An Introduction to Severe Weather

THUNDERSTORMS

What is a Thunderstorm?

Thunderstorm- any storm accompanied by lightning and thunder.

Severe Thunderstorm- for a thunderstorm to be classified as "Severe" the storm must have one of the following criteria:

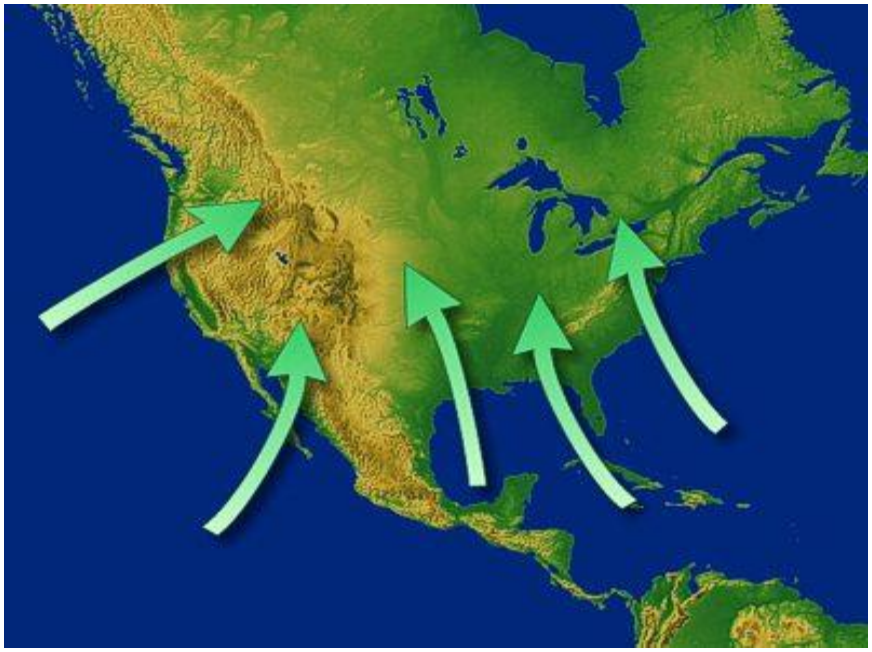
1) winds in excess of 56 mph

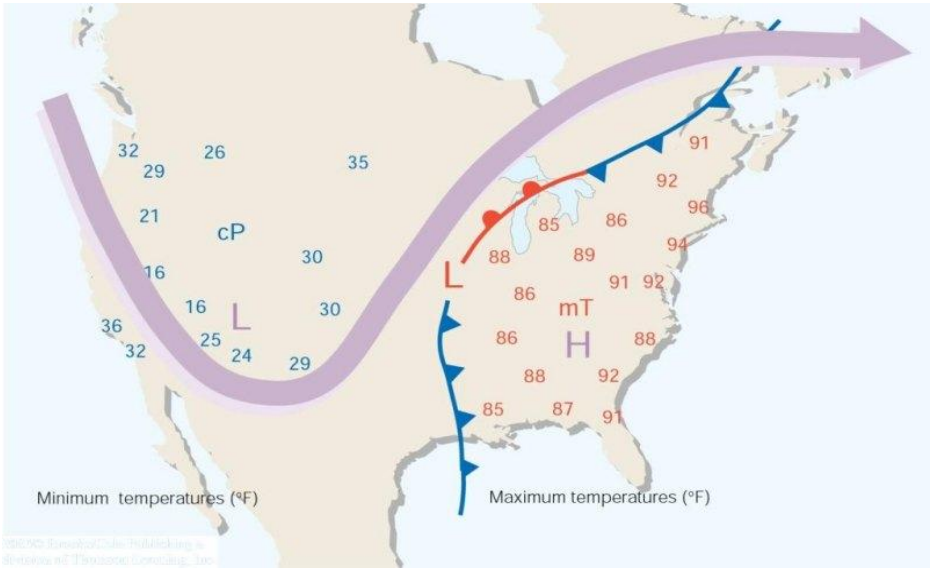
2) ¾ hail

3) a tornado

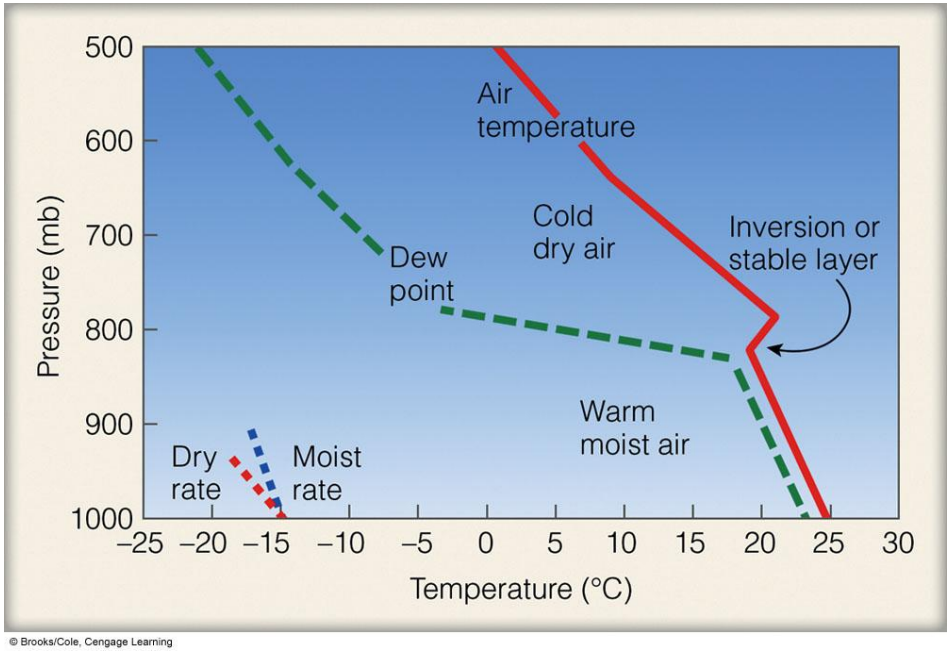
Conditions needed for Thunderstorm development

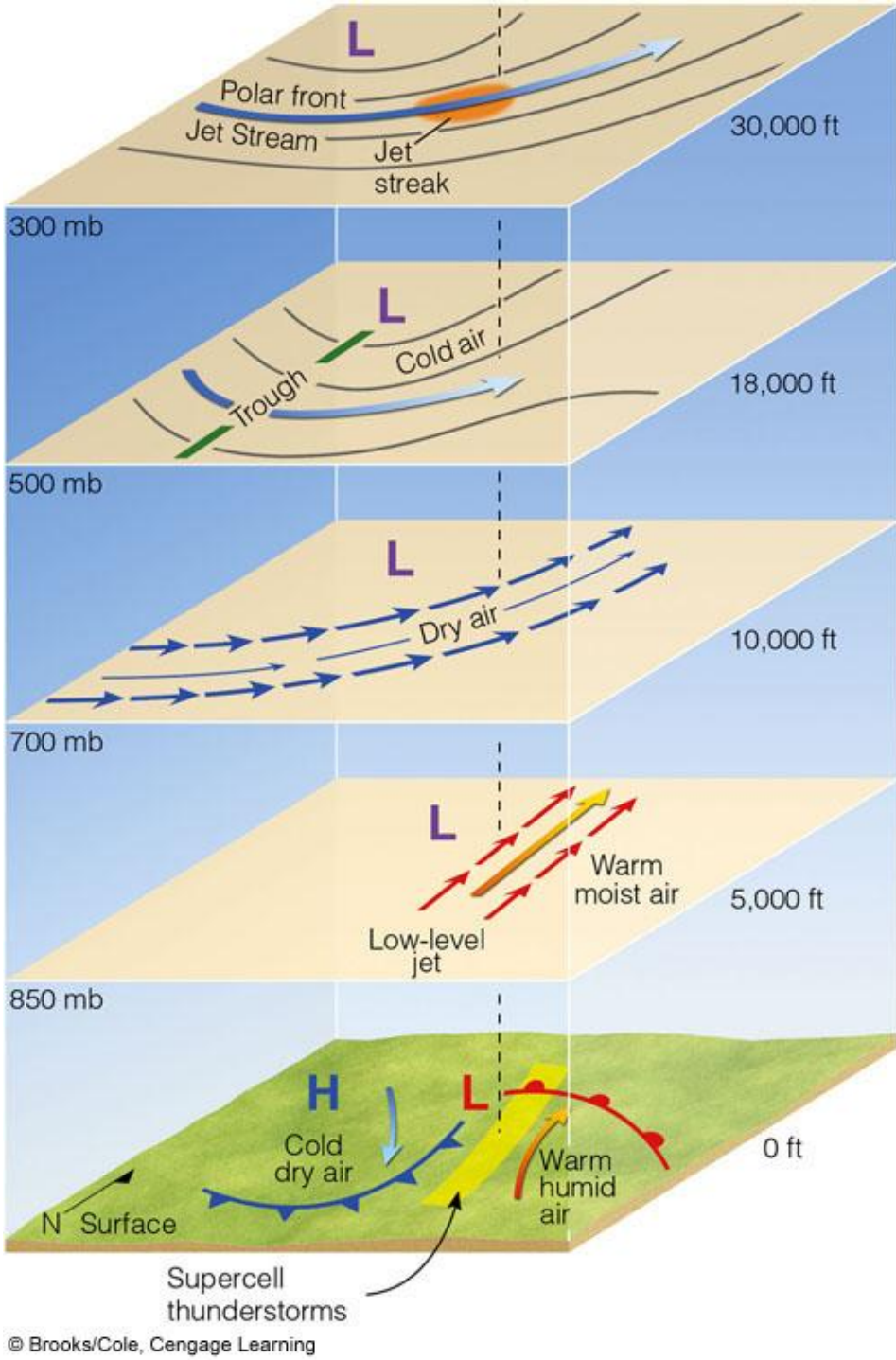
- Warm, humid air
- an unstable atmosphere
- Lifting mechanism
- Diverging upper level winds (trough to the west of the surface Low)



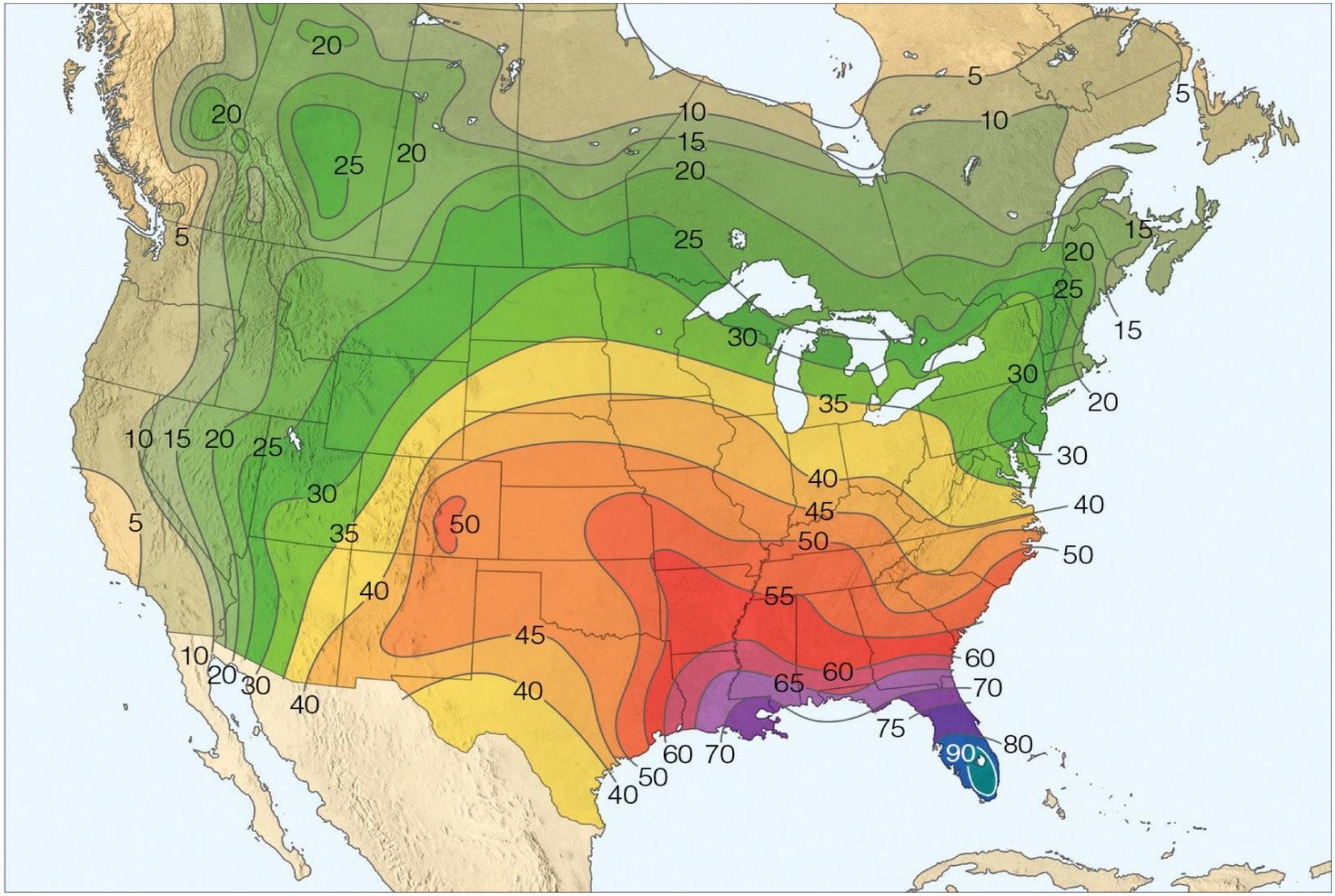


Atmospheric Conditions for Thunderstorm development





Where do most thunderstorms occur?



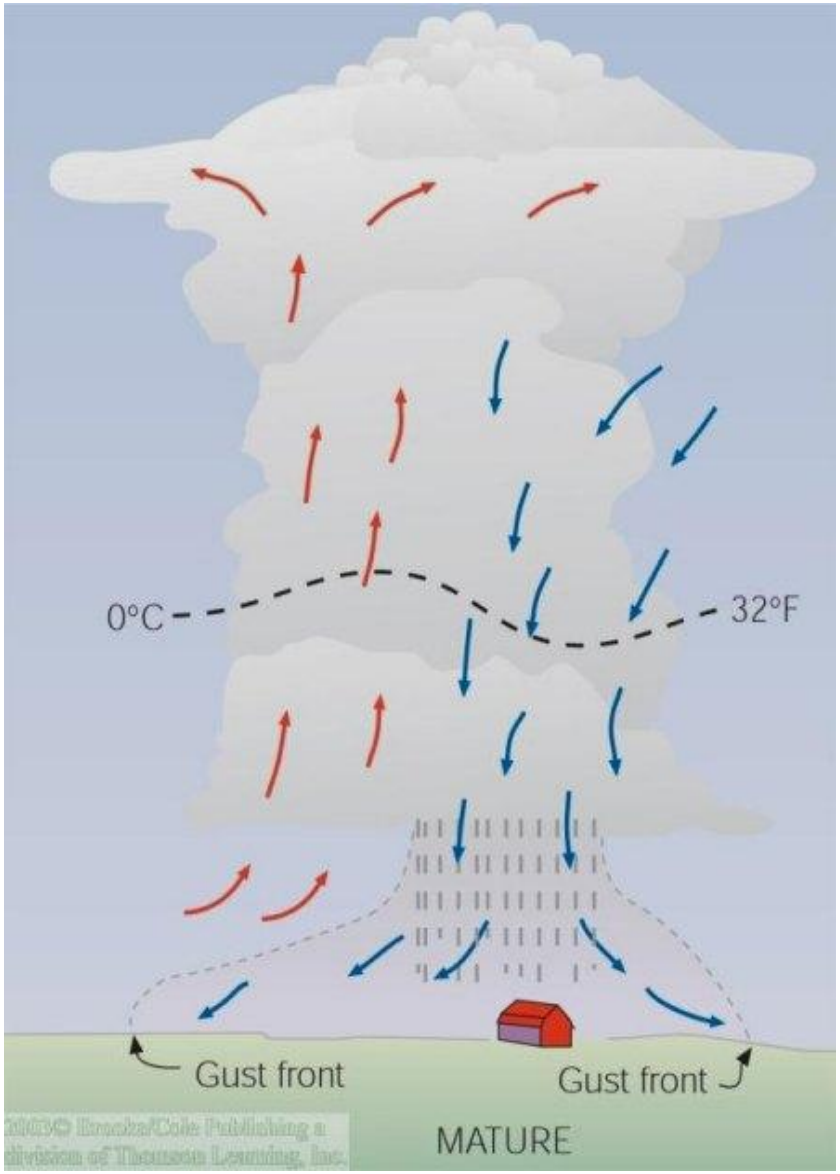
NOAA

The Different types of Thunderstorms

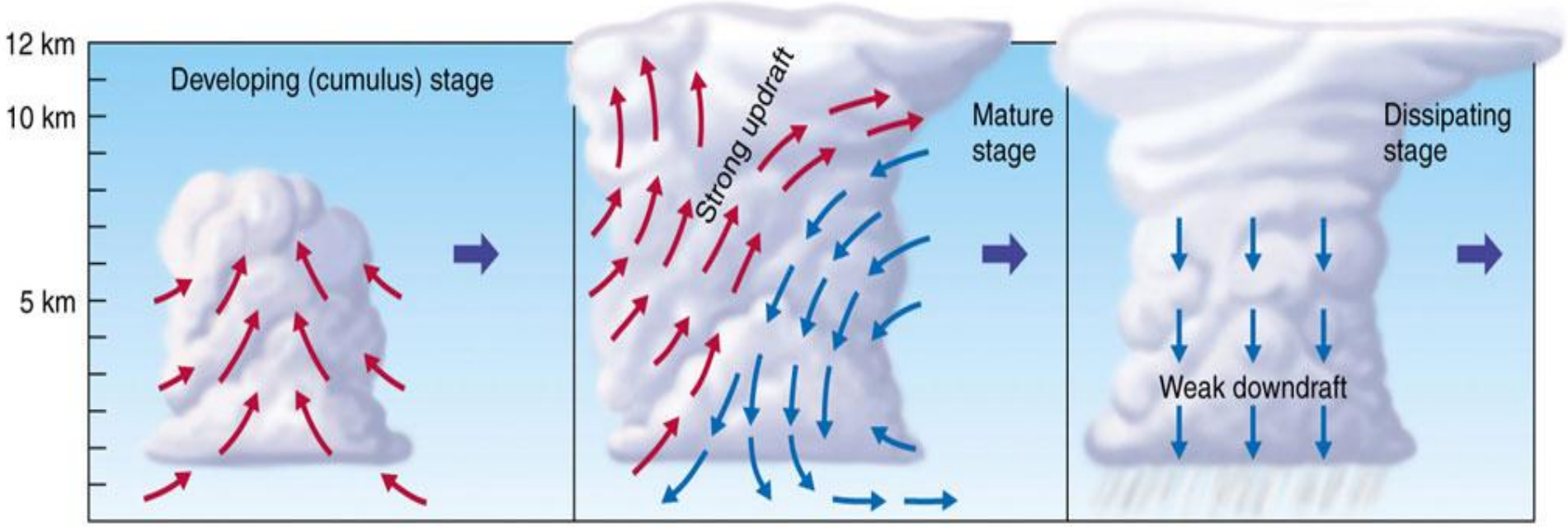
The “Ordinary” Thunderstorm

Structure of an Ordinary Thunderstorm

- Ordinary Cell Thunderstorms
  - Air-mass thunderstorms: limited wind sheer
  - Stages: cumulus, mature, dissipating
  - Entrainment, downdraft, gust front
- Vertical structure allows downdraft to cutoff updraft. This is why these t-storms are short-lived



The Life Cycle of a Thunderstorm



1)Developing Updraft

2)Well developed Updraft and downdraft

3)downdraft dominating the storm

Life Cycle of a Thunderstorm

Stage One of Development

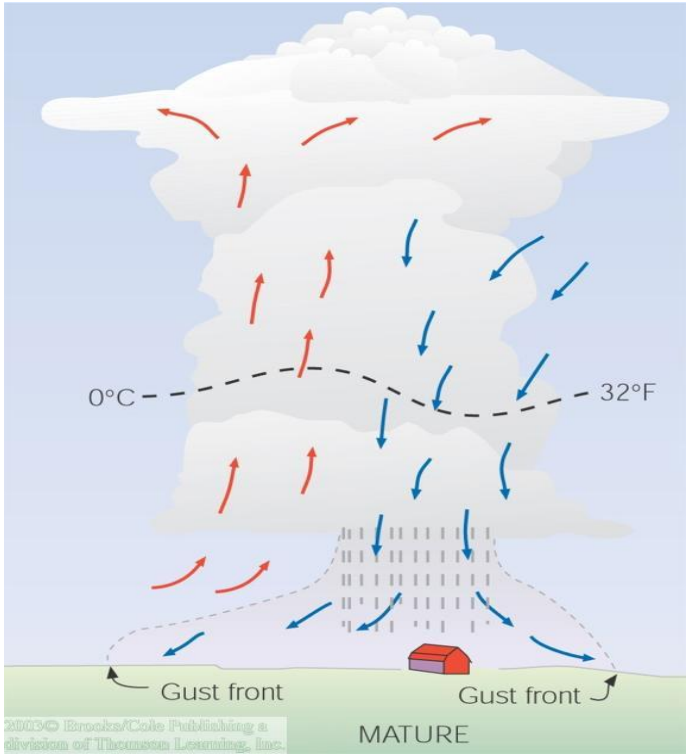
1) Cumulus stage

- **Updrafts dominate**
- Rising air parcels produce cumulus cloud
- Latent heat release ⇨ adds buoyancy ⇨ clouds continue growing vertically
- Precipitation formation aloft above freezing level ⇨ ice crystal growth (Bergeron Process)
- Bottom darkens as cloud thickens

Life Cycle of a Thunderstorm

Stage 2) Mature stage

- **Emergence of the downdraft**
- Precipitation begins falling ⇨ air dragged downward
- **Entrainment**: influx of cool, dry air surrounding cloud ⇨ evaporative cooling strengthens downdraft
- Cooler, denser air spreads laterally at surface
- **Anvil** ⇨ ice-laden cirrus clouds spread laterally via stronger winds aloft
- Most intense phase ⇨ gusty winds, small hail, heavy rain

