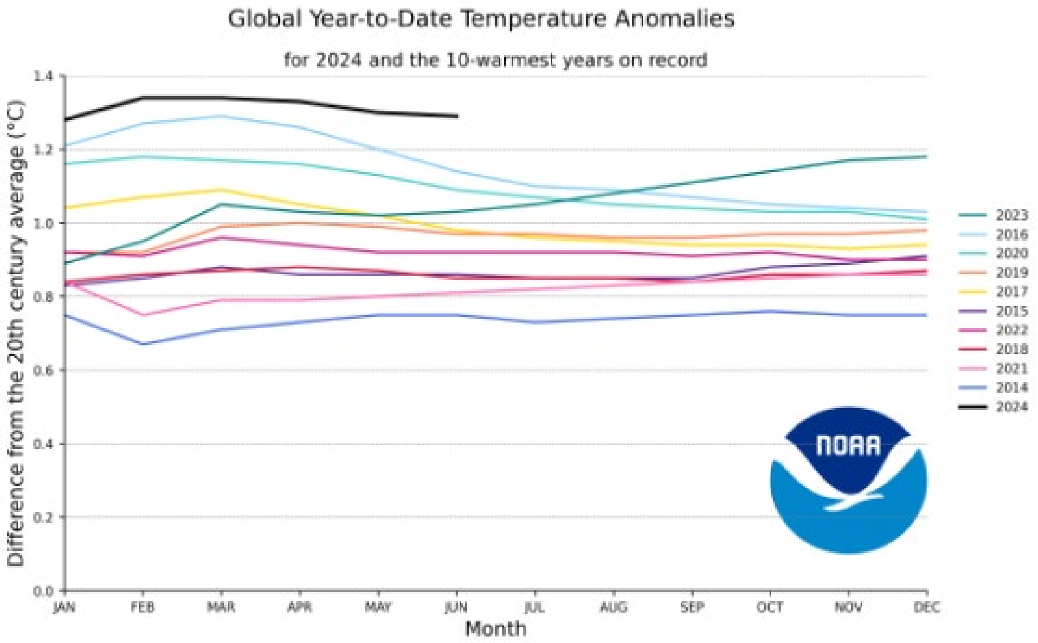
CISA Extreme Weather Outreach

Climate Impacts and Resilience Planning – DMV Area

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

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

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

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

High and Low Pressures: the Carousal of Weather

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

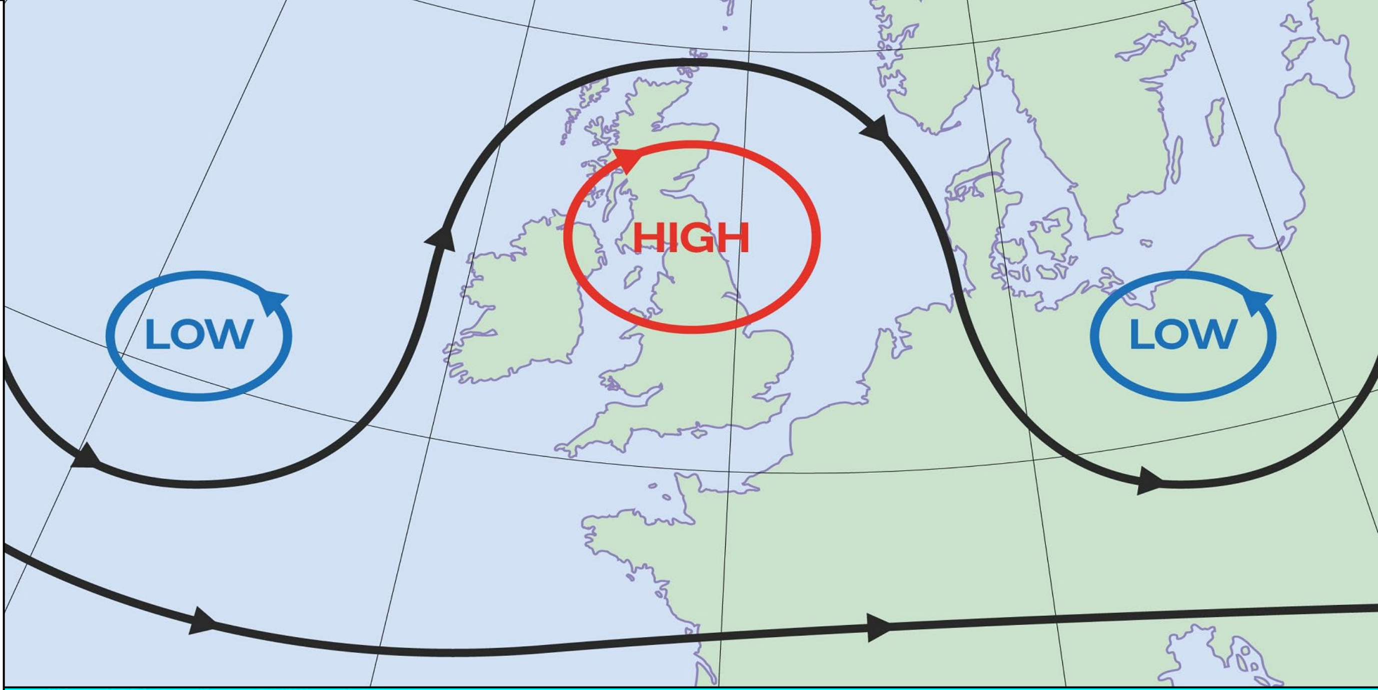
- Because of Earth's spin and the Coriolis effect, winds of a low-pressure system swirl counterclockwise north of the equator.
- As the air rises, the water vapor within it condenses, forming clouds and often precipitation.
- On weather maps, a low-pressure system is labeled with red L.

