The Nature of Storms

Essential Questions:

- How do thunderstorms form?
- What are the different types of thunderstorms
- What is the life cycle of a thunderstorm

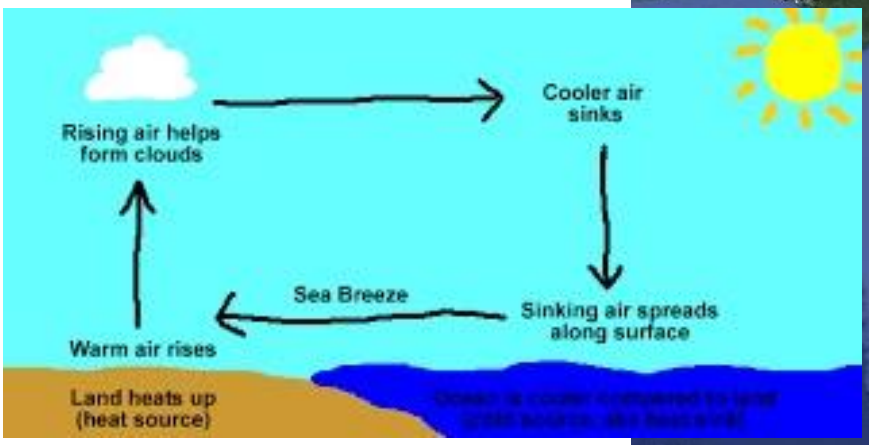
Thunderstorms

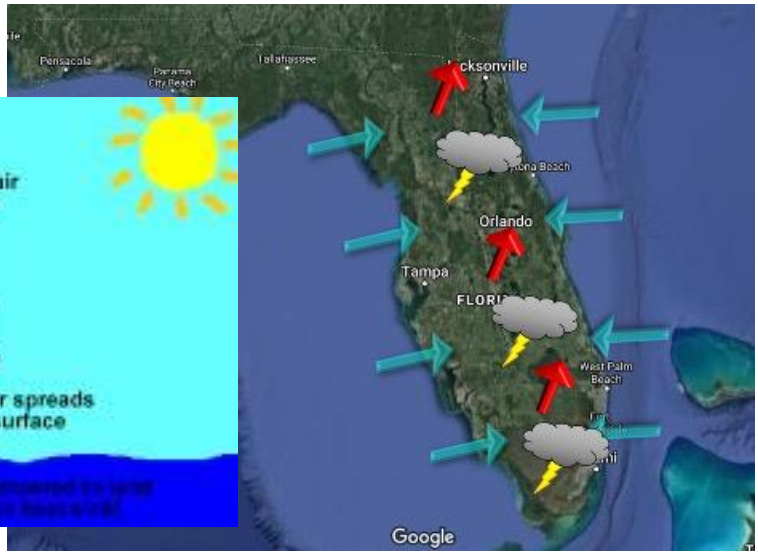
Three things needed to form a thunderstorm

- **Moisture**
  - Abundant moisture in lower atmosphere
    - Water condenses to form clouds
    - Latent heat is released
    - Air is warmed and continues to rise
- **Lifting**
  - Cold front pushing warm air up
  - Mountains
  - Warm water
  - Cities
- **Stability:** the ability of air to resist rising
  - Occurs when the density of the air at the surface and above is the same or nearly the same
  - Unstable air will rise!!
    - Warm air rises: warm air at surface, colder above
    - More unstable during the day because air is warmer at the surface
    - Things that cause lifting cause instability

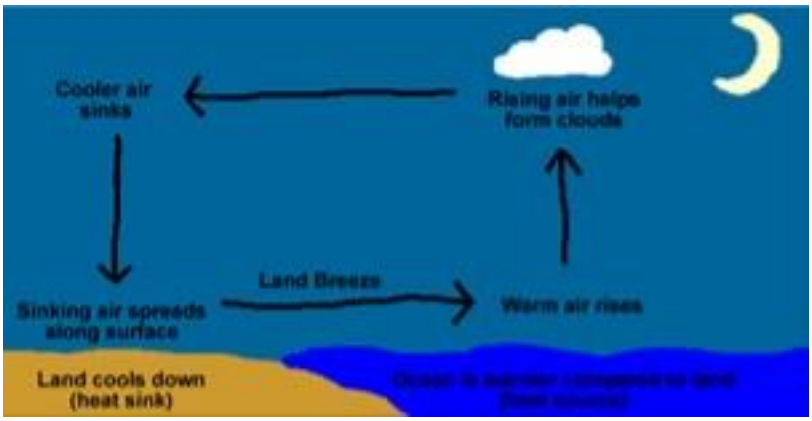
Types of Thunderstorms: Classified by type of lift mechanism

- **Air-mass thunderstorms:** occurs because of unequal heating of Earth's surface
    - **Mountain thunderstorms:** occurs when an air mass rises by orographic lifting. Air moving up the side of a mountain
    - **Sea breeze:** air blowing from the water to land
        - Land warms faster than the water
        - Air rises on above land causing the cooler air above the water to replace the air above the land

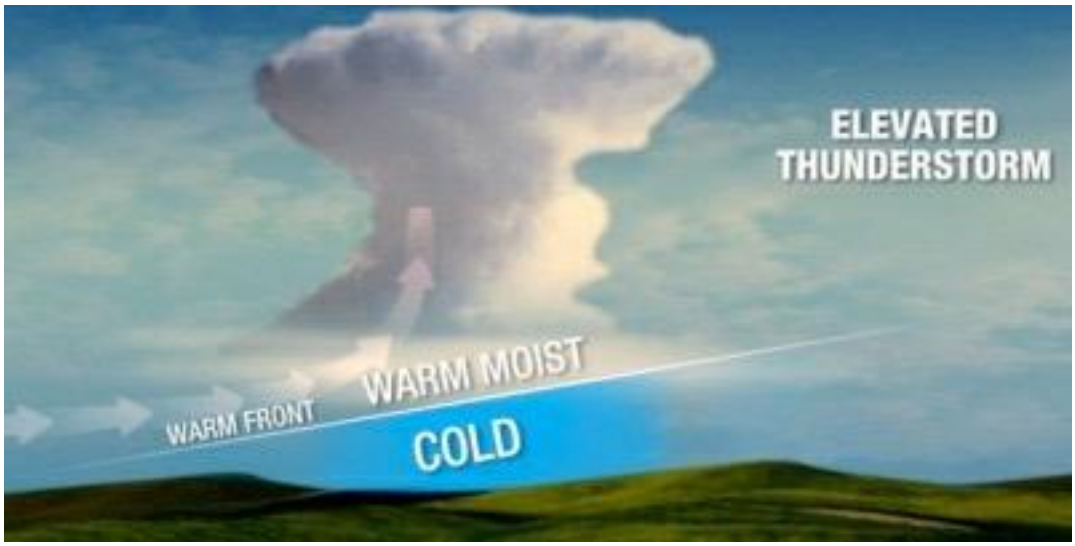




    - **Land breeze:** air blowing from the land to water
        - Does **not** create a thunderstorm on land! Can create rain over water
        - Land cools faster than the water
        - Air rises on above the water causing the cooler air above the land to replace the air above the water