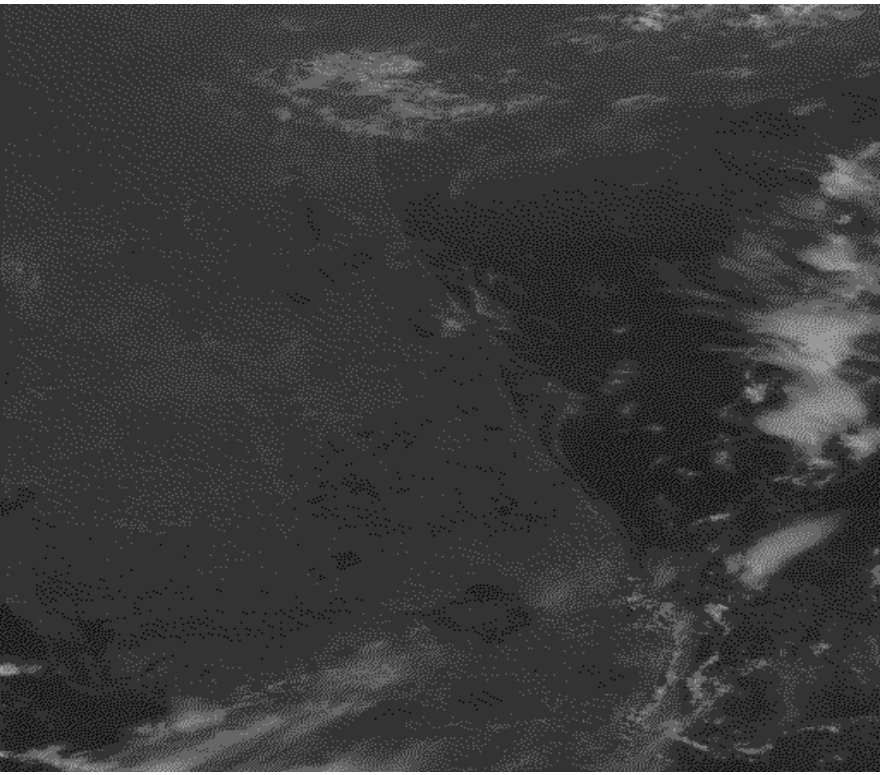


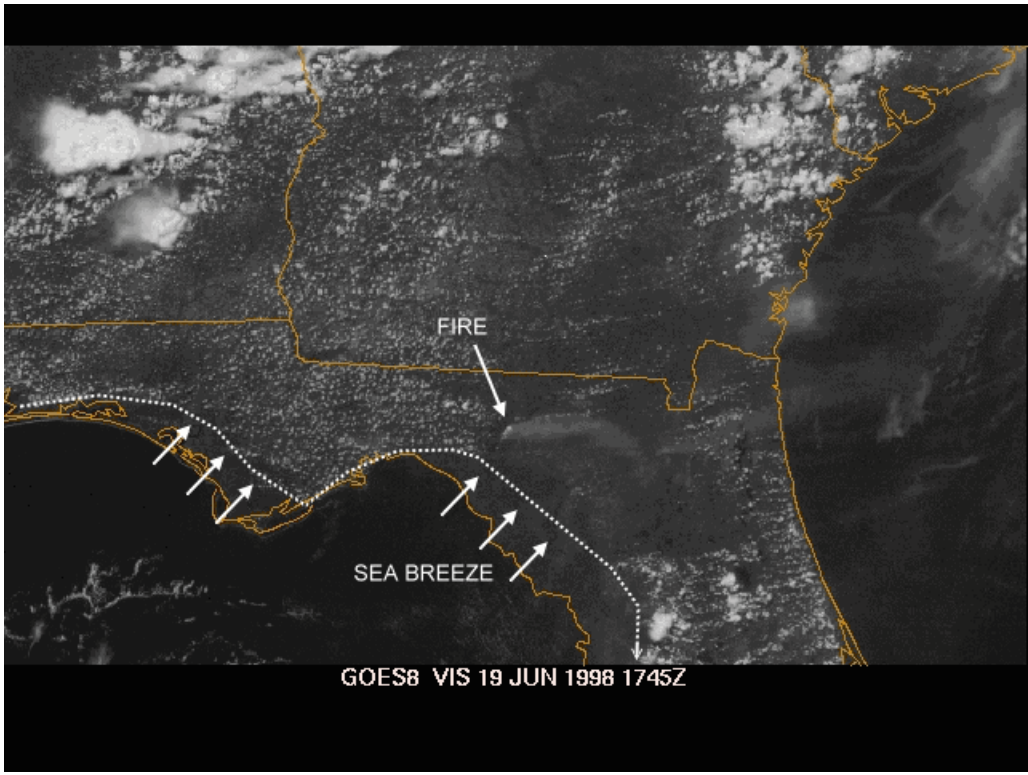
Life Cycle of a Thunderstorm

3) Dissipation stage

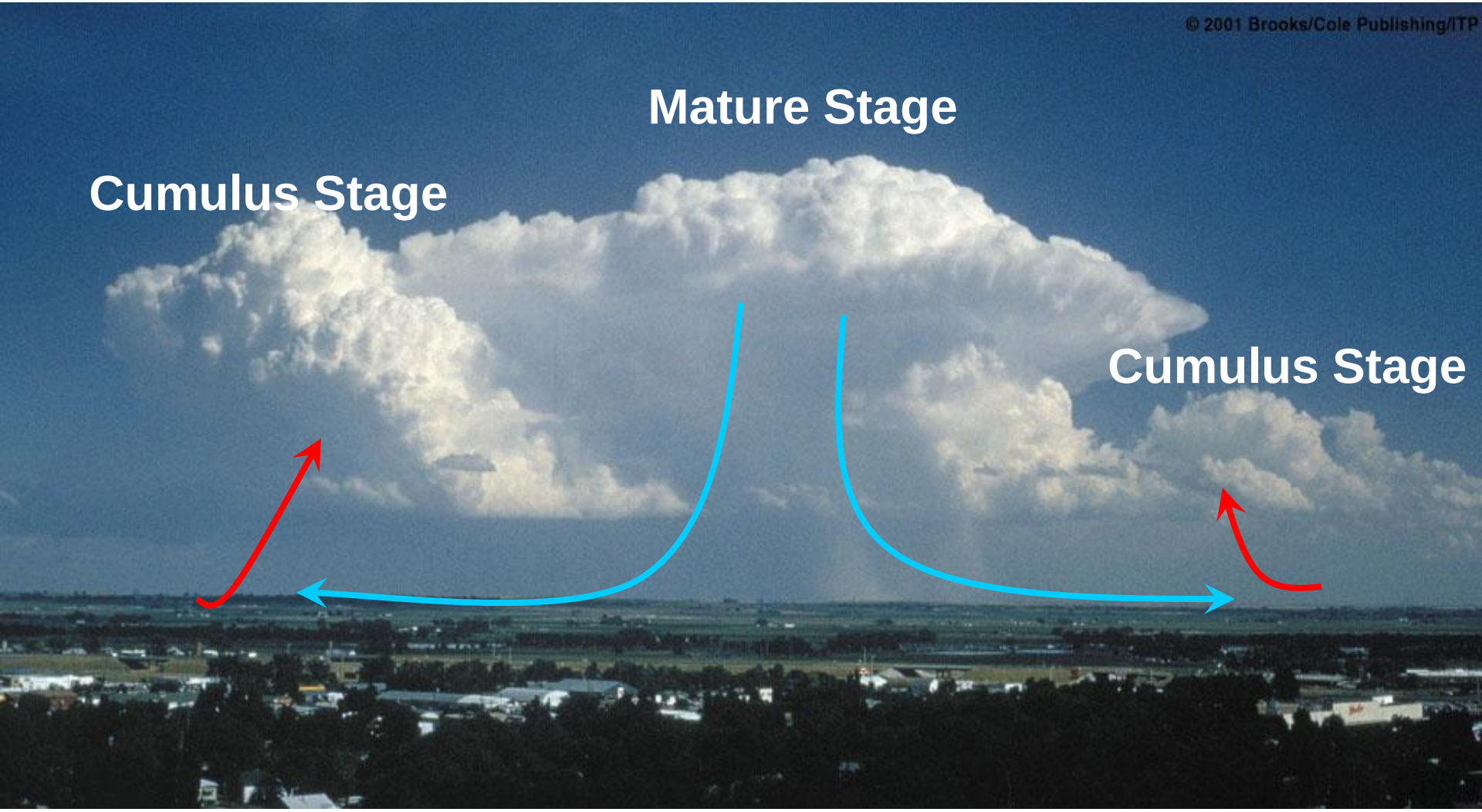
- **Downdraft grows, dominates**
- Enhanced entrainment ⇨ chokes updraft
- Loss of moisture supply ⇨ cloud begins to evaporate
- Cool, downdraft air may initiate new updraft nearby

Convergence (Sea Breeze) Thunderstorms



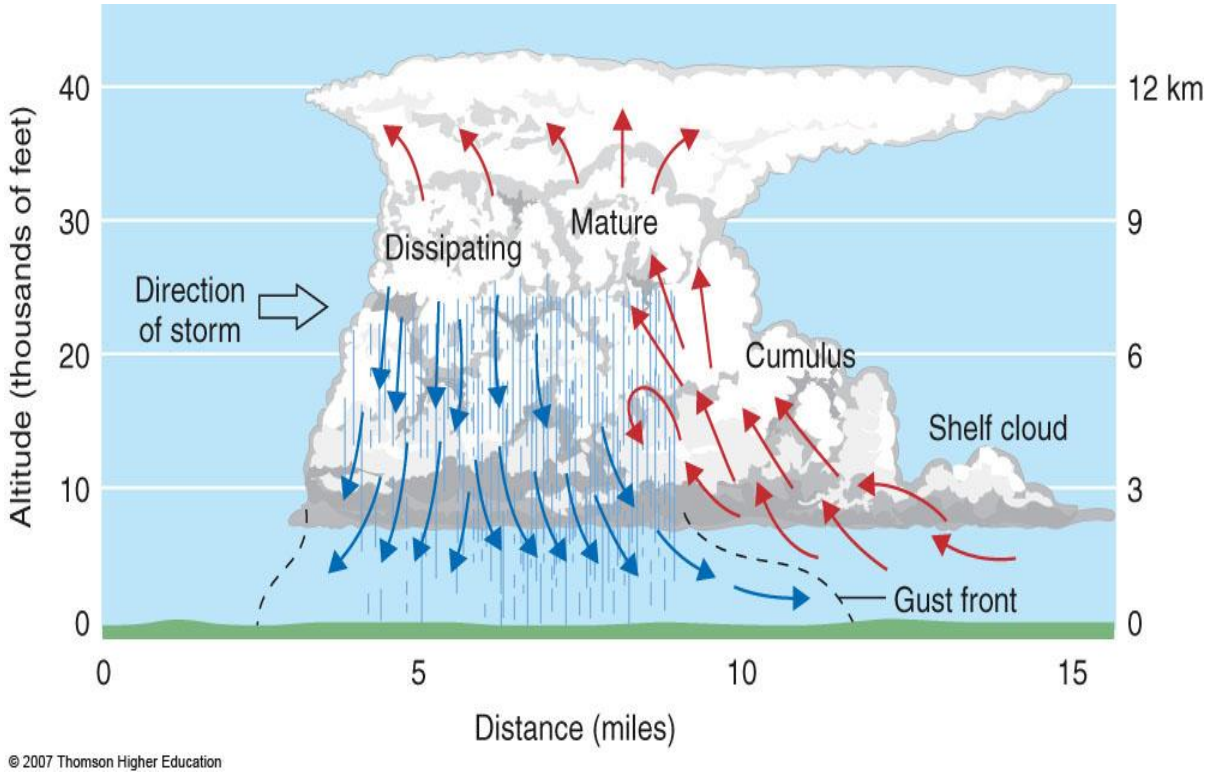


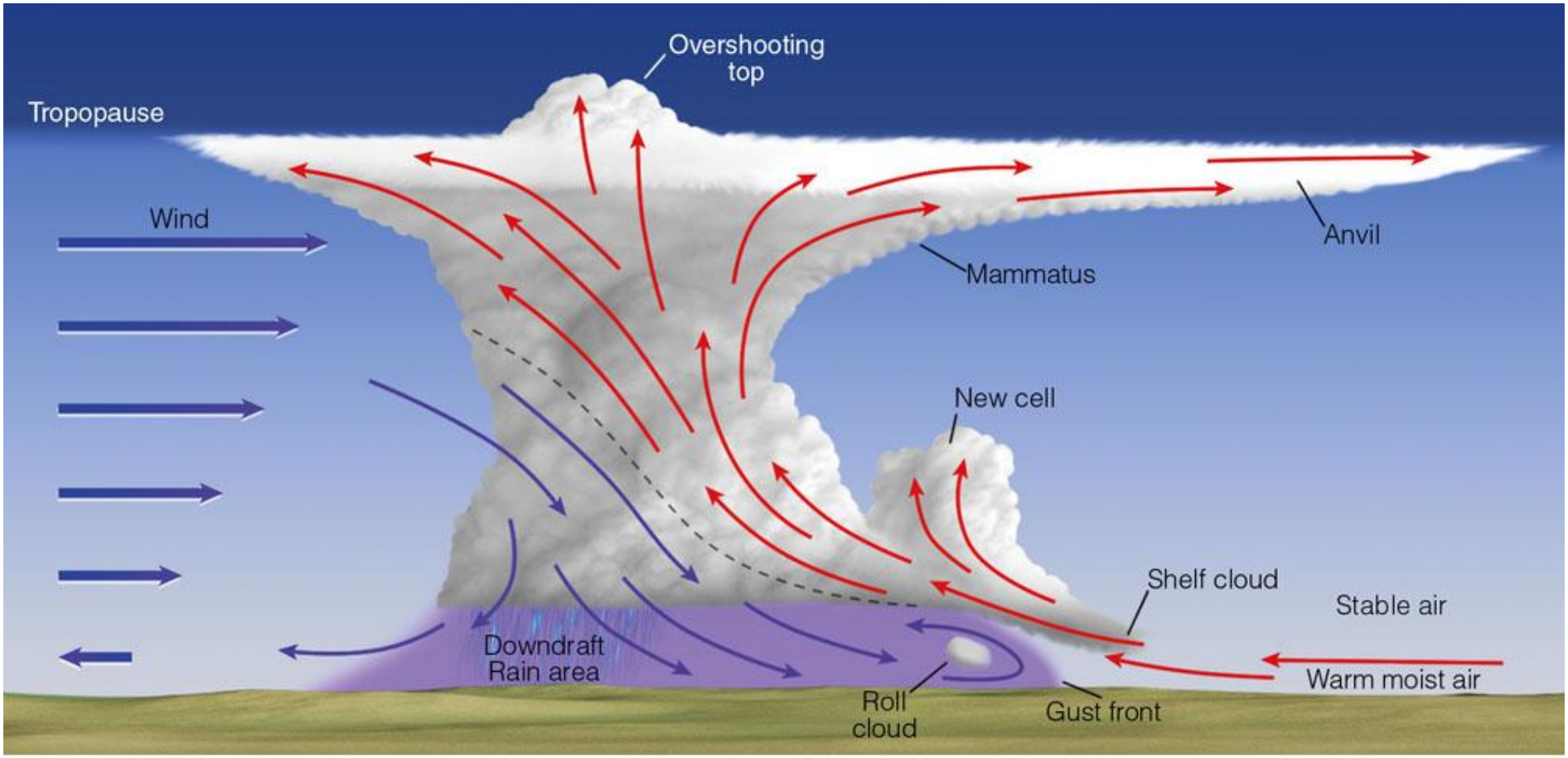
Multi-Cellular Thunderstorms



Thunderstorms

- **Multi-cell Thunderstorms**
  - Thunderstorms that contain a number of convection cells, each in a different stage of development, moderate to strong wind shear; tilt, over shooting top
  - Gust Front: leading edge of the cold air out-flowing air; shelf cloud, roll cloud, outflow boundary
  - Micro-bursts: localized downdraft that hits the ground and spreads horizontally in a radial burst of wind; wind shear, virga

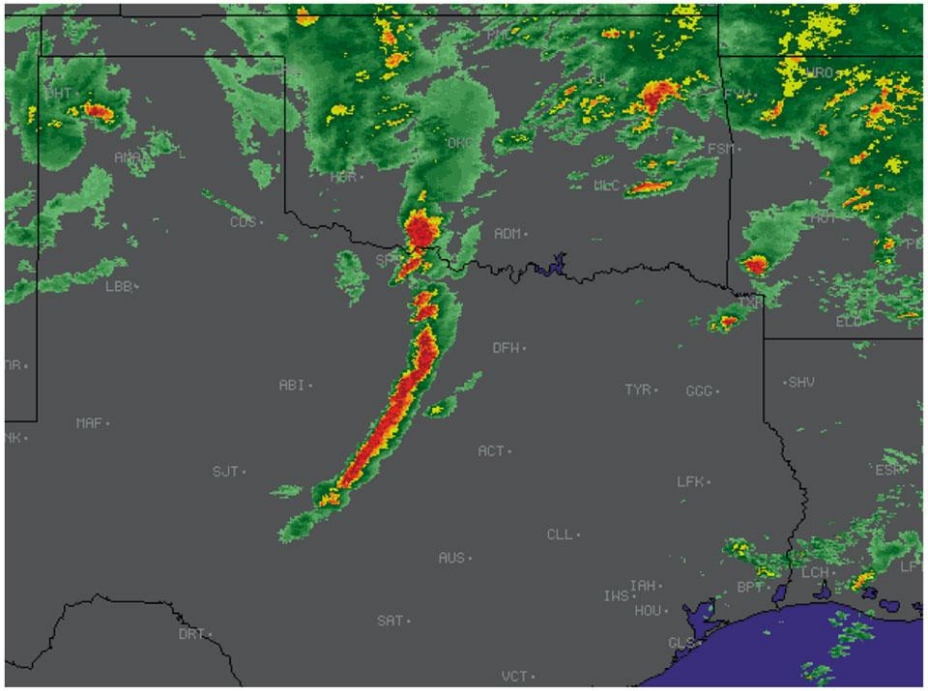




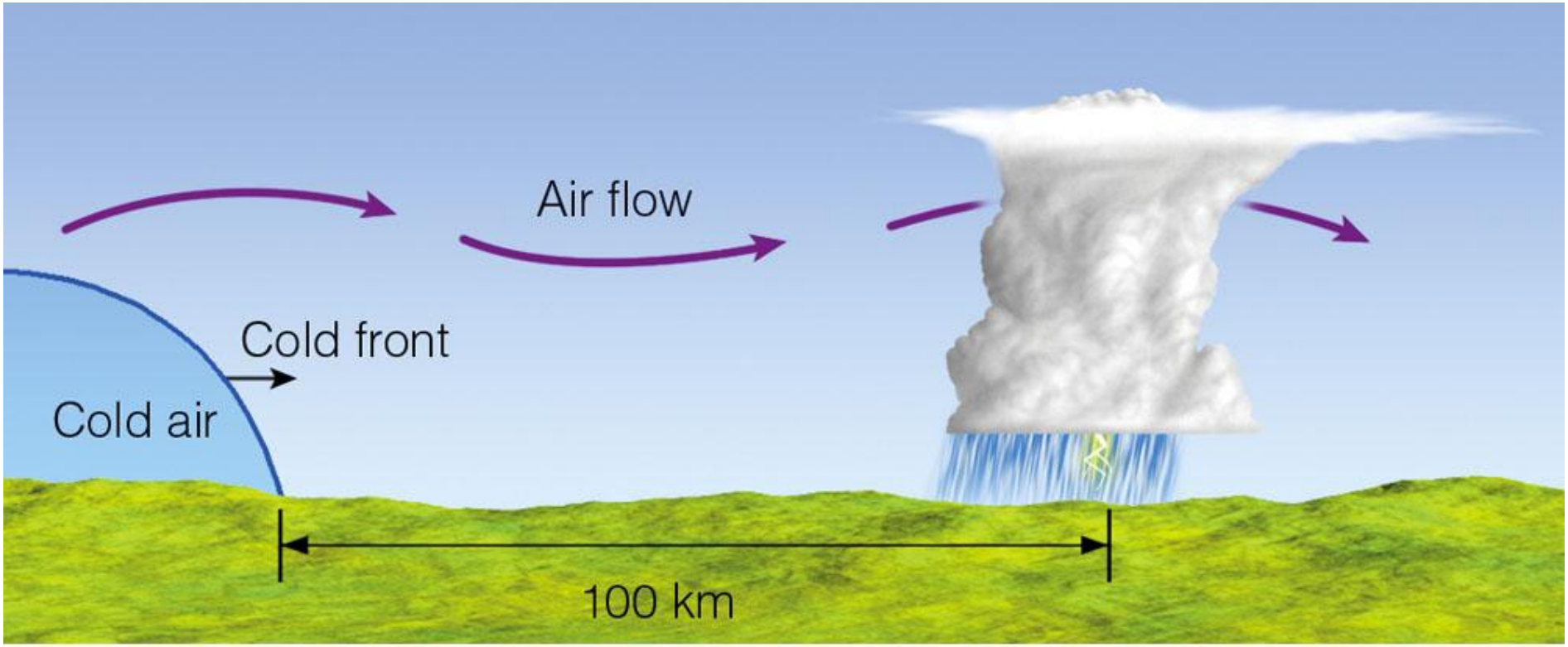
A simplified model describing air motions and other features associated with an intense multicell thunderstorm that has a tilted updraft. The severity depends on the intensity of the storm's circulation pattern.

Frontal Thunderstorms

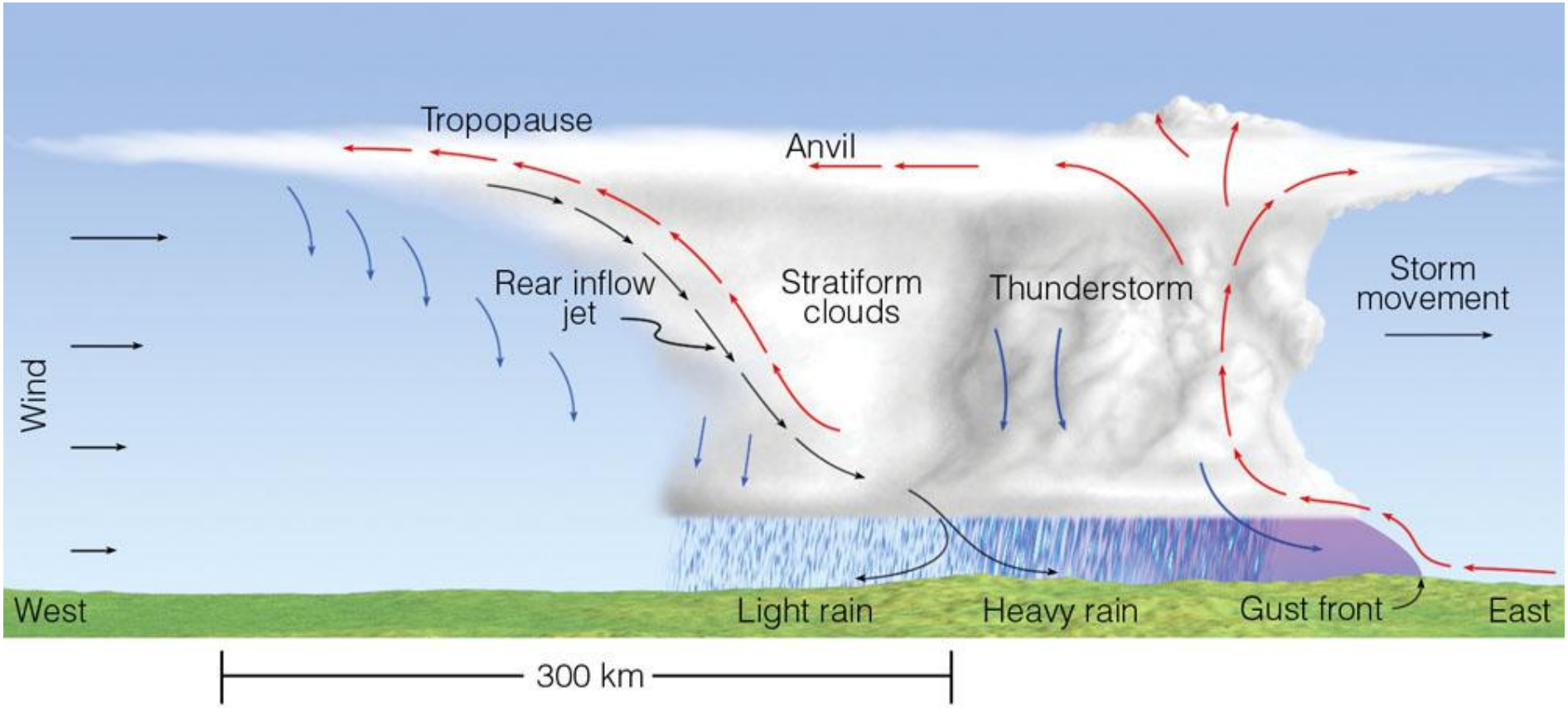
Frontal thunderstorms form along frontal boundaries and are typically called “squall line thunderstorms”



Pre-frontal squall-line thunderstorms may form ahead of an advancing cold front as the upper-air flow develops waves downwind from the cold front.

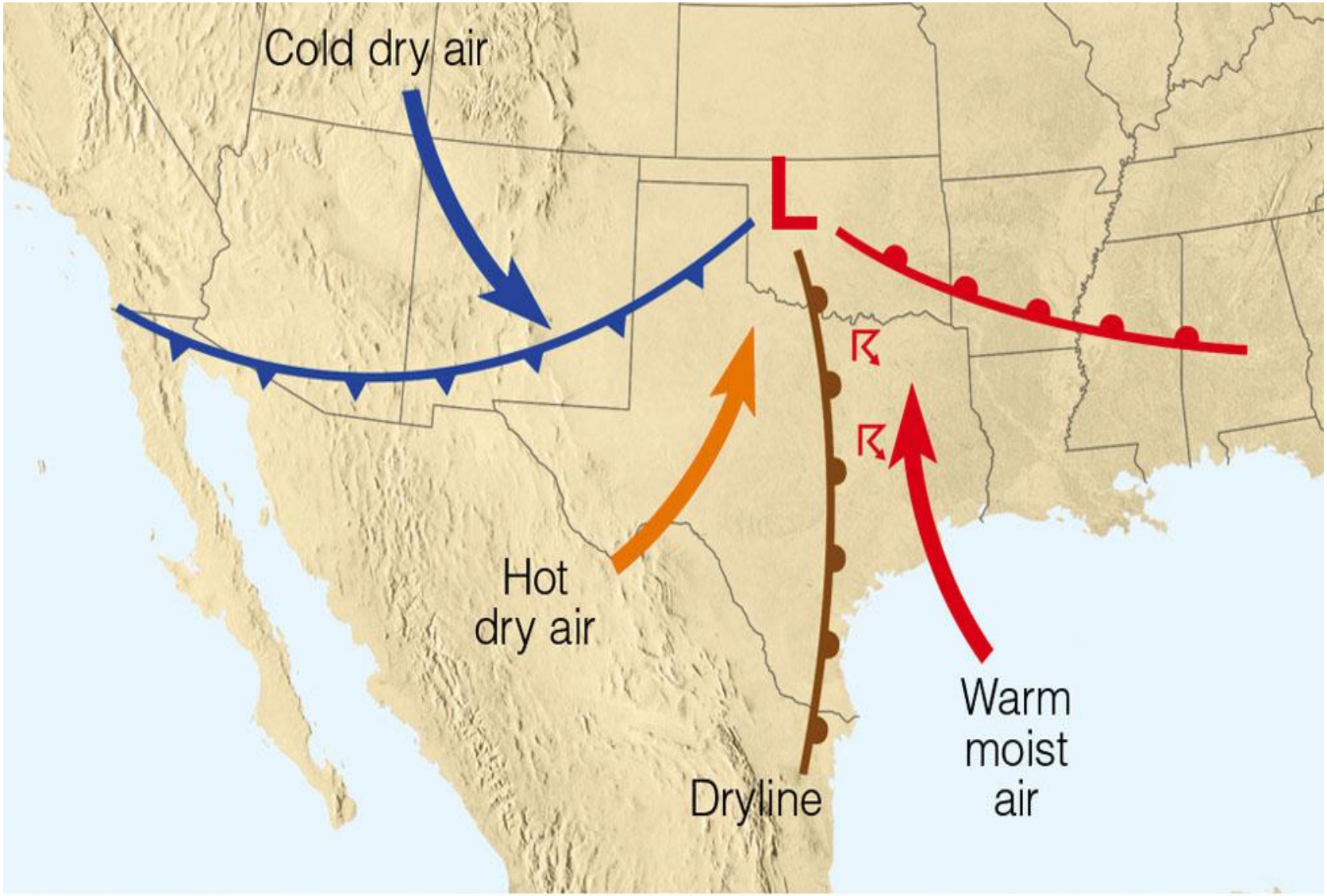


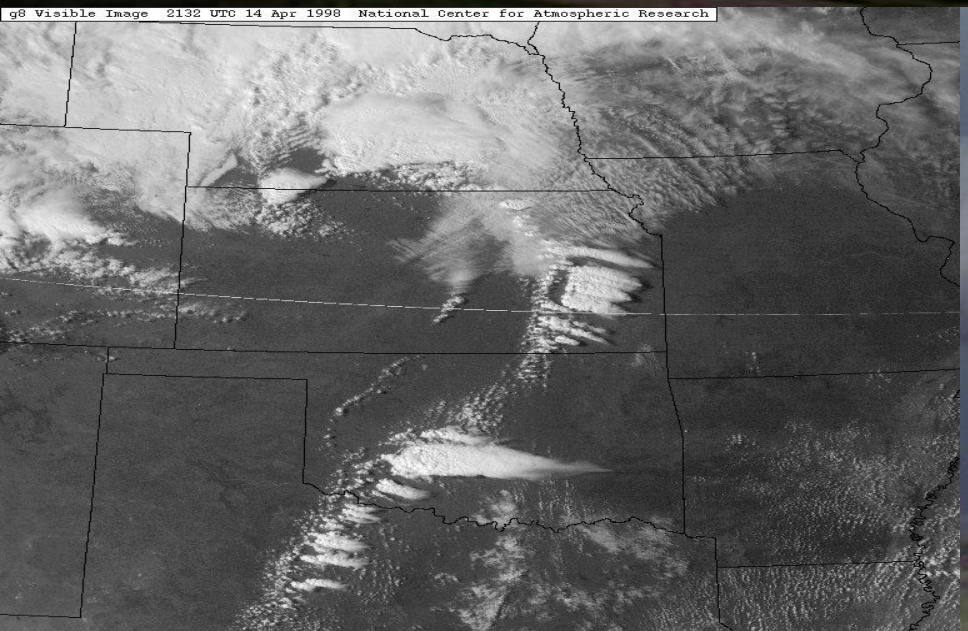
A model describing air motions and precipitation associated with a squall line that has a trailing stratiform cloud layer.



