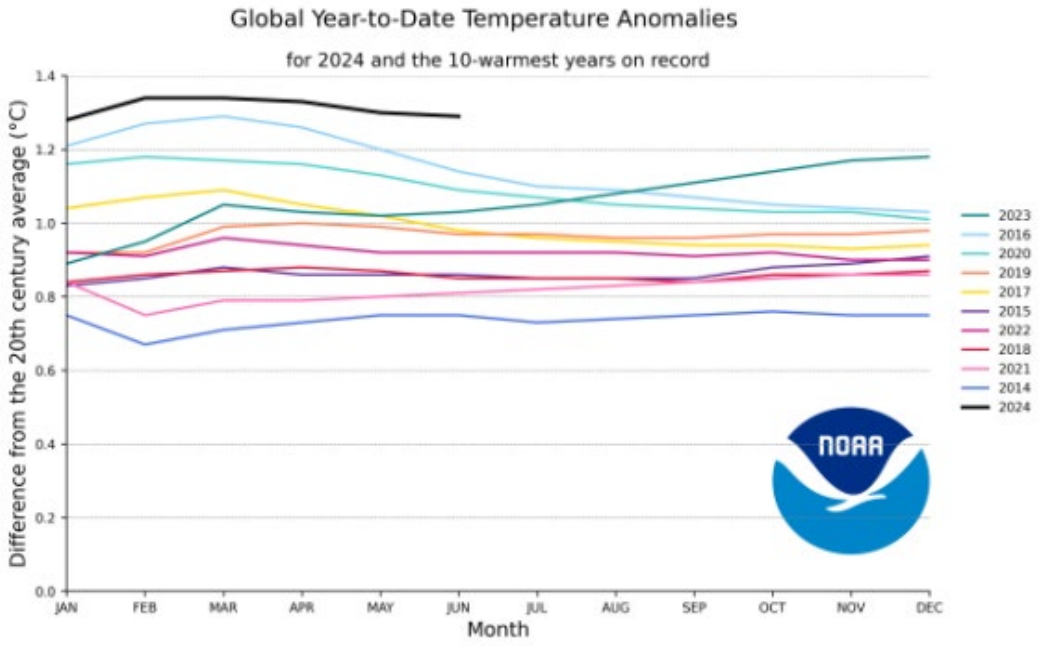
CISA Extreme Weather Outreach

NERC Technical Meeting – Wx Impacts to Energy

"The 10 warmest years in the 143-year record have all occurred since 2010" (NOAA, 2023).



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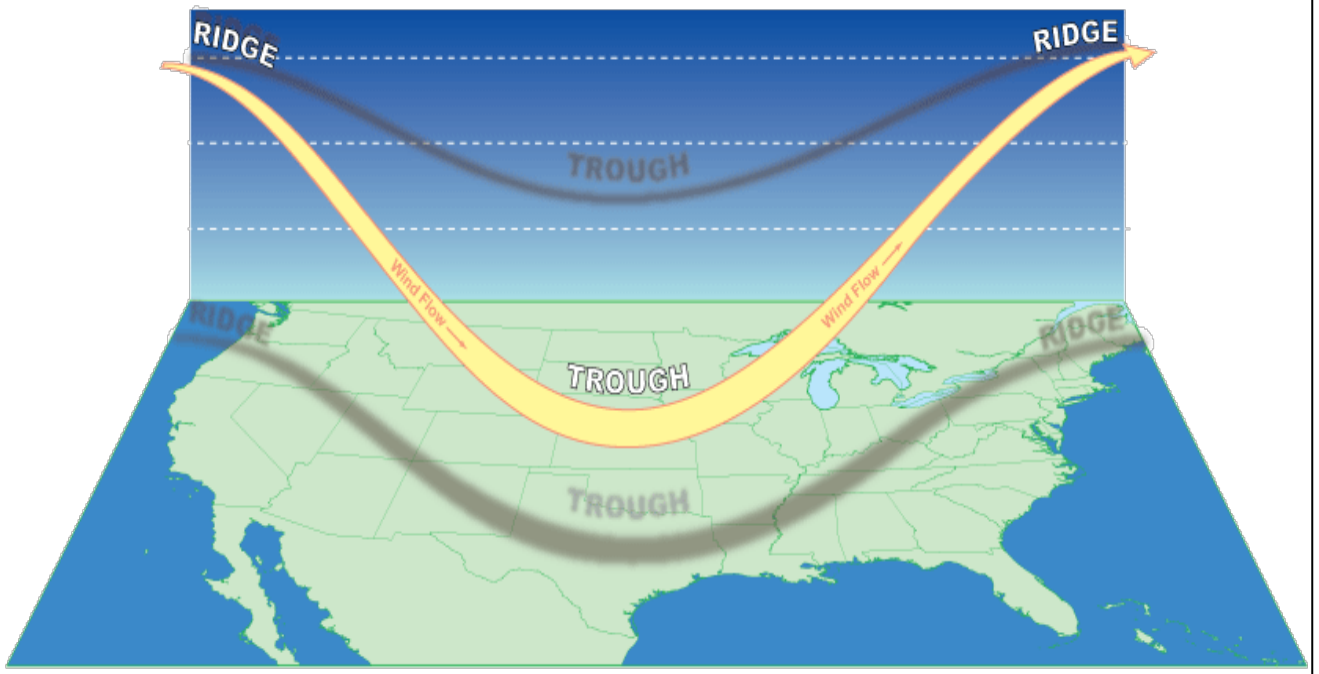
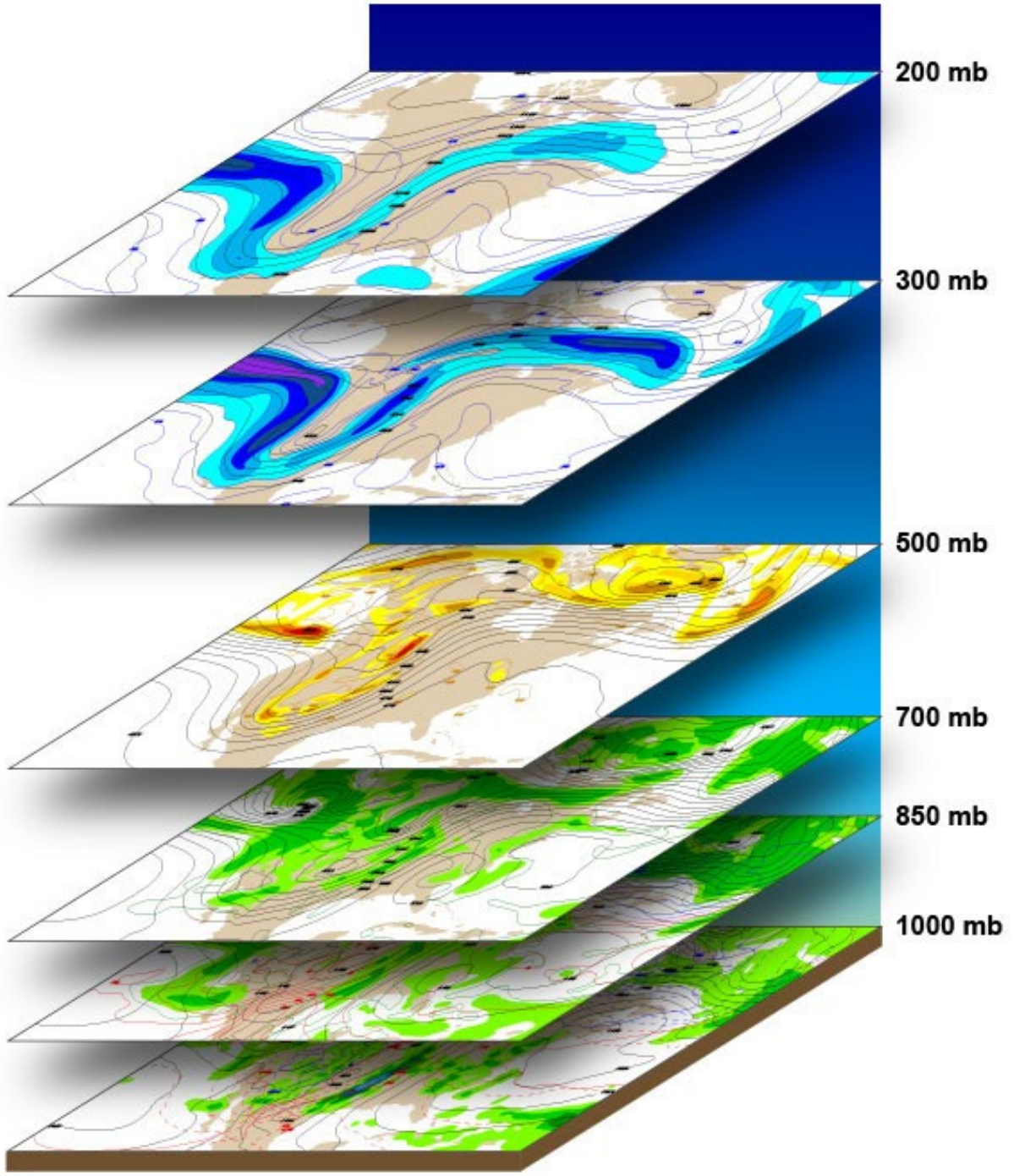
Atmospheric Pressure - Millibar 101

In essence, upper air charts show the atmosphere in three dimensions.

- Wind flowing from a ridge toward a trough is decreasing in height above the surface. Conversely, wind flowing from a trough into a ridge is increasing in height.
- Between the colder, more dense air and the warmer, less dense air is the location of the greatest change (gradient) in heights of any pressure level (NWS Jet Stream). Gradient winds mix cooler winds to the surface.
- By looking at these contours we observe patterns of higher heights (called ridges) and lower heights (called troughs). These ridges and troughs drive the weather we experience at the surface as Highs and Lows.

Atmospheric Pressure is measured with an instrument called a barometer, which is why it is also referred to as barometric pressure.





High and Low Pressures: the Carousal of Weather

A **low-pressure system** has lower pressure at its center than the areas around it. Winds blow towards the low pressure, and the air rises in the atmosphere where they meet.

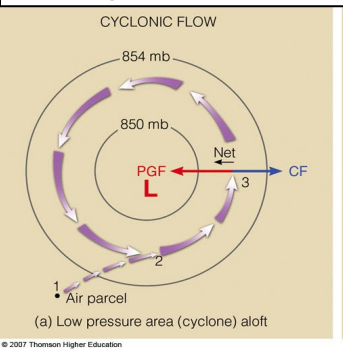
- Because of Earth's spin and the Coriolis effect, winds of a low-pressure system swirl counterclockwise north of the equator.
- As the air rises, the water vapor within it condenses, forming clouds and often precipitation.
- On weather maps, a low-pressure system is labeled with red L.

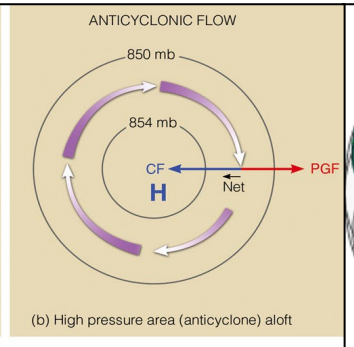
A **high-pressure system** has higher pressure at its center than the areas around it. Winds blow away from high pressure.

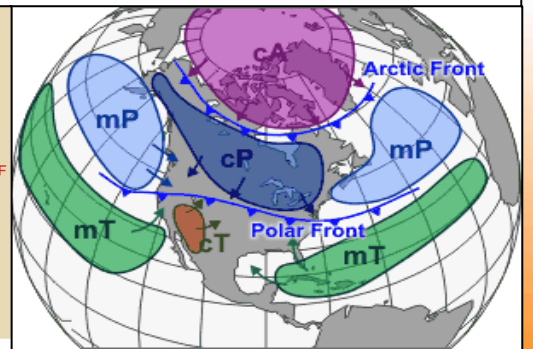
- Swirling in the opposite direction from a low-pressure system, the winds of a high-pressure system rotate clockwise north of the equator (anticyclonic flow).
- Air from higher in the atmosphere sinks down to fill the space left as air is blown outward. On a weather map, you may notice a blue H, denoting the location of a high-pressure system.

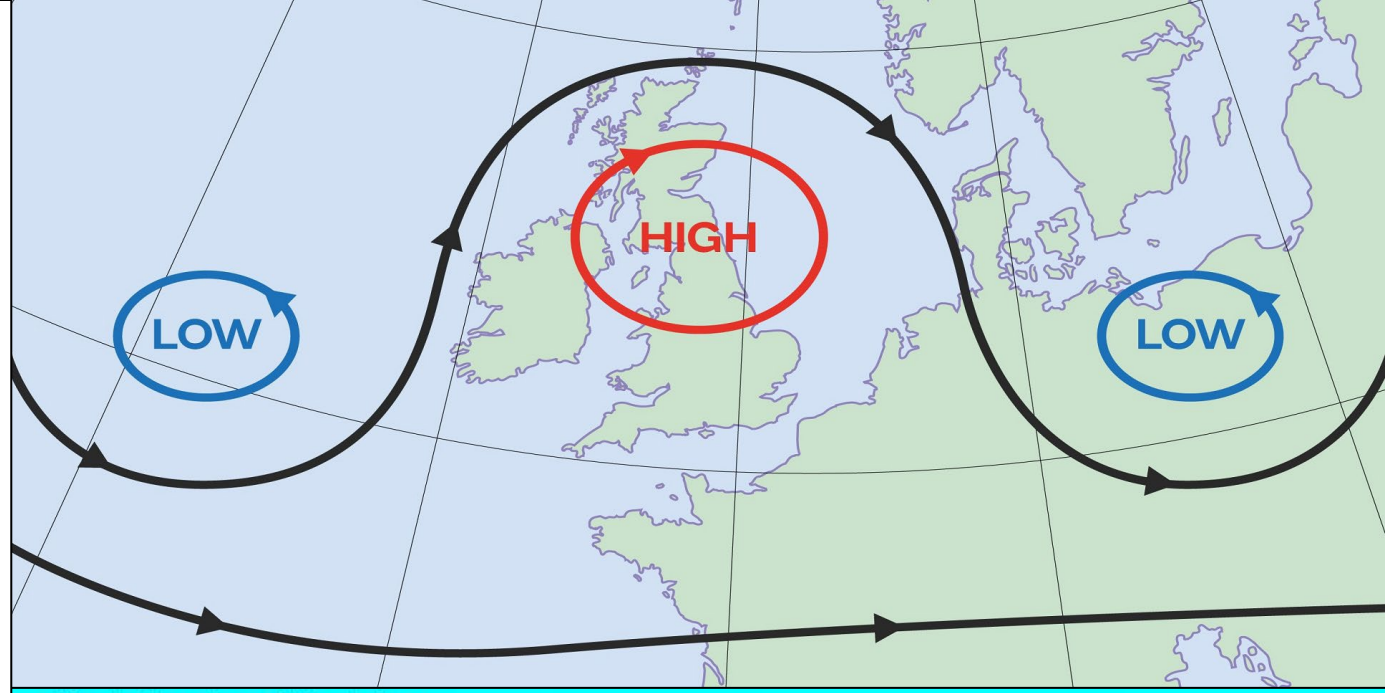
Air pressure depends on the temperature of the air and the density of the air molecules. Air masses differ based off their prevailing fields.

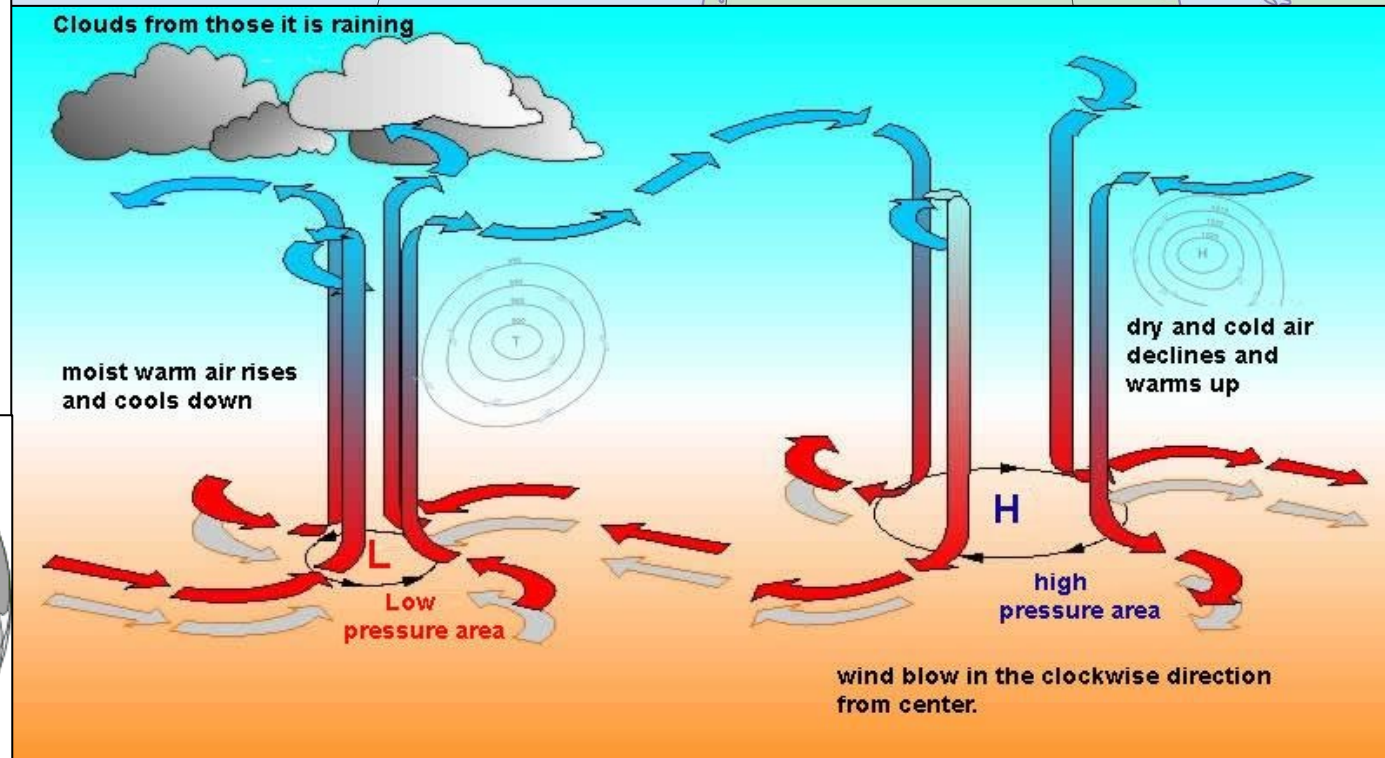
The tighter the gradient between the high and the incoming low, the stronger the winds will be as they mix down from the upper levels.



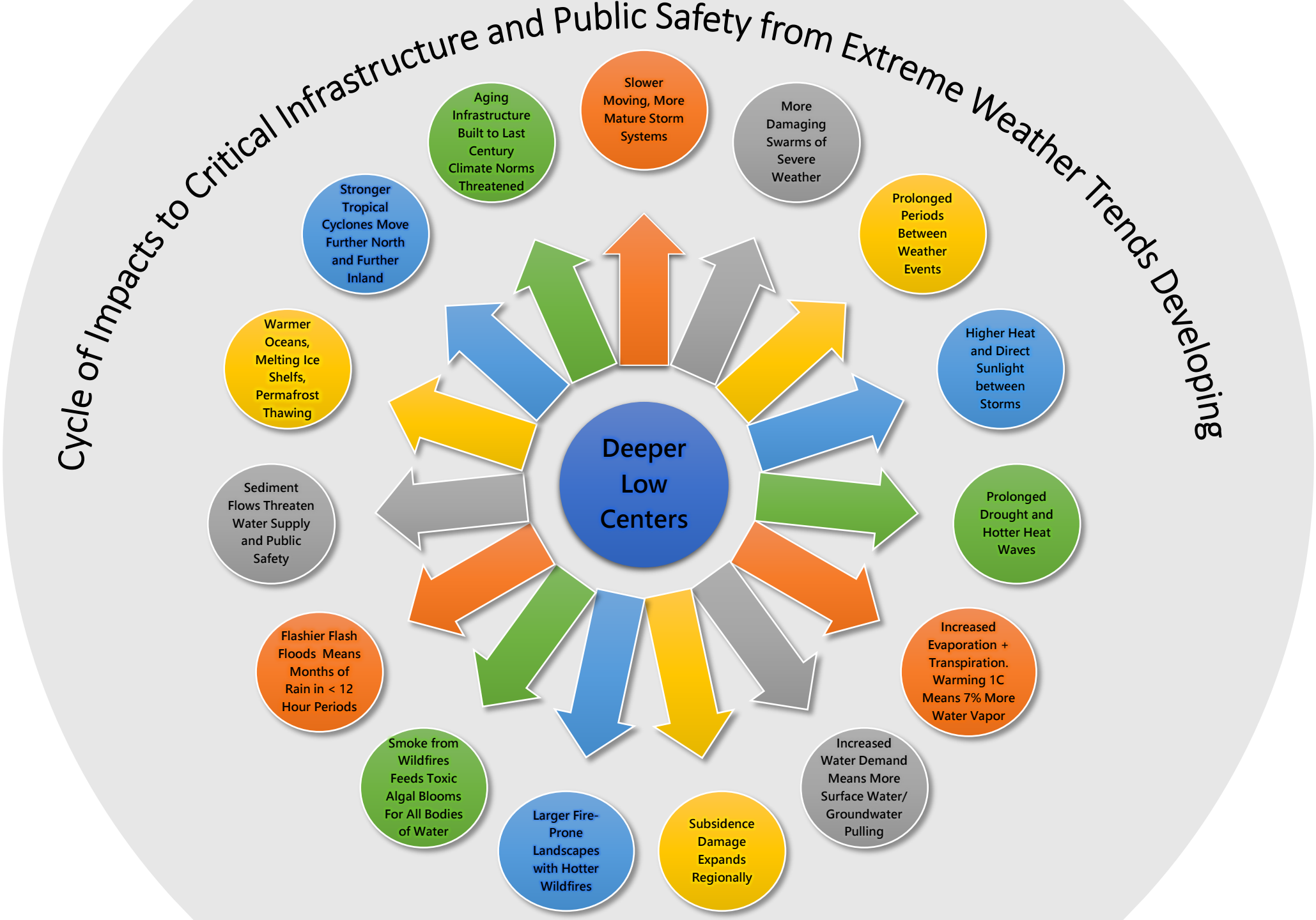








Cycle of Impacts to Critical Infrastructure and Public Safety from Extreme Weather Trends Developing



Weather Event Focus

Eight Main Weather Hazards

1. Extreme Heat
2. Extreme Cold
3. Tropical Cyclones
4. Wildfires
5. Torrential Flooding
6. Drought
7. Severe Storms
8. Sea Level Rise

