2023

CHEMICAL SECURITY SUMMIT

August 29-31, 2023

#ChemicalSecurity

CYBERSECURITY & INFRASTRUCTURE SECURITY AGENCY
CISA

CHEMICAL SECURITY SUMMIT

August 30, 2023

Extreme Weather Threats to Chemical Security

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CISA Extreme Weather Trends and Impacts Implications for Security

"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).

09/29/2023

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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 Central 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

Agenda

- Extreme Weather Trends 2022 to Now
- Supporting Infrastructure Damages and Risks Increasing
- Implications to Physical Security
- Implications to Cybersecurity
- Implications to Transportation
- Impacts to Emergency Managers and Site Staff
- Best Practices and Emerging Solutions Hub
- Extreme Weather Training and Free Resources

2022 Billion Dollar Disasters

Updated: The U.S. has sustained 341 weather and climate disasters since 1980 where overall damages/costs reached or exceeded $1 billion (including CPI adjustment to 2022). **The total cost of these 341 events exceeds $2.475 trillion**.

During 2022, there were **18** separate billion-dollar weather and climate disaster events.

- These events included: eleven severe storm events (tornado outbreaks, high wind, hailstorms and a derecho), three tropical cyclones (Ian, Fiona, Nicole), the Kentucky/Missouri flooding, the late-December Central and Eastern winter storm/cold wave, the Western and Central drought/heat wave and Western wildfires.
- Overall, these events resulted in the deaths of 474 people and had significant economic effects on the areas impacted. The 1980–2022 annual average is 7.9 events (CPI-adjusted); the annual average for the most recent 5 years (2018–2022) is 17.8 events (CPI-adjusted).

The total cost from these events of 2022 was $165.0 billion and was the third most costly year on record, behind 2017 and 2005.

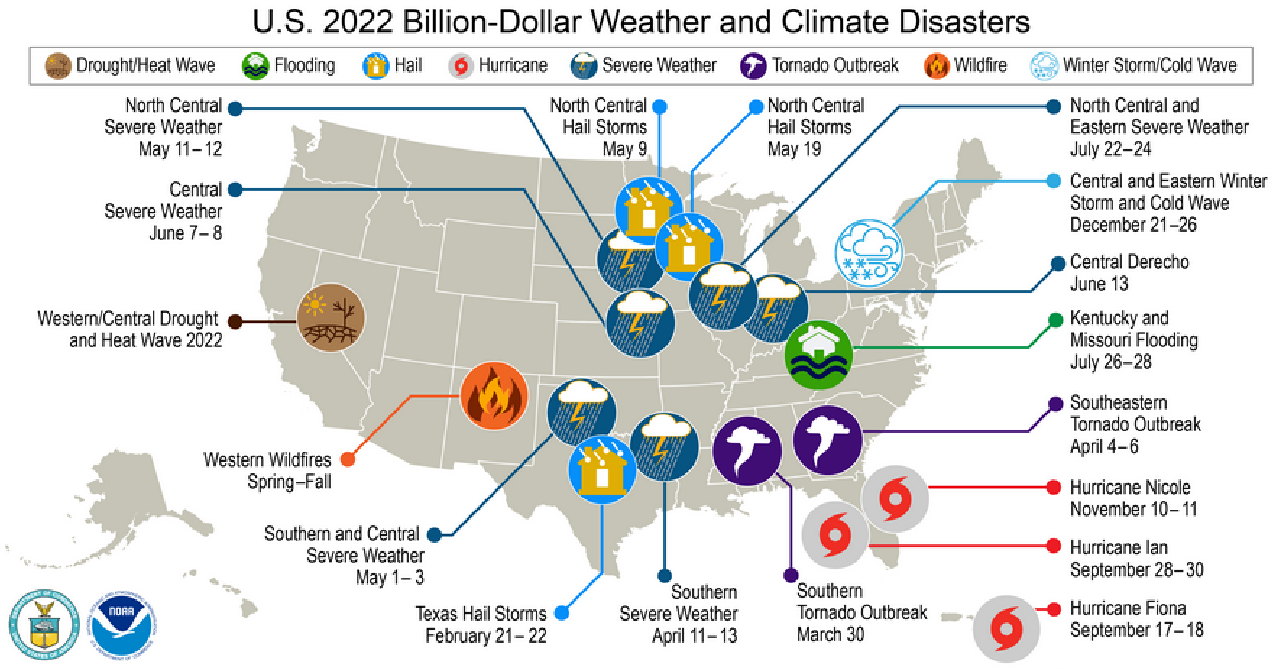
- The annual costs from billion-dollar disasters has exceeded $100 billion in five of the last six years (2017-2022) with 2019 being the only exception.
- The total cost of the last seven years (2016-2022) exceeds $1 trillion while the costs for 341 events from 1980-2022 exceeds $2.475 trillion (inflation-adjusted to 2022 dollars).

2022 was the **eighth consecutive year** (2015-2022) in which **10 or more** billion-dollar weather and climate disaster events have impacted the United States.

- Over the last 43 years (1980-2022), the years with 10 or more separate billion-dollar disaster events include 1998, 2008, 2011-2013, and **2015-2022**.

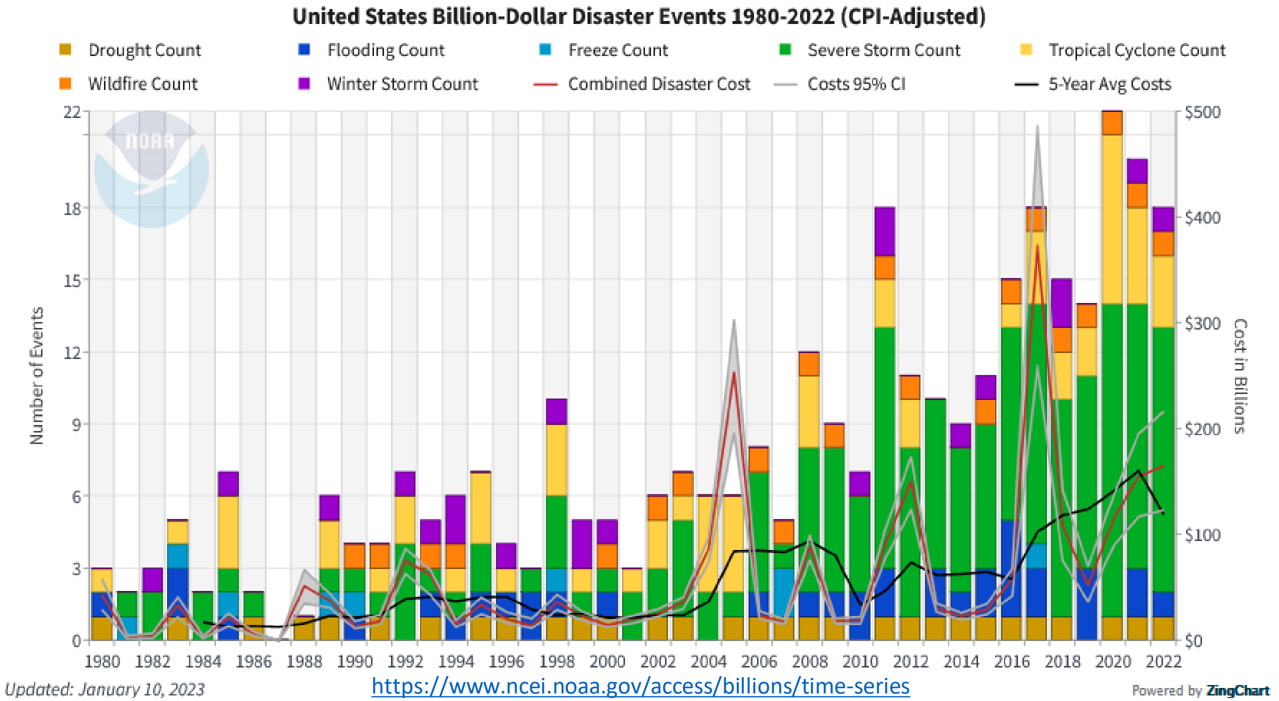
*Inflation has affected our ability to compare costs over time. To reflect this, the graphic also shows events with less than $1 billion in damage at the time of the event, but after adjusting for inflation (Consumer Price Index), now exceed $1 billion in damages.

- Thirteen new events from the 1980-2021 period were added during the 2022 first quarter update to reflect inflation-adjusted event losses over $1 billion.
- This included nine severe storm events, one winter storm, one flood event, one tropical cyclone and one wildfire event.



*This map denotes the approximate location for each of the **18 separate billion-dollar weather and climate disasters** that impacted the United States in 2022.*

https://www.ncei.noaa.gov/access/billions/



https://www.ncei.noaa.gov/access/billions/time-series

2023 July Updates to the Billion-Dollar Disaster Map

For 2023 to-date, **15 weather and climate disasters** have losses exceeding $1 billion:13 severe storms, a winter storm, and a flooding event.

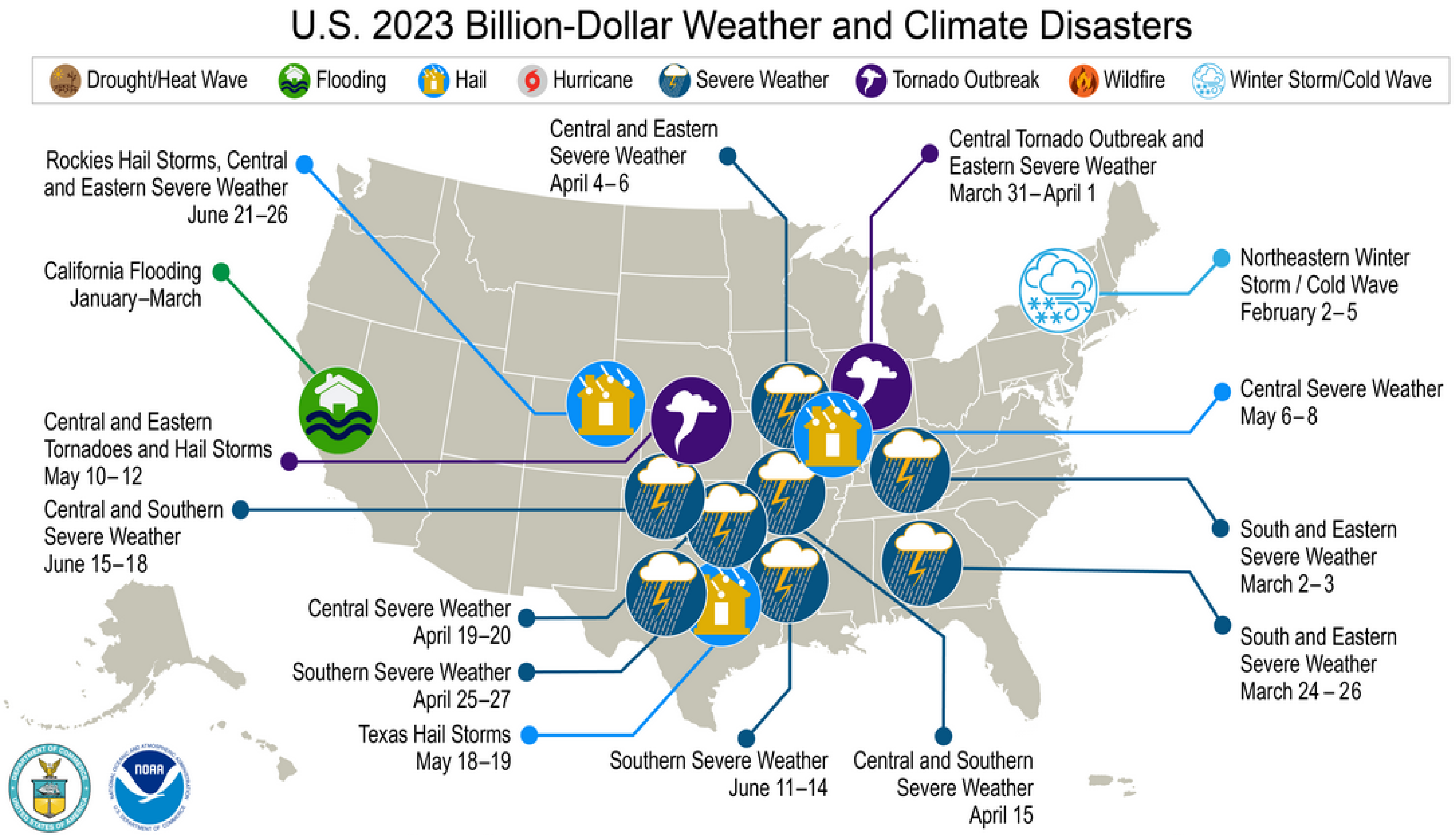
There are three additional weather events pending review for June-July: severe weather, flooding, and drought. This does not include the wildfires in HI.

The very active U.S. severe storm season is reflected in the high count of billion-dollar events that have produced destruction across much of the central and eastern US.

A late winter storm in June produced +8 inches of snow in New Hampshire from a single storm, becoming the snowiest June on record since 1932.

Severe storms have caused the highest number of billion-dollar disaster events (180), while the average event cost is the lowest ($2.4 billion). Tropical cyclones are the second and third most frequent, the most damaging, and the deadliest events historically.