Dryline Thunderstorms

- These storms occur frequently in the southern Great Plains of the US.




g8 Visible Image 2132 UTC 14 Apr 1998 National Center for Atmospheric Research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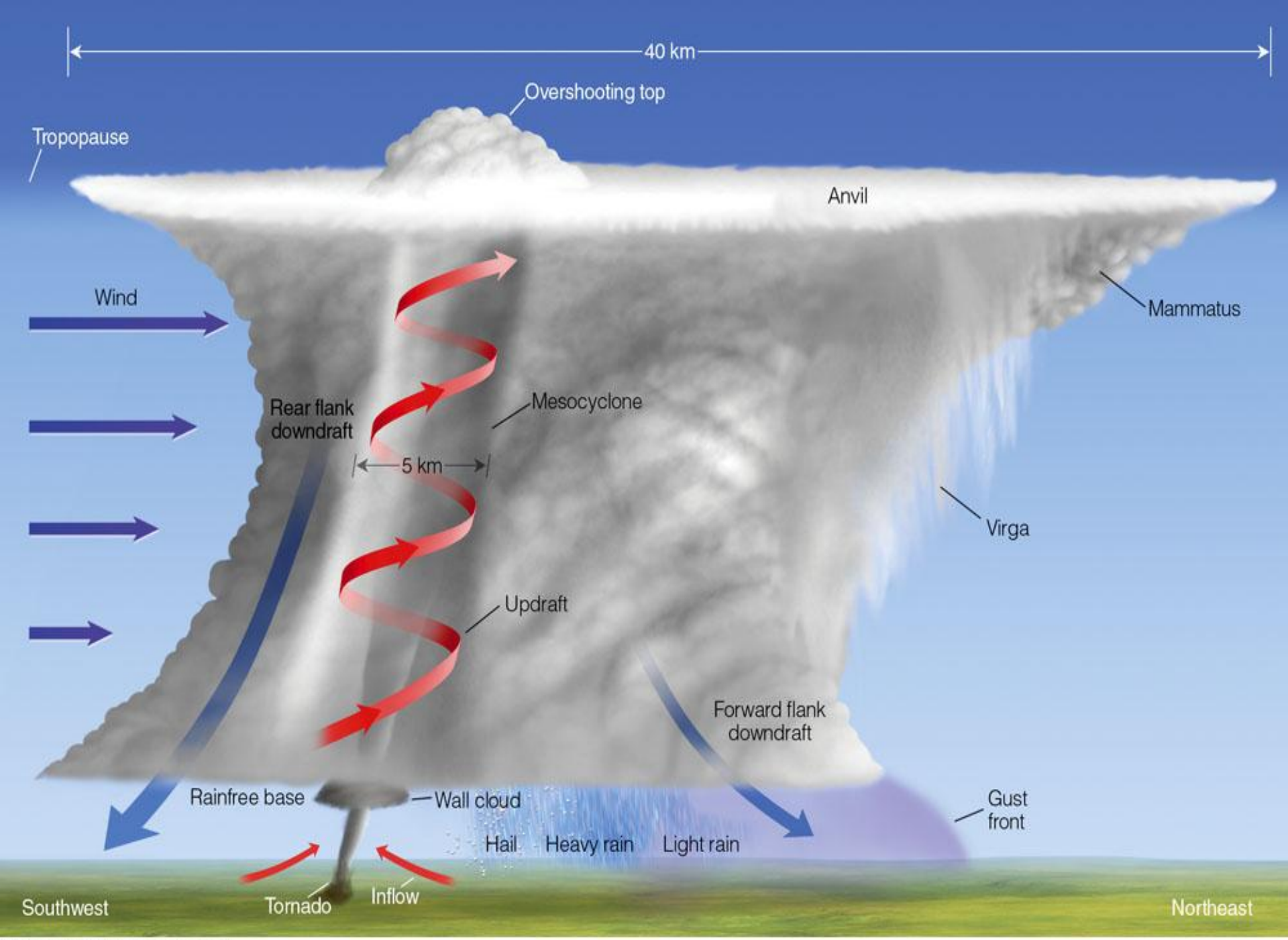
Supercell Thunderstorms

Supercells are characterized by their rotation

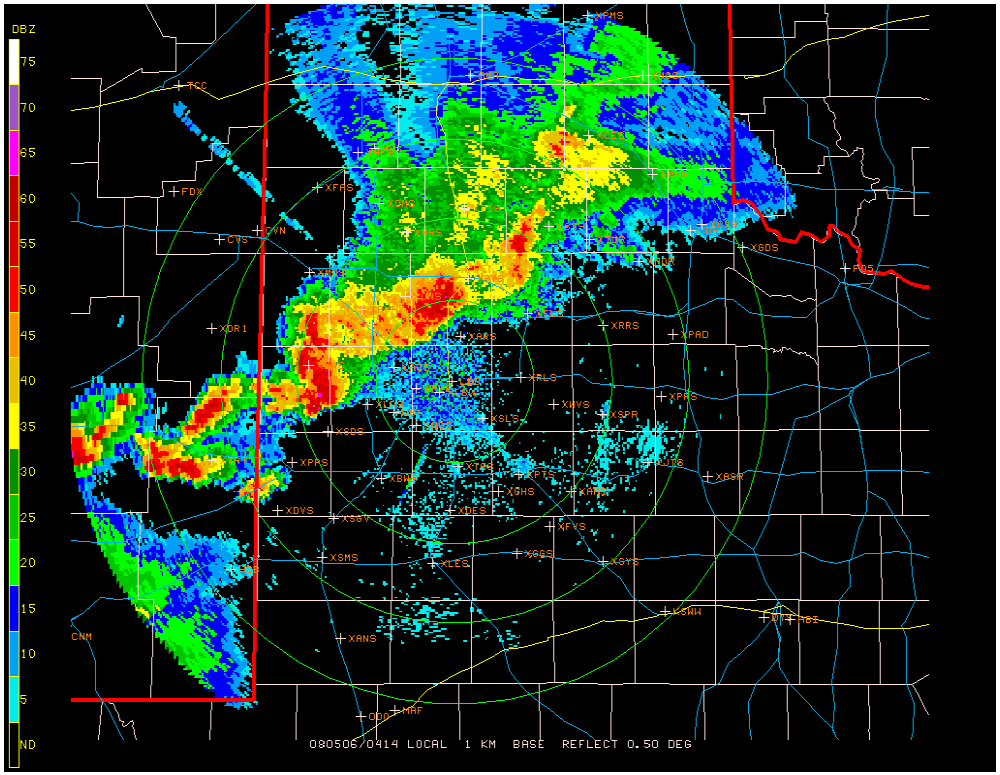
Thunderstorms

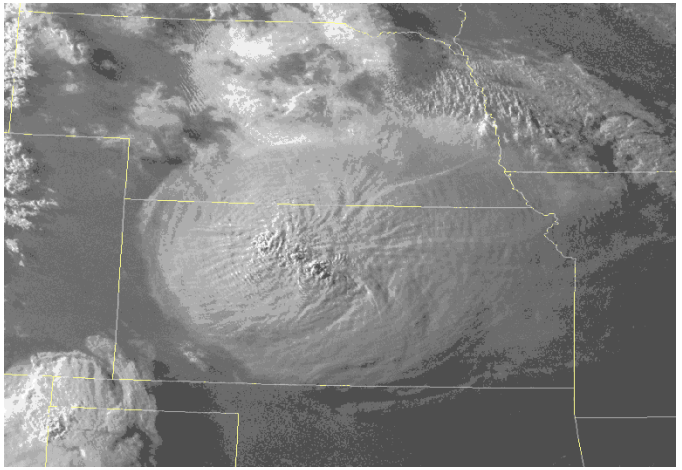
- Supercell thunderstorms
  - Large, long-lasting thunderstorm with a single rotating updraft
  - Strong vertical wind shear
  - Outflow never undercuts updraft
  - Classic, high precipitation and low precipitation supercells
  - Cap and convective instability
  - Rain free base, low-level jet
  - Surface, 850mb, 700mb, 500mb, 300mb conditions

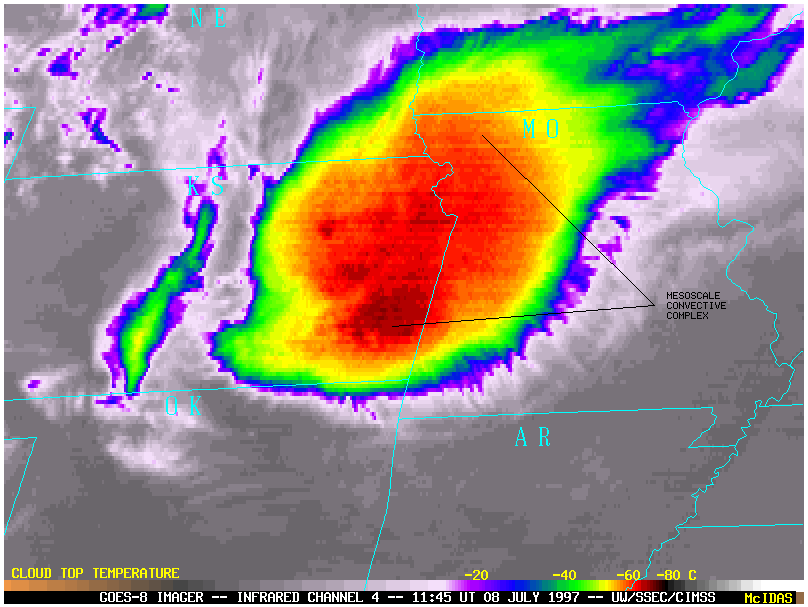


Mesoscale Convective Complexes

Meso-scale Convective Complex: a number of individual multi-cell thunderstorms grow in size and organize into a large circular convective weather system; summer, 10,000km^2

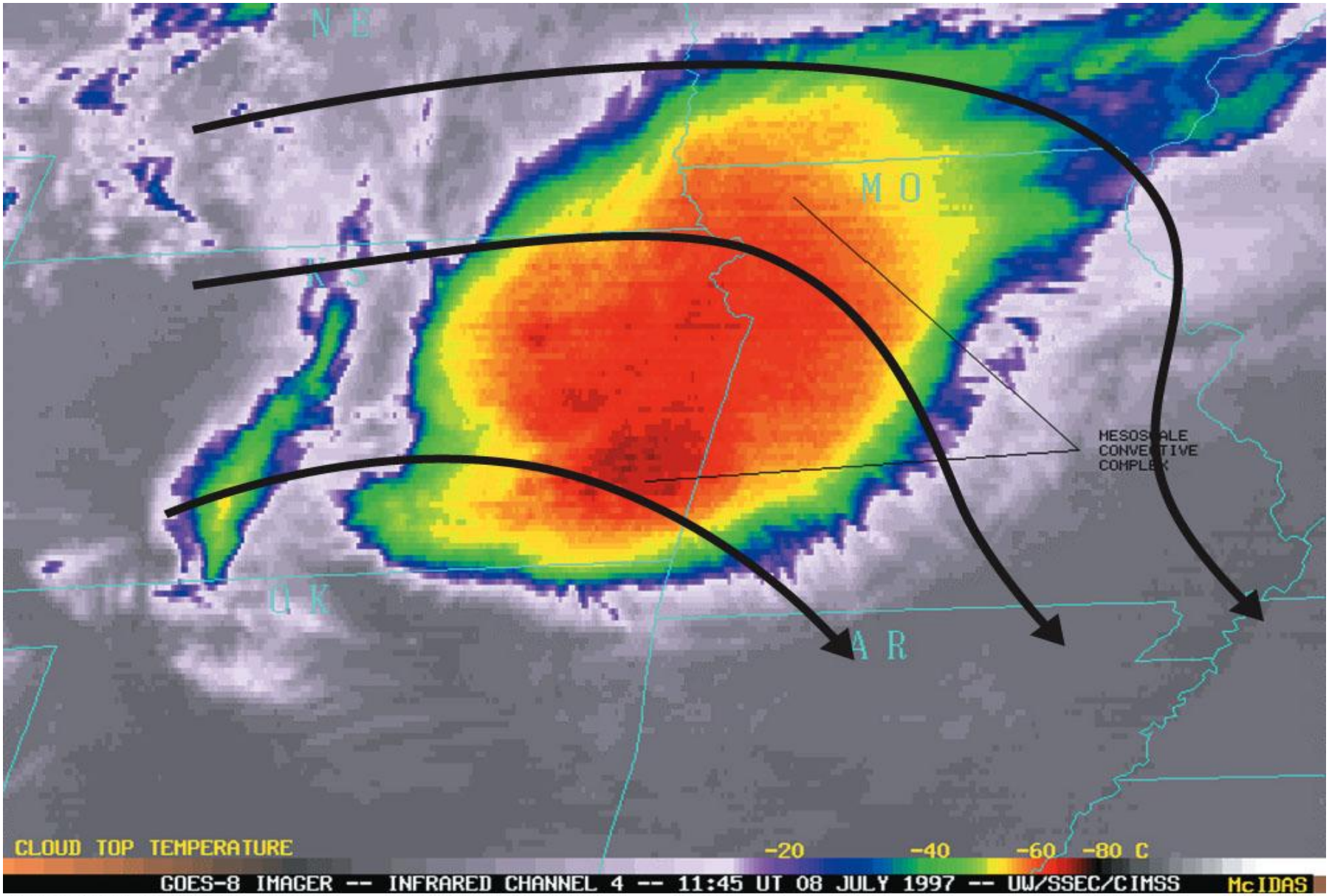






MCC's are very long lived, strong thunderstorms

Infrared image of a mesoscale convective complex over Kansas, July 8 1997.



Mesoscale Convective Complex (MCC) Thunderstorms

Methods of Forecasting Thunderstorms

Meteorologists use upper atmospheric data to depict when conditions are right for thunderstorm development. There are four methods/ models used by meteorologists:

1. **Lifted index**
2. **Totals-Totals**
3. **CAPE**
4. **K-index**

Mitigating the Hazards of Thunderstorms

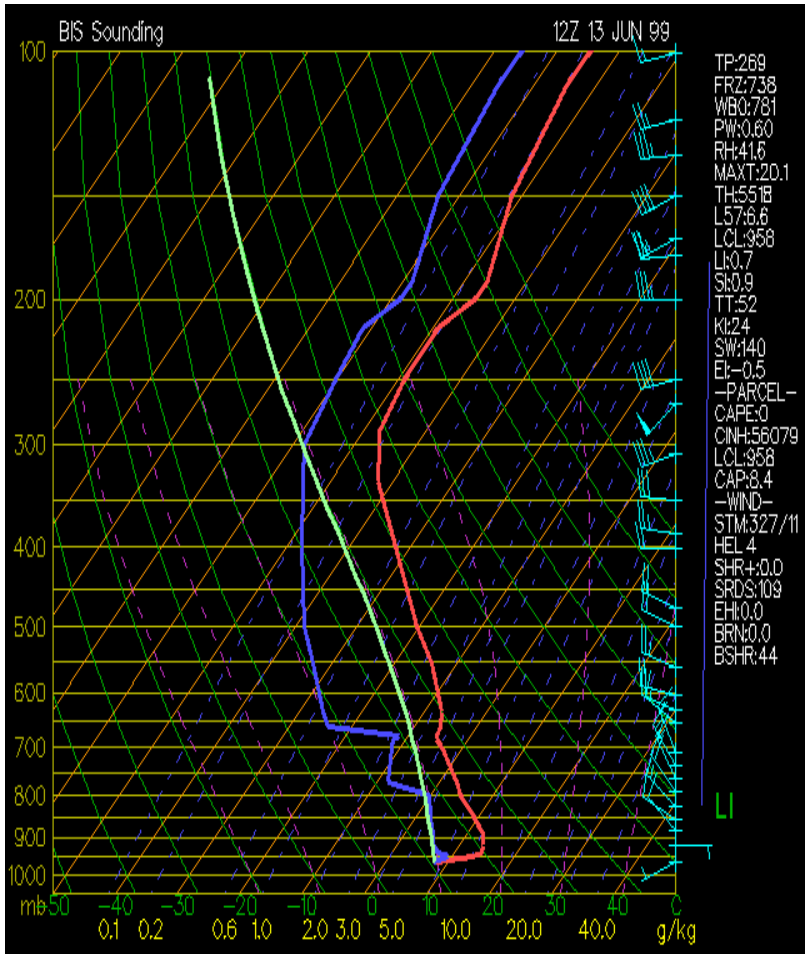
- ***Thunderstorm Watch-*** Atmospheric conditions are right for the development of severe weather.

- ***Thunderstorm Warning-*** a severe weather event is occurring at this moment at any given locale and is heading in your direction

Forecasting Thunderstorm Potential: **The Lifted Index**

500mb T(e) – 500mb T(parcel)

> 0	**Thunderstorms unlikely**
0 - -2	**Thunderstorms possible - trigger needed**
-3 - -5	**Thunderstorms probable**
-5 - -7	**Strong/severe thunderstorms. Tornadoes possible**
-7 - -9	**Move to Alaska**
< -9	**Yikes**



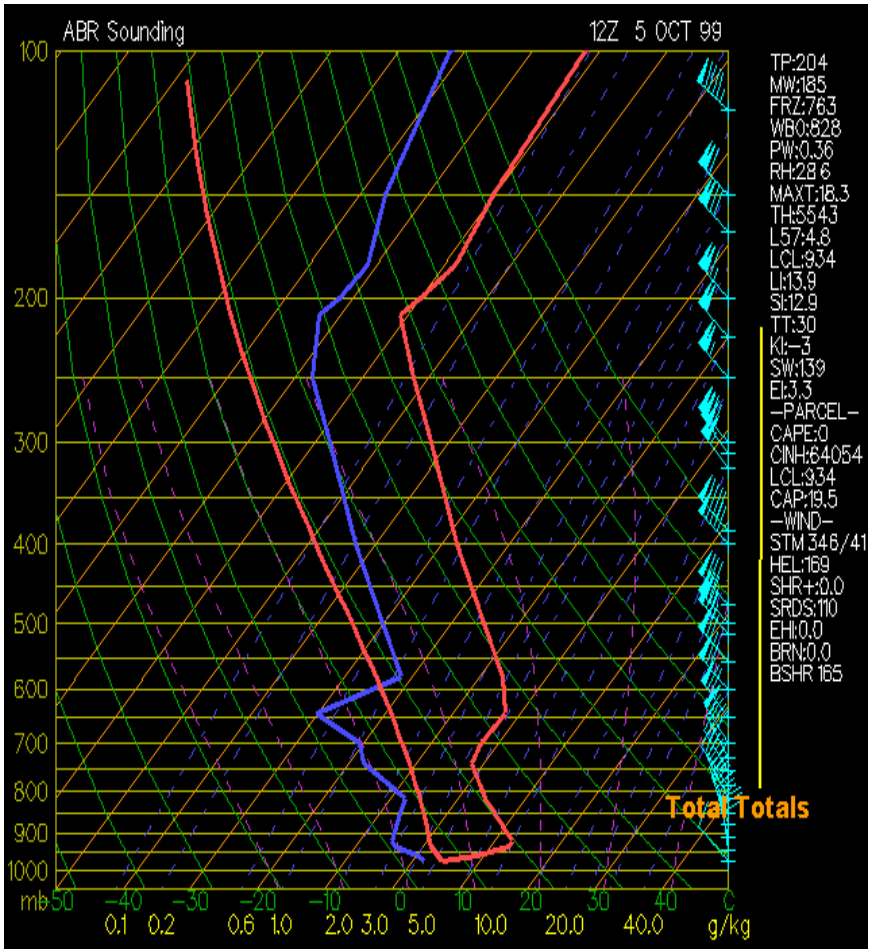
Forecasting Thunderstorms: The Totals-Totals Method

Total Totals

- can be found be found on a skew-t thermodynamic diagram.

TT is: T850mb + Td850mb - 2(T500mb).

< 43	**Thunderstorms unlikely**
43-44	**Isolated thunderstorms**
45-46	**Scattered thunderstorms**
47-48	**Scattered thunderstorms/ isolated severe**
49-50	**Scattered t-storms/few severe/isolated tornadoes**
51-52	**Scattered-numerous t-storms/few-scattered severe /isolated tornadoes**
53-55	**Numerous thunderstorms/ scattered tornadoes**
56+	**You don't want to know**

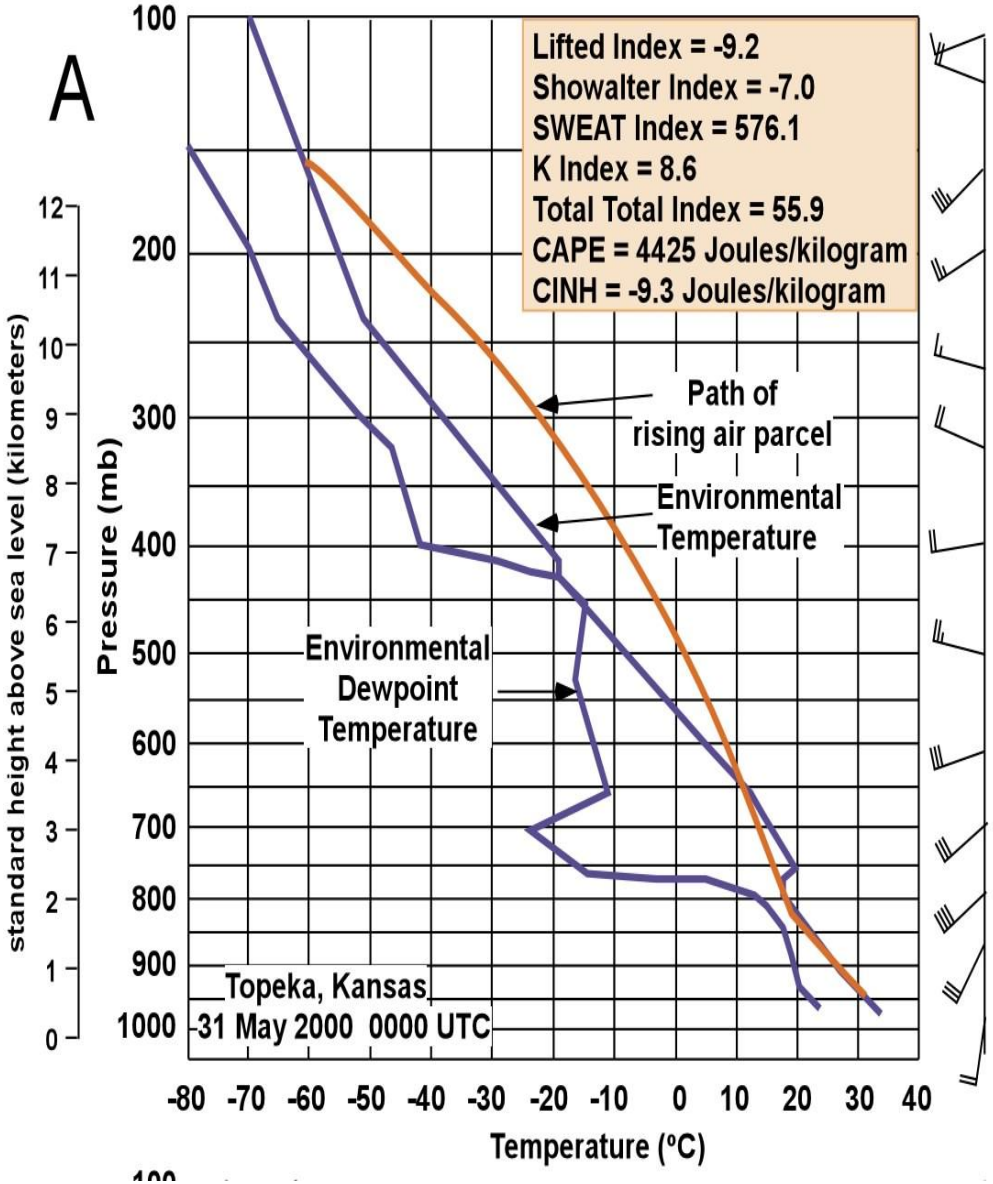


Convective Available Potential Energy (CAPE)

a. When ever the parcel line is to the right of the temperature line then there is CAPE and instability

b. The larger the area between the parcel line and the Temperature line the more CAPE there is

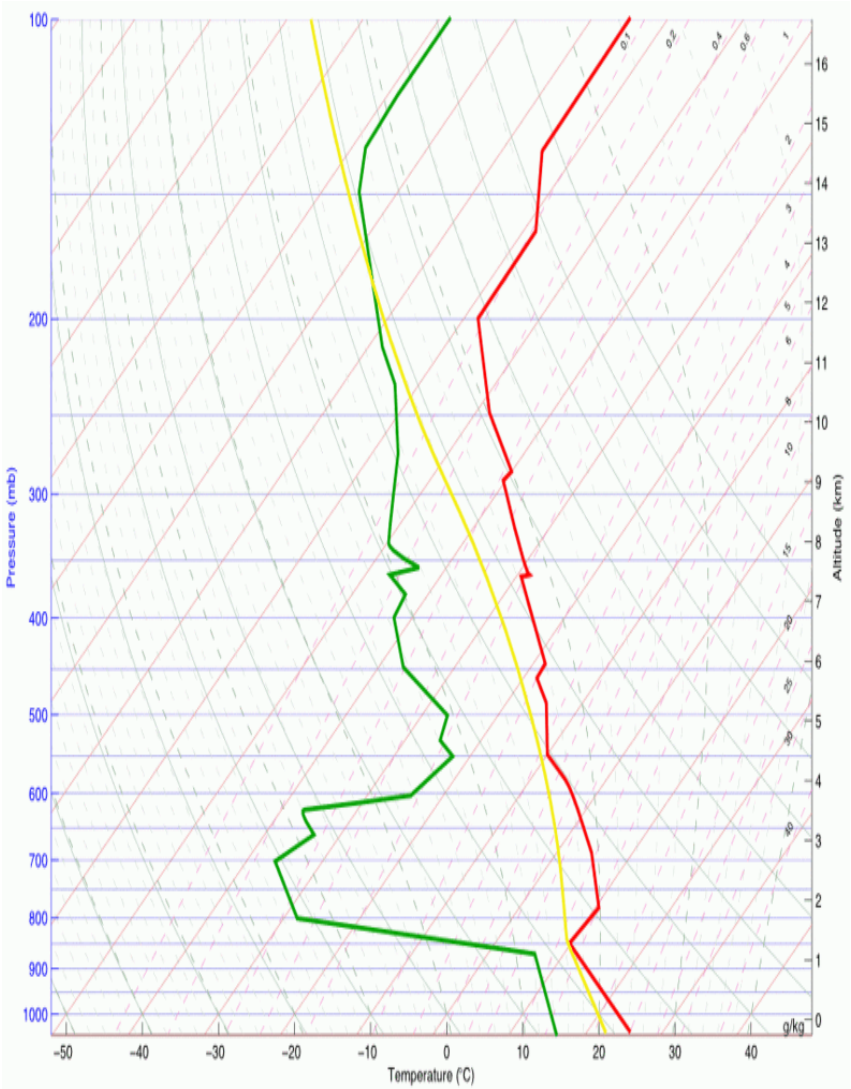
c. The more CAPE there is, the more potential energy a given thunderstorm has