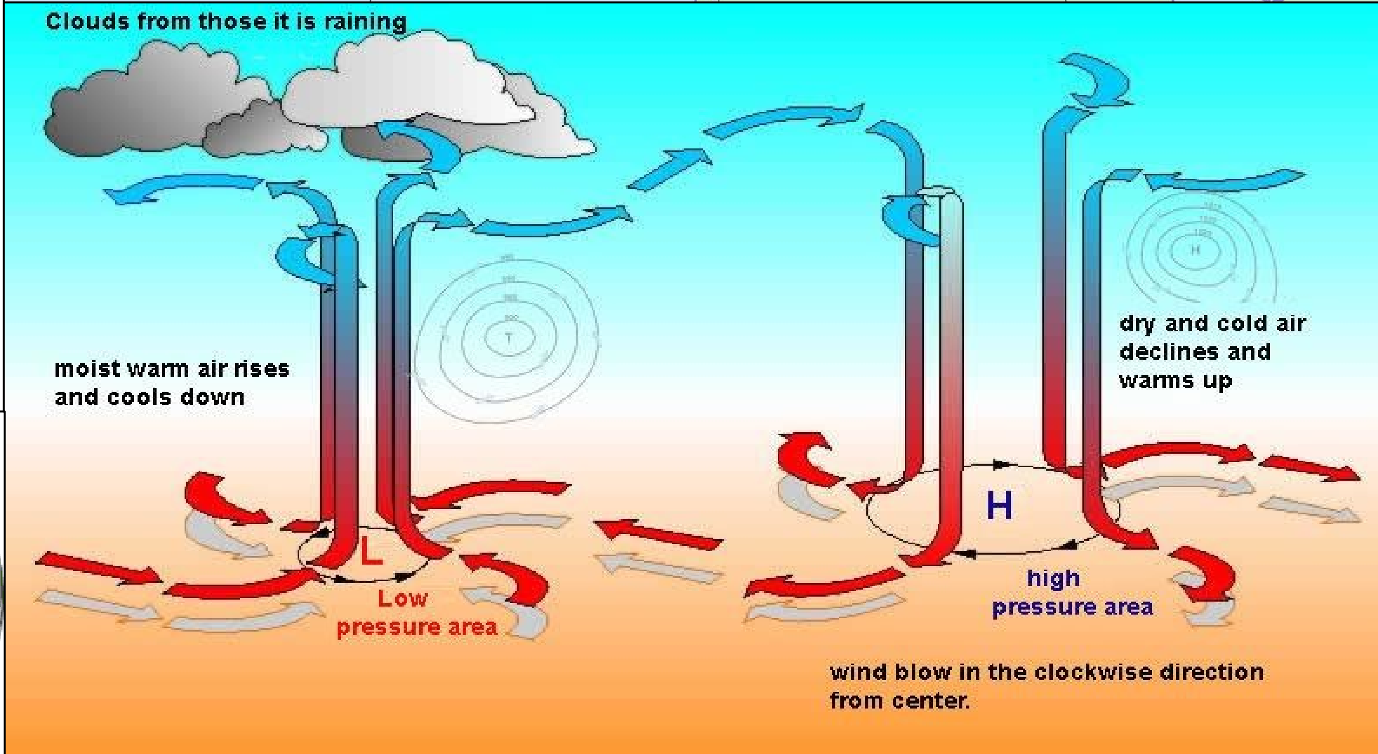
A **high-pressure system** has higher pressure at its center than the areas around it. Winds blow away from high pressure.

