Extreme Weather Trends and the Potential Impact on National Critical Infrastructure and Public Safety

Sunny Wescott, Chief Meteorologist

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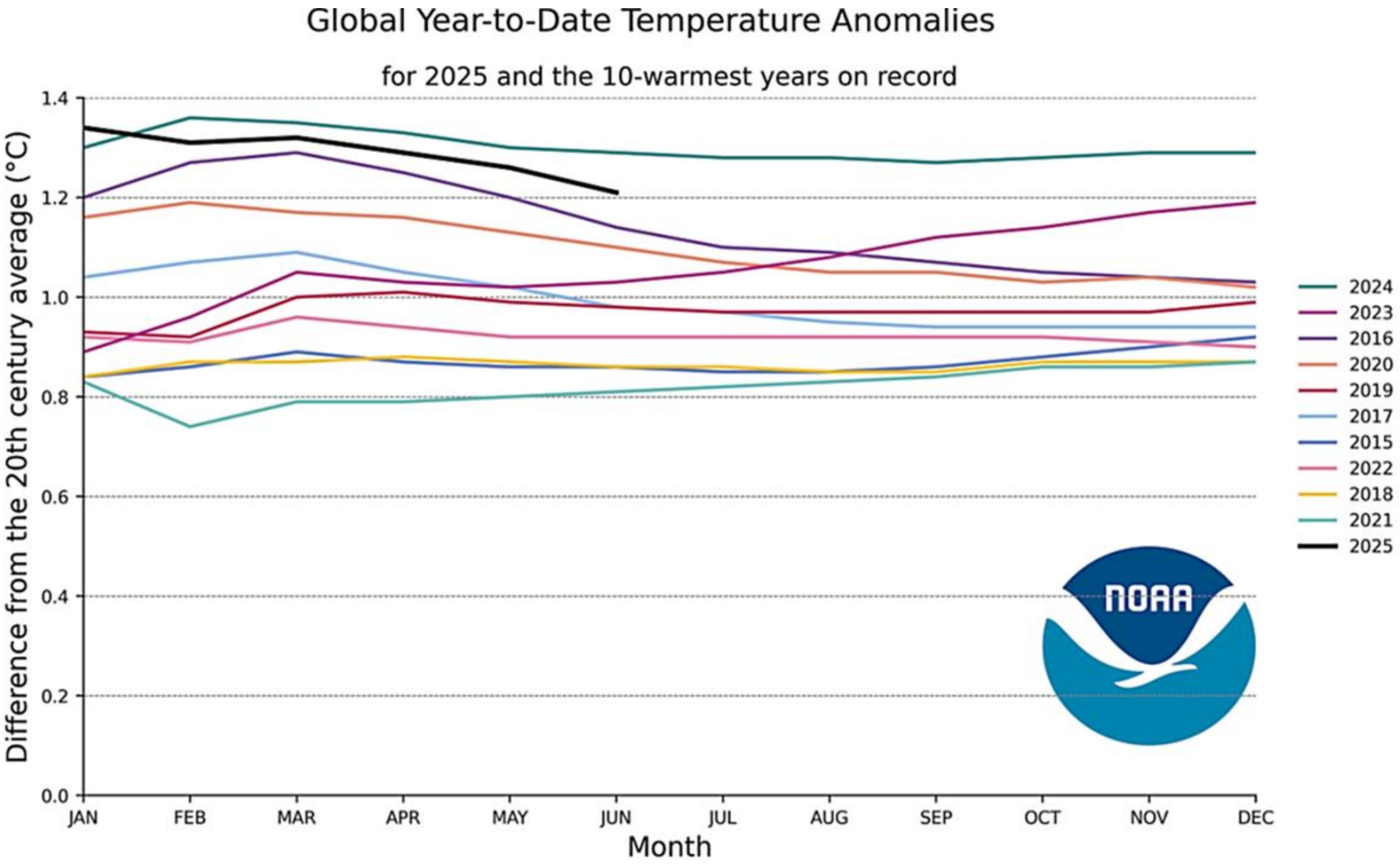
WPPI ENERGY

Amplifying Barometric Swings Yield Weather Extremes

*“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).*



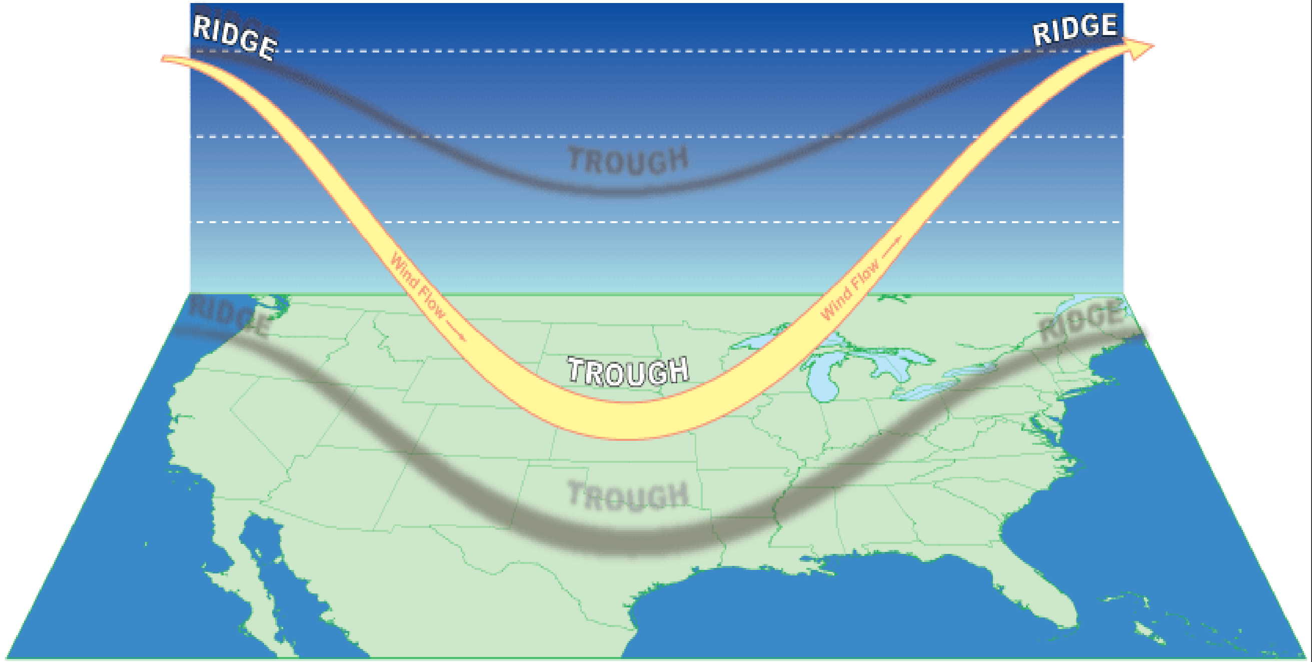
Chief Meteorologist Ms. Sunny Wescott
Critical Infrastructure and Emergency Response Operations

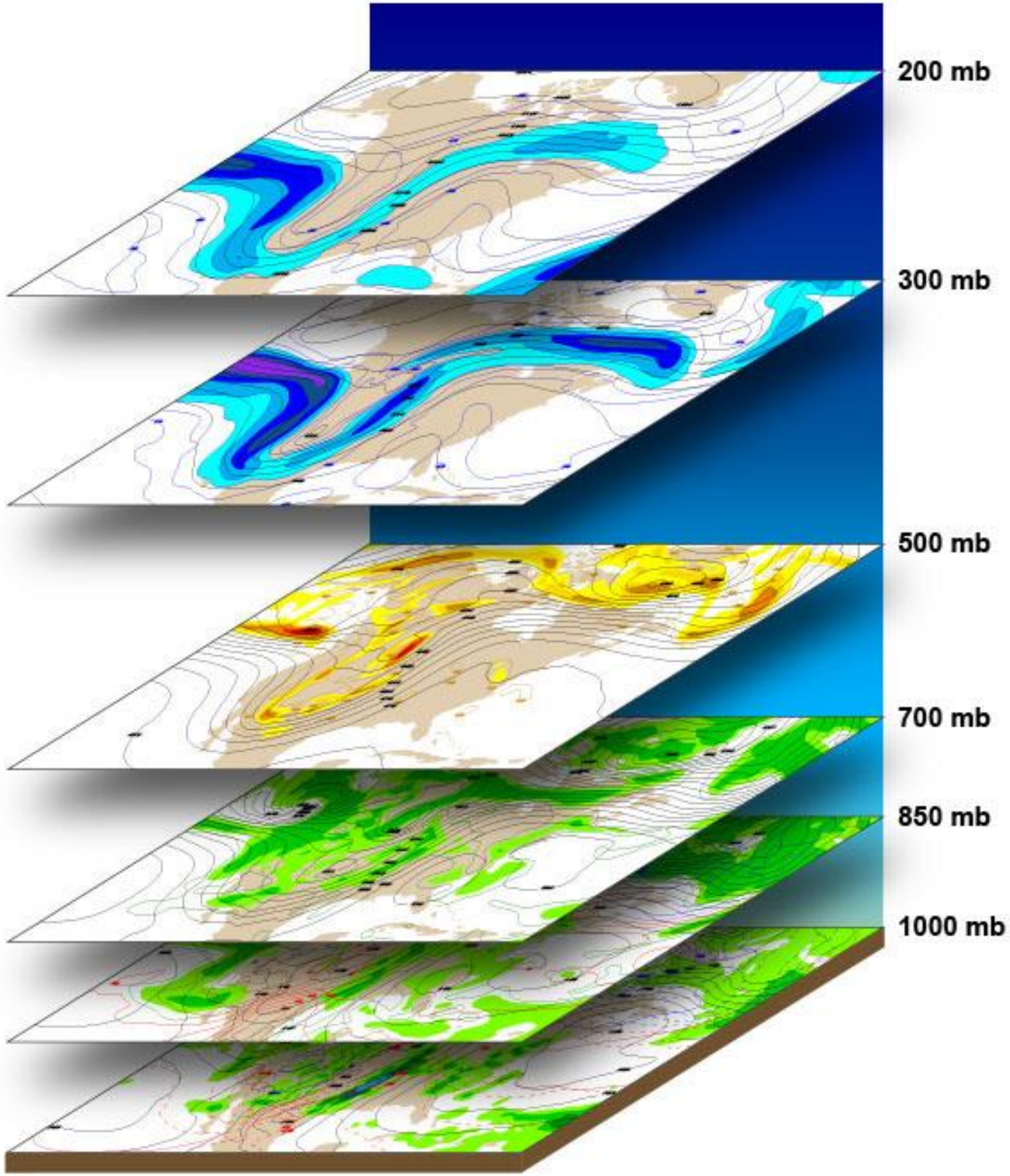
Atmospheric Pressure - Millibar 101

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)
- 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.

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





High and Low Pressures: the Carousel of Weather

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

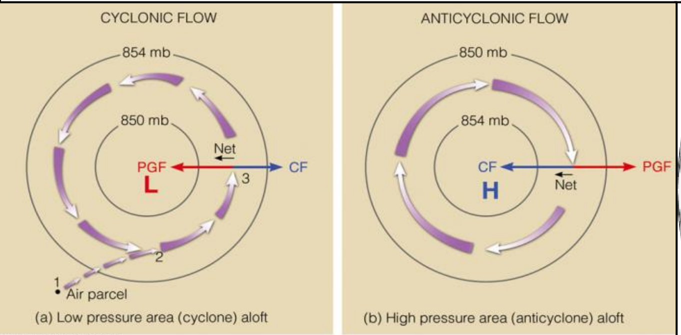
- Because of Earth's spin and the Coriolis effect, winds of a low-pressure system swirl counterclockwise north of the equator.
- As the air rises, the water vapor within it condenses, forming clouds and often precipitation.
- On weather maps, a low-pressure system is labeled with red L.

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

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

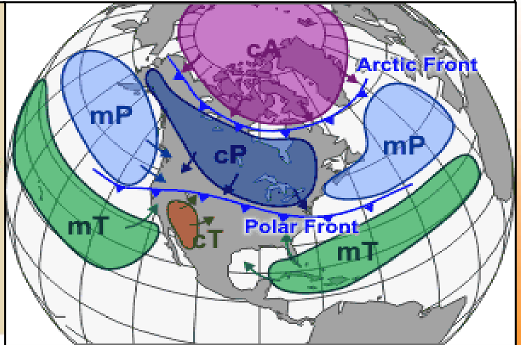
Air pressure depends on the temperature of the air and the density of the air molecules. Air masses differ based off their prevailing fields.

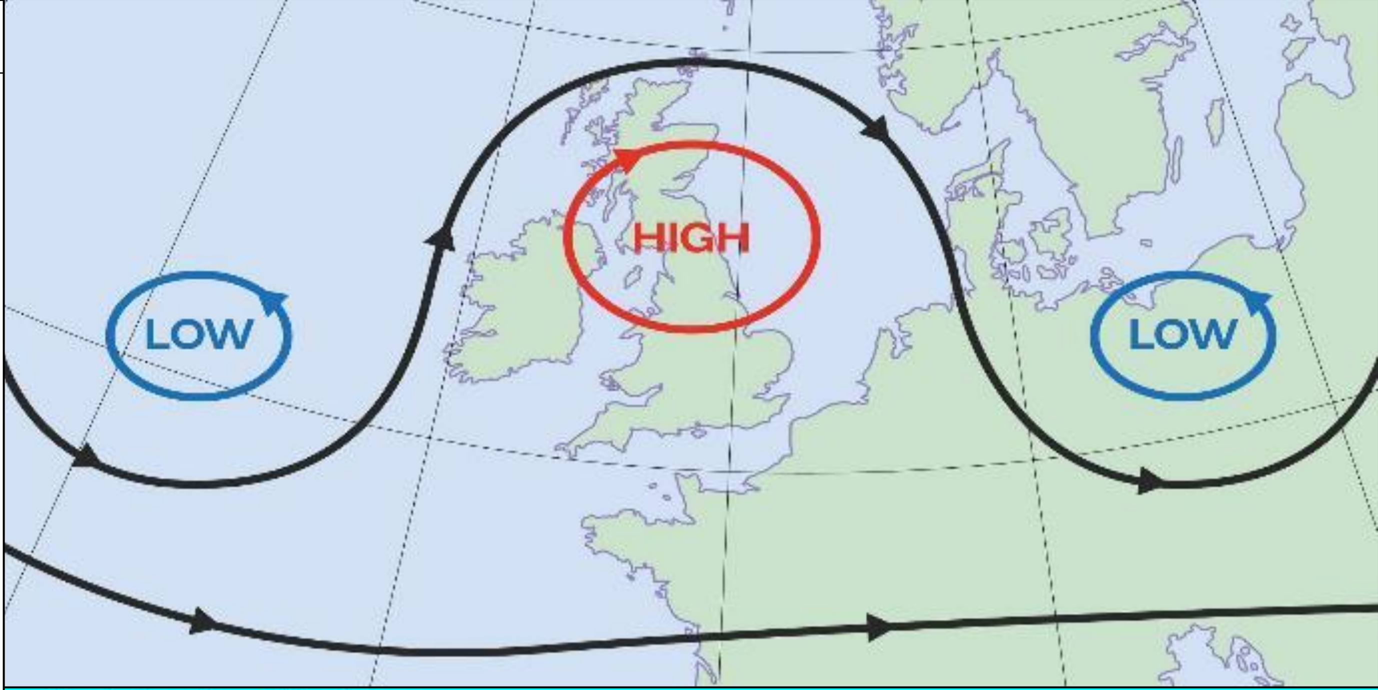
The tighter the gradient between the high and the incoming low, the stronger the winds will be as they mix down from the upper levels.

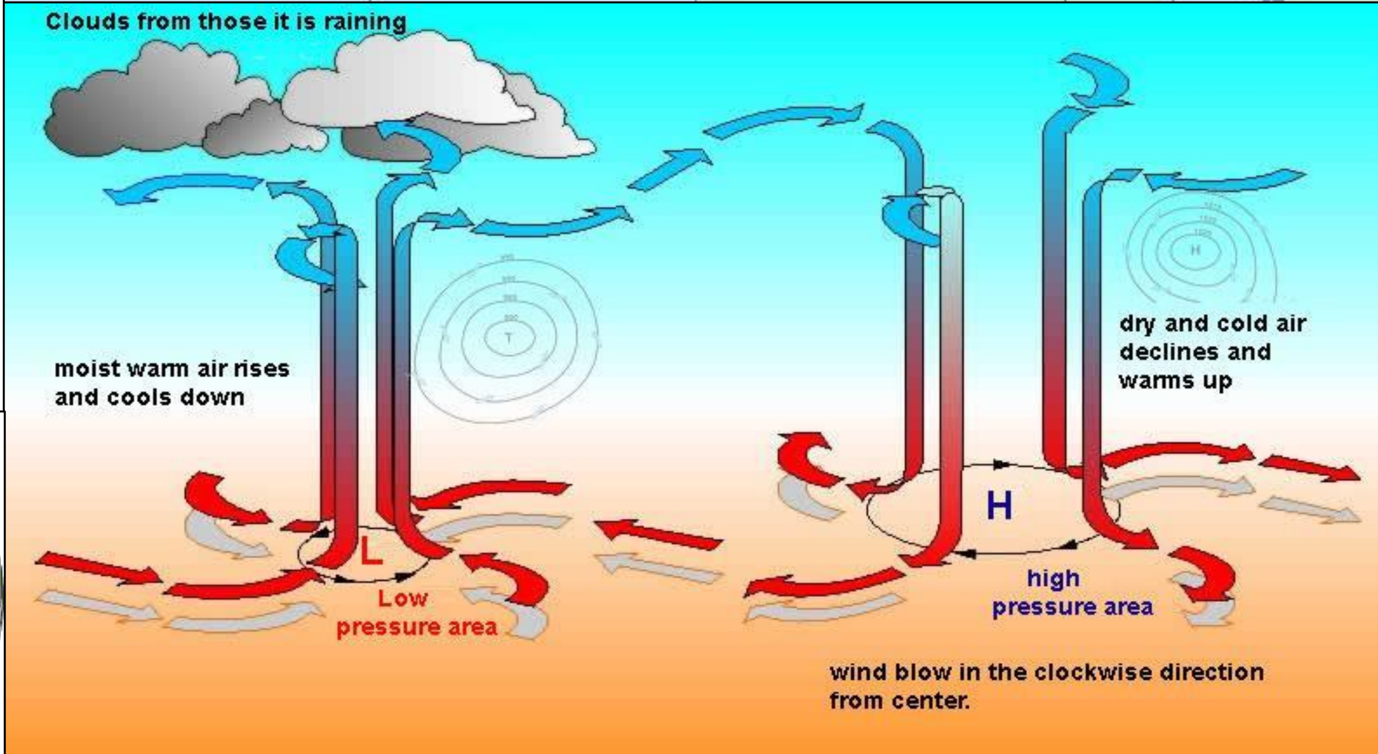


(a) Low pressure area (cyclone) aloft

(b) High pressure area (anticyclone) aloft





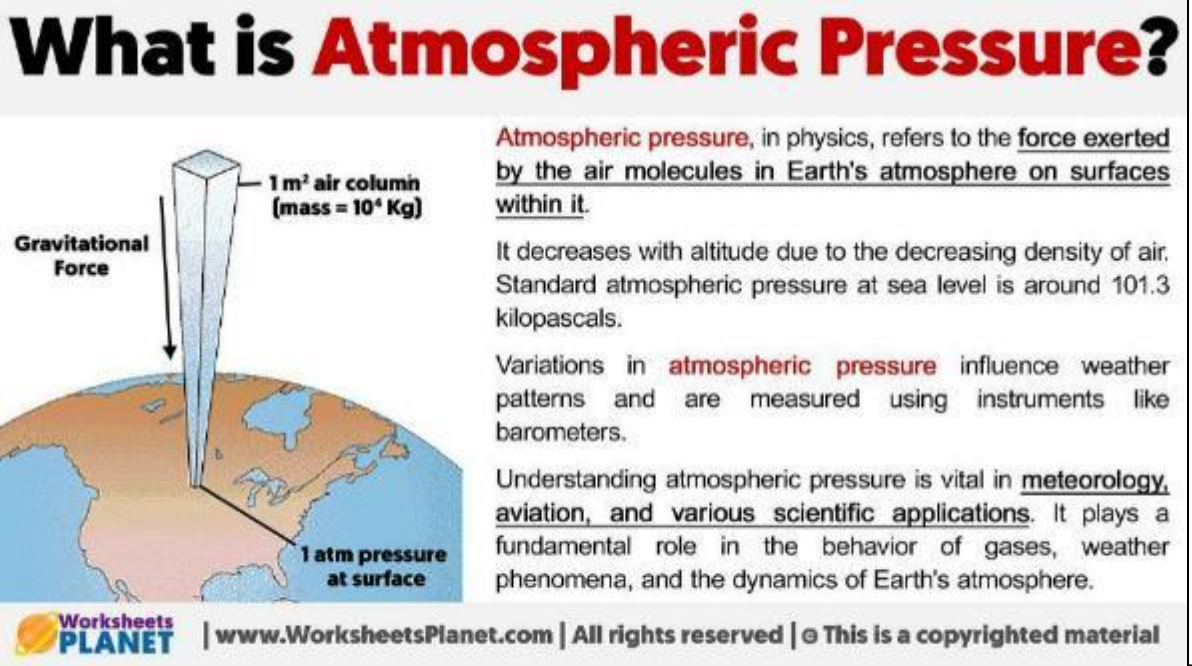


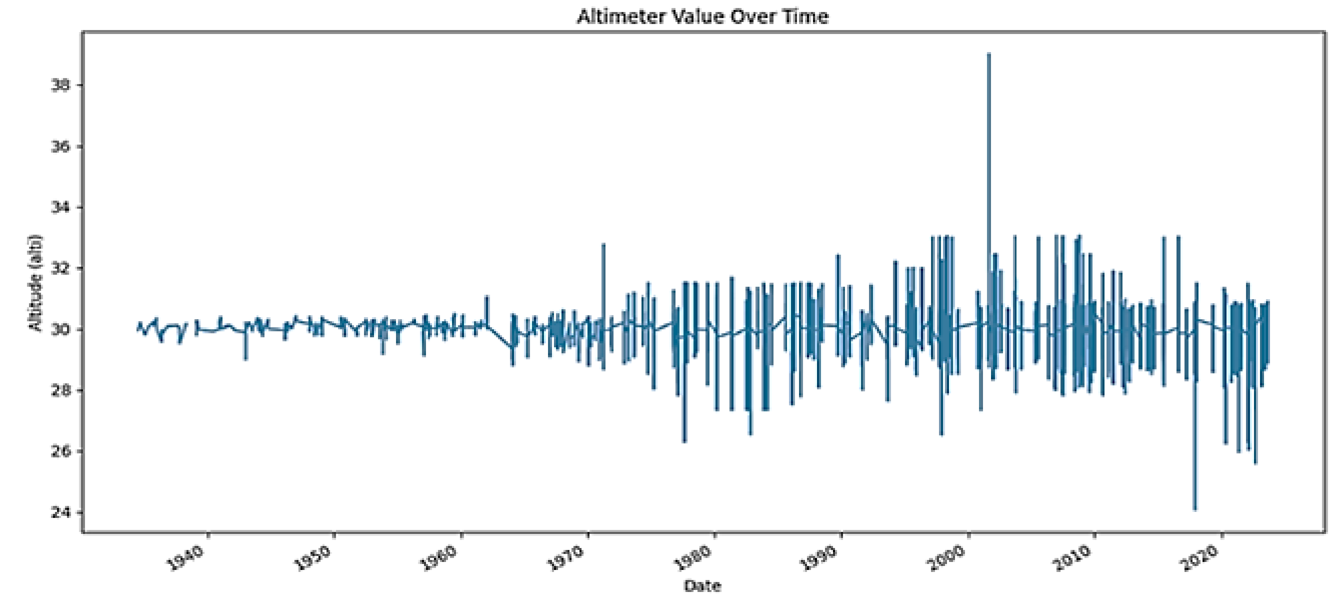
Major Pressure Swings Begin

As low pressures continue to change in depth and intensity, the high-pressure events are left to dominate for longer periods, increase coverage area, and promote significant levels of humidity and water vapor adding to trapped heat.

- The low-pressures drive global cooling winds, bring rainfall and storm events, and are responsible for all notable cloud coverage.
- High-pressures yield clear skies, heat domes, haze, stagnant air, and even the cold air damming periods.

This means a change in either pressure consistency or strength brings immediate consequences for the water cycle.





ASOS Raw Data
National Overview

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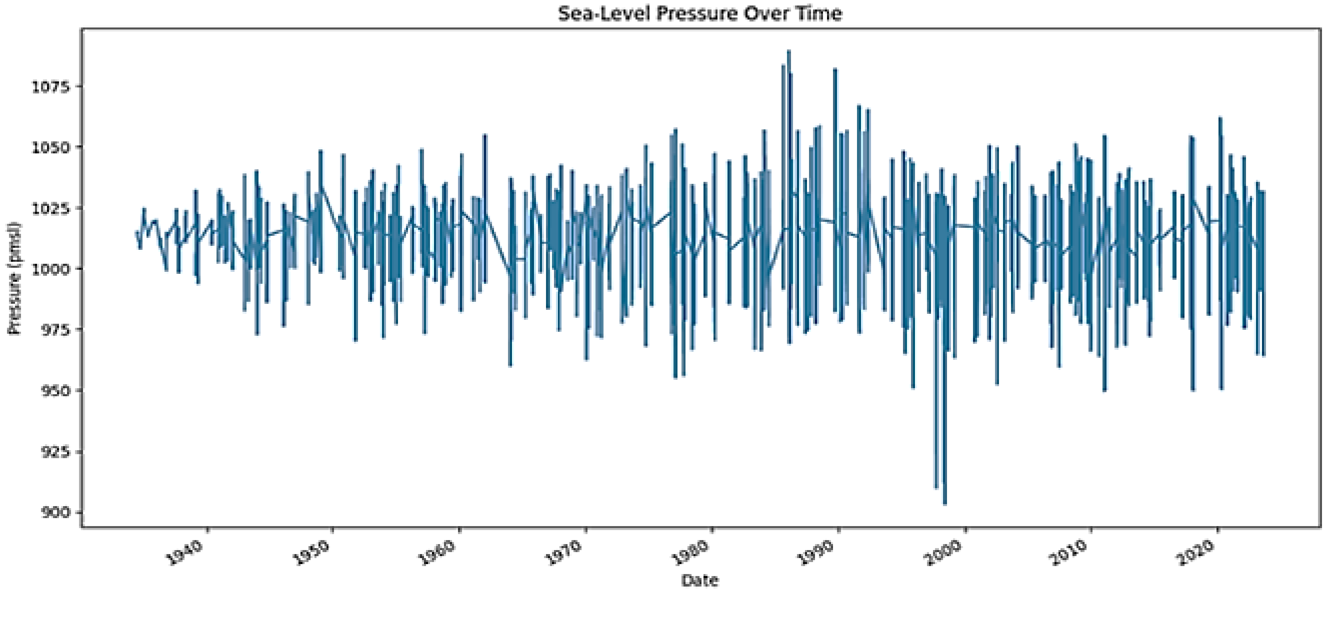
Low- and High-pressure centers are moving into extremes amplifications



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Upper-Level Winds

A recent study, in *Nature Climate Change,* suggests that the fastest upper-level jet stream winds will accelerate by about 2% for every degree Celsius (1.8° Fahrenheit) that the world warms.

- Furthermore, the fastest winds will speed up 2.5 times faster than the average wind.

The Intergovernmental Panel on Climate Change (IPCC) states that climate change will affect aggregate global windspeeds with projected average annual wind speeds dropping by 10% by 2100.

- A 2019 study found that in the preceding nine years the global average wind speed increased nearly 6%.

Extreme regional wind events such as the Santa Ana, Diablo, and Chinook, have increased in general over the last 60 years.

- Shifts in winds carrying major seasonal precipitation like Atmospheric Rivers and Monsoons are forecast to amplify while variations in frequency and timeliness.

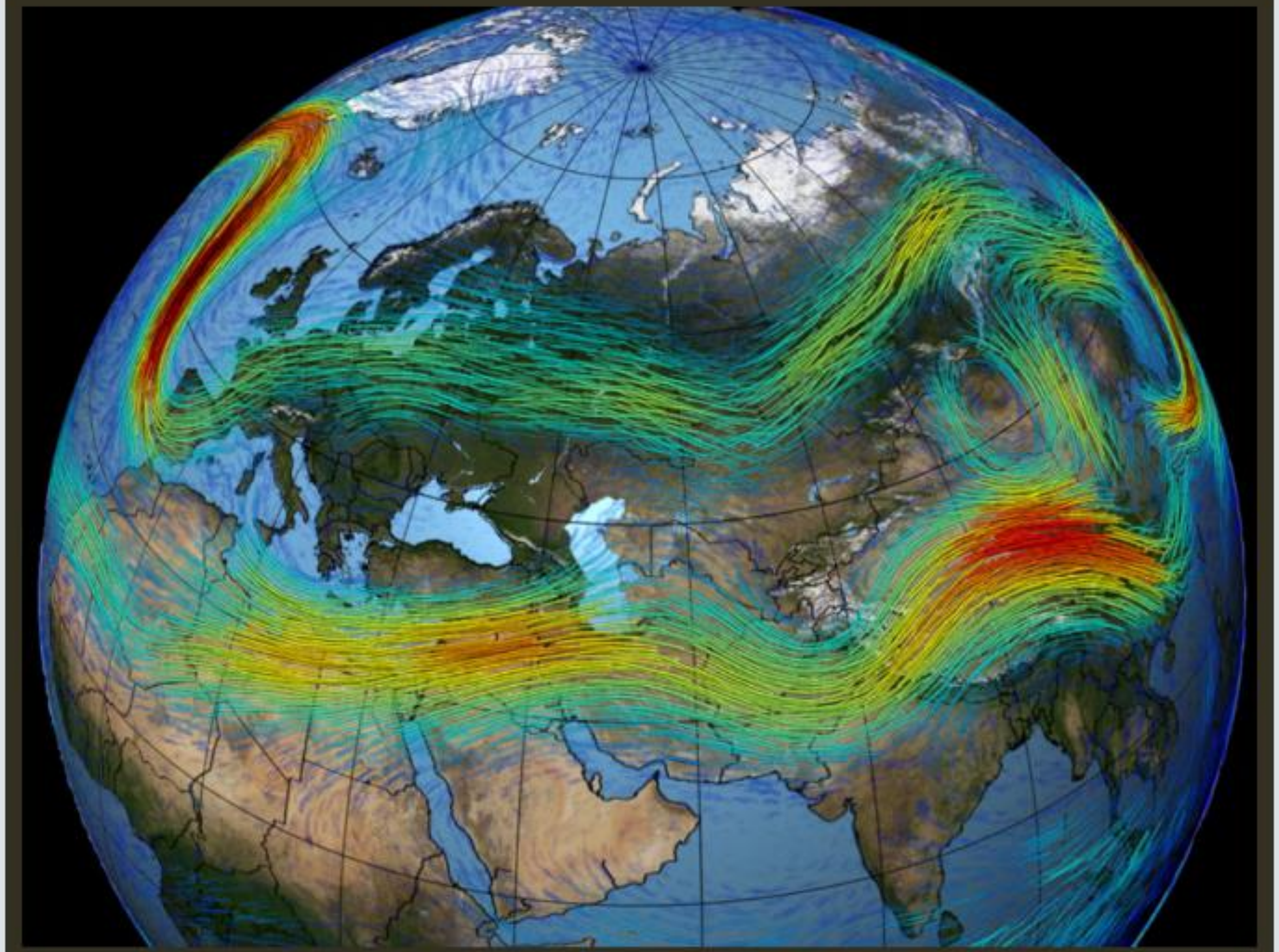
Studies over the past 45 years indicate changes to the tropopause, the top of the troposphere, and the width of the tropical belt may be shrinking, changing the overall storm pattern across the globe.

- The tropopause, has climbed about 50 to 60 meters per decade in the past 20 years.
- The troposphere is the bottom layer of Earth's atmosphere and contains most of the atmosphere's mass, clouds and weather phenomena, and is where the global population and wildlife lives.

JET STREAM WINDS WILL ACCELERATE WITH WARMING CLIMATE

Faster winds likely to cause bumpier flights, more severe weather

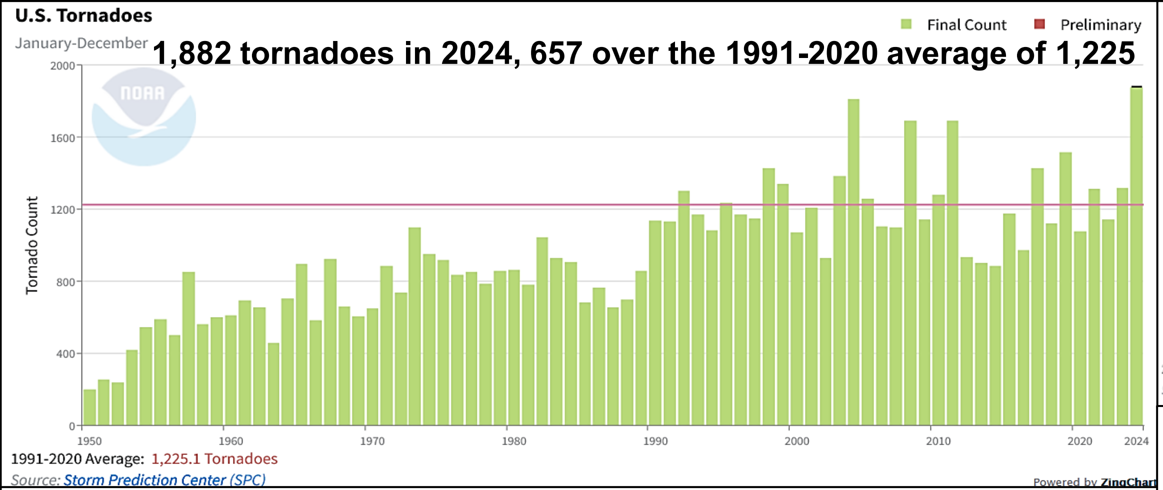
DEC 6, 2023 – BY STAFF

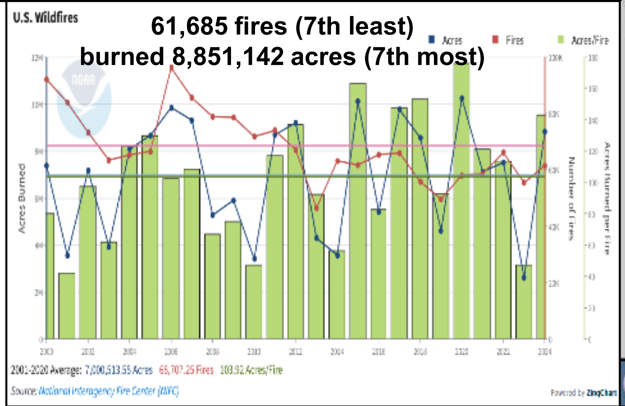


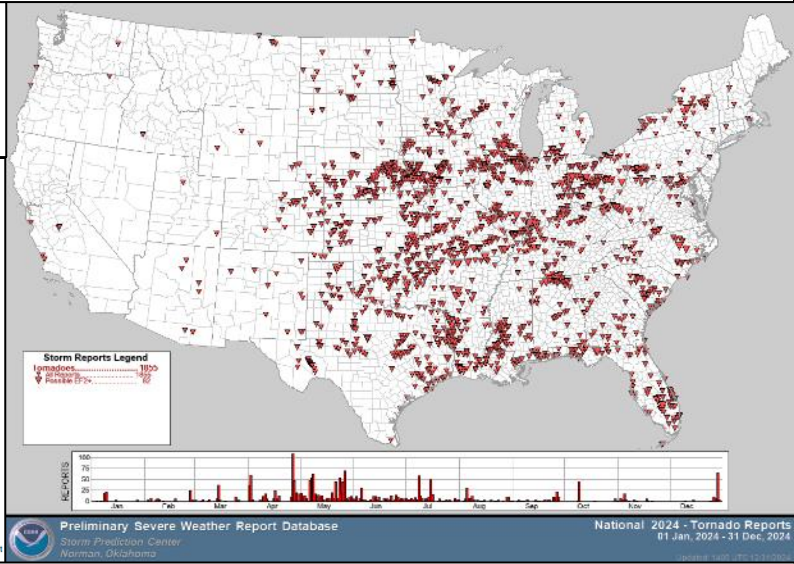
New research shows that the fastest jet stream winds will accelerate with climate change. (Image by NASA/Goddard Space Flight Center Scientific Visualization Studio.)