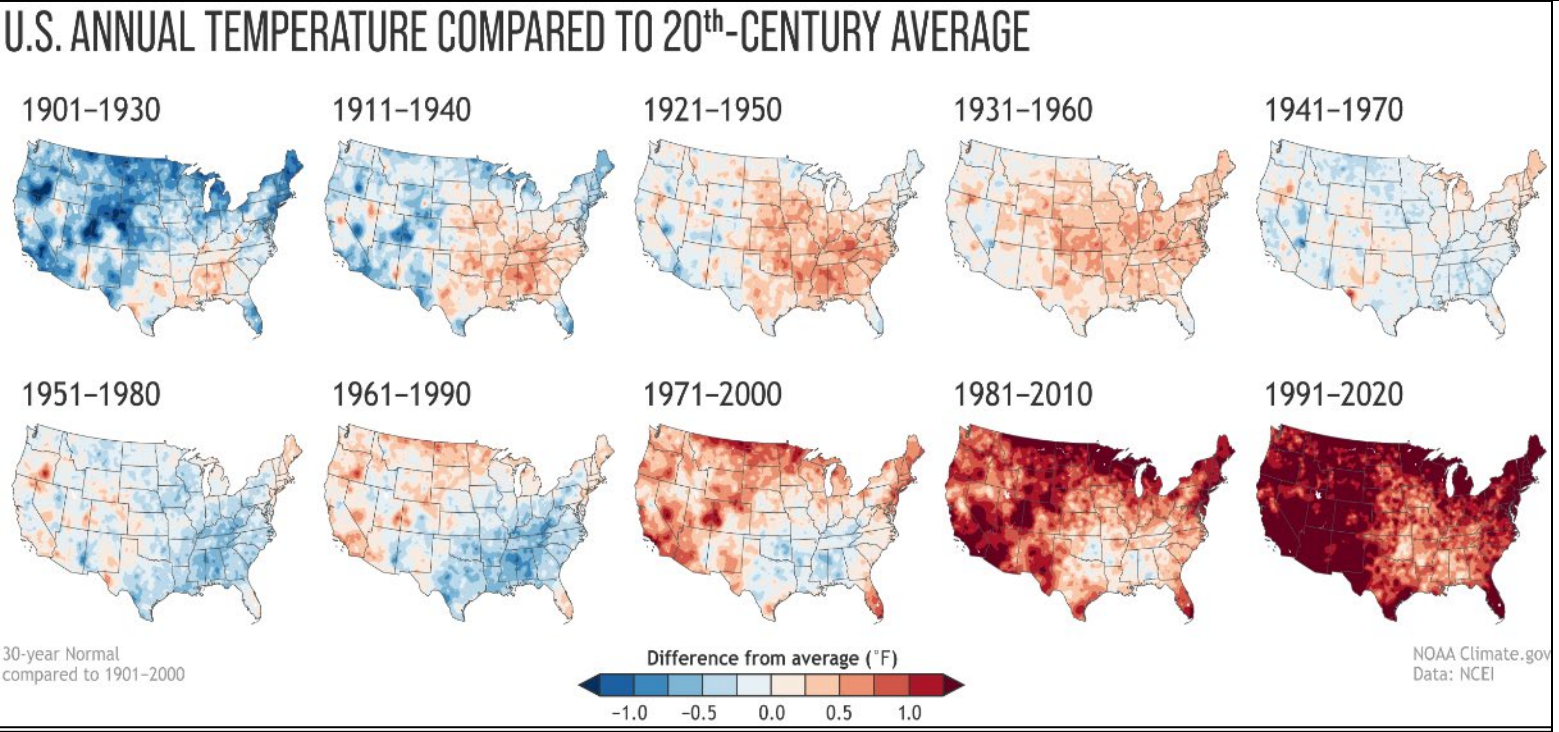
Worsening Trends

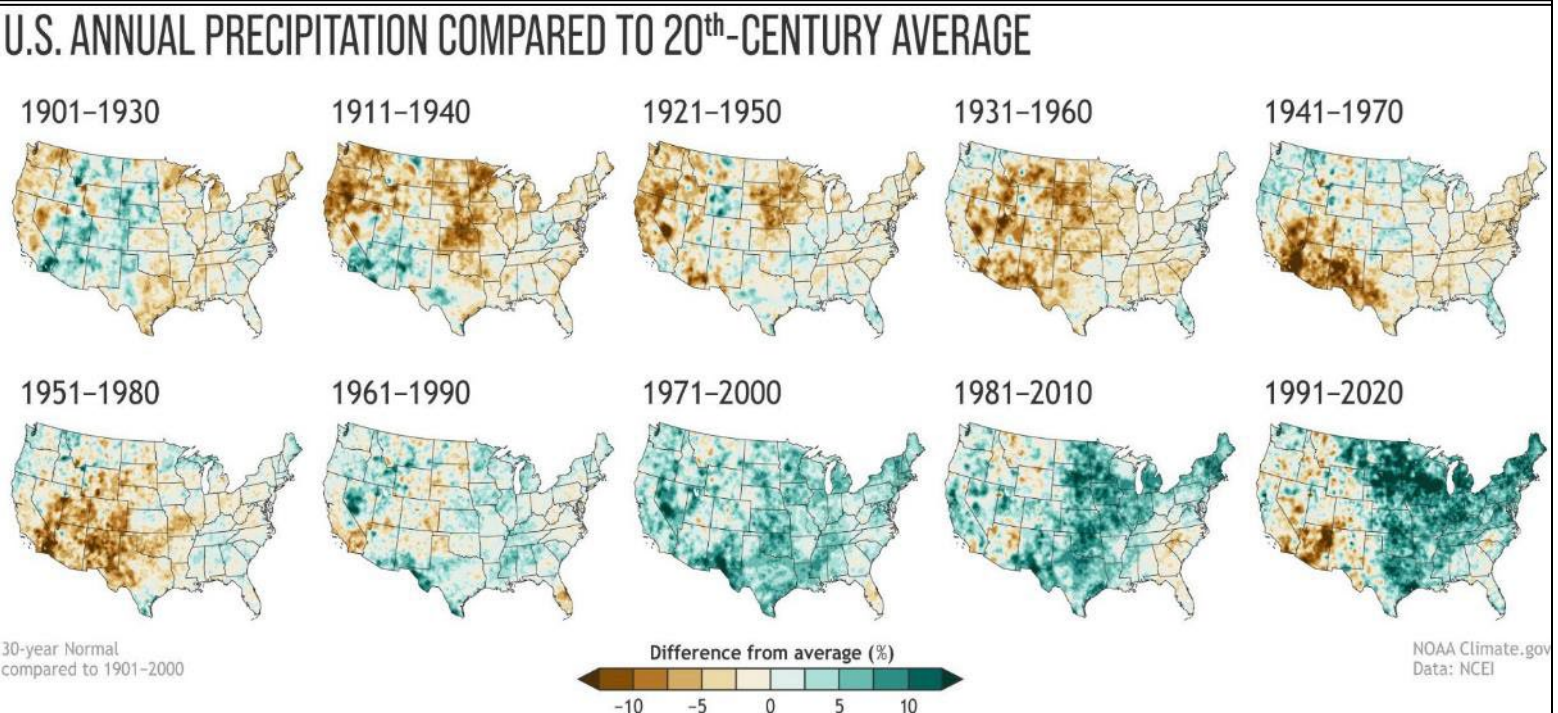
Changes in climatological norms causing more extremes brings cascading impacts across multiple sectors, regions, and infrastructure types.

All regions across the US has already reported impacts from each of the eight weather events highlighted as major concerns with a warming climate.

As hazards worsen in the coming years, there will be a rapidly increasing need for climate resilient facilities and support.

Extreme Weather Events Brings Cascading Impacts to All Critical Infrastructure Sectors and Staff





By 2050, about 63% of the US population could be forced to endure temperatures over 100°F. For areas where triple-digit temperatures are seasonal already, the baseline temperature and the frequency of high heat events will increase.

As average temperatures at the Earth's surface rise, **more evaporation occurs**, which increases overall precipitation. For every 1.8°F of warming, the atmosphere can hold about 7% more moisture.

- Warmer air holds more water because the water vapor molecules it contains move faster than those in colder air making them less likely to condense back to liquid.
    - Sea surface temperatures have risen by 0.5–0.6 °C since the 1950s, and over the oceans this has led to 4% more atmospheric water vapor since the 1970s.
- Heat is released when water vapor condenses to form rain. When the rain falls, it brings the warm air down to the surface raising the temperature throughout the area.
- As temperatures increase at the surface, short-burst heavy rainfall events will increase.
    - The air is on average warmer and moister than it was prior to about 1970 and in turn has likely led to a 5-10% effect on precipitation and storms that is amplified in extreme downpour events.

Wet bulb conditions occur when heat and humidity are too high for sweat to evaporate. Such conditions can be fatal for humans if the temperature and humidity both exceed 95.

- Extreme heat and humidity are growing more common due to the growing distance between major low-pressure centers crossing the US, allowing for direct sunlight heating the surface and a larger presence of greenhouse gases trapping that heat for prolonged periods.

In cities, the air, surface and soil temperatures are on average warmer than in rural areas. This is known as the Urban Heat Island Effect and can contribute to localized downpours.

National Climate Anomalies – June 2024

For June, Arizona and New Mexico each ranked warmest on record. Eighteen additional states ranked among their top-10 warmest June on record.

- A total of 796 counties concentrated across the West, Gulf Coast and Northeast experienced their top-10 warmest June on record, impacting 166 million people.

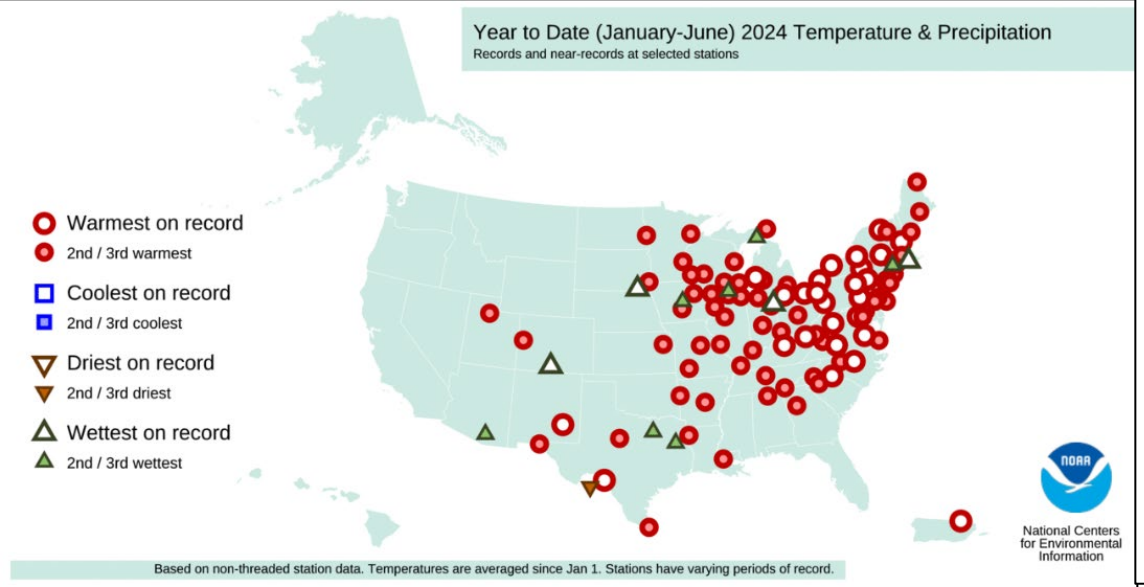
The June precipitation total for the contiguous U.S. was 2.74 inches, 0.18 inch above average, ranking in the driest third of the historical record.

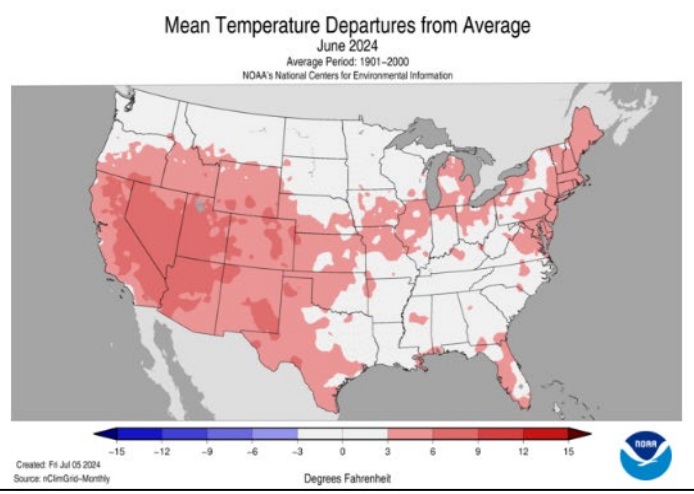
According to the July 2 U.S. Drought Monitor, about 19% of the contiguous U.S. was in drought, up 6% from the end of May.

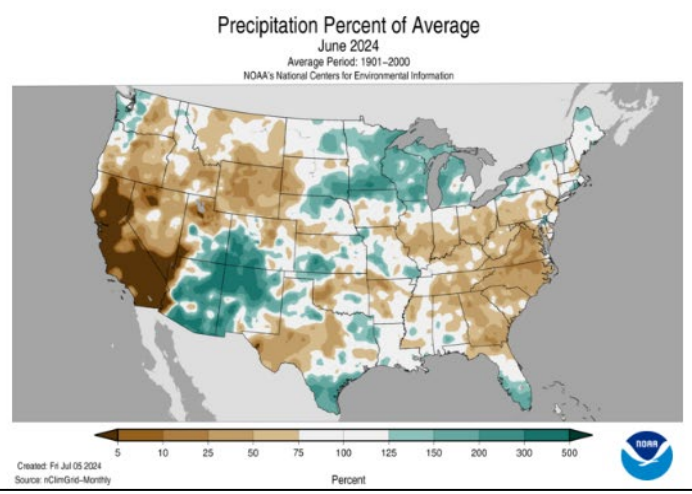
There have been 15 confirmed weather and climate disaster events, each with losses exceeding $1 billion, this year.

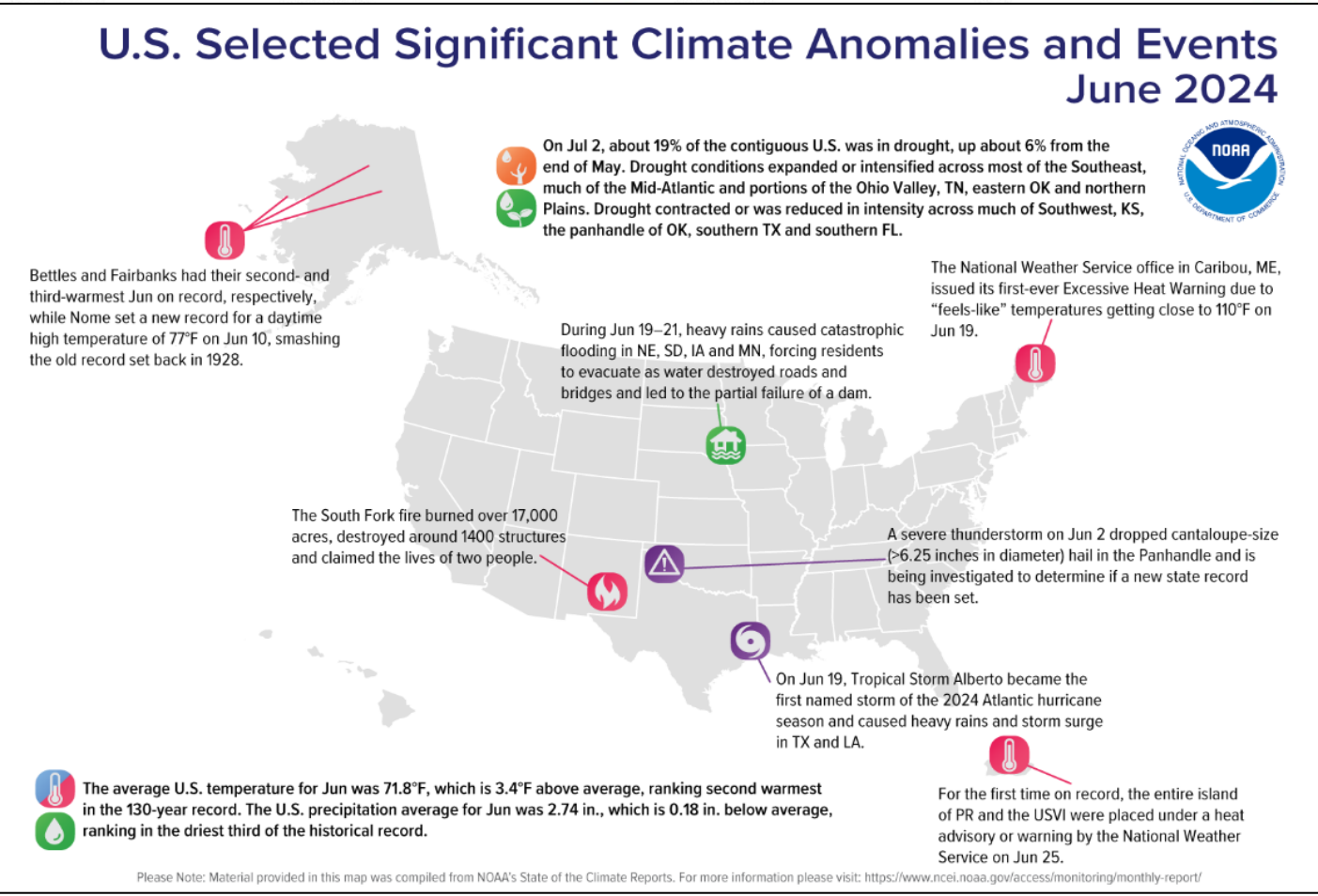
- These disasters consisted of 13 severe storm events and two winter storms.
- The total cost of these events exceeds $37.9 billion, and they have resulted in at least 106 fatalities. There are three pending disasters under review.

In June, some cities reported zero inches of precipitation: Las Vegas, NV, Yuma, AZ, Reno, NV, San Francisco, CA, Los Angeles, CA, Fresno, CA, and Orland, CA.









Global Shifts – June

The June global surface temperature was 1.22°C (2.20°F) above the 20th-century average of 15.5°C (59.9°F).

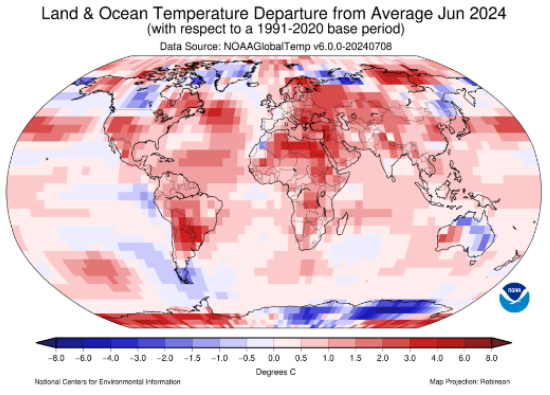
- June 2024 was the warmest June on record for the globe in NOAA's 175-year record.

This is 0.15°C (0.27°F) warmer than the previous June record set last year, and the 13th consecutive month of record-high global temperatures.

- This ties with May 2015-May 2016 for the longest record warm global temperature streak in the modern record (since 1980).

During June 2024, 14.5% of the world's surface had a record-high June temperature, exceeding the previous June record set in 2023 by 7.4%.

- The record temperatures in large parts of South America contributed to early and expansive drying of the Pantanal, the world's largest tropical wetlands.



Selected Significant Climate Anomalies and Events: June 2024

GLOBAL AVERAGE TEMPERATURE

Jun 2024 global surface temperature ranked warmest since global records began in 1850, making it the 13th consecutive record-warm month.

THE ARCTIC

The Arctic had its seventh-warmest Jun and sixth-warmest Jan–Jun. Arctic sea ice extent for Jun was 12th lowest on record.

EUROPE

Europe had its second-warmest Jun and warmest Jan–Jun on record.

NORTH AMERICA

North America had its fourth-warmest Jun and second-warmest Jan–Jun on record.

GREECE

An early-season heat wave hit Greece in Jun, with multi-day temperature exceedances of 38°C (100°F) in many places. The extreme heat led to the deaths of several tourists.

HURRICANE BERYL

Became the first Category 4 hurricane observed in the Atlantic Ocean during the month of Jun. Beryl made landfall in Carriacou, Grenada as a Category 4 hurricane and caused extensive and very severe damage across the Windward Islands before moving further into the Caribbean.

TROPICAL STORM ALBERTO

The first named storm of the Atlantic 2024 hurricane season peaked with sustained winds of 50 mph (80 km/h) before making landfall in northern Mexico, where heavy inland rains led to flooding and reports of several deaths.

ASIA

Asia had its warmest Jun and fourth-warmest Jan–Jun on record.

SOUTHEASTERN CHINA

On top of deadly floods in Apr, more heavy rainstorms in Jun caused loss of homes, roadways and bridges, damage to crops and dozens of reported deaths and missing persons.

EL SALVADOR

Heavy rainfall in El Salvador and neighboring countries caused flooding and landslides that led to widespread displacement and more than a dozen deaths.

BANGLADESH

Heavy monsoon rainfall in Bangladesh affected more than two million people in Jun. Flooding and landslides led to loss of life and damage to homes and infrastructure.

AFRICA

Africa had its warmest Jun and warmest Jan–Jun on record.

SOUTH AMERICA

South America had its warmest Jun and warmest Jan–Jun on record.

CARIBBEAN

The Caribbean region and the Main Development Region for Atlantic hurricanes had their warmest Jun and Jan–Jun on record.

GLOBAL OCEAN

Global ocean surface temperature hit a monthly record high for the 15th consecutive month in Jun.

PANTANAL

More than 2500 wildfires were reported in the world's largest tropical wetlands in Jun, the most ever so early in the year.

SOUTH AFRICA

Heavy rainfall, strong winds and hailstorms affected southern and eastern South Africa in early Jun, causing river overflows and reports of at least 12 fatalities.

OCEANIA

Oceania had its seventh-warmest Jan–Jun on record.

ANTARCTIC SEA ICE EXTENT

Antarctic sea ice extent for Jun ranked second-lowest on record.

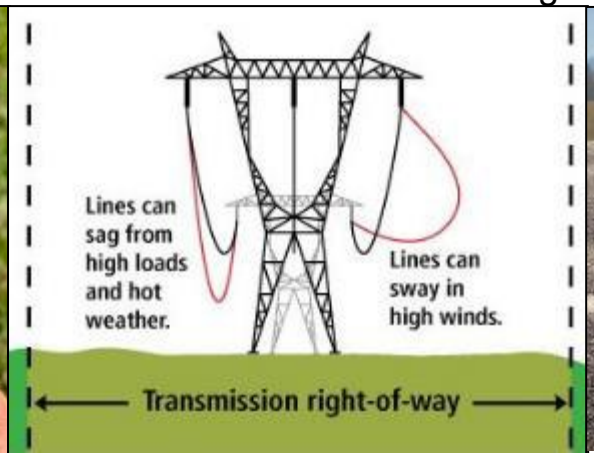
Please note: Material provided in this map was compiled from NOAA's State of the Climate Reports. For more information please visit: https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/

Critical Infrastructure Sectors Risk from Heat

As extreme temperatures continue to swing through the winter, more sites are reporting structural integrity concerns for concrete slabs as building foundations, reservoirs, canals, roadways, runways, and railway platforms.

- **Information technology** services via datacenters are at operational risk from higher heat concentrations and persisting high heat days through increased cooling needs and decreased water availability. Many datacenter hubs are in higher risk areas over the next decade from heat domes.
- **Communication** infrastructure is at risk as phones can become too hot for use, power outages can impact communication services, and heat induced surface degradation (subsidence or upwelling) can collapse towers. Overheating can cause some phones to drop from 5G to 4G connection.
- **Chemicals** stored in high heat threatened regions can face unhealthy emission levels due to air stagnation, some chemicals flash points are a concern for ambient temperature and can vaporize, and transporting chemicals can become a greater risk for non-cooled containers and combustion.
- **Critical manufacturing** requires water cooling in operations and dust management which is at risk during heatwaves, some materials and equipment have temperature threshold for use, delays in the supply chain due to heat warping transportation are likely, and power loss can close plants.
- **Dams and waterways** are at clear risk of concrete degradation to the point of cracking, water evaporation causing unhealthy levels of minerals/metals/bacteria in waterways, fish die offs from hotter waters, ecology damages, and reduced hydroelectric output levels.
- **Nuclear plants and the agricultural sector** require significant water intake and lose operational capabilities on extreme heat days or in heat domes.
- **Emergency services + healthcare** face higher mortality rates, greater vehicle wear/tear, supply chain delays, heat illness, and personnel strain.

Malleable concrete threat: an electric vehicle is about 300 lbs. heavier than a comparable gas car but up to 1,000 lbs. more for larger vehicles like trucks, placing strain on parking garages, driveways, and roads while wearing down tires about 20% faster and increasing the surface temperature via friction.



Physical Security, Site, and Staff Impacts

As severe weather increases the frequency of power outages, causes supply chain delays, amplifies impacts from personnel shortages, damages larger areas causing prolonged restoration times, *negative impacts will increase* for key security personnel and necessary physical security systems.

- Power outages can lead to badging and verification delays, record storing lapse, or loss of site access
- Extreme heat can reduce the physical efficiency and mental capability of security staff (lethargy)
- Severe weather can halt drone monitoring operations and obscure video monitoring
- Flooding can result in sensor delays or destruction
- Evacuations being televised may result in exploitation of decreased security presence
- Damages to physical barriers like fences and gated vehicle entry points
- Extreme heat and frequent staff rotations may cause gaps in external physical security
- Increased rates of depression during low pressures and aggression during heat waves may lead to workplace violence events
- High heat periods may cause loss of sleep further reducing the capabilities of staff
- Extreme heat may cause burns or melt certain materials or cause foundations to crack/dimple
- Supply chain or resource hub damages from heat or storms may cause replacement part delays and heightened demand
- Hail can damage or destroy backup generators
- Resource restrictions may result in targeted violence or theft of site resources (e.g. water)
- Theft of backup generators during recovery from storms
- Extreme heat can impede helicopter operations
- Amplified events may reduce emergency response availability (e.g. fire/EMS)
- Battery backups for security systems and control panels may deplete during prolonged outages





Concrete: If an unrestrained slab or wall 30 meters long has a temperature variation from summer to winter of 38 degrees Celsius, the total thermal movement might be about 1.5 to 1.8 centimeters. Movements occur at the exposed surface of the concrete, which cools off more quickly, before they occur in the interior of the section, leading frequently to additional warping or curling effects.

- In high heat environments over 80F, concrete should not be poured, or it will not set effectively. This can increase setting time from 2-3 days up to 7 days in hot weather.
    - Thermal cracking is found particularly in thick slabs, or mass concrete, where the temperature differential between different areas of the concrete is too high.
        - Examples of this can be found in airport aprons, bridge headsticks, and across numerous highways during the curing process, requiring the sites to be covered.

City Landscapes: Park benches in direct sunlight during summer months can easily reach temperatures of 125F when ambient air is around 82-83F.

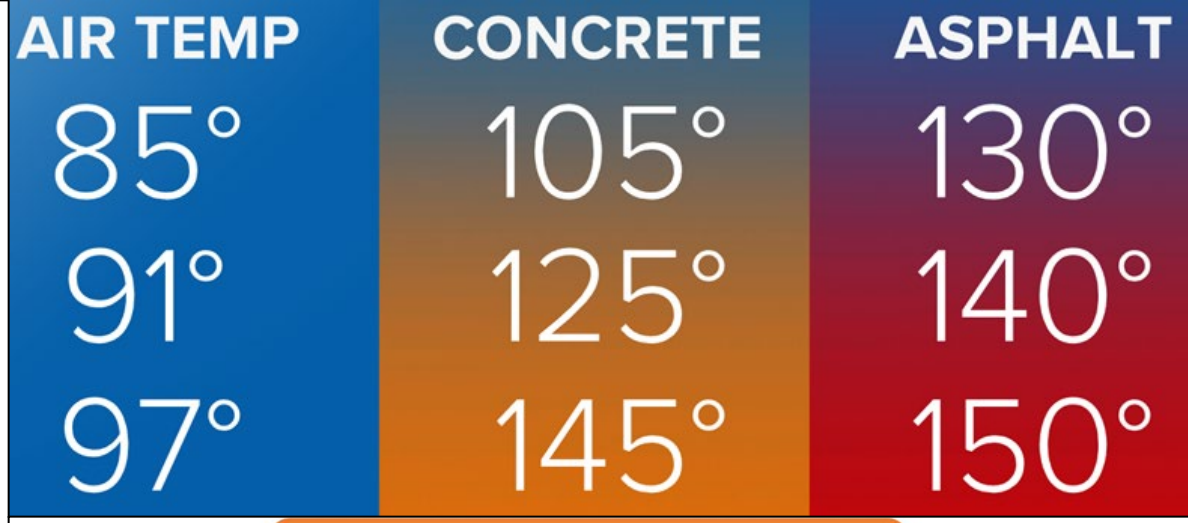
- Metal benches can hit a scorching 136F with coated benches still exceeding 108F.
- Marble benches comparable can range up to 105F while limestone can reach 116 degrees in sunlight. Shade often drops these temperature by 16-18F.
    - Water fountains can reach 95F, bus stop signs/posts can reach 105F, bicycles can range to 104 degrees for seats and 102 for handles, and crosswalk buttons near 98 degrees.

