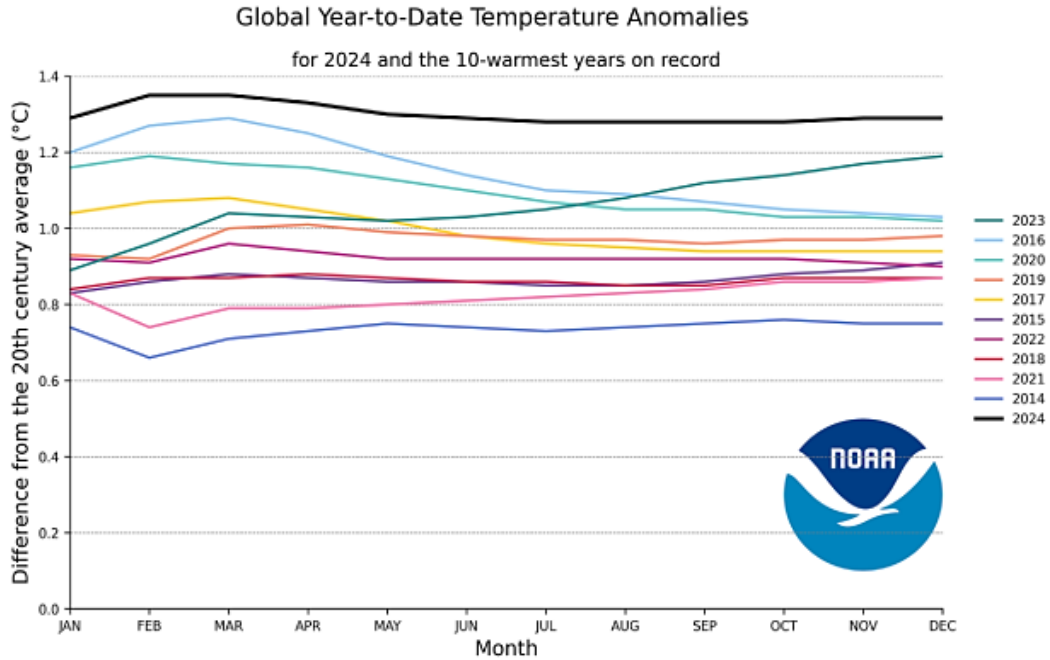
CISA Extreme Weather Outreach

Extreme Weather Impacts to Critical Infrastructure

*"The 10 warmest years in the 143-year record have all occurred **since 2015**. The 2024 January–December 2024 global surface temperature ranked warmest in the 175-year record at 1.29°C (2.32°F) above the 20th century average" (NOAA).*



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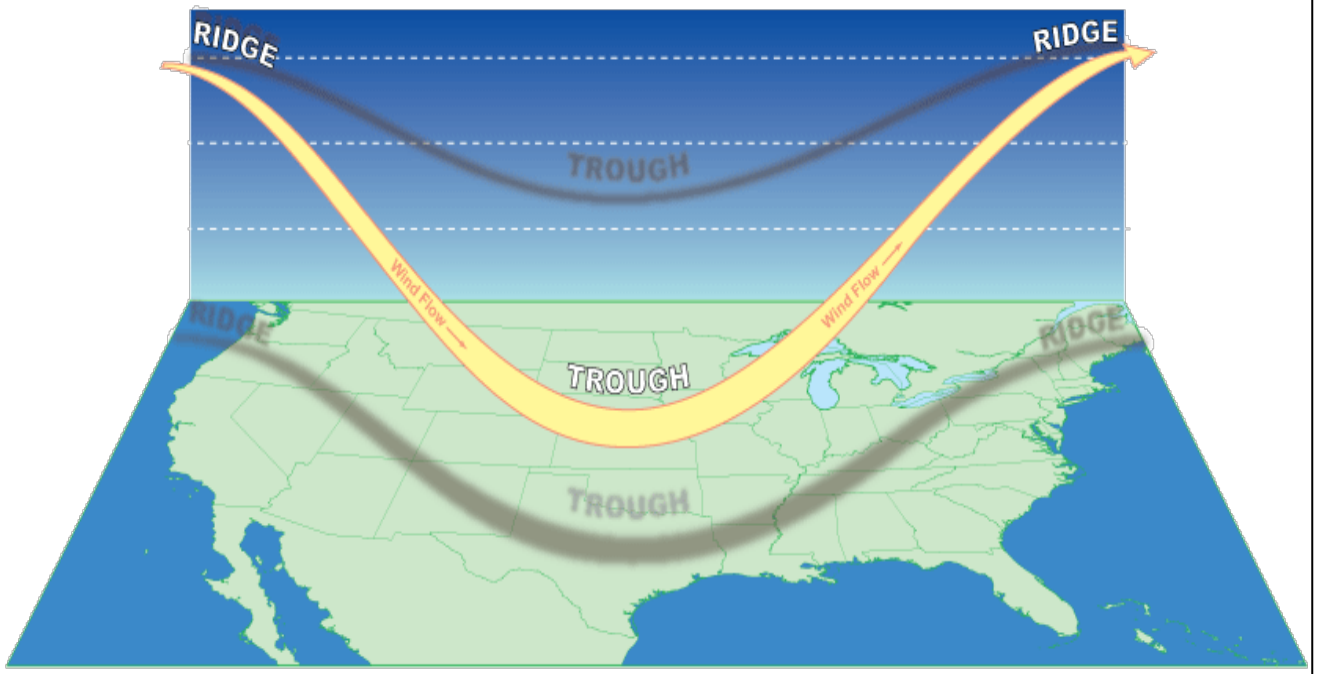
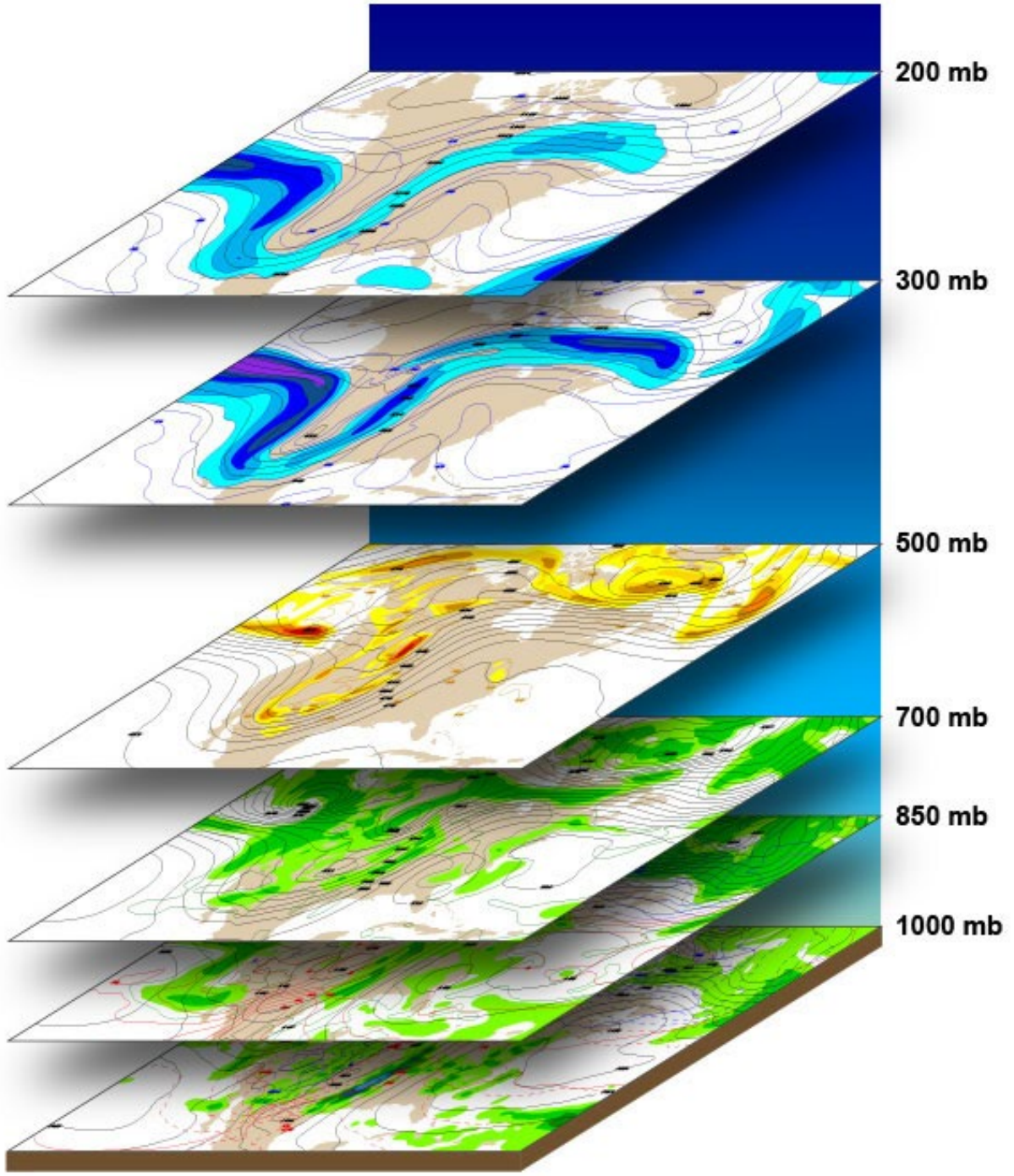
Atmospheric Pressure - Millibar 101

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) Gradients can help identify areas of high winds.
- 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, for precipitation or clear skies.

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





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

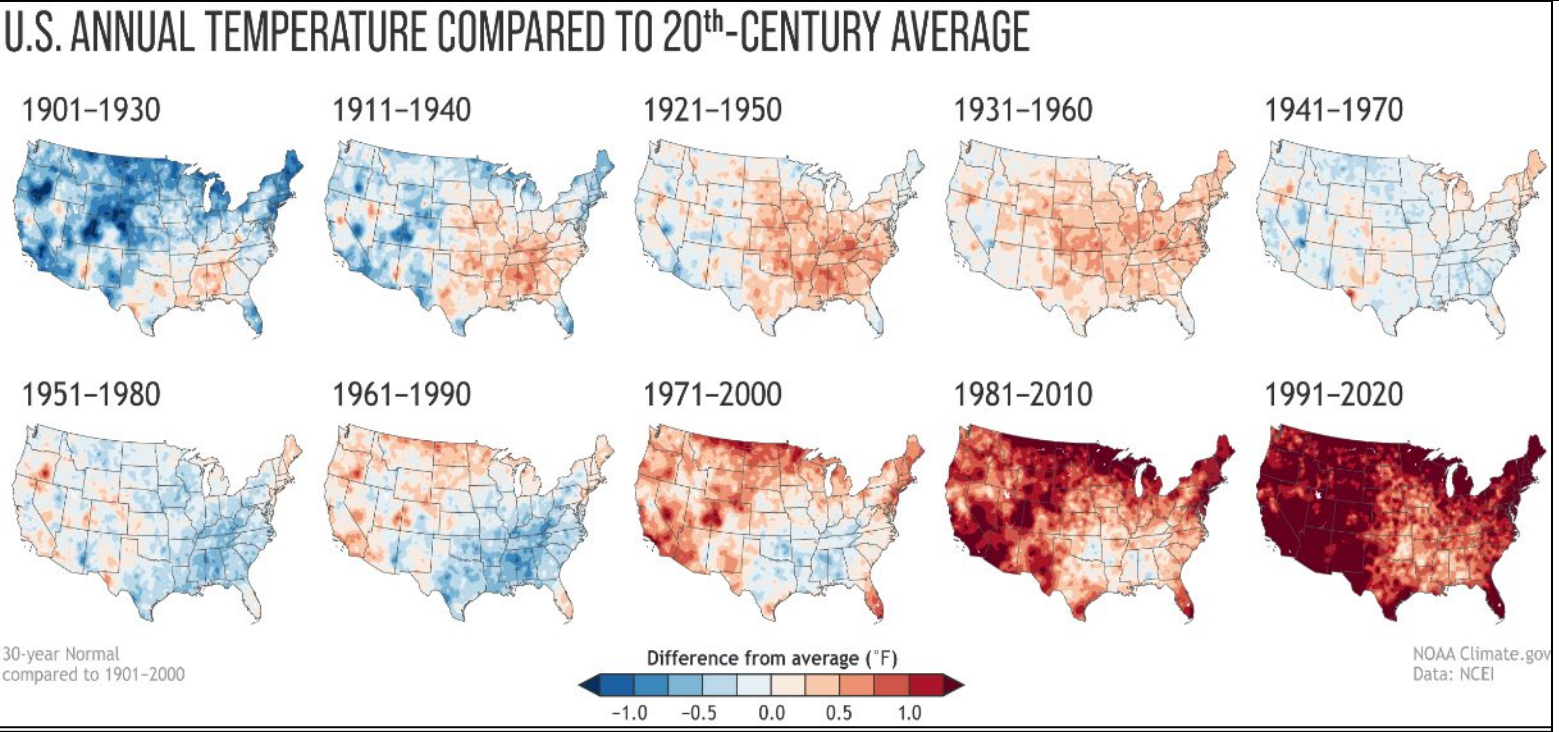
Worsening Trends

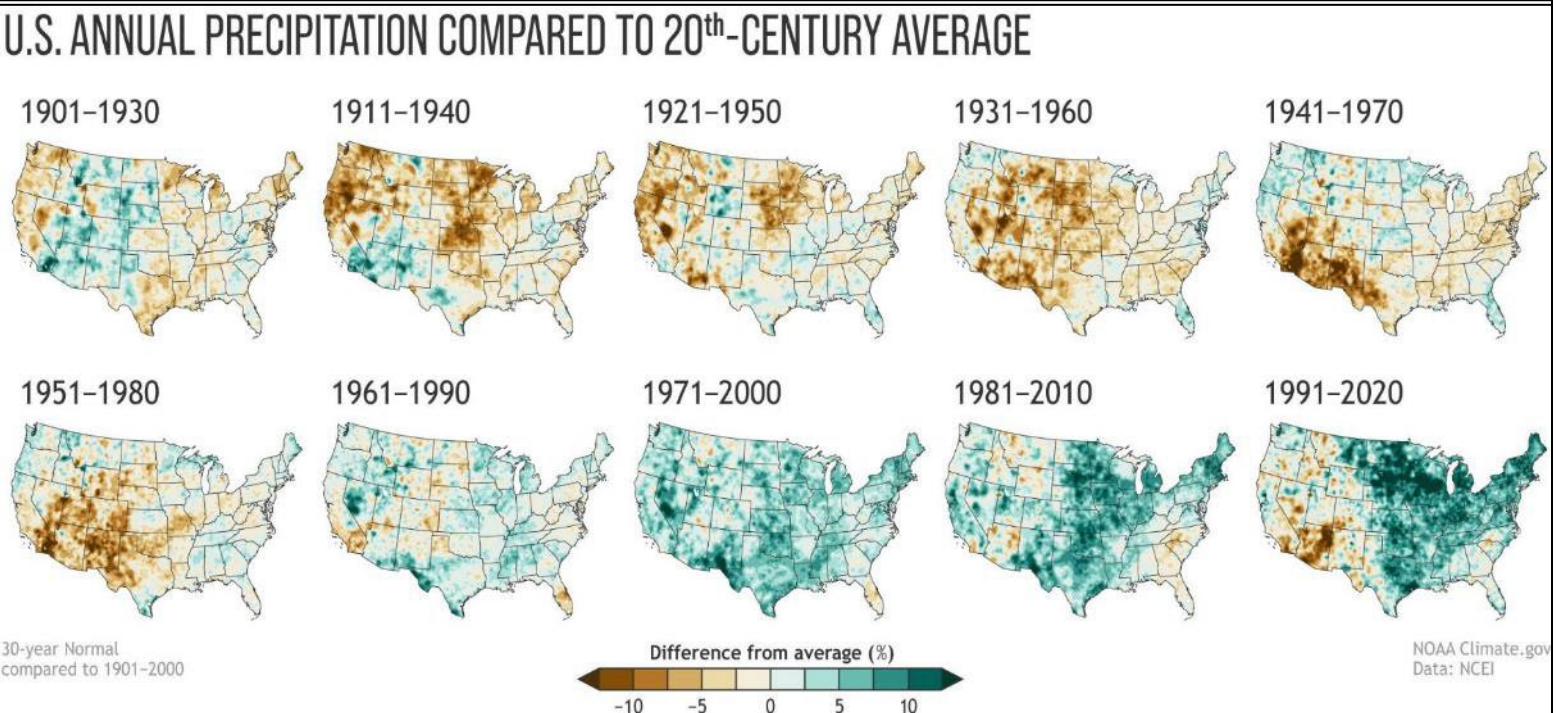
Changes in climatological norms causing more extremes brings cascading impacts across multiple sectors, regions, and infrastructure types.

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.

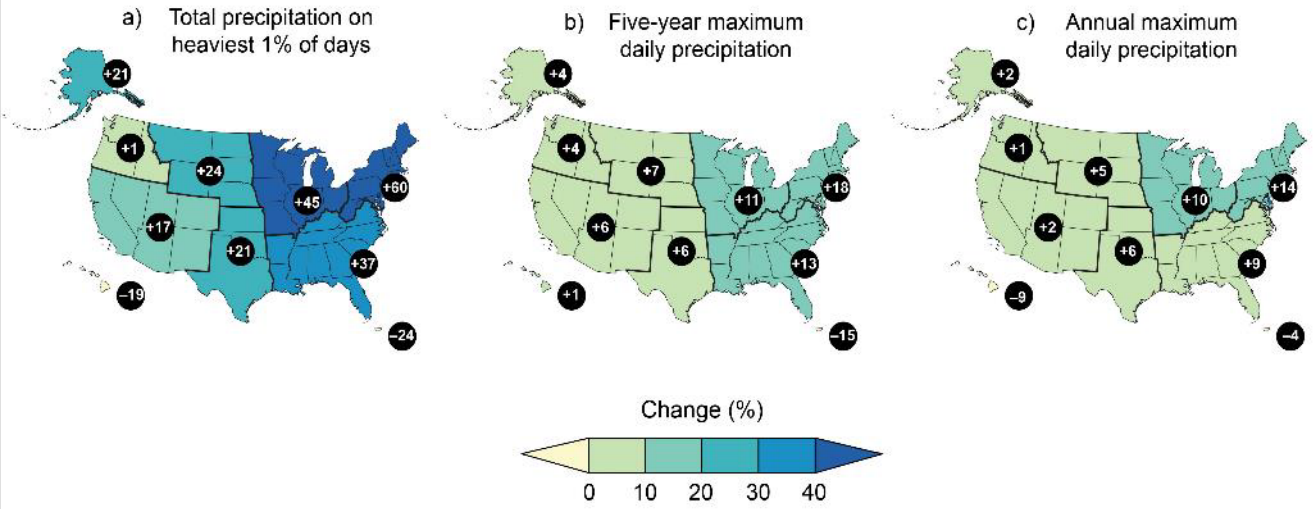
- Extreme heat and humidity are growing more common due to the growing distance between major low-pressure centers crossing the US, allowing for direct sunlight heating the surface and a larger presence of greenhouse gases trapping that heat for prolonged periods.

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.

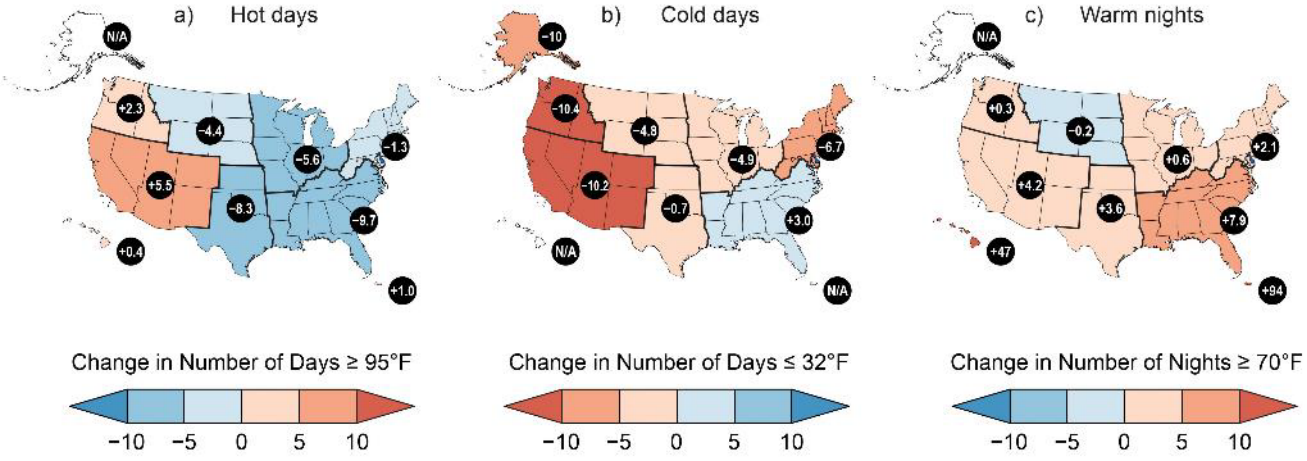
National Changes in Temperature and Precipitation Throughout the Seasons

As these weather events shifts, energy needs will shift to match

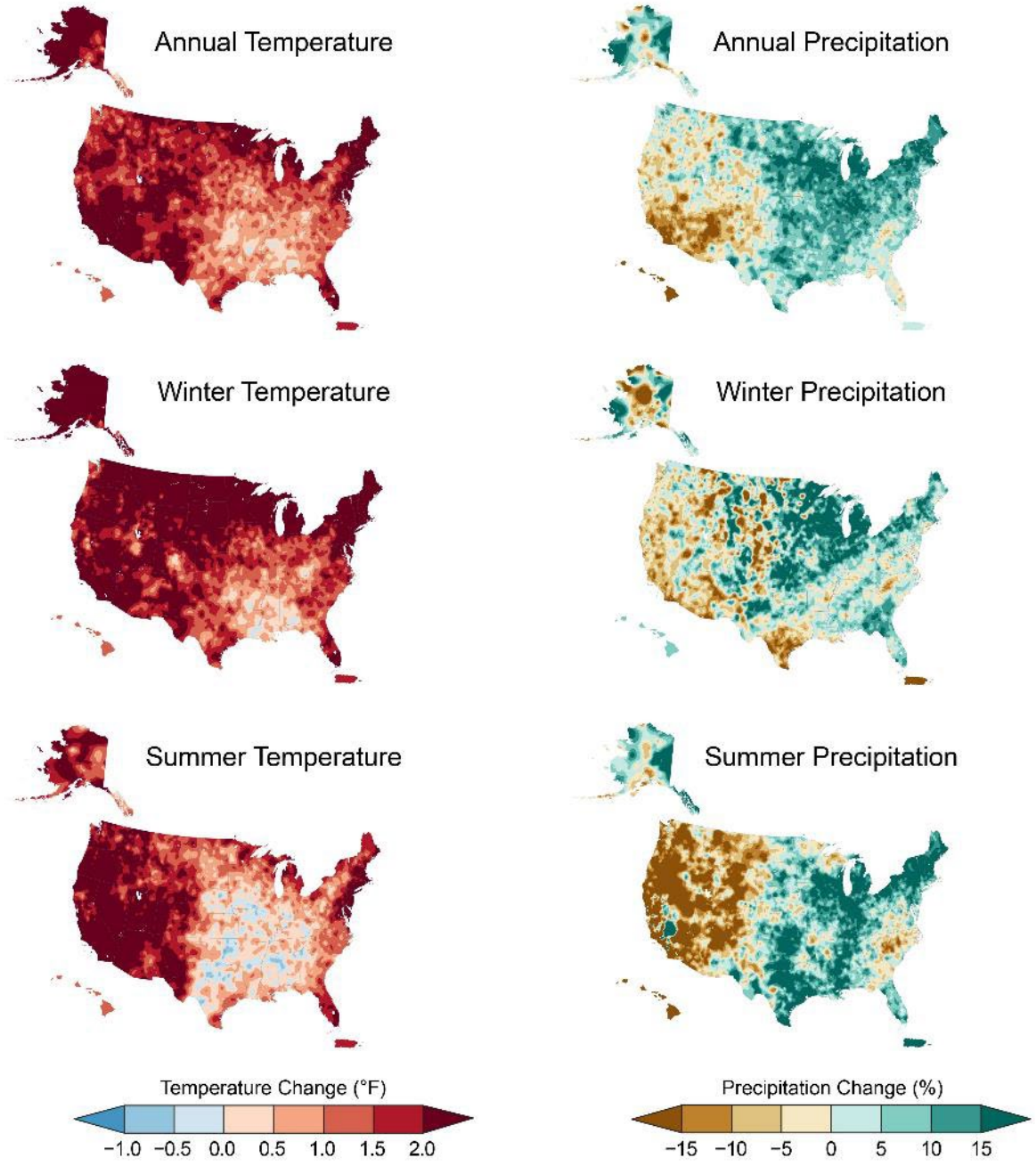
Observed Changes in the Frequency and Severity of Heavy Precipitation Events



Observed Changes in Hot and Cold Extremes



Observed Changes in Annual, Winter, and Summer Temperature and Precipitation



States at Risk Summaries – Region 8

Montana

Montana averages 5 days a year with temperatures exceeding dangerous or extremely dangerous levels. By 2050, the state is projected see nearly 15 such days a year.

Montana faces one of the highest overall threats in the country from widespread summer drought.

Montana is projected to see an approximately 95% increase in severity of widespread drought by 2050. Montana's index of the severity of widespread drought is projected to be 143 by 2050, on a scale where a 100 represents the current worst threat to a state in the U.S. (currently held by Texas).

Over the past 45 years, Montana has seen a larger percentage increase in the number of large fires than any other western state.

More than 600,000 people living in Montana, or 62% of the state's population, are living in areas at elevated risk of wildfire.

Wyoming

Heat wave days in Wyoming are projected to increase five-fold by 2050, from about 10 to about 50 days a year, on average.

Wyoming is projected to see an increase in severity of widespread summer drought of approximately 40% by 2050.

More than 450,000 people living in Wyoming, or 82% of the state's population, are living in areas at elevated risk of wildfire.

North Dakota

Fargo is the 10th fastest-warming city in the U.S. Temperatures across the state are expected to increase 11-12 degrees by 2100 under current emission scenarios.

By 2050, the typical number of heat wave days in North Dakota is projected to increase five-fold from 10 to almost 50 days a year.

In North Dakota, more than 50,000 people are living in areas at elevated risk of inland flooding.

Colorado

Colorado faces a lower threat level from extreme heat than most states. Still, heat wave days are projected to jump from about 10 a year to nearly 50 a year by 2050.

Fort Collins is the 9th fastest-warming city in the U.S.

By 2050, summer drought severity in Colorado is projected to be among the worst in the country.

From a study from University of New Hampshire, during a low snow season Colorado can see a loss of up to $117M in economic value and $154M in ski resort revenue. Colorado has the highest employment of state winter tourism jobs and has the most visitors of any state for winter tourism.

Both heat and drought can have an impact on this integral part of Colorado's economy.

Utah

Utah is projected to see an increase in severity of widespread summer drought of approximately 225% by 2050.

More than 1.3 million people living in Utah, or 45% of the state's population, are living in areas at elevated risk of wildfire.

As the Great Salt Lake dries it will expose minerals and metals naturally found in the riverbed to dust storms and outflow boundaries will produce more hazardous plumes throughout the region and deposit the materials in the higher elevations, reducing overall snowpack potential during winter and degrading water quality.

South Dakota

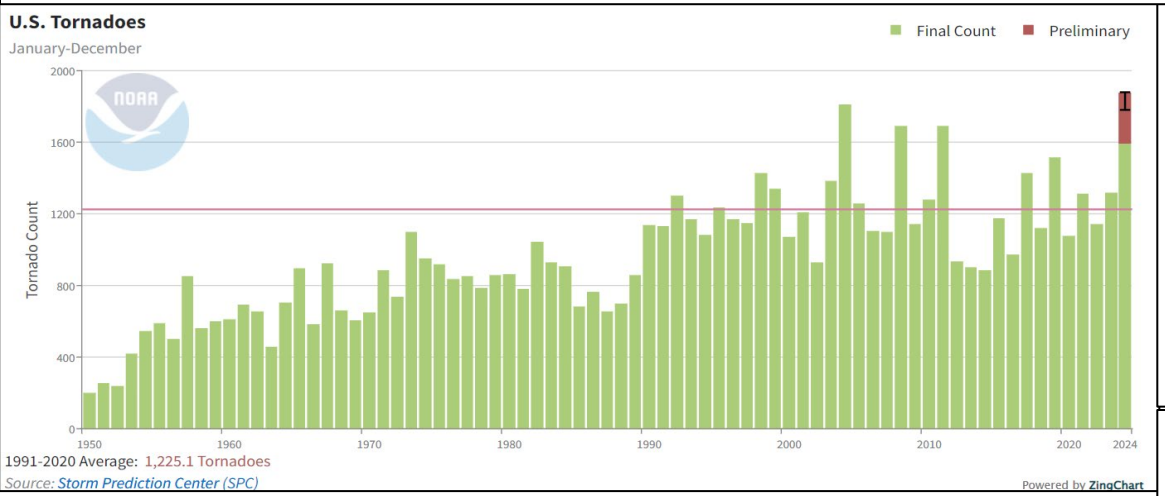
Currently, South Dakota averages 10 dangerous heat days a year. By 2050, South Dakota is projected to see 35 such days annually.