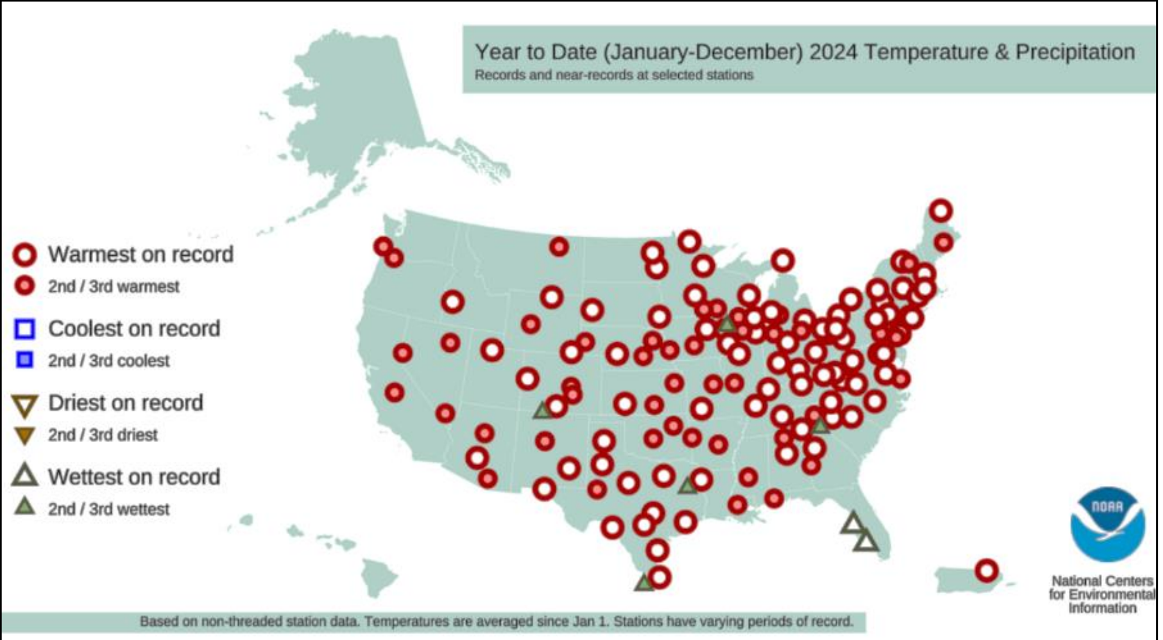
National Temperature Swings Yield Extremes

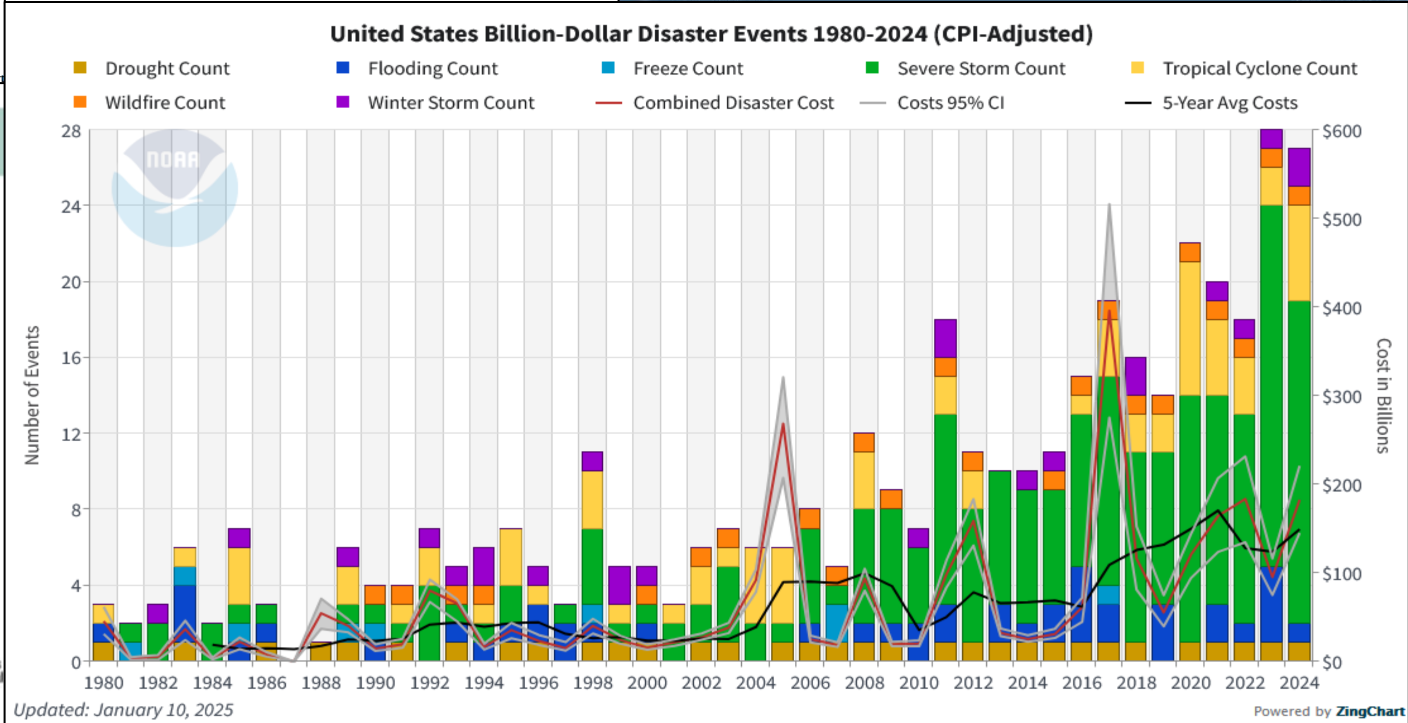
In 2024, there were 27 confirmed weather/climate disaster events with losses exceeding $1 billion each to affect US following the 2023 record 28 billion-dollar events. The total cost from 2024 was $182.7 billion via *17 severe storms, 5 Tropical Cyclones, 1 wildfire, 1 drought/heat event, and 2 winter weather events.*











Changing Spring Conditions

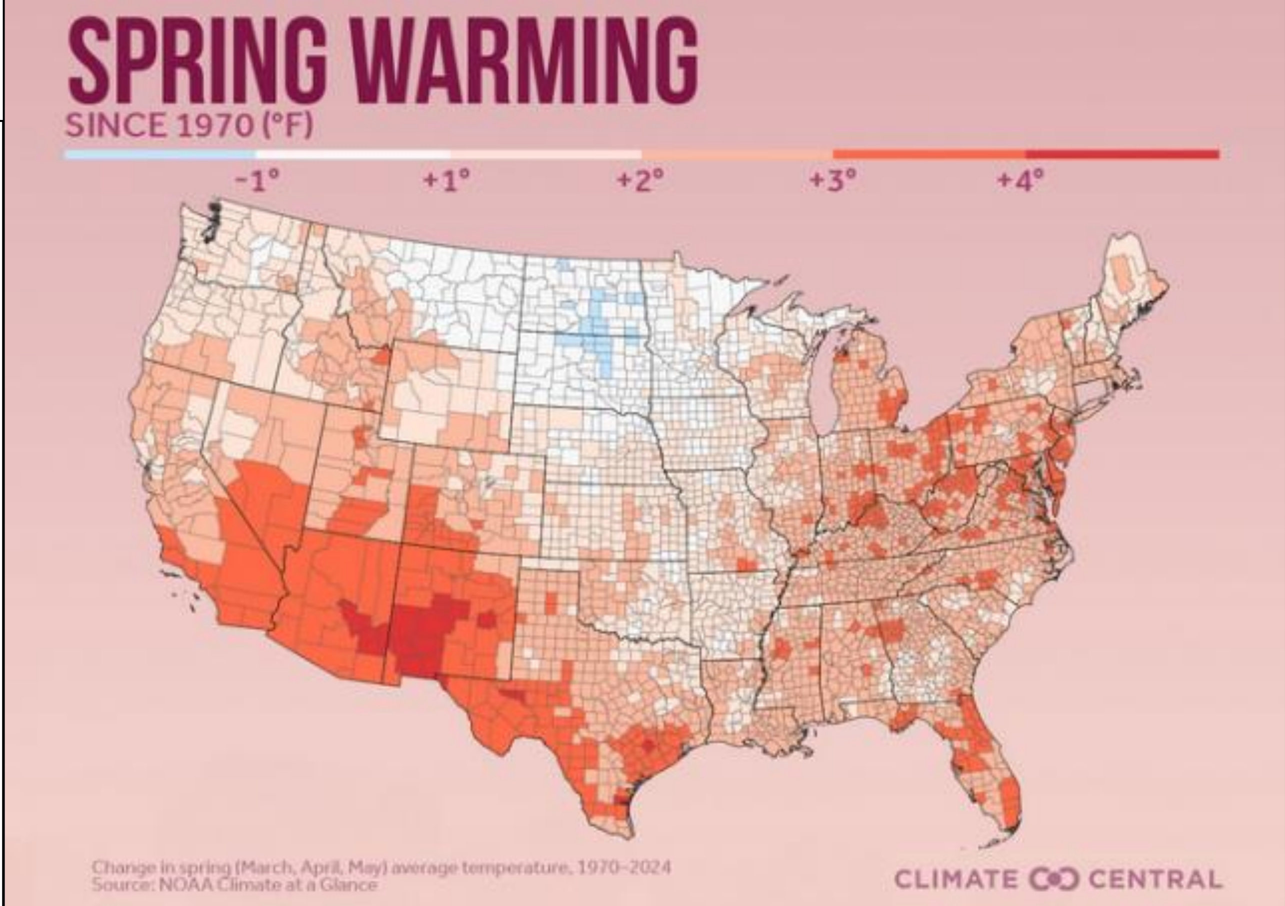
The spring season has warmed in 234 (97%) of the 241 U.S. cities analyzed — by 2.4°F on average.

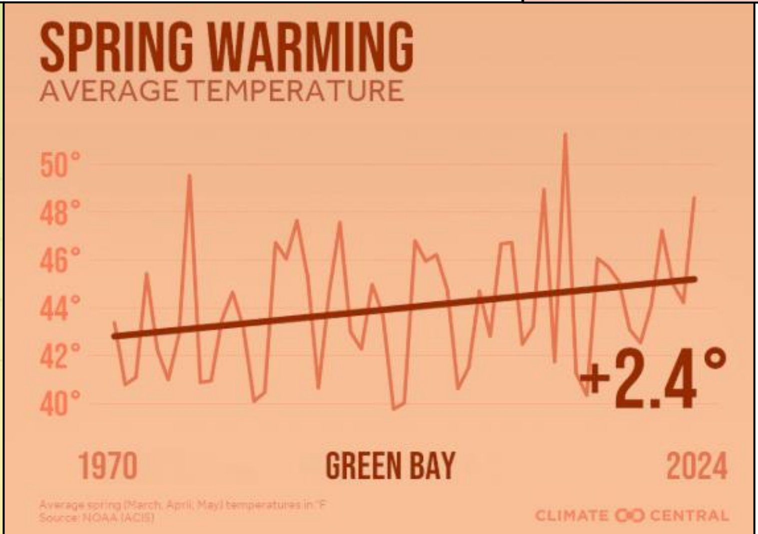
- Unusually warm spring days now happen more often. Four out of every five cities now experience at least one more week of warmer-than-normal spring days than in the 1970s.
- Spring has warmed the most across the southern tier of the country, particularly in the Southwest.
- Spring warming can prolong seasonal allergies, worsen wildfire risk, and limit snow-fed water supplies.

Spring warmed the most, on average, in locations across the southern tier of the country: Southwest (3.4°F), South (2.7°F), Southeast (2.5°F), and Ohio Valley (2.5°F).

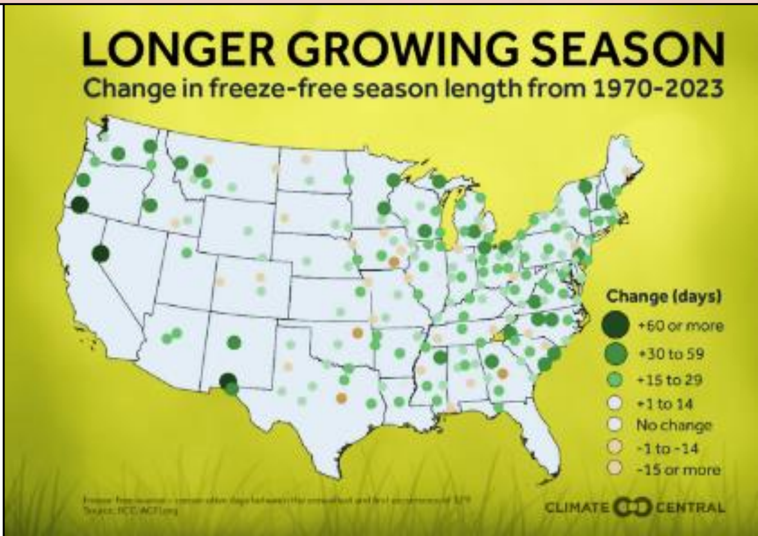
- Most locations (80%, or 194) now experience at least seven additional warmer-than-normal spring days than they did in the early 1970s.

Warmer, shorter winters mean an [earlier spring thaw and later fall freeze].





Warmer spring temperatures result in earlier thaws, heavier spring rainfall, longer growing seasons, double blooms, river system changes, marine and wildlife shifts, and changes to energy needs.

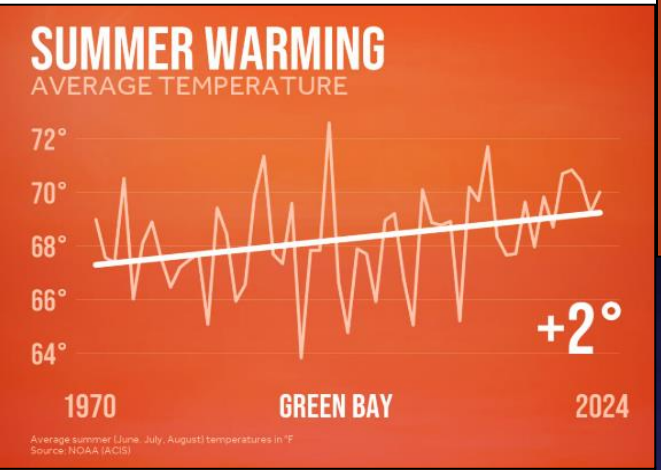


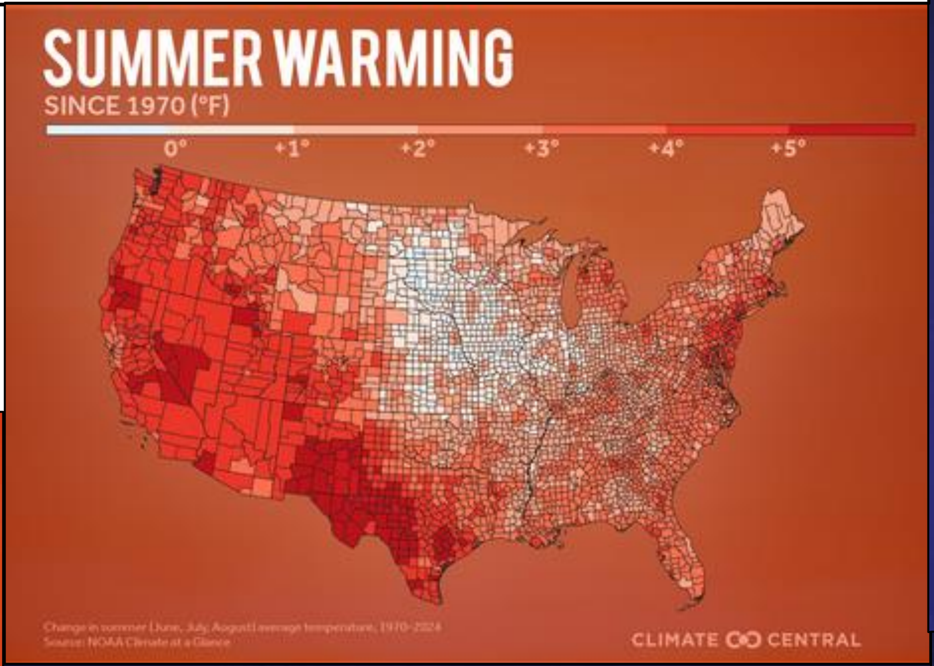
Climate Central’s Warming Seasons Graphics

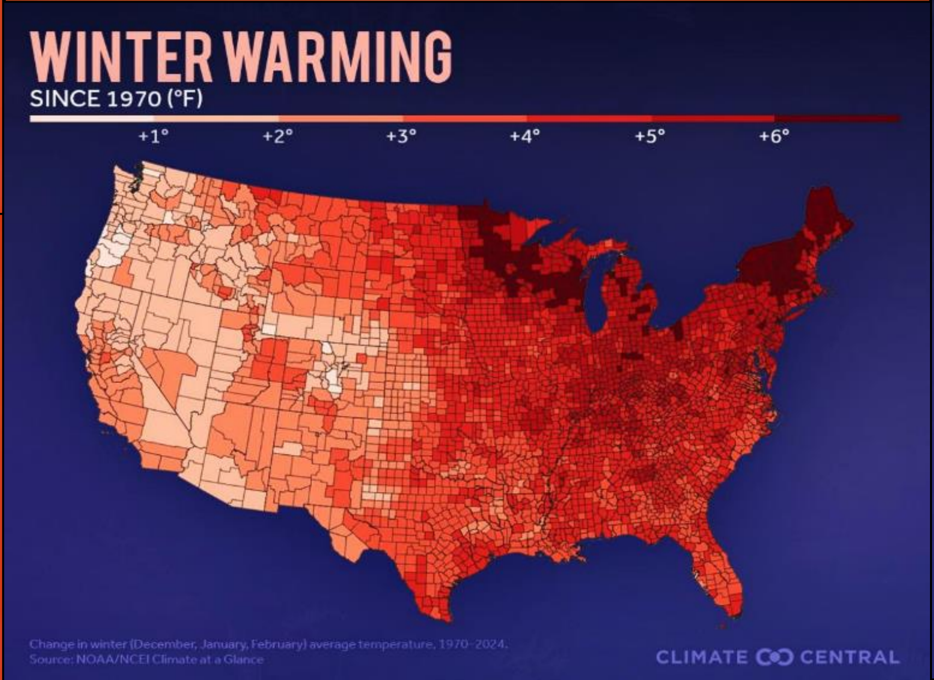
Winters have warmed by 4°F on average across 235 US cities since 1970. Warmer, shorter winters have lingering effects on health, water supplies, and agriculture throughout the year.

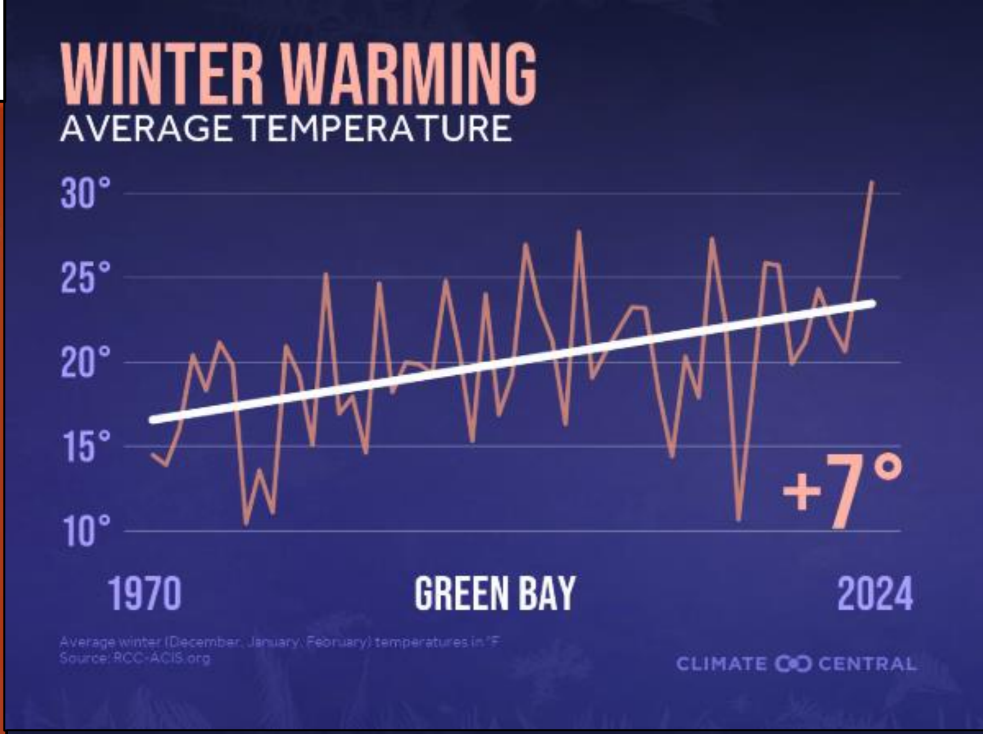
Summers are heating up in 234 of major US cities by an average of 2.6°F since 1970.

Analysis also shows warmer-than-normal summer nights since 1970 in 246 major US cities.









Uneven Snow ~ Avalanche Risk

An uneven snowpack significantly increases the risk of avalanches because different snow densities across a slope can create weak layers, making it more likely for a "slab" of snow to break off and slide down when triggered by weight or movement.

- New and old snow alike can be battered by the wind into ever smaller and smaller pieces, until they look and behave more like tiny grains of sand than the original snowflake that fell from the sky.
- At the larger scale, massive amounts of snow can be moved by the wind, resulting in distribution patterns that vary throughout the landscape.

Atmospheric shifts towards greater rates of warming is linked to the increase in wet snow avalanches in the Western Himalayas.

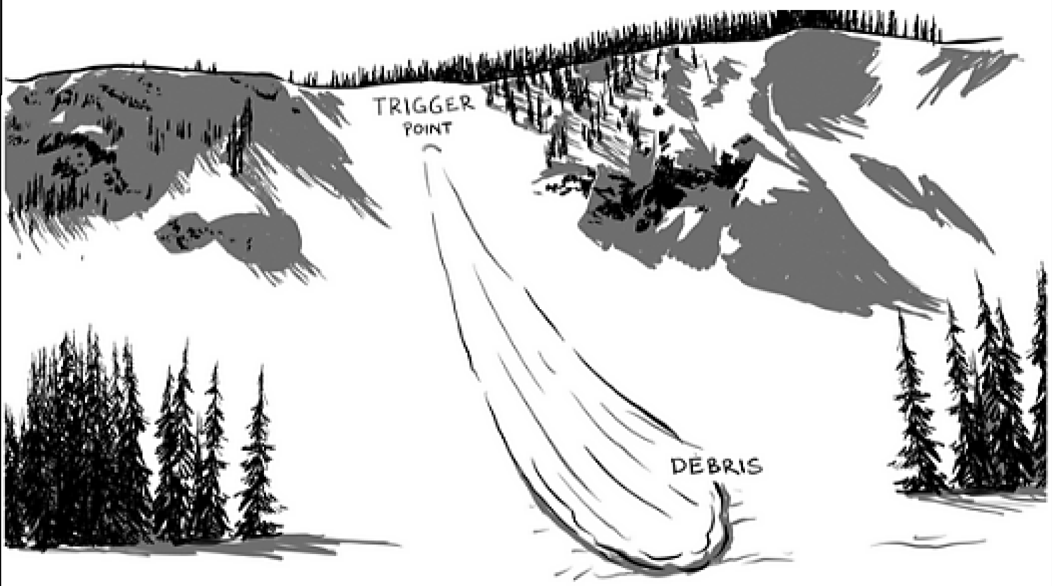
- Melt/freeze layers form when water molecules transition between solid and liquid. When rain falls on snow, or warm air temperatures and/or strong sun bring the snow surface up to 32oF, the snow will end up with some liquid water present.
- Usually in winter this water will stay near the surface and refreeze to form a melt-freeze crust, or percolate and refreeze deeper in the snowpack.
- Any of these melt-freeze layers are weak when wet but strong when frozen.

Snow algae blooms are worsening due to warmer winters, and this can lead to more snow and ice melt. now algae can be found in the Sierra Nevada of California, where it can cause snow to appear red, orange, green, or grey.

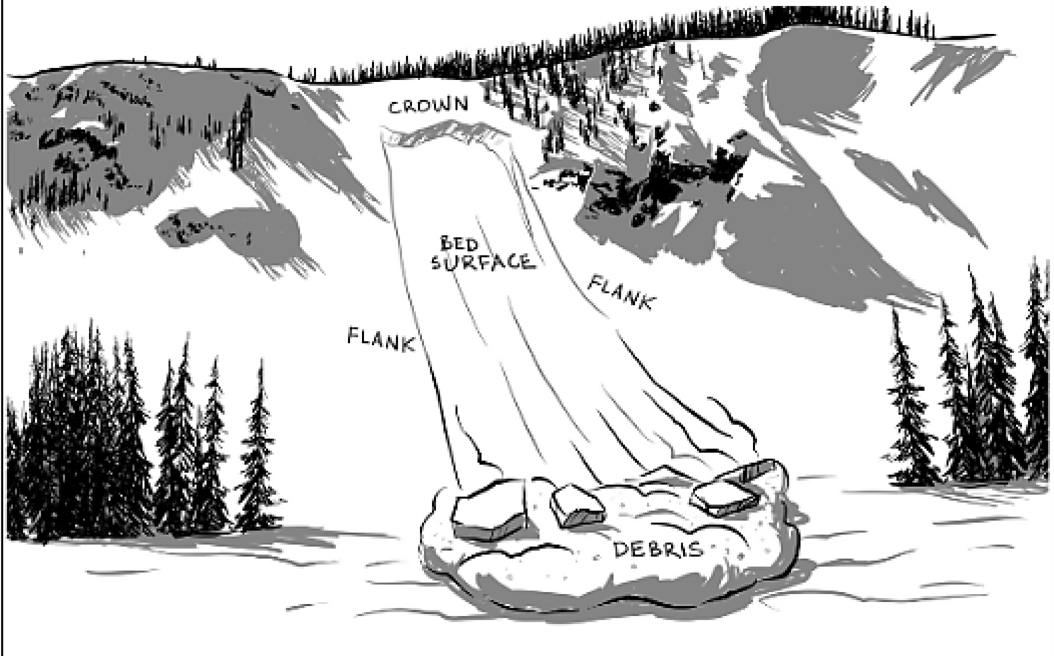
- Snow algae were prevalent in the early summers of 1993 and 1994. Significant negative correlations were found between snow albedo and algal cell numbers.

Wildfire Smoke: tree loss impacts the landing of snow and evaporative capabilities of the wind/sun but the push of ash into the mountains deposits metals and minerals that can darken the albedo of the region and increase warming trends further amplifying the uneven snowpack and risks of premature losses and avalanche threats.

Avalanche Type is a way to categorize avalanches that display similar characteristics because they result from similar snowpack structures. Different avalanche types behave differently, and deserve different safety margins and group management techniques. Primary avalanche types are Loose Snow and Slab avalanches.



Loose Snow avalanches are the release of weak snow at the surface. They start at a trigger point and entrain more snow as they move downhill, forming a fan-shaped avalanche.



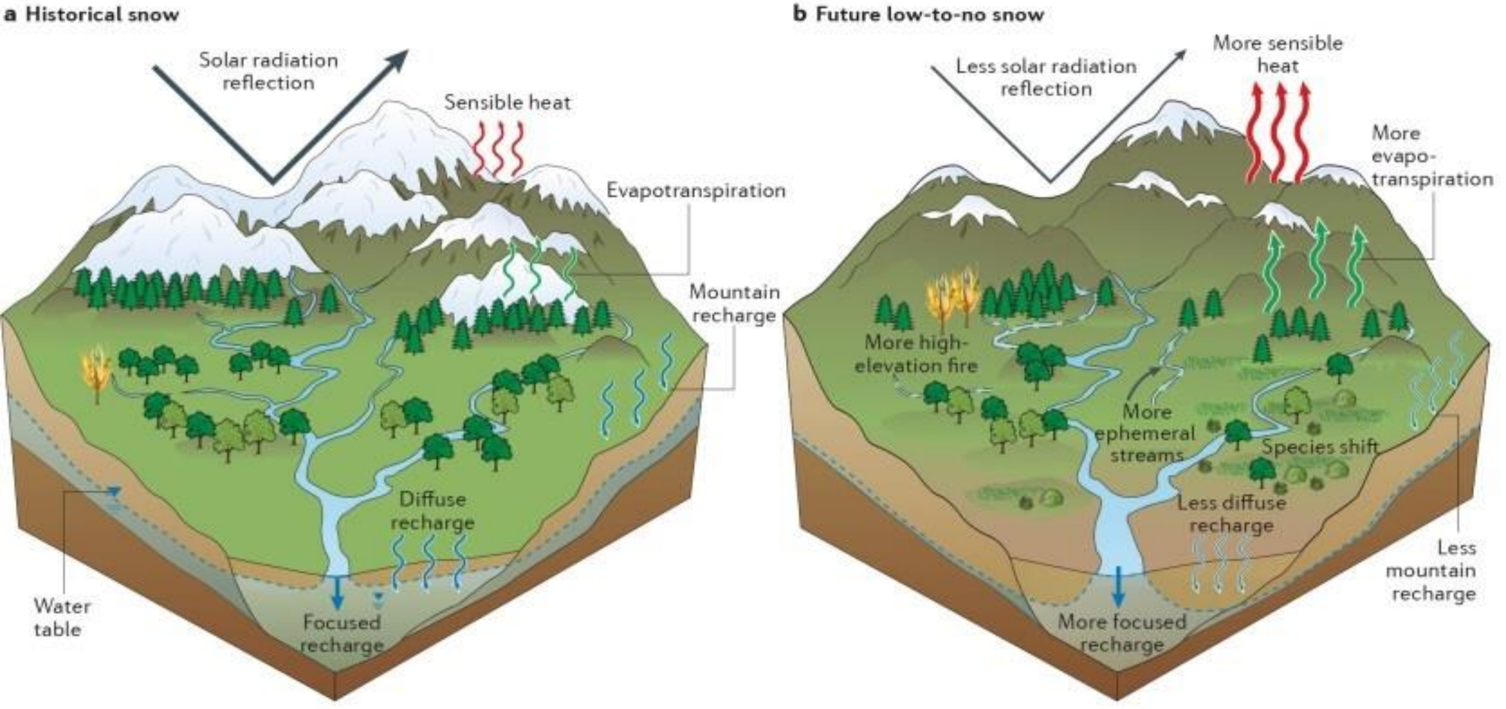
Slab avalanches are the release of a cohesive layer of snow, or slab, with a weak layer below it. The weak layer collapses, which quickly travels, or "propagates," from the initial trigger point.

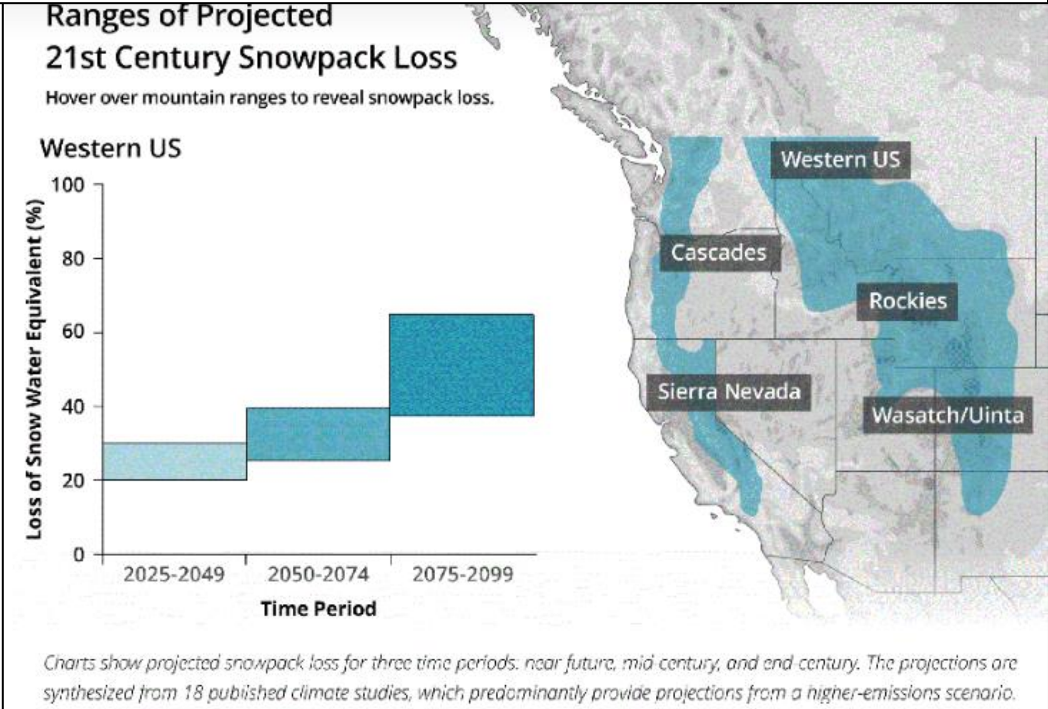
National Snowpack Shifts from Warming

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

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

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





Warm Summer Nights

Since 1970, average summer minimum (nighttime) temperatures have warmed in 231 US locations by 3.1°F on average.

- New analysis shows that climate change is having a growing influence on the frequency of sweltering summer nights since 1970 in all but one of the 247 major U.S. cities analyzed.
- On average, these cities currently experience about 27 warmer-than-normal summer nights with a strong climate change fingerprint each year, compared to one such day annually during the 1970s.
- The top five cities with the largest increases in climate change-fueled warm summer nights are all in Florida.
- Hot summer nights limit our ability to cool off and recover from extremely hot summer days. This can lead to greater heat stress and related health risks.