The total cost from the events of 2022 exceeded $165.0 billion and was the third most costly year on record, behind 2017 and 2005.



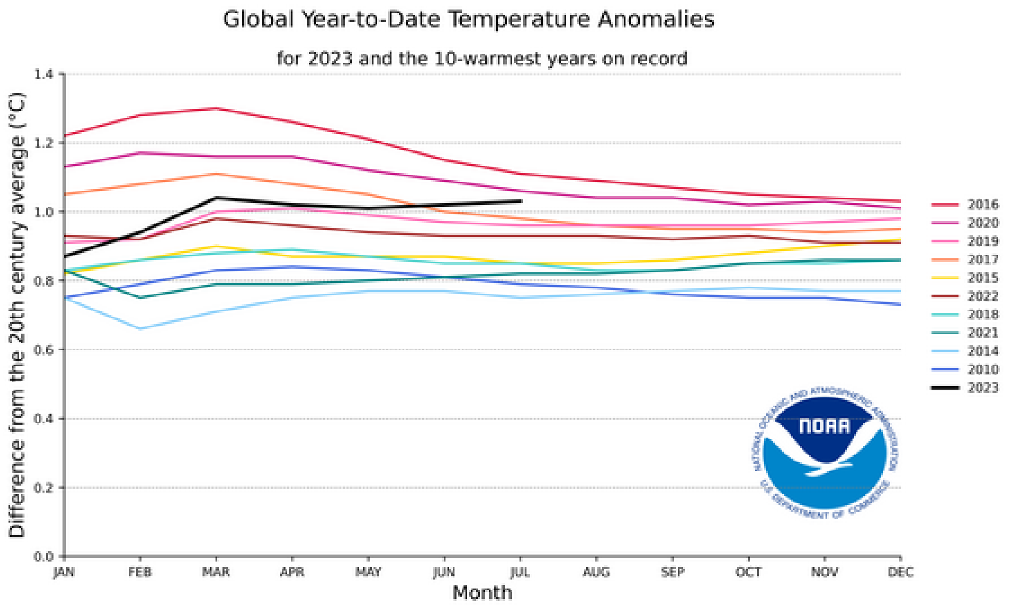
*This map denotes the approximate location for each of the **15 separate billion-dollar weather and climate disasters that impacted the United States through July 2023.***

Global Climate: July 2023

Globally, June 2023 set a record for the warmest June in the 174-year NOAA record. The year-to-date (January–June) global surface temperature ranked as the third warmest such period on record.

The July global surface temperature was 1.12°C (2.02°F) above the 20th-century average of 15.8°C (60.4°F), making it the warmest July in the 174 year record.

- July global ocean surface temperatures also hit a record high and for the fourth-consecutive month remained at record highs.
- This marked the first time a July temperature exceeded 1.0°C (1.8°F) above the long-term average.
- The past nine Julys have been the warmest Julys on record.
- July 2023 was one of the globally wettest Julys on record.
- Severe weather conditions (drought) in Thailand stemming from El Niño could continue to push sugar prices higher with drying rivers leading to supply chain delays in multiple countries.

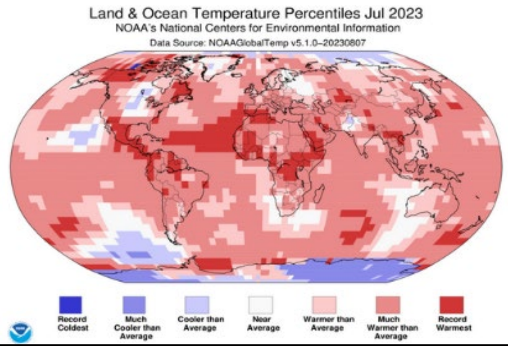


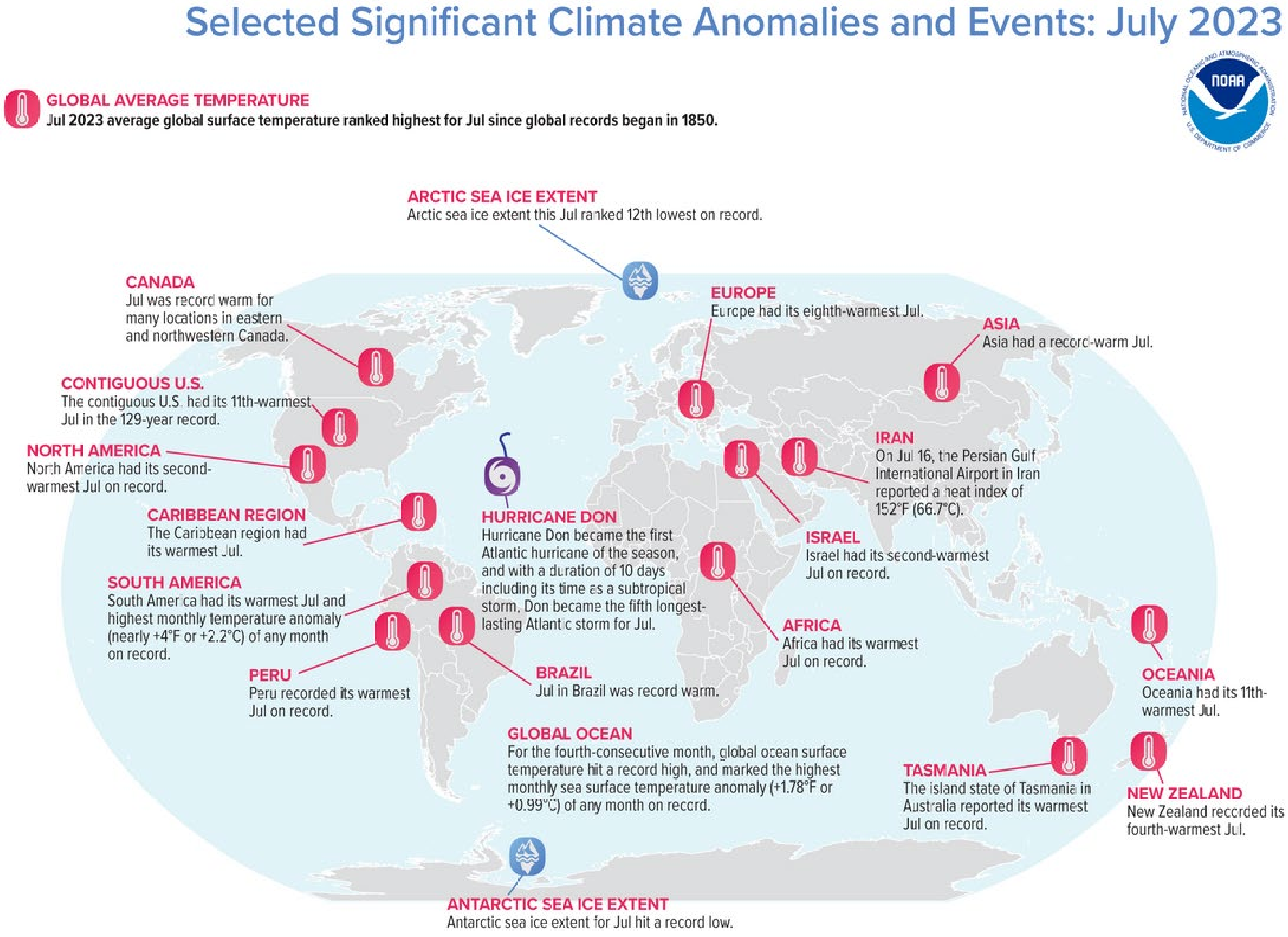
June 2023 recorded the lowest global June sea ice extent on record.

Globally, sea ice extent this June was 330,000 square miles less than the previous record low from June 2019.

Record-warm temperatures covered just over 9.3% of the world's surface this month, which marks the highest July percentage since records began in 1951. The Caribbean region and the Gulf of Mexico had the warmest July on record.

As water continue to heat, hydropower is at a growing risk.





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

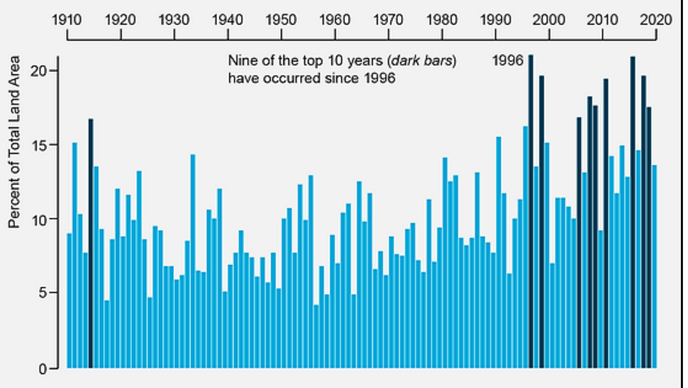
Increases in atmospheric water vapor also amplify the global water cycle. They contribute to making wet regions wetter and dry regions drier. The more water vapor that air contains, the more energy it holds. This energy fuels intense storms, particularly over land. This results in more extreme weather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

Heavier Rains

Extreme rains and snows are happening more frequently, as warmer air and oceans generate more vapor in the atmosphere. An "extreme" storm delivers more precipitation in one event than 90 percent of a year's storms do. In recent decades these events have multiplied across many urban and rural areas and will increasingly become the norm.

Percent of U.S. Land Area* Where Extreme One-Day Rains or Snows Have Supplied Much More of the Annual Precipitation Than Average

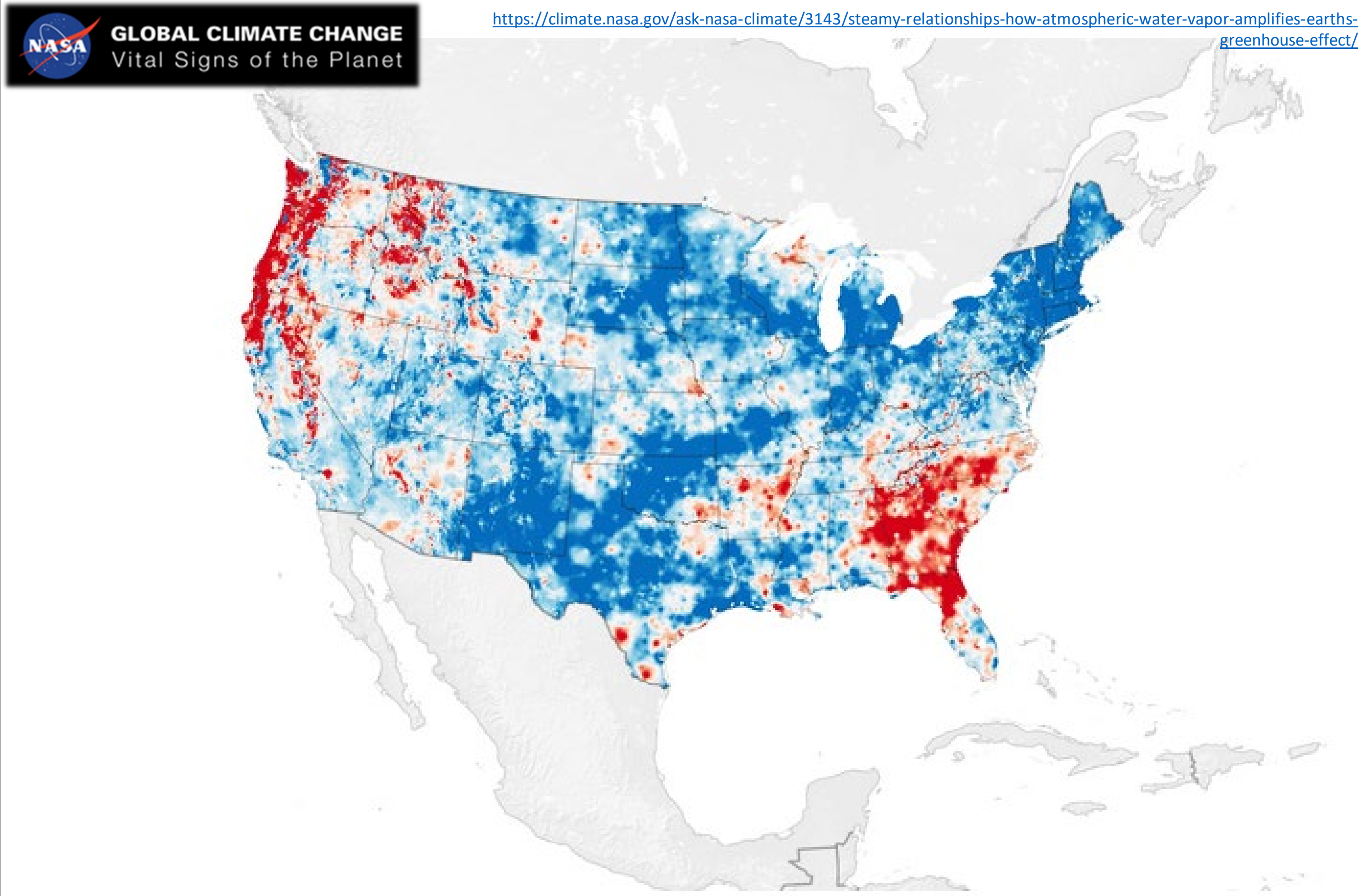


*Contiguous 48 states

- 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.

