

Thunderstorms



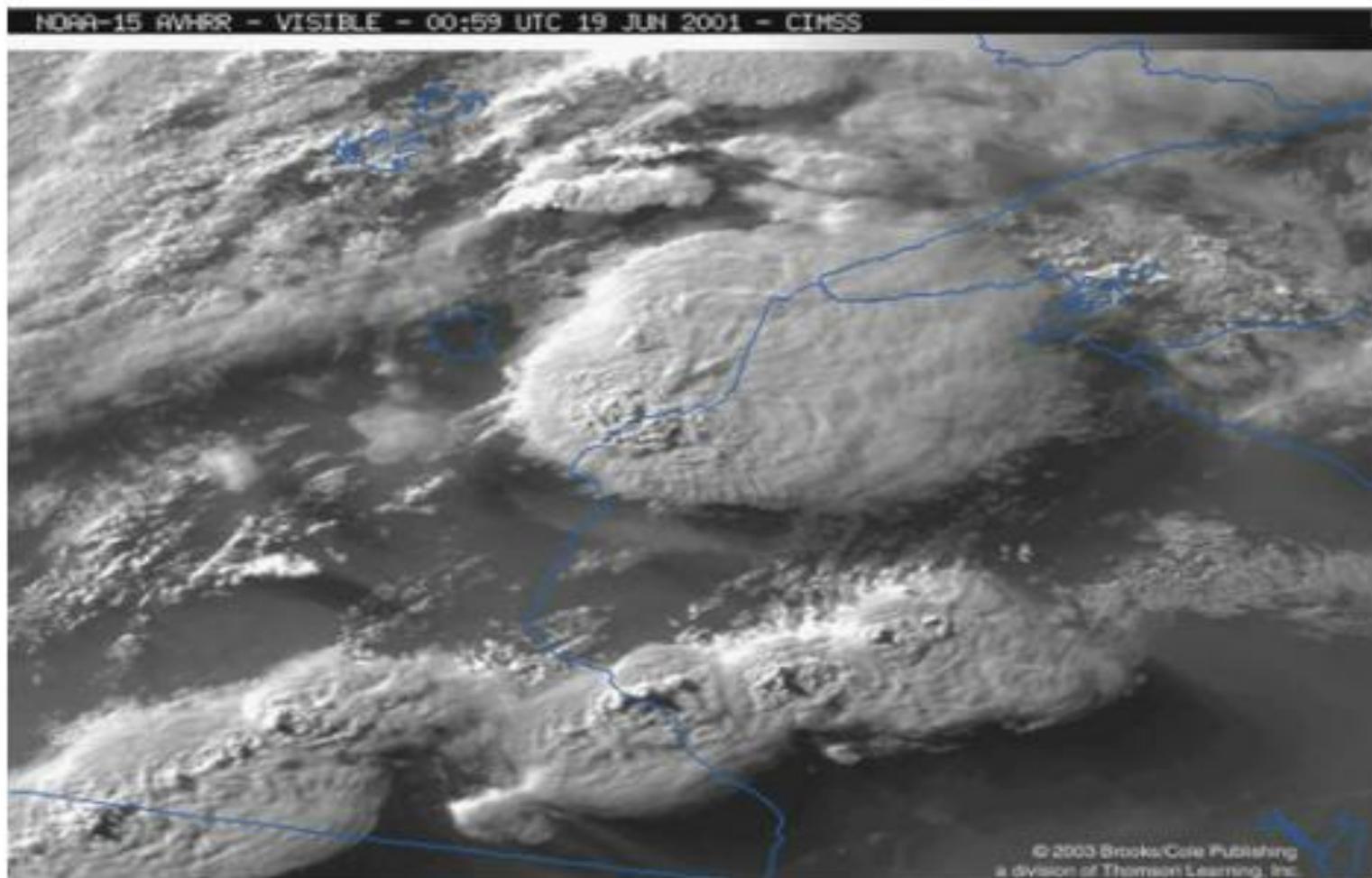
- A **thunderstorm**, also known as:
 - an **electrical storm**,
 - a **lightning storm**,
 - **thundershower** or
 - simply a **storm**
- It is a form of turbulent weather characterized by the presence of lightning and its acoustic effect on the Earth's atmosphere known as **thunder**.
- The meteorologically assigned cloud type associated with the thunderstorm is the cumulonimbus.

- Thunderstorms are usually accompanied by
 - strong winds,
 - heavy rain and
 - sometimes **snow, sleet, hail, or no precipitation** at all.
 - Those that cause hail to fall are called **hailstorms**.

- Thunderstorms result from the rapid upward movement of warm, moist air. They can occur inside warm, moist air masses and at fronts.
- As the warm, moist air moves upward, it cools, condenses, and forms cumulonimbus clouds that can reach heights of over 20 km.
- As the rising air reaches its **dew point**, water droplets and ice form and begin falling the long distance through the clouds towards the Earth's surface.
- As the droplets fall, they collide with other droplets and become larger.
- The falling droplets create a **downdraft of air** that spreads out at the Earth's surface and causes strong winds associated commonly with thunderstorms.