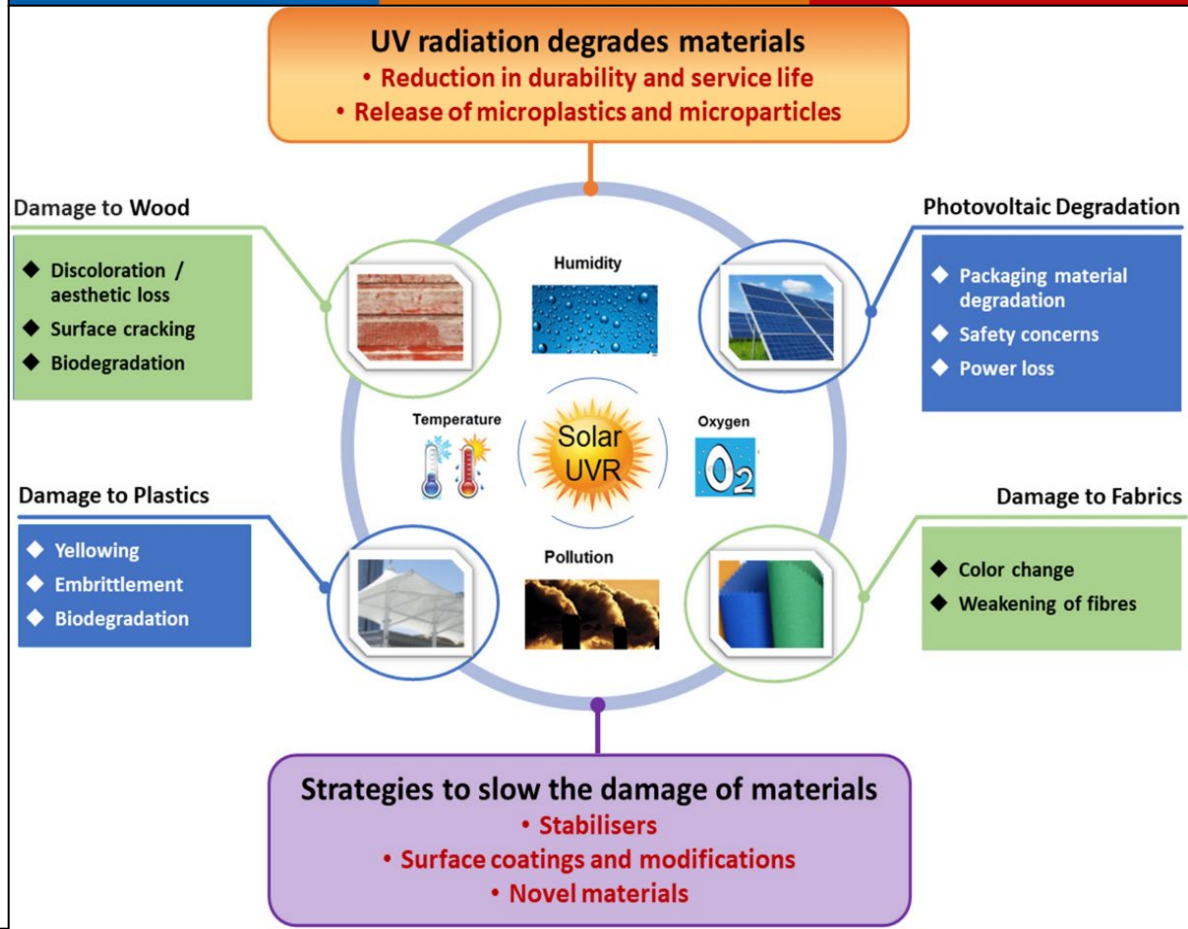
Epoxy: Most heat-resistant epoxies need to be cured at temperatures at or beyond the temperature it will need to endure. If temperatures exceed these maximum service temperatures, the material could start to distort. At a temperature of 135°F or higher, the epoxy may begin to exhibit heat damage.

- Epoxy faces the same concerns of needing a few days to cure but in persistent high heat/humidity levels it could take up to two weeks.
    - If Epoxy cures in too high of a temperature it can become too solid, resulting in less give during temperature swings and may crack.

Metals: Extreme heat causes various metals to expand in addition to impacting the structure, electrical resistance, and magnetism. When metal heats, the bonds begin to break.

- Bridges in New York, Sacramento, and London have all faced thermal expansion or cracking– 95F in New York, 103F in Sacramento, and 65F in London.
    - Costly sprinkler systems, temperature control systems (pedestal chain AC), foil wrapping, and emergency deployed water spraying equipment.





Radiative Heat Threats: Cities + Canals

In the 1980s, concurrent heat waves only occurred for 20-30 days each summer. Global warming has driven a sixfold increase in the frequency of simultaneous heat waves over the last 40 years. The study also found that concurrent heat waves covered about 46% more space and reached maximum intensities that were 17% higher than 40 years ago.

Concrete is a great material for absorbing and storing heat from the sun, meaning it can warm to higher temperatures then most other materials and releases that heat more slowly as direct heating stops. On a hot summer day, concrete that's in the shade can easily average 70°F, however, concrete that's in direct sunlight can reach 135°F. Builders test this with a device called an infrared thermometer. Due to the higher temperature, these mixtures are at risk of expansion-triggered water incursion.

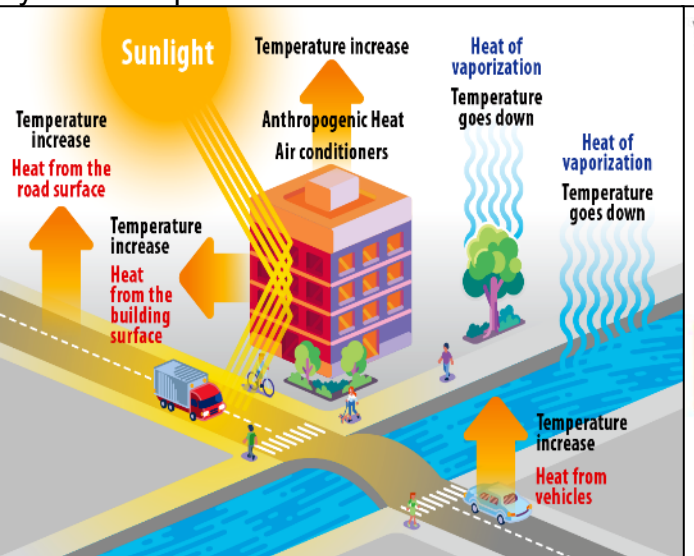
- Grass rarely exceeds 80°F, wood peaks around 90°F, composite decking about 100°F, but concrete can reach a hotter temperature and hold onto that heat longer. This means only developed areas of cityscapes may have cooler temperatures due to the cost of vegetation to water and install yielding temperature disparities.
- Heat islands form because of reduced natural landscapes in urban areas and increases in heat-retentive materials. Trees, vegetation, and water bodies tend to cool the air by providing shade, transpiring water from plant leaves, and evaporating surface water, respectively.

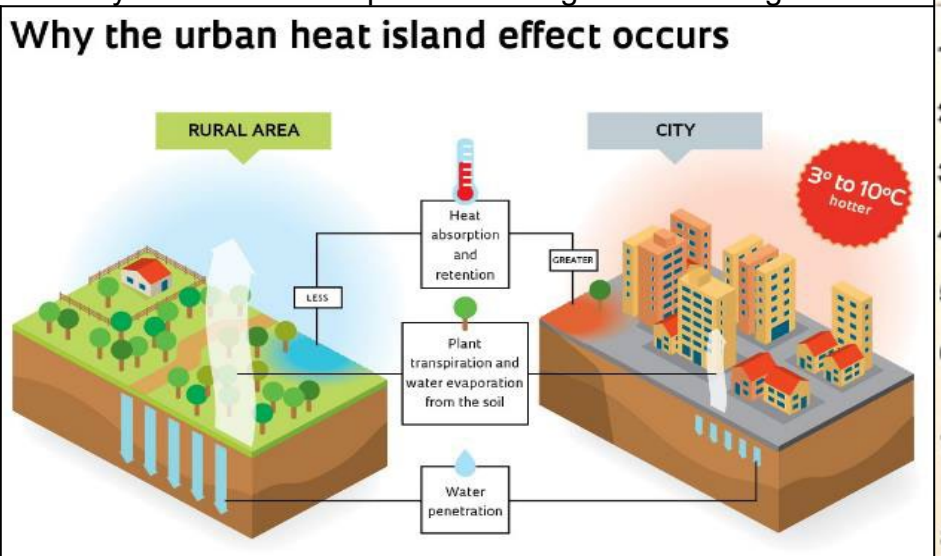
Metal benches, grates, and shopping carts can exceed temperatures of 120°F resulting in burn potential for unhoused populations especially. Without cooling centers staying open overnight, at-risk populations are purged back into an abnormally warm city where pollution concentrations remain high due to the lingering heat.

- The more densely packed a metro car is or a bus is, the greater the ambient temperature will become making it more difficult to cool down between stops.

When asphalt heats it becomes more malleable, making it soft and able to compress under weight and become disformed. High heat also rapidly ages the material, making infrastructure on or near it weaker.

At the current rate of heating, the expansion buffer will not stop the material from buckling more often. This will yield more potholes and lower income communities may not be able to repair at the heightened damage rate.





SURFACE TEMPERATURES

	3/4/22 10:30am	6/21/22 10:30am	6/21/22 3:30pm
AIR TEMPERATURE	52°	84°	104°
1. Concrete (sidewalk)	58°- 61.5°	110°	142°
2. Asphalt (street)	62°- 64°	125°	155°
3. Plants	65°	89°- 91°	105- 115°
4. Turf (grass)	69°- 71°	93.5°	99.5°
5. Bare Dirt	78°	119°	159°
6. Mulch	81°	120°	154°
6a. Soil under mulch		96°	110°
7. Gravel (stones)	82° large 90° small	122° lg. 129° sm.	140° 149°
8. Artificial Turf	90.5°- 93°	143.5°	165°

Critical Manufacturing

CISA: The Critical Manufacturing Sector is crucial to the economic prosperity and continuity of the United States. A direct attack on or disruption of certain elements of the manufacturing industry could disrupt essential functions at the national level and across multiple critical infrastructure sectors.

The Critical Manufacturing Sector identified several industries to serve as the core of the sector:

- Primary Metals Manufacturing
  - Iron and Steel Mills and Ferro Alloy Manufacturing
  - Alumina and Aluminum Production and Processing
  - Nonferrous Metal Production and Processing
- Machinery Manufacturing
  - Engine and Turbine Manufacturing
  - Power Transmission Equipment Manufacturing
  - Earth Moving, Mining, Agricultural, and Construction Equipment Manufacturing
- Electrical Equipment, Appliance, and Component Manufacturing
  - Electric Motor Manufacturing
  - Transformer Manufacturing
  - Generator Manufacturing
- Transportation Equipment Manufacturing
  - Vehicles and Commercial Ships Manufacturing
  - Aerospace Products and Parts Manufacturing
  - Locomotives, Railroad and Transit Cars, and Rail Track Equipment Manufacturing

The Critical Manufacturing Sector focuses on the identification, assessment, prioritization, and protection of nationally significant manufacturing industries within the sector that may be susceptible to manmade and natural disasters.

How does extreme weather impact manufacturing?

Major weather events moving across multiple regions can cause disruptions to transportation, energy supply, supply chain movements, critical personnel, and physical damage to the sites and resource hubs.

An example: coal used for steel making needs to be high in carbon content and low in moisture, ash, sulfur, and phosphorous content. Coal that meets these specifications is known as metallurgical coal.

- The coal hubs can be impacted by torrential flooding, extreme heat, wildfires, high air pollution/heavy smoke days, and winter storms which can destroy the resource or its access points. During high heat, these sites need more water to operate.

In drought regions operating mines becomes a dangerous balance of a limited resource, water. The Department of Energy states the total water used for coal mining nationally ranges from 70 million to 260 millions gallons per day.

- Water is used to cool equipment, provide dust management, and consumption of the mining community itself.

Does production of goods and services stop? Can distribution of crucial supplies be interrupted?

As far as production goes, absolutely not… on a global scale anyway. Locally, yes, some areas will shutter to weather a storm or event and will move to resume operations immediately following the event to reduce losses in productivity.

- Depending on the duration of the delay, the costs of minerals, metals, or shipments may increase as the shipping costs rise to match the impacts to the supply chain.
- During the low-flow on the Mississippi and Panera River's over the past two years, barges had to reduce load and move slower through the river systems resulting in backlogged shipments and high costs for alternative solutions.
- In addition to sea level rise, tropical cyclones or Nor'easters moving or along major ports also result in damages to ports, vessels, and prolonged delays in restoration of cargo movements which can have far-reaching impacts to states without a coastline which are reliant on international shipments.

Extreme Weather is being amplified by the uneven distribution of heating across the globe which results in threats critical facilities, delays for movements of goods such as minerals and metals both at the mines and moving through major import/export hubs,

Transportation Impacts

Extreme heat can degrade the structural integrity of roadways, railways, runways, and pipelines resulting in pivots of resource movement methods.

- When the Mississippi River runs low due to drought events and heat triggered evaporation of the surface waters, the barges must reduce loads and speed causing notable delays in shipments and trucking needs to reduce increasing costs.
    - Heat causing railways to warp can also cause reduced operations by requiring slower movement and reduced loads.

Extreme heat for railways threatens railcars with prolonged exposure to solar radiation when stalled on the tracks and may see material combustion risks or degraded shipping conditions which may impact the supply chain.

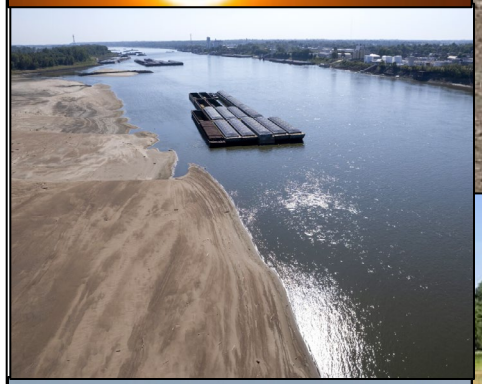
- Warped railways under direct heating may increase derailments.
    - Stalled materials in transport can overheat, damaging the products.

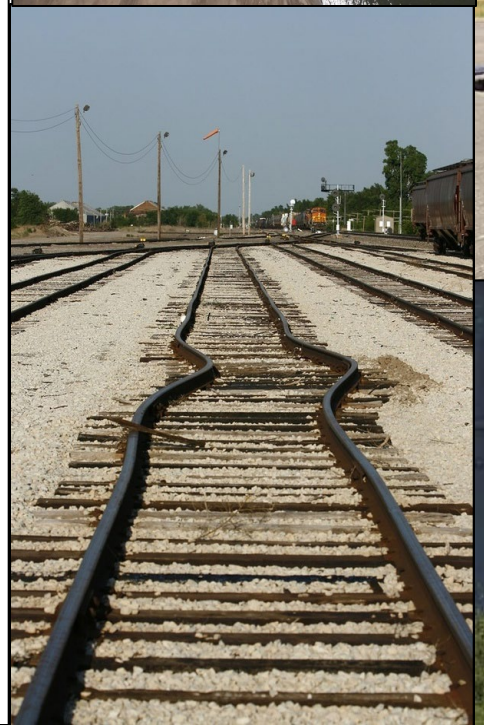
These events are occurring globally, resulting in loss of supply for key materials, minerals, metals, increased demand, rising costs, and subsequently delayed delivery.

As temperatures rise, the performance of the aircraft and their engines can deteriorate which can be amplified in major metropolitan areas due to the surrounding ambient temperatures.

- Planes get 1% less lift with every 5.4°F (3°C) of temperature rise.
- Refueling can be delayed due to heat while internal aircraft temperatures can rise rapidly during gate delays or takeoff delays.
- Thermal turbulence occurs due to uneven surface heating by the sun.
- Like railways and barges, the aircraft also cannot take on additional weight during the summer, resulting in higher transportation costs and delays.

Major outdoor events like concerts/festivals, sport games, racing, vacation destinations, amusement parks, and competition-based events cause an upswing in transportation system use and more individuals outside/commuting placed at a higher risk to include waiting on train platforms, bust stops, stalled in traffic, longer plane boarding times, etc.





Heavier Vehicles Could Damage Malleable Materials

Electric vehicles can weigh up to 50% more than traditional automobiles due to their heavy lithium-ion batteries. Heavy electric vehicles damage roads, bridges and parking garages and may be able to more easily bypass guardrails. Studies found that heavy EVs produce more wear and tear on tires resulting in a greater shed of tiny rubber particles.

- Vehicles such as recycling trucks have begun sinking into roadways weakening under heat waves in the UK in 2023 while a US Airways flight was delayed for three hours after its wheels sank into the runway tarmac after temperatures persisted over 100F during a heatwave in 2012. Softer materials are a greater risk to heavier vehicles.

In extreme heat, your car may not start because of issues with your fuel. When your engine is too hot, fuel cannot circulate well, making it difficult for your engine to start.

- In electric cars the various sensors become at risk while in older gas-powered cars the starter and injectors can be at heightened risk of failure during heatwaves.
- In most of today's EVs, cells are spaced apart to reduce fire risk should one cell overheat, or the battery enclosure become damaged in a crash.

In gas-powered vehicles, between June and July 2022, battery problems were the third highest reason AAA MidAtlantic members in New Jersey called for road service.

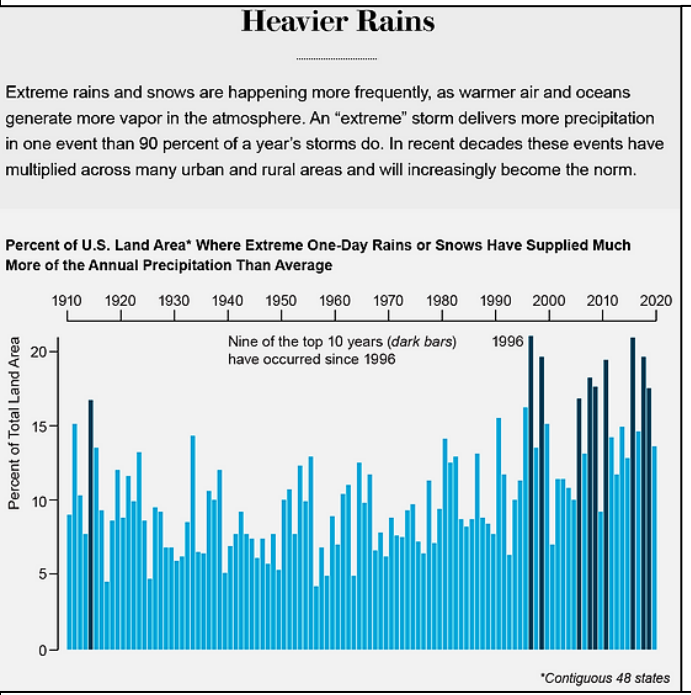
- Overheating can be very damaging to motors with aluminum engine blocks and cylinder heads. Underinflated tires can overheat more easily and fail.
- During hot summer days, your windshield will contract and expand as it adjusts to the changing temperatures.

The metal part of the seat belt buckle in a hot car can reach 130 degrees, which can cause a second-degree burn. The steering wheel can reach almost the same at 133 degrees.

Increases in 1 Hour / 6 Hour / 24 Hour Rainfall Totals

Increases in atmospheric water vapor also amplify the global water cycle. They contribute to making wet regions wetter and dry regions drier. The more water vapor that air contains, the more energy it holds. This energy fuels intense storms, particularly over land. This results in more extreme weather events (NASA).

- More evaporation from the land also dries soils out. When water from intense storms falls on hard, dry ground, it runs off into rivers and streams instead of dampening soils. This increases the risk of drought and floods.

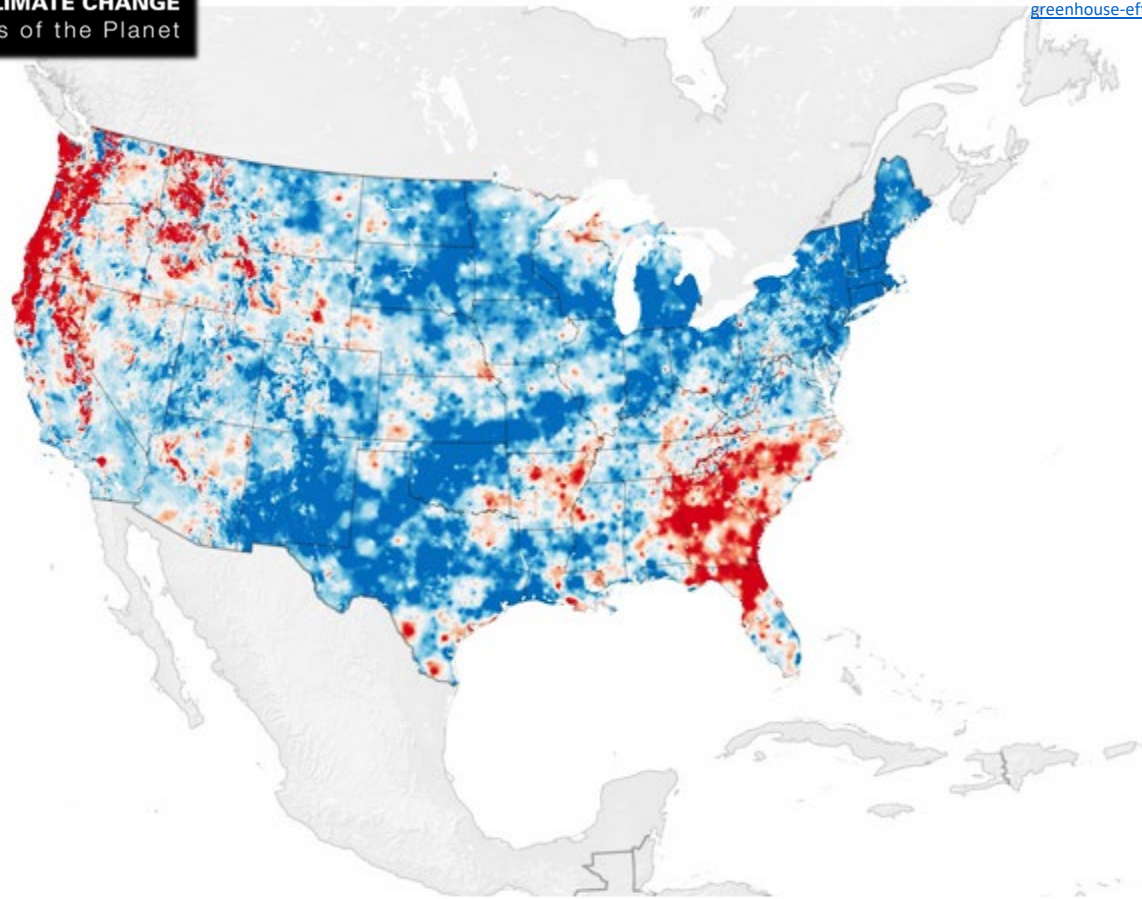


- The average change in hourly rainfall intensity across all 150 stations from 1970 to 2021 was +13%.
- 63% (95/150) of stations had an increase in hourly rainfall intensity of +10% or more (Climate Central).
- 90% of the 150 locations analyzed now experience more average rainfall per hour than in 1970.
- A 2021 report found that one-fourth of critical infrastructure is at risk of failure by flooding.
- Nine of the top 10 years for extreme one-day precipitation events have occurred since 1996 (EPA).

The water-vapor feedback is weakest where vapor is most abundant. In humid areas, the infrared energy absorbed by water vapor is already near its physical limit, so adding some extra moisture has minimal effect. In dry places, however, such as polar regions and deserts, the amount of infrared energy absorbed is well below its potential maximum, so any added vapor will trap more heat and increase temperatures in the lower atmosphere.

GLOBAL CLIMATE CHANGE
Vital Signs of the Planet

https://climate.nasa.gov/ask-nasa-climate/3143/steamy-relationships-how-atmospheric-water-vapor-amplifies-earths-greenhouse-effect/



Scientists from the U.S. Geological Survey (USGS) showed that there has been an increase in the flow between the various stages of the water cycle over most the U.S. in the past seven decades. The rates of ocean evaporation, terrestrial evapotranspiration, and precipitation have been increasing. In other words, water has been moving more quickly and intensely through the various stages.

This map shows where the water cycle has been intensifying or weakening across the continental U.S. from 1945-1974 to 1985-2014. Areas in blue show where the water cycle has been speeding up—moving through the various stages faster or with more volume. Red areas have seen declines in precipitation and evapotranspiration and experienced less intense or slower cycles. Larger intensity values indicate more water was cycling in that region, primarily due to increased precipitation. Credit: NASA Earth Observatory image by Lauren Dauphin, using data from Huntington, Thomas, et al. (2018).

