CISA Extreme Weather Trends and Impacts

Connecticut Focus

"The 10 warmest years in the 143-year record have all occurred since 2010, with the last nine years (2014–2022) ranking as the nine warmest years on record" (NOAA, 2023).

07/20/2023

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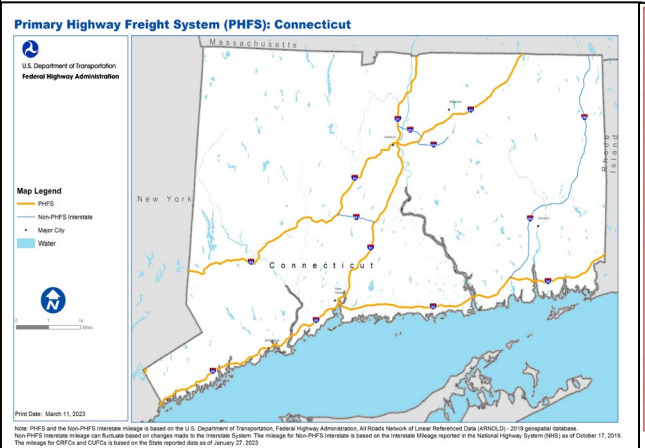
State Billion Dollar Disasters

According to NOAA: Tropical Cyclones have caused $5-10 billion dollars in damages over the past 43 years however, Winter Storms ($2-5 billion) and Severe Storms ($500m-1 billion) have occurred more often.

- Connecticut averages one-billion-dollar disaster a year with most of the events having occurred since the 2010s.
- In Connecticut there have been 26 disaster events totaling at least one-billion-dollars in the past 20 years, while the 20 years from 1980 to 1999 had 19 disaster events.

Connecticut's real Gross Domestic Product (GDP) last year was around $252 billion.

- This ranks the state 43rd but the state boasts a place in the "top 10 richest states".
- Connecticut's economy grew 2.4% in 2022 and was the 17th best in the country.
- The state accounts for a quart of New England's GDP and is the second largest for the region, behind Massachusetts.
    - Given the expectation of increased extreme weather events across the region, supply chain disruption and resource hub damages could result in immediate and longer lasting economic impacts outside of direct loss costs.
- Analyzing the main freight highways and railways depicted below, along with the climate hazards risk map and history of severe weather reports, these methods are at the greatest immediate risk of disruption from damages in-state and regionally.



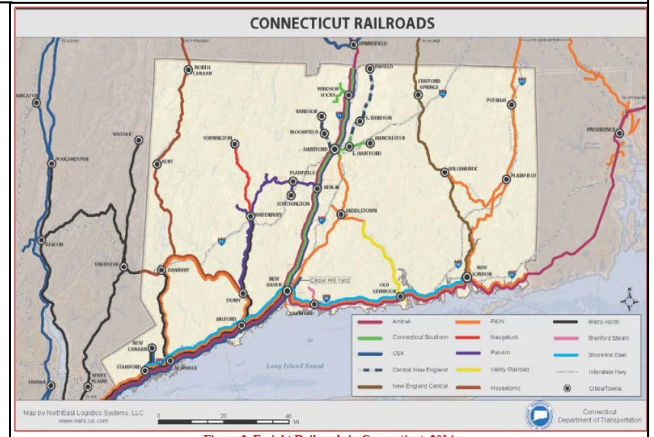
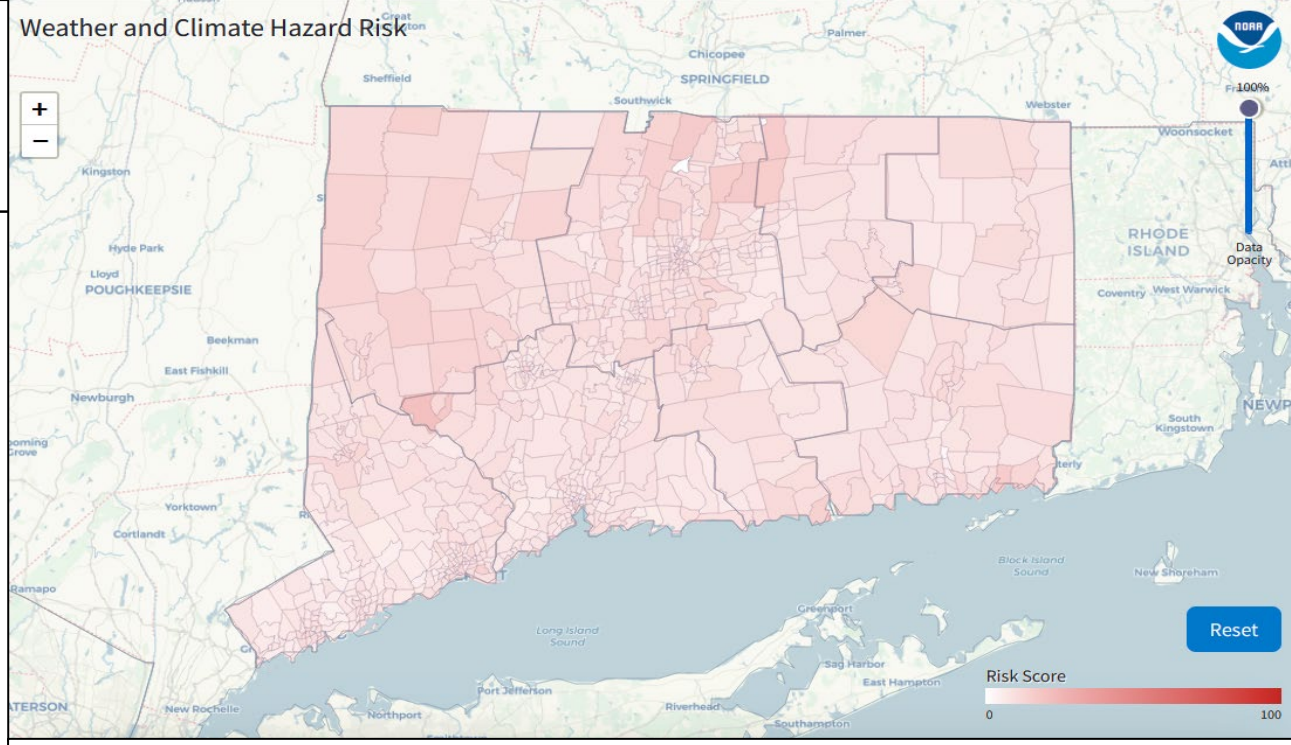
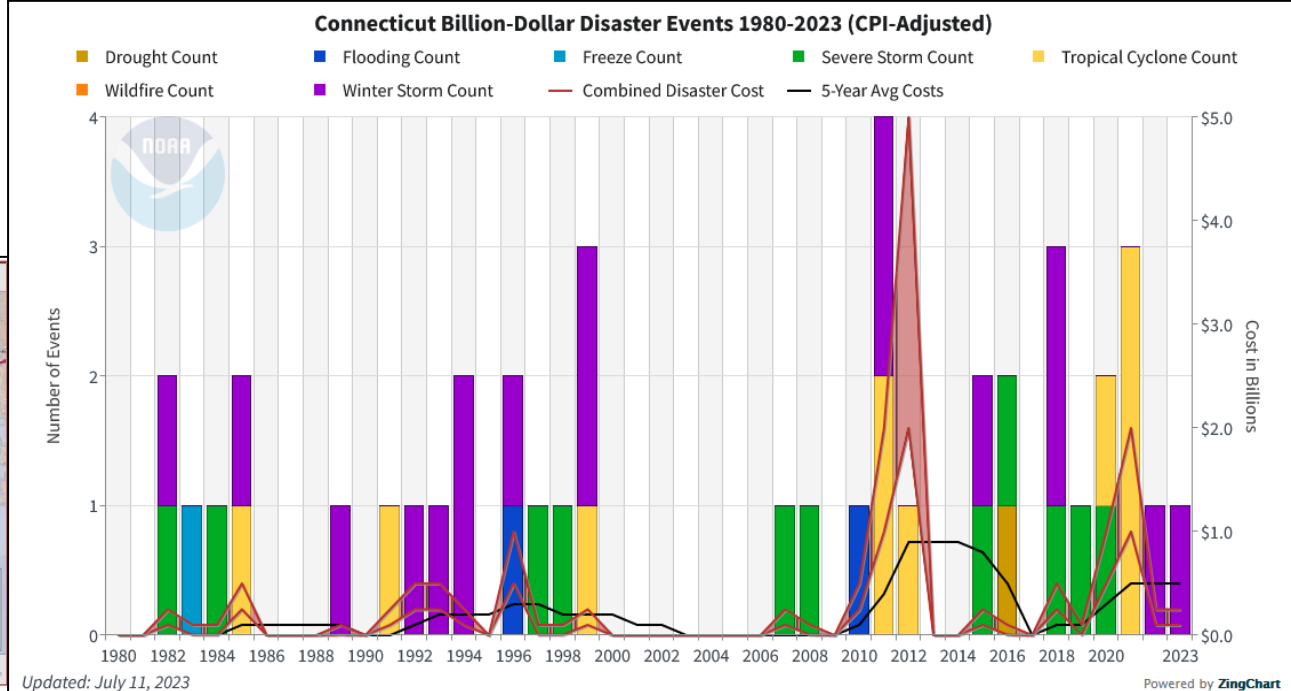
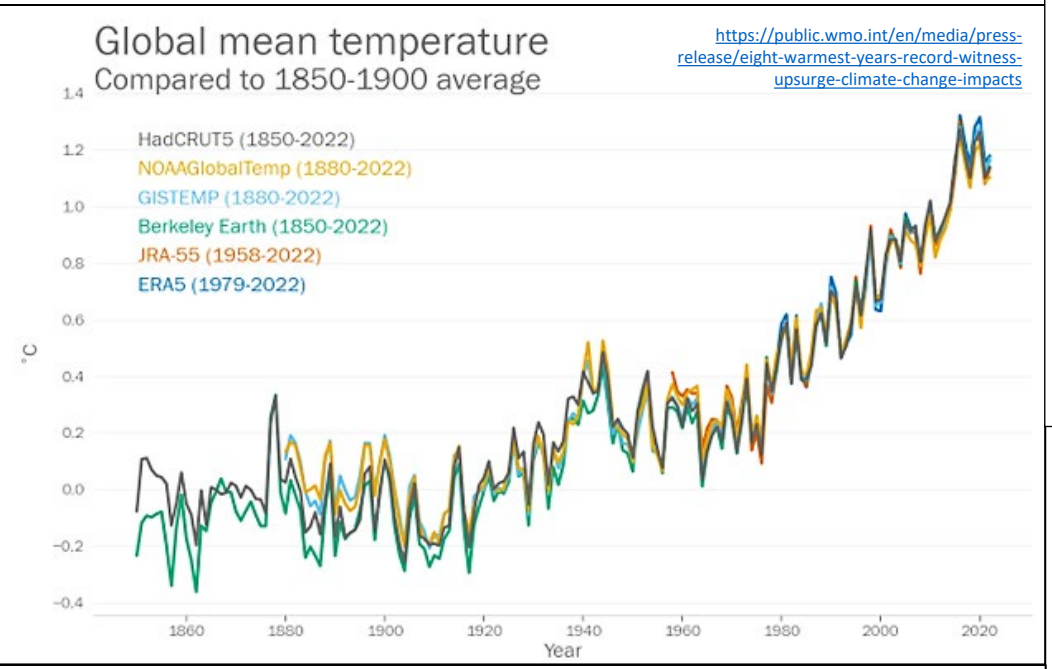


Figure 3. Freight Railroads in Connecticut, 2014

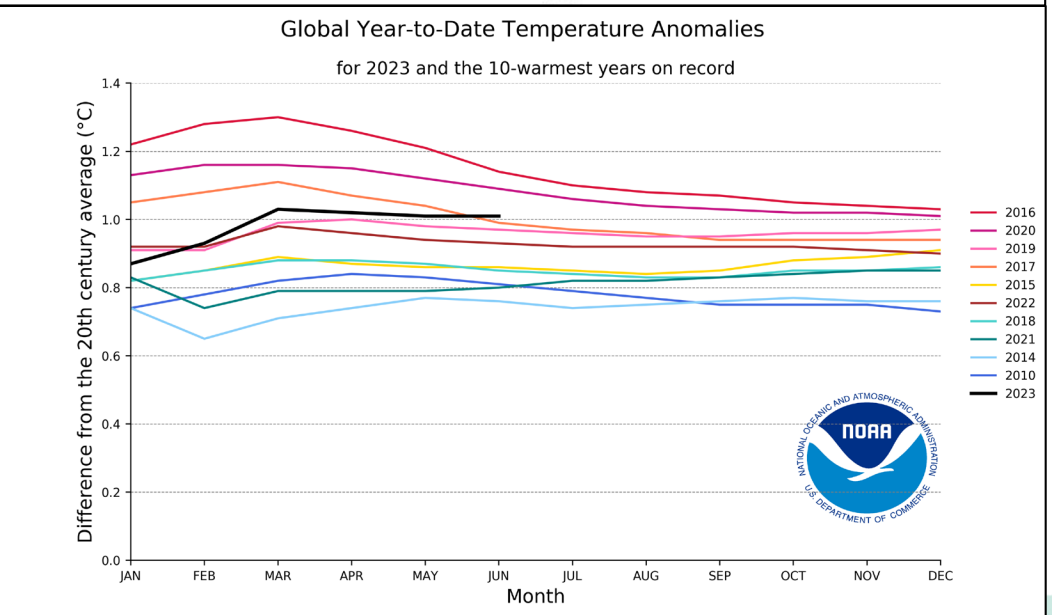


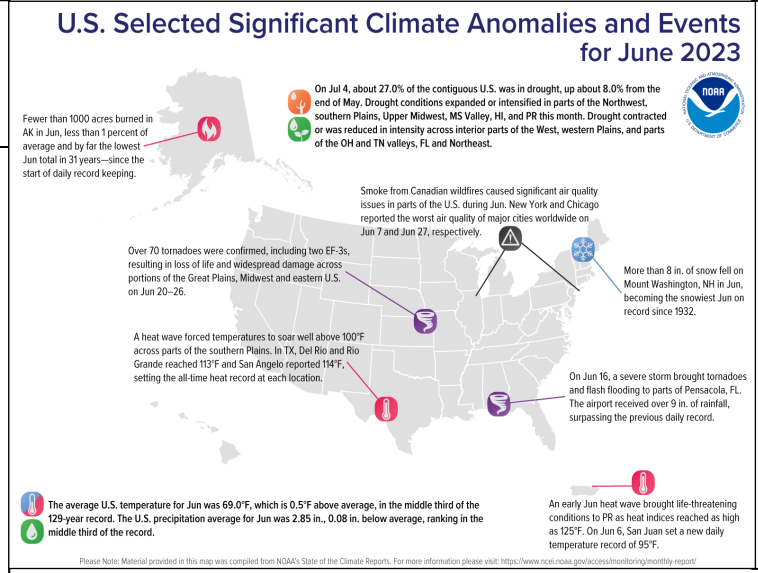


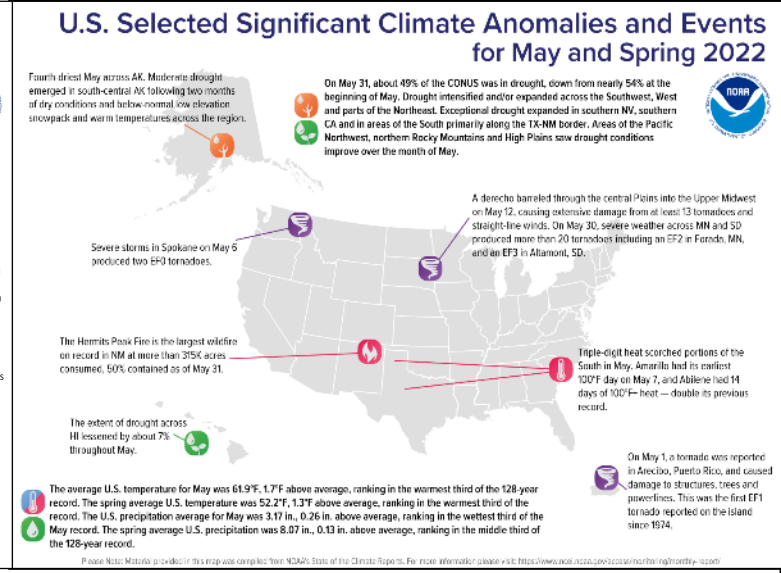
Record Setters



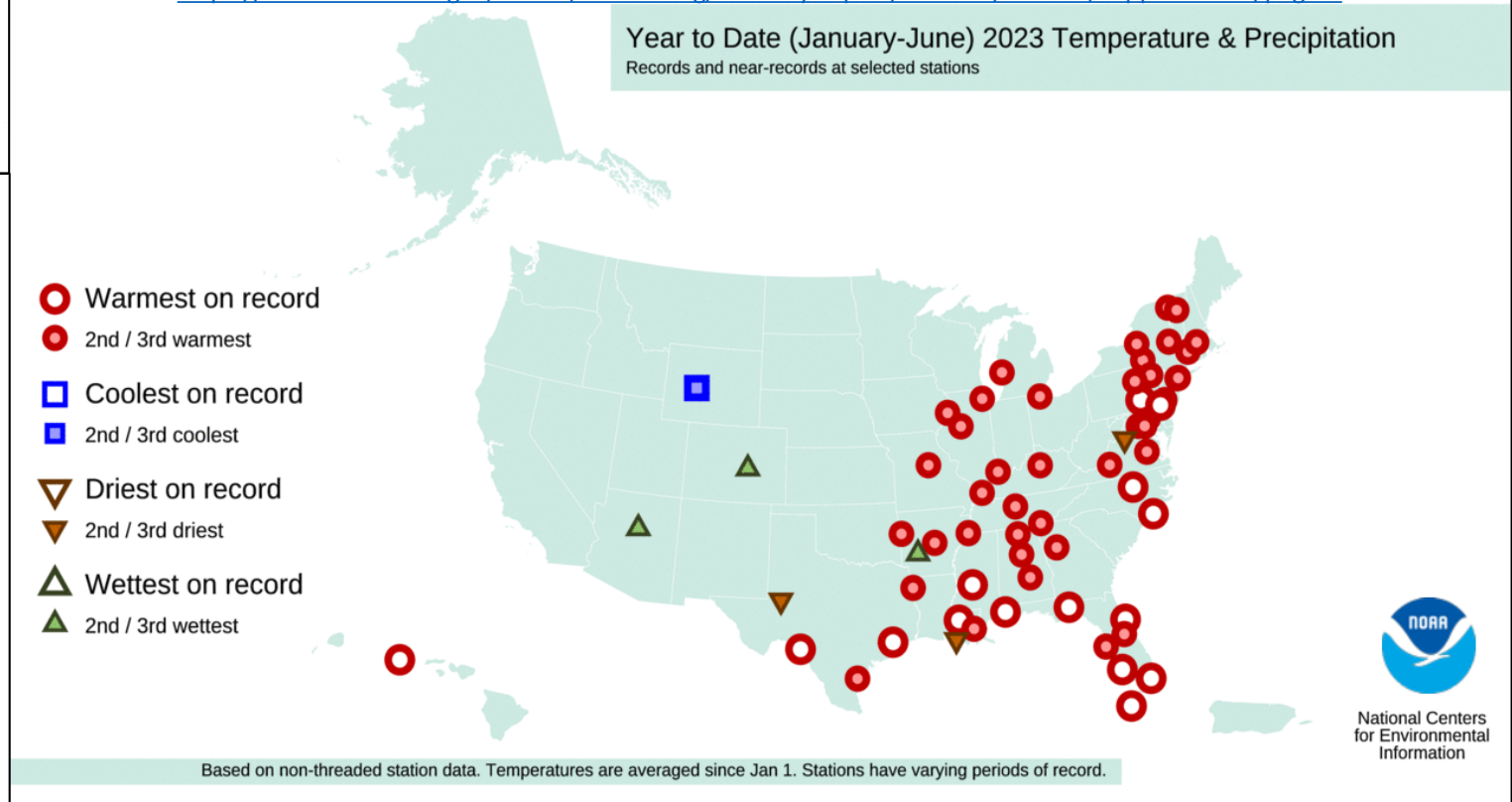
https://public.wmo.int/en/media/press-release/eight-warmest-years-record-witness-upsurge-climate-change-impacts







https://www.ncei.noaa.gov/access/monitoring/monthly-report/national/202211#ytd-highlights
https://www.ncei.noaa.gov/access/monitoring/monthly-report/national/202302/supplemental/page-2



Climatological Anomalies

July 2023: a single rainfall events resulted in flooded streets and basements with a canceled music festival and airport delays or cancellations as a terminal shut down.

- Parts of Fairfield and New Haven counties reported more than 4.5 inches of rain, while some cities in Hartford and Tolland counties reported 3 inches.
- A storm crossing the Northeast mid-month caused a 1-in-1000-year flood event for Vermont, resulting in the parts of the Connecticut River reaching flood stage.

Weather events across the Northeast are not state-specific and result in simultaneous damages to fragile dependencies such as river systems, roadways, railways.

- June 2023 precipitation in the Northeast totaled 4.46 inches, 101% of normal. For the 12 Northeast states, precipitation ranged from 59% of normal in Connecticut to 156% of normal in Maine.
- From January to May, Connecticut approached or set records for warmth both during the day and through the overnight averages against the 129 years of record-keeping.
- This year Bridgeport, Connecticut saw their least snowy winter season on record.
- Hartford, Connecticut, tied its warmest April temperature on record with a high of 96 degrees Fahrenheit on April 14.
- The swing in average temperatures being 106 degrees and dry with sharp shifts to extreme cold reaching -30 degrees Fahrenheit highlights the threat that an unstable atmosphere can bring to the region should these swings lean too heavily one way.
- August 2022 was the hottest August on record for Connecticut, Massachusetts, New Hampshire, and New Jersey.
- As Connecticut warms, more often and record-breaking periods of persisting higher than normal temperatures such as August 2022 will occur. Later heating periods will also persist, much like November 2022 with frosts and snows starting later in the year with extended frost-free periods within the winter season possible.
- Norwalk continued to have water restrictions in place in November due to low reservoir levels with impacts felt across the agricultural sector region-wide.

STATES AT RISK
AMERICA'S PREPAREDNESS REPORT CARD
CONNECTICUT

OVERALL: A-
EXTREME HEAT: A
DROUGHT: –
WILDFIRE: –
INLAND FLOODING: A
COASTAL FLOODING: B

	Transportation	Energy	Water	Health	Communities
CONDUCTING VULNERABILITY ASSESSMENTS					
Has the state published information on how the frequency or severity of extreme heat events may change in the future?	✓	✓	✓	✓	n/a
Has the state conducted extreme heat vulnerability assessments for each sector?	NO	NO	NO	NO	n/a
Is the state tracking extreme heat impacts?	NO	n/a	NO	✓	n/a
CONDUCTING VULNERABILITY ASSESSMENTS					
Has the state published information on how the frequency or severity of inland flooding may change in the future?	✓	✓	n/a	✓	✓
Has the state conducted inland flooding vulnerability assessments for each sector?	✓	NO	n/a	NO	NO
Is the state tracking inland flooding impacts?	✓	n/a	n/a	✓	✓
ADDRESSING CURRENT RISKS					
Does the State Hazard Mitigation Plan cover coastal flooding?	✓	✓	✓	✓	✓
Does the state have a coastal flooding emergency response plan that is updated routinely?	✓	✓	✓	✓	✓
Does the state provide coastal flooding emergency communication materials for citizens?	✓	✓	✓	✓	✓
CONDUCTING VULNERABILITY ASSESSMENTS					
Has the state published information on how the frequency or severity of coastal flooding may change in the future?	✓	✓	✓	✓	✓
Has the state conducted coastal flooding vulnerability assessments for each sector?	NO	NO	NO	NO	NO
Is the state tracking coastal flooding impacts?	✓	n/a	NO	✓	✓

Forecasted Climate Shifts

Using NOAA's CMRA Tool, Hartford is expecting to see an increase of at least 10 days over 90 degrees from the averages most newer homes and buildings would have planned for. The area does not typically exceed 100 degrees, but in both emission scenarios, the state could see this occur.

Regarding drought, the state is likely to see more damaging flood events with fluctuations in the dates and types of precipitation likely such as more rainfall during winter months than historically normal.

Wildfire days are likely to increase from warmer months and more days lacking rainfall.

Hartford has 21.6% of the population listed within disadvantaged communities, meaning changes in climatological norms could have cascading impacts to key transportation modes and significant financial impacts for those unable to work through a disaster event or who experience damages. 22.8% of New Haven's population is listed within disadvantaged communities as well.

In New Haven, about 0.2% of the county is expected to see impacts from global sea level rise but repeats the same threat of less days with rain and yet a higher average annual total for precipitation. This matches the global threat of higher heat content producing more torrential rainfall events in shorter bursts of time between drying days.

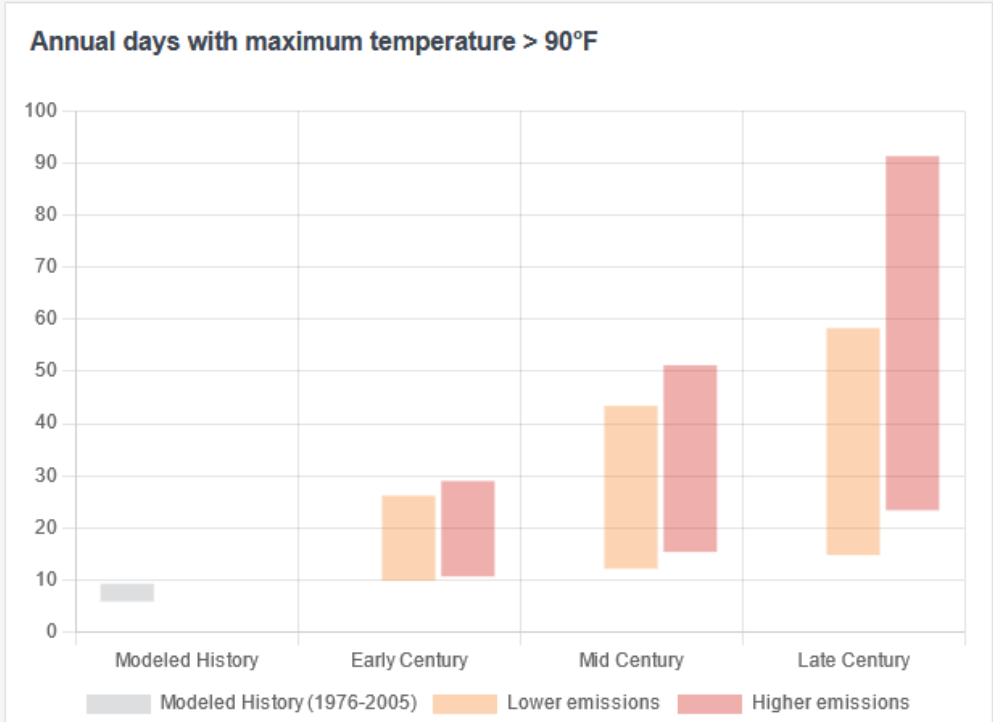
Building codes across the state are listed as 'Lower Resistance' because no part of the listed counties are required to adhere to a hazard-resistant building code.

Risk Factor: There are 136,637 properties (15% of all properties) in Connecticut that have over a 26% chance of being severely affected by flooding over the next 30 years.

Climate Projections for Early Century (2015–2044)

	Lower emissions	Higher emissions
Annual days with maximum temperature > 90°F	18.6 Days + 10.5 since 1976-2005	19.9 Days + 11.7 since 1976-2005
Annual days with maximum temperature > 95°F	4.4 Days + 3.4 since 1976-2005	5.1 Days + 4.0 since 1976-2005
Annual days with maximum temperature > 100°F	0.6 Days + 0.5 since 1976-2005	0.7 Days + 0.7 since 1976-2005
Annual days with maximum temperature > 105°F	0.0 Days No change since 1976-2005	0.1 Days + 0.1 since 1976-2005
Annual single highest maximum temperature	98.0 °F + 3.4 since 1976-2005	98.5 °F + 3.8 since 1976-2005
Annual highest maximum temperature averaged over a 5-day period	92.6 °F + 3.3 since 1976-2005	92.9 °F + 3.6 since 1976-2005

Indicator Details Chart Table



Extreme Heat Trends and Impacts

In most of the United States, extreme heat is a long period (2 to 3 days) of high heat and humidity with temperatures above 90 degrees.

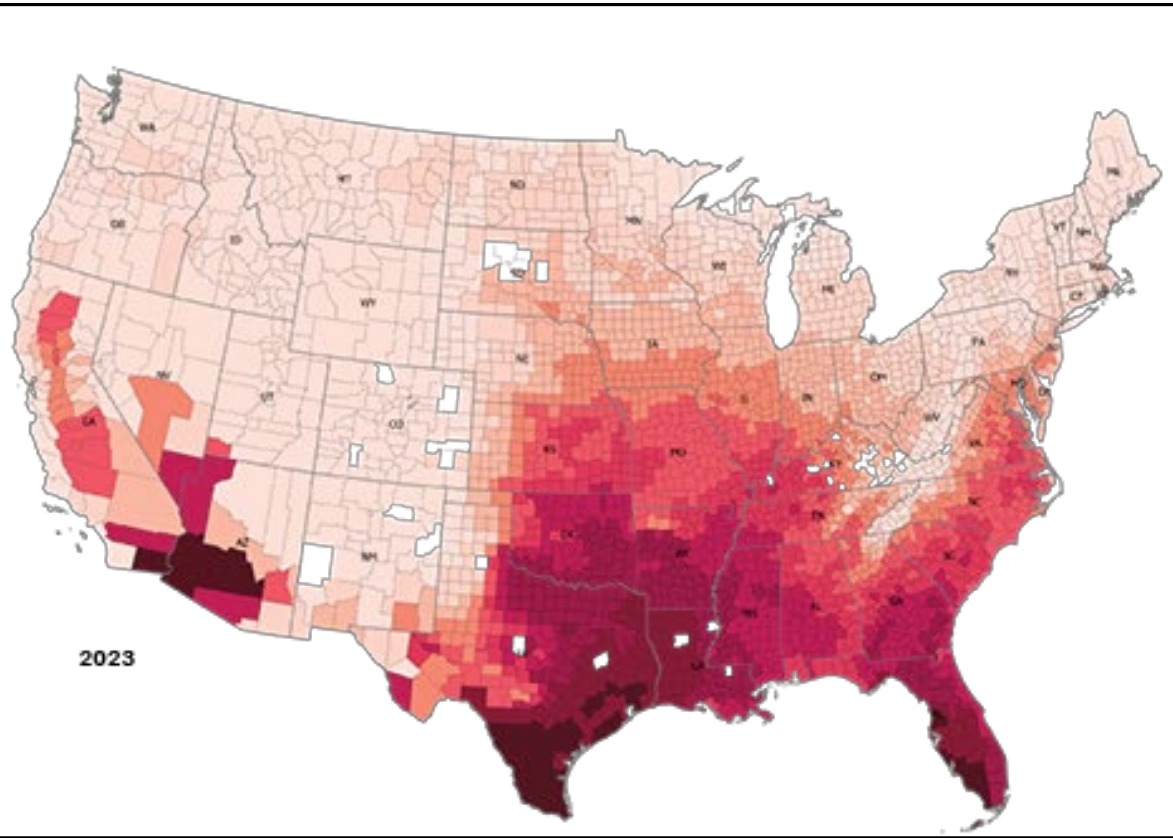
- The heat index, also known as the apparent temperature, is what the temperature feels like to the human body when relative humidity is combined with the air temperature. Some indices can be fatal.
- When perspiration is evaporated off the body, it effectively reduces the body's temperature but when relative humidity is high, the rate of evaporation from the body decreases and the body can overheat.

