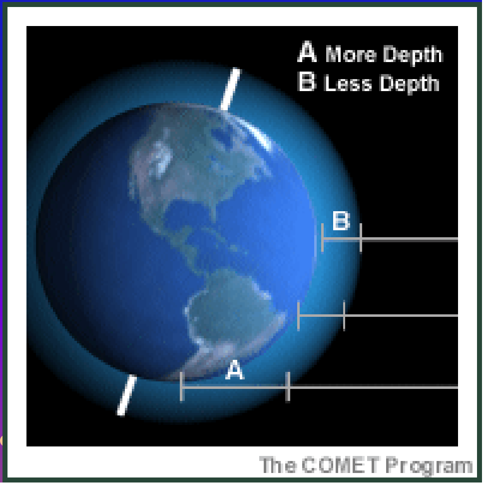
- Why is it warmer in July than January?

Earth is actually closer to the sun in January

It is the tilt of the earth! The earth is tilted toward the sun in the summer (North Hemisphere). This is a larger factor than proximity to sun.

- Why is it colder at the north and south poles?

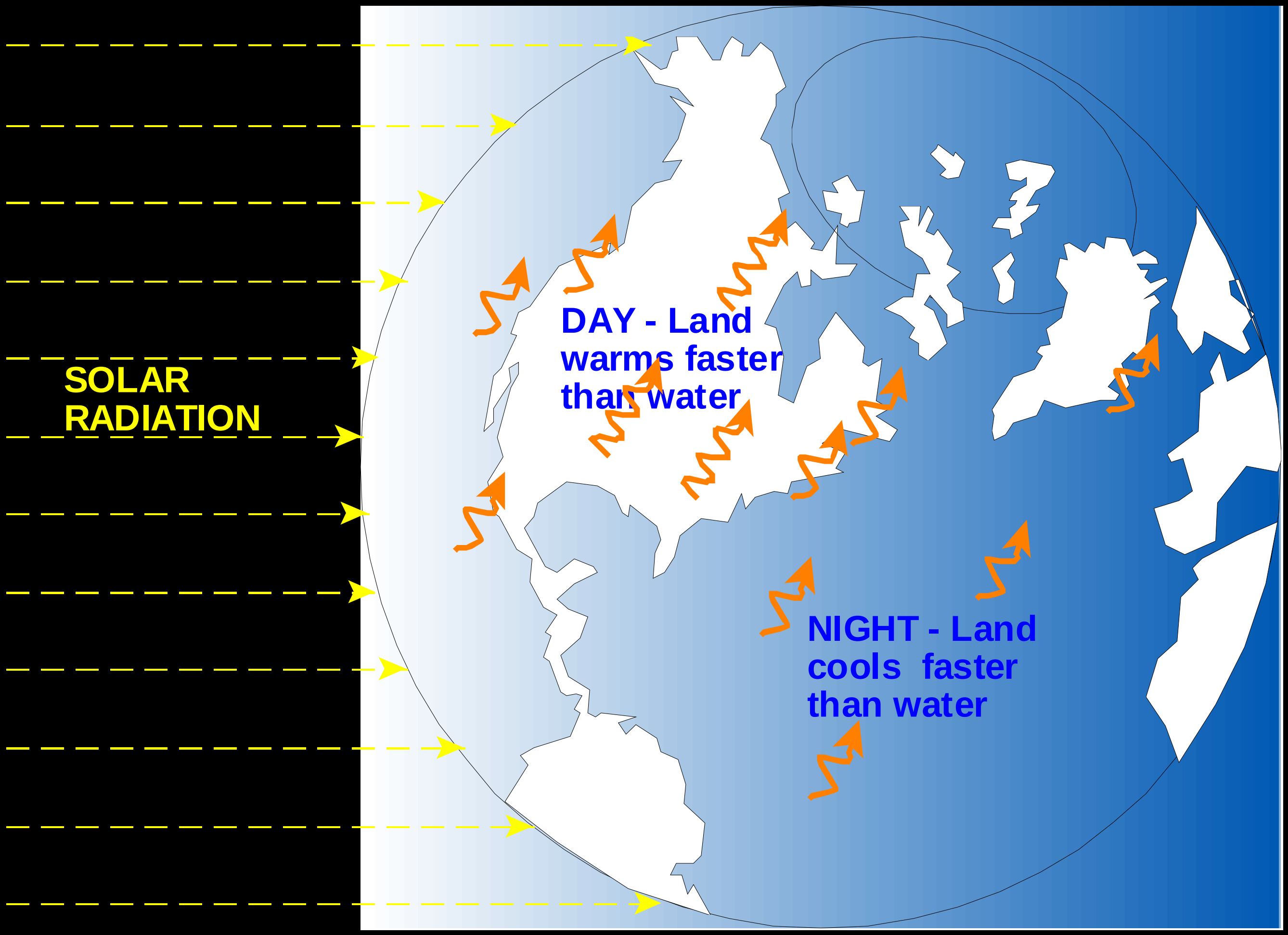
The sun must pass through a larger section of the atmosphere to warm the earth surface.



Temperature

- Most of the heat supplied to the air comes from the earth radiating heat, from heat released by water, and from air movement.
- The amount of solar energy striking the earth depends on the earth's rotation and orbit.
- Molecules will move to equalize temperatures where possible.

Daily Temperature Variations

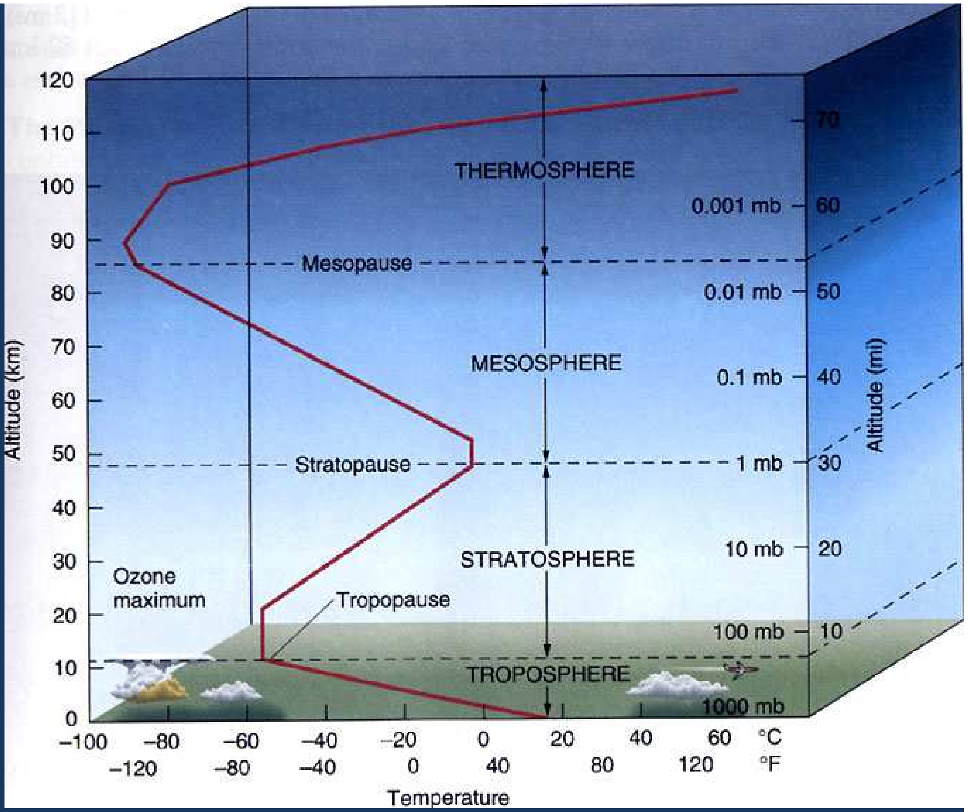


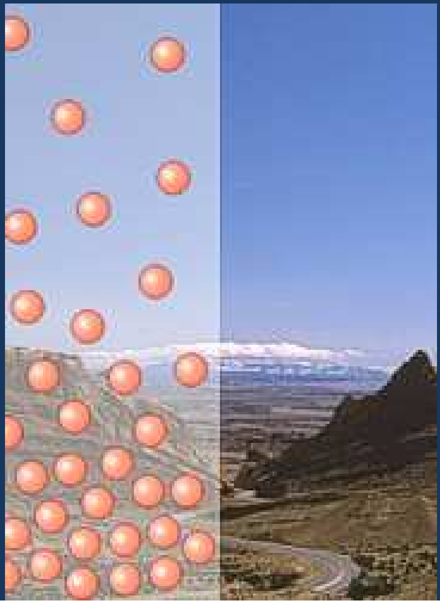
- Various surfaces absorb retain and radiate heat and determine the daily surface air temperatures to 4000 ft.

- Practically no daily temperature variance occurs in the free air above 4000 ft.

Pressure

- A measure of the weight of the atmosphere on top of us.
- Pressure decreases with height. As you go higher in the atmosphere, there are fewer molecules to exert pressure.
- Air pressure depends on the number of air molecules in a given space and how fast they're moving.





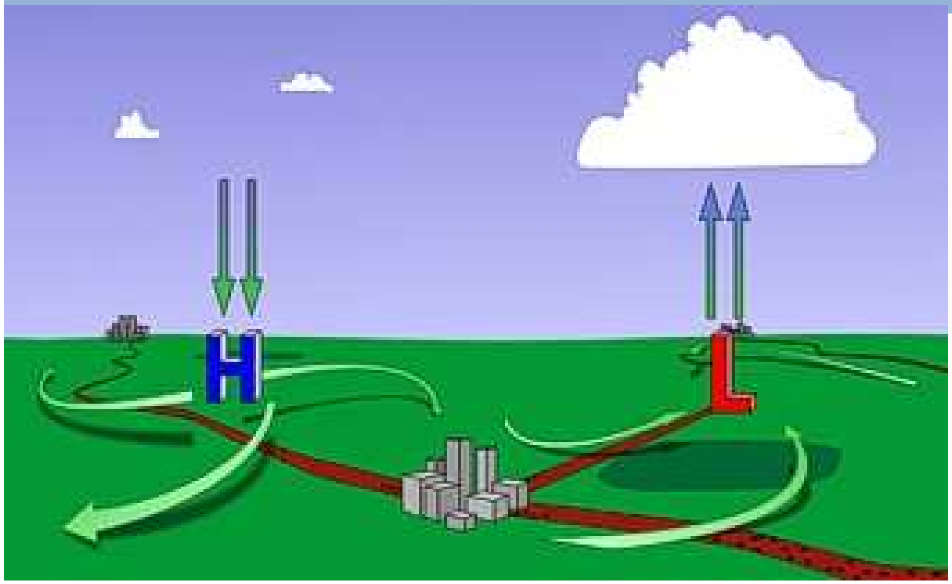
One half of the air molecules in the atmosphere are contained within the first 18,000 feet (5.6 km).

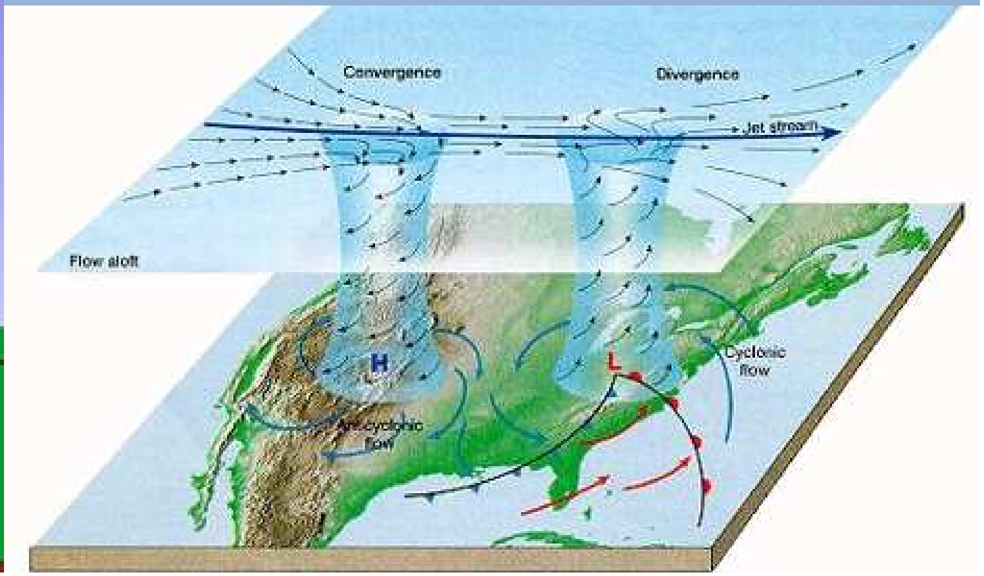
Air Pressure

- Atmospheric pressure at the Earth's surface is one of the keys to weather.
- Molecules in the atmosphere move to equalize pressure, moving from high pressure to low pressure areas.
- The flow of molecules from areas of high to low pressure produces wind.
- High and low pressure areas are important because they affect the weather.

- High Pressure System
  - The wind flows clockwise.
  - Air sinks and warms to bring clear skies

- Low Pressure System
  - The wind flows counterclockwise.
  - Air rises and cools to produce clouds/rain.





ORIGIN OF WIND – AIR IN MOTION

- Wind is the horizontal flow of air caused by differences in temperature and pressure.

- Wind tends to flow around areas of high and low pressure rather than directly from high to low pressure.

- Pressure gradient is the difference in pressure between high and low pressure areas. Wind speed is directly proportional to the pressure gradient. This means the strongest winds are in the areas where the pressure gradient is the greatest.

3 FORCES THAT GOVERN THE WIND

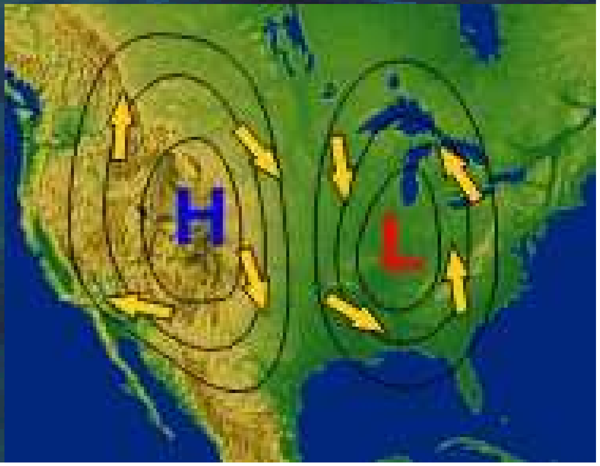
All three forces work together at the same time.

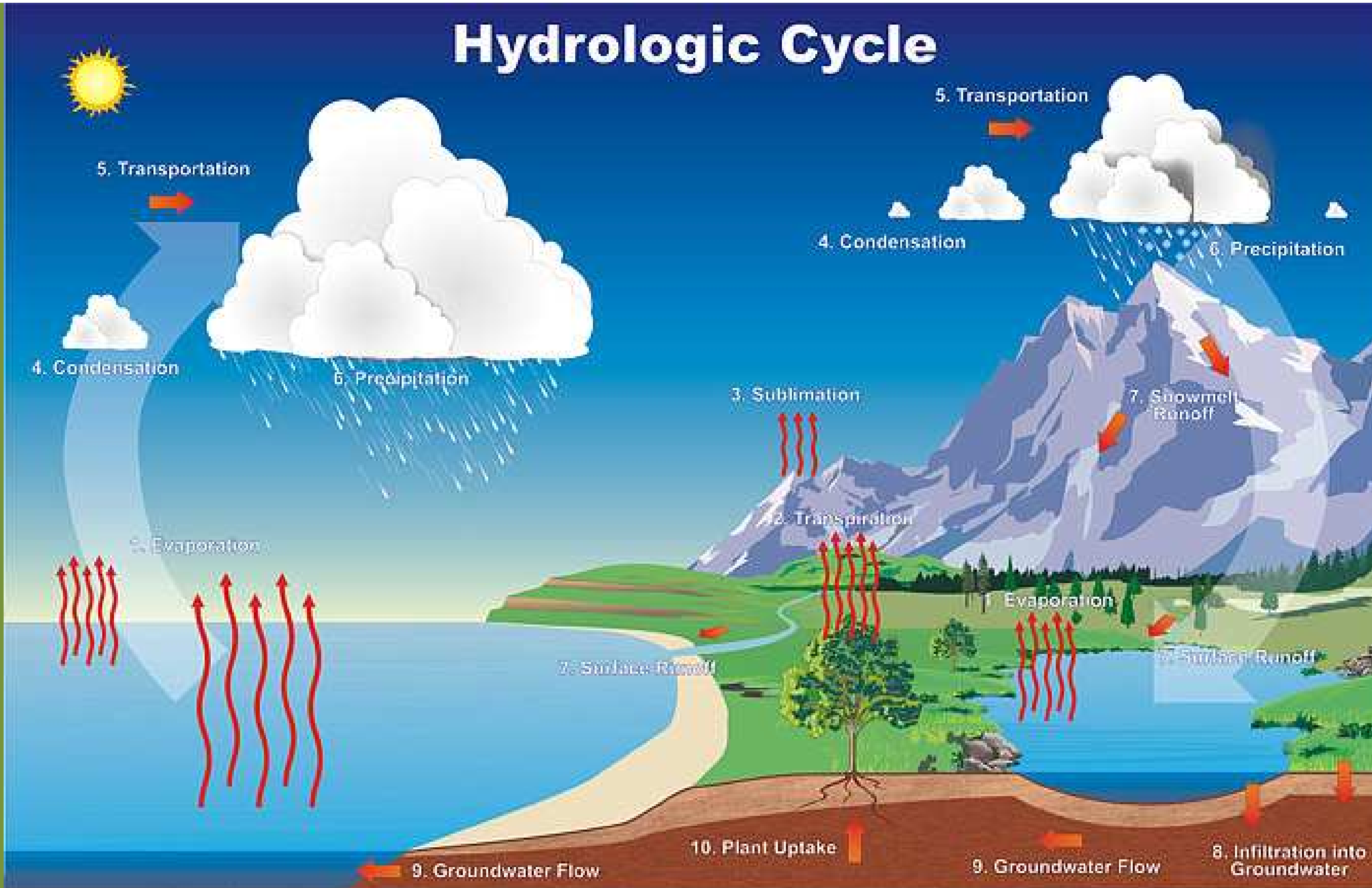
1. The <u>pressure gradient force</u> - a force that tries to equalize pressure differences. Causes high pressure to push air toward low pressure. Air would flow from high to low pressure if the pressure gradient force was the only force acting on it.