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



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

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

Severe Weather on the Rise

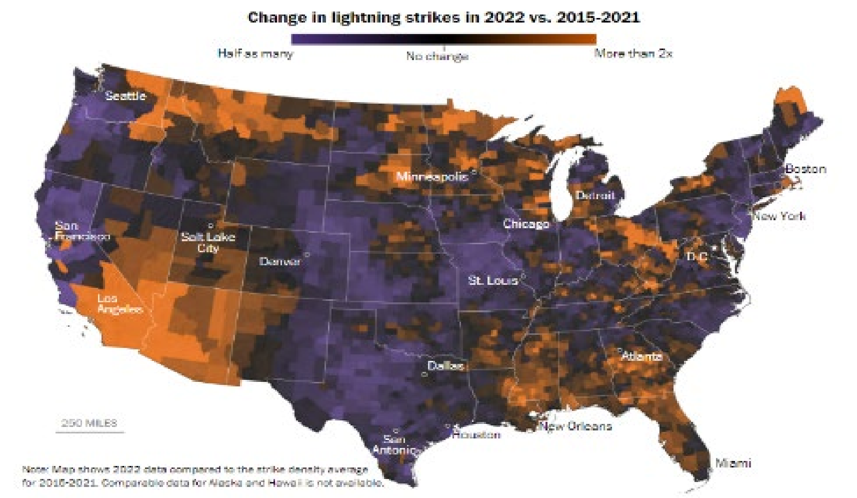
Hail events throughout the US are forecasted to intensify regarding size of the hailstones as warmer climates enable stronger updrafts for supercell storms responsible for large hail. Storms are now forming

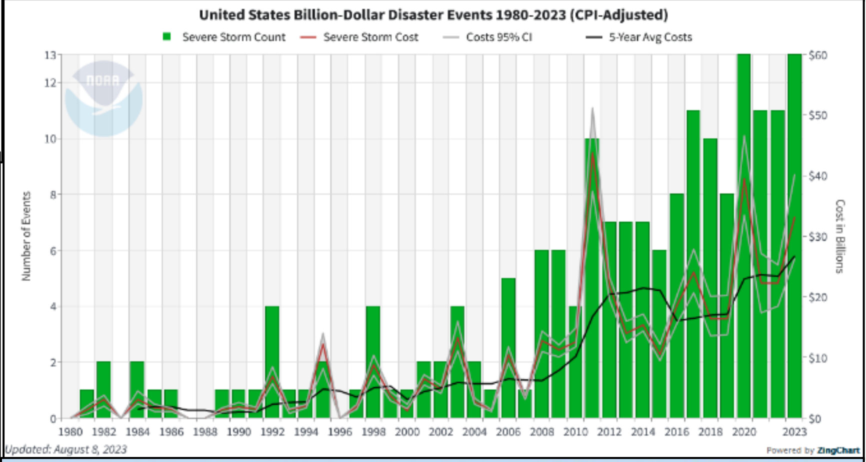
In Texas, Colorado, and Alabama the records for largest hailstone have been broken in the last three years, reaching sizes of up to 6.2 inches in diameter. Insured U.S. hail losses average $8 billion - $14 billion per year, or $80-140 billion per decade.

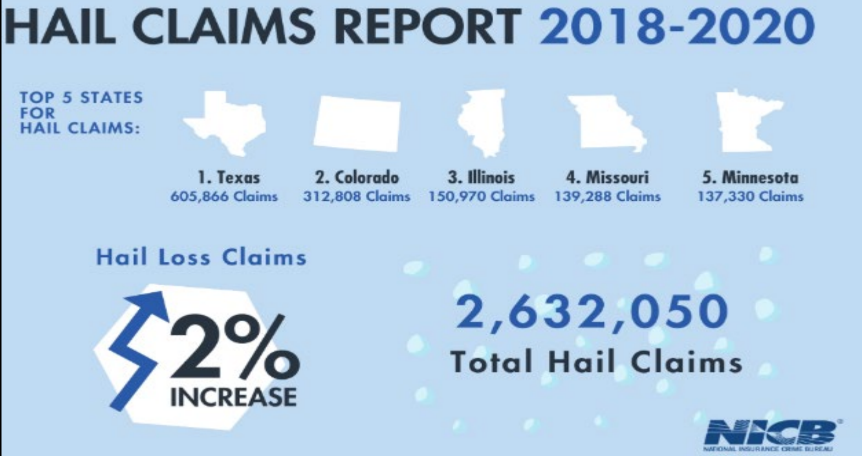
Reports indicate that the 2017 hailstorm caused roughly $2.3 billion dollars' worth of damage and is one of the strongest to ever hit the US. Texas recorded the single largest hailstone in the state's history in 2021: at 1.26-pounds, measuring 6.4-inch inches in diameter. Tornado events have become more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

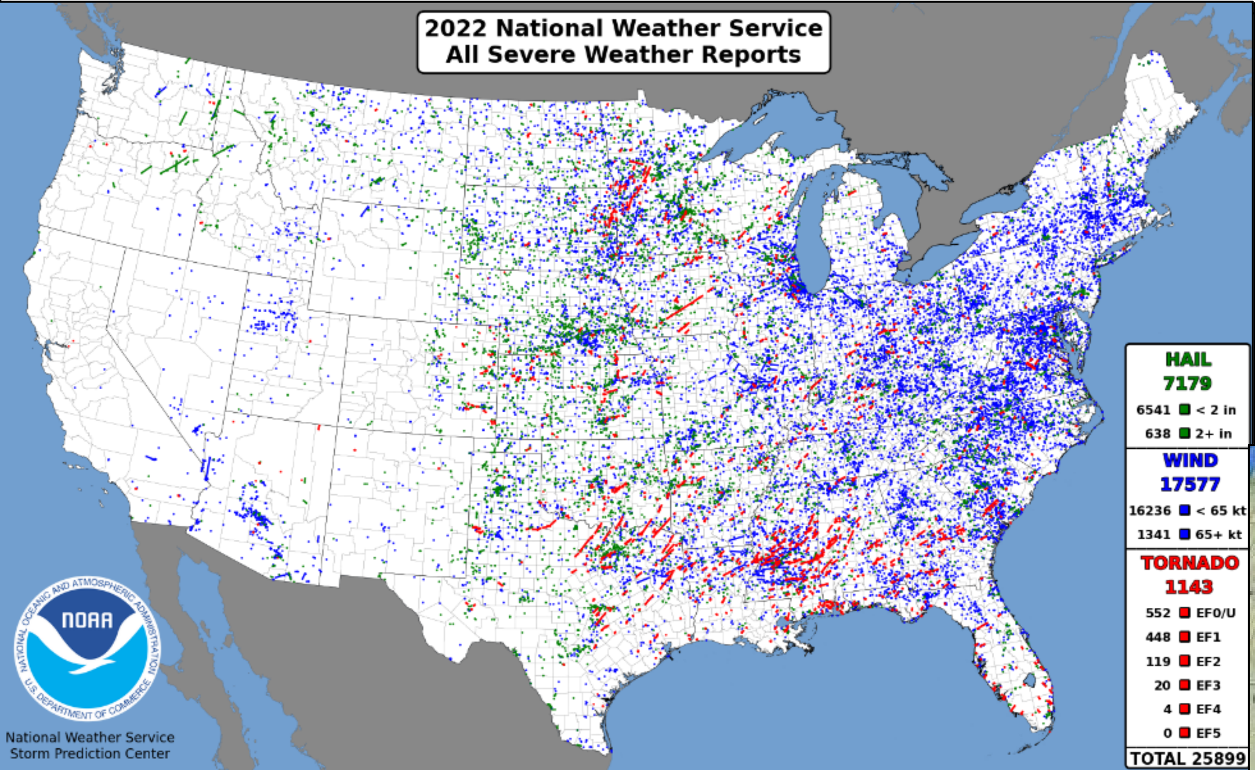
Tornado activity from 2008-2021 in comparison with 1991-2010 indicates the seasonal frequency has remained the same but the location and intensity of tornadic supercells has expanded from "Tornado Alley" to "Dixie Alley" producing larger, longer supercells. Dixie Alley includes Eastern TX, AR, LA, TN,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

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









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.

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.

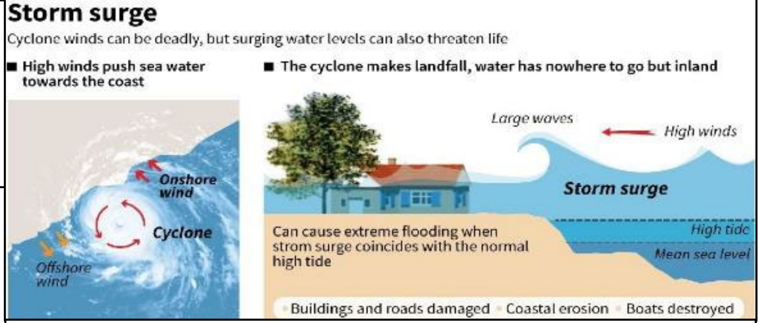
- One assessment suggests an increase in intensity, proportion of the most intense storms, and the occurrence of storms with extreme rainfall events.

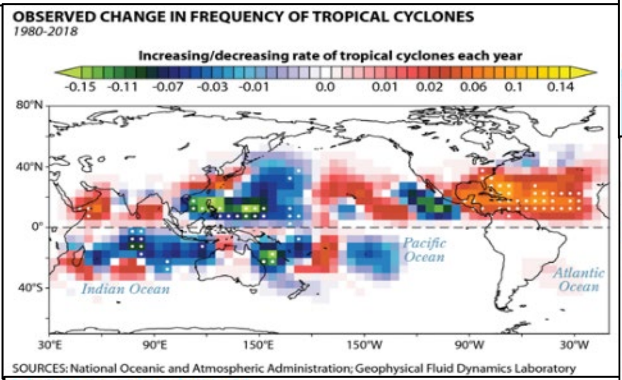
- A recent study from Yale using data from 2020’s cyclone Alpha and 2021’s cyclone Henri states the next 75 years will see an expansion of hurricanes/typhoons into mid-latitude regions, including major cities such as New York, Boston, Beijing, and Tokyo

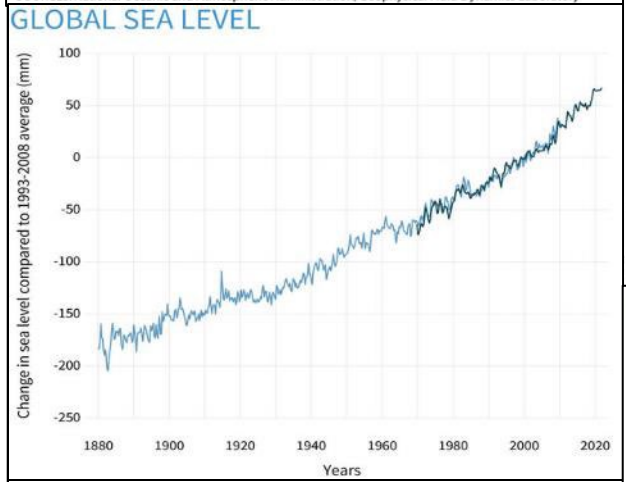
- A recent assessment indicated an increase of global tropical cyclone rainfall rates at 7% per degree of Celsius of warming with an observational finding of a 1.3% global increase in tropical cyclone rainfall rates per year since the early 1900s.

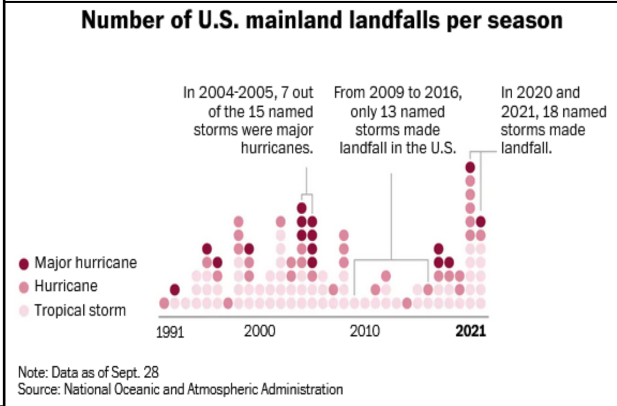
NOAA recently released a new explanatory guide: This information could be a useful guide to distribute to staff, as it succinctly covers the dangers of hurricanes and how to plan for them. 57% of fatalities during tropical cyclones have been caused by storm surge.