- **Frontal Thunderstorms:** produce mainly by cold fronts
    - Dense, cold air pushes under the warm air, causing the warm air to rapidly rise
    - Produces a line of thunderstorms along the edge of the cold front
    - Can occur day or night
    - Last longer and more severe than air mass thunderstorms
    - Warm fronts can sometimes produce *mild* thunderstorms. Very uncommon.

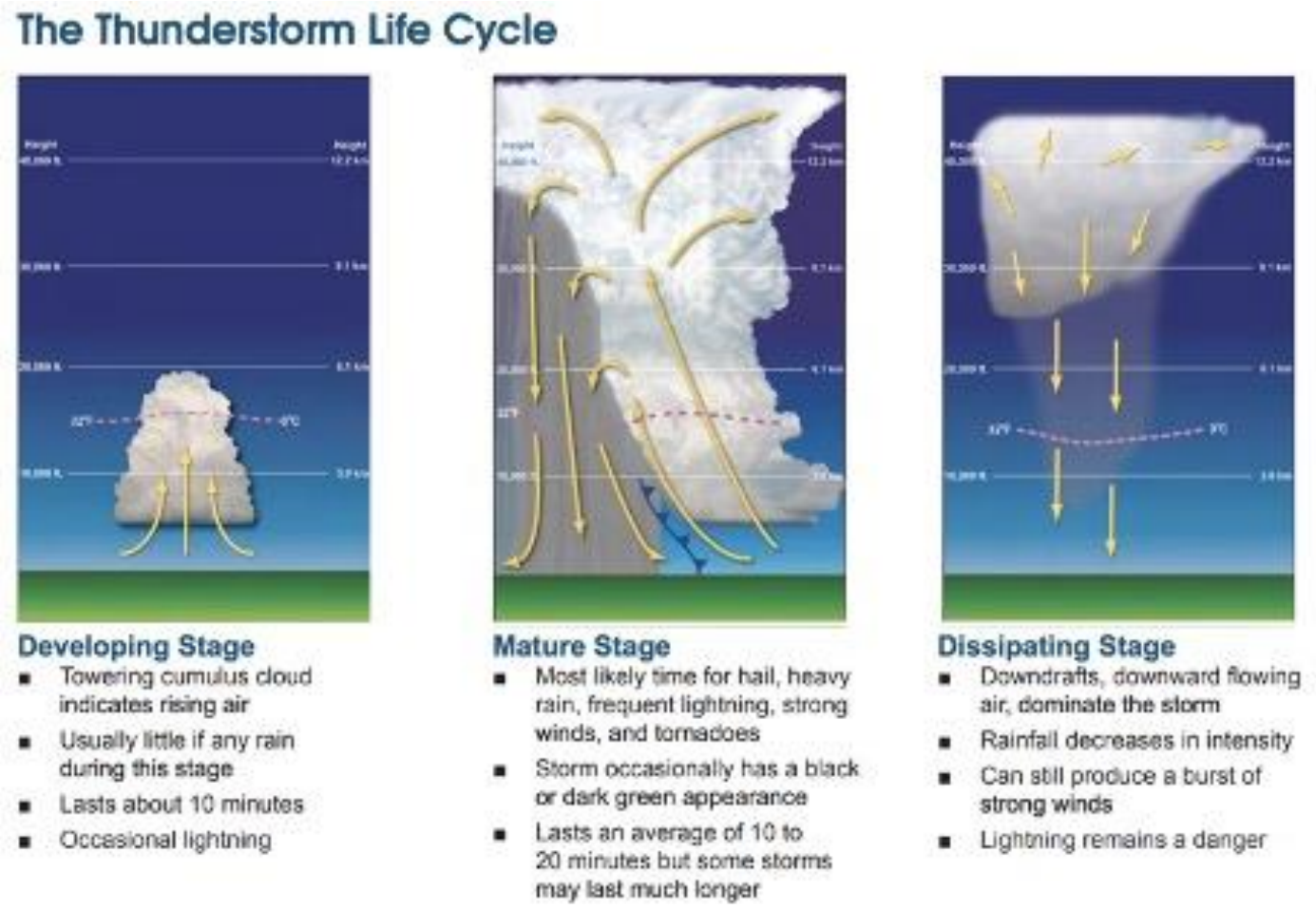


Thunderstorm Development: Three stages. Classified by direction of air movement

- **Cumulus Stage:** "Baby" cumulus
    - Warm air rises, creating updrafts. The air cools until it reaches its dew point
    - At this point, water vapor condenses, causing cumulus cloud formation and releasing latent heat
    - Latent heat causes the air to warm and rise

- **Mature Stage:** Shown by tall & active cumulonimbus
    - Precipitation/rain begins, cooling surrounding air
    - Cooled, dense air sinks to the ground with rain, causing downdrafts
    - Equal amounts of updraft and downdrafts form convection cells with strong winds
    - Heavy rain, sometimes hail is possible. Updrafts keep "tossing" small ice pieces back up in the cloud causing larger and larger hail to form

- **Dissipation Stage**
  - Downdrafts dominate
  - Updrafts slow down and eventually stop
    - Stops because there is little warm, moist air left on the surface
    - This happens because the downward cool air pushes the warn air away removing the "fuel"
  - Clouds stop growing and start to shrink or "dissipate"



Hazards of Severe Thunderstorms
(Lightning, Floods,& Tornadoes)