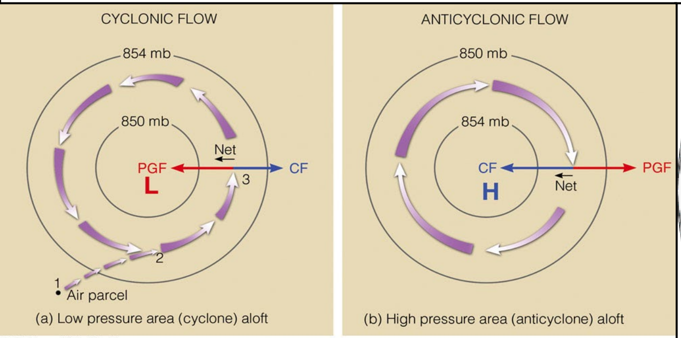
- Swirling in the opposite direction from a low-pressure system, the winds of a high-pressure system rotate clockwise north of the equator (anticyclonic flow).
- Air from higher in the atmosphere sinks down to fill the space left as air is blown outward. On a weather map, you may notice a blue H, denoting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

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

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

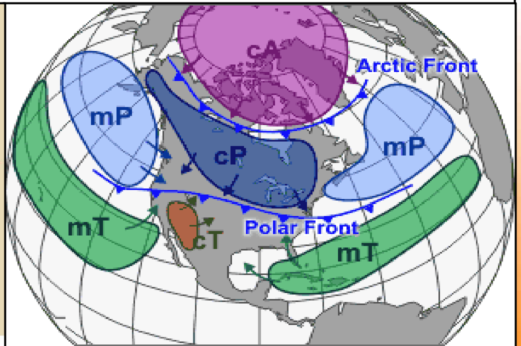






(a) Low pressure area (cyclone) aloft

(b) High pressure area (anticyclone) aloft



National Climate Anomalies – June 2024

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

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

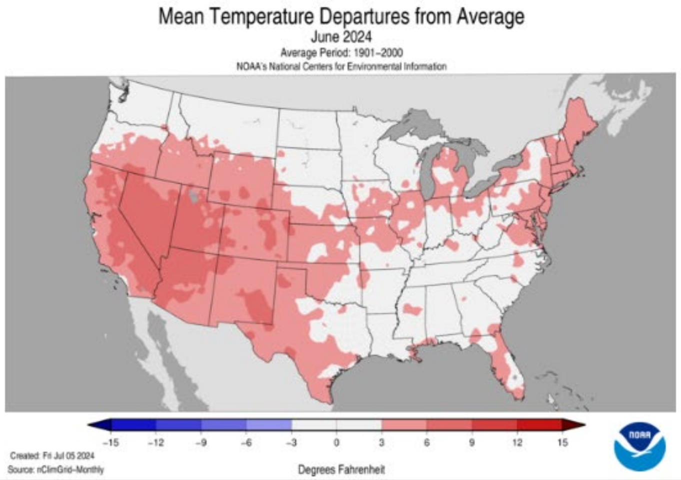
The June precipitation total for the contiguous U.S. was 2.74 inches, 0.18 inch above average, ranking in the driest third of the historical record.