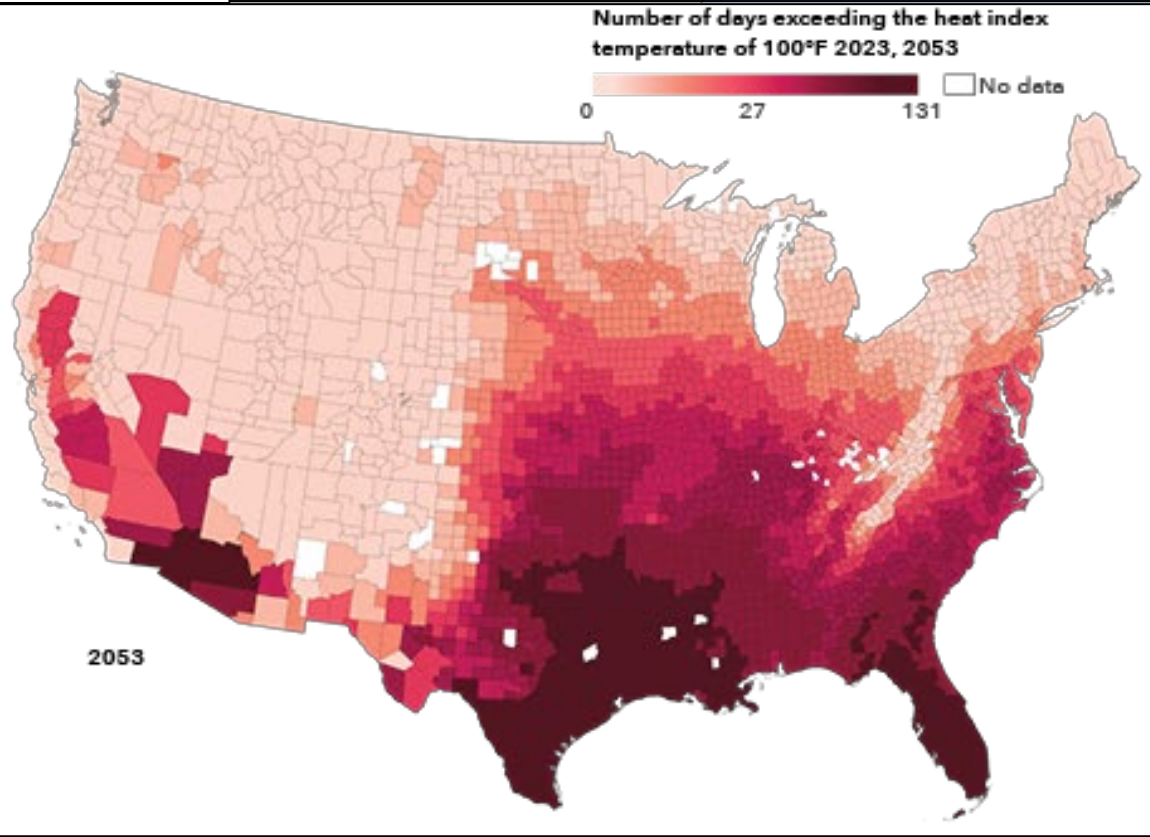
Connecticut has an annual average around 50 degrees Fahrenheit with the winter average around 27 degrees and the summer ranging around 73 degrees. As the climate trends warmer over the next 25 years (depicted below), impacts can include damages to concrete mixtures, power lines, transformers, railways, runways, roadways, and operational capabilities for first responders and outdoor workers.

Extreme Heat records for the state were set in August 1916 at 106 degrees with a repeat event in July 1995. As averages continue to rise across the state, materials built to the previous heat average will see degradation from the continuous warming throughout the year with minimal overnight relief. Impacts have already been reported in 2023.

Due to persisting heat in the Northeast in 2023, Amtrak has slowed train operations in order to prevent rail damages or engine failures.

- Extreme heat can cause rail, bridge and overhead wires to expand.
- Heat amplified thunderstorms have produced record-breaking rains.





Drought Trends and Impacts

The State Interagency Drought Workgroup has made a list of drought recommendations such as after-actions post drought and defining key relationships:

- https://portal.ct.gov/-/media/Water/Drought/Subworkgroup_Summary_of_Recommendations_2021-06-04.pdf
- More information can be found: https://portal.ct.gov/Water/Drought/Data-and-Reports

Precipitation which falls across the region is first absorbed by thirsty soils then by vegetation before eventually the rivers and drainage basins can seep into the groundwater, replenishing wells and aquifers.

- Connecticut is mainly comprised of two types of aquifers. Bedrock-till formations underlie the entire state. Stratified drift formations lie in river valleys.
- The main cause of subsidence is groundwater removal from human activity while the state also has subsurface soil loss after heavy rains and abandoned mine collapse.

There are about 322,578 residential wells in the state which serves about 23% of the population, or 820,000 residents.

- In the last 20 years Connecticut has experienced drought 10 percent to 20 percent of the time. In 2000, 2016, and 2020, the region experienced historic drought conditions not seen since the 1960s.

In 2022, eastern Connecticut reported significant issues operating within worsening drought conditions. In East Lyme, 30% of the water supply was either running at a reduced rate or completely offline by the end of August.

- One municipal well cost nearly a million dollars to replace but stream flows were too low for it to operate. In some cases, trucking in water from other sources
- In Putnam, the Little River is one of three main sources of the town's water supply. It is at its lowest recorded flow in nearly 50 years, keeping the town from running its water treatment plant that draws from the river.
    - Putnam then moved to ban non-essential water use, including watering lawns and gardens and washing cars.

Subsidence Threat

Land subsidence occurs when large amounts of groundwater have been withdrawn from certain types of rocks, such as fine-grained sediments.

- The rock compacts because the water is partly responsible for holding the ground up.
- When the water is withdrawn, the rocks falls in on itself.

Most of Connecticut's population resides along the stratified-drift aquifers with sedimentary-rock. Drought threatens the integrity of these areas.

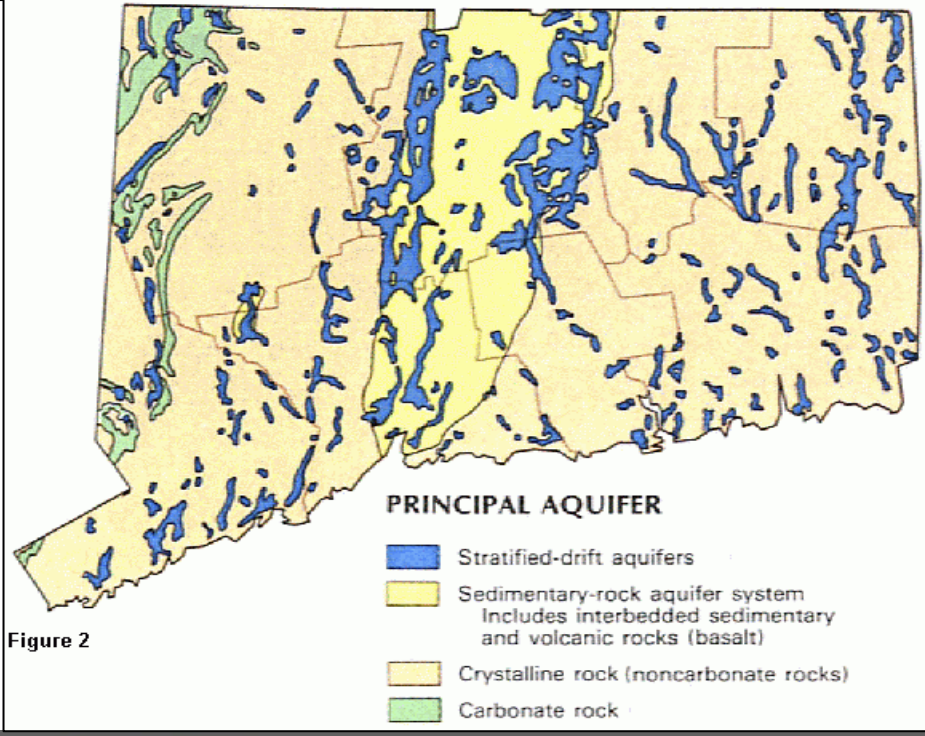
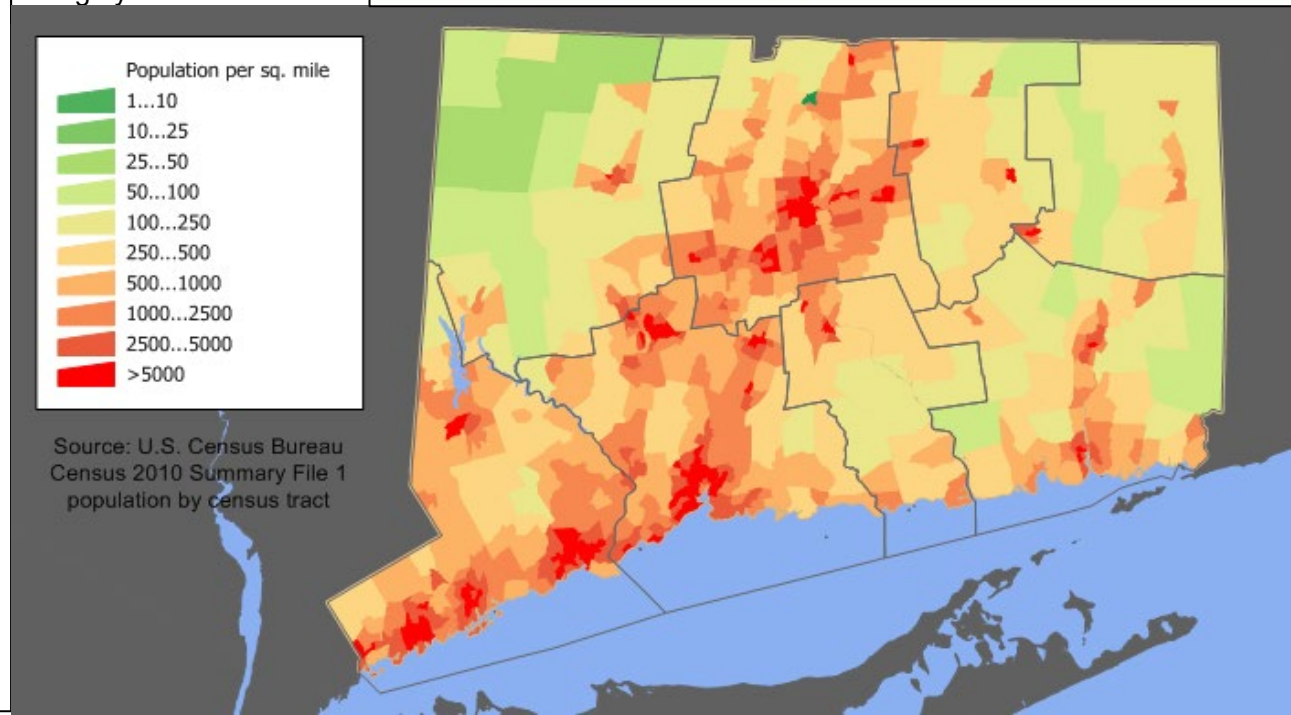


Figure 2



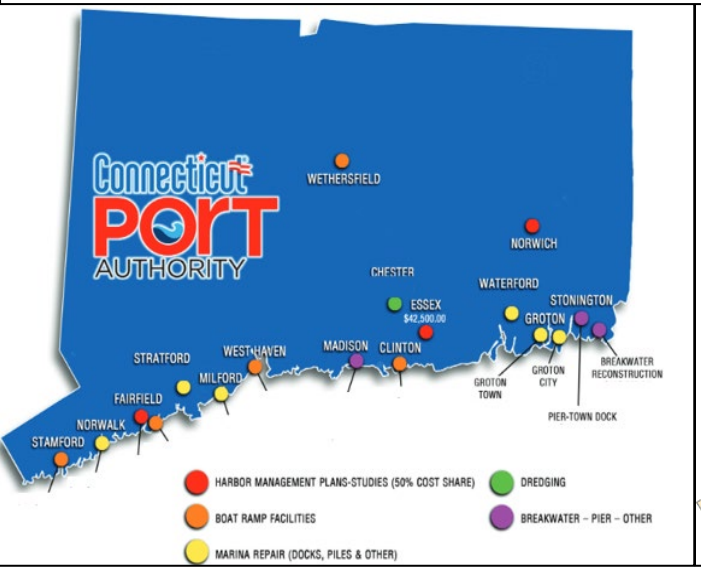
The Connecticut River

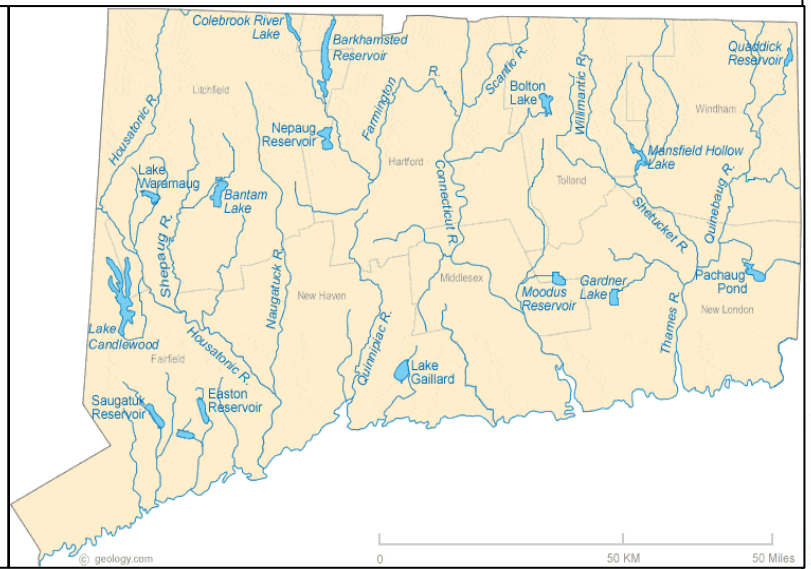
The Connecticut River is the longest river in New England with numerous connections in the Northeast.

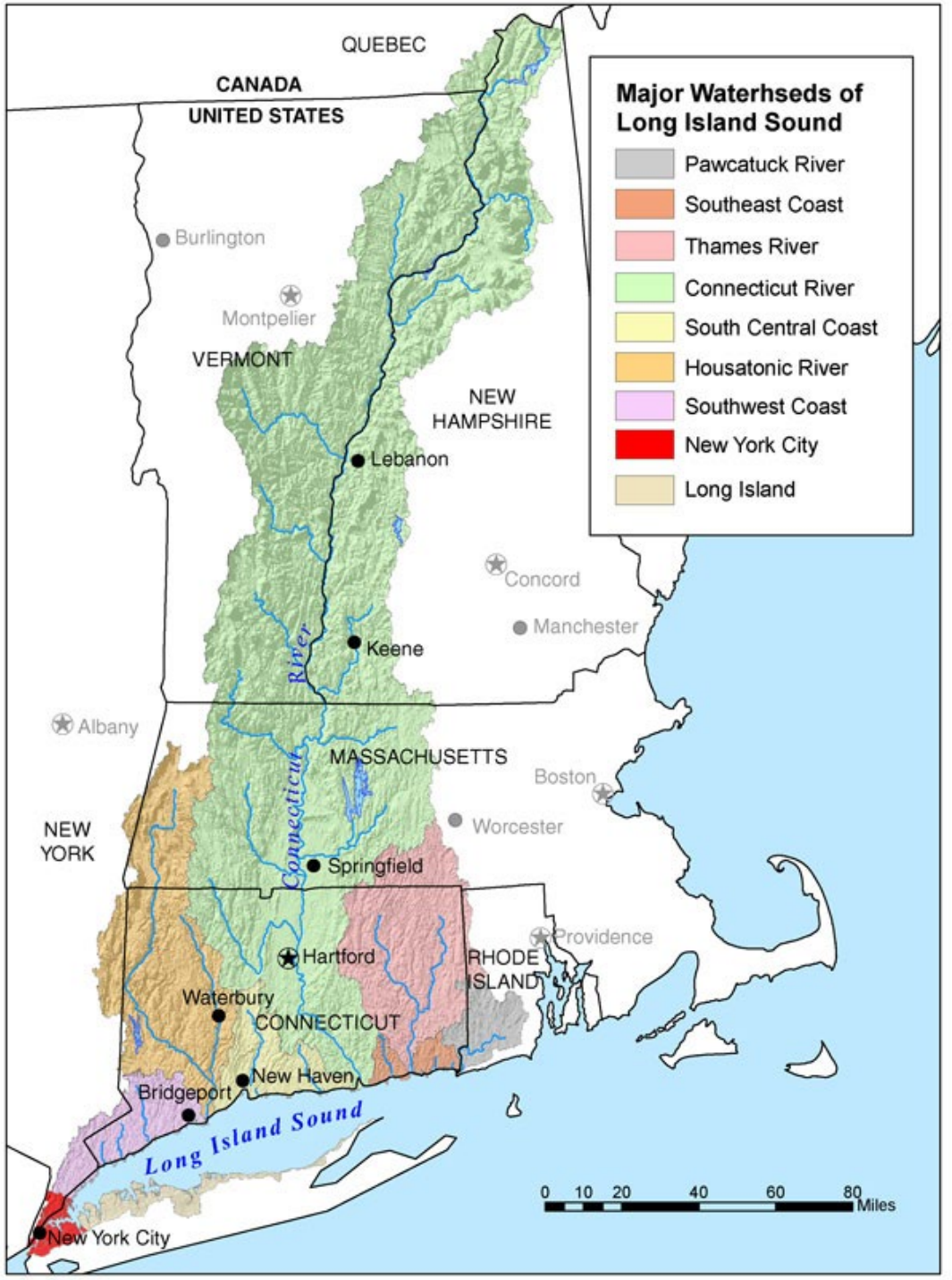
- 2023 a Mid-July rainfall event caused the Connecticut River in Massachusetts achieved its highest reading, about 4-feet above flood conditions as floodwater from Vermont surged to the south.
- As storms moved across the region, each state recorded amplified rainfall which increased river flows across the region ahead of the drainage from Vermont, meaning even Connecticut saw river flooding.
- Given recent dry and abnormally warm conditions over the past year across the region, the sudden fluctuation in when and how fast rainfall occurs, and the drop in river flow, the river is at risk of increased disruption.

Numerous rivers run through Connecticut and the state contains the estuaries for several major rivers.

- The river flows 410 miles from Quebec-New Hampshire border to Old Lyme, Connecticut.
    - The river runs through New Hampshire, Vermont, Massachusetts, and Connecticut.
- It has over a thousand dams on its tributaries and 16 dams spanning its main stem, 12 of which are hydropower projects. The first full main stem barrier was built at Turners Falls in 1798.
- Aeration of dams to withstand major temperature swings was not established until 1945.

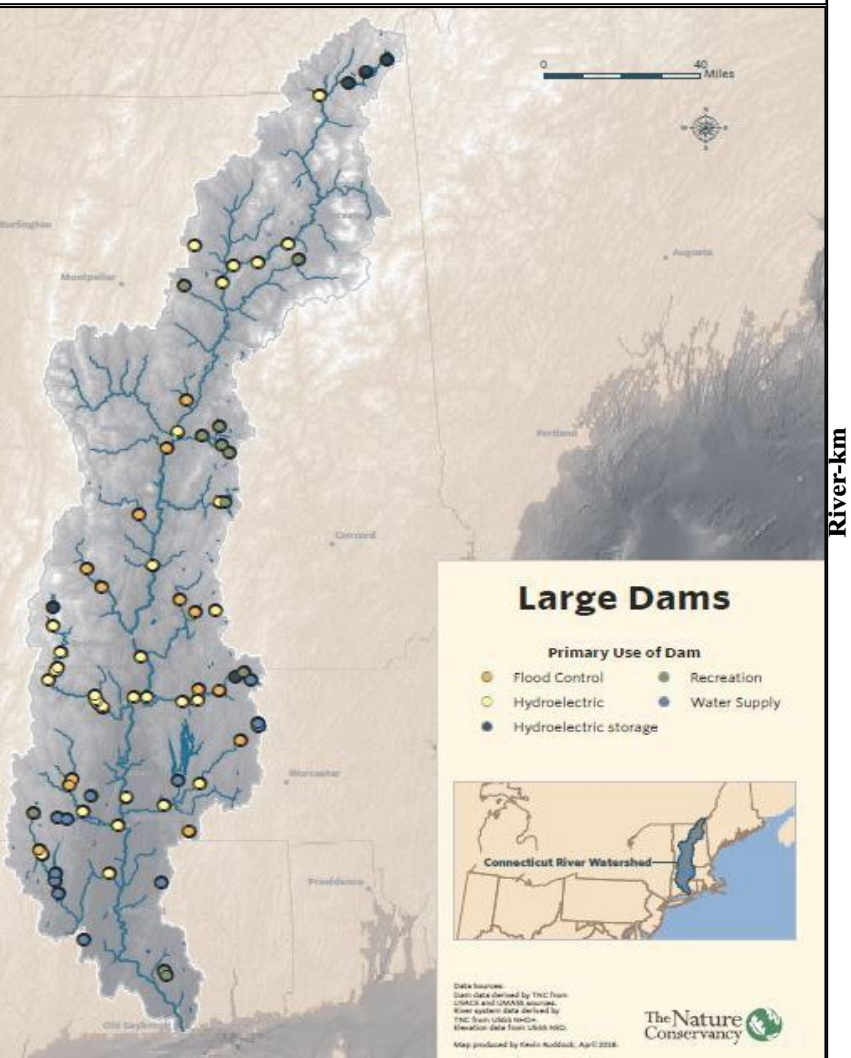






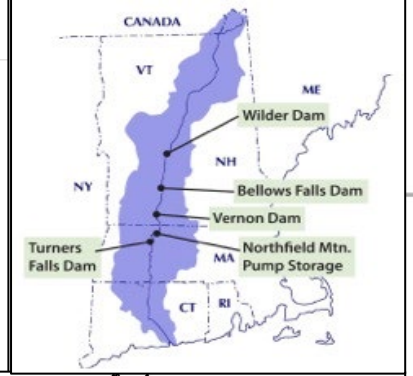
Connecticut Dams

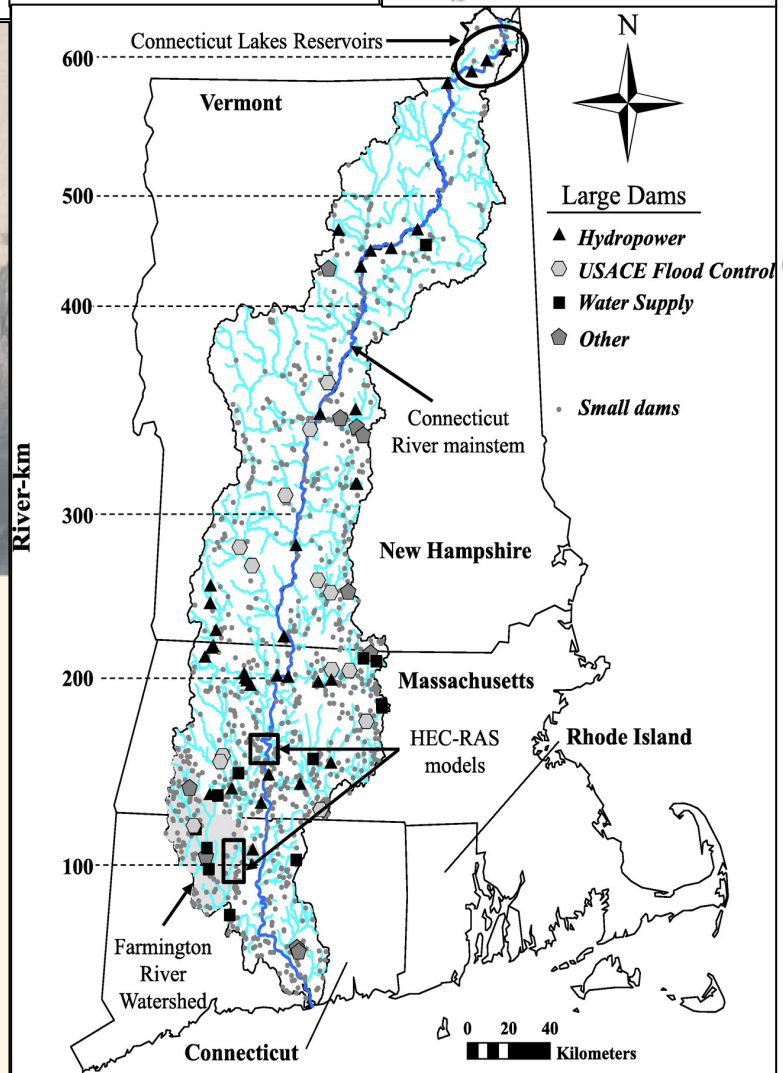
Connecticut has 238 high hazard dams with 21 miles of levees. As is evident by the maps, the river systems in the state are highly dependent on the flow and functionality of upstream dams and tributaries.

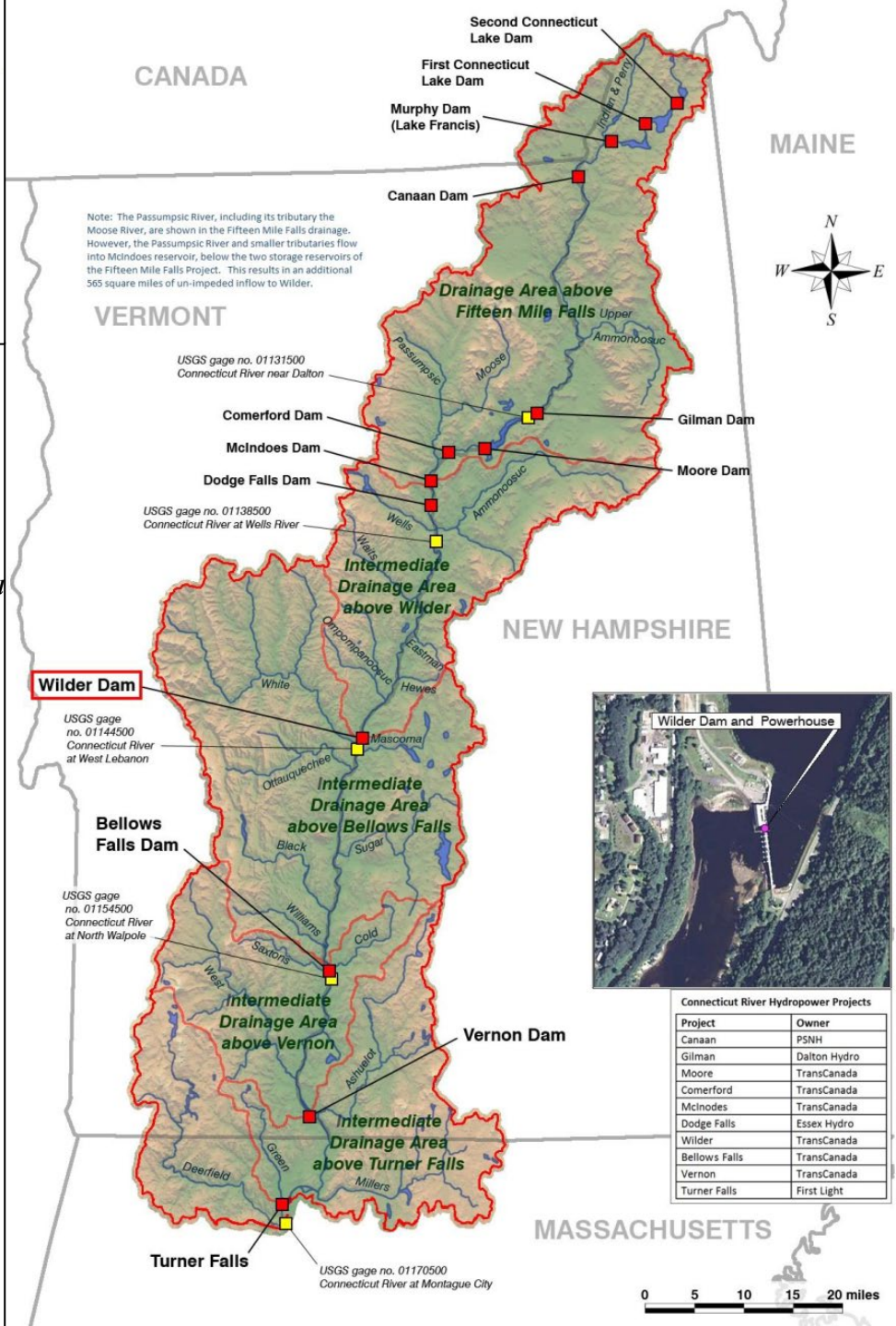


CONNECTICUT

478,000 Conventional Hydropower in MWh	44,080,000 Total Electricity in MWh
2,377,000 Total Renewable Energy in MWh	1% Hydro as a % of the Total Energy
20% Hydro as a % of the Renewable Energy	32 Total Powered Dams







Aging Dams

Concrete Deterioration Risk Analysis: When was the structure constructed? What are the properties of the concrete (to the extent known)? What construction equipment and methods were used and what potential "defects" may have resulted from these methods? What are the environmental conditions and loading on the structure? What deterioration mechanisms (if any) may be acting on the structure? Is the structure resisting these deterioration mechanisms? What is the rate of deterioration? What dam failure modes are being affected by this deterioration? ***Seals, Gates, Valves, Composite Materials – What are the thresholds?***

Statistics: Over the last 20 years, the number of high-hazard-potential dams has more than doubled as development steadily encroaches on once-rural dams and reservoirs.