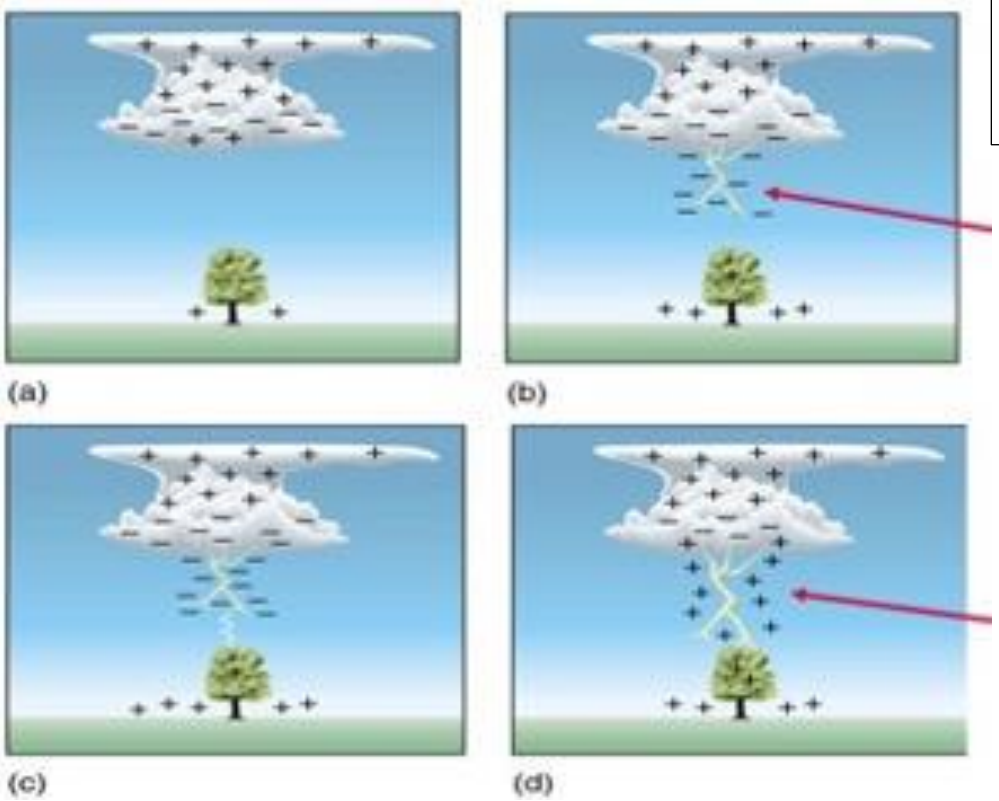
- **Lighting:** Electricity created by rapid rush of air in the cloud, due to friction between updrafts and downdrafts.

    - Friction rubs/knocks electrons off
    - Negative charges drop to bottom of cloud and positive charges carried to top of cloud
    - Negative charges at bottom of the cloud attracts positive charges on the ground
    - Charge builds up and becomes too great, lightning/current jumps from negative area (cloud) to positive area (ground). Could also go from negative area of a cloud to positive area of a cloud.
    - 5x hotter than sun

- **Thunder:** due to rapid expansion (heating), followed by immediate contraction of air.
    - Sends out sound wave at 5 miles/sec.
    - Count seconds between lightning flash and thunder. Divide by 5 to get how many miles away the lightning occurred

Thunderstorm w/ lightning

https://www.youtube.com/watch?v=gVKEM4K8J8A



- **Flash Flooding:** Causes the most deaths out of all thunderstorm hazards
  - Causes of flash flooding:
    - Heavy rain in short amount of time
    - Multiple thunderstorms over same area
    - Urban areas receiving lots of rain in a short time. Buildings, roads, and parking lots cause faster run off, overwhelming storm drains
  - Rain falls faster than the ground can absorb and faster than the rivers can transport
  - Flash flooding occurs within 6 hours of its cause. That is the difference between a regular flood

Dayton Flood of 1913 Pictures

Cleveland 9-2020: flash flooding

https://www.youtube.com/watch?v=ieKa1ySrzNk

Severe Weather

Essential Questions:

- Why are some thunderstorms more severe than others?
- What are the dangers of severe weather?
- How do tornadoes form?

- Not all thunderstorms are created equal!
- Severe thunderstorms can develop into self-sustaining, extremely powerful storms called supercells
- These furious storms can last for several hours and can have updrafts as strong as 150 mph

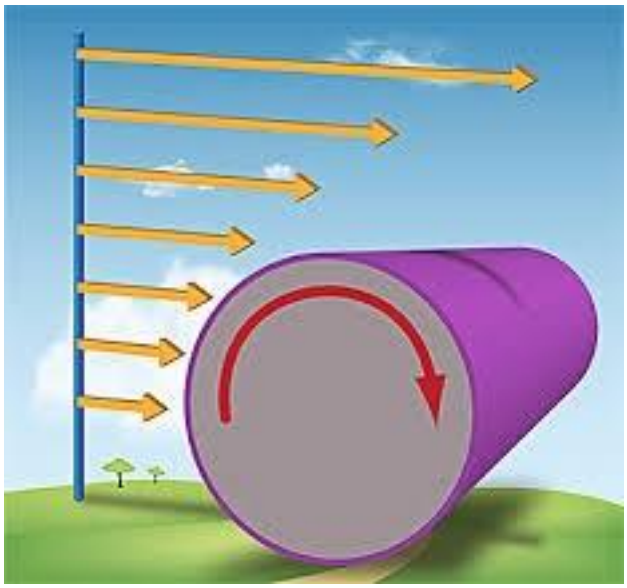
- **Supercells**
  - An anvil shaped cumulonimbus cloud is characteristic of many severe thunderstorms
  - Very few supercells generate tornadoes

- **Strong Winds**
  - Violent downdrafts that are concentrated in a local area are called downbursts
  - Based on the size of the area they affect; downbursts are classified as either macrobursts or microbursts
    - Macrobursts
      - path of destruction up to 5km wide
      - wind speeds >200 km/hr
      - last up to 30 minutes
    - Microbursts
      - path of destruction < 3km wide
      - wind speeds >250 km/hr
      - last < 10 minutes
- **Hail**
  - Precipitation in form of balls of ice.
    - Water droplets rise high enough in a cumulonimbus cloud where the temperature is below freezing
    - The frozen droplets moves up and down in the updrafts and downdrafts, growing in size

Hailstorm
https://www.youtube.com/watch?v=QuoLFnxCK1M

- **Tornadoes:** Third hazard of severe thunderstorms
  - Violent, whirling, column of air in contact/touching the ground
  - Prior to ground contact, it is a funnel cloud
  - Form when wind speed & direction change suddenly with height, creating *wind shearing*.

