Funding provided by NOAA
Sectoral Applications Research Project

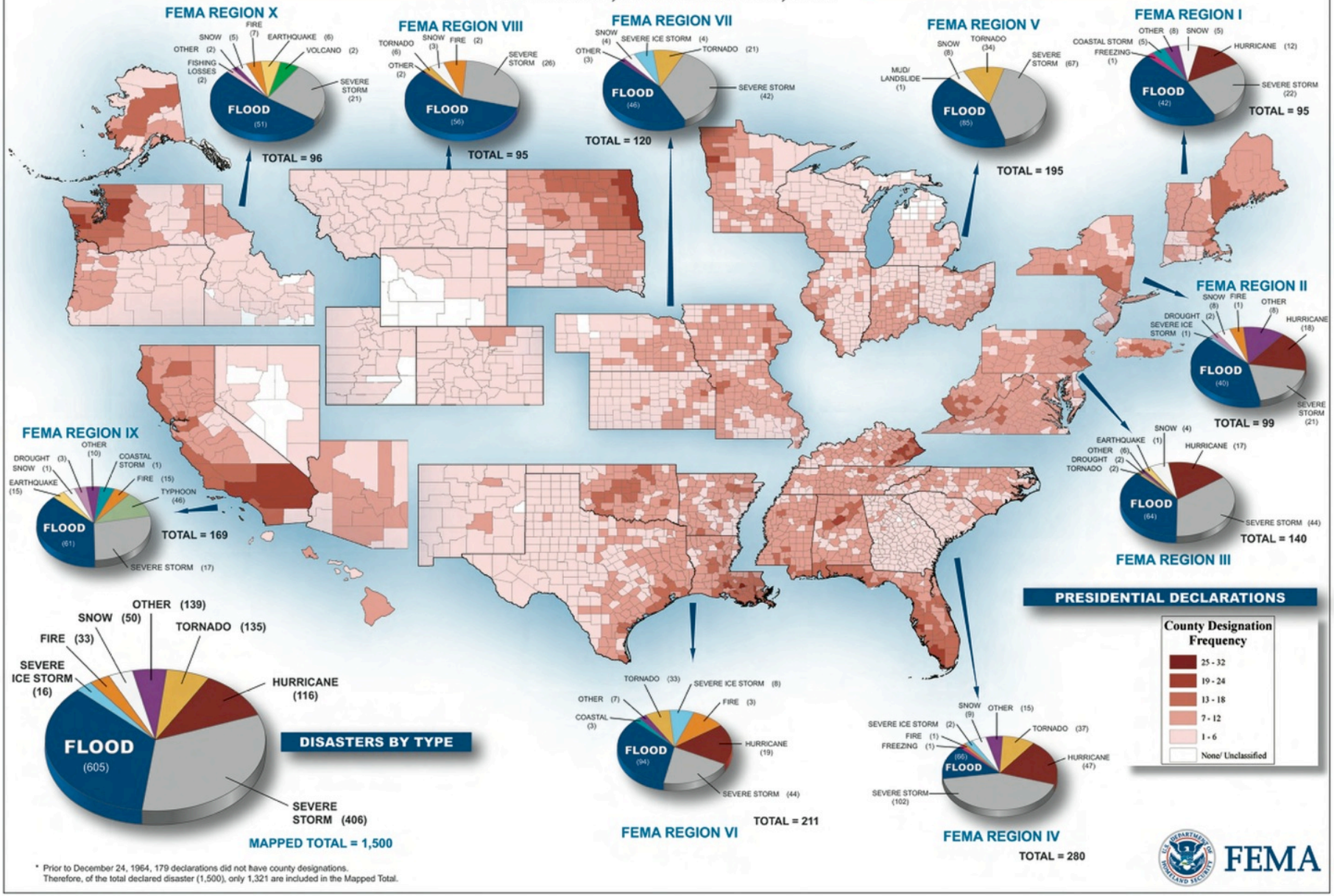
WEATHER HAZARDS

Basic Climatology

Oklahoma Climatological Survey

PRESIDENTIAL DISASTER DECLARATIONS

December 24, 1964 to March 3, 2007



* Prior to December 24, 1964, 179 declarations did not have county designations. Therefore, of the total declared disaster (1,500), only 1,321 are included in the Mapped Total.

Recent Declared Disasters in Oklahoma

Wildfires (Apr 09)

Ice Storm (Jan 09)

Tornadoes (Feb 09)

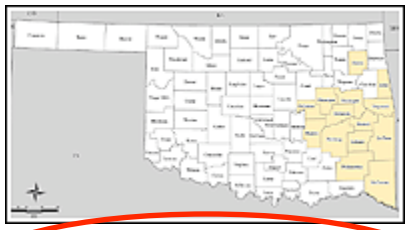
Storms (Sep 08)

Drought (Julo8)

Floods (Jun 08)

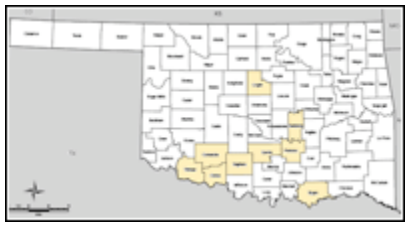
Tornado (May 08)

Floods (Apr 08)

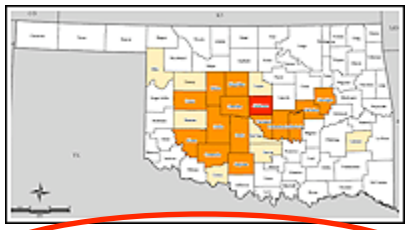


Floods (May 08)

Ice Storm (Dec 07)

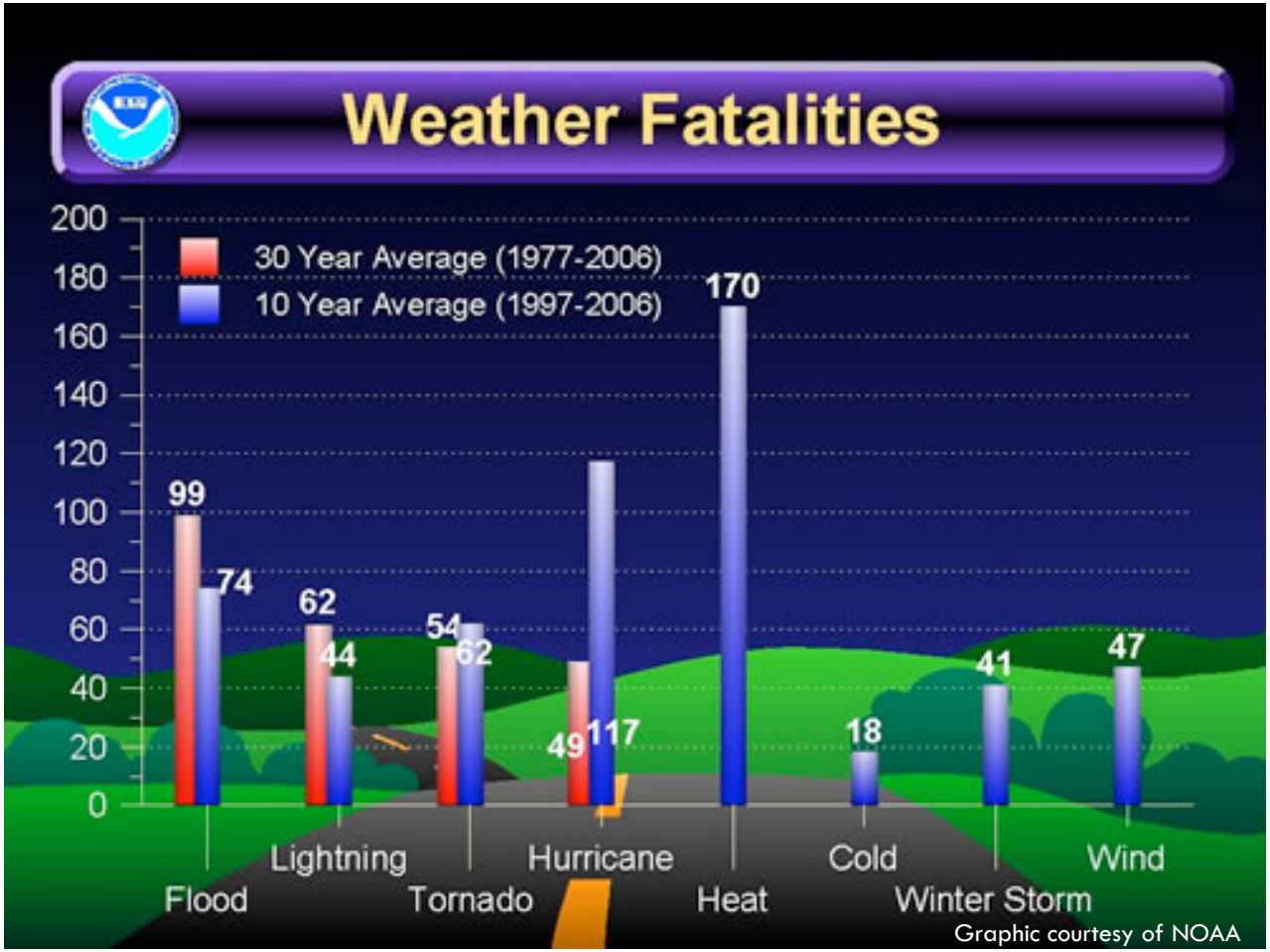


Floods (May 07)



Storms (Aug 07)

National Weather Fatalities



Thunderstorm Facts

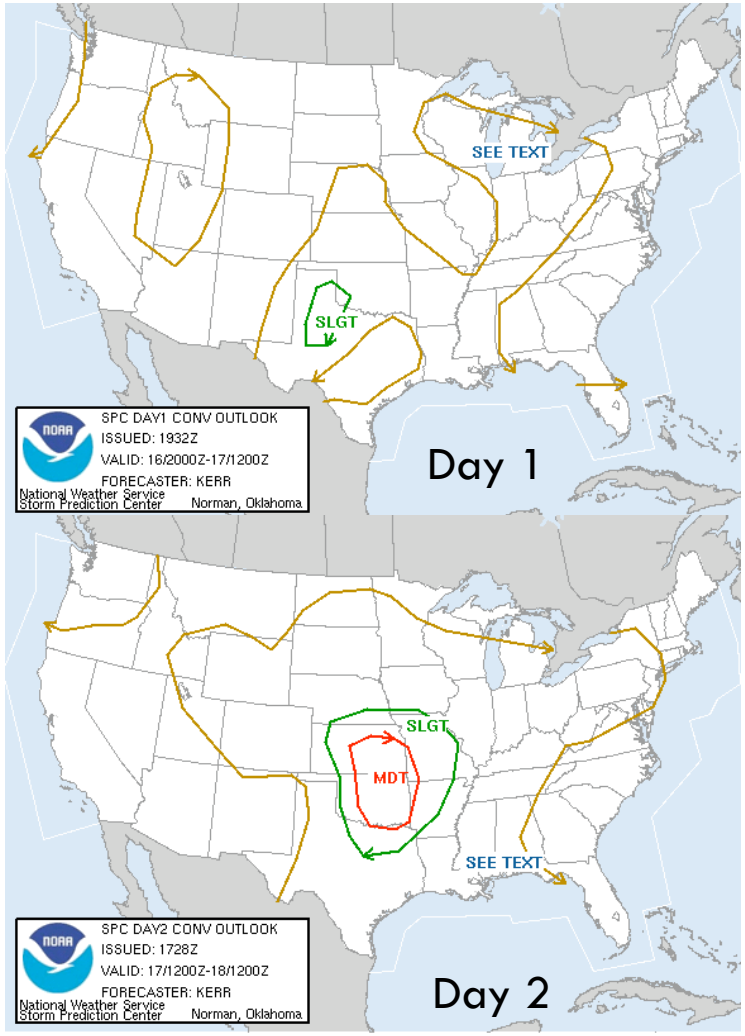
- Thunderstorms affect relatively small areas when compared to hurricanes & winter storms
  - The typical thunderstorm is 15 miles in diameter & lasts an average of 30 minutes
- Nearly 1800 thunderstorms are occurring at any moment around the world – 16 million a year!
  - 100,000 each year in the United States
  - Of these, about 10% are severe
- Thunderstorms are most likely to happen in the spring & summer months & during the afternoon & evening hours, but they can occur year-round & at all hours
- Despite their small size, all thunderstorms are dangerous because they produce lightning, and also may generate heavy rain, strong winds, hail, & tornadoes