- A high-hazard-potential rating means that if failure were to occur, the resulting consequences would likely be a direct loss of human life and extensive property damage.
- The average age of a US dam is near 62 years; by 2030 70% of the dams in the US will be over 50 years old. This means they were built to the climate norms of 1920-1940.
- In 2017 the Association of State Dam Safety Officials' (ASDSO) cost estimate for the combined total to rehabilitate the nation's non-federal dams exceeded $66 billion. To rehabilitate just those high-hazard-potential dams would cost nearly $20 billion. Additional estimates show the need to rehabilitate federal dams is approximately $27.6 billion.
    - The 2022 update has risen to more than $75 billion, according to a 2022 update of a report from ASDSO. The cost to rehabilitate those dams where the risk is highest exceeds $24 billion. Current figures place the total cost estimated for non-federal dams at $75.69 billion, up from the 2019 estimate of $65.89 billion.

Aging infrastructure and weather event changes: Even as more dams establish Emergency Action Plans, the plans may not consider the full scope of the shift in weather. Areas marked for evacuation based off inundation may be significantly larger with more acute response times necessary. Freeze and heat events could become more damaging.

- Rivers flowing lower than normal will result in exposed materials which previously were kept cool and moist from the water levels prior to a multi-year-long prolonged drought.
    - Direct heating on exposed concrete which previously were under water could damage the material and freeze events can cause waters to freeze at lower levels than before as waterways become shallower potentially resulting in damages.
- Deeper low centers can bring more damaging weather events to supporting infrastructure like instrument buildings, the powerhouse, and residential homes for operators. Specific to the barge traffic, stronger storms could produce more damaging winds possibly increasing the amount of barge breakoffs during torrential rains and flooding with the barges floating downstream and colliding with bridges and other critical infrastructure like the lock systems.

Freeze-Thaw-Freeze Concerns Ice expands about 9% upon freezing, causing forces of up to 30,000 lbs/in2 , which can crack concrete if it is not mitigated. Aeration was not developed until 1945, thereby dams built prior to 1945 are weaker to expanding water during major temperature shifts. The northeast contains the oldest dams operating.

- The earliest concretes made by Reclamation were not very frost resistant, failing in as few as 50 to 100 Freeze-Thaw cycles. As the compressive strength of concrete increased, the Freeze-Thaw resistance increased, but the concrete still typically failed in about 200 cycles.
- Modern frost resistant concrete should normally resist well over 1,000 cycles of Freeze-Thaw. As heavier rainfall events bring more runoff and debris, abrasion-erosion damage is likely increasing and damaging the water structures.
- Abrasion erosion damage can be quite severe in large dams and in the sandy rivers.

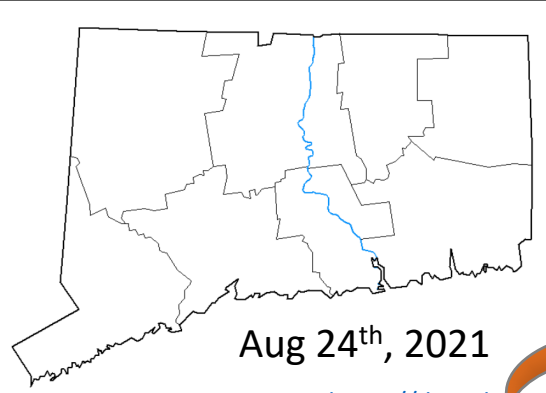
Association of State Dam Safety Officials Year	Funding Needs, Non-Federal Dams	Funding Needs, Non-Federal HHPD
2003	$34 billion	$10.1 billion
2009	$51.46 billion	$16 billion ($8.7b public, $7.3b private)
2012	$53.69 billion	$18.2 billion ($11.2b public, $7b private)
2016	$60.7 billion	$18.71 billion
2019	$65.89 billion	$20.42 billion
2022	$75.69 billion	$24.04 billion

Drought Conditions

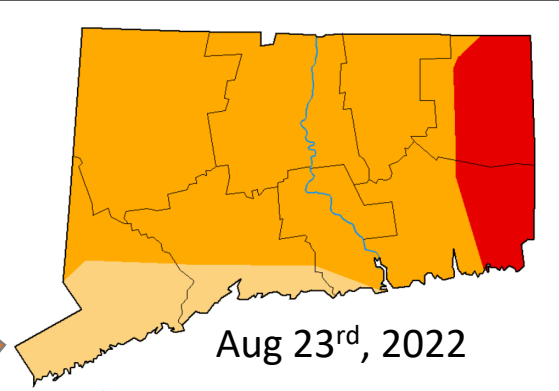
In the last 100 years, there have been at least three major US droughts. The 1930s Dust Bowl drought and the 1950s drought, each lasted 5-7 seven years and covered large areas of the country with significant impacts (NDMC). The current multi-year drought across the West is the most extensive and intense drought in the 22-year history of the US Drought Monitor with conditions rapidly deteriorating since 2020 (NIDIS).

- The likelihood of extreme multiyear droughts will increase, threatening regional water supplies according to the Center for Climate and Energy Solutions.
- 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 -- United Nations. Depicted here, despite wet conditions in a few states, national drought levels persist.
- 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.

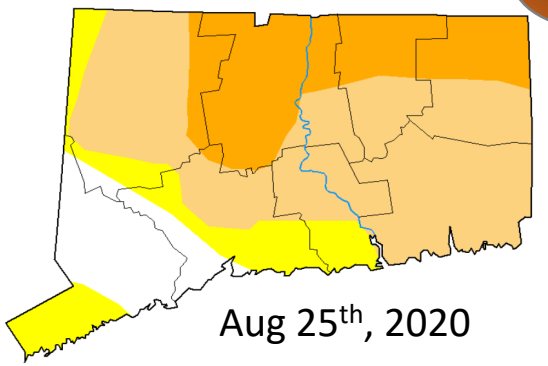


Aug 24th, 2021

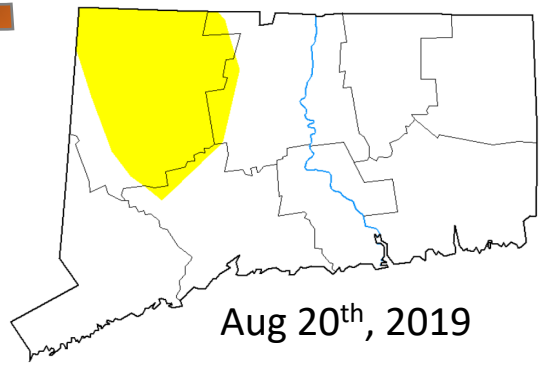


Aug 23rd, 2022

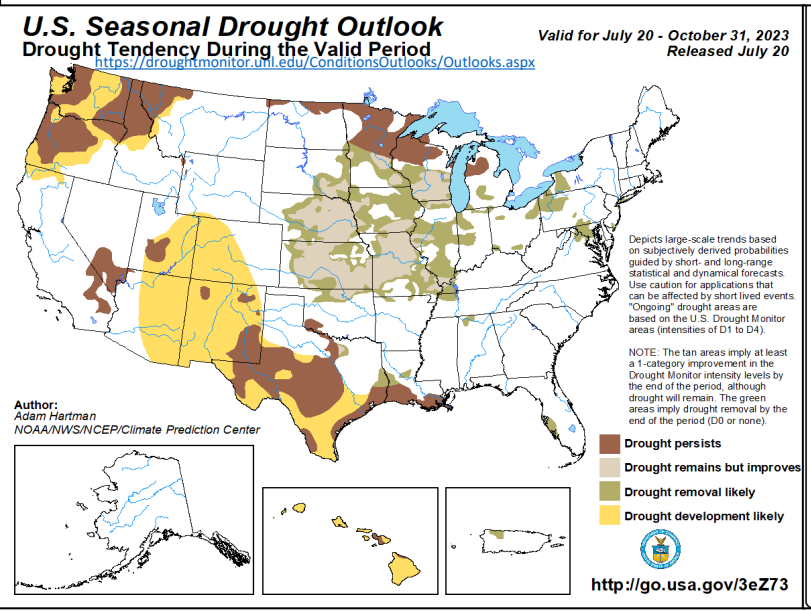
https://droughtmonitor.unl.edu/Maps.aspx

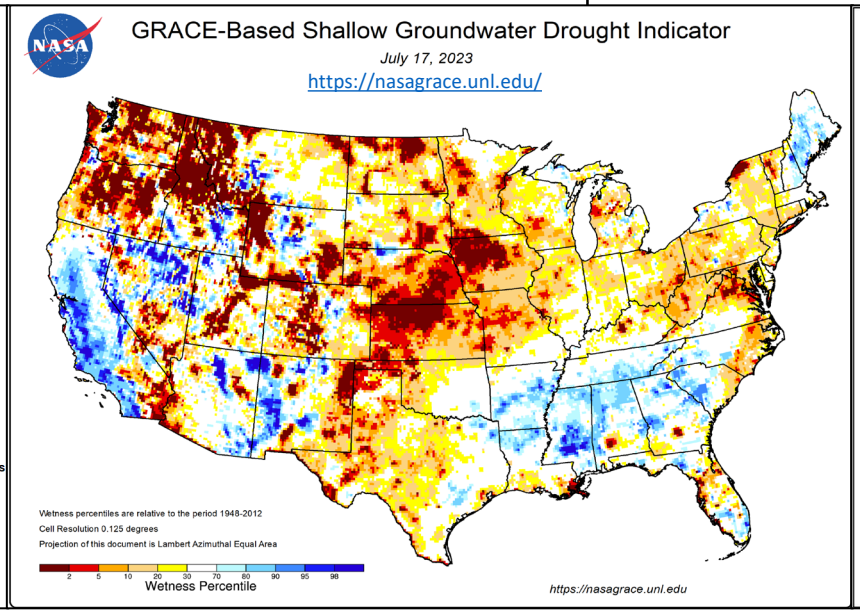


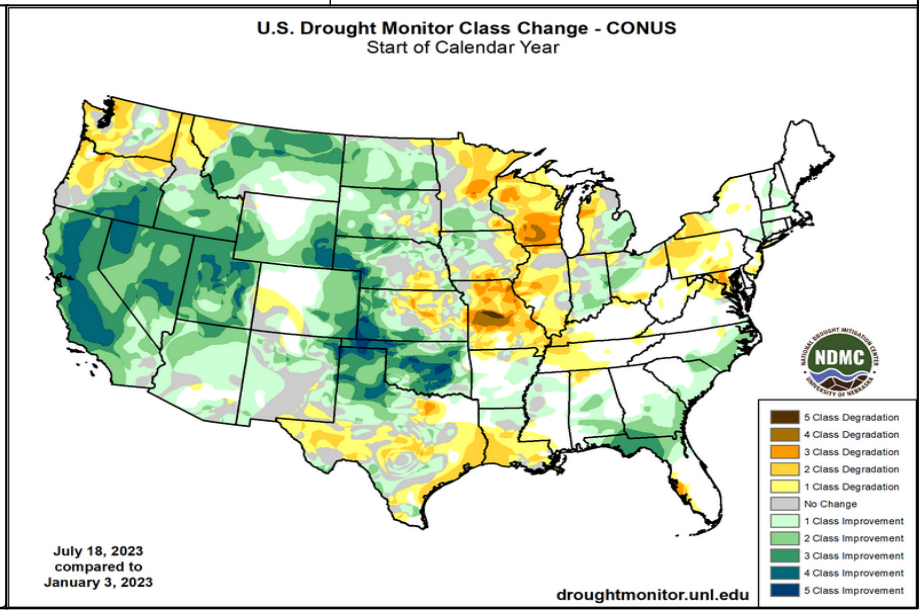
Aug 25th, 2020



Aug 20th, 2019







Cascading Threats to Agriculture in the Northeast

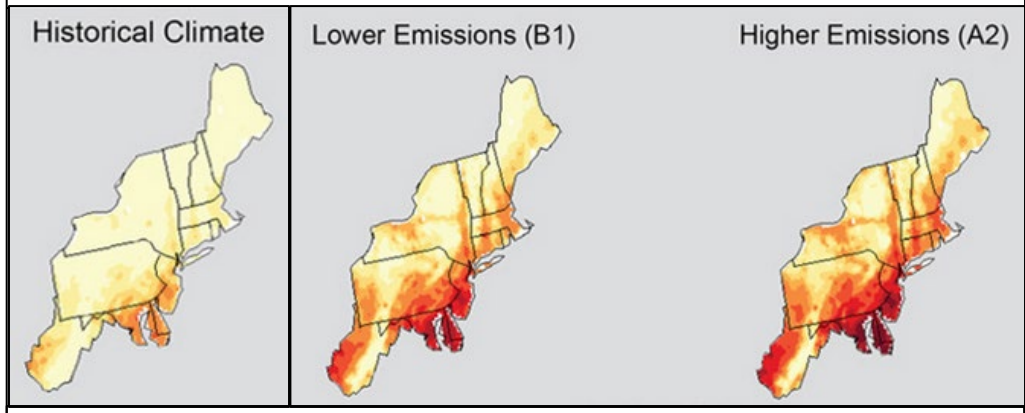
Just days before harvest in 2023, flooding in Vermont wiped out numerous farms by submerging hay lots, pumpkin fields, corn fields, and other crops. The flooding across the area drained into the Connecticut River System flooding numerous fields across Connecticut as well and further damaging the regional crop outputs.

Widespread impacts were felt in 2022 from the drought conditions in the region as farmers irrigated crops earlier than usual and more stressed crops were reported regionally. The demands of irrigation starting early and lasting longer increased workloads and raised operation costs. Crop yields were also reportedly smaller than typical.

2022 Drought: Impacts from drought to crops and farming sustainability

- One Massachusetts farmer estimated additional costs of up to $100,000 due to irrigation, while another Massachusetts farmer was paying $3,000 a day to water his apple crop.
    - Growers also contended with irrigation water supplies that ran low, dried up, or had water quality issues. Some farmers hauled in water, adding additional costs.
- The lack of rain, combined with above-normal temperatures, led to stunted and drought-stressed crops, reduced yields, and crop losses in parts of New England, New York, and Pennsylvania.
- Hay quality and yields were reduced in drought-stricken areas, with some farmers getting only one cutting of hay instead of three and some using supplemental feed, further increasing operational costs.
- Christmas tree saplings dried up in multiple areas, with one Rhode Island grower estimating a loss of 70% of their crop worth equating to around $70,000 and some New England farms not fully opening or raising prices.
- Some farmers reported smaller but sweeter apples and fewer or smaller-sized pumpkins. Between reduced yields and increased costs to farmers, prices of crops, such as fall-favorite apples and pumpkins, increased in some areas.
    - For instance, to offset costs, one grower on Long Island, New York, raised prices by 15%. However, the drought conditions generally led to fewer crop diseases.
- The dry conditions also stressed trees, causing them to drop leaves prematurely and making them more prone to insects, disease, and falling.

Projected Increases in the Number of Days over 90°F



Between 1895 and 2011, temperatures rose by almost 2°F and projections indicate warming of 4.5°F to 10°F by the 2080s.

Between 1958 and 2012, the Northeast saw more than a 70% increase in the amount of rainfall measured during heavy precipitation events, more than in any other region in the US.

State	Direct Sales of Farming, Fishing & Forestry	Direct Processing Revenue	Total Economic Impact	Jobs Supported
Connecticut	$682 million	$2.4 billion	$5.2 billion	29,163
Maine	$1.7 billion	$5.0 billion	$11.7 billion	74,523
Massachusetts	$1.3 billion	$6.5 billion	$13.3 billion	70,537
New Hampshire	$510 million	$1.3 billion	$2.9 billion	17,880
New Jersey	$1.4 billion	$7.0 billion	$13.6 billion	66,144
New York	$5.8 billion	$20.2 billion	$47.2 billion	209,956
Rhode Island	$168 million	$800 million	$1.5 billion	7,846
Vermont	$911 million	$3.0 billion	$7.1 billion	36,969
8-State Total	**$12.4 billion**	**$46.0 billion**	**$102.4 billion**	**513,018**

National Agricultural Risk

The Western US accounts for most of the the nation's fruits and vegetables. Should these areas suffer major cross loss due to drought and heat, there would be national impacts.

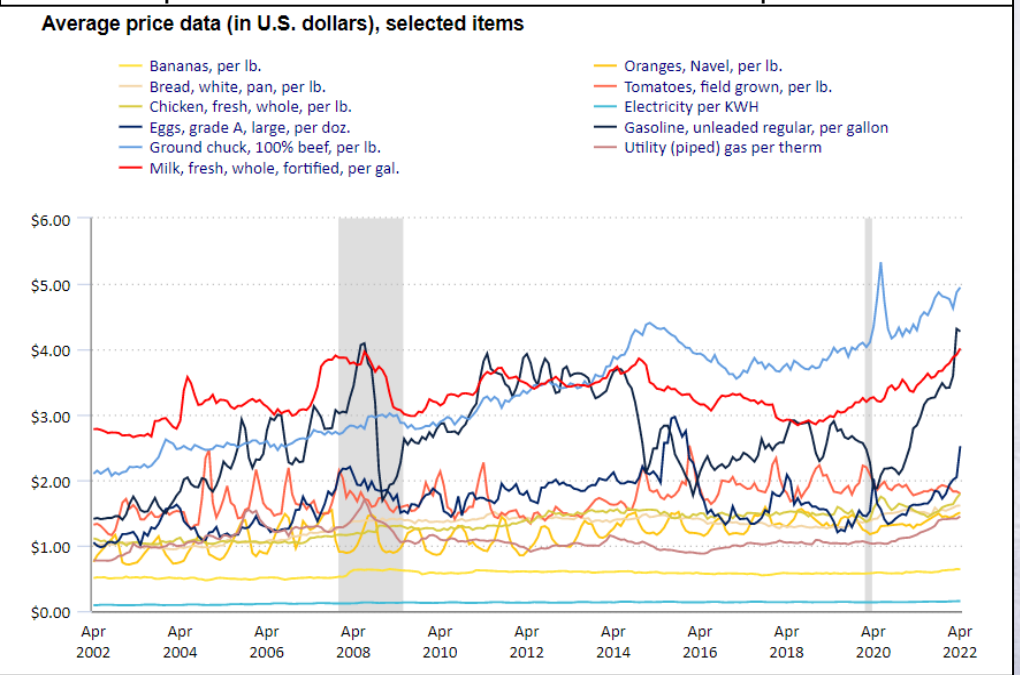
- Well drilling is backlogged in many regions and rising in cost reaching $120,000-$150,000 to drill a 650-foot irrigation well. Some farmers cannot drill new wells due to soil salinity.

The ultimate effect of drought is decreased forage production, resulting in diminished feed available for cattle. This can lead to problems such as reduced pregnancy rates, loss of body condition of the cow, and lower milk production, which lowers weaning weights.

- Additional effects can range from herd culling due to a lack of resources, to widespread livestock production decreases regionally and pricing impacts due to high supply as more ranchers and farmers lose capability during extreme weather.

In 2021, the United States was the world's largest beef producer, second-largest importer, and second-largest exporter by volume.

- Beef exports accounted for 11% of U.S. domestic production.



*The billion-dollar disaster assessment puts total crop and rangeland losses from major 2022 disasters at **over $21.4 billion***

Drought & Wildfires
(AR, AZ, CA, CO, ID, IA, KS, MN, MT, NE, ND, NM, NV, OK, OR, SD, TX, UT, WA, WY)

Hurricanes Ian, Nicole, and Fiona
(FL)

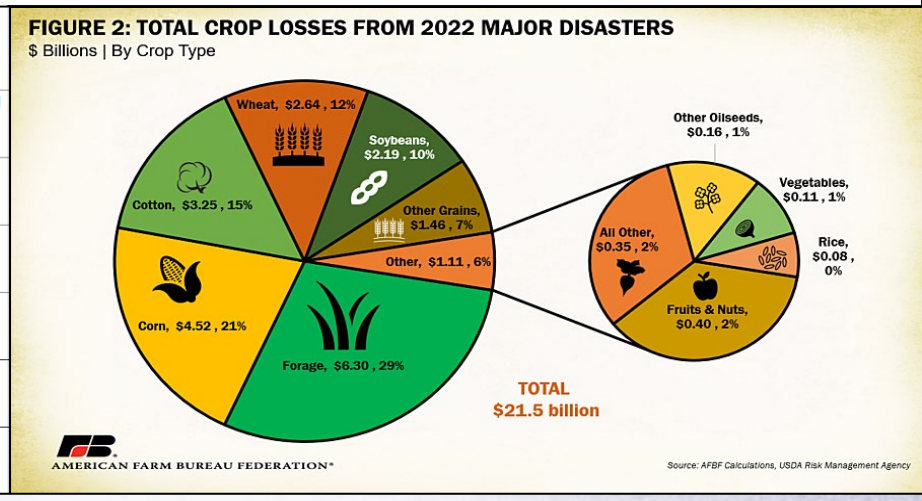
Central Derecho & Severe Weather (Jun)
(IL, IN, NE, OH, WI)

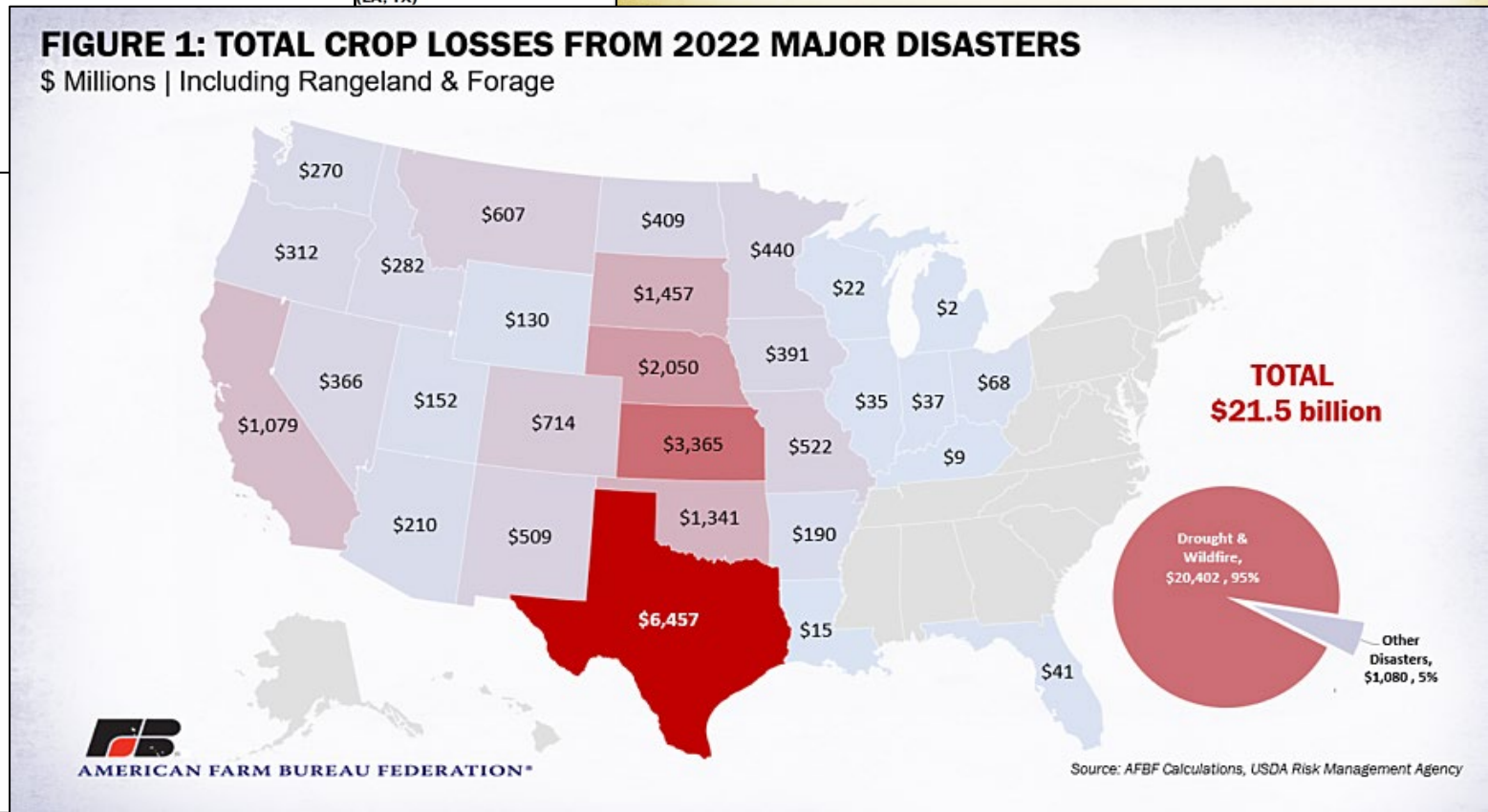
Kentucky & Missouri Flooding
(KY, MO)

Hail Storms & Severe Weather (May)
(MN, OK, SD, TX, WI)

North, Central, & Eastern Severe Weather (Jul)
(IL, IN, MI, MN)

Southern Severe Weather & Tornadoes (Apr)
(LA, TX)





Evaporative Impacts to Wildfire Spread

The Evaporative Demand Drought Index (EDDI) - an experimental tool that examines how anomalous the atmospheric evaporative demand (E0; "the thirst of the atmosphere") is for a given location over a given period.

- EDDI can serve as an indicator of both rapidly evolving "flash" droughts (developing over weeks) and sustained droughts (developing over months but lasting years).
- Flash drought is what the Northeast is prone to threats from.
- This mapping can be a sign of increasing fire weather conditions.

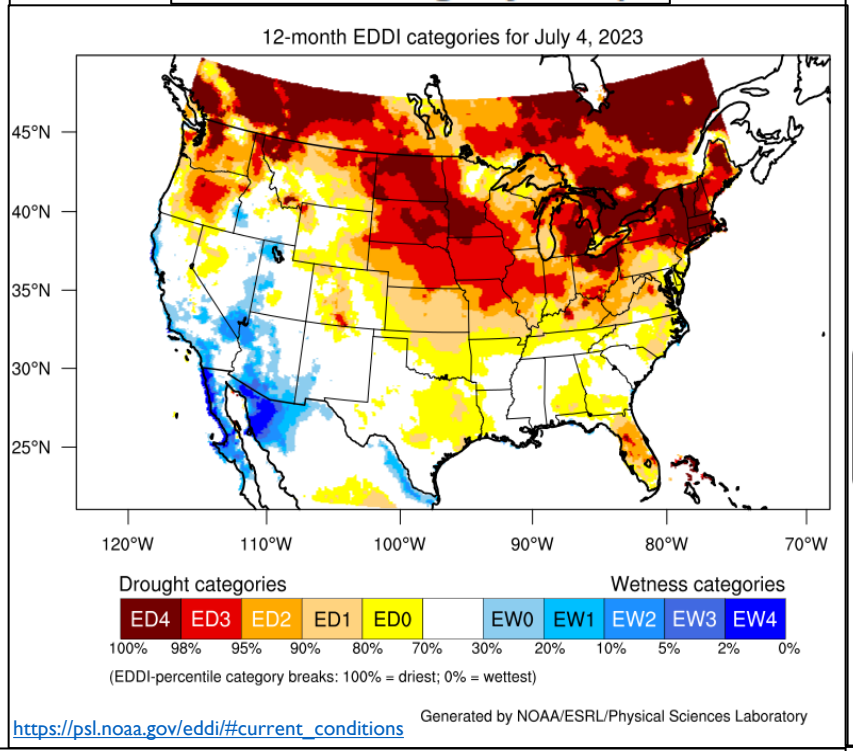
Flash drought - the rapid onset or intensification of drought. This occurs when lower-than-normal rates of precipitation are accompanied by abnormally high temperatures, winds, and radiation.

Evapotranspiration - the process by which water is transferred from the land to the atmosphere by evaporation from the soil, other surfaces, and by transpiration from plants.

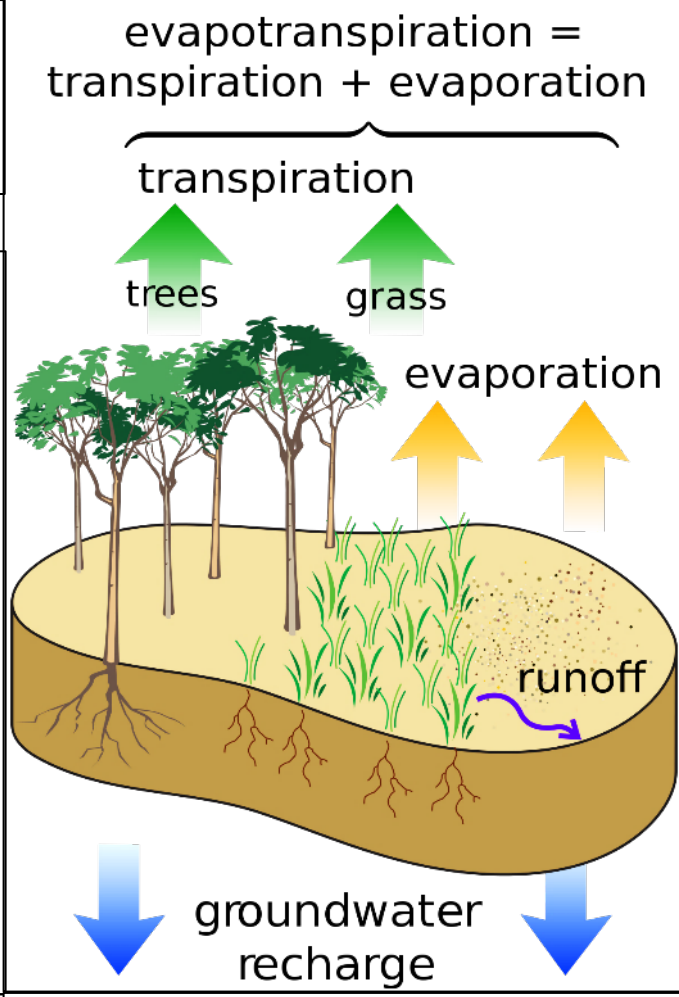
Excessive Heat Warning - a heat index of 105 °F or greater that will last for 2 hours or more.