Forecasting Thunderstorms:

The K- Index

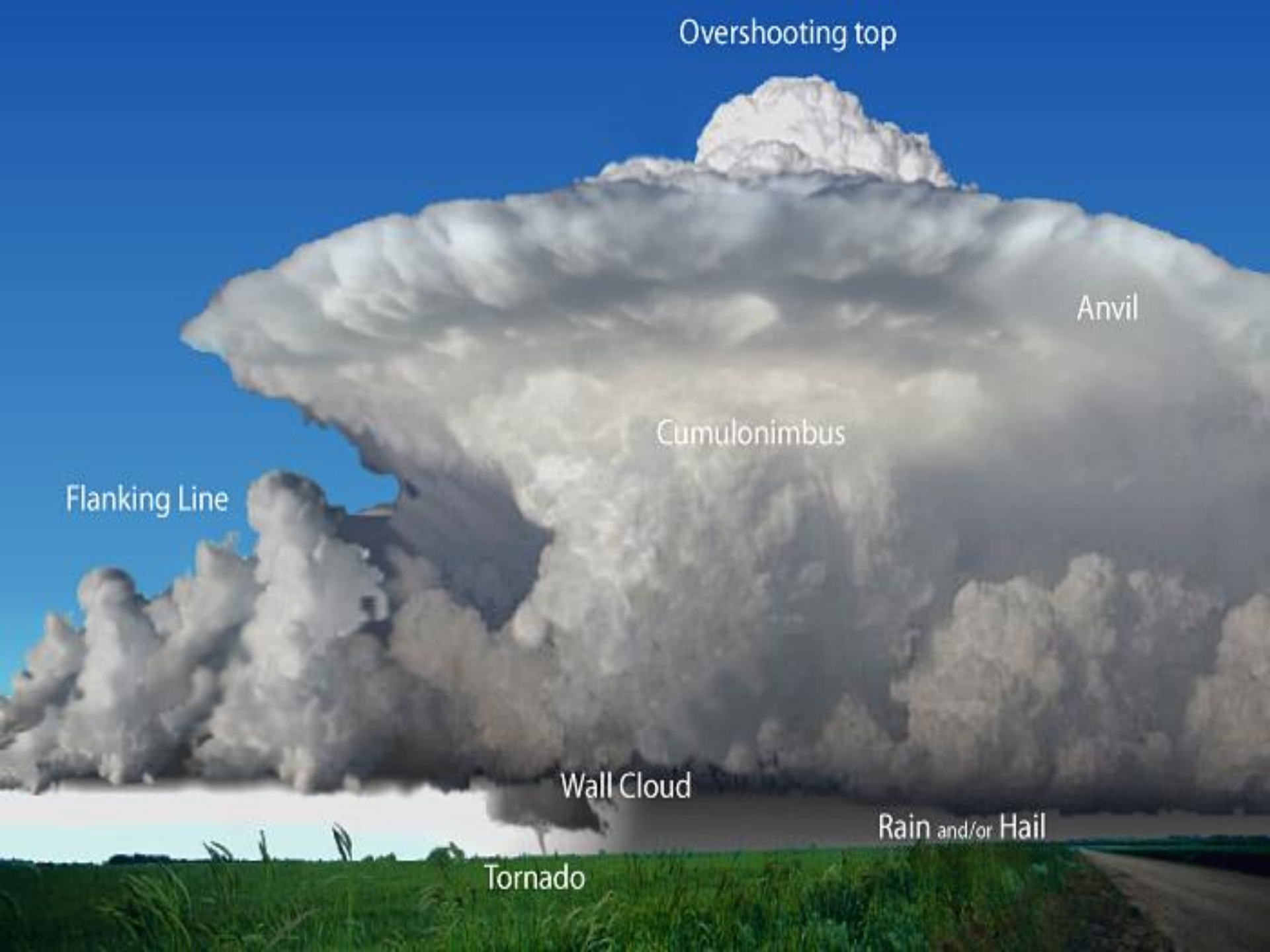
KI = (T850 - T500) + (Td850 - Tdd700)

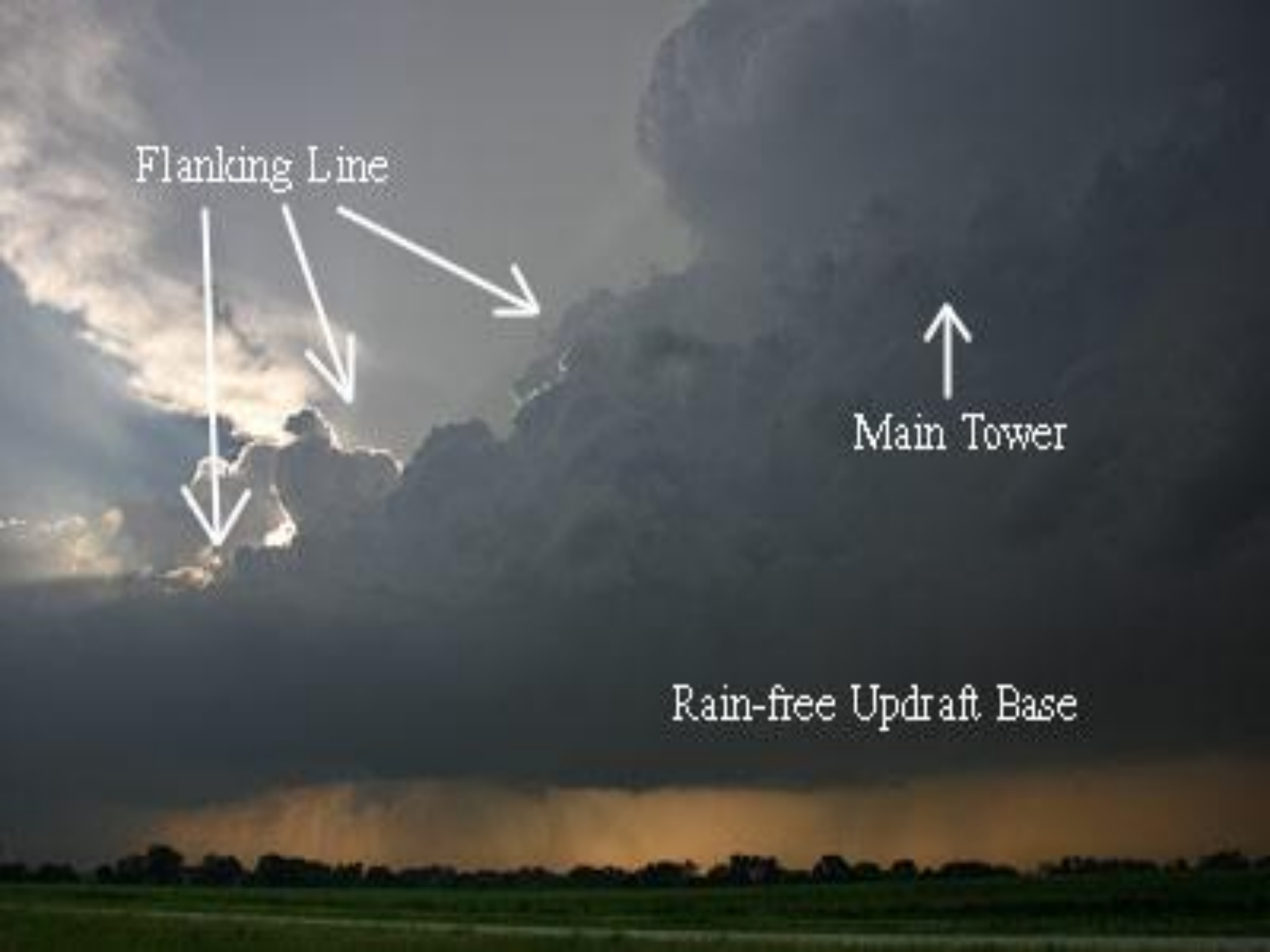


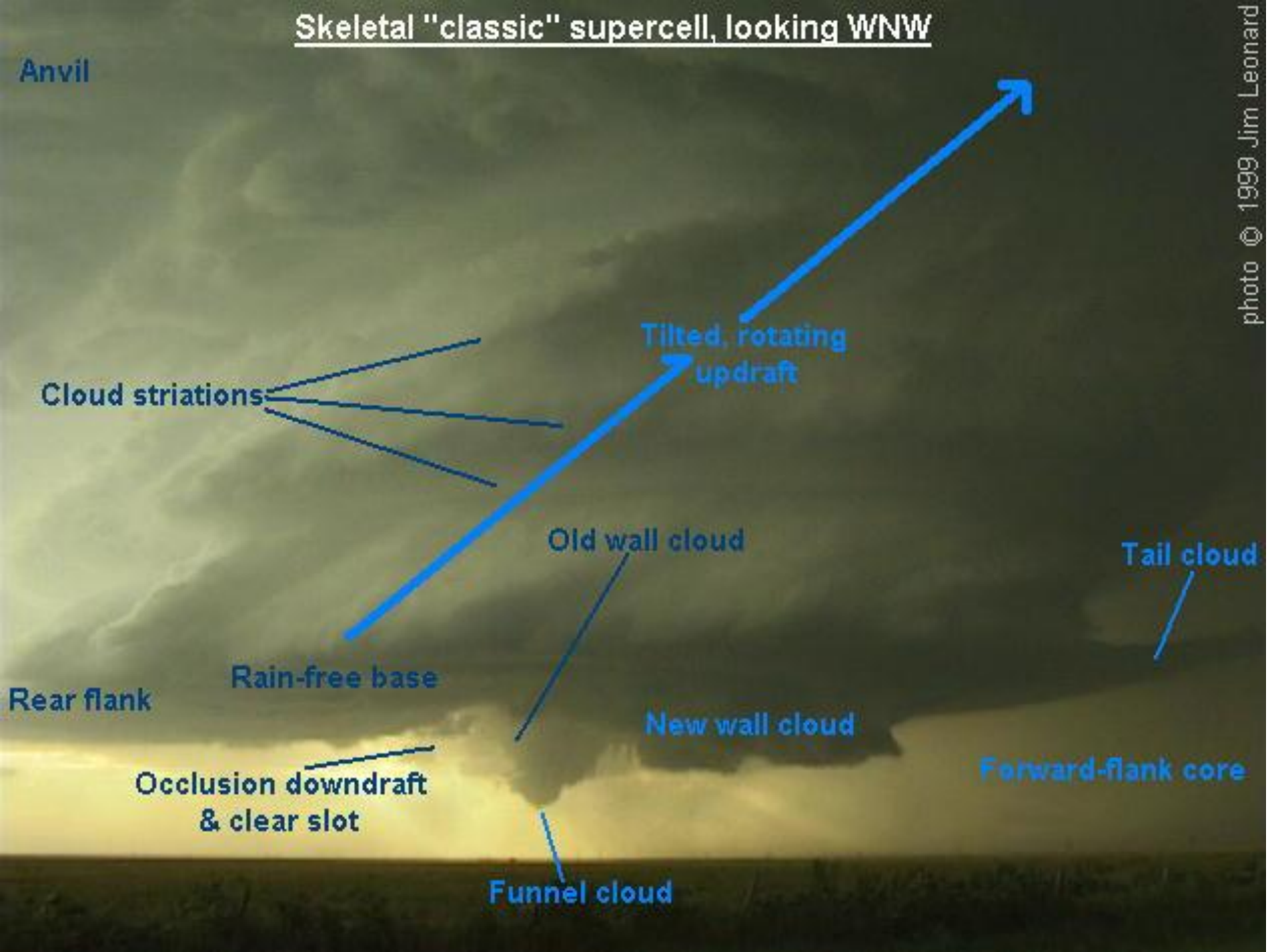
K INDEX	
15-25	**Small convective potential**
26-39	**Moderate convective potential**
40+	**High convective potential**

The Lower the K-index the higher the potential for Severe Thunderstorms
(see relationship between the KI and the Totals-Totals)

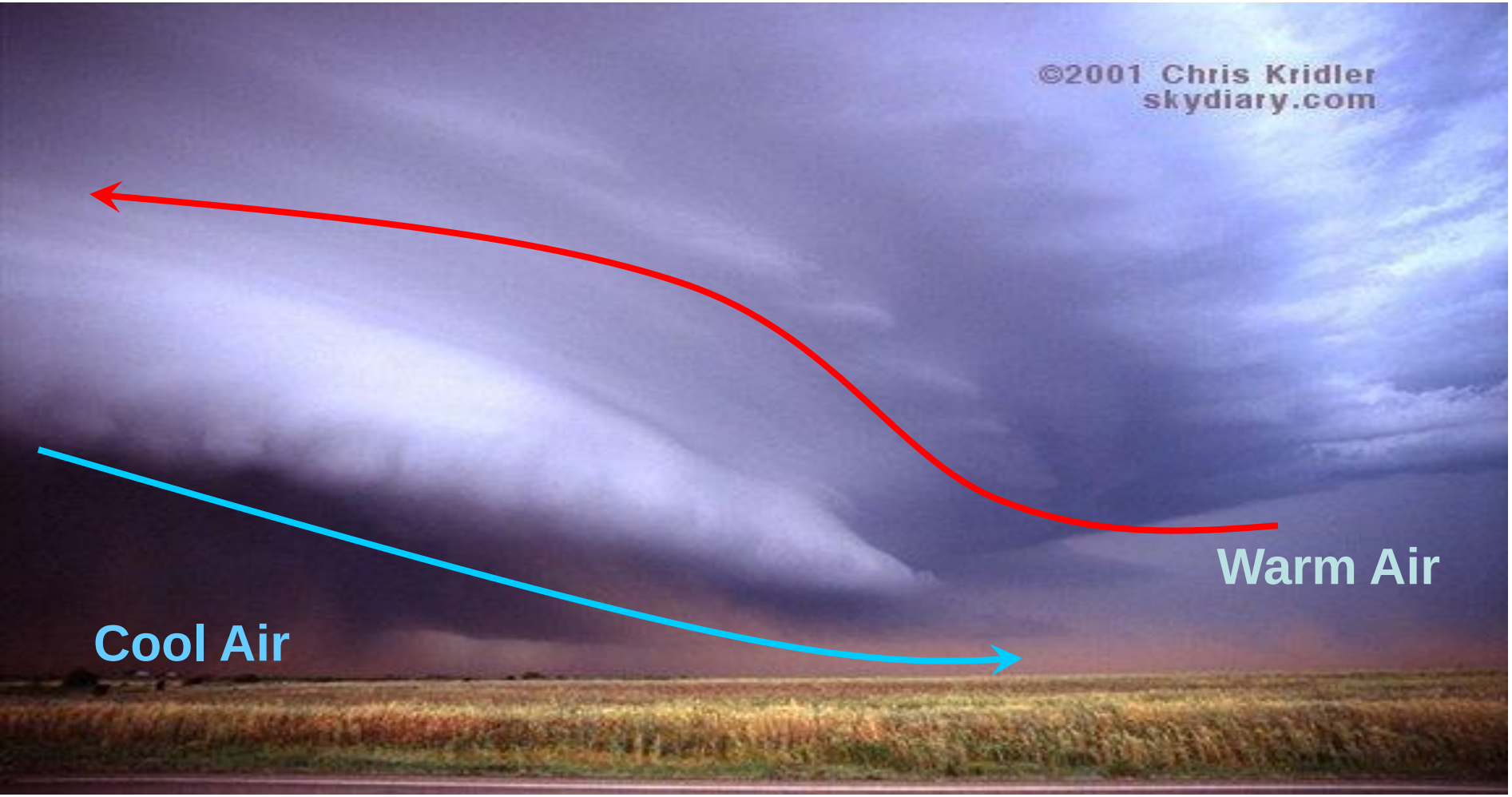
The Features of a Thunderstorm


Overshooting top
Anvil
Cumulonimbus
Flanking Line
Wall Cloud
Rain and/or Hail
Tornado

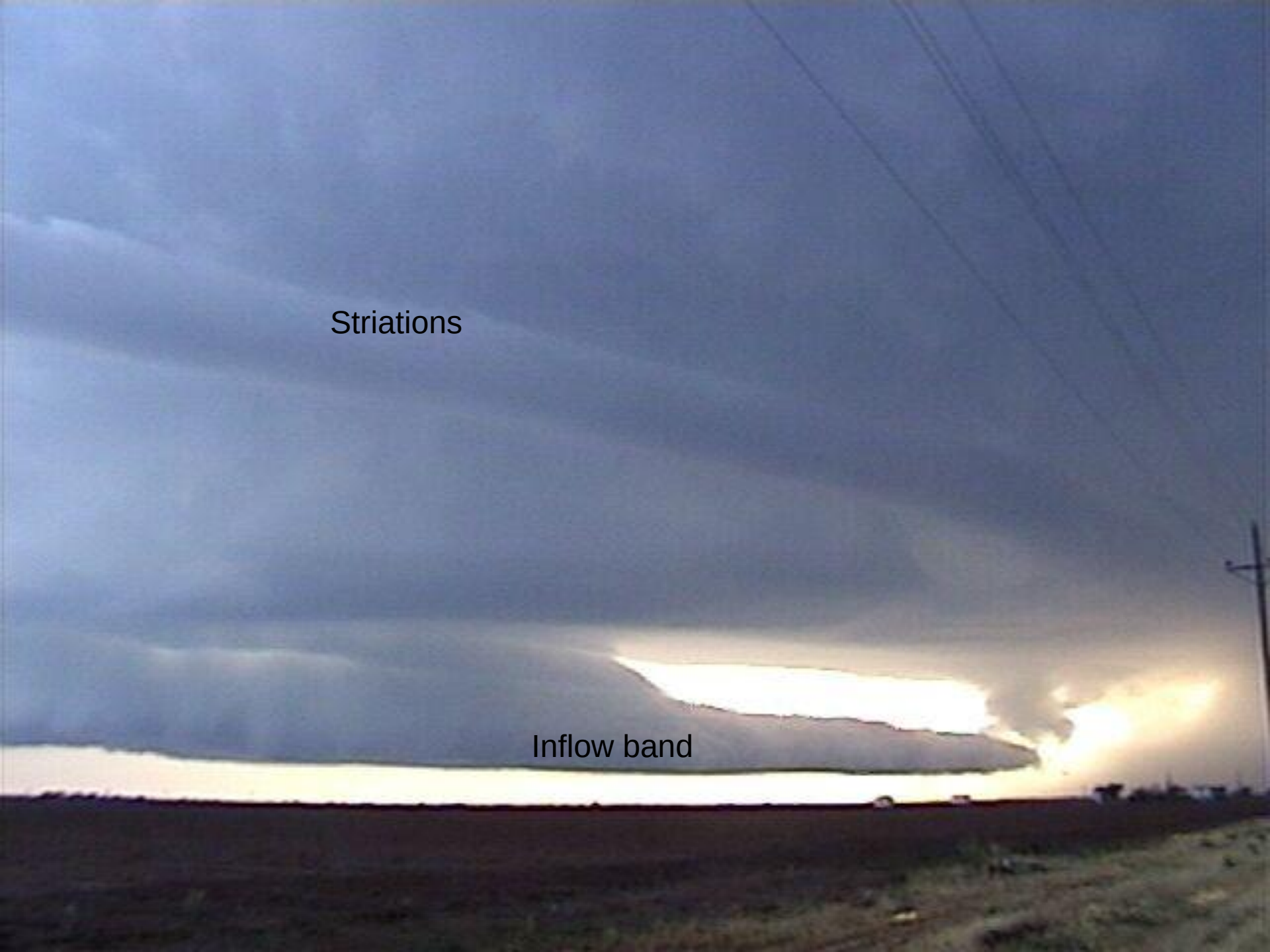

Flanking Line
Main Tower
Rain-free Updraft Base


Skeletal "classic" supercell, looking WNW
Anvil
Tilted, rotating updraft
Cloud striations
Old wall cloud
Tail cloud
Rain-free base
Rear flank
New wall cloud
Forward-flank core
Occlusion downdraft & clear slot
Funnel cloud
photo © 1999 Jim Leonard

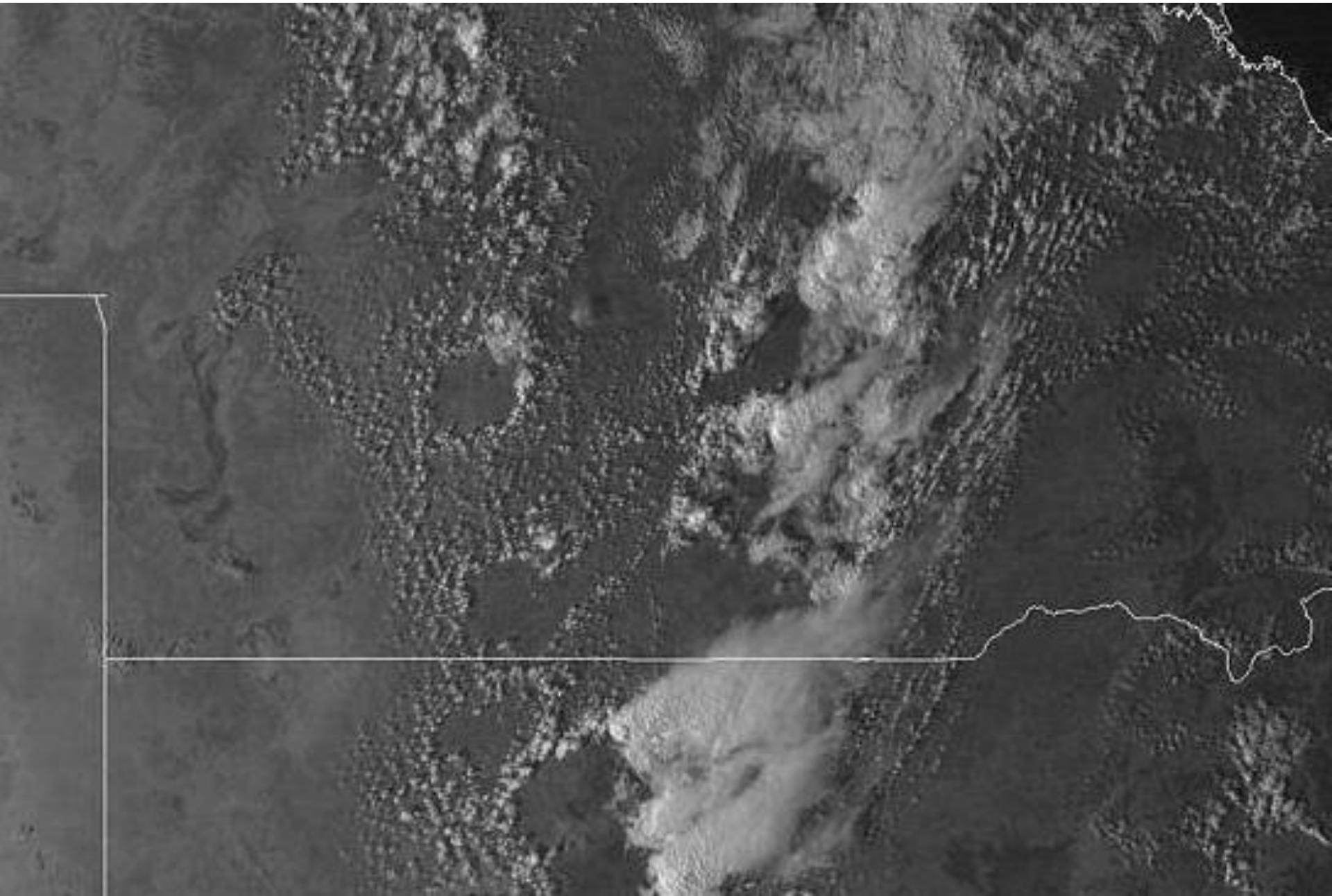
- **Shelf cloud (arcus cloud):**
  - Forms at the leading edge of the gust front as the warm air rises, cools, and condenses