2. Because of the earth's rotation, a second force, the <u>Coriolis force</u>, affects the direction of wind flow. This force causes objects in the northern hemisphere to turn to the right.

The combination of these two forces would cause the wind to blow parallel to straight isobars (lines of constant pressure) with high pressure on the right.

3. <u>Friction</u>: The surface of the earth is rough and it not only slows the wind down but it also causes the diverging winds from highs and converging winds near lows.





- The Hydrologic Cycle involves the continuous circulation of water in the Earth-atmosphere system.

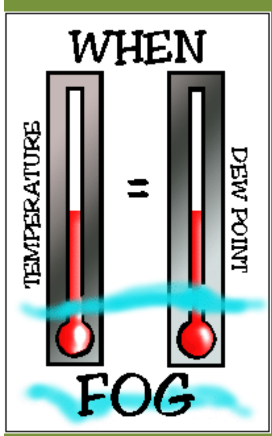
- The oceans are the primary source of moisture for the atmosphere, but lakes, rivers, swamps, moist soil, snow, ice fields and vegetation are also sources.

Moisture: Dewpoint vs. Relative Humidity

Dew Point- Temperature to which air must be cooled to be saturated. If the dew point increases, it is only because the amount of moisture in the air increases.

- Used by meteorologists – gives a more accurate picture of amount of moisture in atmosphere

Relative Humidity- a measure of the amount of water vapor in the air (at a specific temperature) compared to the maximum amount of water vapor air could hold at that temperature.



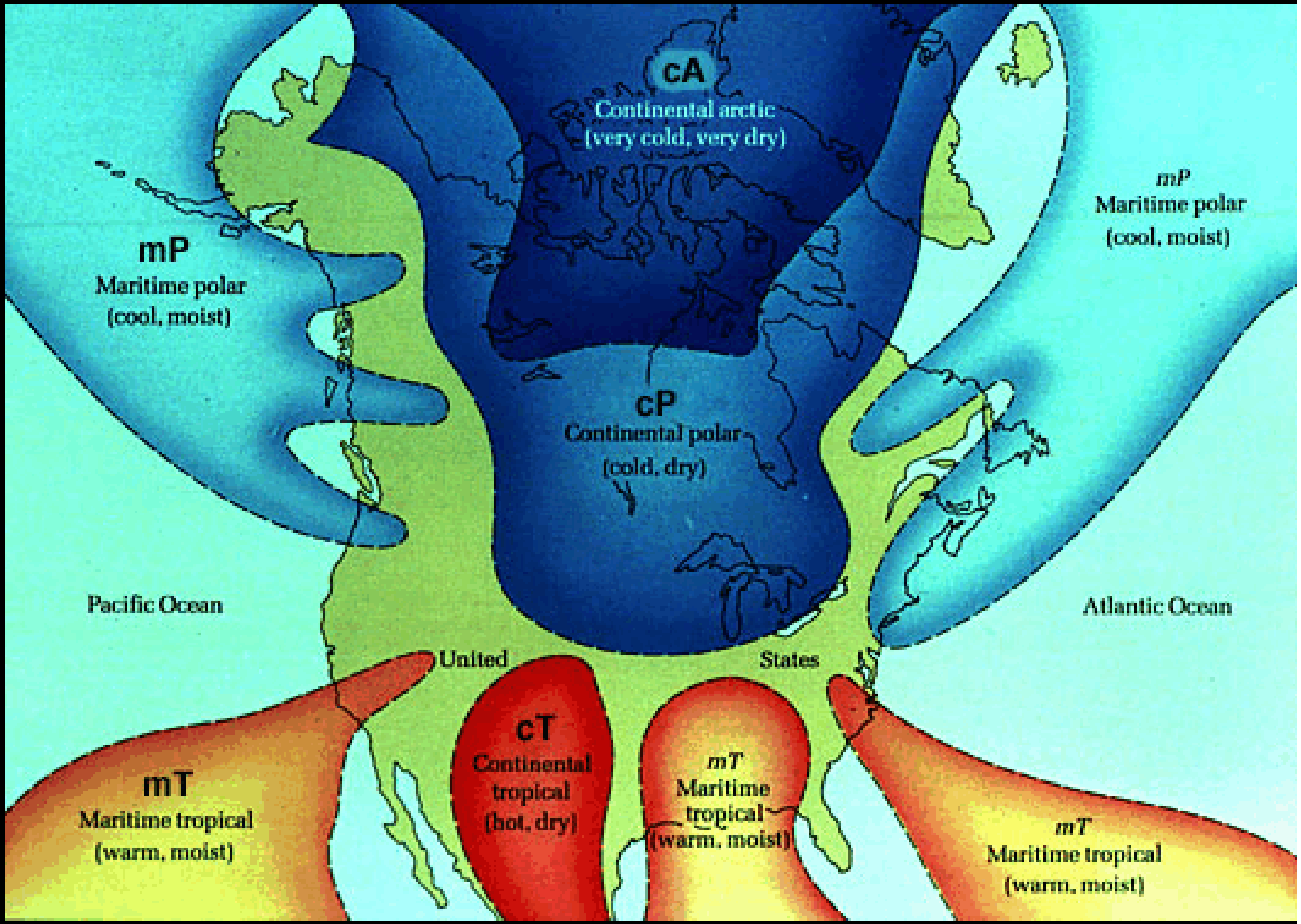
SATURATION!

Dew Point Temp. °F	Human Perception	Relative Humidity Air Temp 90°F
75°+	Extremely uncomfortable, oppressive	62%
70° - 74°	Very Humid, quite uncomfortable	52% - 60%
65° - 69°	Somewhat uncomfortable for most people at upper limit	44% - 52%
60° - 64°	OK for most, but everyone perceives the humidity at upper limit	37% - 46%
55° - 59°	Comfortable	31% - 41%
50° - 54°	Very comfortable	31% - 37%
49° or lower	Feels like the western US a bit dry to some	30%

A dew point of 95 °F was reported in Dhahran, Saudi Arabia on July 8, 2003. The temperature was 108 °F, resulting in heat index of 176 °F

Air Masses

- An air mass is a large body of air with generally uniform temperature and humidity.
- The area from which an air mass originates is called a "source region."
- Air mass source regions range from extensive snow covered polar areas to deserts to tropical oceans.

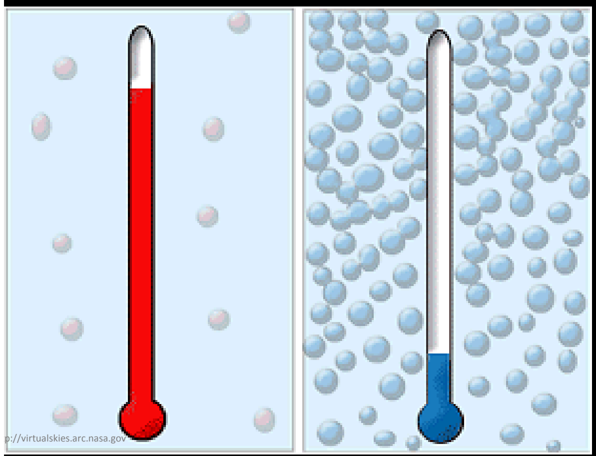


geography.sierra.cc.ca.us

Fronts

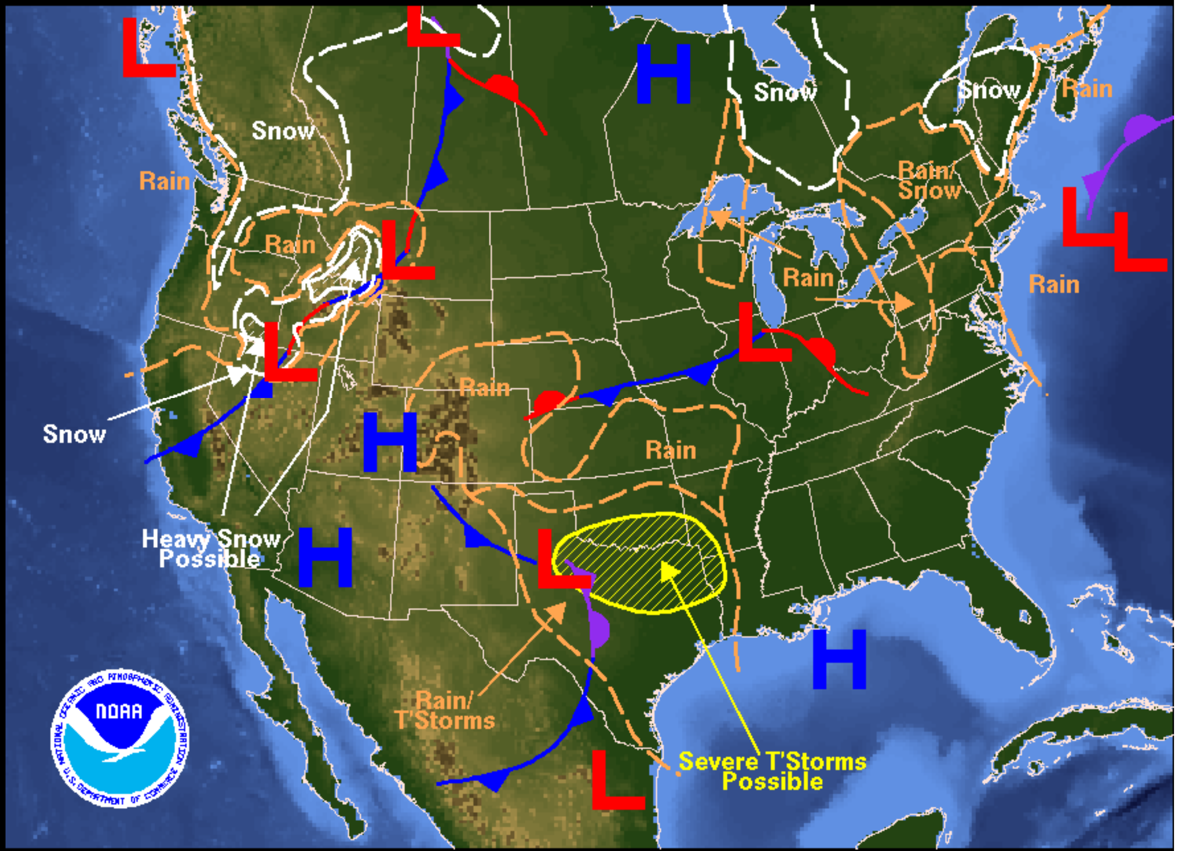
Boundaries between air masses

- Meteorologists use fronts to determine the edge of an air mass
- The symbols used represent the type of air mass moving into an area
- Recall that cold air is heavy and dense:



Warm Air
Not as many molecules

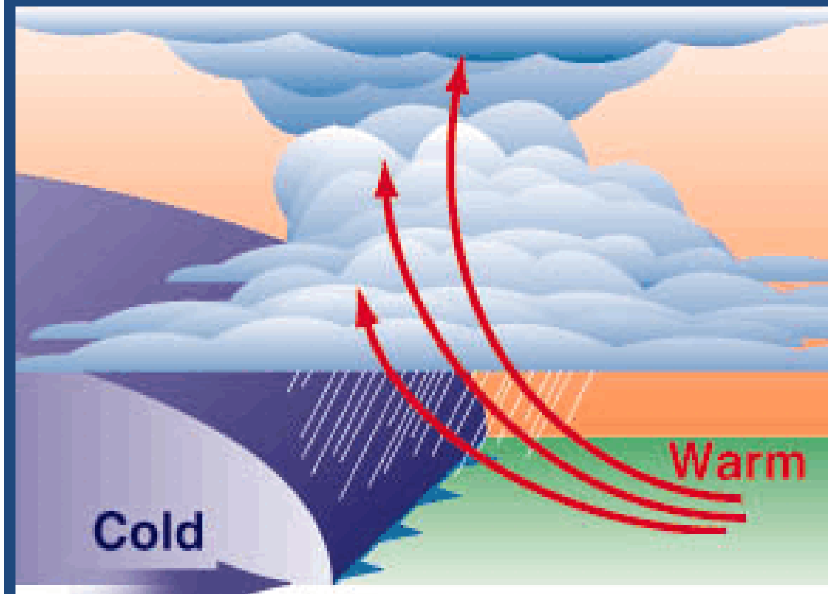
Cold Air
Many molecules



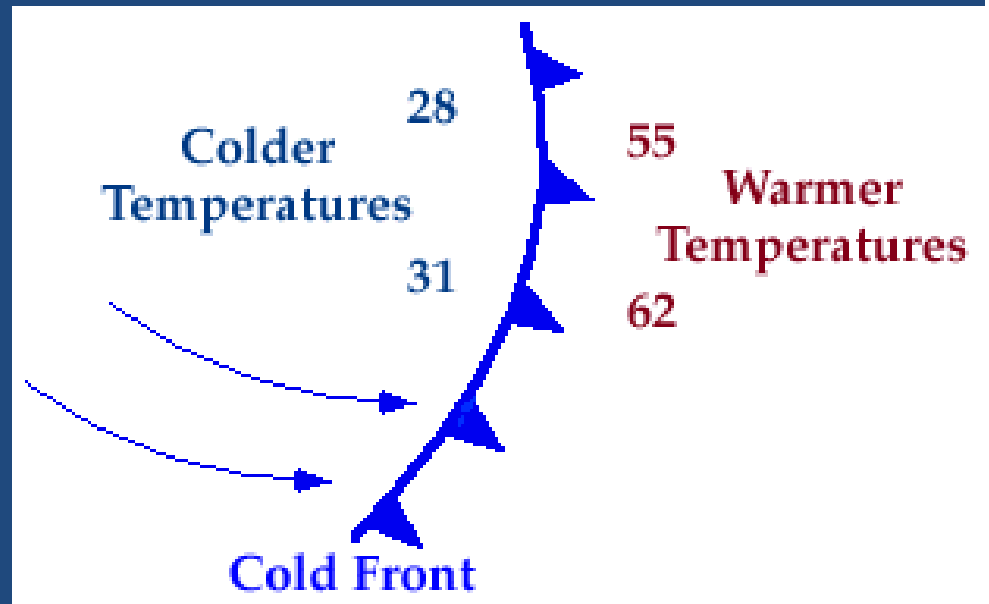
Weather Forecast for Tuesday, April 17, 2007
DOC/NOAA/NWS/NCEP/Hydrometeorological Prediction Center
Prepared by Otto based on HPC, SPC, and TPC forecasts.

COLD Fronts

Cold air is more dense than warm air



University Corporation for Atmospheric Research (UCAR).



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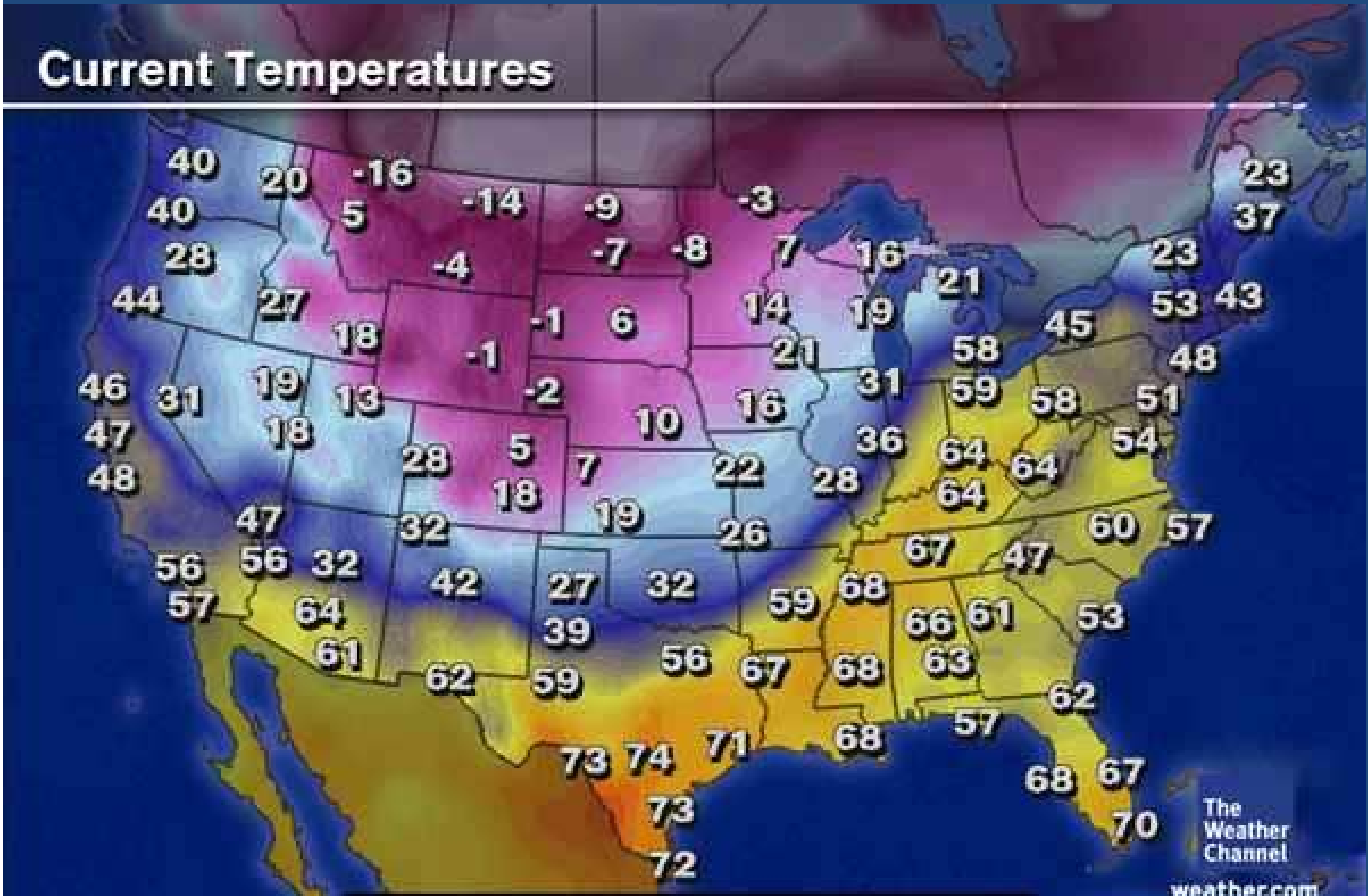
Thunderstorms possible…

A cold front is defined as the transition zone where a cold air mass is replacing a warmer air mass.