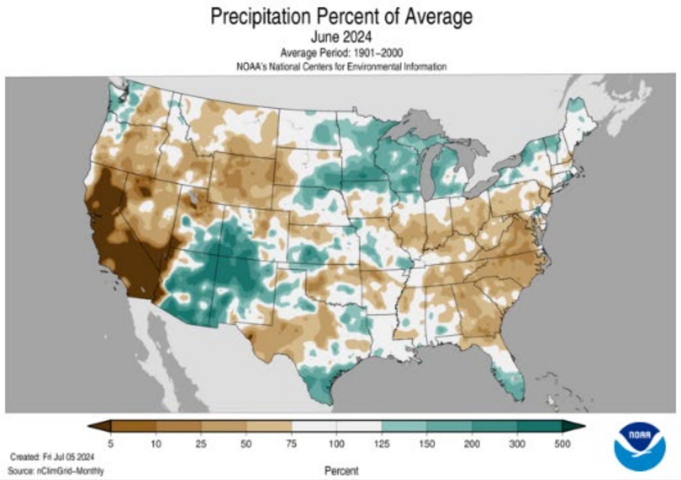
According to the July 2 U.S. Drought Monitor, about 19% of the contiguous U.S. was in drought, up 6% from the end of May.

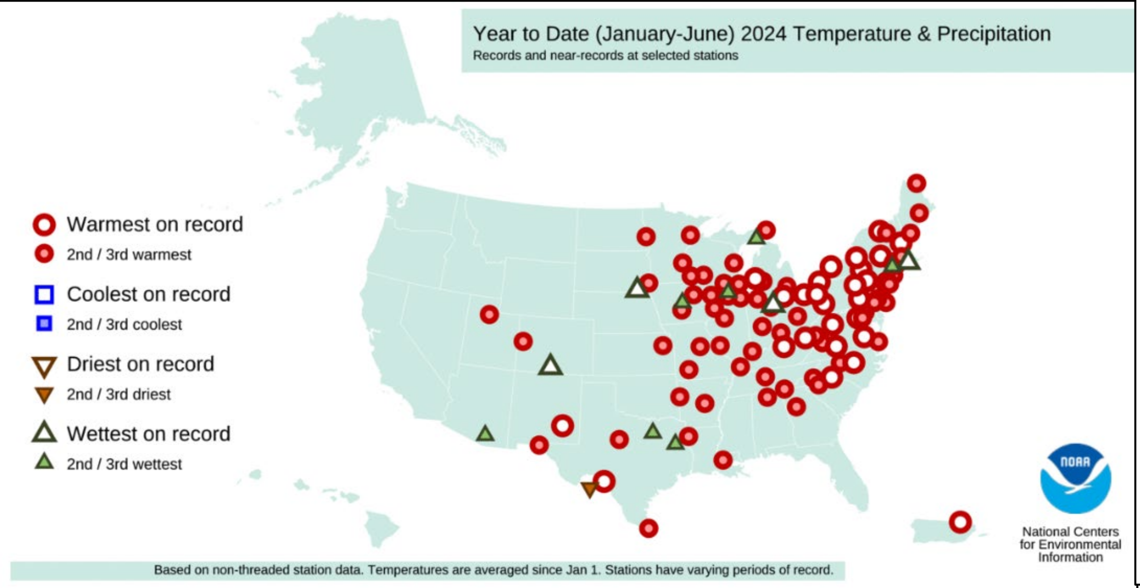
There have been 15 confirmed weather and climate disaster events, each with losses exceeding $1 billion, this year.