Severe Weather on the Rise

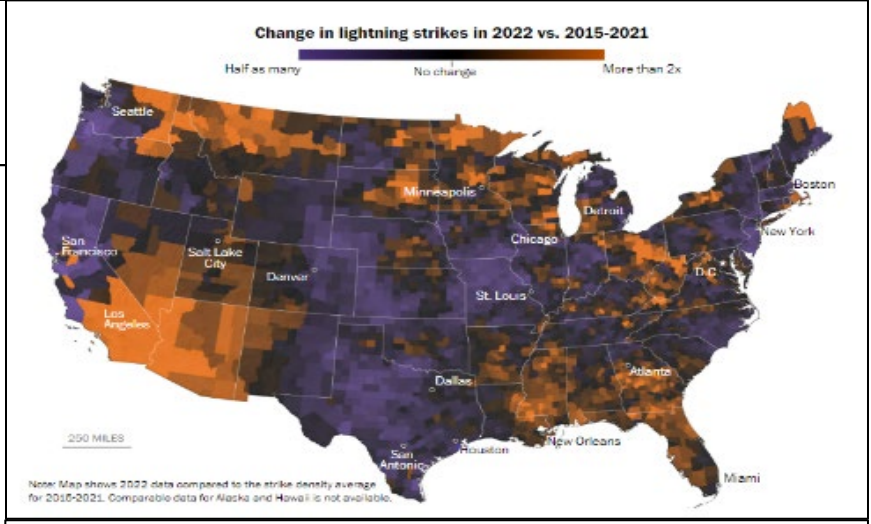
Hail events throughout the US are forecasted to intensify regarding size of the hailstones as warmer climates enable stronger updrafts for supercell storms responsible for large hail especially across less hardened areas.

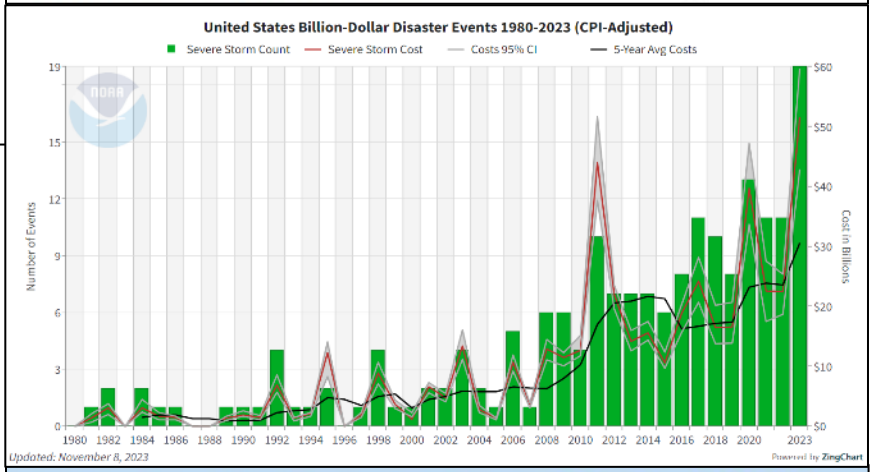
In Texas, Colorado, and Alabama the records for largest hailstone have been broken in the last three years, reaching sizes of up to 6.2 inches in diameter. Insured U.S. hail losses average $8 billion - $14 billion per year, or $80-140 billion per decade.

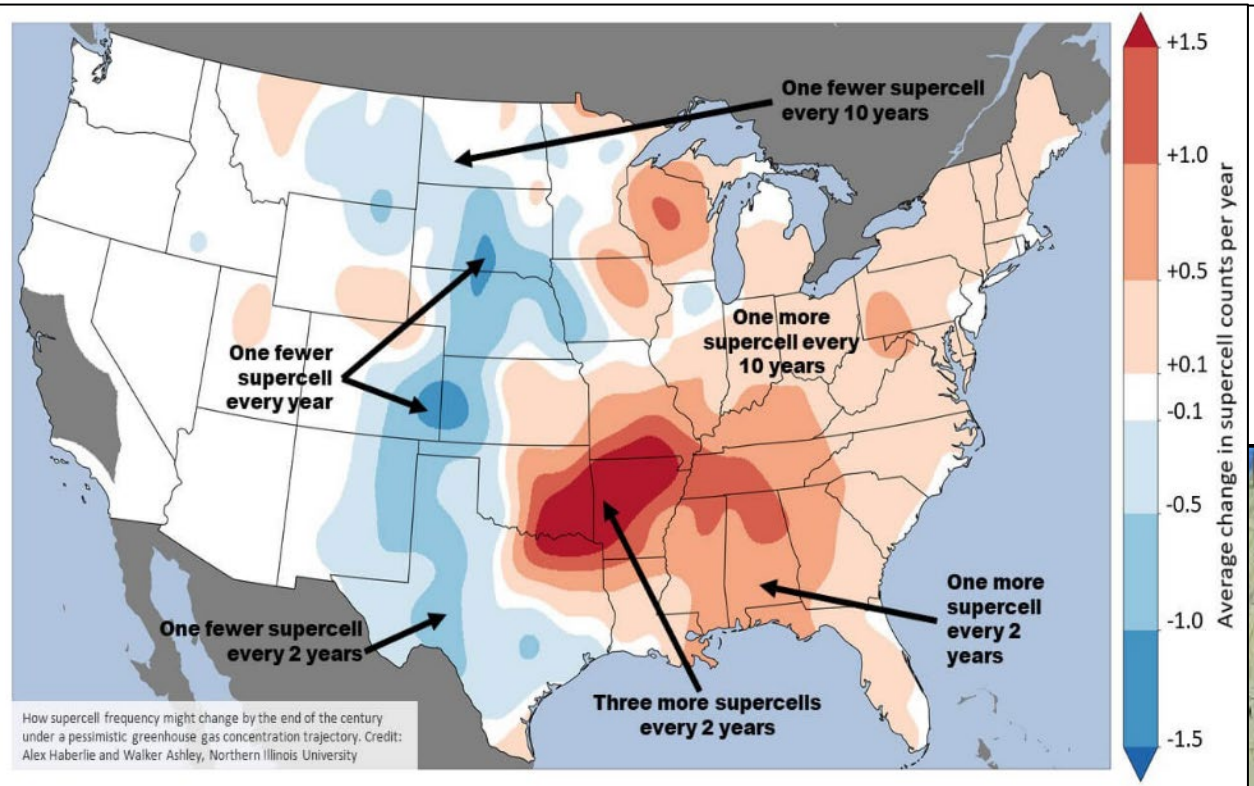
A new study published by the National Center for Atmospheric Research finds there has been "a fivefold increase in the area affected by straight-line winds since the early 1980s" in the central U.S. Straight-line winds are often produced by thunderstorms and can impacts like that of a tornado. These winds have increased at a rate of 13% per degree of warming.

Tornado activity from 2008-2021 in comparison with 1991-2010 indicates the seasonal frequency has remained the same but the location and intensity of tornadic supercells has expanded from "Tornado Alley" to "Dixie Alley" producing larger, longer supercells. Dixie Alley includes Eastern TX, AR, LA, TN, KY, MS, AL, GA, South MO, Southeast OK, and the FL panhandle.

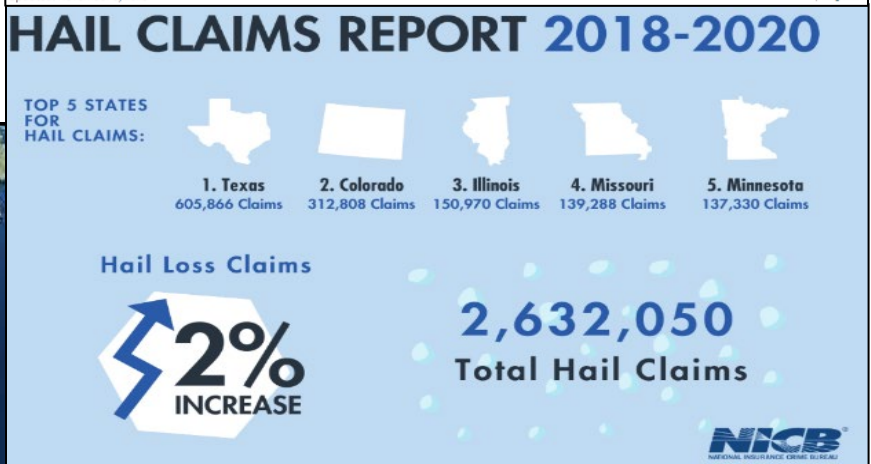
A recent study predicts a nationwide 6.6% increase in supercells and a 25.8% expansion in the area and time supercells remain over land by the year 2100. This may result in areas which do not often see tornadic activity reporting an increase in events too.







Over the past two years more severe weather has been reported in the way of large, damaging hail and more tornadic activity in the Spring and late Winter months reaching further north than usual. This is amplified in the higher tornado count in 2023 and multiple months in 2024 reporting 2-3x their average tornado counts placing 2024 in line with the annual average for tornado reports within the first six months.



The Role of Heat in Storm Growth

Severe thunderstorms are defined as having sustained winds above 93 kilometers (58 miles) per hour or unusually large hail, and there are two key factors that fuel their formation: convective available potential energy (CAPE) and strong wind shear.

- Scientists have evidence that global warming should increase CAPE by warming the surface and putting more moisture in the air through evaporation.
- Research by Climate Central has shown an increase of 10 to 15 high-CAPE-value days annually between 1979 and 2021 across much of the eastern US.
- According to NASA, disproportionate warming in the Arctic should lead to less wind shear in mid-latitude areas prone to severe thunderstorms. So, one factor makes severe storms more likely, while the other makes them less so.
- Cities such as Atlanta and New York City could see a doubling of the number of days that severe thunderstorms could occur.

Lightning: Each 1 degree Celsius of warming could spur a 12% increase in lightning frequency, boosting the flash rate to about four times per second by 2090, up from nearly three times per second in 2011. Many datacenters take this into consideration and implement lightning protection systems.

- Flashes that touch down amid minimal or no rainfall, known as dry lightning, are especially effective fire starters.
- Currently about 20 million lightning bolts touch down each year within the continental United States.
- Climate change may boost updraft within thunderstorms, causing hot lightning flashes to increase in frequency to about 4 strikes per second globally — about a 40% increase from 2011.
- The rate of all cloud-to-ground strikes might increase to nearly 8 flashes per second (+28%).

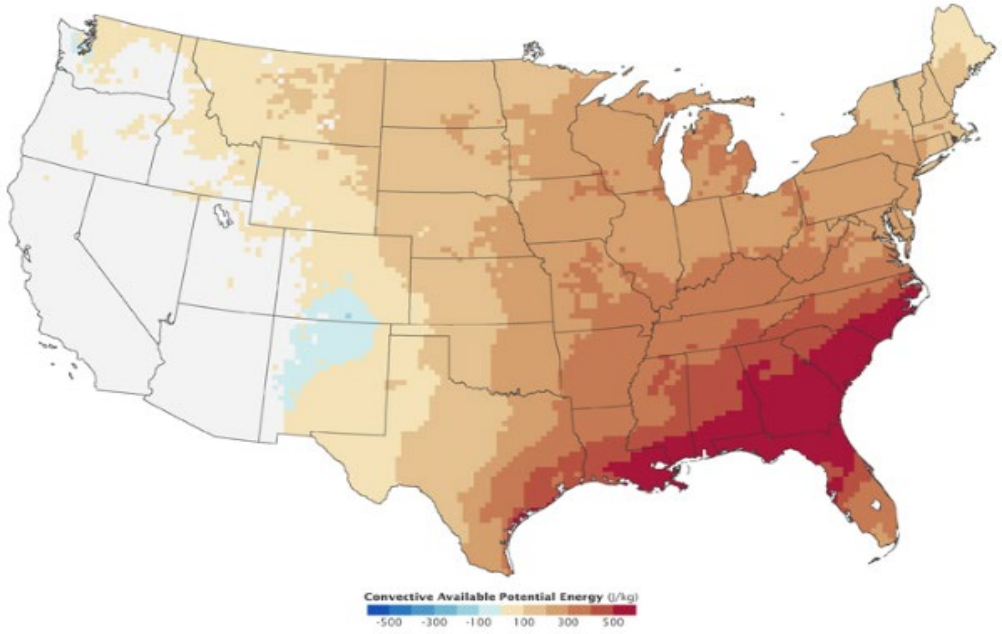
Hail: increasing temperatures and humidity could fuel larger hail and could mean smaller pellets are more likely to melt before hitting the ground.

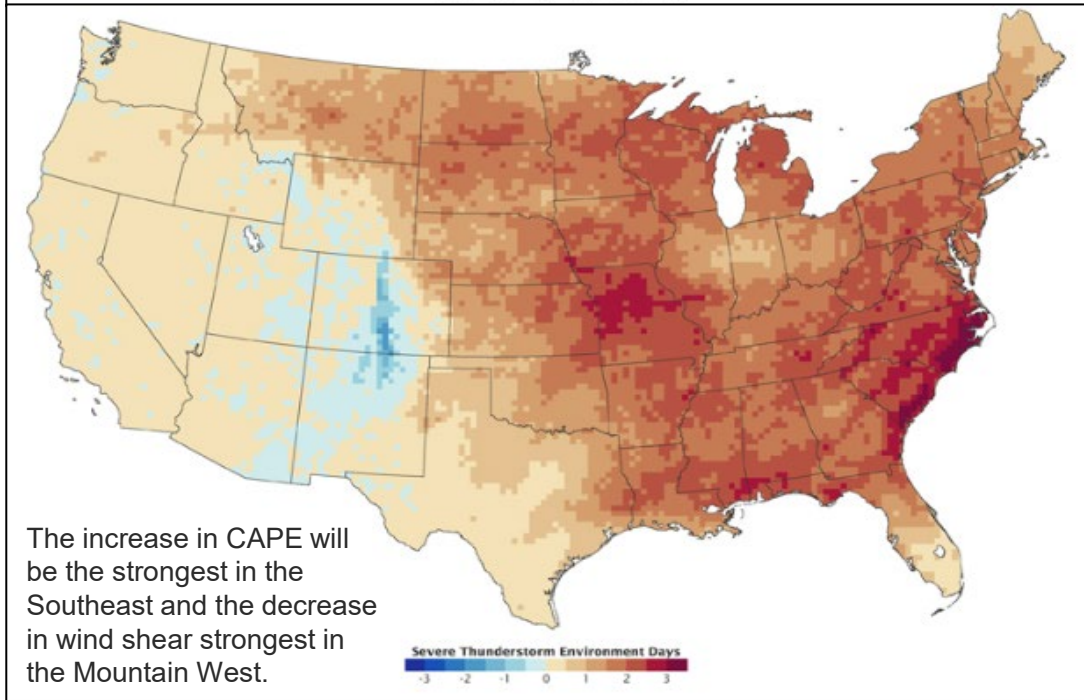
- Damage from severe thunderstorms has been inching up by about 7% annually for 30 years.
- Worldwide, thunderstorm losses were almost 90% higher than the previous five-year average of $32 billion, and more than double the previous 10-year average of $27 billion.

Derechos, Heat Bursts, Outflow Boundaries, Microbursts, and Macrobursts could all increase.

Severe thunderstorms and climate change

Models compare the summer climate from 1962–1989 to future climate projections for CAPE indices in 2072–2099.



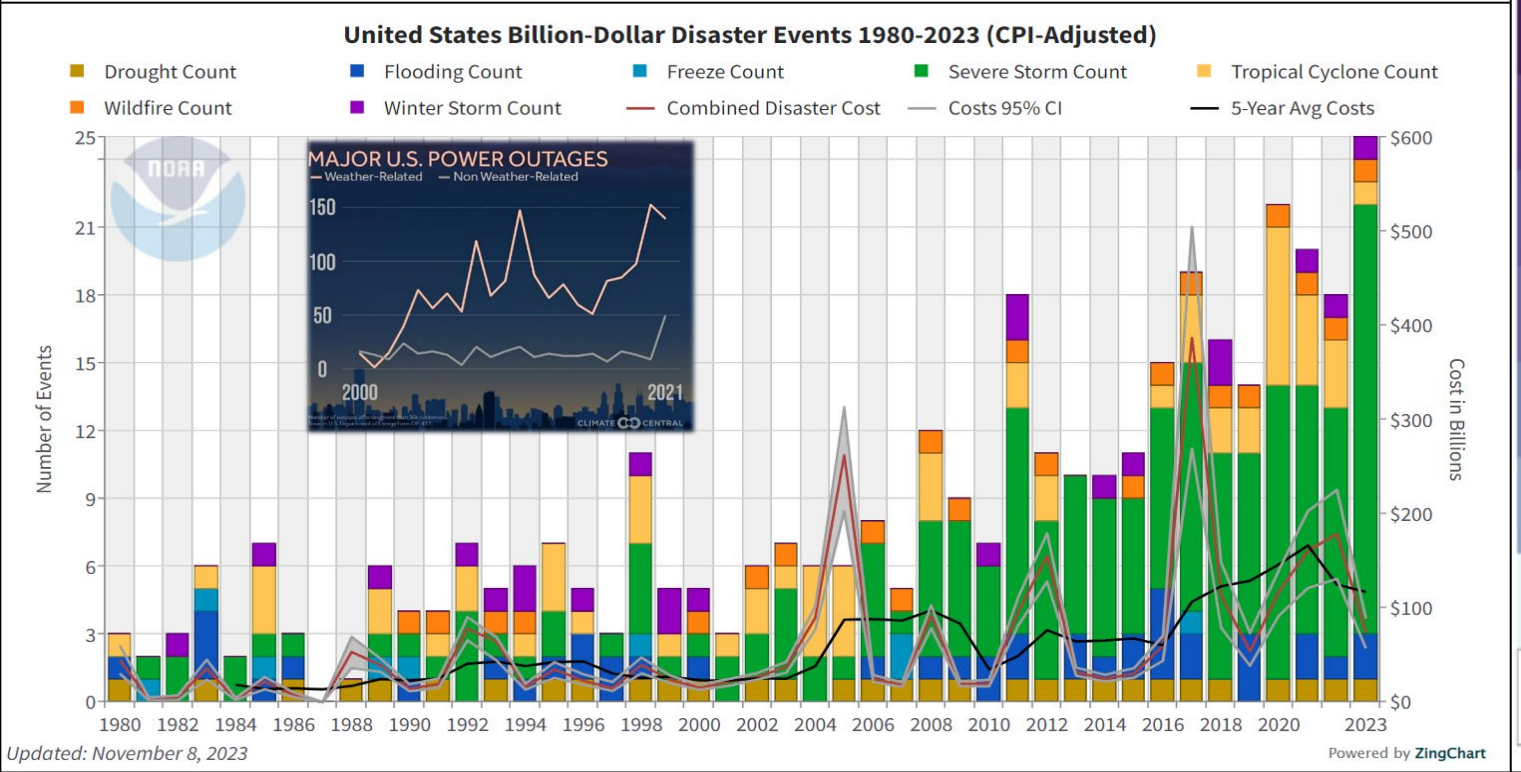


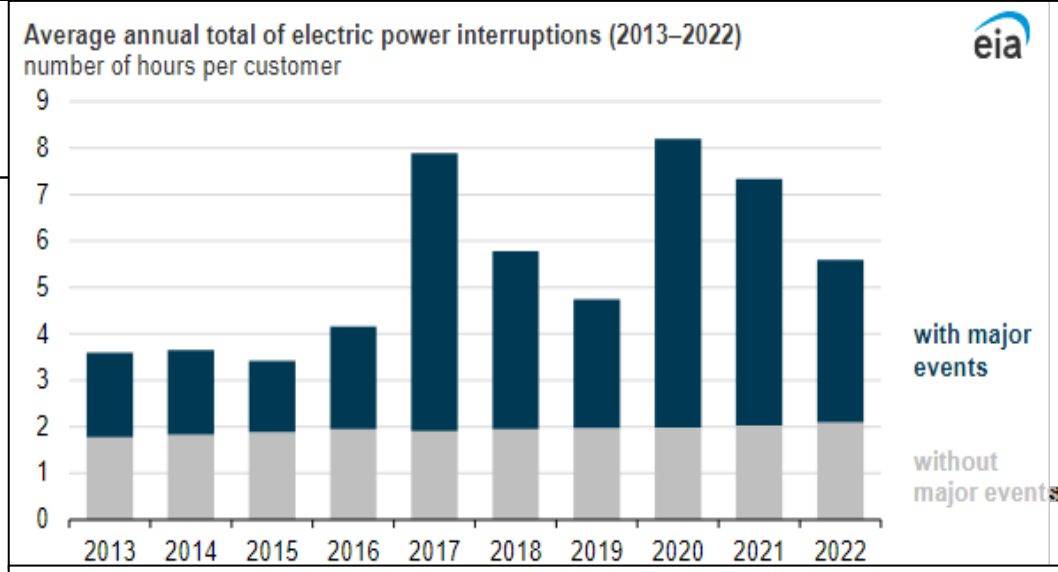
The increase in CAPE will be the strongest in the Southeast and the decrease in wind shear strongest in the Mountain West.

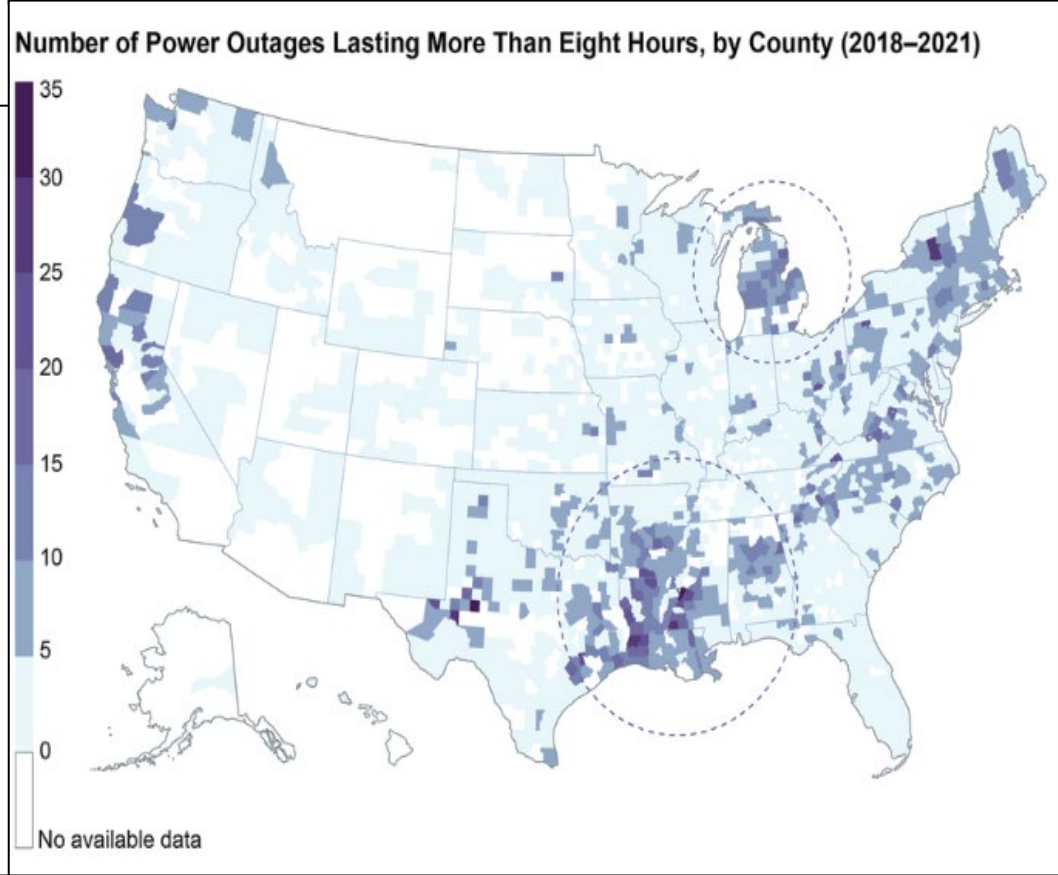
Energy Sector Loss - Weather

Between 2000 and 2021, about 83% of reported major outages in the U.S. were attributed to weather-related events. Severe hailstorms can damage other renewables like wind turbines and solar power.

- The average annual number of weather-related power outages increased by roughly 78% during 2011-2021, compared to 2000-2010.
- The decade from 2011-2021 experienced 64% more major power outages than that from 2000-2010.
    - From 2000-2021, there were 1,542 weather-related power outages nationally.
- Most outages were caused by severe weather (58%), winter weather (22%), and tropical cyclones (15%). These events are all likely to increase in damages caused and duration of outages to rise.
- Wind turbines/solar panels exposed to freeze events or extreme icing may see significant output loss.
- Drought: In 2021-2022 the Upper Missouri River saw numerous hydroelectric plants shutdown earlier than normal due to low water levels. The Colorado River saw a 33% drop in hydroelectric output.







Renewables at Risk this Summer

Subsidence induced settlement is an identified hazard for natural gas pipelines in Central California and has two components: vertical and horizontal.

- Subsidence is a threat to all built infrastructure on the surface.

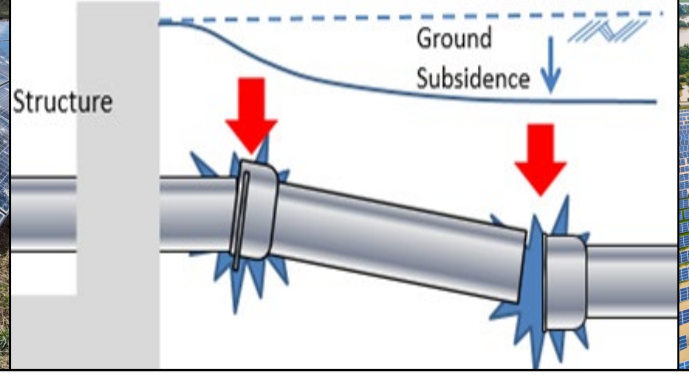
The continuous swings in temperatures during winter may cause increased icing on wind turbines resulting in a loss of efficiency, damaged components, or loss of operational capabilities due to weight.