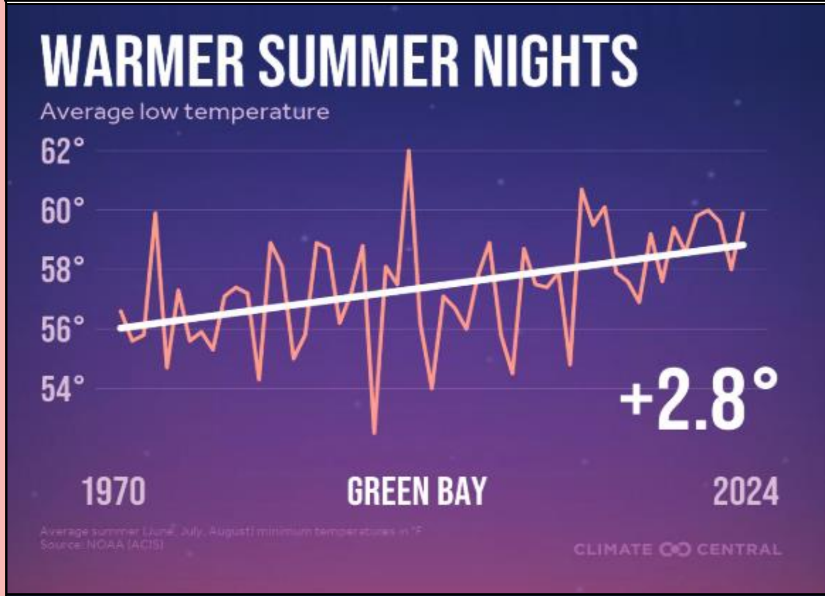
When nights don't cool off enough relative to peak daytime temperatures, people have a harder time cooling off.

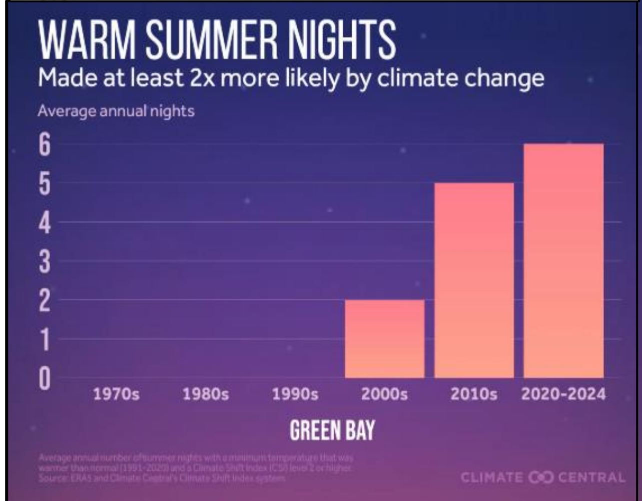
- Heat is the deadliest weather-related hazard in the U.S., and warm nights can worsen heat stress and related health risks during the hottest time of year.
- Summer nights have warmed the most since 1970 in the Southwest, where summer nights have warmed by 4.5°F on average across 11 locations.

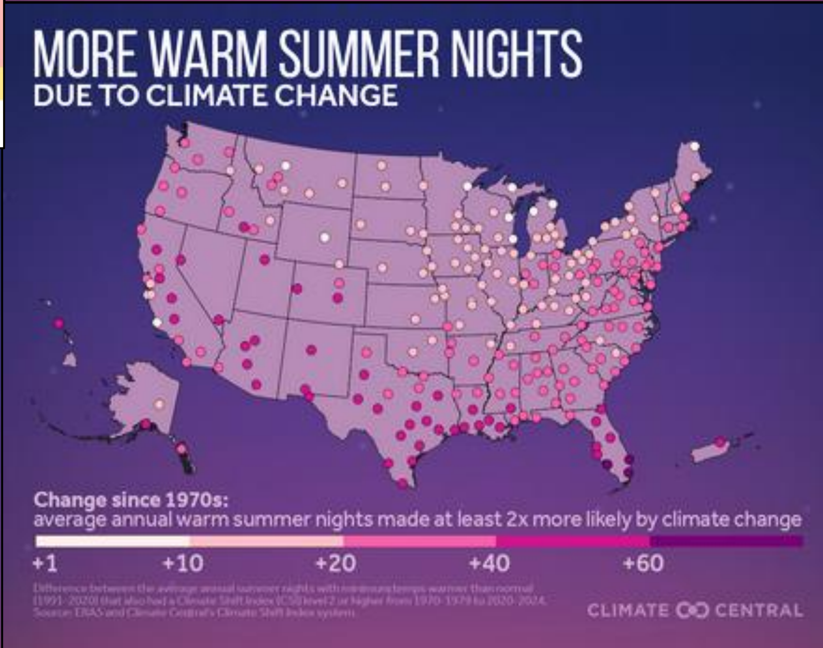
Sleepless Nights, a 2024 report from Climate Central, quantifies the influence of human-caused climate change on the frequency of hot summer nights globally.

More warm nights also mean higher demand for air conditioning.

Abnormally high temperatures overnight present risks of wildfire threats, stressed vegetation, greater rates of evaporative demand, and increased aggression rates.



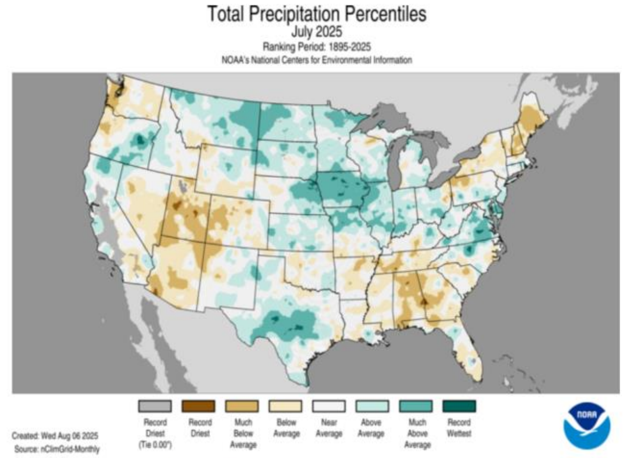




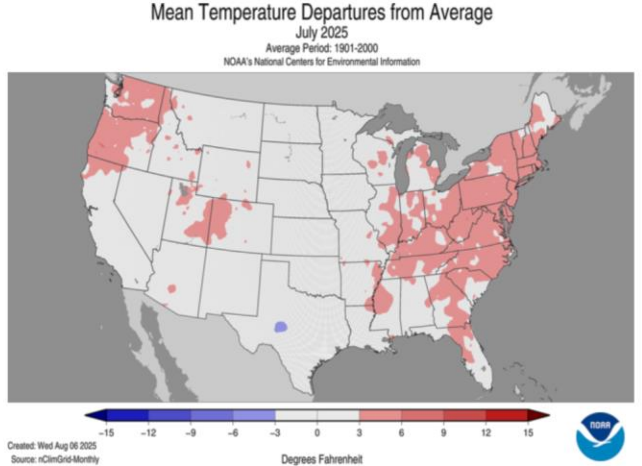
In July, 1,434 flash flood warnings—the second-highest July total in 40 years—and 17 flash flood emergencies were issued nationwide, along with over 2,000 preliminary flood-related storm reports.

The average temperature for the contiguous U.S. (CONUS) in July 2025 was 75.4°F, 1.8°F above the 20th-century average

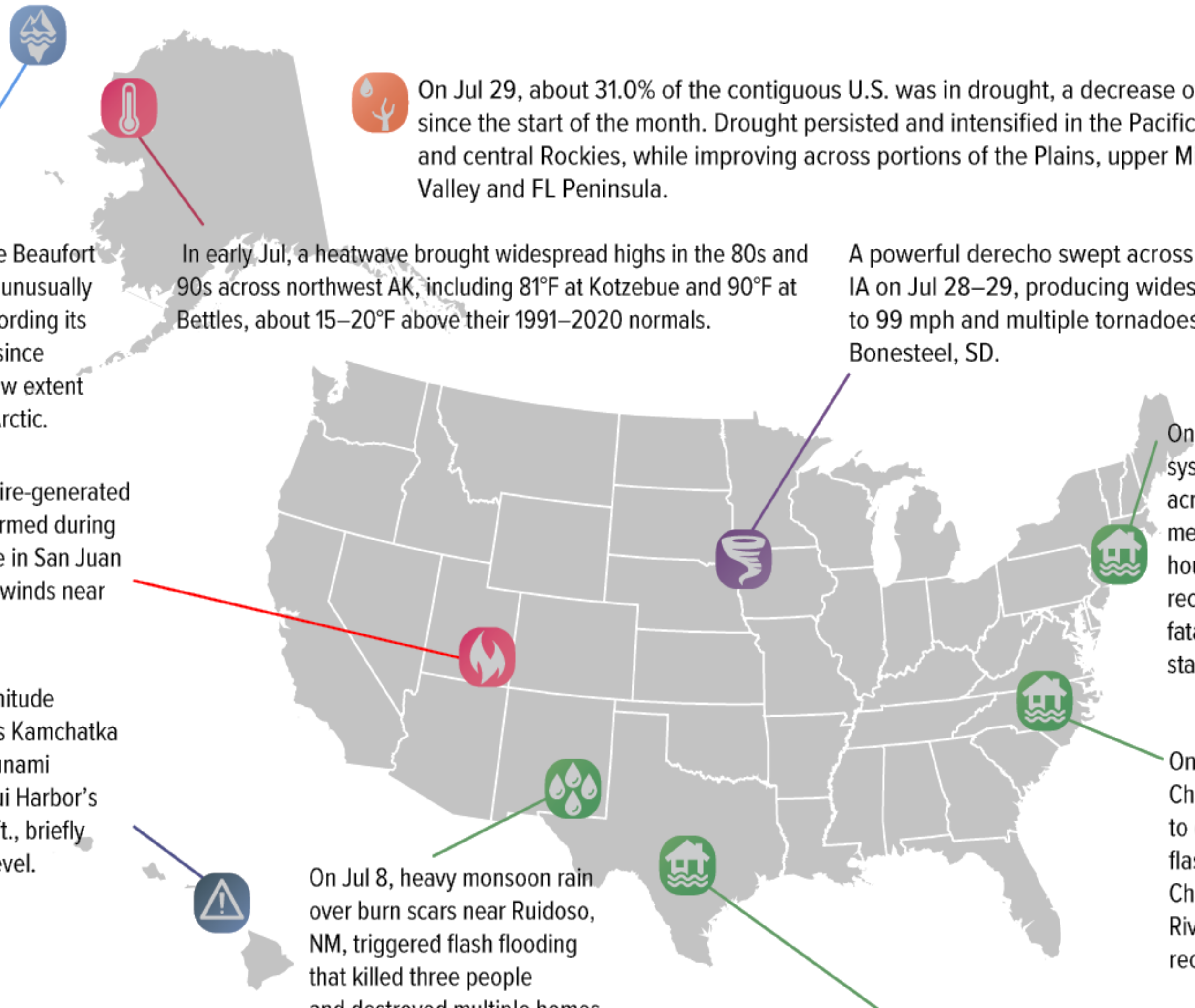
Record overnight warmth in 12 states in the Southeast, Mid-Atlantic and Ohio Valley.



July 2025 U.S. Total Precipitation Percentiles



U.S. Selected Significant Climate Anomalies and Events July 2025



On Jul 29, about 31.0% of the contiguous U.S. was in drought, a decrease of about 1.4% since the start of the month. Drought persisted and intensified in the Pacific Northwest and central Rockies, while improving across portions of the Plains, upper Mississippi Valley and FL Peninsula.

Jul sea ice extent in the Beaufort and Chukchi Seas was unusually high—the Beaufort recording its greatest Jul coverage since 2006—in contrast to low extent across the rest of the Arctic.

In early Jul, a heatwave brought widespread highs in the 80s and 90s across northwest AK, including 81°F at Kotzebue and 90°F at Bettles, about 15–20°F above their 1991–2020 normals.

A powerful derecho swept across southeast SD and northern IA on Jul 28–29, producing widespread damaging winds of up to 99 mph and multiple tornadoes, including an EF-2 near Bonesteel, SD.

On Jul 12, a rare EF-2 fire-generated tornado ("firenado") formed during the Deer Creek wildfire in San Juan County, UT, with peak winds near 122 mph.

On Jul 14–15, a slow-moving storm system dropped 3–6+ in. of rain across parts of NJ and the NYC metro area, with over 2 in. in one hour in at Central Park—a Jul record. Flash flooding led to two fatalities in NJ and prompted states of emergency in both states.

On Jul 29, an 8.8-magnitude earthquake off Russia's Kamchatka Peninsula triggered tsunami warnings for HI. Kahului Harbor's gauge peaked at 9.16 ft., briefly reaching major flood level.

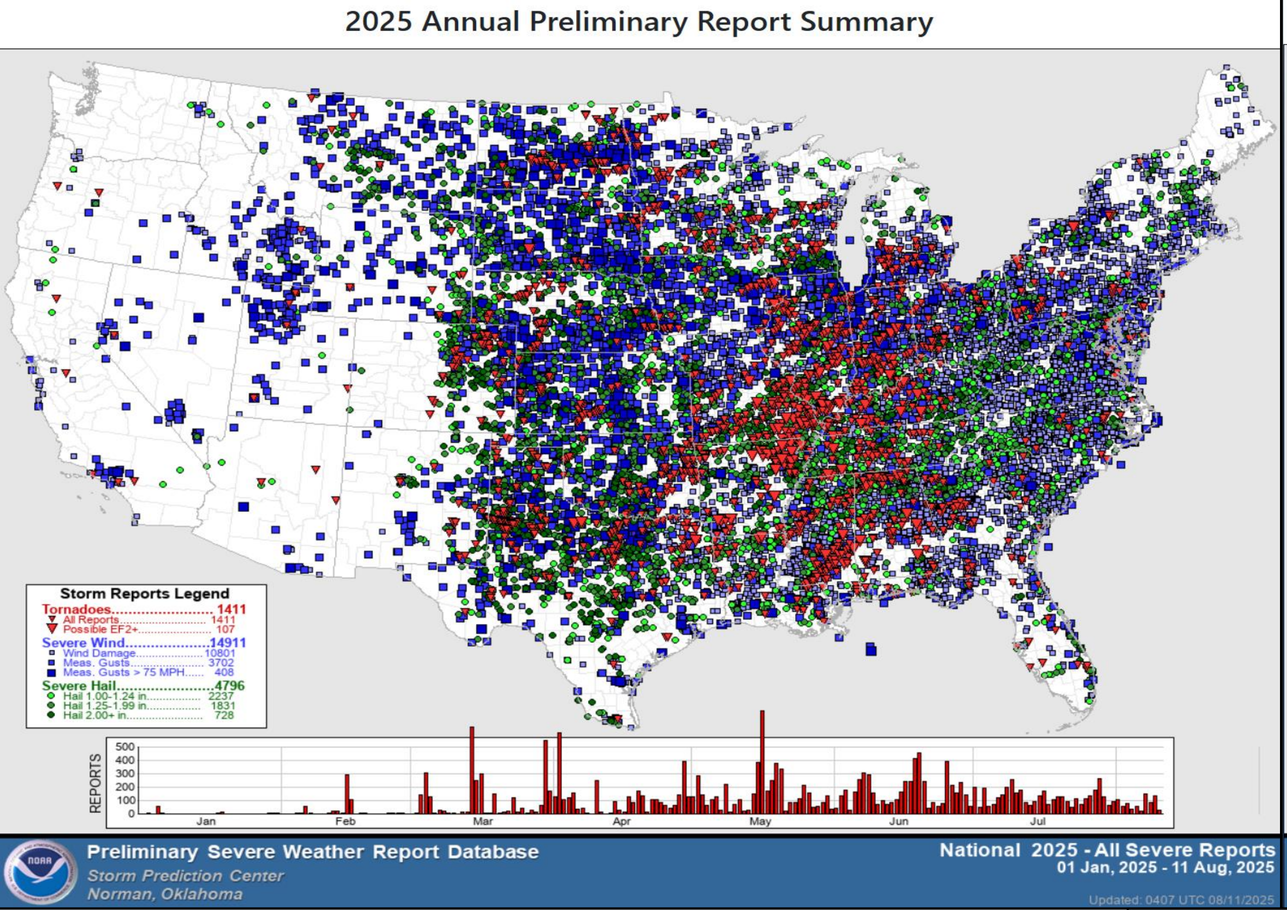
On Jul 5–7, remnants of TS Chantal brought 8–12 in. of rain to central NC, causing deadly flash flooding. Three died in Chatham County and the Eno River crested over 23 ft.—a new record.

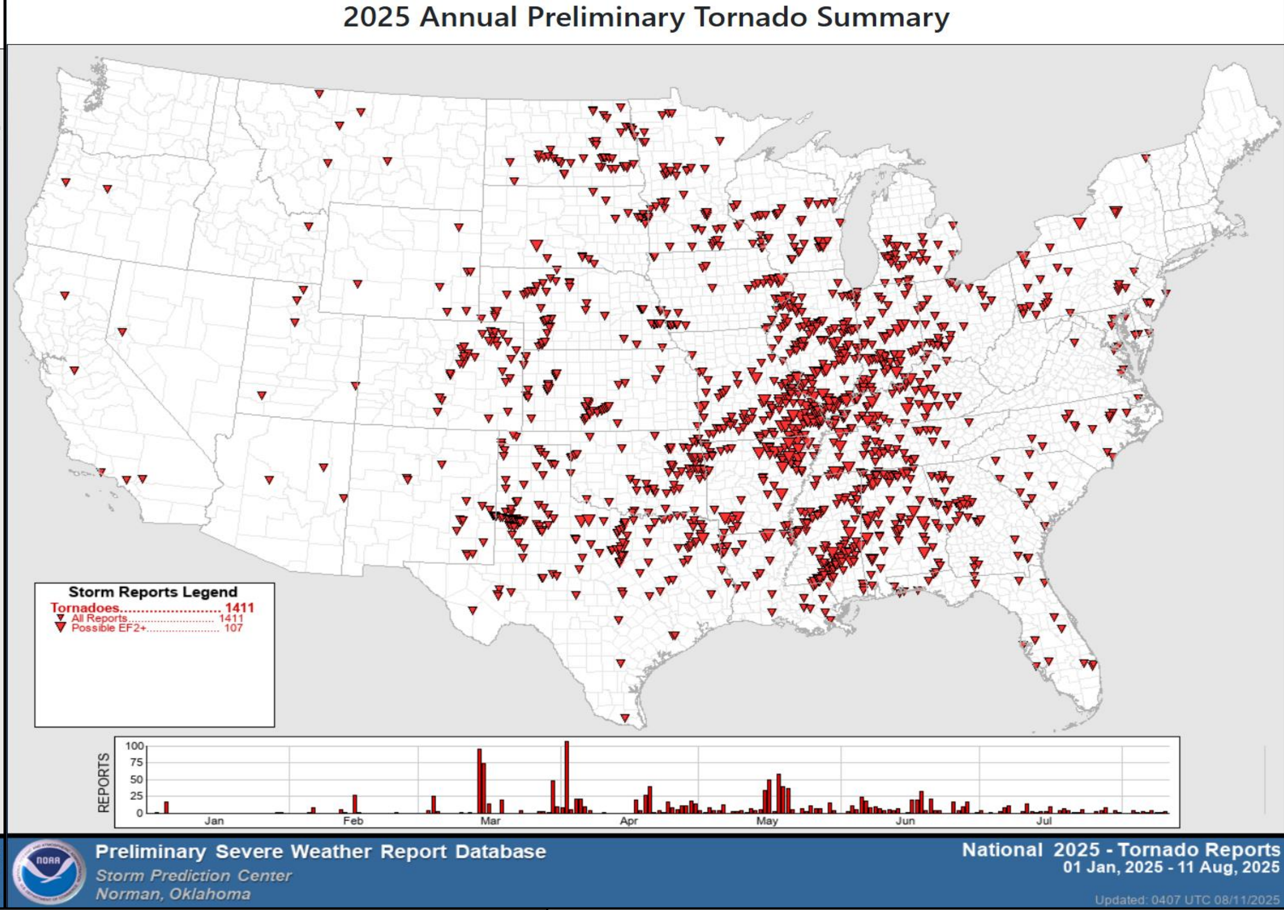
On Jul 8, heavy monsoon rain over burn scars near Ruidoso, NM, triggered flash flooding that killed three people and destroyed multiple homes.

On Jul 4–7, catastrophic flash flooding in Texas Hill Country killed at least 135 people after up to 20 in. of rain fell in just a few days, producing widespread 1-in-100-year flooding and localized 1-in-1000-year flood events.

The average U.S. temperature for Jul was 75.4°F, 1.8°F above average, ranking in the warmest third of the 131-year record. The U.S. precipitation average for Jul was 3.00 in., 0.22 in. above average for the month.

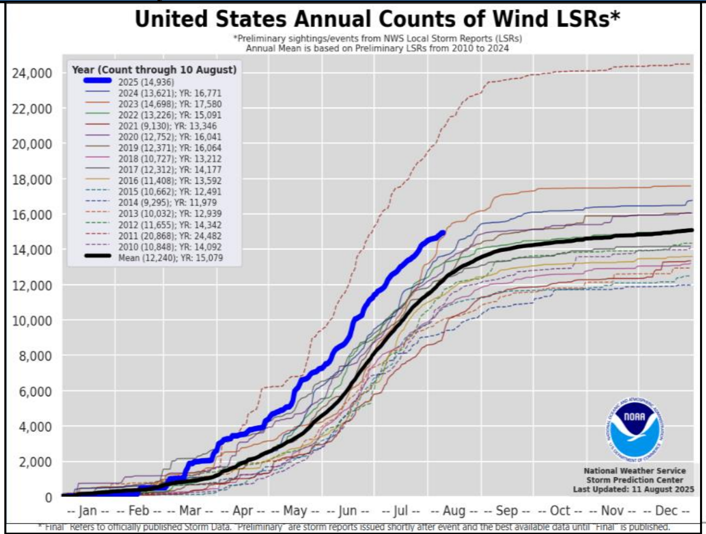
Please Note: Material provided in this map was compiled from NOAA's State of the Climate Reports. For more information please visit: https://www.ncei.noaa.gov/access/monitoring/monthly-report/

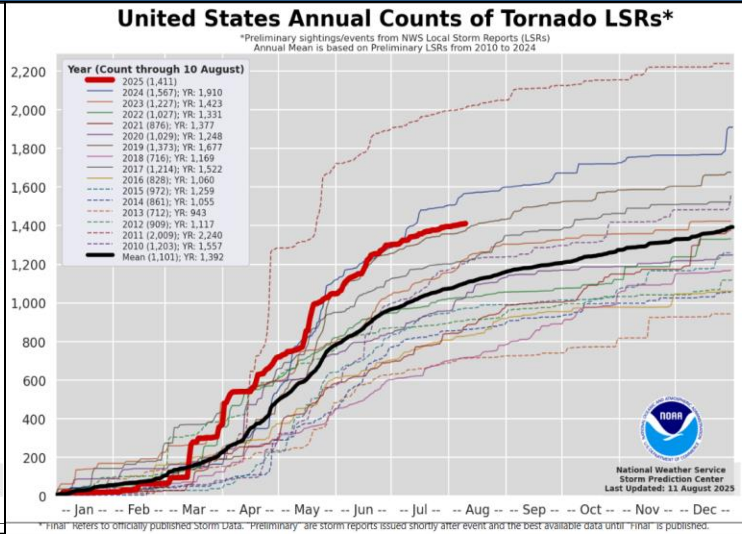




Awareness: The US is well above the annual average (1,200 events) for tornadic activity at 1,411 events, with only two prior years with more tornadic activity to date being 2011 and 2024.

- For the year-to-date of January to August 2025 there have been over 107 EF2 or stronger tornadoes reported across the continental US with 67 fatalities.
- This year has already produced more tornadoes than the entire year of all prior years except 2024, 2023, 2019, 2017, 2011, and 2010 but is on track to be a top 3 year easily.
- Wind reports show this year is well above average for this period and is likely to be in the top two years, behind 2011.





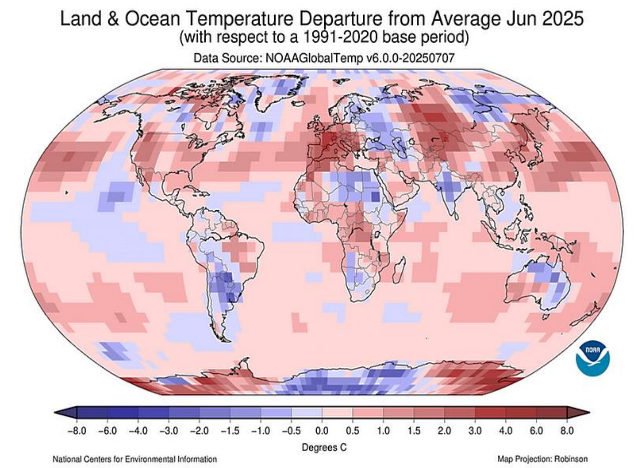
June 2025 recorded the third-highest June global surface temperature in NOAA's 176-year record, which dates to 1850.

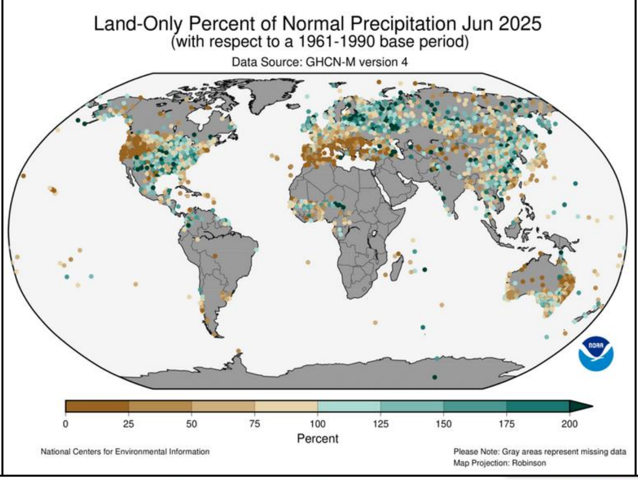
All ten warmest Junes on record have occurred since 2016. June 2025 extended the streak of consecutive Junes with above-average global temperatures to 49 years.

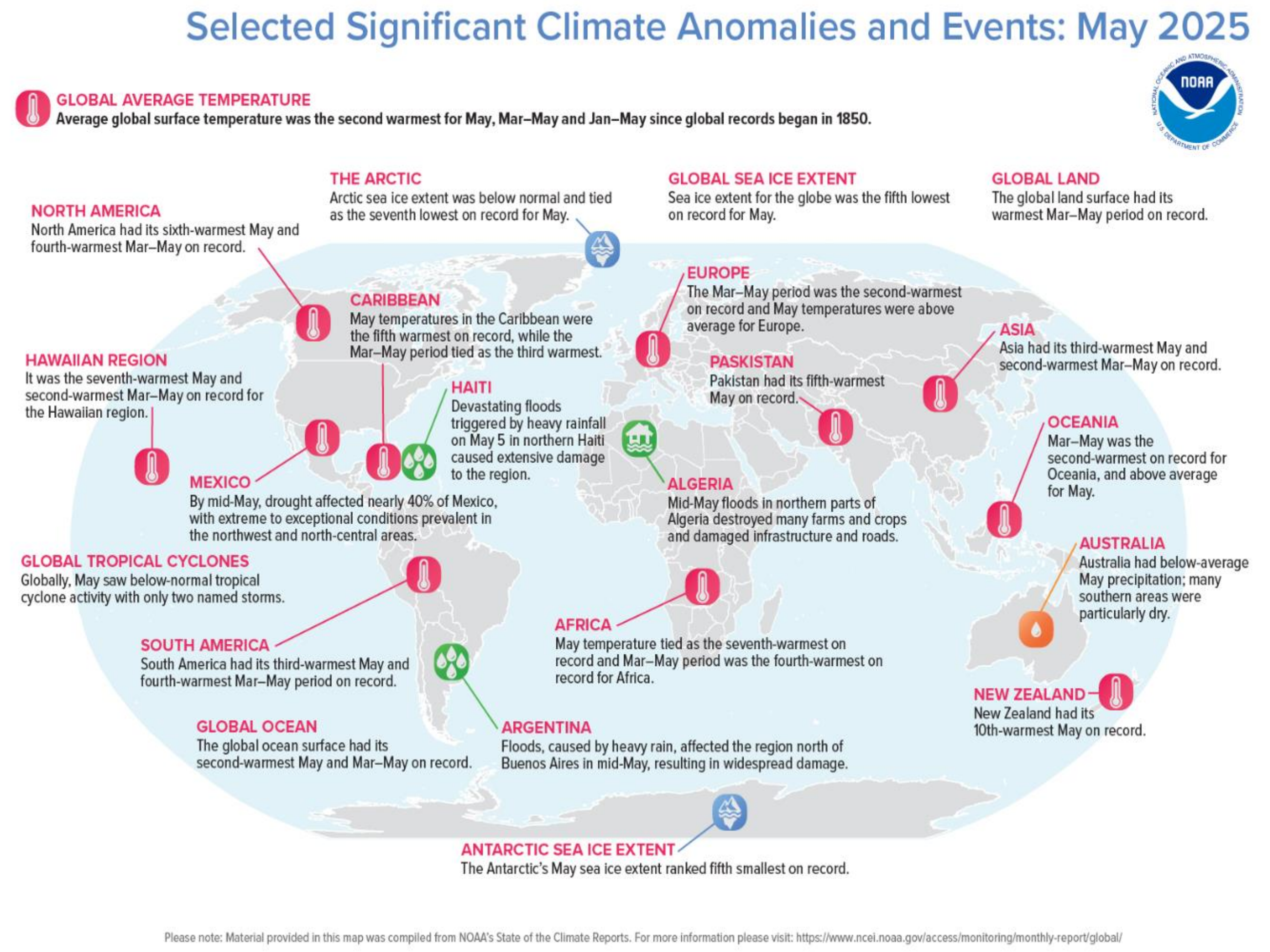
The global land-only surface temperature for May 2025 was also the second-highest in the 176-year record, with a temperature 1.61°C (2.90°F) higher than the 20th-century average.

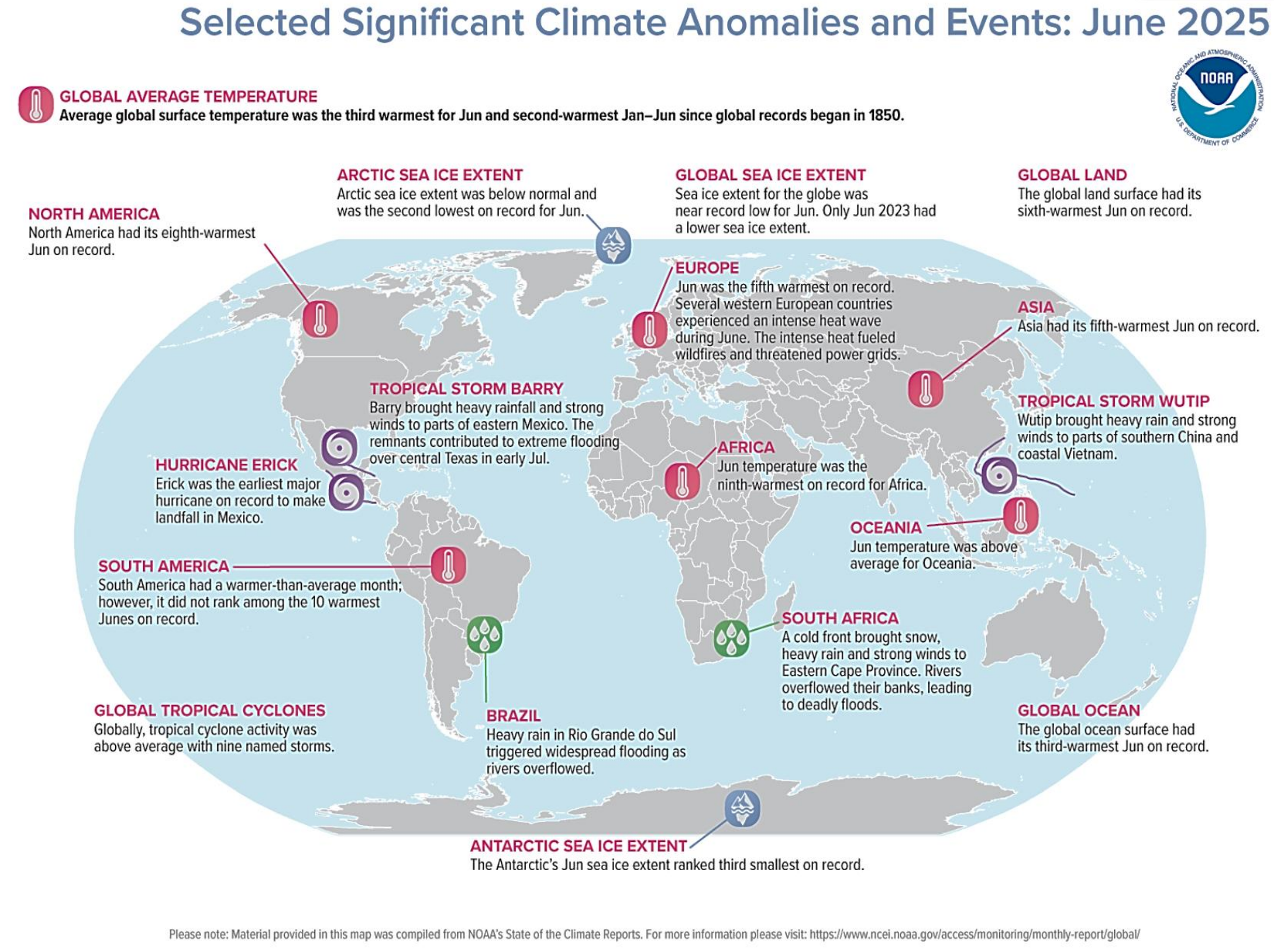
Japan recorded its warmest June since national records began in 1898, with a national average temperature of 2.34°C (4.21°F) above average.

Regionally, Europe and Asia both experienced their fifth-warmest June on record.









Concrete: In high heat environments over 80°F, 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: airport aprons, bridge headsticks, and highways where repaving needs have been increasing.