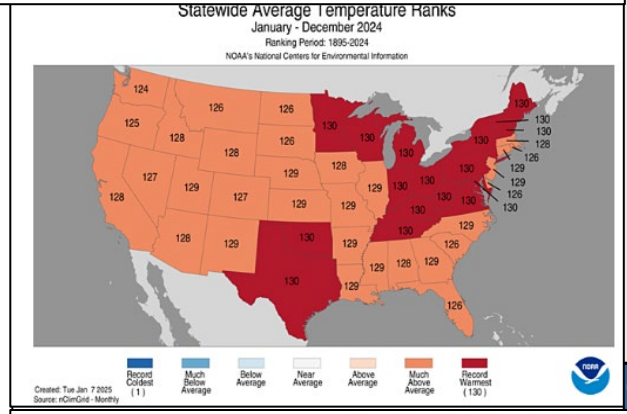
South Dakota is projected to see an increase in severity of widespread summer drought of approximately 75% by 2050.

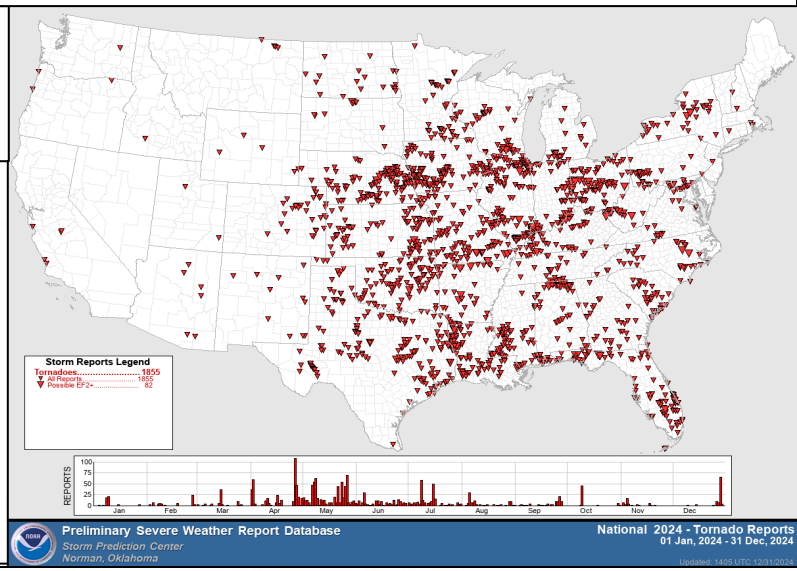
In South Dakota, there are nearly 45,000 people living in areas at an elevated risk of inland flooding.

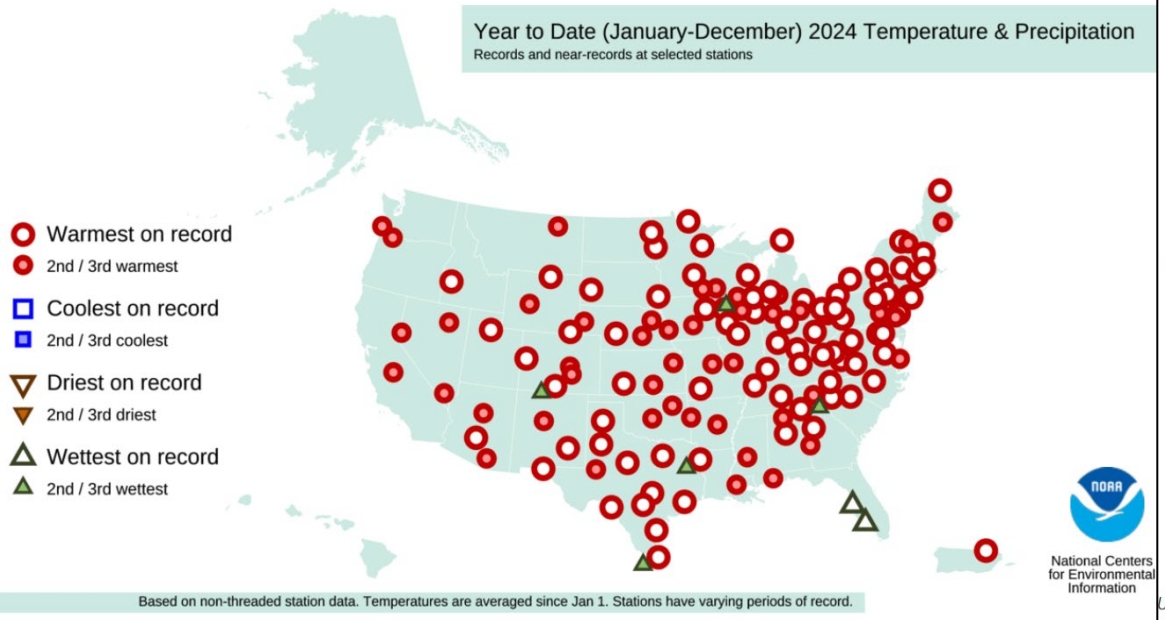
National Temperature Swings Yield Extremes

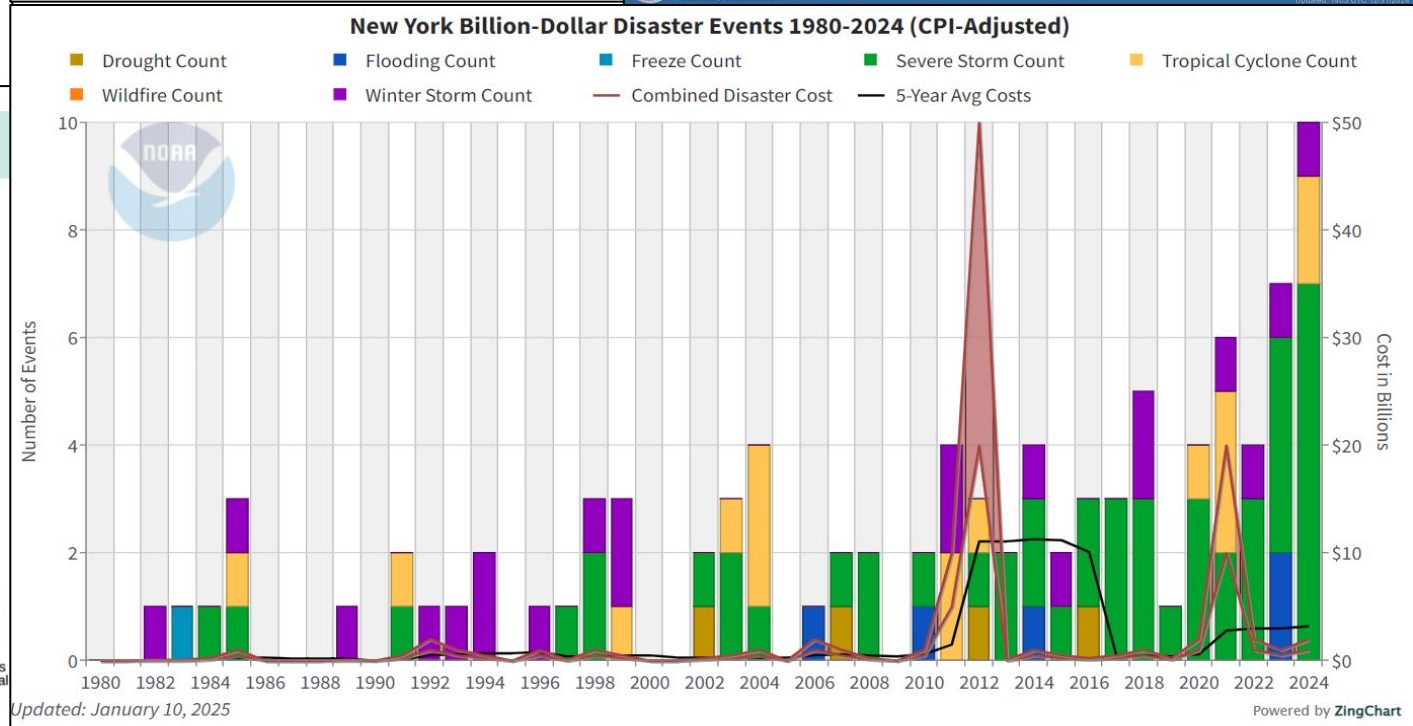
In 2024, there were 27 confirmed weather/climate disaster events with losses exceeding $1 billion each to affect US. New York averages 10 tornadoes annually, while July of 2024 produced 18 tornadoes in New York with the 2024 total reaching at least 29 by September, the most ever recorded for New York.









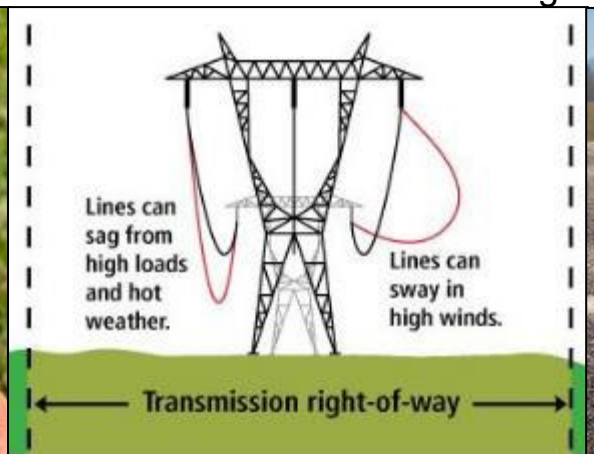


Critical Infrastructure Sectors Risk from Heat

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.

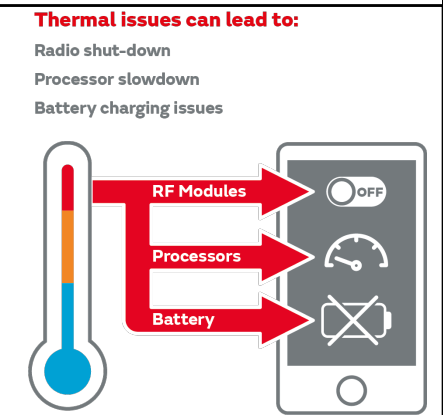


Extreme Weather Trends vs Communications

Transformer damages from severe storms producing hail, tornadoes, straight line winds over 60 mph, downed trees/branches, flooding, lightning strikes, and even extreme heat damages to components within transformers, cement platforms holding towers and generators, and transmission line sags/snaps.

- Extreme temperatures degrade cellphone functionality to the point of overheating and dropping to 4G from 5G as 5G uses more energy than LTE.
- Subsidence, ground sinking, due to drought stresses on groundwater availability can result in tower leans or collapse due to uneven compression.
- Wildfire expansion can threaten communication infrastructure, energy generation equipment, and result in relocation of customer bases.
- Sea level rise, while a slower onset than other weather hazards amplified by climate shifts, can increase the coastal flooding threats from all low-pressure centers such as tropical cyclones or Nor'easters which can result in damage to various energy systems and communities.
- Drought impacts to waterways in the form of higher temperatures and greater rates of evaporation can reduce hydroelectric outputs and result in water restrictions for equipment which requires water for cooling such as datacenters or nuclear power plants.
- Flooding and larger hail due to stronger thunderstorms during abnormal heating periods can damage end offices, cause power outages, and impact industry sites while prolonging restoration timelines due to the larger geographical footprint of destruction.
- Shifts in winter precipitation frequency and intensity can trigger greater rates of avalanches, stress vegetation, and even threaten roofs for buildings.

Natural disasters across the globe are expected to increase 37% by 2025 and overwhelm existing National Emergency Telecommunications Plans (NETPs). Most communication infrastructure is owned by the private sector, with the dependent infrastructure such as the information technology sector, financial services, emergency services, energy services, and the transportation systems sector all facing amplified impacts from shifts in climate stability with supply chain delays or losses, negative impacts to regional ecology and key resource hubs, and physical damages to sites and staff.



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

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.

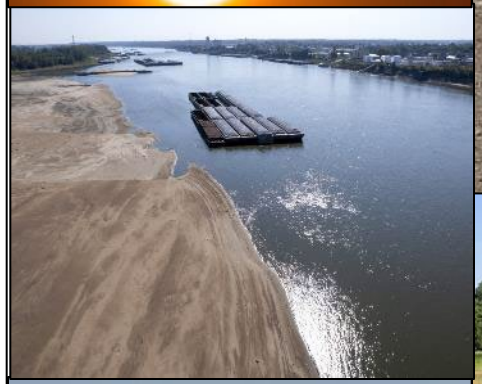
- Warped railways under direct heating may increase derailments.
    - Stalled materials in transport can overheat, damaging the products.

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.



Fire Weather

Nationwide, the number of existing properties facing at least a 1% risk will almost quadruple, to 2.5 million by 2050; not accounting for subdivisions to be built in the intervening years.

Over 7 million American homes currently have a "major" risk of wildfire damage, increasing to 13 million over the next 30 years, according to a national wildfire assessment by the First Street Foundation in May 2022.

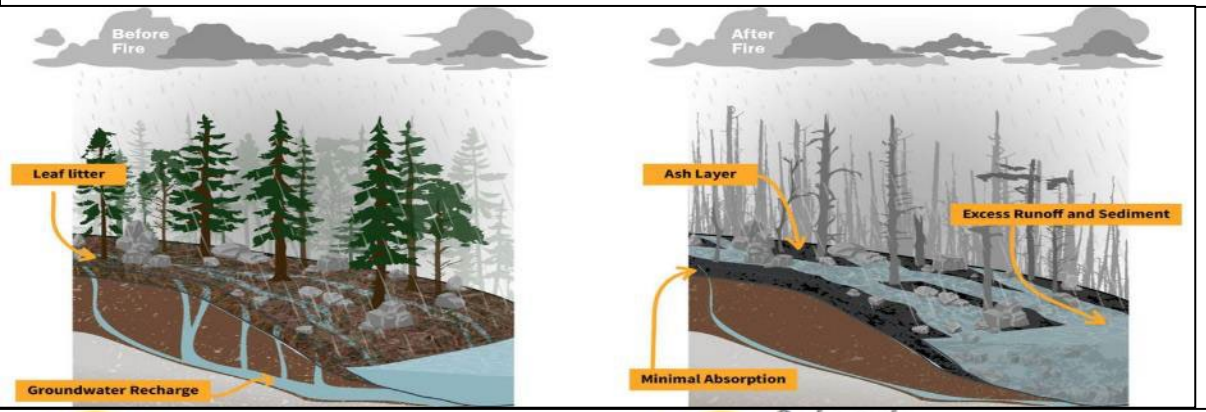
A study from the University of Colorado states wildfires have become larger, more frequent, and more widespread since the year 2000.

Analysis of coincident 1000-hour fuel moistures indicated that as fuels dried out, satellites detected increasingly larger and more intense wildfires with higher probabilities of nighttime burns.

A new study from the University of Montana highlights burn scar impacts to tree regrowth across various regions, indicating new tree seedlings are unable to survive in hotter climates where parent trees remain. The study indicated that if large areas of the forested parts of the Rocky Mountains burned, only 50% would recover.

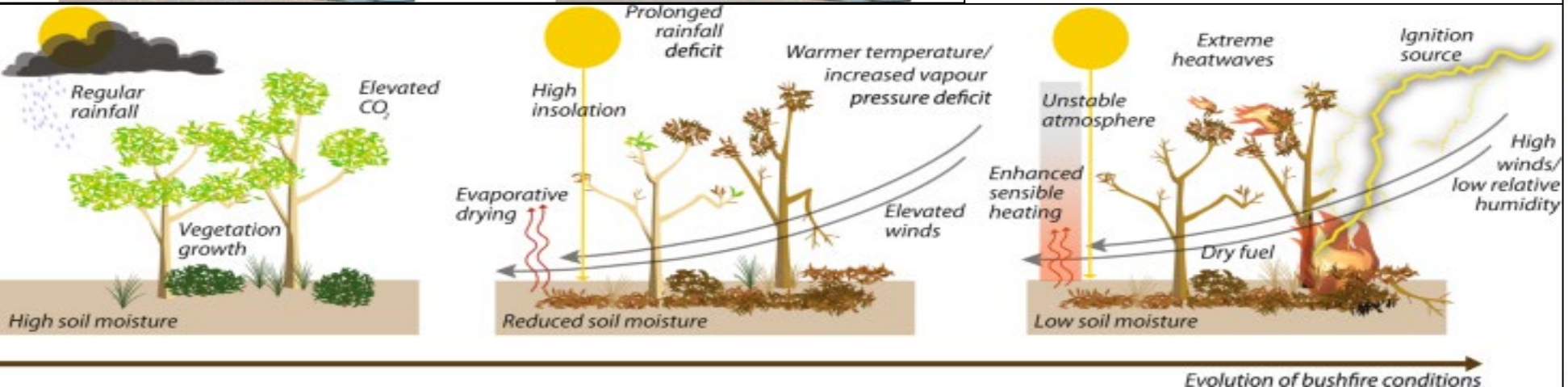
Satellite imagery and state/federal fire history records from 28,000 fires in 1984-2018 showed more fires occurred in the past 13 years than the previous 20 years. On the West and East coasts, fire frequency **doubled**. In the Great Plains, fire frequency **quadrupled**.

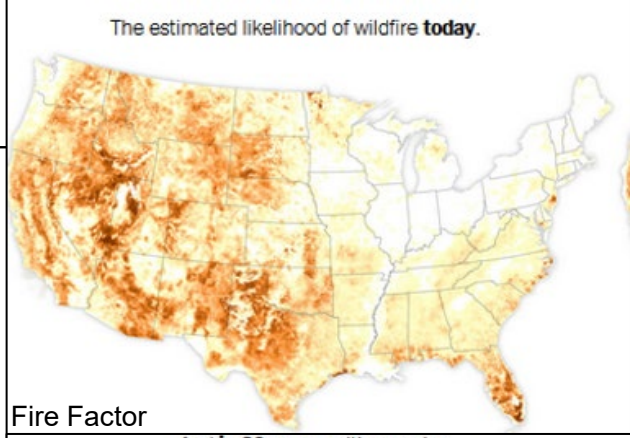
Burned vegetation and charred soil form a water repellent layer which blocks water absorption along with compacted soil from months to years of drought which also inhibits water absorption regionally. These major soil changes cause short rainfall events to be less beneficial for long term



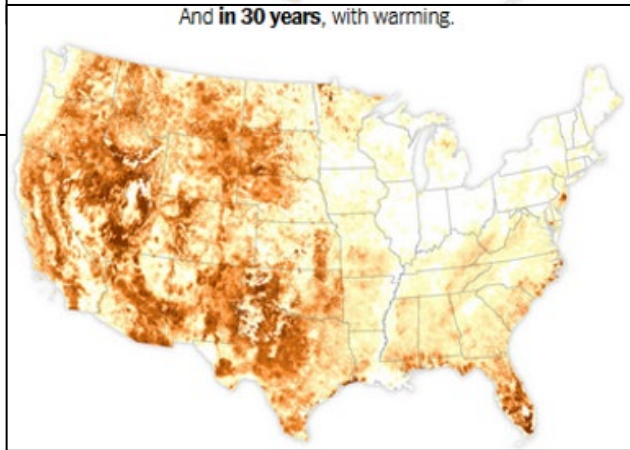
Disasters related to weather, climate, or water hazards happen five times more often now than they did in the 1970s. Droughts that may have occurred only once every decade or so now happen 70% more often.

- The IPCC states heavy rainfall that used to occur once every 10 years now occur 30% more often.
- 61% of western wildfires have occurred since 2000 with a steady increase in the number of wildfires the last 60 years.

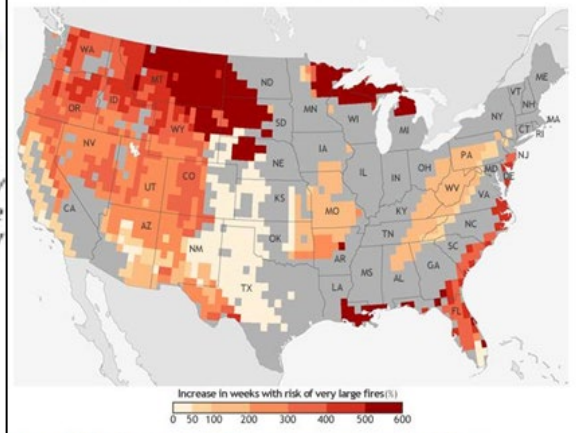




Fire Factor



The map below shows the projected increase in the number of "very large fire weeks" —periods where conditions will be conducive to very large fires—by mid-century (2041-2070) compared to the recent past (1971-2000). The projections are based on scenarios where carbon dioxide emissions continue to increase.



Source: NOAA Climate.gov map, based on data from Barbera et al, 2015.

Impacts from Changing Drought Conditions

The likelihood of extreme multiyear droughts will increase, threatening regional water supplies. Flash droughts start and intensify quickly, over periods of weeks to months, compared to years or decades for conventional droughts. The Environmental Protection Agency (EPA) stated the estimated price tag of fully funding US water infrastructure is *over $3 trillion over the next 20 years*.

- As higher heat and widespread prolonged drought continue to expand in coverage, intensity, and longevity, almost half the world's population will be living in areas of greater water stress by 2030. This can lead to trade shifts, allocation arguments, and infrastructure changes in both material creation and development of regions lacking natural water security.

From 1980-2022, there have been 30 drought events totaling $309.4 billion dollars according to the Billion Dollar Weather and Climate Disasters report NCEI.

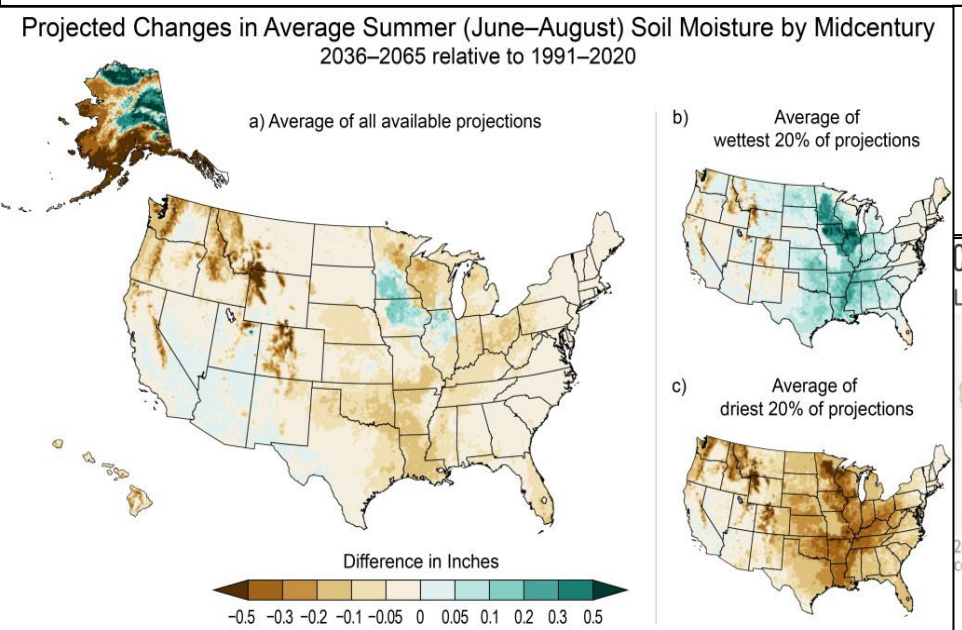
- Surface water is under threat from evaporation, dried soils, increased use for agricultural needs, theft for private consumer use, and a rapidly changing ecology from the drying climate.

If a weather pattern that results in a precipitation deficit lasts for a few weeks or months, it is considered short-term or flash drought. If the pattern and precipitation deficits last for more than six months, it is typically considered long-term or prolonged drought. Increasing the

- Flash droughts, characterized by rapid onset and intensification, are increasingly occurring which can lead to sudden water losses and subsequent cascading allocation restrictions.

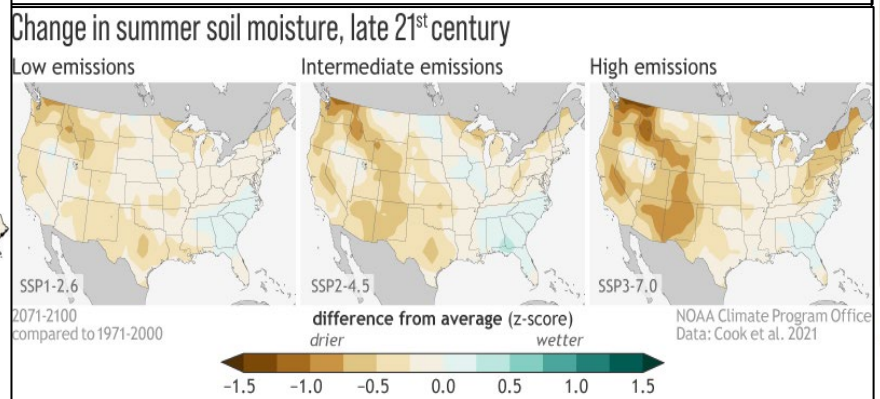
Reductions in water availability can halt developers and certain building repairs, renovations, or retrofitting. Impacts from persisting drought can be mitigated with water recycling such as black or grey water recycling, closed-loop systems, or alternative resources for backup if the primary source becomes threatened such as water trucks or cross basin water sharing infrastructure.

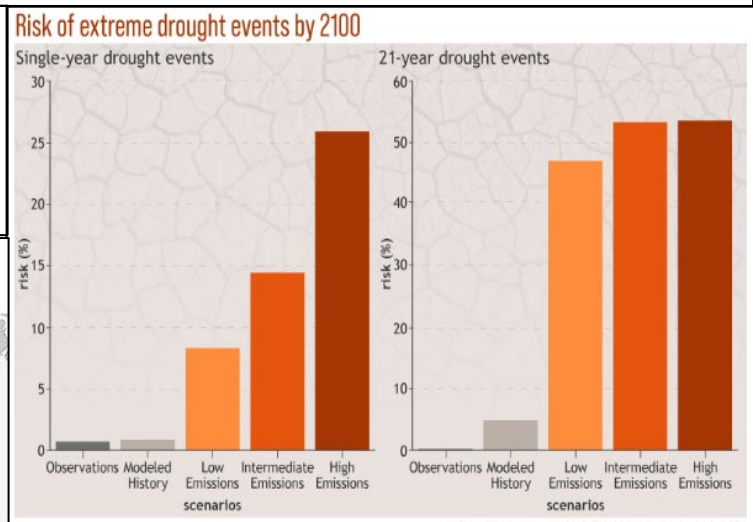
- Clay-based soil types dry and shrink when a drought occurs, resulting in uneven settling that can damage a building's foundation. Low soil moisture causes contraction away from the foundation, compromising the bond. This leads to foundation cracking, damaged pipes, sloping floors, and warped windows and doors.
    - Retaining walls, bridges, sidewalks, pavement, runways, railway platforms, canals, and dams all face the risk of drought-related harm.



Drought can reduce the amount of water available for hydropower and contribute to degraded energy infrastructure critical for the technology sector.

Wildfire, which can be exacerbated by drought, can damage energy generation systems.





As greenhouse gas emissions increase and Earth's temperature rises, new research forecasts the southwestern United States will become drier, with the risk of future soil moisture deficits increasing as emissions increase. From figure 8 of the new study.

Credits: NOAA Climate Program Office / Anna Eshelman

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.

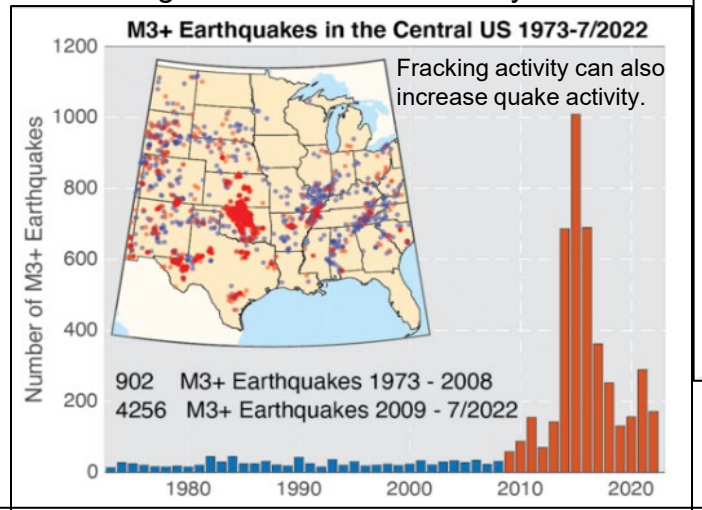
The areas around fault lines have valleys where the plates meet and are at their weakest point. Due to the lower elevations around these topography features, water tends to pool at the lowest elevation and thereby river systems were naturally located in the weaker spots of the fault line.