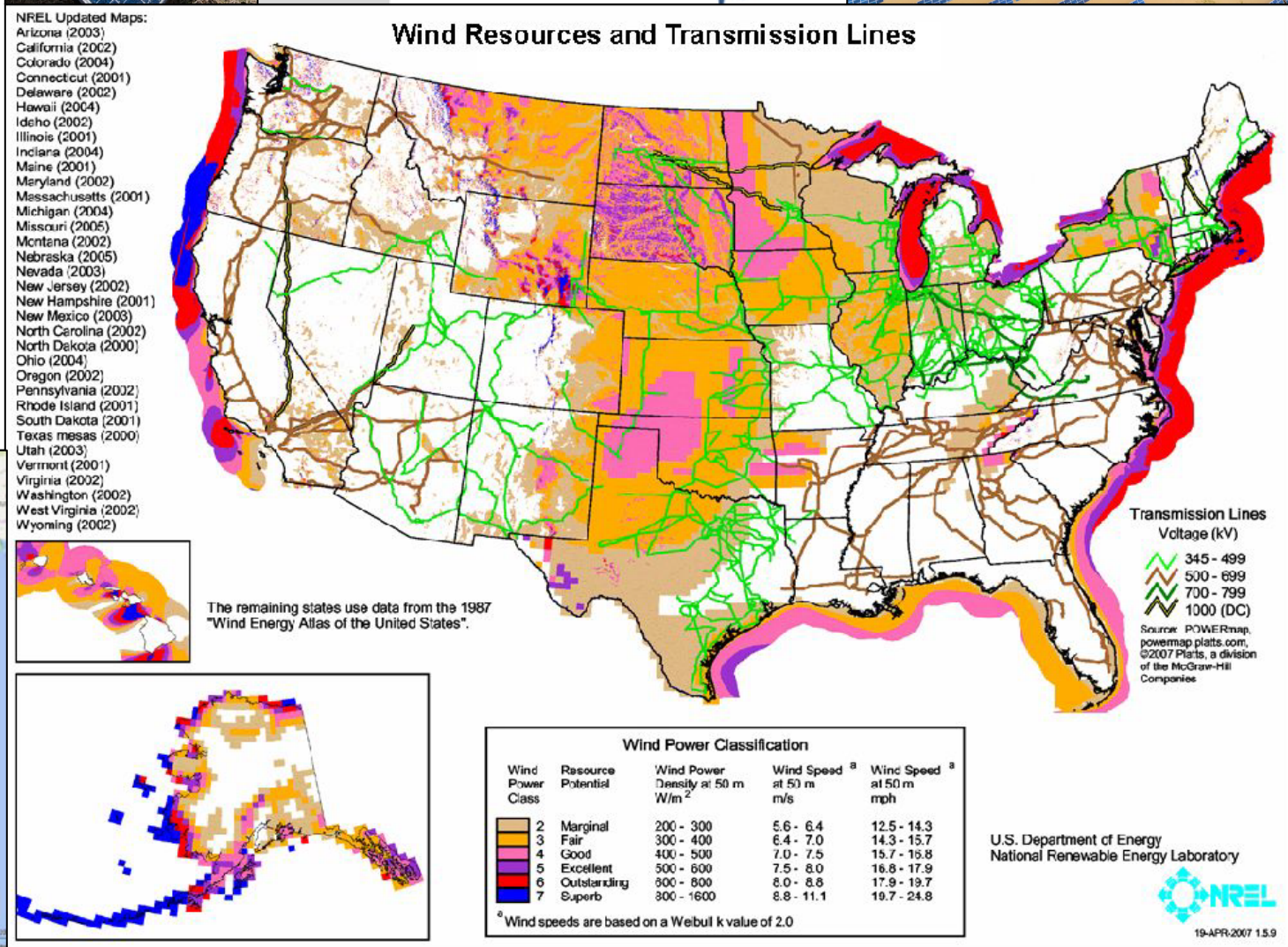
- This year multiple states reported temperatures at or below -20F, when turbines are impacted.

As thunderstorms take on more intense attributes, such as larger/heavier hail and longer lasting tornadic cells

- In Texas this March, a 3,300 acres solar farm capable of producing 350 MW reported significant hail damage from a passing single storm cell.
- Hail in northern states over the past two years has fallen at ranges of 100-150 mph, carrying with it far more impact force than average.

Solar panels can also lose efficiency in extreme heat as well as the removal of trees for the panel farms can result in heightened flood damages.





Transmission Impacts from Extreme WX

Shifting the scale of the grid system to being more impervious to weather events requires an expansion of the grid in a localized approach.

- Interconnecting hubs to improve resiliency across multiple states and regions, ideally creating a national system of transmission.
- As storms get larger in size and intensity, the grid will need resiliency to feed through the backside of the storm, being able to locally respond from unimpacted areas in transmission needs.
- Ensuring a diversified portfolio of energy generation within renewables will prevent any one storm from reducing production in full and will disperse supporting energy infrastructure efficiently.

No one industry is immune, industry and federal sectors will need to invest in mitigation through maintenance and innovative solutions to safeguard from worsening weather events.

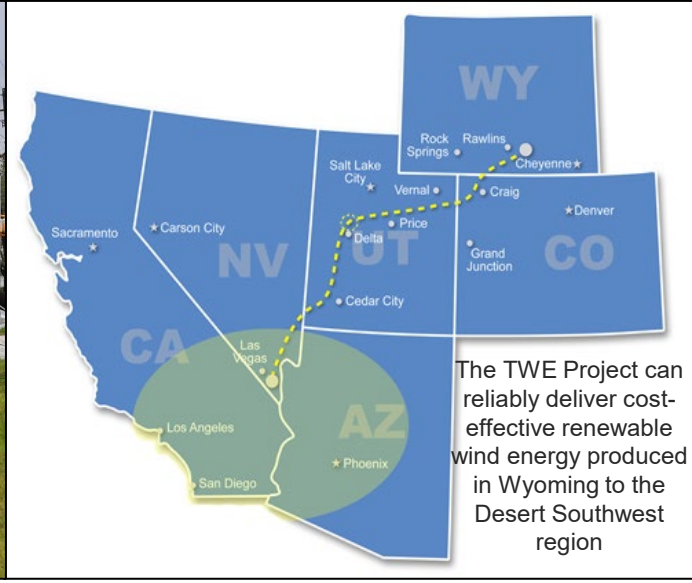
- A new study by Texas A&M and Potsdam Institute showed that Storm-proofing as little as 1% of the power lines in an electricity grid could slash the chance of hurricane-induced blackouts by between fivefold and 20-fold in a study done using the Texas electricity grid.

As drought continues to prematurely decay vegetation across the nation, wildfire threats will rise, and the number of downed trees will increase.

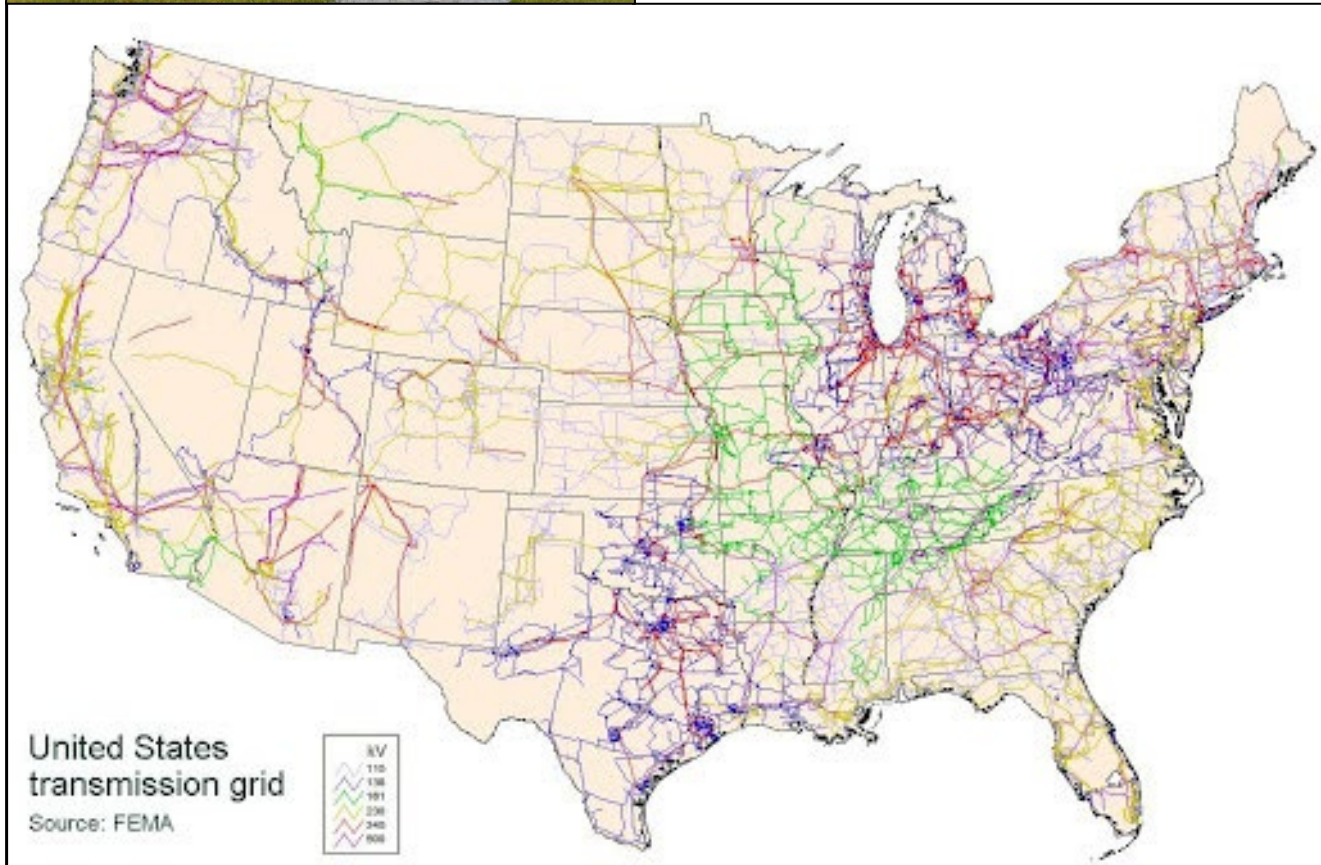
- The climate crisis is driving more extreme weather which means more heat-stressed power lines, fallen trees, flooding, and more AC usage.
- Combined, the added stress on the aging infrastructure means that each storm or heat wave makes outages more likely.

As there is no one climate-friendly energy source to thrive in all extreme weather events, there is no one grid system or infrastructure layout which is impervious to threats from the worsening trends either.

- Not every region of the US will have the same level of benefit from each renewable, this will require attention to the shifts in weather patterns when planning new generation methods and ensuring to interlink and dual-purpose projects, such as floating solar on reservoirs or solar mounted dam walls.



The TWE Project can reliably deliver cost-effective renewable wind energy produced in Wyoming to the Desert Southwest region



Worsening Weather Impacts to the Grid

Customers in Florida, West Virginia, Maine, Vermont, and New Hampshire experienced the most interrupted power in 2022, ranging from an average of 10.3 hours in New Hampshire to 19.1 hours in Florida.

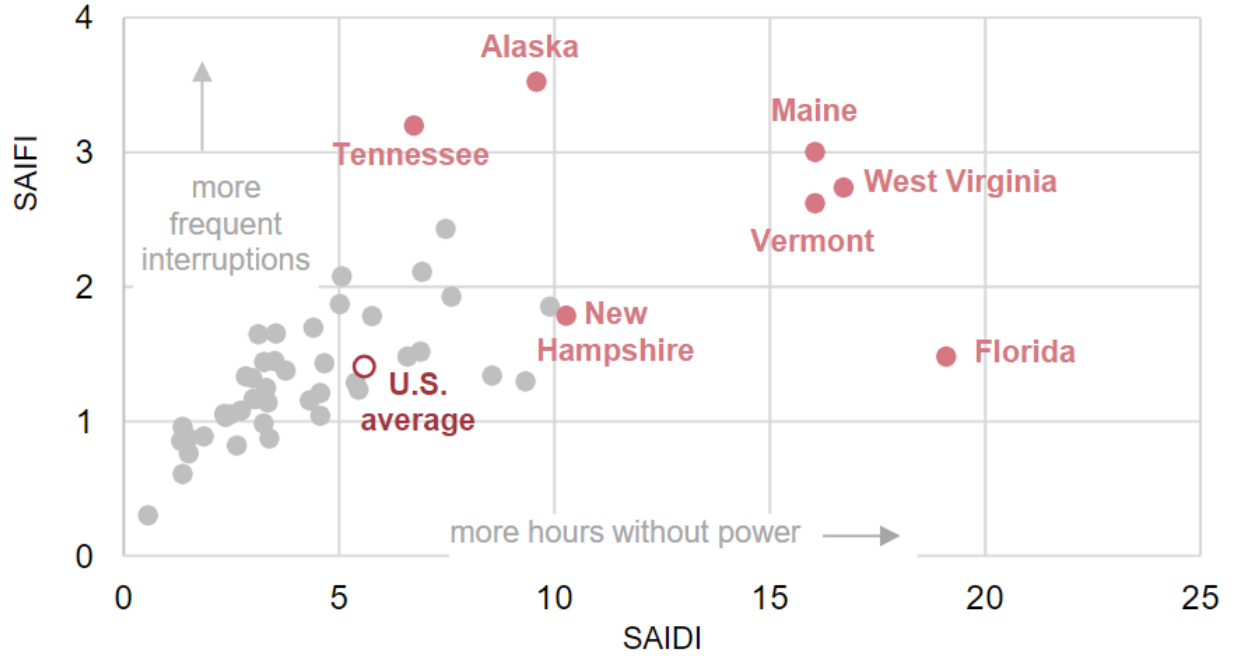
- Nationwide, electricity customers in the District of Columbia, Delaware, Rhode Island, Nebraska, and Iowa had the shortest total electricity interruptions in 2022, ranging from an average of 34 minutes in the District of Columbia to 85 minutes in Iowa.

By analyzing county-level power outage data from 2018 to 2021, the study authors found that heavy precipitation was the predominant weather event linked to power outages (though they said their study could not specify a direct causal link between the two).

- The highest frequency of outages was observed from April to August. Power lines are prone to sagging from extreme heat during the summer months, and an increased number of people using air conditioners can also strain the electrical grid.

Average annual total electric power interruptions by U.S. state (2022)

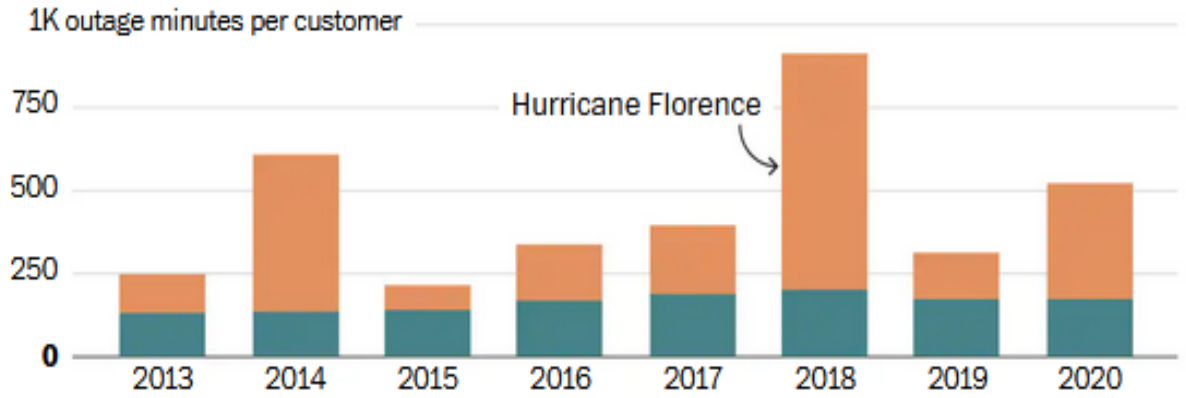
number of interruptions and duration (hours) per customer



Data source: U.S. Energy Information Administration, *Annual Electric Power Industry Report*

Despite growing investments by utilities, power grids remain fragile

Outages experienced by Duke Energy Carolinas customers in North Carolina during normal power outages and major events, such as hurricanes.



Percent of outage periods that stemmed from major events

Based on the number of minutes the average U.S. electricity customer was without power.

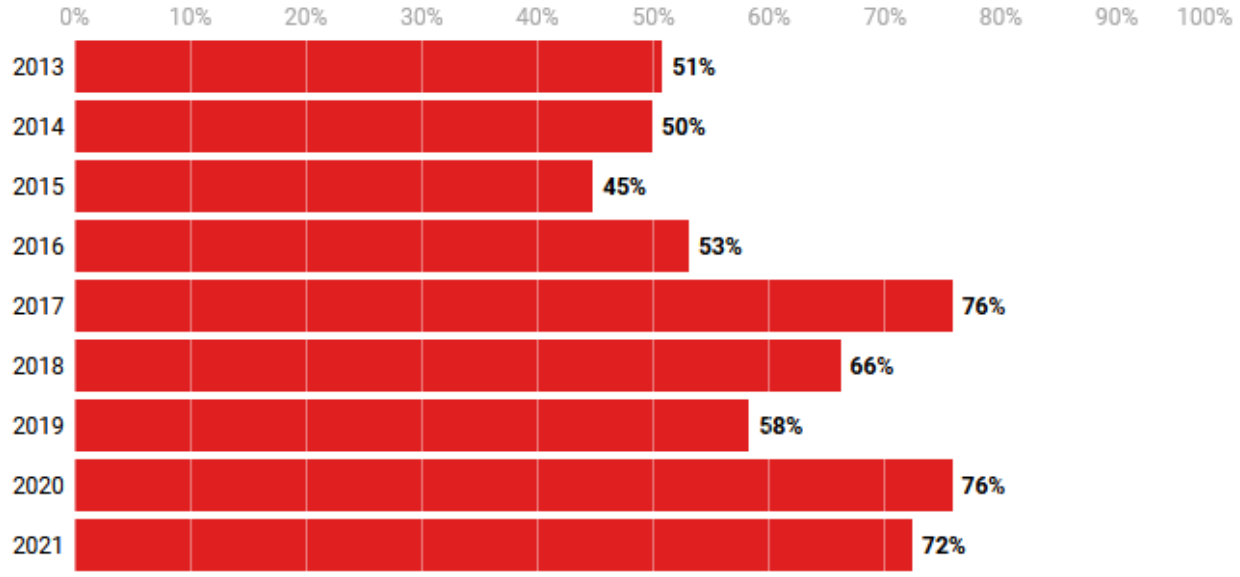


Chart: Emily Barone • Source: EIA

TIME

Hydroelectric Dams Impacts

A recent study published in the journal *Earth's Future* found that hydro availability and summer air temperatures are likely the biggest determinants in Western electricity prices.

- Hydropower plants in the United States can produce about 80 gigawatts (GW) of energy, about 7% of total energy production.
- Glen Canyon Power Plant has a contract with the Palo Verde Generating Station, the country's largest nuclear power plant, to provide black start and emergency shutdown power.

In 2021, a historic drought that affected much of the western United States led to reduced water supply and, as a result, lower hydropower generation in the Pacific Northwest and California.

- Electricity generation at California's hydropower plants was 48% below the 10-year average (2011–2020). The Lake Oroville Dam was shut down for the first time since 1967 due to low water levels and Lake Shasta's dam was generating about 30% less power than usual.
- The Hoover Dam was down 25% while the Glen Canyon output reduced about 35% in 2022.
- In the Pacific Northwest hydropower generation was 14% below the 10-year average with the Grand Coulee dam at 12% below the 10-year average.
- St. Cloud hydroelectric dam shut down in August 2021 when Mississippi River flows fell below 700 cubic feet per second for first time since 1988 when it was last shut down due to low flows.

The six mainstem hydroelectric power plants for the Missouri River System are Fort Peck, Garrison, Oahe, Big Bend, Fort Randall and Gavins Point.

- Together, they generated 832 million kWh of electricity in September 2022, compared with typical energy generation for the month of 902 million kWh.
- The power plants generated 7.4 billion kWh of electricity in 2022, compared to the long-term average of 9.4 billion kWh annually. The region saw twice the drought coverage of normal.

At current reservoir sedimentation rates, the existing global reservoir storage capacity could be nearly halved by 2100. Sedimentation rates vary widely according to the river basin's geologic and physical condition. Causing some dams to age faster than others due to sedimentation alone.

- The estimated loss of storage capacity in reservoirs in the US due to sedimentation ranges to a loss of $100 million. The annual cost for promoting the removal sediments is about $6 billion. Semi-arid locations are more susceptible for reservoir problems as they have higher capacities.

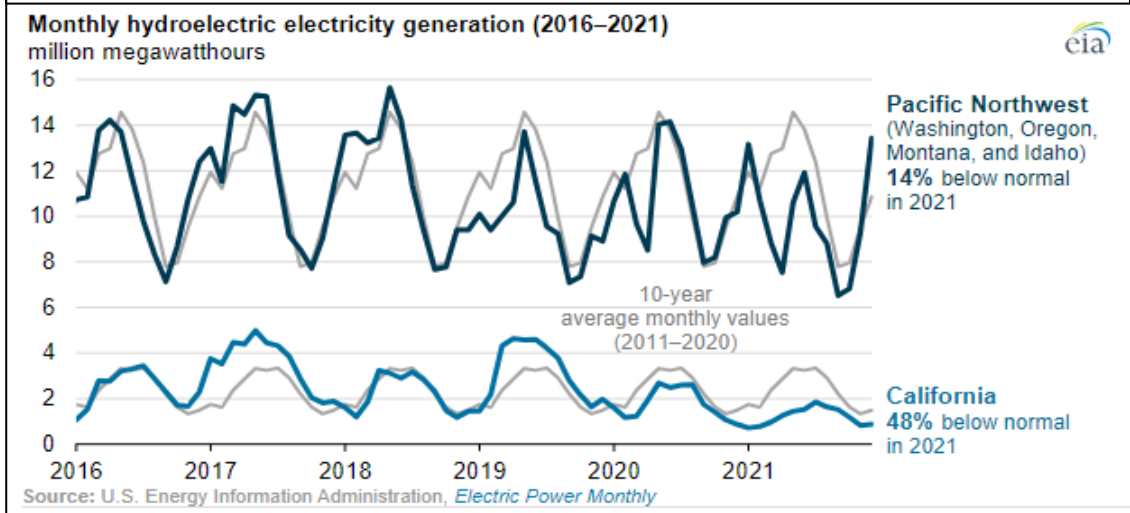
A 2022 study published in 'Water' assesses the risks of floods and water scarcity to hydropower projects and how those risks may shift with multiple regions highlighted for risk of water scarcity by 2050.

- Future droughts could potentially create challenges for hydropower projects, especially in Montana, Nevada, Texas, Arizona, California, Arkansas and Oklahoma.
- By 2050, 61% of all global hydropower dams will be in basins with very high or extreme risk for droughts, floods or both. By 2050, 1 in 5 existing hydropower dams will be in high flood risk areas as abnormal heating amplifies rainfall totals, up from 1 in 25 today.
- Only 2% of planned dams are in basins that currently have the highest level of flood risk, but by 2050, nearly 40% of this same group of dams will be in basins with the highest flood risk.

The hydropower shortfall from January 2021 to July 2022 caused WAPA to spend $78m of a $146m buffer fund as it had to buy alternative power for its customers in times of shortages. Customers faced a 40% price increase.

- Navajo Tribal Utility Authority reported its operating costs rose by $4.5m in 2022 due to the drought.

Water flow in the Colorado river could drop 30% by 2050 and 55% by 2100 due to greenhouse gas emissions. About 1.9 million acre-feet (13% of the water from the reservoirs across the entire river) evaporates each year.