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

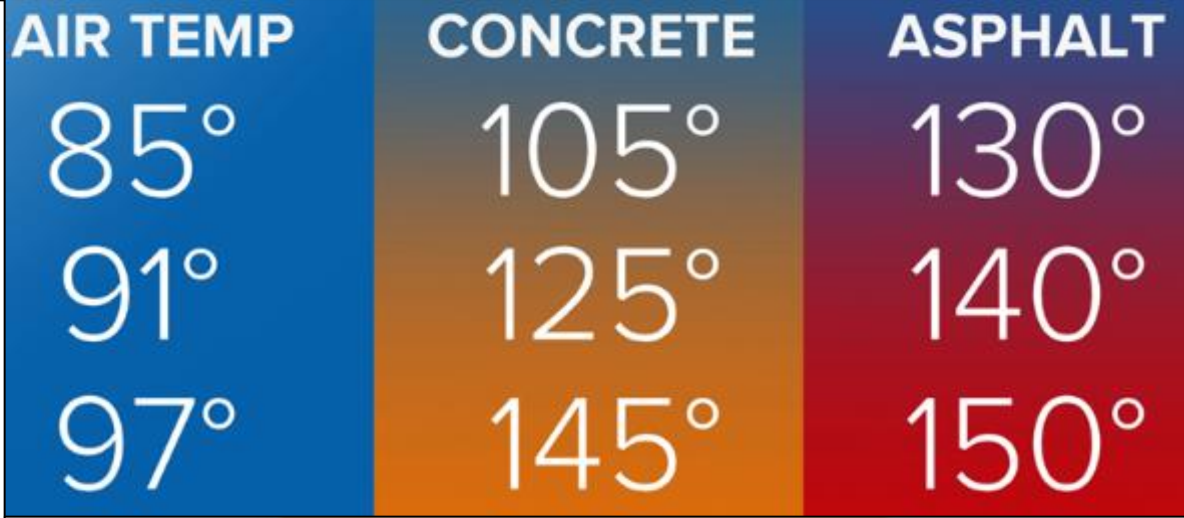
- Metal benches can reach 136°F with coated benches still exceeding 108°F.
- Marble benches comparable can range up to 105°F while limestone can reach 116 degrees in sunlight. Shade often drops these temperature by 16-18°F.
    - Water fountains can reach 95°F, bus stop signs/posts can reach 105°F, bicycles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

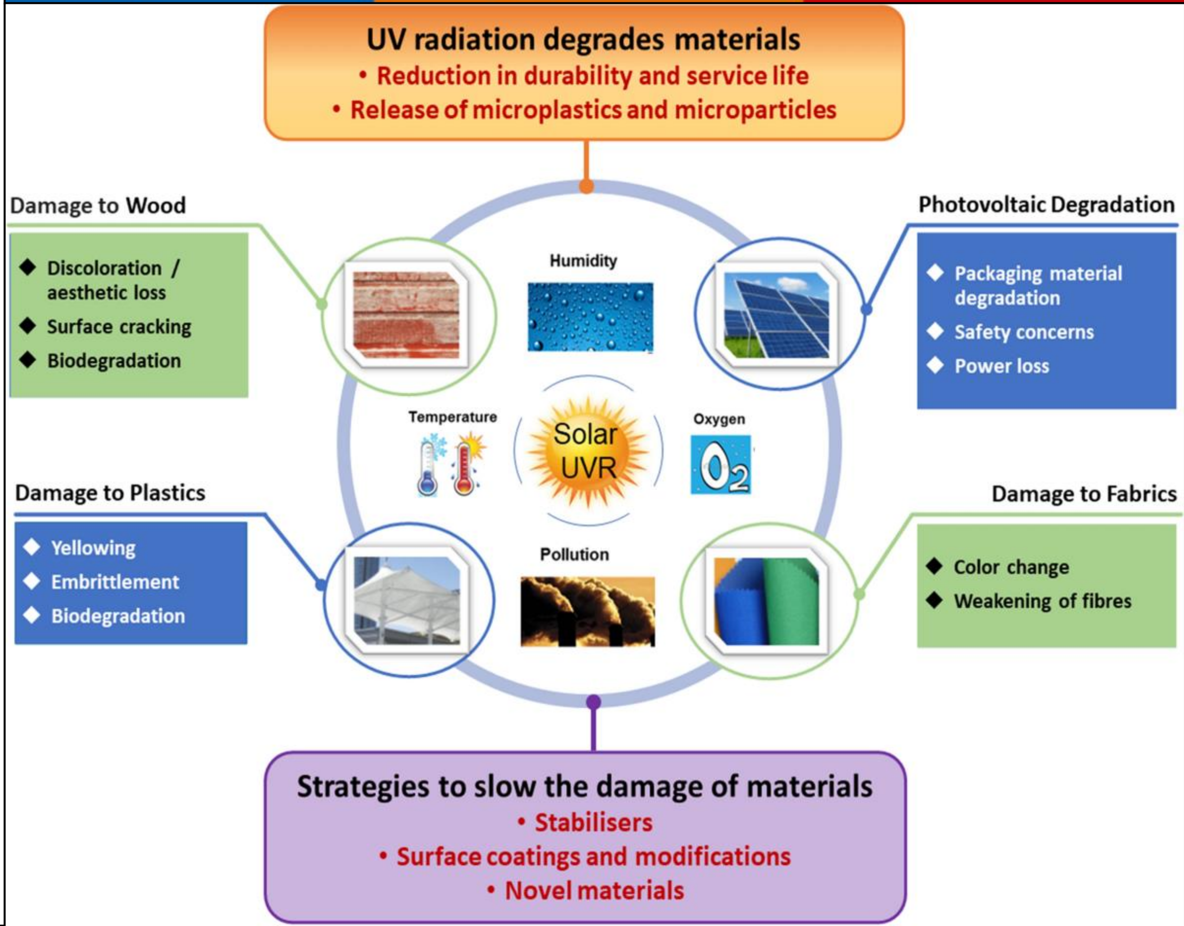
Epoxy: Most heat-resistant epoxies need to be cured at temperatures at or beyond the temperature it will need to endure. If temperatures exceed these maximum service temperatures, the material could start to distort. At a temperature of 135°F or higher, the epoxy may begin to exhibit heat damage.

- 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 faced thermal expansion or cracking– 95°F in New York, 103°F in Sacramento, and 65°F in London.





Radiative Heat Threats: Cities + Canals

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

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

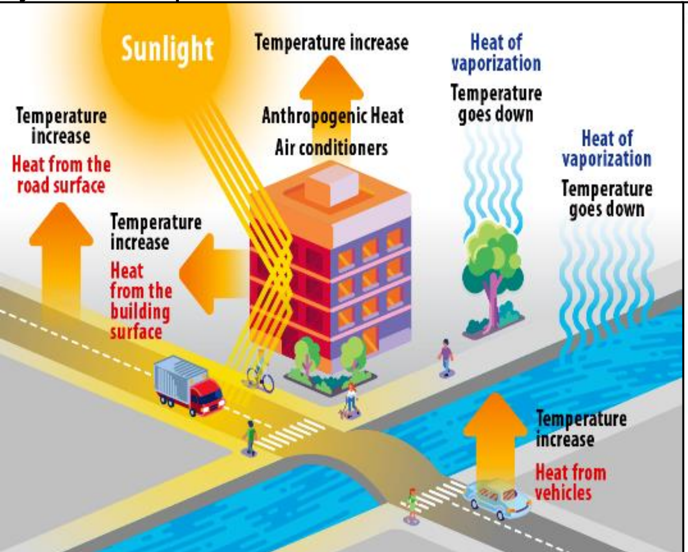
- Grass rarely exceeds 80°F, wood peaks around 90°F, composite decking about 100°F, but concrete can reach a hotter temperature and hold onto that heat longer. In cities, the developed areas of cityscapes may have cooler temperatures due to additions of vegetation and shading, creating significant heat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

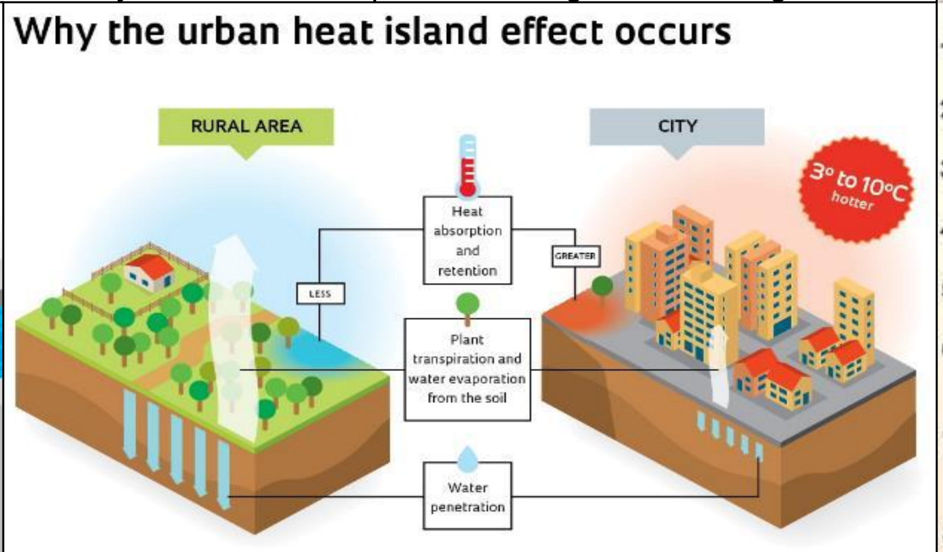
Metal benches, grates, and shopping carts can exceed temperatures of 120°F resulting in burn potential for unhoused populations especially. Without cooling centers staying open overnight, at-risk populations are purged back into an abnormally warm city where pollution concentrations remain high due to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

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

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

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





SURFACE TEMPERATURES

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

Extreme Heat vs Infrastructure

Infrastructure Impacts from Heat: Impacts are likely to carry across all industries.

- Security – Staff and Systems
- Emergency Services/Medical – Staff, Supply Chain, and Equipment
- IT Sector – Heat vs Datacenters
- Water Sector – Quantity and Quality
- Energy Sector – Cooling and Capacity
- Critical Manufacturing – Supply Chain and Sites
- Food/Ag – Crops and Livestock
- Financial/Commercial Facilities – Materials and Operations
- Nuclear – Cooling and Stability
- Government Facilities – Sites, Staff, Society
- Transportation – Functionality and Stability
- Telecommunications – Connection Sites and Interdependencies
- Dams/Chemical – Structural Integrity and Risk

Heat fueled rains: Extreme rainfall events will increase in number and severity in the future because of climate change.

- By the end of the century, cities could experience as much as 30% more annual rainfall than today, and 1.5 times as many days with more than one inch of rain.

The University of Bristol study forecasts average annual flood losses would increase by 26.4% from $32 billion currently to $40.6 billion in less than 30 years.

- The national floodplains are expected to grow by approximately 45% by 2100.
- Just one inch of floodwater can cause up to $25,000 in damage (FEMA).

Severe Weather on the Rise

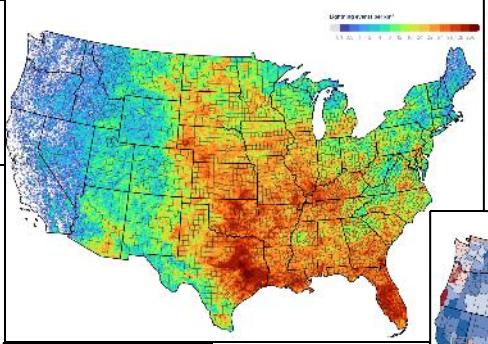
Hail events throughout the US are forecasted to intensify regarding size of the hailstones as warmer seasons across multiple regions can enable stronger updrafts for supercell storms responsible for large hail especially across less hardened areas.

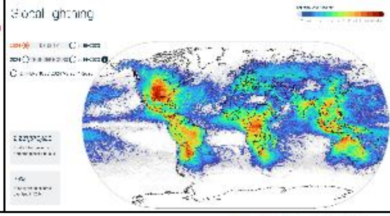
- Insured U.S. hail losses average $8 billion - $14 billion per year, or $80-140 billion per decade.

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.



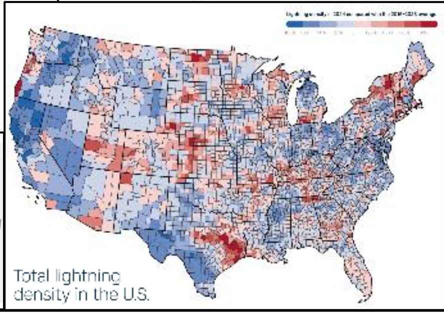


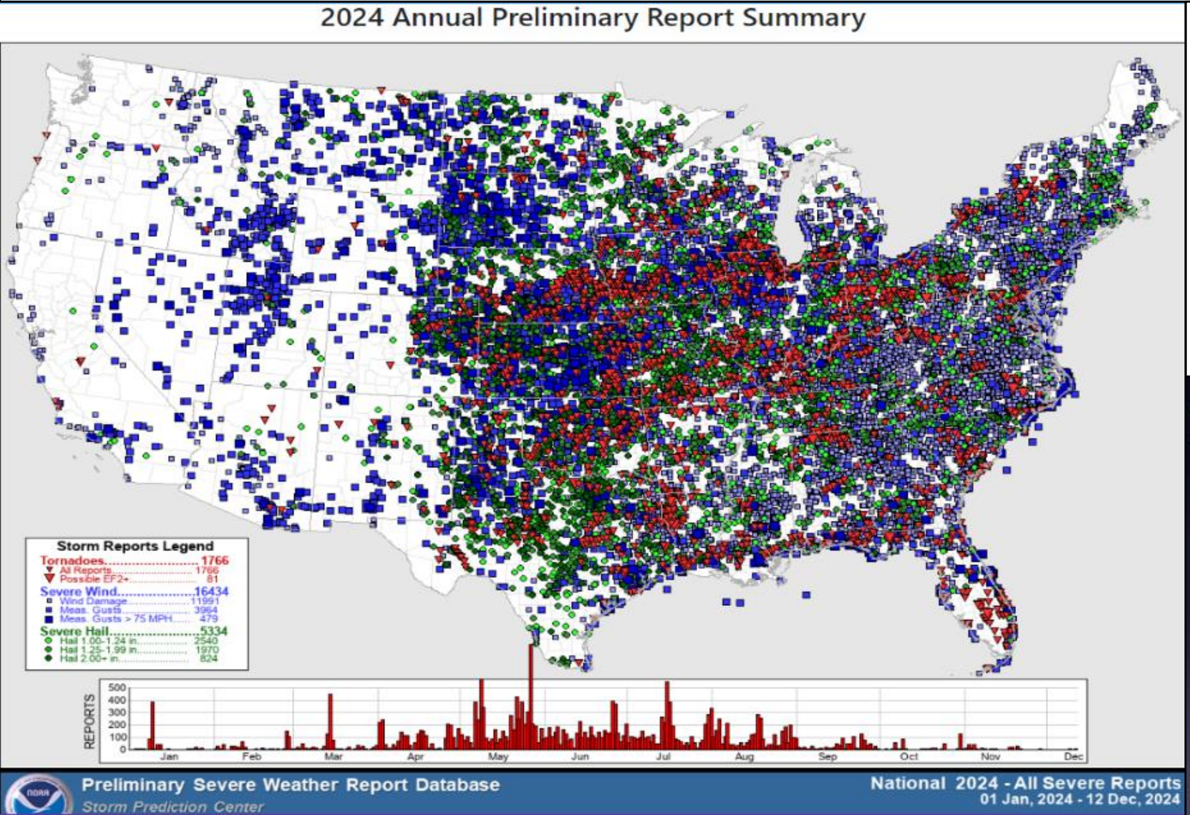
#1 by count

Polk County, Florida, saw 851,938 lightning events in 2024

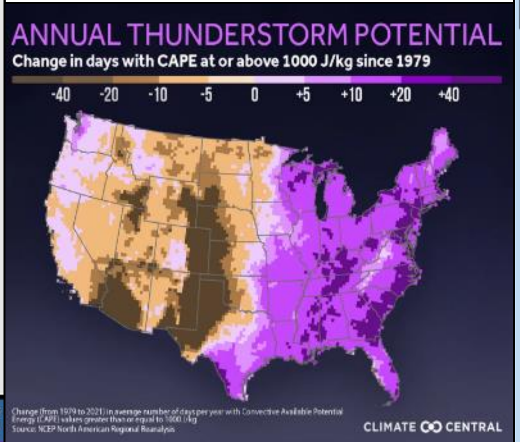
#1 by density

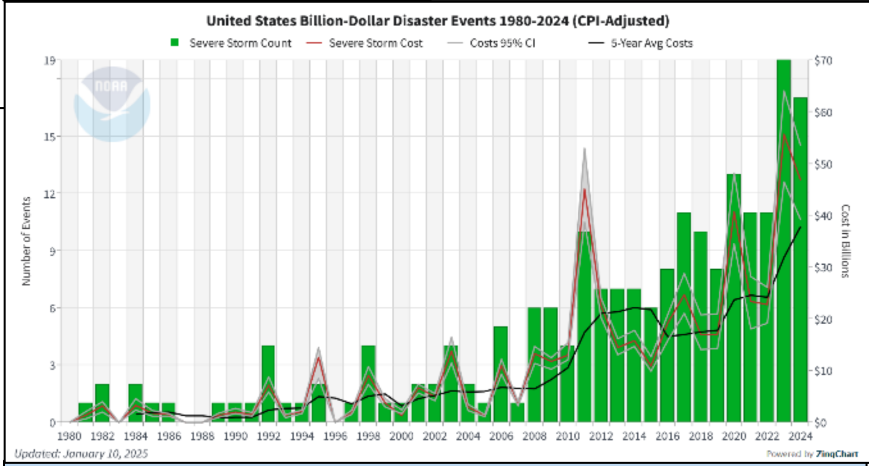
Walker County, Texas, saw 318 lightning events per km² (825 per square mile)

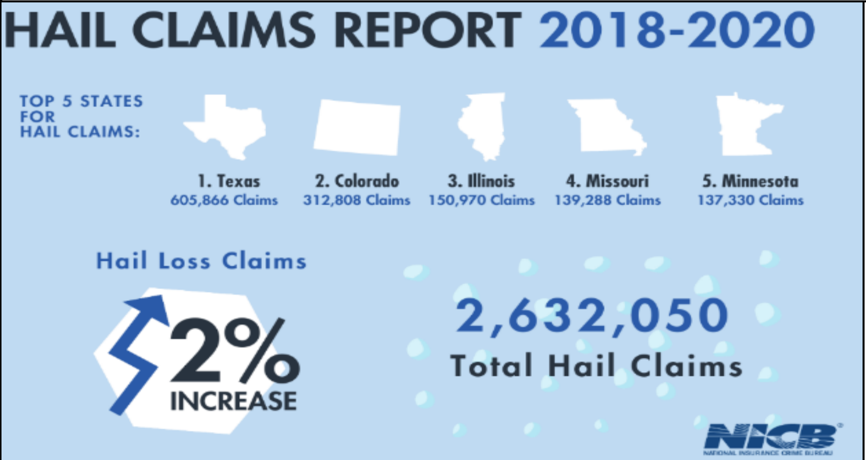




-- March 2025 produced a new record for tornadic activity in the US while April yielded 2x the average tornado count.
-- Hail reaching DVD size (4-5 inches) aka grapefruit size, has been reported in numerous states at increasing rates with last year producing melon size (+6 inches). Our largest piece of hail was reported 15 years ago in South Dakota as bowling ball size (8 inches) in diameter.







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.

- 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.
- 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.

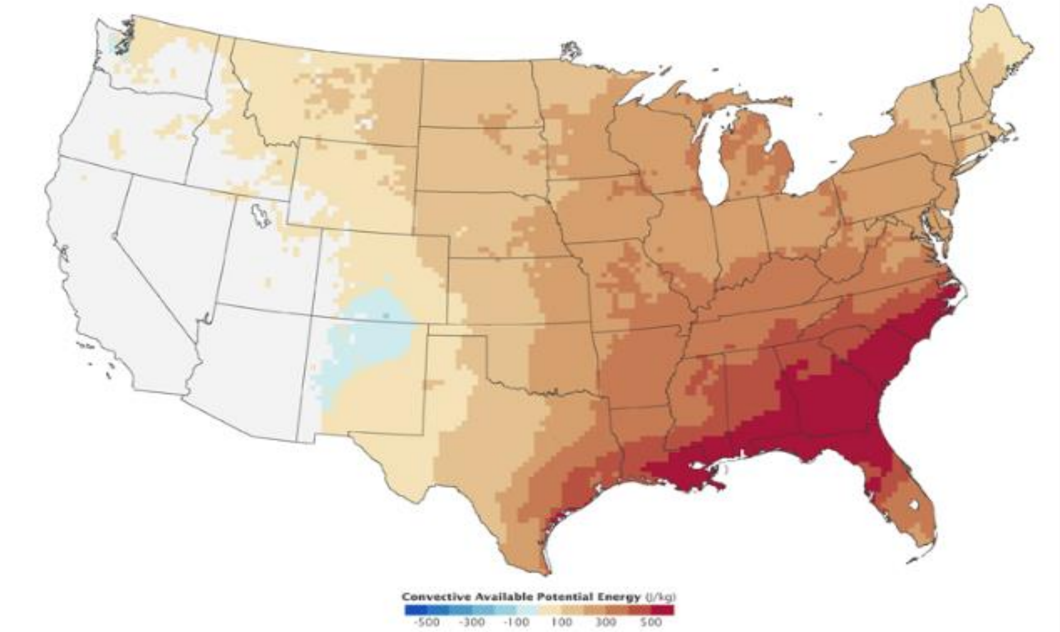
- Flashes that touch down amid minimal or no rainfall, known as dry lightning, are especially effective fire starters.
- Currently about 20 million lightning bolts touch down each year within the US.
- Hotter days may boost updraft within thunderstorms, causing lightning flashes to increase in frequency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

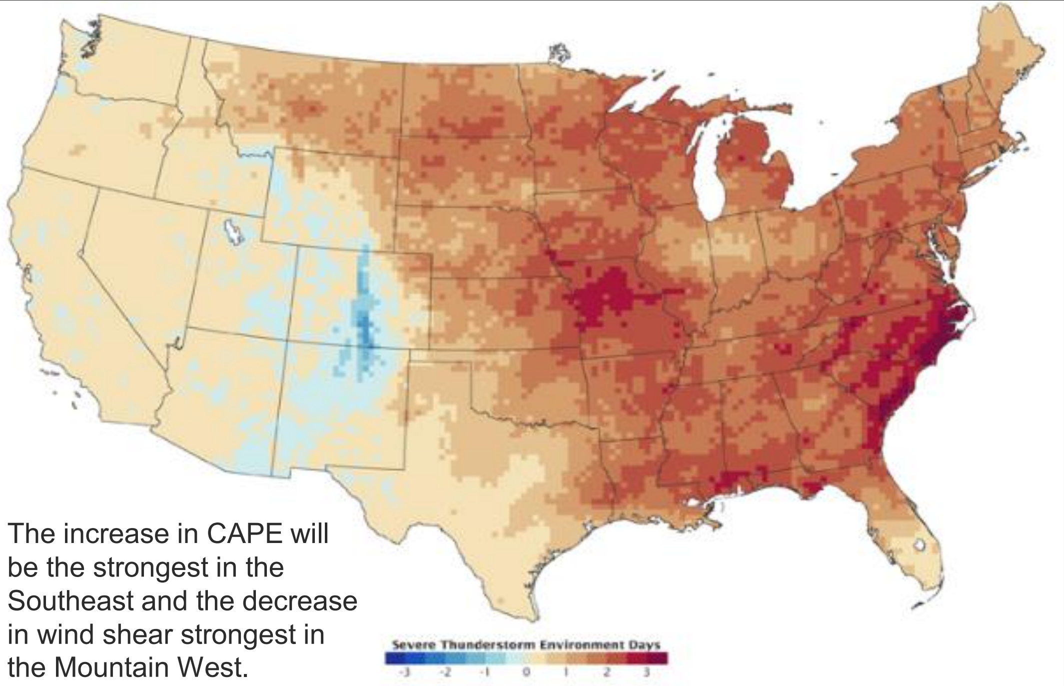
Hail: increasing temperatures and humidity could fuel larger hail and could mean smaller pellets are more likely to melt before hitting the ground.

- Damage from severe thunderstorms has been inching up by about 7% annually for 30 years. This raises concerns for supply chain delays and market driven pricing.
- Worldwide, thunderstorm losses were almost 90% higher than the previous five-year average of $32 billion and over <u>double</u> the previous 10-year average of $27 billion.

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.

Changes in Severity: Lightning and Hail

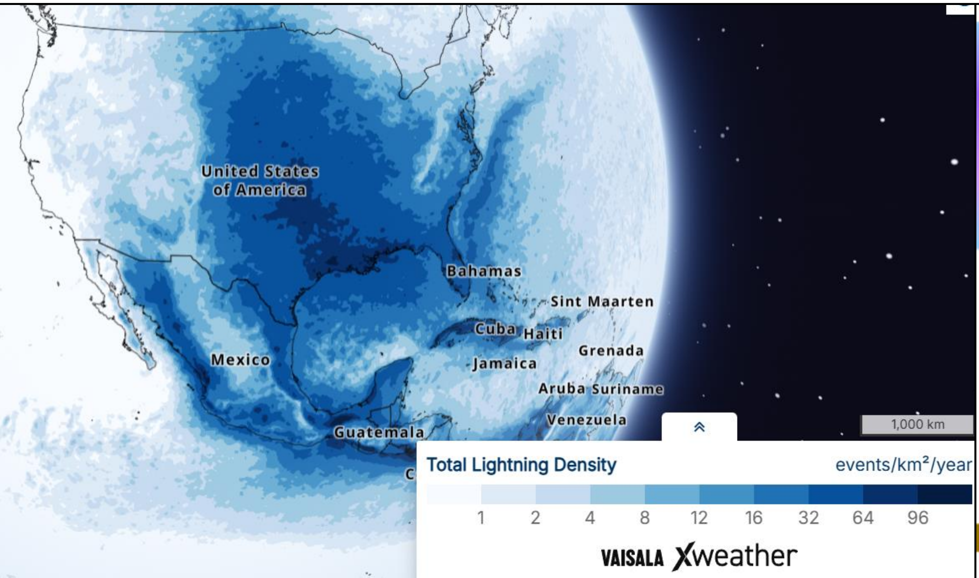
Hail is formed when strong updrafts in thunderstorms lift raindrops high into the atmosphere, where they freeze and grow larger by colliding with supercooled water droplets.

- The updraft essentially acts as a conveyor belt, carrying these frozen droplets upward and allowing them to gather more ice before eventually falling back to the ground as hail.
- As updrafts get taller due to the atmospheric height rising, the general stability of the storm will also weaken, causing a rise in microbursts and outflow events.
- Near-surface hailstones <4 cm are found to decrease in frequency by an average of 25%, whereas the largest stones are found to increase by 15–75% depending on the greenhouse gas emissions pathway.

Cloud heights increasing can be compared to the height of storms in the tropics reaching 19 kilometers versus about 12 kilometers in the temperate regions.

Lightning increases from taller clouds can result in more sprites and elves, which is when lightning pushes into the ionosphere and can mimic EMPs affecting radio wave propagation.

Atmospheric and Ionospheric Gravity Waves are also triggered by lightning modifying storms.



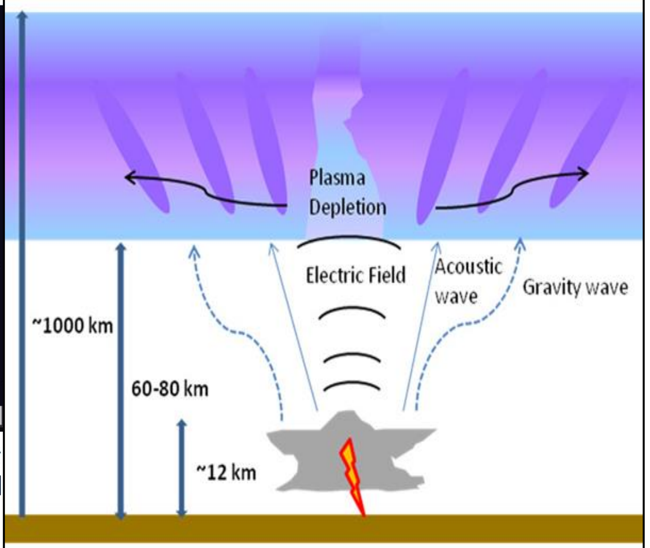
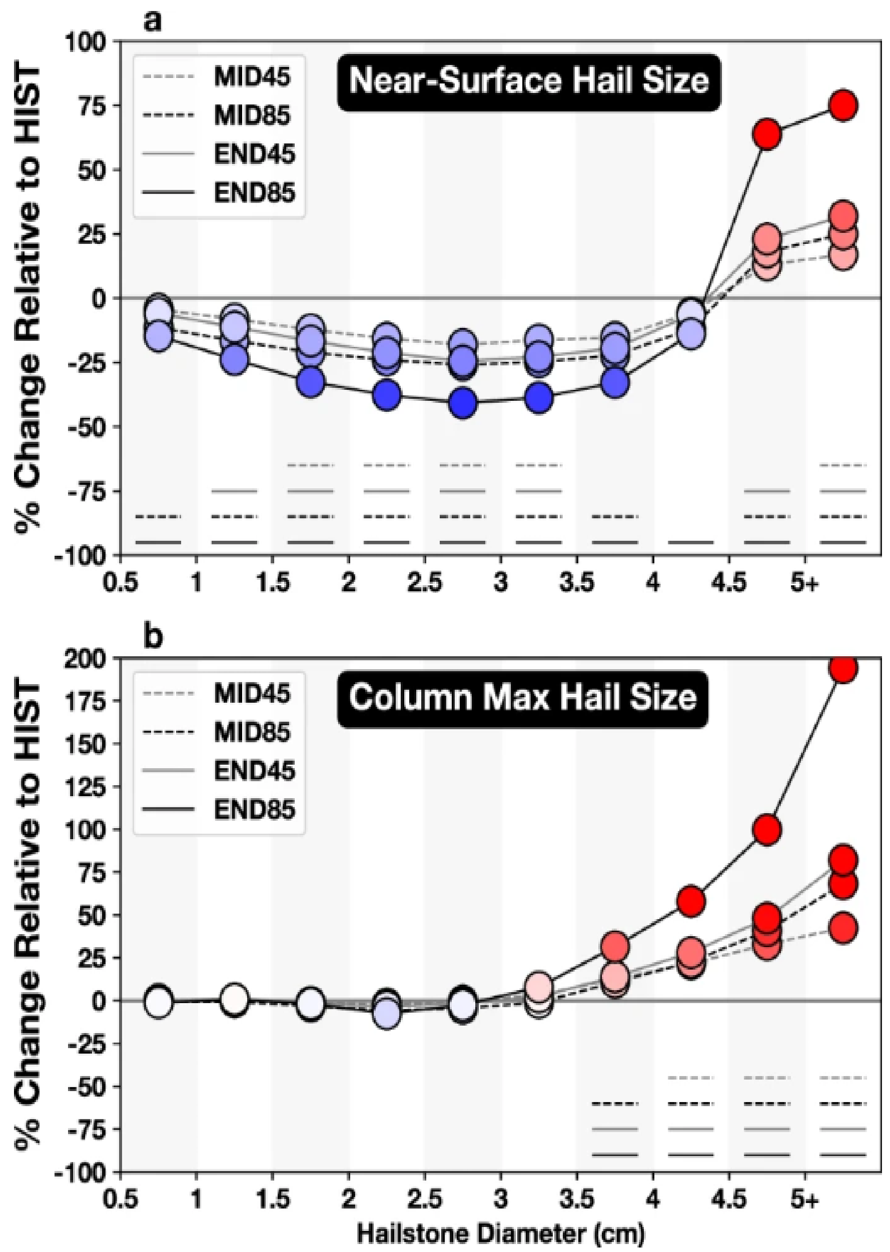


Fig. 1: Projected hailstone size changes.



Binned a near-surface and b column max hailstone diameter frequency for each WRF-BCC future epoch expressed as percent change relative to HIST. Statistically significant differences are displayed along the abscissa for each bin (i.e., horizontal lines corresponding to each experiment).

Hail Records Continue to Rise

2010: A hailstone was discovered in South Dakota measuring 8.0 inches in diameter, 18.625 inches in circumference, and weighing 1.94 pounds.

2016/2022/2024 Colorado reports 2-feet of hail requiring plow trucks to move and triggering flooding as the ice melted quickly at the surface.

2023-2025: Multiple states report melon-size hail (+6-inch diameter).

2025: Texas's new record hailstone reported at 7.25-inch diameter.

Pollution can influence hail formation and potentially lead to larger hailstones.

Pollutants provide cloud condensation nuclei, affecting the size and number of stones.

Hail severity will increase in most regions of the world while Australia and Europe are expected to experience more hailstorms.

Insured U.S. hail losses now average $8 billion to $14 billion per year, or $80-140 billion per decade (as of 2022).

This outpaces the total of $14.1 billion in insured US property loss from tornadoes over the decade from 2010 to 2020.

TEXAS Record MONSTER Hailstone!

Documented 7.25" hailstone 3 miles WNW of Vigo Park, Texas at 7:37pm Sunday set a new state record (pending) shattering the previous record of 6.4" in Hondo, TX in 2021.

Permission: Val and Amy Castor 7:25 PM · Jun 4, 2024

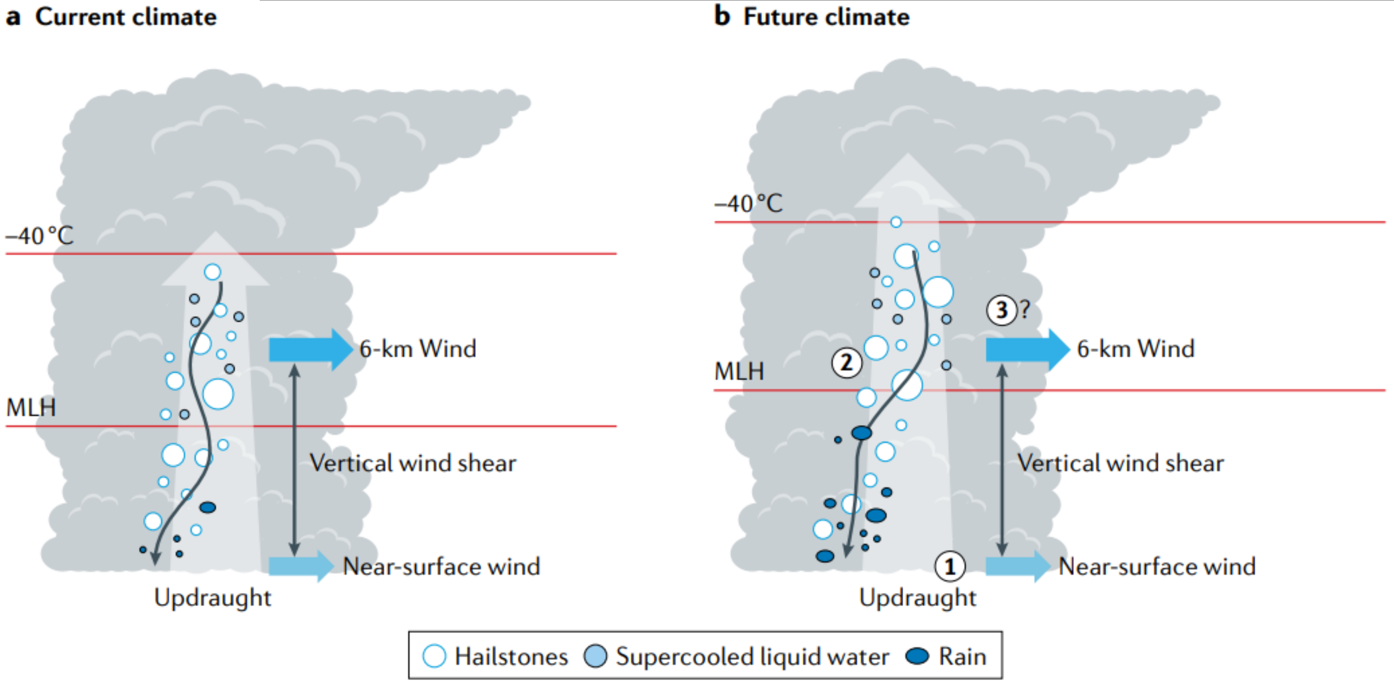


Fig. 1 | **Hail-relevant atmospheric phenomena in current and future climates.** The expected changes in hail-relevant atmospheric phenomena between the current (panel **a**) and future (panel **b**) climates. The numbers in panel **b** correspond to the following changes: (1) increased low-level moisture leads to increased convective instability and updraught strength; (2) an increase in the melting level height (MLH) leads to enhanced melting of hailstones and a shift in the distribution of hailstone sizes towards larger hailstones; and (3) changes in vertical wind shear may affect storm structure and hailstone trajectories, but are generally overshadowed by instability changes.