Outlooks, Watches and Warnings

- Outlook
  - Indicates that hazardous weather **may develop** – useful to those who need considerable lead time to prepare for a possible event
  - Issued by National Weather Service (NWS) Office or Storm Prediction Center (SPC)
- Watch
  - Atmospheric conditions are right for hazardous weather – hazardous weather **is likely to occur**
  - Issued by SPC
- Warning
  - Hazardous weather is either **imminent or occurring**
  - Issued by local NWS office

Outlooks—SPC

- Storm Prediction Center (SPC) Outlook=Convective Outlook

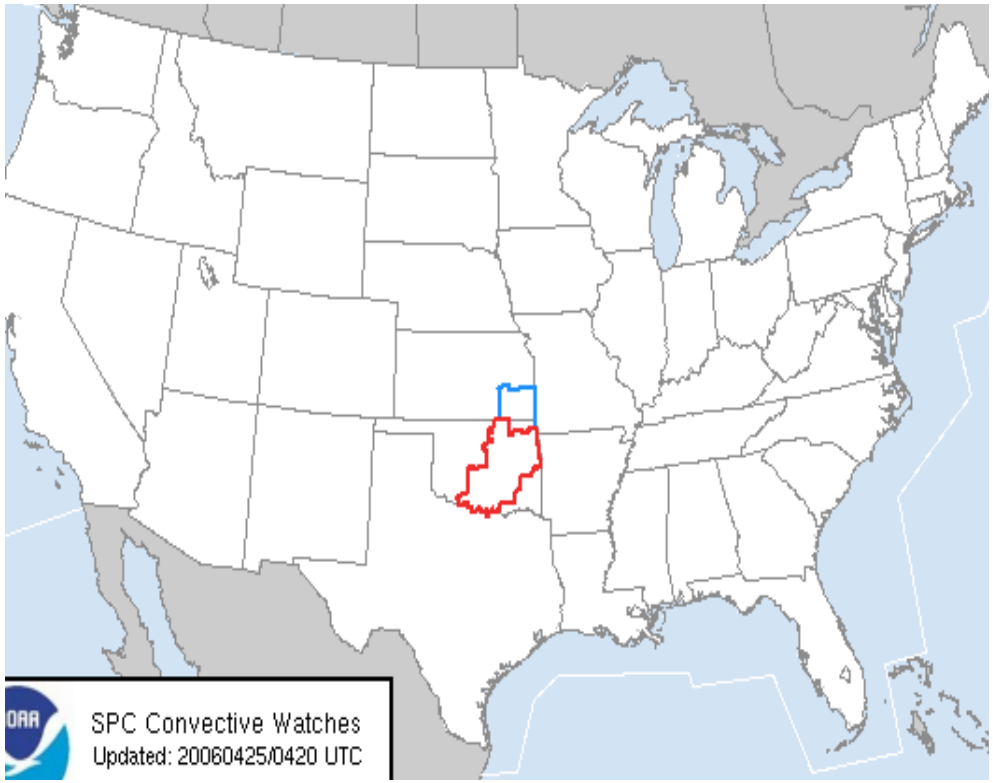


- Preview of the day's chances for severe weather—hazardous weather that **may develop**

- Day 1 = Today, Day 2 = Tomorrow, Day 3 = Day after tomorrow

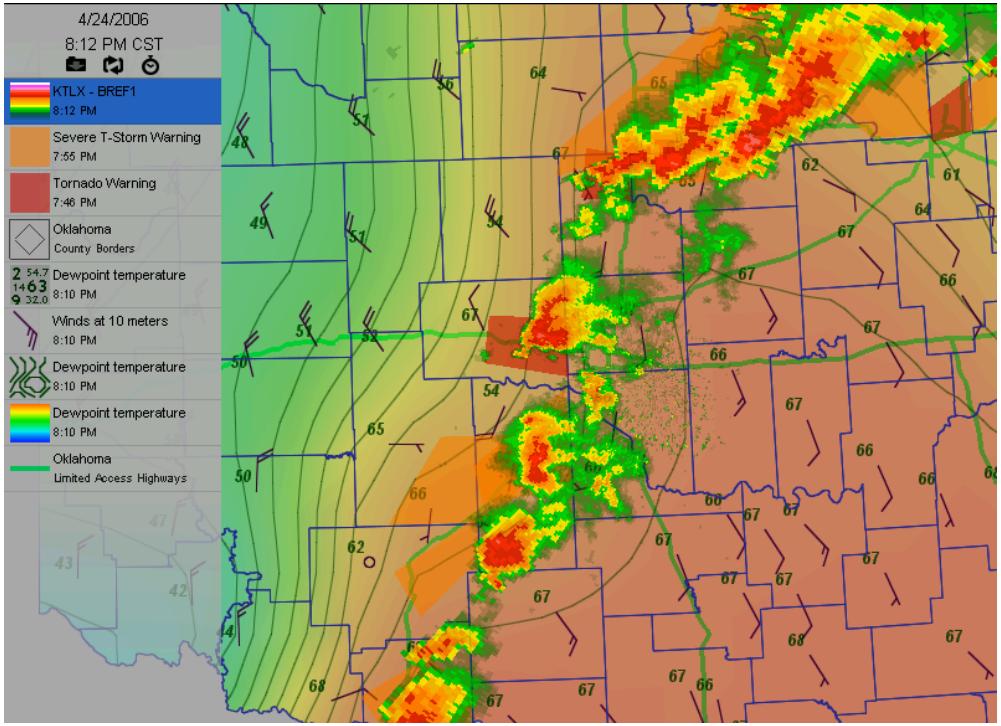
DAT-266 In the wake of cataclysmic climatic changes, tornadoes destroy most of Los Angeles.

Watches



- Conditions are **favorable** for a particular weather hazard within the next several hours
- Clusters of counties
- Issued by SPC

Warnings

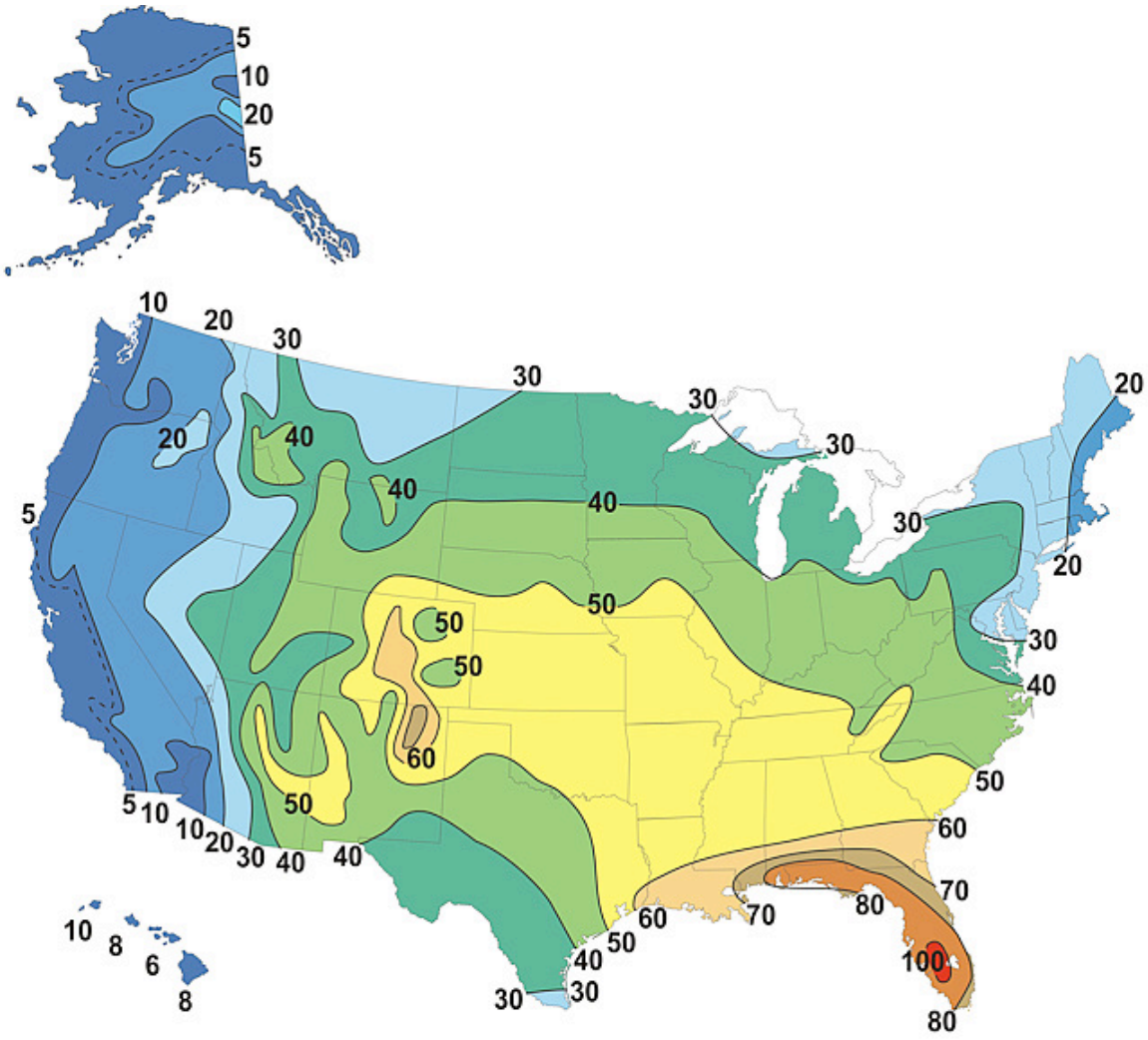


- Hazardous weather is either **imminent or occurring**
- Small polygons
- Issued by local NWS office
- Area in IMMEDIATE danger

What Is A Severe Thunderstorm?

- ✓ Tornadoes
- ✓ Wind Speeds greater than 57 mph
- ✓ Hail greater than ¾-inch diameter
  - ✓ NWS is revising this to 1-inch
- Lightning: no criteria
- Heavy/Flooding Rainfall: no criteria
  - Separate flood warnings may be issued

Severe Thunderstorm Climatology

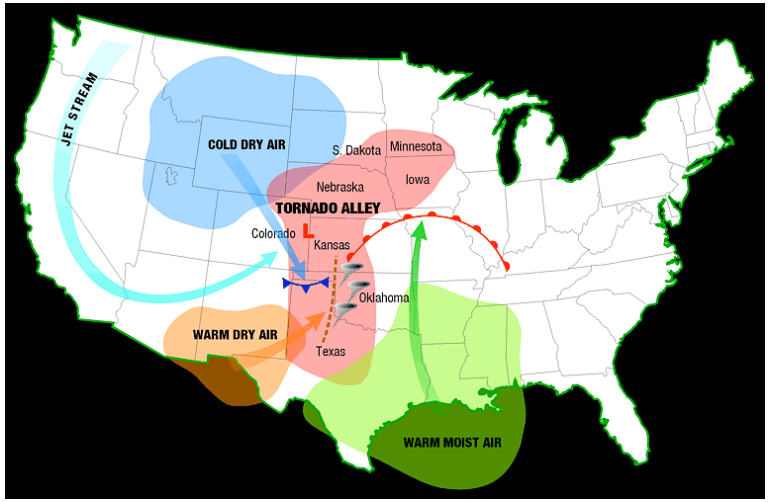


Source: NOAA National Weather Service Jetstream

SEVERE THUNDERSTORMS

Tornadoes

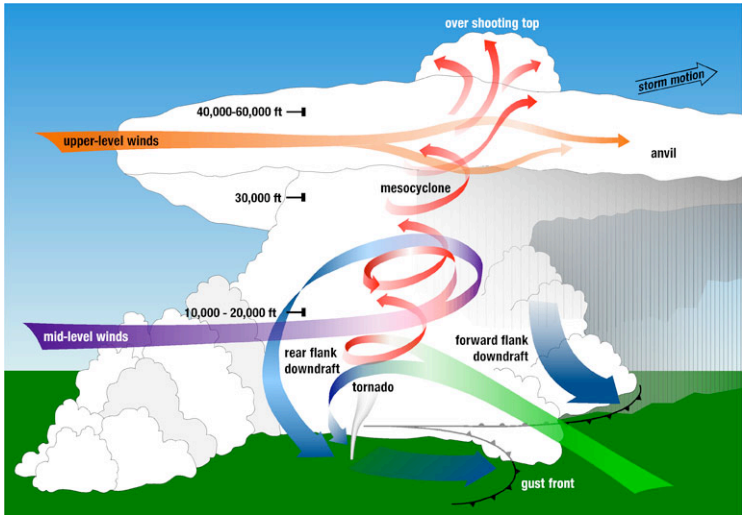
- A violently rotating column of air descending from a thunderstorm and in contact with the ground
  - May have wind speeds over 300 mph
- Usually brief, but may last more than an hour and travel for tens of miles
- Nearly 1,000 tornadoes occur in the U.S. each year, with an average of 62 fatalities
  - Most occur across the plains and South
- Rotation in the *mesocyclone* causes a hook-shaped feature on radar that may help identify regions favorable for a tornado to form



Source: NOAA National Severe Storms Laboratory

How Do Tornadoes Form?