The air behind a cold front is noticeably colder and drier than the air ahead of it.



Current Temperatures
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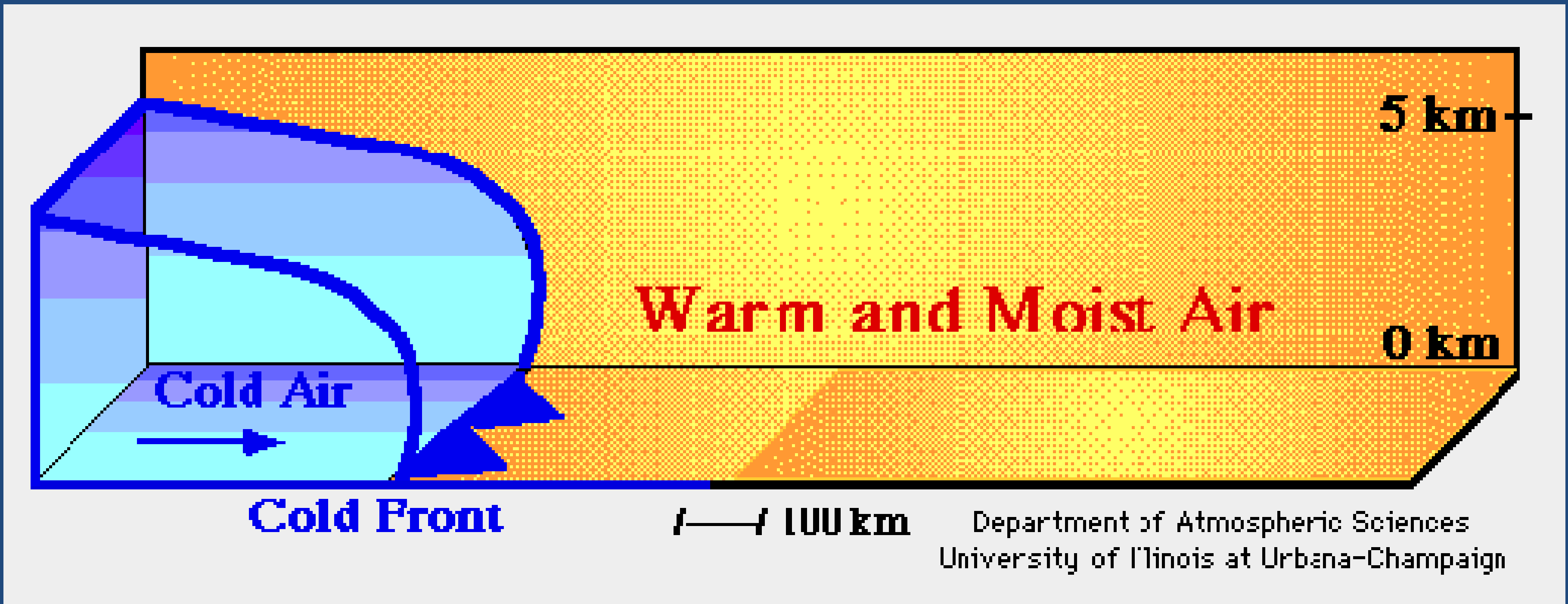
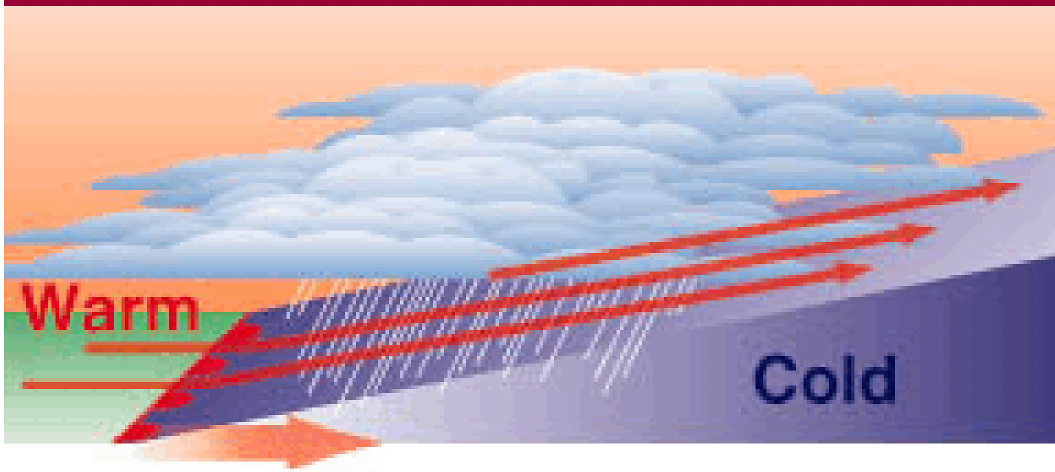
The Weather Channel
weather.com

Animation: COLD FRONT



WARM Fronts

Warm air is less dense than cold air



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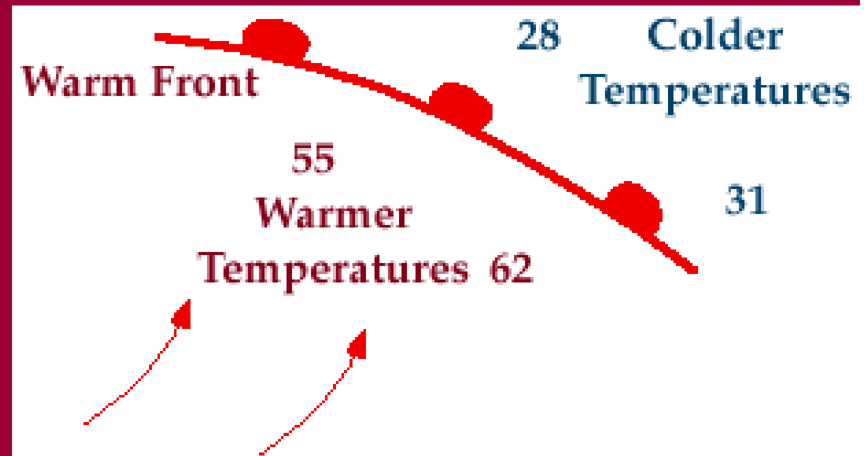

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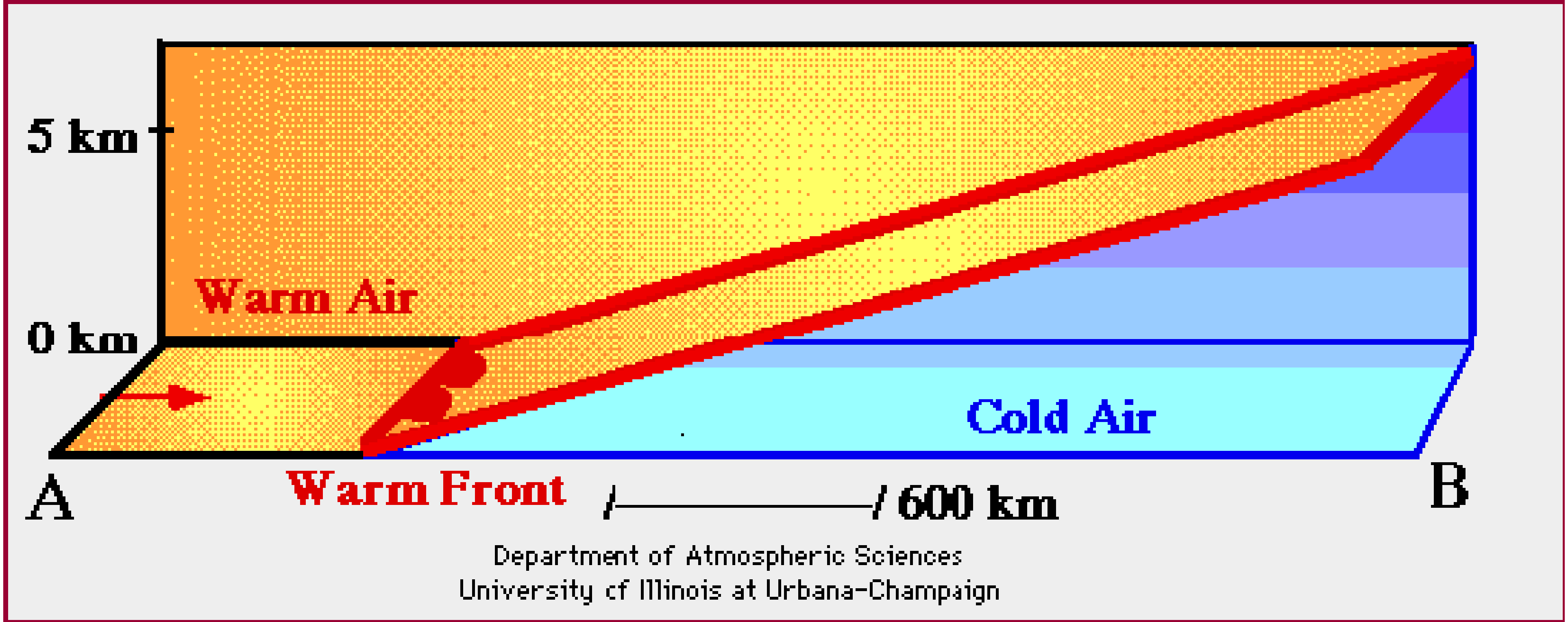
Steady rain possible…

A warm front is defined as the transition zone where a warm air mass is replacing a cold air mass.

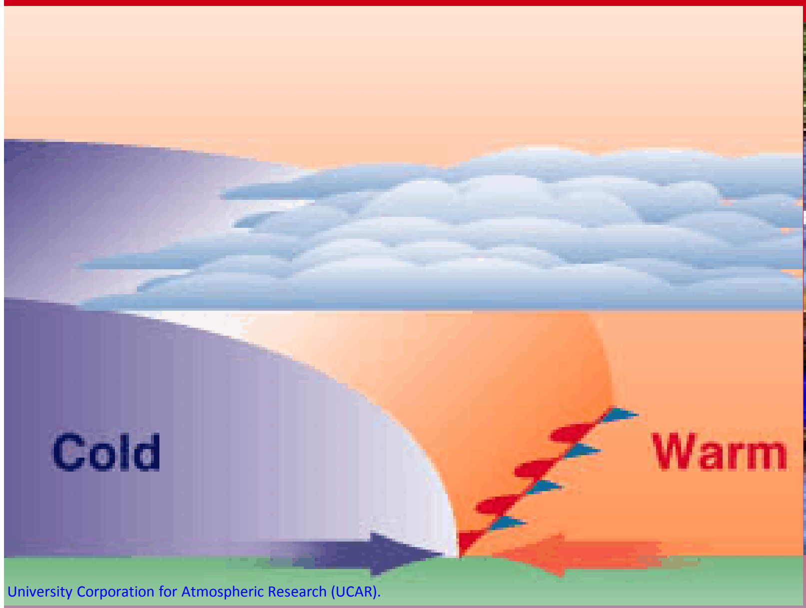
When a warm front passes through, the air becomes noticeably warmer and more humid than it was before.

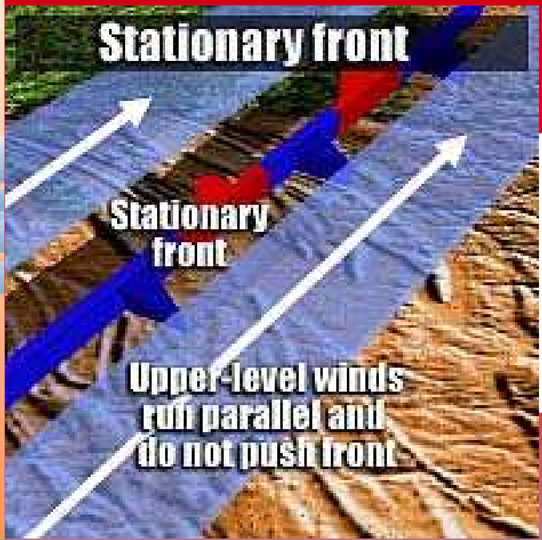
Animation: WARM FRONT

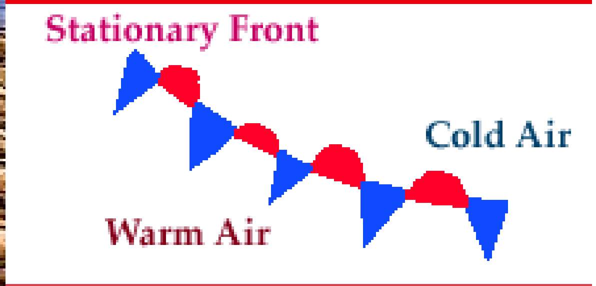


STATIONARY Fronts

Nothing is moving!







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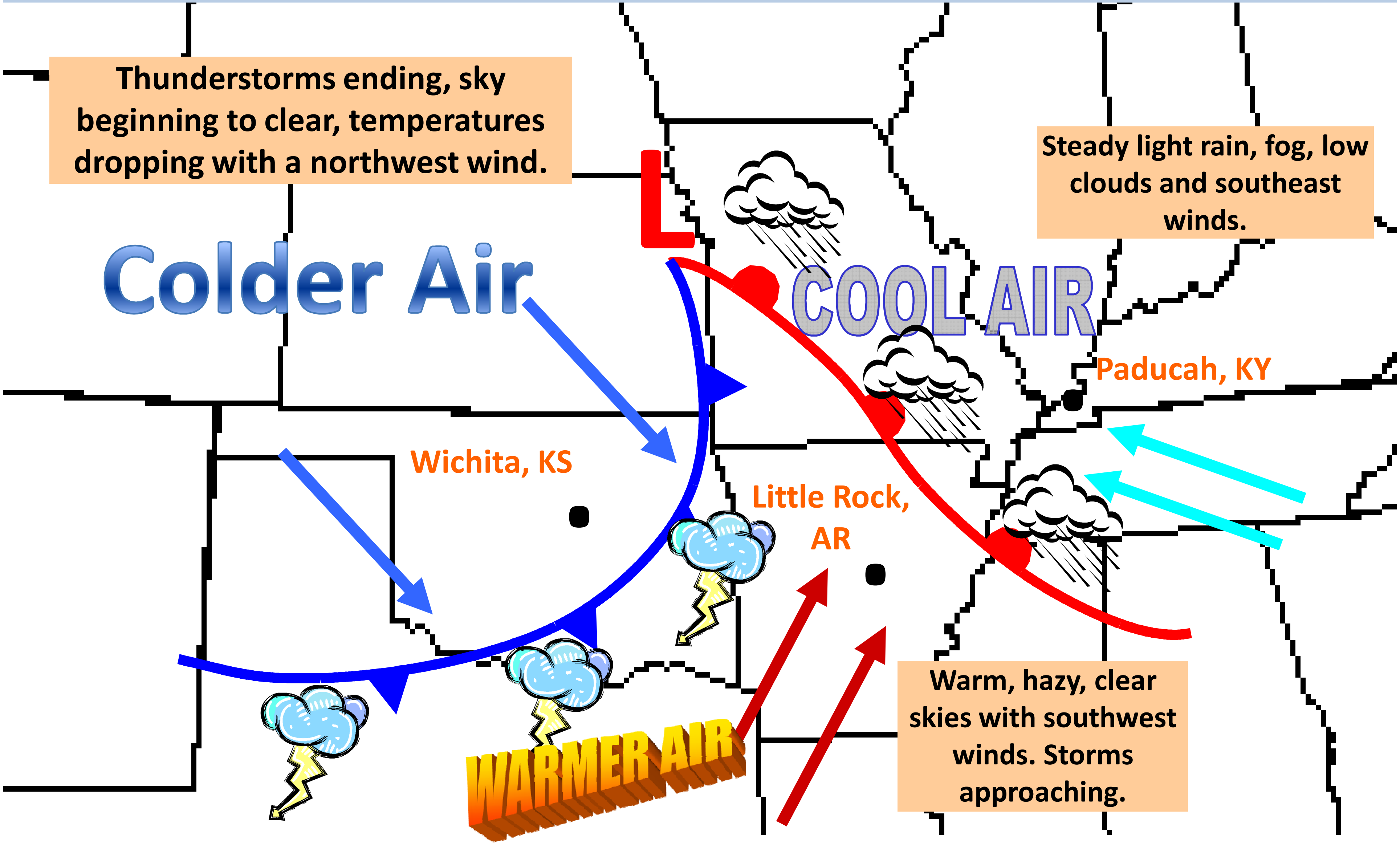
Widespread cloudiness probable…

Neither the cold nor the warm air is advancing, it's a standoff!