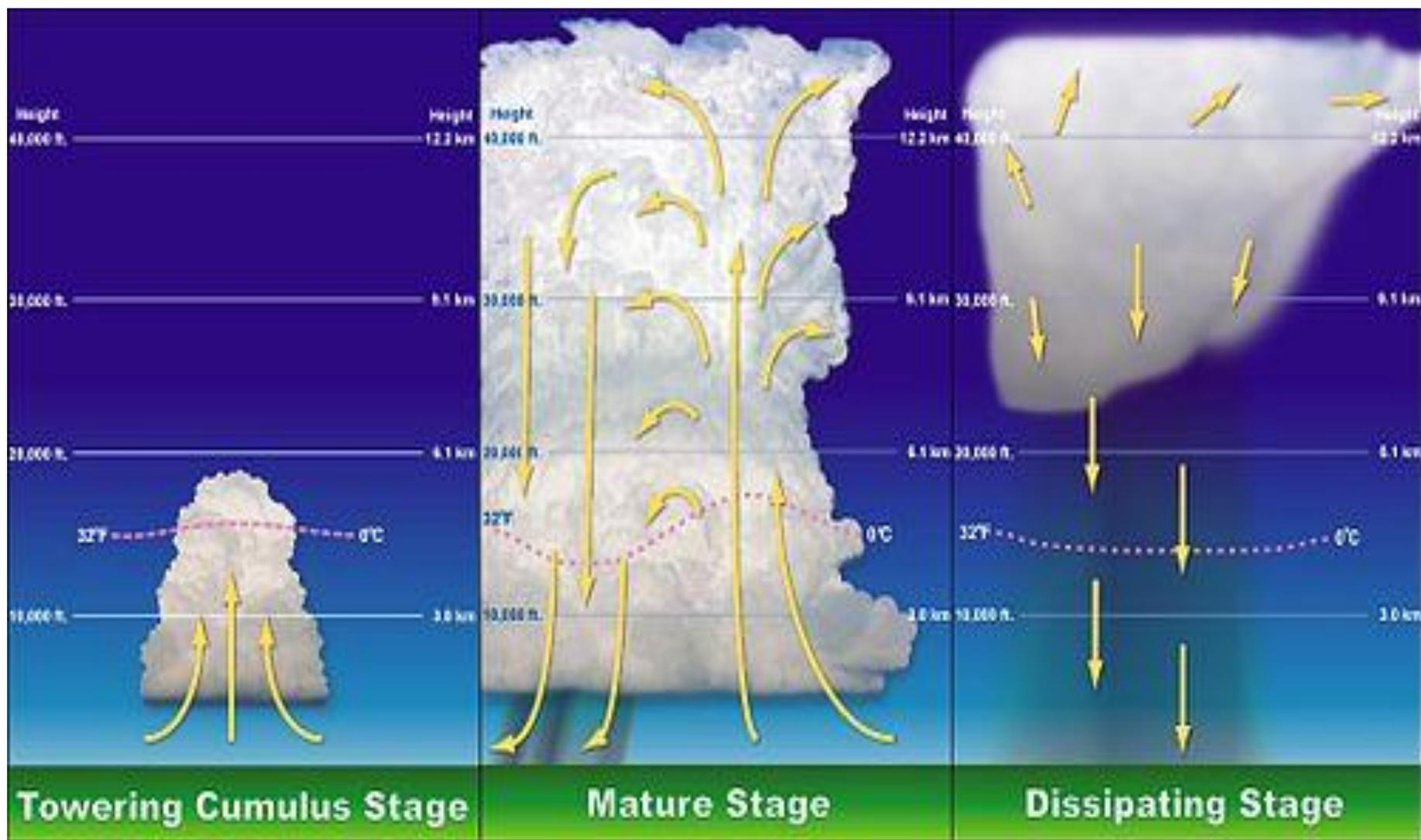
- Thunderstorms form most frequently within areas **located at mid-latitude** when warm moist air collides with cooler air.
- Stronger thunderstorm cells are capable of producing **tornadoes and waterspouts**.
- A 1953 study found that the **average thunderstorm over several hours** expends enough energy to equal **50 A-bombs of the type** that was dropped on Hiroshima, Japan during World War Two.

Satellite View



Life cycle

- Generally, thunderstorms require three conditions to form:
 - Moisture
 - An unstable airmass
 - A lifting force (heat)
- All thunderstorms, regardless of type, go through three stages:
 - the **developing stage**,
 - the **mature stage**, and
 - the **dissipation stage**.
- The average thunderstorm has a 24 km (15 mi) diameter.
- Depending on the conditions present in the atmosphere, these three stages take an average of **30 minutes to go through**.