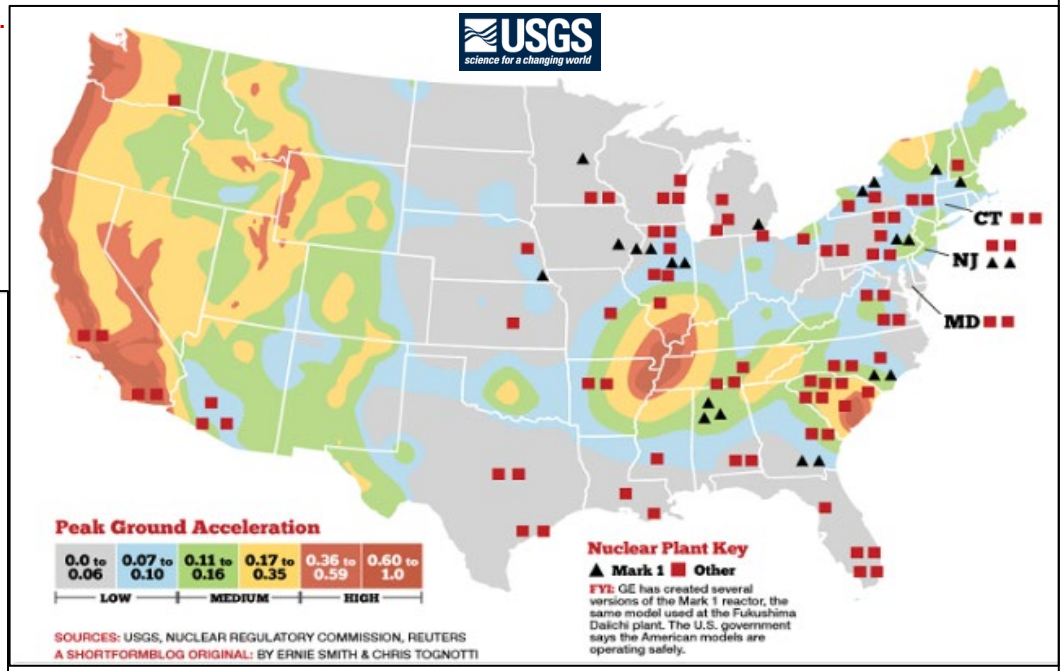
- Damming up the river system resulted in compounding water in different areas than were natural along some faults. As dams were installed, an increase in seismic activity was reported and subsequently as drought has developed, activity has increased again near the river/dam systems.

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.



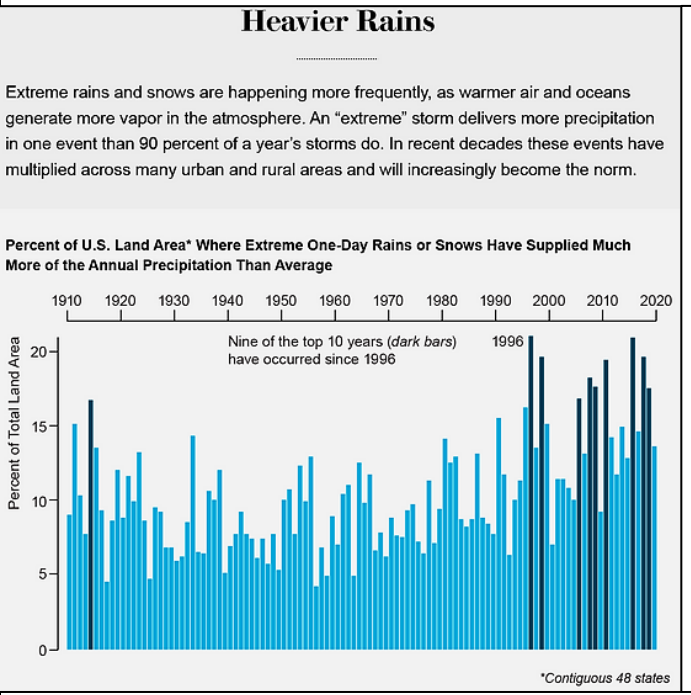


USGS Seismic Hazard Model areas of Risk with Nuclear Power Plants: Comparing these major fault line and tectonic plate boundary areas with persisting surface drought shows the potential instability of quake activity.

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.

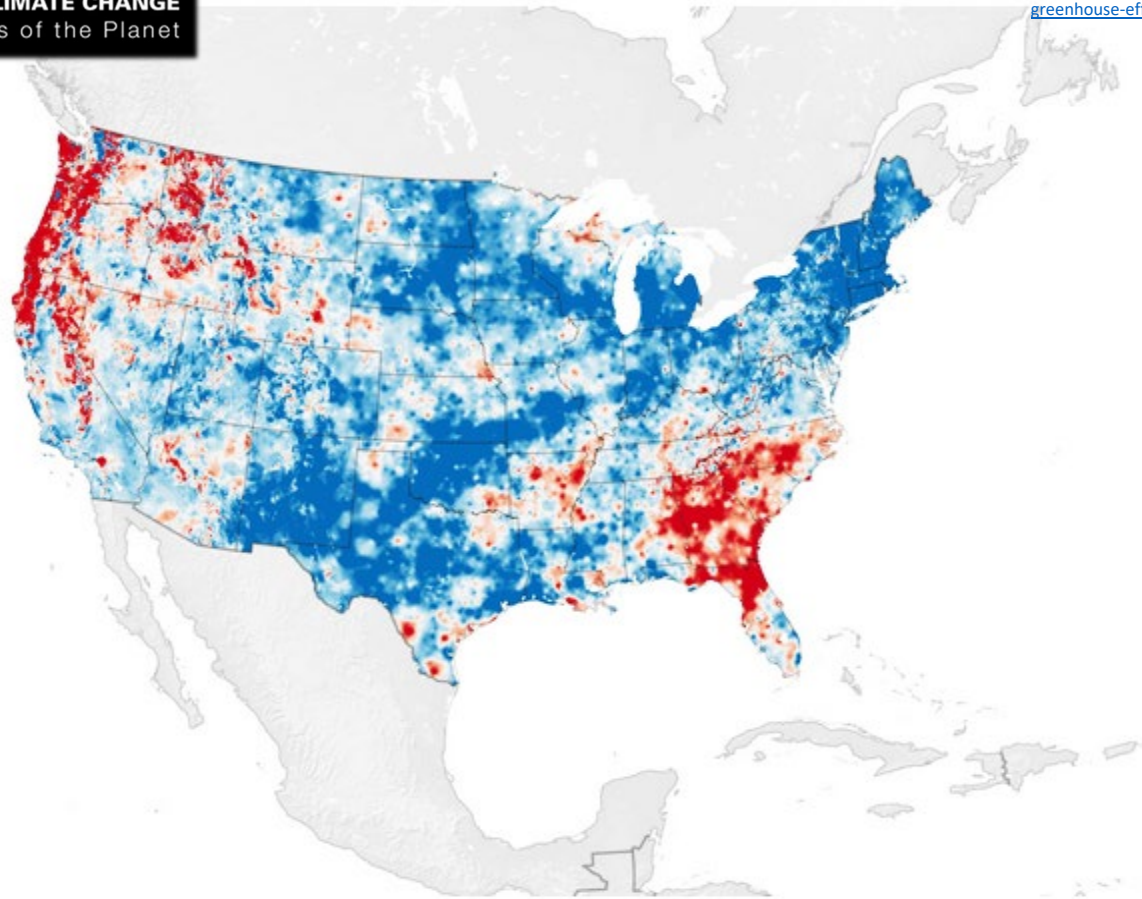


- The average change in hourly rainfall intensity across all 150 stations from 1970 to 2021 was +13%.
- 63% (95/150) of stations had an increase in hourly rainfall intensity of +10% or more (Climate Central).
- 90% of the 150 locations analyzed now experience more average rainfall per hour than in 1970.
- 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).

Impacts to Earthen Dams

There are more than 91,000 dams across all 50 states, with over more than 9,000 large dams. The average dam age is 60 years, and more than 8,000 dams are over 90 years old.

- >85% of all U.S. dams will be more than 50 years old by 2030.

Earthen dams are typically constructed by compacting layers of soil, clay, and rock materials to create a stable barrier and then reinforced with a concrete or metal liner to prevent erosion and seepage.

- These dams can be impacted by direct solar radiation and heat as well as subsidence and erosion from greater intensity precipitation events and other 'natural' shifts.

Tailings dams are used to impound waste materials. They are constructed of industrial or mining waste or waste mineral processing materials.

- Tailing dams are often the most significant environmental liability for a mining project. Failures of tailings dams occur at a significantly higher frequency compared to water storage dams.

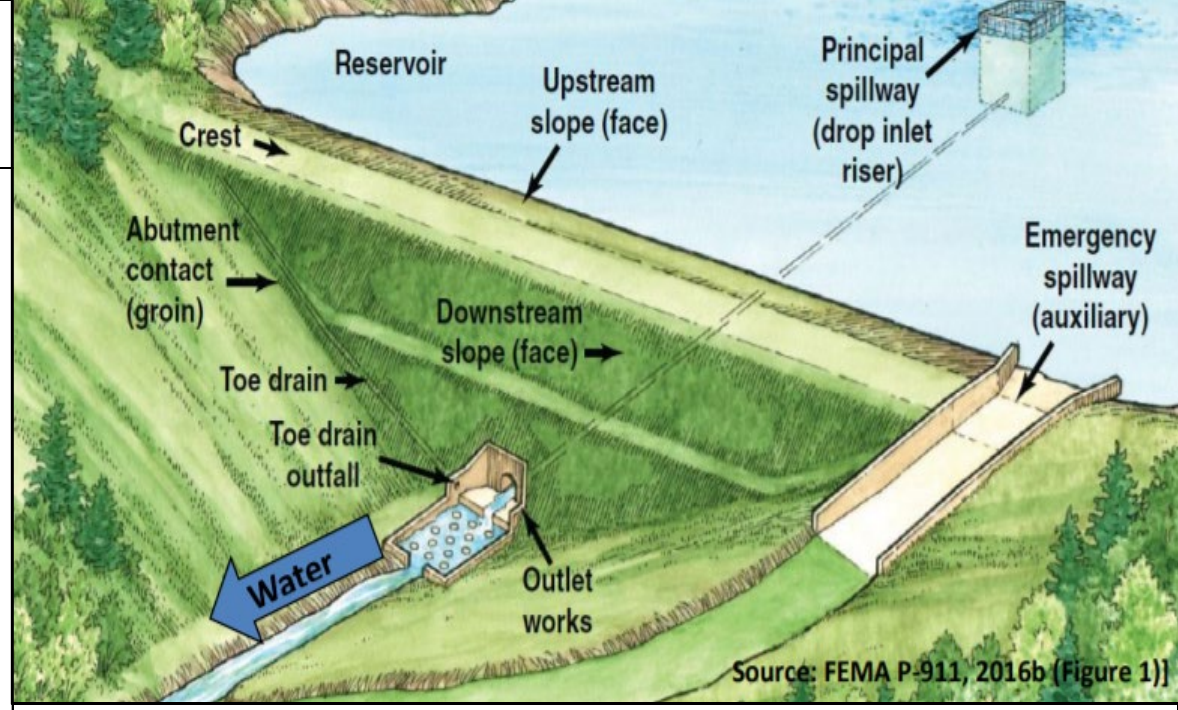
Abnormal swings in temperature can threaten both normal components (such as the population exposure downstream of the dam) and extreme components (such as the flood events) of risk.

- Extreme rainfall events can cause overtopping. Overtopping of earthen dams can often cause them to fail catastrophically and completely unless they are designed to overtop.
- Failure by overtopping is one of the most common forms of dam failure (34% of all failures).
- 20% of US dam failures have been caused by piping (internal erosion caused by seepage).
- Erosion and scour from flood flow can damage earthen channels and canals such as irrigation canals and drainage ditches.

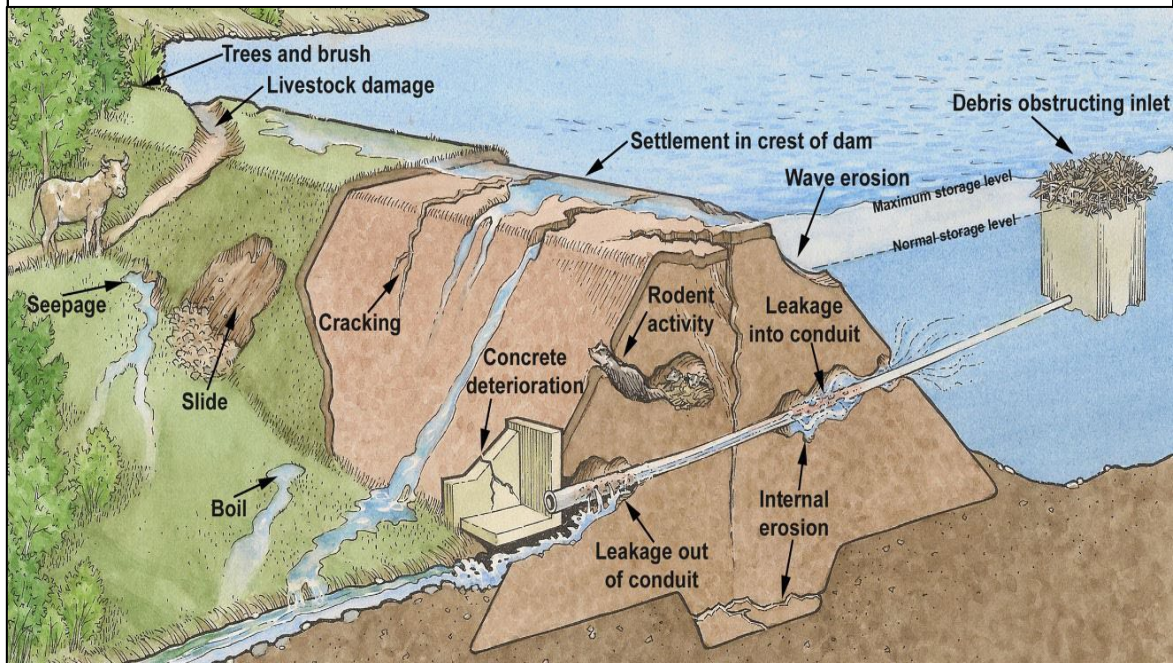
One of the most common issues with structures designed to move water is clogging from silt or debris. Some clogging is from normal wear and tear on the system, but clogging can be an enormous issue after a storm.

With higher global sea levels, storm surges are more likely to overwhelm sea defenses. Heavy rainfall can combine with a storm surge to cause a compound flood.

- High water levels can impede stormwater draining into the sea, causing flooding inland, or high rainfall can add yet more water to an existing tidal flood.



Earthen Dams 101 and Causes of Failures



River System Impacts

In 2022, the Mississippi dropped to record low depths, affecting barge traffic on one of the major arteries for moving coal, oil, natural gas, chemicals and commodities in the US. Drought conditions in 2023 are more expansive across the Mississippi and Missouri River Systems.

- Low river levels can force the US Army Corps of Engineers to dredge channels to allow ship traffic. 2022's low levels contributed to about $20 billion in economic losses.
- A single river barge, fully loaded, can haul as much as 16 rail cars or 70 semi trucks. In all US inland waterways, about 578 million tons of cargo is shipped annually, mostly along the Mississippi system.

An analysis of recorded US dam failures (https:// damsafety.org/Incidents) suggests that +75% of the failures occurred after 50 years of age. The average US dam age is 60.

Additional threats

Hotter water from low-levels and increased direct sunlight downstream of established dams may increase evaporation rates, algal presence, mosquito breeding grounds, and increased subsidence rates.

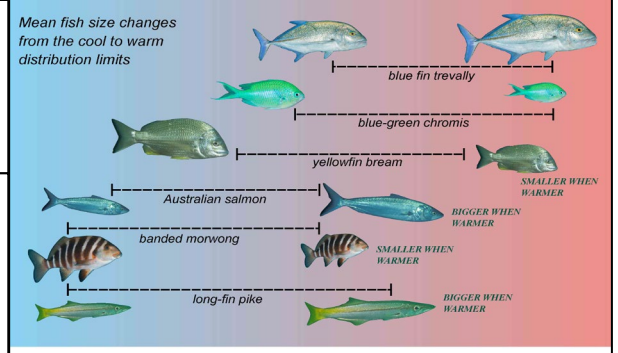
When exposed clay is heated continuously through solar radiation the water inside the material evaporates causing notable cracking.

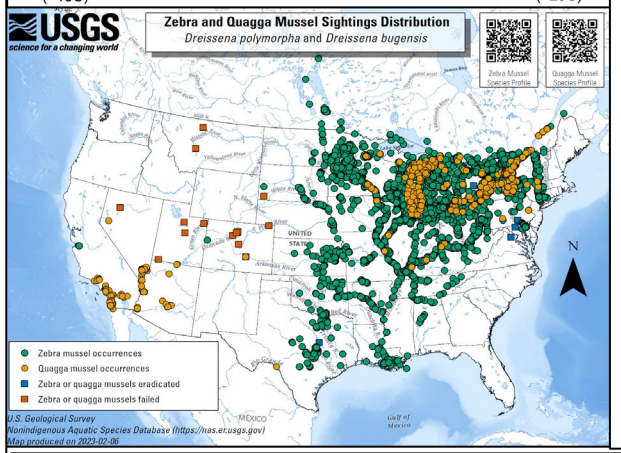
Harmful algal blooms are becoming more common in rivers, lakes, ponds and reservoirs and are contaminating fresh water sources. These can block water intake and can interrupt the free movement of water.

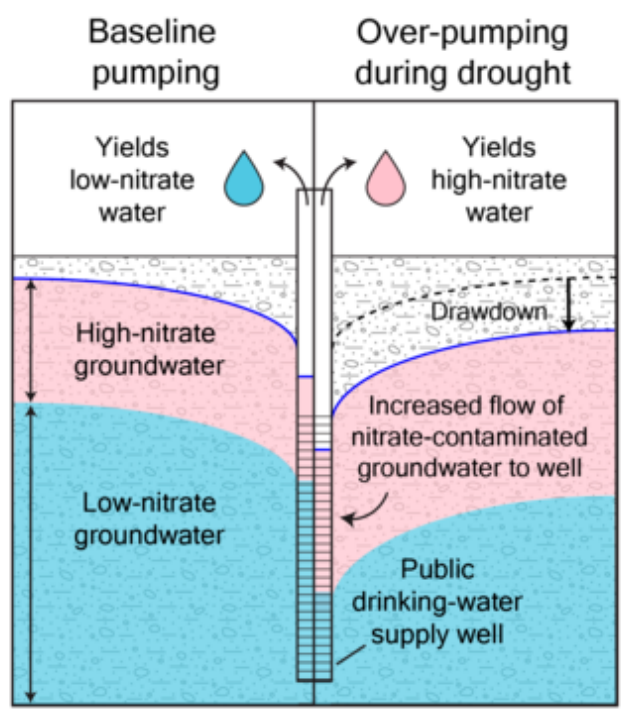
Fish adapt into larger sizes and eels move invasive mussels (like Zebra) further north.

Subsidence has damaged some critical water conveyance arteries, including the Friant-Kern Canal (40% of capacity lost in some stretches), and the California Aqueduct (more than 20% of capacity lost). Bridges over these and other canals are sinking. Subsidence can permanently reduce the capacity of aquifers to store water.

- Valley aquifers may have lost as much as 3.25% of their capacity from soil compaction during the 2012–16 drought.







Over-pumping during drought can increase nitrate at public-supply wells.

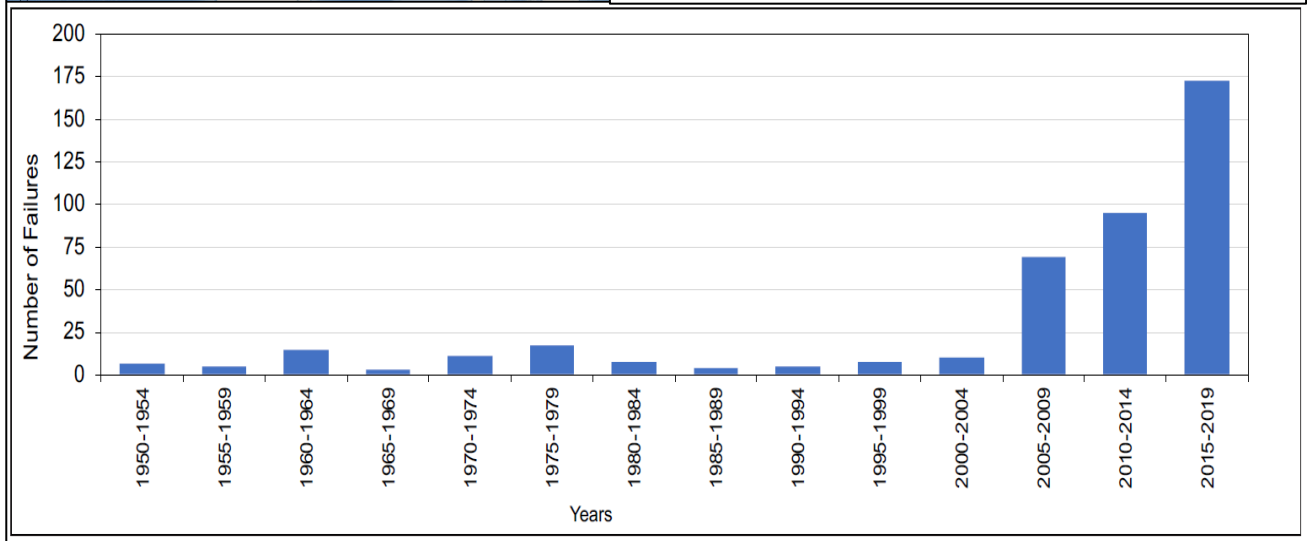


Figure 6. A time series of recorded dam failure accidents from 1950 to 2019.
Data sources: http://self.gutenberg.org/articles/list_of_dam_failures; https://en.wikipedia.org/wiki/Dam_failure; https://damsafety.org/Incidents

Severe Weather on the Rise

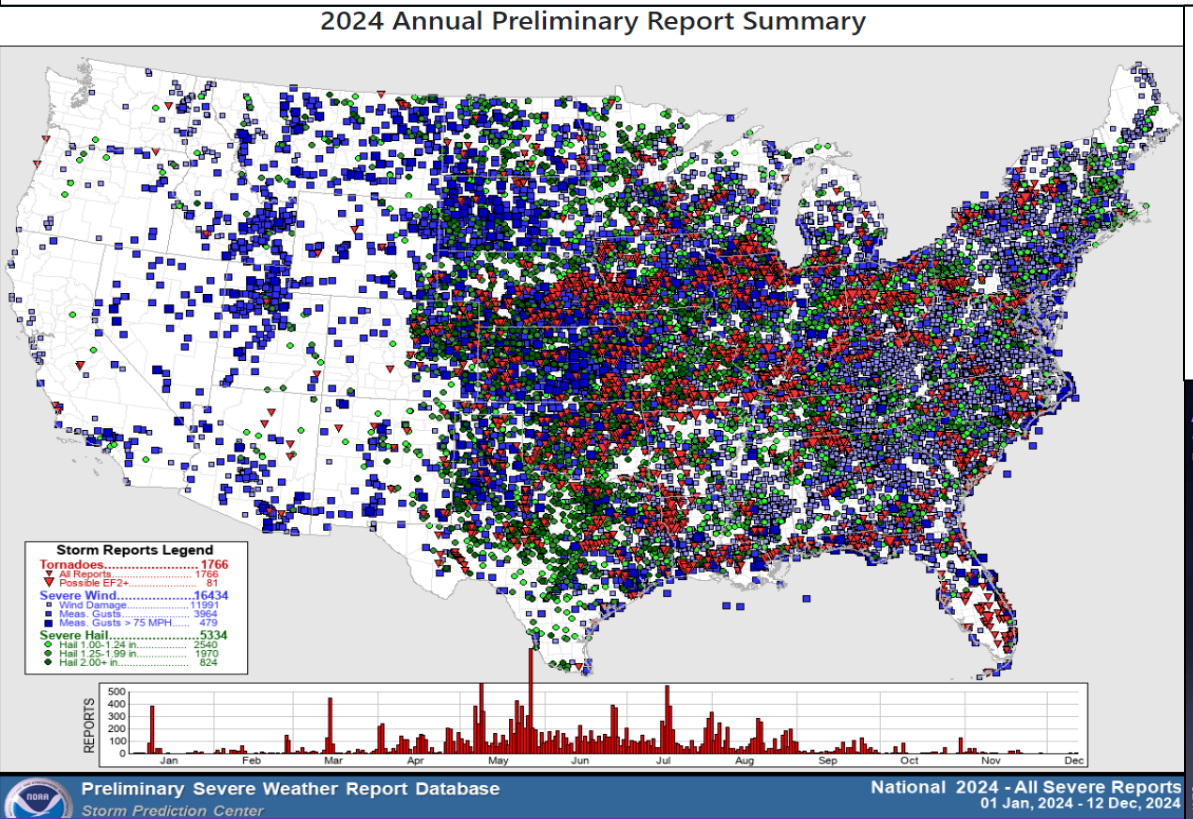
Hail events throughout the US are forecasted to intensify regarding size of the hailstones as warmer seasons across multiple regions can enable stronger updrafts for supercell storms responsible for large hail especially across less hardened areas.

Insured U.S. hail losses average $8 billion - $14 billion per year, or $80-140 billion per decade.

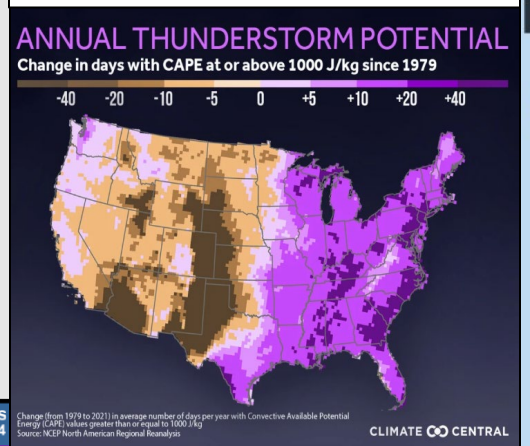
A new study published by the National Center for Atmospheric Research finds there has been "a fivefold increase in the area affected by straight-line winds since the early 1980s" in the central U.S. Straight-line winds are often produced by thunderstorms and can impacts like that of a tornado. These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

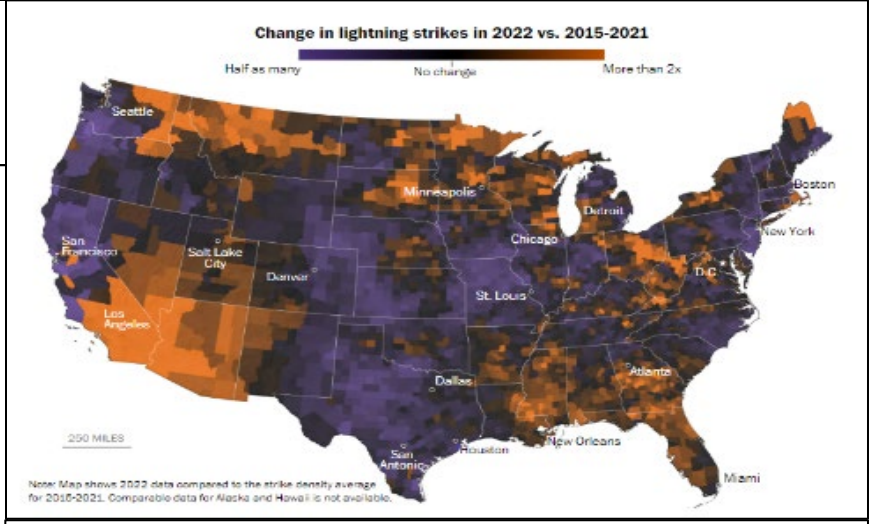
Tornado activity from 2008-2021 in comparison with 1991-2010 indicates the seasonal frequency has remained the same but the location and intensity of tornadic supercells has expanded from "Tornado Alley" to "Dixie Alley" producing larger, longer supercells. Dixie Alley includes Eastern TX, AR, LA, TN,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

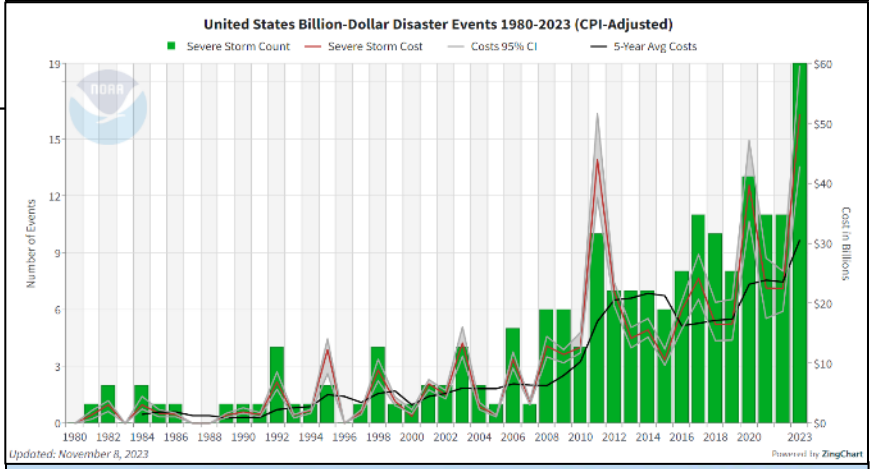
A recent study predicts a nationwide 6.6% increase in supercells and a 25.8% expansion in the area and time supercells remain over land by the year 2100. This may result in areas which do not often see tornadic activity reporting an increase in events too.