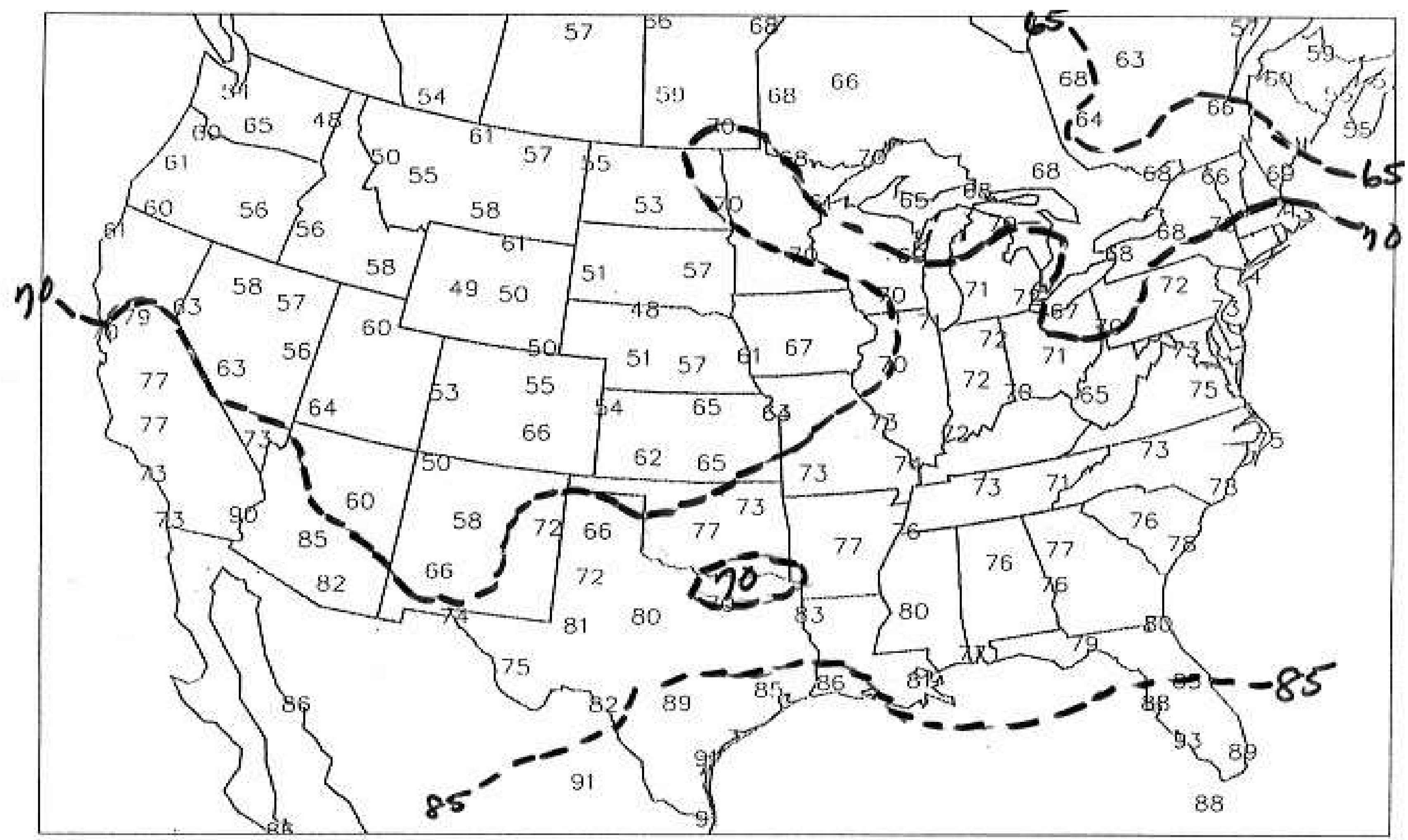
Once this boundary resumes its forward motion, it once again becomes a warm front or cold front.

Low Pressure System

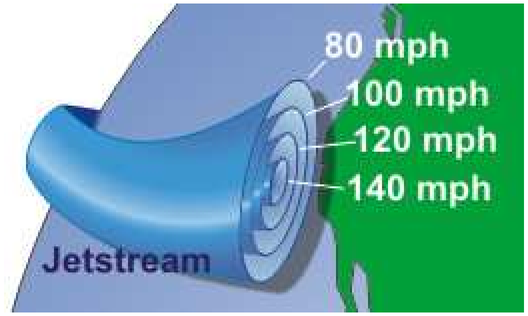


Temperature Exercise: YOU be the meteorologist!

- Use the blank temperature map
- Analyze every 5 degrees
- You are playing connect the dots!



Jet Stream: Rivers of Air

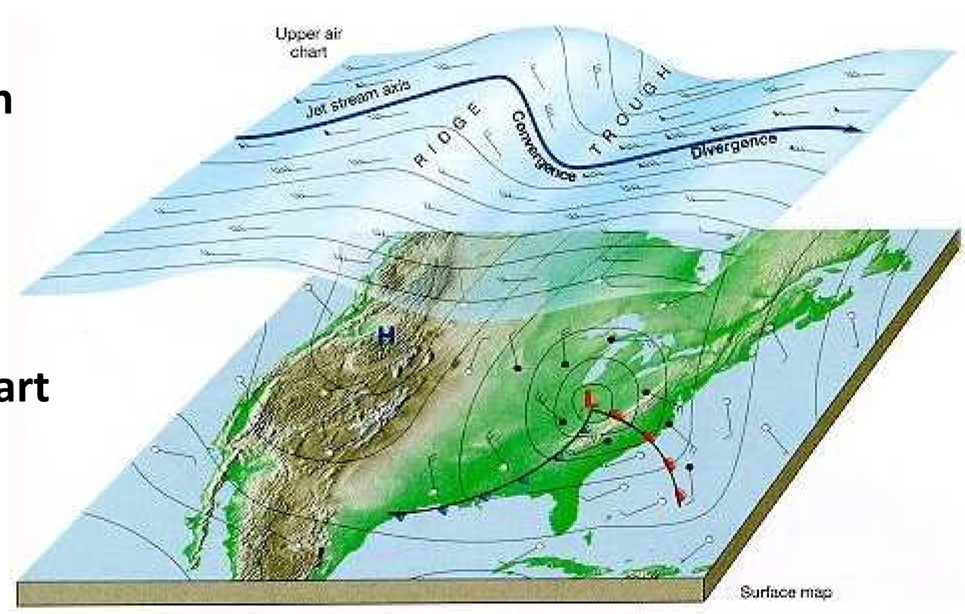


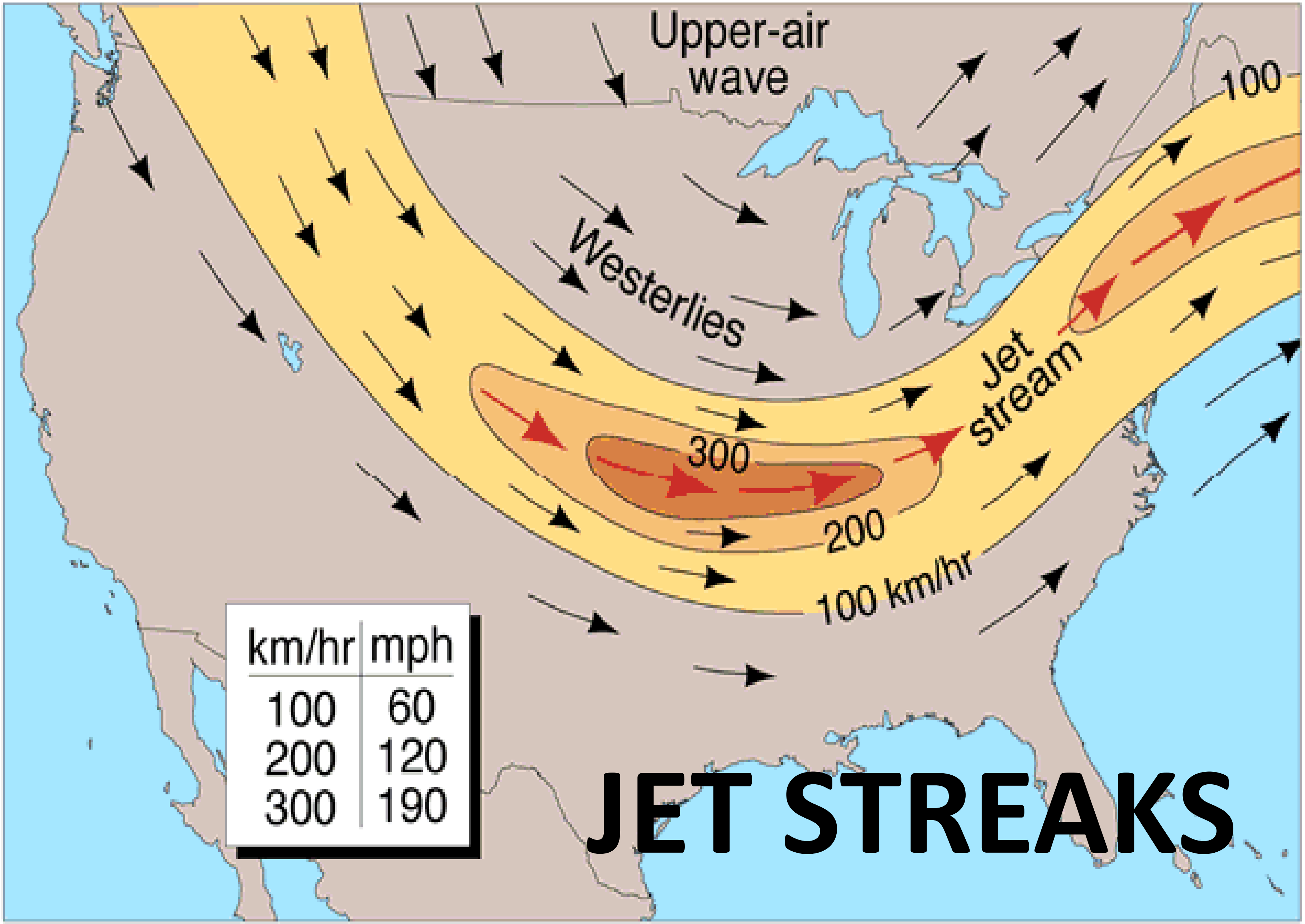
• Jet streams are relatively narrow bands of strong wind in the upper levels of the atmosphere.

•The winds blows from west to east in jet streams but the flow often shifts to the north and south.

•Jet streams follow the boundaries between hot and cold air. Since these hot and cold air boundaries are most pronounced in winter, jet streams are the strongest for both the northern and southern hemisphere winters.

•The path of jet streams steers cyclonic storm systems at lower levels in the atmosphere, and so knowledge of their course is an important part of weather forecasting.





JET STREAKS

National Weather Service.

The Thunderstorm

Information condensed from Dr. Dave Arnold

Ingredients needed for development:

Buoyancy/Instability: *the force that causes air parcels to accelerate vertically.*

Lifting Mechanism: *lifting of air by mechanical means such as a front.*

Moisture

Shear: *change in wind speed and/or direction in the vertical. Critical in determining potential for severe thunderstorms.*

Buoyancy/Instability:
How quickly can we get air to move

- The thermals creating clouds work similarly to a hot air balloon.

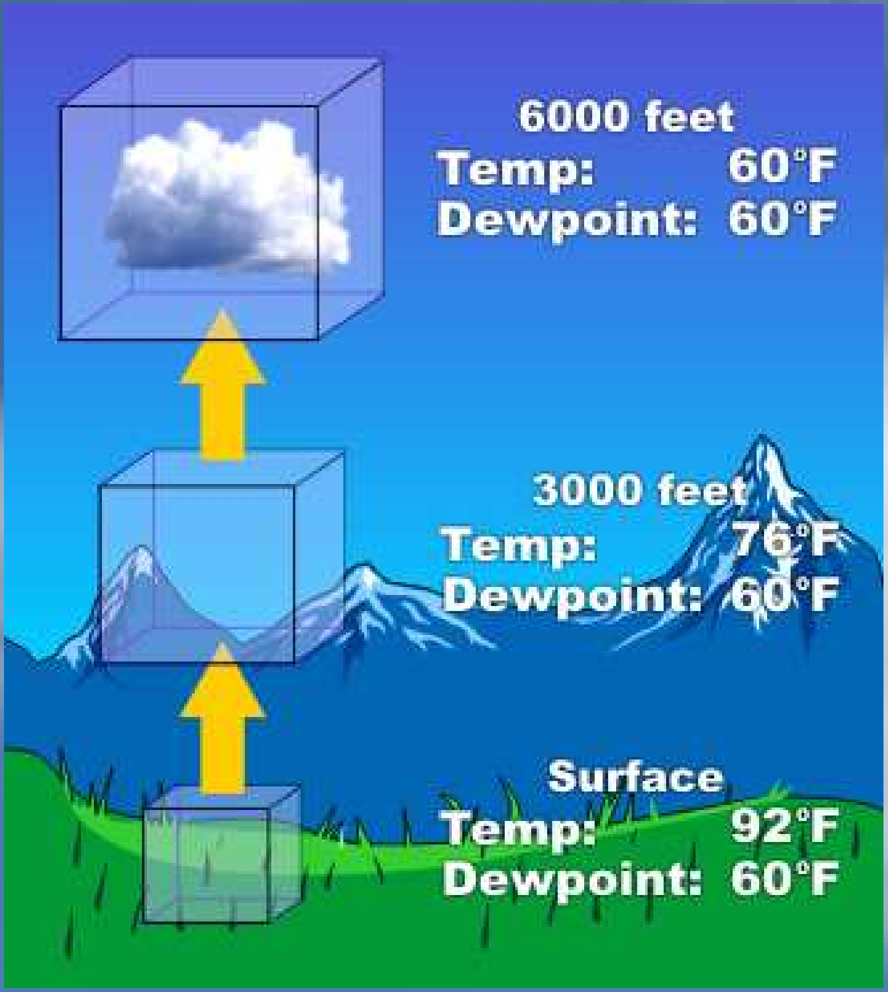
- Though rising air is continually mixing with surrounding air of slightly different temperature, moisture and thus density values, a hot air balloon has little mixing and typically only receives hot air.

- Hot air in the balloon is less dense, “lighter” than air surrounding balloon, so balloon rises.

- Greater the density (temperature) difference, the greater the rate of rise .

Cloud Formation

- Clouds form when air is cooled to its dewpoint. The most common way air can reach saturation is through lifting.
- As a parcel of air rises, it expands. This requires energy which takes heat away from the parcel. So as air rises, it cools. This is called an adiabatic process.
- Since cold air can hold less water vapor than warm air, some of the vapor will condense onto tiny clay and salt particles called condensation nuclei and produce clouds.
- Lapse Rate: Rate at which a parcel cools with increasing height. Lapse rate of unsaturated air (dry lapse rate) is 10°C/km.



Thunderstorm Updraft:

- A relatively small scale current of air with a marked upward motion.
- The updraft that produces a thunderstorm is a vertical acceleration.