Cumulus stage

- The first stage is the **cumulus stage, or developing stage**.
- masses of moisture are lifted upwards into the atmosphere.
- The trigger for this lift can be [insolation](#) heating the ground producing [thermals](#), areas where two winds converge forcing air upwards, or where winds blow over terrain of increasing elevation.
- The moisture rapidly cools into liquid drops of water due to the cooler temperatures at high altitude, which appears as [cumulus](#) clouds.
- As the water vapor condenses into liquid, [latent heat](#) is released, which warms the air, causing it to become less dense than the surrounding dry air.
- The air tends to rise in an *updraft* through the process of **convection** (hence the term **convective precipitation**).
- This creates a **low-pressure zone** beneath the forming thunderstorm.
- In a typical thunderstorm, approximately 5×10^8 kg of water vapor are lifted into the Earth's atmosphere.

Mature stage

- The warmed air continues to rise until it reaches even warmer air and can rise no further.
- Often this 'cap' is the **tropopause**.
- The air is instead forced to spread out, giving the storm a characteristic **anvil shape**. The resulting cloud is called *cumulonimbus incus*.
- The water droplets **coalesce** into larger and heavier droplets and freeze to become ice particles. As these fall they melt to become rain.

Mature Stage Thunderstorm



During the mature stage, updrafts may stop at the troposphere where the cloud ice crystals are pushed horizontally by winds and form an anvil top, or they may overshoot further into the tropopause.

- If the updraft is strong enough, the droplets are held aloft long enough to become so large they do not melt completely, and fall as **hail**.
- While updrafts are still present, the falling rain creates *downdrafts* as well.
- The simultaneous presence of both an updraft and downdrafts marks the mature stage of the storm, and produces Cumulonimbus clouds.
- During this stage, considerable
- **internal turbulence** can occur in the storm system, which manifests as strong winds, severe lightning, and even tornadoes

Dissipating stage

- In the dissipation stage, the thunderstorm is dominated by the downdraft.
- If atmospheric conditions do not support super cellular development, this stage occurs rather quickly, approximately 20–30 minutes into the life of the thunderstorm.
- The downdraft will push down out of the thunderstorm, hit the ground and spread out. This phenomenon is known as a [downburst](#).
- The cool air carried to the ground by the downdraft cuts off the inflow of the thunderstorm, the updraft disappears and the thunderstorm will dissipate.

Dissipating Stage of Thunderstorm

Once downdrafts dominate updrafts, the storm ends as precipitation leaves the cloud faster than it is replenished by rising, condensing air.

Often, lower level cloud particles will evaporate leaving an isolate cirrus anvil top section.



- **There are four types of thunderstorms:**
 - single-cell / air-mass thunderstorms,
 - multicell cluster,
 - multicell lines/ squall line and
 - supercells.

Which type forms depends on the instability and relative wind conditions at different layers of the atmosphere ("wind shear")

Single-cell thunderstorms

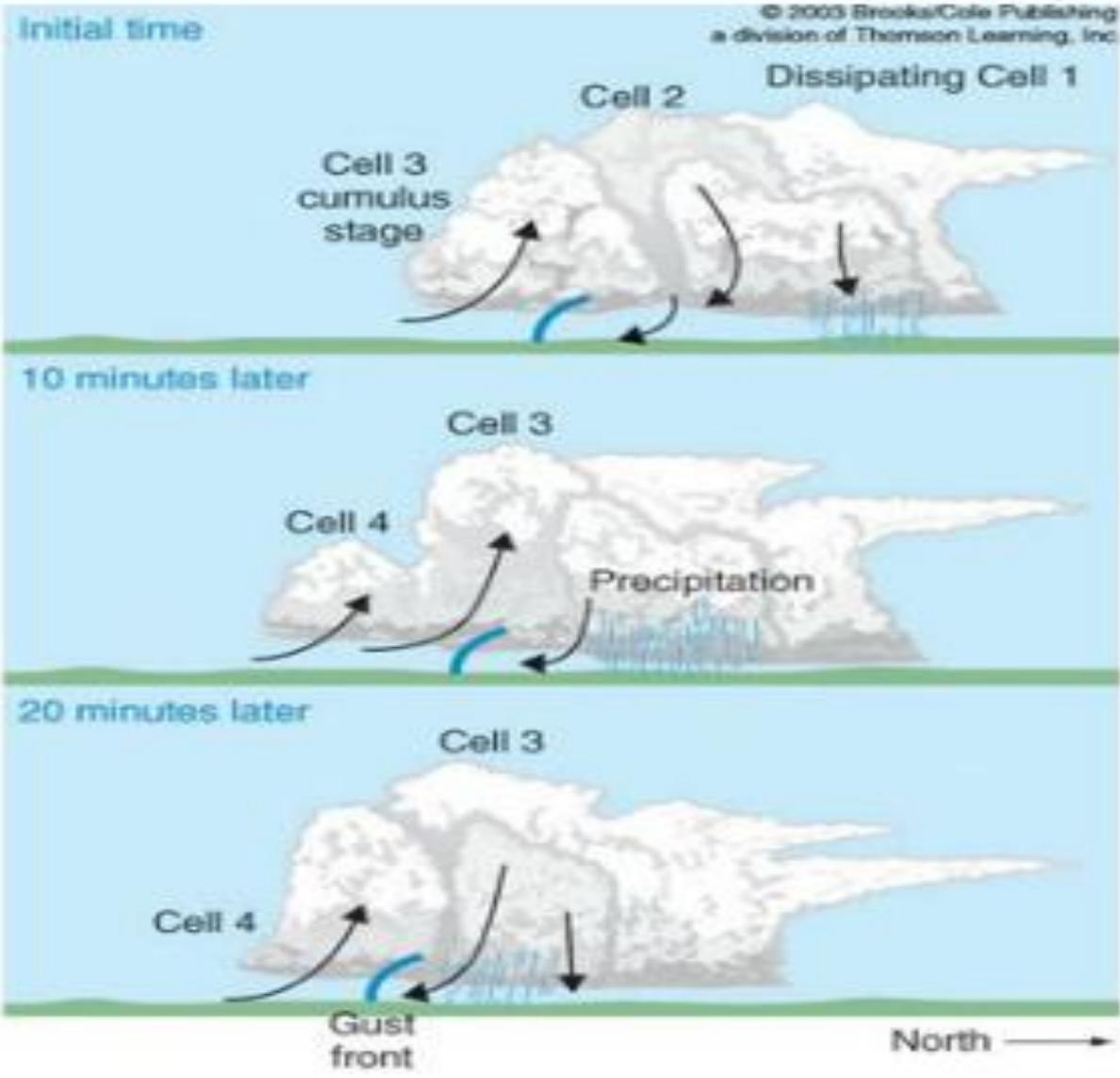
- normally last 20–30 minutes
- Within a cluster of thunderstorms, the term "cell" refers to each separate principal updraft.