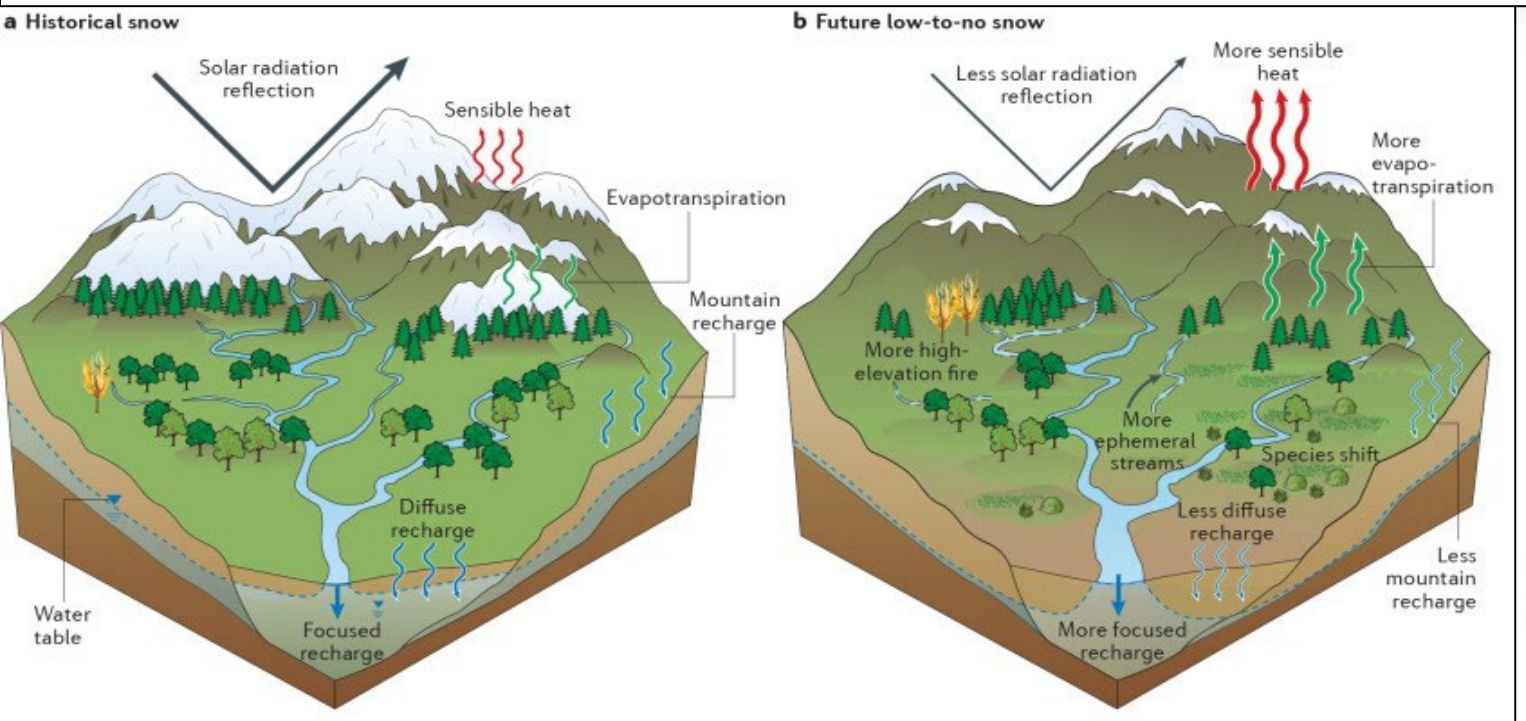


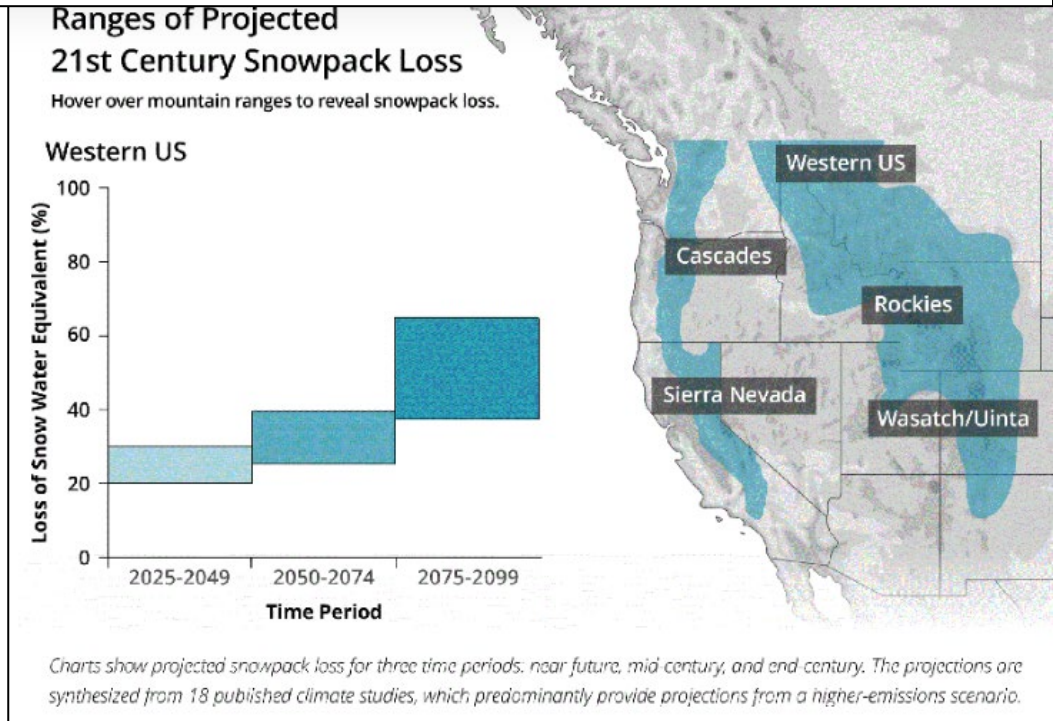
National Snowpack Shifts from Warming

A recent study highlighted that there has been a 21% decline in the April 1st snowpack water storage in the western U.S. since the 1950s – which is equivalent to Lake Mead's storage capacity. Reports of changes across the Western US may provide early notice to the Eastern US mountains and the stability of the snowpacks across the US.

- There have been decreases in peak snowpack volume and earlier occurrences across the West, with the peak occurring approximately 8 days earlier in the year for every 1.8F of warming. There is a correlating shift in premature blooming for plants and double-bloom capabilities in some regions straining soil nutrients and water storage in shallow aquifers.
    - The peak annual *snowpack in the Cascades could decrease by 25% in the next 30-60 years* according to the study.
    - California could experience episodic low-to-no snow beginning in the late 2040s and low-to-no snow in the 2060s.
        - This could cause cascading snow loss into Central US as the storms crossing the West will pick up warmer, drier air from the darker albedo associated with exposed vegetation and landscapes versus what had historical coverage of snow and cold air damming in the valleys.
- For other parts of the western U.S. persistent low-to-no snow emerges in the 2070s which extends across the Rocky Mountains. This will result in more precipitation falling as rain versus snow, changing the way the rivers and reservoirs operate and amplifying concerns of avalanches over the next 45 years as short bursts of precipitation prevail.

Earlier onset snowpack melt can amplify drought and fire threats as runoff throughout the winter can grow short brush which dries out quickly and reduces riverway storage through ahead of agricultural assessments of water levels for distributing industry water needs. Lower river systems can warm at faster rates further compounding the issue.





Charts show projected snowpack loss for three time periods: near future, mid century, and end century. The projections are synthesized from 18 published climate studies, which predominantly provide projections from a higher-emissions scenario.

Tropical Cyclones

An assessment by hurricane experts correlates an increase in intensity and the proportion of the most intense storms, as well as increase in the occurrence of storms resulting in extreme rainfall rates over 3-hour timeframes which increased by 10% while 3-day total rainfall accumulations increased by 5% for tropical storm strength to hurricane strength systems.

- Extreme rainfall rates when focusing on *hurricane strength only* saw increases for 3-hourly rainfall rates of 11% and 3-day total accumulated rainfall by 8%. Damaging winds associated with tropical low centers are also expected to increase.
- A study in February 2022: “Extreme Atlantic Hurricane Seasons are made twice as likely by ocean warming” with data indicating overactive seasons are now twice as likely as they were in the 1980s. Back-to-back hurricanes are also now more likely.

Recent Hurricane Season Studies

- A study analyzing the 2020 North Atlantic hurricane season found that hourly hurricane rainfall totals were around 10% higher compared to hurricanes recorded in the pre-industrial (1850s) era.

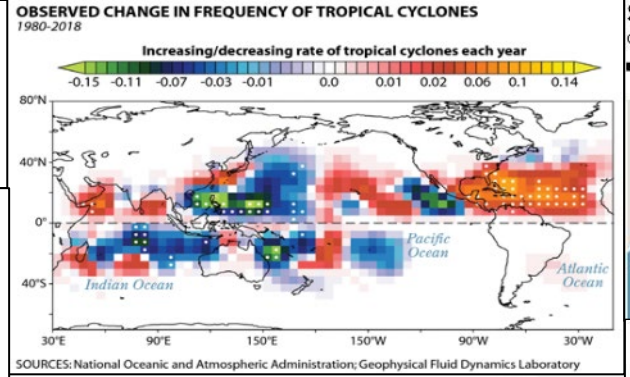
- One assessment suggests an increase in intensity, proportion of the most intense storms, and the occurrence of storms with extreme rainfall events.

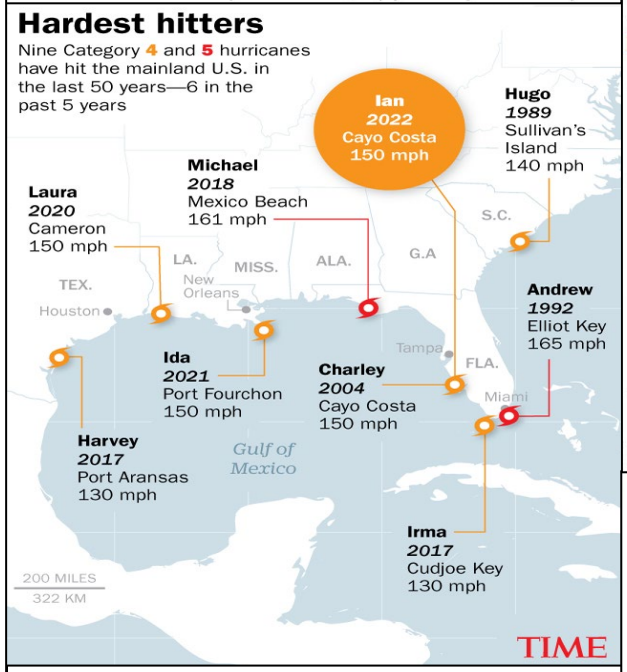
- A recent study from Yale using data from 2020’s cyclone Alpha and 2021’s cyclone Henri states the next 75 years will see an expansion of hurricanes/typhoons into mid-latitude regions, including major cities such as New York, Boston, Beijing, and Tokyo

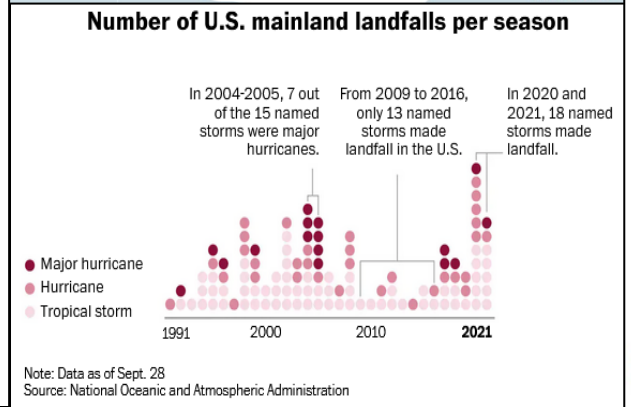
- A recent assessment indicated an increase of global tropical cyclone rainfall rates at 7% per degree of Celsius of warming with an observational finding of a 1.3% global increase in tropical cyclone rainfall rates per year since the early 1900s.

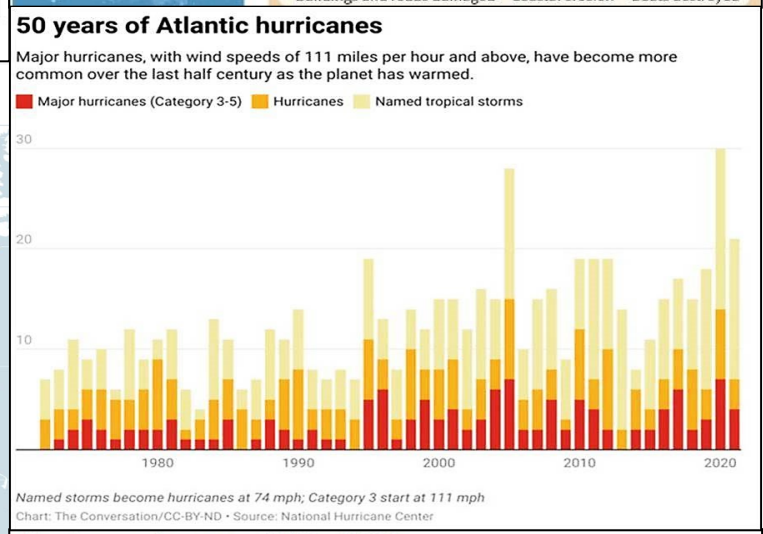
NOAA recently released a new explanatory guide: This information could be a useful guide to distribute to staff, as it succinctly covers the dangers of hurricanes and how to plan for them. 57% of fatalities during tropical cyclones have been caused by storm surge.

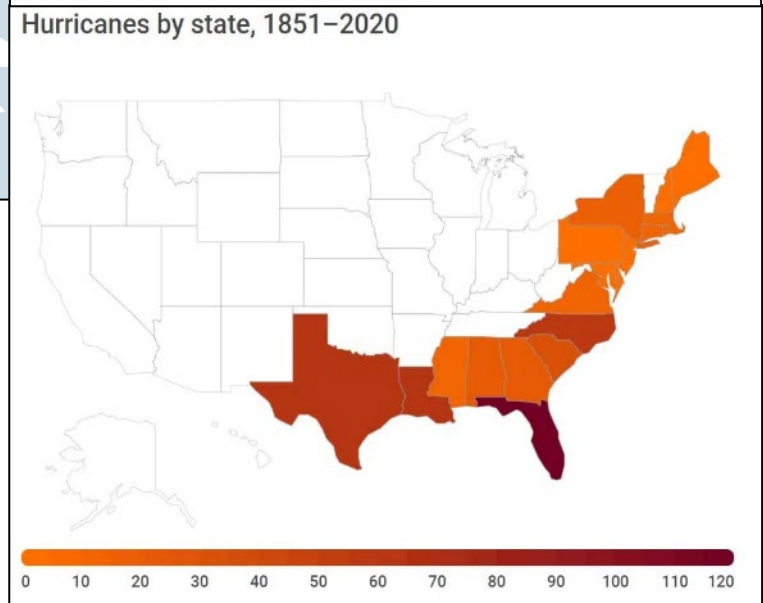
- Storm inundation levels during hurricane surge events will increase due to sea level rise, anticipated to rise by about 2 to 3 ft by 2100.
- Strongest winds of tropical storms and hurricanes are projected to increase about 3%.
- Due to human-caused climate change, precipitation rates within tropical storms and hurricanes are projected to increase by about 15% and the number of Atlantic hurricanes reaching Category 4 or 5 intensity are projected to increase about 10%.











Sea Level Rise Impacts

The Sea Level Rise Technical Report states flooding is rising toward a nationwide average of 3 to 7 days per year by April 2023 and 45 to 70 days per year by 2050. According to the report, high tides driven by rising seas flooded coastal areas more than 500 times over the past year.

- https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html

Since 1900, global average sea level has risen by about 7–8 inches. Global average sea level is projected to rise another 1–8 feet, with a likely range of 1–4 feet, by 2100.

- Nuisance floods are events in which water levels exceed the local threshold (set by NOAA NWS) for minor impacts.
    - These events can damage infrastructure, cause road closures, and overwhelm storm drains. The additional weight can increase subsidence and erosion effects also.

Higher sea levels will likely increase the probability for major flooding events.

- According to the National Flood Insurance Program (NFIP), “the increase in the expected annual flood damage by the year 2100 for an insured property subject to sea level rise is estimated to increase by 36 to 58% for a one-foot rise” in sea level.
    - Due to local land subsidence, sea level rise along most of the coastal Northeast is expected to exceed the global average rise.

A sea level rise of two feet, without any changes in storms, would more than triple the frequency of dangerous coastal flooding throughout coastal areas of the US.

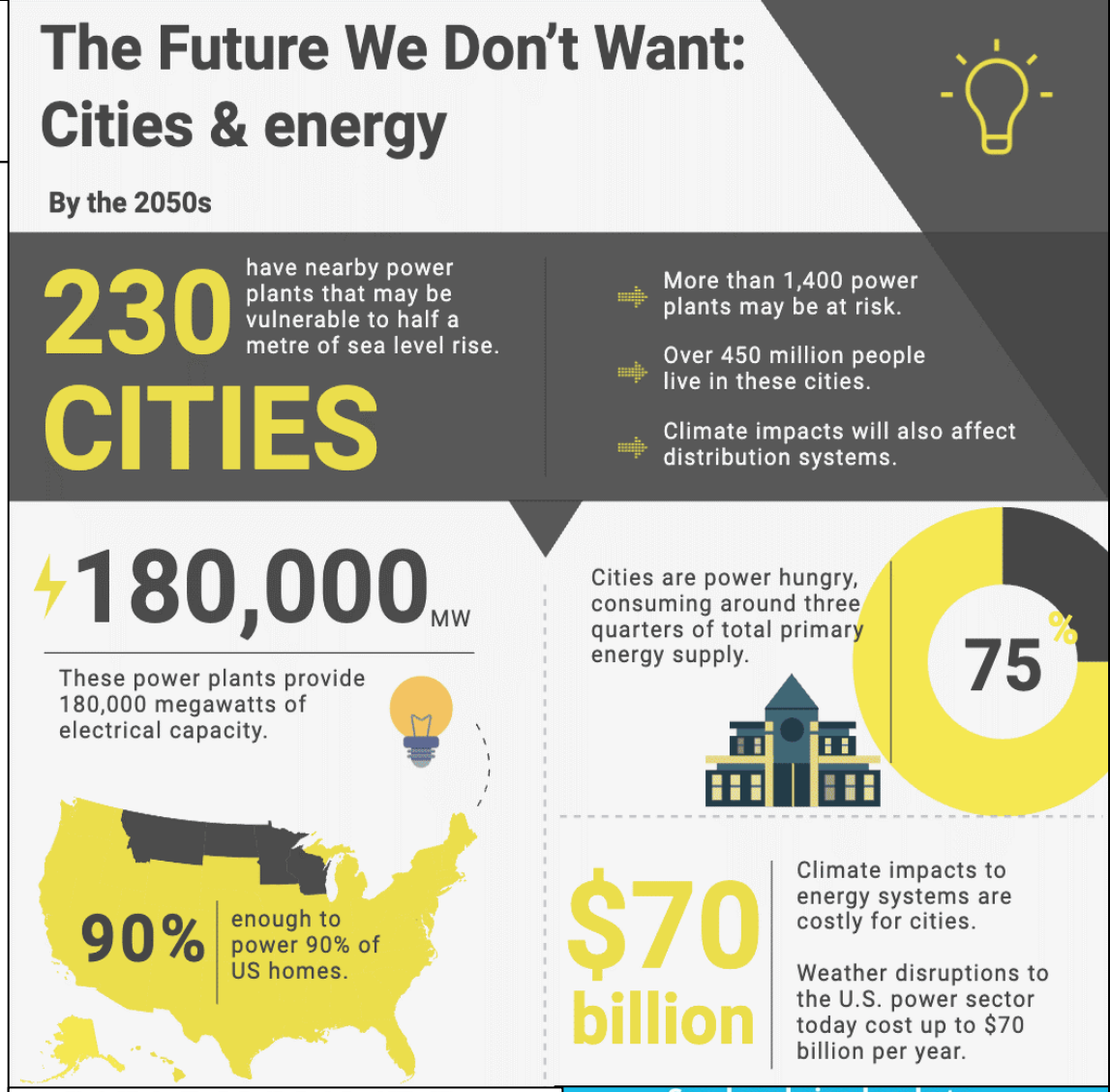
Extreme flooding will continue to be concentrated in regions where humans have built on floodplains or low-lying coastal regions, causing greater risk.

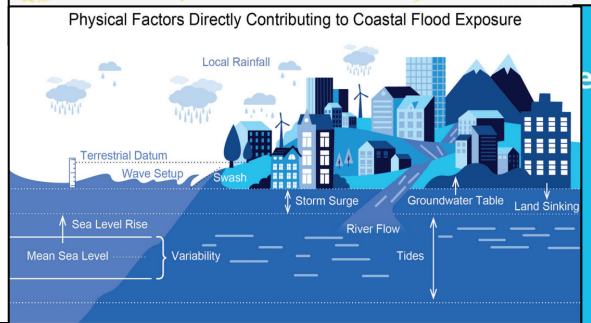
- The rate of rise this past century was greater than any other century in the past 2,000 years.

Over 8.6 million Americans live in areas susceptible to coastal flooding, especially from lows such as a hurricane or nor’easter, push a surge of water from the ocean onto land.

Sea level rise is poised to shift the way rivers naturally chart their paths to the shoreline. The nature of that change will depend on both the rate of rise and the sediment load carried by the river, according to 2020 National Science Foundation-funded research.

- If sea levels rise faster than rivers can deposit sediment, the zone of deposition and avulsion will shift upstream, introducing new avulsion hazards to upstream communities.





Energy Needs on the Rise

AI Implications: Recent research shows that the enormous computing power, larger chips and additional servers required for AI not only add significantly to electricity demands, but also make many of those data centers much thirstier.

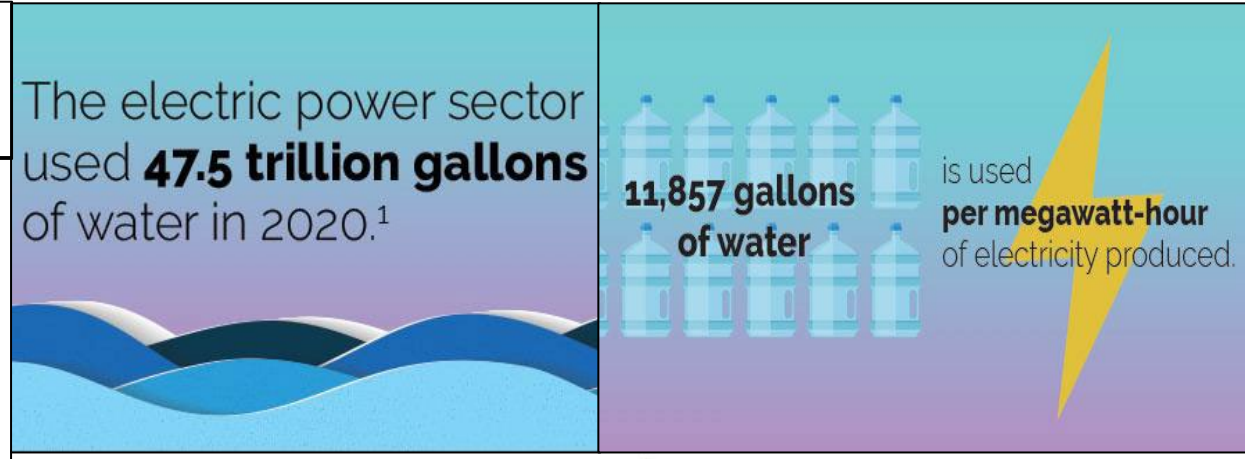
- Projections for the coming years show global AI growth could require more water than some small nations consume.
- Training GPT-3 in Microsoft's high-end data centers can directly evaporate 700,000 liters, or about 185,000 gallons, of water.
- For every 10-50 responses made, GPT requires about 16oz of water which is 20 times more water to have a ChatGPT conversation than to run a Google search.
- Global AI demand could result in as much as 6.6 billion cubic meters, or 8.6 billion cubic yards, of water withdrawal by 2027.

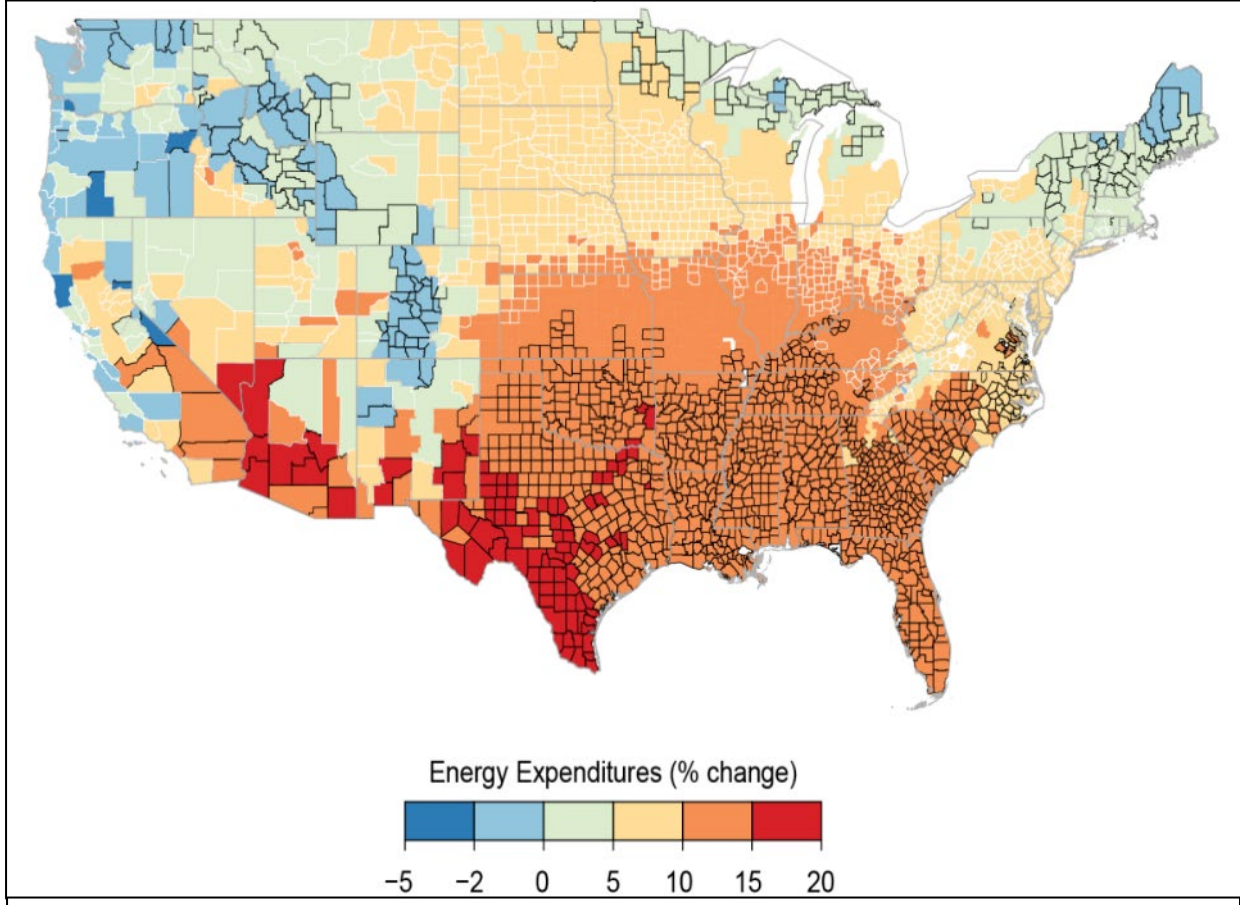
Google, Microsoft and Facebook parent Meta have all said they will replenish more water than they consume by 2030.