- This increase is driven primarily by rising air temperatures and will significantly boost the risk of extreme wildfires.

EDDI Category Map



https://psl.noaa.gov/eddi/#current_conditions

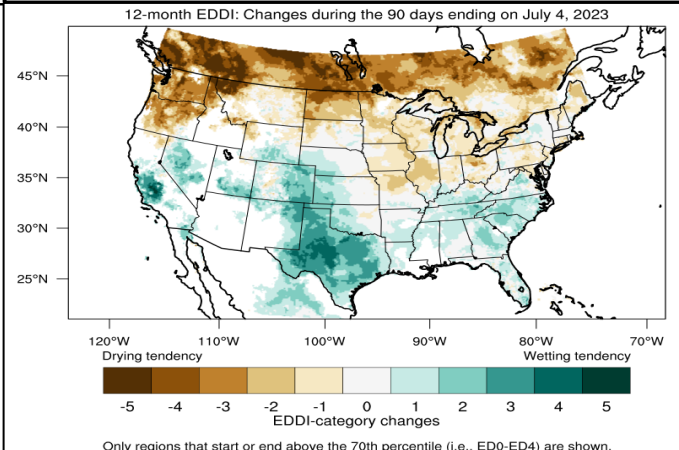


Research shows the likelihood of extreme multiyear droughts will increase, threatening regional water supplies.

Currently, EDDI is generated daily—though with a 5-day lag-time—by analyzing a near-real-time atmospheric dataset. This lag-time results from the procedures to quality control the meteorological data used to estimate evaporative demand.

- EDDI can offer early warning of agricultural drought, hydrologic drought, and fire-weather risk by providing near-real-time information on the emergence or persistence of anomalous evaporative demand in a region. A particular strength of EDDI is in capturing the precursor signals of water stress at weekly to monthly timescales, which makes EDDI a strong tool for preparedness for both flash droughts and ongoing droughts.

Wildfire damage can amplify the drought impacts at the surface by removing trees and exposing soils to direct sunlight due to a lack of shade, stronger winds due to a lack of blocking which could cause additional drying and move loose, dried soil causing an increase in larger dust storms throughout the West increasing threats of fungal spread for threats like Valley Fever.



Children, older adults, people with chronic disease or mental health issues, those who work or exercise outdoors and live in low-income and minority communities need special attention during major heat events.

Neighborhoods with the fewest resources are most susceptible to shift in weather stability and often lack resources to evacuate or relocate.

People living on coastlines, floodplains, or in areas prone to severe storms are more vulnerable to *extreme weather.*

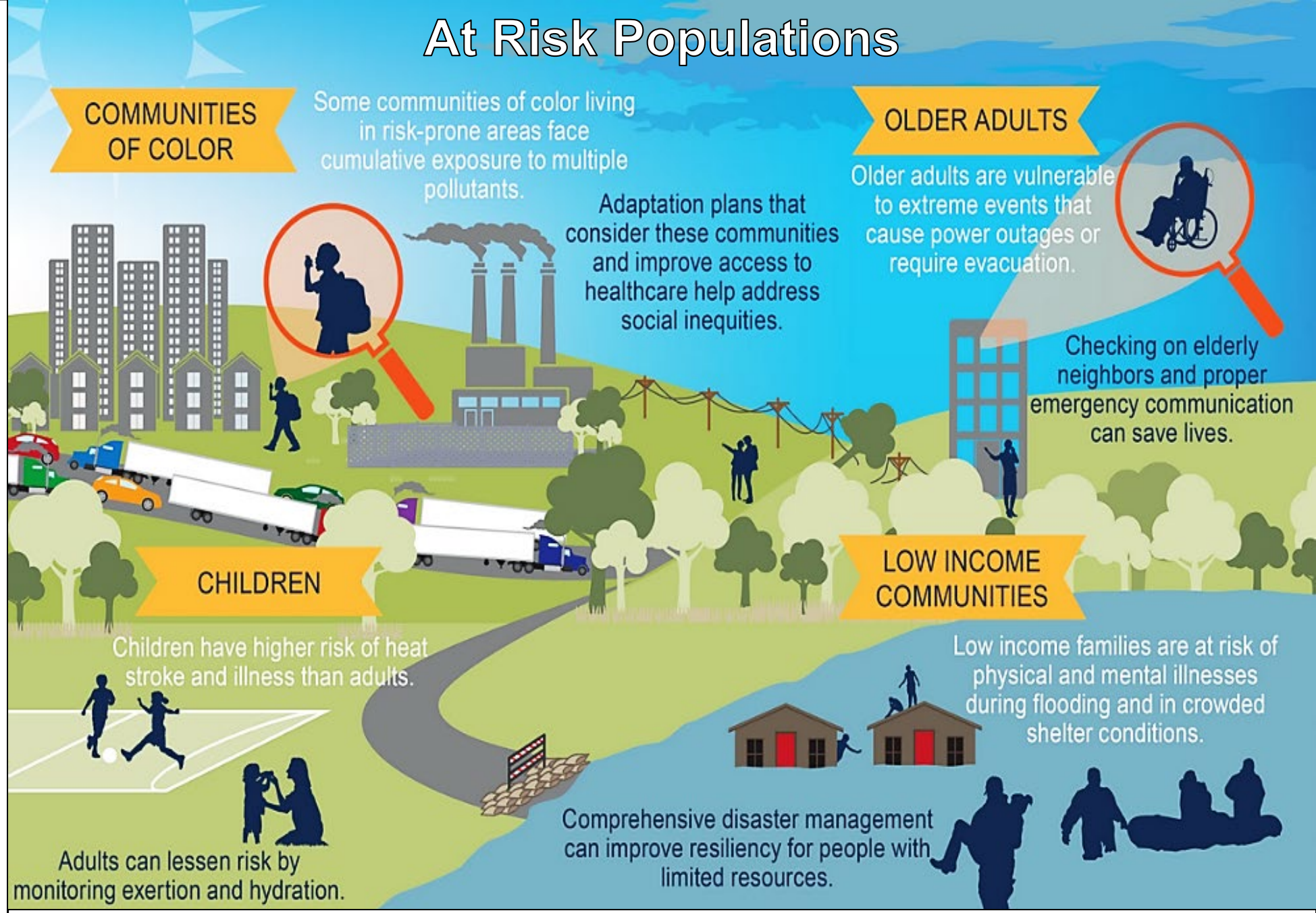
With a 2°C rise, Black Americans are 40% more likely than other groups to live in areas with the highest estimates for climate-driven extreme temperature related deaths *(EPA, 2021).*

- A 2°C rise in extreme heat will result in 14 hours of labor lost each year for outdoor workers due to heat illness. Hispanics are 43% more at risk of living in high-impact areas.
- American Indians are 37% more at risk of living in regions where labor hours are lost each year due to extreme temperatures.

People with low incomes or who have not graduated high school are 25% more likely to live in areas of extreme heat, and 13% more at risk of living on coastal floodplains.

- They are also 50% more at risk of living in coastal areas with the highest projected increases in traffic delays from flooding.

When HVAC systems break, low-income households are more likely to put off repairs and risk heat exposure.



← Study found here: https://www.thenationshealth.org/content/51/9/7.1

Extreme weather exposure information: https://www.apha.org/climate

Fire Trends and Impacts

Dried ground and vegetation acts as fuels for wildfires, causing fires that start by natural sources such as lightning to ignite more easily, and causing wildfires with human sources such as campfires and poorly disposed charcoal to get out of control more rapidly.

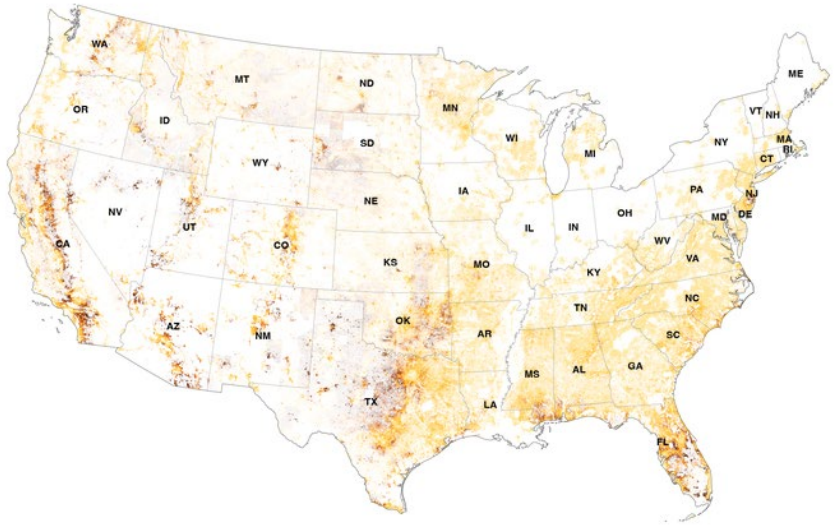
Connecticut traditionally experiences high forest fire danger in the Spring from mid-March through May. The state has 1.8 million acres of forested land.

In an average year approximately 500 acres of Connecticut woodland are burned by forest fires. Connecticut has a predominately volunteer fire department.

71.8 M
Properties at risk today

79.8 M
Properties at risk in 30 years

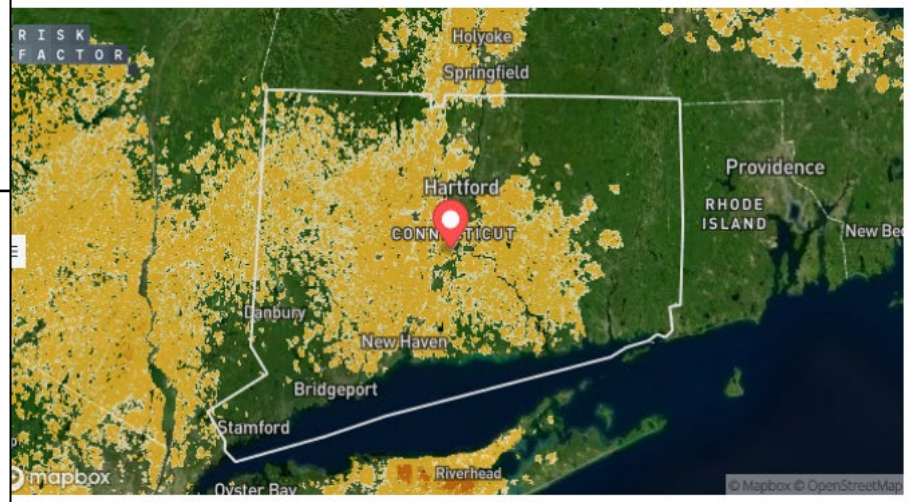
11.1 %
Change in risk



Fire Factor distribution of properties at risk* (145M analyzed)

- Minor - 49.4M
- Moderate - 20.2M
- Major - 6.0M
- Severe - 2.7M
- Extreme - 1.5M

* RISK IS CALCULATED AS THE PROBABILITY OF WILDFIRE REACHING THE BUILDING.



Properties at risk

434,119
Today

550,577
In 30 years

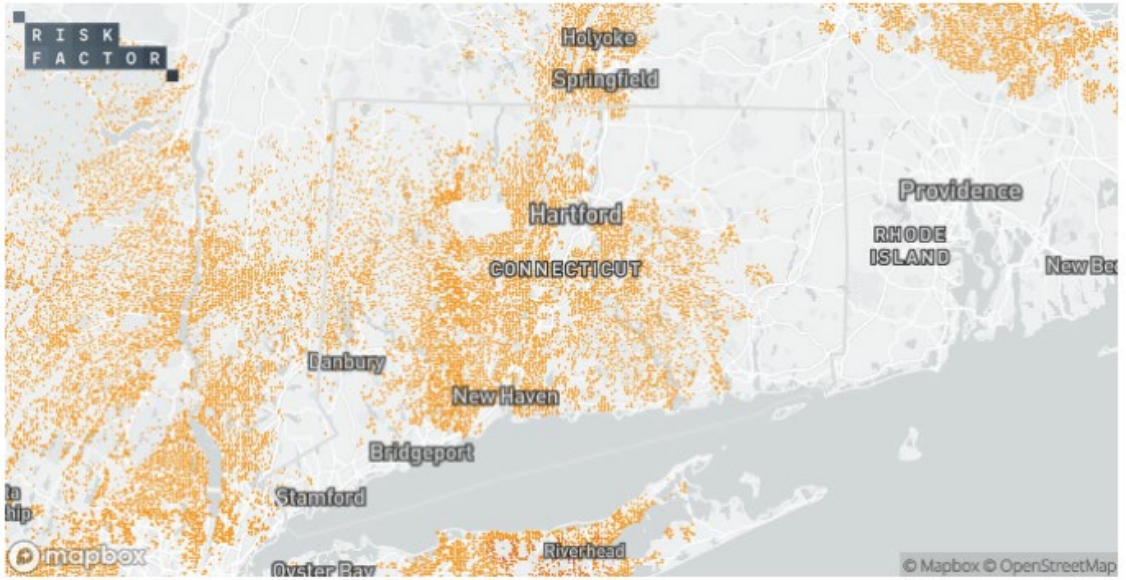
0.1% 0.2% 0.5% 1% 2%+

% likelihood of wildfire

FIRE FACTOR™

There are **550,577** properties in **Connecticut** that have some risk of being affected by wildfire over the next 30 years. This represents **47%** of all properties in Connecticut.

In addition to damaging properties, wildfire can also cut off access to utilities, emergency services, impact evacuation routes, and may impact the overall economic well-being of an area.



Fire Weather

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

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

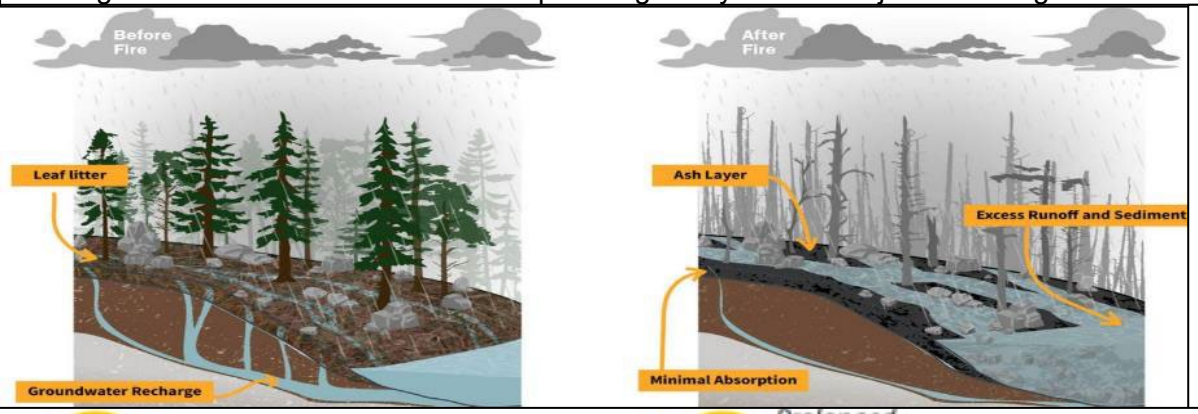
A study from the University of Colorado states wildfires have become larger, more frequent, and more widespread since the year 2000.

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

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

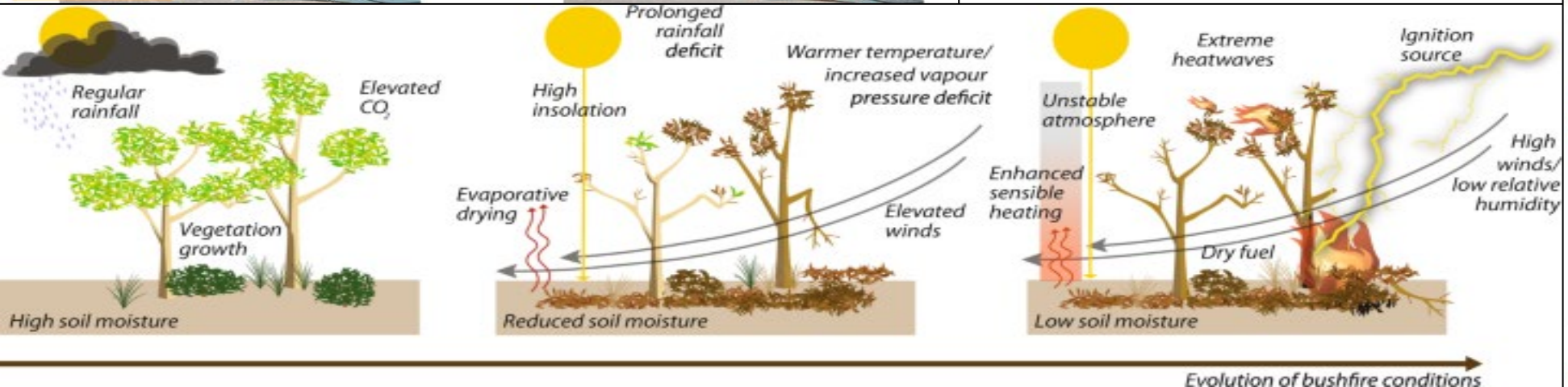
Satellite imagery and state/federal fire history records from 28,000 fires in 1984-2018 showed more fires occurred in the past 13 years than the previous 20 years. On the West and East coasts, fire frequency **doubled**. In the Great Plains, fire frequency **quadrupled**.

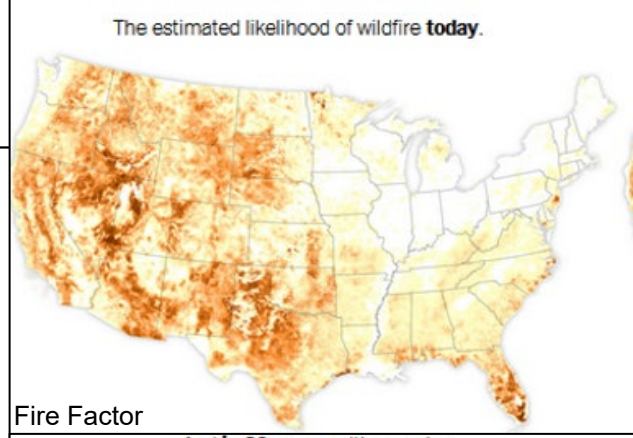
Burned vegetation and charred soil form a water repellent layer which blocks water absorption along with compacted soil from months to years of drought which also inhibits water absorption regionally. These major soil changes cause short rainfall events to be less beneficial for long term



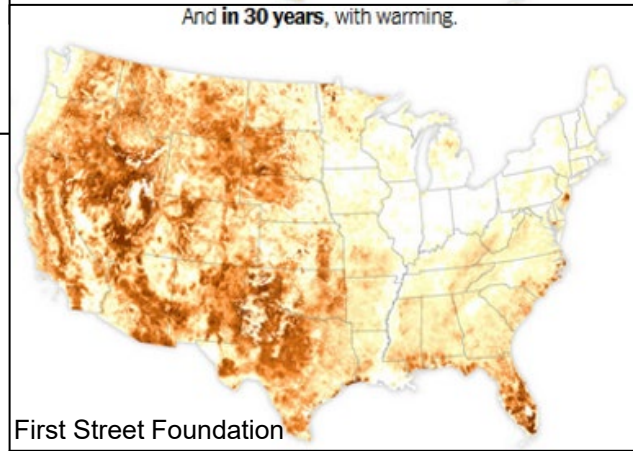
Disasters related to weather, climate, or water hazards happen five times more often now than they did in the 1970s.

- Droughts that may have occurred only once every decade or so now happen 70% more often.
- The IPCC states heavy rainfall that used to occur once every 10 years now occur 30% more often.
- 61% of western wildfires have occurred since 2000 with a steady increase in the number of wildfires the last 60 years.



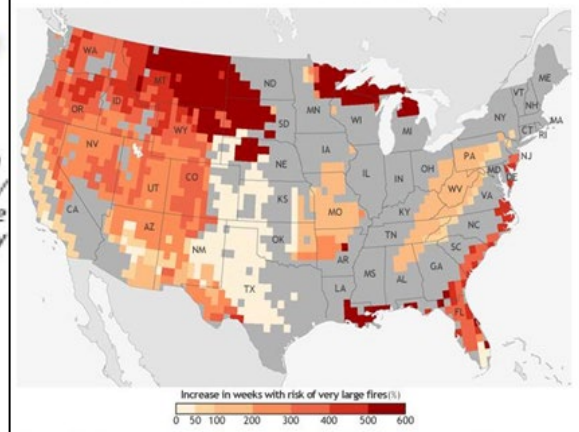


Fire Factor



First Street Foundation

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.

Fire intensity describes the rate at which a fire produces thermal energy. Fire intensity is most frequently used for fire line intensity because the measure is related to flame length.

Fire severity describes ecosystem responses to fire and is to describe the effects of fire on the soil and water system. Severity reflects the amount of energy (heat) that is released by a fire and the degree that it affects the soil and water resources.

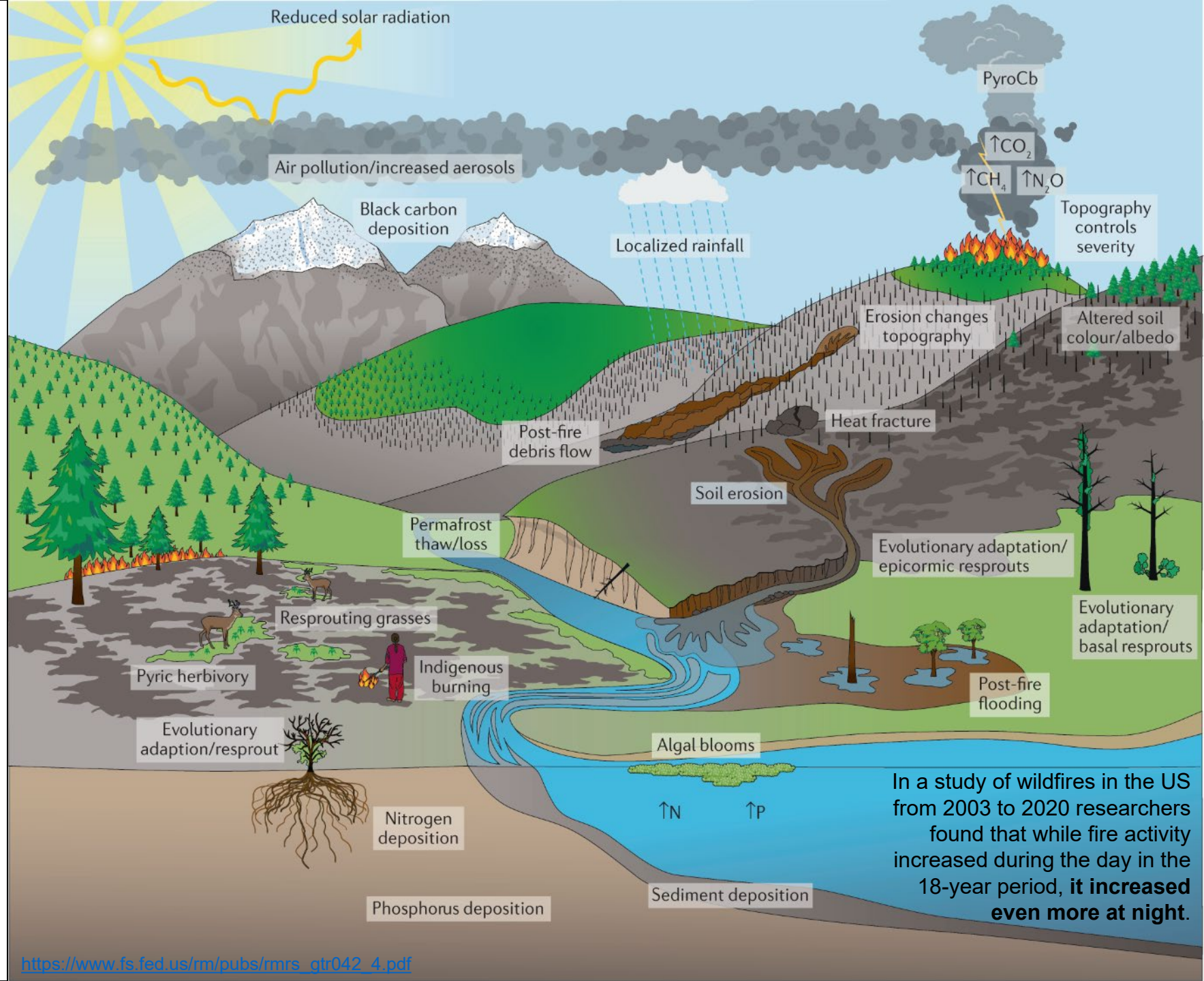
- Heat transfer can damage soil quality outside of the burn area and aerosolize harmful microbes.
- Combustion is the rapid physical-chemical destruction of organic matter that releases the large amounts of energy stored in fuels as heat.
- High intensity fires can produce high severity changes in the soil and cause water phobic layers.

As fires burn wider areas and into higher elevations topography shifts from tree-creep, soil composition changes, soot deposits, debris flows, burn scars, vegetation/foliage decay, early blooms, flooding post-burn, less wildfire activity, and increased pollution from wildfire smoke, the cycle of heightened wildfire activity will worsen each year.

- Damaged soil from heat transfer result in less fire-resistant plant retention and more scraggly brush growing back between fire weather active periods.

Large wildfires in the right atmospheric conditions can create Pyro-cumulus clouds which can amplify fire growth as they develop severe storm cell traits by causing erratic surface wind gusts, lightning ignitions, downbursts, and even tornadic activity. These clouds reduce flight ability in the area and surface visibility.

Fires are getting larger and harder to extinguish



In a study of wildfires in the US from 2003 to 2020 researchers found that while fire activity increased during the day in the 18-year period, **it increased even more at night**.

https://www.fs.fed.us/rm/pubs/rmrs_gtr042_4.pdf

Large Wildfires and Ash Deposits

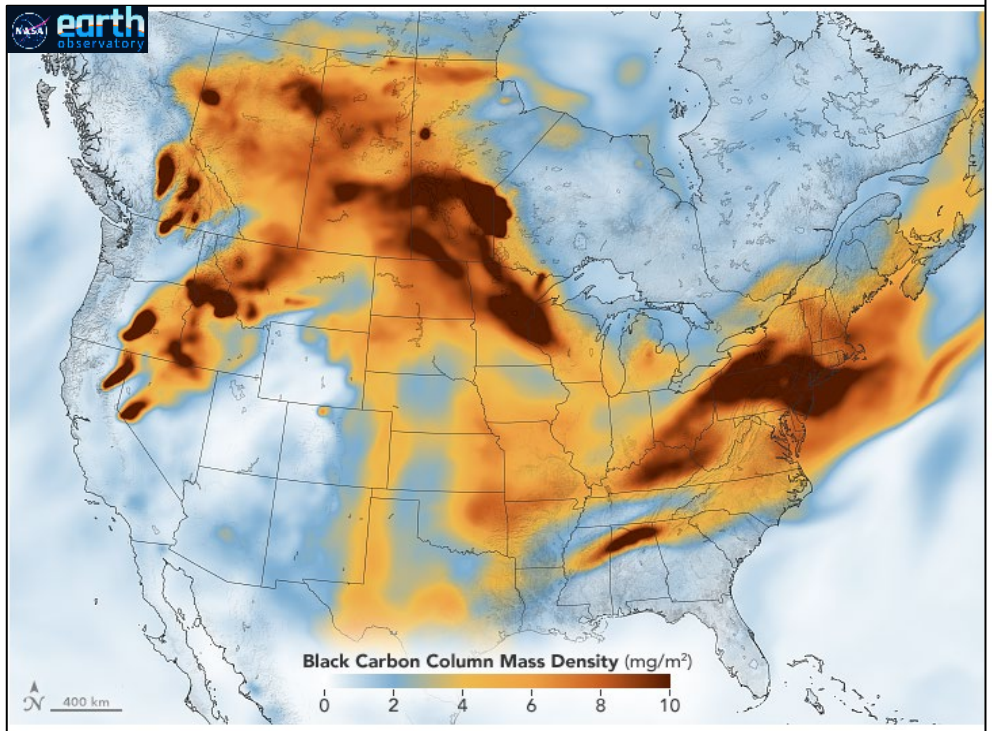
Algal blooms can rapidly grow when feeding off a sudden increase in nutrients such as nitrogen and phosphorus (found in agricultural fertilizers) and, as new studies have confirmed the link to, wildfire ash deposits carried across the nation by wind. Toxic algal blooms, also known as HAB's, have been found in surface waters across the nation.

- "In some regions, more than 60% of total landscape sediment production is fire-related. Much of that sediment loss can occur the first few years after a wildfire, though in some cases, sediment accumulations may take decades or even longer to recover to pre-fire conditions" (Barkley).
    - "Smoke and ash from the 2019-20 Australian wildfires triggered widespread algal blooms in the Southern Ocean thousands of miles downwind. The study is the first to conclusively link a large-scale response in marine life to fertilization by iron aerosols from wildfire emissions." The pyrogenic iron from wildfires can fertilize the algal blooms in oceans/rivers/reservoirs, increasing carbon uptake.
        - Pyrogenic aerosols are produced when trees, brush and other forms of biomass are burned. Aerosol *particles are light enough to be carried in a fire's windborne smoke and ash for months*, often over long distances.