Ordinary Single Cell



Multicell clusters

- This is the most common type of thunderstorm development.
- *Mature thunderstorms* are found near the center of the cluster, while dissipating thunderstorms exist on their downwind side.
- *Multicell storms* form as clusters of storms but may then evolve into one or more squall lines.
- While each cell of the cluster may only last 20 minutes, the cluster itself may persist for hours at a time.
- These type of storms are stronger than the single-cell storm, yet much weaker than the supercell storm.
- Hazards with the multicell cluster include :
 - moderate-sized hail,
 - flash flooding, and
 - weak tornadoes



Multicell Storms



Cool downdrafts leaving a mature and dissipating storm may offer relief from summer heat, but they may also force surrounding, low-level moist air upward.

Hence, dying storms often trigger new storms, and the successive stages may be viewed in the sky.

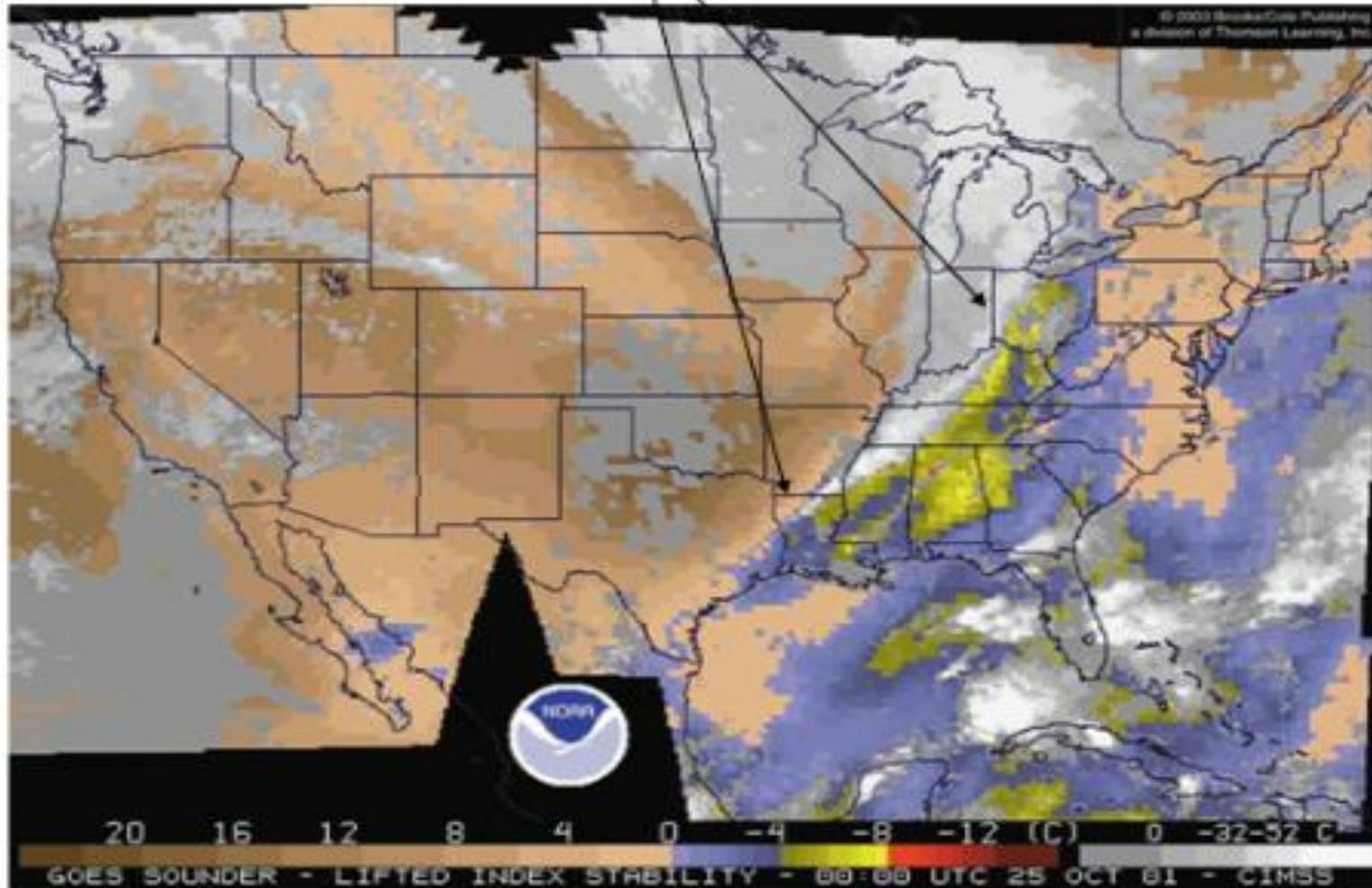
Multicell lines

- A squall line is an elongated line of severe thunderstorms that can form along and/or ahead of a cold front.
- The squall line contains heavy precipitation, hail, frequent lightning, strong straight line winds, and possibly tornadoes and waterspouts.
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Squall Line