- *Wind Shear* in the atmosphere causes rotation
  - Changes in direction and speed with height
- The horizontal rotation created by the wind shear gets tilted vertically into the *updraft*
  - The rotation in the parent thunderstorm is called a *mesocyclone*
  - The rotating mesocyclone often appears as a 'hook' shape on radar
- *Convergence* of surface winds underneath the updraft enhance rotation at lower levels, creating a tornado
  - rotation may be aided by a *rear flank downdraft* of descending air near the updraft that enhances convergence
  - Fewer than 20% of *supercell* thunderstorms actually produce tornadoes!



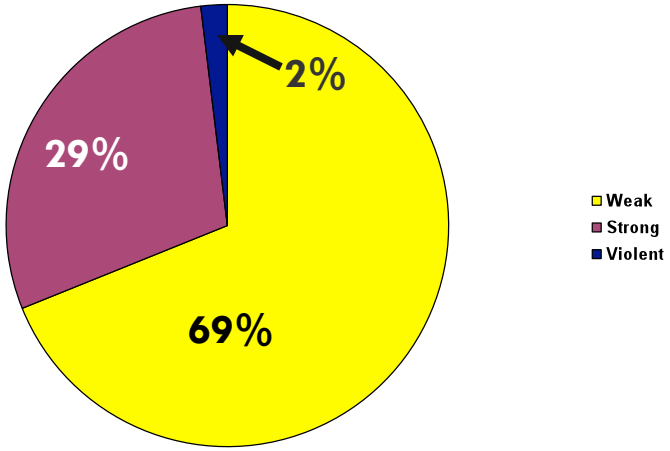
Source: NOAA National Severe Storms Laboratory

Enhanced Fujita (EF) Scale

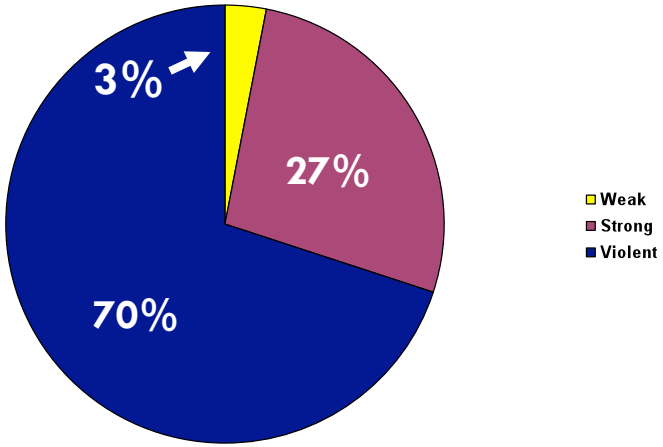
F Number	Wind Speed (mph)*	EF Number	Wind Speed (mph)*
F0 Weak	45-78	EF0	65-85
F1 Weak	79-117	EF1	86-109
F2 Significant/ Strong	118-161	EF2	110-137
F3 Significant/ Strong	162-209	EF3	138-167
F4 Significant/ Violent	210-261	EF4	168-199
F5 Significant/ Violent	262-317	EF5	200-234

*Estimated

Tornado Strength

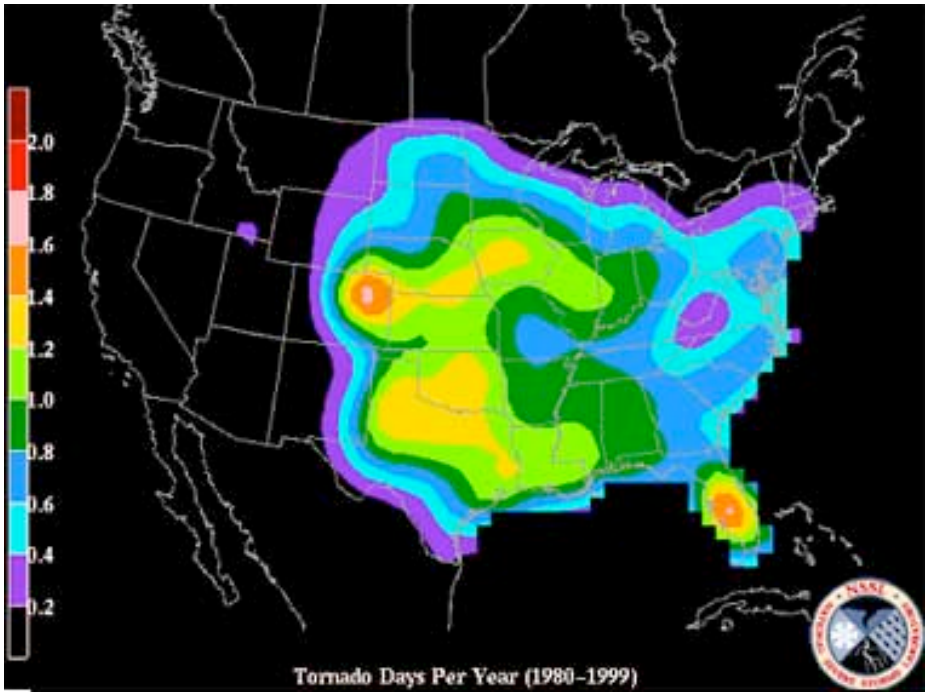


Number of Tornadoes by F-scale

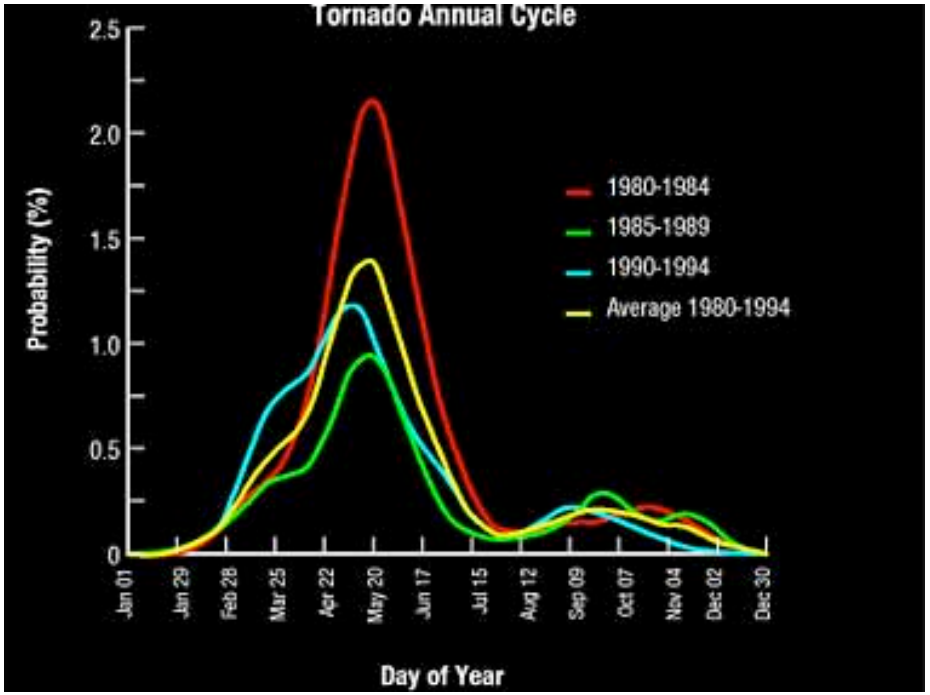


Tornadoes Deaths by F-scale

Where and When Do They Occur?



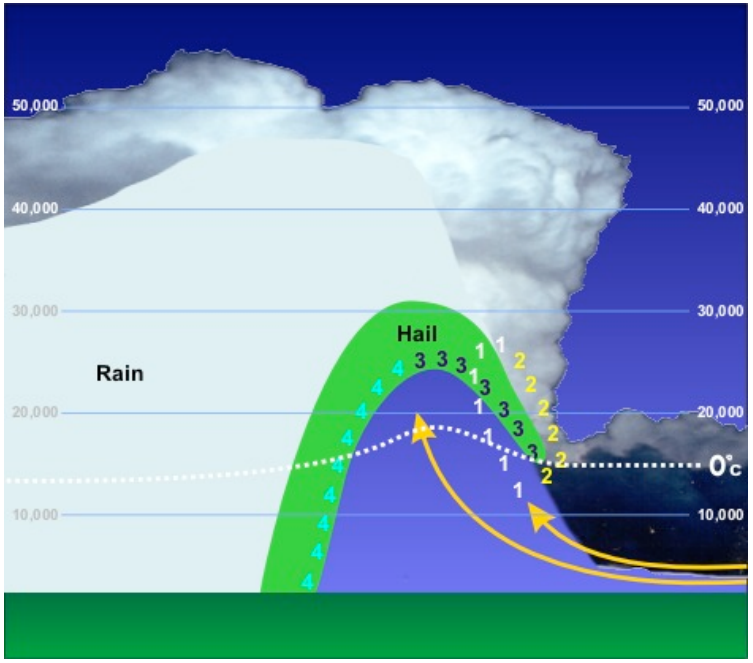
Source: NOAA National Severe Storms Laboratory



Source: NOAA National Severe Storms Laboratory

Hail

- Hail forms by collision of *supercooled drops* – raindrops that are still liquid even though the air around them is below freezing
- The hailstone continues to grow, supported by the updraft, until it is too heavy to remain aloft
  - The stronger the updraft, the bigger the hail size
- Large hail occurs most frequently in the great plains, but can occur anywhere
- Causes $1 billion damages yearly, but few fatalities