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CAPE: **C**onvective **A**vailable **P**otential **E**nergy

"Quantifies the Amount of Upward Push or Acceleration"

CAPE:

- **The amount of energy available in the atmosphere to create convection (thunderstorms).**

- **The larger the CAPE, the greater the strength of the updraft (and typically, the larger the hail and the stronger the downdraft).**

- **Therefore, higher values of CAPE indicate an increasing possibility for severe weather.**

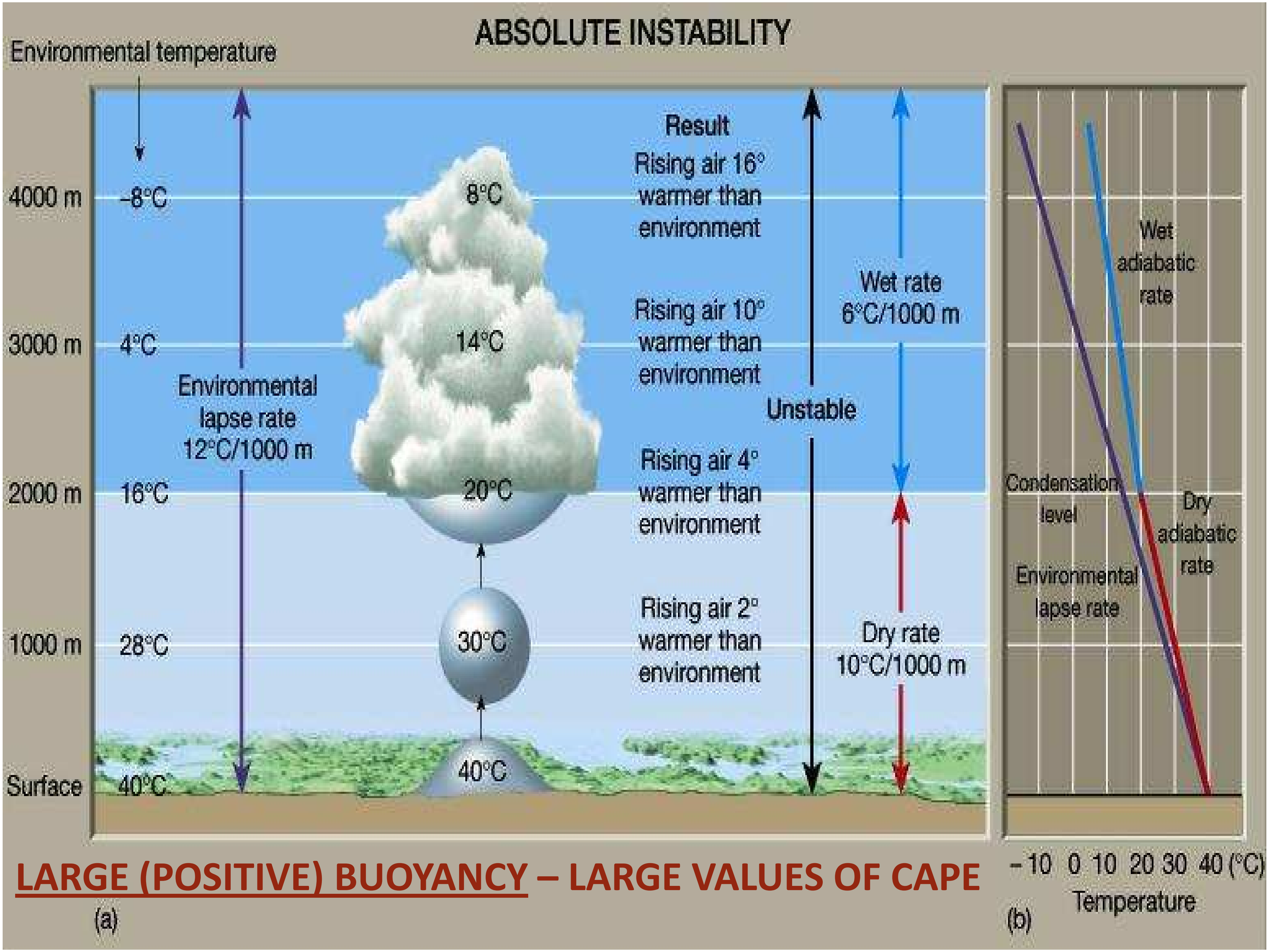
- **Large values of CAPE are usually the result of large amounts of heat and humidity near the surface and cold dry air aloft.**

- **The height to which a storm reaches is a function of the amount of CAPE, which accelerates the parcels of air upward.**

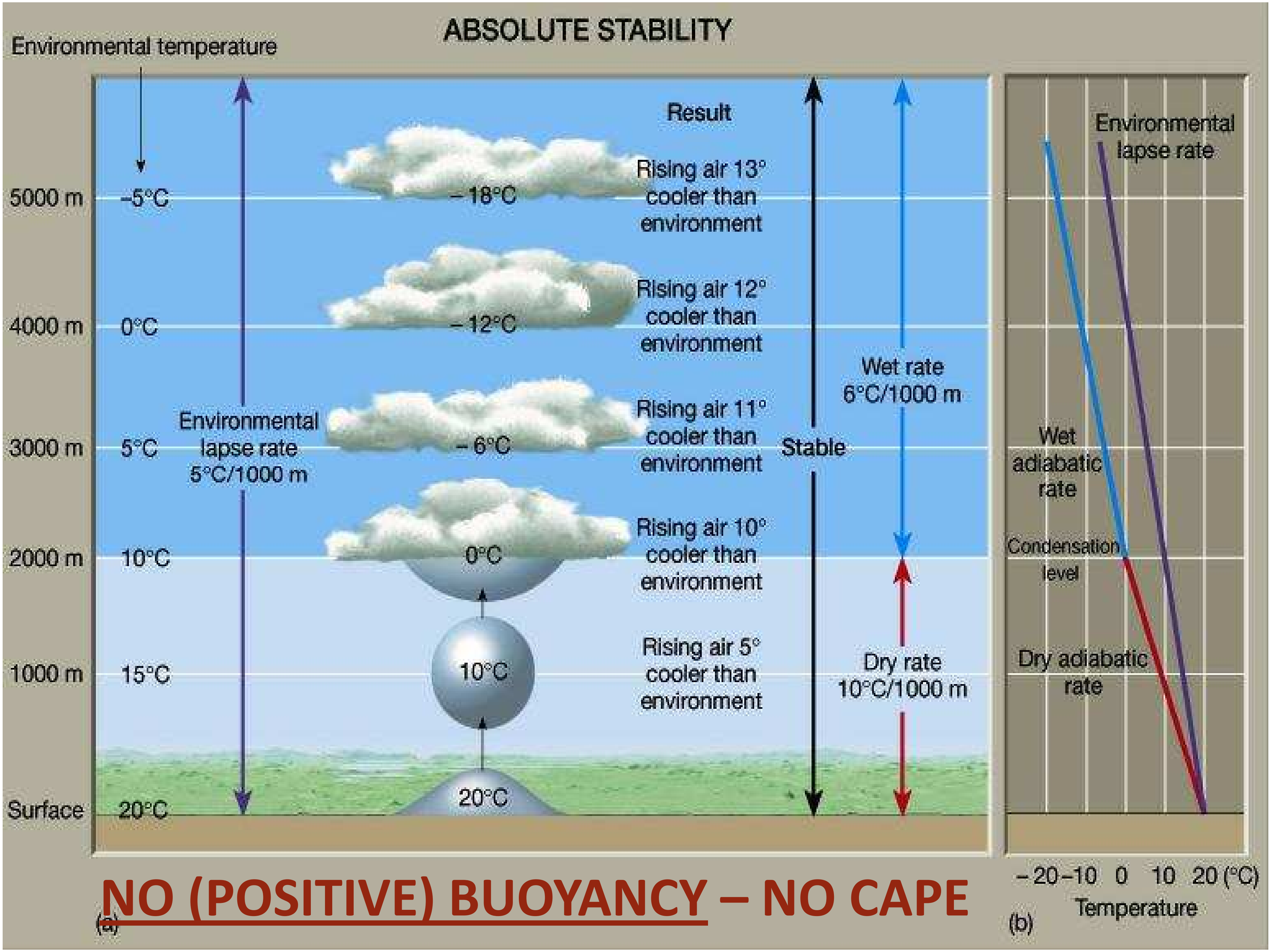
CAPE VALUES

< 100 J/KG	INCONSEQUENTIAL	FAIR WEATHER CUMULUS
100-1000 J/KG	SMALL BUOYANCY	UPDRAFT = 30-50 MPH
1000-2000 J/KG	MODERATE BUOYANCY	UPRDAFT = 50-70 MPH
2000-3000 J/KG	LARGE BUOYANCY	UPDRAFT = 70-90 MPH
3000-4000 J/KG	VERY LARGE BUOYANCY	UPDRAFT = 90-110 MPH
> 4000 J/KG	EXTREME BUOYANCY	UPDRAFT = > 110 MPH

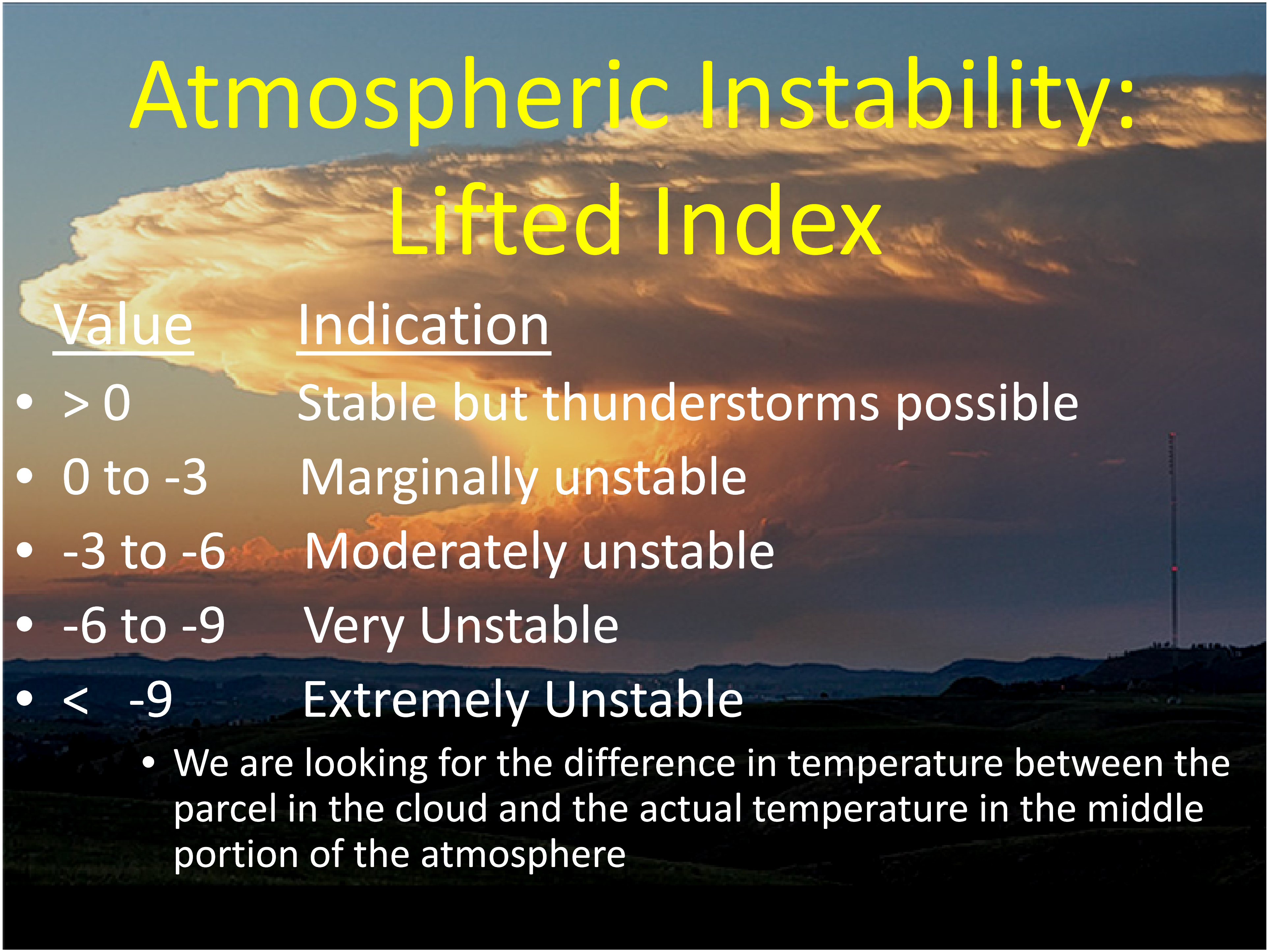
Recent research suggests that 0- 3 km CAPE may be as or more important than total CAPE in an attempt to assess the degree of low level vertical acceleration important in the tornadogenesis process.



LARGE (POSITIVE) BUOYANCY – LARGE VALUES OF CAPE



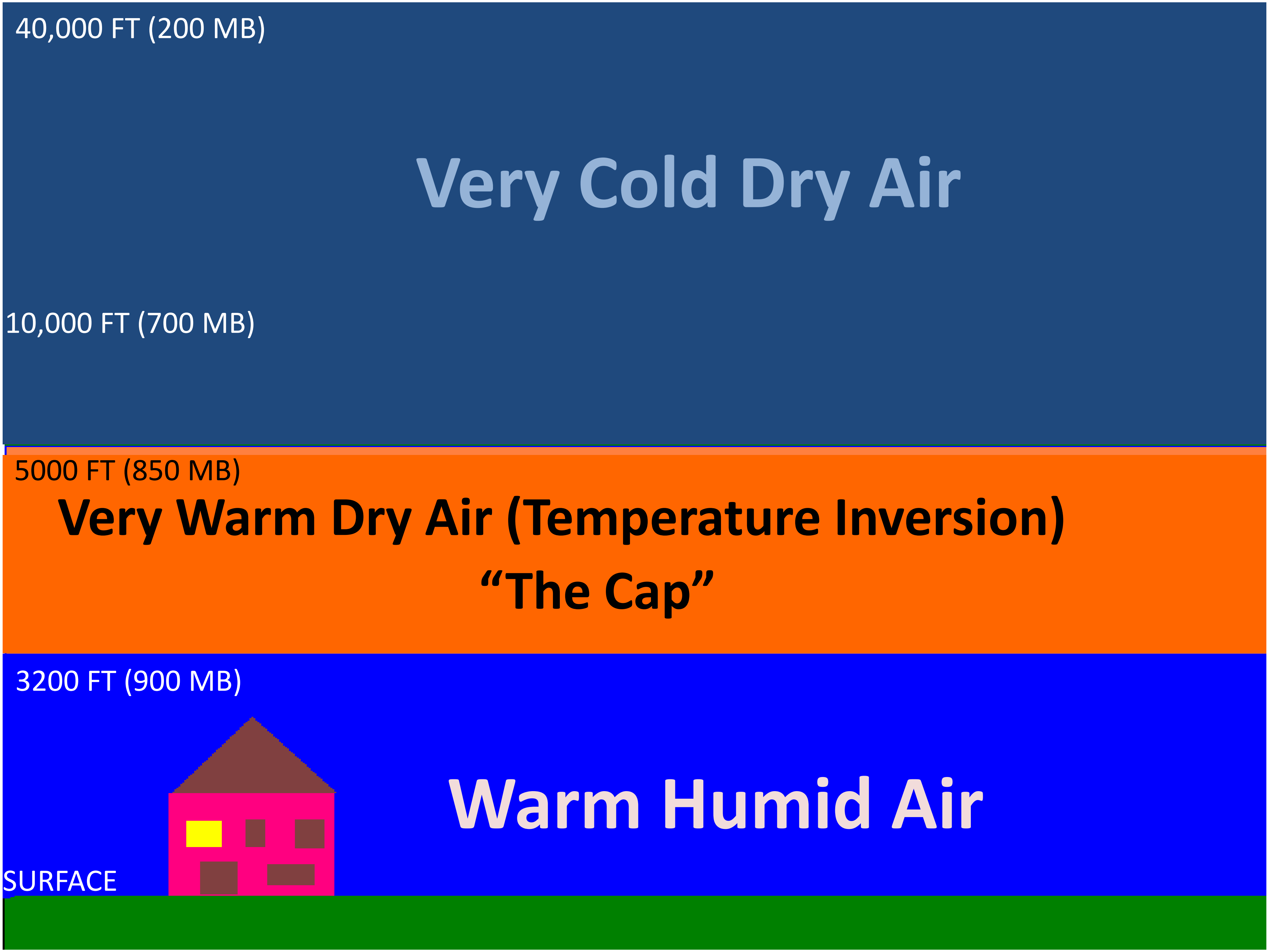
NO (POSITIVE) BUOYANCY – NO CAPE



Atmospheric Instability: Lifted Index

Value	Indication
• > 0	Stable but thunderstorms possible
• 0 to -3	Marginally unstable
• -3 to -6	Moderately unstable
• -6 to -9	Very Unstable
• < -9	Extremely Unstable

- We are looking for the difference in temperature between the parcel in the cloud and the actual temperature in the middle portion of the atmosphere


40,000 FT (200 MB)
Very Cold Dry Air
10,000 FT (700 MB)
5000 FT (850 MB)
Very Warm Dry Air (Temperature Inversion)
“The Cap”
3200 FT (900 MB)
Warm Humid Air
SURFACE

CAP Strength

- Cap usually layer from 5,000 – 10,000 feet
  - Cap strength determined by warmth and depth of layer (stronger when warmer, deeper)
- Amount of CAPE below cap and more importantly, strength of kicker, or erosion of cap from above (cooling) determine when/where cap is broken, cloud/storm reaches level of free convection

“The Killer Cap”

REGARDLESS OF THE MAGNITUDE OF CAPE, A CAP MUST USUALLY BE OVERCOME FOR THUNDERSTORMS TO DEVELOP

IF NO CAP EXISTS THEN THE CAPE IS QUICKLY EXHAUSTED OVER A LARGE AREA – THE END RESULT IS NUMEROUS NON-SEVERE STORMS (WITH PERHAPS A “PULSE SEVERE STORM” OR TWO)

IF THE CAP HOLDS UNTIL LATER AFTERNOON OR EVENING, IT ALLOWS CAPE VALUES TO INCREASE OVER TIME (PRIMARILY DUE TO SURFACE HEATING) SINCE THE BUILDING POTENTIAL ENERGY IS NOT RELEASED UNTIL IT REACHES PEAK INTENSITY

IF THE CAP BREAKS OVER VERY LIMITED AREAS THEN A RELATIVELY SMALL NUMBER OF SEVERE STORMS WILL BE ALLOWED TO ERUPT SINCE THE COMPETITION FOR ENERGY (CAPE) IS MINIMAL