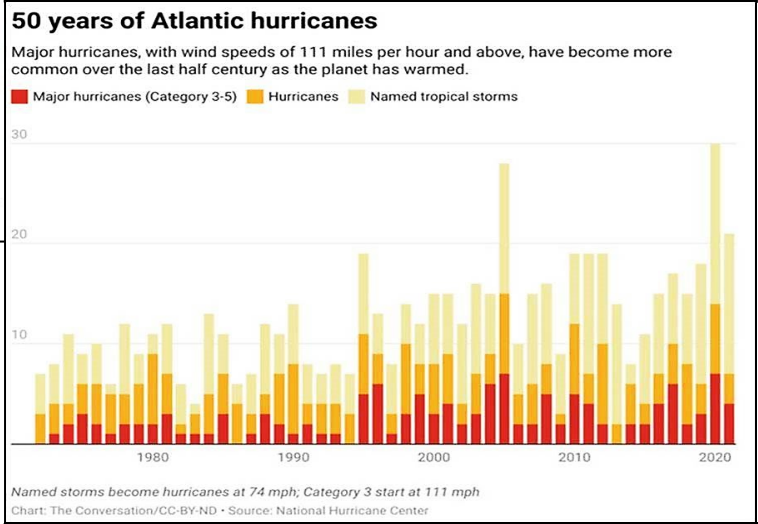
- Storm inundation levels during hurricane surge events will increase due to sea level rise, anticipated to rise by about 2 to 3 ft by 2100.
- Total numbers of Atlantic tropical storms and hurricanes combined are projected to decrease by 15%, but with uncertainty; a minority of studies project an increase.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

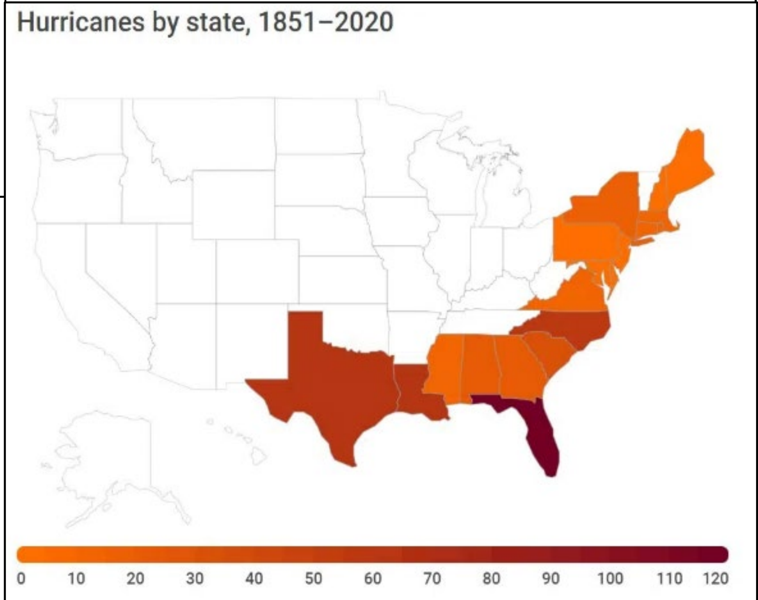












Tropical Cyclones Changes

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.

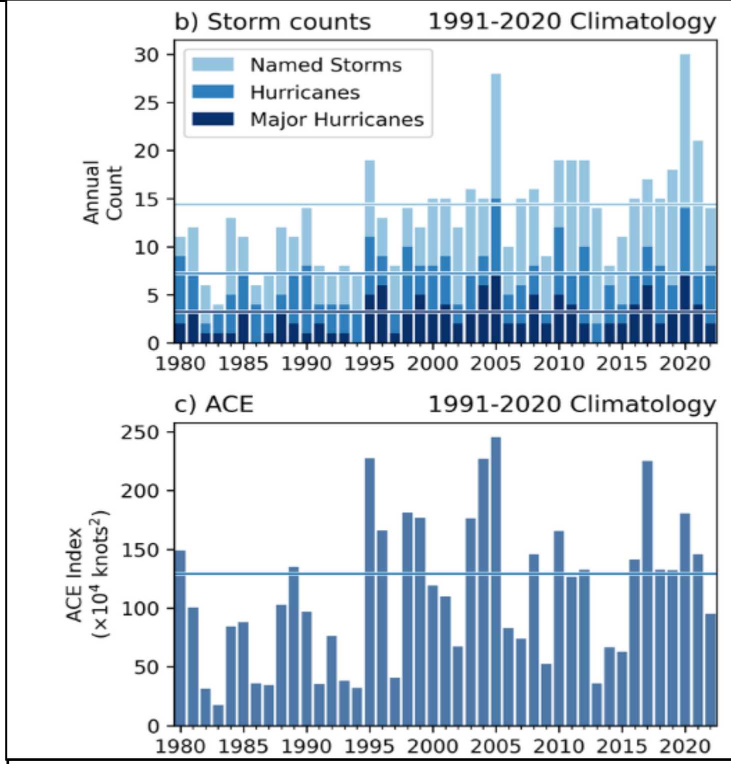
- More intense and frequent extreme rainfall and associated flooding in many regions including coastal and other low-lying cities, and increased proportion of and peak wind speeds of intense tropical cyclones (IPCC 2023).

<u>New Tropical Study by Iowa State University</u>: 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.

<u>Tropical Record</u>: 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.

Loop Current Summary

Current SST: https://weather.msfc.nasa.gov/sport/sst/

What is a Loop Current: https://www.aoml.noaa.gov/phod/gom/

BLUF: A current, named the Loop Current for its shape and route in SST maps, began in early May and has been pulling abnormally warm water into the Gulf of Mexico from the Caribbean. The current is a semi-regular event for the region and twice a year can pulse out a ring from the apex of the loop into the Gulf called an Eddy. When an Eddy breaks off during hurricane season, tropical cyclones which pass over it are given a boost in strength by the warmer water. This event was present in 2005 during the peak of the destructive hurricane season and amplified three hurricanes which crossed it: Katrina, Rita, and Wilma.

For 2023, the Sea Surface Temperatures of the Gulf of Mexico began warming abnormally early in the year, with the Loop Current starting in February in even warmer waters during a time of heightened moisture presence indicating the loop could persist through the start of Hurricane season and result in more damaging landfalls from higher intensity hurricanes which cross into the Gulf of Mexico and pass over the loop.

- **Hurricane Rita** reached Category 5 Hurricane strength, reached the fourth-lowest recorded pressure center, and caused $18.5 billion in damages (2005 USD). Rita produced 15-foot storm surface and near 7 inches of rainfall upon landfall.
- **Hurricane Wilma** reached Category 5 Hurricane strength and was one of the five costliest storms in the US history at $20 billion (2005 USD). In Mexico, Wilma produced a 10-foot storm surge and 64 inches of rain, setting a hemisphere-wide record for 24-hour total rainfall.
- **Hurricane Katrina** reached Category 5 Hurricane strength and caused $161 billion in damage along the Gulf Coast destroying over 850,000 homes, 350,000 vehicles, and 2,400 ships and vessels. 33 Tornadoes were produced, and storm surge reached 30 feet along with flooding from 7.8 inches of rain in 48 hours.
- **Hurricane Ian in 2022:** Ian grew rapidly from a Tropical Storm to a Major Hurricane in one day causing +$112 billion in damage in Florida.

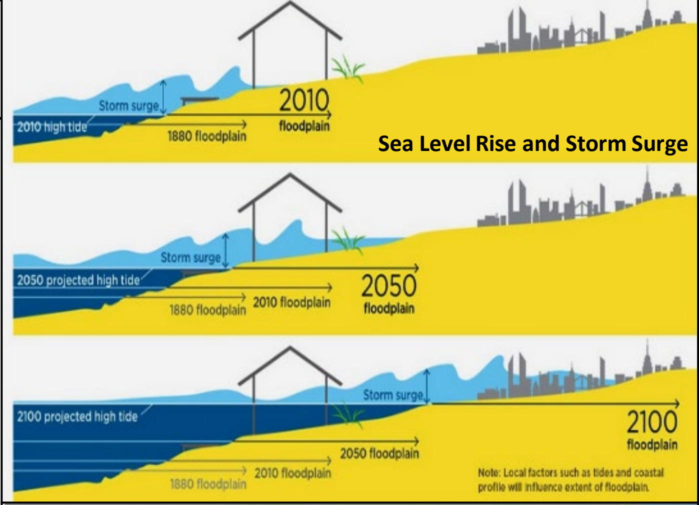
The Loop Current is associated with high sea surface height, measured by altimetry, and by warm waters visible in Sea Surface Temperature.

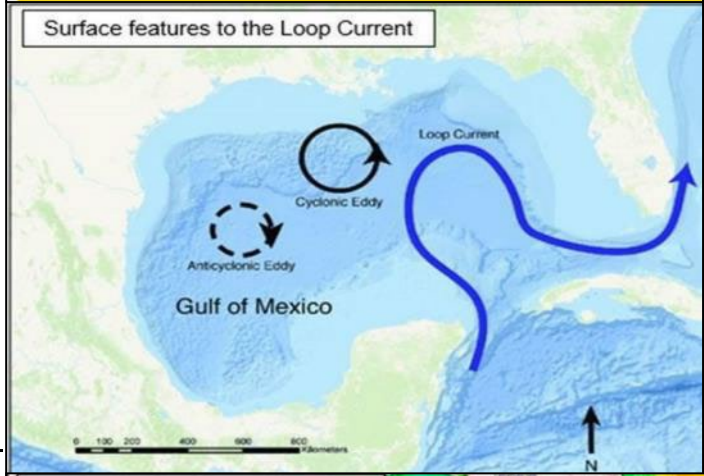
- https://cwcgom.aoml.noaa.gov/cgom/OceanViewer/index.html - Global Sea Surface Temperatures to identify this event in the Gulf of Mexico ahead of tropical cyclones. Comparable to the NASA Sport Map provided above. Global SST: https://www.seatemperature.org/

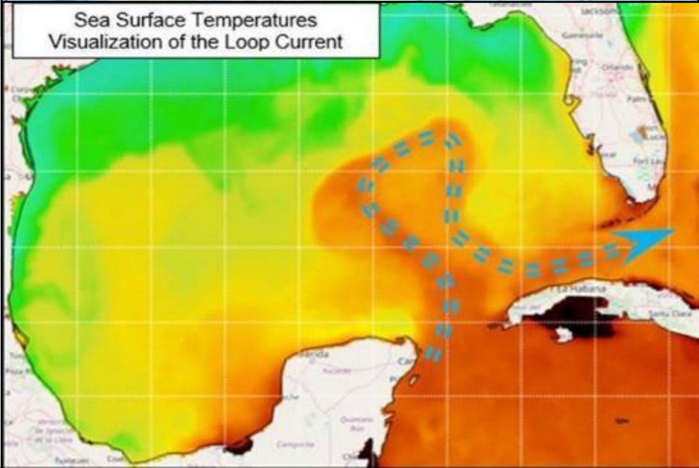
Impacts to Oil: In the extended state, the Loop Current will spin off warm-core, anticyclonic eddies (LCEs), roughly 300 kilometers across and 500 to 1,000 meters deep, which can maintain current speeds up to 4 knots within circulations even after disconnecting from the Loop Current.

- These energetic LCEs generally propagate to the west and often threaten oil and gas operations in the northern, central, and western Gulf.
- Smaller, more measurable, and significantly cyclonic cold-core eddies have been observed to spin from the edges of the LCE and the extended LC itself. Just like hurricanes, tropical cyclones, and strong winter storms, LCEs are named. The LCS sees an extended state with significant eddy shedding occurring at intervals from a few weeks to 19 months, with an average shedding period of 8-9 months.
    - During the 18-month period from June 2014 to December 2015 operators in the Mississippi Canyon, Atwater Valley, Green Canyon, and Walker Ridge lease areas observed significant delays and downtime due to the adverse impact of elevated currents on critical current-sensitive operations, including, but not limited to, platform installation, hull wet tows, spar upending, drift-ins, riser installation, suction pile installation, unlatching the rig, subsea tree installation, pipe laying, remotely operated vehicle (ROV) deployments, and dynamic positioning.
        - These eddies can impact the oil plumes in the water from oil platform operations and can separate tendons anchoring down oil rigs in the Gulf from the ocean floor and causing billions of dollars in damages if heightened activity persists.

Sea Level Rise and the Loop Current: https://www.washingtonpost.com/climate-environment/2023/04/10/sea-level-rise-southern-us/







Aging Dams

<u>Concrete Deterioration Risk Analysis</u>: 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 and Seismic Activity

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

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

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

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

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

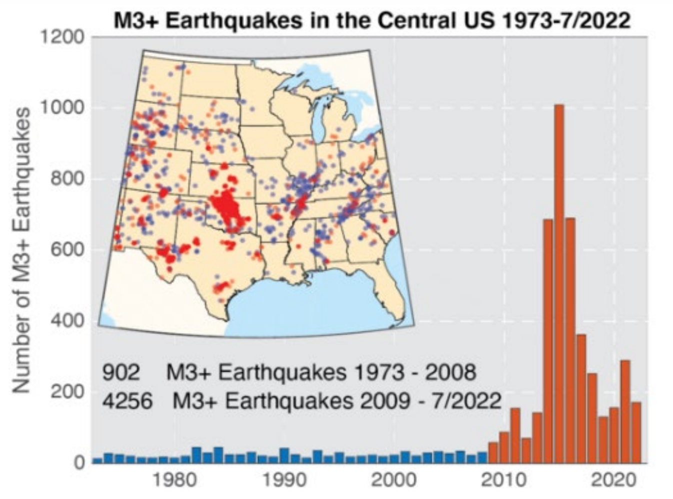
The areas around fault lines have valleys where the plates meet and are at their weakest point. Due to the lower elevations around these topography features, water tends to pool at the lowest elevation and thereby river systems were naturally located in the weaker spots of the fault line.