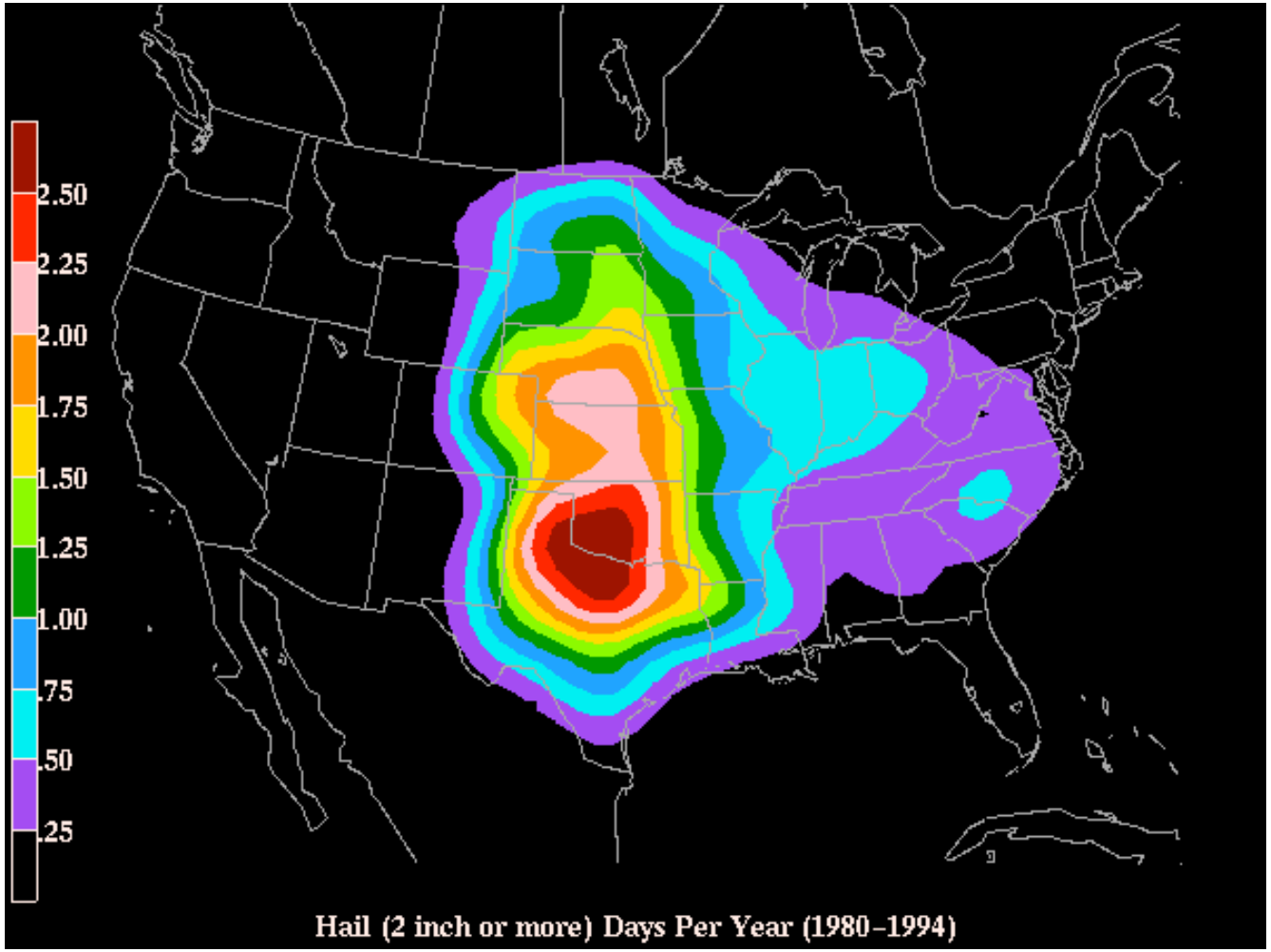


Source: NOAA National Weather Service Jetstream

Hail Size

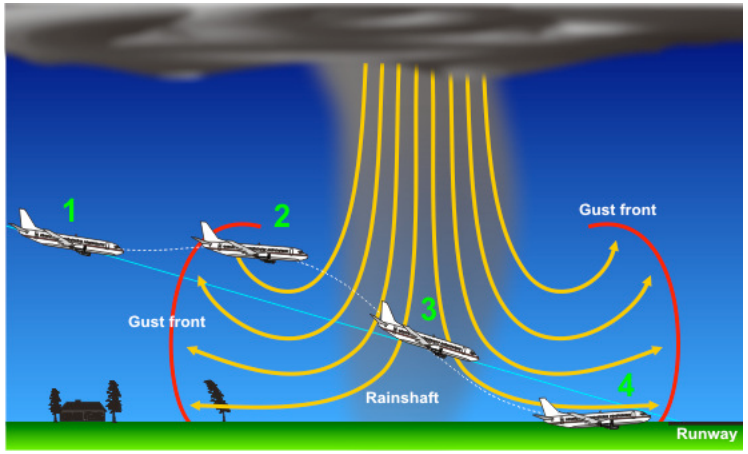
Hailstone size	Measurement		Updraft Speed	
	in.	cm.	mph	m/s
bb	**< 1/4**	< 0.64	< 24	< 11
pea	1/4	0.64	24	11
marble	1/2	1.3	35	16
dime	7/10	1.8	38	17
penny	3/4	1.9	40	18
nickel	7/8	2.2	46	21
quarter	1	2.5	49	22
half dollar	1 1/4	3.2	54	24
walnut	1 1/2	3.8	60	27
golf ball	1 3/4	4.4	64	29
hen egg	2	5.1	69	31
tennis ball	2 1/2	6.4	77	34
baseball	2 3/4	7.0	81	36
tea cup	3	7.6	84	38
grapefruit	4	10.1	98	44
softball	4 1/2	11.4	103	46

Where Does Hail Occur?

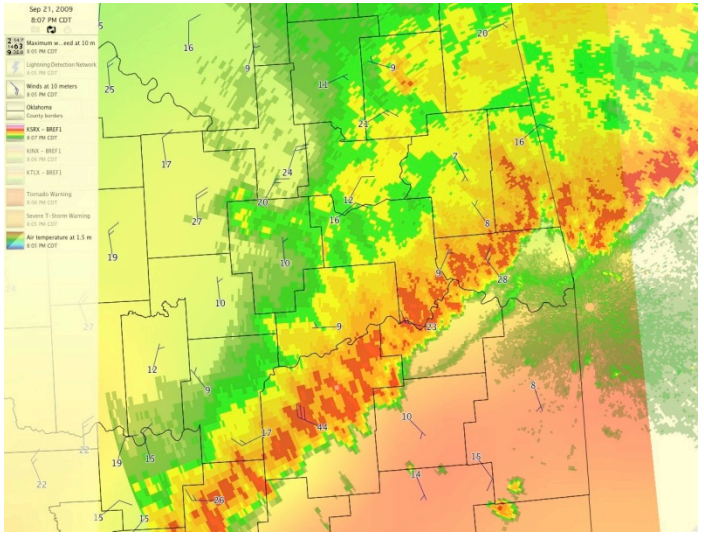


High Winds

- Responsible for most thunderstorm damage
  - Much larger area affected than tornado paths
- Winds may exceed 100 mph
- *Downdraft* originates as rain falls, pulling air downward
  - *Evaporative cooling* accelerates downdraft
- Air spreads out horizontally when it hits the ground, creating *gust fronts*
- Most often associated with squall lines or supercells (*microbursts*)
- Average 47 fatalities annually



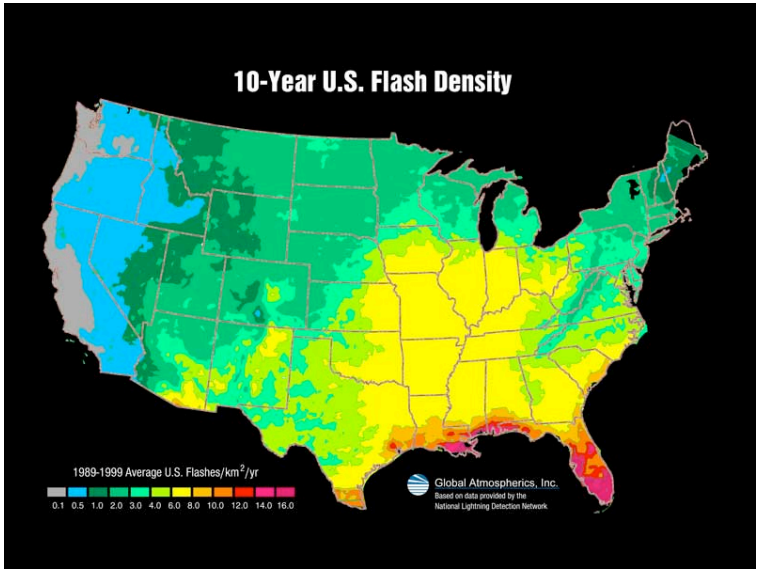
Source: NOAA National Weather Service Jetstream



Microburst Damage July 2007, Norman, OK

Lightning

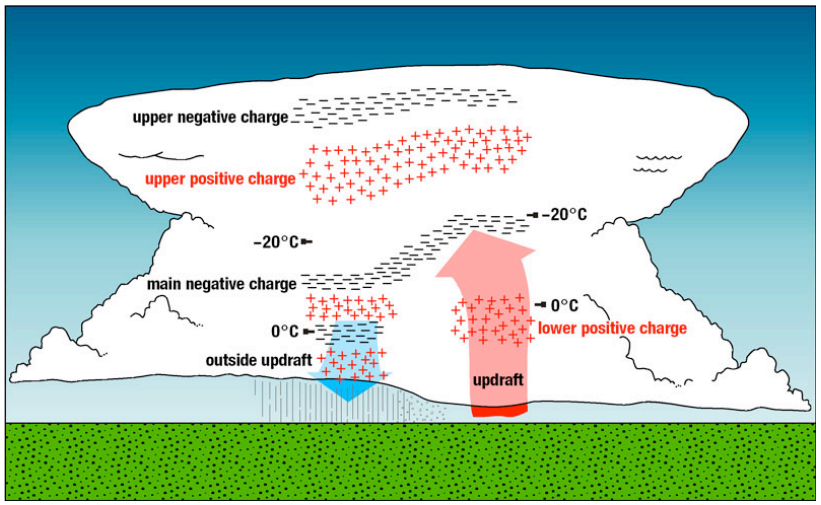
- Lightning is essentially a large spark of static electricity
  - Like when you touch a doorknob on a dry day
- Lightning occurs about 40 times per second, worldwide, in about 2,000 thunderstorms simultaneously
- Lightning strikes about 400 people in the U.S. each year, killing 58
  - Many victims are caught outdoors
  - Lightning can travel along telephone lines, pipes, tree roots, and other good conductors
- Lightning can strike well away from the storm, as far as 10 miles



Source: NOAA National Severe Storms Laboratory

How Lightning is Created

- Collisions between cloud droplets, hail, and ice nuclei create *free electrons* which are separated in the storm through updrafts and downdrafts
  - Positive charge accumulates near the storm top, negative charge near the bottom
  - These separate charge centers create an *electric field* between them
- When the strength of the electric field exceeds the insulating properties of the atmosphere, a breakdown occurs, which we see as lightning
- The negative charge center at the base of the storm *induces* a positive charge in the ground
  - The field between the charge centers in the cloud is greater than the field between cloud and ground, so 75-80% of lightning occurs within the cloud rather than cloud-to-ground

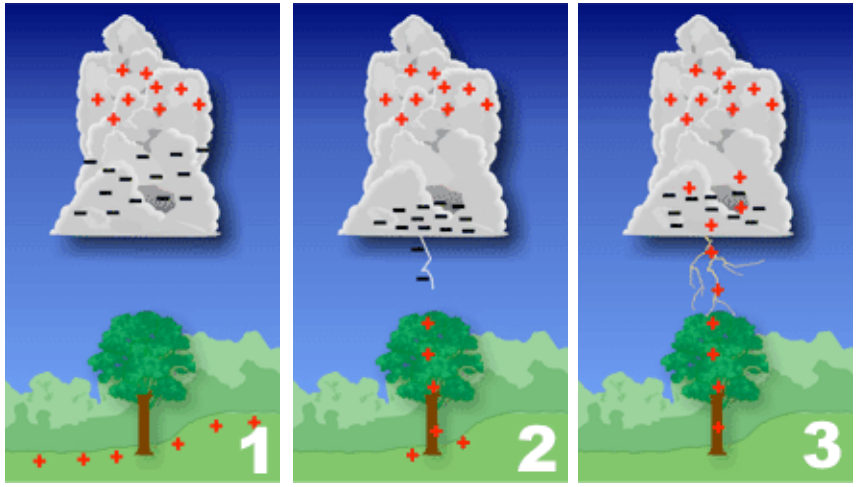


Source: NOAA National Severe Storms Laboratory

Cloud-to-Ground Lightning

1. Negative charge descends from the cloud in a series of *stepped leaders*
2. As it nears the ground, the positive charge sends up a *streamer*
3. When the *streamer* connects to the *stepped leader*, an electrical circuit is created which transfers charge between the two charge centers in a *return stroke*, which we see as lightning
4. If additional charge remains, additional *return strokes* may occur, which gives lightning a flickering effect