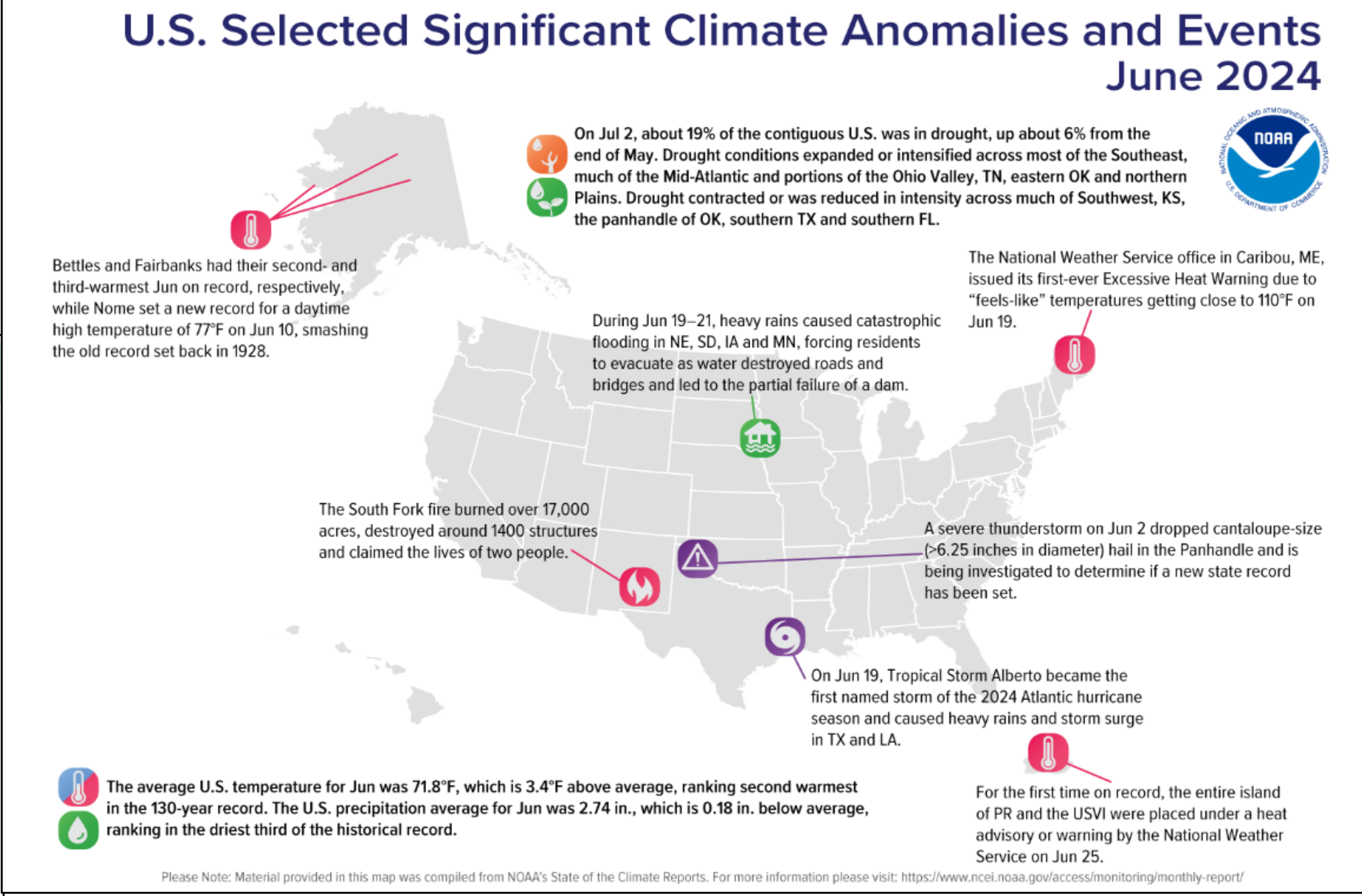
- These disasters consisted of 13 severe storm events and two winter storms.
- The total cost of these events exceeds $37.9 billion, and they have resulted in at least 106 fatalities. There are three pending disasters under review.

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









Global Shifts – June

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

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

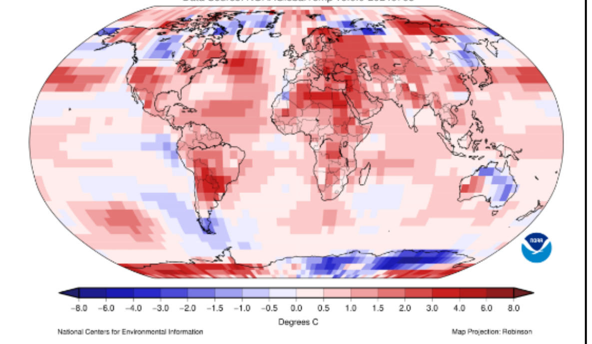
This is 0.15°C (0.27°F) warmer than the previous June record set last year, and the 13th consecutive month of record-high global temperatures.