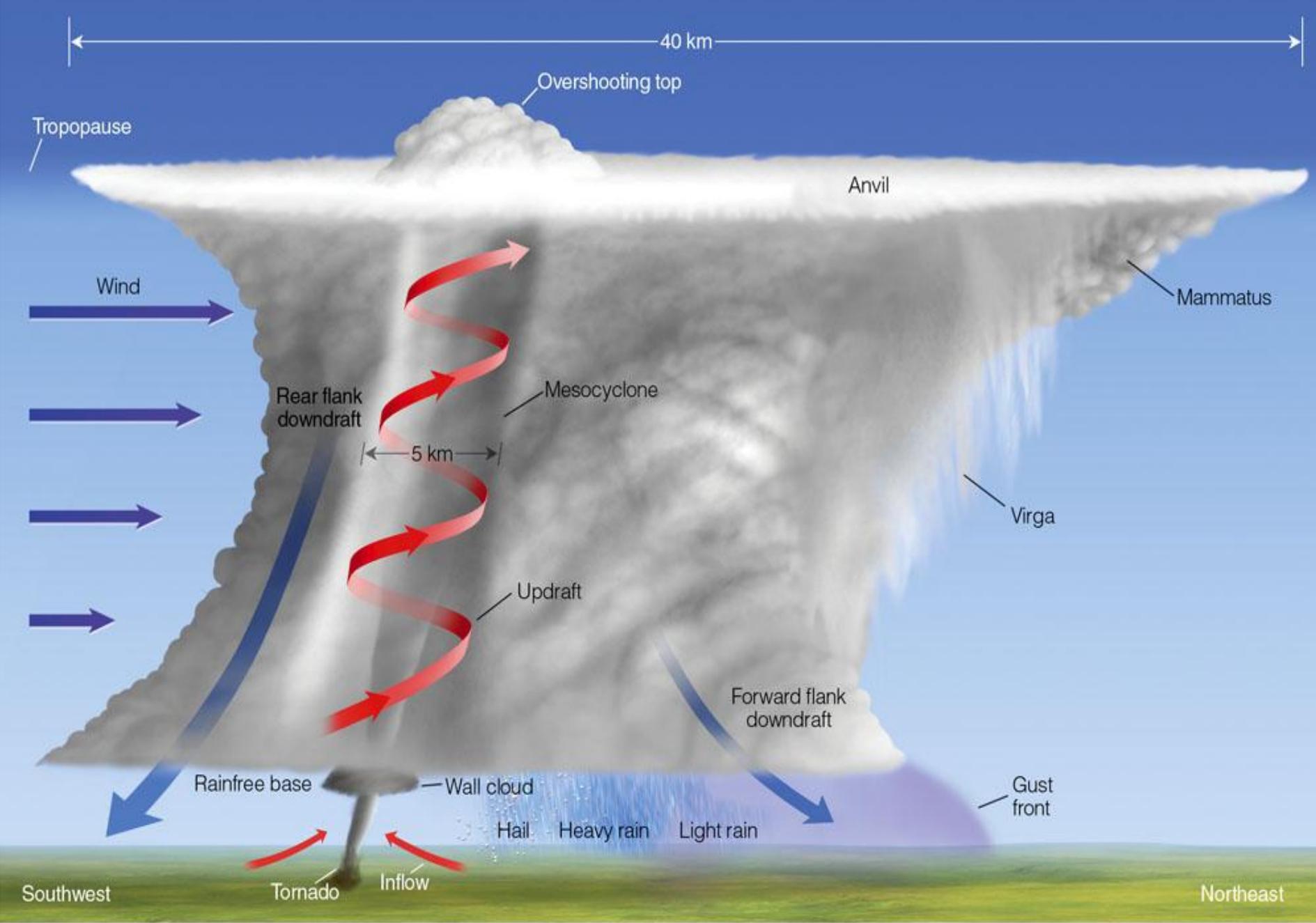
Squall line



Supercells

- **Supercell storms are:**
 - large, severe quasi-steady-state storms with wind speed and direction that vary with height ("wind shear")
 - separate downdrafts and updrafts (i.e., precipitation is not falling through the updraft) and a strong, rotating updraft (a "mesocyclone").
- These storms normally have such powerful updrafts that the top of the cloud (or anvil) can break through the troposphere and reach into the lower levels of the stratosphere and can be 15 miles (24 km) wide.
- At least 90 percent of this type of thunderstorm bring severe weather.

- These storms can produce destructive tornadoes, extremely large hailstones (4 inches / 10 centimetres diameter), straight-line winds in excess of 80 mph (130 km/h), and flash floods.
- In fact, most tornadoes occur from this type of thunderstorm.
- Supercells are the most powerful type of thunderstorm.



Tornado

A rapidly rotating column of air often evolve through a series of stages, from dust-whirl, to organizing and mature stages, and ending with the shrinking and decay stages.

Winds in this southern Illinois twister exceeded 150 knots.



Waterspout Funnel

Warm, shallow coastal water is often home to waterspouts, which are much smaller than an average tornado, but similar in shape and appearance.

The waterspout does not draw water into its core, but is a condensed cloud of vapor.

A waterspout may, however, lift swirling spray from the water as it touches the water surface.



Lightning & Thunder

Charge differences between the thunderstorm and ground can cause lightning strokes of $30,000^{\circ}\text{C}$, and this rapid heating of air will create an explosive shock wave called thunder, which requires approximately 3 seconds to travel 1 kilometer.