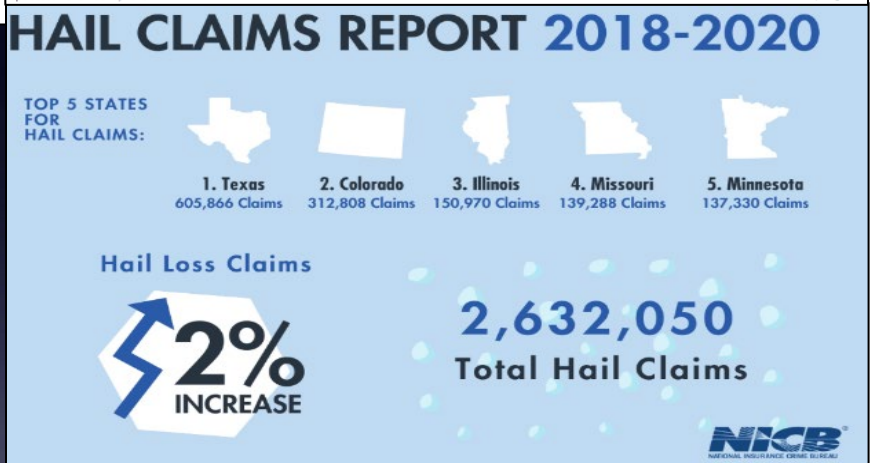


Over the past two years more severe weather has been reported in the way of large, damaging hail and more tornadic activity in the Spring and late Winter months reaching further north than usual. This is amplified in the higher tornado count in 2023 and multiple months in 2024 reporting 2-3x their average 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 sites across the US reportedly do not invest in lightning protection systems.

- Flashes that touch down amid minimal or no rainfall, known as dry lightning, are especially effective fire starters. This fire threat is noted in 2024 with the increase in plume fires merging together.
- Currently about 20 million lightning bolts touch down each year within the continental United States.
- Hotter days may boost updraft within thunderstorms, causing 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%).

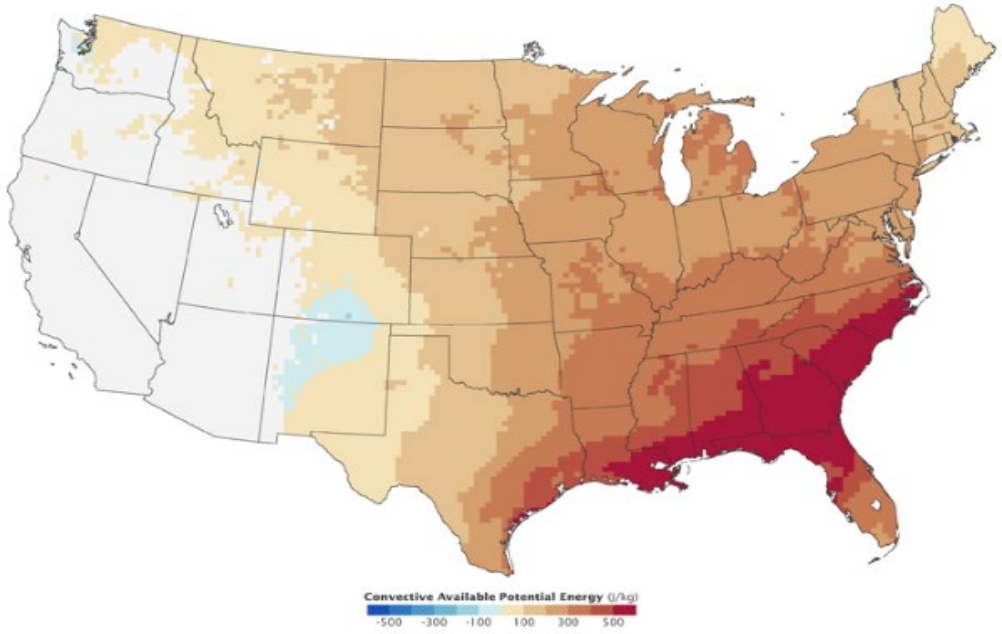
Hail: increasing temperatures and humidity could fuel larger hail and could mean smaller pellets are more likely to melt before hitting the ground.

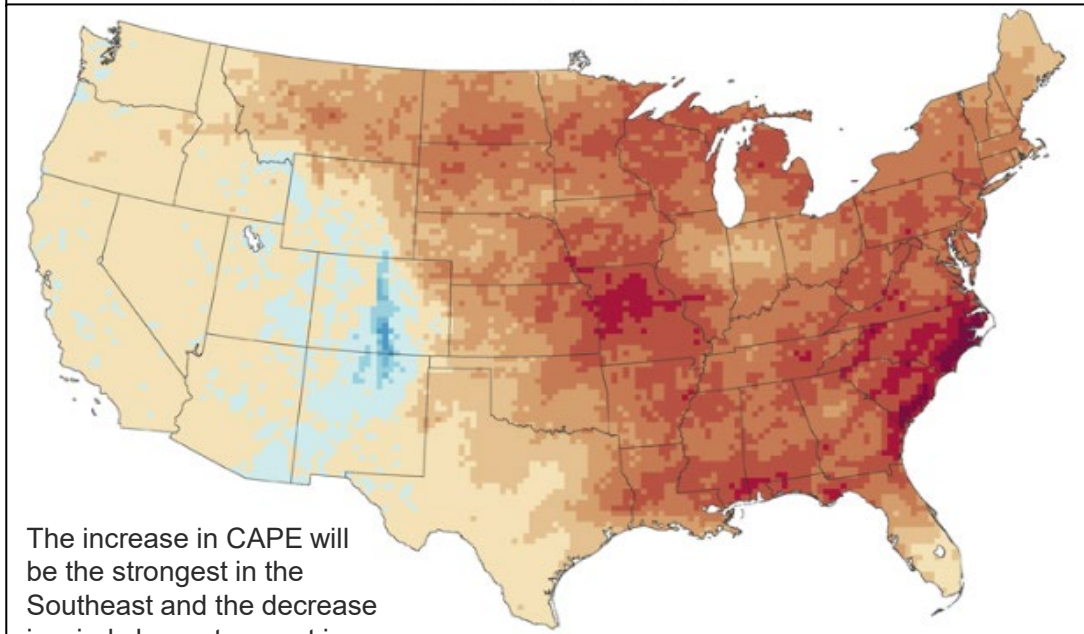
- Damage from severe thunderstorms has been inching up by about 7% annually for 30 years.
- Worldwide, thunderstorm losses were almost 90% higher than the previous five-year average of $32 billion, and more than double the previous 10-year average of $27 billion.

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.

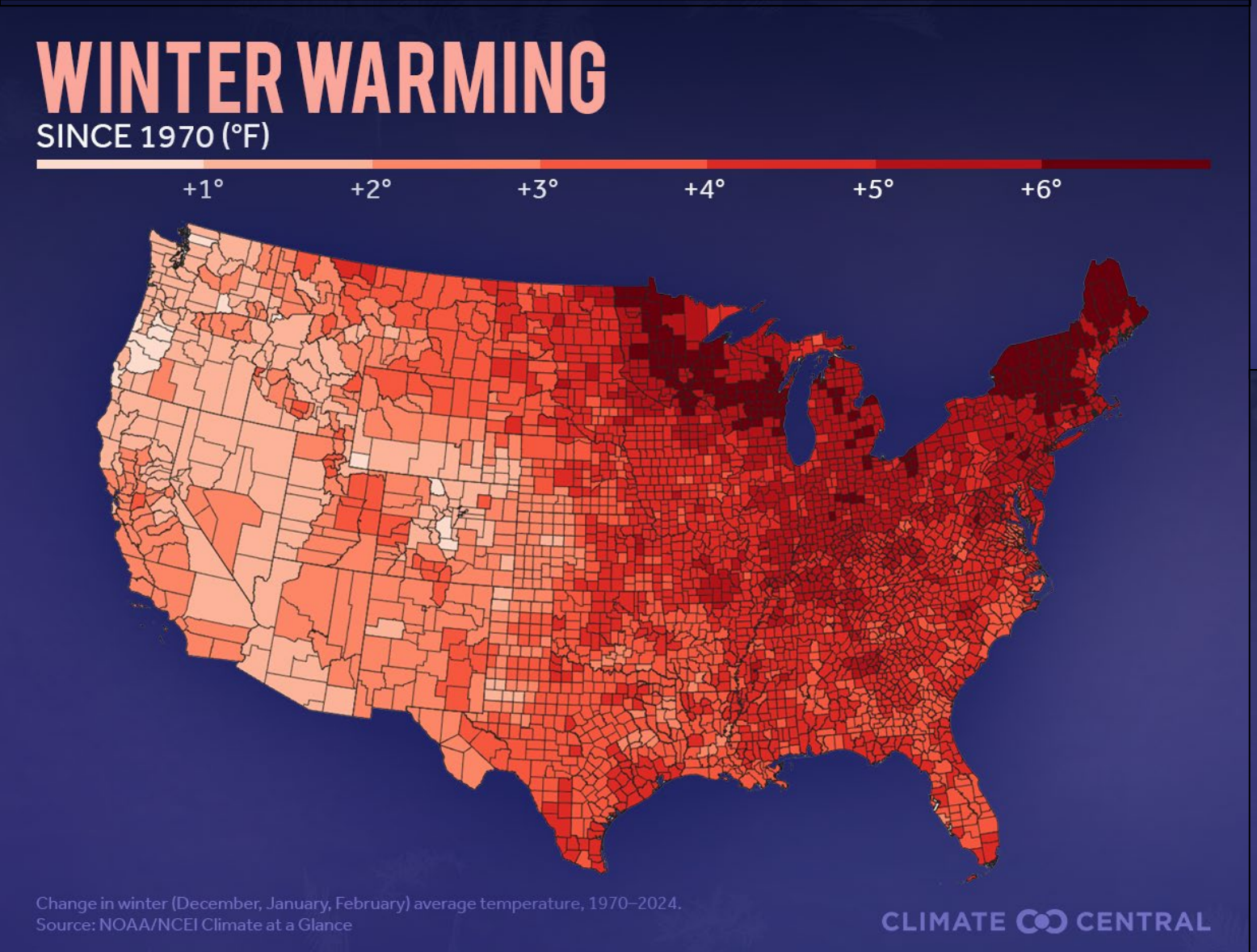


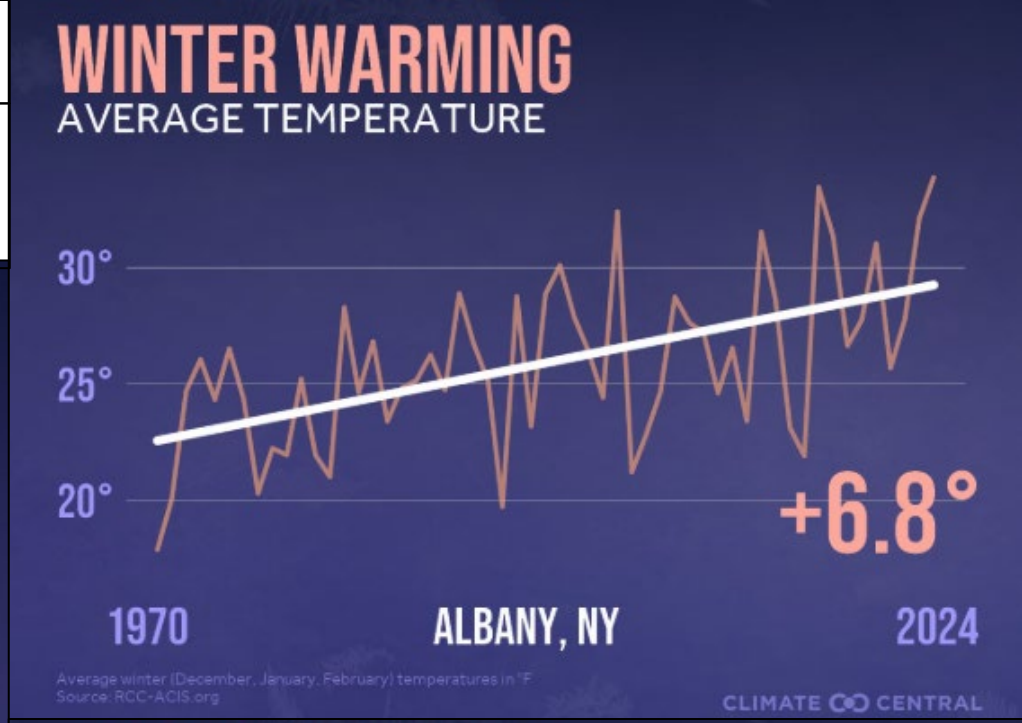


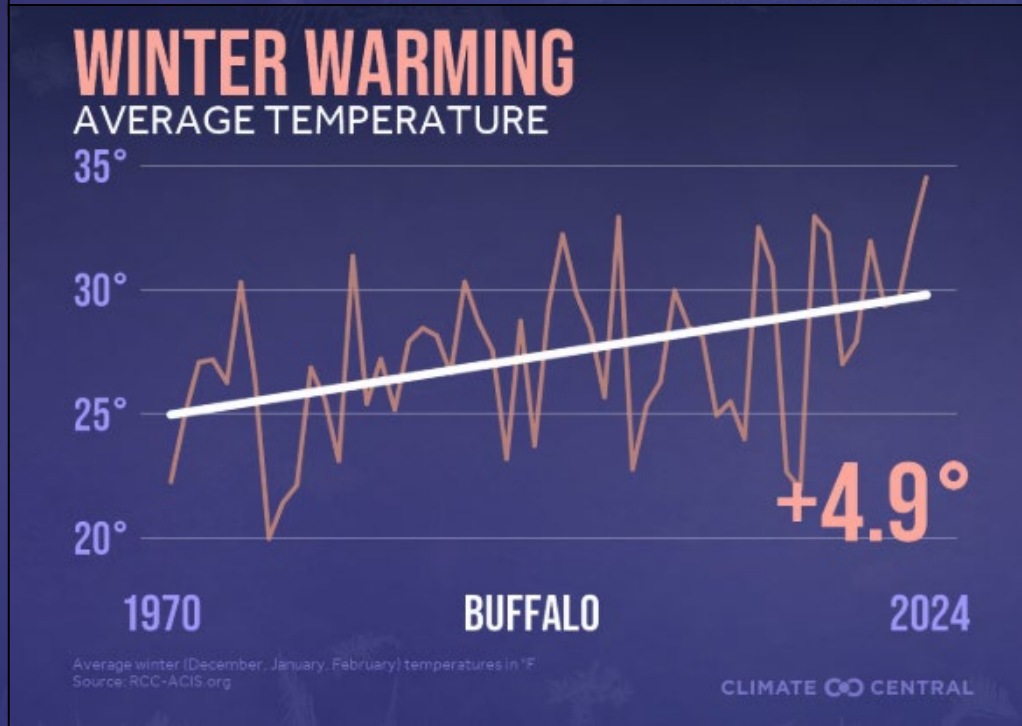
The increase in CAPE will be the strongest in the Southeast and the decrease in wind shear strongest in the Mountain West.

Climate Central's Warming Winter Graphics

Winters have warmed by 4°F on average across 235 U.S. cities since 1970. Warmer, shorter winters have lingering effects on health, water supplies, and agriculture throughout the year.







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.

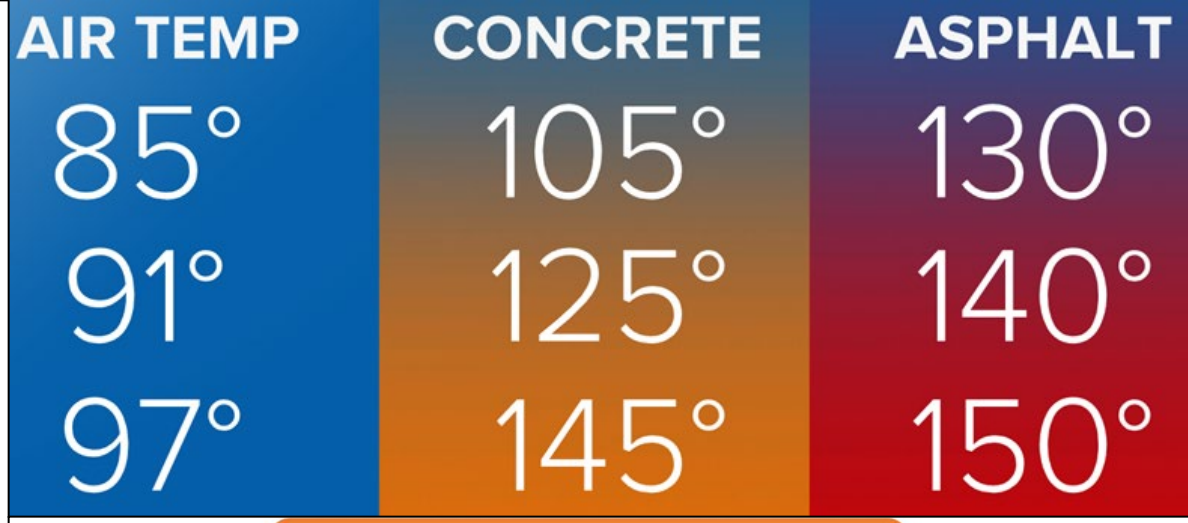
- Metal benches can hit a scorching 136F with coated benches still exceeding 108F.
- Marble benches comparable can range up to 105F while limestone can reach 116 degrees in sunlight. Shade often drops these temperature by 16-18F.
    - Water fountains can reach 95F, bus stop signs/posts can reach 105F,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

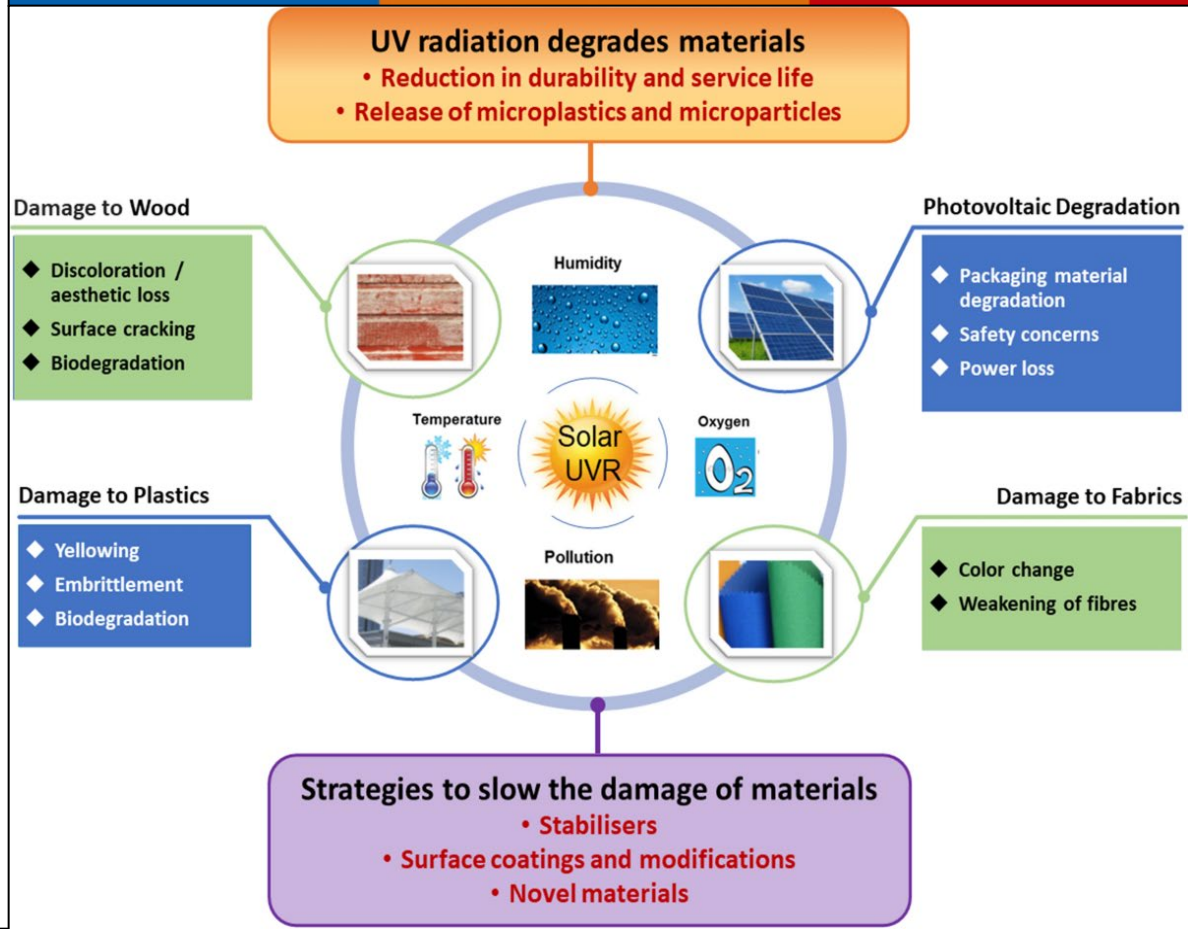
Epoxy: Most heat-resistant epoxies need to be cured at temperatures at or beyond the temperature it will need to endure. If temperatures exceed these maximum service temperatures, the material could start to distort. At a temperature of 135°F or higher, the epoxy may begin to exhibit heat damage.

- 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.





Extremist Implications

According to a PwC study, 75% of firms in the U.S. experience a major supply chain disruption annually (PwC, 2015). Hurricanes, wildfires, and other major events can cause severe disruption.

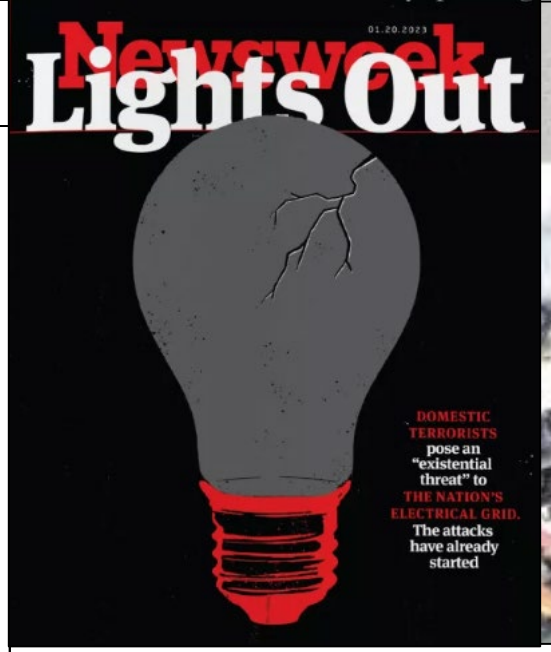
- Extremists seeking to increase power outage frequency aspire to use the cover of chaos from sudden outages to instigate race-war violence.
    - Plans like those of the extremists are unlikely to work because disaster solidarity tends to involve forming a united front against outsiders e.g. “Hurricane BBQ Parties”
    - A study from Penn State advocated “There’s a fair amount of evidence that there’s an early period after a disaster when people are fairly cooperative”.

Utilizing heatwaves for grids overwhelming is one potential threat from amplified outages to cause chaos, the other is using material fail points.

- Electronic equipment such as EV motorcycles, scoots, and bicycles can explode in extreme heat and can be easily placed in high-traffic areas.

First responders facing greater call volume and need from those facing medical risk and increased unrest in heatwaves or panic in floods may leave fewer personnel available for enforcement.

- Crimes of opportunity during the initial surge of the extreme weather event are not uncommon in most countries, however as events increase this threat expands across multiple regions and may be focused on material goods, survival needs, or resiliency supplies.
- Generator theft from stores and from critical sites can cause insurance issues as claims rise. GPS monitoring equipment is still difficult to retrieve initially post-disaster due to the persisting power and telecommunication outages across the area.



One white supremacist Telegram channel included calls for attacks against substations, railways and commercial sites such as grocery stores and Amazon distribution centers.
A short video appeared to show two men shooting a "water plant" with rifles.

- *The same channel celebrated the Moore County attacks as an act of "magnificent sabotage" and "beautiful escalation" in an anti-LGBTQ culture war.*
- *Others called for large-scale attacks on New York City, Washington, D.C. and other cities.*

A user on 4Chan, who self-identified as "the current Chancellor of the 4th Reich," called on like-minded individuals to attack substations in any area of the country that was "not majority white."

Exploding e-scooters kill four as heatwave damages batteries

There have been near daily reports of electric scooters catching fire across India amid record-breaking temperatures

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.

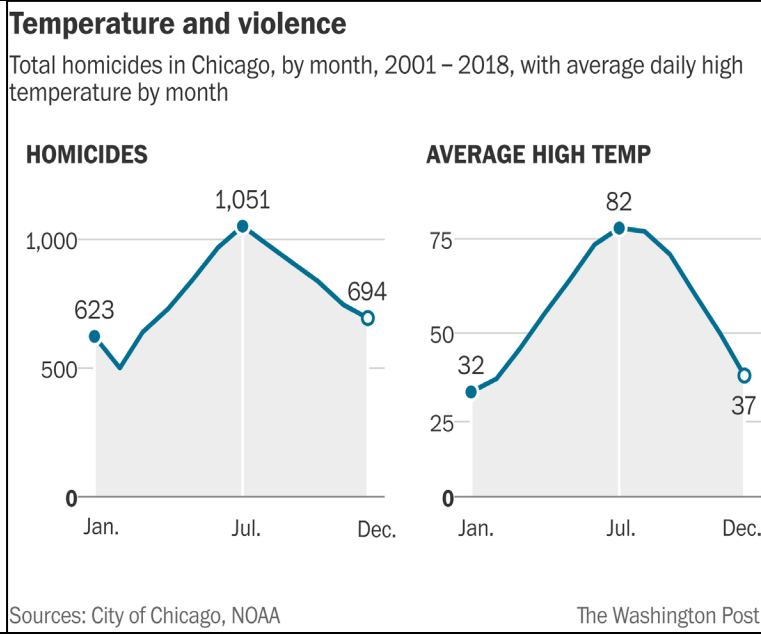
- A 2019 study from Stanford University found climate change contributed to between 3% to 20% of conflicts over the last century with the potential influence set to increase substantially due to warming global temperatures.
- Research from Mexico, which took 16 years' worth of daily crime records from 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.

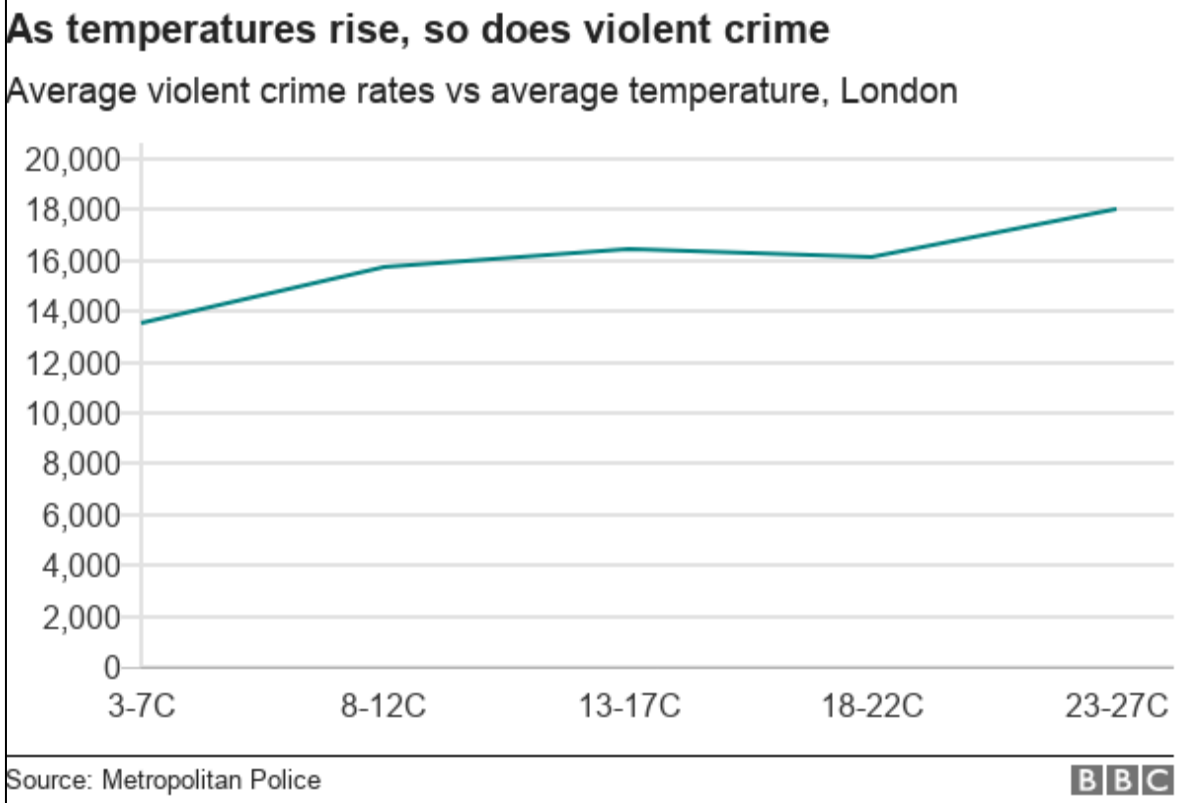
A study of Los Angeles, CA: On average, overall crime increases by 2.2% and violent crime by 5.7% on days with maximum daily temperatures above 85F (29.4C) compared to days below that threshold. Moreover, heat only affects violent crimes while property crimes are not affected by higher temperatures.

- 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.