Inches Per Hour and Peak Wind Risks Rise

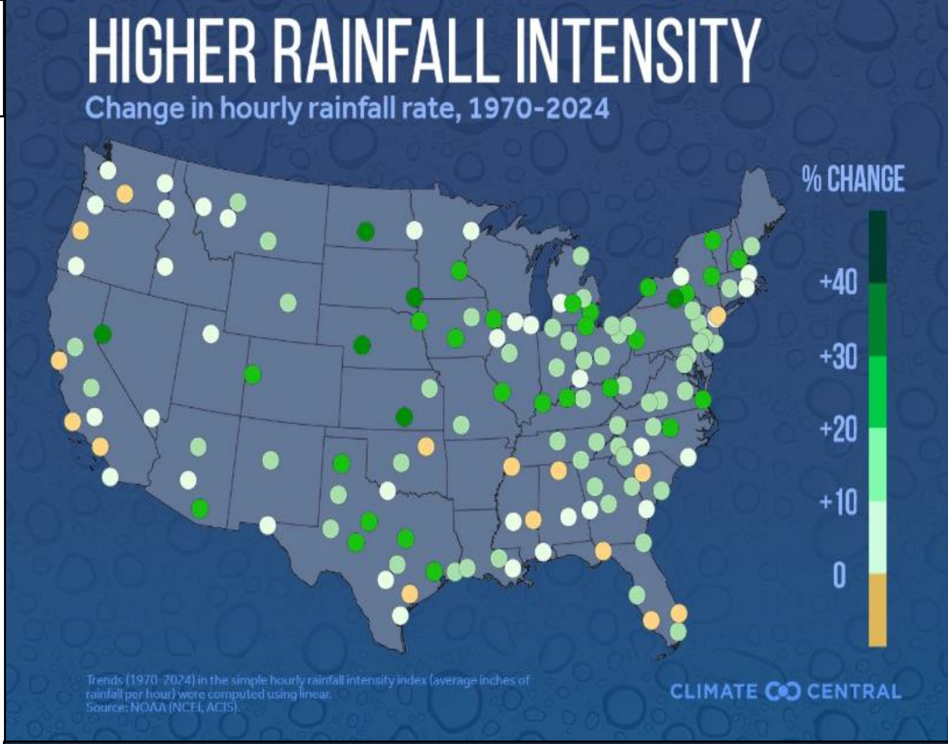
With 2°C (3.6°F) of global warming, the majority (85% or 2,645) of 3,111 total U.S. counties are likely to experience a 10% or higher increase in precipitation falling on the heaviest 1% of days.

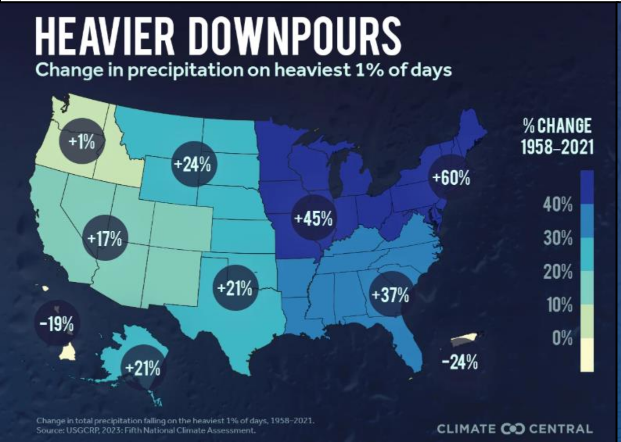
A 2024 study by Climate Central found that 126 of 144 US cities they examined saw an increase in hourly rainfall intensity from 1970 to 2022.

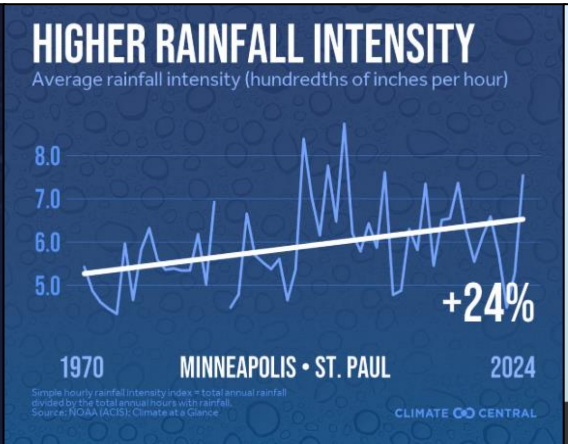
- Rainfall hours became 15% wetter on average across the 126 cities studied with an 88% increase in hourly rainfall rates.
  - The highest known one-hour rainfall total in the US is 12 inches in Holt, Missouri, on June 22, 1947. This rainfall occurred in just 42 minutes.
  - The highest known 1-minute total is also held by the US in Unionville, Maryland at 1.23 inches in 1956.
  - The record 6-hour rainfall was in Smethport, PA at 34.5 inches. A record 42 inches were reported in 24 hours in Alvin, Texas in 1979.

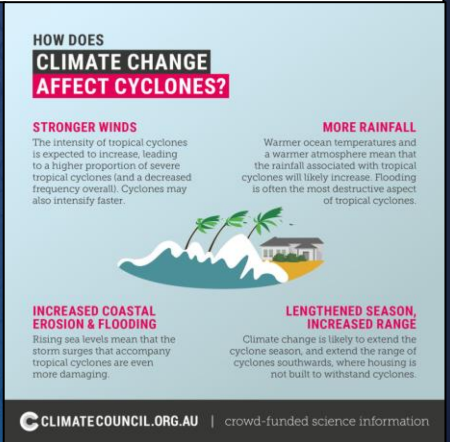
A new study finds the strongest nor'easters have intensified over the last 80 years, with a 6% increase in peak wind speeds resulting in a nearly 20% increase in destruction potential.

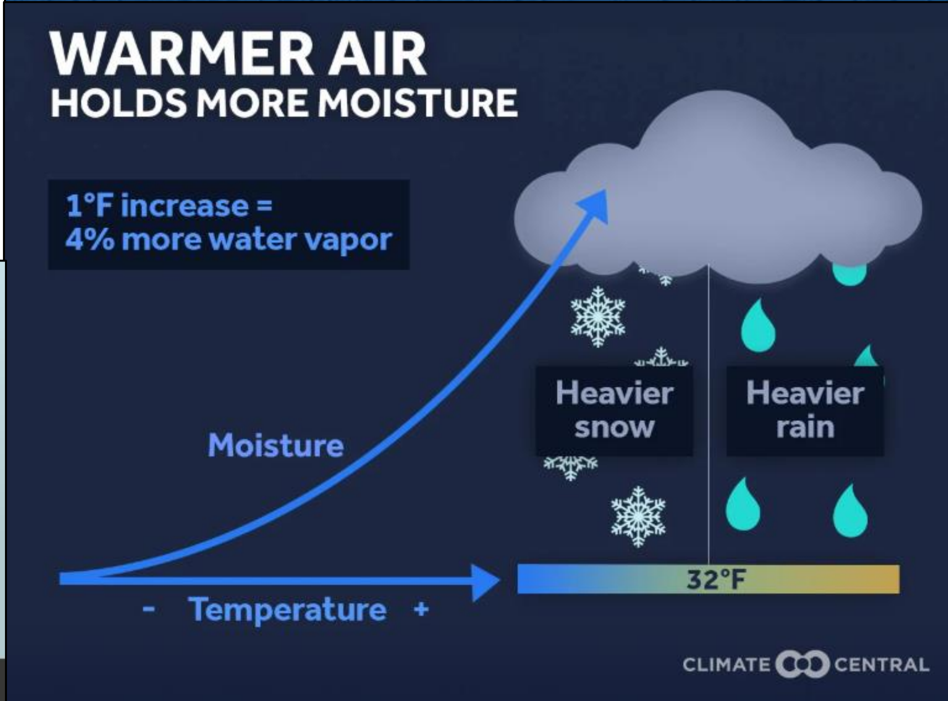
- [Previous studies](#) published have predicted an increase in the intensity of extratropical storms close to the northeastern US due to warming during the cool season.
  - The strongest wind gust recorded in the US was 231 mph at Mt. Washington in 1934











Flooding Changes: Flashier Flash Floods

Floods are the most common natural disaster in the US and about 41 million U.S. residents are at risk from flooding along rivers and streams.

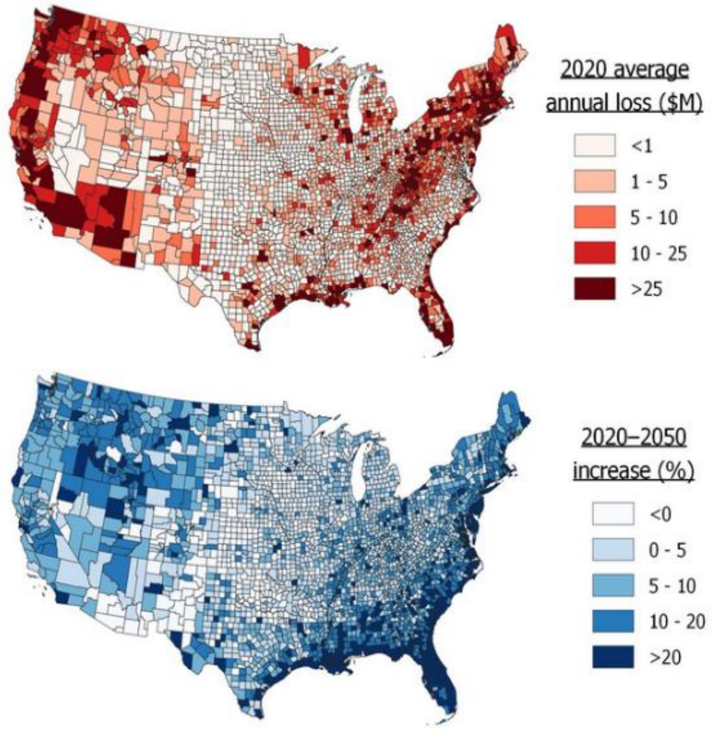
- River flooding can result from heavy rainfall, rapid snow melt, or ice jams thawing resulting in riverbank damages.
- Urban flooding refers to flooding that occurs when rainfall overwhelms the local stormwater drainage capacity of a densely populated area causing water to continue to overflow into communities and infrastructure sites.

Extreme flooding will continue to be concentrated in regions where humans have built on floodplains or low-lying coastal regions. As extreme weather events increase, risks will extend into new areas.

- 1,000-year flood events will occur more often due to increased land use and heavier precipitation. The term "1,000-year flood" means a flood of that magnitude (or greater) has a 1 in 1,000 chance of occurring in any given year. In 2022, the US reported five 1-in-1,000-year flood events in different states causing catastrophic damages.

New research shows as the baseline temperature annually creeps upward due to moderate to high emission rates, flooding events would become 8% "flashier" by the end of the century. This means that heavy rainfall events are likely to occur quickly and in concentrated areas that could lead to torrential flooding.

- A more than 10% increase in flash flooding in the Southwest U.S. which accounts for the greatest increase in "flashiness" among hot spots. Flooding is a factor in over 90% of disaster-related property damage in the US.
- "The 20-year return floods will more likely occur every two to five years, especially alarming for the emerging flashiness hotspots that will be facing unprecedented challenges with aging infrastructure and outdated flood risk measures" Yang Hong.. https://www.un.org/en/climatechange/reports?gclid=Cj0KCQjwjN-SBhCkARIsACsrBz6h_uH-xJnN2929g3CDEV9GZVLFEGh6KWfiNgneXUlf6d78n4Tlk24aAg3fEALw_wcB

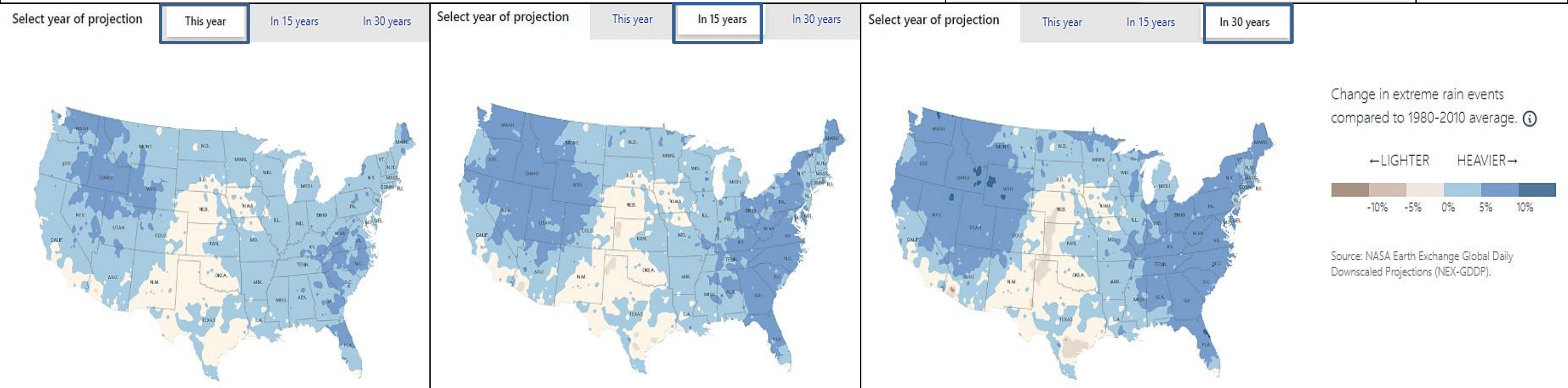


Map of US annual average loss due to flooding by county, and its projected change by 2050. (fathom.global)

A 2021 study indicated the average annual flood losses are forecast to increase by 26% by 2050, from $32 billion to $40.6 billion, based on 2021-dollar values.

The average annual exposure of the population to floods is expected to rise 97% from current levels by 2050, to over 7 million by 2050.

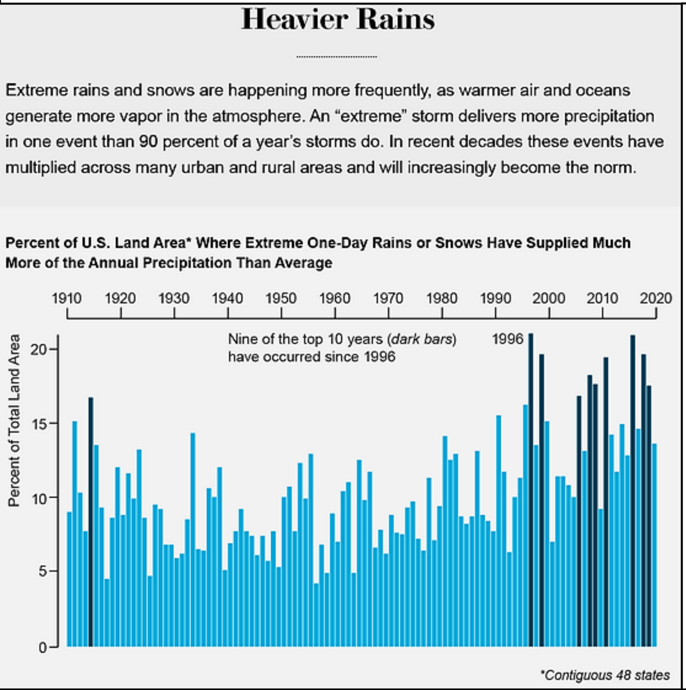
A flood can impact anyone.



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

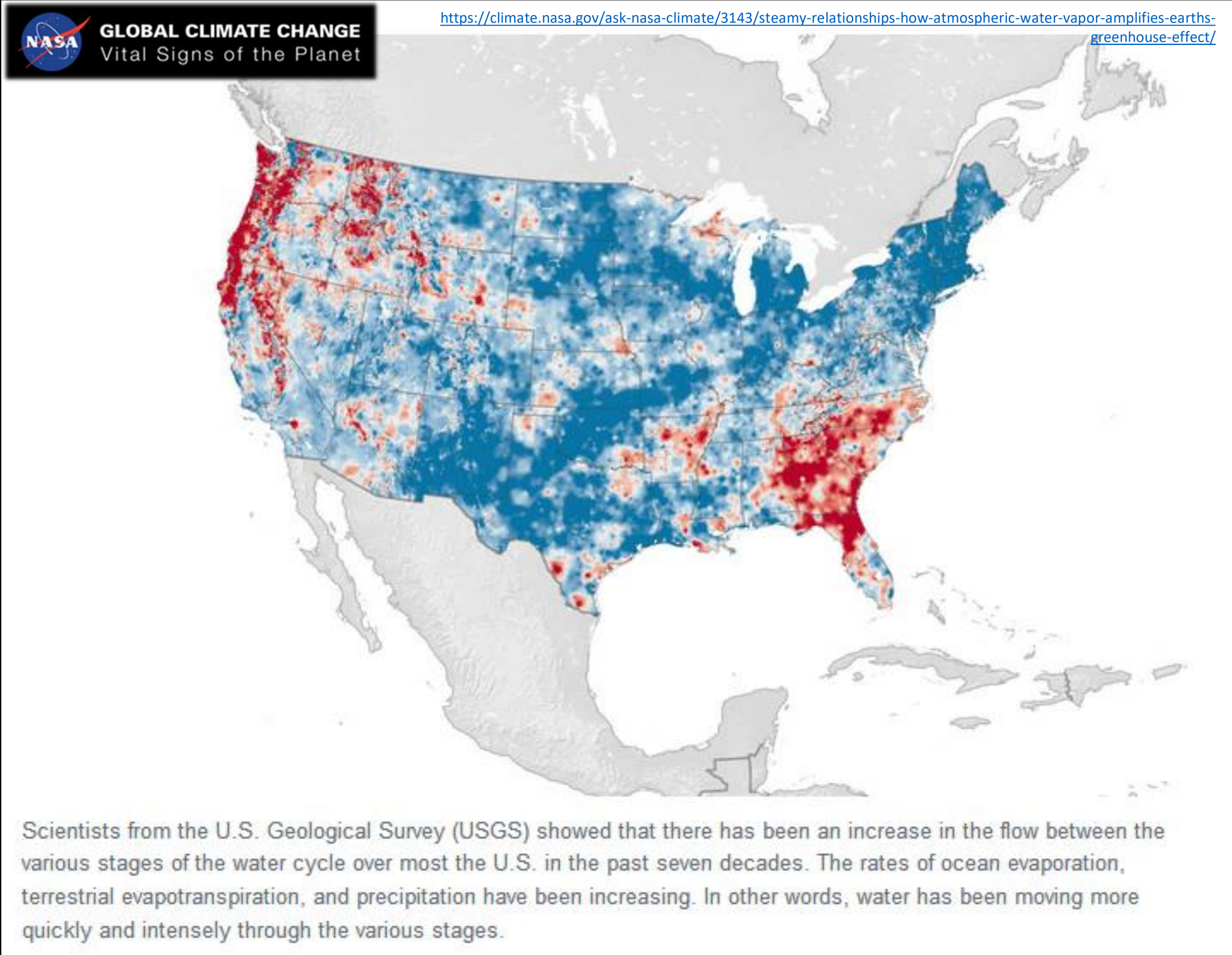
Increases in atmospheric water vapor also amplify the global water cycle. They contribute to making wet regions wetter and dry regions drier. The more water vapor that air contains, the more energy it holds. This energy fuels intense storms, particularly over land. This results in more extreme weather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

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



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).

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.

BLUF: Extreme Weather Trends for Stormwater

Extreme rain can cause flooding in low-lying areas that have poor drainage and insufficient stormwater infrastructure systems.

This can cause flooding throughout the city, even for inland neighborhoods. Rain-driven flooding can occur suddenly and intensely, but flood conditions may subside more quickly compared to coastal surge flooding.

Extreme rainfall events will increase in number and severity in the future because of the change in baseline temperatures.

By the end of the century, cities could experience as much as 30% more annual rainfall than today, and 1.5 times as many days with over an inch of rain.

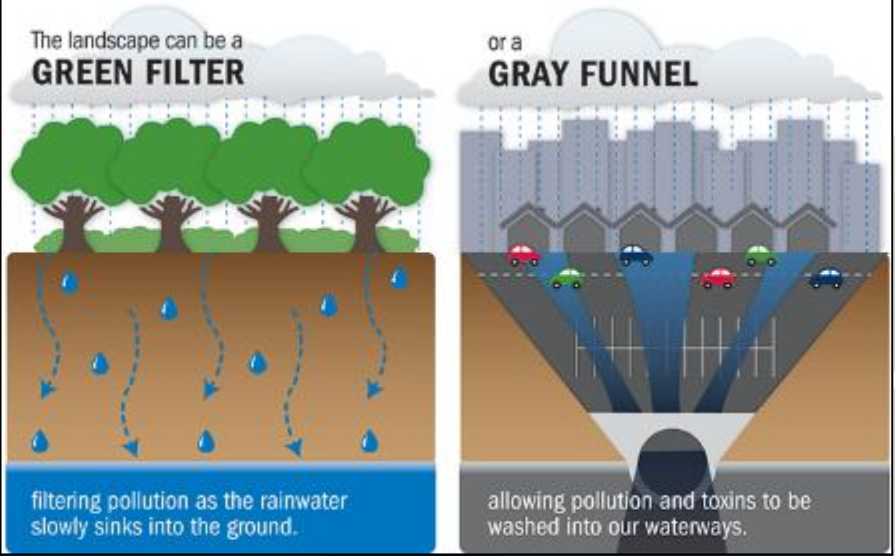
As sea level and groundwater tables rise, stormwater will drain more slowly and contribute to flooding.

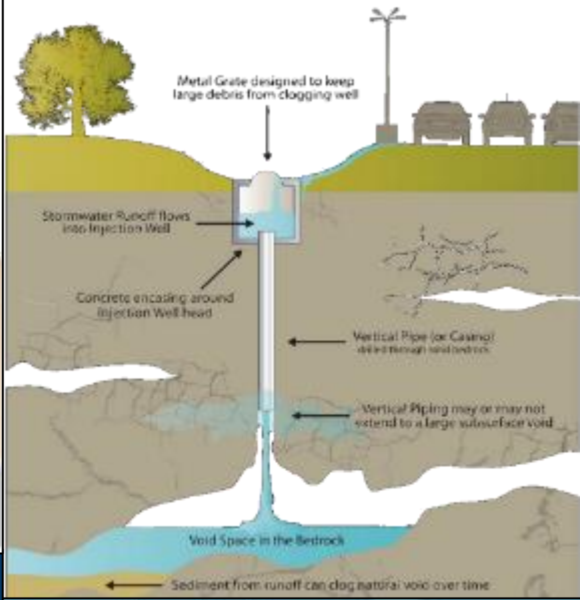
- Record rainfall events in 2019 resulted in more than 100 Minnesota communities releasing partially treated wastewater into area rivers and streams.
- Untreated sewage carries pathogens and other contaminants that pose human health and ecological risks.

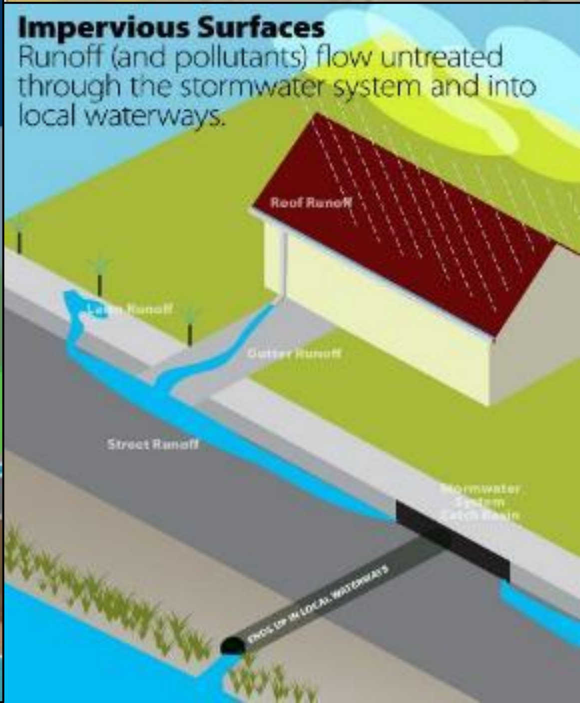
Extreme temperature swings can degrade the quality of materials in addition to the aging process already underway.

- Canals, reservoirs, earthen dams, roadways, sidewalks, and drainage ditches require water to hold the soils together.

Sinkholes are just one of many forms of ground collapse, or subsidence. Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement.







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.

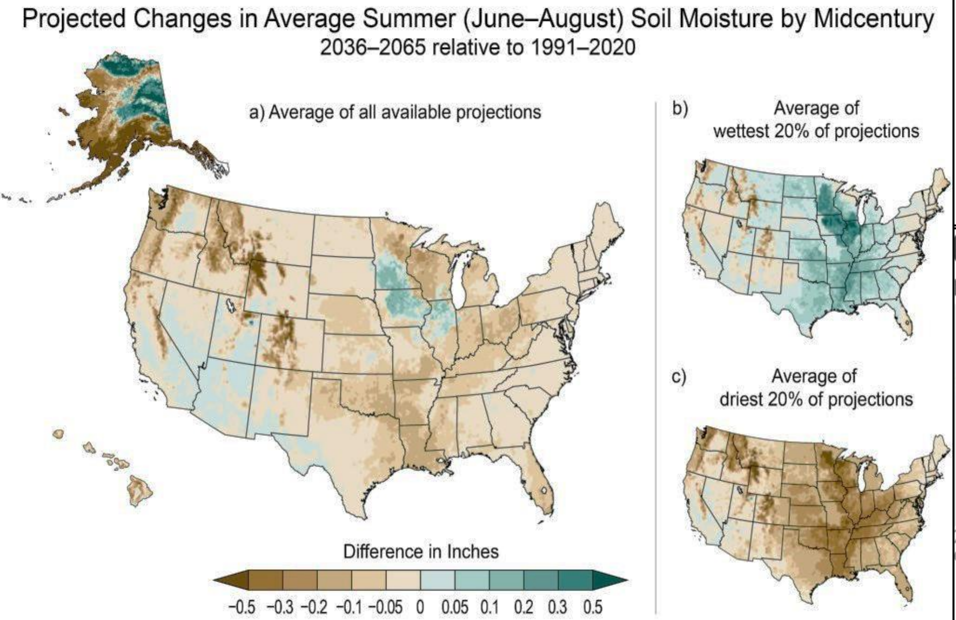
- Surface water is under threat from evaporation, dried soils, increased use for agricultural needs, theft for private consumer use, and a rapidly changing ecology from the drying climate.

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.

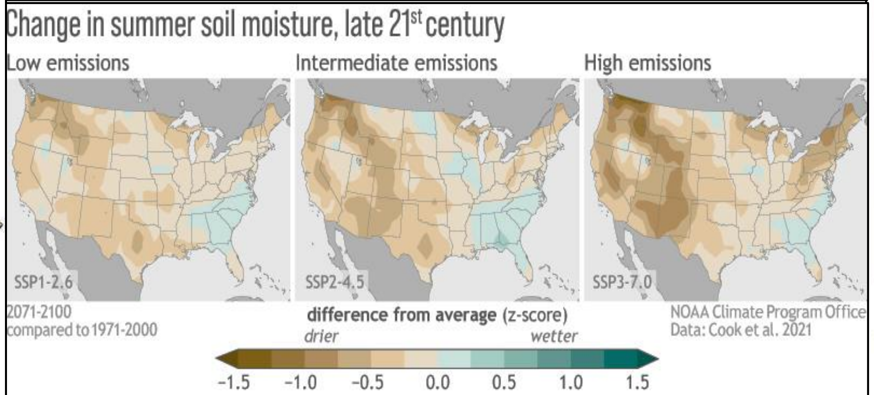
Reductions in water availability can halt developers and certain building repairs, renovations, or retrofitting. Impacts from persisting drought can be mitigated with water recycling such as black or grey water recycling, closed-loop systems, or alternative resources for backup if the primary source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

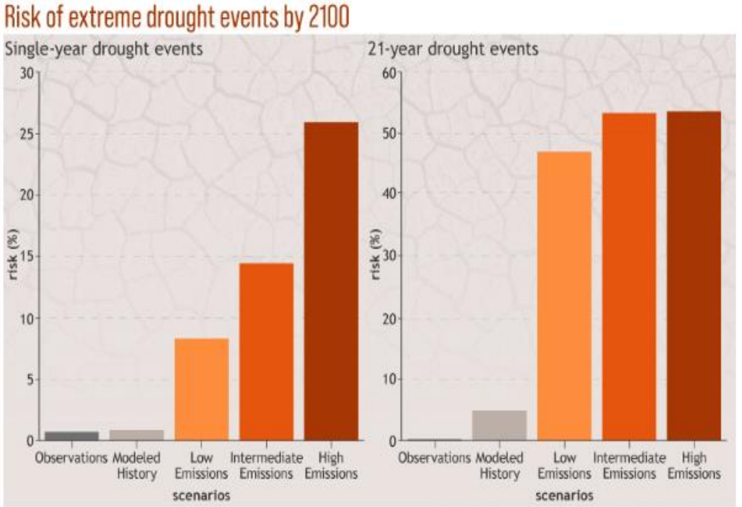
- Clay-based soil types dry and shrink when a drought occurs, resulting in uneven settling that can damage a building's foundation. Low soil moisture causes contraction away from the foundation, compromising the bond. This leads to foundation cracking, damaged pipes, sloping floors, and warped windows 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.

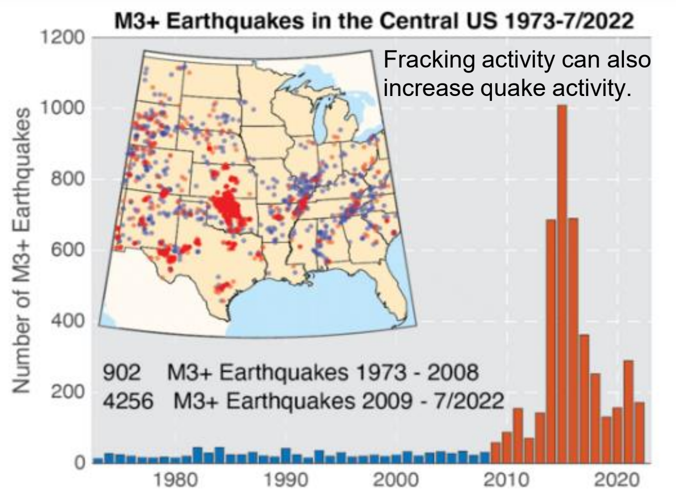
The areas around fault lines have valleys where the plates meet and are at their weakest point. Due to the lower elevations around these topography features, water tends to pool at the lowest elevation and thereby river systems were naturally located in the weaker spots of the fault line.

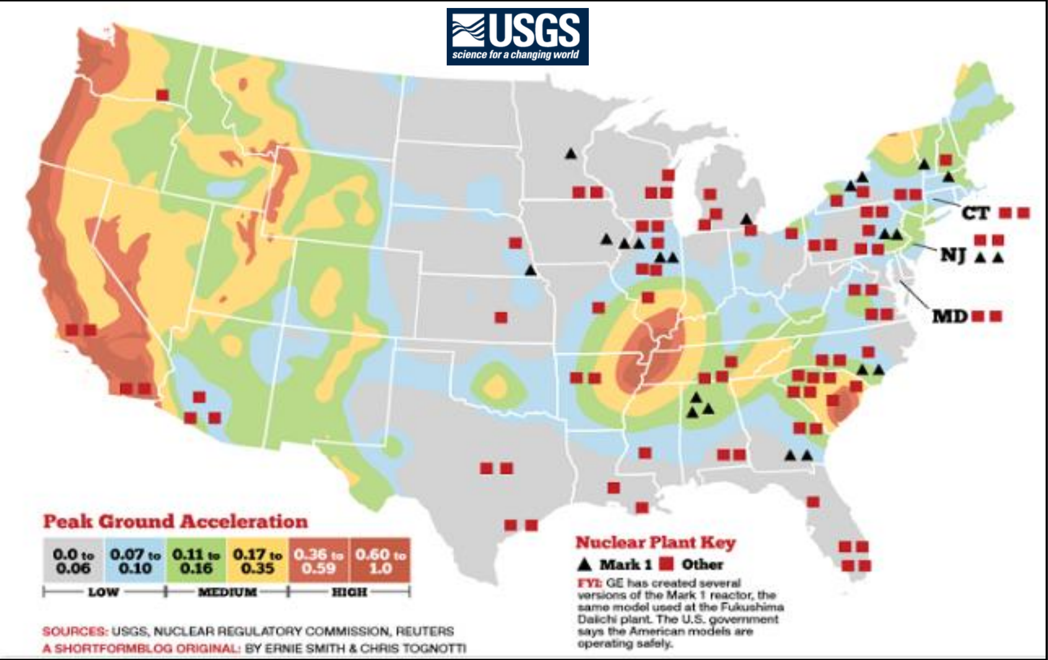
- Damming up the river system resulted in compounding water in different areas than were natural along some faults. As dams were installed, an increase in seismic activity was reported and subsequently as drought has developed, activity has increased again near the river/dam systems.

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.

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.

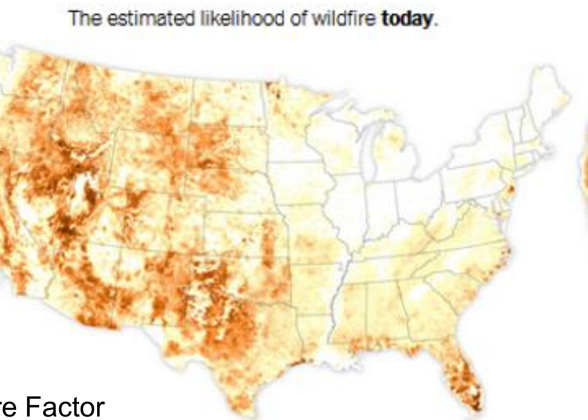
A study from the University of Colorado states wildfires have become larger, more frequent, and more widespread since the year 2000.

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.

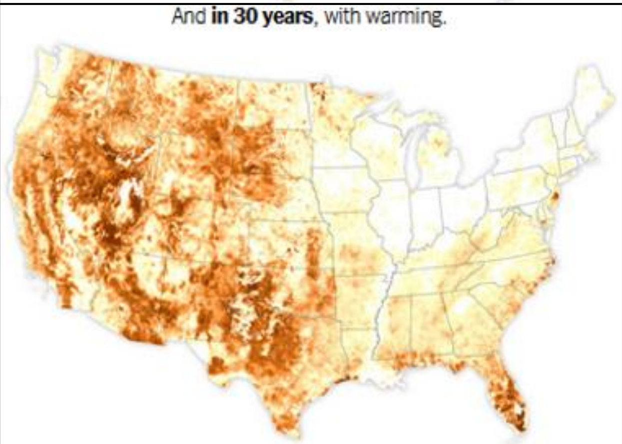
A new study from the University of Montana highlights burn scar impacts to tree regrowth across various regions, indicating new tree seedlings are unable to survive in hotter climates where parent trees remain. The study indicated that if large areas of the forested parts of the Rocky Mountains burned,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

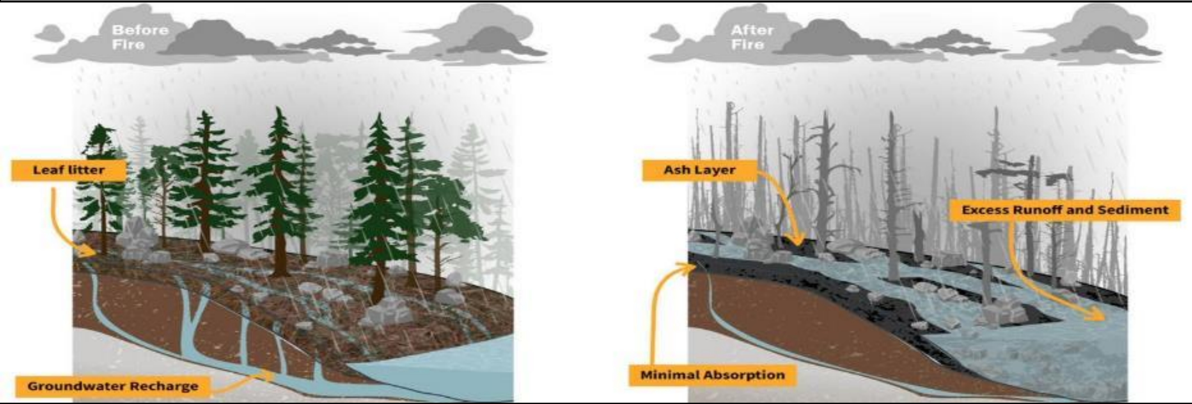
Satellite imagery and state/federal fire history records from 28,000 fires in 1984-2018 showed more fires occurred in the past 13 years than the previous 20 years. On the West and East coasts, fire frequency **doubled**. In the Great Plains, fire frequency **quadrupled**.