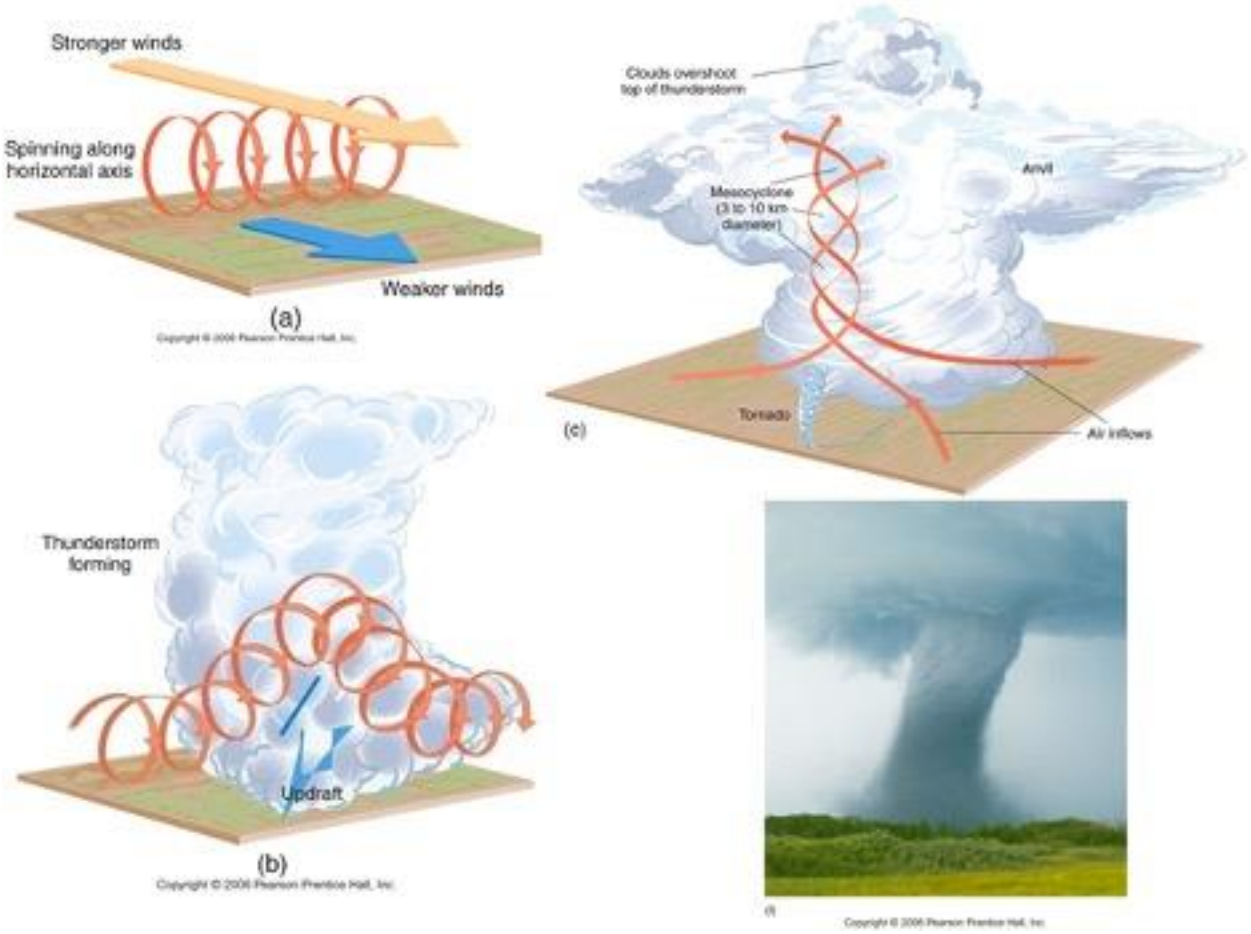
https://www.youtube.com/watch?v=uH9A-7Y3lL0



- Begins with air moving horizontally → on the surface
- Air begins to stretch out. More stretching = faster air/wind
  - This stretching is *wind shearing*
- Storm updrafts flip/tilts the air up ↑

Wind sheering

https://www.youtube.com/watch?v=E8KF0z0ey4E



- **Tornado classification**
  - Enhanced Fujita Tornado Intensity Scale: based on wind speed and damage
    - Determined after the tornado has passed-when damage can be determined
    - Takes into account the type of structure combined with damage
      - Buildings more poorly constructed will have more damage

EF Rating	Wind Speeds	Expected Damage		
EF-0	65-85 mph	'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.		
EF-1	86-110 mph	'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.		
EF-2	111-135 mph	'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.		
EF-3	136-165 mph	'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.		
EF-4	166-200 mph	'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse.		
EF-5	> 200 mph	'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped.		