- Solutions considered include working with local water utilities, better recycling of water and less water-intensive cooling methods. In some instances, moving sites to underwater or underground facilities near water. Some chip companies are now turning to direct-to-chip liquid cooling for its superior heat transfer capabilities to reduce drought and heat risks.

North America accounts for most of the world's data center capacity, but the Asia Pacific data center market is expected to grow 12.2% by year's end, with Southeast Asia alone growing at 12.9% followed by Europe, the Middle East and Africa at 11.1% and North America at 6.4%.

- Proposed locations for datacenter or cryptocurrency development should be selected for their natural safeguards to extreme heat, drought, or floods.





Projected increases in energy consumption from 2012 to the average of the 2080–2099 period. Source: USGCRP, Fourth National Climate Assessment, 2018.

Extreme WX: Coal Mines

When coal, exposed at or near the surface by erosion, combines with oxygen, a chemical reaction produces heat. That process can build for years; low-grade, soft coals can spontaneously combust, at temperatures as low as 104F. Lightning, large wildfires, or a brush fire can also ignite soft coal.

- Coal seam fires have accounted for up to 15% of fires in coal mines.
- The fires burn downward, acquiring air through fissures in rock and microscopic spaces between grains of dirt. These can create surface sinkholes or additional subsidence.
- These fires can burn for decades or longer. For example, scientists estimate that Australia's Burning Mountain, the oldest known coal fire, has burned for 6,000 years.
- The Brennender Berg fire in Germany has been burning since the 17th century potentially due to spontaneous coal combustion, when the right combination of pressure and oxygen causes the coal to ignite.
- Subsidence events triggered by burning subterranean coal turning to ash can create underground voids and cause the surface to crack and collapse, allowing more air in and fanning the fire.
- Coal mine fires have global impacts as they produce large amounts of pollutants such as sulfur and nitrogen oxides, CO2, fly ash, arsenic, mercury, and selenium.

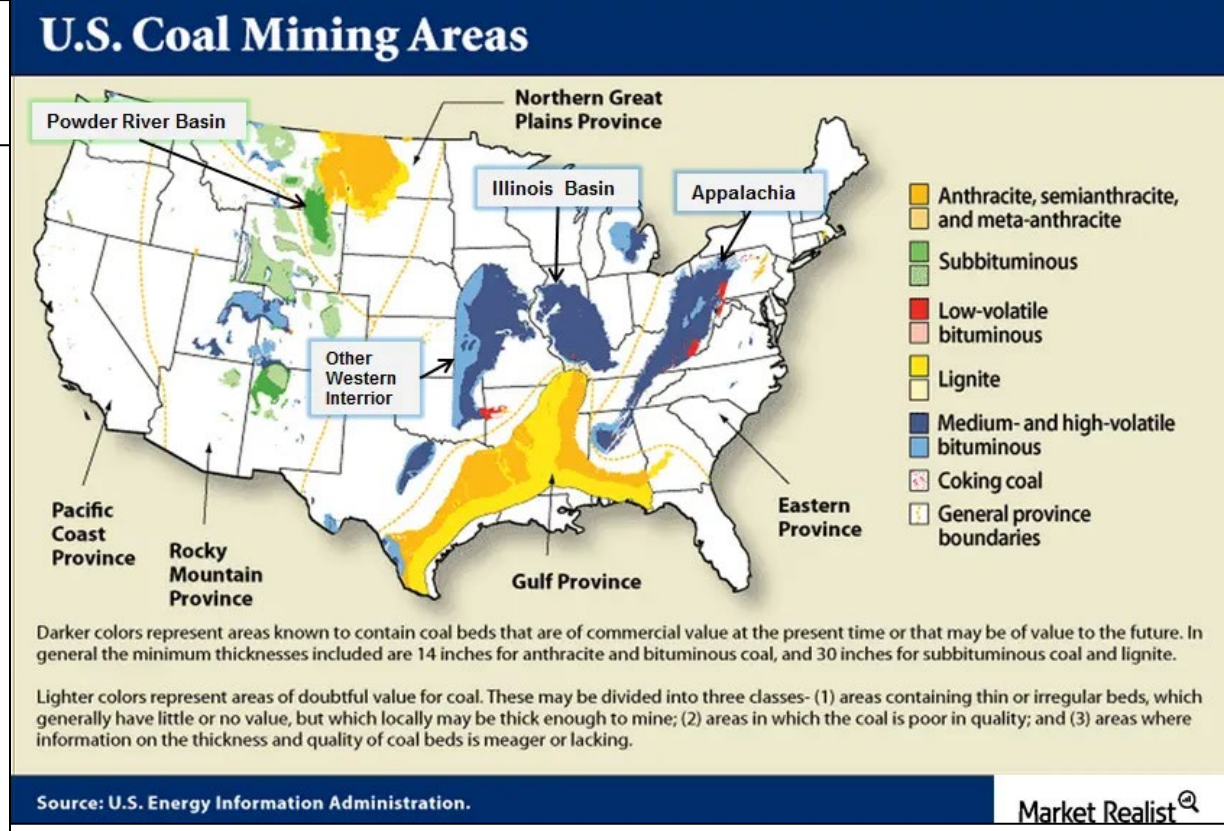
Region 8

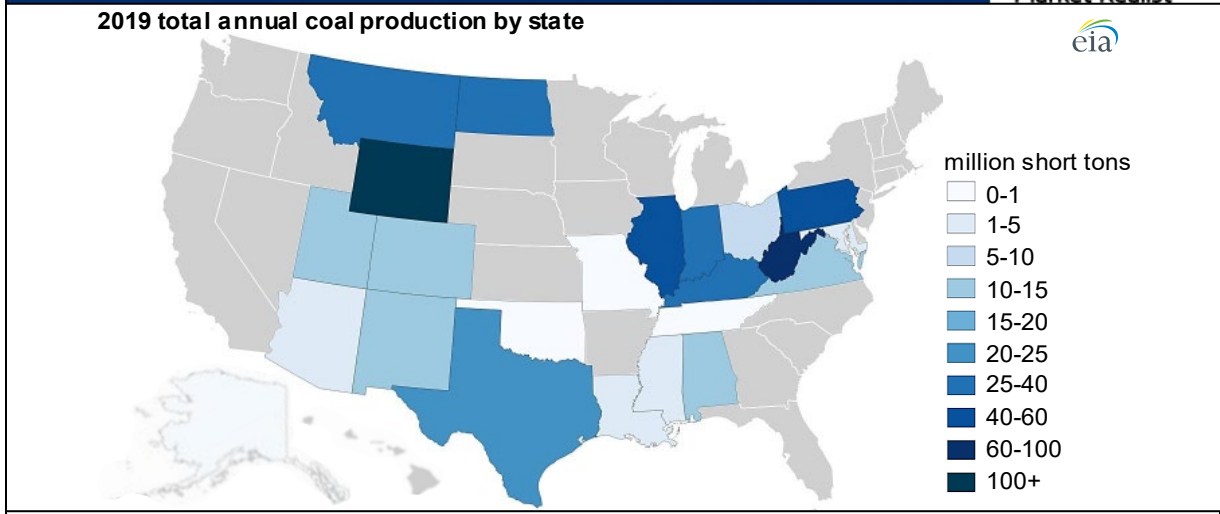
Colorado: 'Near Glenwood Springs, Colorado, for example, an old coal mine has burned for the past 100 years. In the summer of 2002, the blaze ignited a forest fire that consumed 12,000 acres and 43 buildings. Putting the fire out cost $6.5 million and the mine still burns'.

Utah: September 2022, an underground coal mine just outside the town of East Carbon in rural Utah caught fire. The coal mine is one of the busiest in the state and produces about 28% of Utah's coal. About 40% of the state's coal is produced from Lila Canyon which goes to two major power plants in Utah.

Montana: In 2021 over 170,000 acres burned in Rosebud County due to an underground coal seam as the largest fire in the state that year.

North Dakota: 47 coal seam fires were put out between 2003 and 2012, mostly on Forest Service land, at a cost of $170,000.





Coal production makes up 21.9% of U.S. energy production, according to EIA.

Estimates of coal lost to fires range from 20 million to 600 million metric tons of coal annually.

Drought and Seismic Activity

A fault is formed in the Earth's crust as a brittle response to stress. Generally, the movement of the tectonic plates provides the stress, and rocks at the surface break in response to this. Faults form when rock above an inclined fracture plane moves downward, sliding along the rock on the other side of the fracture. Normal faults are often found along divergent plate boundaries, such as under the ocean where new crust is forming. Long, deep valleys can also be the result of normal faulting.

- Collisions zones are where tectonic plates push up, resulting in mountain ranges such as the Himalayas and the Rocky Mountains. The San Andreas Fault in California is the largest in the world at more than 800 miles from the Salton Sea to Cape Mendocino. A devastating earthquake is reportedly 'due' by 2030 along this fault.

The number of earthquakes in the central U.S. has increased dramatically over the past decade. Between the years 1973–2008, there was an average of 25 earthquakes of magnitude three and larger in the central and eastern US. Since 2009, at least 58 earthquakes of this size have occurred each year, and at least 100 earthquakes of this size every year since 2013. The rate peaked in 2015 with 1010 M3+ earthquakes. In 2019, 130 M3+ earthquakes occurred in the same region.

"**The Gravity Recovery and Climate Experiment (GRACE measurements) reveals that major earthquakes (Mw 5 and above) always occur in the dry stage, indicating drought and associated groundwater extraction is an important trigger for major earthquakes**." Earthquakes result from strain build-up and weakening from within faults.

- The loss of an estimated 63 trillion gallons of water in West, most of it groundwater, was reported in a study done by researchers at the Scripps Institution of Oceanography. The loss of the water has caused the ground to rise more than a half-inch in California's mountains in 2017.

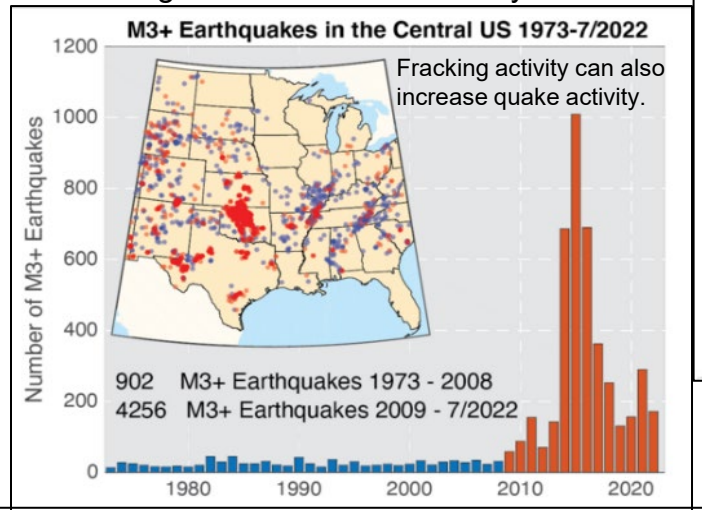
The areas around fault lines have valleys where the plates meet and are at their weakest point. Due to the lower elevations around these topography features, water tends to pool at the lowest elevation and thereby river systems were naturally located in the weaker spots of the fault line.

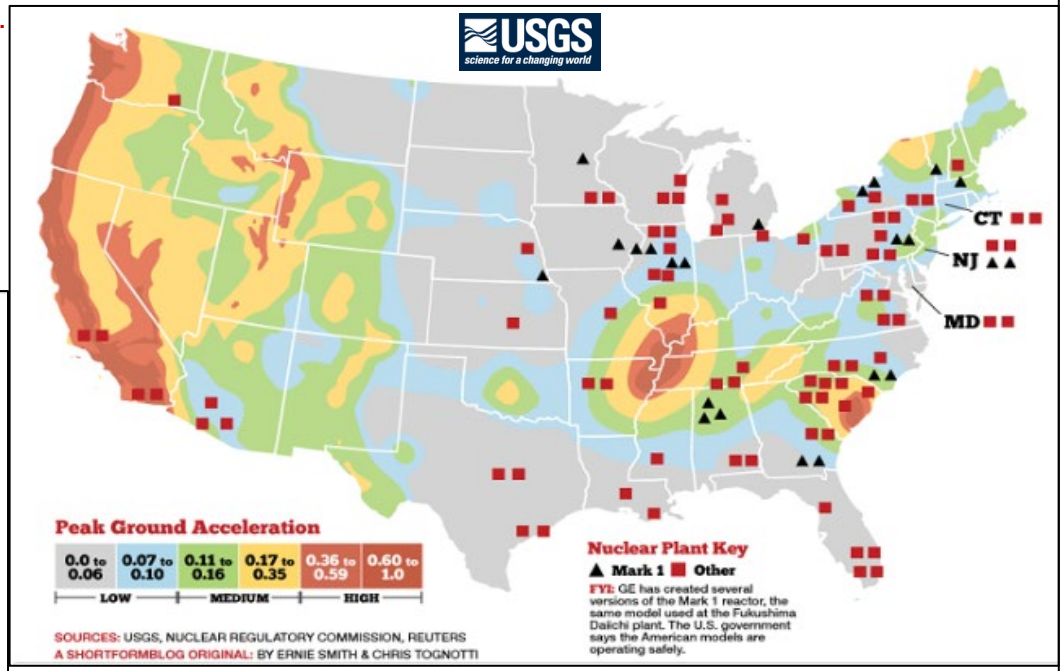
- Damming up the river system resulted in compounding water in different areas than were natural along some faults. As dams were installed, an increase in seismic activity was reported and subsequently as drought has developed, activity has increased again near the river/dam systems.

Water weighs about 8lbs per gallon of water, with more water falling in single events, rapid onsets of pressure on weak pooling points will have downward impacts as will sudden drying from increased evaporation and the drying of soils lifting the pressure on the plate upward.

Recent research has confirmed this correlation of water weight on the crust as a form of water-stress triggering earthquakes during major precipitation shift events.

There are a notable amount of nuclear power plants built along river systems in the US and in areas experiencing increasing drought conditions presenting additional seismic concerns for public safety.





USGS Seismic Hazard Model areas of Risk with Nuclear Power Plants: Comparing these major fault line and tectonic plate boundary areas with persisting surface drought shows the potential instability of quake activity.

Cross-Border Transmission System Risks

Electricity Canada: Canadians and Americans share a highly integrated electricity grid, connected by 37 cross-border transmission lines. Every Canadian province along the US border is electrically interconnected with at least one neighboring US state.

International supply chain strain: CEO of the industry association Electricity Canada, said there is virtually nowhere the electricity grid isn't vulnerable to the rising severity and duration of climate change-related extreme weather.

A 2023 WAPA (Western Area Power Authority) study revealed: Among the highest priority items are circuit breakers and large power transformers.

- Circuit breakers interrupt fault current, protect equipment and isolate transmission lines within WAPA's area of responsibility.
    - Lead times have escalated from six months to 4.5 years for voltage classes 245-kilovolt and below and 5.5 years for 345-kV voltage classes and above.
        - Supply and demand have bumped up circuit breaker costs by 140% over the past two years.
- Transformer cost has also sharply increased to over 200% of the original pricing, surpassing the Consumer Price Index.

A 2022 study stated a pad-mount transformer now costs 3x more than 2019 with delivery times rising by 12 months. Large transformer manufacturing will also face major long-term issues, with demand expected to double by 2027 and the steel industry already hitting maximum capacity.

Flood: about four inches of rain fell in Toronto one July day this year; nearly the average rainfall the city receives in all of July. At Pearson Airport, 97.4 millimeters fell in about 3.5 hours. Flood forces

Hail: sizes ranging +golf ball sized in boundary storms to 3-inches in diameter in Talbot.

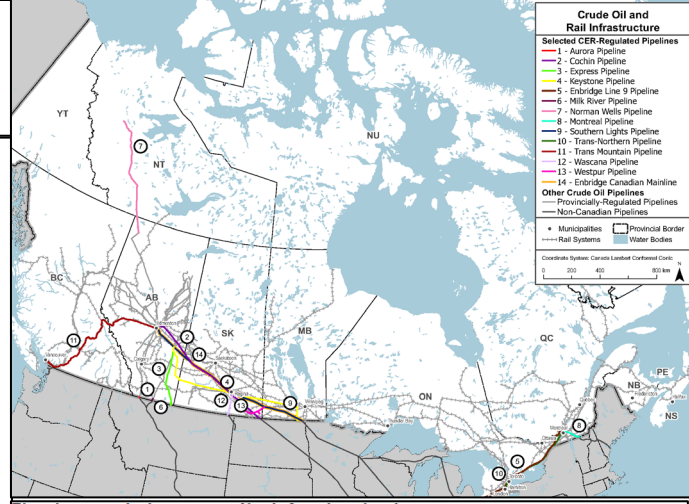
Lightning: Nova Scotia reported outages in August over 1,000 due to lightning storms. Lightning damage to powerlines or substations can cause significant replacement costs. Lightning is the leading cause of wildfires this year for Canada.

Winds: over 100km/h or +62 mph damage powerlines across the country. These winds can occur with any MCS or boundary storm across both countries and are becoming more frequent due to higher persisting baseline temperatures and damage transmission lines, bring down trees, threaten supply trucks, and result in higher costs for repairs.

Tornadoes: over 230 tornadoes occur in Canada annually, mostly in Southern Ontario, the Prairies and Southern Quebec. Canada's first tornado of 2024 was reported in April, along with Alaska. Tornadoes can damage energy infrastructure and stations.

Heat: In June, Independent Electricity System Operator (IESO) in Ontario stated megawatt usage was near peak levels due to a heatwave. Solar panels generate less voltage and are less efficient in high temperatures and surface water evaporation along with increased use can result in low flows to hydroelectric plants across major basins.

Cold: Extremely cold temperatures can cause problems for wind turbines if snow accumulates or ice forms on the turbine blades. Pipelines can crack while use and need continue to rise across multiple regions for heating both commercial and residential sites.



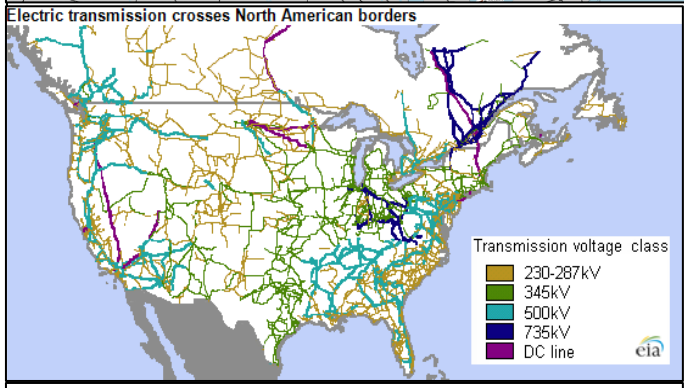
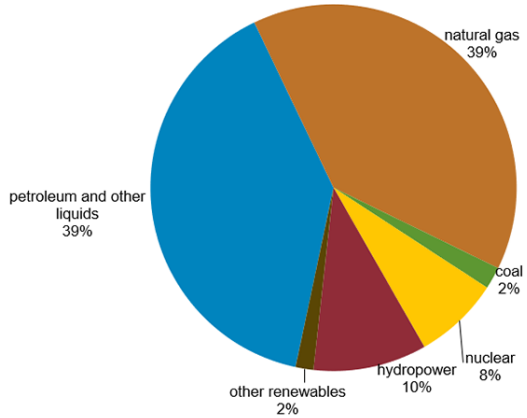


Figure 2. Canada's total energy consumption by fuel type, 2022
percentage of total energy consumption



eia Data source: U.S. Energy Information Administration, International Energy Statistics; Energy Institute, *Statistical Review of World Energy 2023*

International Climate Impacts to CI Sectors

2021 Heat Wave China: Sichuan is rich in mineral resources like lithium and polysilicon, key raw materials in the solar photovoltaic and electronics industry.

- Many international semiconductor companies have plants in Sichuan, including Texas Instruments, Intel, Onsemi, and Foxconn. Chinese lithium battery giant CATL, which supplies batteries to Tesla, also has a factory in the region.
- Officials from the manufacturing hub of Chongqing notified factories August of 2022 that mandated power cuts in the municipality were extended until further notice, affecting both PC and Apple suppliers. Relocation was widely communicated.

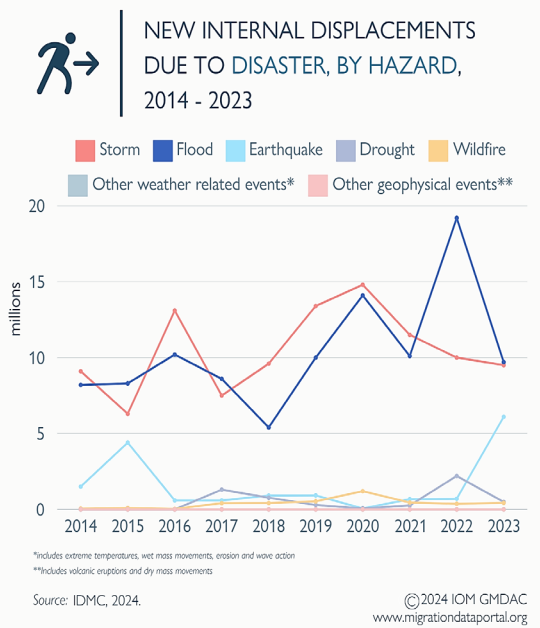
2022-2023 Toxic Air: The Energy Policy Institute at the University of Chicago (EPIC), states that bad air could reduce the life expectancy of Delhi residents by as much as nine years. Shutdowns due to air quality impacted more than 75 million people.

- School and business closures as well as roadway use bans were put in place with construction halts and crop burning pauses.

2023 Drought: Critical rivers in South America, Europe, US, China, and across Africa reported record lows impacting water for manufacturing, energy sector cooling, agriculture, cargo shipments, and built infrastructure through soil stability.

2024 Floods: Brazil, Texas, China, France, Germany, Russia, and the Middle East all reported record rains, snowmelts, and floods impacted major transportation networks, manufacturing hubs, supply chain capabilities, and overall functionality.

- More than 600,000 people globally were displaced along with hundreds of millions in direct economic losses and damages.



Hong Kong (CNN Business) — China's Sichuan province has ordered all factories to shut down for six days to ease a power shortage in the region as a scorching heat wave sweeps across the country.

Sichuan is a key manufacturing location for the semiconductor and solar panel industries and the power rationing will hit factories belonging to some of the world's biggest electronics companies, including Apple (AAPL) supplier Foxconn and Intel (INTC).

The province is also China's lithium mining hub — a key component of electric car batteries — and the shutdown may push up the cost of the raw material, analysts said.

China is facing its fiercest heat wave in six decades, with temperatures crossing 40 degrees Celsius (104 degrees Fahrenheit) in dozens of cities. The extreme heat has caused a spike in demand for air conditioning in offices and homes, putting pressure on the power grid. The drought has also depleted river water levels, reducing the amount of electricity produced at hydropower plants.

Sichuan, one of China's largest provinces with 84 million people, told 19 out of 21 cities in the region to suspend production at all factories from Monday to Saturday, according to an "urgent notice" issued on Sunday by the provincial government and the state grid.

For the third day this week, air quality in the city passed the "severe" threshold, reaching 445 on Friday, India's Ministry of Earth Sciences said. The figure is 10 times the target level established in the World Health Organization's 2021 air quality guidelines, which advises a 24-hour mean of 45.

As the smog descended on Delhi and the surrounding areas, officials on Friday ordered schools, factories and construction sites closed and banned diesel trucks from bringing nonessential goods to the capital. About half of the city's government employees were urged to work from home.

(CNN) — Lahore has become the latest megacity to shut down as pollution chokes swathes of South Asia, where nearly 50 million people have been breathing toxic air for nearly a week.

Pakistan's second most populous city – of more than 13 million people – has shut schools and closed public parks, malls and offices after the air quality index (AQI) this week spiked to more than 400, according to IQAir. That number is considered "hazardous" by the Swiss air tracking company.

Authorities in Pakistan's Punjab province have imposed an "environmental and health emergency" in three cities – Gujranwala and Hafizabad in addition to Lahore – until the situation improves, its chief minister Mohsin Naqvi said this week. The three cities combined account for more than 15 million people.

"There shall be a limited movement of people to and from these areas by public and private transport," a statement from Naqvi's office said Tuesday.

Atmospheric Changes and Wildlife

Experts theorize air pressure changes affect a fish's swim bladder, which is used to help a fish maintain neutral buoyancy. The bladder is filled with air and is thereby sensitive to pressure changes that occur when moving between different depths, likely to be affected by changing air pressure.

- Low pressure can cause the swim/air bladder to expand, which may cause fish discomfort and to retreat to a lower depth to relieve the bloating. Conversely, higher pressure can cause certain species of fish to suspend.
- Recent studies found that temperature indeed drives spatial and temporal changes in fish body size, but not consistently in the negative fashion expected. Around 55% of species were smaller in warmer waters (especially among small-bodied species), while 45% were bigger.