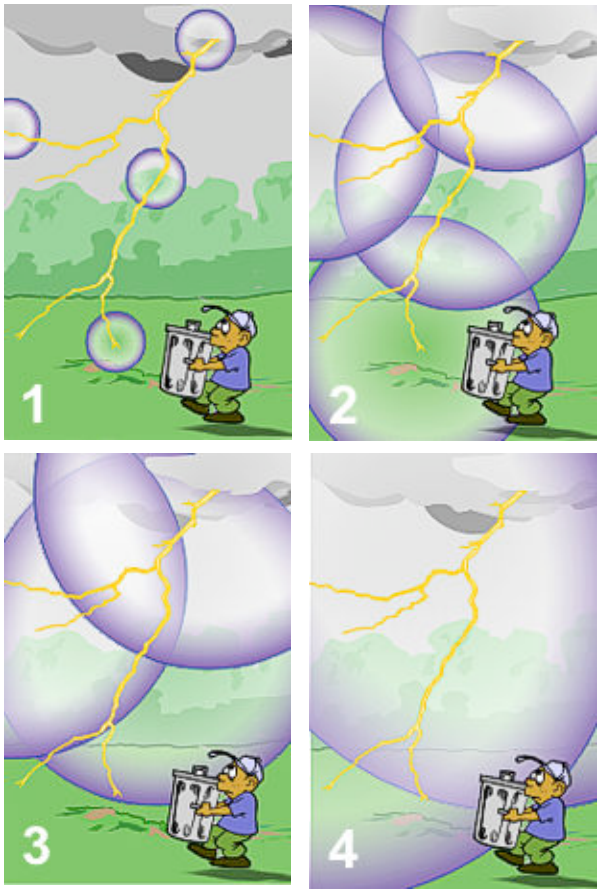
- Although lightning is attracted toward taller objects (shortest path), it may strike other objects nearby
  - less air resistance
  - Sharp points tend to concentrate charge, building up a larger electric field
  - Branches off the main channel



Source: NOAA National Weather Service Jetstream

What Makes Thunder

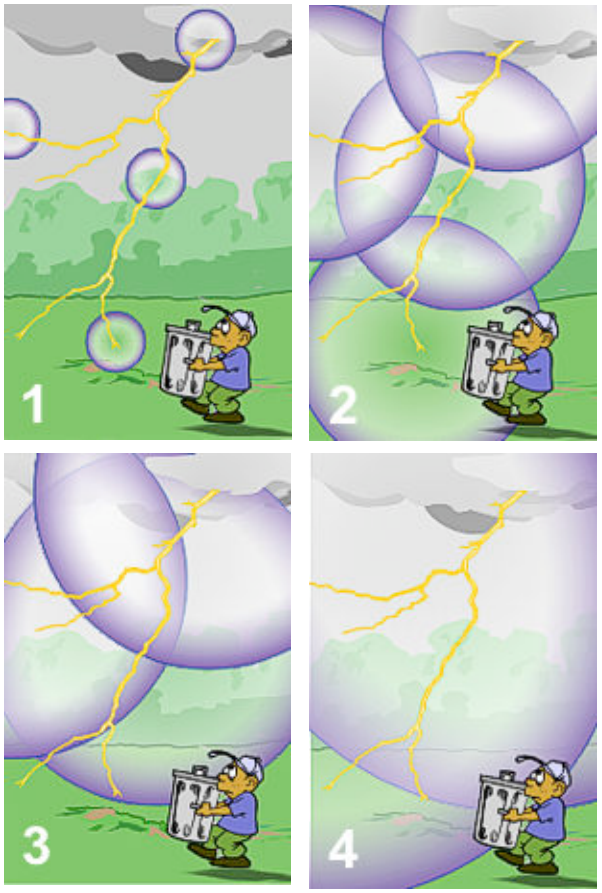
- Thunder is a *shock wave* created by the rapid expansion of air in the lightning channel
  - Lightning heats the air to 18,000°F – hotter than the surface of the sun!
- The "crackle" you may hear before the main "boom" is from the *stepped leaders* and *ground streamer*
- The rumble you hear is due to different times-of-arrival of the shock wave from different parts of the lightning channel
  - Parts of the channel near the cloud base are further away from you than parts near the ground



Source: NOAA National Weather Service Jetstream

What Makes Thunder

- Light travels about 186,000 miles per second (670 million miles per hour) while sound travels only 0.2 miles per second (750 mph)
  - Consequently, the flash is instantaneous and the time it takes to hear the thunder can determine its distance
  - Count the seconds between the flash and the sound of thunder; for roughly every 5 seconds, the strike is one mile away
- Know the *30/30 rule*: seek shelter if the time from flash-to-bang is less than 30 seconds and remain inside for 30 minutes until after the last thunder is heard



Source: NOAA National Weather Service Jetstream

Flooding

- Flooding causes an average 127 deaths per year
  - As little as 6 inches of moving water can sweep a person away
  - Nearly half these deaths are vehicle-related; two feet of water can float a vehicle
- Primary causes:
  - Slow-moving thunderstorms
  - *Training echoes* – a series of storms tracking over the same location
  - Tropical systems
- If ground is saturated from previous rainfall, a less-intense storm can cause flooding
- Extended periods of rain can result in river flooding
  - Water rises more slowly but flooding may last for days or weeks

Graphic courtesy of KOTV, Tulsa, OK

(Tropical Storm Erin flooding)

Flash Flooding

- Flash floods occur with little or no warning!
- Flash floods are capable of:
  - Moving large objects like boulders
  - Tearing out trees
  - Destroying buildings or bridges
  - Scouring new channels
  - Creating mud slides
- Rocky areas or very dry soils may behave like concrete, with very little rainfall soaking in and most running off into streams

Photo by Leif Skoogfors/ FEMA

Flash Flooding

- Areas most susceptible to flash floods:
  - Low-lying areas (water runs downhill)
  - Urban areas
  - Underpasses
  - Dry creek beds or near the banks of streams & rivers
  - Canyons: a creek only 6 inches deep can become a 10-foot-deep raging river in less than an hour
  - Downstream of a dam or levee
  - Downstream of an ice jam
  - Upstream from a bridge
  - Recent burn areas
- Be prepared when hiking or camping
  - Watch for signs of thunderstorms, especially in upstream areas
  - If at all possible, carry a device capable of checking weather alerts, such as a NOAA Weather Radio, cell phone, or pager
  - If water starts rising, seek high ground immediately
  - Even if it is not raining where you are, water can come downstream quickly

The 100-year Flood

- The *"100-year flood"* is a one percent probability that a flood of a certain magnitude will occur
  - 50-year flood: expected to occur once every 50 years, or a 2% chance in any given year
  - 25-year flood: expected to occur once every 25 years, or a 4% chance in any given year
- An event is equally likely to occur at any time
  - Just because the 100-year flood occurred last year does not mean it will not happen this year
  - Can have occurrences in successive years, or even multiple occurrences in a single year!
- Based on prior events – their frequency and magnitude
  - In fact, once the event is added into the statistics, it becomes *more likely* (statistically-speaking) that the event will occur again, because you now have 2 events at the extremes
- Factors other than rainfall change the areas susceptible to flooding
  - Upstream development / more concrete increases runoff
  - Changes in land features & ecosystems
  - Climate changes: storms may be different now from what they were 25 or 50 years ago

Flooding—Turn Around, Don't Drown

- National Weather Service slogan for flooding dangers
- Why should you not go through water on the roadway?

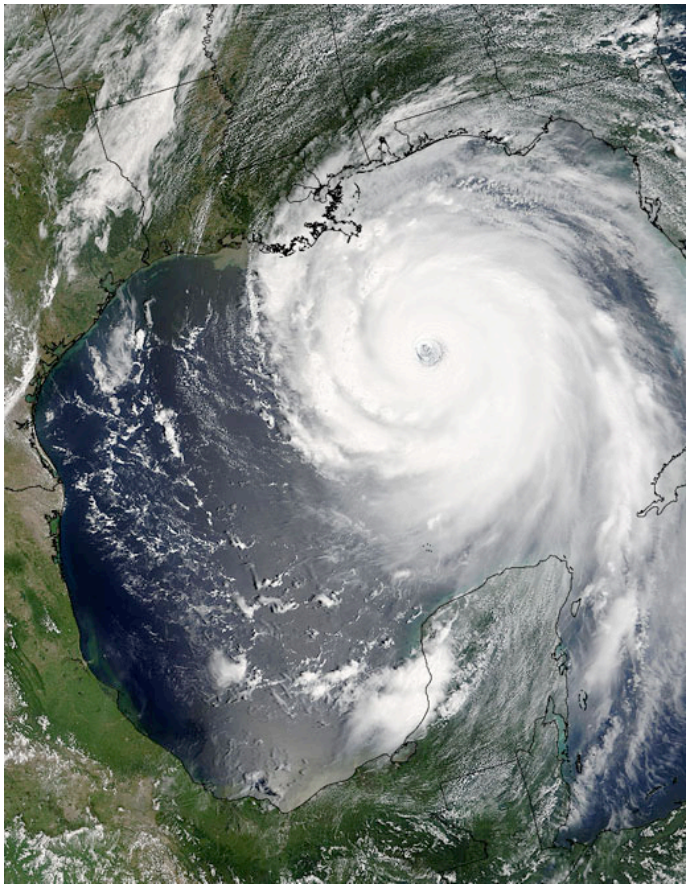
It's easy to underestimate the depth and force of floodwat especially at night and in unfamiliar areas.

Floodwaters often conceal damage to the roadbed.

OTHER WEATHER HAZARDS

Tropical Cyclones

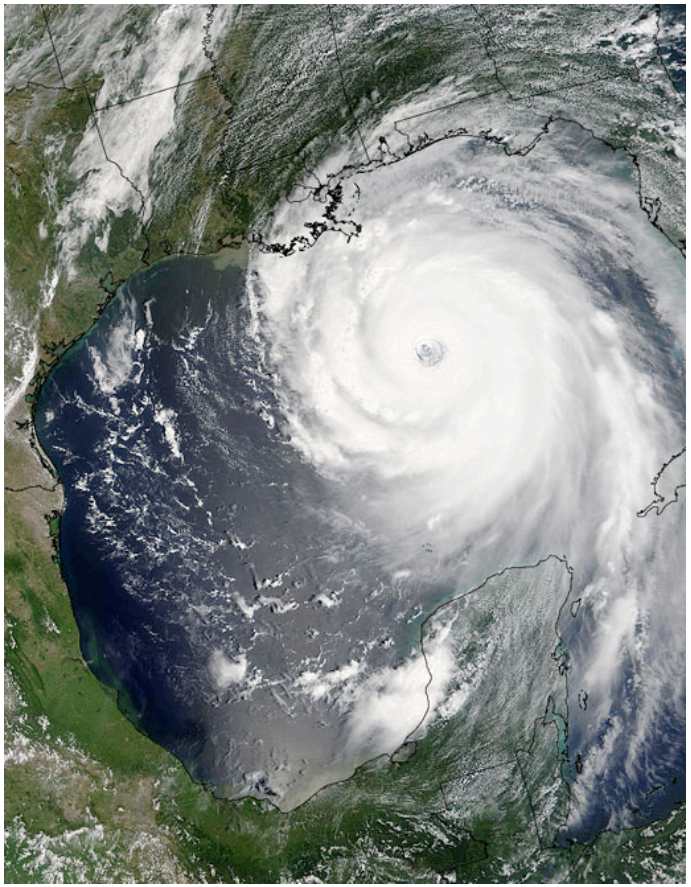
- While not much of a direct hazard in Oklahoma, their impacts can affect our state
- Main threats:
  - *Storm surge*: "pushes" ocean water against the coast raising water level by 15 feet or more
  - Winds: Sustained winds over 160 mph with gusts over 200 mph recorded in the most intense hurricanes
  - Inland flooding: tropical rains may drop several feet of rain in a few days; 60% of deaths are related to inland flooding
  - Tornadoes: Often occur in the right-front quadrant of the storm, embedded in *rainbands*