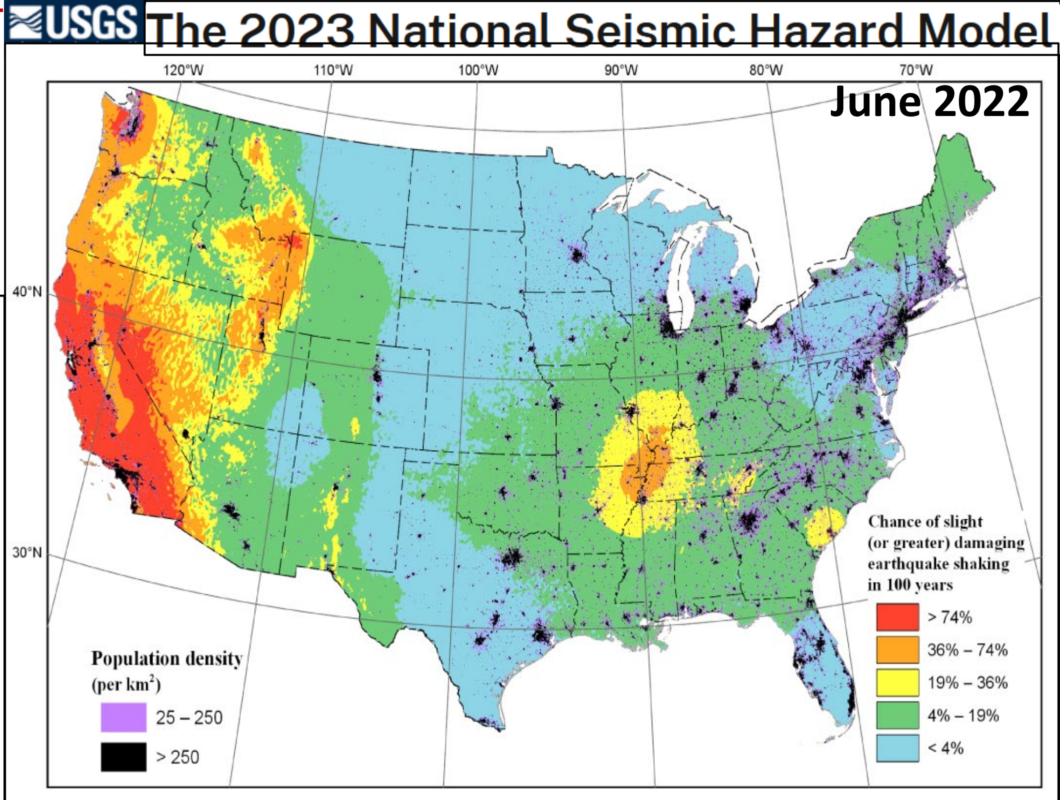
- Damming up the river system resulted in compounding water in different areas than were natural along some faults. As dams were installed, an increase in seismic activity was reported and subsequently as drought has developed, activity has increased again near the river/dam systems.

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

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

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

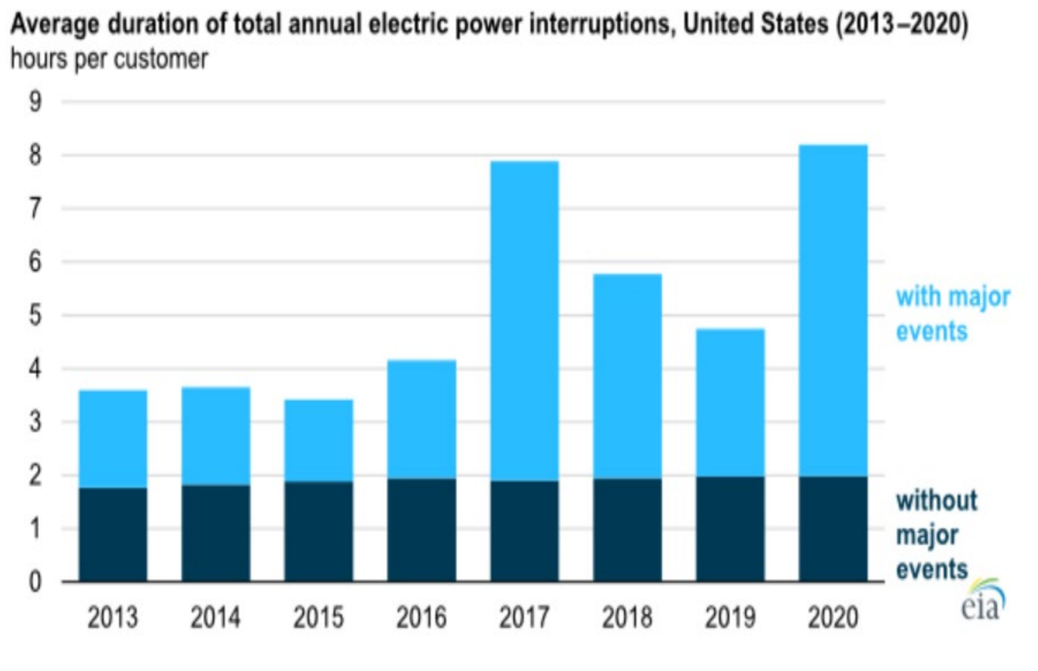


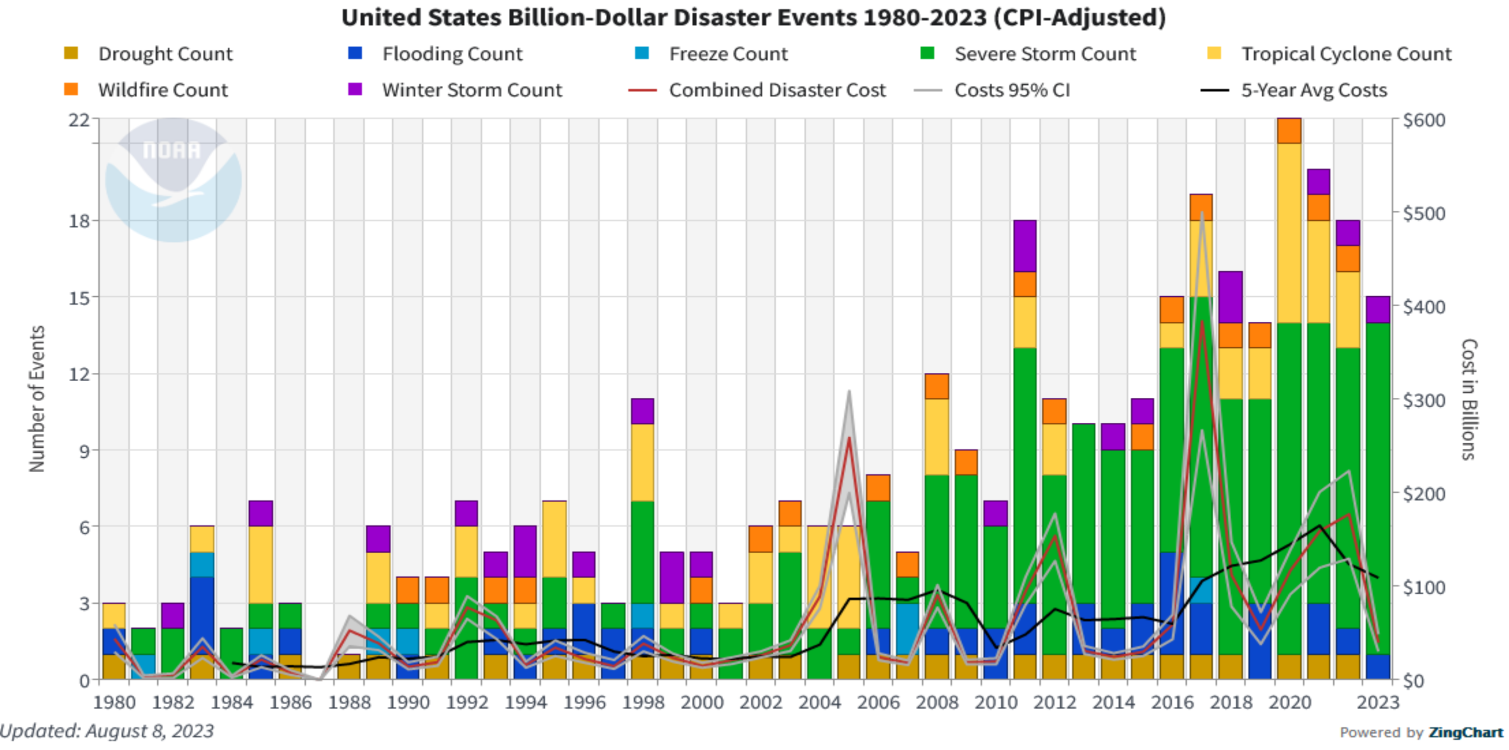


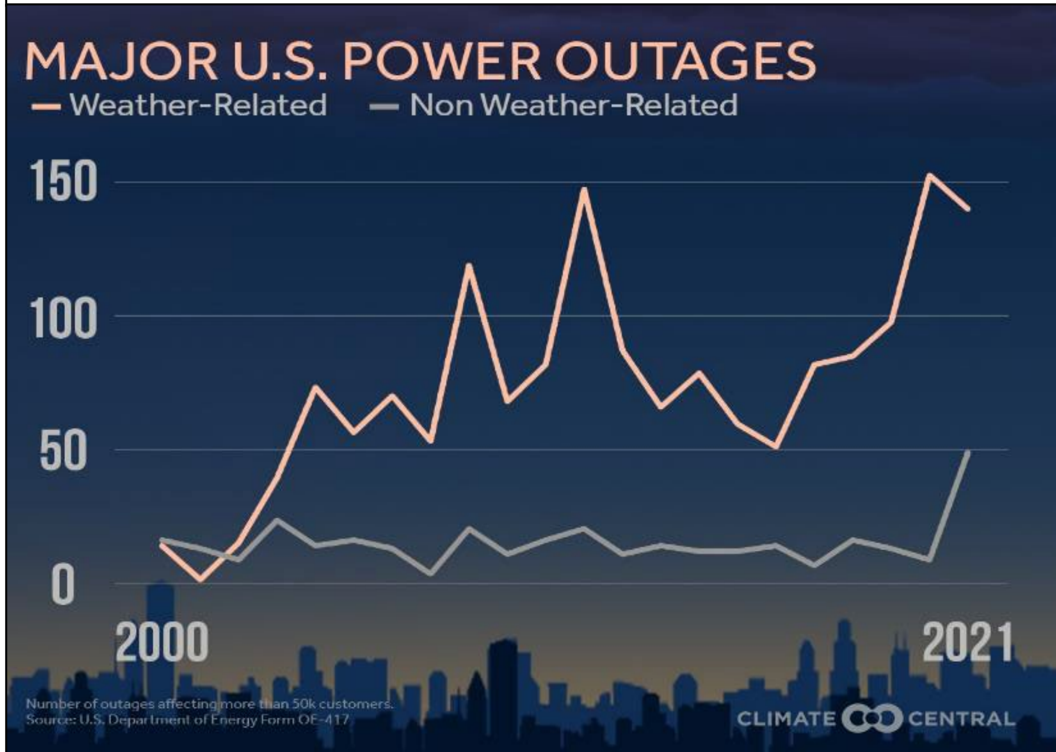
Energy Sector Loss - Weather

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.
- 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.







Drone Use in Extreme Weather Response

In 2021, NOAA began using UAV for damage survey's in hard-to-reach locations post-storm for events like tornadoes in Mississippi and Alabama. Drones are now a critical part of emergency response efforts in many areas for wind and flood damage as well as for hotspot deployment to improve telecommunications in disasters.

- The New York City Police Department is testing new drones that are designed to transmit audio messages to the public, such as announcements warning of dangerous weather or nearby emergencies.
- Drones equipped with speakers in Shanghai, China, and Madrid, Spain, were deployed during the covid-19 pandemic, playing messages about lockdown restrictions.
  - Shanghai also deployed its own robo-dog to bark health announcements as it patrolled around the neighborhoods.

Drones have also entered the market in search and rescue communities to identify tornado tracks and debris fields to improve areas for resource deployment. Drones are now in use for some wildfire response activities.

- DJI, the Chinese drone giant that controls 80% of the drone market in the United States, makes high-end drones like the industrial-grade Matrice, which has thermal capabilities that can be deployed to scan for live victims in a climate disaster.
  - DJI and other firms also make some models with "lidar," a laser tech that can be used to see 3-D images of a disaster site.
- Draganfly, a Saskatchewan-based company, specializes in emergencies and has spent years developing drones and software specifically to help first responders and is testing medical supply delivery methods in Texas.
  - Using drones to survey damage can result in more efficient use of helicopters and rescue staff.
- Drones can also be used for improved mapping of various topographical features, vegetation health, soil composition, subsidence, and elevations to improve flood zones mapping.

As uneven heating of the atmosphere continues, severe storm outbreaks and persisting gradient winds will reduce capability of critical drone deployments given the current constraints of the equipment for winds and rain.

- Most drones can not fly in winds of 48 mph or greater, which are typical with severe storms and tropical cyclones, and could end up contributing to the debris if winds or rain severely impact operations.
  - As a general rule, drones can manage to fly in winds *up to* two-thirds of their maximum speed.

Drones can be used by adversaries to map areas with power outages or damaged security equipment.

Drones cannot operate in extreme heat conditions, deep freezes, rainfall, snow, or high winds. Latest models can operate briefly in temperatures ranging negative 4 degrees ***up to*** *120 degrees.*

Drones which break mid-storm may fall without mitigation to landing impact and can contribute to storm damage for buildings/cars.