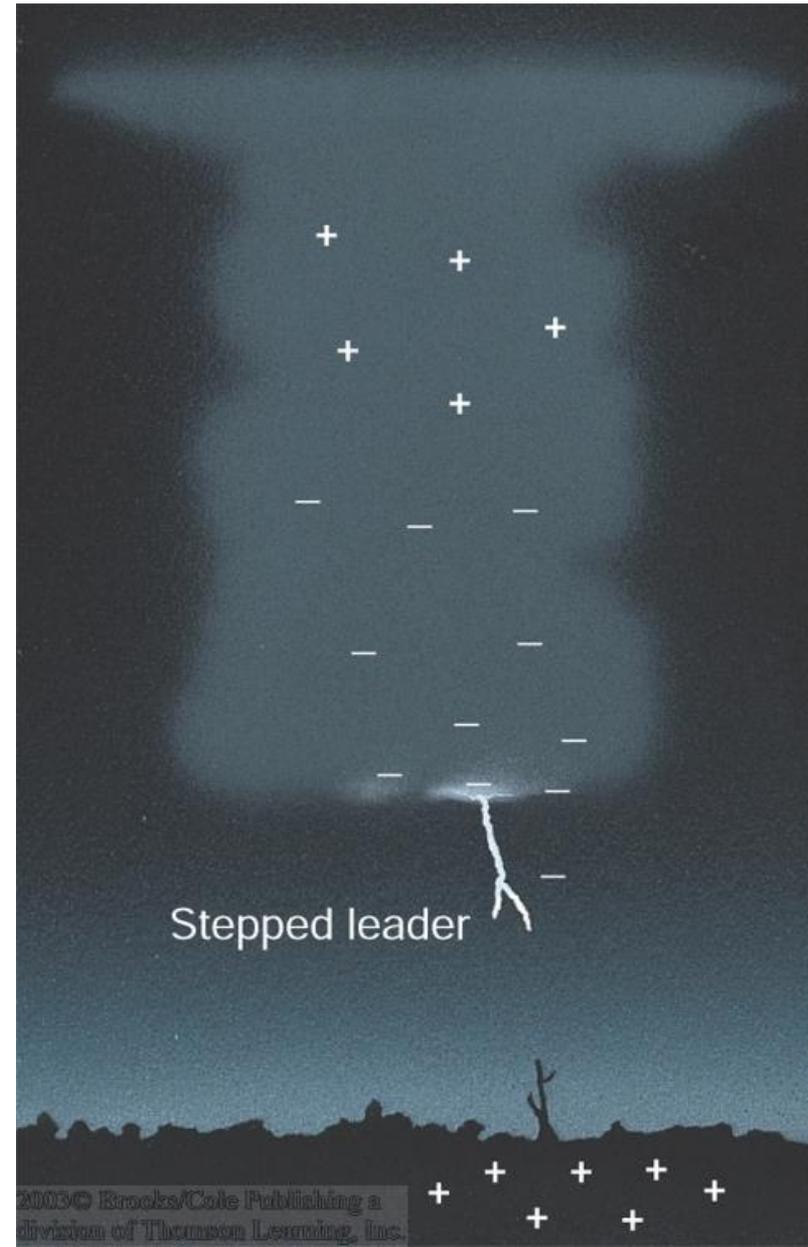


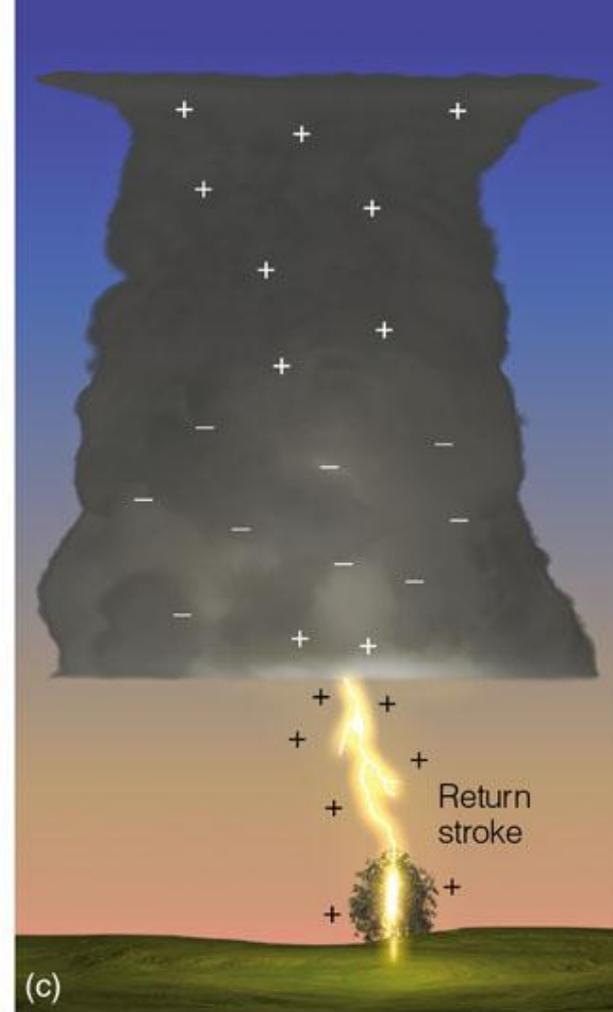