Shelf Cloud
Outflow of
Thunderstorm


Striations
Inflow band


Outflow boundary




Striations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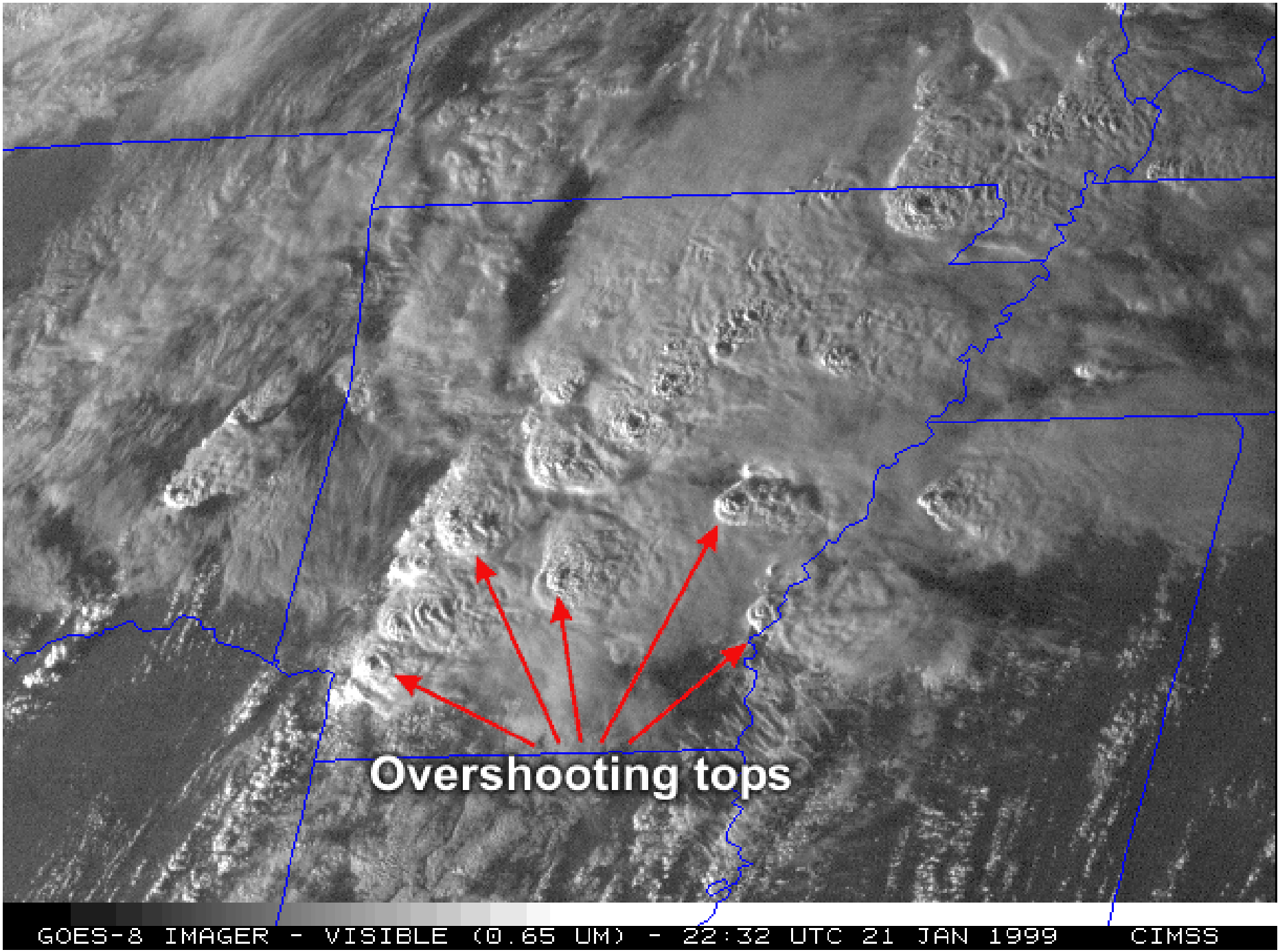
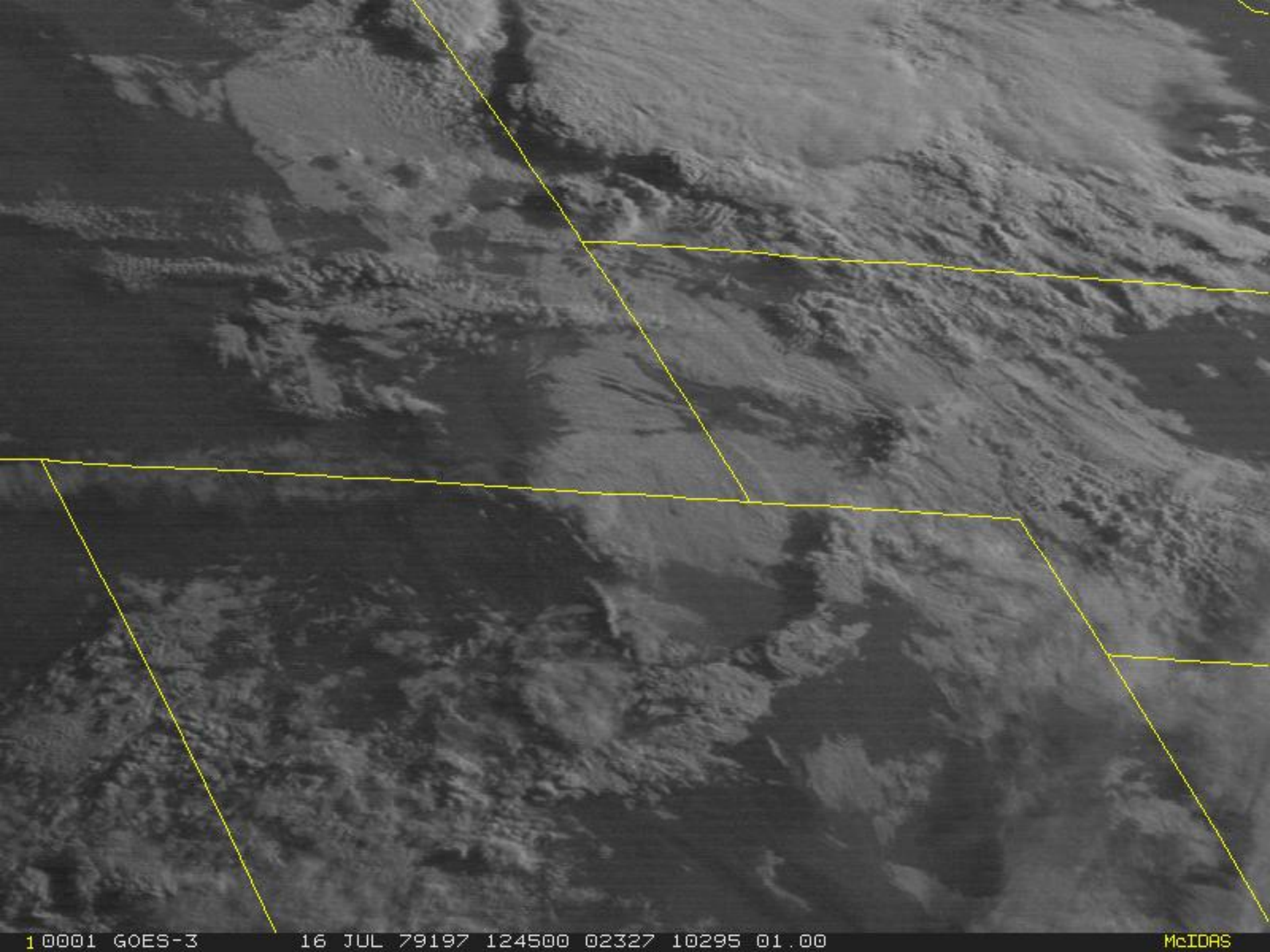
Rain Shaft


Overshooting Top


Overshooting tops
GOES-8 IMAGER - VISIBLE (0.65 UM) - 22:32 UTC 21 JAN 1999 CIMSS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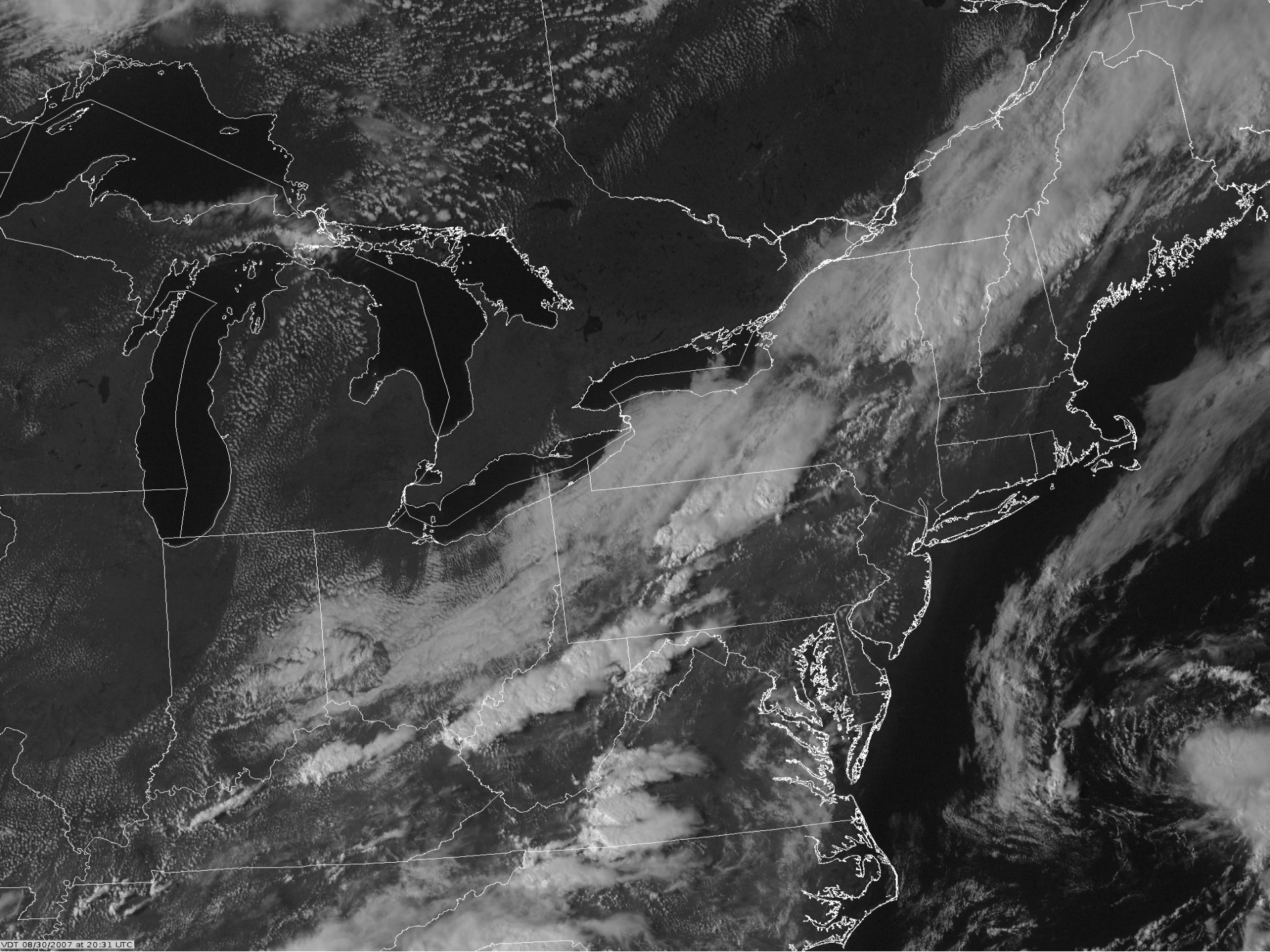

VDT 08/30/2007 at 20:31 UTC

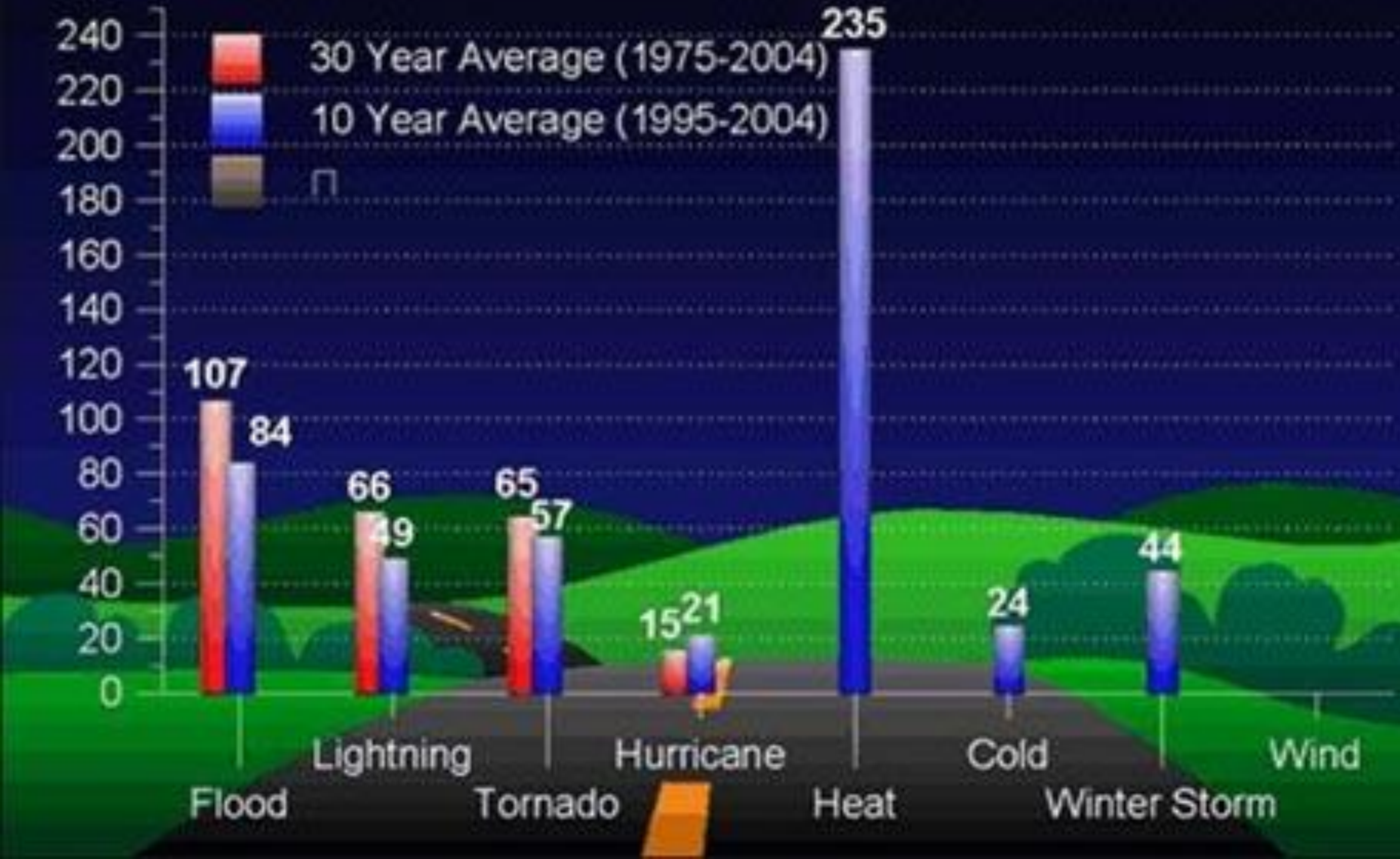

Gust Front


Wall Cloud


RFD

The Hazards of Thunderstorms

Weather Fatalities

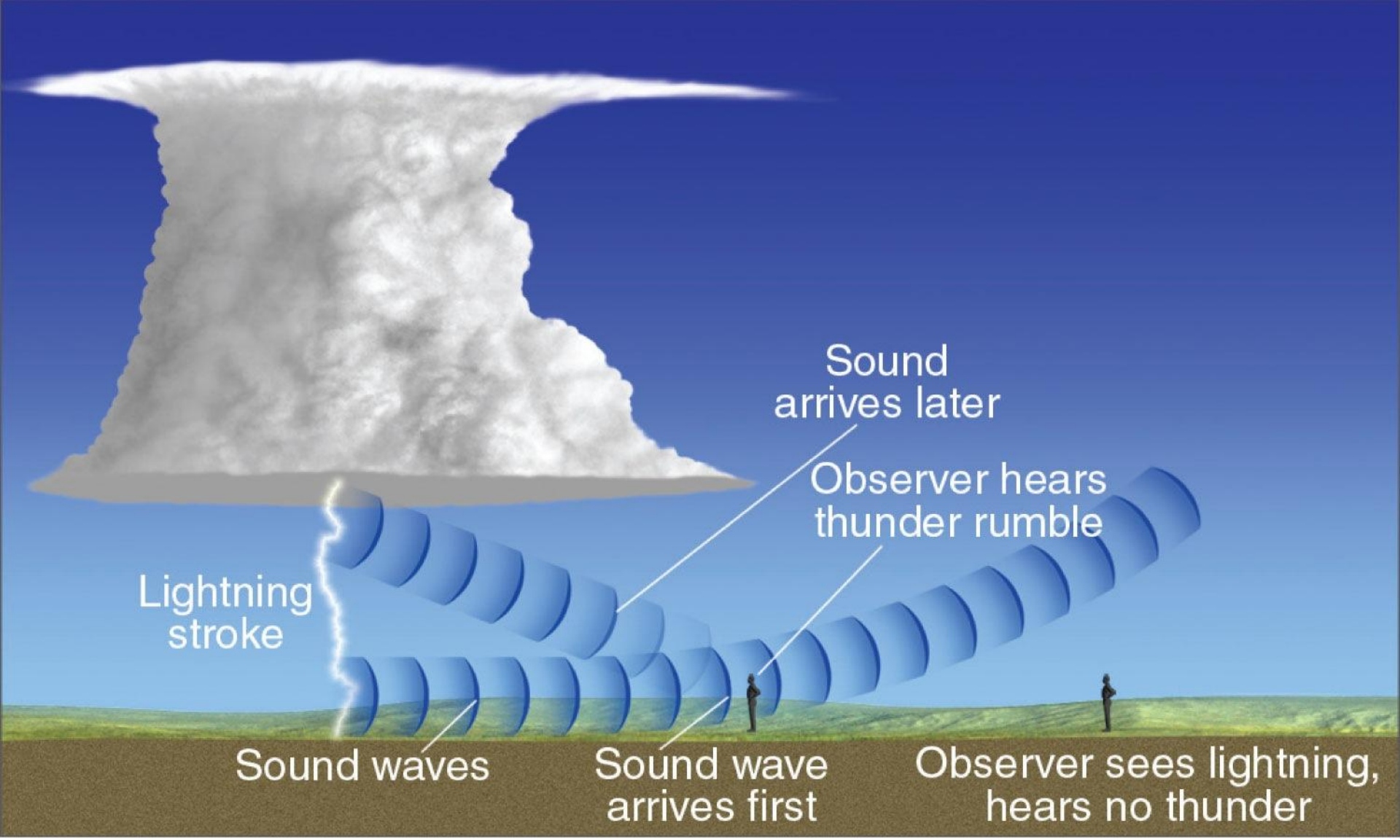


Thunderstorms

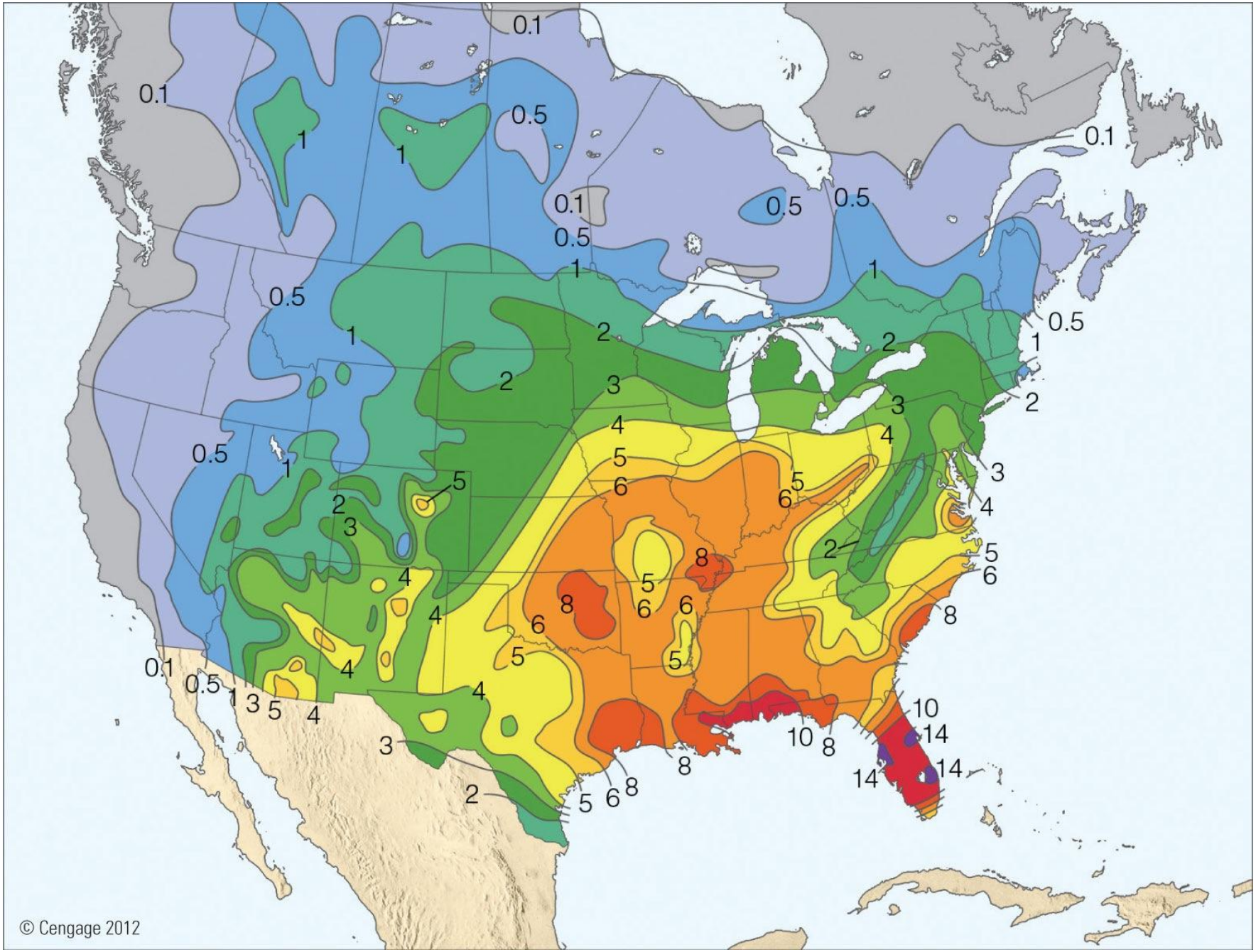
- Lightening and Thunder
  - Lightening: discharge of electricity in mature storms (within cloud, cloud to cloud, cloud to ground)
  - Thunder: explosive expansion of air due to heat from lightening
  - Electrification of Clouds: graupel and hailstones fall through supercooled water, ice crystals become negatively charged
  - Upper cloud positive, bottom cloud negative