According to a 2018 study published in *Nature Climate Change*, a 1.8°F (1°C) increase in average temperature in the U.S. and Mexico correlates to a 1% increase in suicides. Poor quality sleep may be one of the driving factors.

- Heat also plays a role in perceiving an aggressive tone or transgression when interacting with others. Violence in prisons also increases during extreme heat with days ranging over 27C increasing the probability of violence by 18%.

Twitter sees hate tweets and online aggression increase during heatwaves, along with phrasing that researchers have linked to anxiety and depression.

Analysis showed that productivity started dropping when average daily maximum temperatures rose above 20° C. The researchers' calculations suggest that average annual output will decrease by 2.1% if average daily temperatures warm by 1 degree C over current conditions; annual gross domestic product, or the value of goods and services produced in a single year, would drop by 3%.

- **Impacts to venue operations could be experienced in decreased productivity, more aggressive crowds, losses in supply chain, heightened damages, quicker quitting staff, burnout, greater damage to operational capabilities, and delays/cancellations of performances/events.**

Portland sees spike in gun violence as heat wave blankets metro area

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As the temperature rose across Portland, so has violent crime, with six shootings since July 4. According to a local sociology professor, that is a predictable pattern.

According to the Mississippi Department of Public Safety, the violent crime rate in **Mississippi** increased by 2.4% in 2022 from the previous year.

- The most common violent crimes in Mississippi are aggravated assault, robbery and murder.

Research from Lancet Planetary Health states for every 5°C (9°F) increase in the average daily temperature, there was a 4.5% uptick in sex offenses in the following week across several major U.S. cities.

- On days when the temperature gauge exceeded 85°F (29.4°C), overall crime jumped by 2.2%, and violent offenses surged by 5.7%.

With each 5°C rise in temperature, **Chicago**'s homicide rates shot up by 9.5%, and **New York City** wasn't far behind with an 8.8% increase.

In 1988, during the periods warmest summer on record, the US reported record-breaking violence (1.56 million cases).

- This is a global phenomena and risk.

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.

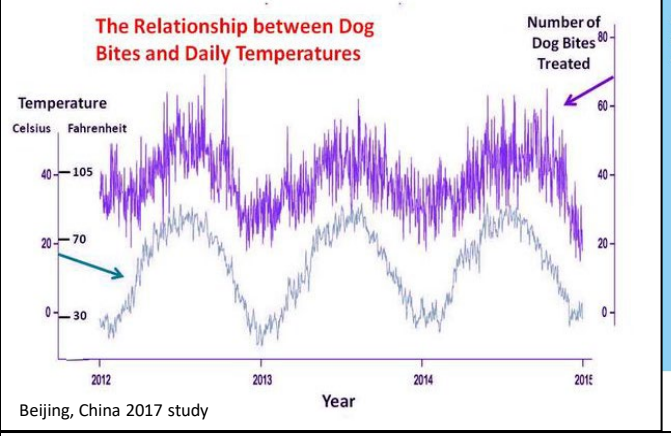
Wild and domestic animals will show a shift in their eating habits once high heat begins, because seasonal changes in daylight and temperature trigger significant hormonal changes in mammals.

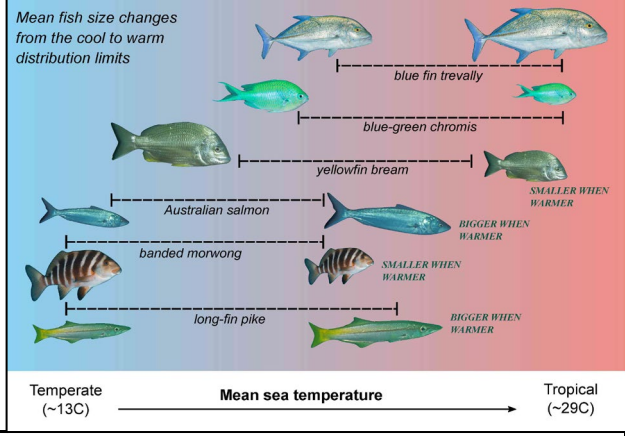
- These shifts alter the animal's metabolism and greatly influence food intake. As temperatures increase, mammals become less active and therefore burn less energy.
- This impact is especially recorded in birds as water availability becomes stressed.

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.

Meteorological Intelligence

On the backside of a very deep low, bringing a severe storm event, a drop in winds across the region is typical due to the onsetting high pressure.

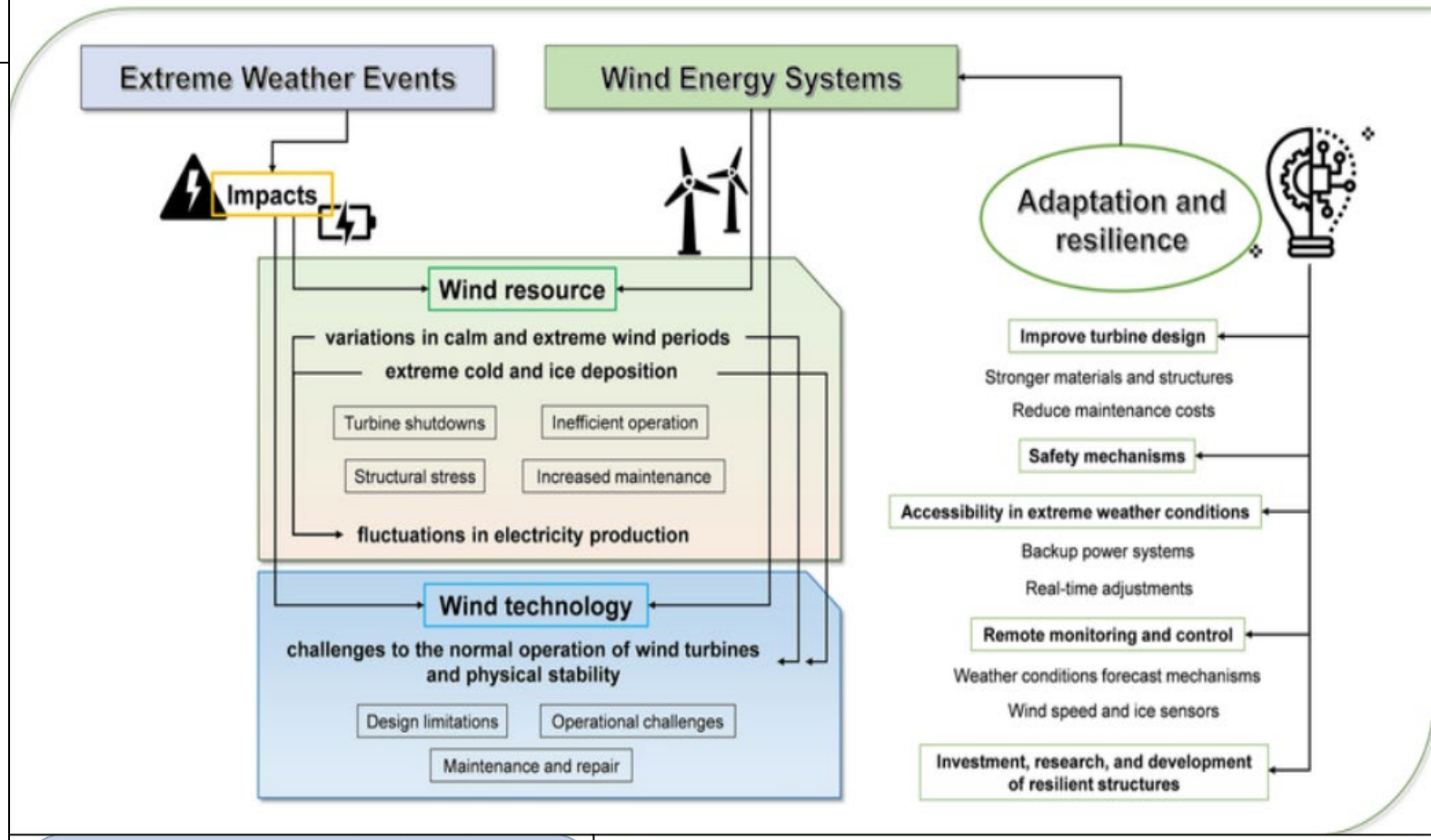
- Knowing when the weather shift is coming can enable preparation measures like testing backup generators.

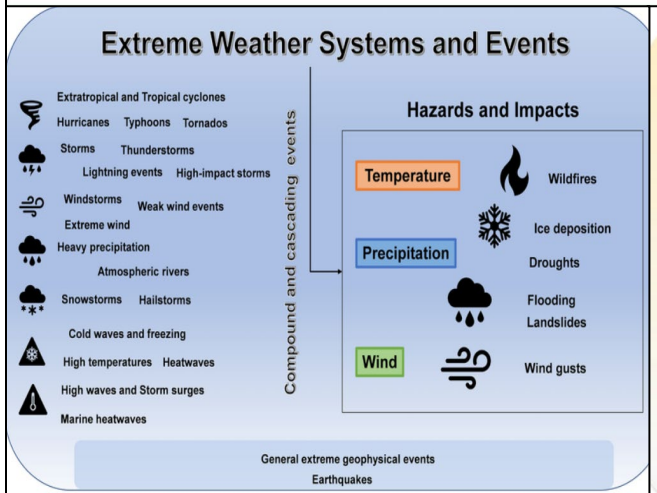
According to a recent study, hackers are leveraging these weather trends to target energy systems when they are at their most critical.

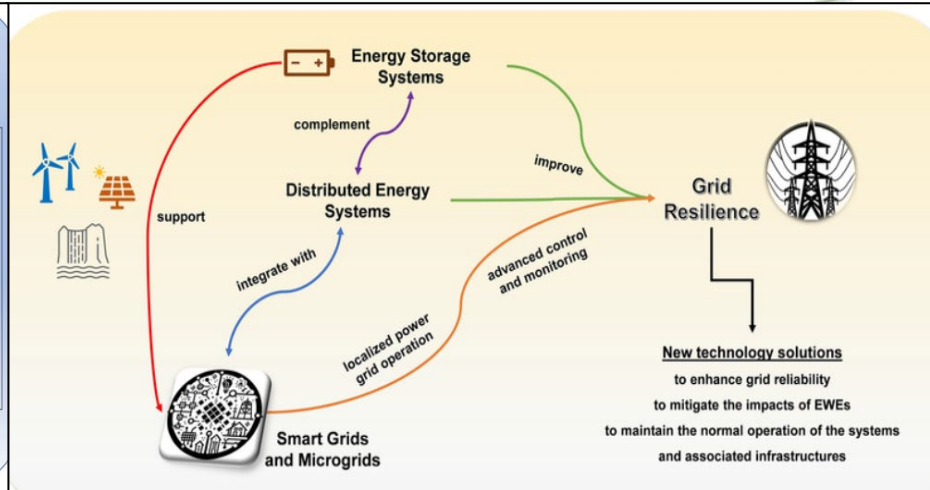
- The study, titled "*Operational and economy-wide impact of compound cyber-attacks and extreme weather events on power networks*", concluded that an attack carried out in the wake of a weather event increased the potential impact 3x more than a standalone cyberattack.
- Local economies could experience a 37% drop-in economic activity if faced with a compound threat.
    - These events led to a 12% of energy demand going unmet and a daily GDP reduction up to 3.1%.

Example Event in Long Island:

- One conclusion listed that a 9% increase in demand during a heatwave.
- A lone cyberattack could lead to 4% of demand going unmet.
    - Combined they could yield 12%, or nearly 200,000 customers.







Climate Migration Patterns

Climate migrants are **people who leave their homes because of climate stressors**. Climate stressors, such as changing rainfall, heavy flooding, and sea level rise, put pressure on people to leave their homes and livelihoods behind. It makes their homes uninhabitable.

- Since 2008 over 318 million people around the world have been forcibly displaced by floods, windstorms, earthquakes or droughts, 30.7 million in 2020alone.This is equal to one person being displaced every second. The number of people affected by climate change could double by 2050

13 million U.S. coastal residents are expected to be displaced by 2100 due to sea level rise. In the worst-case scenario, in which sea levels rise by six feet by 2100, the resulting map shows portions of almost all counties on the East and West Coasts, and along the Gulf of Mexico, under water.

The 2018 wildfire that displaced some 50,000 residents in and around the city of Paradise, California. “It’s increased the property values of neighboring towns,” he says. One such town is Chico, which became the top refuge destination and turned into a boomtown almost overnight. By the end of that year, home sales doubled, and housing prices jumped 21%, compared to December 2017.

- People may also flock to major urban centers like Dallas and Houston, which the model predicts will absorb the most migrants, and drive up the pace of urbanization.
- Heat waves will drive people north—and could make cities like Duluth and Buffalo “climate havens.” Urban flooding will reshuffle populations within a city.

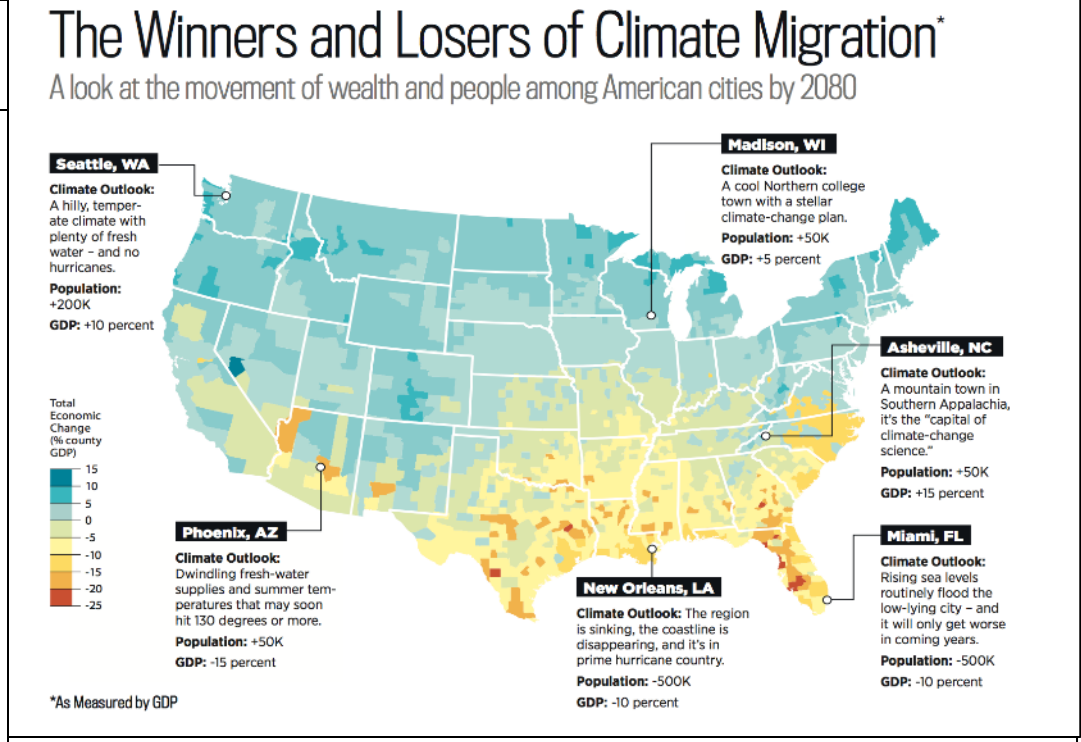
Climate change related-migration, as used in this report, is an umbrella term describing the spectrum of climate change’s relationship with human mobility—including the circumstances of “trapped populations” for whom migration is not an option despite exposure to climate-related threats. Even in the United States, one extreme event can result in a relatively high degree of permanent relocation of low-income populations exposed to chronic and worsening conditions over time.

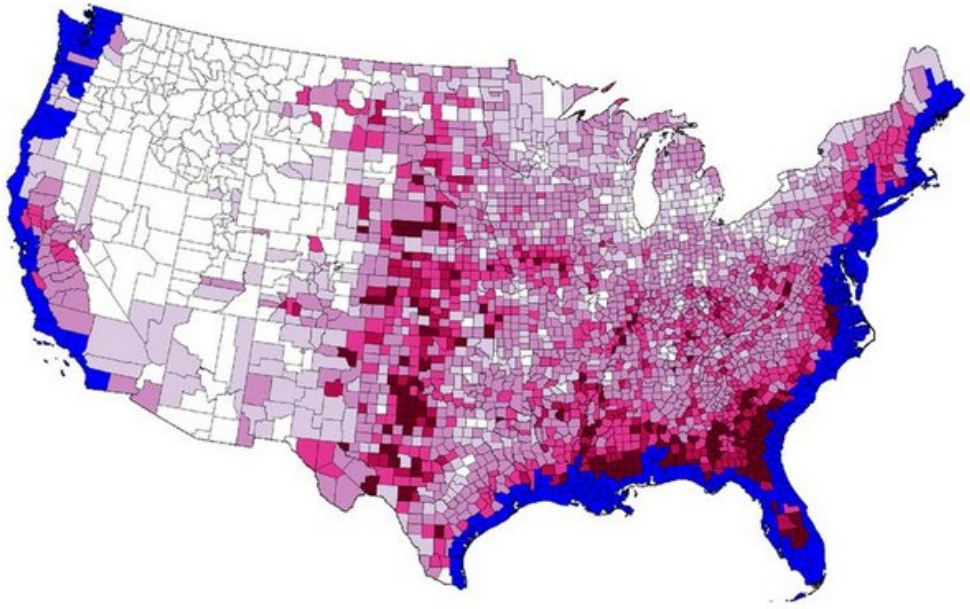
https://www.whitehouse.gov/wp-content/uploads/2021/10/Report-on-the-Impact-of-Climate-Change-on-Migration.pdf

Extreme weather events and conflict are the top 2 drivers of forced displacement globally, together responsible for the annual movement of nearly 30 million people from their homes.

Climate change can cause or exacerbate resource scarcity, which may drive conflict directly as well as induce migration of populations in vulnerable situations attempting to secure safety or livelihoods.

The subsequent movement of large numbers of people, by force or by choice, brings new groups into contact with one another, potentially shifting power balances, causing further resource scarcity, or igniting tensions between previously separated groups



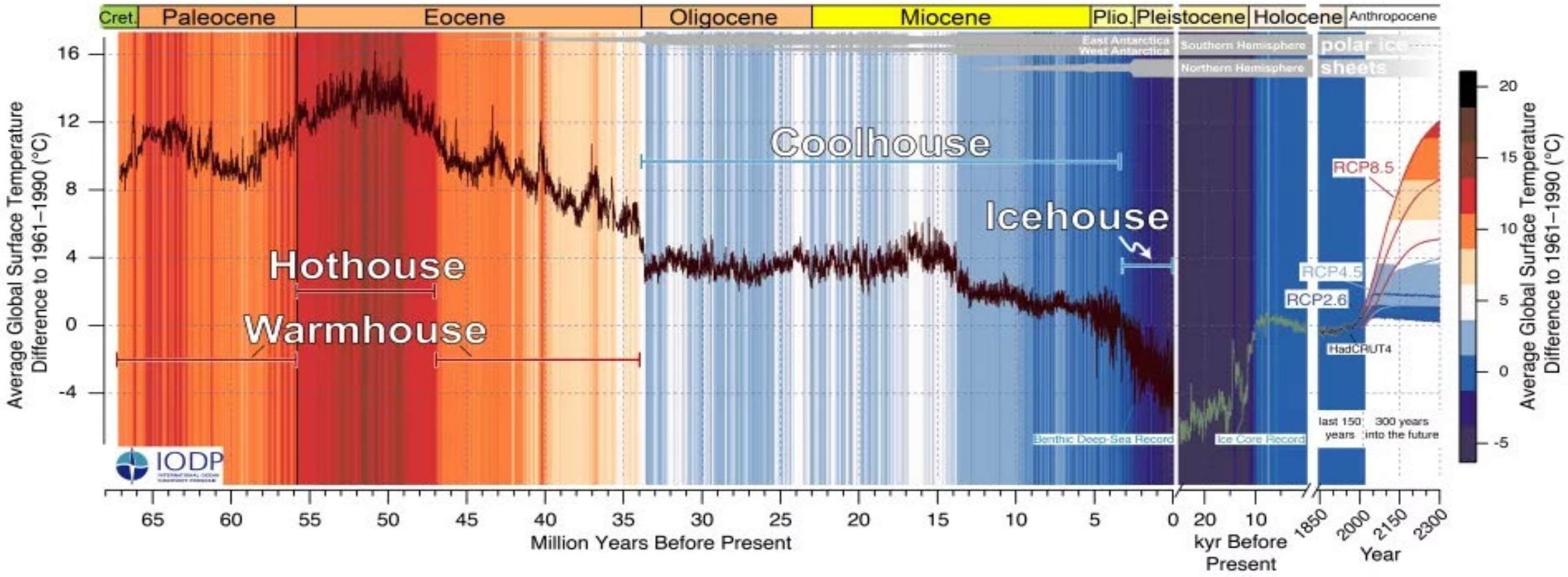


Sea level rise could displace some 13 million people. Here's where they might go. *PLOS One*

Defined Threat: Condensed Periods to Adjust

The change in heating is not just that it is baseline creeping upwards, it is that we built to norms from a window of time in stable conditions that we will not be returning to during the next few lifetimes. This means infrastructure was simply not build to withstand.

- The climate hazards defined in previously slides will amplify rapidly in coming decades.



South Dakota State Summary – NCICS

Due to its location in the center of the US, far from the moderating effects of the oceans, the state experiences large temperature extremes.

- Average January temperatures range from less than 10°–15°F in the northeast to more than 25°F in the southwest, while average July temperatures range from about 65°F in Black Hills National Forest to more than 75°F in the south-central region. Temperatures of 100°F or more occur nearly every year.

Temperatures in South Dakota have risen almost 2°F since the beginning of the 20th century.

- Temperatures in the first two decades of this century have been higher than in any other historical period.
- Warming has occurred in all four seasons but has been largest in the winter.
- The lack of summer warming is reflected in a below average number of extremely hot days since 1990.

Nighttime minimum temperatures have risen at about twice the rate of daytime maximum temperatures, which may be attributed to an increase in absolute humidity.

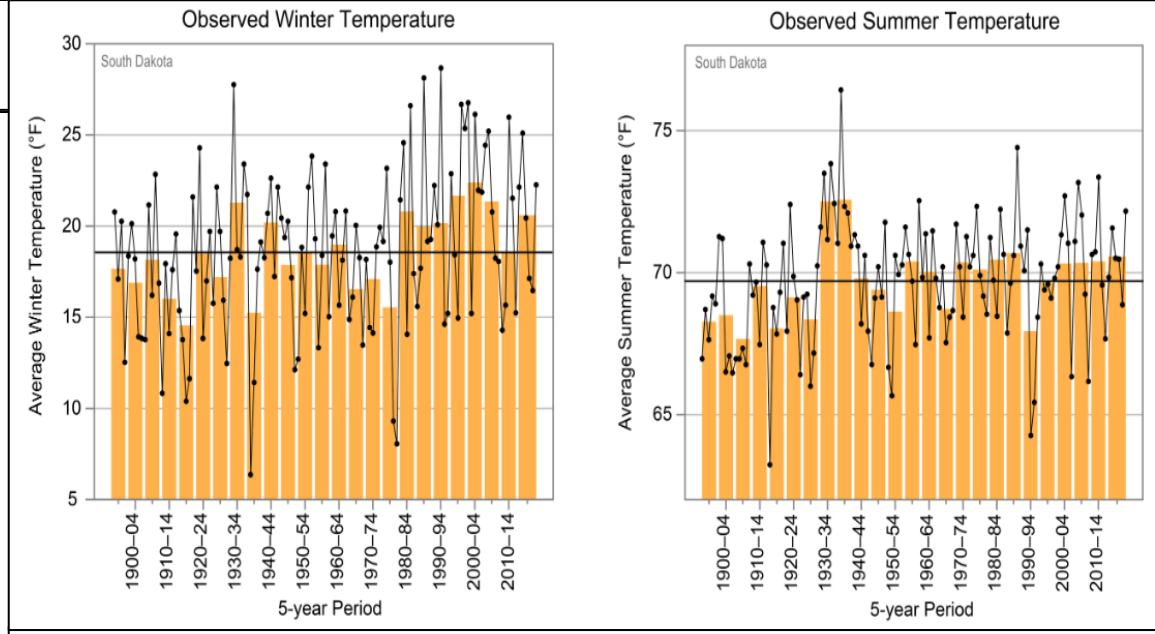
- Winter warming is reflected in a below average number of very cold days since 2000.

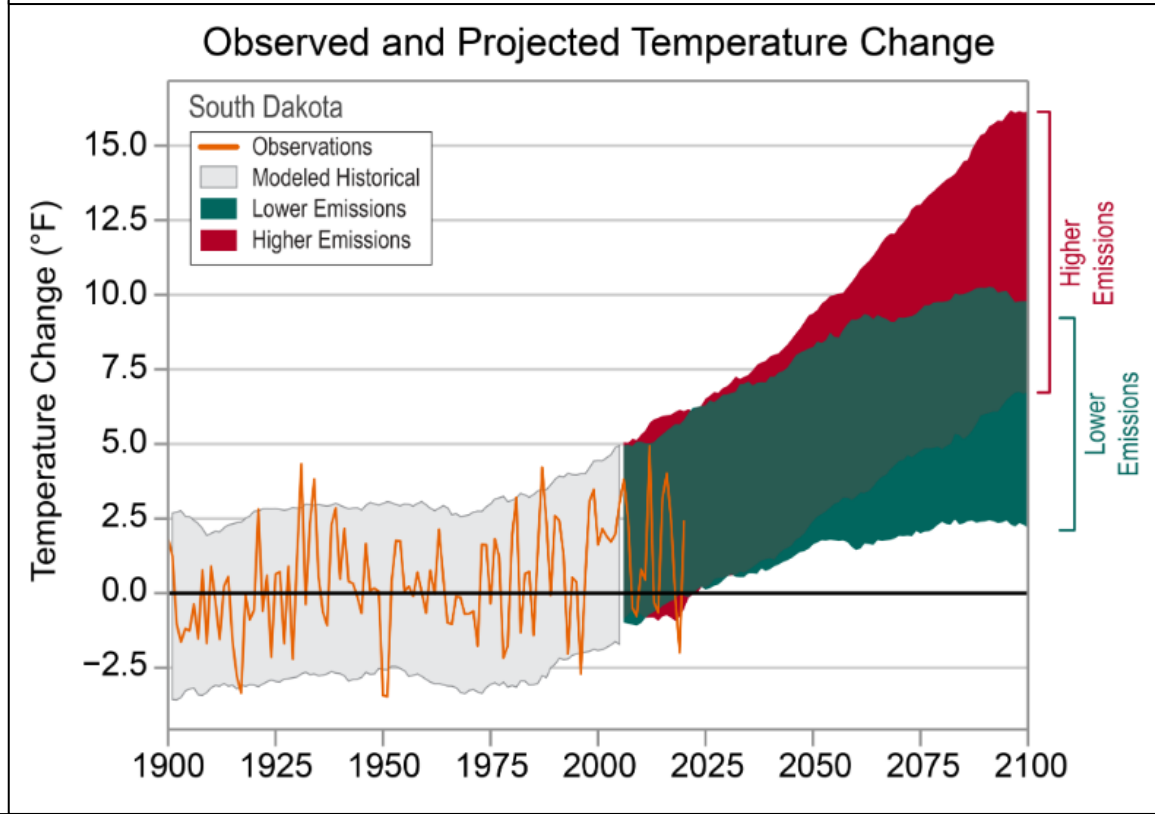
Annual average precipitation ranges from around 16 inches in the northwest to about 28 inches in the southeast.

- While most of the state averages at least 30 inches of snow annually, portions of Black Hills National Forest can receive upwards of 70 inches annually.

Most of the state's precipitation falls between April and September.

- A hailstone from a severe thunderstorm that fell on July 23, 2010, in Vivian holds the national record for hail weight (1.938 pounds) and diameter (8.00 inches).





South Dakota Climate Averages by Month

Due to its location in the center of the US, far from the moderating effects of the oceans, the state experiences large temperature extremes.

- Average January temperatures range from less than 10°–15°F in the northeast to more than 25°F in the southwest, while average July temperatures range from about 65°F in Black Hills National Forest to more than 75°F in the south-central region. Temperatures of 100°F or more occur nearly every year.
- Increases in evaporation rates due to rising temperatures may increase the rate of soil moisture loss and the intensity of naturally occurring droughts.