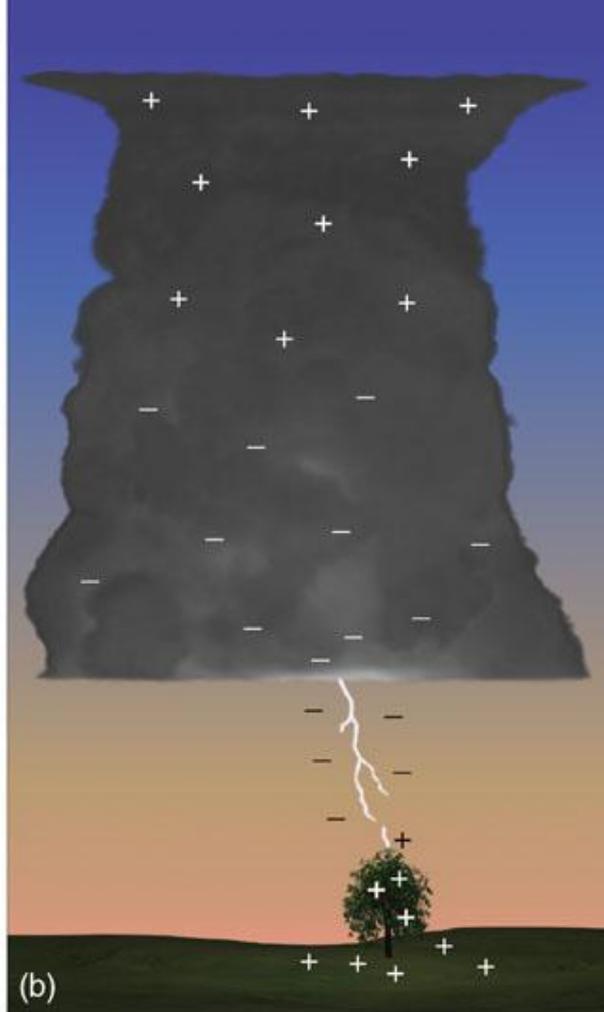
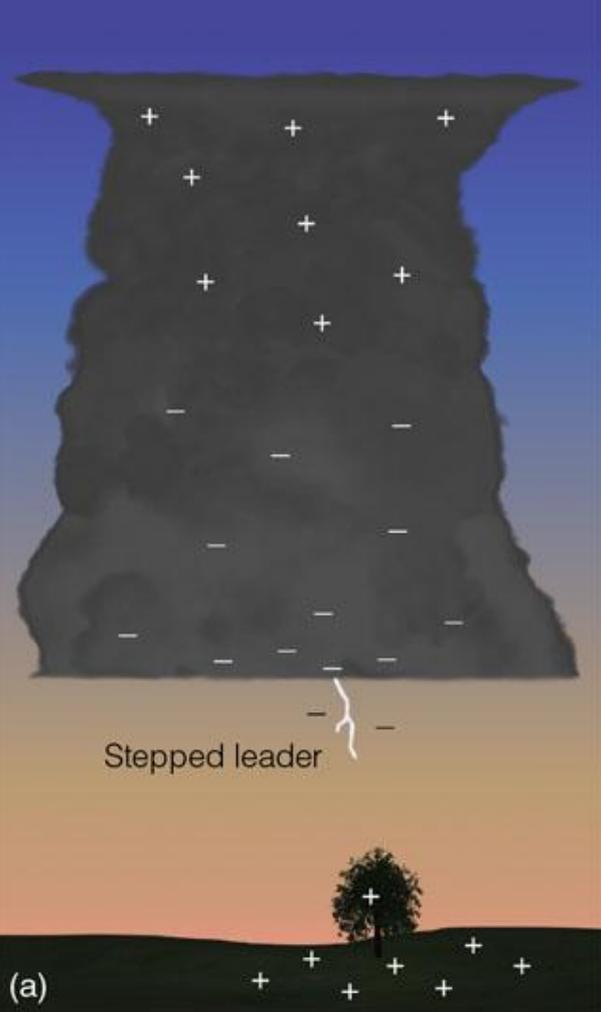
Lightning Stroke Development