Enhanced Fujita Scale for Tornados

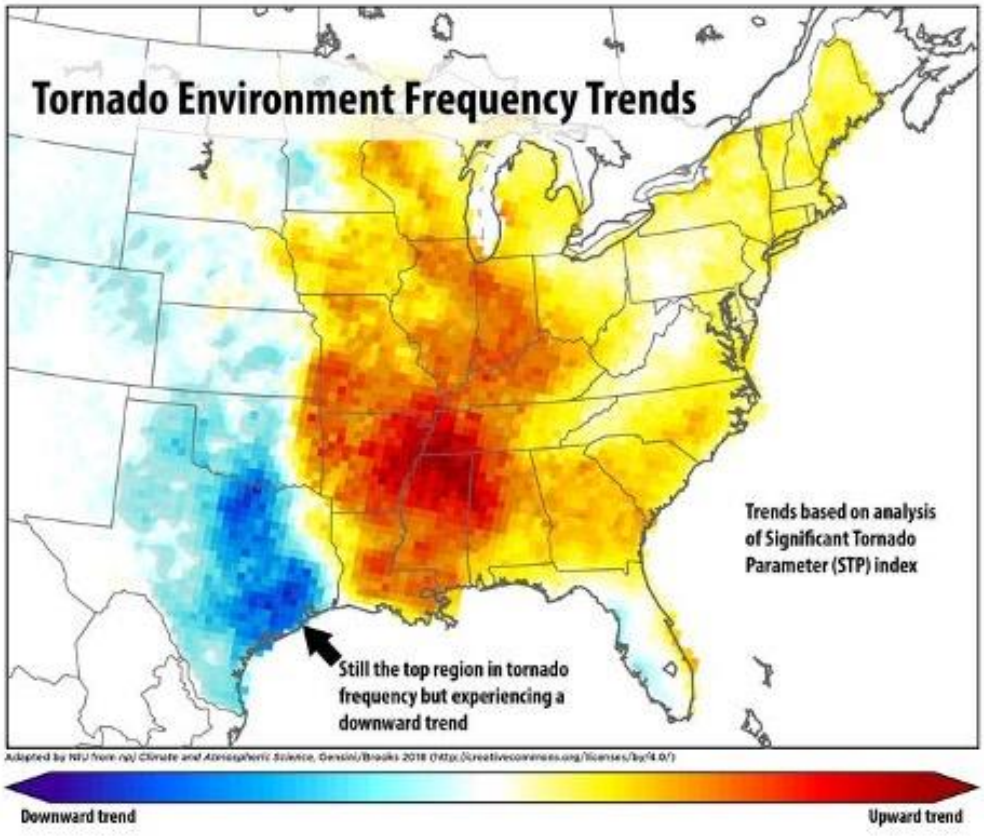
The Enhanced Fujita Scale (EF), introduced in 2007, provides estimates of tornado strength based on damage surveys. The original scale was developed by Dr. Theodore Fujita and implemented in 1971.

Wind Speed	EF Scale	Typical Damage
65-85 mph	0	Peels surface off some roofs, some damage to gutters or siding
86-110 mph	1	Roof severely stripped, mobile homes overturned or badly damaged, loss of exterior doors, windows and other glass broken
111-135 mph	2	Roofs torn off well-constructed homes; foundations of frame homes shifted; mobile homes completely destroyed
136-165 mph	3	Entire stories of well-constructed homes destroyed; severe damage to large buildings such as shopping malls
166-200 mph	4	Well-constructed houses and whole-frame homes completely leveled
200+ mph	5	Strong frame houses leveled off foundations and swept away; high-rise buildings have significant structural deformation

Source: Weather Underground (*www.wunderground.com/resources/severe/fujita_scale.asp*)

CITIZENS

- **Tornado Distribution:** When and where tornadoes occur
  - Occur most often in the spring in the central U.S. where cold cP air mass collides with mT air mass. Large temperature difference between the two air masses.
  - As the warm, moist mT air mass moves north during February to May, tornado occurrences also move north.
  - Usually occur in the late afternoon
  - Many of the 700 plus tornadoes in the U.S. each occur in **"Tornado Alley"**



Know tornado safety

American Red Cross

Join us. Get prepared.

Myth	Fact
Opening windows in a home or building during a tornado will help equalize pressure.	Opening windows will have no effect. Stay away from windows and exterior walls. Take shelter in the basement, storm cellar or an interior room without windows on the lowest floor.
If you are caught driving during a tornado, you should always get out of your car and get in a ditch.	Try to drive to the closest sturdy shelter. If there is flying debris, pull over and park. Stay in the car with the seat belt on and the engine running. Put your head below the windows, covering your head with your hands and a blanket.
Cities are protected from tornadoes because of the tall buildings.	Tall buildings do not protect from tornadoes. Cities cover a small geographical area so the chances of being directly hit are small. However, tornadoes can strike anywhere.
Taking shelter in the southwest corner of your home will protect you.	This is based on an outdated theory that all tornadoes come from the northeast. Tornadoes can move from any direction and no one corner of your home is always safe.

Download our Tornado App and other apps at redcross.org/mobileapps.

Tropical Storms

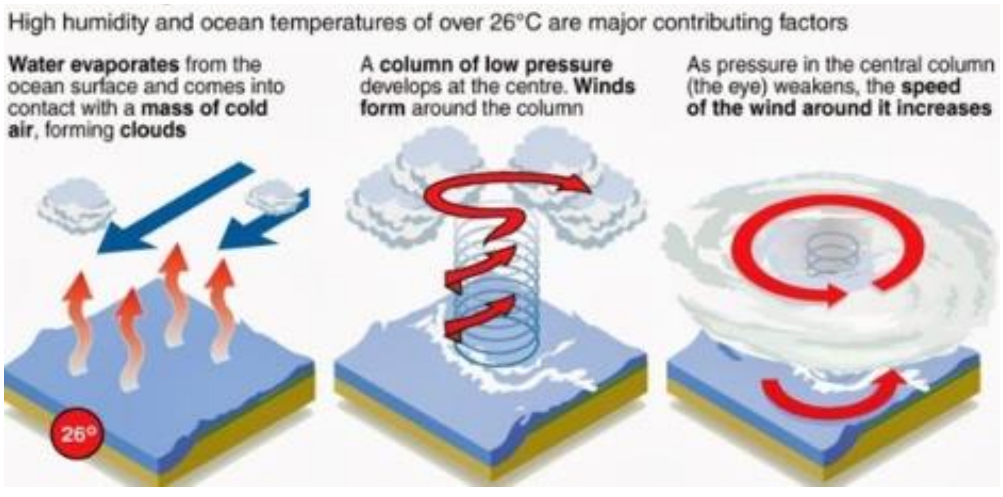
Essential Questions:

- How do tropical cyclones form?
- What is the life cycle of a cyclone?
- What are some dangers associated with hurricanes?