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



Fire Factor

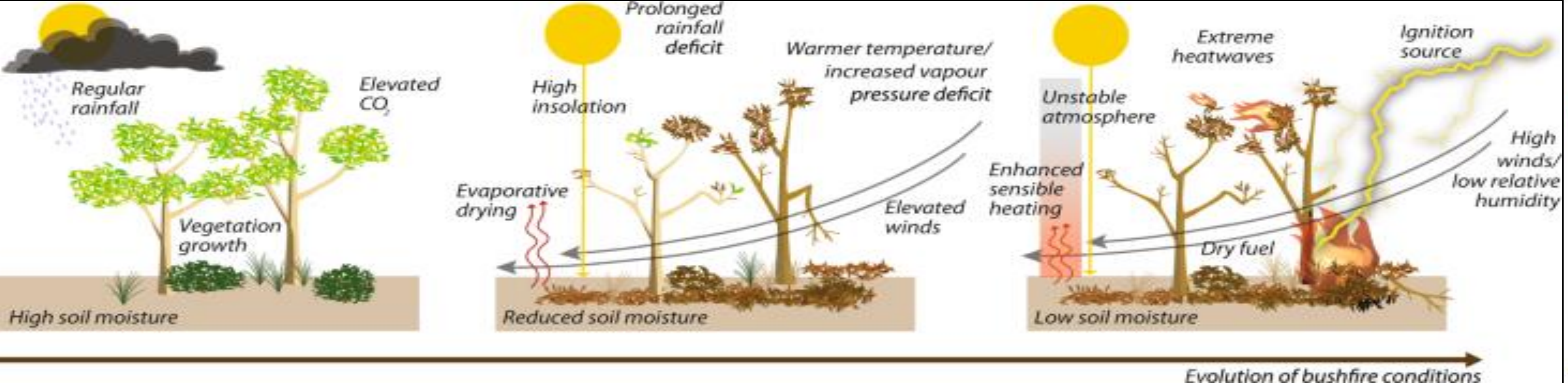


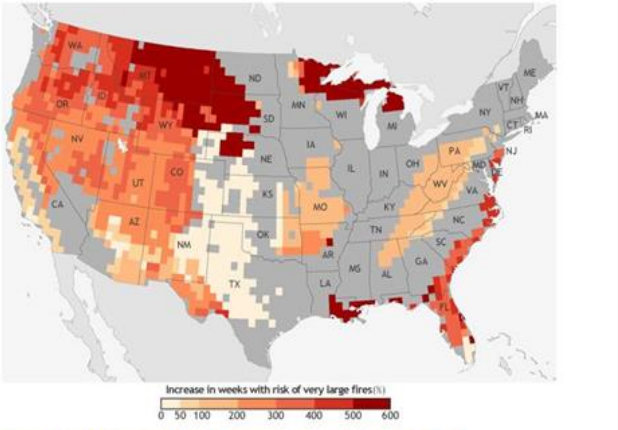


Disasters related to weather, climate, or water hazards happen five times more often now than they did in the 1970s. Droughts that may have occurred only once every decade or so now happen 70% more often.

- 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.

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 to Infrastructure

Since the beginning of the 20th century, temperatures in Wisconsin have risen more than 2°F, and temperatures in the 2000s have been warmer than in any other historical period.

- Like much of the Midwest, this warming has been concentrated in the winter and spring. Warmer spring temperatures present the additional threat of frost-freeze damage to early-budding fruit trees.
- The increase in winter temperatures has also reduced lake ice cover. Ice coverage in the Great Lakes has been declining since the 1970s.
    - These upward trends are attributed to warmer air temperatures, which create more moisture availability due to warmer surface water temperatures and reduced lake ice coverage.
        - Annual snowfall totals have increased over Wisconsin since 1930.

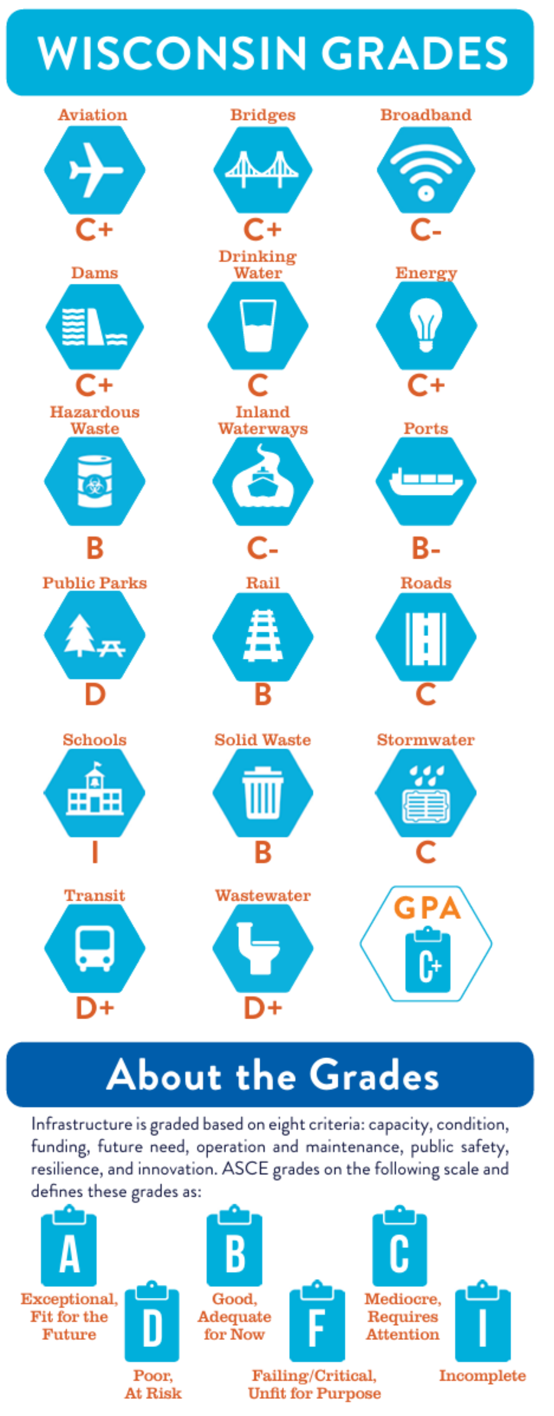
As of Aug. 12, Milwaukee will have endured 24 days of poor air quality from the Canadian wildfire smokes, 38 days of extreme heat and a mess of disasters from the past weekend's 1,000-year flood.

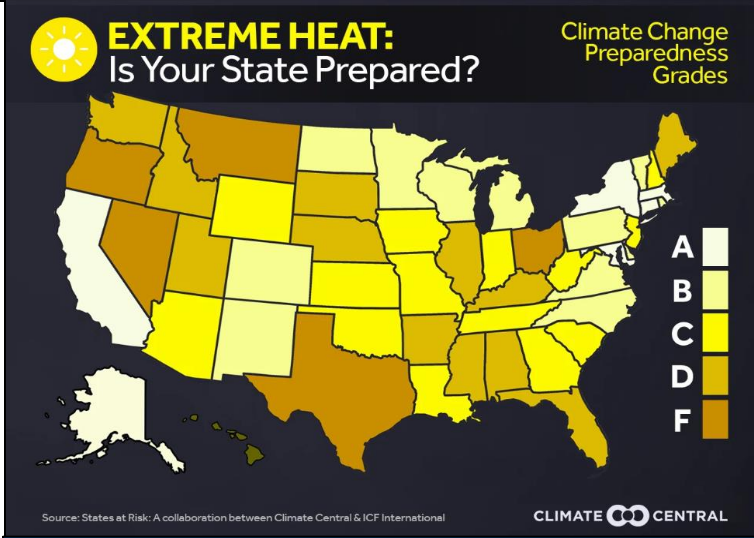
- Green Bay had 10 extra days of above-average summer temperatures, Milwaukee's had eight, totaling 38 days of above-average heat. “It hasn't been this humid in Wisconsin since 1979, state climatology office says”.

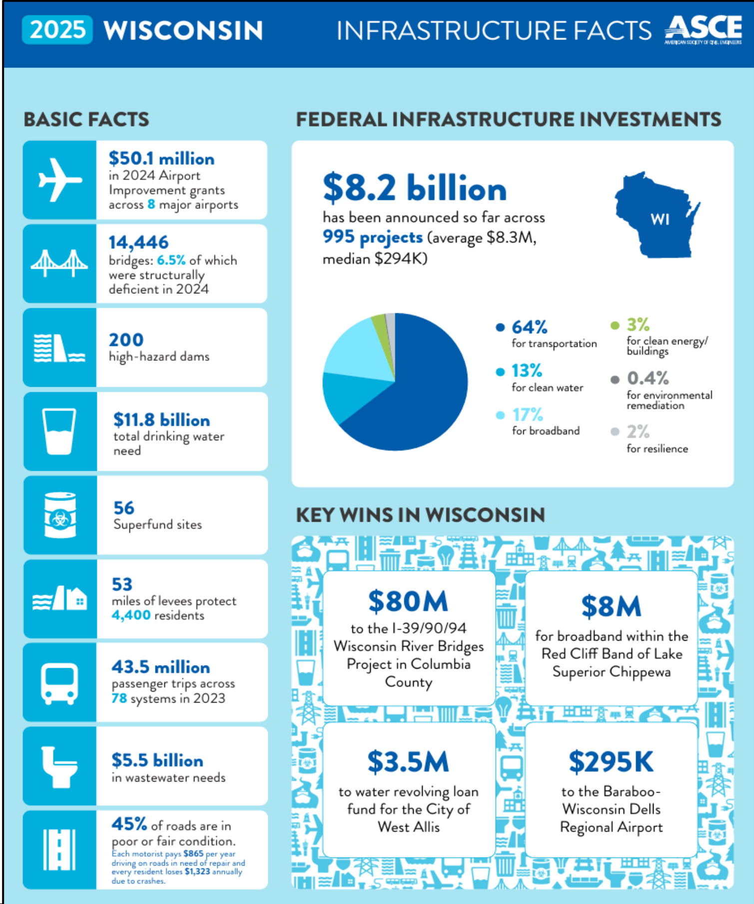
Energy CI Review: Coal power production has dropped by one-third while natural gas production has increased by two-thirds from 2015 to 2020.

- Wind, hydroelectric, and solar increased in that span, but remain fractional compared to gas generation, where overreliance on one source presents resilience risks.
- Electric rates help to fund significant portions of energy grid projects connecting power from sources to uses, and Wisconsin’s $0.14 per KWh rate is slightly higher than the national average.

Precipitation is projected to increase for Wisconsin, with the most likely increases occurring during the winter and spring. but snowfall is projected to decline due to warmer temperatures. Additionally, extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods.



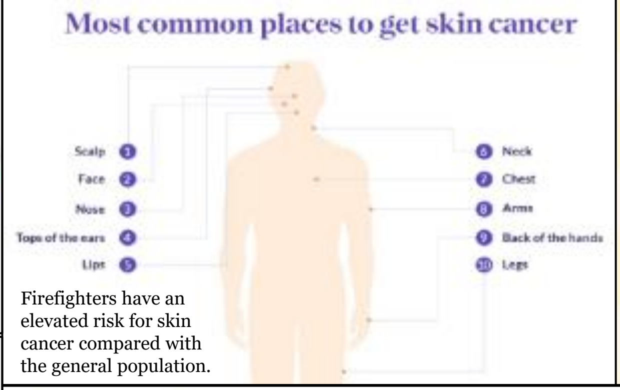


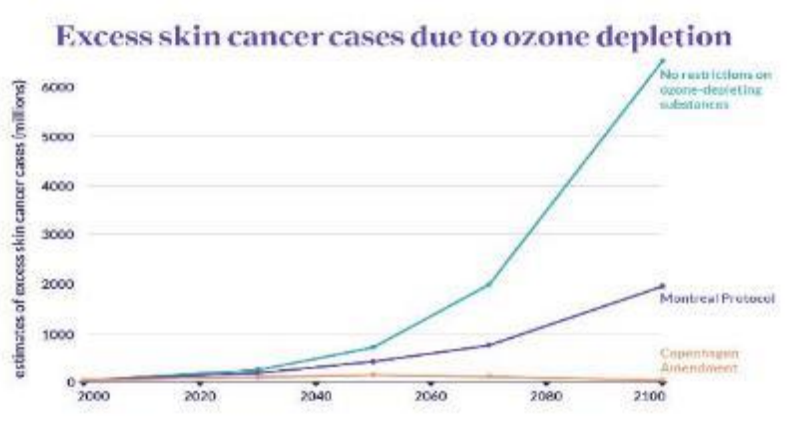


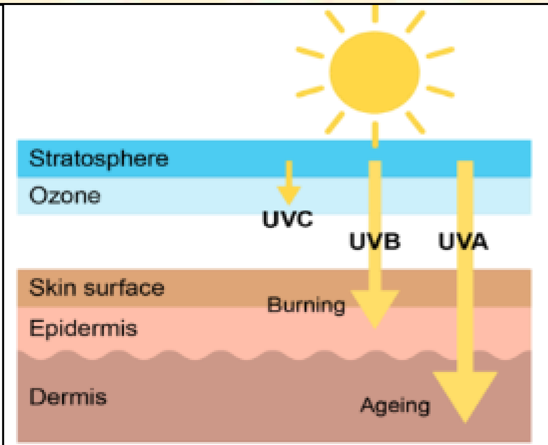
‘Too Hot To Op’

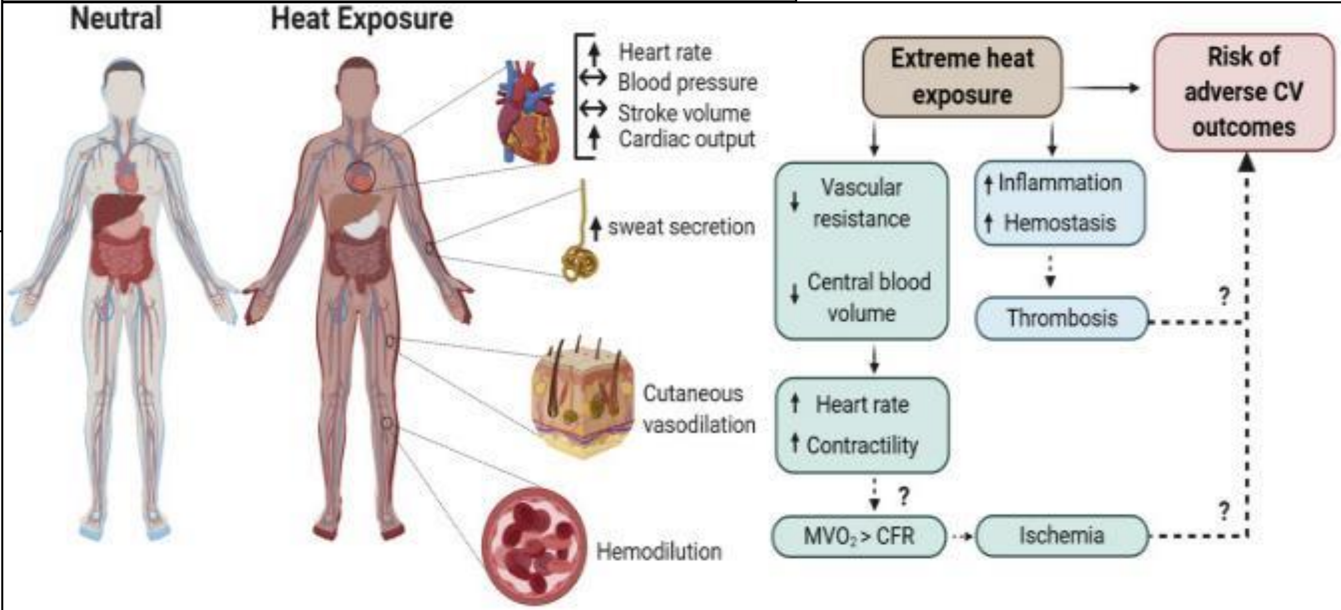
First Responders/Operators Risks from Heat

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



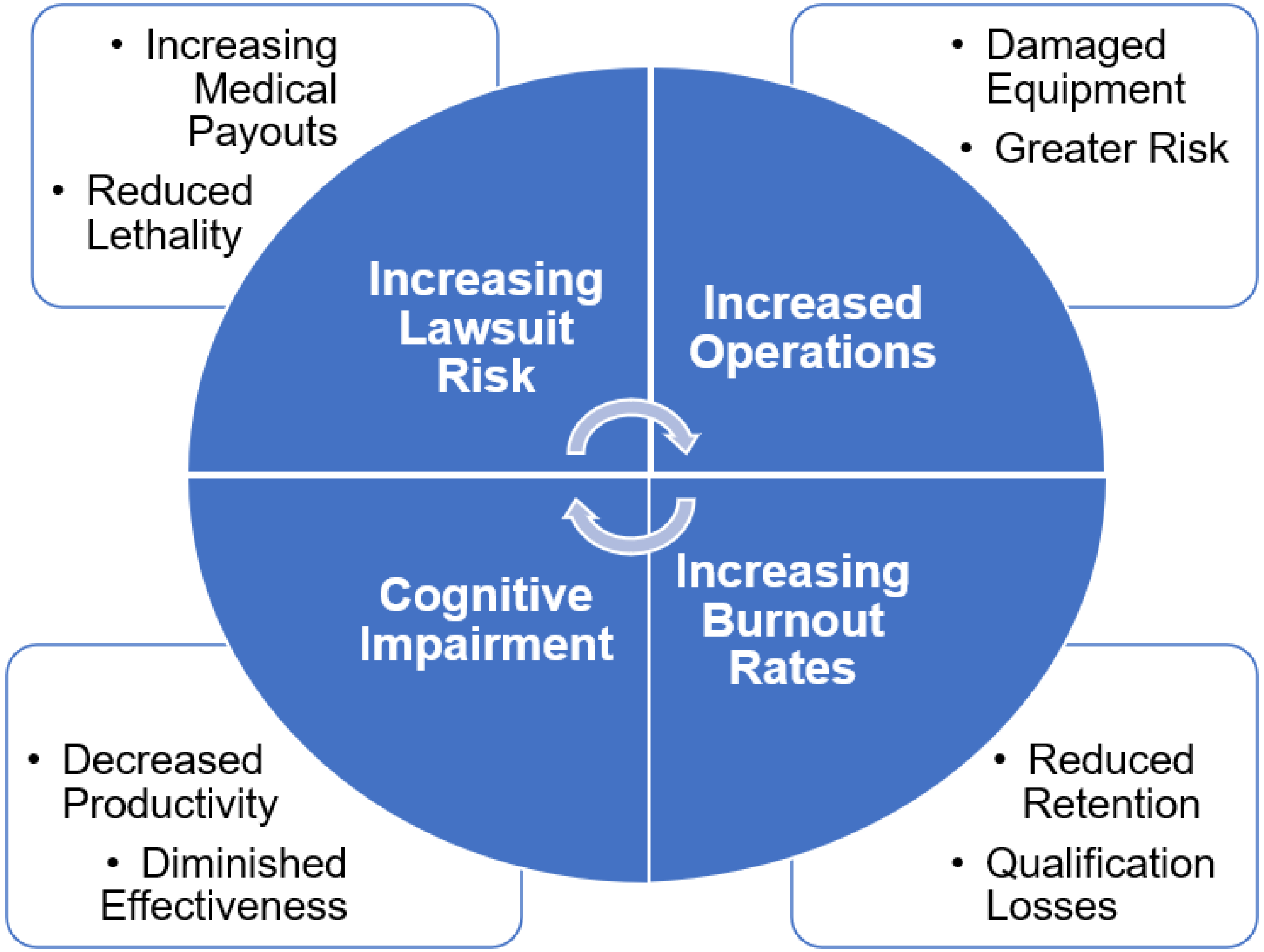


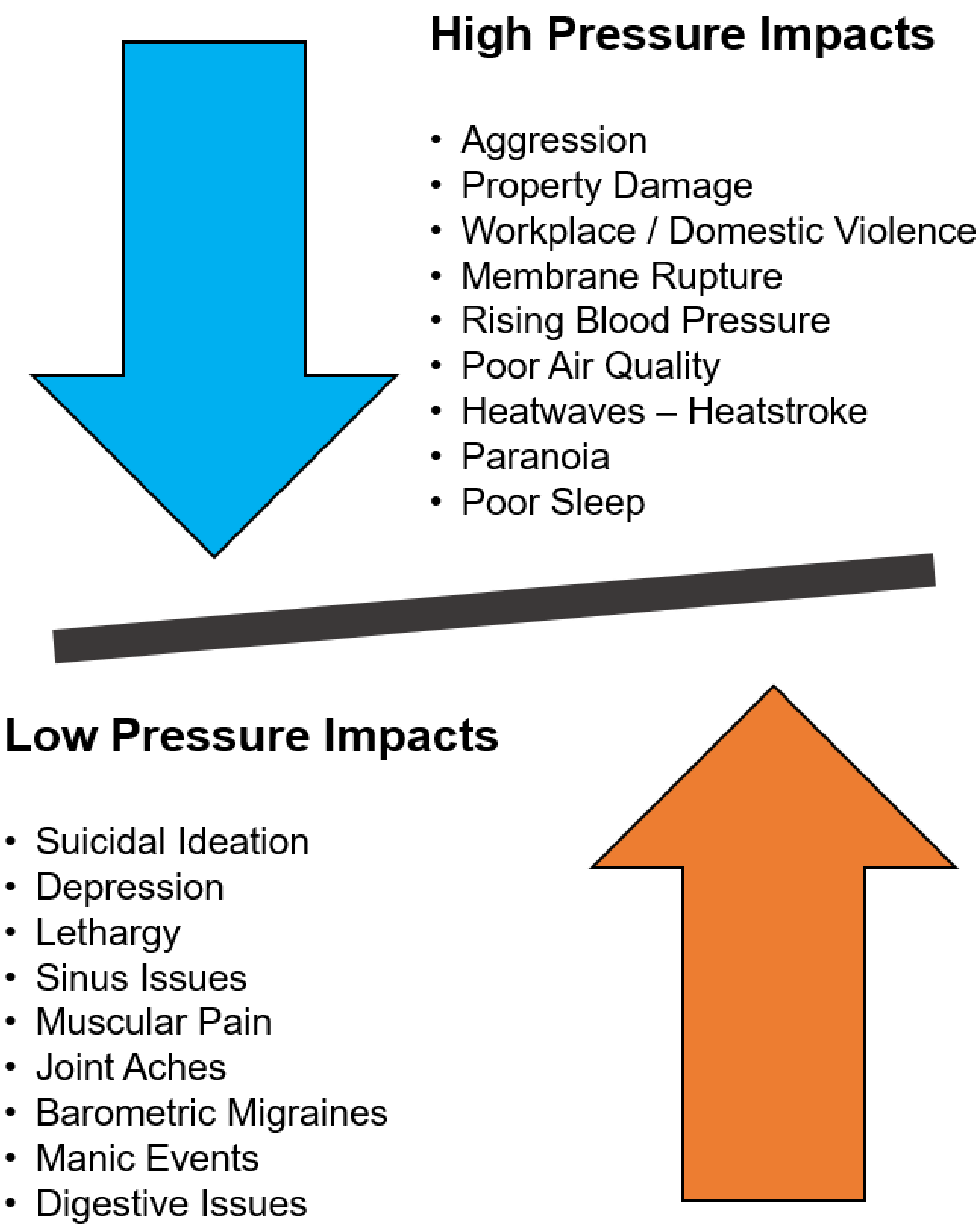




Higher Highs → Lower Lows

Variations outside of the normal for barometric centers present growing operational risks to emergency managers as many struggle to understand the impacts from this invisible threat and are thereby caught off-guard by the symptoms degrading their work performance and destabilizing societal norms.





High-Pressures and Humans

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 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 weather instability contributed to between 3% to 20% of conflicts over the last century with the potential influence set to increase substantially due to warming temperatures.
- Research from Mexico took 16 years' worth of daily crime records and found an increase in temperature of 1C correlated with an increase across all types of crime by 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: Overall crime increases by 2.2% and violent crime by 5.7% on days with maximum temperatures above 85F (29.4C).

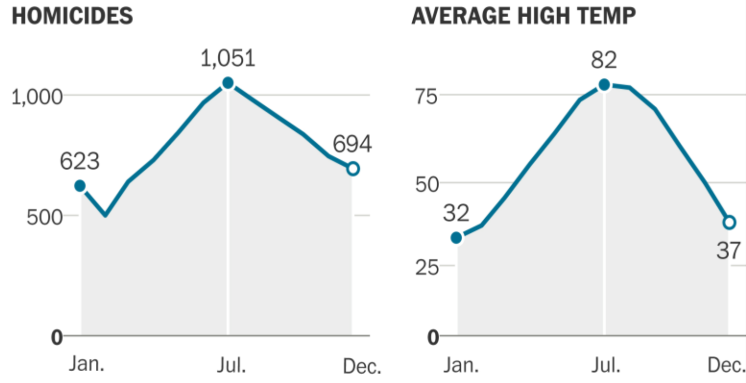
A 2019 study on terrorist attacks found that not only were terrorist attacks more common on hotter days, but also that the number of fatalities per attack were higher.

Even if the world's countries managed to keep "global temperature rise this century well below 2C 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.

Temperature and violence

Total homicides in Chicago, by month, 2001 – 2018, with average daily high temperature by month

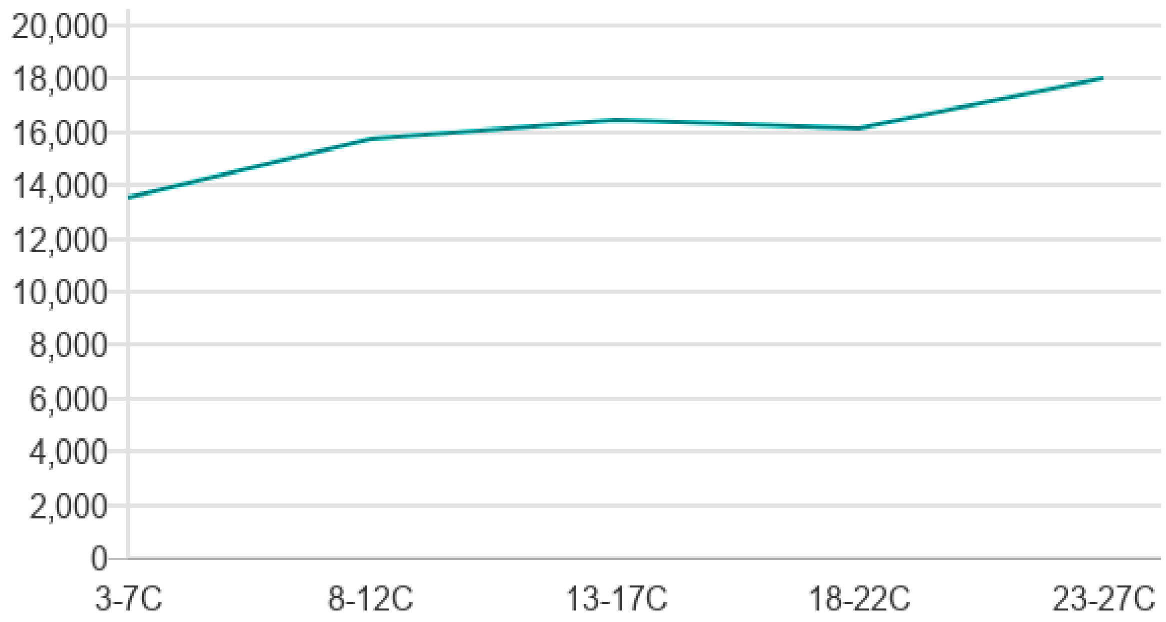


Sources: City of Chicago, NOAA

The Washington Post

As temperatures rise, so does violent crime

Average violent crime rates vs average temperature, London



Source: Metropolitan Police

BBC

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.

Recent studies found that temperature indeed drives spatial and temporal changes in fish body size. Around 55% of species were smaller in warmer waters (especially among small-bodied species), while 45% were bigger.

Dogs are more likely to attack people on days with higher UV levels, according to Harvard Medical School research.

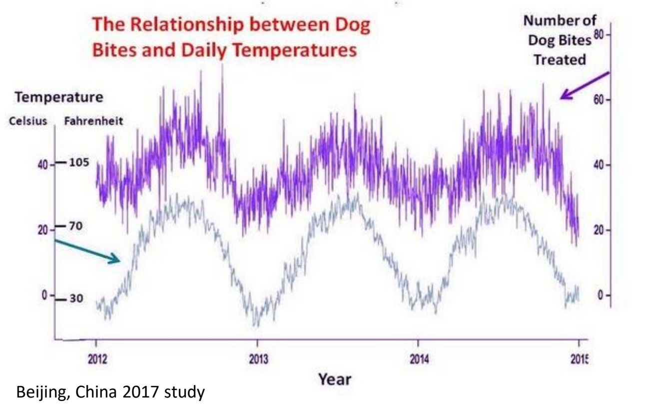
- Dog bites increased by 11% on days with higher UV levels, 4 percent on hotter days, and 3 percent on days with increased ozone levels.

Previous studies have linked high temperatures and air pollution to increased aggression in humans, rats, and monkeys.

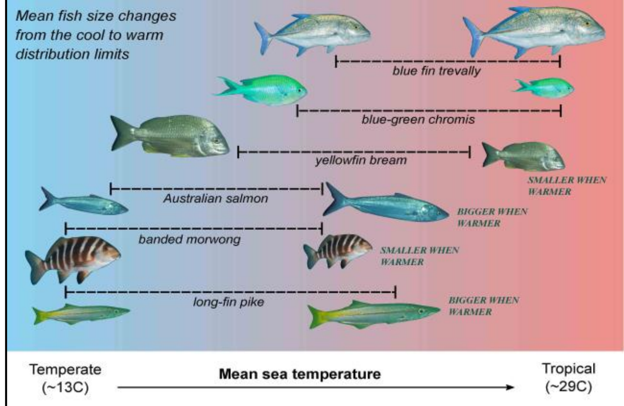
As a warm weather loving animal, a hotter environment could allow North Carolina's alligators to expand their limited distribution to areas further inland and away from wet, boggy coastal areas.

- 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 in the last 22 years, from (2000-2022).

An uptick in human-shark interactions has been occurring on the shores of Long Island, New York -- closing beaches as surfers, lifeguards and swimmers suffer bites from sharks in search of food.



Beijing, China 2017 study



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 over 500 locals seeking medical attention due to stings.
- 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 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, unstable weather reduced vegetation for blue sheep (bharal), forcing them to feed on human crops, drawing snow leopards into town.

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 reduces 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 (fences/ gates)

- 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 costs

- Resource restrictions may result in targeted violence or theft of site resources (e.g., water)
- Theft of backup generators during recovery from storms possible during prolonged events
- 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
- Missed cybersecurity updates and patches can result in easier exploitation as systems restore




SwissRE: Extreme Heat and Insurance

Extreme heat poses a growing threat to the insurance industry, with property, specialty and L&H business most exposed. It increases the risk of electrical outages and wildfire risk, and can damage and cause disruption to transport, water and energy infrastructure, thus driving up property and specialty claims.

- During June 2023-April 2024, there were 76 heat waves in 90 countries impacting over 6 billion people (about 78% of the global population) with at least 31 days of extreme heat.
  - Since 1991, such conditions have become twice as likely to occur.

According to the World Economic Forum (WEF), conditions of extreme heat will likely cause damage to corporate fixed assets, driving annual losses of USD 404-448 billion across all listed companies by 2035.

- As of 2020, around 71% of the world's working population was exposed to excessive heat.
  - Hot weather has impacted ambulance call-out response times and led to cancellations of surgeries and overheating in surgical theatres.
- Global insured losses due to wildfires have risen in the last decades, reaching $74 billion during 2014-2023.

Extreme Heat Impacts by Sector or Dependencey

Energy

- Extreme heat increases demand for electricity demand, stressing the power grid and increasing the risk of blackouts and power shortages.
- It affects thermoelectric power generation by impacting water availability and temperature, both critical for cooling operations.
- Power transmission becomes inefficient in high temperatures, reducing the capacity of generators, transformers and transmission lines.
- Solar panels and wind turbines also experience reduced efficiency.

Transportation

- High heat can cause road ruts, buckling and pavement cracking, leading to damage to rail tracks, bridges, and power cables for railways and streetcars.
- Train rails and bridges are vulnerable to heat-induced deformation.

Construction

- Extreme heat can damage building materials, accelerate rust, and cause steel and iron beams to expand, leading to structural vulnerabilities.

Telecommunications

- High risk due to sensitivity of data centers and network infrastructure to extreme heat, more so where there are limitations to access to water.
- Fixed asset losses projected at USD 518-563 million/year by 2035.
- Extreme heat can cause terrestrial cable materials to expand and contract, leading to sagging, equipment malfunction, and insulation degradation.
- Strain on data center cooling systems, potentially leading to overheating or equipment failure.

Batteries

- Prolonged exposure to temperatures above 30°C can cause pre-mature degradation of lithium-ion batteries.
- Battery degradation can reduce electric vehicle range by 20%. Elevated risk of thermal runaway, which can potentially lead to battery fire or explosion.

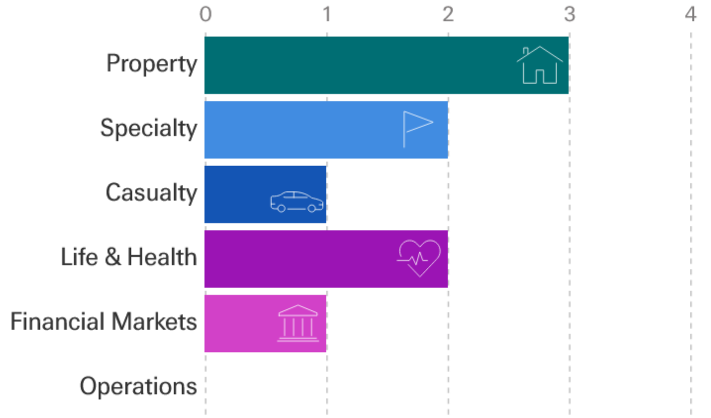
Agriculture

- Extreme heat and drought cause economic losses in forest productivity and also crop and livestock farming.