Charge layers in the cloud are formed by the transfer of positive ions from warmer hailstones to colder ice crystals.

When the negative charge near the bottom of the cloud is large enough to overcome the air's resistance, a stepped leader forms.

A region of positive ions move from the ground toward this charge, which then forms a return stroke into the cloud.





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 positive charge upward into the cloud.

Types of Lightning

Nearly 90% of lightning is the negative cloud-to-ground type, but positive cloud-to-ground lightning can generate more current and more damage.

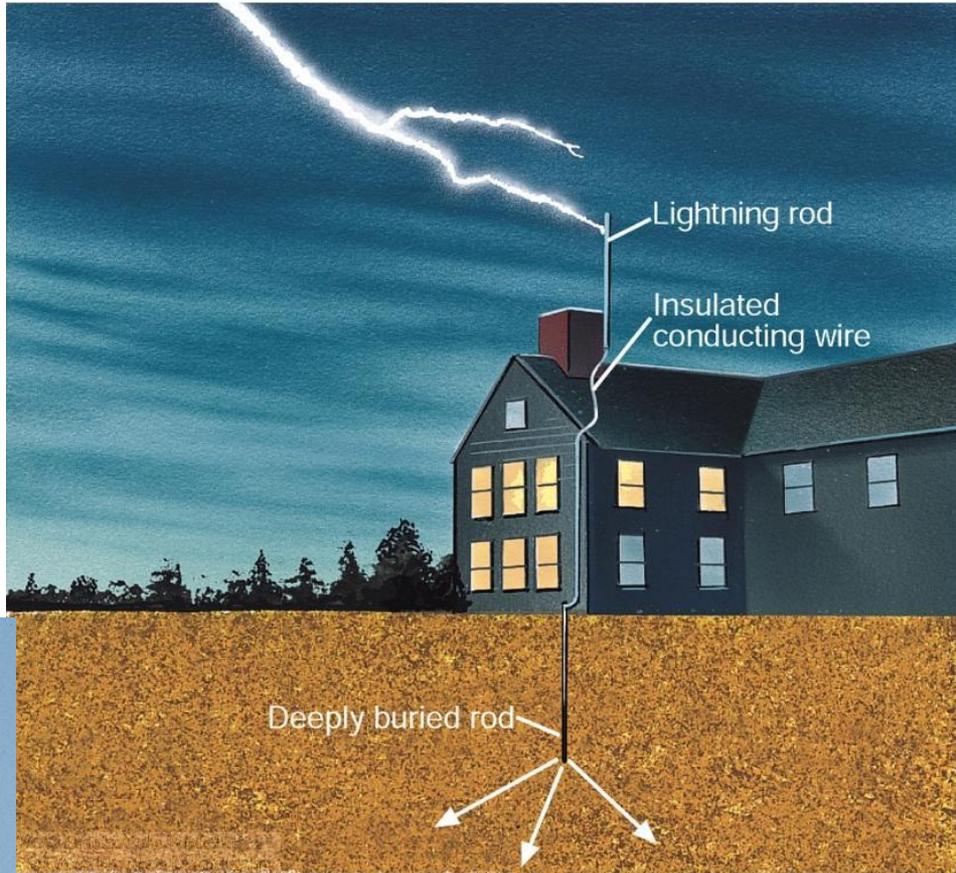
Several names, such as forked, bead, ball, and sheet lightning describe forms of the flash.

Distant, unseen lightning is often called heat lightning.



Lightning Rods & Fulgurite

Metal rods that are grounded by wires provide a low resistance path for lightning into the earth, which is a poor conductor.



The fusion of sand particles into root like tubes, called fulgurite, may result.