Source: NASA (Hurricane Katrina)

Tropical Cyclones

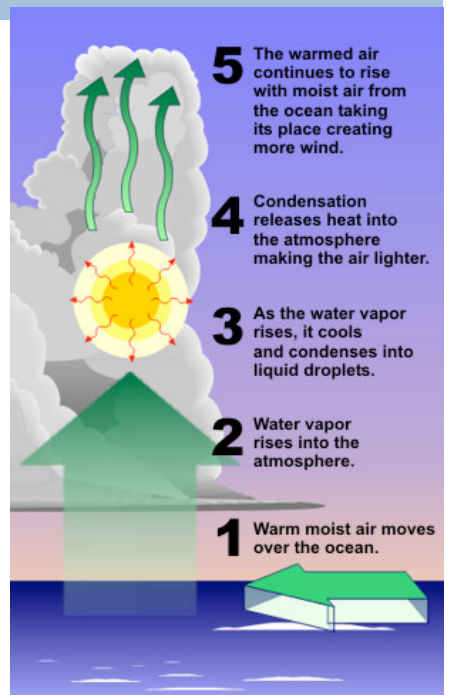
- Ingredients for formation:
  - Warm ocean waters (80°F)
  - Unstable atmosphere
  - Moist air throughout the troposphere
  - Pre-existing surface disturbance
  - Very little vertical wind shear
  - At least 300 miles from the equator (5° latitude)
- Given different names around the world: hurricane, typhoon, tropical cyclone

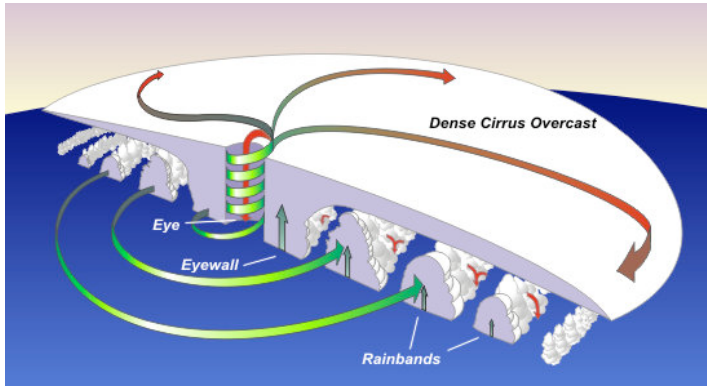


Source: NASA (Hurricane Katrina)

Tropical Cyclones Structure

- Tropical cyclones form as air rises from a warm ocean surface
  - *Condensation* releases heat which adds to the strength of the updraft
- Air spirals inward toward the circulation center (surface low pressure), creating spiral *rainbands*
- As air nears the center, *centrifugal force* counteracts the pressure gradient force, forming an area ~20-40 across, where rising motion ceases
  - Air in the center is replaced by sinking air from the top of the storm, creating an eye (descending air warms and dries)
- Tropical storm winds extend outward about 300 miles in mature hurricanes
  - the largest on record was 675 miles across; the smallest just 30

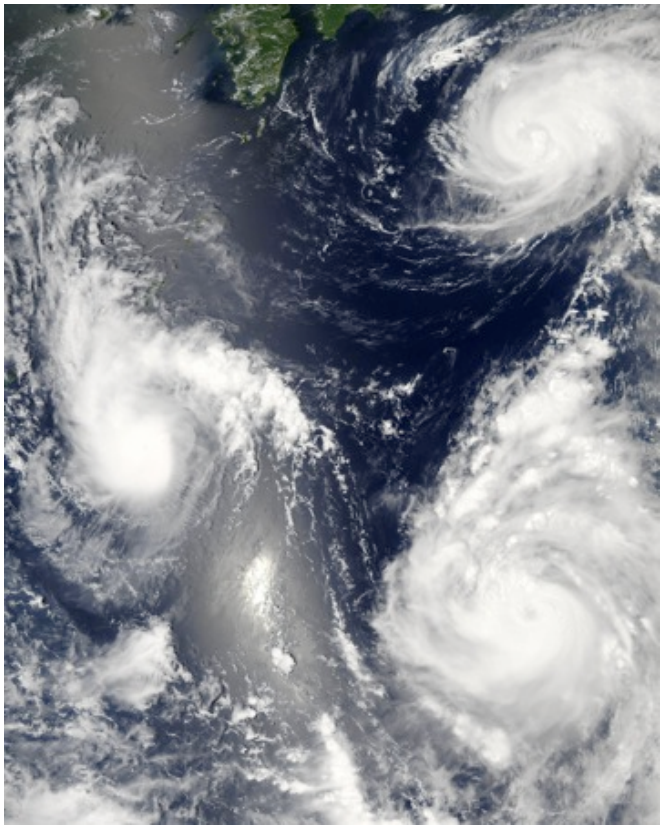




Source: NOAA National Weather Service Jetstream

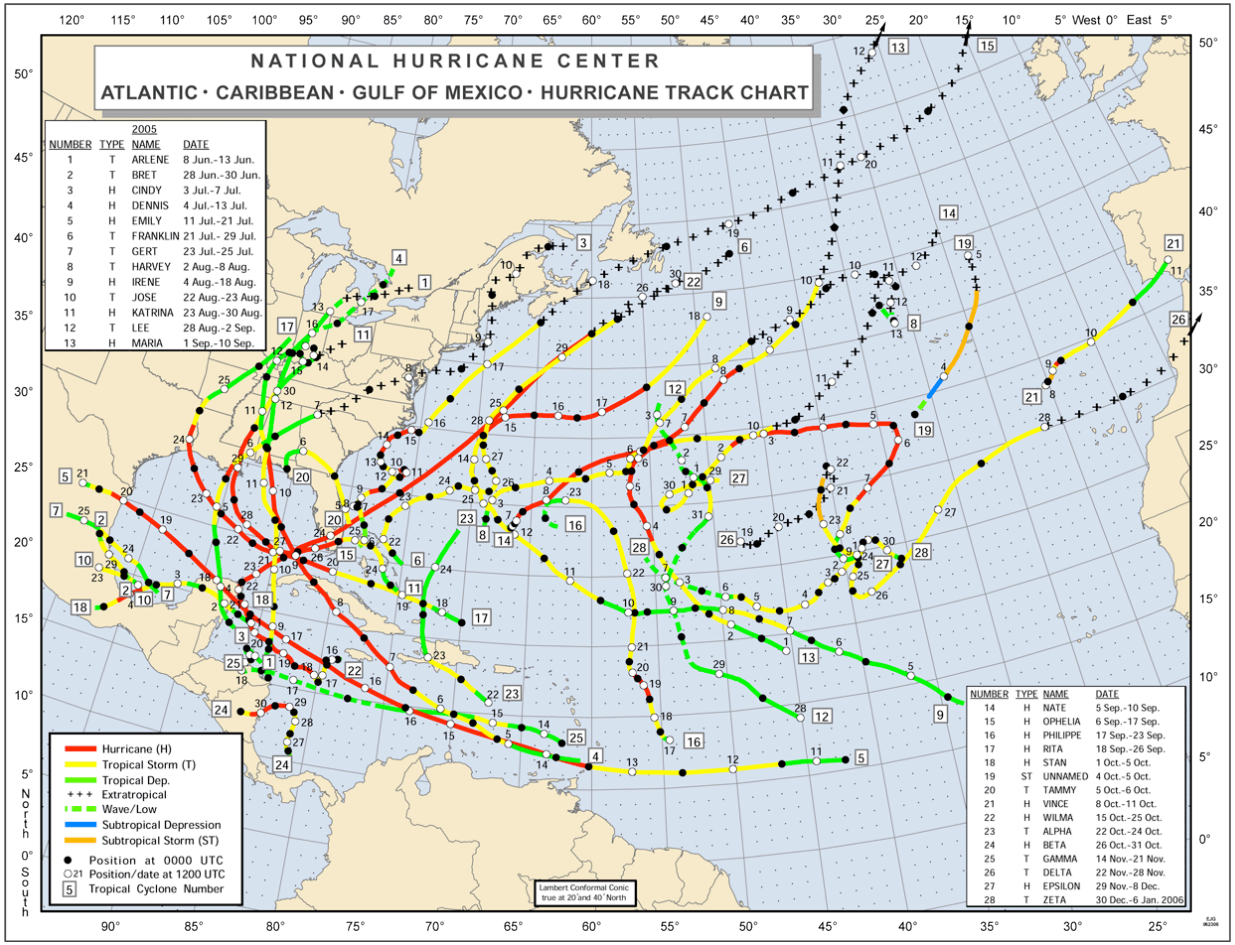
Tropical Cyclones Stages

- Hurricanes go through stages of growth:
  - *Tropical Depression*: circulation with sustained wind speeds of up to 38 mph (storm not yet named)
  - *Tropical Storm*: sustained wind speeds 39-73 mph (the storm receives a name)
  - *Hurricane*: sustained wind speeds of 74 mph or greater
- Hurricanes are further assigned a category (1-5) based on their sustained wind speed
  - Category 1: 74-95 mph; little damage
  - Category 2: 96-110 mph; roof and tree damage
  - Category 3: 110-130 mph; some structural damage; storm surge up to 12 feet
  - Category 4: 131-155 mph; widespread damage, some structural failure; storm surge to 18 feet
  - Category 5: >155 mph; complete structural failures; storm surge greater than 18 feet
- Category 3-5 is considered a "major hurricane"
  - These account for 83% of damage, but are only 21% of landfalling (U.S.) hurricanes
- When hurricanes make landfall, two things happen:
  - They lose their source of energy – conversion of warm, moist ocean air into heat that sustains the updrafts
  - Friction increases, slowing wind speeds and allowing more *convergence* of air into the center



Source: Wikipedia / NASA

Hurricane Tracks (2005)

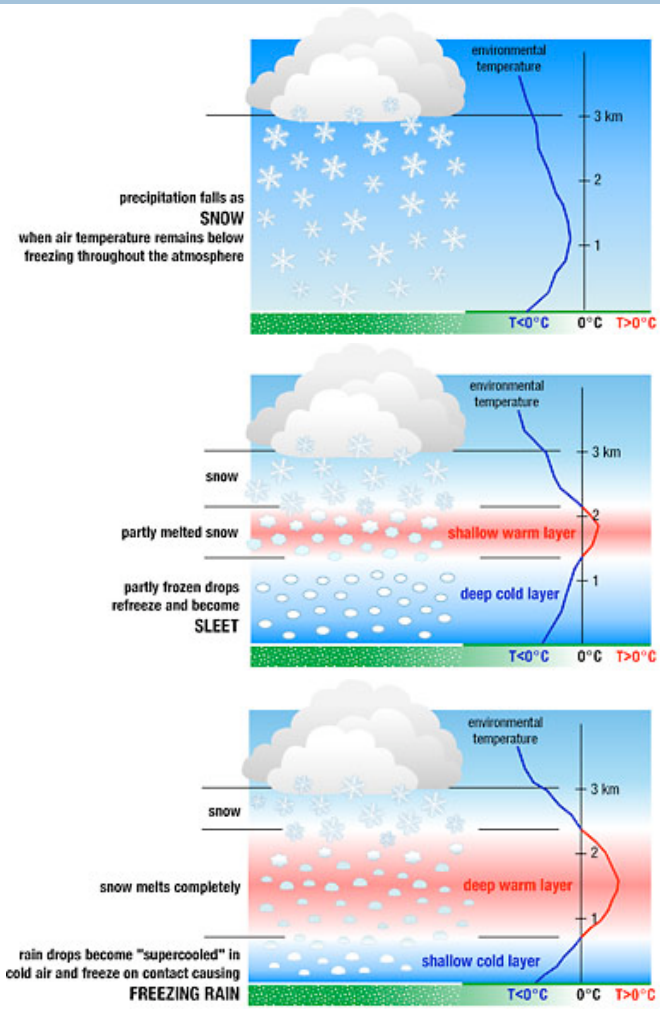


Winter Storms

- All winter storms are basically regular storms but in a cold environment
- Ingredients (sound familiar?):
  - Moisture
  - Instability
  - Lift
  - \+ Cold layer through which precipitation falls
- Dangers
  - Snow squalls: brief intense periods of snow can cause 'white out' conditions
  - Blowing snow: reduces visibility and creates drifts
  - Blizzard: winds over 35 mph with snow falling, reducing visibility to ¼ mile or less for at least 3 hours
  - Avalanche: heavy snow in mountains can slide downhill, collecting more snow along the path
- Most risks are not directly related to the storm:
  - Traffic accidents (70% of fatalities)
  - *Hypothermia* from prolonged exposure to the cold (25% of fatalities)
  - Falling on the ice
  - Heart attacks while shoveling snow / clearing debris
  - Falling tree limbs, power lines, or falling ice