Overlooked Cascading Threats

Given the recent shifts in weather events across the nation and the expected amplified effects from the prolonged warming occurring, there are numerous connections to first responders who must continue to operate regardless of the worsening conditions.

First responders moving within amplified heat events face risks of heat exhaustion, heat stroke, increased fatigue, depression, and greater exposure to natural threats. Following the heavier rainfall fueled flooding events there are increased risks of contaminated water from algal or even the ‘brain eating ameba’, infection from injuries sustained during operations, infectious disease exposure, more aggressive wildlife, increased tree fall threats, and exhaustion/burn out from the increased rate of workload regardless of seasons causing threats to retention of expertise and staffing shortages.

Secondary issues often overlooked: many newer phones will not operate in extreme temperatures or charge causing the potential inability to contact emergency services during a heat crisis, those on antidepressants or certain medications are at heightened susceptibility to heat, increased asthma and migraine effects from the weather, shifts in suicidal tendencies, longer delays in transportation to/from work or abroad, and even heightened aggression from the general public and to/from intimate partners.

- A recent study found that a 1-degree Celsius increase in annual mean temperature was associated with a 4.5% increase in intimate partner violence. Other studies noted the increase in sexual violence against women and heightened workplace violence during heat events.
    - Although the study showed a heat-related increase in violence across all income groups, the largest increases were among lower-income and rural households
- Many citizens are ill-prepared for evacuation or sheltering in place, especially those residents having recently relocated to the region from a previous weather-related disaster, resulting in greater needs for assistance and stretching emergency response personnel and supplies further.
- Those who were symptomatic during covid face risks of long-term effects which may make them susceptible to greater risks from other respiratory illness like the flu, colds, pneumonia, and can worsen the symptoms of other medical issues like heart disease.
- Helicopters and single-engine aircraft have functionality issues in extreme heat, resulting in reduced capability for search and rescue teams to operate.
- Wildfire smoke exposure has been linked to long-term memory loss and increased rates of mercury/arsenic in untested well water can cause illness in rural communities.

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

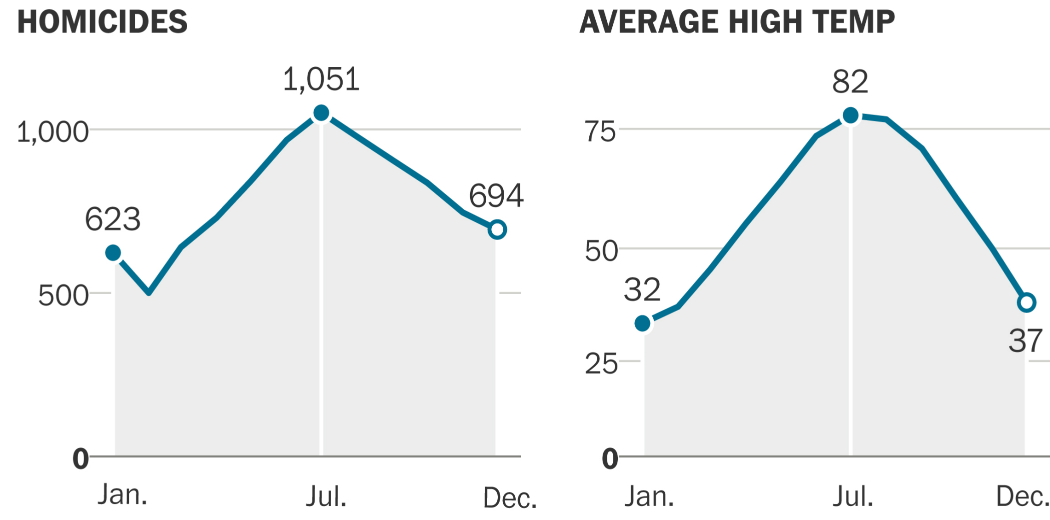
A 2019 study on terrorist attacks found that not only were terrorist attacks more common on hotter days, but also that the number of fatalities per attack were higher. (Studies in Conflict & Terrorism)

- Paris accord where the world’s countries agreed to keep “global temperature rise this century well below 2 degrees Celsius above preindustrial levels,” global terrorist attacks would increase by 14% solely as a result of hotter days, according to the study. Total terrorism fatalities would rise by 24%.

On average, overall crime increases by 2.2% and violent crime by 5.7% on days with maximum daily temperatures above 85 degrees Fahrenheit (29.4° C) compared to days below that threshold

Temperature and violence

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



https://www.washingtonpost.com/business/2019/07/16/two-new-studies-warn-that-hotter-world-will-be-more-violent-one/

Sources: City of Chicago, NOAA

The Washington Post

Emergency Managers and Planning Staff

How to plan for these changes:

Exercise no-power events with non-typical critical infrastructure like chemical sites and others, test the potential for rotations of shorter work shifts, engage communities on prolonged response times and methods of safeguarding while in wait, identify resilience hubs within communities, create a check-in for the well-being of staff during rapid succession events, establish greater distance compacts with other regions, heat map your city for areas needing immediate resilience measures.

Gear changes possible:

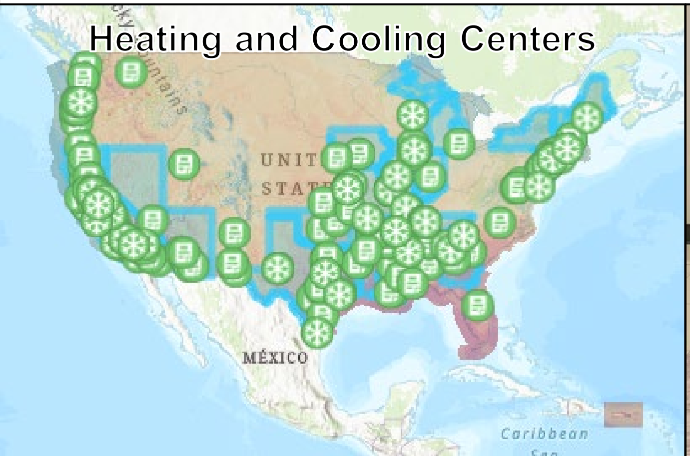
Cooling vests, mosquito netting for deployable sites, insect repellent clothing, reflective vehicles and uniforms, improved n95 and respirators to reduce exposure to fungus/smoke/airborne viruses, ensure working AC in all first responder vehicles, solar charging mats for the tops of emergency vehicles can charge batteries able to be rapidly distributed, kinetic powered backup items like flashlights, portable shades, UV protective garments and lotions, topography maps for flood event resource planning.

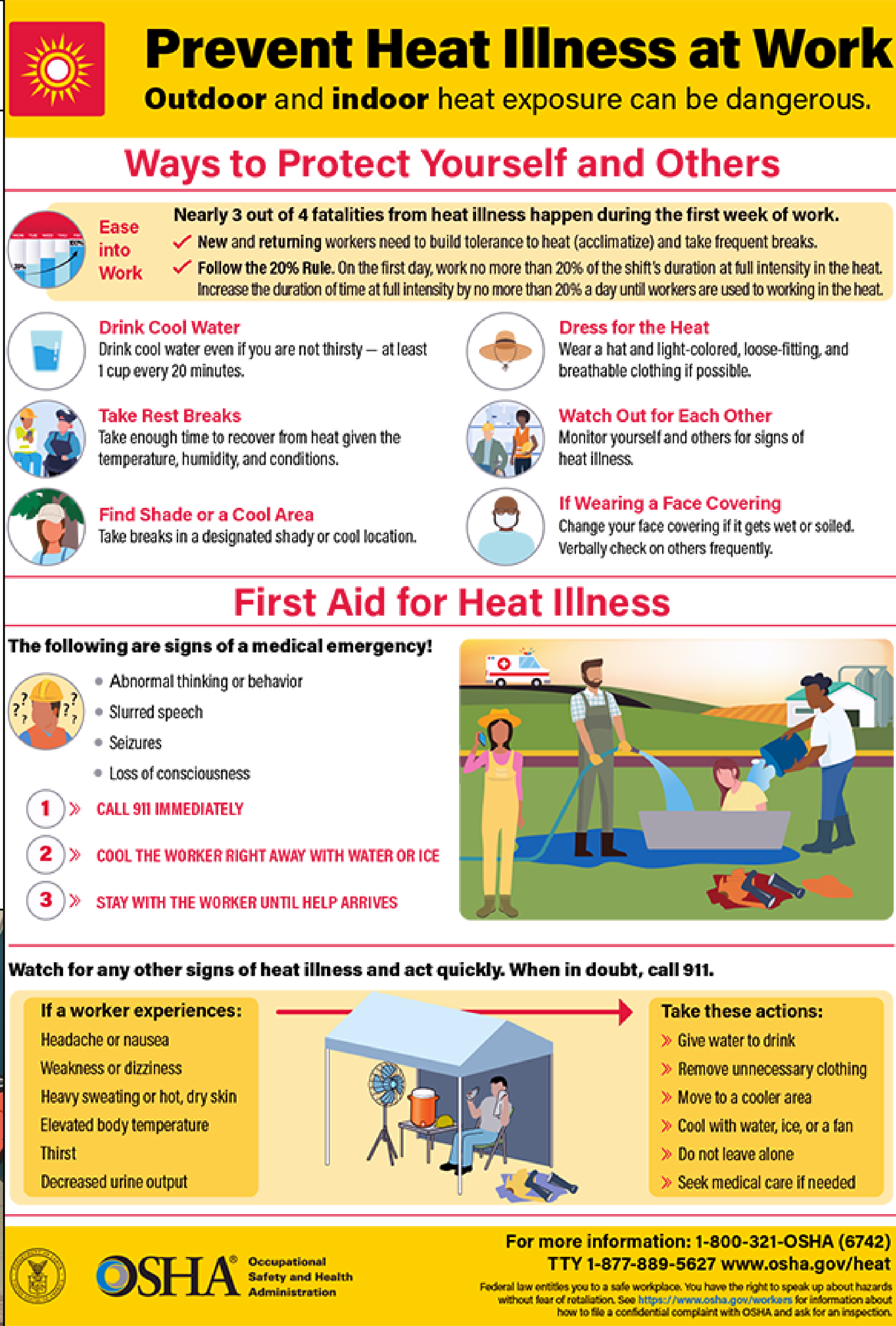
Exposure remedies:

Adjustments in gear, mapping all cooling facilities with backup generators, portable blackwater systems/de-salination kits, and dried foods storage packs for operators.

Plan for potential setbacks from resiliency:

Cooling vests weigh more than no cooling vest, the areas outside of the cooling vest will still heat, mobility may decrease due to the frozen packs, condensation from the vests may cause clothing to become wet or drips, causing an additional hazard set. Battery powered air cooling jackets with fans mainly cool the back.





Physical Security, Site, and Staff Impacts

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

- Power outages can lead to badging and verification delays, record storing lapse, or loss of site access
- Extreme heat can reduce the physical efficiency and mental capability of security staff (lethargy)
- Severe weather can halt drone monitoring operations and obscure video monitoring
- Flooding can result in sensor delays or destruction
- Evacuations being televised may result in exploitation of decreased security presence
- Damages to physical barriers like fences and gated vehicle entry points

- Extreme heat and frequent staff rotations may cause gaps in external physical security
- Increased rates of depression during low pressures and aggression during heat waves may lead to workplace violence events
- High heat periods may cause loss of sleep further reducing the capabilities of staff
- Extreme heat may cause burns or melt certain materials or cause foundations to crack/dimple
- Supply chain or resource hub damages from heat or storms may cause replacement part delays and heightened demand

- Hail can damage or destroy backup generators
- Resource restrictions may result in targeted violence or theft of site resources (e.g. water)
- Theft of backup generators during recovery from storms
- Extreme heat can impede helicopter operations
- Amplified events may reduce emergency response availability (e.g. fire/EMS)
- Battery backups for security systems and control panels may deplete during prolonged outages

Cyber Security Impacts – Power Outages + Patches, Going Green Risks, and Datacenters

Data center impact: generate large amounts of heat, making cooling systems critical. The data center industry is responsible for 1% of the global electricity consumption. On average, a data center uses 1.8 L of freshwater per kWh of IT power consumed. (57 L of water produces 1 kWh of electricity).

- During cooler months, outside air is directly supplied to the data center without using any water also known as adiabatic cooling. During warmer months, the warm air is drawn through water-moistened pads and as the water in the pads evaporates, the air is chilled and pushed into the server halls. In hotter climates, cooling towers and chillers use more water. There are three main types of cooling towers, defined by how water or air pass through them: crossflow, counterflow, and hyperbolic.
- Longer heatwaves cause energy infrastructure to degrade in efficiency and risk of component damages or sparking nearby brush resulting in more load shedding events or rolling blackouts. Datacenters will see critical surface waters needed for cooling may heat too much for use

Extended power loss at a site may result in missed patches and updates causing heightened risk when resuming operations from 'cold'.

- Sites with mis-, dis-, mal information regarding extreme weather events may advertise false resources or information increasing cyber security risks.
- Scams regarding fake restoration crews have been reported immediately following recent storms during power outages, preventing verification.

80% of organizations surveyed across critical infrastructure in the US say that environmental challenges are hindering their efforts to safeguard critical systems and data (Bridewell).