Potential insurance impacts

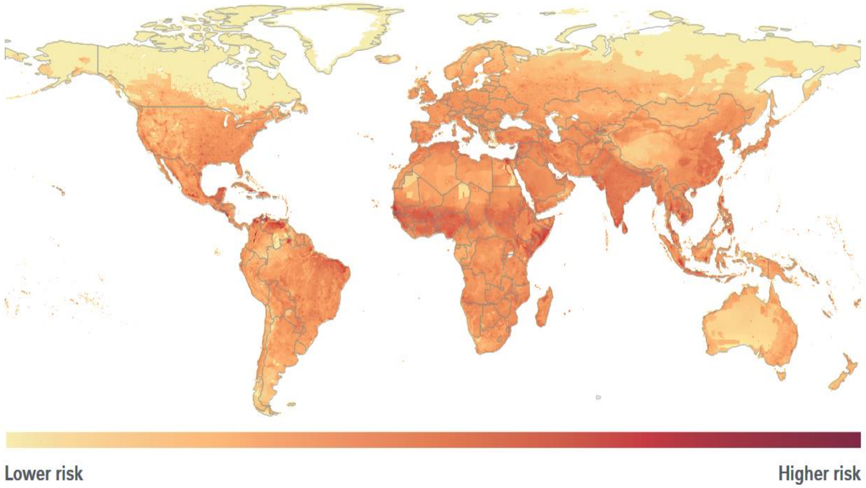
Impact rating

0=no impact; 4=high impact



Source: Swiss Re Institute

Regions of extreme heat risk by 2040*



*Note: as a function of a) population in 2040 (as a proxy for people and assets exposed; this would exclude agricultural assets and nature) and b) change in number of days per year above 35°C between 2005 and 2040 for "intermediate" climate change scenario SSP2-4.5. Source: Gao J. GeoTIFF_SSP2_total_2010-2050.zip, Global 1-km Downscaled Population Grids, SSP-Consistent Projections and Base Year, v1.01 (2000–2100), Harvard Dataverse, vol 1, 2020; CMIP6 climate projections, 2021 and ERA5 hourly data on single levels from 1940 to present, 2023, Copernicus Data Store, Climate Change Service; Swiss Re

Energy Sector Losses – Ex Wx

Between 2000 and 2023, 80% of reported major outages in the U.S. were due to weather-related events. Severe hailstorms can damage renewables like wind turbines and solar power.

- The average annual number of weather-related power outages increased by roughly 78% during 2011-2021, compared to 2000-2010.

The US experienced about two times more weather-related outages during the 10 years 2014-2023 versus the first 10 years analyzed of the 2000's (2000-2009).

- Future impacts: A two-week outage could cause a hit to the gross domestic product of the greater Chicago metropolitan area as high as $17.1 billion, with more than 70% of those costs coming from resilience tactics.

Solar panels and turbines exposed to icing, freezes, or hail may see significant output loss, damage, or exponential deterioration rates.

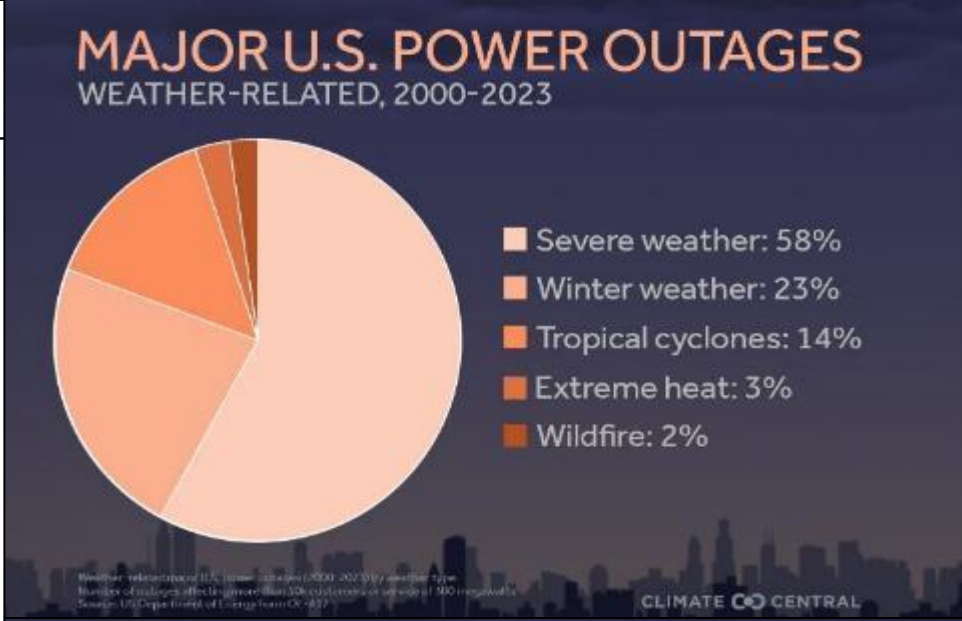
- Wind turbines also face significant costs from lightning at +$100 million a year and accounts for about 60% of the blade losses.

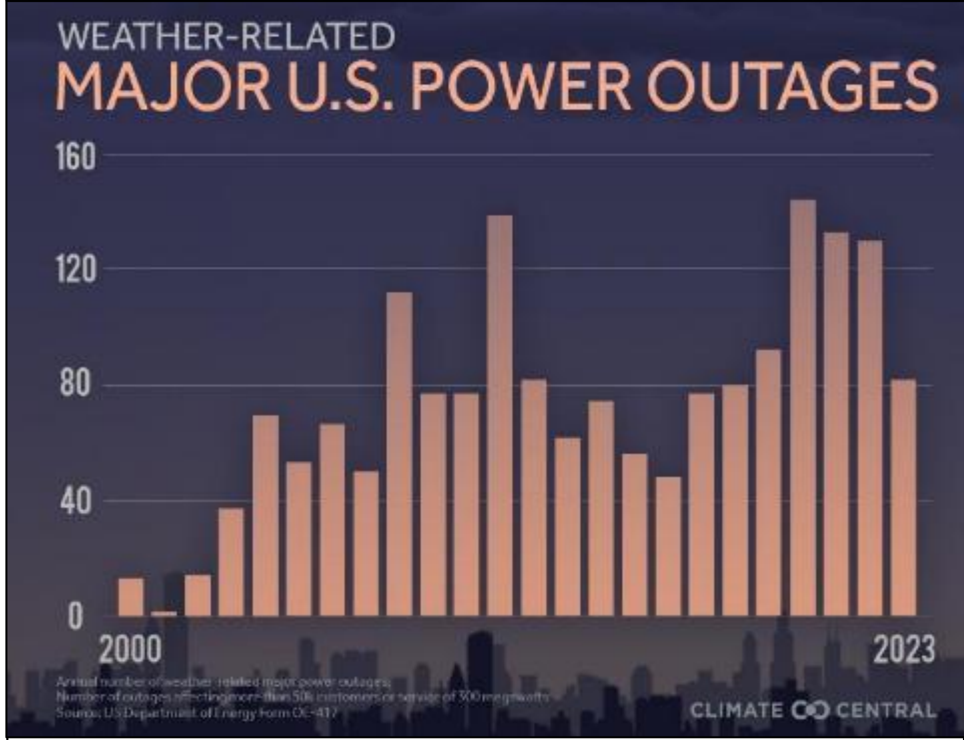
A new survey from the USC Center for Risk and Economic Analysis of Threats and Emergencies on power outages increasing nationally showed that 71% of large enterprises had some backup capacity, compared to only 22% of small businesses and 12% of residential customers.

- Researchers estimate that doubling the number of customers with generation capacity could reduce losses to gross domestic product by up to 14%

Texas Freeze 2021: Widespread power outages knocked out electricity service for more than 10 million people, some for more than three days.

- The state suffered economic losses estimated to be as high as $130 billion.





The Southeast (360), South (352), Northeast (350), and Ohio Valley (301) experienced the most weather-related outages from 2000 to 2023.

Worsening Weather Impacts to the Grid

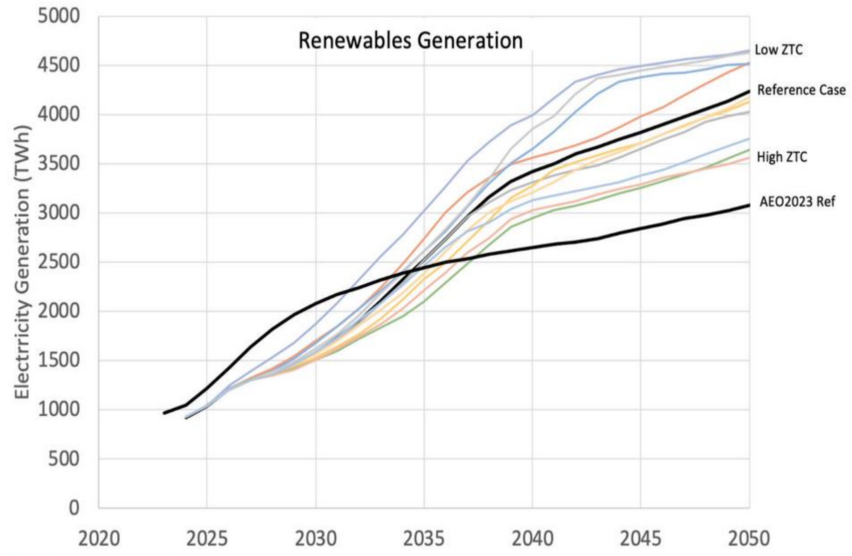
The new 2025 EIA report states: coal-fired electricity generation is expected to nearly disappear entirely by 2034.

- Under the reference case, carbon dioxide emissions from energy are expected to be 17% lower in 2050 than in the EIA reference scenario for 2023 (likely due to EPA regulations and lower battery costs coupled with the Inflation Reduction Act).
    - States with the most electrical downtime pre-2020 were Florida, Maine, South Carolina, West Virginia, Georgia, North Carolina, Mississippi, Kansas, Oklahoma, and Texas.

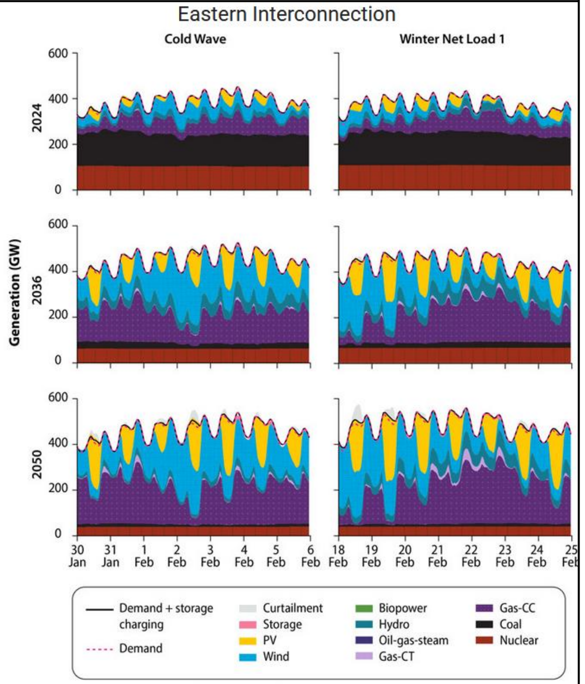
According to NREL, Renewable resource availability is less impacted by extreme weather events than by direct damage to generation, transmission, and distribution infrastructure.

- Hydropower availability and flexibility are key to mitigating system stress during extreme weather events.

NREL's 2024 forecast for energy provision sources from 2024 to 2050 show a pull away from coal in the winter towards more Gas, Wind, Solar, and Battery Storage >>



mage credit: EIA Annual Energy Outlook 2025

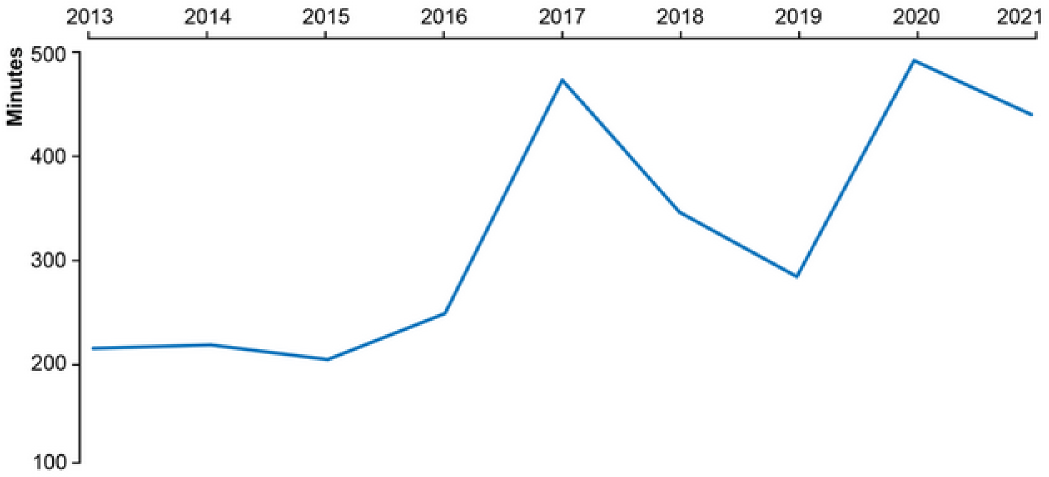


In the February 2011 and 2008 cold waves, wind and solar continue to serve 50% of the load after the front moves through while the load is elevated. *Graphic by NREL*

The U.S. Energy Information Administration uses System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) as measures of electricity reliability.

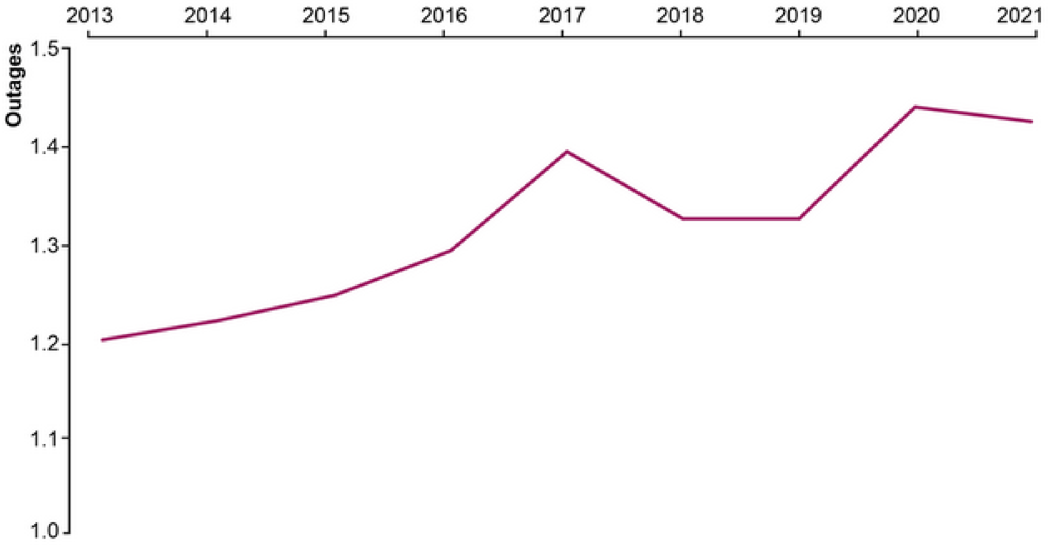
Duration of Power Interruptions

SAIDI refers to the number of minutes of nonmomentary electric interruptions a customer experiences in an average year.



Frequency of Power Interruptions

SAIFI is the number of interruptions a customer experiences in an average year. It measures the frequency of power outages.



Credit: June Kim; Source: Reliability Metrics of U.S. Distribution System, U.S. Energy Information Agency

Energy Use: Global Rise

New ICF Study: The global consulting and technology services company predicted that electricity demand could jump at least 25% in the next five years and as much as 78% by 2050 — findings that far outpace historical trends over the past two decades.

- Demand-side management can handle 10% of U.S. load in 2030, but annual generation deployments need to double to keep pace with expected longer-term demand.
- Service territories covering parts of Virginia, Georgia and West Texas could all see 6% growth in overall and peak load through 2035

Threat level: The consumption surge could raise retail rates by 15% to 40%, depending on the market, ICF finds.

- Demand management, efficiency and behind-the-meter tech (think home solar and storage) will be key to mitigate price spikes, ICF said.
- "Broad promotion of these programs could help meet 10% or more of electricity demand by 2030 compared to 8% in 2025."

Stunning stat: On the generation side, new power-producing capacity additions need to rise to roughly 80 gigawatts per year from 2025-2045 — around double the pace of the past five years.

- The report notes that the Energy Information Administration's 2025 annual outlook saw a 12% demand rise in 2030 in their "high" economic growth case and 9% in their "reference" case.

But adding newer data from regional grid planners — including PJM, ERCOT, MISO and parts of SERC — paint a very different picture, ICF said.

- In California, 35% of the increase through 2040 is EVs, building electrification and data centers.
- In Texas, new "large loads" like crypto-mining lead.
- In PJM, the huge mid-Atlantic and Midwest region, it's a combo of new manufacturing (including semiconductors), data centers, building electrification, EVs and more.

Electricity costs are also expected to rise and outpace inflation, with experts predicting a jump of 6% in 2025 — an average of $784 per household for the summer period.

- That would mark a 12-year record, according to a new analysis from the National Energy Assistance Directors Association.

Power Outages in US Metros

Average outage minutes per customer per month, with outliers removed.

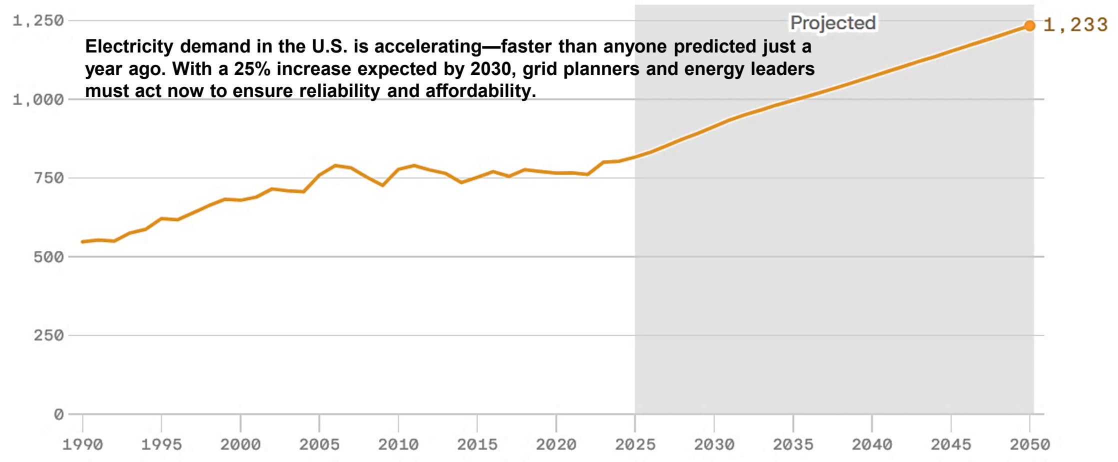
City	2018	2019	2020	2021	2022	2023	2024
Atlanta	9.9	10.9	14.9	11.1	15.3	11.0	17.5
Phoenix	5.1	6.5	6.2	7.2	8.3	6.6	7.1
Bay Area	9.6	17.1	20.2	15.4	17.2	22.2	22.9
Boston	11.4	8.5	19.9	8.7	11.1	13.2	8.5
Philadelphia	12.4	17.9	12.2	14.9	9.4	12.1	18.2
DC	9.6	11.9	10.6	12.8	13.1	9.1	10.8
Miami	9.6	9.4	9.9	9.3	8.7	10.5	9.4
Houston	14.1	23.4	20.4	19.7	21.6	21.6	19.7
Dallas	11.3	13.0	12.9	12.4	17.1	16.0	13.8
Chicago	7.4	8.9	6.3	7.5	7.2	6.3	6.4
LA	12.8	12.6	12.8	14.2	14.1	15.0	12.0
NYC	8.3	9.6	9.6	9.9	9.3	8.5	10.1

Table: Brian Potter • Source: Poweroutage.us

IFP

U.S. peak electricity demand

In gigawatts; Annually, 1990-2024, 2025-2050 projected



Data: ICF; Chart: Axios Visuals

U.S. electricity needs are slated to rise 25% by 2030 and 78% by 2050 compared to 2023, sinus-clearing estimates from the consulting firm ICF seen first by Axios show.

AI Infrastructure Burden

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

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

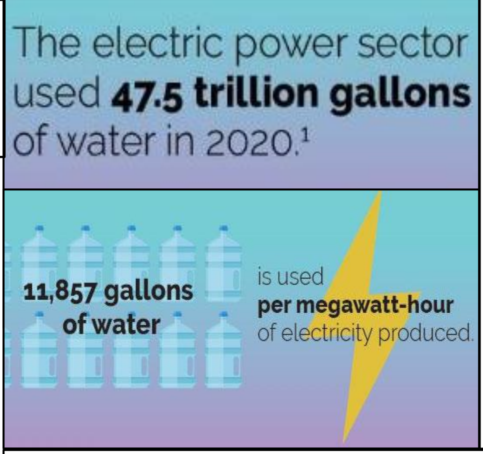
North America accounts for most of the world's data center capacity, but the Asia Pacific data center market is expected to grow 12.2% by year's end, with Southeast Asia alone growing at 12.9% followed by Europe, the Middle East and Africa at 11.1% and North America at 6.4%.

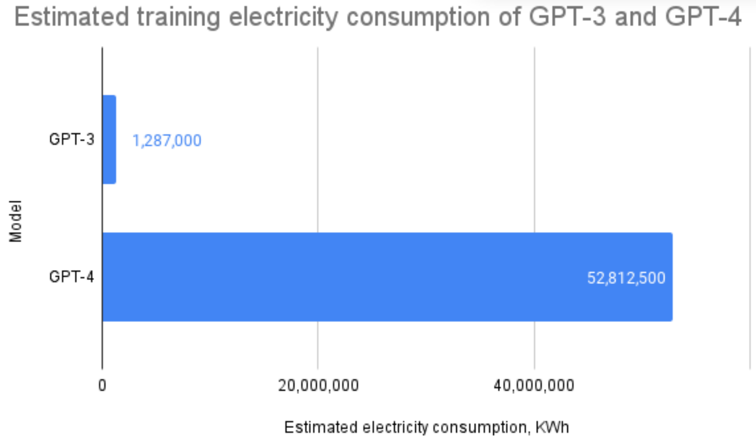
- Proposed locations for datacenter or cryptocurrency development should be selected for their natural safeguards to extreme heat, drought, or floods.

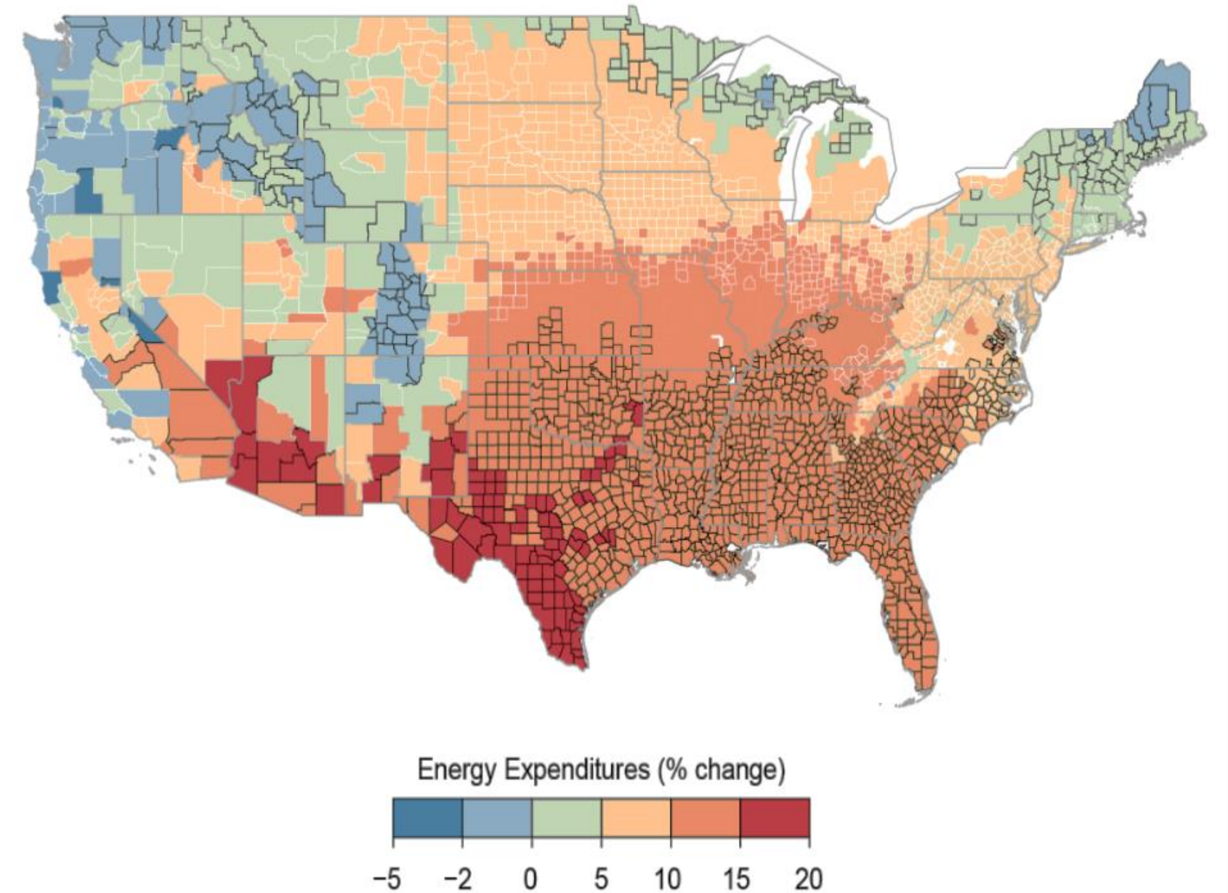
In July 2022, the month before OpenAI stated it completed its training of GPT-4, Microsoft used about 11.5 million gallons of water for the cluster of Iowa data centers, according to the West Des Moines Water Works.

- That amounted to about 6% of all the water used in the district, which also supplies drinking water to the city's residents.

GPT-4, the model currently used by ChatGPT, has a much larger size and use case margin, hence consumes more water than GPT-3.







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

Exploiting Weather and EV Flaws

In 2019 a 19-year-old security researcher gained access to the digital car keys of more than 25 Tesla EVs scattered across the globe.

- From a remote location, the hacker ran programs that disabled the vehicles' security mode, unlocked their doors and opened their windows.

The 2022 Brokenwire attack: hackers wirelessly send signals to targeted electric vehicles. This causes electromagnetic interference and interrupts the connection between a public EV charging station and the vehicle.

- The charging station won't provide the vehicle with a charge until the attack ends.
- There are ransomware attacks possible that could lock out the owner from operating the vehicle until the fee is paid.
- Extreme temperatures can cause electric vehicles (EVs) to charge slower and potentially for a longer duration resulting in a greater window of cyber risk.

These scams and infiltrations are critical to keep in mind for government fleets, emergency vehicles, and key staff which could result in vehicle shutdown or erroneous exposure of microphone access, personal data, routes, contacts, and more.

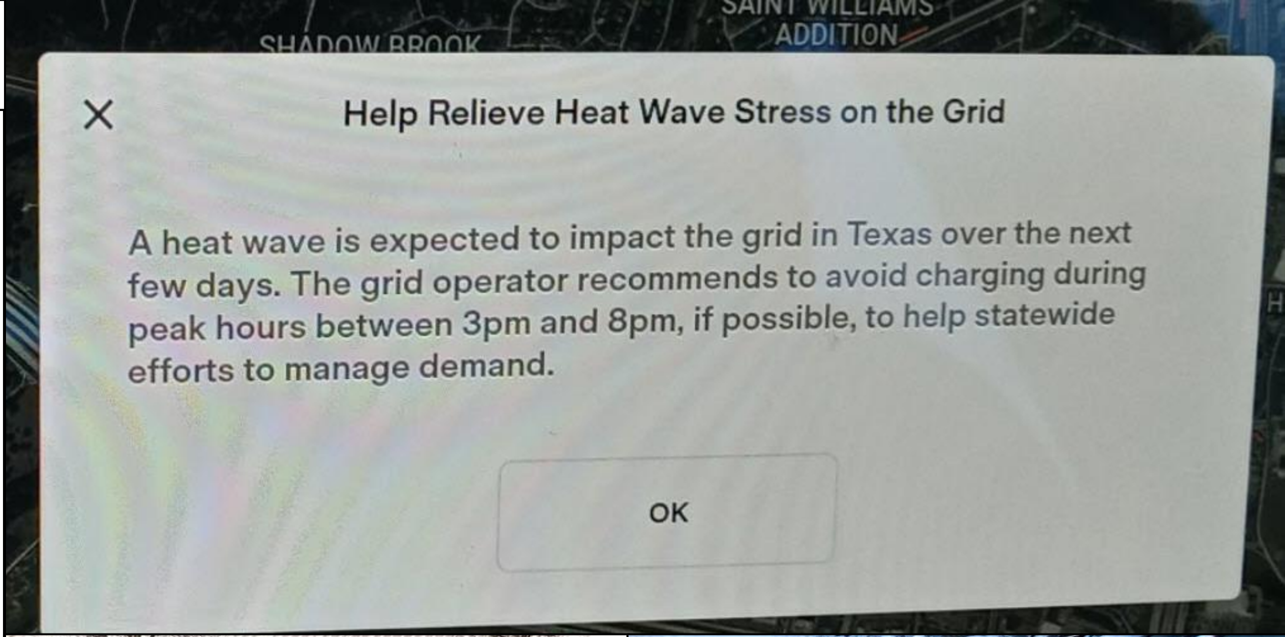
- Vehicles locking down for updates, forced or selected, can often be slower than anticipated during extreme temperatures.

Vehicles may also see their touch screens lifting due to extreme temperatures as heatwaves continue to intensify in longevity and intensity.

- Many electric vehicles do not have bypass physical systems installed where users can still access certain features or in some cases even turn on the vehicle without the main dashboard screen functioning.

Weatherproof QR codes can be used to share vital information like evacuation routes, emergency contacts, and safety guidelines, even when power and internet access are limited.

- **QRLjacking**: involves a cybercriminal spreading malware to an individual's devices after a fraudulent QR code directs the user to a malicious URL.
- **Device hacking**: Under certain circumstances, a malicious actor may be able to access a user's device if they scan a fraudulent QR code.



Extreme Temperatures and EV Fleet Risk

When temperature drop significantly, electric vehicle (EV) charging can become impaired at public stations. When extreme heat causes public safety power shut offs (PSPS) public vehicle charging can also be hindered.

- Electric cars can also face decreased ranges from the wear and tear major temperature fluctuations can have on their battery storage capabilities. Some charging stations may not report when they are shut down due to power loss from storms or temperatures.

Extreme Cold: Full EVs, which run exclusively on battery packs, typically lose 30-41% of their range when outdoor temperatures drop to 20F and the heat's cranked on (AAA/Recurrent).

- Recurrent measured the range loss for a number of EVs and found extremes such as the range for the Kia Kona EV drops 34% in freezing weather, while the loss for a Tesla Model S was 28%.

Extreme Heat: EVs can lose up to 20% of their range in 95 degrees or hotter. Some companies provide rentals during blackouts.

- Some of the highest levels of EV adoption are in hot places. California, Florida, Texas, Arizona and Georgia are home to 56% of the nation's battery-powered cars, according to the Department of Energy.
  - As EVs are nearly 50% heavier than a standard gas-powered vehicle, wear and tear rates on parking lots and garages may be shifted towards charging station users with garage fire risks rising from heat.

Strategic planning at Cox Automotive Inc., said 4 out of 5 EV shoppers consider battery longevity when buying

- When temperatures climb, the ions in a car battery speed up. Once that happens, they often have trouble attaching to the anode or cathode. The pressure and speed can also create small cracks, which slow chemical reactions and make for less usable battery life.
- EVs with heat pumps lose an average 20% of their range in extreme weather, compared with up to 40% in those without heat pumps

Consumer Reports' testing of four popular EV models — the Hyundai Ioniq 5, the Volkswagen ID-4, the Ford Mustang Mach-E and the Tesla Model Y — also found significant battery depletion in cold weather.

Battery range dropped 25% from spring to winter and 30% from summer to winter, with the researchers looking at temperatures near zero Fahrenheit for the coldest conditions and around 80 degrees in the summer.

Meteorological Intelligence

Power outages can significantly impact physical bank locations by disrupting essential services like ATMs, payment processing, and security systems, potentially leading to temporary closures and hindering customer access to funds

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.

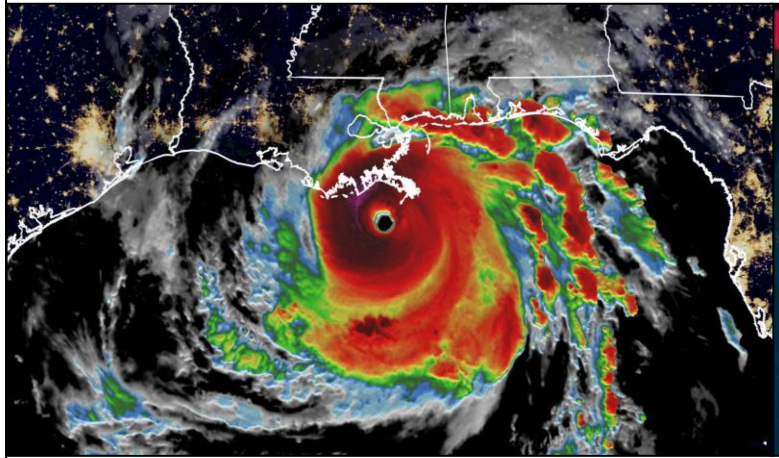
- Local economies could experience a 37% drop-in economic activity if faced with a compound threat.
- These events led to a 12% of energy demand going unmet and a daily GDP reduction up to 3.1%.

Example Event in Long Island:

- One conclusion listed 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.

HHS Office of Civil Rights states ransomware attacks on healthcare have surged by 264% over the last five years.

In 2021, [Hurricane Ida](#) in Louisiana left over one million people without power or internet. In the days following the storm, malicious actors launched a "malware attack" on the 24th Judicial District Court, disrupting its database and extending its storm-related closure.



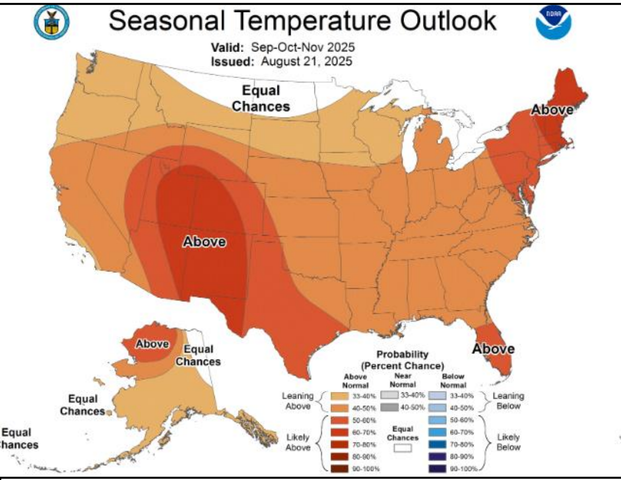
A cyberattack on financial institutions during an extreme weather event can have a significant negative impact on GDP due to several compounded factors:

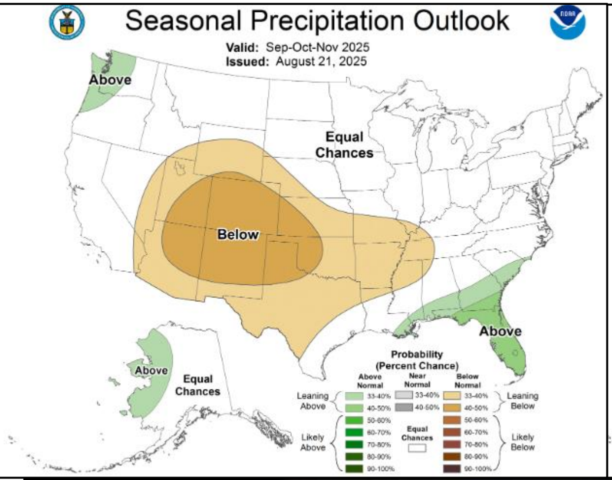
1. **Financial Disruption**: Interruptions in banking services (payments, loans, trading) slow down economic activities, and disruption for ATM access.
2. **Loss of Confidence**: Combined crises can undermine trust in financial systems, causing reduced investment and spending.
3. **Resource Diversion**: More resources are diverted to crisis management and recovery, limiting productive economic activity.
4. **Supply Chain Effects**: Financial interruptions ripple across supply chains, delaying payments and contracts and slowing economic flow.
5. **Long-term Damage**: Data breaches and operational damage can lead to prolonged recovery times and increased costs, reducing economic growth.