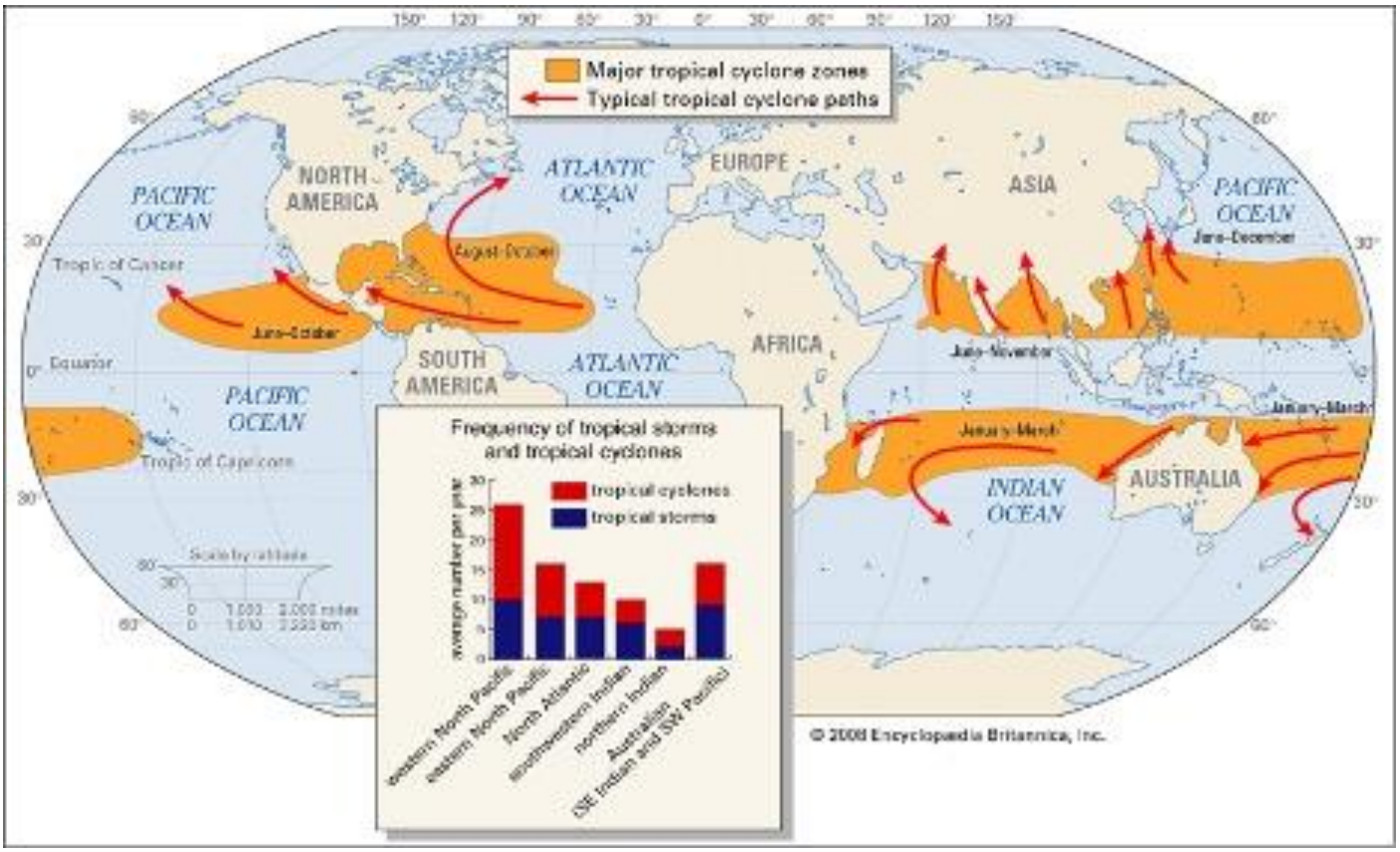
Review Coriolis effect

- **Tropical cyclones:** during late summer and fall, the tropics experience conditions ideal for the formation of large, rotating, low pressure tropical storms called tropical cyclones
  - Cyclone location: all tropical oceans except the South Atlantic Ocean and Pacific Ocean off the west coast of South America. The waters are to cool at these locations.
    - Called hurricanes in U.S. & Atlantic Ocean
    - Called typhoons in the Pacific

- **Tropical Cyclone Formation:** Needs two things
  1. Warm water
  2. Disturbance causing lift: low pressure/rising air at equator; ITCZ
  - Warm moist air rises, condenses, releasing latent heat, and the rise continues!
    - Released heat causes continued rising, increased energy and increased spinning speed. The spinning causes the wind to increase
  - Overall result:
    - Low pressure in the cyclone center
    - Spiraling surface wind speed increases. The lower the pressure the stronger the storm!

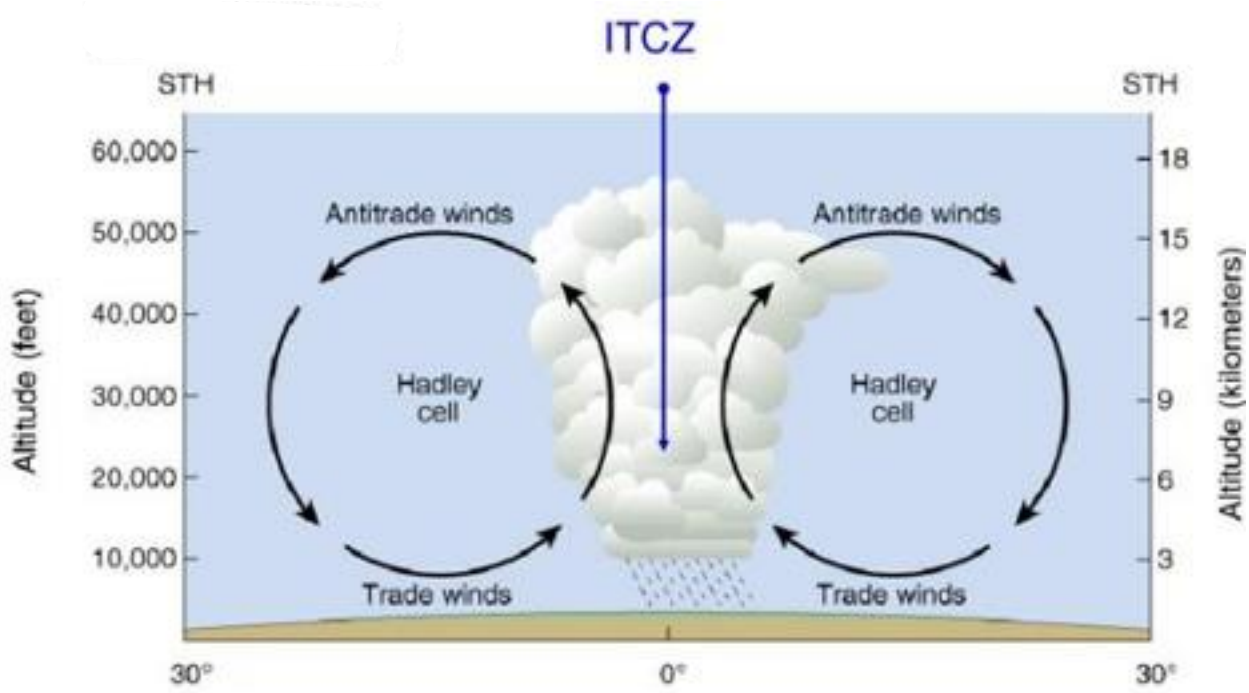


- **Tropical Cyclone Movement**
  - Moves with wind currents that steer them: Trade Winds
  - Lasts until no warm ocean water energy is available to sustain it. Energy no longer available when it reaches…
    1. Land: losses moisture
    2. Cold water: losses warmth (heat)