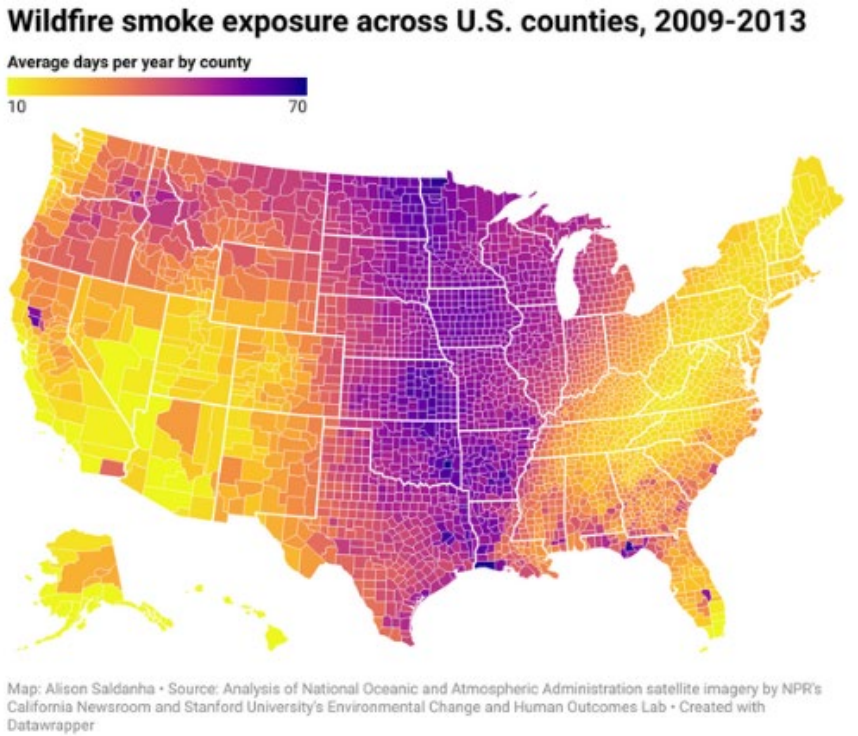
Ash deposits also carry harmful minerals/metal concentrations in the river and surface water systems, enabling warming from yet another mechanism of extreme weather as wildfires are now burning throughout the year and across more regions.

- In areas already affected by wildfire hazard, the fire season is likely to increase in duration and include a greater number of days with fire weather due to less rainfall.

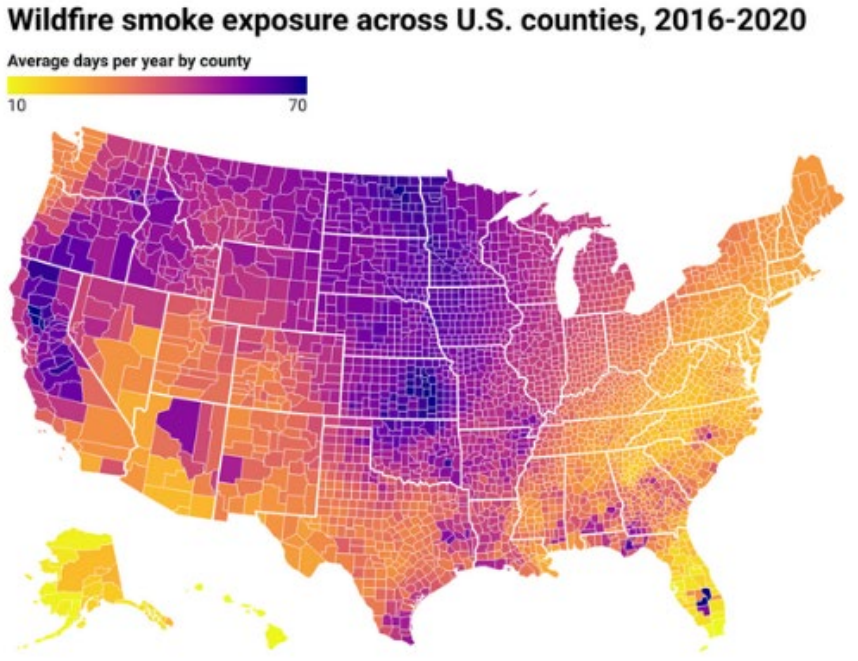
As fires burn wider areas and into higher elevations topography shifts from tree-creep, soil composition changes, soot deposits, debris flows, burn scars, vegetation/foliage decay, early blooms, flooding post-burn, less wildfire activity, and increased pollution from wildfire smoke, the cycle of heightened wildfire activity will worsen each year.



July 21, 2021



Map: Alison Saldanha • Source: Analysis of National Oceanic and Atmospheric Administration satellite imagery by NPR's California Newsroom and Stanford University's Environmental Change and Human Outcomes Lab • Created with Datawrapper



Increased Flooding Contributes to More Algal Blooms

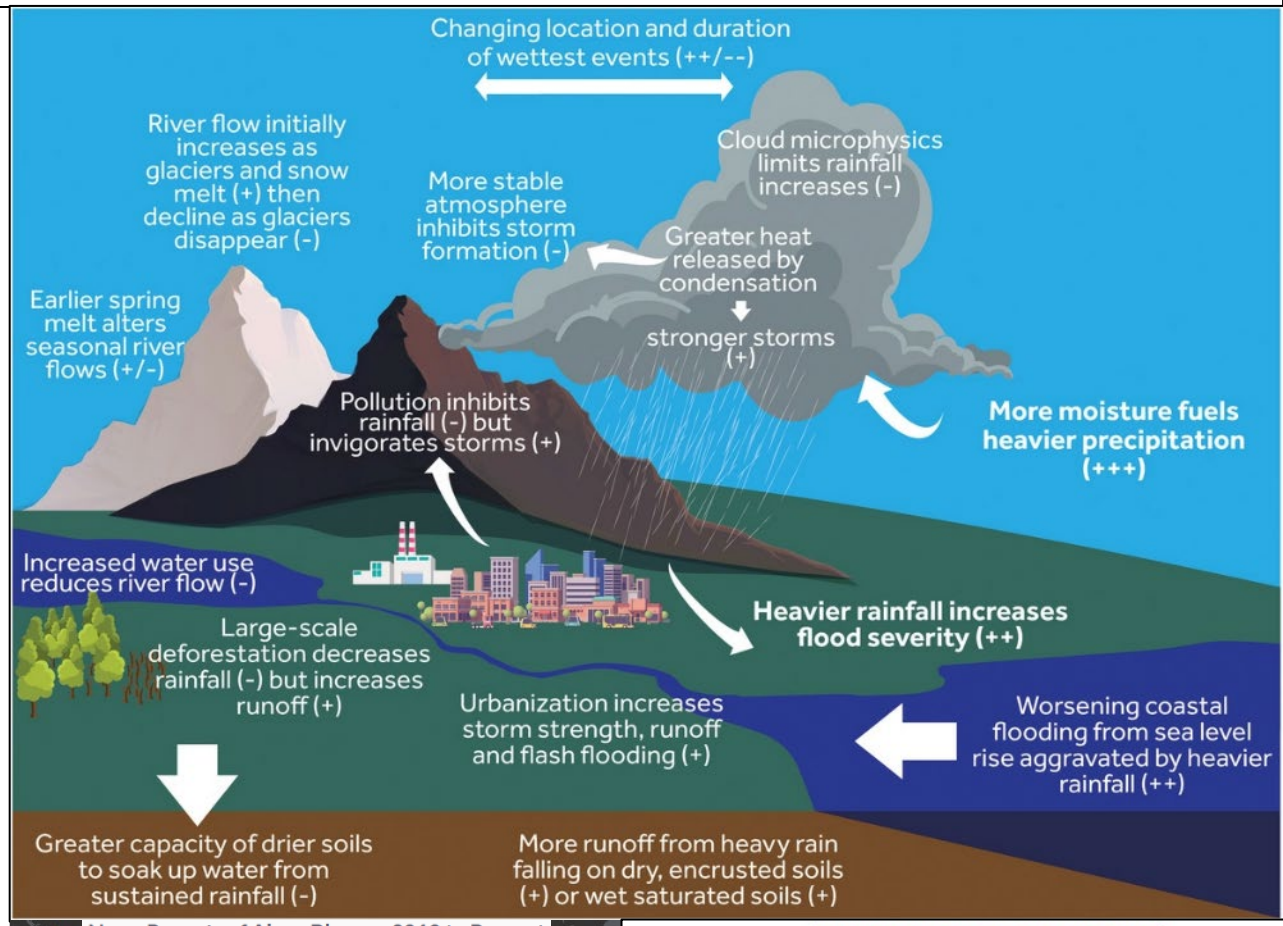
Stormwater runoff, which often includes pollutants like heavy metals, pesticides, nitrogen, and phosphorus, can end up in lakes, streams, and bays.

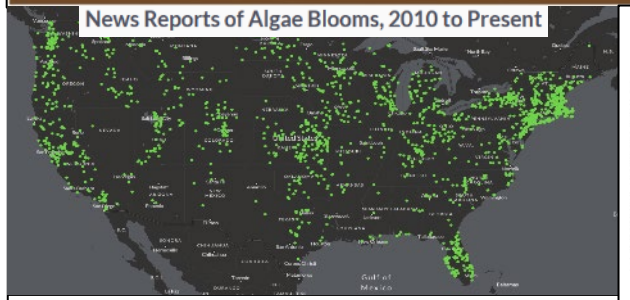
Nitrous oxide (N2O) is a potent greenhouse gas, with a warming potential of approximately 300 times that of carbon dioxide. From fertilizer runoff in farm fields, an increasing load of nitrogen is washing into rivers and streams.

Sediment can clog fish gills, reducing resistance to disease, lowering growth rates, and affecting fish egg and larvae development.

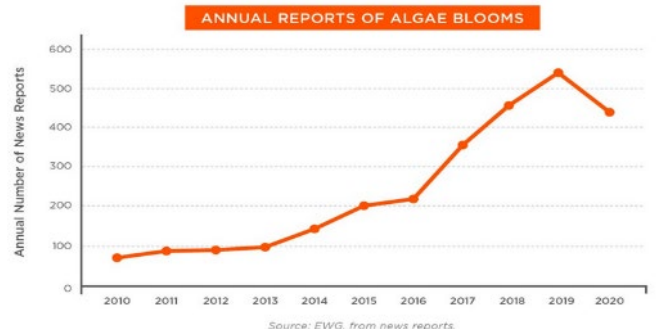
Approximately 80% of the freshwater resources in the U.S. originate on forested land, and more than 3,400 public drinking-water systems are in watersheds containing national forest lands (USDA, 2006).

- More than 12 million acres of land, including important forested water-supply watersheds, have burned in the southwestern U.S. in the past 30 years.
- When rains come, contaminants from urban ash and debris can be mobilized by the rainfall runoff and wind. These contaminants have the potential to seriously affect the quality of water supplies and sensitive habitat areas or ecosystems.
- Storms following wildfires are known to impair drinking water supplies in the southwestern U.S., as burn areas are prone to greater rates of erosion, increasing the downstream accumulation of sediment in streams, rivers, and reservoirs (USGS).
- Wildfires increase susceptibility of watersheds to flooding and erosion and can have both short- and long-term impacts on water supplies, such as increased treatment costs, need for alternative supplies, and diminished reservoir capacity (Smith, 2011).
- In a study published in May 2016, USGS scientists noted the presence of multiple trace metals in post-fire storm water. Scientists discovered elevated levels of iron, lead, nickel, and zinc in the streams near Los Angeles, and traced the contaminants back to the 2009 Station Fire in the nearby Angeles National Forest. The study examined the effect of the fire on trace metal contamination in nearby streams, comparing post-fire stormwater quality to criteria for aquatic life.
    - https://ca.water.usgs.gov/wildfires/wildfires-water-quality.html





https://www.ewg.org/interactive-maps/algal_blooms/map/



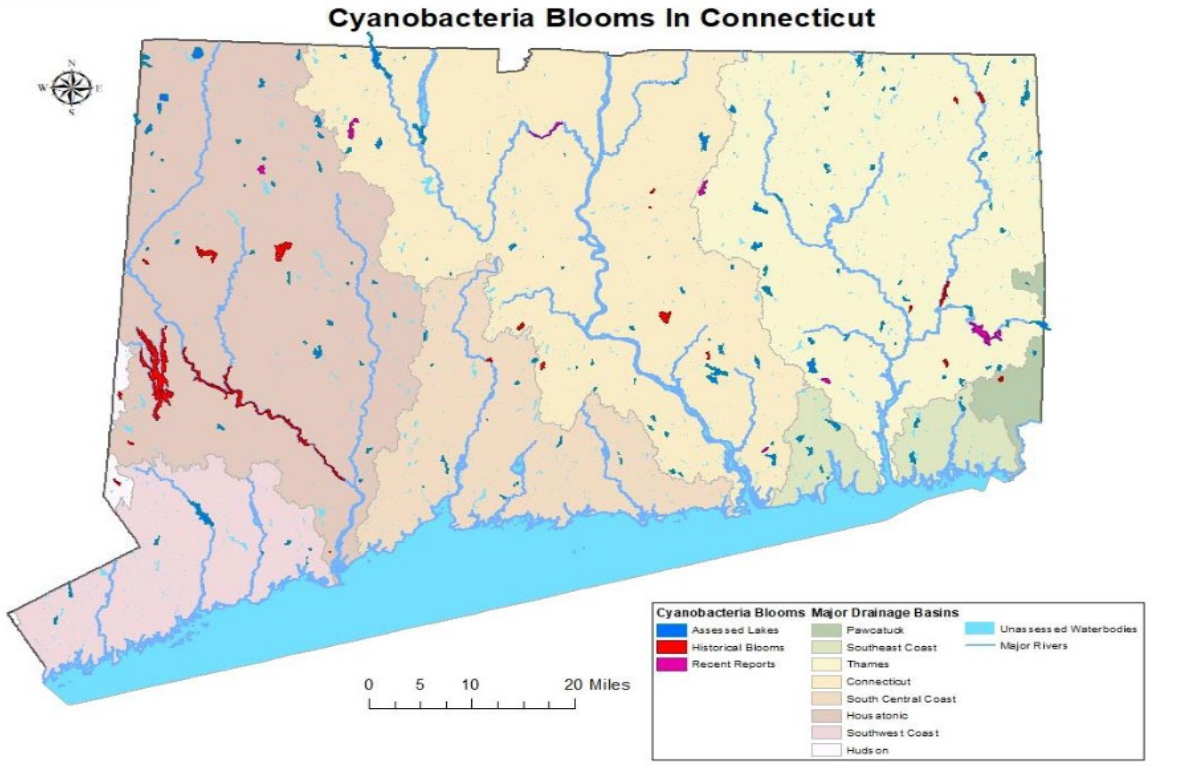
Algal Blooms and More

Connecticut has had historical instances of West Nile Virus, Malaria, Cholera, and E. Coli. which are spread through warming waters, increased presence of bacteria and increased breeding grounds for mosquitos.

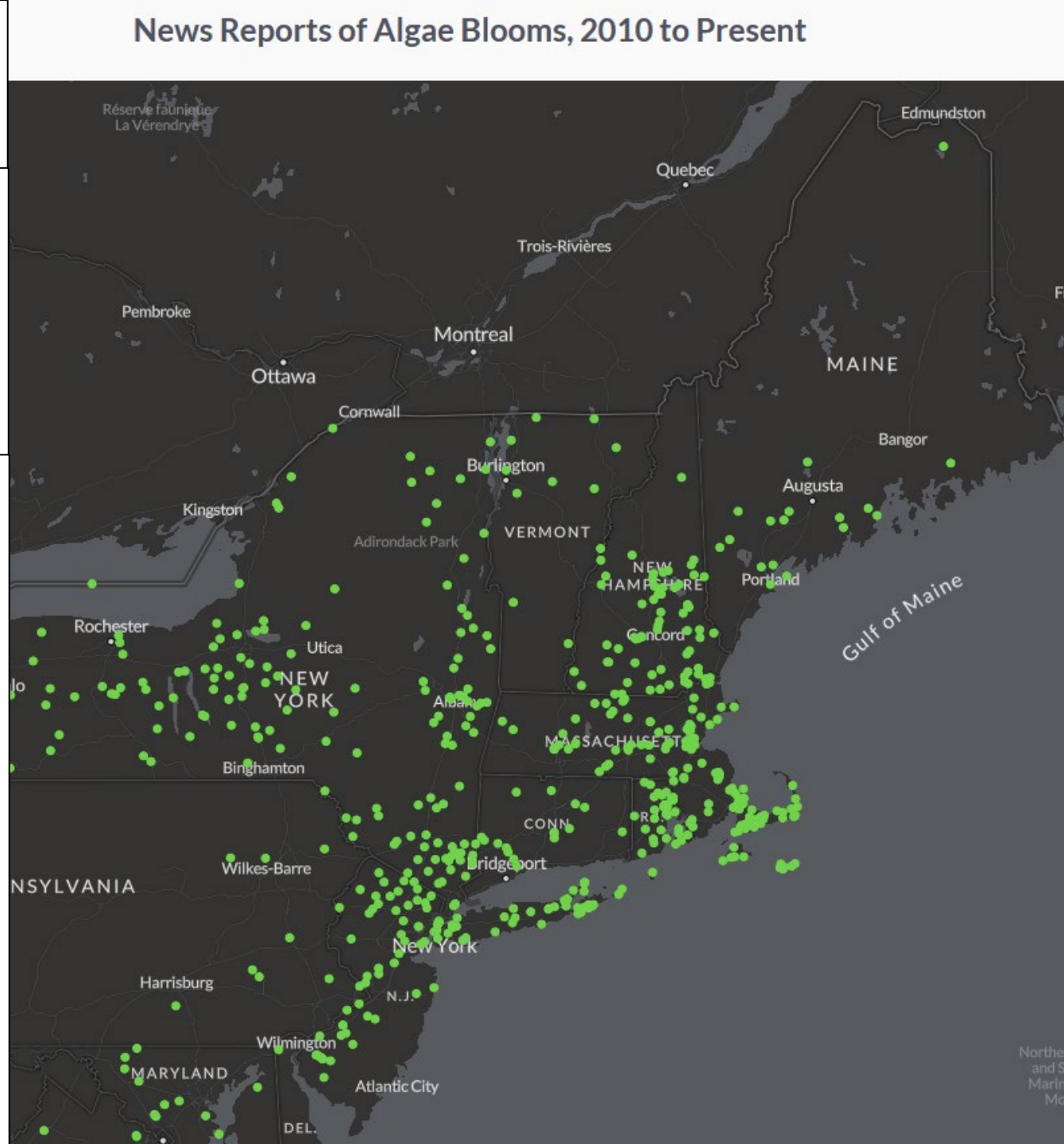
Eastern equine encephalitis is a rare but serious disease caused by a virus that is spread by adult mosquitoes. On average, there are five cases each year in the United States.

In 2013, there was one reported human case of EEE in Connecticut. In 2019, Connecticut had four human cases of EEE, three of which were fatal.

Figure 1: Assessed lakes and ponds (dark blue), lakes and ponds with historical cyanobacteria blooms (red) and recent cyanobacteria blooms (magenta).



Last Updated: 6/1/2020



Severe Weather on the Rise

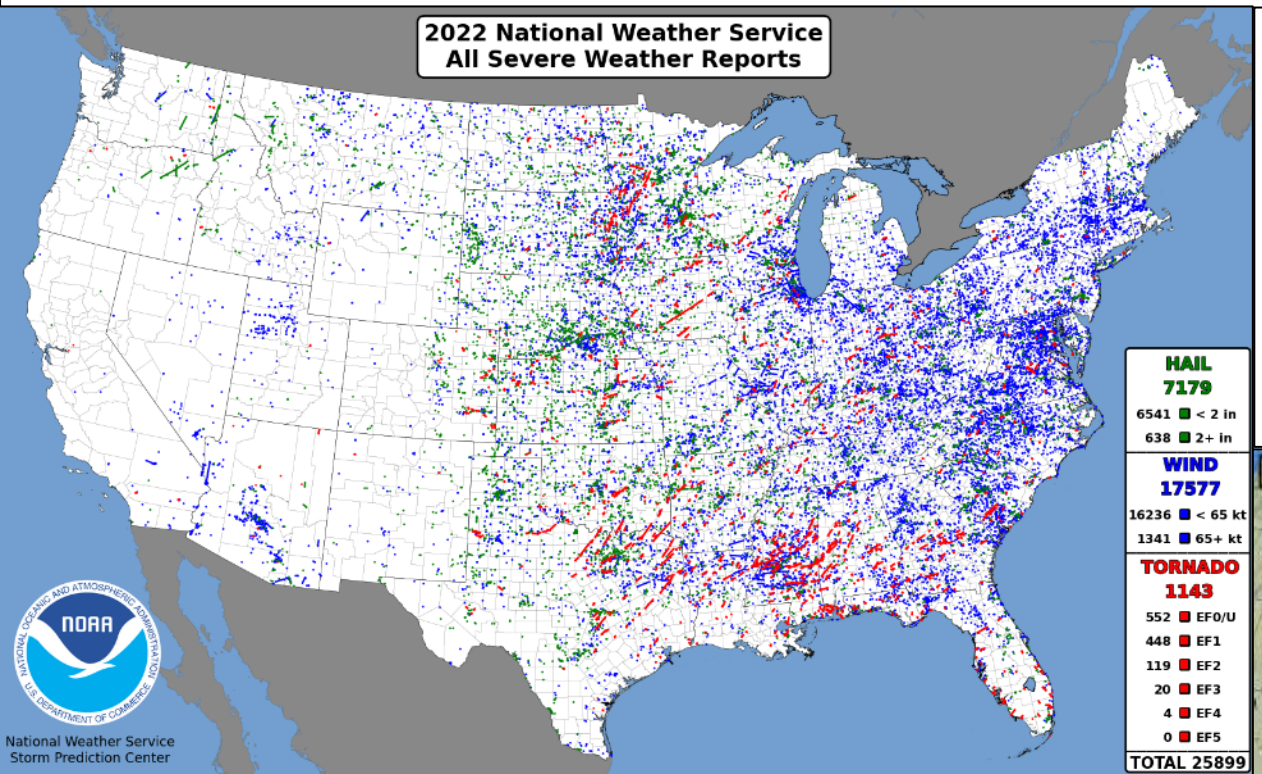
Hail events throughout the US are forecasted to intensify regarding size of the hailstones as warmer climates enable stronger updrafts for supercell storms responsible for large hail. Storms are now forming

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

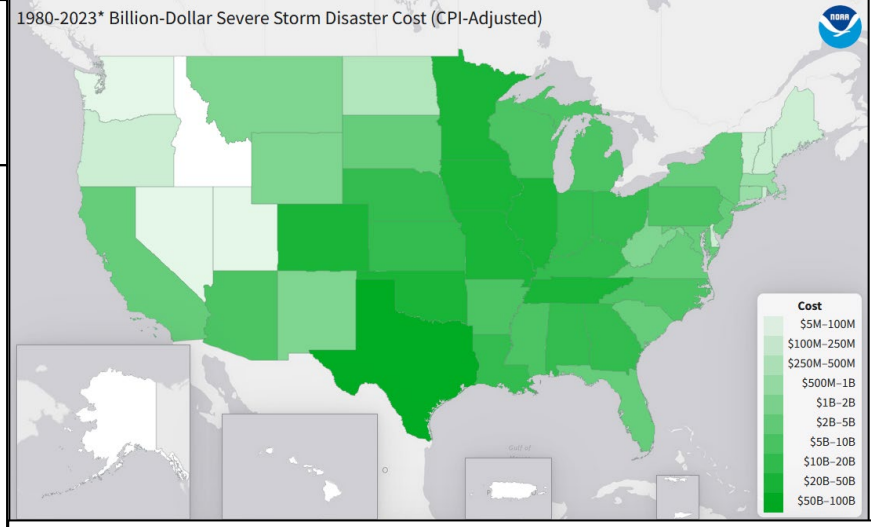
Reports indicate that the 2017 hailstorm caused roughly $2.3 billion dollars' worth of damage and is one of the strongest to ever hit the US. Texas recorded the single largest hailstone in the state's history in 2021: at 1.26-pounds, measuring 6.4-inch inches in diameter. Tornado events have become more clustered, with outbreaks of multiple tornadoes becoming more common.

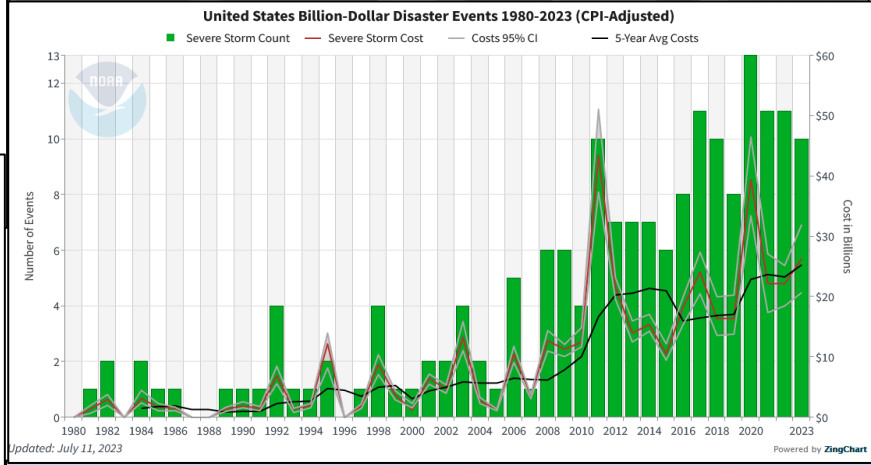
Tornado activity from 2008-2021 in comparison with 1991-2010 indicates the seasonal frequency has remained the same but the location and intensity of tornadic supercells has shifted to expand "Tornado Alley" to "Dixie Alley" producing larger, longer supercells. Dixie Alley includes Eastern TX, AR, LA,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

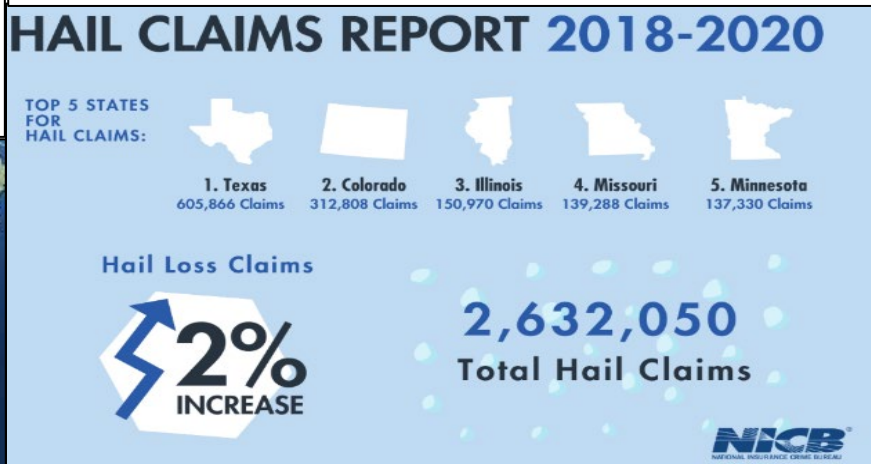
Factors impacting increases: population increase for witness accounts, dual-pol radar, internet access to report, increase in spotter network, combining first responder data with storm reports, and overall heat increases.



According to data from NOAA's Storm Prediction Center, 2023 has already produced record tornado activity. In *January* there were 168 tornadoes, fix times the average of 35 tornadoes. in *February*, there were 55 tornado reports, nearly double the 1991-2010 monthly average of 29 tornadoes. During *March*, there were 244 tornado reports which is more than triple the 1991-2010 monthly average of 80 tornadoes.







Severe Storm Records

For January 2023: In addition to the nine atmospheric rivers which produced over 500 landslides/mudslides in California and numerous avalanches across the western US; the National Weather Service received 168 tornado reports (compared to January's national average of 34 tornados). The last two years saw more tornadoes annually than the average.

- Iowa experienced its first January tornado since 1967, potentially the furthest northwest tornados ever observed during January.

Lightning activity in 2022 was closer to average (between 20 to 25 million flashes per year) than the concerning lows of 2020 and 2021, but the distribution of strikes across regions was unusual.

- The Vaisala Xweather report reveals a total of 198,227,289 in-cloud and cloud-to-ground lightning events in the continental United States, the highest total count since 2019.
- The Four Corners saw 1,229 lightning events per square mile in 2022, the highest density of lightning of any community in the country.
- https://www.vaisala.com/en/press-releases/2023-01/vaisala-xweather-annual-lightning-report-explores-2022s-extremes-record-breaking-volcano-major-snowstorms-and-exceptional

A recent study predicts a nationwide 6.6% increase in supercells and a 25.8% jump in the area and time supercells stay over land and cause destruction by the year 2100.

According to NOAA's Storm Prediction Center, during 2022, there were 1,329 preliminary tornado reports. This was above the 1991-2010 U.S. annual average of 1,251 tornadoes.

- The most prolific months during 2022 were March, April, May, June, and November, as each of these months reported +100 tornadoes. https://www.ncei.noaa.gov/access/monitoring/monthly-report/tornadoes/202213

Stronger surface heating at higher elevations tied to aridification and earlier snowmelt could result in earlier severe storm events each year the overall atmospheric temperature increases, and drought conditions continue to worsen across the US.