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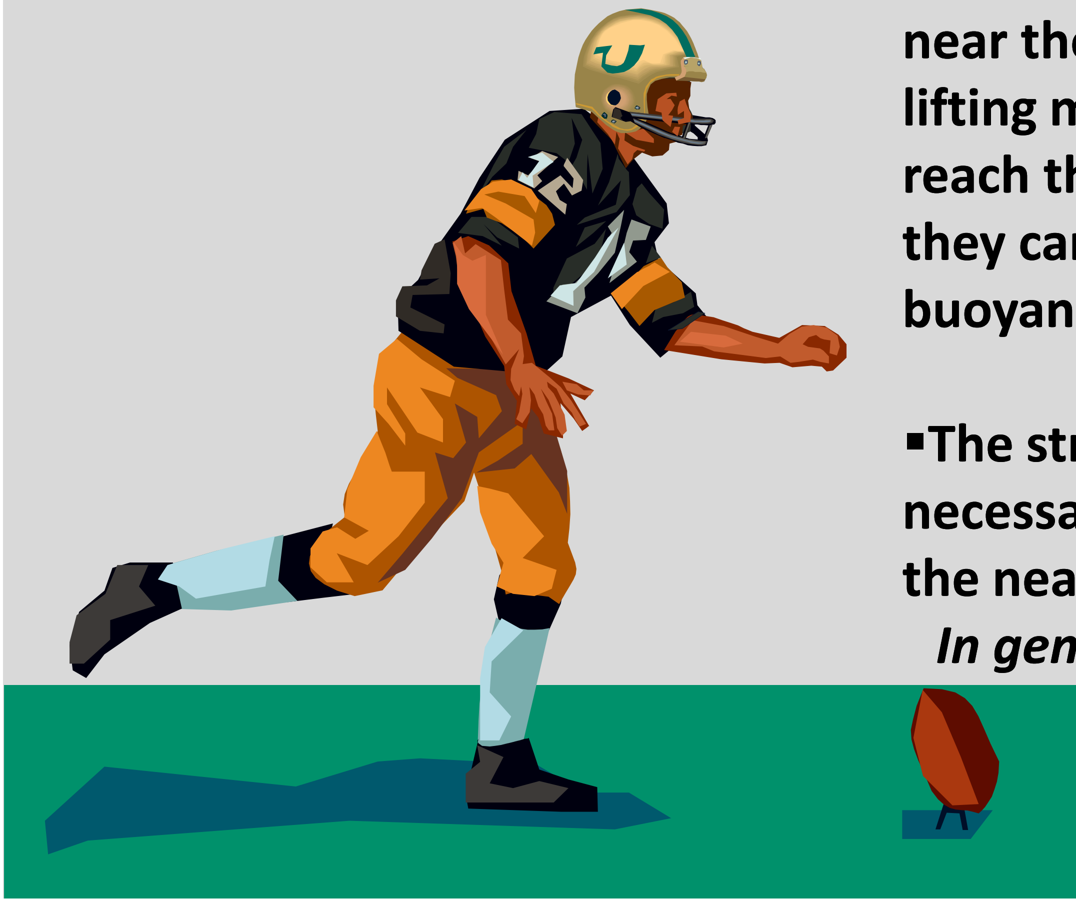
A CIN (Convective Inhibition) of 50 or below indicates a weak cap while 200 and above indicates a very strong cap.

Lifting Mechanisms or "Kickers"



- Often times the air near the surface will not rise unless acted upon by an outside force.
- *This outside force is called a lifting mechanism.*
- A lifting mechanism is needed to force air near the surface to initially rise. Without a lifting mechanism, parcels of air will not reach the point in the atmosphere where they can rise on their own due to positive buoyancy (Level of Free Convection - LFC).
- The strength of the lifting mechanism necessary to reach the LFC is a function of the near surface relative humidity.

In general, the greater the humidity, the less up lift is needed to advance the parcel to the LFC.

LIFTING MECHANISMS

THESE MECHANISMS CAN OCCUR IN THE FOLLOWING FORMS:

1) MECHANICALLY-FORCED ASCENT (e.g. a HILL or WARM FRONT)

2) DYNAMICALLY-FORCED ASCENT (e.g. a SHORTWAVE, JET STREAK, or COLD FRONT)

3) CONVERGENCE (e.g. a DENSITY DISCONTINUITY – KNOWN AS A “BOUNDARY” or a LOW-LEVEL JET)

4) THERMODYNAMICALLY-FORCED (e.g. BUOYANCY THAT DEVELOPS AT THE SURFACE (DUE TO STRONG SURFACE HEATING) WHEN NO CAP EXISTS

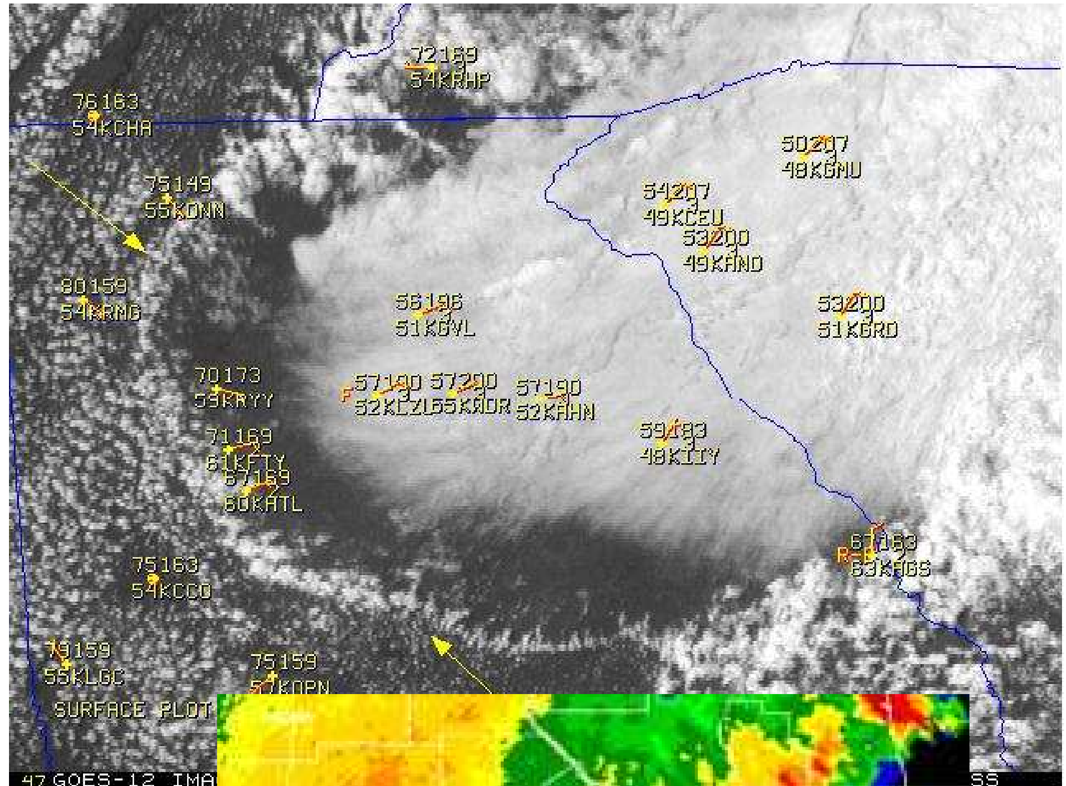
BOUNDARIES

There are times when the atmosphere is so primed that no additional energy sources are needed. However, more times than not, an extra source of energy is required for storms to become tornadic.

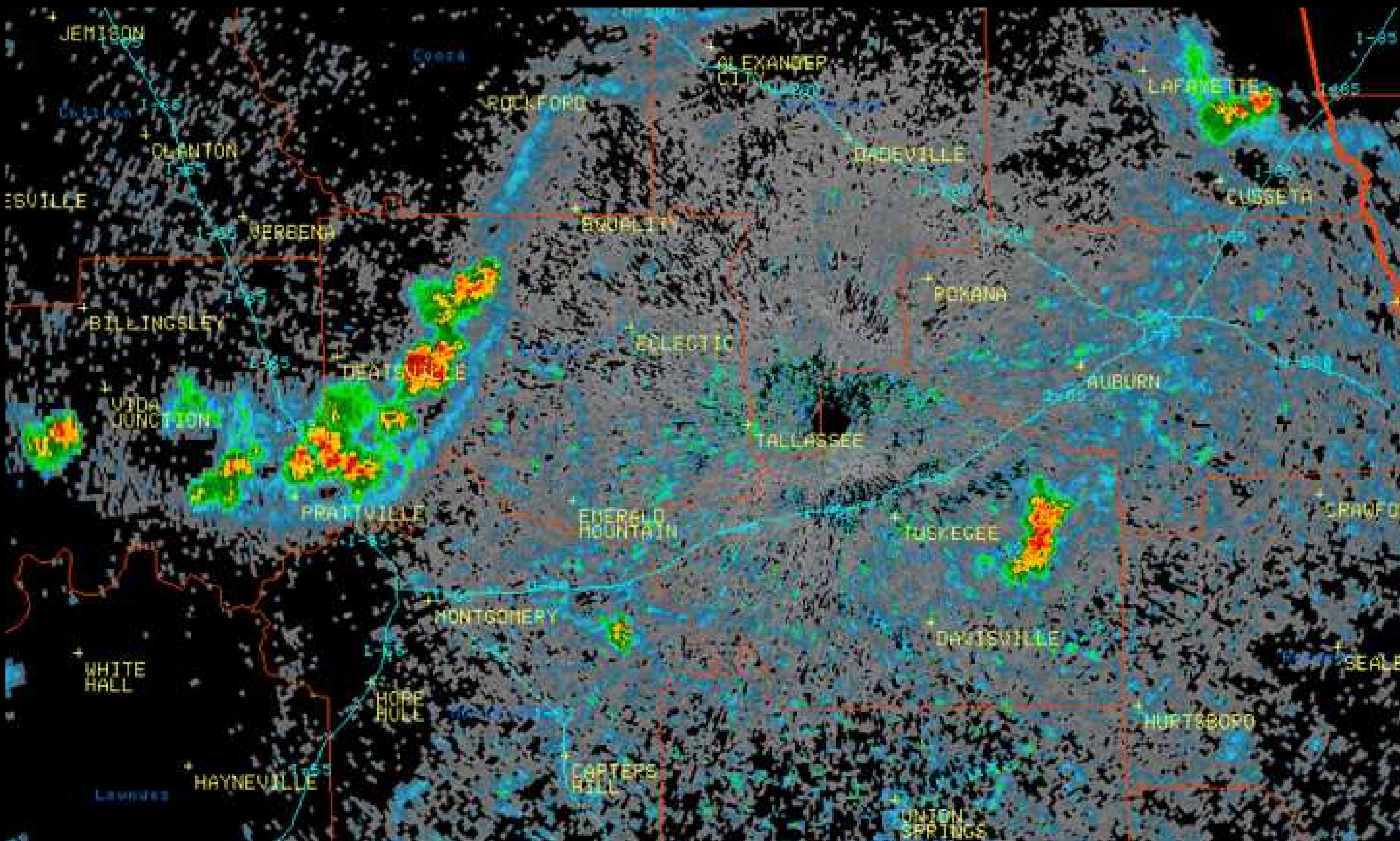
Boundaries are defined by wind shifts, temperature contrasts, dew point contrasts, or differential heating.

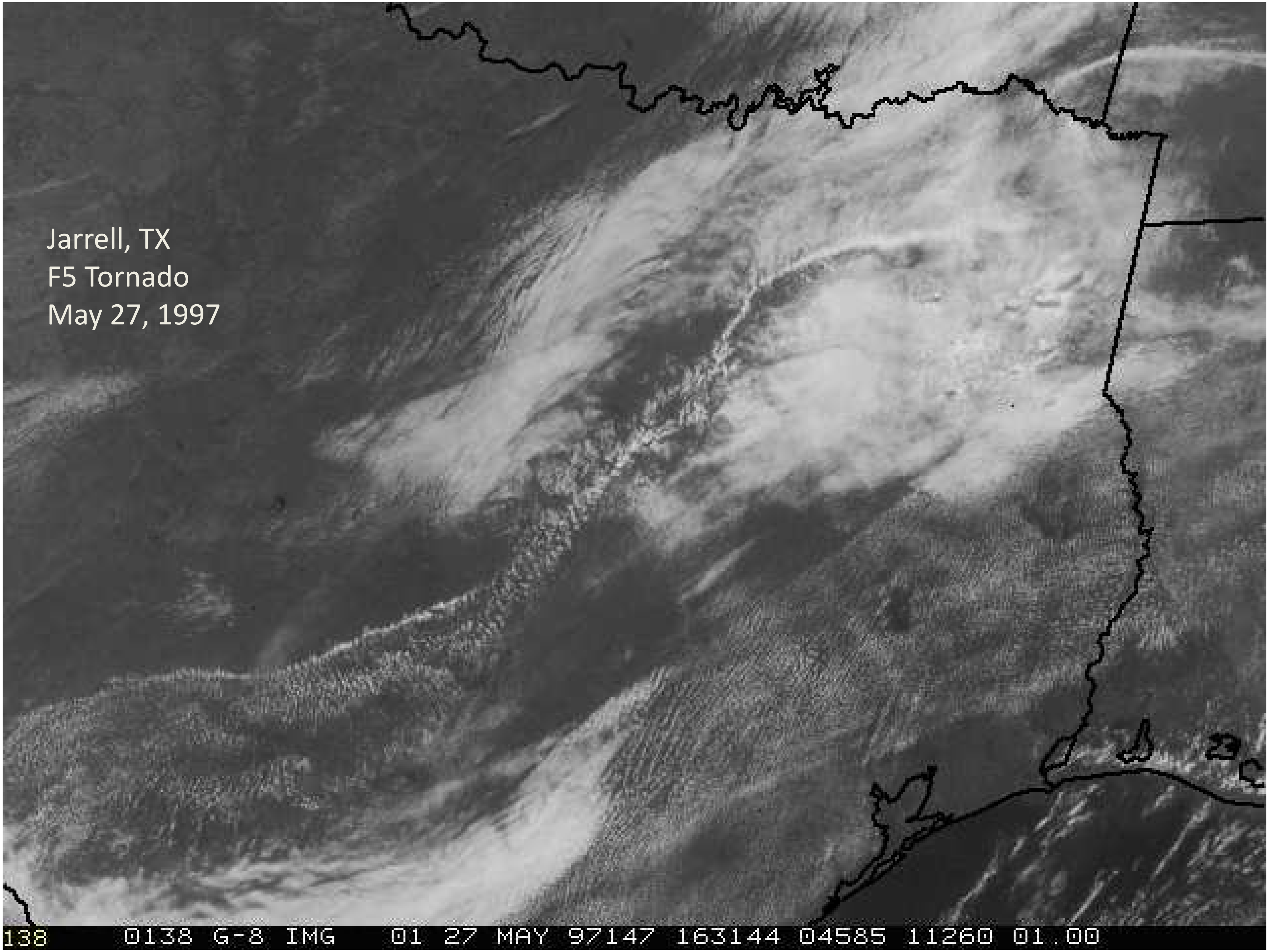
An outflow boundary is a storm-scale or mesoscale boundary separating thunderstorm-cooled air (outflow) from the surrounding air.

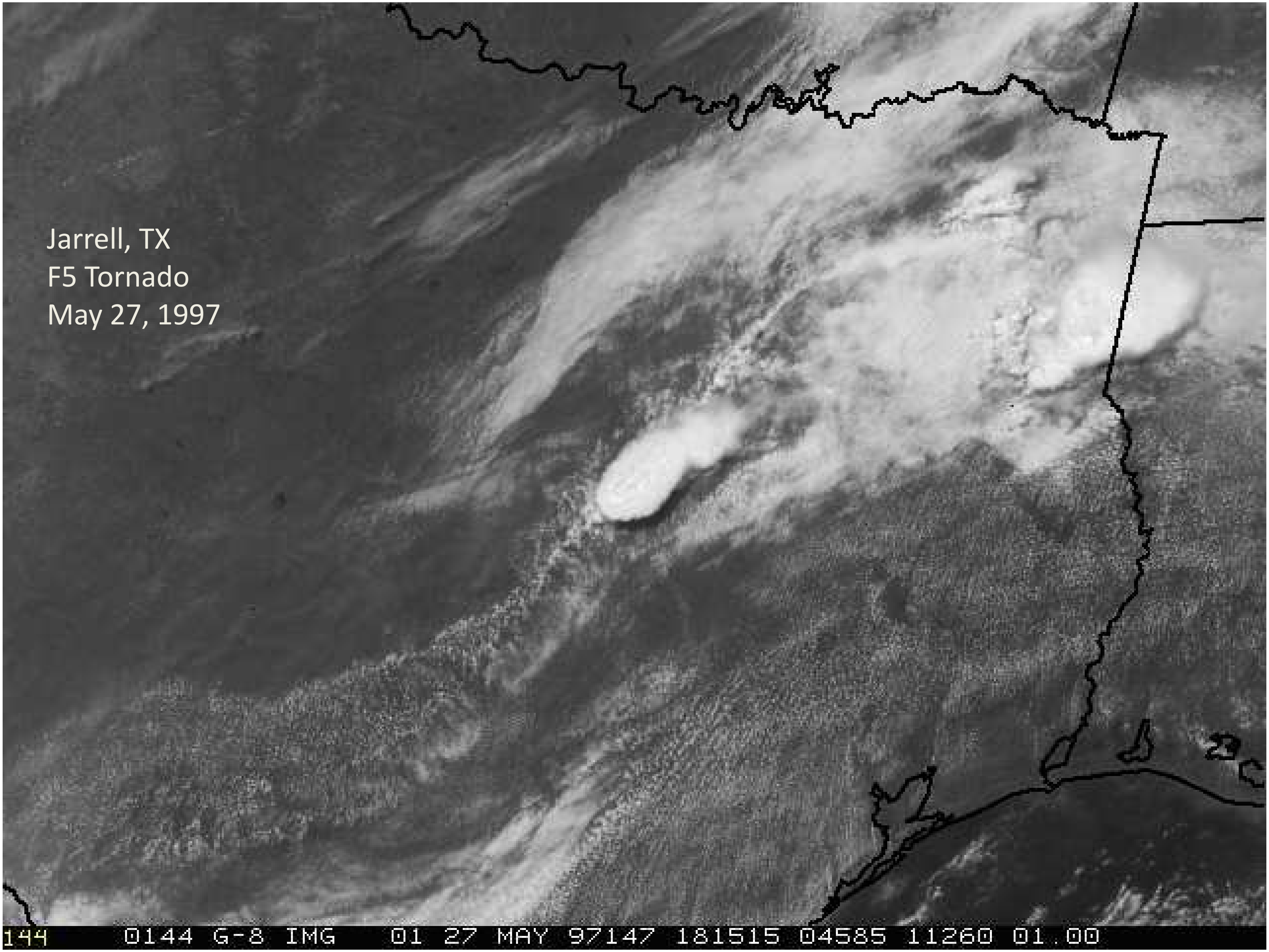
New thunderstorms often develop along outflow boundaries, especially near the point of intersection with another boundary (cold front, dry line, another outflow boundary, etc.)