- **Tropical Cyclone Stages**

  - **Tropical Disturbance:**
    - Weak low pressure system where air *<u>rises</u>* because it is *<u>warm</u>* or lifted by ITCZ (Intertropical Convergence Zone)
    - May be a band of thunderstorms located in the tropics



ITCZ = Inter-tropical convergence Zone (Low Pressure)

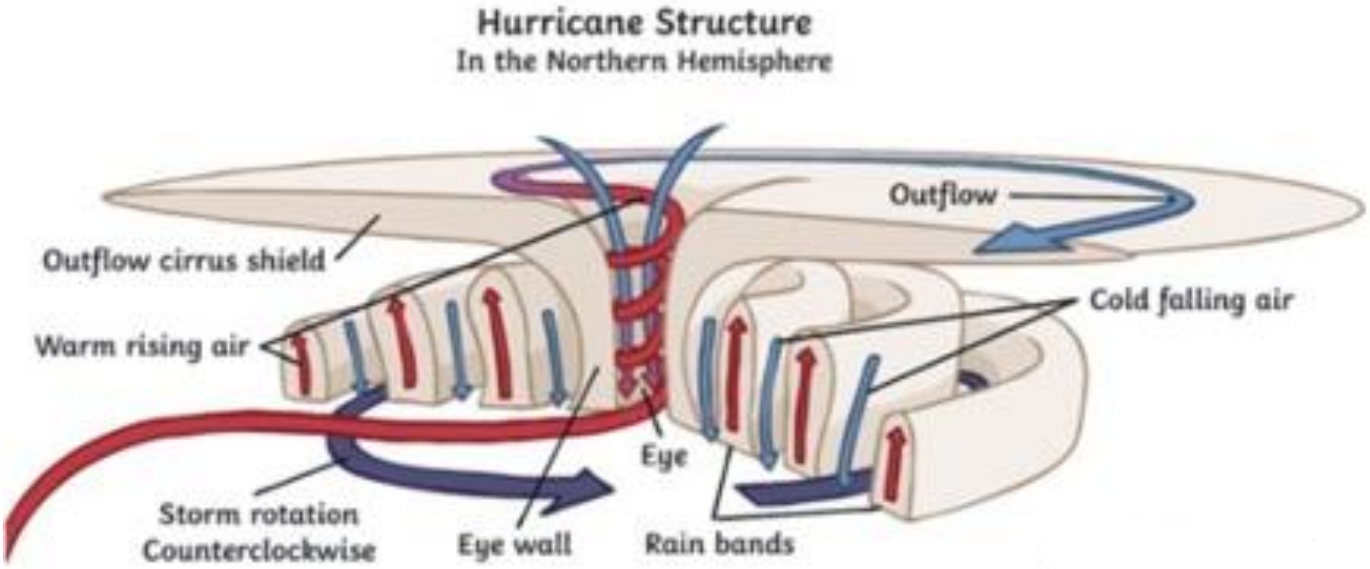
STH = Sub-tropical High (High Pressure)

- **Tropical Depression & Tropical Storm**

  - **Tropical Depression**
    - Formed when spinning around the low pressure center begins
  - **Tropical Storm**
    - Forms when wind speeds exceed 62 km/h

- **Tropical Cyclone/Hurricane**

  - **Hurricane**
    - Formed when winds exceed 119 km/h, and the *eye* is present
    - The eye is calm and an area of extremely low pressure even though air is sinking
    - The *eyewall* (band of wind around the eye) has the strongest/fastest winds



https://www.youtube.com/watch?v=zP4rgvu4xDE

Hurricanes Hazards
(storm surge, wind & flash flooding)

- **Saffir-Simpson Hurricane Scale**
  - Based on the current conditions
    - Current wind speed
    - Current pressure
    - *Storm surge* damage potential
      - not actual damage like the Fujita Tornado Scale
  - Based a 1-5 scale
  - A hurricane move up & down through the different levels throughout its life

Tropical Cyclone Categories			
Category	**Wind Speed (mph)**	**Damage at Landfall**	**Storm Surge (feet)**
1	74-95	**Minimal** While wind speeds are quicker than the speed a cheetah can run, there is not much damage to property.	4-5
2	96-110	**Moderate** Wind speeds are as fast or faster than a baseball pitcher's fastball. This category cyclone may break windows and destroy trees.	6-8
3	111-129	**Extensive** This wind speed is similar, or close, to the serving speed of many professional tennis players. This category cyclone can break windows and doors.	9-12
4	130-156	**Extreme** With winds quicker than the world's fastest rollercoaster, there is much damage to property in this category cyclone.	13-18
5	157 or higher	**Catastrophic** This category cyclone causes the most damage. With wind speeds similar to the speed of some high-speed trains, it destroys buildings.	19+

- **Storm Surge**
  - Huge wall of water that is pushed over the land by the hurricane waters
  - Causes 90% of all hurricane deaths

https://www.youtube.com/watch?v=XTvkrLESrwU

- **Wind Damage**
  - 75-150 mph
  - Changes in intensity depending on the path of the hurricane