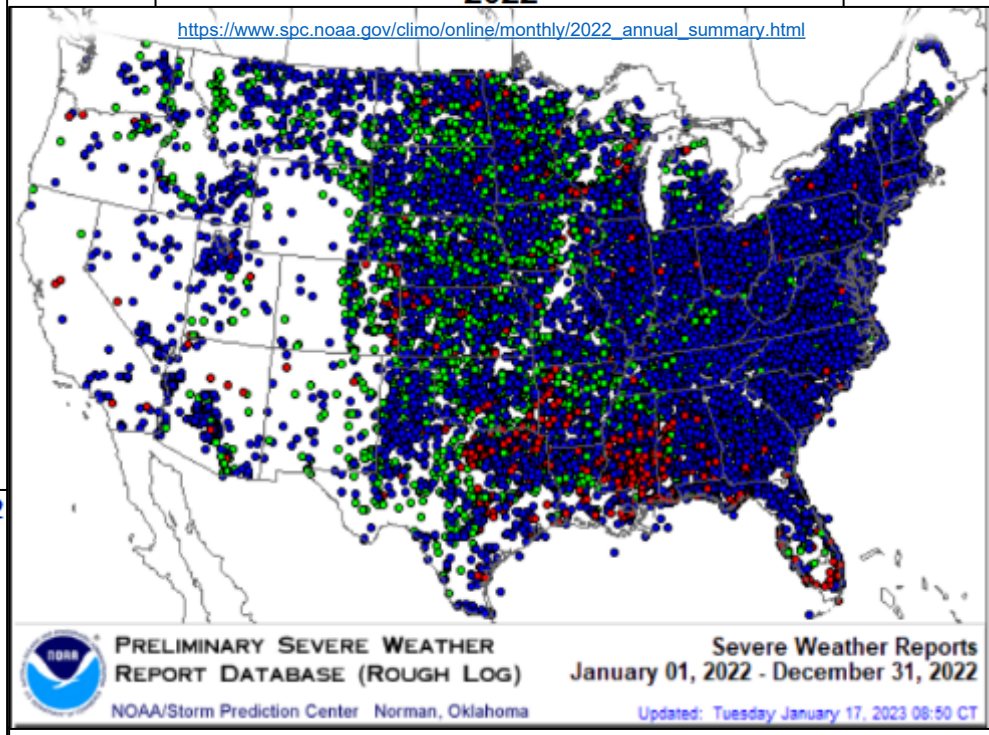
Top Ten Active Days of 2022

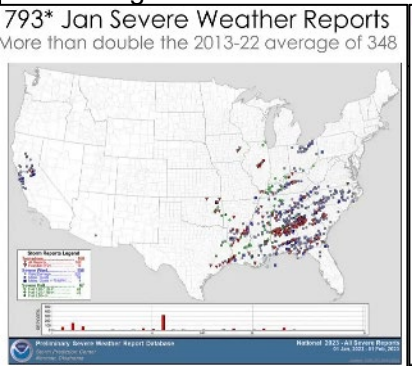
Rank	Date	Total Reports
1	06/17/22	496
2	06/13/22	439
3	06/16/22	432
4	05/12/22	421
5	07/23/22	394
6	07/12/22	348
7	04/13/22	341
8	05/06/22	315
9	06/07/22	314
10	03/30/22	311

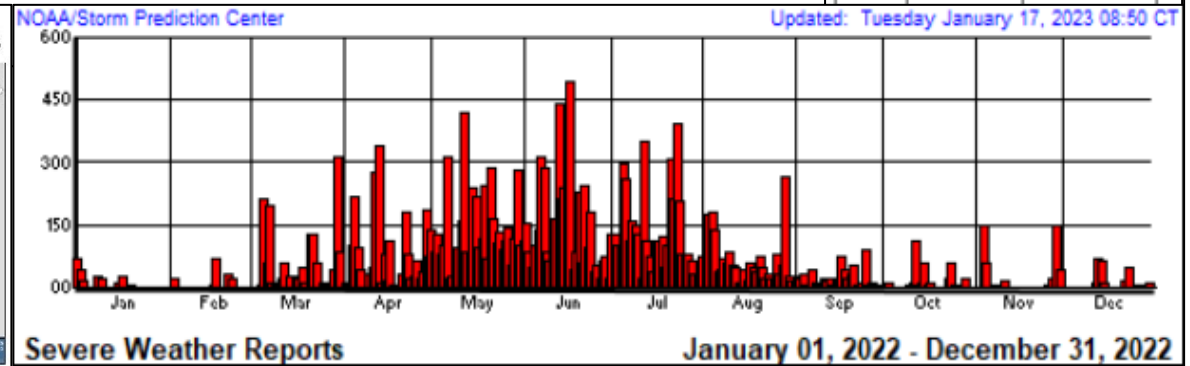
Top Ten Tornado Days of 2022

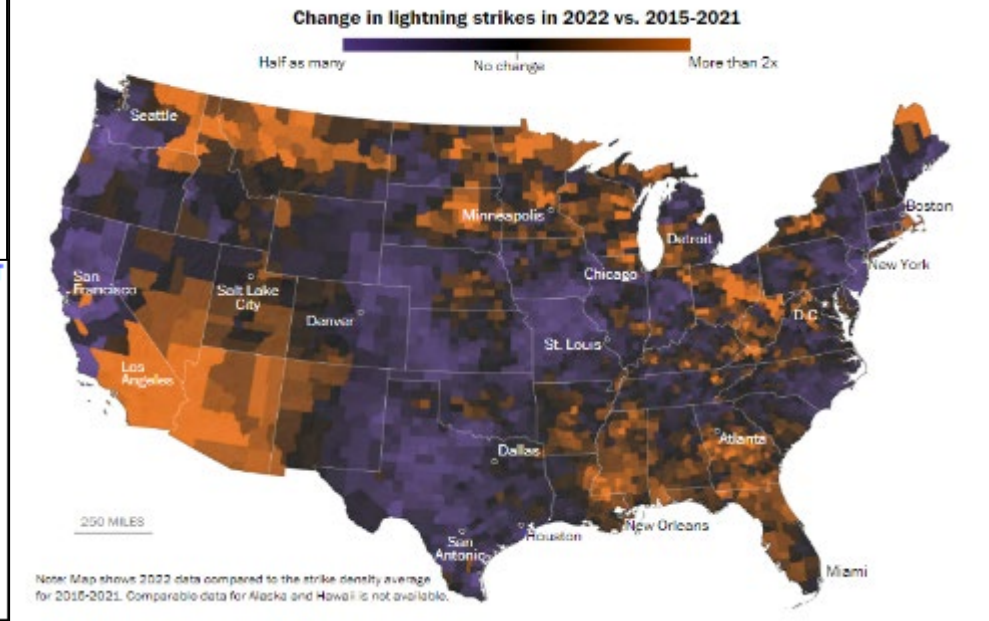
Rank	Date	Tornadoes
1	03/30/22	84
2	04/05/22	76
3	11/04/22	62
4	03/22/22	56
5	03/21/22	52
6	11/29/22	45
7	12/14/22	44
8	03/05/22	43
9	12/13/22	41
10	04/13/22	40

Annual Severe Weather Report Summary 2022









Tornado and Hail Events

Compared with other States, Connecticut ranks number 42 for frequency of Tornadoes, 30 for number of deaths, 25 for injuries and 20 for cost of damages.

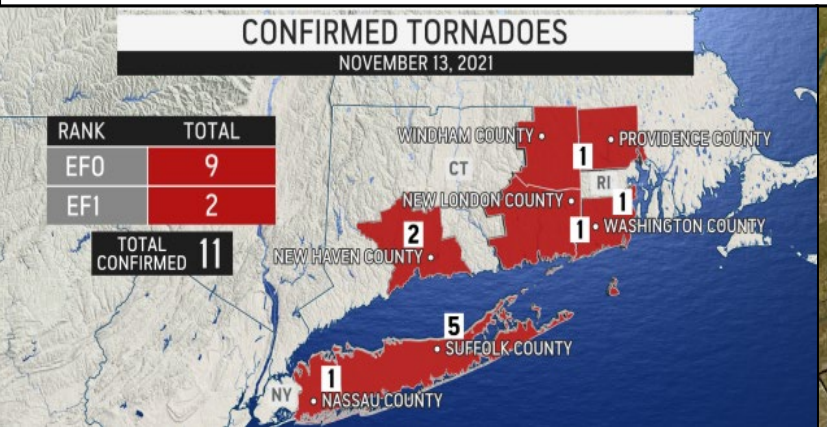
When comparing these statistics to other States by the frequency per square mile, Connecticut ranks number 24 for the frequency of tornadoes, number 25 for fatalities, number 2 for injuries per area and number 2 for costs per area (based on data from 1950 – 1995).

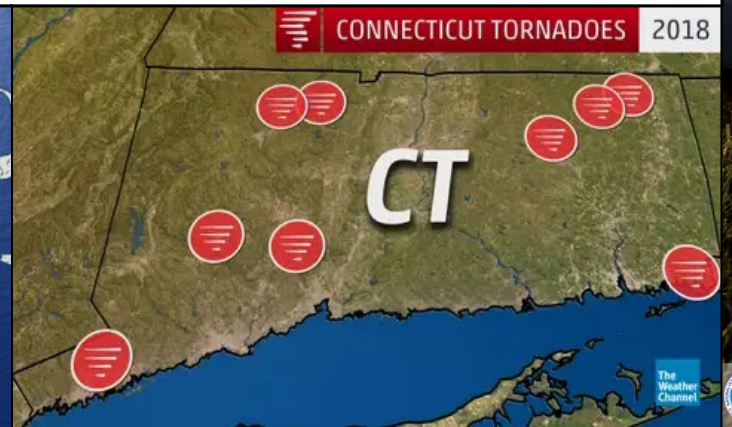
As temperatures continue to rise during the day and at night for the state, more evapotranspiration at the surface will enable high humidity content and increasing the potential for severe thunderstorms.

- With each major frontal boundary that enters the area, heat content which builds in other states upstream can provide a significant increase in moisture content available to rain out in hyper-condensed periods.
- Higher heat content in the area can result in greater updrafts within thunderstorms causing faster onsets of hail. Given the rapid formation of ice from the stronger updraft, more dense hailstorms are likely, to mean that hailstones may be the size of a golf ball but will be heavier than normal.
- Heavier hailstones means the hail will come down at a faster rate, producing more force on surfaces like roofs, bridges, and roadways. The hail can also cause more damage to trees and powerlines.

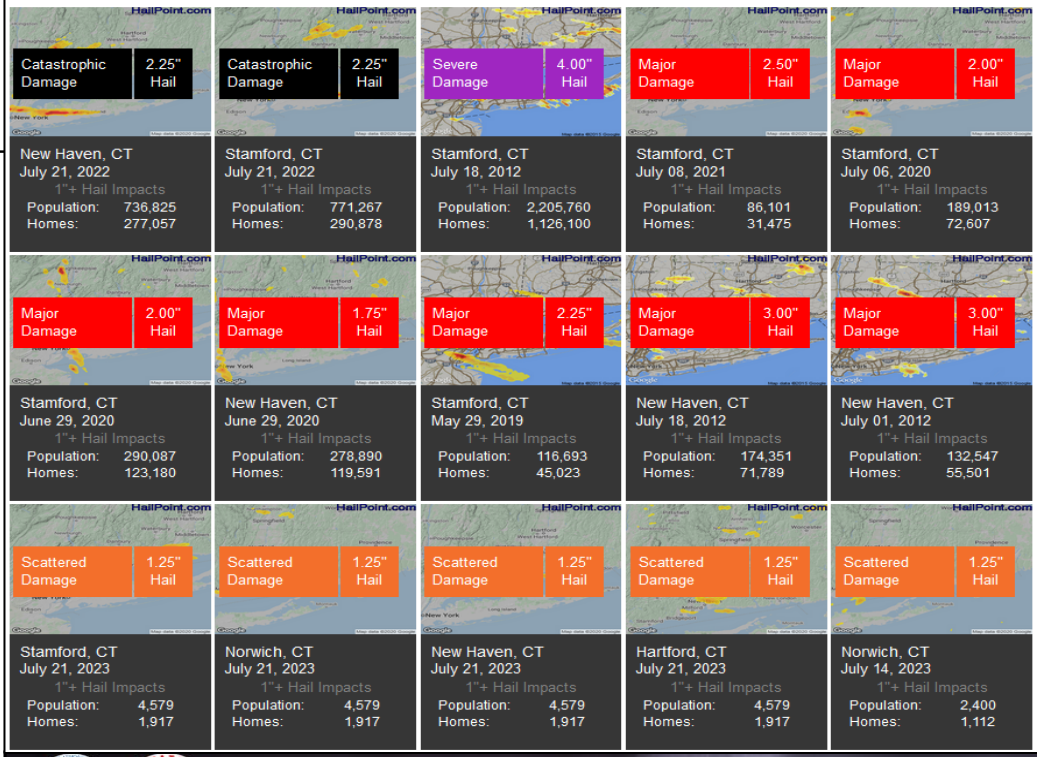
As listed on previous slides, tornadic activity and severe storms will likely increase both in span of time for impact and frequency of events capable of damage.

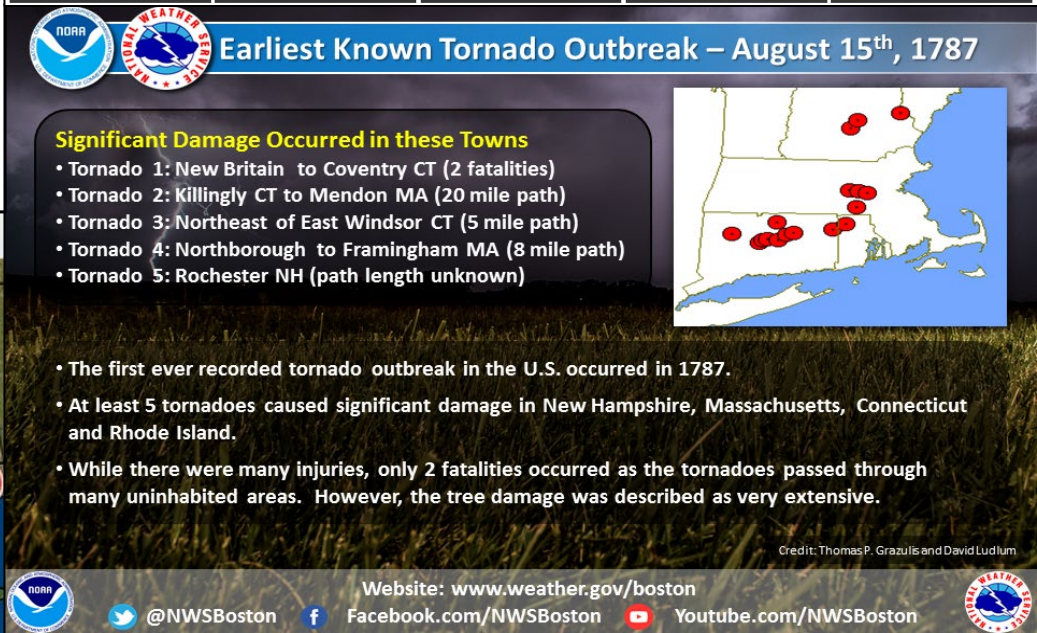
- According to NOAA, CT now sees an annual 38% increase in precipitation, which makes for new weather patterns and expectations. Storms are more intense, increasing in frequency and amount of water provided with each storm. Storms form and move faster and with greater strength, powered by heat and moisture.





Hail Maps





Sea Level Trends and Impacts

Additionally, higher sea levels lead to more severe storm surges associated with coastal storms.

20 inches (0.5 meters) of sea level rise is expected to occur in Long Island Sound by 2050, compared to the base period of 1983–2001.

- Sea level rise will continue after 2050, possibly reaching 80 inches (6.7 feet) by 2100 if global greenhouse gas emissions are not curbed rapidly.

High tide flooding is projected to occur more frequently and for longer durations of time. That is, “today’s food will become tomorrow’s high tide.” Researchers have projected the number of high tide flooding days annually under different climate change scenarios.

- Under an “intermediate” scenario (1-meter global sea level rise by 2100), the number of high tide food days along coastal Connecticut is significant: approximately 167 days in New London and 129 days in Bridgeport by 2050; by 2100, high tide flooding would occur nearly every day of the year in both locations.
- From 2000–2016 there were on average three high tide food days in New London and four in Bridgeport.

Driven by sea level rise, minor high tide flooding is disruptive but not typically damaging. However, as flooding becomes more common or greater in magnitude, it may lead to direct and indirect health effects of concern.

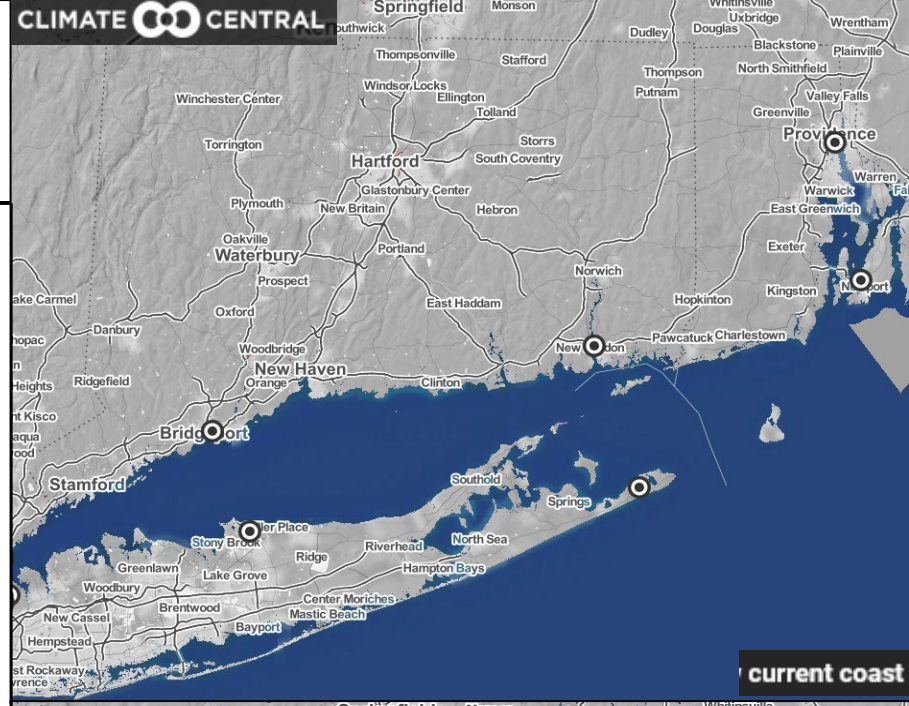
- Saltwater flooding can transmit pathogens such as Vibrio bacteria, which can cause wound infections in people directly exposed to the water. Saltwater can contaminate drinking water sources near the coast, as well as coastal agricultural fields.
- With a highly developed coastline, Connecticut is also at risk for high tide flooding affecting many roads, homes, businesses, and other infrastructure.

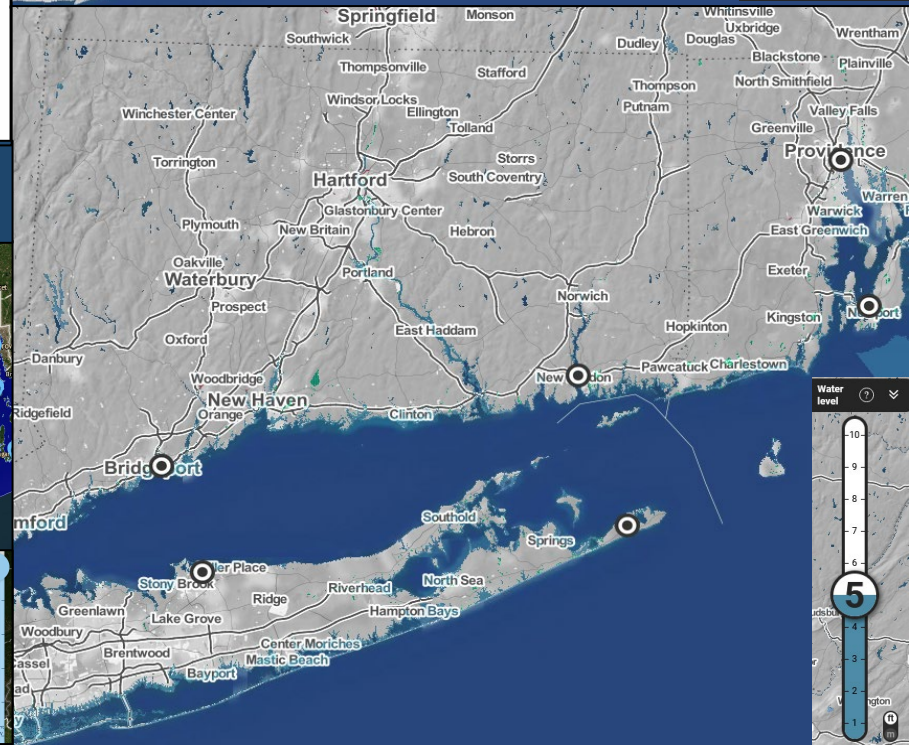
In the Northeast, sea level has risen by approximately 1 ft since 1900, which has caused more frequent flooding of coastal areas.[1]

Globally, sea level is projected to rise by 1 to 4 ft by the end of this century.

In the Northeast, even higher sea level rise is possible, due to the combined effects of warming waters and local land subsidence (sinking).

Sea level rise and coastal flooding are likely to disrupt and damage important infrastructure, including communication systems, energy production, transportation, waste management, and access to clean water.[1]





Tropical Cyclone Trends and Impacts

The state's worst weather event on record is the Hurricane of 1938 which made landfall east of New Haven. Flooding placed parts of Hartford and Middletown well into inundation levels while 5,000 buildings were destroyed, and 25,000 homes were damaged. This was the deadliest and costliest storm in the state's 350-year history.

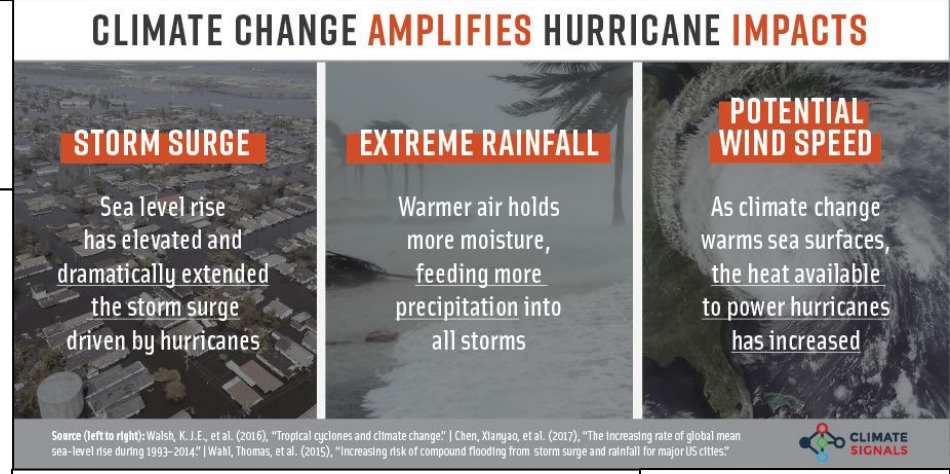
- In 1954, Hurricane Carol caused $460 million in damages (adjusted to current). This was the costliest natural disaster in US history for the time, until the next year.
- Hurricane Gloria in 1985 made landfall in September and caused widespread power outages lasting over a week with heavy damages to four communities wastewater facilities.100 state roads were closed due to downed powerlines and trees. This caused near $900 million in damages and was the worst hurricane to hit since 1938, retiring the name Gloria from the tropical cyclone list.

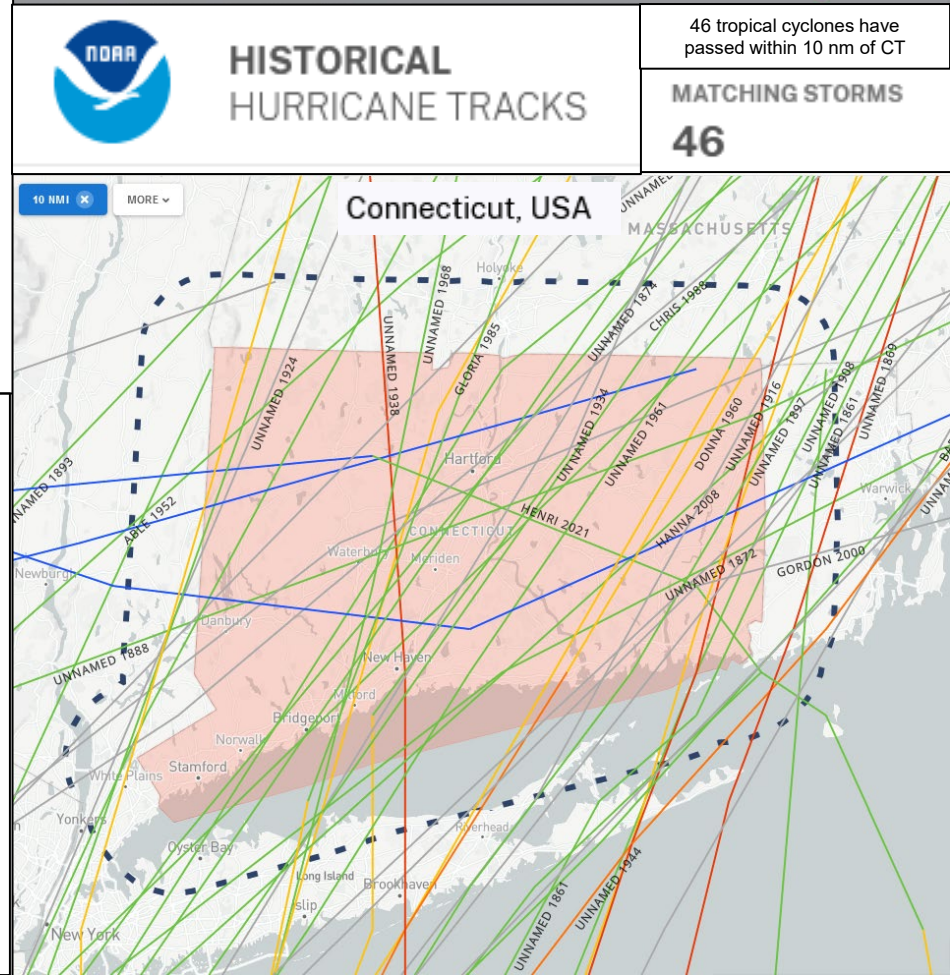
Research predicts that the 21st century's tropical cyclones will likely occur over a wider range of latitudes than has been the case on Earth for the last 3 million years.

- As the climate warms, temperature differences between the equator and the poles will decrease, the researchers say. In summer months, this may cause weakening or even a split in the jet stream, opening a window in the mid-latitudes for tropical cyclones to form and intensify.
- The researchers noted that simulations of warmer climates during the Eocene (56 million to 34 million years ago) and Pliocene (5.3 million to 2.6 million years ago) epochs saw tropical cyclones form and intensify at higher latitudes.

NOAA has released an explanatory guide providing an overview of how the agency approaches hurricane prediction, covering the specific topics of hurricane forecasting, impacts, hurricane hunting, Atlantic hurricanes, and hurricane preparedness tips for coastal residents.

- This information could be a useful guide to distribute to staff, as it succinctly covers the dangers of hurricanes and how to plan for them. It provides an overview of the Atlantic hurricane season and warns about the risk of storm surge, as 57% of fatalities during hurricanes and tropical storms have been caused by it.
- Storm inundation levels during hurricane surge events will increase due to sea level rise, anticipated to rise by about 2 to 3 ft by 2100. This sea level rise will contribute toward more coastal destruction and increased economic damages.
- Total numbers of Atlantic tropical storms and hurricanes combined are projected to decrease by 15%, but with large uncertainty; a minority of studies project an increase.
- The strongest winds of tropical storms and hurricanes are projected to increase about 3%.
- Due to human-caused climate change, precipitation rates within tropical storms and hurricanes are projected to increase by about 15%. And the number of Atlantic hurricanes reaching Category 4 or 5 intensity are projected to increase about 10%.





Tropical Cyclones Changes

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

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

Recent Hurricane Season Studies

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

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

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

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

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

- Storm inundation levels during hurricane surge events will increase due to sea level rise, anticipated to rise by about 2 to 3 ft by 2100.
- Total numbers of Atlantic tropical storms and hurricanes combined are projected to decrease by 15%, but with uncertainty; a minority of studies project an increase.
- Strongest winds of tropical storms and hurricanes are projected to increase about 3%.
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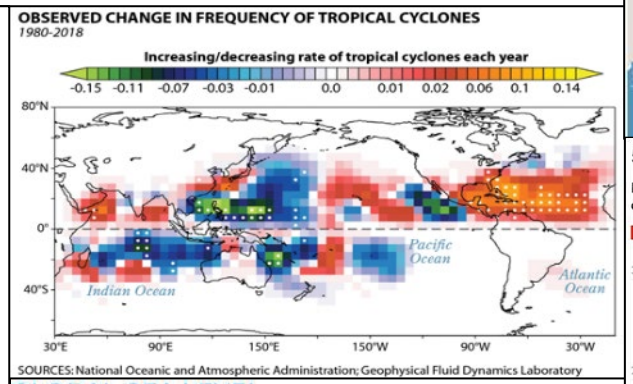
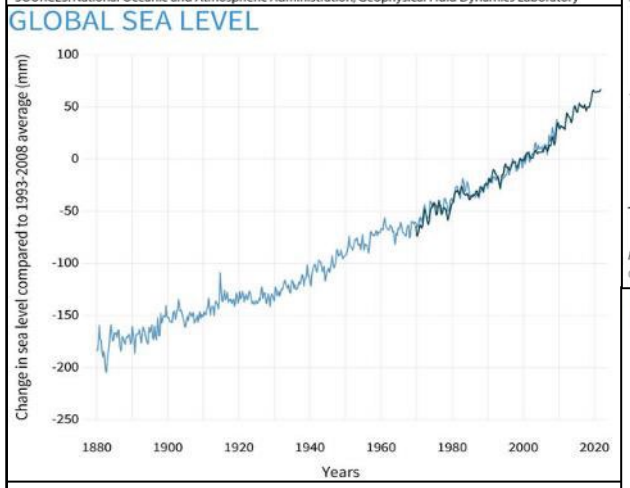
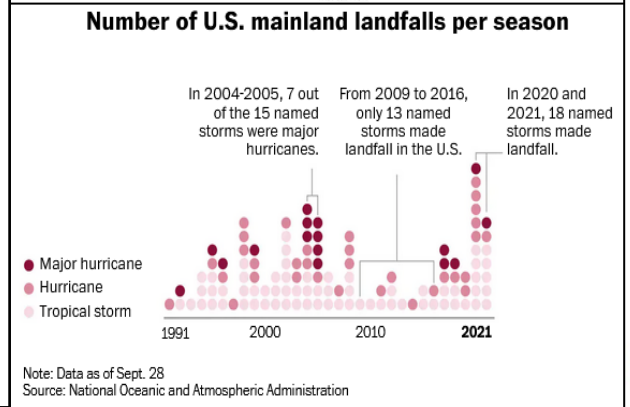
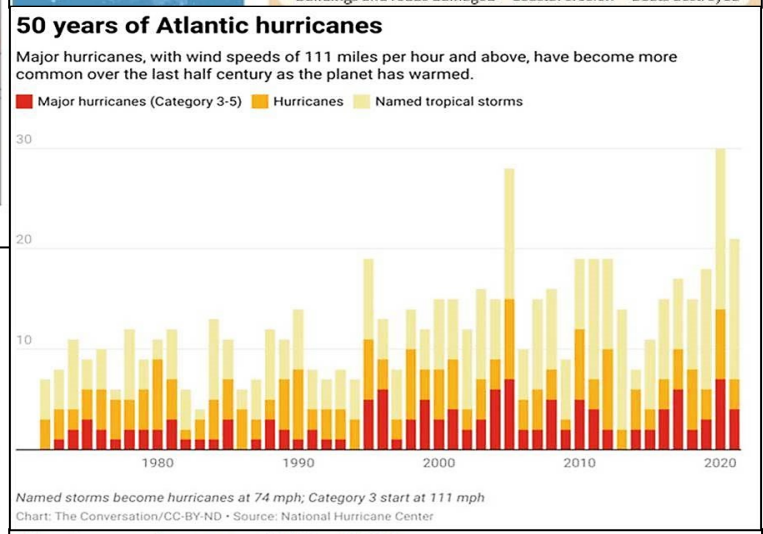
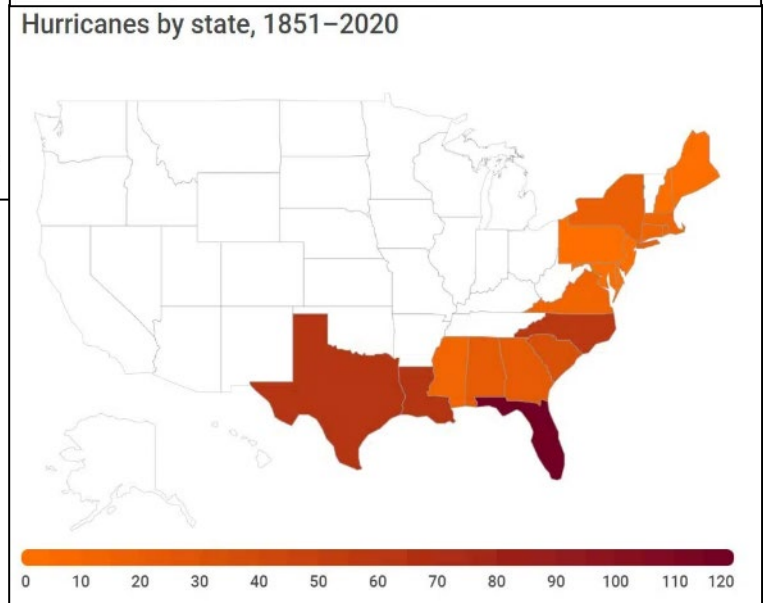










Tropical Cyclones Changes

According to the 2021 Sixth Assessment Report from the Intergovernmental Panel on Climate Change, the global frequency of tropical cyclones will likely hold steady or decrease as global warming continues. Among those tropical cyclones, though, the proportion that reach Category 4 or 5 will very likely increase.