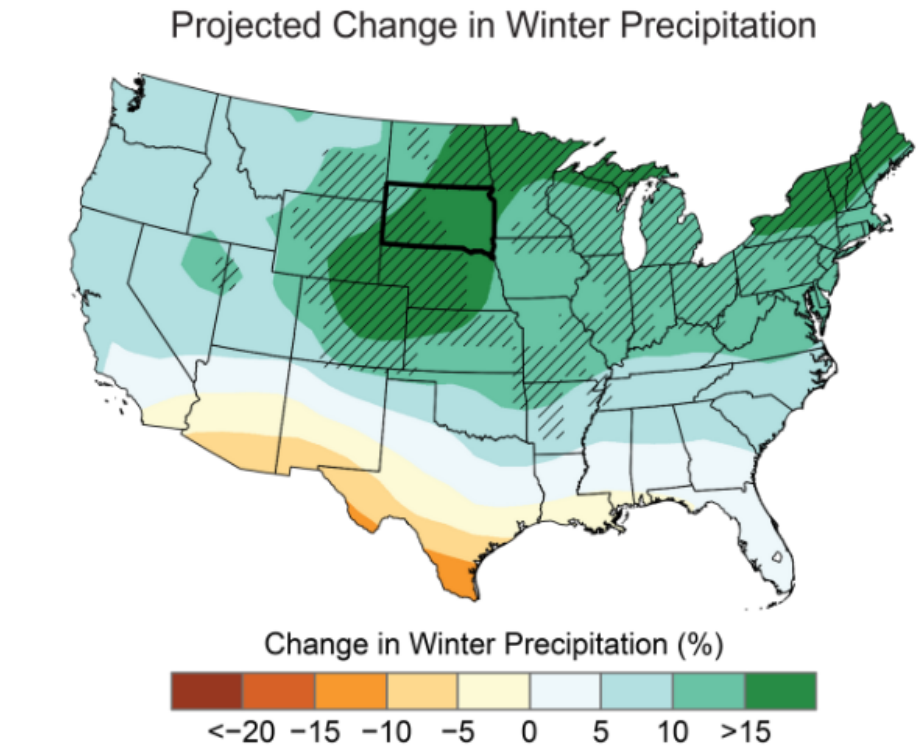


Figure 7: Projected changes in total winter (December–February) precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Sources: CISESS and NEMAC. Data: CMIP5.

Annual precipitation is projected to increase, with the largest increases occurring during spring and winter.

Increased winter and spring precipitation can impact South Dakota's agricultural economy both positively (increased soil moisture) and negatively (loss of soil nutrients, planting delays, and yield losses).

Increases in the frequency and intensity of extreme precipitation events are also projected, potentially leading to increased runoff and flooding, which can reduce water quality and erode soils.

Increased winter snowfall, rapid spring warming, and intense rainfall can combine to produce devastating floods.

Drought intensity is projected to increase.

November and December mark the beginning of winter in the Black Hills. Despite cooler temperatures and more snow; the area still has many mild, sunny days.

By December, daytime temperatures are in the 30s with nighttime readings in the teens and sometimes below zero in the Black Hills. Occasionally cold air from Canada will bring subzero temperatures to the entire area; however, warmer weather returns quickly.

Snowfall averages about five inches each month with only two days typically receiving more than one inch of snow. Storms early in the season produce heavy, wet snow. As the winter progresses, storm tracks from the northwest bring drier snow. Rapid City's chances for a white Christmas (defined as having inch or more of snow on the ground) is about 50 percent.

December Average	High Temp	Low Temp	Snow	Percent Sunshine
Rapid City	36	13	5.3	55
Denver	44	16	8.9	67
Minneapolis	26	11	10.0	42
Chicago	34	20	8.7	43
Kansas City	40	23	4.3	49

January and February are the coldest months of winter. Daytime temperatures average in the 30s, but Chinook winds can warm temperatures into the 50s and 60s. Occasional intrusions of Arctic air are short-lived and temperature inversions sometimes produce warmer conditions in the Black Hills.

Low temperatures average from 10 to 20 degrees above zero. Below zero readings are not uncommon in the higher valleys of the Black Hills.

Average monthly snowfall ranges from five inches in Rapid City to 15 inches in the Black Hills. The snow on the plains usually melts within a few days, with deeper snow in the Black Hills providing good winter recreation conditions.

January Average	High Temp	Low Temp	Snow	Days low temp < 0 E
Rapid City	34	11	5.2	8
Denver	43	15	7.7	4
Minneapolis	22	4	13.5	14
Chicago	30	14	11.3	7
Kansas City	36	18	5.8	4

March and April is western South Dakota's snow season and temperatures are still cool enough in the higher elevations to retain the snow cover. March is typically the snowiest month of the year, with average snowfall 15 to 25 inches in the northern Black Hills and eight to 12 inches over the southern Hills. Normal highs are in the 40s and lows are in the 20s.

Snow often occurs in April, although temperatures are warmer. Normal snowfall for the Black Hills is 10 to 20 inches in the north and five to 10 inches in the south. Average daytime temperatures are in the 50s with lows in the 20s and 30s.

March Average	High Temp	Low Temp	Snow	Days with snow > 1.0"
Rapid City	47	23	9.1	3
Denver	54	25	11.6	3
Minneapolis	41	24	10.4	3
Chicago	46	29	6.0	2
Kansas City	54	33	2.6	1

May and June weather is mild and precipitation changes from rain showers to thunderstorms. Storms typically develop over the Black Hills during the afternoon and move onto the plains in the evening. However, Rapid City still sees an average of 20 clear to partly cloudy days and 65 percent of its possible sunshine in June.

Temperatures warm rapidly as summer approaches. Daytime highs average in the 60s during May and 70s during June. Overnight temperatures are still chilly, especially in Black Hills, where May minimums are in the 30s and 40s. Lows are typically in the 40s and 50s during June.

June Average	High Temp	Low Temp	Rain	Clear-partly cloudy days
Rapid City	77	52	2.83	20
Denver	82	53	1.56	22
Minneapolis	79	58	4.34	19
Chicago	79	57	3.63	19
Kansas City	84	63	4.44	19

Summer is warm, dry, and sunny. **July and August** are the warmest months of the year, when daytime temperatures climb into the 70s and 80s--and sometimes 90s. Breezy winds and low humidity levels help make the hot days comfortable.

Early mornings are cool, so a jacket or sweater may be needed for outdoor activities. Low temperatures average in the 50s, although 40s--and even 30s--can occur at the higher elevations like Deerfield.

Thunderstorms produce less rainfall, and drier conditions increase the wildfire potential in the Black Hills. Rapid City records an average of 9 thunderstorms days in August, but only 1.67 inches of rain.

Rapid City receives 75 percent of its possible sunshine. Because the elevation of the Black Hills are between 4000 and 7000 feet, the sun is very intense.

August Average	High Temp	Low Temp	% Humidity	Days high temp > 90 E
Rapid City	86	57	39	11
Denver	86	57	35	9
Minneapolis	80	61	56	4
Chicago	81	62	61	4
Kansas City	87	66	58	12

Sunny, mild days and cool nights are characteristic of **September and October** weather. Temperatures begin to cool around Labor Day, with September highs averaging in the 60s and 70s, falling into the 50s and 60s in October. Lows drop from the 30s and 40s into the 20s and 30s. The average first freeze in Rapid City is October 4 and late August through September in the Black Hills.

The area's first snowfall is usually in October, although higher elevations sometimes receive snow in September. Occasional cold fronts moving through the area bring blustery northwest winds.

October Average	High Temp	Low Temp	Snow	Days low temp < 32 E
Rapid City	62	35	1.8	11
Denver	66	36	3.9	9
Minneapolis	58	39	0.6	7
Chicago	62	42	0.3	5
Kansas City	68	46	0.3	2

Precipitation Events of Note – Rapid City

Typically, the Rapid City weather forecast office issues around 300 Severe Thunderstorm and Tornado Warnings per year (shown at left), with the majority coming from late May through August.

- As a result, during most years, Rapid City is are among the top ten offices in terms of warnings issued. In 2020, the count of 426 was fifth in the country.
- Recent thunderstorms have produced over 5 inches of rain in less than 3-hours resulting in runoff triggering mudslides and street flooding events.
- Wind gusts over 100 mph have been reported more frequently in the past decade with river levels in many areas setting or competing for record heights from sudden onset flash floods or premature snowpack melts.

Squall Line: account for a larger fraction of severe straight-line winds and fewer tornadoes and large hailstones (also known as a Quasi-Linear Convective Systems).

Microburst: a localized downdraft of air associated with a thunderstorm that is < 2.5 miles in diameter and can produce winds over 120 mph causing significant damages.

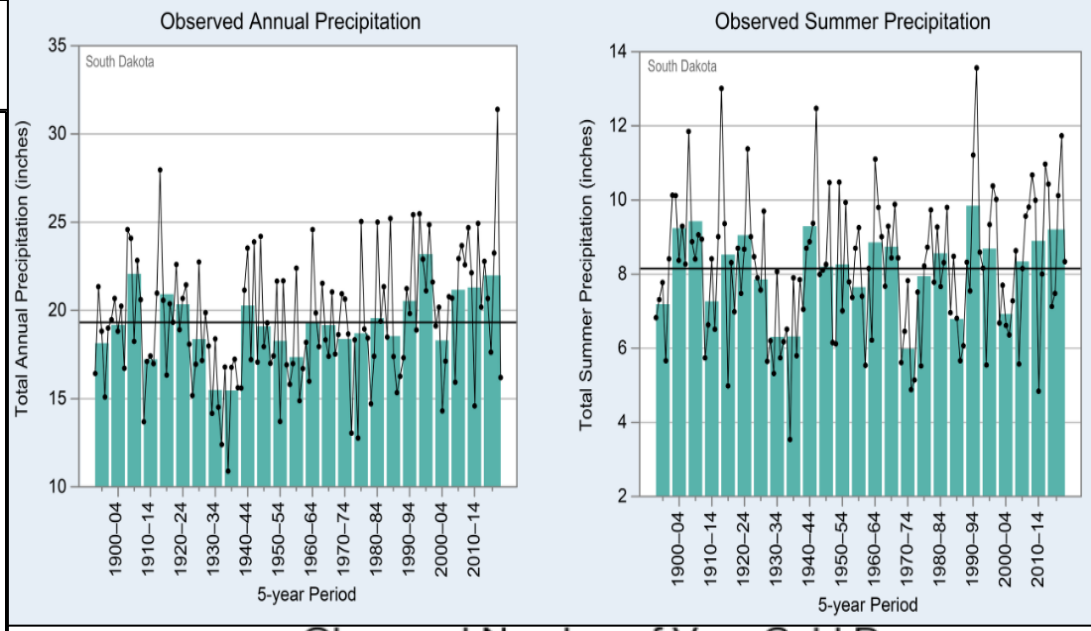
Derecho: a line of intense, widespread, and fast-moving windstorms / thunderstorms that moves across a great distance and is characterized by damaging winds.

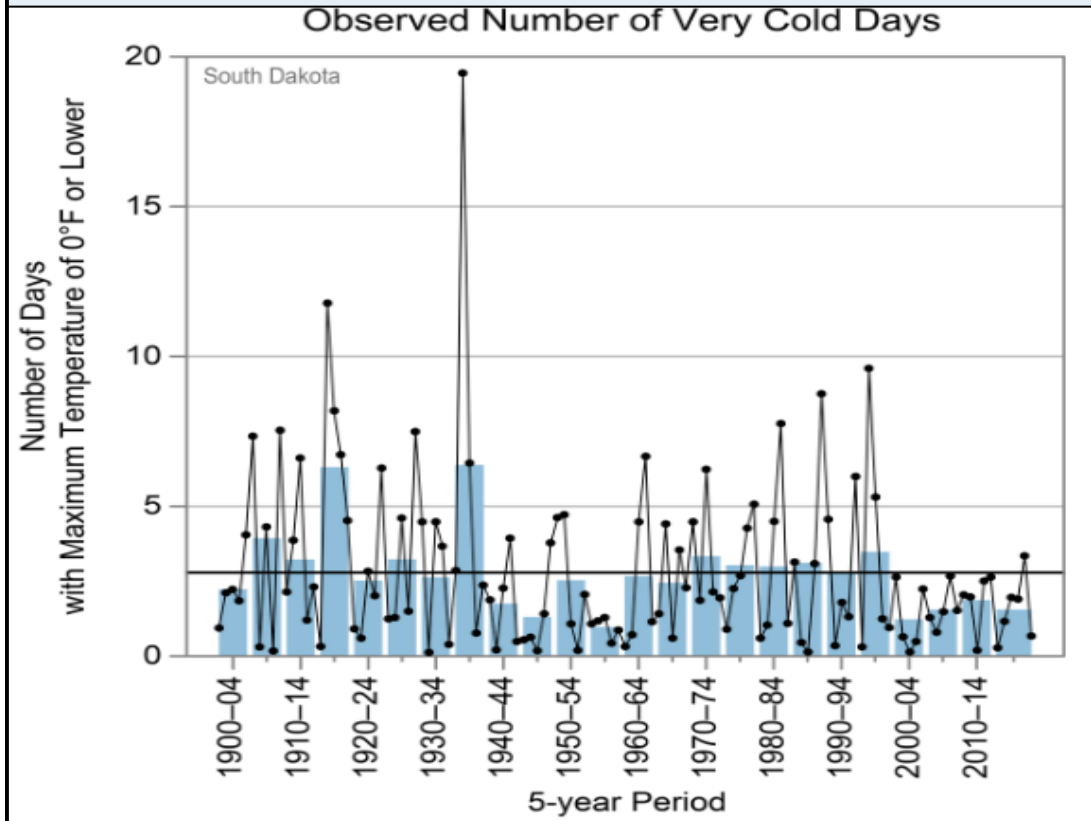
Straight Line Winds: A straight-line wind is any strong wind resulting from a thunderstorm that does not rotate.

Supercells: Most strong tornadoes and large hailstones are associated with supercells. Supercells are particularly strong thunderstorms that are characterized by a persistent, rotating updraft.

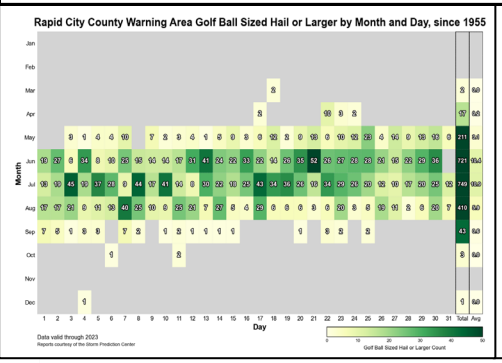
- Classic supercells are typically identified on radar by their distinctive hook echo feature, which is evidence of rotation within the storm.

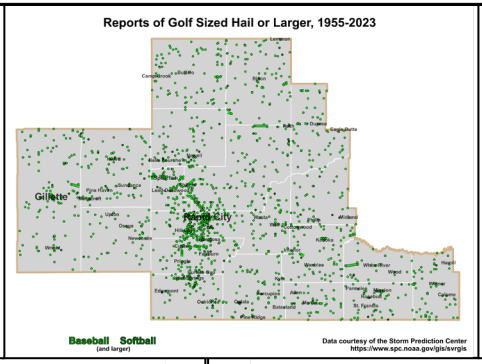
Bow Echoes/Outflows: an echo is used to describe how bands of rain showers or thunderstorms "bow out" when the storm's strong winds reach the surface and spread, while outflows are the term used to identify the winds associated with the bow.

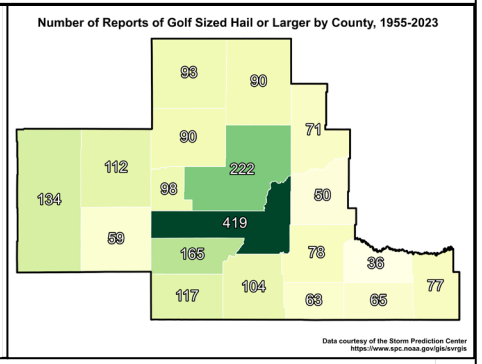


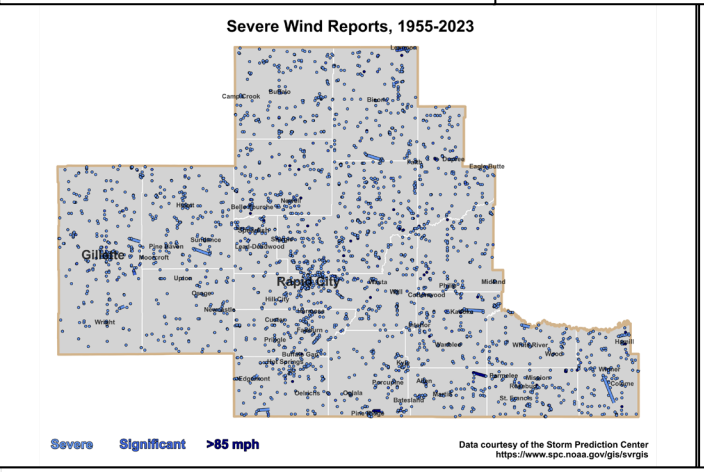


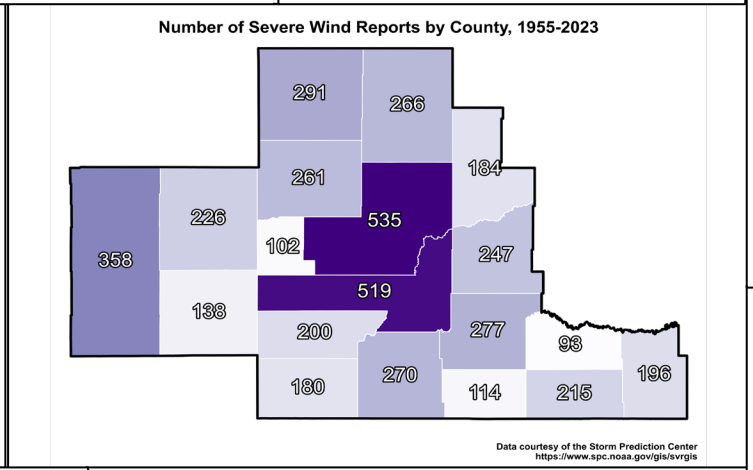
Severe Weather Ranges – Rapid City

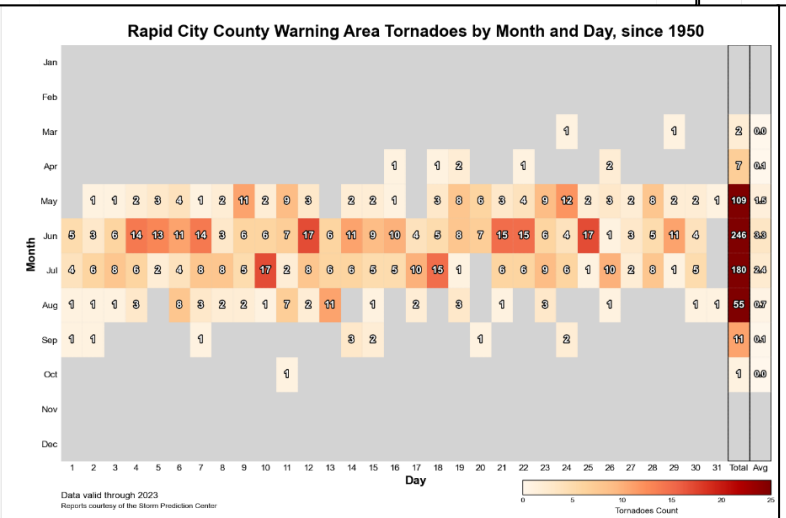


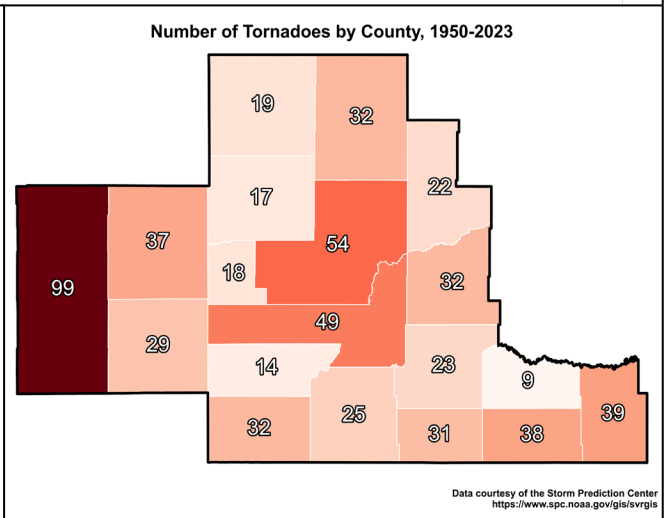


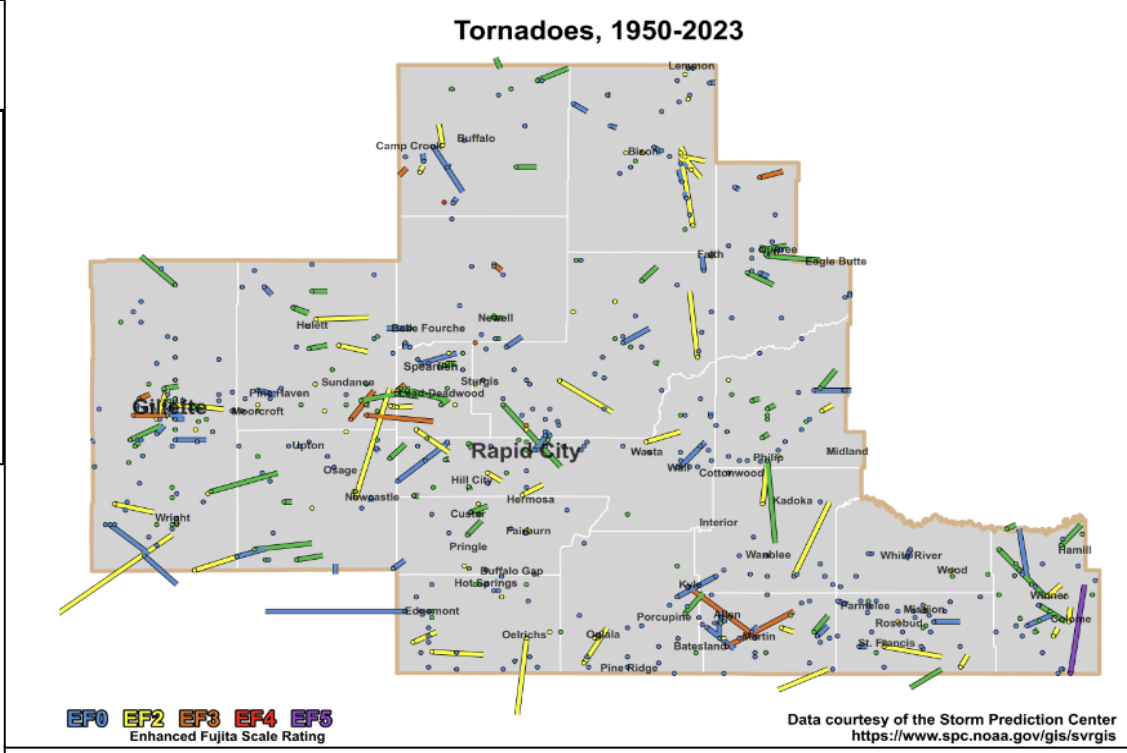


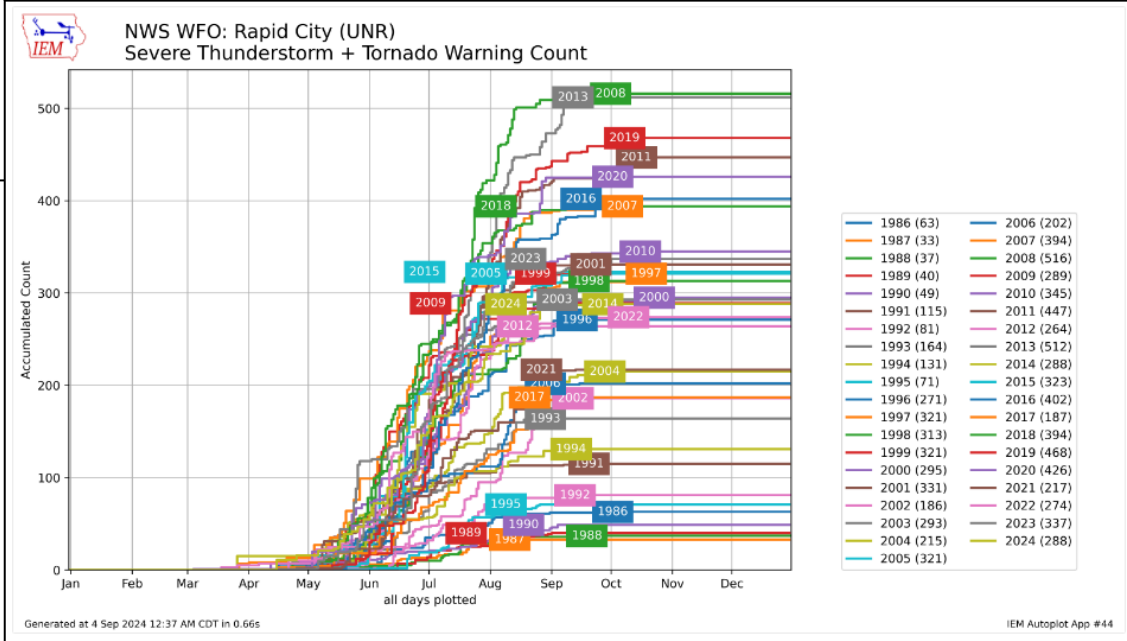












Total Severe Thunderstorm and Tornado Warning count by year for our county warning area, since 1996. Credit Daryl Herzmann at the Iowa Environmental Mesonet (https://mesonet.agron.iastate.edu/).

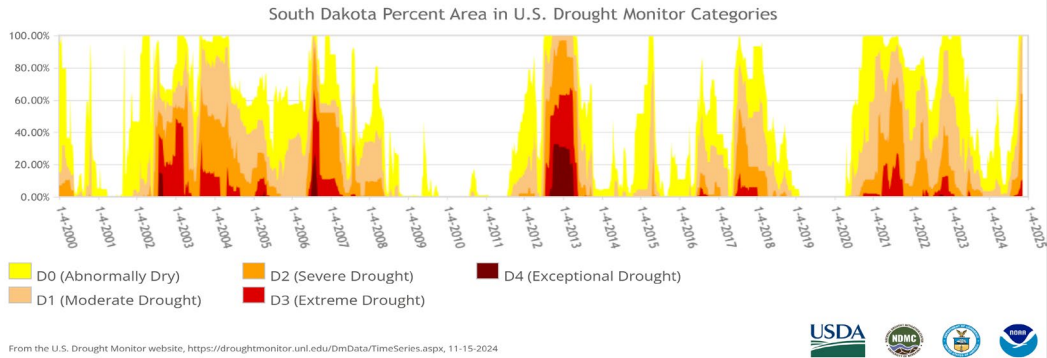
Aquifer Locations and Losses

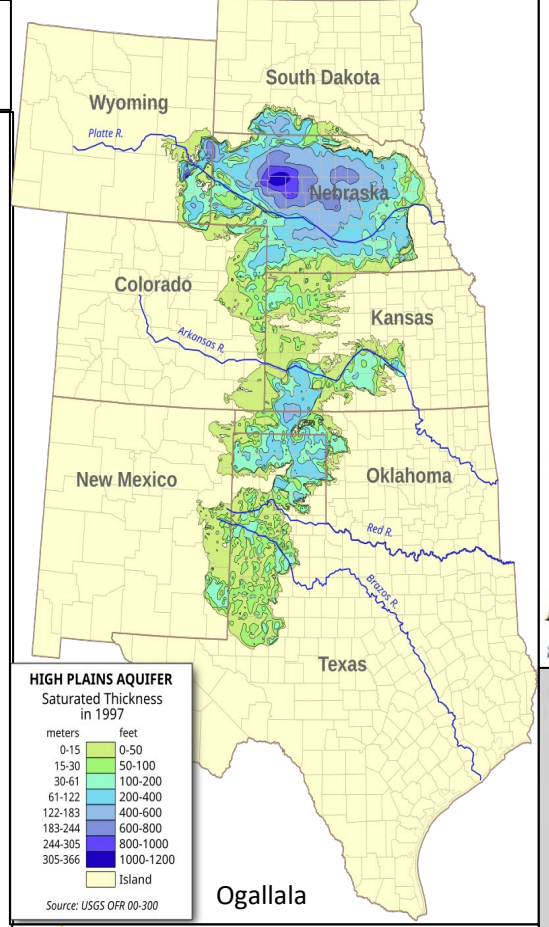
In Rapid City: City water supplies are obtained from wells completed in the Madison and Minnelusa aquifers, collection galleries in the alluvium along Rapid Creek, and surface water from Rapid Creek.

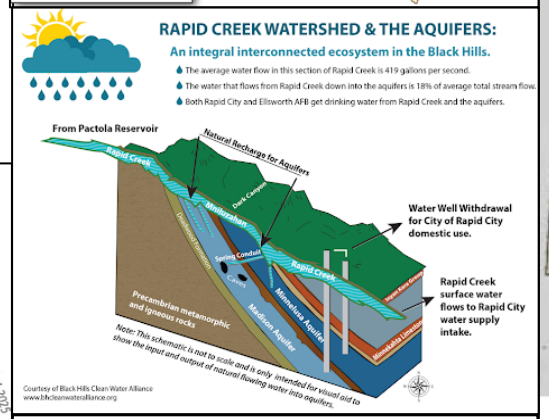
- The Madison aquifer is especially vulnerable to contamination in the Rapid City area because of (1) bedrock outcrop areas west of Rapid City; (2) direct connections to potential surface contaminants through streamflow loss zones; and (3) fast travel paths through solution-enhanced openings and fractures.

The Ogallala Aquifer region, located in the Great Plains of the central US, is the largest freshwater aquifer in North America, supporting one of the most agriculturally productive regions in the world.