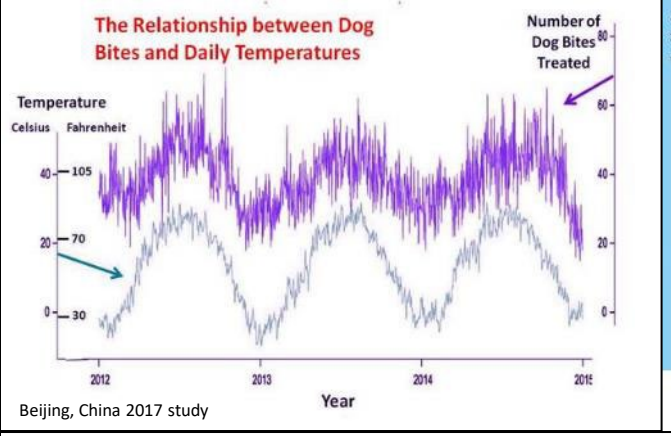
Wild and domestic animals will show a shift in their eating habits once high heat begins, because seasonal changes in daylight and temperature trigger significant hormonal changes in mammals.

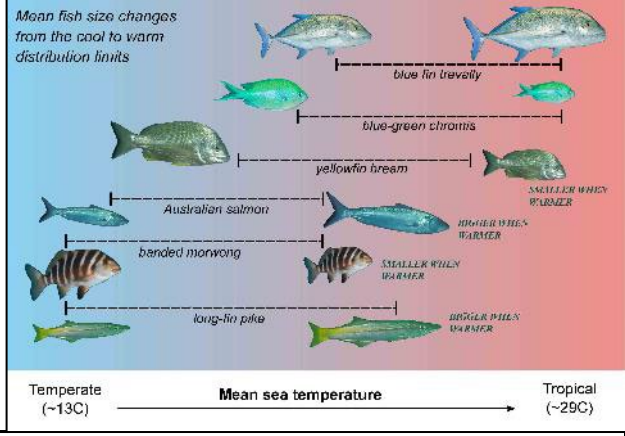
- These shifts alter the animal's metabolism and greatly influence food intake. As temperatures increase, mammals become less active and therefore burn less energy.
- This impact is especially recorded in birds as water availability becomes stressed.

As a warm weather loving animal, a hotter environment could allow North Carolina's alligators to expand their limited distribution to areas further inland and away from wet, boggy coastal areas.

- Warmer temperatures could also result in changes to reproductive rates, allowing for earlier sexual maturity and changes in body size for alligators. This could have implications for similar creatures globally.
- Florida has seen a significant rise in alligator attacks, with the Florida Fish and Wildlife Conservation Commission (FWC) reporting an upward trend in the number of alligator bites and fatalities.
- Almost half of the 453 alligator bites reported in Florida between 1948 and 2022, around 47%, occurred only in the last 22 years, from 2000 to 2022.

An uptick in human-shark interactions has been occurring on the shores of the Atlantic Ocean off Long Island, New York -- so much so that beaches have closed as surfers, lifeguards and swimmers alike suffer bites from curious sharks in search of food.





International Climate Impacts to Animal Movement

While the onset of overall changes in heat can drive migration threats for animals, the amplification of intensity for storms (both continental and tropical) can trigger bursts of movement and subsequent threats to population centers which normally are not exposed to sudden influxes of insects, rodents, or predators.

- Sudden floods from a rare storm in Egypt flushed swarms of scorpions and tarantulas from their underground burrows into people's homes resulting in more than 500 locals seeking medical attention due to stings overnight.
- Torrential floods in Tanzania led to more lion attacks after their usual prey migrated away from floodplains.
- Higher air temperatures in Australia triggered more aggressive behavior in eastern brown snakes, leading to more incidents of snake bites.
- Wildfires in Sumatra, Indonesia drove Asian elephants and tigers out of reserves and into human-inhabited areas, leading to at least one death.
- Disruption of terrestrial food webs in the Americas drove black bears in New Mexico and foxes in Chile into human settlements in search of food.
- Warmer air and ocean temperatures in a severe El Nino led to an increase in shark attacks in South Africa.

In India, long-term climate change has reduced the amount of preferred vegetation for blue sheep, or bharal, which have moved into lower elevations to feed on human crops.

- The movement of bharal has also drawn down snow leopards, which creates additional problems.

High-Pressures and Humans

A heat dome occurs when a persistent region of high-pressure traps heat over a particular area, and it can linger for days to weeks.

Hot weather increases body temperature, which in turn increases heart rate and blood pressure. Increased blood pressure and heart rate can lead to discomfort, which can be attributed to the correlation between high heat and increased anger and violence.

- A recent study in India found that a 1C increase in annual mean temperature was associated with a 4.5% increase in intimate partner violence. Other studies noted the increase in sexual violence against women and heightened workplace violence during heat events.

When the barometric pressure is high, more pressure is pushed against our body, limiting tissue expansion, increasing blood pressure with an increased possibility of heart attacks.

- A 10-millibar decrease <1016 millibar and a 10-millibar increase >1016 mbar were associated with a 12% increase and an 11% increase in myocardial infarction and coronary death events.

Studies have focused on temperatures more than the high-pressure centers enabling persisting heat events over regions for longer periods.

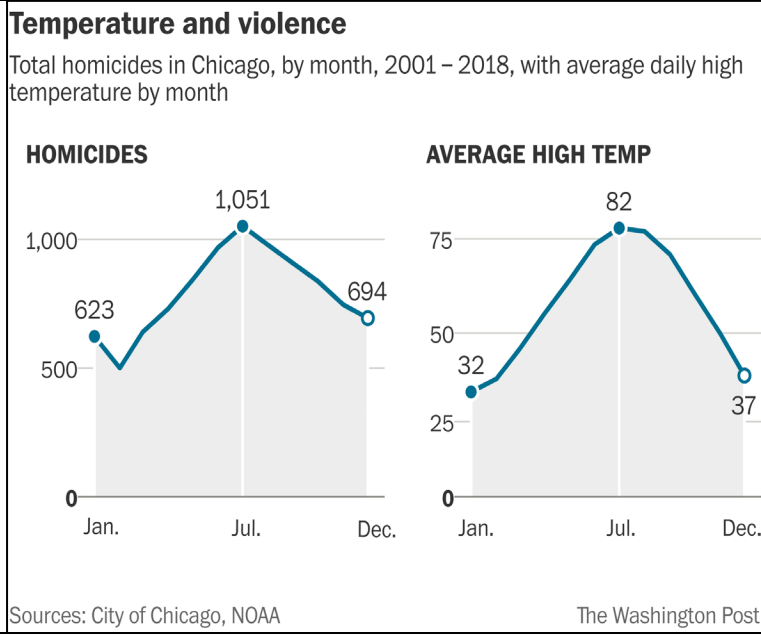
- A 2019 study from Stanford University found climate change contributed to between 3% to 20% of conflicts over the last century with the potential influence set to increase substantially due to warming global temperatures.
- Research from Mexico, which took 16 years' worth of daily crime records from different municipalities found an increase in temperature of 1C correlated with an increase across all types of crime of 1.3%.
- There were about a third more accusations of crime per population on days hotter than 32C than on days cooler than 10C.

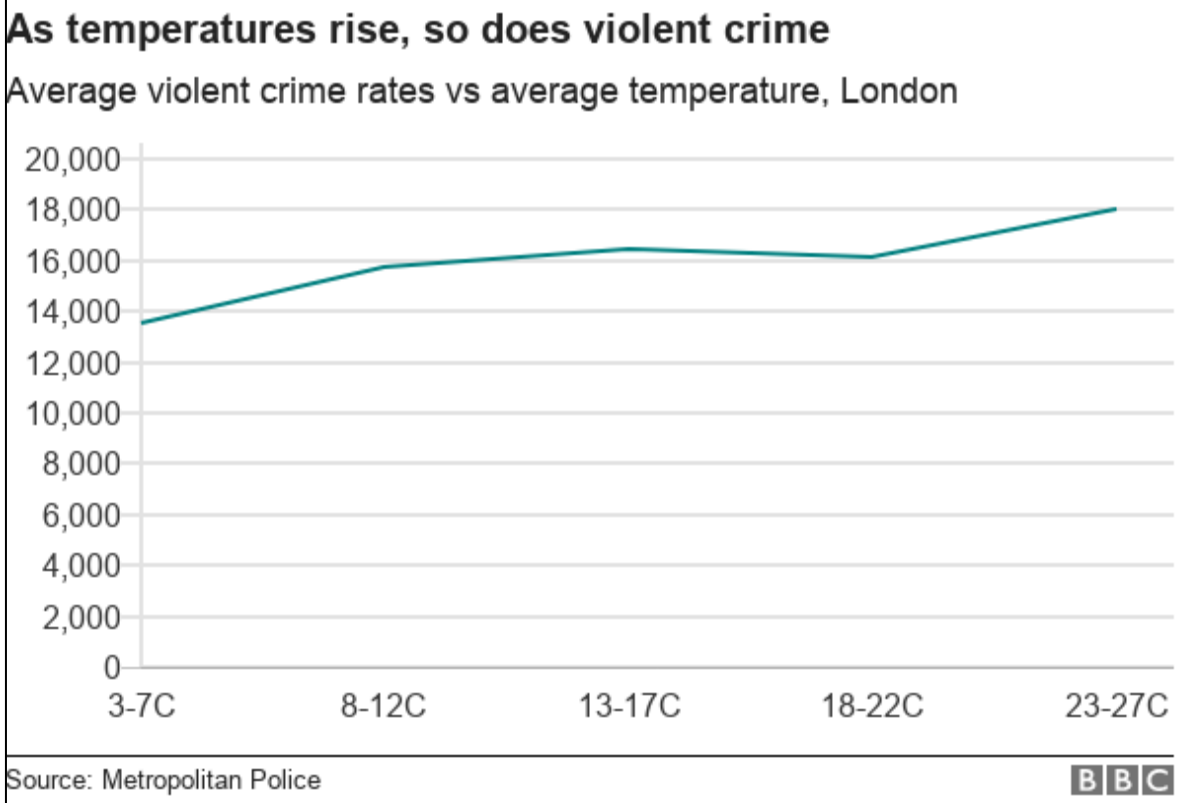
A study of Los Angeles, CA: On average, overall crime increases by 2.2% and violent crime by 5.7% on days with maximum daily temperatures above 85F (29.4C) compared to days below that threshold. Moreover, heat only affects violent crimes while property crimes are not affected by higher temperatures.

- A laboratory experiment found that participants demonstrated an increase in the joy of destruction when subject to increasing ambient temperatures.

A 2019 study on terrorist attacks found that not only were terrorist attacks more common on hotter days, but also that the number of fatalities per attack were higher. (Studies in Conflict & Terrorism)

- Even if the world's countries managed to keep "global temperature rise this century well below 2 degrees Celsius above preindustrial levels," global terrorist attacks would increase by 14% solely due to hotter days. Total terrorism fatalities would rise by 24% to include the increase in populations being outside more and larger events.

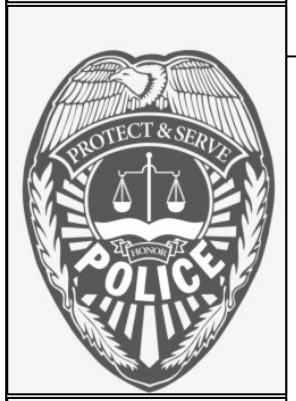


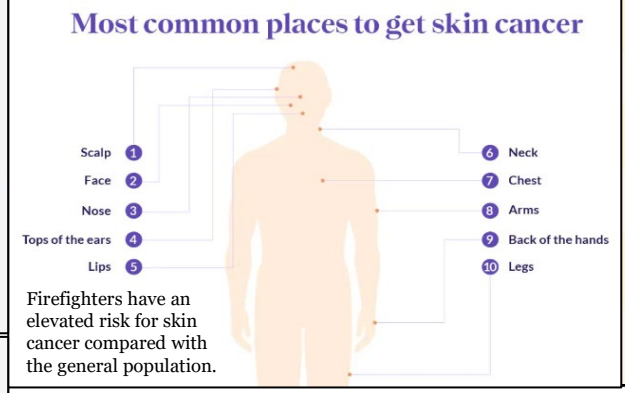


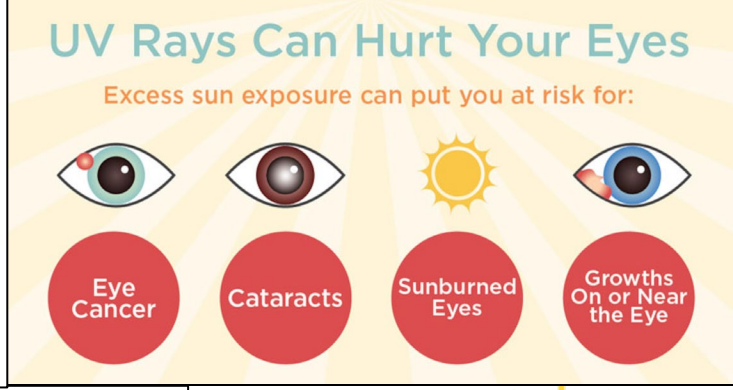
‘Too Hot To Op’

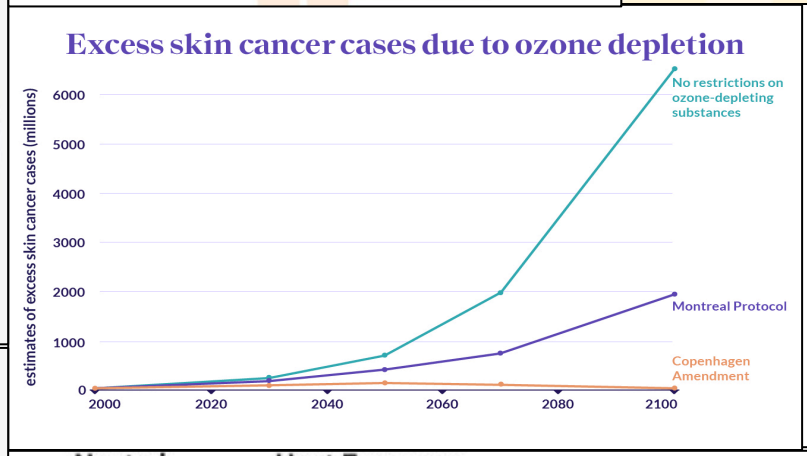
First Responders/Operators Risks from Heat

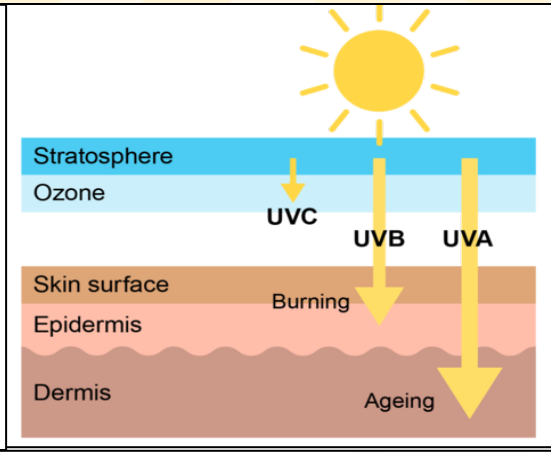
- Higher Rates of Skin Cancer
- Inhalation of Greater Concentrations of Pollution
- Vision Impairment due to Reflectivity
- Overheating – Gear Amplification
- Equipment Degradation
- Dehydration
- Heat Exhaustion/Stroke
- Sweat Induced Rashes
- Eczema Flareups – Heat
- Higher Heart Attack Risk
- Syncope (fainting)
- Cramps or Swollen Legs (reduced mobility)
- Increased Risk of Kidney Disease
- Extended Muscle Recovery Times
- Blisters from Burns/Heat Exposure
- Brittle Hair/Hair Loss from UV Light Exposure
- Increased Ingrown Nails or Bunions/Hammertoes
- Amplified PTSD Reactions – Heat-Induced Anxiety
- Sleep Disturbance – Persisting Body Temperature
- Development of Secondary Hyperhidrosis

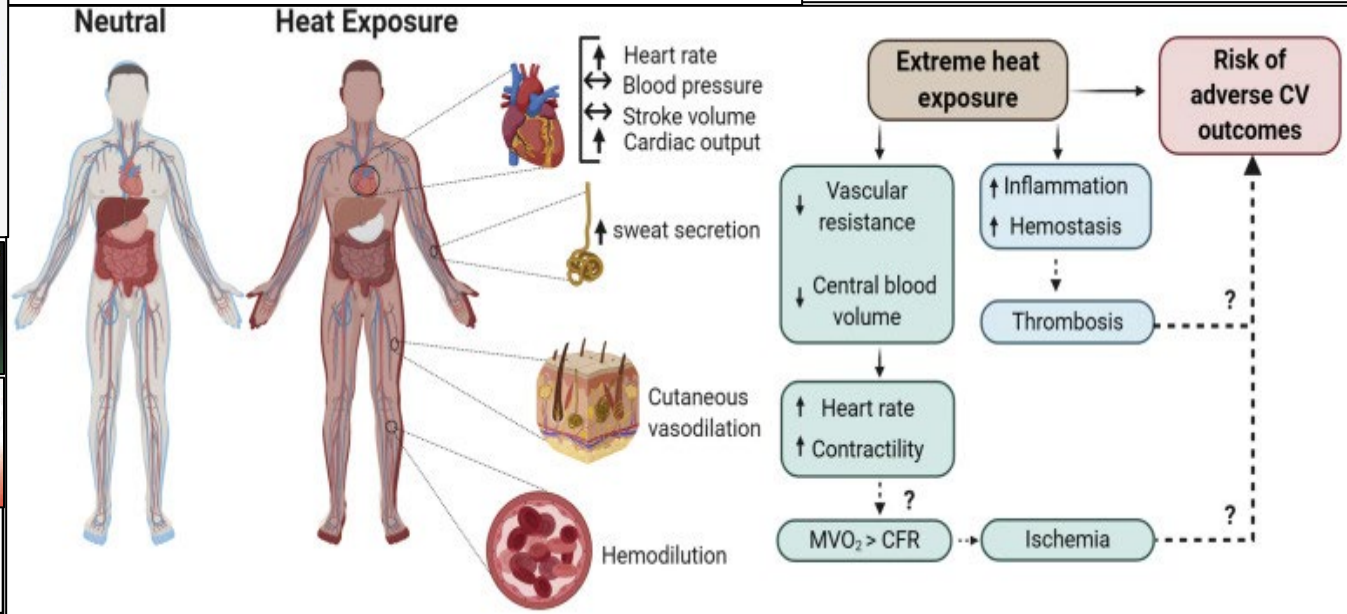












Repurposing Coal Mines

The Lewis Ridge Pumped Storage Project by Rye Development in Kentucky will create about 1,500 construction jobs to build what officials described as a first-of-its-kind coal-to-pumped storage hydropower facility.

- Once built, the facility will create 30 operations jobs and generate enough energy to power nearly 67,000 homes.

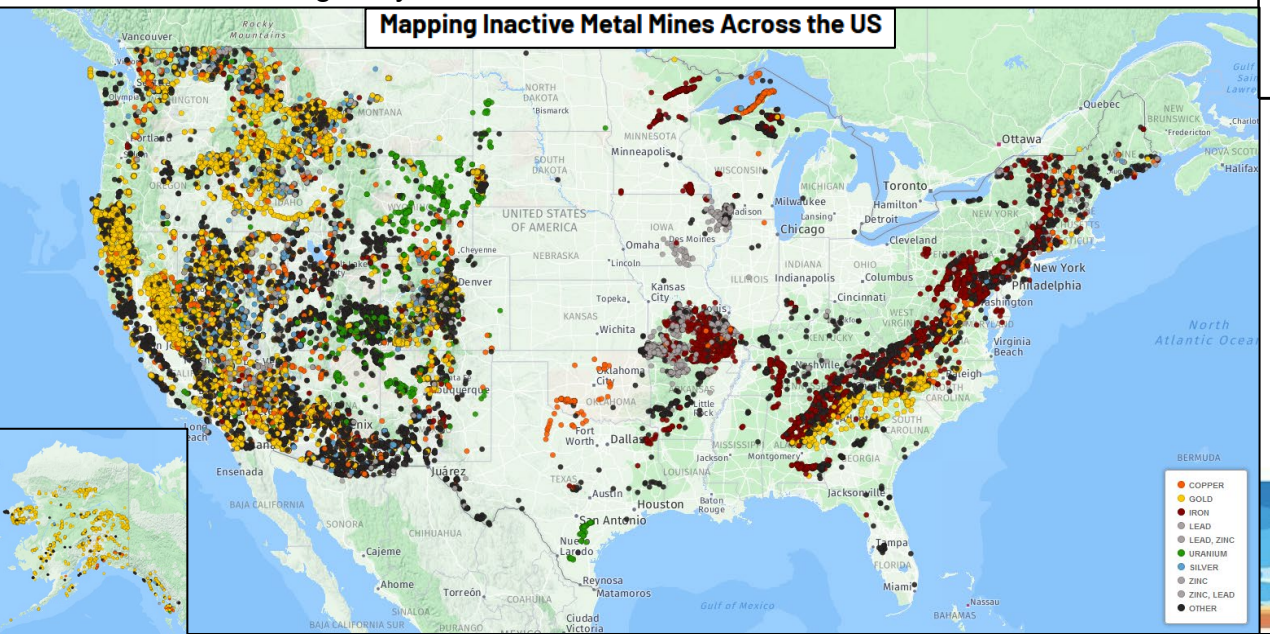
A project in Clearfield County, Pennsylvania, to repurpose nearly 2,700 acres (1,090 hectares) of former coal mining land to create a utility-scale solar facility.

- In November, it announced that it had a 20-year contract to supply power to New York's grid once completed in 2026.

A project in Nicholas County, West Virginia, to repurpose two former coal mines with a utility-scale solar system that would power about 39,000 homes.

- The two inactive mine sites provide land and access to existing energy infrastructure that will transmit the solar energy the project generates to the grid.

According to the National Renewable Energy Laboratory, the U.S. needs to add up to 10,000 miles a year of high voltage transmission to hit the administration's target of renewable-dominant grid by 2035.



Tidal Power

Tidal energy is a form of power produced by the natural rise and fall of tides caused by the gravitational interaction between Earth, the sun, and the moon.

- The US does not have any commercially operating tidal energy power plants.
    - Producing tidal energy economically requires a tidal range of at least 10 feet.

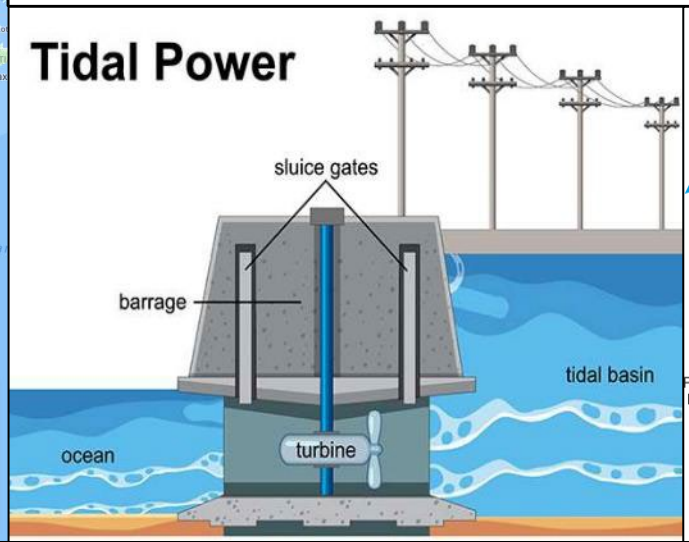
There are two methods of harnessing tidal power: One method resembles a hydroelectric dam, called tidal barrages, and another relies on underwater turbines that have blades that rotate as water flows by, powering a generator in the process.

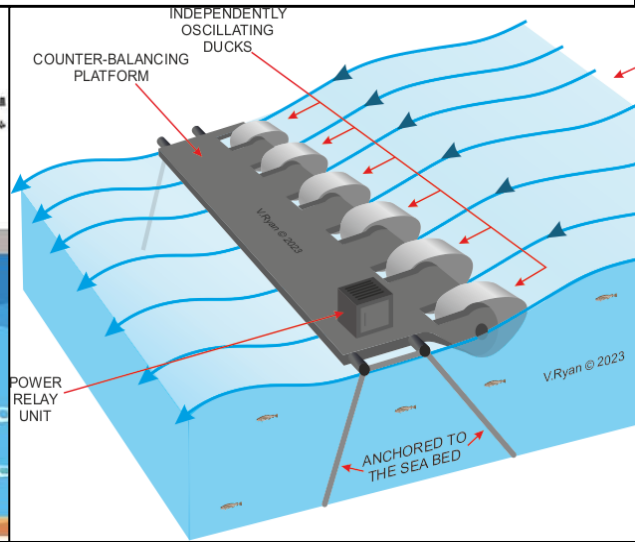
- Tidal power can reduce wave intensity to shorelines where critical energy transmission infrastructure for cities and major supply chain hubs are at threat from sea level rise.
- Because water is roughly 830 times denser than air, tidal or ocean currents can generate more energy per unit area than winds.

In 2021, the Department of Energy announced a $27 million investment in research and development around tidal and wave energy technology.

- Tidal power has one advantage over other renewable energy resources like wind and solar: predictability.

The oldest and second-largest operating tidal power plant is in La Rance, France





NOT AFFILIATED WITH NWS/NOAA/NHC – CISA ISD Meteorological Engagement Effort

Global emissions need to fall 9% every year until 2030 to keep the 1.5°C pre-industrial temperature baseline increase obtainable.

Weekly National-International Climate Summary:

Abnormal Weather Events, Climate Headlines, Forecasted Threats, Global Impacts, Wildfires, Tropical Cyclone Updates, and Graphics/Studies.

Bi-Weekly CISA Extreme Weather Working Group:

Regional Data Sharing, Upcoming Product Developments, Climate Education, Sector Impacts, Resiliency Best Practices, and National Coordination-Collaboration.

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