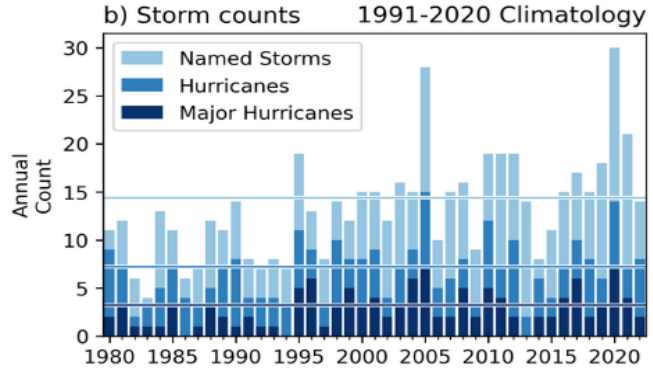
- More intense and frequent extreme rainfall and associated flooding in many regions including coastal and other low-lying cities, and increased proportion of and peak wind speeds of intense tropical cyclones (IPCC 2023).

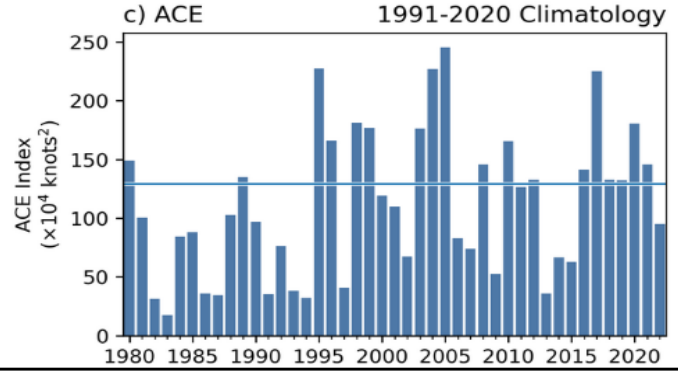
New Tropical Study by Iowa State University: A warming climate will increase the number of tropical cyclones and their intensity in the North Atlantic, potentially creating more and stronger hurricanes, according to simulations using a high-resolution, global climate model.

- The research team ran simulations using the Department of Energy's Energy Exascale Earth System Model and found that **tropical cyclone frequency could increase 66%** during North Atlantic hurricane seasons by the end of the century.
    - The numbers of tropical cyclones could increase by 34% during inactive North Atlantic hurricane seasons.
    - In addition, the simulations project an increase in storm intensity during the active and inactive storm seasons.
- Tropical cyclones were stronger, peak formation of the storms shifted from September to August, and the formation region shifted from the coast of North Africa to the Gulf of Mexico.
    - In the U.S., hurricanes caused more than $400 billion in direct economic losses over the historical period 1980-2014, with losses peaking at more than $150 billion in 2005, the year when hurricane Katrina made landfall.
- The study also finds that already in the present climate, national insurance solutions may be insufficient to effectively mitigate the economic losses caused by extreme weather events in strongly affected developing countries.
    - For Haiti, as a small island developing state strongly affected by hurricanes, the study shows that even if climate risk insurance were as well developed as in the US, growth losses would still be six times higher.

Tropical Record: Hurricane Ian is the third-most destructive storm on record, behind Hurricane Katrina in 2005 and Hurricane Harvey in 2017. Hurricane Maria is ranked 4th and Hurricane Sandy is ranked 5th.

- The cost of those disasters, adjusted for inflation, stand at roughly $186 billion and $149 billion, respectively. Ian is likely to eclipse the $114 billion mark and numbers continue to be refined.





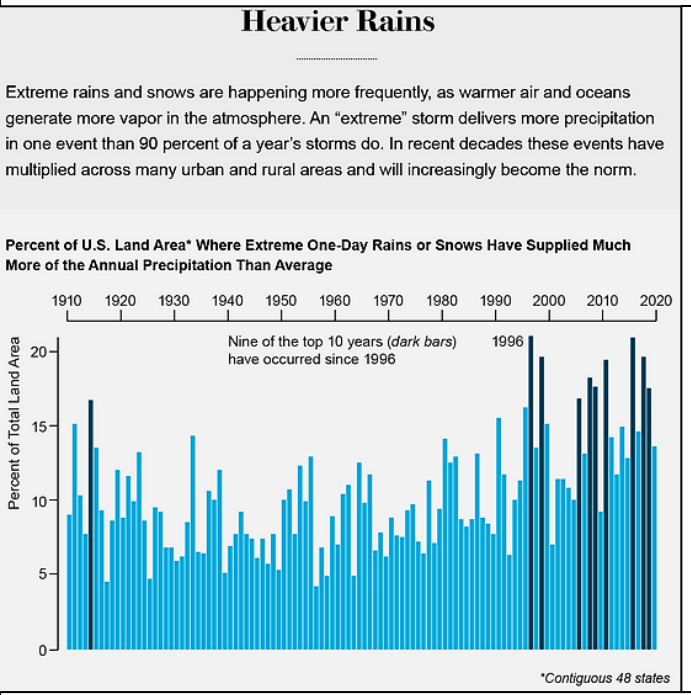
Tropical cyclone is a more generic term than hurricane. Hurricanes are relatively strong tropical cyclones.

- Tropical cyclone is a general reference to a low-pressure system that forms over tropical waters with thunderstorms near the center of its closed, cyclonic winds.
- When those rotating winds exceed 39 mph, the system becomes a named tropical storm.
- At 74-plus mph, it becomes a hurricane in the Atlantic and East Pacific oceans, a typhoon in the northern West Pacific.

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

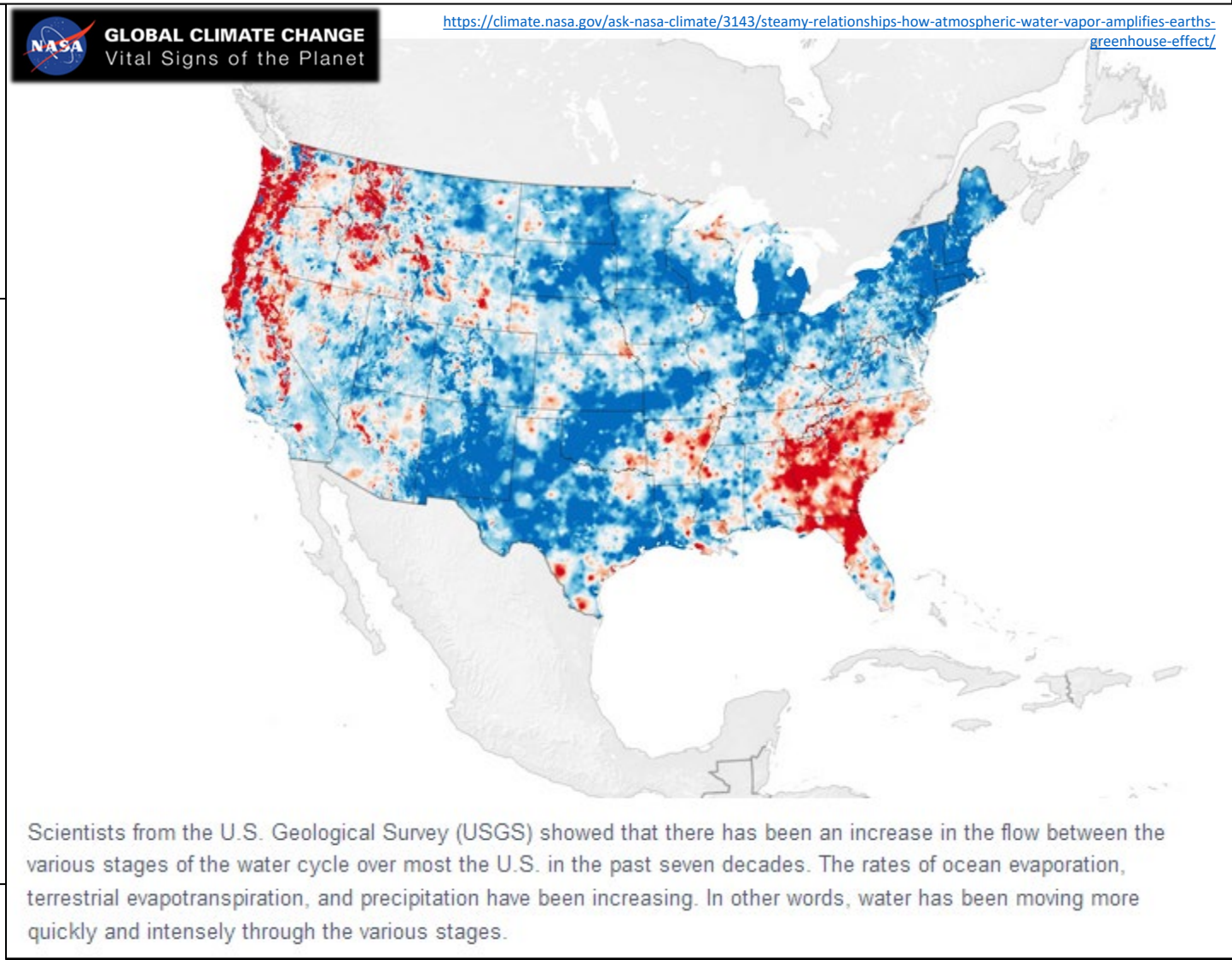
Increases in atmospheric water vapor also amplify the global water cycle. They contribute to making wet regions wetter and dry regions drier. The more water vapor that air contains, the more energy it holds. This energy fuels intense storms, particularly over land. This results in more extreme weather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



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

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



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).

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.

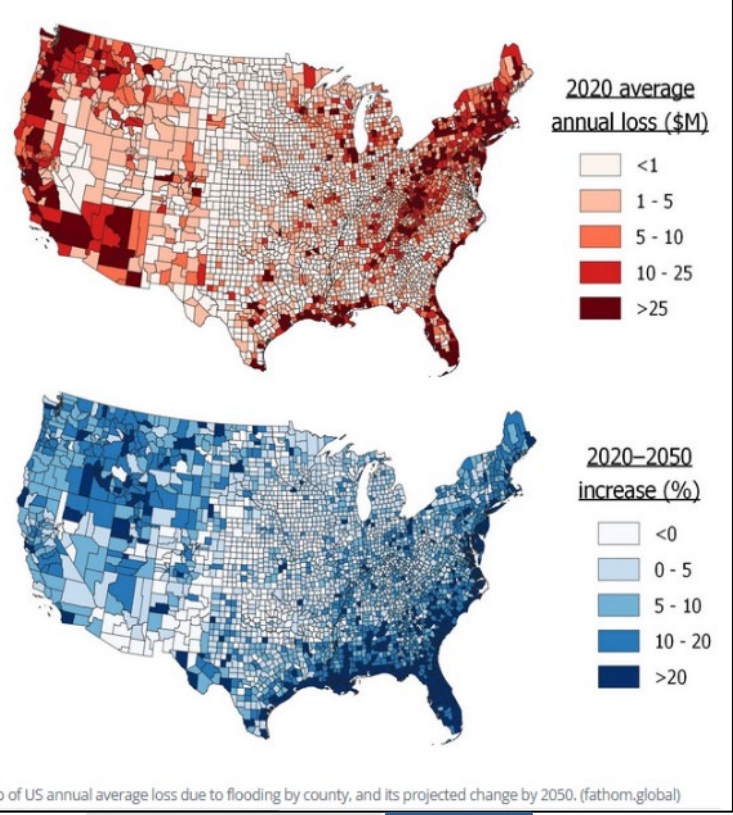
- River flooding can result from heavy rainfall, rapid snow melt, or ice jams thawing resulting in riverbank damages.
- Urban flooding refers to flooding that occurs when rainfall overwhelms the local stormwater drainage capacity of a densely populated area causing water to continue to overflow into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

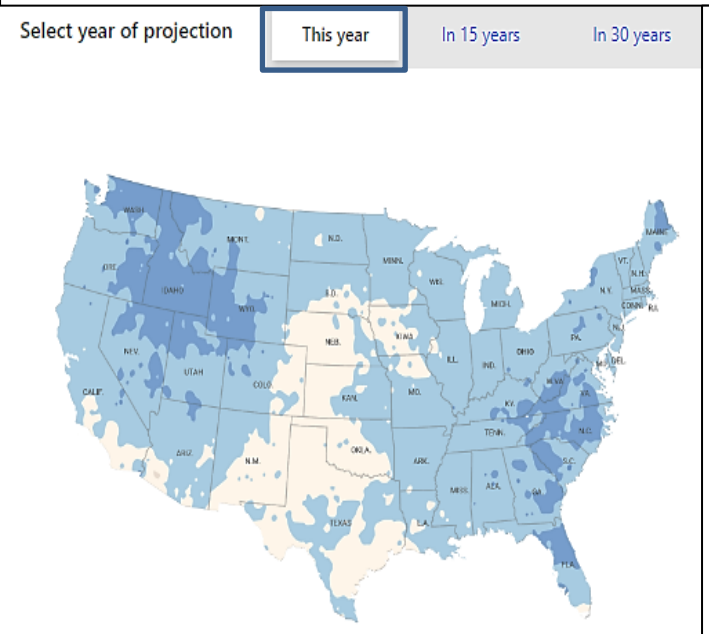


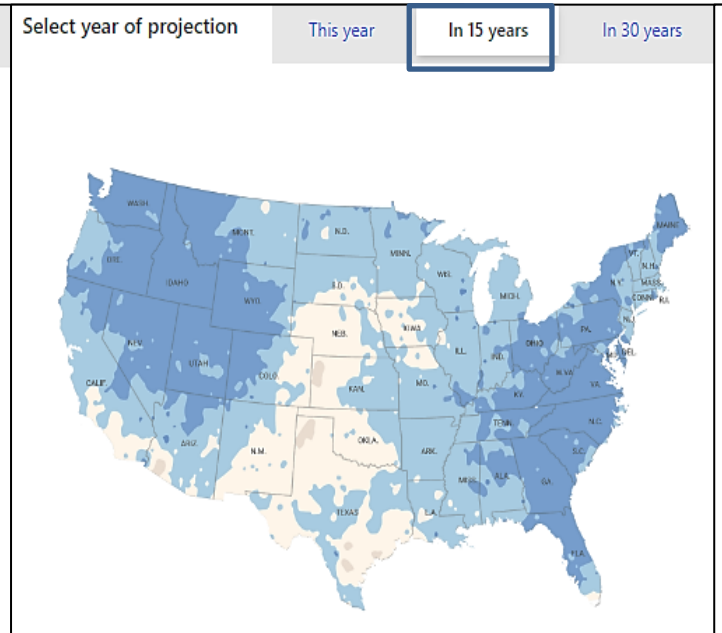
Map of US annual average loss due to flooding by county, and its projected change by 2050. (fathom.global)

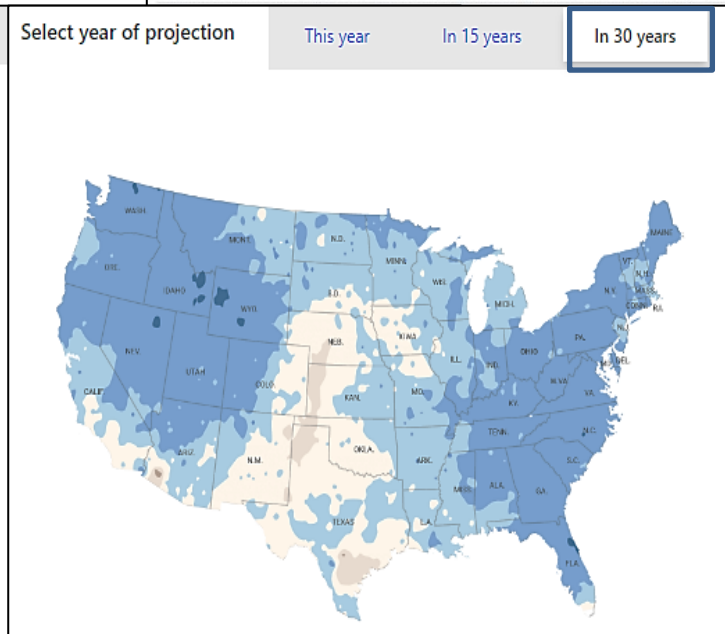
A 2021 study indicated the average annual flood losses are forecast to increase by 26% by 2050, from $32 billion to $40.6 billion, based on 2021-dollar values.

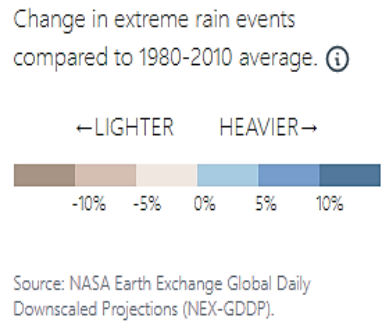
The average annual exposure of the population to floods is expected to rise 97% from current levels by 2050, to over 7 million by 2050.

A flood can impact anyone.









Flooding Impacts

From a recent Yale review: From 1960 to 2019, the annual number of heavy rainfall events (defined as three consecutive days with total precipitation of three inches or more) increased in New Haven, Hartford, Litchfield, Tolland, and Windham counties.

For the state, total precipitation in 2018 was 37% higher than last century's average, and summer precipitation increased by 10 to 20% across the state from 1950 to 2013.

However, year-to-year precipitation in Connecticut is variable, with average precipitation in six of the last 10 years lower than the 20th century average of 46.9 inches.

- Aside from the immediate threats to life, impacts to energy, critical infrastructure, and key dependencies, there are cascading threats such as contaminated waters and increased risk to health for recovering communities.
- Heavy rain and flooding can also adversely affect indoor air quality. This occurs when food waters enter basements or the ground floors of homes, damaging building walls and foundations. Such damage can lead to indoor mold, dust mites, chemical of-gassing from damaged building material, and other air contaminants.
- In Connecticut, increases in precipitation are expected primarily during the winter and spring. Total annual precipitation is projected to increase across the state by 8.5% by mid-century. In addition to an increased total precipitation, heavy rainfall events are projected to continue to increase as climate change progresses.
- By mid-century key indicators of food risk are expected to increase substantially: the number of days with over one-inch of precipitation, the number of heavy precipitation days (days with more precipitation than the 1970–1999 99th percentile), and maximum one-day and five-day precipitation amounts.

WEATHER DISASTERS

Immediate dangers from severe storms and flooding include drowning or injuries due to high water or strong winds. Road flooding can also cut people off from safely evacuating. During and after storm events, there can be damage to electricity, sanitation, water treatment and water supplies, food refrigeration, communications, and transportation systems.[10] Loss of such critical infrastructure has wide ranging health effects, including interference with medical care and access to medication, which can be life threatening, particularly for those with chronic illness.[11, 12] Ambulances may be slowed due to roads blocked by flooding or downed trees. During a power outage, the improper placement of gas-powered generators or charcoal grills indoors can lead to carbon monoxide poisoning, which can be fatal.[13]

There are also important, though less visible, downstream impacts to health from severe storms. Individuals whose households experienced a flood or risk of flood report higher levels of depression and anxiety, and these impacts can persist several years after the event.

ABOUT THIS SERIES

YCCCH released *Climate Change and Health in Connecticut: 2020 Report* in September 2020. The comprehensive report tracks 19 indicators on climate change and health in Connecticut across four domains: temperature, extreme events, infectious diseases, and air quality. The issue brief series mirrors the four domains, summarizing key findings from the Report and extending it to include policy recommendations. To read the full report, visit:

https://publichealth.yale.edu/climate/policy_practice/connecticut/

- **People with Chronic Illness:** People with chronic illness may have more difficulty evacuating prior to a storm, and storm-related power outages can be life threatening for someone requiring electricity-dependent medical equipment (e.g., supplemental oxygen). People with chronic illness are also more susceptible to temperature extremes to which they could be exposed if power is lost, along with home air conditioning or home heating. The stress and anxiety of experiencing an extreme event can exacerbate existing medical conditions and even lead to death.[32] People with pre-existing mental illness are at higher risk during and following an extreme event, both because of compounding stress and because their mental health services or support networks may be disrupted.[33] Health systems strained during an extreme weather event may not be able to provide the full care necessary, due to surges in demands and disruptions to services such as electricity, water, cooling, supply delivery, equipment reprocessing, and transportation of both health care workers and patients.

- **Low-income Communities:** Low-income communities have fewer material resources to support preparing for and recovering from extreme weather events. As one example, a prolonged storm-related power outage can cause refrigerated food to spoil, which has economic impacts and can worsen household food security. Infrastructure in low-income communities is often in poor condition.[34] Lack of vehicle ownership—more commonly the case for urban and suburban low-income households—makes storm evacuation more difficult.[35] Low-income households are disproportionately underinsured for protection against damage from storms and floods and often lack access to emergency credit to recuperate from property loss.[36] Renters, in particular, are vulnerable to displacement after a disaster, for reasons including that they lack control over whether or when the property will be repaired or rebuilt.[37]

Landslides, Erosion, and Subsidence

Landslides triggered by heavy precipitation have increased across the region over the past decade. Increases in tropical precipitation can also amplify landslides, which are also expected to increase in the warming climate.

- Mid-July 2023, during an abnormally strong rainfall event which resulted in regional flooding on the scale of 1-in-1000-year rainfall event in parts of Vermont and New York, Barre reported upwards of 40 landslides, according to the State Geologist. The city manager said they were monitoring 20 incidents in the Barre area.
- Drought events will continue in the region, weakening the stability of soils and increasing landslide risks.

Landslide

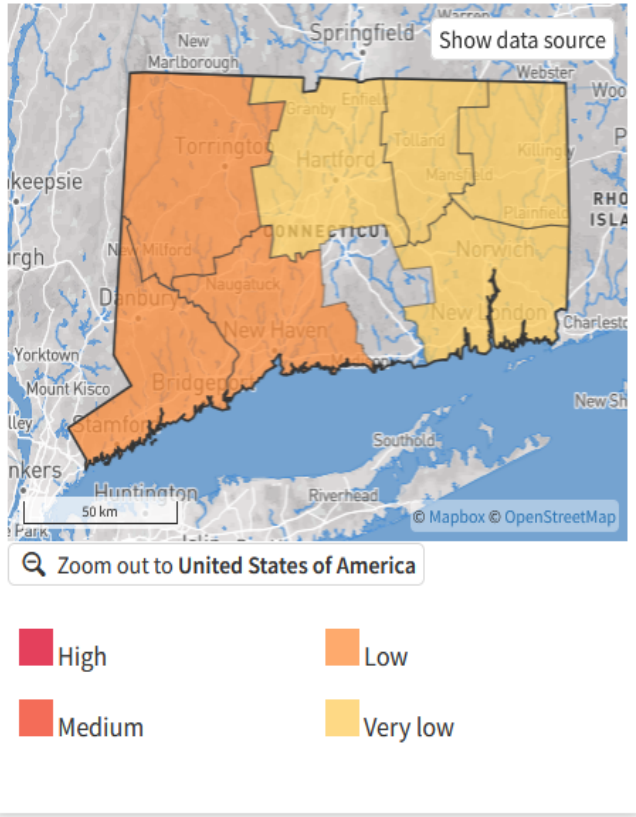
Hazard level: Low

In the area you have selected landslide susceptibility is classified as low according to the information that is currently available. This means that this area has rainfall patterns, terrain slope, geology, soil, land cover and (potentially) earthquakes that make localized landslides an uncommon hazard phenomenon. Based on this information, planning decisions such as project siting, project design, and construction methods, may want to consider the potential for landslides. Further detailed information should be obtained to better understand the level of landslide susceptibility in your project area.

Climate change impact: Climate change is likely to alter slope and bedrock stability through changes in precipitation and/or temperature. It is difficult to determine future locations and timing of large rock avalanches, as these depend on local geological conditions and other non-climatic factors.

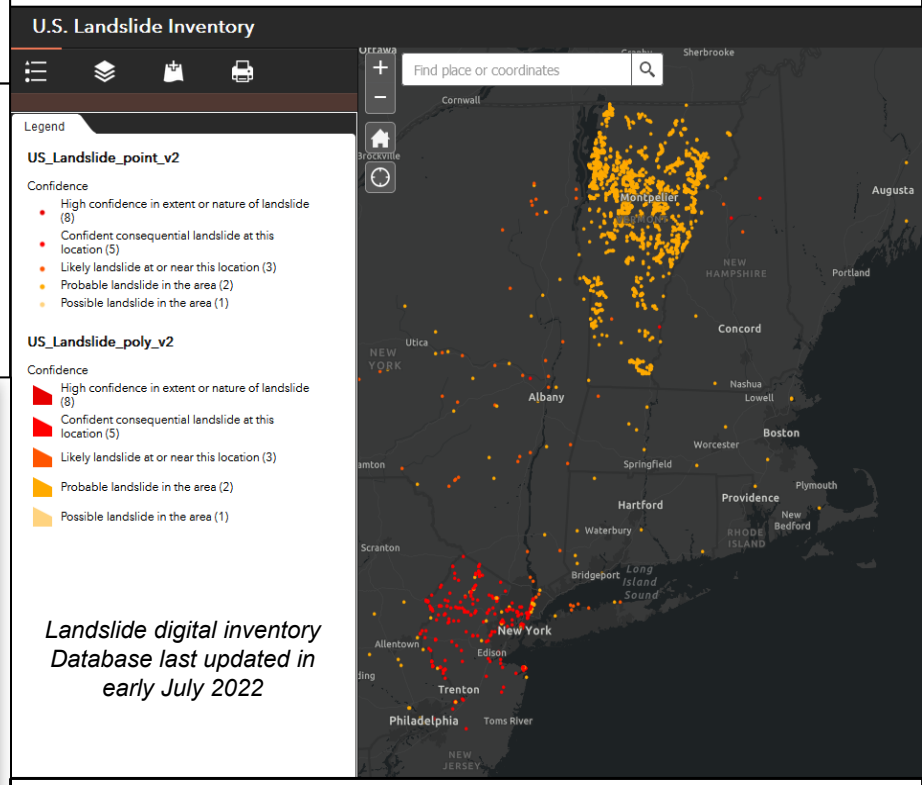
Recommendations

- GOVERNMENT EXPERTISE: Contact the governmental organizations responsible for management of landslides in the project country (e.g. ministry of environment, national geological survey and/or local authorities) to obtain more detailed information on areas previously affected by landslides and areas considered to be highly susceptible. More information



Contacts

Wildfire activity increasing due to hotter averages and decreased days of rainfall can also yield more landslide activity in debris flows during rainfall events post-burn.



Landslide digital inventory Database last updated in early July 2022

Erosion in Connecticut is generally caused by storms, rising sea levels, changes in sand availability, and is exacerbated by the construction of jetties, groins and seawalls.

Sand availability can change when sand is moved offshore during storms and is no longer available for beaches, or when sand transported landward during storms is removed as debris.

Erosion may also be caused by stormwater runoff from the adjacent uplands and solutions to this type of erosion will likely be different than those discussed here.

According to a 1999 report, 9% of Connecticut's shoreline is considered critically eroding.

Winter Storm Trends and Impacts

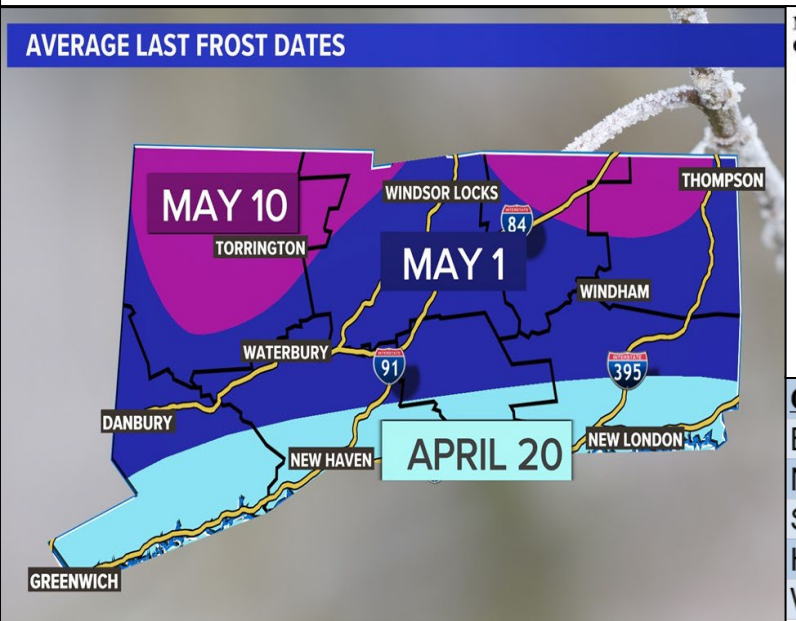
Extreme cold of -9 degrees was recorded in Bridgeport, February of 2023 while further inland saw temperatures drop into the -30 range during an abnormally warm season in which the state reported its second warmest February on record.