- The Ogallala supports nearly 30% of all crop and animal production for the US and accounts for 15% of all groundwater withdrawals making this region critical to the global food supply chain.
- The Ogallala provides critical drinking water to 82% of the people living within the aquifer boundary.
- Water for this aquifer is being depleted at a higher rate than recharge capability with available water supplies in many areas of the aquifer having already been reduced by more than 40% to 75% since predevelopment.
- Much of the most agriculturally productive areas of the aquifer from Texas north through Kansas are at risk of depletion by the yr 2100







The Rapid Creek aquifer is a source of drinking water for Rapid City, South Dakota, and Ellsworth Air Force Base. The aquifer is fed by water that flows from Rapid Creek into two underground aquifers.

Figure 1: Surface Geology of South Dakota. *Map available at: http://jurassic2.sdgs.usd.edu/pubs/pdf/G-10-text.pdf*

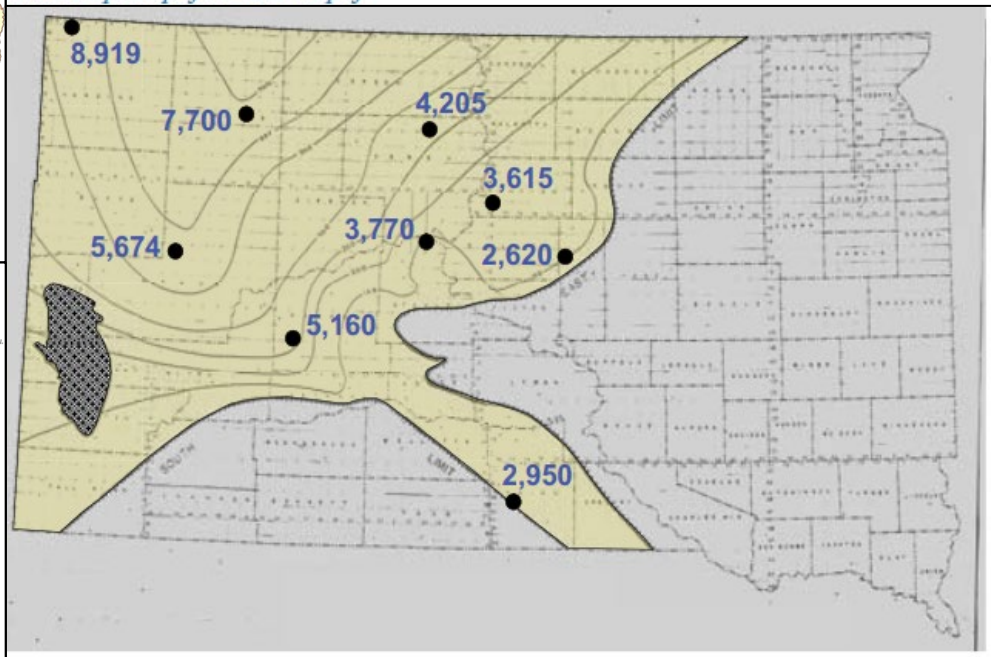


Figure 2: Approximate extent and depth, in feet, of the Deadwood-Winnepeg Formations. *Aquifer extent taken from a map prepared by J.P. Gries. Depths are from the files of the Department of Environment and Natural Resources.*

Seismic Activity Risk

Small earthquakes occasionally happen in South Dakota but are not large enough to be considered threatening to life or property.

- South Dakota fault lines are predominately in the Black Hills National Forest.
- There have been almost 100 documented earthquakes in South Dakota since the first recorded one in 1872.
- Likely causes of these earthquakes are adjustments deep in the basement rocks underlying the state or ongoing rebound of the earth's crust from compression by ice sheets during the last ice age.

Occurrences of a magnitude 4.3 earthquake have been documented three times in South Dakota's history (1934, 1982, 2002).

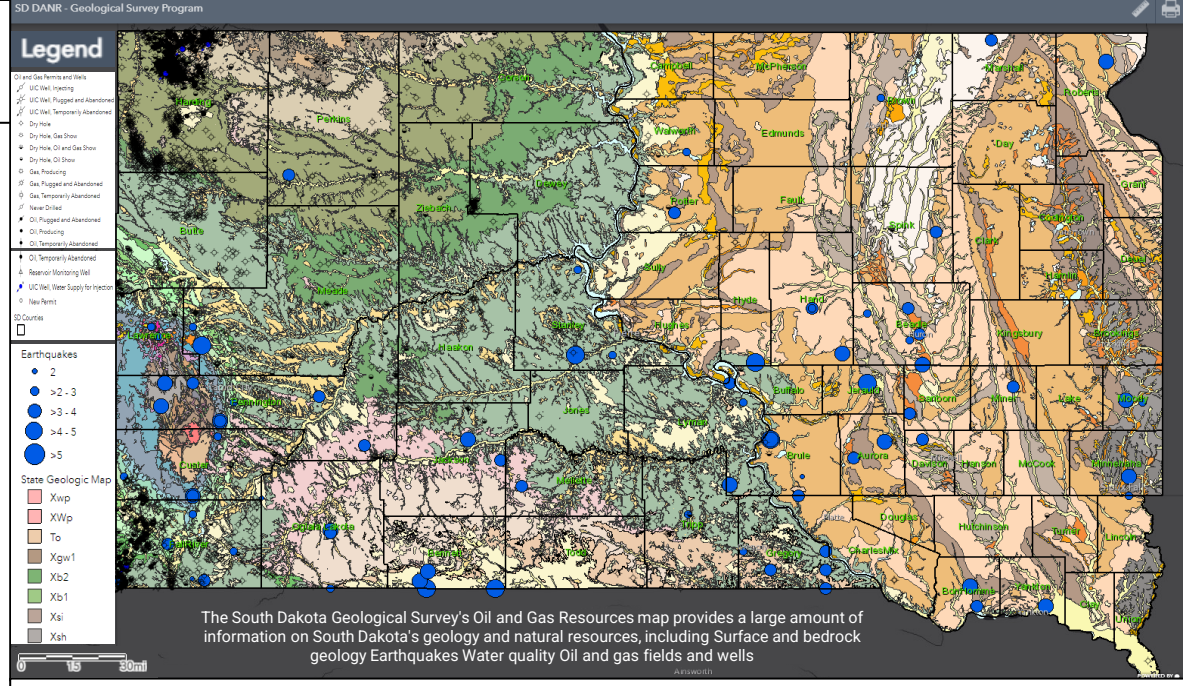
- In 1934, the quake event was the final of three earthquakes recorded within eight months.
- Southwestern South Dakota experienced significant tremors on March 28, 1964, from an earthquake registering 5.1 on the Richter scale. Centered near Merriman, Nebraska, the quake caused cracks in roadways, collapsed riverbanks, falling plaster, and damage to goods in homes and stores.
    - A day before, the most powerful earthquake in US history, a magnitude 9.2 occurred in the southern parts of Alaska.
- Overall, according to the United States Geological Survey, there have been 71 earthquakes reported in South Dakota.

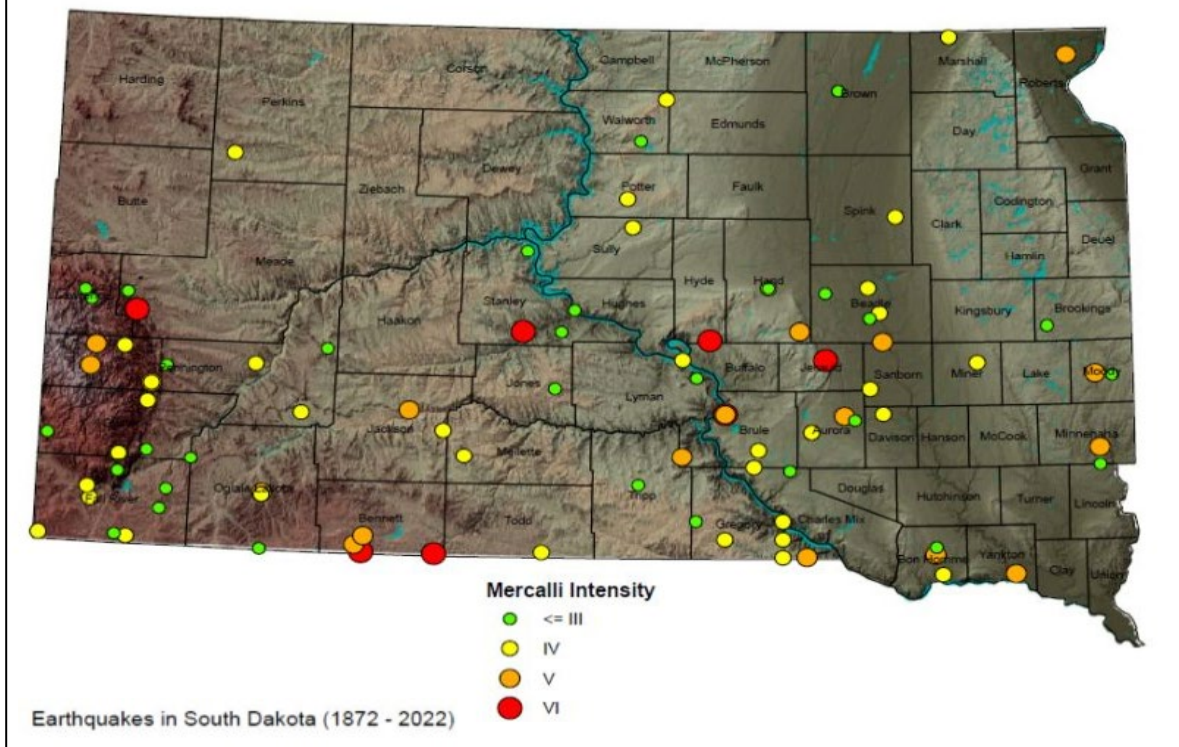
As of October 2022, there are 151 oil wells and 42 gas wells in production. There are fewer fault lines in the Dakota's to be triggered by the pressure induced from wastewater deposal wells associated with fracking.

- Regulatory efforts to backfill some injection wells with cement and reduce injection volumes have been effective in lowering induced earthquake rates, according to a study in *The Seismic Record* (*TSR*).

The average water flow in this section of Rapid Creek is 419 gallons per second. The water that flows from Rapid Creek down into the aquifers is 18%.

- A mining spill (including cyanide, arsenic, or other heavy metals) could pollute Rapid Creek and its related aquifer. Responsible development of domestic mineral supplies is important to transitioning to a clean energy economy.





Surface and Groundwater Areas

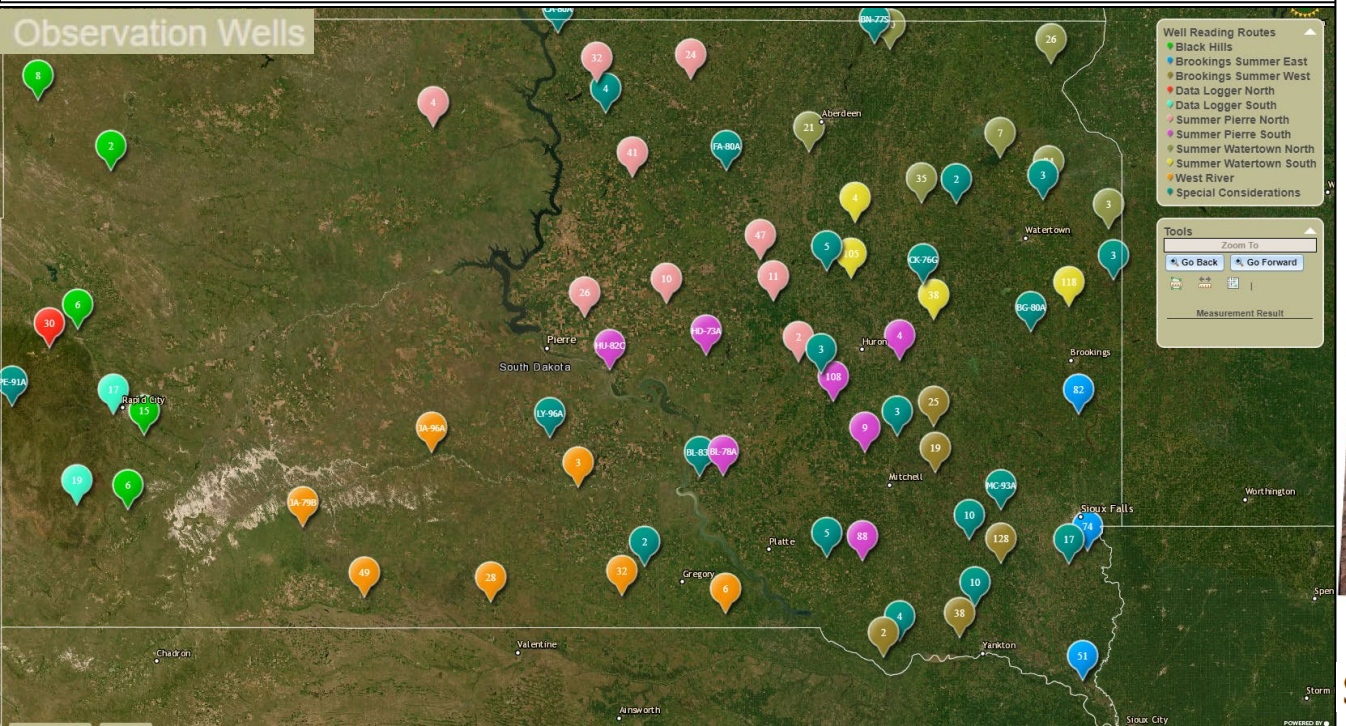
The South Dakota Department of Environment and Natural Resources provides an interactive map of groundwater levels at over 1000 observation wells across the state.

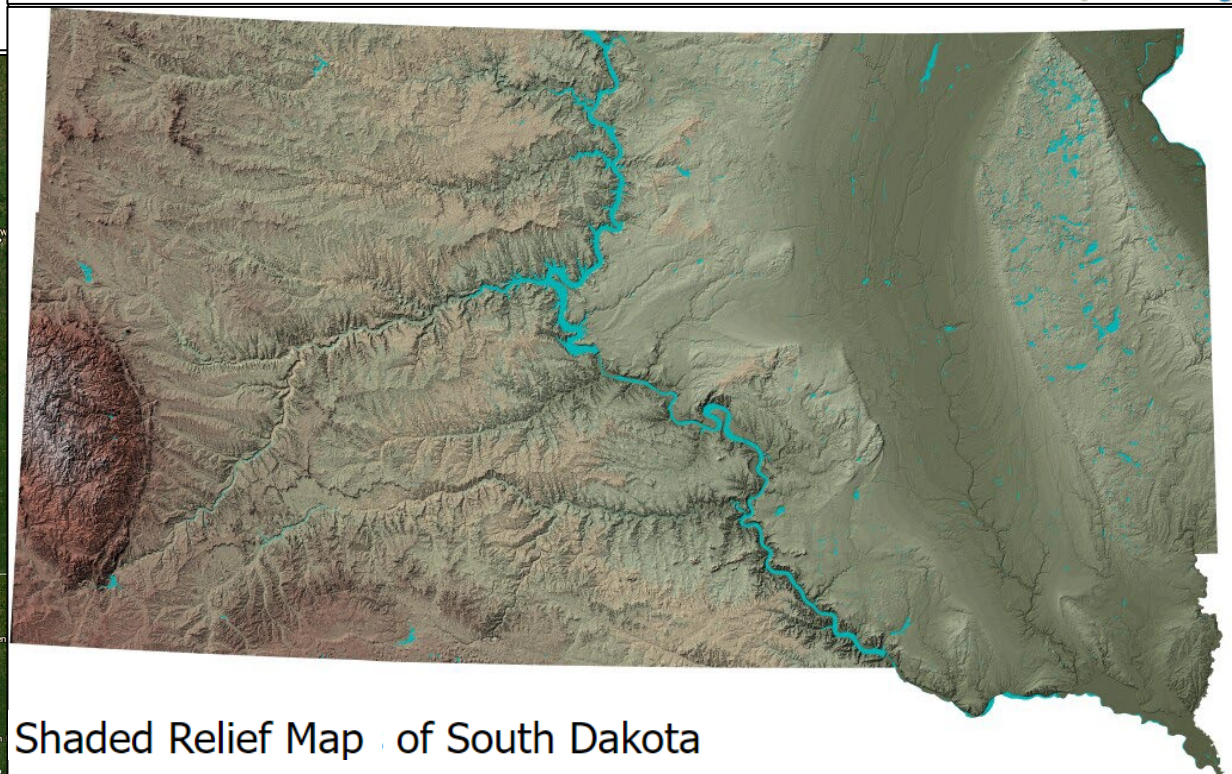
- About 42% of the water used in South Dakota comes from groundwater, which is about 251 million gallons per day.
- About 78% of the state's public water supplies come from groundwater, which serves 545,104 people.

The James River originates in central North Dakota between the cities of Harvey and Fessenden and generally flows south-southeast for approximately 710 miles until it empties into the Missouri River near Yankton, South Dakota.

The Rapid Creek originates from springs in the Black Hills National Forest and flows east through Rapid City, the area of formation is aligned with the fault lines in the region.

- Rapid Creek is critical to the health, economy, and survival of Rapid City and other western South Dakota communities.





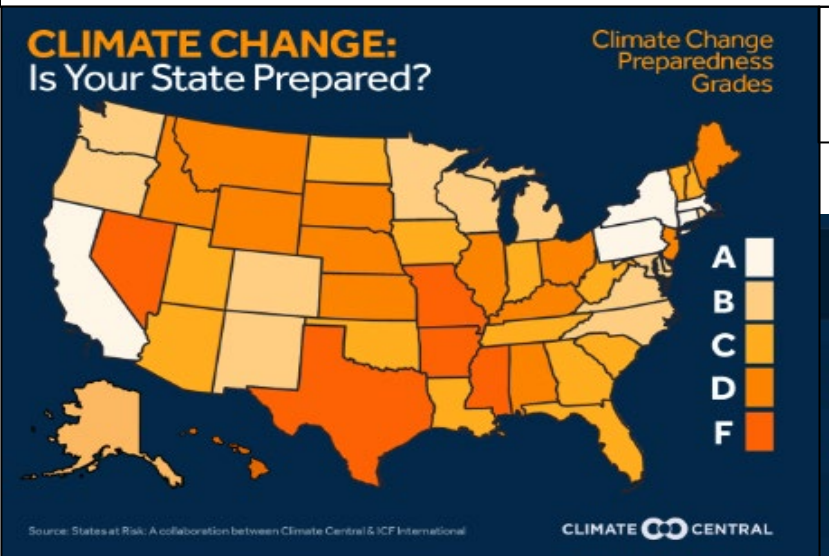
South Dakota – Infrastructure Grade

Lake Oahe is the fourth largest man-made lake in the United States, stretching 230 miles from Pierre, South Dakota to Bismarck, North Dakota.

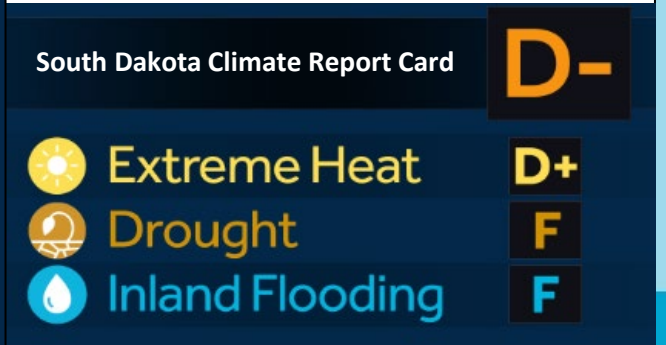
- The dam consists of an earthen embankment, an outlet structure with six tunnels for releasing stored water, a powerhouse, and eight spillway gates on a concrete-lined spillway.
- During normal operations, USACE releases water through the powerhouse to generate power and balance reservoir levels for other uses.
- As operations shift to reducing flood risks during periods of high runoff, water also is released through the outlet structure and if needed, USACE dam operators can release more water through the spillway gates.

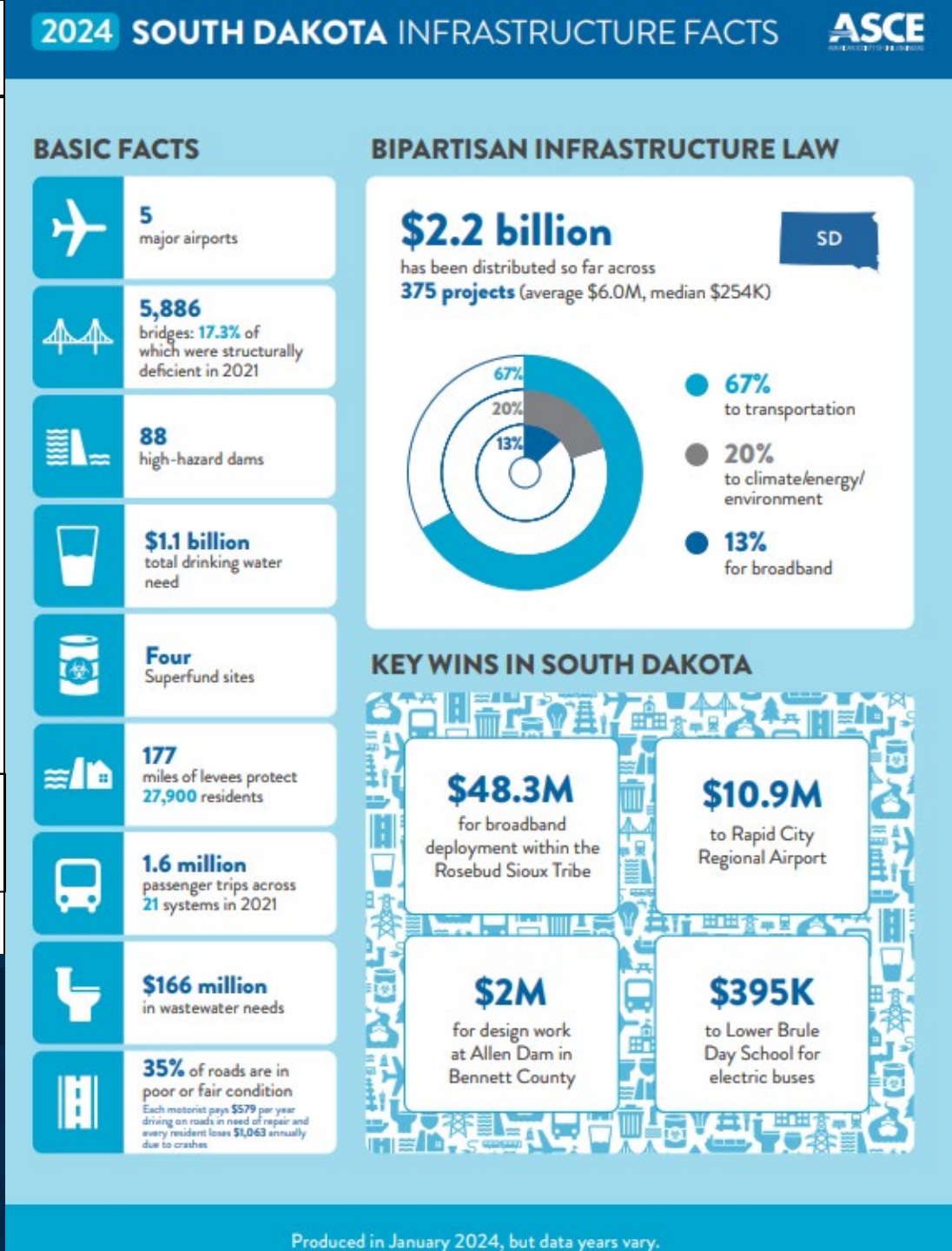
Ellsworth Air Force Base (AFB) is a United States Air Force (USAF) base located about 10 miles northeast of Rapid City is one of only two B-1B bases in the world.

- The base is the Black Hills, along with the headwaters to the aquifer for Rapid City and the location of the fault lines for the state. Continuing to develop the region could lead to overpulling of the aquifer and increased subsidence/quake rates.

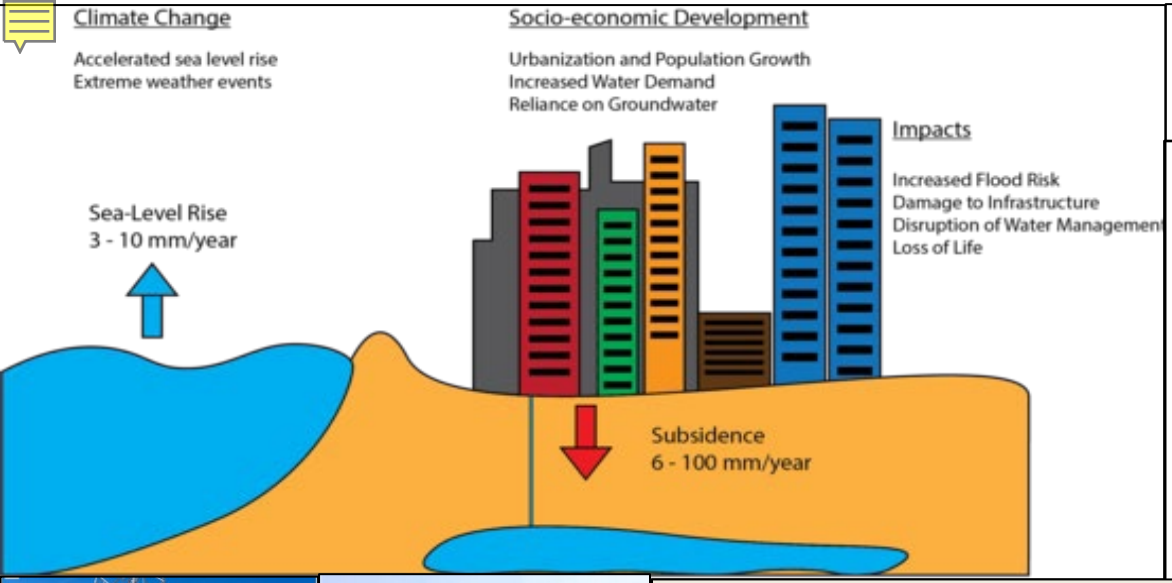


South Dakota has experienced subsidence in several areas, including the Black Hawk area and the town of Lead





Regional Subsidence Threat



Subsidence has been recorded in the US at a rate of nearly 2-feet over three years for some aqueducts.

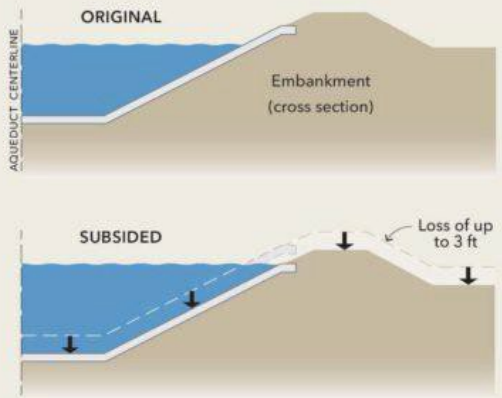
- Utilizing aqueducts to channel water from one area to another, pulling from wells at a faster rate, digging new wells to pull from the underground aquifers, pumping water from lakes/rivers, and creating supplementary channels along canals to siphon water from set provisions has compounded the upstream water provision in major riverways and tributaries out west and in other countries.

Subsidence from well water overpulling the groundwater aquifers and subsidence from degrading coal mines have similar impacts across developing regions. Residents of the areas may not be aware of the decreasing stability of their infrastructure until there is a partial or full collapse of a road, home, or canal resulting in permanent damage to the topography of the region.

- Wells dropping 4-8 feet throughout the Northern Rockies and up to 20 feet along the Pacific Northwest coastline indicates aquifer losses of 100-120 feet are possibly spreading across the west.

Impacts on the Aqueduct

- Decreased delivery capacity
- Increased cost to deliver water
- Decreased system reliability
- Increased operations and maintenance



State Water Project operations decrease water levels to keep it below the (subsided) top of liner which means less flow capacity in the Aqueduct.

It takes more than 3-years for shallow aquifers to recover stored groundwater from droughts, not accounting for the severe drought periods or the water being pulled from the aquifers via wells or aqueducts for the use of residents' daily needs.

https://www.sciencedirect.com/science/article/abs/pii/S0022169421009677

It takes about two years for rainwater drought to become groundwater drought, though in some cases it takes up to 15 years if rainfall persists below average throughout a region.

Subsidence in the United States has directly affected more than 17,000 square miles in 45 states, and associated annual costs are estimated to be over $125 million.

The principal causes of subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydro compaction, natural compaction, sinkholes, and thawing permafrost (National Research Council, 1991).

As the ground drops across the state due to the compacting soils, the varying rates of sinking will increase flash flood total accumulation as water pools in the lowest lying points.

- Subsidence may cause areas which were not previously the lowest-lying area to take on more water than previous flood plans accounted for.

Once subsidence causes ground collapse at the surface, the soils and materials which fall into the drying aquifer cause permanent damage to the groundwater system.

Soil collapse along roadways and sewar system pipelines can cause hazardous materials to enter the aquifer system and degrade water quality for all wells pulling downstream of the impacted site.

Even minimal subsidence can threaten critical infrastructure

South Dakota – Subsidence Risk

In April 2020, a sinkhole formed revealing an abandoned gypsum mine in Hideaway Hills. Since that first giant collapse, more holes and sinkings have appeared and there are now “too many to count”.