The Hazards of Thunderstorms

Lightning



Thunder travels outward from the lightning stroke in the form of waves. If the sound waves from the lower part of the stroke reach an observer before the waves from the upper part of the stroke, the thunder appears to rumble. If the sound waves bend upward away from an observer, the lightning stroke may be seen, but the thunder will not be heard.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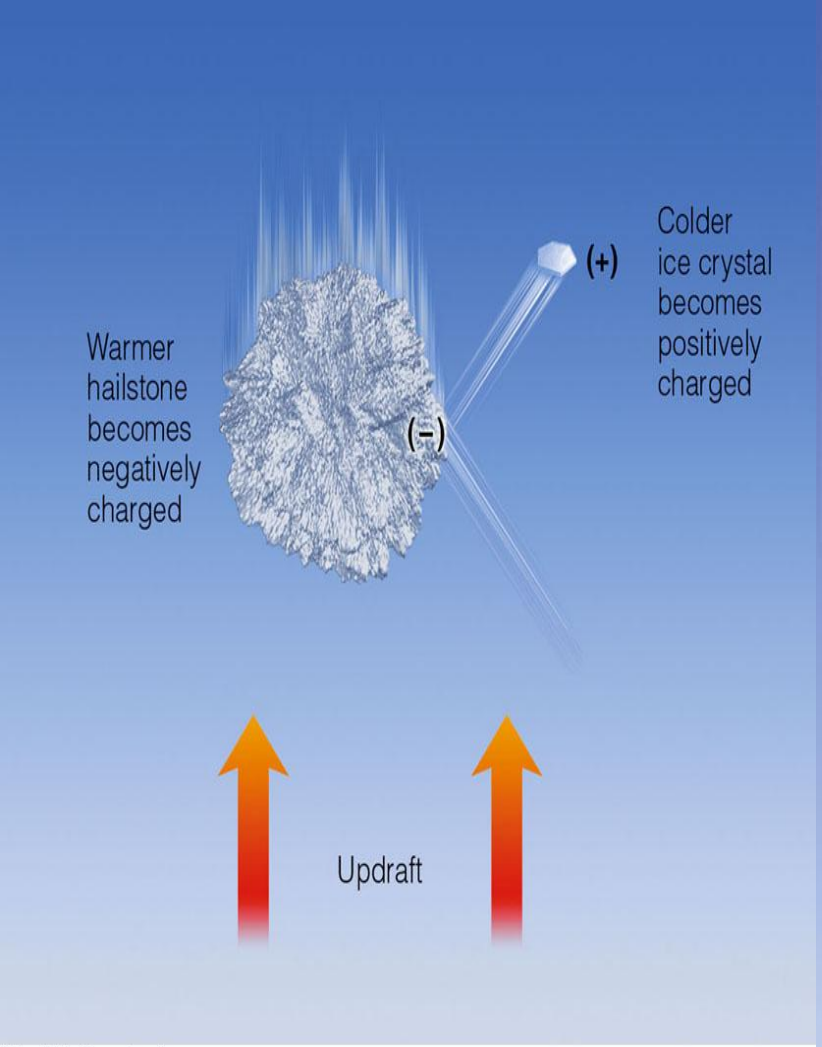
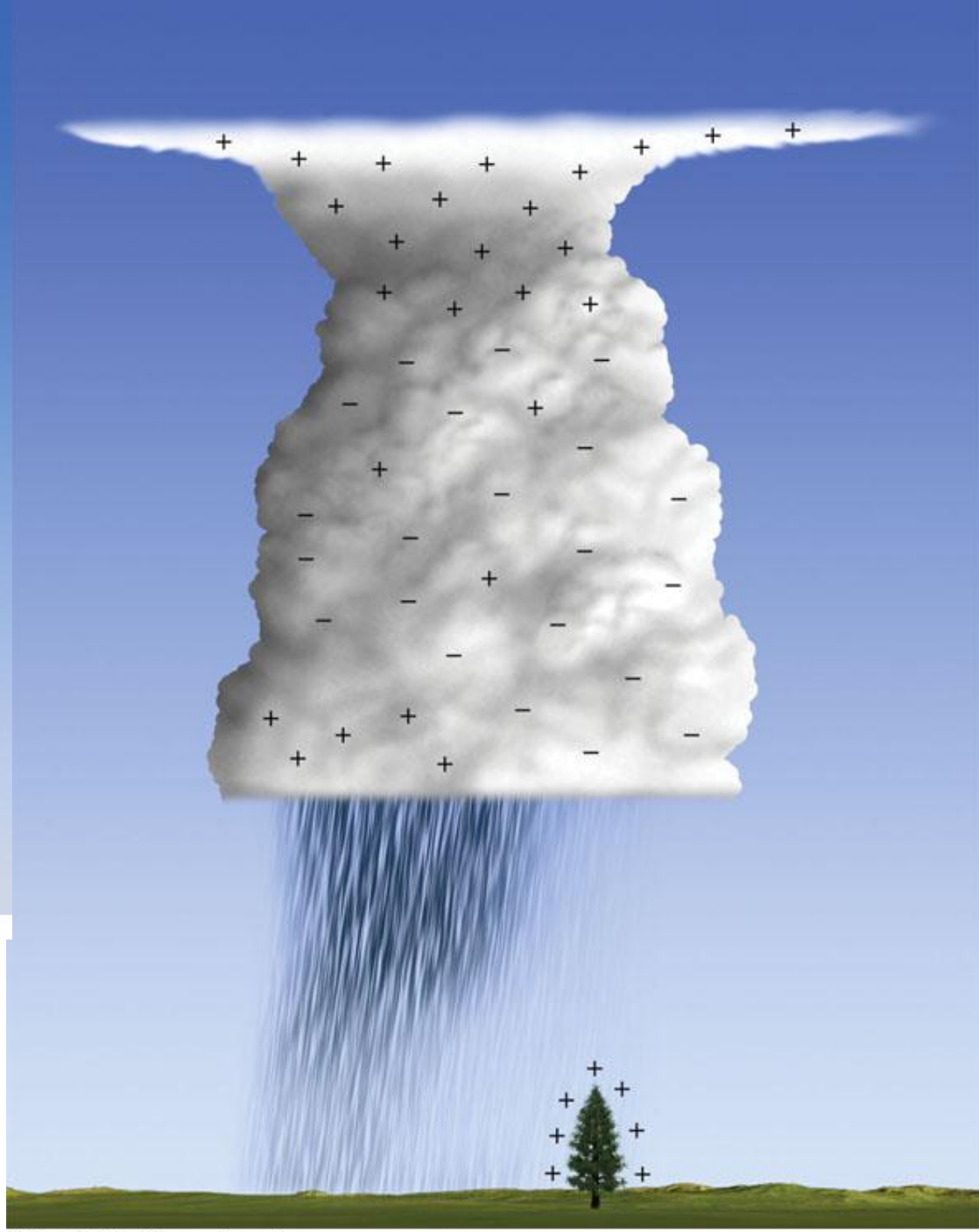
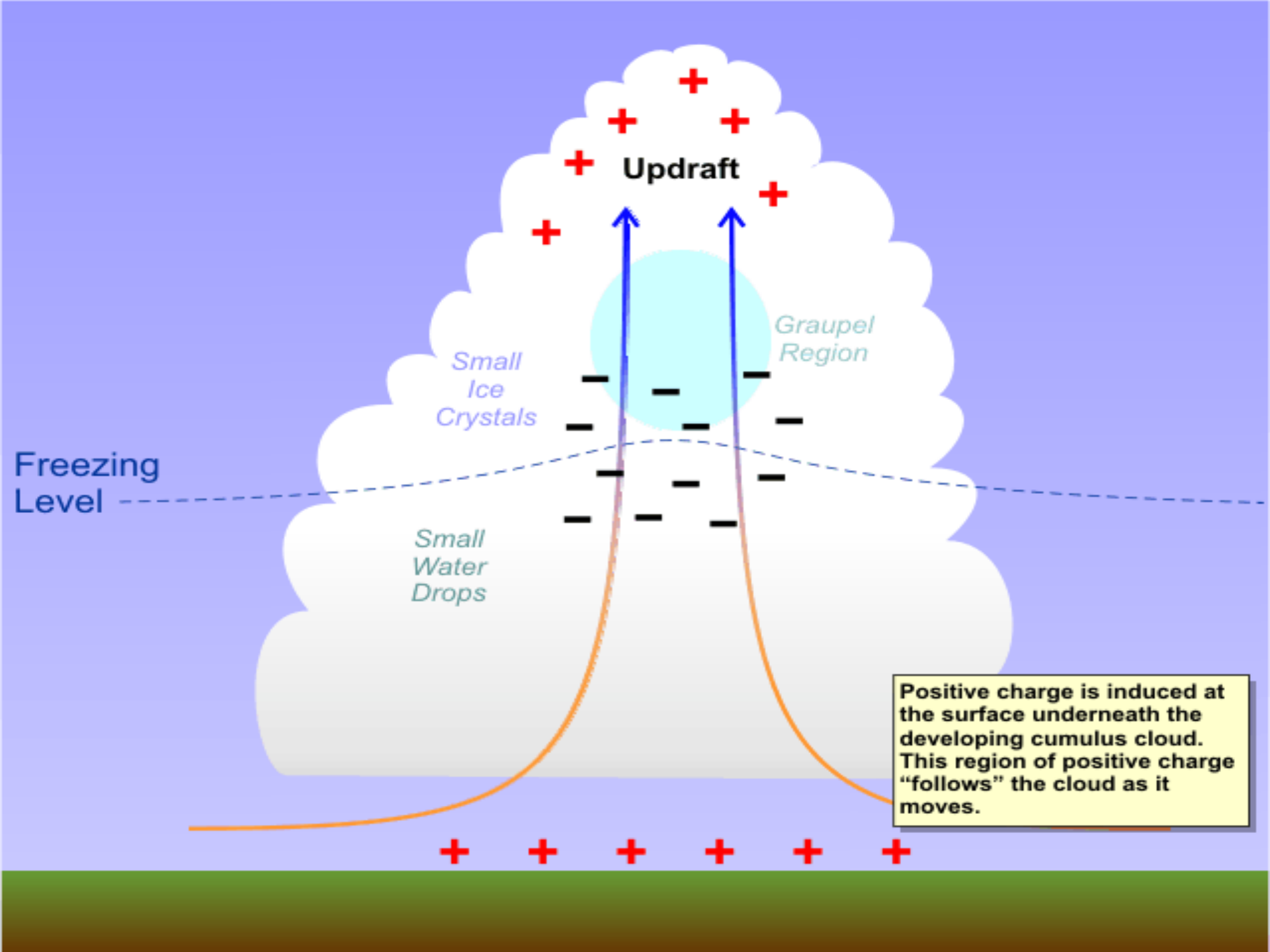
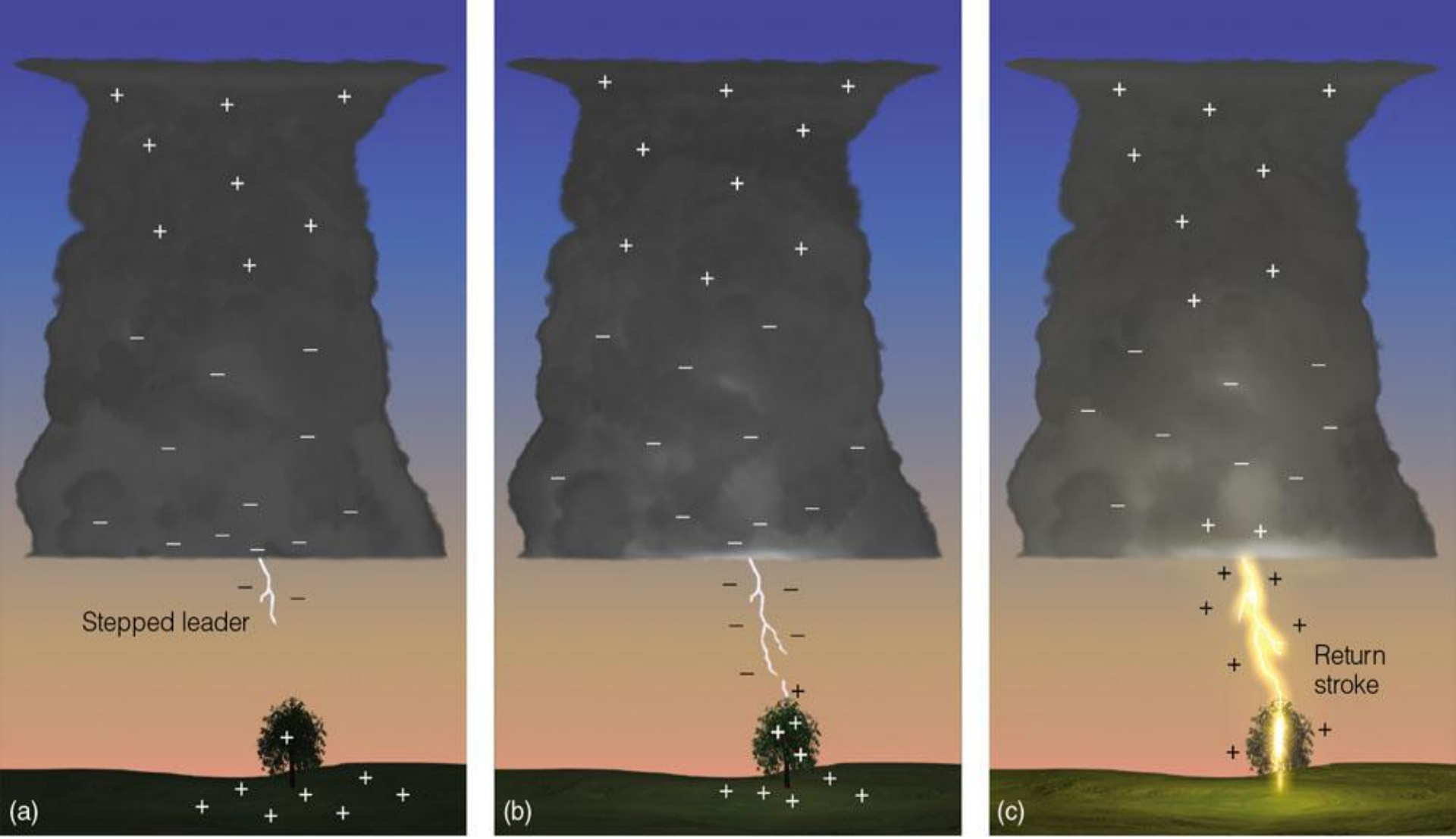





Updraft
Graupel Region
Small Ice Crystals
Freezing Level
Small Water Drops
Positive charge is induced at the surface underneath the developing cumulus cloud. This region of positive charge "follows" the cloud as it moves.



The development of a lightning stroke. (a) When the negative charge near the bottom of the cloud becomes large enough to overcome the air's resistance, a flow of electrons — the stepped leader — rushes toward the earth. (b) As the electrons approach the ground, a region of positive charge moves up into the air through any conducting object, such as trees, buildings, and even humans. (c) When the downward flow of electrons meets the upward surge of positive charge, a strong electric current — a bright return stroke — carries

Time exposure of an evening thunderstorm with an intense lightning display near Denver, Colorado. The bright flashes are return strokes. The lighter forked flashes are prob-ably stepped leaders that did not make it to the ground.

LIGHTNING KILLS
Play It Safe !

Lightning Facts...

- ✔ No place outside is safe during a thunderstorm.
- ✔ Lightning kills more people annually than tornadoes or hurricanes.
- ✔ If you hear thunder, you're likely within striking distance of the storm.

Outdoors...

- ✔ Plan outdoor activities to avoid thunderstorms.
- ✔ Monitor weather conditions. If you hear thunder, get inside a substantial building immediately.
- ✔ If a substantial buiilding is not available, get inside a hard-topped metal vehicle.
- ✔ Avoid open areas and stay away from isolated tall objects.

Indoors...

- ✔ Avoid contact with any equipment connected to electrical power, such as computers or appliances.
- ✔ Avoid contact with water or plumbing.
- ✔ Stay off corded phones.
- ✔ Stay away from windows and doors.
- ✔ Remain inside for 30 minutes after the last rumble of thunder is heard.

If Someone Is Struck...

- ✔ Victims do not carry an electrical charge and may need immediate medical attention.
- ✔ Call 911 for help.
- ✔ Monitor the victim and begin CPR or AED, if necessary.

National Lightning Safety Institute

For more information, visit:

www.lightningsafety.noaa.gov

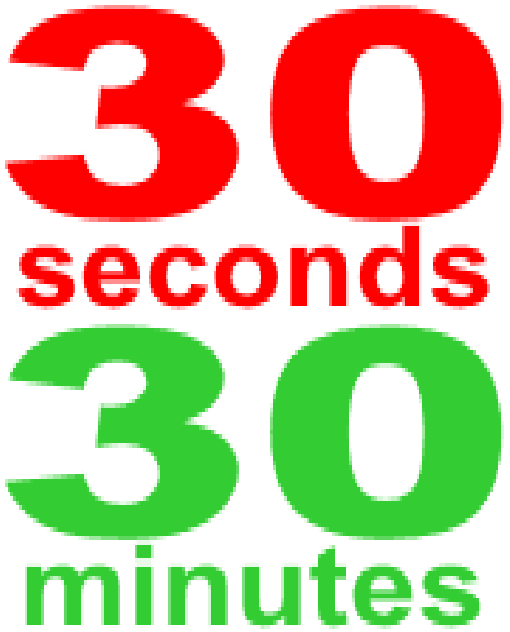
Lightning Safety

Determining the Distance to a Storm.

- **For every 5 seconds between lightning stroke and sound of thunder = 1 mile**

30/30 Rule

The 30/30 Rule states that people should seek shelter if the "Flash-To-Bang" delay (length of time in seconds between a lightning flash and its subsequent thunder), is 30 seconds or less, and that they remain under cover until 30 minutes after the final clap of thunder



Lightning can be both hair-raising and deadly. This photograph, taken by Mary McQuilken, shows her younger brother, Sean (on the left), and older brother, Michael (on the right), standing beneath a thunderstorm atop Moro Rock in California's Sequoia National park. Shortly after this photo was taken, Sean was struck by lightning and seriously injured, and a nearby hiker was killed by the same lightning strike.

Lightning Safety


© Caters News Agency

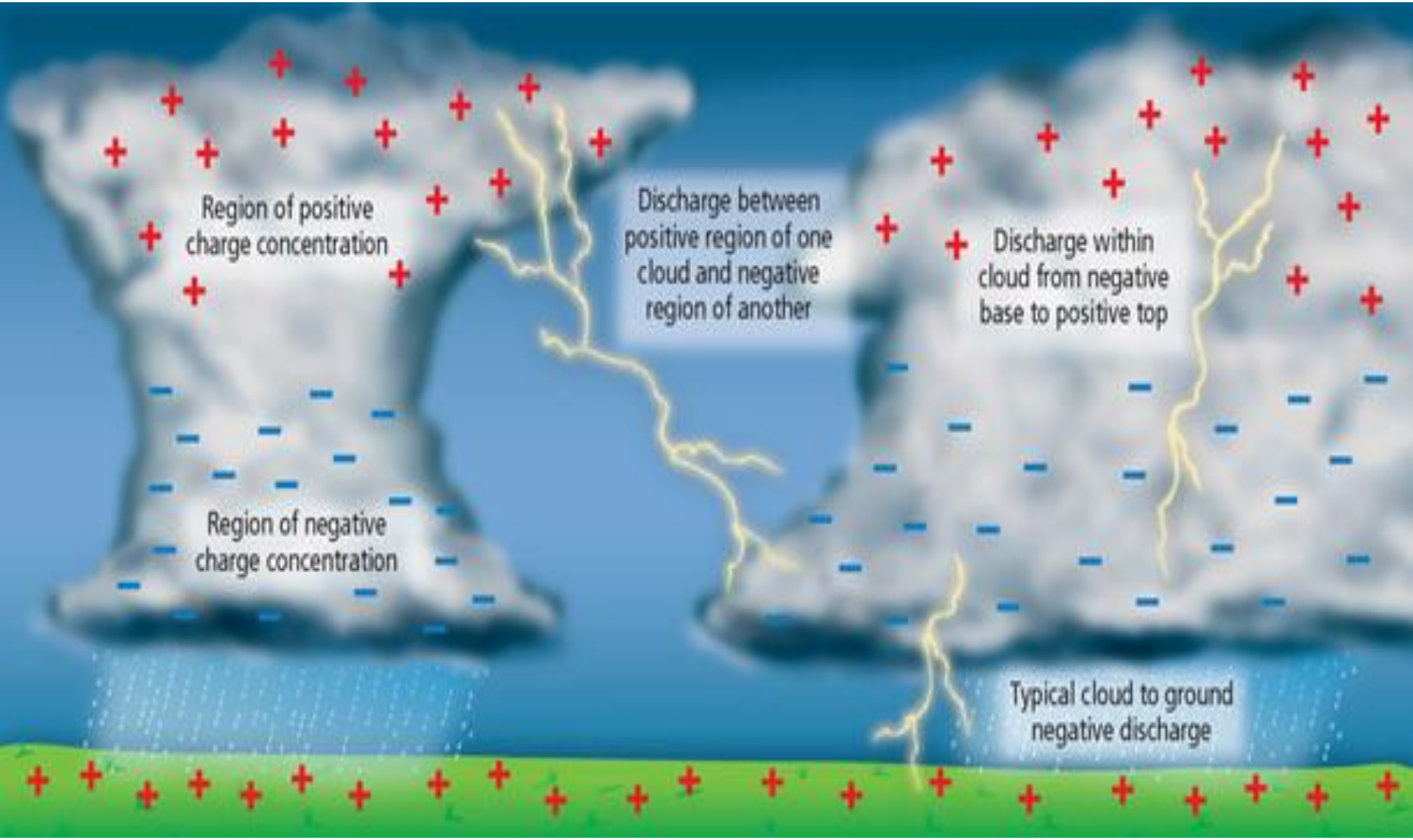
Types of Lightning

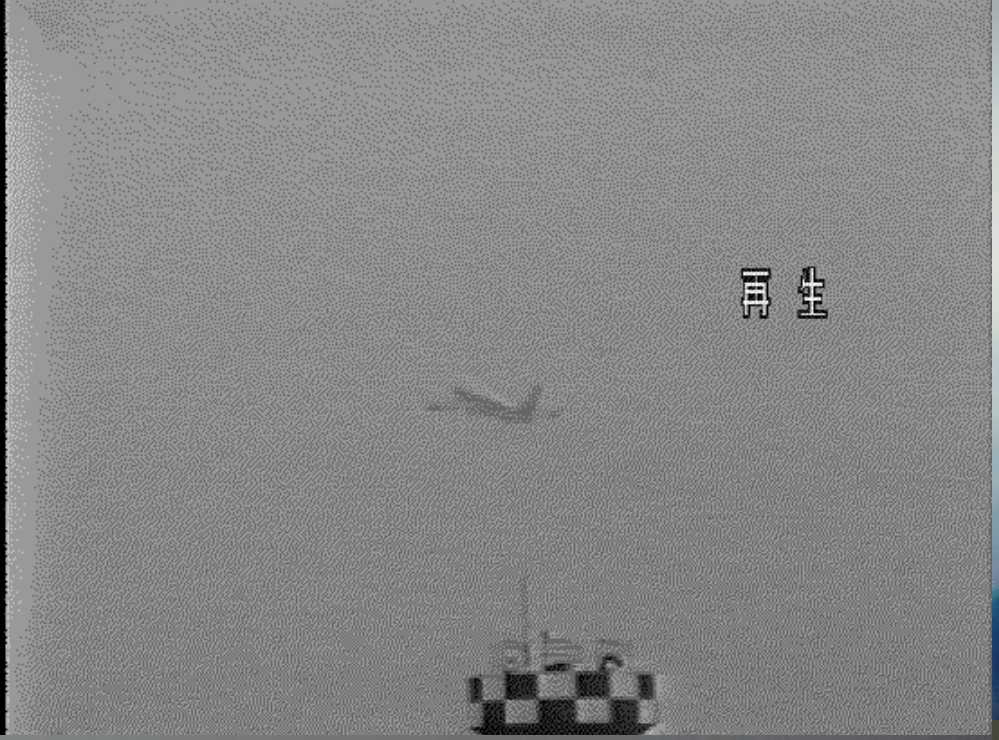
Heat Lightning

Ball Lightning

Sheet Lightning

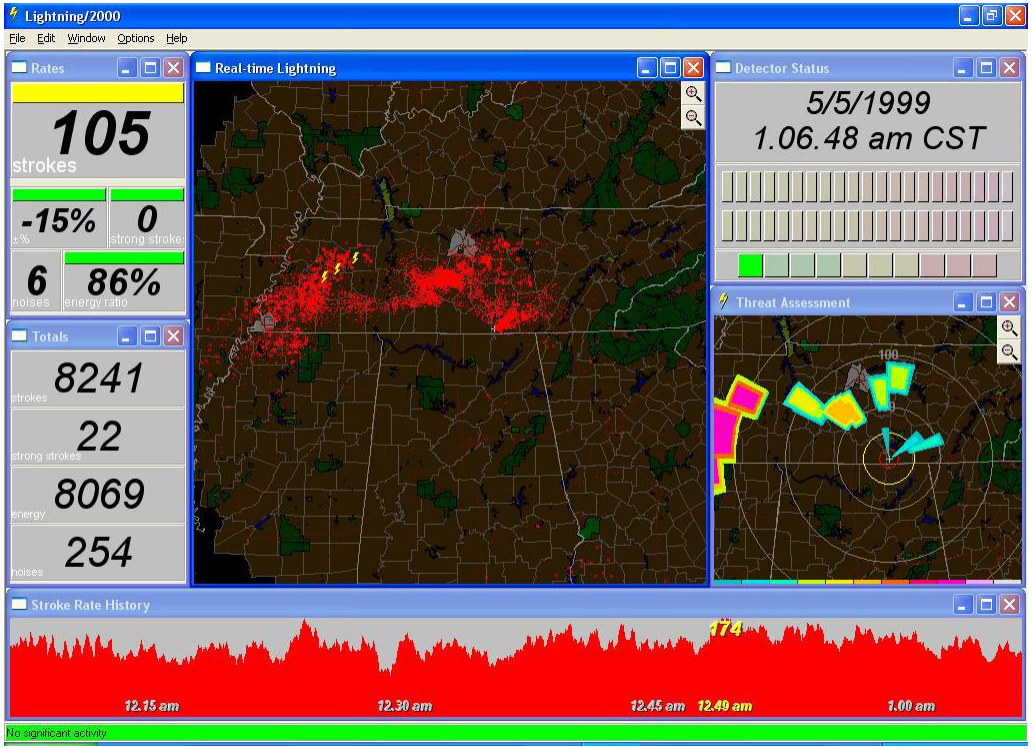

Cloud-to-Ground Lightning (CG)

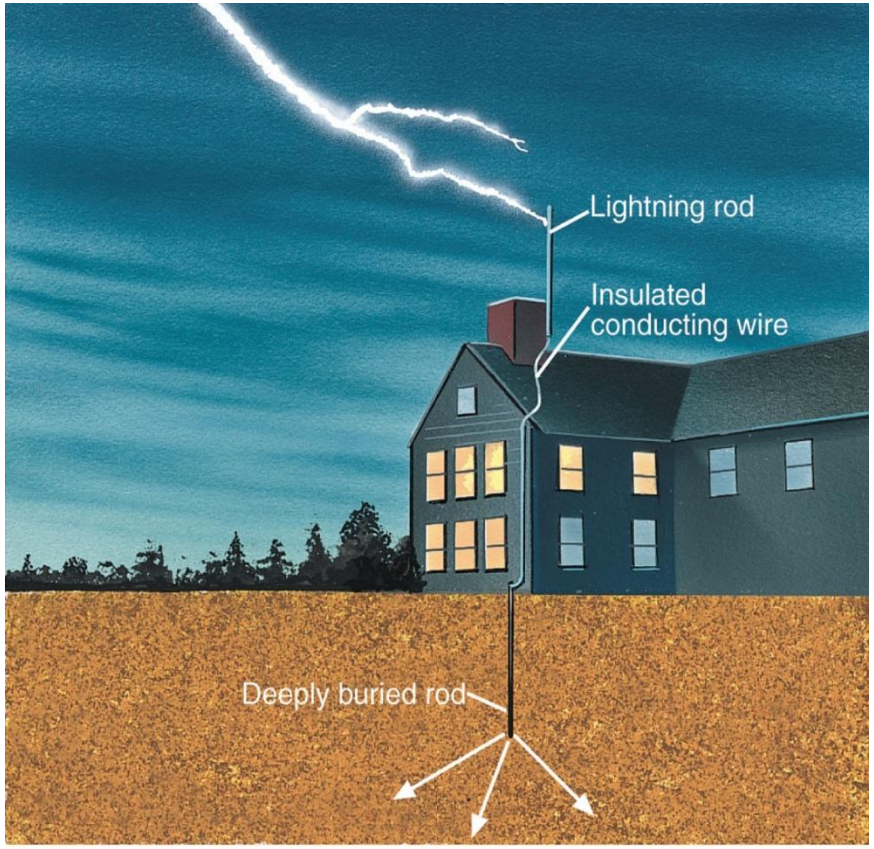

Region of positive charge concentration
Region of negative charge concentration
Discharge between positive region of one cloud and negative region of another
Discharge within cloud from negative base to positive top
Typical cloud to ground negative discharge


再生


B F

Lightning Detection





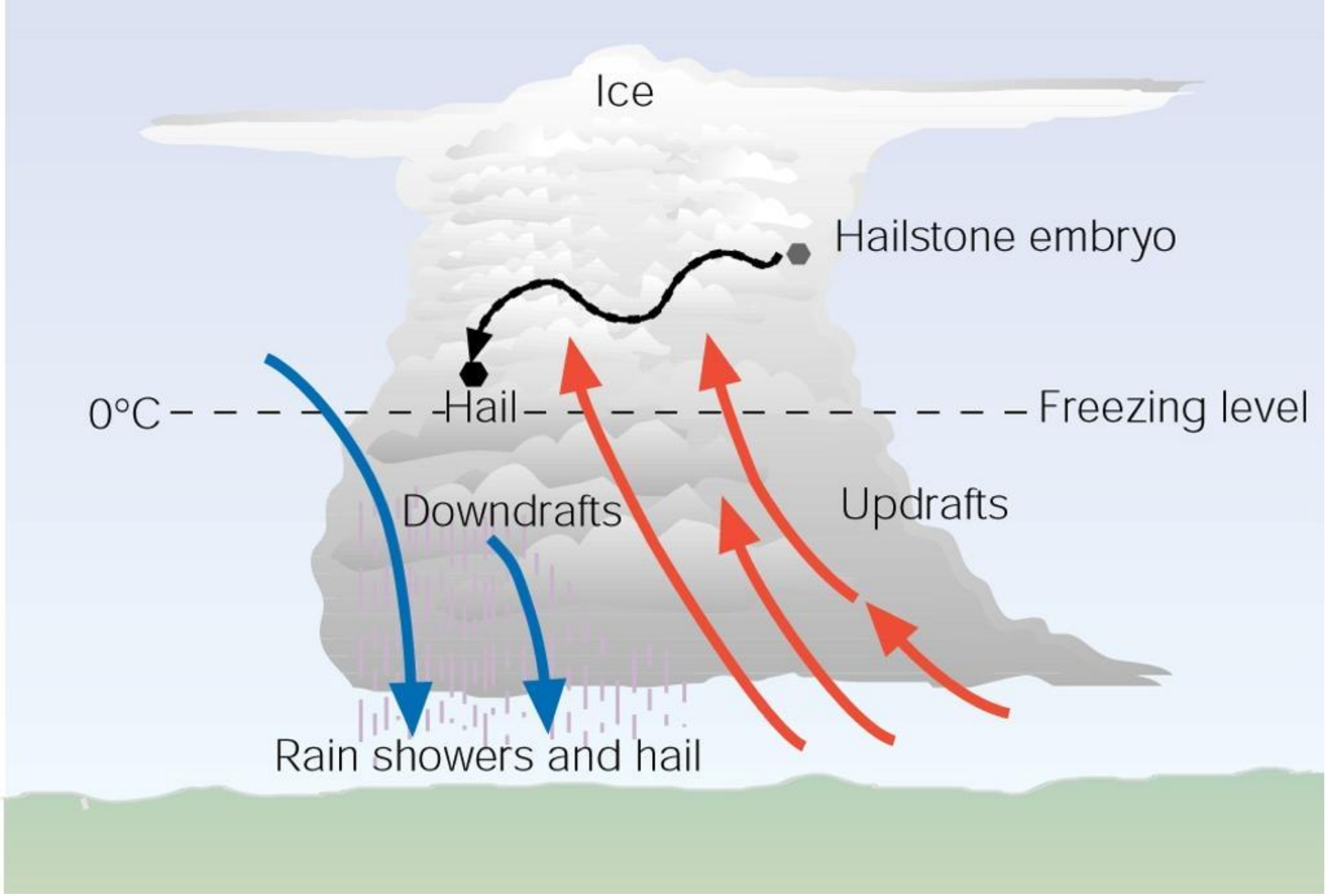
The lightning rod extends above the building, increasing the likelihood that lightning will strike the rod rather than some other part of the structure. After lightning strikes the metal rod, it follows an insulated conducting wire harmlessly into the ground.