Outflow boundaries in motion




Jarrell, TX
F5 Tornado
May 27, 1997
138 0138 G-8 IMG 01 27 MAY 97147 163144 04585 11260 01.00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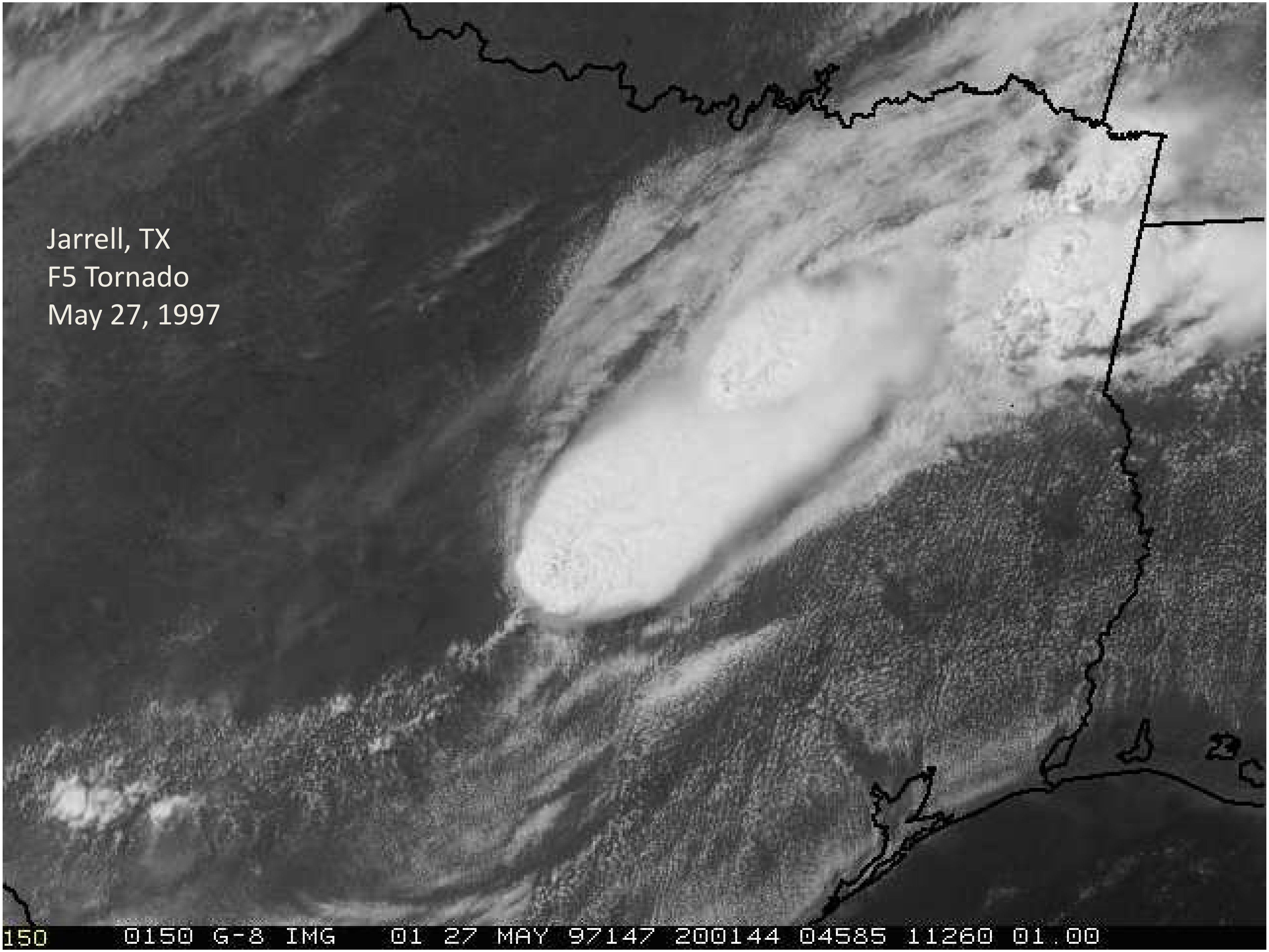
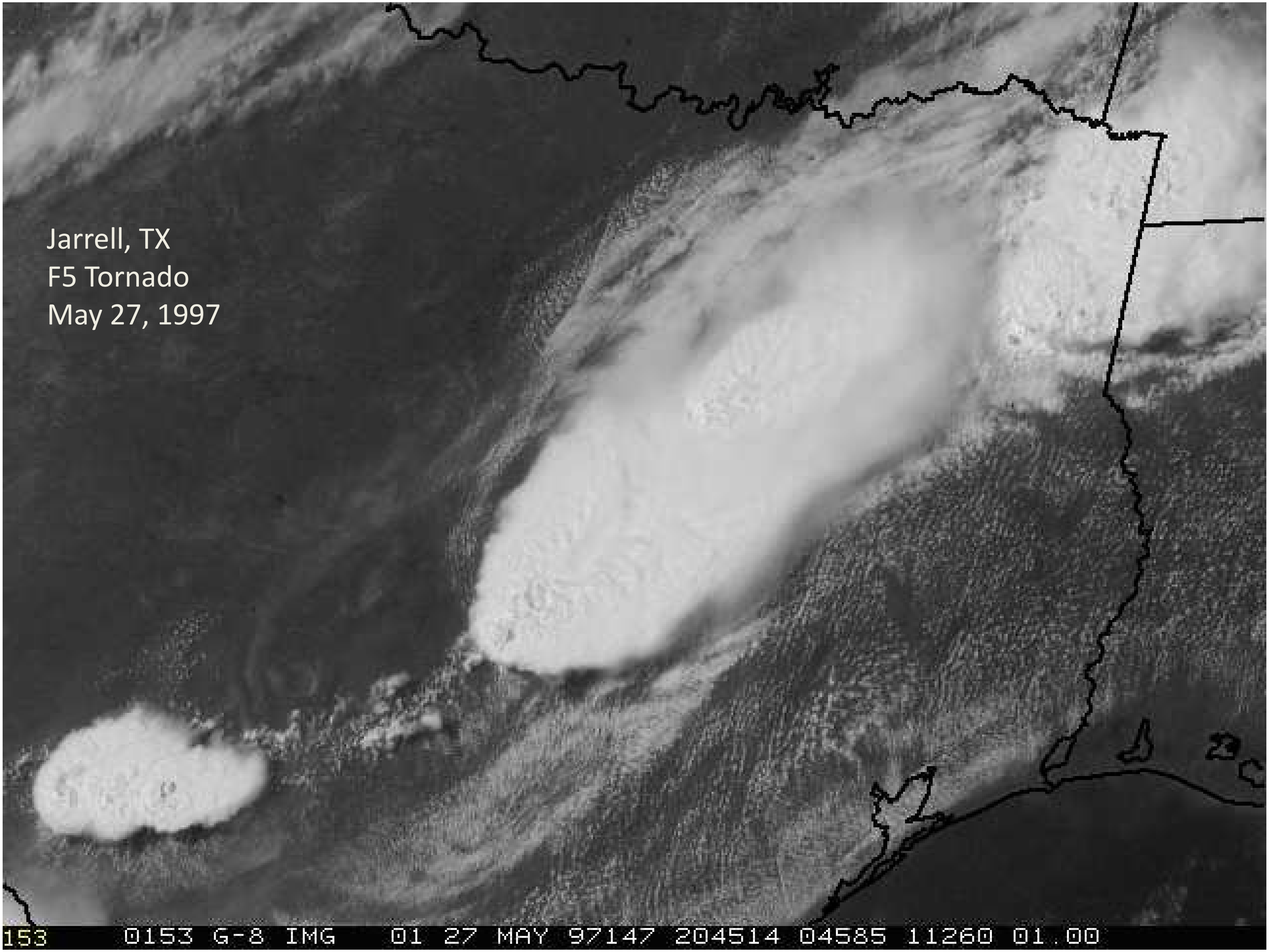
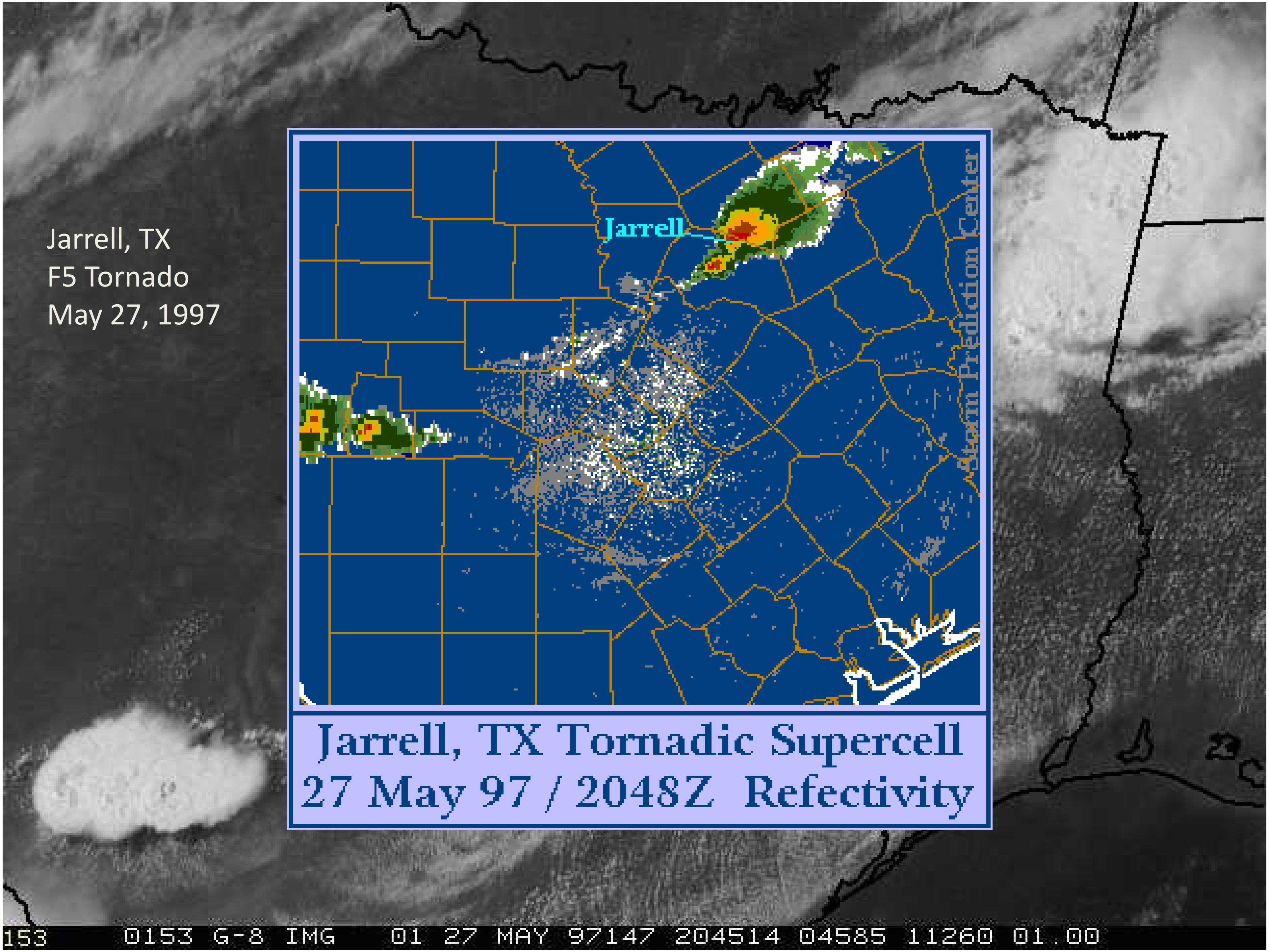
F5 Tornado
May 27, 1997
144 0144 G-8 IMG 01 27 MAY 97147 181515 04585 11260 01.00

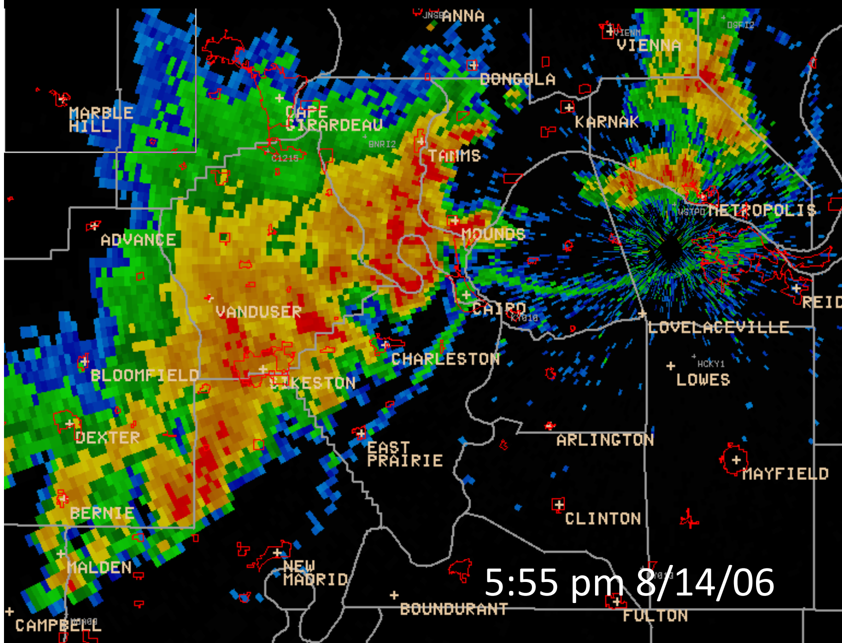

Jarrell, TX
F5 Tornado
May 27, 1997
150 0150 G-8 IMG 01 27 MAY 97147 200144 04585 11260 01.00

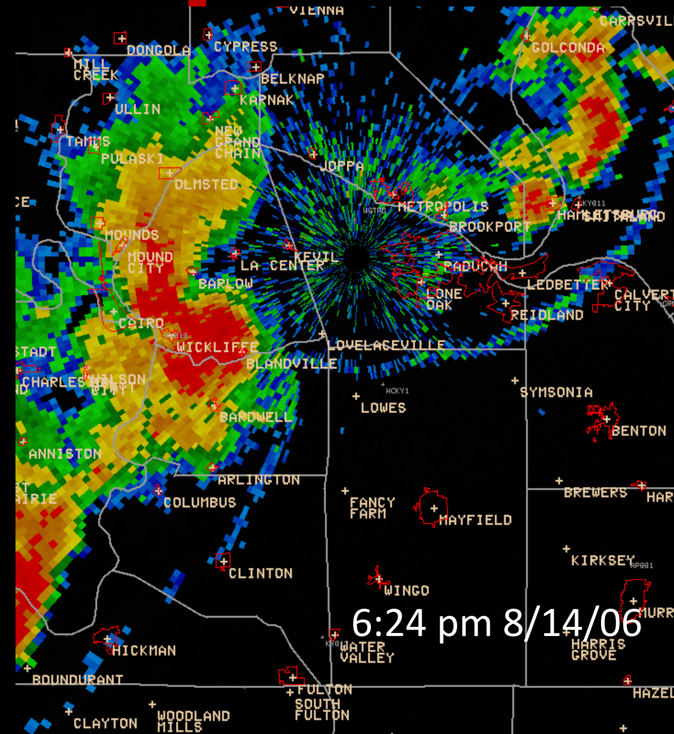

Jarrell, TX
F5 Tornado
May 27, 1997
153 0153 G-8 IMG 01 27 MAY 97147 204514 04585 11260 01.00