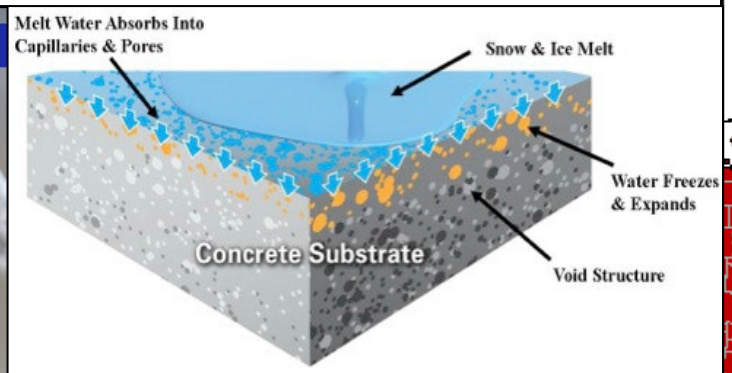
- The coldest temperature recorded was -37 degrees in 1943 and repeated in 1961.

The all-time snowfall record for Connecticut was recorded in Ansonia from Feb. 8-9, 2013, when 36 inches of snow fell in 24 hours, according to the regional climate center.

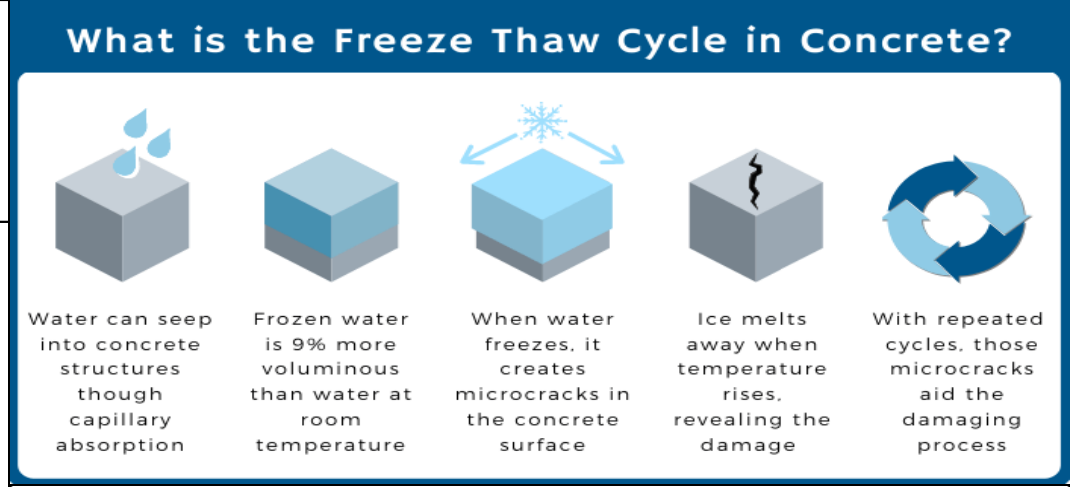
In extended hard freezes, the water in between and within the cells of the plants will freeze, causing the cells to expand and rupture and resulting in damaged plant tissue. This type of damage is typically irreversible. The warming coastal waters will contribute significantly to stronger winter storms.

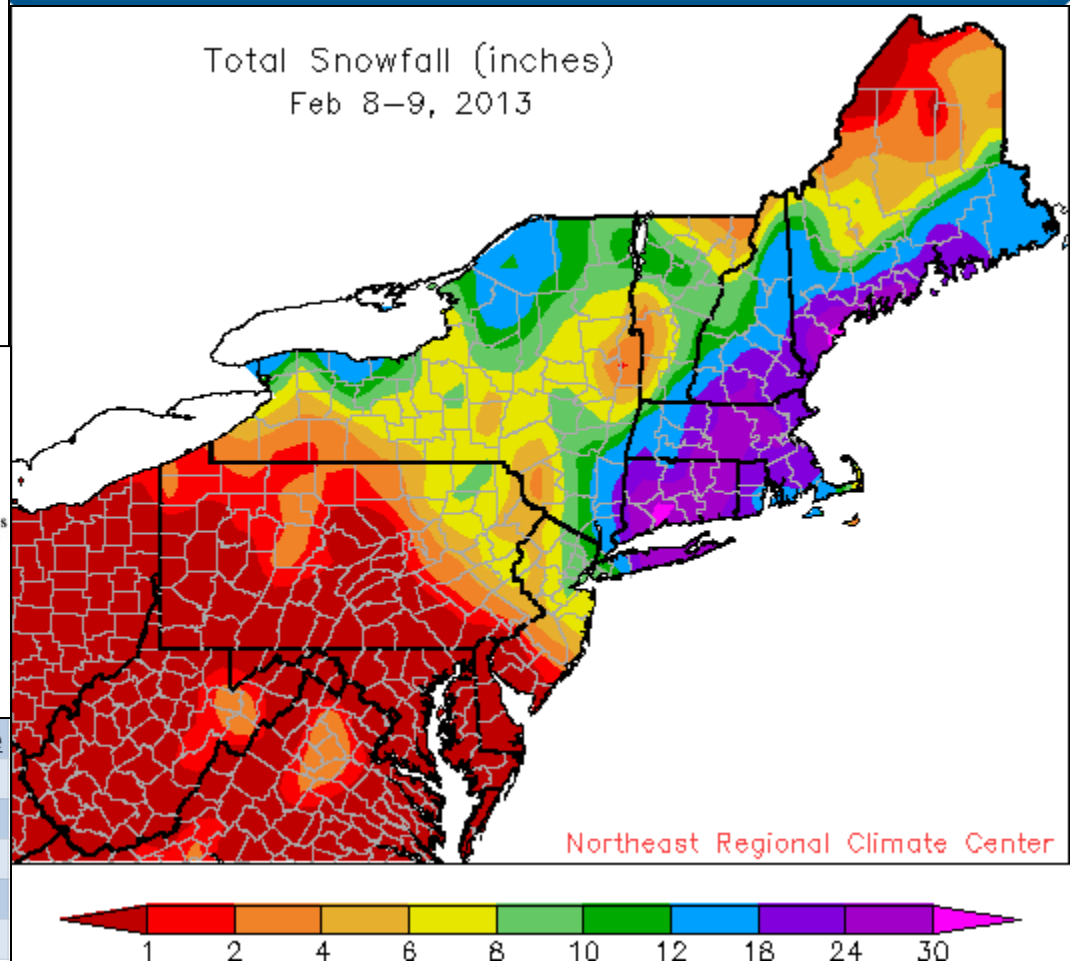
- Six of Boston's top 10 snowstorms have occurred since 2003, and nine of its top 10 since 1978. Similar trends have been seen in New York City, Philadelphia and Washington, D.C.
- Computer modeling studies show an intensification of the bigger storms, even as smaller snow events become rare.





City	Last Frost Date	First Frost Date
Bridgeport	April 12th	October 28th
New Haven	April 30th	October 10th
Stamford	April 30th	October 11th
Hartford	May 1st	October 8th
Waterbury	May 21st	September 27th





Weather Event Focus

Eight Main Weather Hazards

1. Extreme Heat
2. Extreme Cold
3. Tropical Cyclone Changes
4. Larger Wildfires
5. Torrential Flooding
6. Prolonged Drought
7. More Severe Storms
8. Sea Level Rise

Worsening Trends

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

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

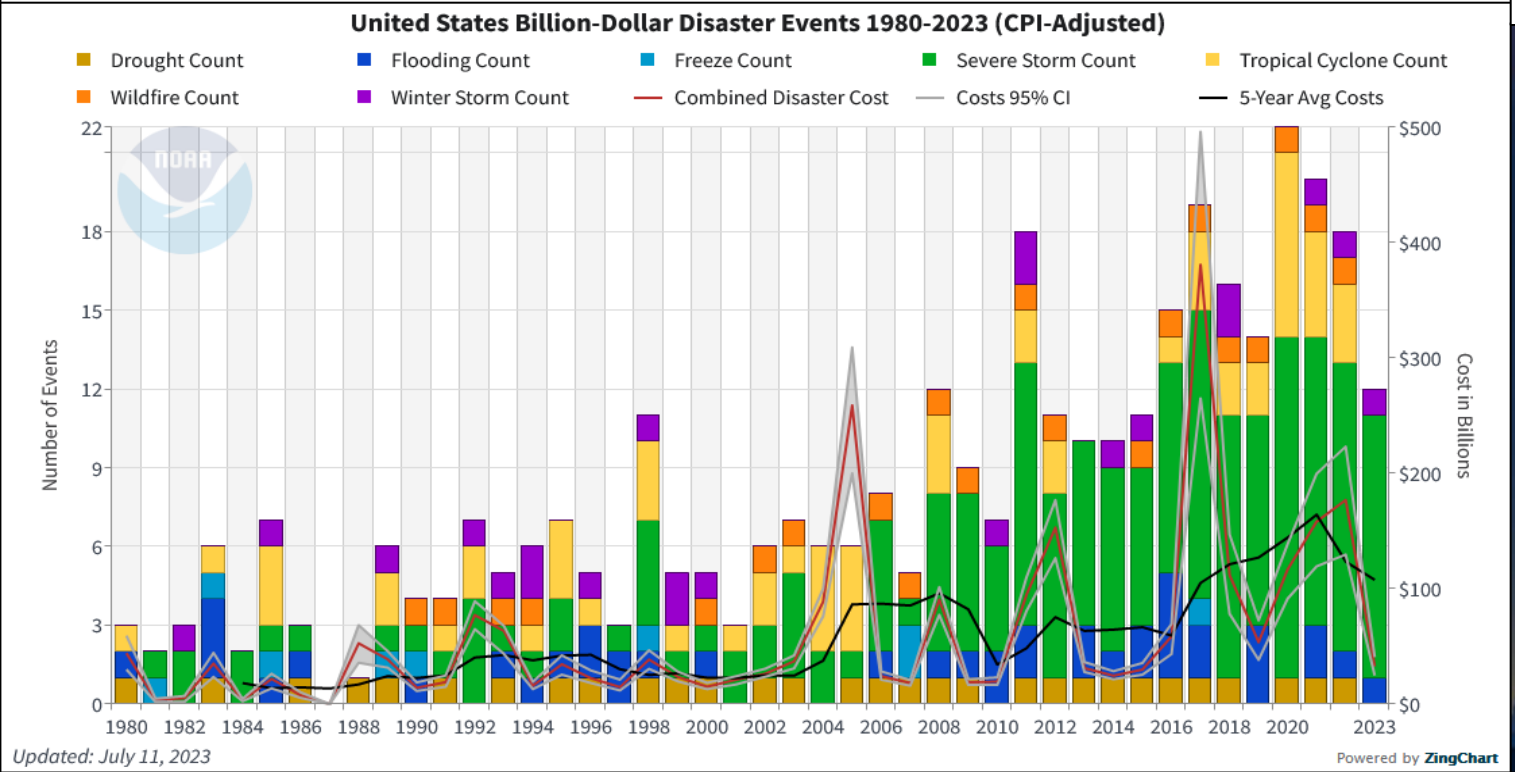
As hazards worsen in the coming years, the Southwest will face a rapidly increasing need for climate resilient facilities and support.

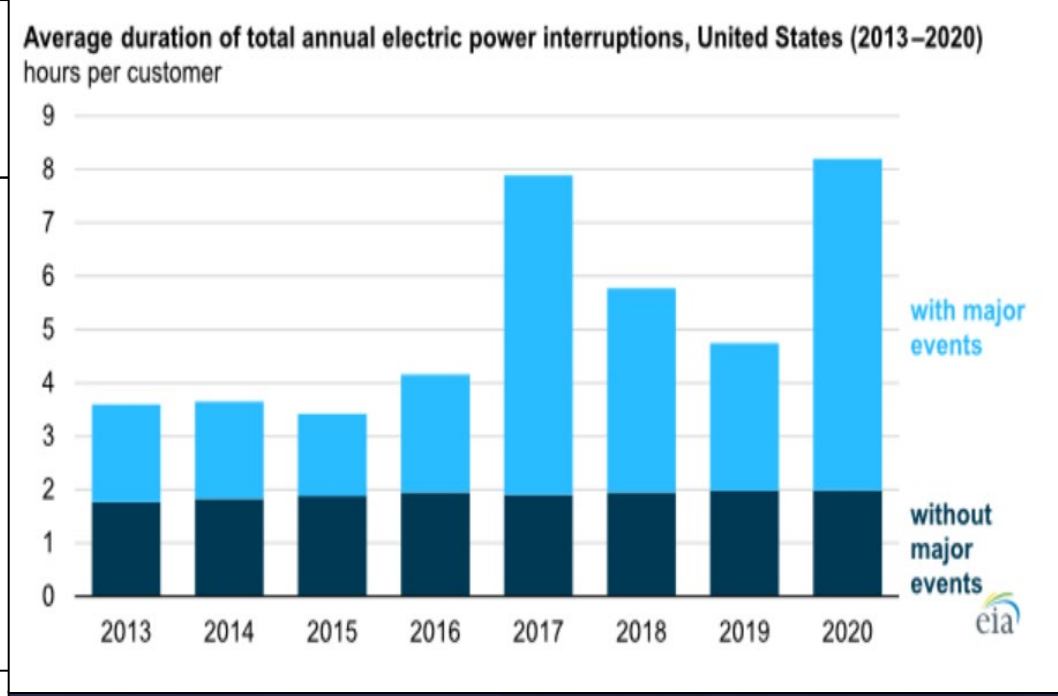
Extreme Weather Events Brings Cascading Impacts to All Critical Infrastructure Sectors and Staff

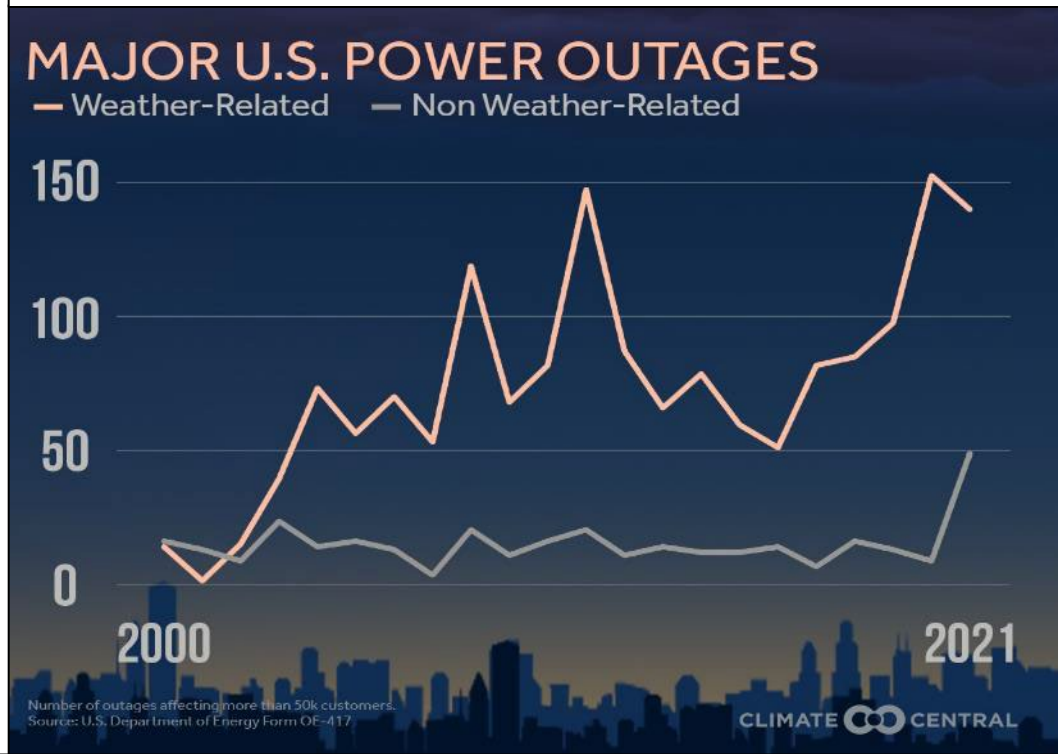
Energy Sector Loss - Weather

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

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







Community Impacts

Natural disasters displaced more than 3 million Americans in 2022, including nearly 1 million in Florida alone, according to data from the U.S. Census Bureau.

- A report by the National Centers for Environmental Information released this week found natural disasters cost the United States at least $165 billion last year.
    - “The NCEI said final cost figures may rise when the agency is able to account for winter storms that hit the country in the final weeks of the year, snarling flights and traffic over the Christmas holiday.”
- Last year marked the eighth consecutive year in which 10 or more separate billion-dollar disasters impacted the United States. In the last five years, an average of 17.8 billion-dollar events have occurred; since 1980, the average was 7.9 billion-dollar events.

https://pluribusnews.com/news-and-events/millions-of-americans-displaced-by-natural-disasters-in-2022/

Recent studies have suggested that people who experience the impacts of hurricanes, catastrophic flooding or other severe weather events are more likely to believe in, and be concerned about, climate change in the wake of the disaster.

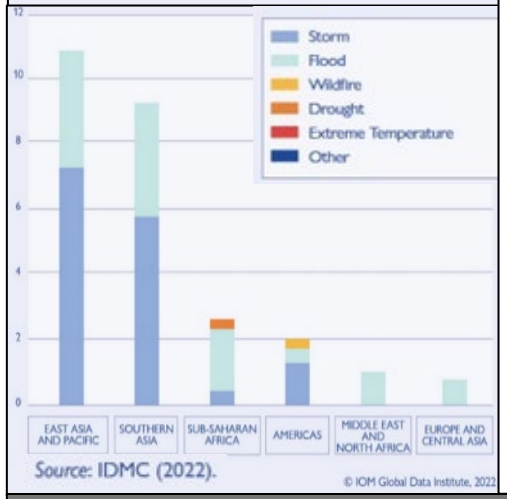
- People who perceived that damage had occurred at such a broad scale were more likely to believe that climate change is a problem and is causing harm, they were also more likely to perceive a greater risk of future flooding in their community.
- In contrast, individual losses such as damage to one's own house appeared to have a negligible long-term impact on climate change beliefs and perceptions of future risks.
    - https://www.sciencedaily.com/releases/2019/05/190531135815.htm

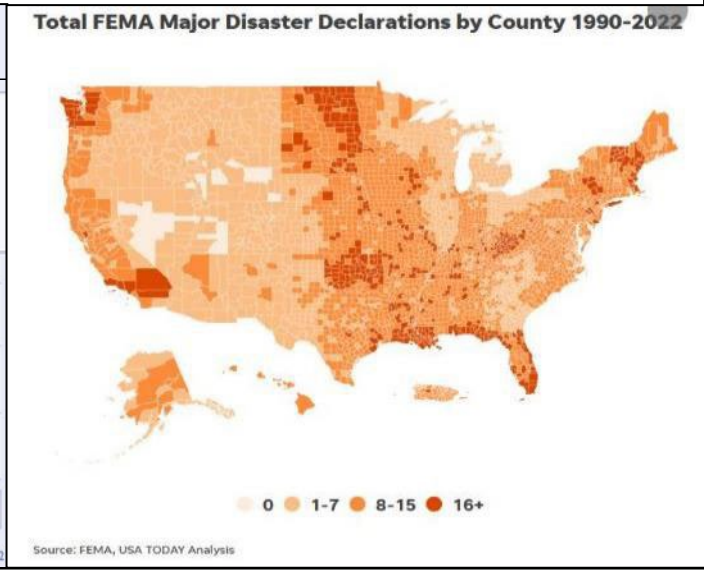
Research supported by NIEHS and others have shown that preparation, adaptation, and mitigation actions can reduce poor health outcomes and infrastructure disruption during and after an extreme weather event.
https://www.niehs.nih.gov/research/programs/climatechange/health_impacts/weather_related_morbidity/index.cfm

- Older residents make up a larger share of the population in warmer areas of the United States. These areas will likely experience higher temperatures, tropical storms, or extended droughts in the future. The amount of the U.S. population composed of adults over age 65 is projected to grow from 13% in 2010 to 20% by 2050 according to the EPA.

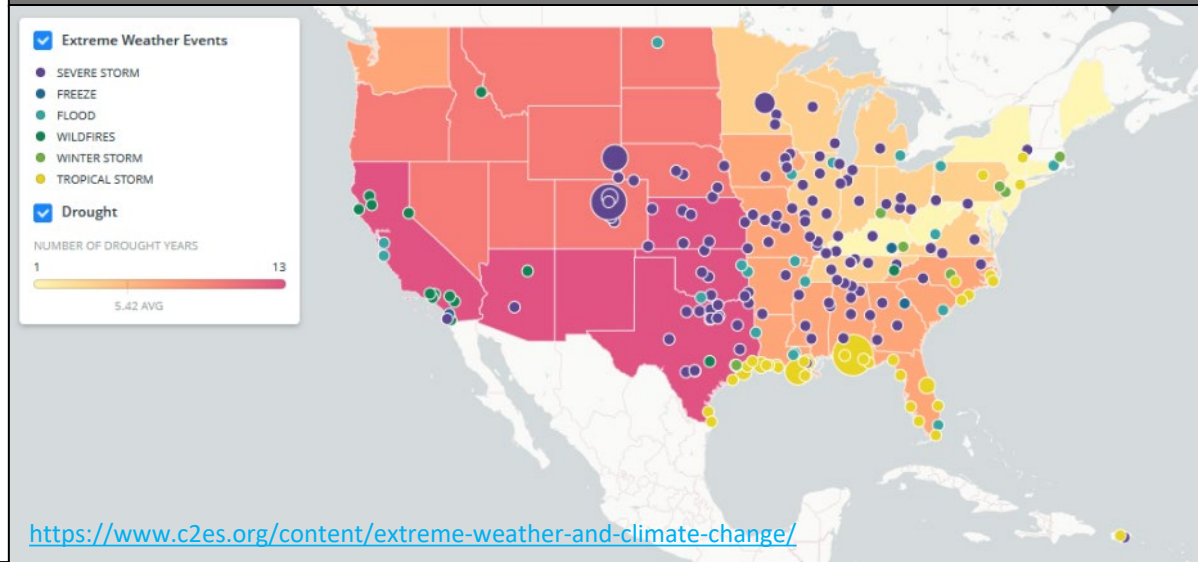
According to UNHCR, the UN’s refugee agency, an annual average of 21.5 million people have been forcibly displaced by weather-related events – such as floods, storms, wildfires and extreme temperatures – since 2008. These numbers are expected to surge in coming decades with forecasts from international thinktank The IEP predicting that 1.2 billion people could be displaced globally by 2050 due to climate change and natural disasters.

Annual Weather-Related Displacements in Millions (2012-2021 Average)





Billion-Dollar Extreme Weather Events, 2000-2021



https://www.c2es.org/content/extreme-weather-and-climate-change/

Climate Migration Patterns

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

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

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

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

People may also flock to major urban centers like Dallas and Houston, which the model predicts will absorb the most migrants, and drive up the pace of urbanization.

Heat waves will drive people north—and could make cities like Duluth and Buffalo “climate havens.” Urban flooding will reshuffle populations within a city.

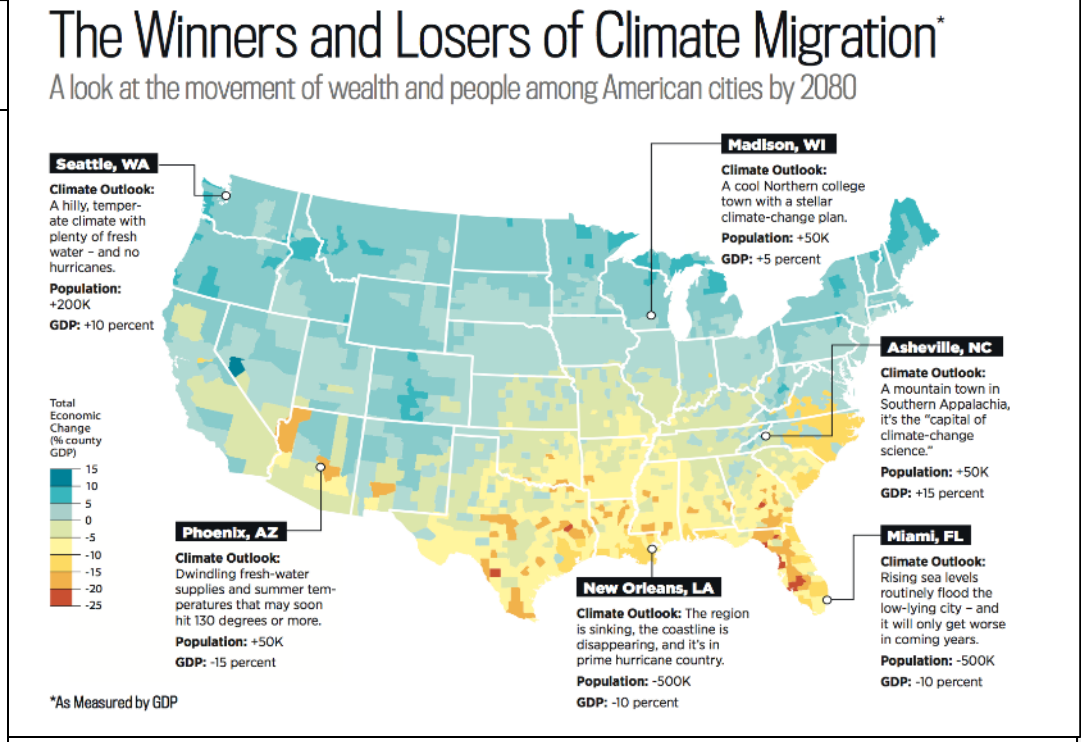
Climate change related-migration, as used in this report, is an umbrella term describing the spectrum of climate change’s relationship with human mobility—including the circumstances of “trapped populations” for whom migration is not an option despite exposure to climate-related threats. Even in the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

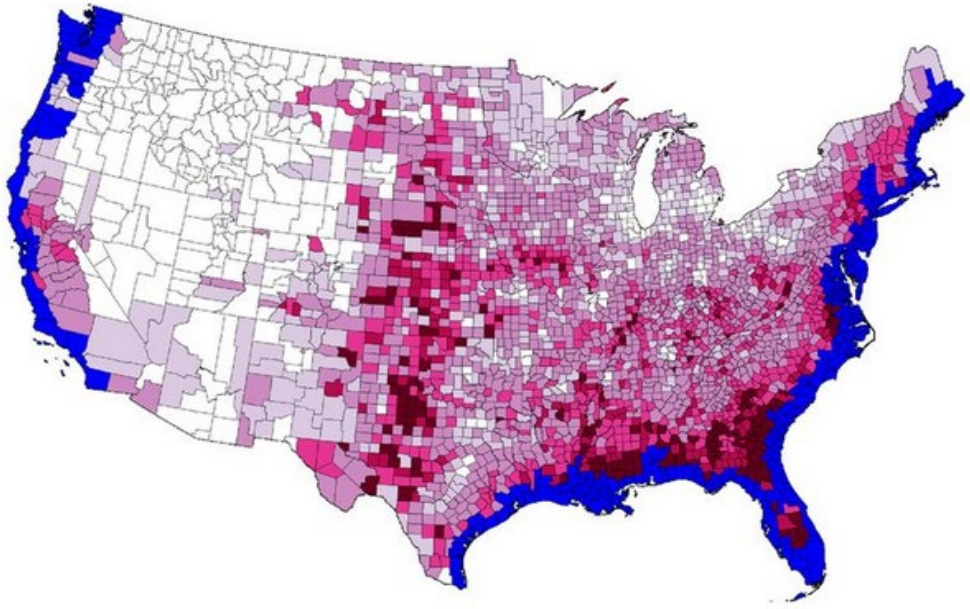
https://www.whitehouse.gov/wp-content/uploads/2021/10/Report-on-the-Impact-of-Climate-Change-on-Migration.pdf

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

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

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





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

While most climate displacement in the past has typically happened internally, with people returning soon after the disaster, increasingly the impacts of climate change are making certain areas uninhabitable and returning difficult.

- Insurance providers have remarked that rates are expected increase as flooding, fires, and heat waves increase with the potential that some insurance companies may leave the business which would decrease the competition regionally. Individuals renting may not have the same protections and reimbursement as homeowners impacted by extreme weather events damaging residential areas.

Population displacement can create competition, for food and clean water access, but also on labor markets, while also exacerbating existing ethnic tensions, or gender violence. Furthermore, climate migration often combines with conflict-related displacement, and worsens the situation in already sensitive regions touched by war and violence

<u>Where people live influences their vulnerability to climate change:</u>

About 80% of the U.S. population lives in urban areas. As a result, increases in heat waves, drought, or violent storms in cities would affect a larger number of people than in suburban or rural areas

- Over the past 40 years, population has grown rapidly in coastal areas and in the southern and western regions of the United States. These areas are most sensitive to coastal storms, drought, air pollution, and heat waves.
- Populations in the Mountain West will likely face water shortages and increased wildfires in the future.
- Arctic residents will likely experience problems caused by thawing permafrost and reduced sea ice.
- Along the coasts and across the western United States, both increasing population and changes in climate place growing demands on transportation, water, and energy infrastructure.

The top 10 counties that lost the most population were concentrated in California, New York, Illinois and Florida. Los Angeles County lost the most residents, around 185,000, and New York County had the greatest percentage loss of residents with a negative 6.9% rate.

- **The states that had the largest growth rates were Utah, Texas, California, Arizona and Florida.** The county that added the most residents was Maricopa County in Arizona, which contains the state's biggest city, Phoenix, adding around 58,000 residents. Utah County came in at the 10th spot on the list by adding just under 22,000 residents to bring its population to around 685,000 people.
- St. George, Utah grew by nearly 10,000 new residents between July 1 of 2020 and July of 2021, a 5.1% increase. Two other Utah cities made the list of top-10 fastest-growing metro areas, with the Provo-Orem area ranked eighth at 3.3% and the Logan area ranked 10th at 2.9%.

Climate change can impact the health and well-being of indigenous tribes by making it harder for tribes to access safe and nutritious food including traditional foods important to many tribes' cultural practices. Many tribes lack access to safe drinking water and wastewater treatment in their communities. Climate change could increase health risks associated with water quality problems like contamination and may reduce availability of water during droughts.