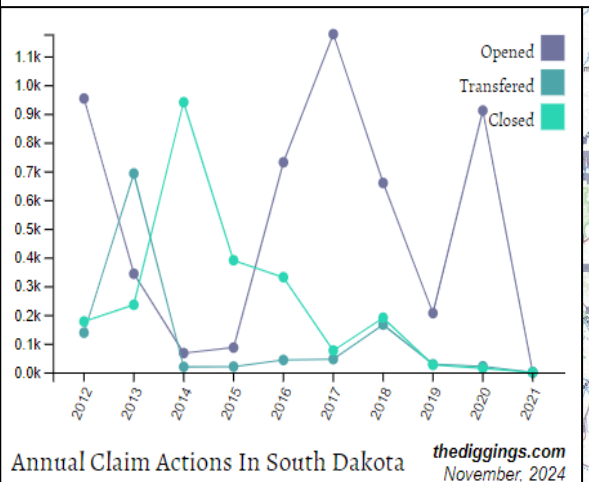
- There are currently 12 homes in an evacuation zone and a total of 158 homes are threatened due to their foundations having nothing stable to sit on.
    - The destabilized land is now impacting the areas roads and utilities.
- The state traced the area’s mining history to the 1900s, noting a company that mined underground and on the surface before 1930. Beginning in 1986, the state-owned cement plant mined for several years.

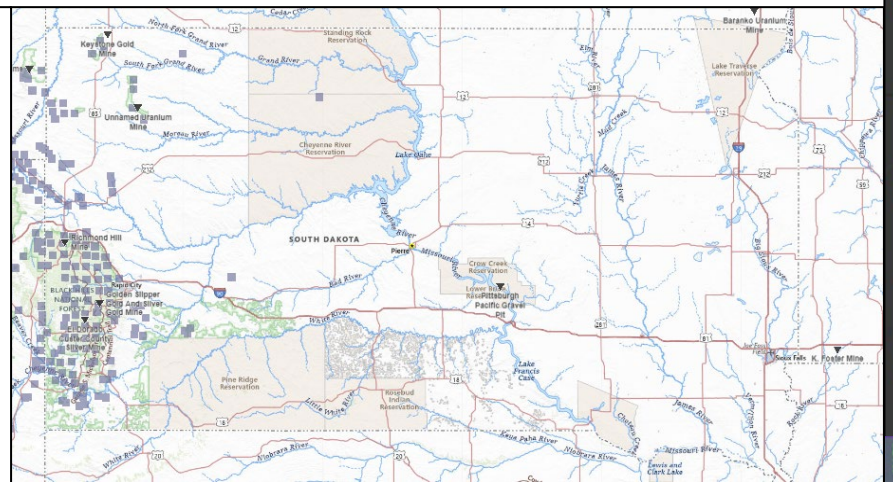
Years of undermining caused portions of Lead, South Dakota to sink into the ground during the 1920s and '30s.

- South Dakota has 50,758 records of mining claims on public land managed by the Bureau of Land Management and 1,128 records of mining mines listed by the United States Geological Survey (USGS).
    - Gold, Silver, Uranium, Tin, and Beryllium mines located in South Dakota.
    - There are 6,818 active mining claims and 43,940 closed mining claims.

The Geological Survey Program has drilled more than 22,600 test holes and wells in South Dakota.

- The discovery of gold in the Black Hills led to a rush of miners from other gold boom areas and some mining areas are reported to have contaminated river systems in the region.

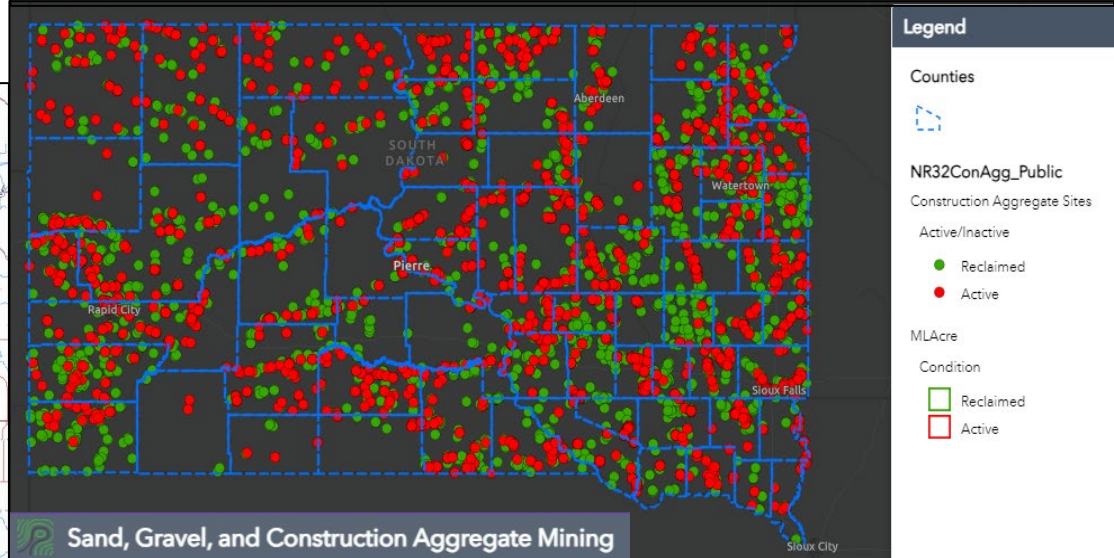




Pennington, Lawrence, and Custer are the most active counties for mining in South Dakota.

- 151 mines in South Dakota were observed to have ore mineralization in an outcrop, shallow pit, or isolated drill hole.
    - South Dakota has 144 prospect mines.

	Land Type	Total Claims	Active Claims	Closed Claims	Active Acres	Total Mines	Prospects	Occurrences	Plants	Producers
Black Hills National Forest	National Forests	41,406	4,312	37,094	91,253.92	847	97	123	1	626



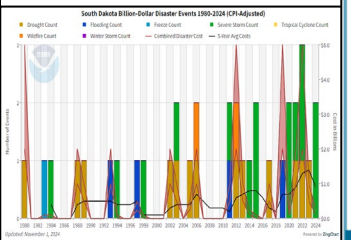
South Dakota Climate Hazards

From 1980–2024, there have been 35 confirmed weather / climate disaster events with losses exceeding $1 billion each to affect South Dakota.

These events included 13 drought events, 4 flooding events, 1 freeze event, 15 severe storm events, and 2 wildfire events.

The 1980–2023 annual average is 0.8 events; the annual average for the most recent 5 years (2019–2023) is 1.8 events.

June 2024 produced two severe weather events reaching billion-dollar losses with tornadoes/hail.



EPA United States Environmental Protection Agency

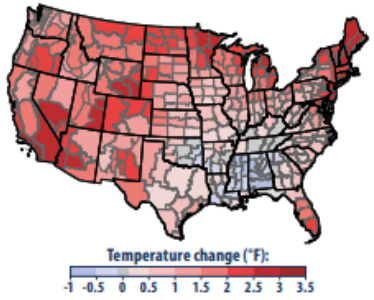
August 2016
EPA 430-F-16-043

What Climate Change Means for South Dakota

South Dakota's climate is changing. In the past century, most of the state has warmed by one to two degrees (F). Rainstorms are becoming more intense, and annual rainfall is increasing. In the coming decades, summers are likely to become increasingly hot, which may amplify some risks to human health and decrease yields of some crops while lengthening the growing season for others.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years, and sea level is rising, at an increasing rate. Warming is causing snow to melt earlier in spring.



Rising temperatures in the last century. The warming in South Dakota has been more than the average warming nationwide. Source: EPA, Climate Change Indicators in the United States.

Precipitation and Water Resources

Changing climate is likely to increase the demand for water and make it more available. Rising temperatures increase evaporation and water use by plants, which make soils drier. But rainfall is likely to increase enough to allow soil moisture to increase slightly or remain about the same as today. More water is likely to run off into the Missouri River and its tributaries.

The resulting increase in river flows could benefit recreational boating, public water supplies, and electric power generation. During droughts, decreased river flows can lower the water level in lakes and reservoirs, which may limit municipal water supplies and impair swimming, fishing, and other recreational activities. But if more water flows through the rivers before or during a drought, these problems will be less likely. Higher water flows also increase hydropower production, which accounts for almost 40 percent of the energy produced in South Dakota. Nevertheless, droughts are likely to become more severe in downstream states. When droughts lower water levels enough to impair navigation, the U.S. Army Corps of Engineers releases water from the upstream dams, making less water available to South Dakota.

Rising Temperature and Heavy Storms

Warmer air tends to have more water vapor, so more water can be potentially released in a storm. During the last 50 years, the amount of rain falling during the wettest four days of the year has increased about 15 percent in the Great Plains. Over the next several decades, heavy downpours will account for an increasing fraction of all precipitation. Larger river flows and more intense rainstorms would each increase the risk of flooding.

Scientists do not know how the frequency and severity of tornadoes will change. Rising concentrations of greenhouse gases tend to increase humidity, and thus atmospheric instability, which would encourage tornadoes. But wind shear is likely to decrease, which would discourage tornadoes. Research is ongoing to learn whether tornadoes will be more or less frequent in the future.

Agriculture

Rising temperatures and changes in rainfall are likely to have both negative and positive effects on South Dakota's farms and ranches. Hot weather causes cows to eat less and grow more slowly, and it can threaten their health. Increased winter and spring precipitation could leave some fields too wet to plant, and warmer winters may promote the growth of weeds and pests. During drought years, hotter summers will dry the soil. Within 70 years, the frequency of days above 100°F is likely to double. Even where ample water is available, higher temperatures would reduce yields of corn in the warmest parts of the state.

The overall yield of corn, however, is likely to increase in cooler parts of the Great Plains. Although higher temperatures would reduce yields of wheat and soybeans, increased concentrations of carbon dioxide are likely to increase yields enough to offset the impact of higher temperatures. Increased precipitation at the beginning of the growing season could also benefit some crops. Warmer and shorter winters may allow for a longer growing season, which could allow two crops per year instead of one in some instances. Warmer winters may also benefit cattle, offsetting some of the harm from hotter summers: during the winter of 1996–1997, for example, high winds and heavy snow killed half of the newborn calves and 100,000 adult cows in the northern Great Plains.

Forests

Longer growing seasons and increased carbon dioxide concentrations could increase the productivity of forests. Although forests generally benefit from higher productivity, warmer conditions make forests more susceptible to pests. Temperature controls the life cycle and winter mortality rates of pests such as bark beetles, which have infested and killed trees in the Black Hills in recent decades. With higher winter temperatures, some pests can persist year-round, and new pests and diseases may become established.

Trees killed by a mountain pine beetle infestation in the Black Hills. Credit: Blaine Cook, USDA Forest Service.

Human Health

Extremely hot and cold days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. The elderly may be particularly prone to heat stress and other heat-related health problems, including dehydration, cardiovascular strain, and respiratory problems. Those with low incomes may be particularly vulnerable due to a lack of air conditioning. Power failures due to severe weather can also present risks, especially in lightly populated areas where access to the necessary support services may be limited. While these risks will increase as the climate becomes warmer, illnesses and deaths due to cold weather and snow are likely to decline.

Climate change may also increase the length and severity of the pollen season for allergy sufferers. For example, the ragweed season in the northern Great Plains and Upper Midwest is now 10 to 21 days longer than it was in 1995, because the first frost in fall is later.

A photo of a ragweed plant, a common source of allergens in South Dakota. Like many crops and pollen sources, ragweed will have a longer growing season as temperatures rise. Stock photo.

The sources of information about climate and the impacts of climate change in this publication are: the national climate assessments by the U.S. Global Change Research Program, synthesis and assessment products by the U.S. Climate Change Science Program, assessment reports by the Intergovernmental Panel on Climate Change, and *EPA's Climate Change Indicators in the United States*. Mention of a particular season, location, species, or any other aspect of an impact does not imply anything about the likelihood or importance of aspects that are not mentioned. For more information about climate change science, impacts, responses, and what you can do, visit EPA's Climate Change website at www.epa.gov/climatechange.

South Dakota Crops – Economic Implications of Drought and Water Loss

South Dakota farmers have received nearly $10 billion in crop insurance payouts over the past two decades. The Environmental Working Group (EWG) says there is a strong correlation between rising crop insurance payouts and climate change. The 2017 drought was the worst to impact the Northern Plains in decades, causing $2.6 billion in agricultural losses in the US.

2022 CENSUS OF AGRICULTURE *County Profile*

Pennington County
South Dakota

Total and Per Farm Overview, 2022 and change since 2017

	2022	% change since 2017
Number of farms	650	-1
Land in farms (acres)	1,166,970	+2
Average size of farm (acres)	1,795	+3
Total	($)	
Market value of products sold	84,757,000	+40
Government payments	11,639,000	+81
Farm-related income	5,805,000	-21
Total farm production expenses	82,118,000	+38
Net cash farm income	20,084,000	+38
Per farm average	($)	
Market value of products sold	130,395	+41
Government payments [a]	49,741	+117
Farm-related income [a]	20,732	-20
Total farm production expenses	126,335	+39
Net cash farm income	30,898	+40

1 Percent of state agriculture sales

Share of Sales by Type (%)

Crops	43
Livestock, poultry, and products	57

Land in Farms by Use (acres)

Cropland	242,020
Pastureland	890,381
Woodland	18,723
Other	15,846

Acres irrigated: 7,189
1% of land in farms

Land Use Practices (% of farms)

No till	12
Reduced till	6
Intensive till	4
Cover crop	2

Farms by Value of Sales

	Number	Percent of Total [b]
Less than $2,500	180	28
$2,500 to $4,999	43	7
$5,000 to $9,999	41	6
$10,000 to $24,999	100	15
$25,000 to $49,999	52	8
$50,000 to $99,999	58	9
$100,000 or more	176	27

Farms by Size

	Number	Percent of Total [b]
1 to 9 acres	39	6
10 to 49 acres	130	20
50 to 179 acres	139	21
180 to 499 acres	87	13
500 to 999 acres	72	11
1,000+ acres	183	28

USDA United States Department of Agriculture
National Agricultural Statistics Service
www.nass.usda.gov/AgCensus

Pennington County
South Dakota, 2022
Page 2

2022 CENSUS OF AGRICULTURE *County Profile*

Market Value of Agricultural Products Sold

	Sales ($1,000)	Rank in State [c]	Counties Producing Item	Rank in U.S. [c]	Counties Producing Item
Total	**84,757**	**54**	**66**	**1,546**	**3,078**
Crops	**36,232**	**52**	**66**	**1,491**	**3,074**
Grains, oilseeds, dry beans, dry peas	28,717	52	66	1,162	2,917
Tobacco	-	-	-	-	267
Cotton and cottonseed	-	-	-	-	647
Vegetables, melons, potatoes, sweet potatoes	16	34	47	2,000	2,831
Fruits, tree nuts, berries	25	15	31	1,818	2,711
Nursery, greenhouse, floriculture, sod	4,404	2	35	509	2,660
Cultivated Christmas trees, short rotation woody crops	-	-	8	-	1,274
Other crops and hay	3,069	36	66	1,056	3,035
Livestock, poultry, and products	**48,525**	**44**	**66**	**1,113**	**3,076**
Poultry and eggs	75	33	66	1,470	3,027
Cattle and calves	43,348	32	66	393	3,047
Milk from cows	-	-	34	-	1,770
Hogs and pigs	(D)	52	60	(D)	2,814
Sheep, goats, wool, mohair, milk	155	40	64	1,157	2,967
Horses, ponies, mules, burros, donkeys	1,046	3	65	276	2,907
Aquaculture	(D)	4	6	(D)	1,190
Other animals and animal products	3,690	5	65	65	2,909

Producers [d]	**1,238**
Sex	
Male	774
Female	464
Age	
<35	81
35 – 64	680
65 and older	477
Race	
American Indian/Alaska Native	12
Asian	-
Black or African American	1
Native Hawaiian/Pacific Islander	-
White	1,200
More than one race	25
Other characteristics	
Hispanic, Latino, Spanish origin	20
With military service	148
New and beginning farmers	390

Percent of farms that:

Have internet access	84
Farm organically	-
Sell directly to consumers	7
Hire farm labor	26
Are family farms	95

Top Crops in Acres [e]

Forage (hay/haylage), all	69,728
Wheat for grain, all	39,318
Sunflower seed, all	19,756
Corn for grain	7,642
Sorghum for grain	3,691

Livestock Inventory (Dec 31, 2022)

Broilers and other meat-type chickens	446
Cattle and calves	62,931
Goats	159
Hogs and pigs	52
Horses and ponies	1,772
Layers	2,880
Pullets	373
Sheep and lambs	156
Turkeys	(D)

[a] Average per farm receiving. [b] May not add to 100% due to rounding. [c] Among counties whose rank can be displayed. [d] Data collected for a maximum of four producers per farm. [e] Crop commodity names may be shortened; see full names at www.nass.usda.gov/go/cropnames.pdf. [f] Position below the line does not indicate rank. (D) Withheld to avoid disclosing data for individual operations. (NA) Not available. (Z) Less than half of the unit shown. (-) Represents zero.

USDA is an equal opportunity provider, employer, and lender.

TOP 5 SOUTH DAKOTA CROPS, 2016
VALUE OF PRODUCTION

CORN
$2.6 BILLION

HAY/HAYLAGE
$490.4 MILLION

WHEAT
$439.6 MILLION

SOYBEANS
$2.3 BILLION

SUNFLOWER
$178.6 MILLION

SOURCE: NORTH DAKOTA AGRICULTURAL STATISTICS SERVICE

DakotaFarmer

South Dakota Crops Energy Profile

There are six investor-owned utility companies that provide electric service to specific geographic areas in South Dakota that are regulated by the PUC.

- Over two dozen electric cooperatives provide power to rural customers and residents of many South Dakota towns. Each customer is a member and owner of the co-op.
- Three power cooperatives – Basin, East River and Rushmore – are generation and transmission cooperatives.

Three investor-owned natural gas companies provide service to South Dakota customers: Montana-Dakota Utilities Co., MidAmerican Energy Co., and NorthWestern Energy and are regulated by the PUC.

- The communities of Crooks, Garretson, Humboldt and Watertown are served by municipally-owned natural gas utilities.

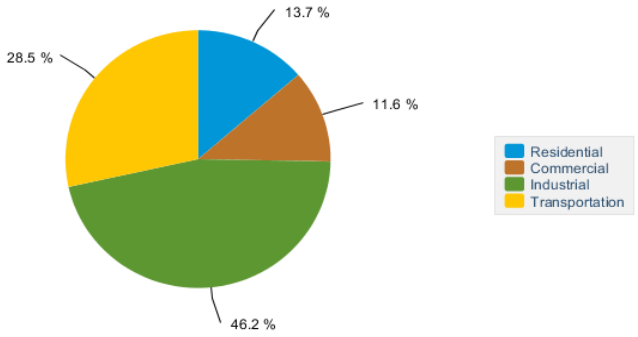
Three of South Dakota's four largest power plants by capacity and the two largest by generation are hydroelectric facilities located on the upper Missouri River operated by USACE.

- The northernmost is the Oahe Dam, which forms a 231-mile-long lake that is the fourth-largest man-made reservoir in the nation.

2023: South Dakota's remaining net generation comes almost entirely from natural gas / coal.

- Coal's contribution declined from more than half of the state's net generation in 2008 to 9%. Natural gas exceeded coal and provided about 14% of South Dakota's net generation.
- Petroleum, biomass, and solar energy together contributed less than 1%.

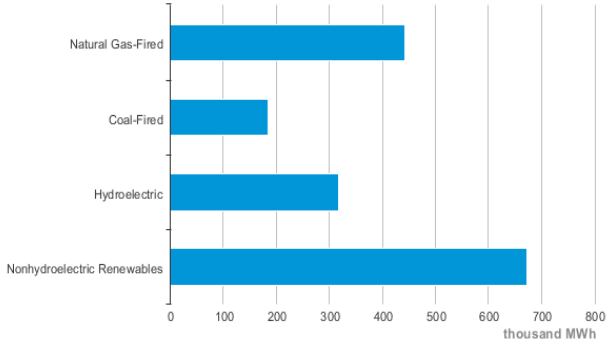
South Dakota Energy Consumption by End-Use Sector, 2022



eia Source: Energy Information Administration, State Energy Data System

South Dakota Net Electricity Generation by Source, Jul. 2024

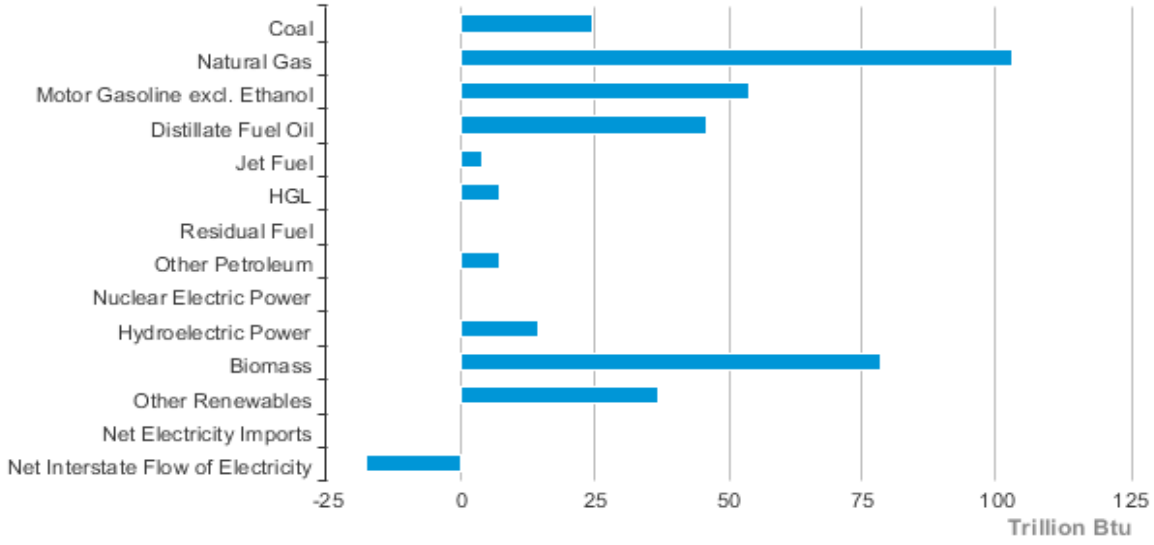
In 2023, wind provided 55% of South Dakota's total electricity net generation.



Wind surpassed the state's previous leading electricity source, hydroelectric power, for the first time in 2021.

eia Source: Energy Information Administration, Electric Power Monthly

South Dakota Energy Consumption Estimates, 2022



eia Source: Energy Information Administration, State Energy Data System

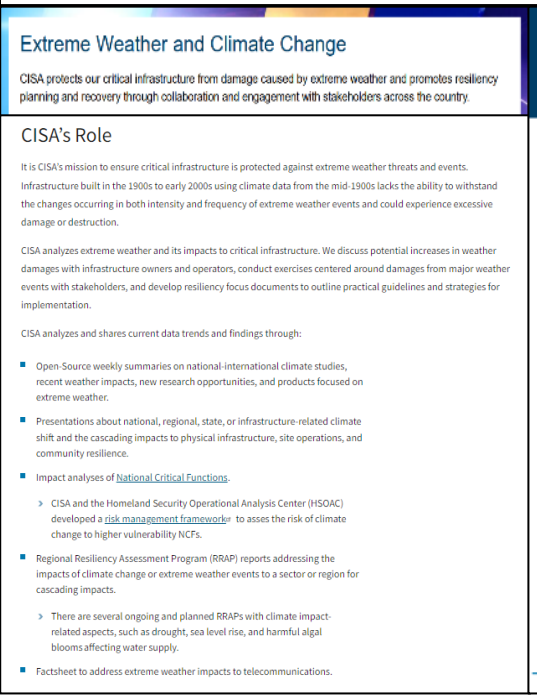
EIA: South Dakota is the nation's fourth-largest fuel ethanol producer and accounted for about 9% of total U.S. fuel ethanol output in 2022. The state's 16 fuel ethanol plants can produce about 34 million barrels annually.

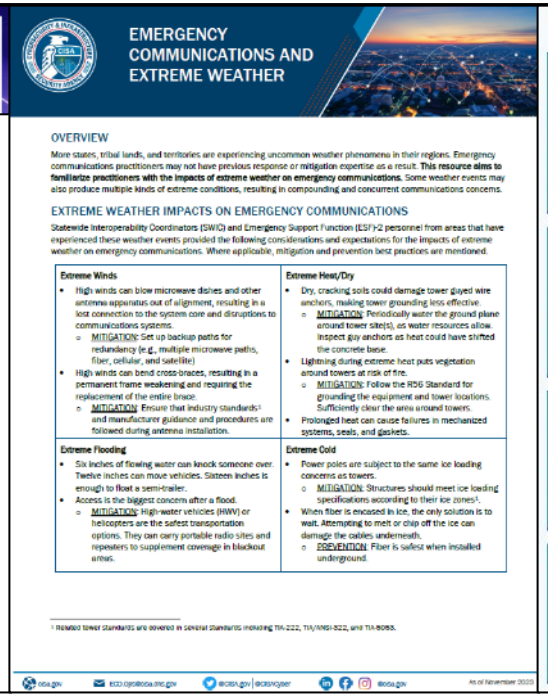
- In 2023, renewable resources generated 77% of South Dakota's total in-state electricity net generation (including small-scale solar). Wind power provided 55% of South Dakota's total electricity generation, a larger share than any other state except Iowa.
- Crude oil production in South Dakota has ranged between about 1 million and 2 million barrels per year for four decades. In 2023, production fell to 929,000 barrels, the lowest level since before 1981.
- South Dakota uses less total petroleum than all but three other states. However, in part because of the state's small population, its petroleum use per capita is among the highest 10 states.
- Wind power exceeded hydropower's contribution to South Dakota's in-state electricity generation for the first time in 2021. Wind energy generated nearly three times as much electricity as hydropower in the state in 2023.

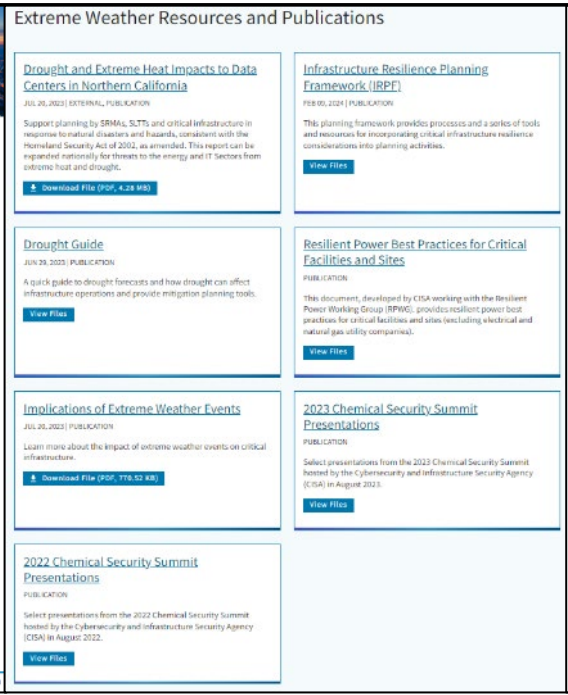
CISA Extreme Weather and Best Practices

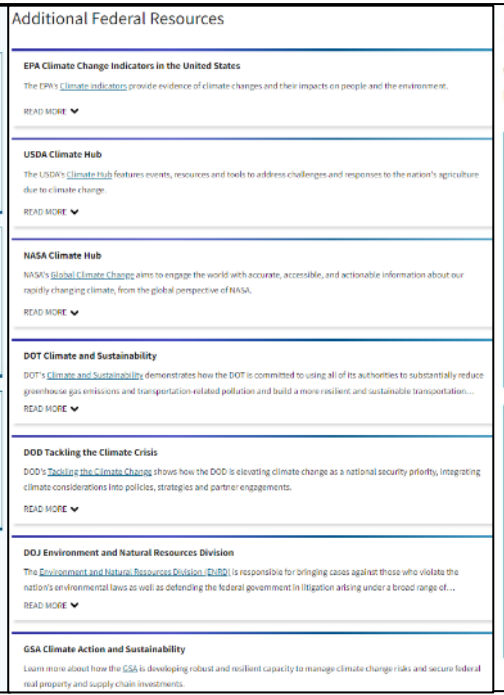
Stakeholder Engagement effort: share feedback to the CISA Extreme Weather Website or the AEP Climate Hub Survey for Critical Infrastructure Sites.

- CISA Extreme Weather and Climate Change Site: https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/extreme-weather-and-climate-change
- CISA Understanding Seasonal Risks to CI Operations: https://www.youtube.com/watch?v=KP6kjqkU6KQ
- The Implications of Extreme Weather AEP Climate Hub: https://experience.arcgis.com/experience/a1ec0d1276064ae387c863f2a14b11e1/
- Resilient Power Best Practices Guide: https://www.cisa.gov/resources-tools/resources/resilient-power-best-practices-critical-facilities-and-sites
- CISA Drought and Infrastructure: A Planning Guide: https://www.cisa.gov/sites/default/files/publications/Drought_and_Infrastructure_A_Planning_Guide_508c.pdf
- Infrastructure Resilience Planning Framework: https://www.cisa.gov/sites/default/files/publications/Infrastructure-Resilience%20Planning-Framework-%28IRPF%29%29.pdf
- RAND National Critical Functions Climate Impacts Report: https://www.rand.org/pubs/research_reports/RRA1645-7.html









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

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.

For Questions Contact:

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