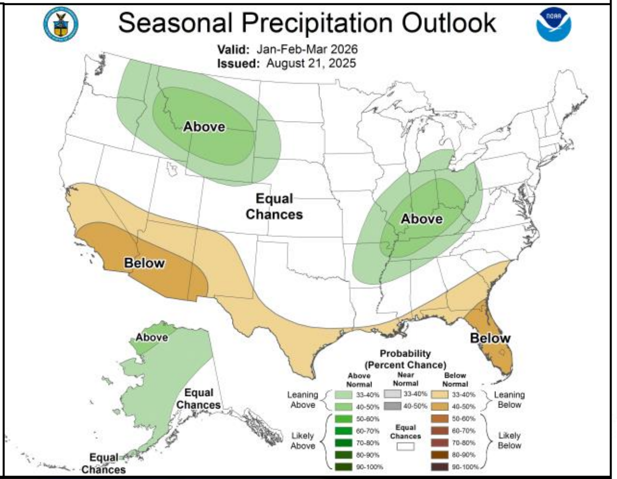
Cybercriminals often intensify phishing and ransomware attacks in the aftermath of natural disasters, targeting affected regions and organizations that are already under stress.

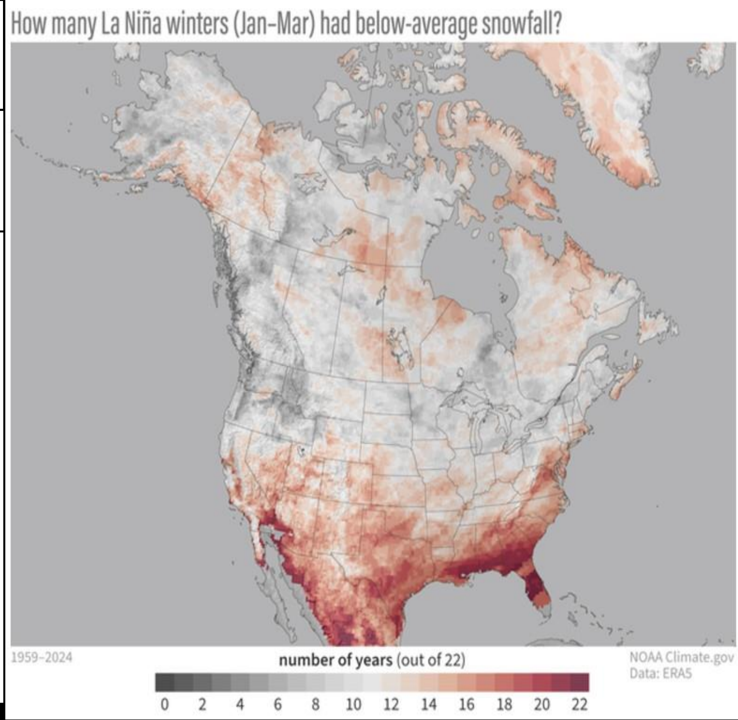
Winter 2025-26: Major Swings Between Extremes

Recent trends in winter activity during La Niña years have proven to reduce the persistence of heavier snowfall totals on the region against the climatological norms, stressing water systems.

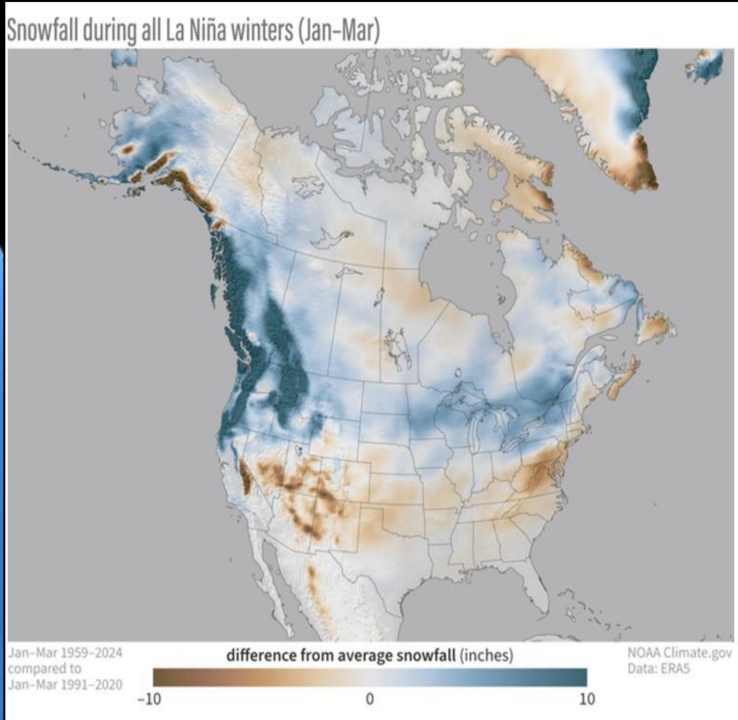








This year the upper-level cold air pockets which have formed are indicating for the northern hemisphere a greater 'wobble' in the stability of storm events likely to persist through Autumn and Winter, causing more polar vortex events.

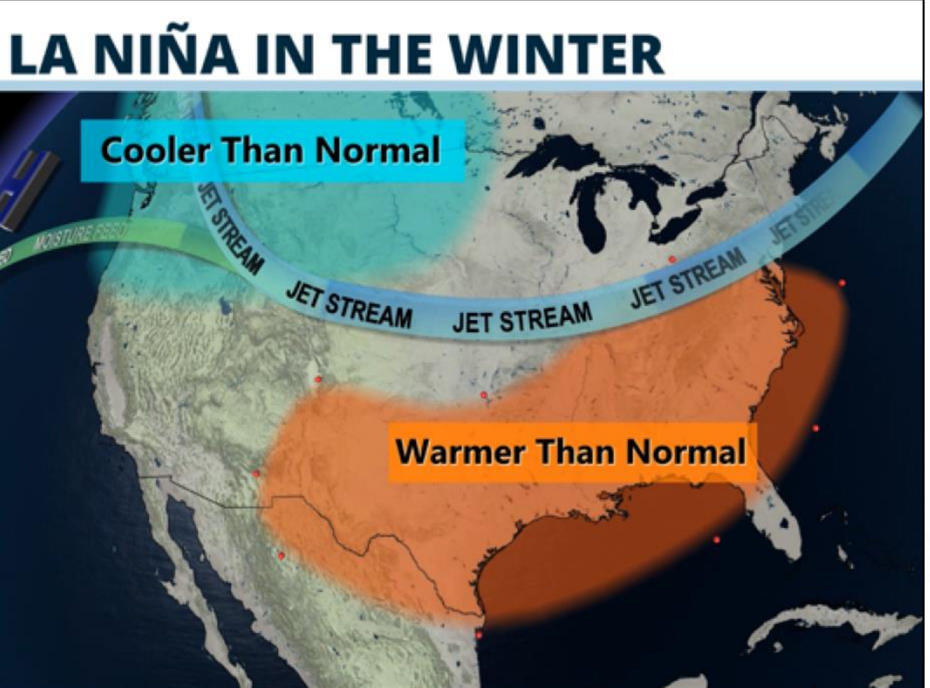


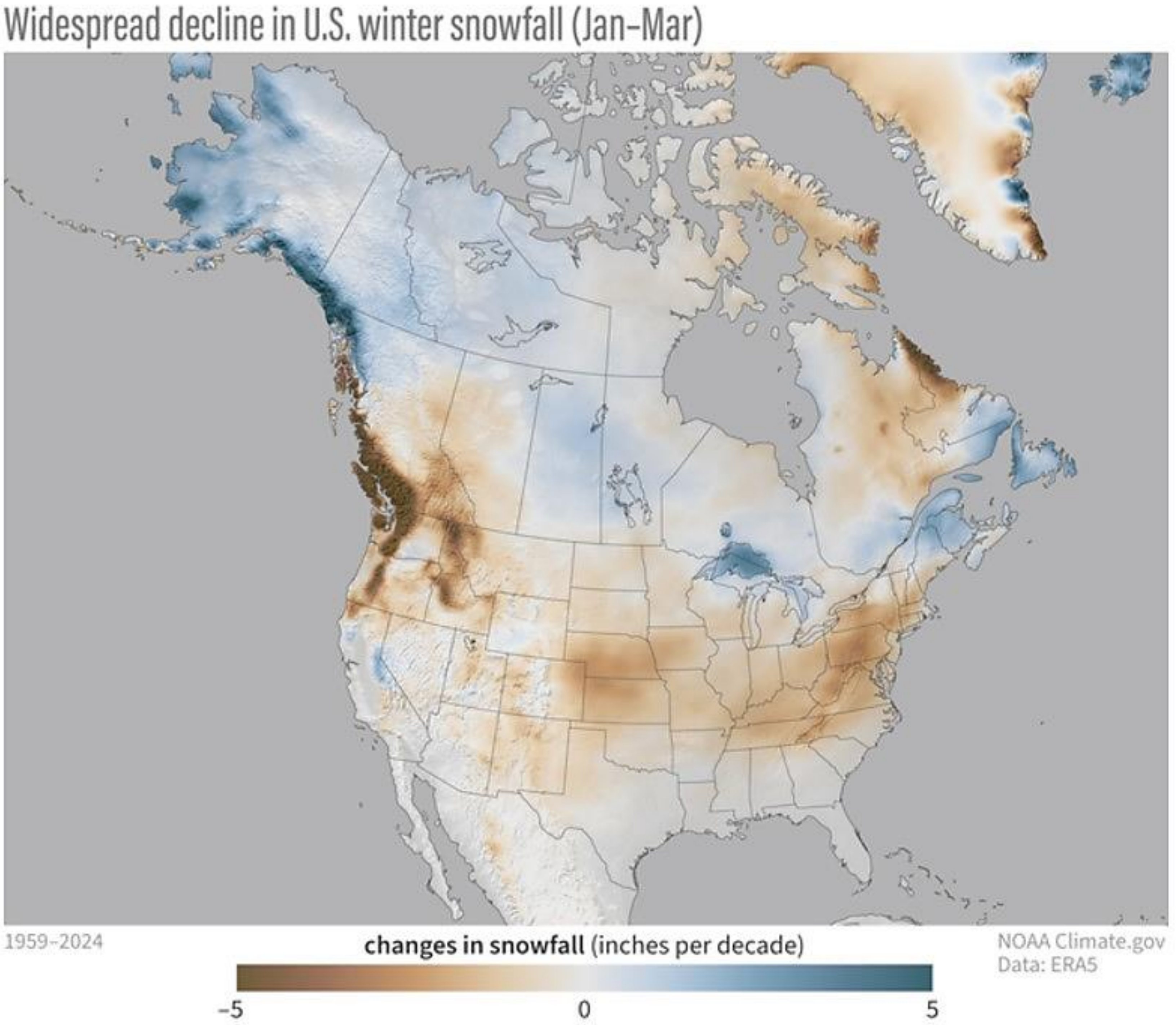
Winter Snowfall Outlooks

Across many regions, winter is the fastest-warming season.
NOAA's anticipated odds of La Niña peak during a three-month stretch between October and December. Then, the agency predicted, ENSO will return to its neutral phase.

- In terms of ski conditions, La Niña tends to favor the northwestern U.S., where states like Washington, Oregon, and Idaho have, seen higher-than-average snowfall during these years.
- The opposite is true for Southern California, Arizona, and New Mexico.

Snowfall averages by ski resort and last year (La Niña) are provided HERE





Australia Winter Comparison

The Bureau of Meteorology said it has already been Sydney’s wettest August since 1998, with 345.2 mm recorded as of 9am on Thursday morning. (The monthly total in 1998 was 482.6mm.)

The NSW State Emergency Service (SES) had more than 30 warnings, including several “watch and act” alerts, in place for areas stretching from Sydney’s south up to the Central Coast, north coast, New England region and states north-west.

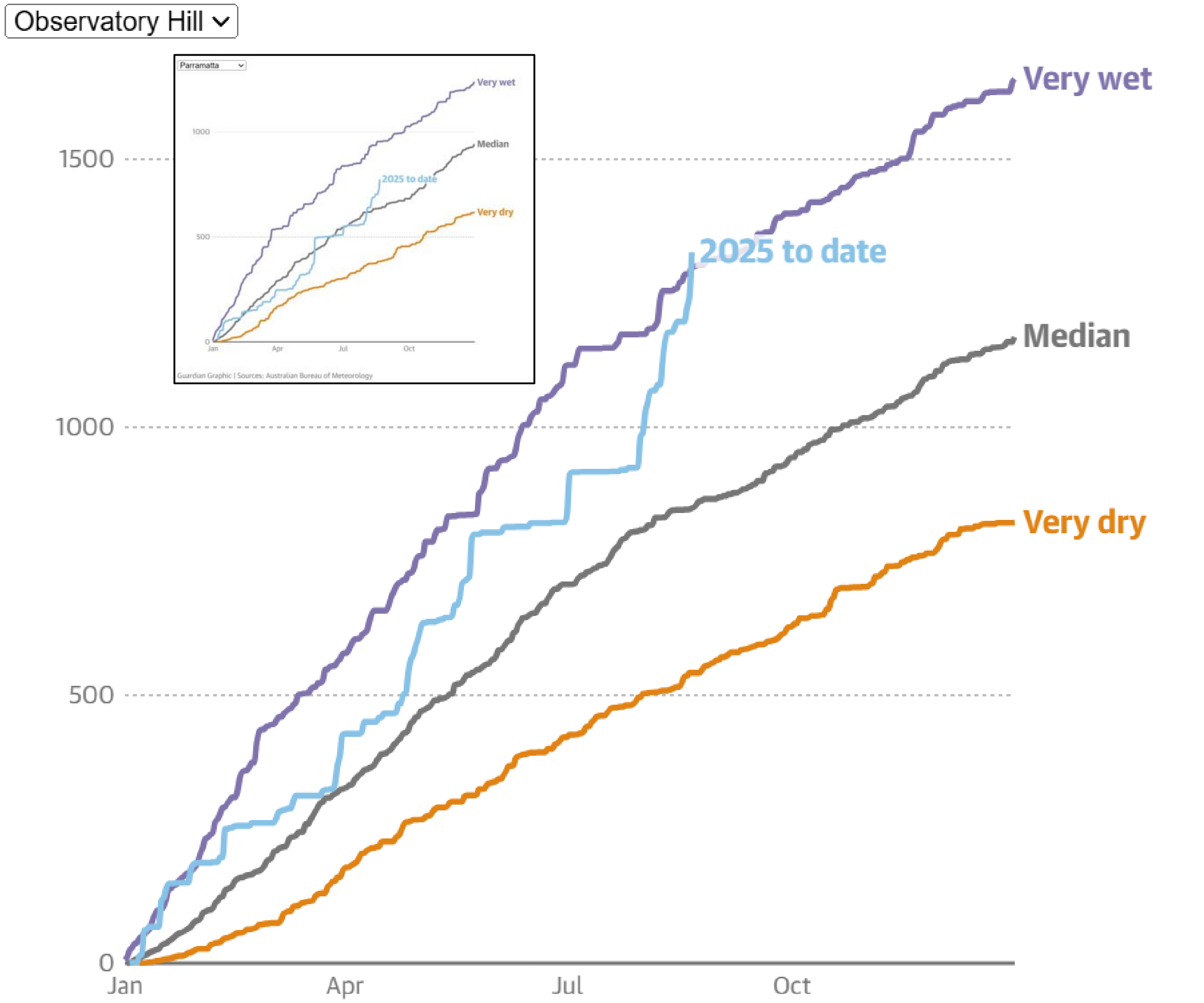
“We are starting now to see road closures across many parts of NSW, and these road closures are going to cause isolation to many communities,” she said. Flooding or adverse weather has caused hundreds of road incidents.

2 weeks ago: Several towns in eastern Australia were blanketed with their thickest layer of snow in decades as wild weather swept the area this weekend, causing floods, stranding vehicles and cutting power to thousands of homes, authorities said.

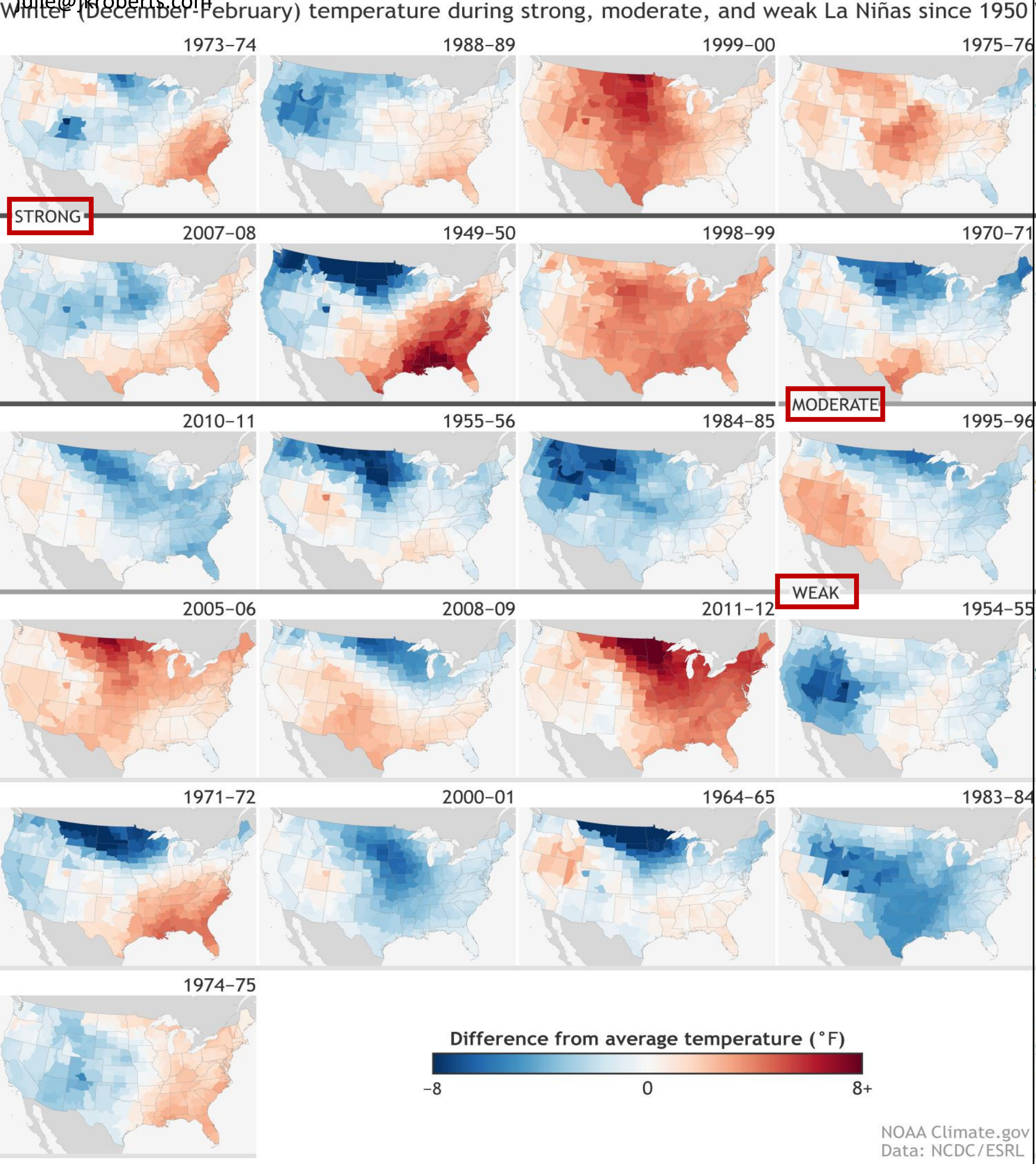
- A cold air front dropped as much as 40 cm (16 inches) of snow on parts of northern New South Wales on Saturday, the most since the mid-1980s.
- Snow also settled in areas of the neighboring state of Queensland for the first time in 10 years

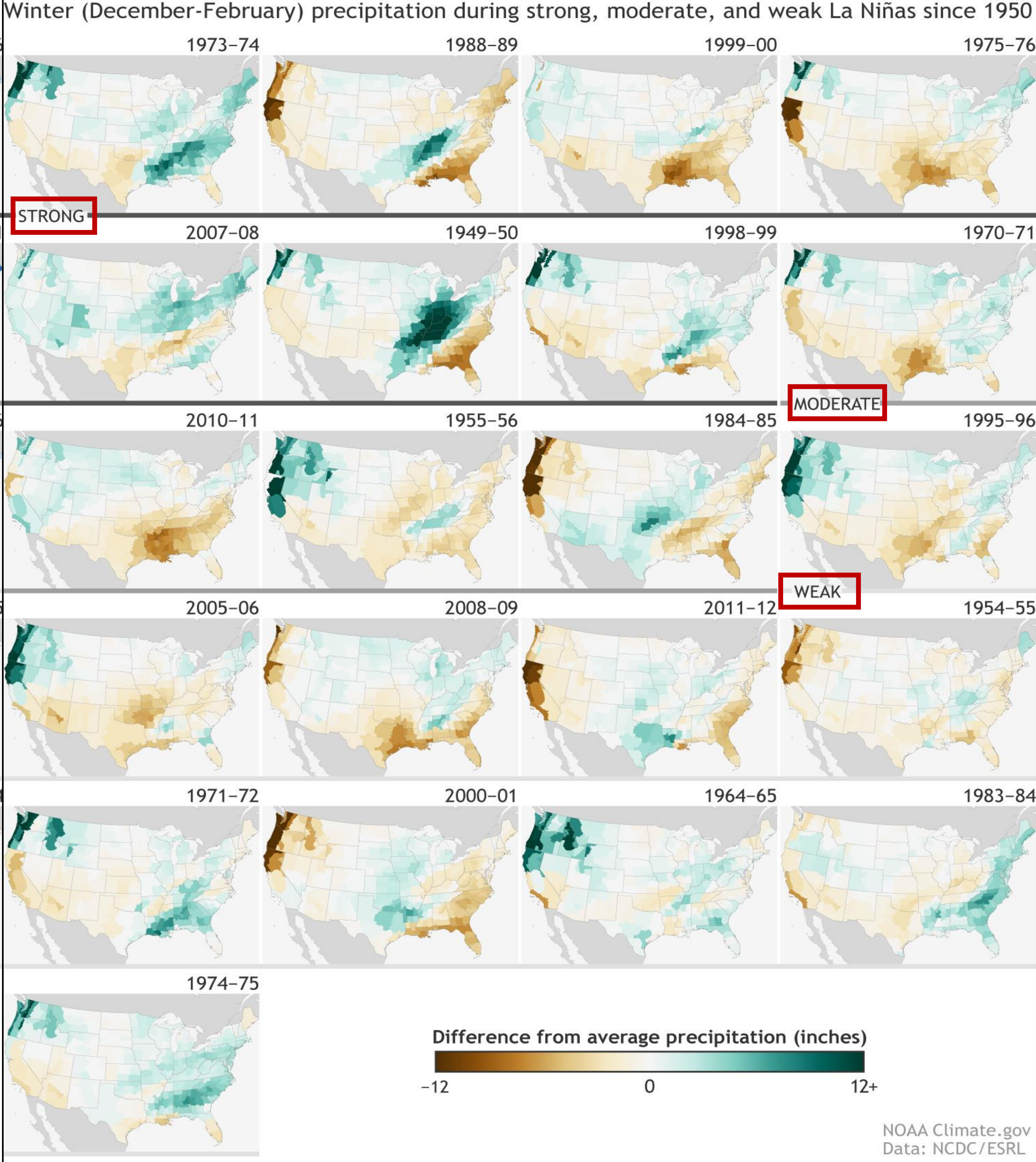
Cumulative rainfall compared to long-term averages

Showing daily cumulative rainfall (mm) for this year, compared to the median, 10th percentile (very dry) and 90th percentile (very wet) of rainfall for all years at each weather station location. Last updated 21 August



Guardian Graphic | Sources: Australian Bureau of Meteorology


julie@jkroberts.com
Winter (December-February) temperature during strong, moderate, and weak La Niñas since 1950
1973–74
1988–89
1999–00
1975–76
STRONG
2007–08
1949–50
1998–99
1970–71
MODERATE
2010–11
1955–56
1984–85
1995–96
WEAK
2005–06
2008–09
2011–12
1954–55
1971–72
2000–01
1964–65
1983–84
1974–75
Difference from average temperature (°F)
–8
0
8+
NOAA Climate.gov
Data: NCDC/ESRL


Winter (December-February) precipitation during strong, moderate, and weak La Niñas since 1950
1973–74
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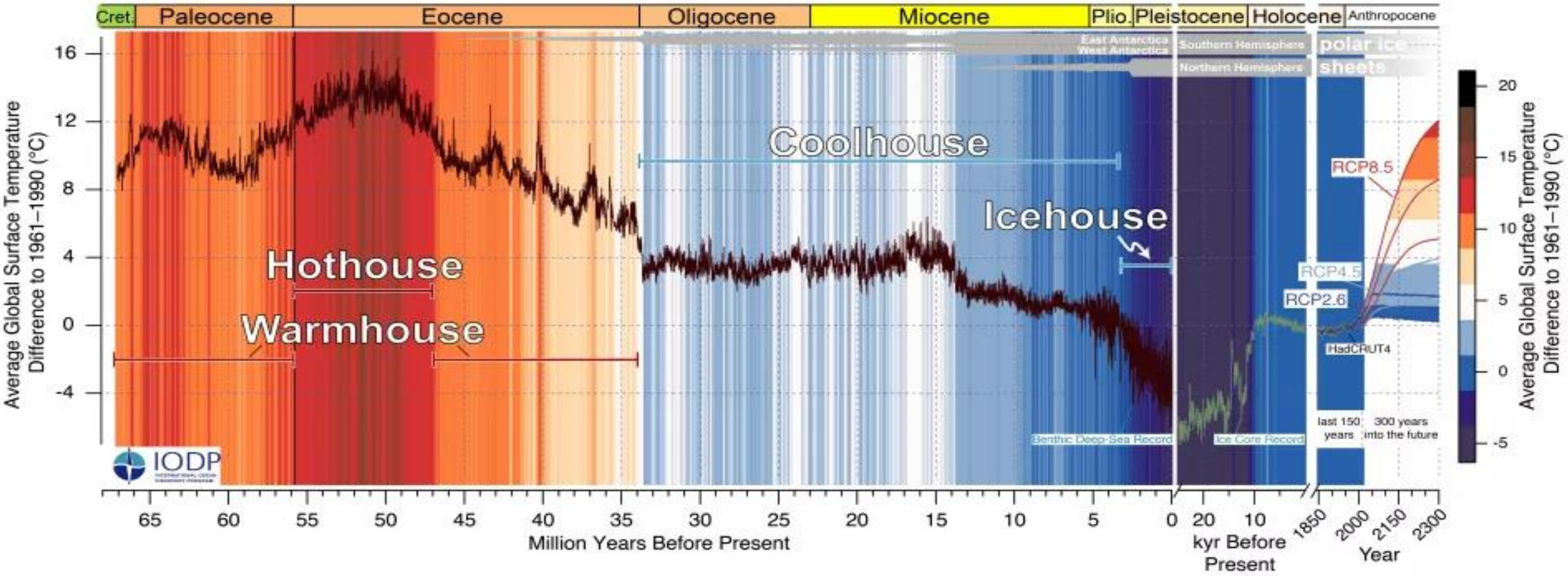
1970–71
MODERATE
2010–11
1955–56
1984–85
1995–96
WEAK
2005–06
2008–09
2011–12
1954–55
1971–72
2000–01
1964–65
1983–84
1974–75
Difference from average precipitation (inches)
–12
0
12+
NOAA Climate.gov
Data: NCDC/ESRL

Defined Threat: Condensed Period 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 weather hazards defined in previously slides will amplify rapidly in coming decades as the temperature continues to rise.
- Acclimation periods will reduce rapidly as temperatures varying outside of human capacity, materials will face comparable strain.

When comparing the historic warming period, it is critical to annotate which materials shift from rapid heating and may push against or pull away from partnered materials or stress the binding type.



CONTACT

Infrastructure Support: Extreme Weather Emergency Response and Operations

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HELPFUL STARTS

- NOAA Repository: https://www.ncei.noaa.gov/cdo-web/
- Frontal Boundaries: https://aviationweather.gov/gfa/#progchart
- Infographics: https://www.climatecentral.org/
- World Meteorological Organization: https://wmo.int/topics/extreme-weather

Number of Severe Power Outages Per Year

State	2018	2019	2020	2021	2022	2023	2024
Alabama	2	0	4	0	0	2	0
Alaska*	0	0	0	1	2	3	2
Arizona	0	0	0	0	0	0	0
Arkansas	1	1	2	1	1	6	2
California	0	3	0	0	0	1	1
Colorado*	0	1	0	0	0	0	1
Connecticut	3	1	2	0	1	1	0
Delaware	1	0	1	0	0	0	1
District of Columbia	1	0	0	0	0	0	0
Florida	2	0	1	0	2	1	3
Georgia	1	0	1	0	0	2	3
Hawaii	0	0	0	0	2	1	0
Idaho*	0	0	2	1	0	0	0
Illinois	0	0	1	0	0	1	1
Indiana	1	0	1	0	1	1	2
Iowa	0	0	2	1	0	0	0
Kansas*	0	0	0	1	0	1	1
Kentucky	2	0	1	3	1	3	3
Louisiana	0	3	8	6	1	2	3
Maine	5	2	7	1	5	5	7
Maryland	1	0	0	0	1	1	0
Massachusetts	3	1	2	1	0	1	0
Michigan	3	3	3	10	2	4	3
Minnesota	0	0	0	0	1	0	1
Mississippi	0	2	6	3	0	3	4
Missouri	0	1	0	1	0	4	2
Montana***	0	0	0	1	0	0	1
Nebraska*	0	0	0	2	0	0	2
Nevada	0	0	0	0	0	0	0
New Hampshire	3	2	2	1	2	2	3
New Jersey	2	1	2	0	0	0	0
New Mexico*	0	0	0	0	0	0	2
New York	4	0	1	0	0	0	0
North Carolina	4	1	2	1	2	0	3
North Dakota**	0	1	1	0	3	1	0
Ohio	0	0	0	0	1	3	2
Oklahoma	0	1	3	0	0	2	1
Oregon	0	1	1	3	2	0	2
Pennsylvania	2	1	2	0	0	1	2
Rhode Island	2	2	2	3	0	1	0
South Carolina	1	1	2	0	1	0	2
South Dakota**	0	1	1	0	1	0	0
Tennessee	0	0	1	1	3	3	1
Texas	0	1	1	2	0	3	5
Utah	0	0	1	0	0	0	0
Vermont	3	1	0	0	3	4	4
Virginia	3	0	1	2	2	0	2
Washington	1	2	1	2	1	0	1
West Virginia	4	3	2	4	7	4	5
Wisconsin	0	2	0	3	1	1	2
Wyoming**	0	0	1	0	0	0	0
US Total	55	39	71	55	49	68	80

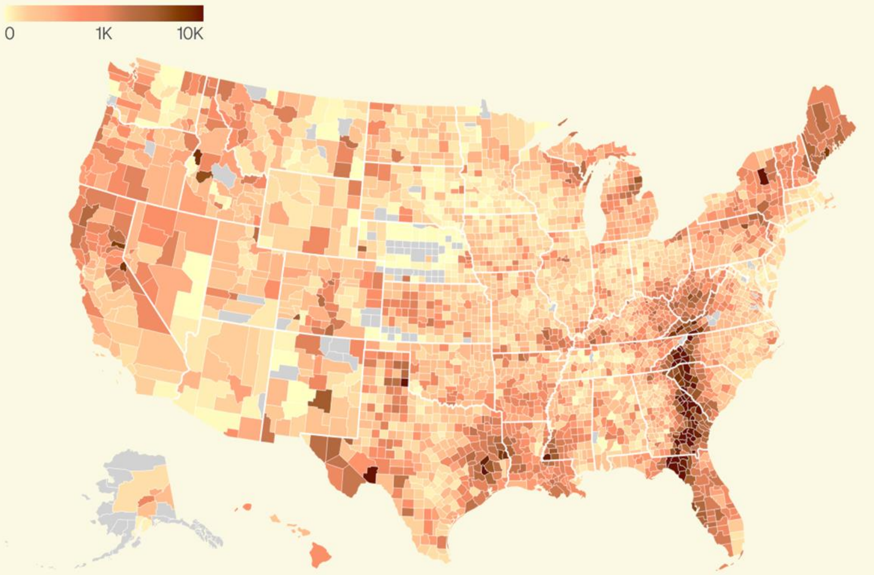
* = 2018 data is incomplete

** = 2018 and 2019 data is incomplete

*** = 2018, 2019 and 2020 data is incomplete

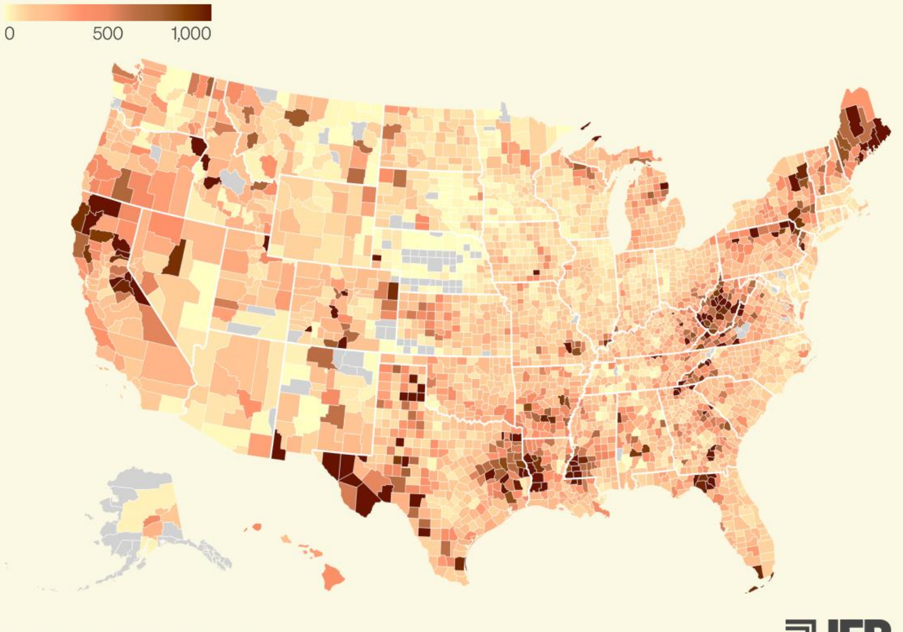
Power Outages in the US in 2024

Power outage minutes per customer, by county



US Power Outages in 2024 Minus Outliers

Power outage minutes per customer, with the 3 worst weeks for each county removed.



Map: Brian Potter • Source: Poweroutage.us

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Outage minutes per customer in 2024 were more than 50% higher than in 2023.