- 91% of security leaders surveyed agree that newly implemented sustainable technologies and tools will become a major new pathway for cyber-attacks within critical infrastructure in the next five years, raising concerns about a fresh wave of attacks impacting daily life and the economy.
- For 47% of critical infrastructure operators, the challenges of managing and protecting rapidly deployed 'green' technologies are compromising their organization's cybersecurity, while 43% lack the skilled resource to safely integrate these tools into their existing systems.
- Almost half (49%) of organizations surveyed also lack C-suite understanding of the cyber threats emerging from sustainable technologies, revealing significant blind spots at the highest levels of national security decision-making.
    - A quarter (25%) of organizations are already seeing climate events damaging their critical infrastructure and compromising critical networks, while 22% report that economic stress caused by climate change is causing an increase in cybercrime.
    - Following a recent surge in ideologically motivated cyber-attacks against the financial services industry, almost a third (28%) of finance **organizations have seen a rise in 'hacktivism' due to climate change**, creating further opportunities for critical systems to be targeted.

Transportation Impacts

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

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

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

- Warped railways under direct heating may increase derailments.

Torrential flooding has increased damages to bridge supports causing closures of key bridges requiring repairs post-storm, washed away key roadways on steep elevations, moved debris onto the road, and can cause lengthy delays if drainage is slow in low-lying areas with standing water.

- Increases in short notice flooding events can cause delays for trucking but can also wash away semi-trucks with enough rainfall.

Severe weather events increasing instances of tornadic activity and large hail will cause delays on the tracks resulting in exposed railcar segments.

- Sites will face damages as will their supply chain as events expand in active months and move into ‘new’ regions, straining response abilities.

These events are occurring globally, resulting in loss of supply for key materials, minerals, metals, etc. and increased demand, rising cost.



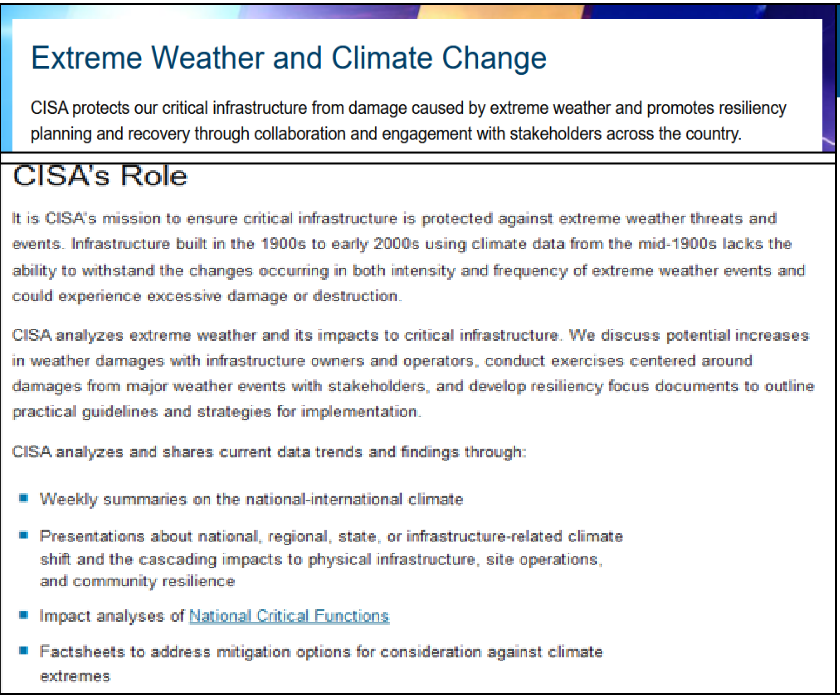




Extreme Weather and Best Practices

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

- The **new** Implications of Extreme Weather AEP Climate Hub**:** https://experience.arcgis.com/experience/a1ec0d1276064ae387c863f2a14b11e1/
- Prioritize and plan – take action: Esri's GIS for Climate Resilience collection.
- CISA Extreme Weather and Climate Change Site: https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/extreme-weather-and-climate-change
- Resilient Power Best Practices Guide: https://www.cisa.gov/resources-tools/resources/resilient-power-best-practices-critical-facilities-and-sites
- CISA Drought and Infrastructure: A Planning Guide: https://www.cisa.gov/sites/default/files/publications/Drought_and_Infrastructure_A_Planning_Guide_508c.pdf
- Infrastructure Resilience Planning Framework: https://www.cisa.gov/sites/default/files/publications/Infrastructure-Resilience%20Planning-Framework-%28IRPF%29%29.pdf
- RAND National Critical Functions Climate Impacts Report: https://www.rand.org/pubs/research_reports/RRA1645-7.html


Extreme Weather and Climate Change

CISA protects our critical infrastructure from damage caused by extreme weather and promotes resiliency planning and recovery through collaboration and engagement with stakeholders across the country.

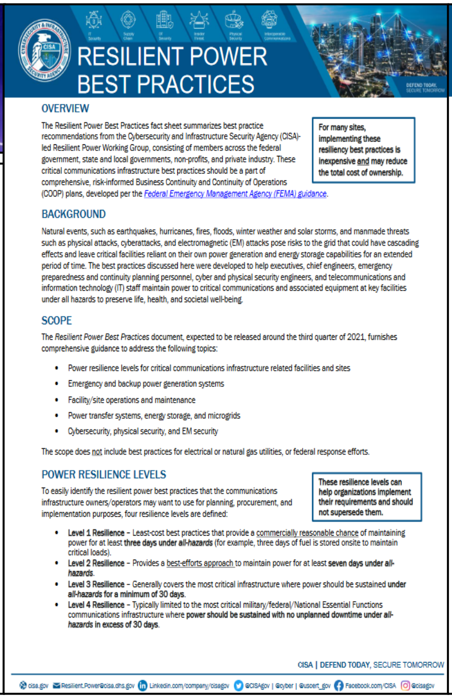
CISA's Role

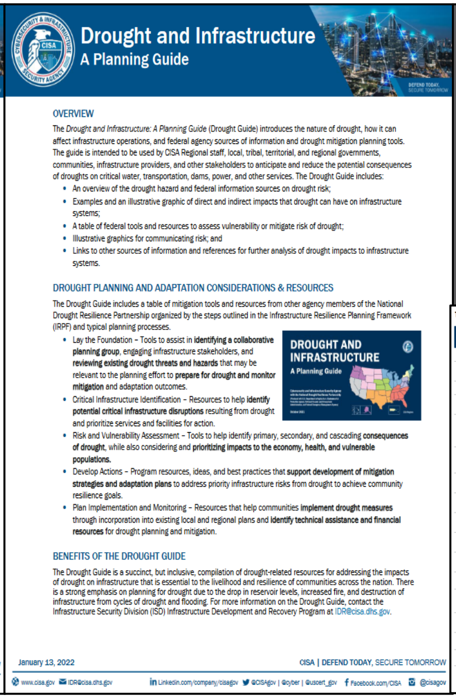
It is CISA's mission to ensure critical infrastructure is protected against extreme weather threats and events. Infrastructure built in the 1900s to early 2000s using climate data from the mid-1900s lacks the ability to withstand the changes occurring in both intensity and frequency of extreme weather events and could experience excessive damage or destruction.

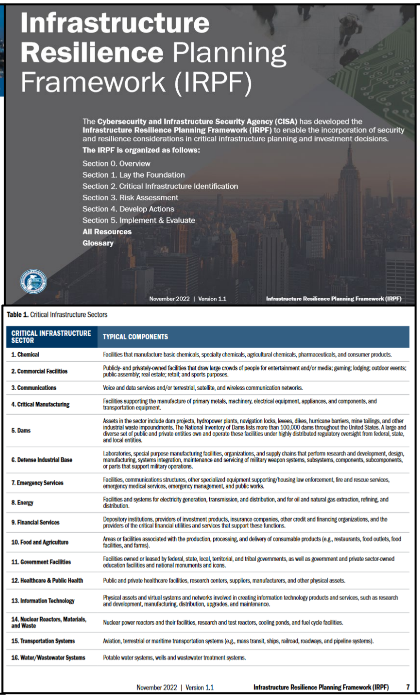
CISA analyzes extreme weather and its impacts to critical infrastructure. We discuss potential increases in weather damages with infrastructure owners and operators, conduct exercises centered around damages from major weather events with stakeholders, and develop resiliency focus documents to outline practical guidelines and strategies for implementation.

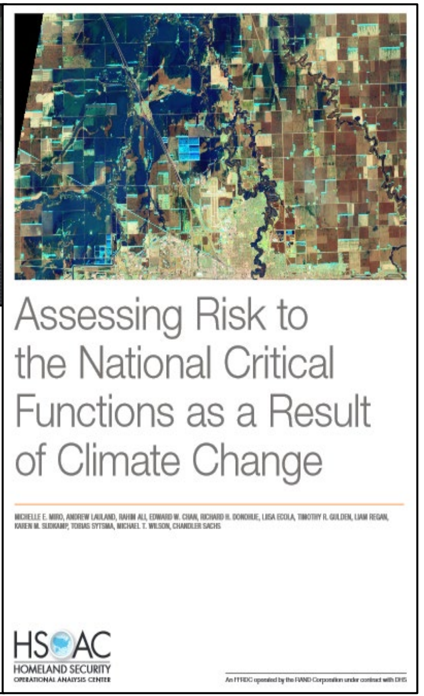
CISA analyzes and shares current data trends and findings through:

- Weekly summaries on the national-international climate
- Presentations about national, regional, state, or infrastructure-related climate shift and the cascading impacts to physical infrastructure, site operations, and community resilience
- Impact analyses of National Critical Functions
- Factsheets to address mitigation options for consideration against climate extremes









Federal Climate Plans, Resource Sites, Funding

Atlas of Disaster: https://rebuildbydesign.org/wp-content/uploads/2022/12/ATLAS-OF-DISASTER.pdf

EPA Federal Funding and Technical Assistance for Climate Adaptation: https://www.epa.gov/arc-x/federal-funding-and-technical-assistance-climate-adaptation

EPA Climate resilience and evaluation tool: https://www.epa.gov/crwu/climate-resilience-evaluation-and-awareness-tool-creat-risk-assessment-application-water

EPA Investing in America Climate Action Funding Resource Guide: https://www.epa.gov/inflation-reduction-act/investing-america-climate-action-funding-resource-guide

DOI Climate Action Plan – Climate Adaptation and Resilience Plan: https://www.doi.gov/ppa/climate

DOE Climate Adaptation and Resilience Plan: https://www.energy.gov/articles/doe-announces-agency-climate-adaptation-and-resilience-plan

DOD – Climate Crisis Action Plan: https://www.defense.gov/Spotlights/Tackling-the-Climate-Crisis/

NOAA Ready to fund green/grey resilience: https://repository.library.noaa.gov/view/noaa/46459

DHS Disasters and Emergencies - Response Tools: https://www.ready.gov/

FEMA IS: Introduction to Retrofitting Flood-Prone Buildings: https://training.fema.gov/is/courseoverview.aspx?code=IS-279.a&lang=en

FEMA Continuity planning: https://www.fema.gov/emergency-managers/national-preparedness/continuity/toolkit

FEMA Hazard resilience/ safe spaces: https://www.fema.gov/emergency-managers/risk-management

FEMA Risk Assessment/THIRA Assessment: https://www.fema.gov/emergency-managers/national-preparedness/goal/risk-capability-assessment

FEMA Building code/ hurricane + flood handbook : https://www.fema.gov/emergency-managers/risk-management/building-science/publications/hurricane-and-flood-mitigation-handbook-public-facilities

FEMA Substantial Damage Estimation Tool: https://www.fema.gov/emergency-managers/risk-management/building-science/substantial-damage-estimator-tool

FEMA Building science resource guide: https://www.fema.gov/emergency-managers/risk-management/building-science/publications

City specific Hubs: https://geohub.lacity.org/

Applied Climate Information System – Climate Data Mapping: https://www.rcc-acis.org/index.html

Federal hub for all heat-related products and response: https://www.heat.gov/

Climate 101 and Mitigation Trainings

University Corporation for Atmospheric Research (UCAR) MetEd – Comet: https://www.meted.ucar.edu/

- The MetEd website provides education and training resources to benefit the operational forecaster community, university atmospheric scientists and students, and anyone interested in learning more about meteorology, weather forecasting, and related geoscience topics.

NOAA Meteorology 101: https://www.weather.gov/education/presentation

- NOAA Severe Weather 101: https://www.nssl.noaa.gov/education/svrwx101/
- NWS Online Weather School: https://www.noaa.gov/jetstream/jetstream
- Additional Weather Education Resources: https://www.weather.gov/learning

FEMA Independent Study (IS): 271.a: Anticipating Hazardous Weather and Community Risk: https://training.fema.gov/is/courseoverview.aspx?code=IS-271.a&lang=en

- IS-66 Preparing the Nation for Space Weather Events, IS 324.a Community Hurricane Preparedness, 320 Wildfire Mitigation Basics for Mitigation Staff, 322 Flood Mitigation Basics for Mitigation Staff, 323 Earthquake Mitigation Basics for Mitigation Staff, 162 Hazard Mitigation Floodplain Management in Disaster Operations.