Types of Winter Storms

- Snow
  - Ice crystals form in the cloud and stick together, making snowflakes
  - Cold throughout the depth of the storm
- Sleet
  - An intervening layer of warm air between the cloud and surface
  - Some snow melts and then re-freezes before reaching the ground
  - Results in a combination of snow and ice pellets
- Freezing Rain
  - Deeper warm layer; snow melts completely
  - Falls into shallow cold layer at surface where it becomes *supercooled*
  - Does not have time to re-freeze (like sleet)
  - Freezes on contact with below-freezing surfaces (roads, trees, cars, …)
- Thundersnow
  - Simply a thunderstorm in cold air
  - Still has convective properties (updraft, charge separation)
  - Can occur with any of these types



Winter Storm Oklahoma, 9-10 December 2007

Wind Chill

- Wind blows heat away from your body
  - Shortens the amount of time needed to cool
  - *Wind chill* is based on the rate of heat loss due to wind on exposed skin
- Risks of extreme cold are increased
  - *Frost bite* occurs when tissue (skin) freezes; most commonly extremities such as toes, fingers, ears, or nose
  - *Hypothermia* occurs when the body temperature drops below 95°F
- It will not reduce inanimate objects (like pipes) to that temperature

- Stay Warm:
  - Wear layers (traps heat)
  - Avoid sweating (evaporation)
  - Cover head (50% of heat loss)
  - Cover mouth (protect lungs)

Wind (mph)	Temperature (°F)																				
	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
0	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
5	37	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-58	-63	-69	-75	-81
10	34	27	21	15	11	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72	-78	-84	-90
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77	-83	-90	-96
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81	-88	-94	-101
25	29	23	16	9	3	-4	-11	-17	-24	-31	-38	-44	-51	-58	-64	-71	-78	-84	-91	-98	-104
30	28	22	15	8	1	-6	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87	-94	-101	-107
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-83	-89	-96	-103	-110
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91	-98	-105	-112
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93	-100	-107	-114
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95	-102	-109	-116

Wind Chill	Cold Threat
40°F to 21°F (4°C to -6°C)	COLD. Unpleasant.
20°F to 1°F (-7°C to -17°C)	VERY COLD. Very unpleasant.
0°F to -19°F (-18°C to -28°C)	BITTER COLD. Frostbite possible. Exposed skin can freeze within 5 minutes.
-20°F to -69°F (-29°C to -56°C)	EXTREMELY COLD. Frostbite likely. Exposed skin can freeze within 1 minute. Outdoor activity becomes dangerous.
≤ -70°F (≤ -57°C)	FRIGIDLY COLD. Exposed skin can freeze in 30 seconds.

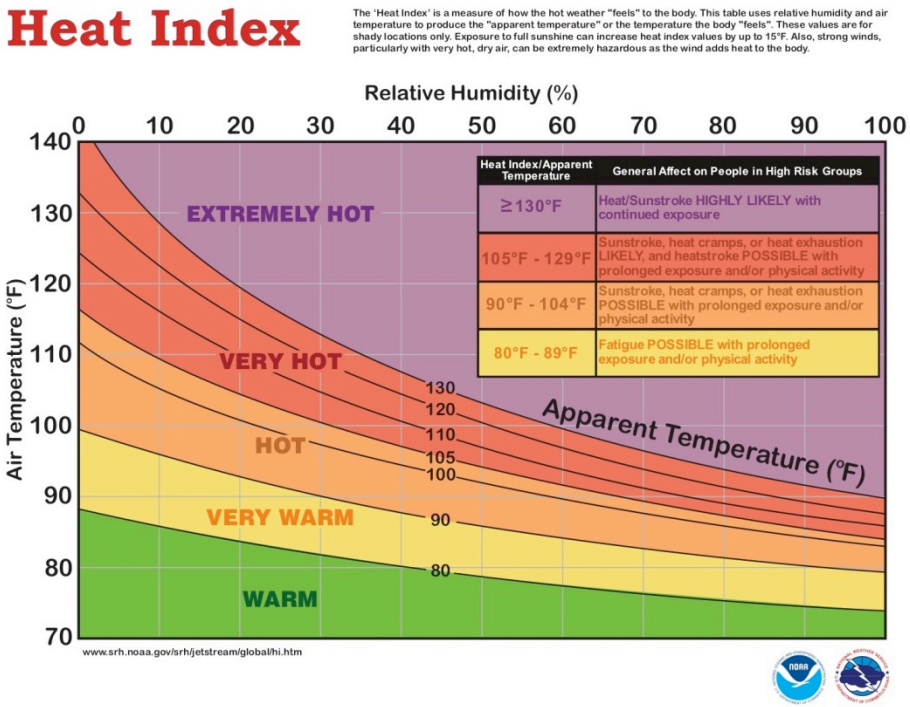
Extreme Heat

- Heat waves are the #1 weather-related killer in the United States
  - Responsible for an average of 170 deaths per year
- Effects are increased in urban areas
  - Concrete absorbs and retains heat very efficiently
  - Does not cool down much at night; body does not get relief
  - Some urban heat events have killed thousands
- Heat is dissipated through *radiation, convection*, or *evaporation*
  - At lower temperatures, radiation and convection efficiently dissipate heat
  - Above 95 degrees (air temperature), these no longer work, so we sweat in order to cool by evaporation
- "At risk" populations include the elderly, children, and sick people, but even healthy people may succumb to the heat

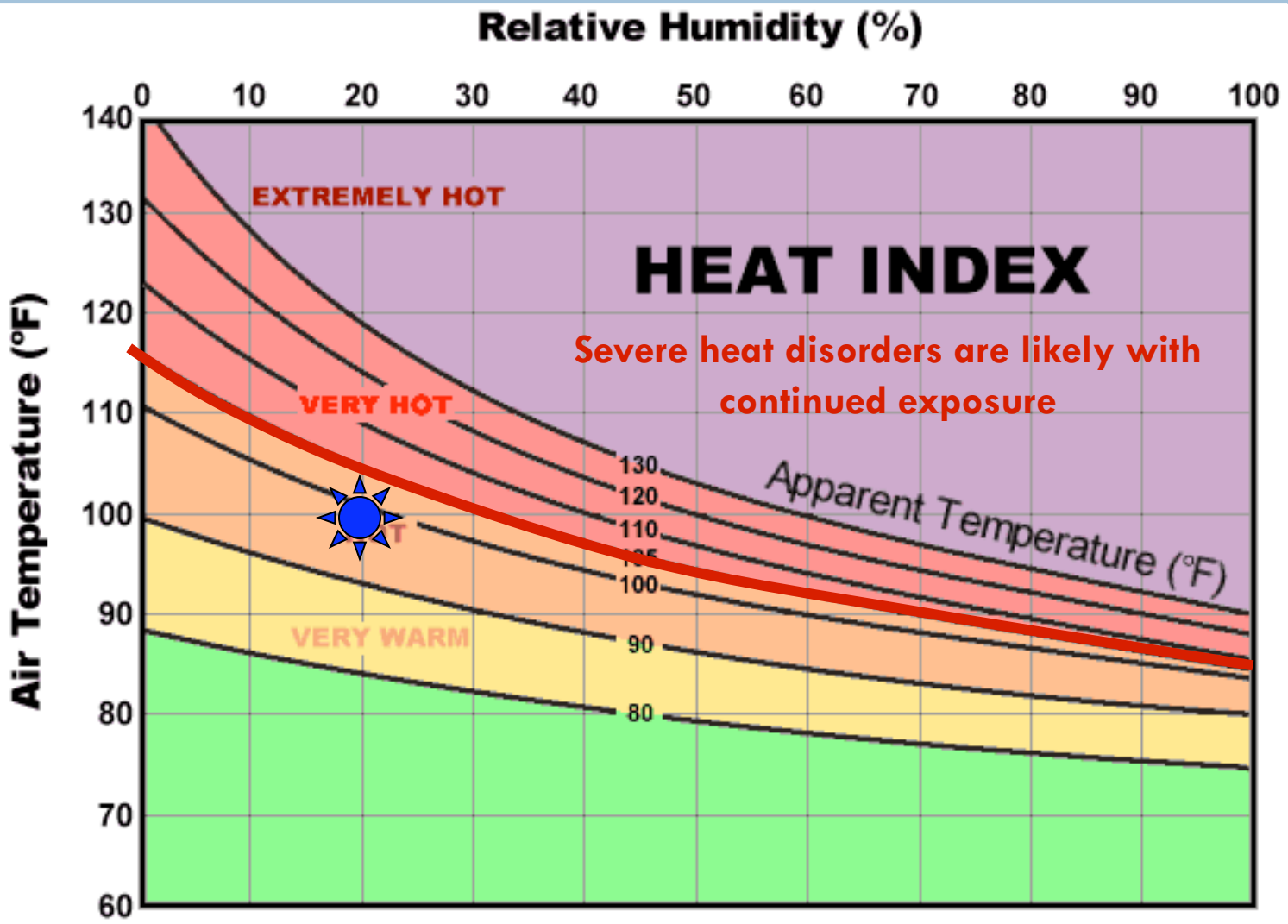
Source: NOAA National Weather Service Jetstream

Heat Index

- It's not the heat, it's the humidity
  - Well, actually it's both!
- High humidity retards evaporation, so dissipation of heat through sweating is less effective
- The *apparent temperature*, or heat index, is based on a combination of temperature and humidity
  - The equivalent of what the temperature would have to be if humidity was negligible
  - Based on shady areas, light winds; full sunshine and/or strong winds can add 15 degrees to this
- Prolonged exposure can lead to heat cramps, heat exhaustion, or heatstroke