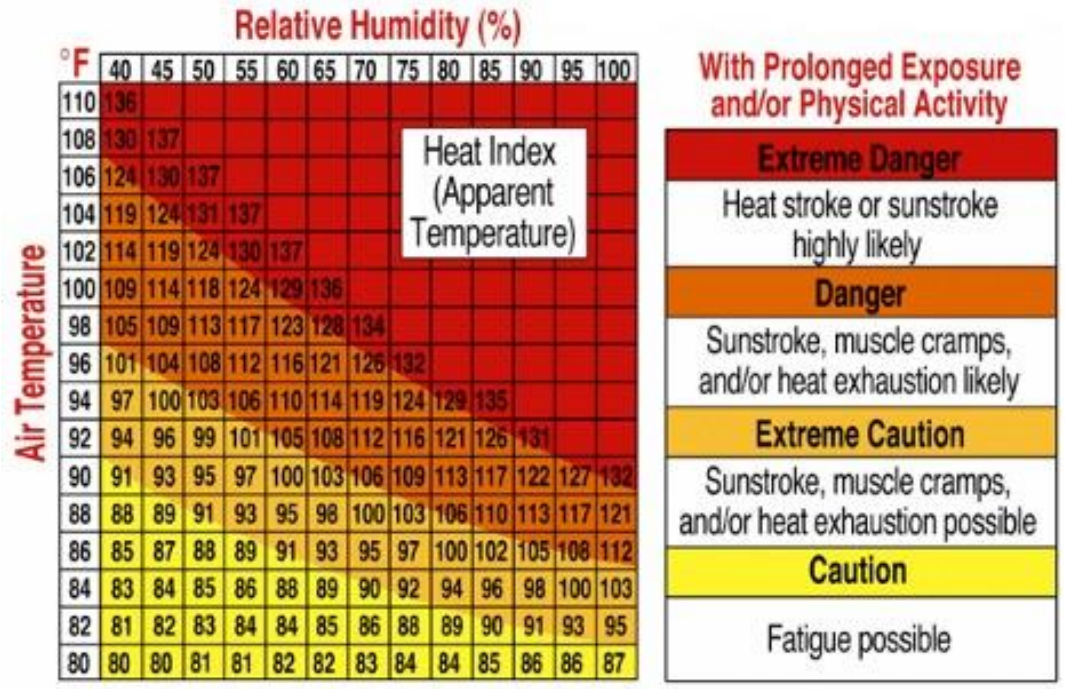
- **Flash Flooding**
  - Due to heavy rain in small amount of time
  - Worse if combined with storm surge

Reoccurring Weather

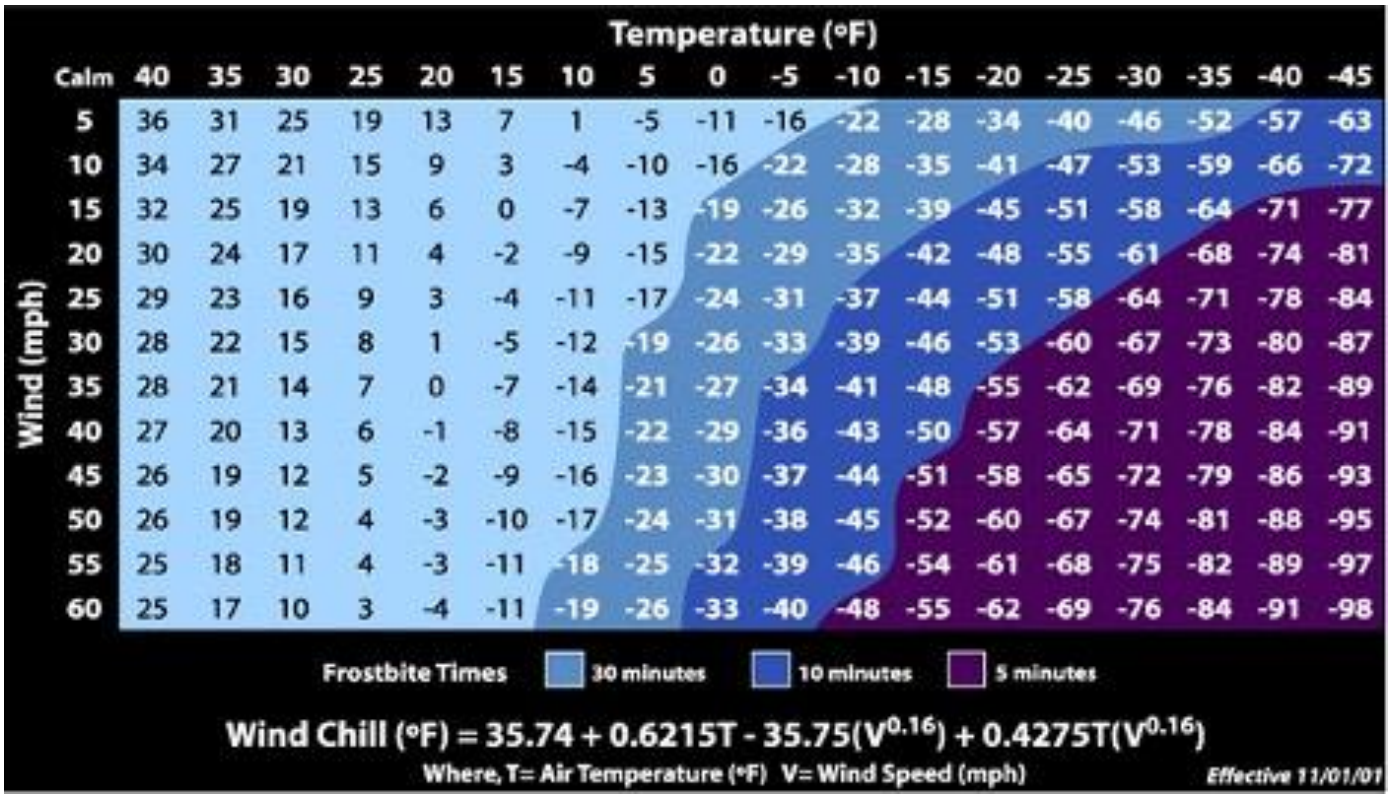
(floods, droughts/heat waves & cold waves)

- **Droughts:** lack of rain fall
  - Extended with no rain or below average rainfall
  - Result of high pressure system. Why?

- **Heat Wave:** Extended period of above normal temperature
  - With a high pressure system there are no clouds because air is sinking, so the sun is intense
  - Usually accompany droughts
  - Winds blowing out/away from center prevent cool air masses from moving in
  - Health problems
  - Heat index: compares combined temperature and humidity to the body's ability to sweat & cool off



- **Cold Wave**: Extended period of below normal temperature
  - Also due to high pressure system, but polar/artic in origin: cP/cA air mass
  - Influenced by jet stream
  - Wind chill factor: how cold the air feels based on the estimated heat loss from skin due to cold temperature & wind



Wind (mph) \ Temperature (°F)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
Calm																		
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph) *Effective 11/01/01*