Weather events and disaster response by ESRI: https://www.esri.com/en-us/disaster-response/overview

Wildfire hubs: https://www.esri.com/en-us/disaster-response/disasters/wildfires and https://gis-fema.hub.arcgis.com/pages/wildfires

DC Flood Maps: https://doee.dc.gov/service/flood-risk-maps

Heat Island Community Actions Database: https://www.epa.gov/heatislands/heat-island-community-actions-database

Snow climatology data toolbox: https://www.purdue.edu/newsroom/releases/2022/Q4/new-online-toolbox-offers-many-ways-to-view-snow-data-in-the-continental-us.html

Hurricane hubs: https://gis-fema.hub.arcgis.com/pages/hurricanes

State Summaries: https://statesatrisk.org/

Using Heat Forecast Tools to Provide Decision Support for Extreme Heat Threats

Lesson

Skill level : 2 - Intermediate
Publish Date: 7/30/2023

Using Satellite Products to Differentiate Extraordinary & Typical Tropical Rainfall Events

Lesson

Skill level : 2 - Intermediate
Publish Date: 6/1/2023

Monitoring for Potential Flash Flood & Debris Flow Threats

Lesson

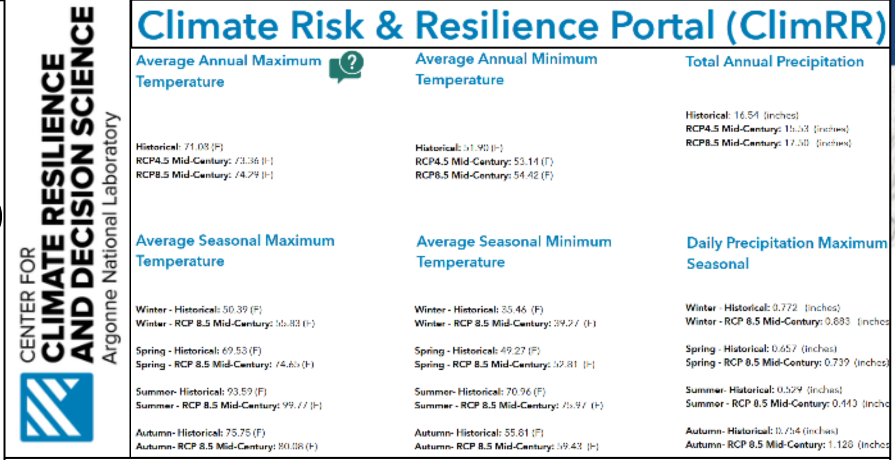
Skill level : 2 - Intermediate
Publish Date: 5/22/2023

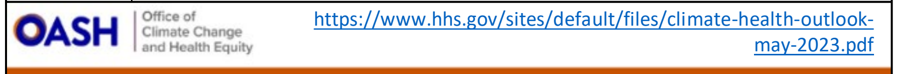
Smoke Forecasting and Communication

Lesson

Skill level : 2 - Intermediate
Publish Date: 2/1/2023

Climate Mapping Hubs and Impacts for Site Planning





https://www.hhs.gov/sites/default/files/climate-health-outlook-may-2023.pdf

Climate and Health Outlook

ISSUED MAY 2023

The Climate and Health Outlook is an effort to inform health professionals and the public on how our health may be affected in the coming months by climate events and to provide resources for proactive action. An associated webpage includes additional resources and information, including more detail on the wildfire and drought outlooks and populations at risk.

Northern Great Plains: Major spring flooding expected for the Milk River in Montana, the Red River of the North in North Dakota and the James and Vermillion rivers in South Dakota. Minor flooding is also possible in parts of Nebraska and Wyoming. Drought is favored to persist in portions of western and eastern Montana, in western North Dakota, in a small portion of northern and much of southern South Dakota, parts of eastern and western Wyoming and most of Nebraska. Below normal wildland fire potential is forecast for portions of northeastern Montana and much of North Dakota.

Northwest: Minor spring flooding potential is expected to be above normal the Upper Snake River Basin in eastern Idaho. Drought is favored to persist in parts of northern Idaho and northeastern Washington and much of Oregon.

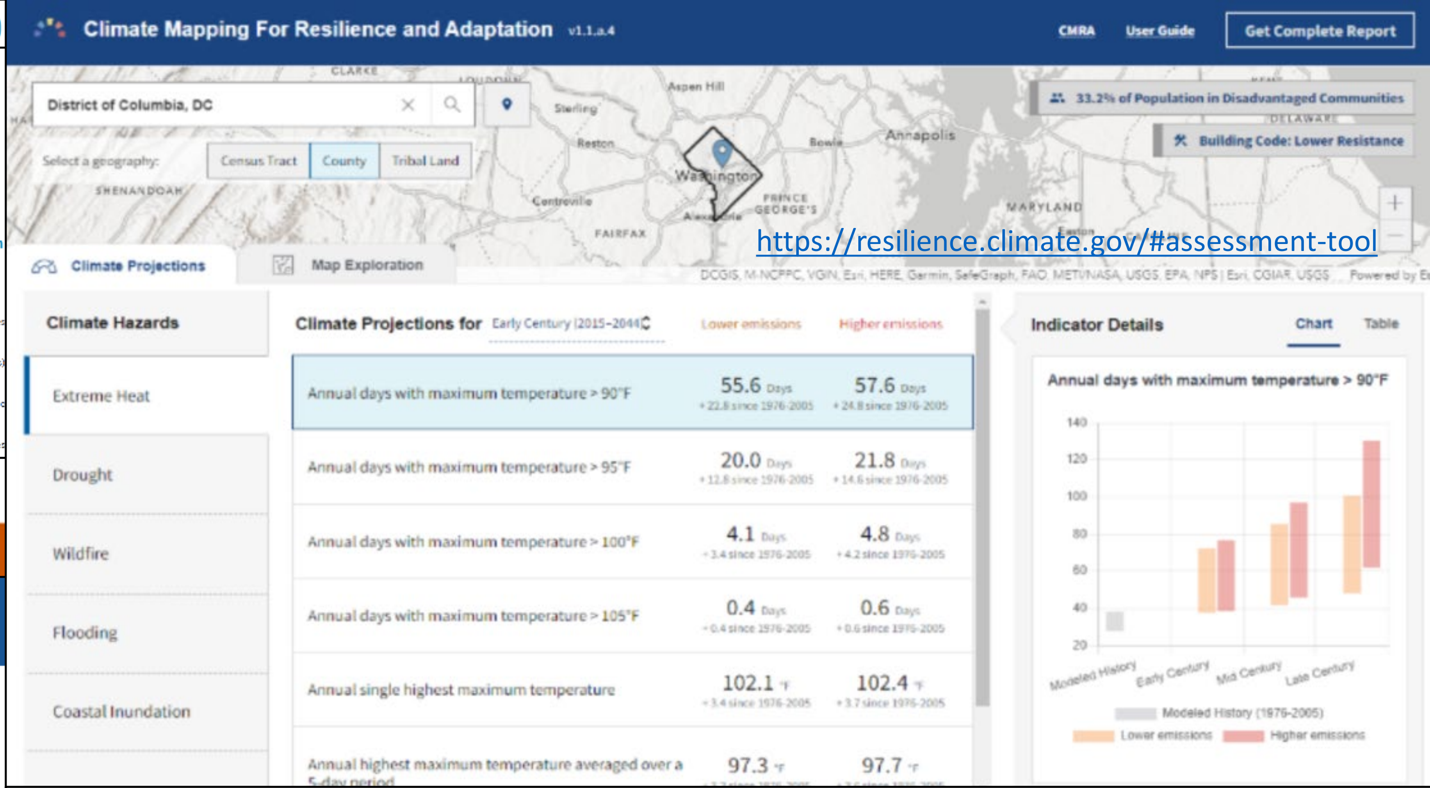
Southwest: Minor to moderate spring flooding potential is expected to be above normal in California across the Sierra Nevada foothills and the upper San Joaquin Valley. Moderate flooding and isolated major flooding is also possible in much of the rest of California and Nevada as well as in northeast Utah and western Colorado. Drought is favored to persist in a small portions of southern California, Nevada, central Utah, northwest Arizona, and much of eastern New Mexico and Colorado. Drought improvement and removal is likely in parts of Colorado and Nevada. Below normal wildland fire potential is forecast for much of western New Mexico and northern Arizona, parts of south Utah and Nevada, and the southern California coast.

Southern Great Plains: Counties in Texas (11) are projected to have more than five heat exceedance days** in May. Minor spring flooding potential is expected to be above normal in parts of eastern Kansas, Oklahoma, and Texas. Drought is favored to persist in much of Texas, Kansas, and parts of western Oklahoma. Drought development is likely in northeastern Kansas. Drought improvement and removal is favored for much of Oklahoma, central and small portions of southeastern Texas, and southwest Kansas. Above normal wildland fire* potential is forecast for portions of western Texas.

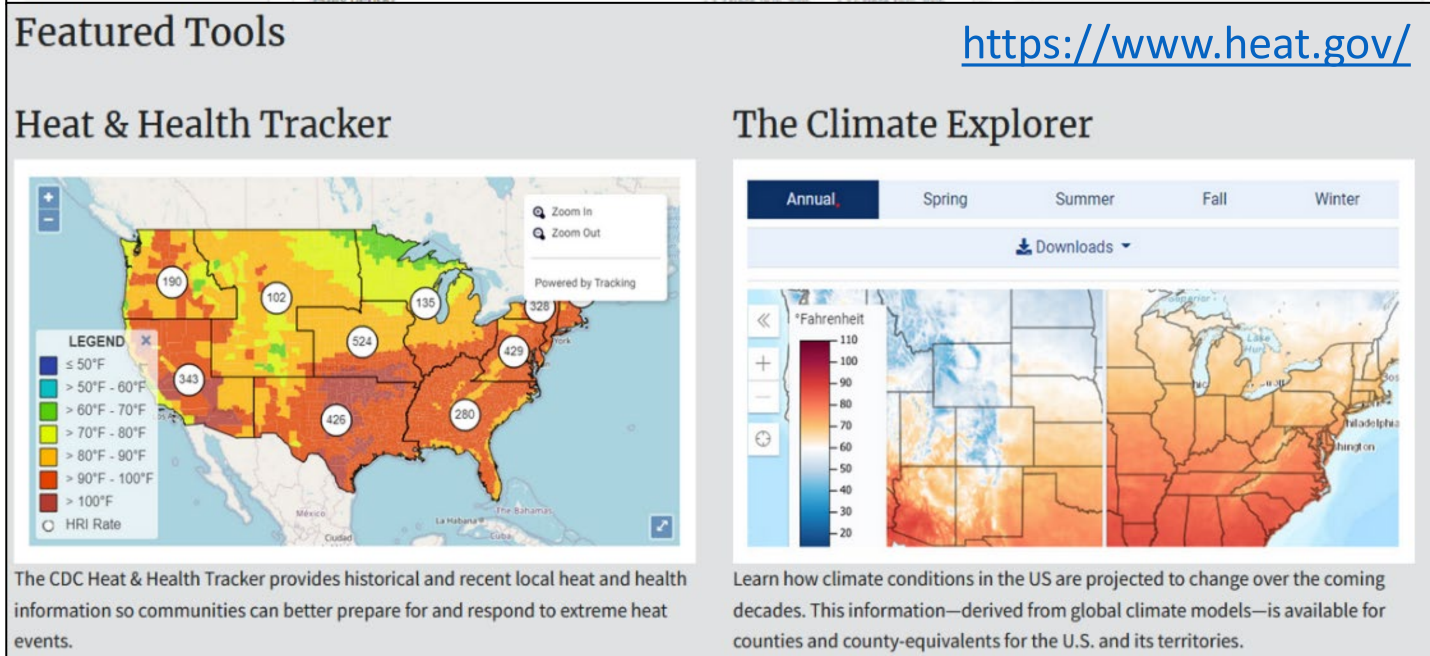
Midwest: Major spring flooding is ongoing along the mainstem of the Mississippi River from the Twin Cities, Minnesota to Keokuk, Iowa. Moderate flooding is also possible along portions of the Mississippi River mainstem from Keokuk, Iowa to St. Louis, Missouri. Minor to moderate flooding is possible across much of the region, including in Iowa, Illinois, Indiana, and Missouri. Drought is favored to persist in parts of central Missouri, western Iowa, and a small portion of southern Minnesota. Drought development is likely in parts of central Iowa, northern Missouri, and western Illinois.

Southeast: Minor spring flooding potential is expected to be above normal in Alabama, Arkansas, Kentucky, Mississippi, Tennessee and most of Georgia and Louisiana. Minor flooding is also possible in Northern Florida and parts of North Carolina, South Carolina, and Virginia. Drought removal and improvement is favored in northern and eastern Virginia, northeast North Carolina, and much of Florida.

Drought Wildfire Flooding Heat



https://resilience.climate.gov/#assessment-tool



https://www.heat.gov/

The CDC Heat & Health Tracker provides historical and recent local heat and health information so communities can better prepare for and respond to extreme heat events.

Learn how climate conditions in the US are projected to change over the coming decades. This information—derived from global climate models—is available for counties and county-equivalents for the U.S. and its territories.

Weekly National-International Climate Summary:

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

Bi-Weekly CISA Extreme Weather Working Group:

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

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