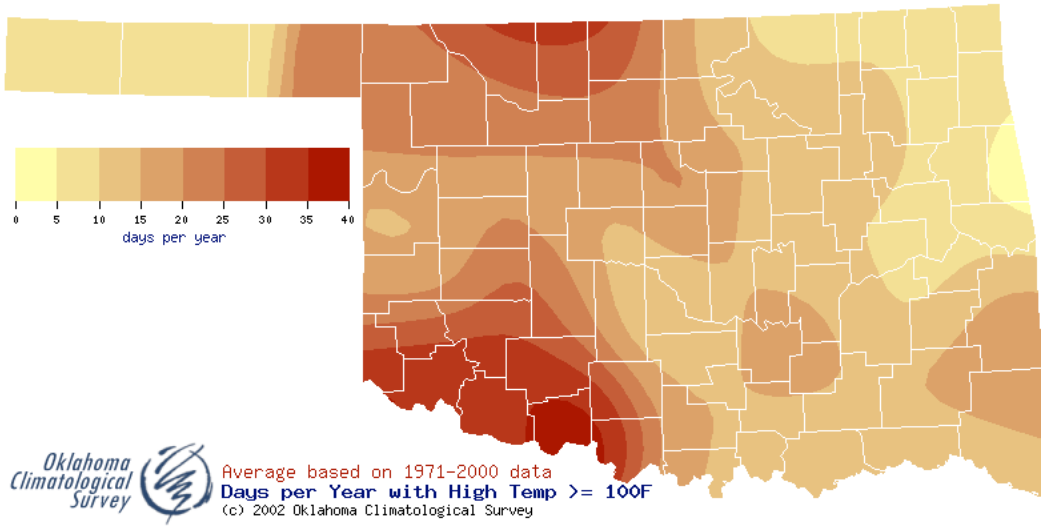


Heat Index Chart



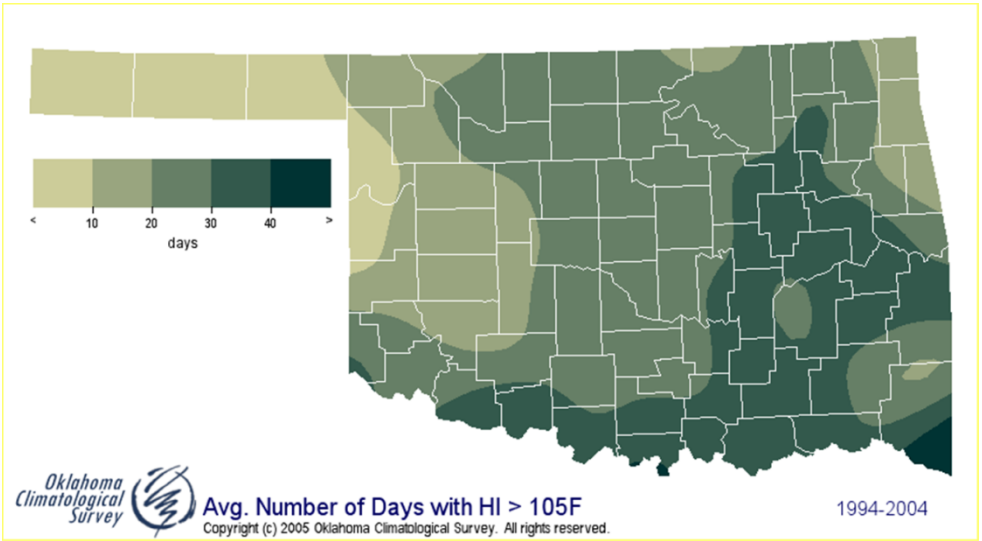
Graphic courtesy of the NWS

Heat Index in Oklahoma



Actual Temperature

Heat Index

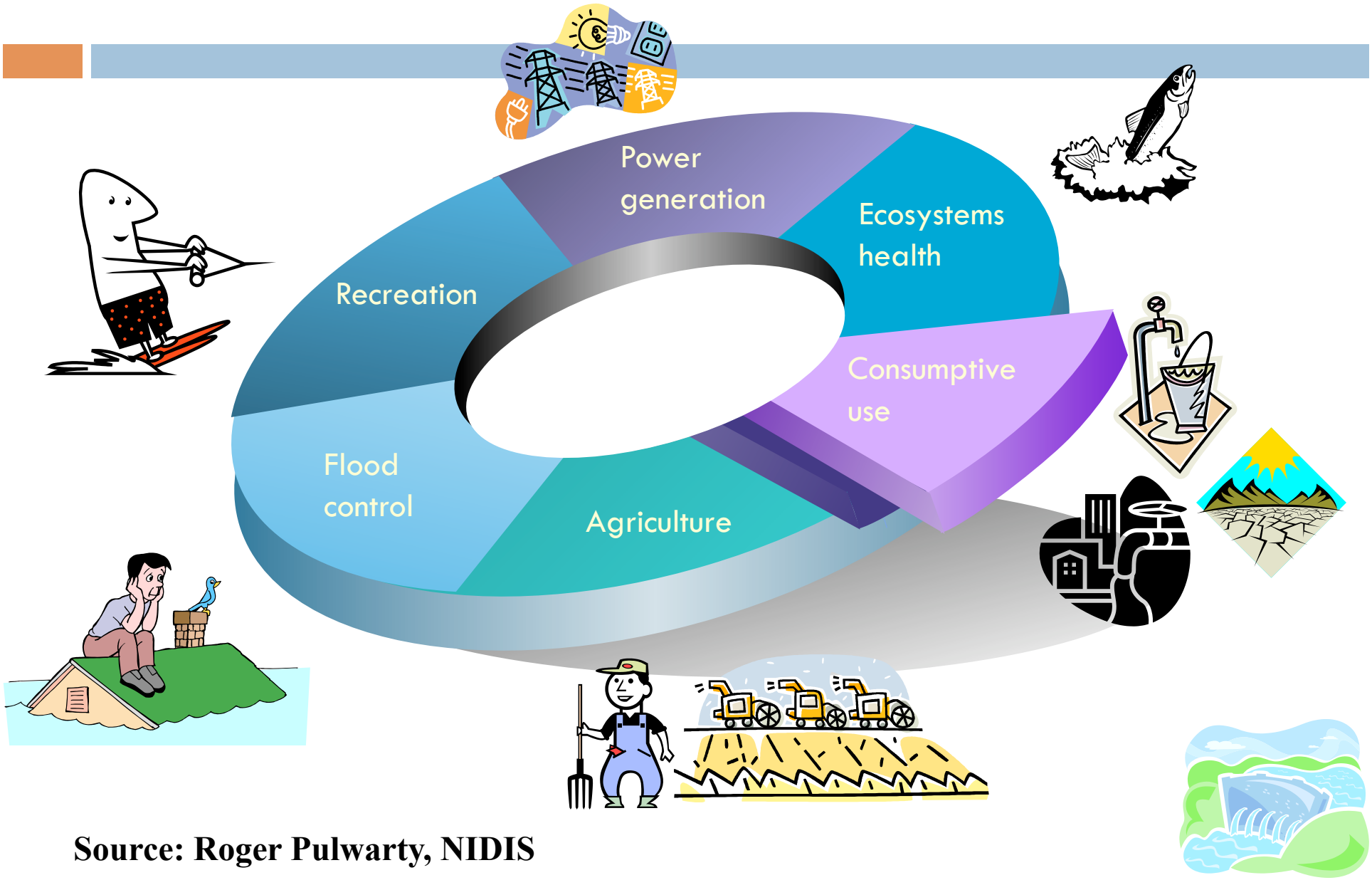


Drought

- Persistent period of unusually dry weather that leads to impacts on crops and/or water supplies
- May be severe short-term effects or prolonged, extended droughts
  - "agricultural drought" – usually shorter term, affecting crop growth & pastures
  - "meteorological drought" – extended period of below-normal precipitation
  - "hydrologic drought" – prolonged dryness affecting streams, lakes, and ground water supplies
  - "socio-economic drought" – impacts causing severe economic losses and/or social disruptions
- Associated hazards:
  - Heat waves
  - Wild fires
  - Expansive soils

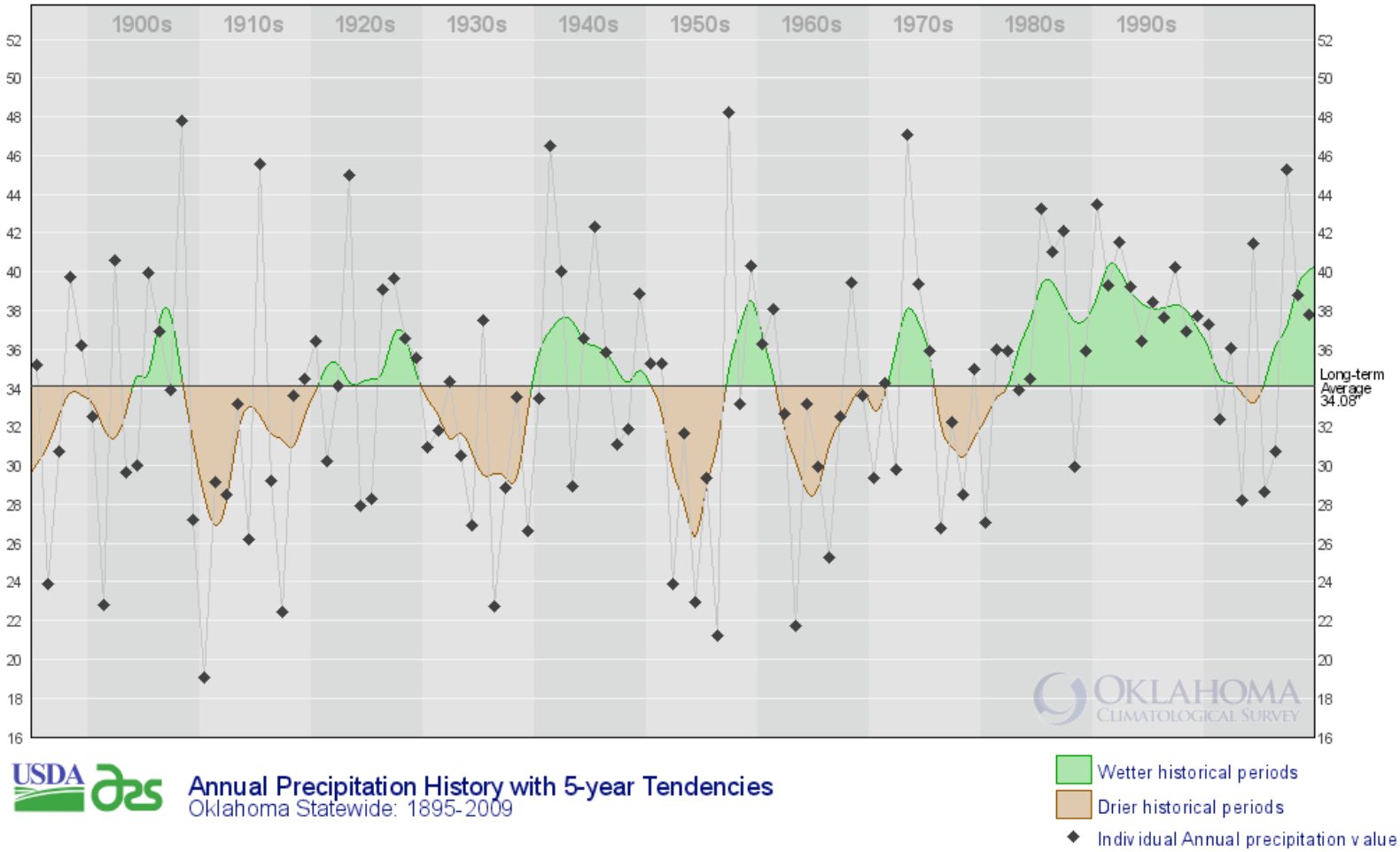
Source: NASA Earth Observatory

Multiple competing values, Multiple competing objectives



Source: Roger Pulwarty, NIDIS

Droughts are a part of Oklahoma



Wildfires

- Over 140,000 wildfires occur each year in the U.S., destroying 900 homes on average
- Key ingredients:
  - Low humidity
  - Relatively high temperatures (large difference between temperature and dewpoint; actual temperature less of a factor)
  - Moderate to strong winds, gusty
  - Dry fuels (leaves, twigs, vegetation)
- These conditions can happen at nearly any time
  - It does not take months or even weeks of dry weather to create explosive conditions
  - Most common conditions from late fall – early spring in the Southern Plains
- The *urban-wildland interface* is particularly susceptible
  - Development in formerly-prairie or woodland areas puts homes close to potential fire fuels
  - Outlying areas may lack fire-fighting capacity (fire hydrants, limited access to vehicles)

Source: NOAA

Protecting Yourself From Wildfires

- Outdoors:
  - Build fires away from nearby trees or bushes.
  - Always have a way to extinguish the fire quickly and completely.
  - Never leave a fire burning unattended.
  - Avoid open burning completely, and especially during dry season.
- Around Your Home:
  - Create a survivable space around your home; an irrigated area near the home, low-growing plants and shrubs further away, clear away dead branches and prune low branches, thin highly flammable vegetation
  - Install fire-resistant roofing materials; hot embers (firebrands) can be blown from a nearby fire onto your roof
  - Vents and chimneys should be screened
  - Clear any debris beneath decks; box them with fire-resistant materials
  - Make sure roads are clearly marked so fire vehicles can get to your home easily

Source: Kelly Hurt, Arkansas Firewise