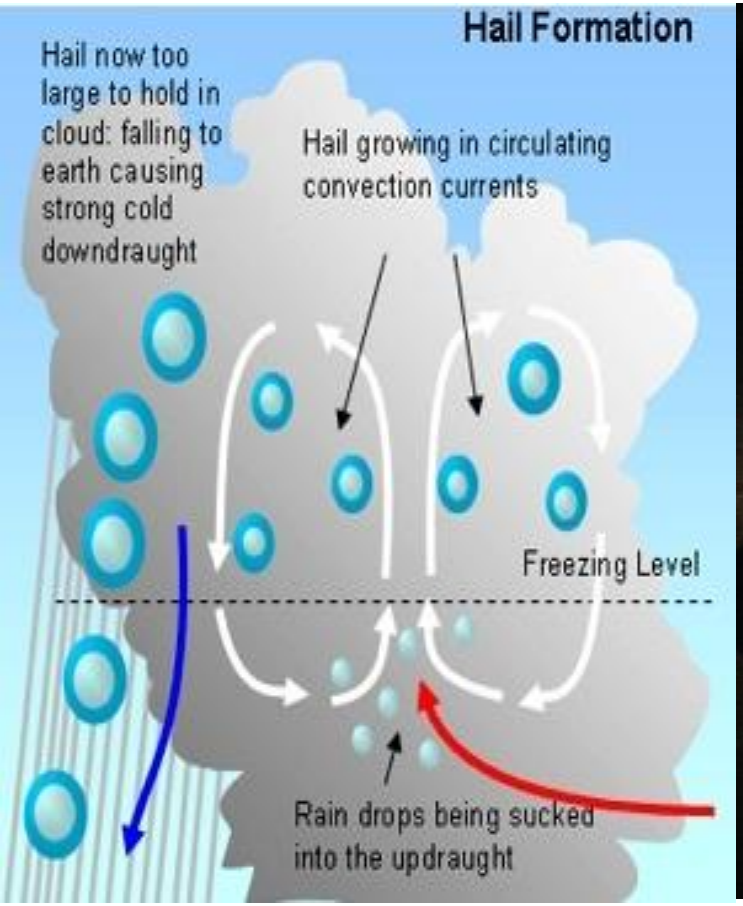
Fulgarites

The Hazards of Thunderstorms

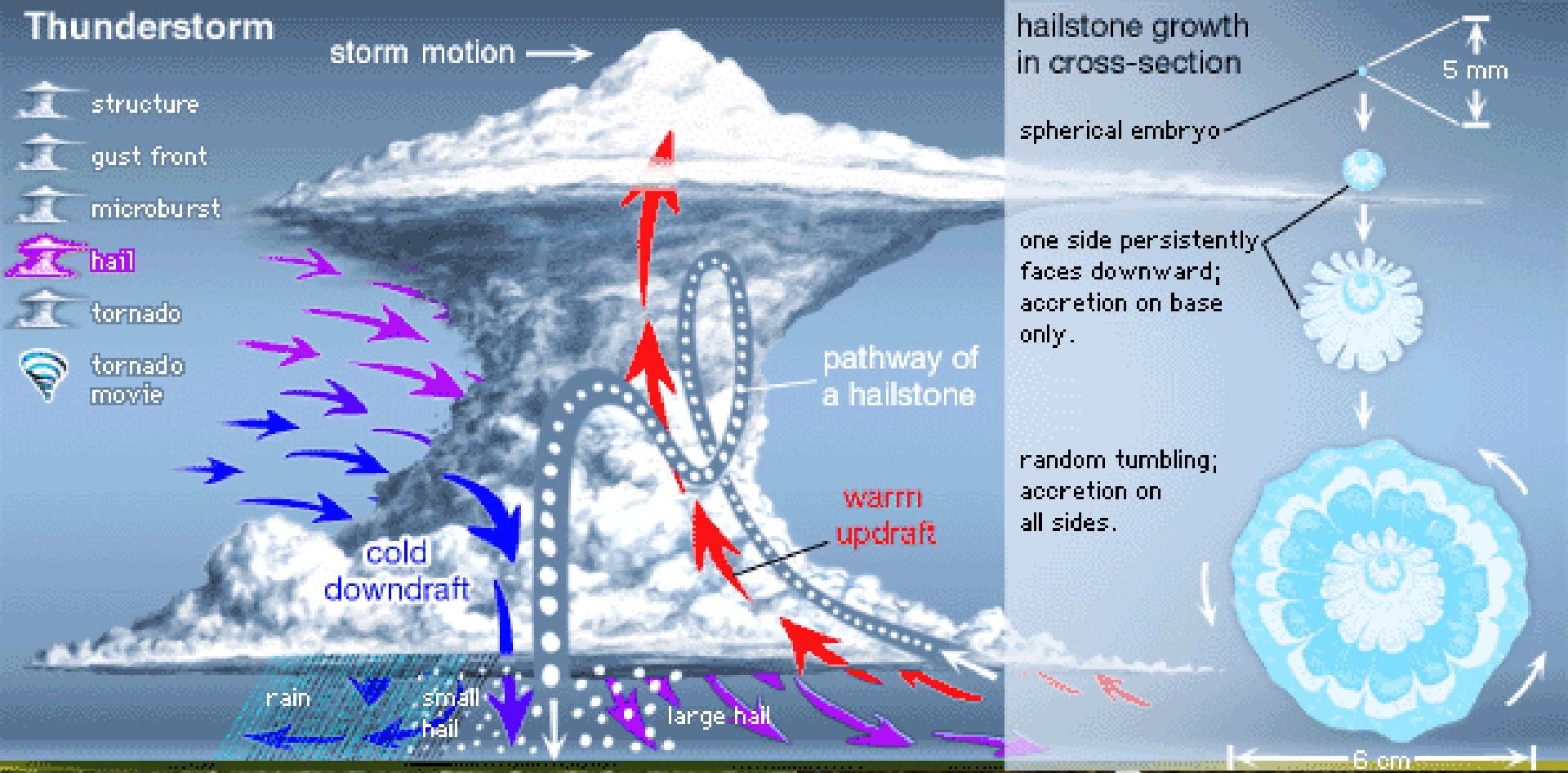
Hail

Thunderstorm Hazards: Hail


Ice
Hailstone embryo
0°C
Hail
Freezing level
Downdrafts
Updrafts
Rain showers and hail

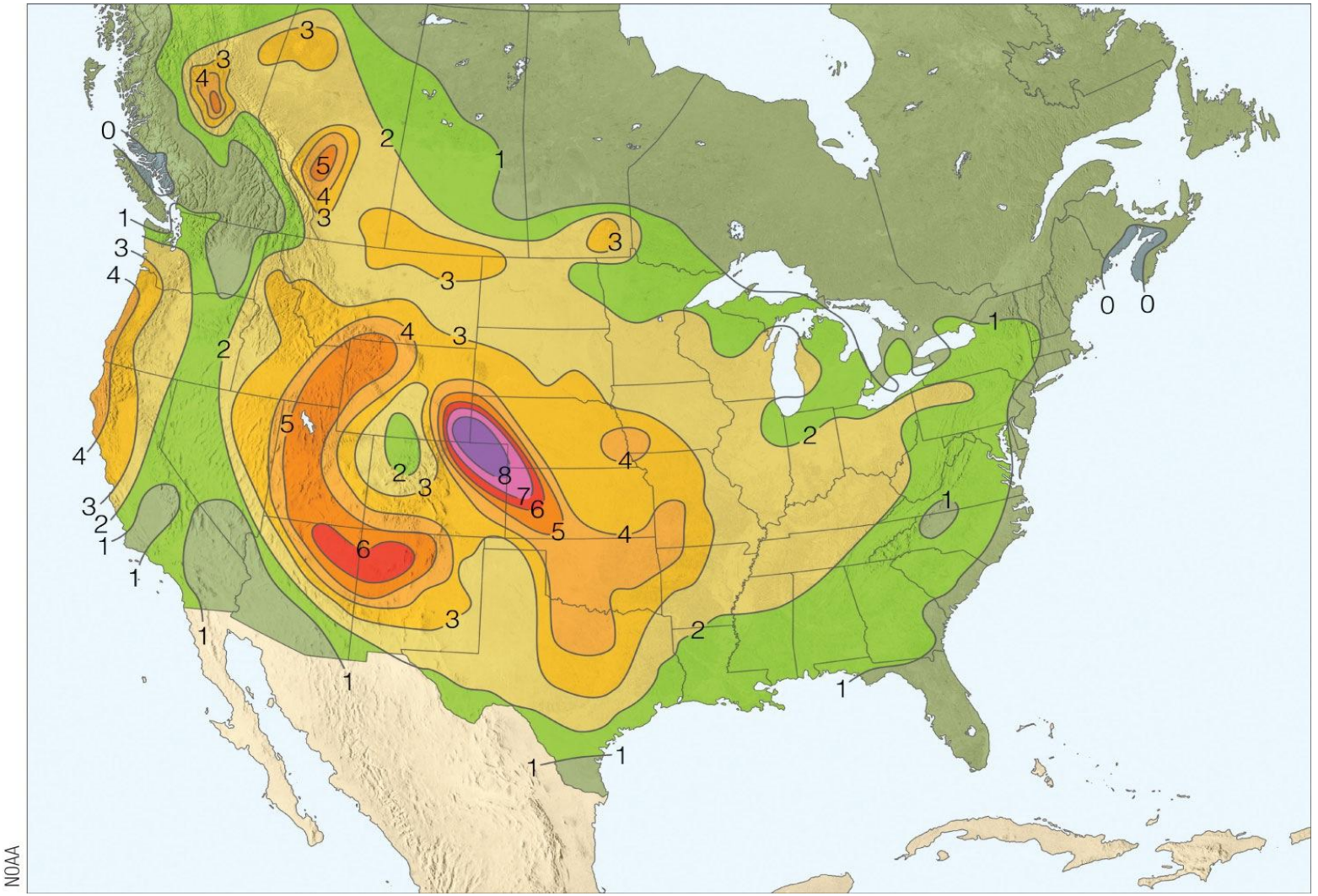

Hail Formation
Hail now too large to hold in cloud: falling to earth causing strong cold downdraught
Hail growing in circulating convection currents
Freezing Level
Rain drops being sucked into the updraught


Layers reflect each time the hail stone circulated from the top of the storm to the bottom before falling to the ground.


Thunderstorm
storm motion
structure
gust front
microburst
hail
tornado
tornado movie
pathway of a hailstone
warm updraft
cold downdraft
rain
small hail
large hail
hailstone growth in cross-section
5 mm
spherical embryo
one side persistently faces downward; accretion on base only.
random tumbling; accretion on all sides.
6 cm

Hail Frequency

- Wyoming, Nebraska, and Colorado are the states leading the way in hail occurrence

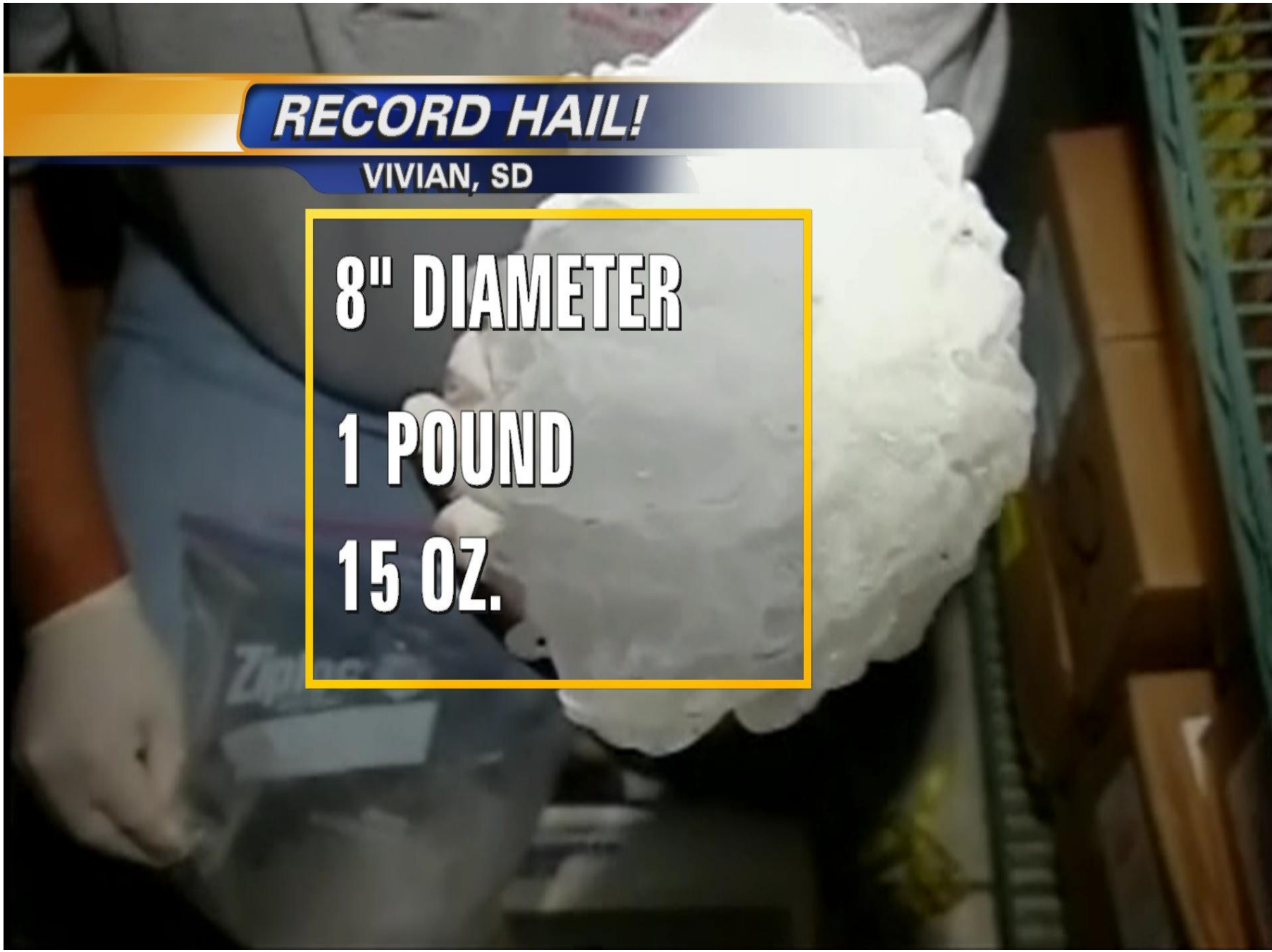


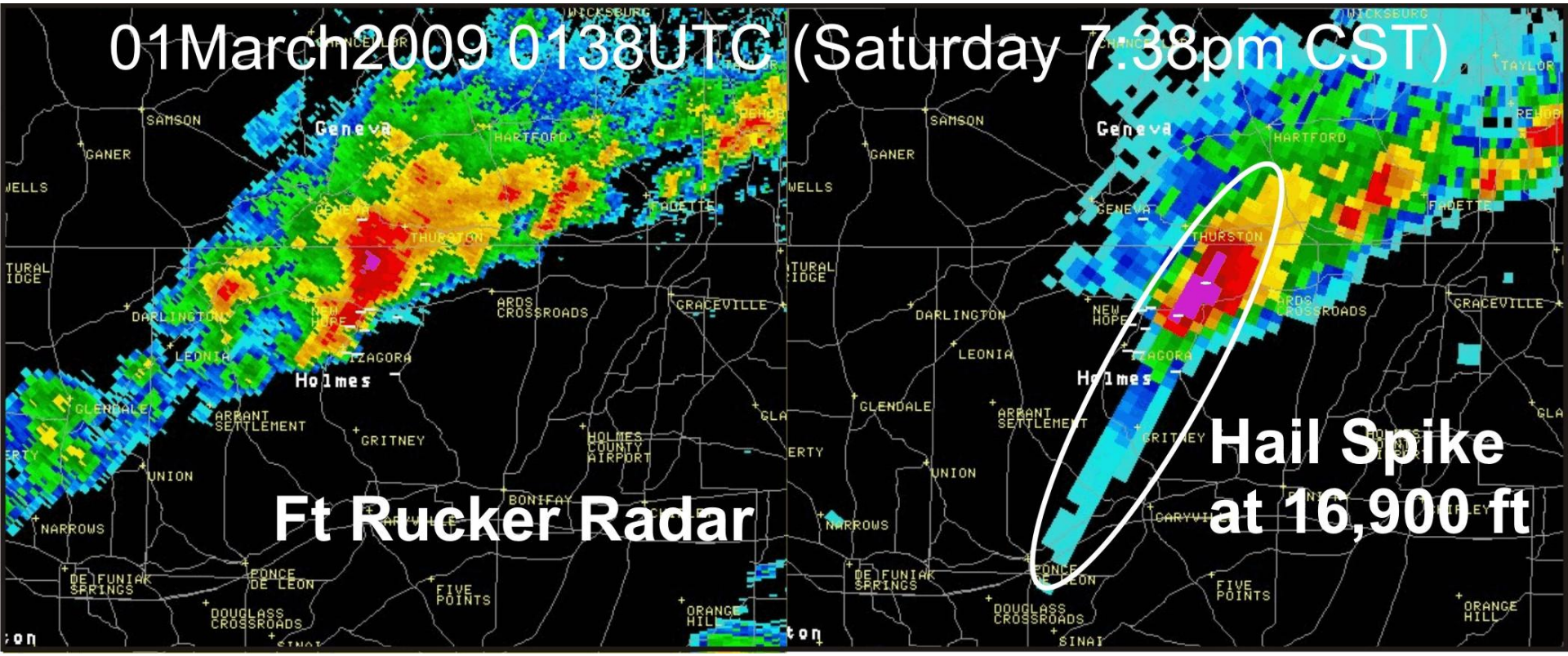
HAIL

Report the largest size stone you see

Compare to common objects

Dime/Penny	0.75 inches
Nickel	0.88 inches
Quarter	1.00 inches
Half Dollar	1.25 inches
Ping Pong Ball	1.50 inches
Golf Ball	1.75 inches
Hen Egg	2.00 inches
Tennis Ball	2.50 inches
Baseball	2.75 inches
Tea Cup	3.00 inches
Grapefruit	4.00 inches
Softball	4.50 inches

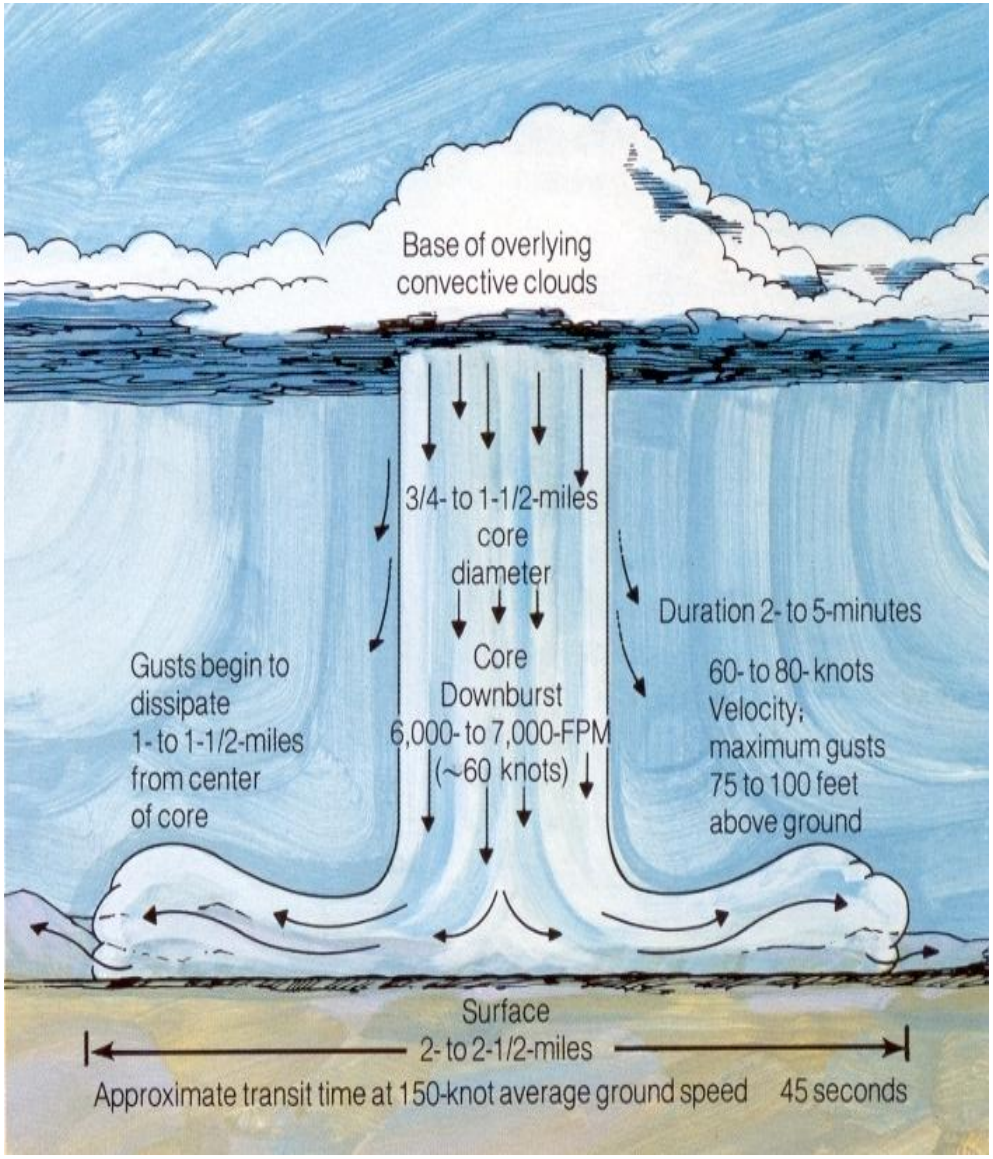

RECORD HAIL!
VIVIAN, SD
8" DIAMETER
1 POUND
15 OZ.

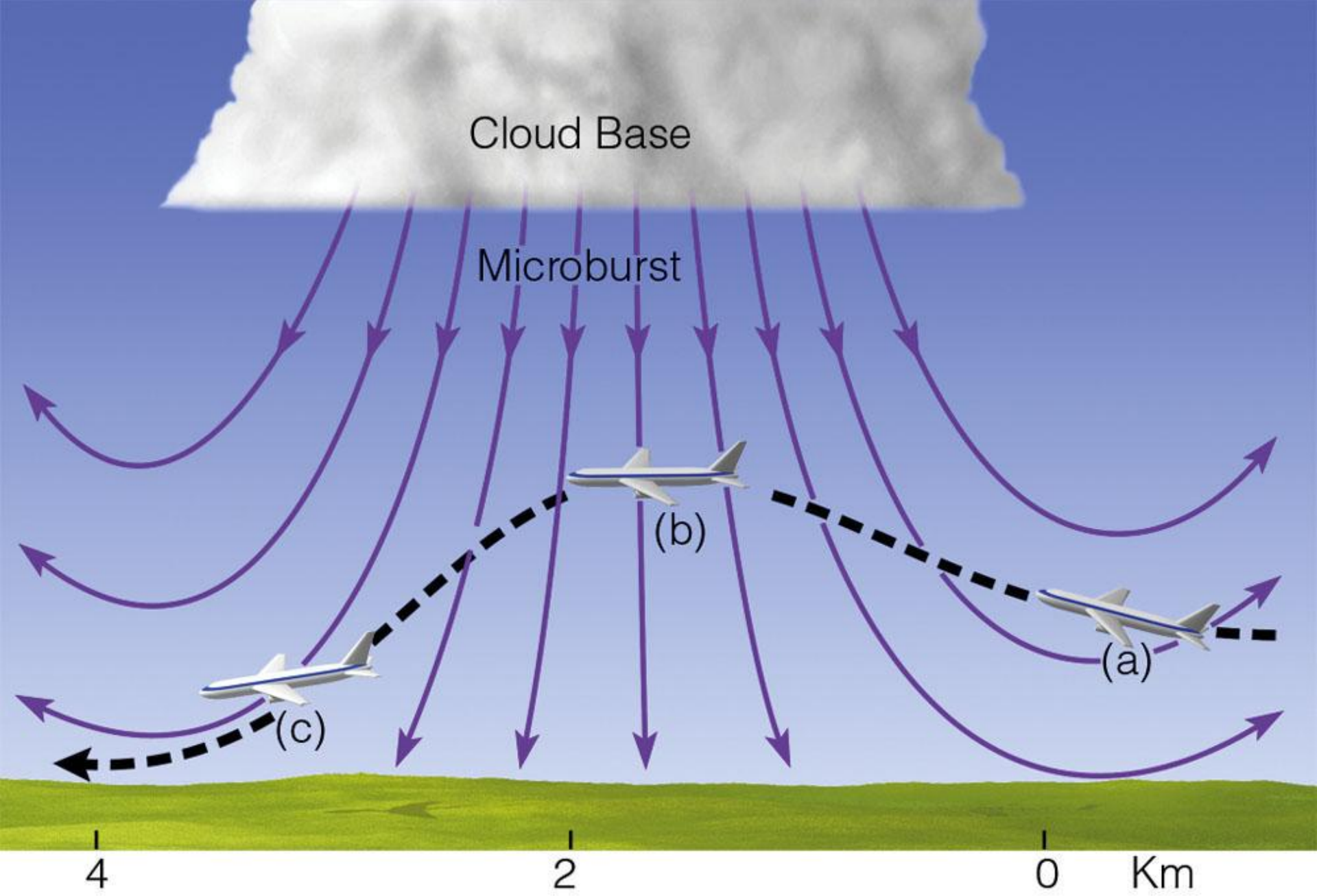

01March2009 0138UTC (Saturday 7:38pm CST)
Ft Rucker Radar
Hail Spike
at 16,900 ft
Geneva
Holmes
SAMSON
GANER
HARTFORD
THURSTON
DARLINGTON
LEONIA
GRACEVILLE
GLENDALE
ARBANT SETTLEMENT
GRITNEY
UNION
NARROWS
DE FUNIAK SPRINGS
PONCE DE LEON
FIVE POINTS
DOUGLASS CROSSROADS
SINAI
ORANGE HILL
HOLMES COUNTY AIRPORT
BONIFAY
CARYVILLE