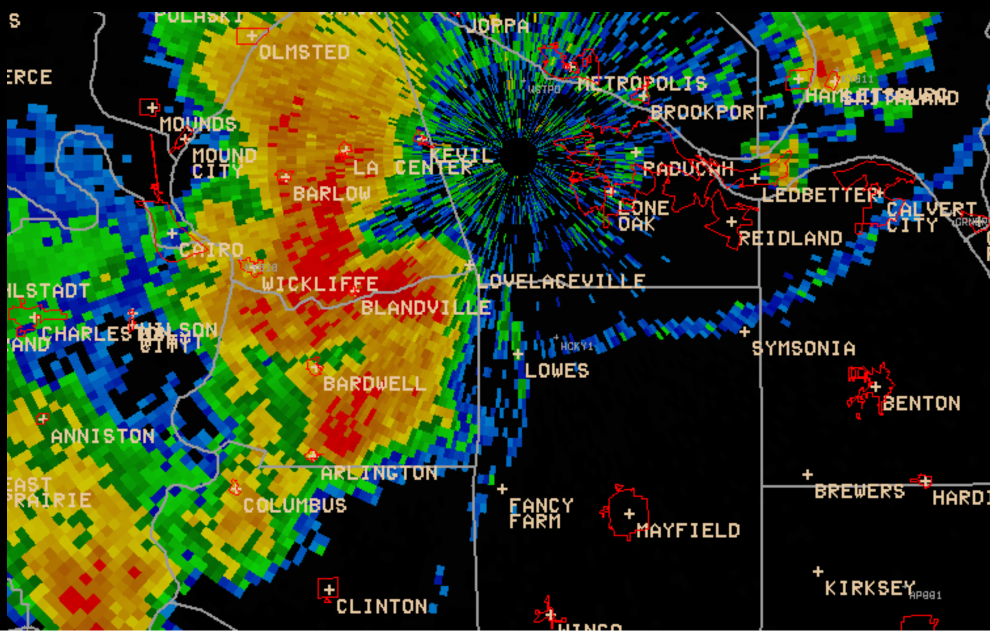
Jarrell, TX
F5 Tornado
May 27, 1997



Another example:





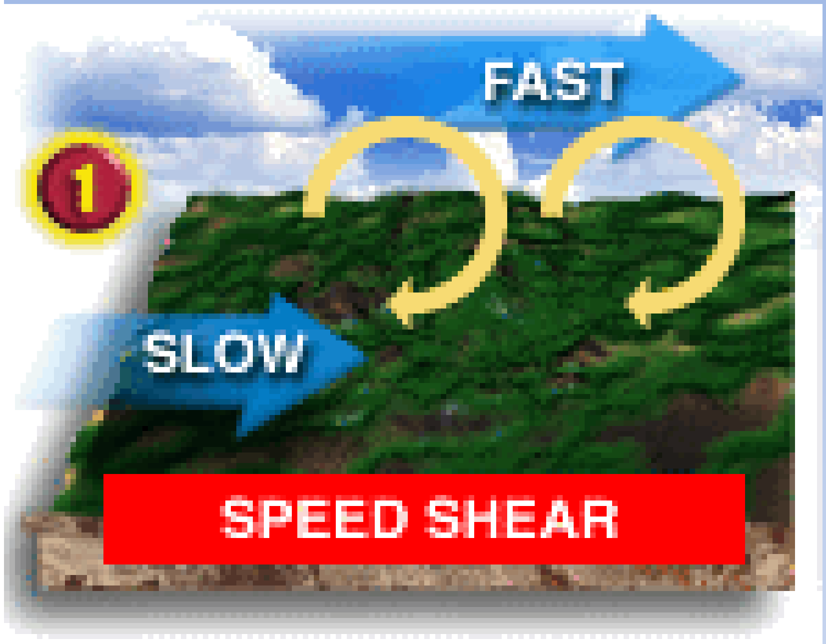


At 6:34 P.M. CDT, a brief F0 tornado occurs at Cunningham, KY. Cunningham is located just southeast of Blandville on the radar image to the left. The tornado occurred about the time that the storm encountered the intersection of two outflow boundaries.

Moisture

- **Low-level moisture is the fuel for a thunderstorm.**
- **Severe thunderstorms are more likely when the surface dew point is generally 58 F or higher in our area.**
- **Low dew points inhibit sufficient energy release in the atmosphere and significantly reduce the threat of severe storms.**
- **The depth of moisture in the lower troposphere and the rate of moisture advection are also important.**
- **A lack of moisture in the middle of the atmosphere can actually increase the threat of severe weather. Dry air in the middle layers of the atmosphere can aid in the development of strong downbursts.**

Wind Shear: Speed/Directional



A change in wind direction and/or speed with height

Greatest impact on storm organization!

Wind at 30,000 ft - from W at 90 mph

Wind at 15,000 ft – from W at 50 mph

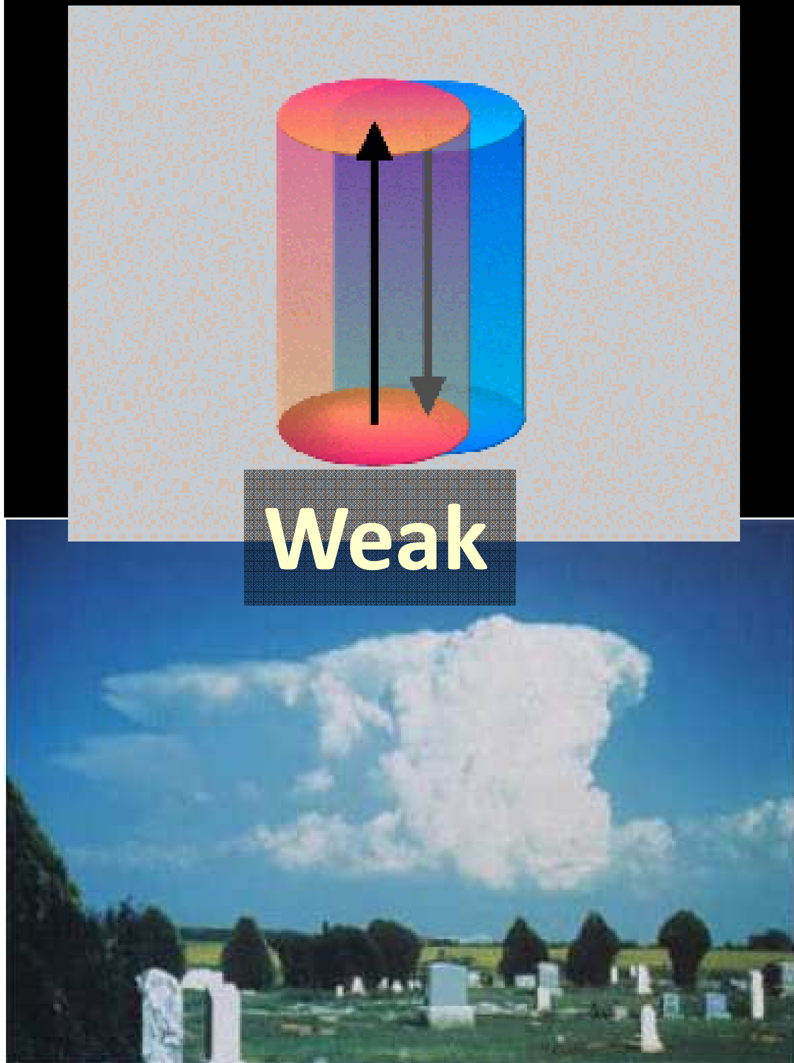
Wind at the ground - from W at 15 mph

Wind at 30,000 ft - from W at 50 mph

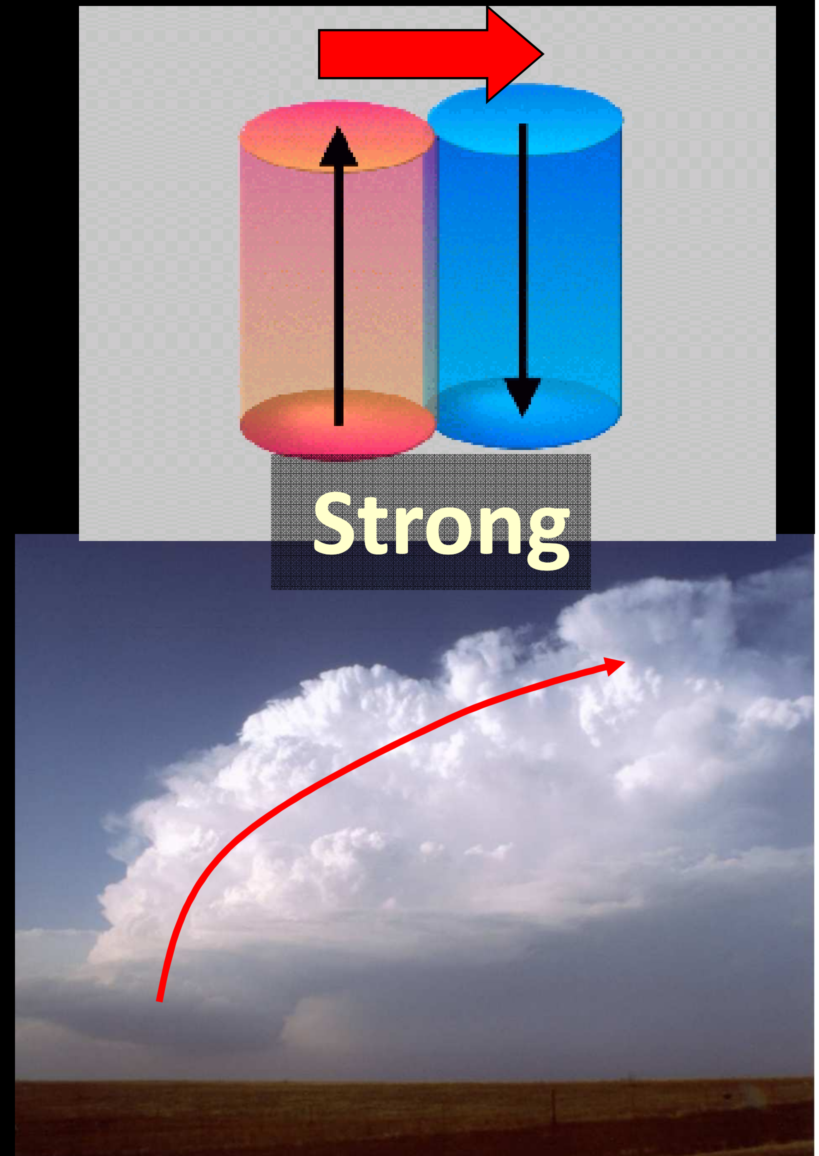
Wind at 15,000 ft - from SW at 30 mph

Wind at the ground - from SE at 15 mph

Wind Shear



Very little separation between updraft and downdraft. Downdraft chokes updraft causing storm to be short-lived.



Updraft & downdraft are separated, so they co-exist - storm lives longer.

MEASUREMENT OF (VERTICAL) WIND SHEAR

SPEED SHEAR

0-6 KM ("DEEP LAYER") SHEAR

DIFFERENCE IN WIND SPEED BETWEEN THE SURFACE (0 KM) & THE 6 KM ABOVE GROUND LEVEL HEIGHT

THE GREATER THE SHEAR THE MORE LIKELY DEVELOPING THUNDERSTORMS WILL BECOME SEVERE

< 35 KNOTS SEVERE STORMS UNLIKELY

DIRECTIONAL SHEAR

0-3 KM STORM RELATIVE ENVIRONMENTAL HELICITY (SREH)

A MEASURE OF THE POTENTIAL FOR A STORM TO ACQUIRE A ROTATING UPDRAFT.

THE GREATER THE SREH, THE MORE LIKELY DEVELOPING THUNDERSTORMS WILL BECOME SEVERE & THE MORE LIKELY SOME OF THOSE WILL BECOME SUPERCELLULAR

< 150 SUPERCELLS UNLIKELY

SMALLER SREH VALUES (100-200) CAN BE COMPENSATED FOR BY VERY LARGE VALUES OF CAPE (> 2000 J/KG)

The presence of high values of CAPE and SRH is important to the rapid development and persistence of a rotating updraft.

Rotating updrafts…

Mesocyclone definition

Wall Clouds

- A localized, persistent, and sometimes abrupt, lowering from a rain-free base
- Suggests strongest area of updraft
- Attached to the cloud base
- May exhibit rapid upward motion and cyclonic rotation. However, not all wall clouds rotate. If rotating, the wall cloud will have visible signs of rotation.
- Tail cloud extending out of wall cloud slopes down and towards precipitation

Rotating Wall Cloud

Classic Plains Supercells vs. Local Supercells

We typically see a more ragged based to supercell thunderstorms.

Because of terrain and obstructions, it may be difficult to see striations or the strong updrafts as can be seen in the flatter, more open plains.

However, the key is to look for a lowered base under the updraft that is rotating.

3 Ingredients for Tornado Formation

- Supercell tornado formation appears to follow a process of:
  1) Development of a persistent rotating updraft
  2) Development of a "special" rear flank downdraft that contains rotation to aid in the development of rotation to the ground
  3) Focusing of that low-level rotation through convergence and upward spin-up into the updraft
- All 3 ingredients must occur in concert to form significant (F2 or higher) tornadoes; since these ingredients are uncommon in the atmosphere, the joint occurrence of all 3 make significant tornadoes also uncommon.
- Weaker, short- lived tornadoes can occur within supercells or nonsupercells without all 3 ingredients.

The "RFD": Rear Flank Downdraft

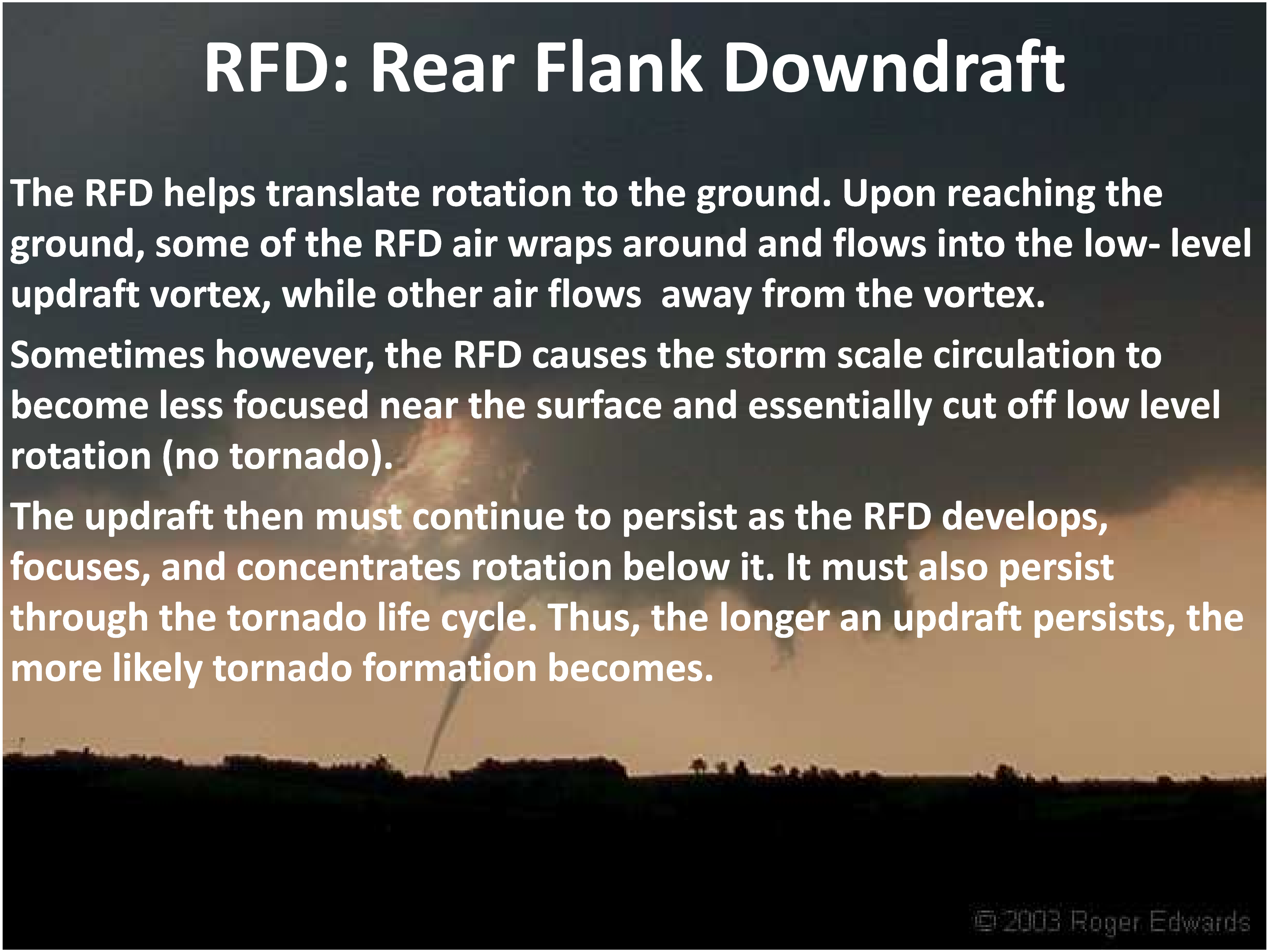
“Clear slot”

RFD: Rear Flank Downdraft

The RFD helps translate rotation to the ground. Upon reaching the ground, some of the RFD air wraps around and flows into the low- level updraft vortex, while other air flows away from the vortex.

Sometimes however, the RFD causes the storm scale circulation to become less focused near the surface and essentially cut off low level rotation (no tornado).

The updraft then must continue to persist as the RFD develops, focuses, and concentrates rotation below it. It must also persist through the tornado life cycle. Thus, the longer an updraft persists, the more likely tornado formation becomes.



RFD: Rear Flank Downdraft

Studies have shown that a warm and bouyant RFD contributes to more frequent tornadogenesis.

The warmer and more bouyant RFD allows more air to flow into the rotating updraft zone and stretch vertically, thereby enhancing low-level rotation.

What governs the thermodynamic character of the RFD?

- low- level humidity, i.e., small surface/low- level dewpoint depressions and low LCLs (cloud bases), in the near storm environment (not always common).

- size and type of precipitation particles in the hook echo (i.e., the rear-side precipitation cascade)