The Hazards of Thunderstorms

Straight Line Winds

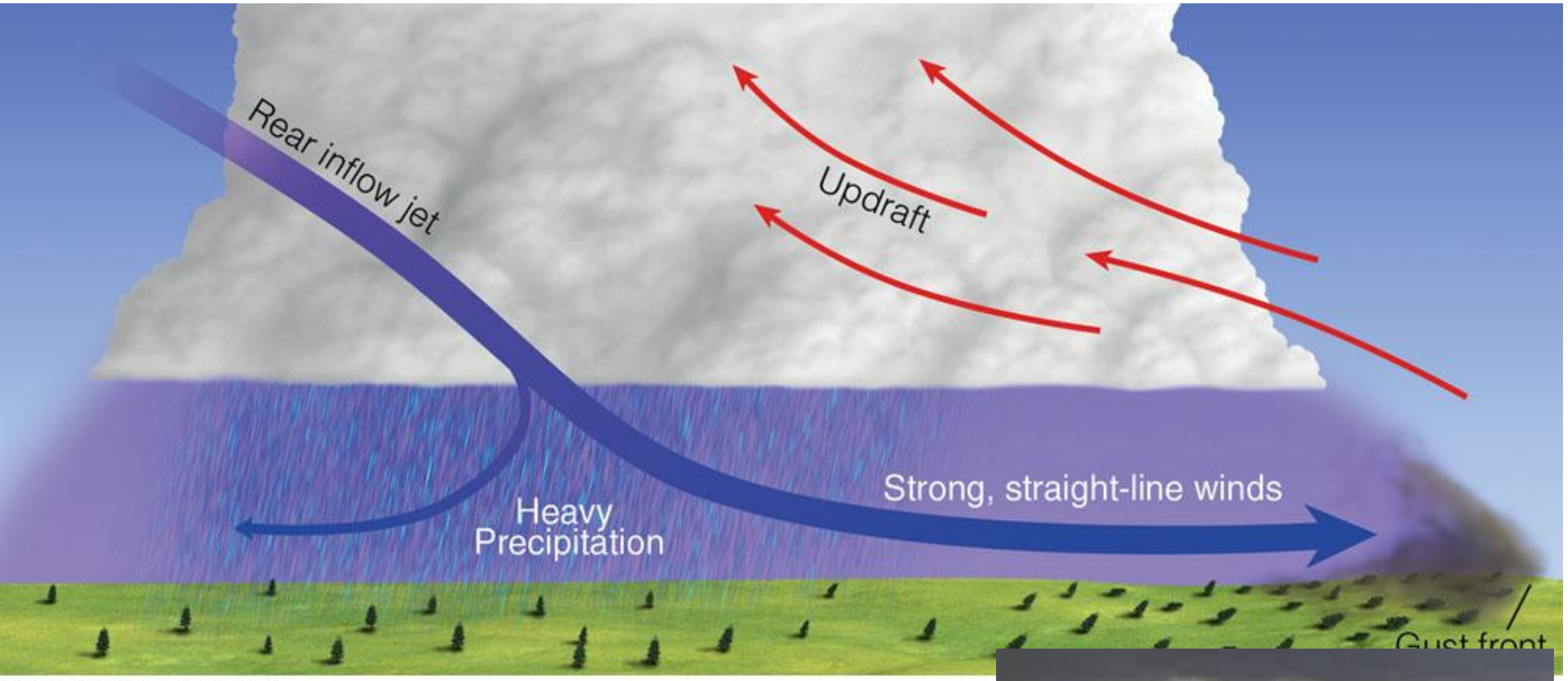
Macro/Microbursts

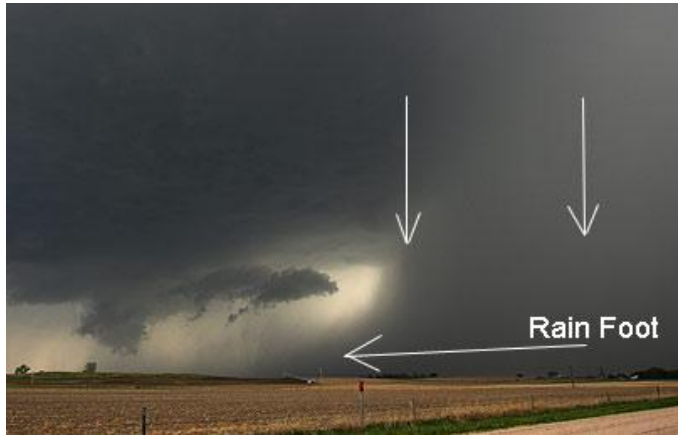


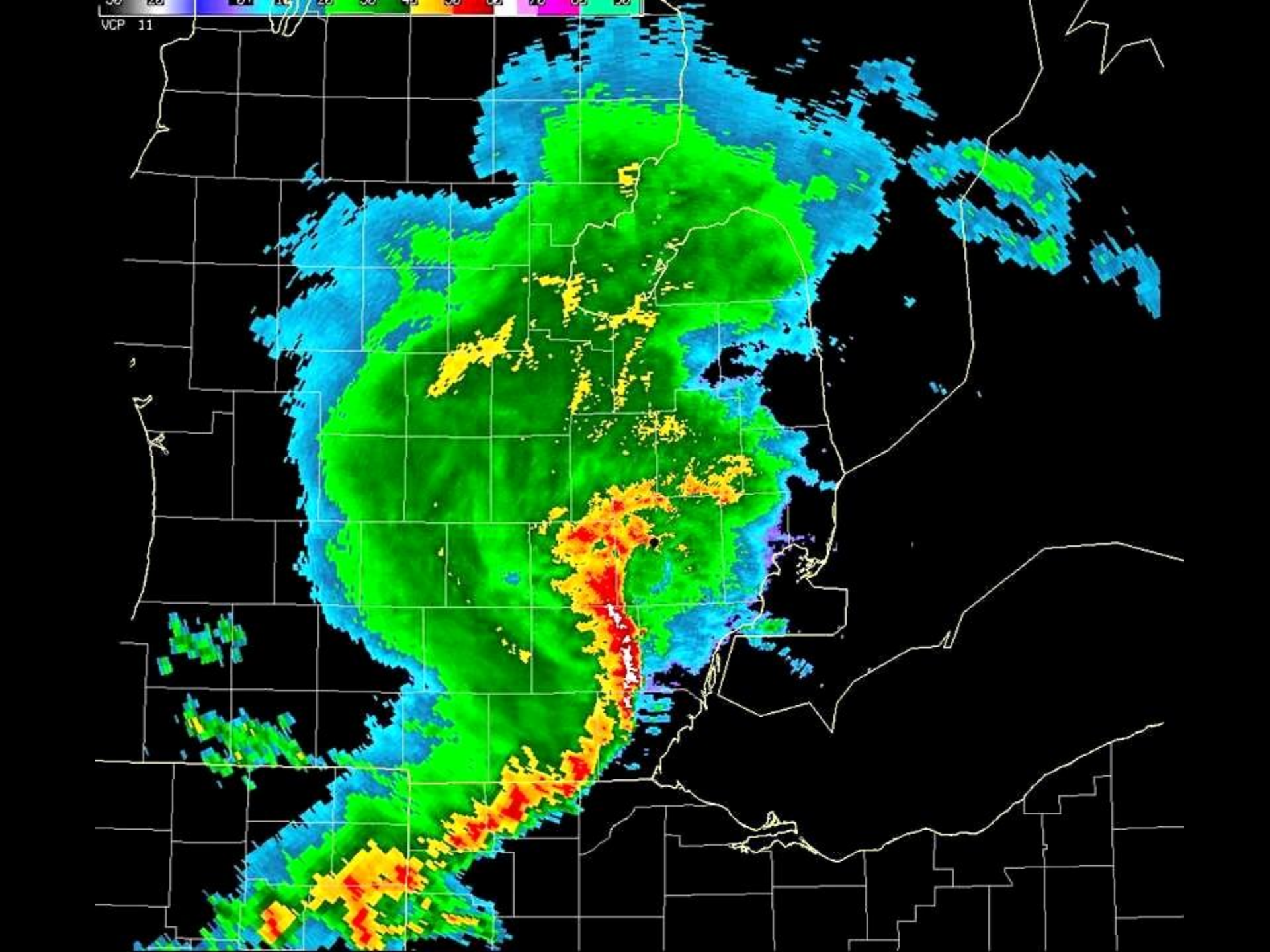



What is responsible for this damage?

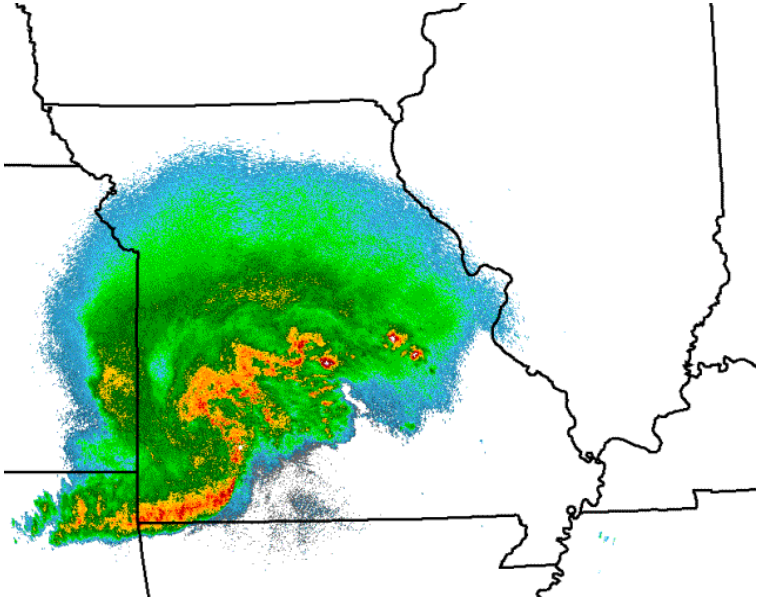
Straight Line Winds

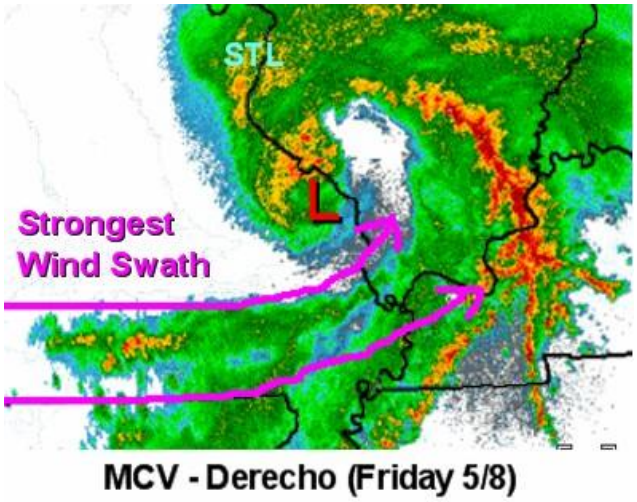





VCP 11

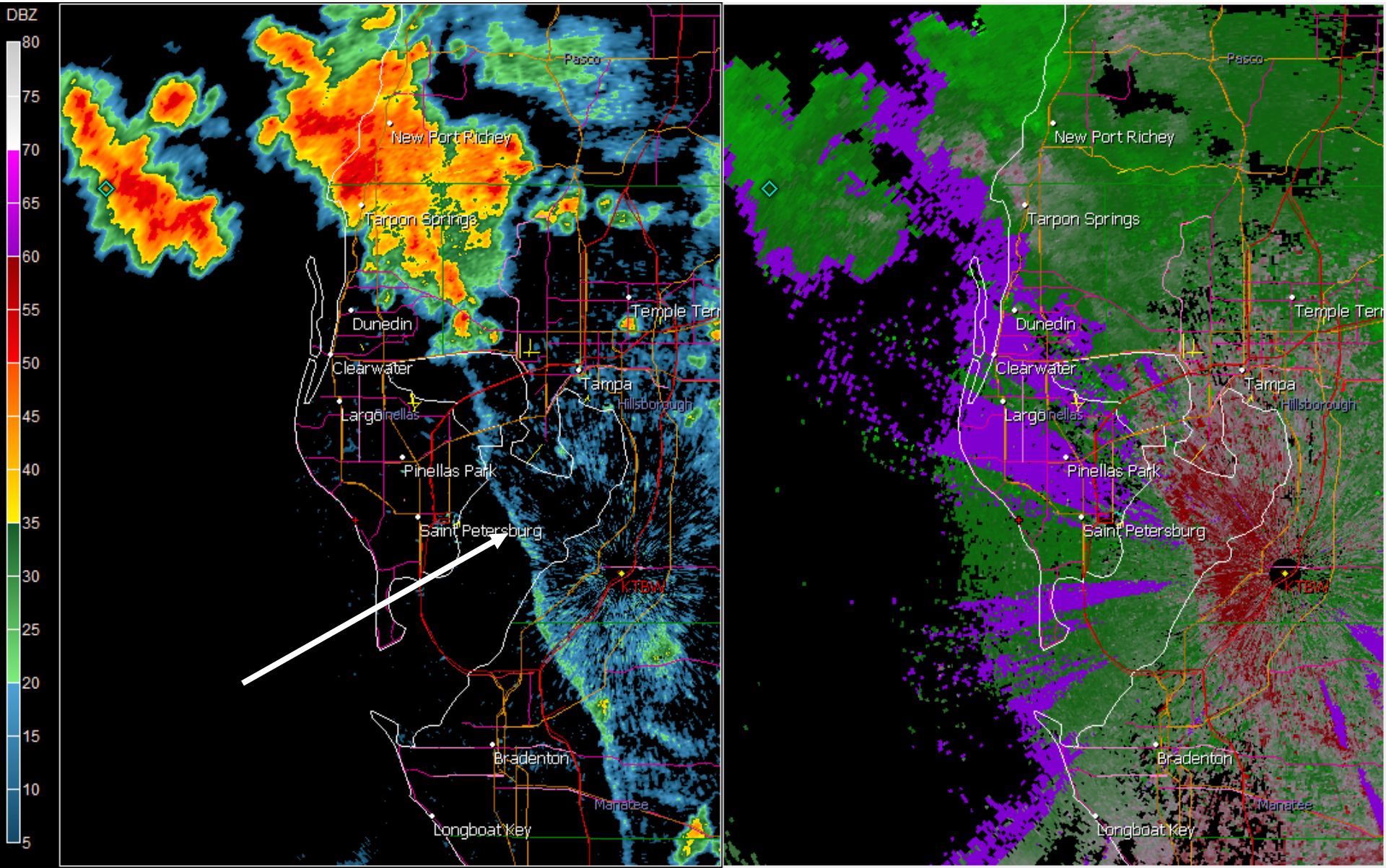
The Ultimate Straight Line Wind: *Derechos*



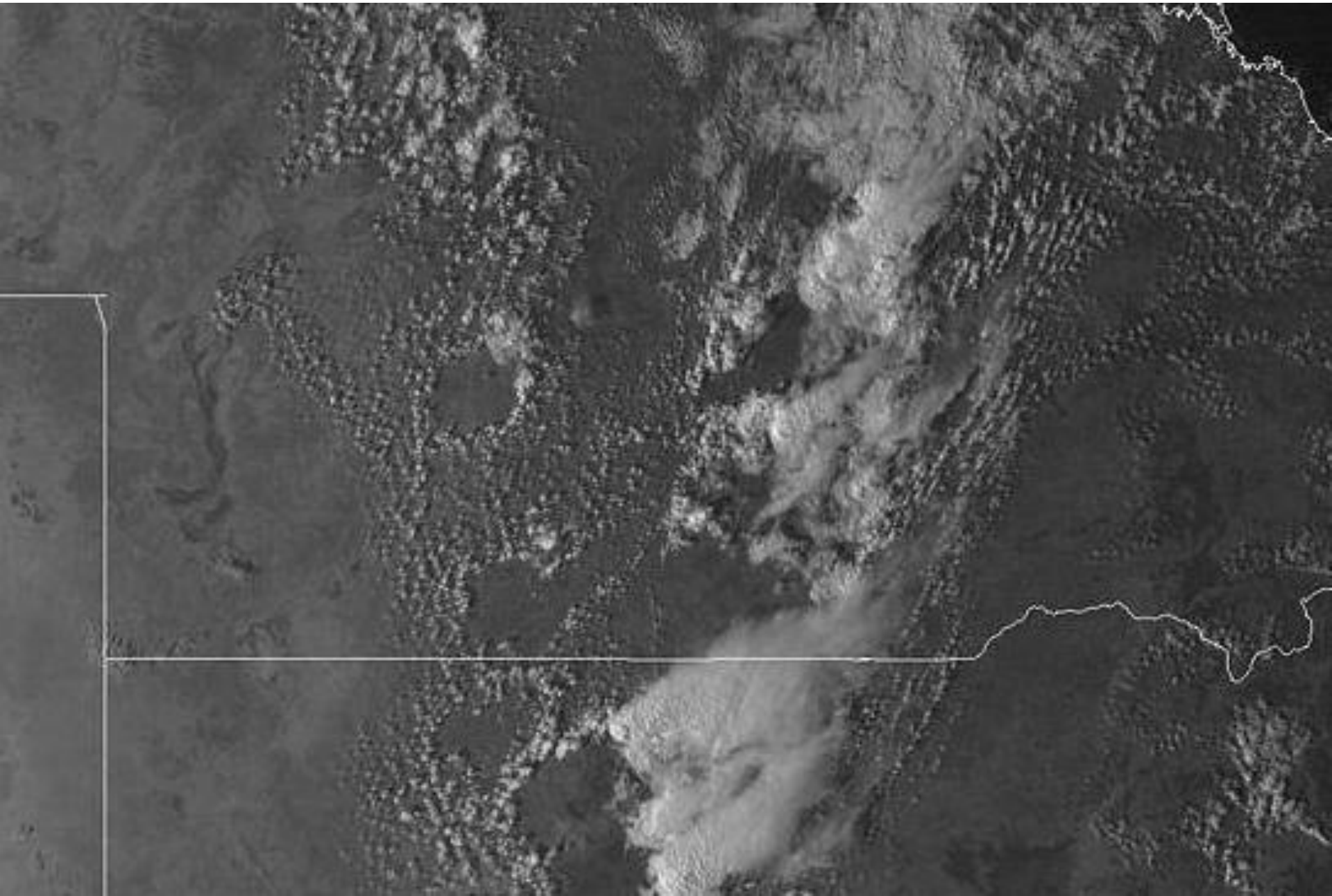


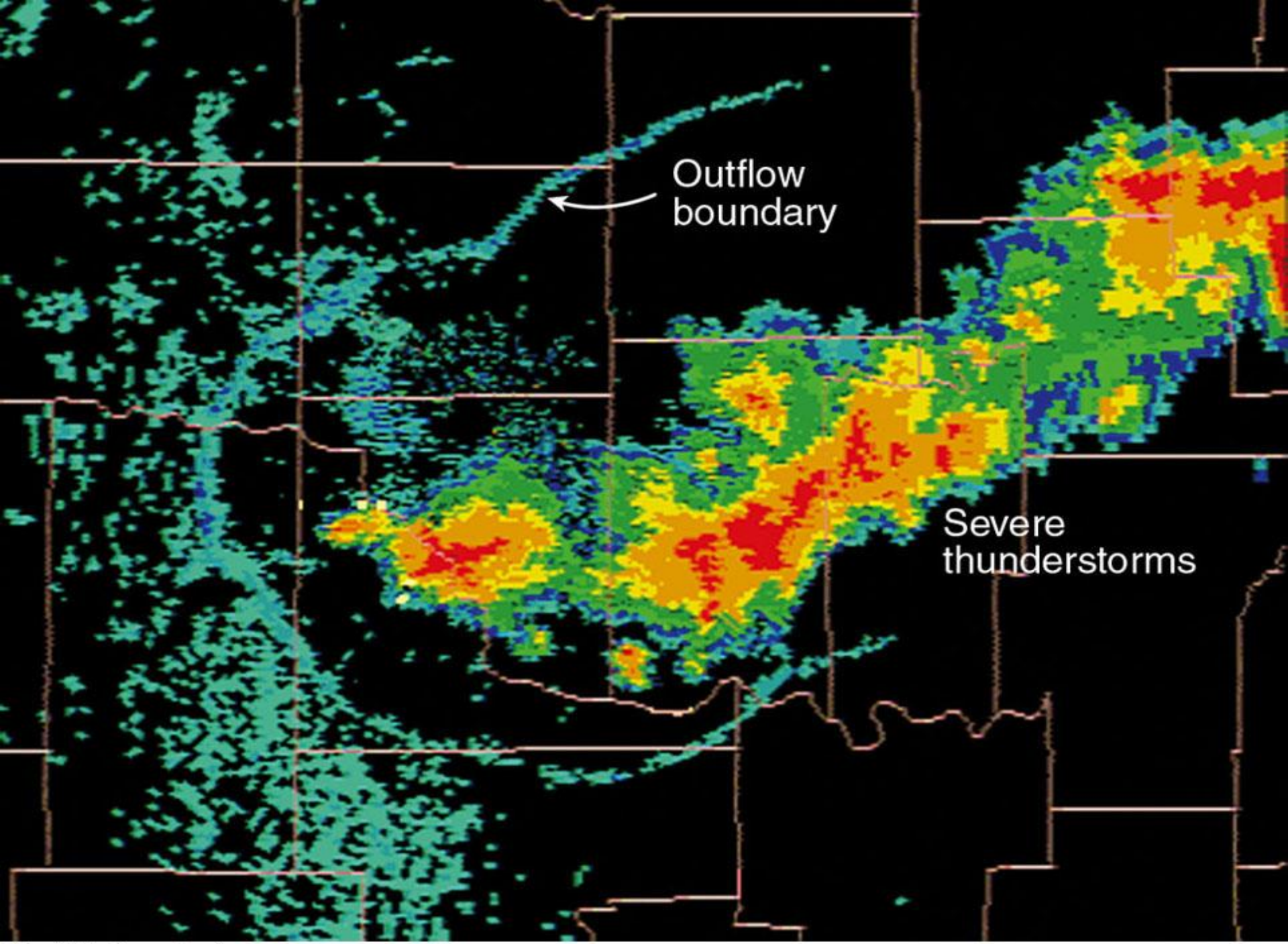
MCV - Derecho (Friday 5/8)

Outflow Boundary on Doppler Radar



Outflow Boundary






When the cool air from the
downdraft reaches the surface....
... it creates the outflow which pushes forward and
provides lift for clouds to form (along the black line.

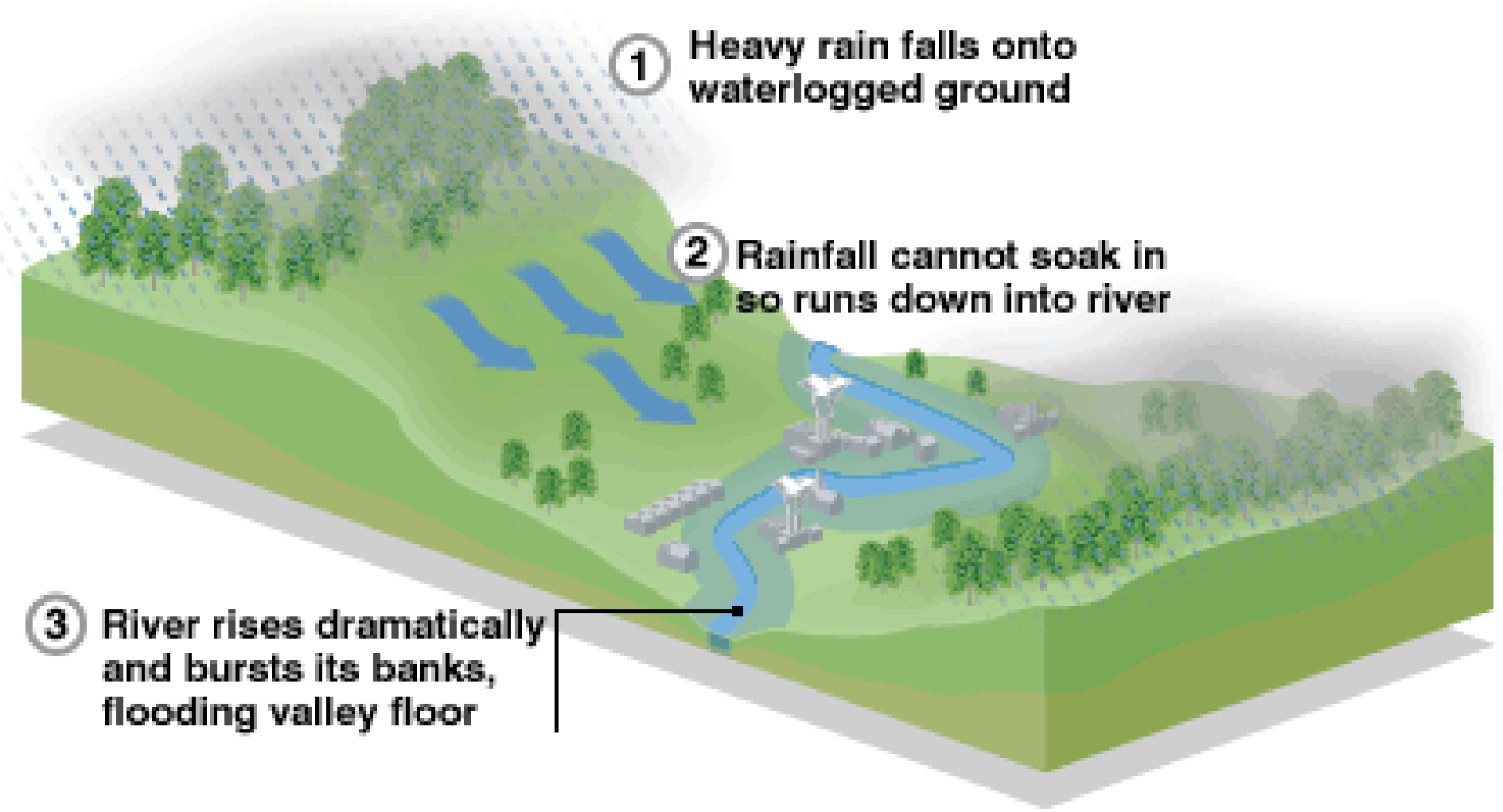
The Hazards of Thunderstorms

Flooding

Flash Flooding

A Flash Flood occurs within 6 hours of a heavy rainfall

HOW FLASH FLOODS OCCUR



Confluence of Mississippi and Missouri Rivers, August 1993. Extensive floods in the Mississippi River Basin during the spring and summer of 1993 caused $20 billion in damages. (Photograph, Srenco Photography, St. Louis, Mo.)

The Hazards of Thunderstorms

Tornadoes


This Concludes the Unit on Thunderstorms