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

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

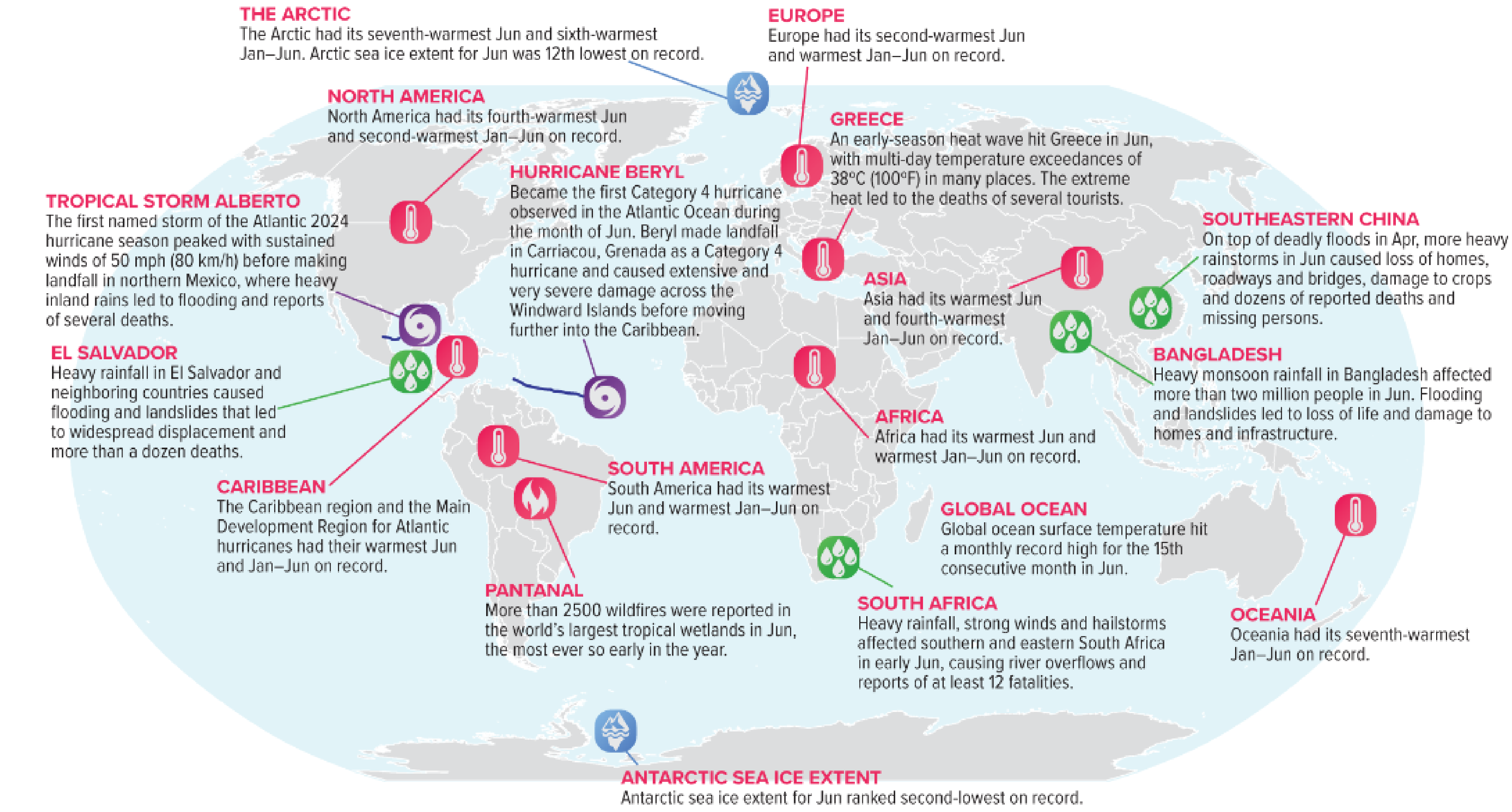
- The record temperatures in large parts of South America contributed to early and expansive drying of the Pantanal, the world's largest tropical wetlands.

Land & Ocean Temperature Departure from Average Jun 2024
(with respect to a 1991-2020 base period)
Data Source: NOAAGlobalTemp v6.0.0-20240708

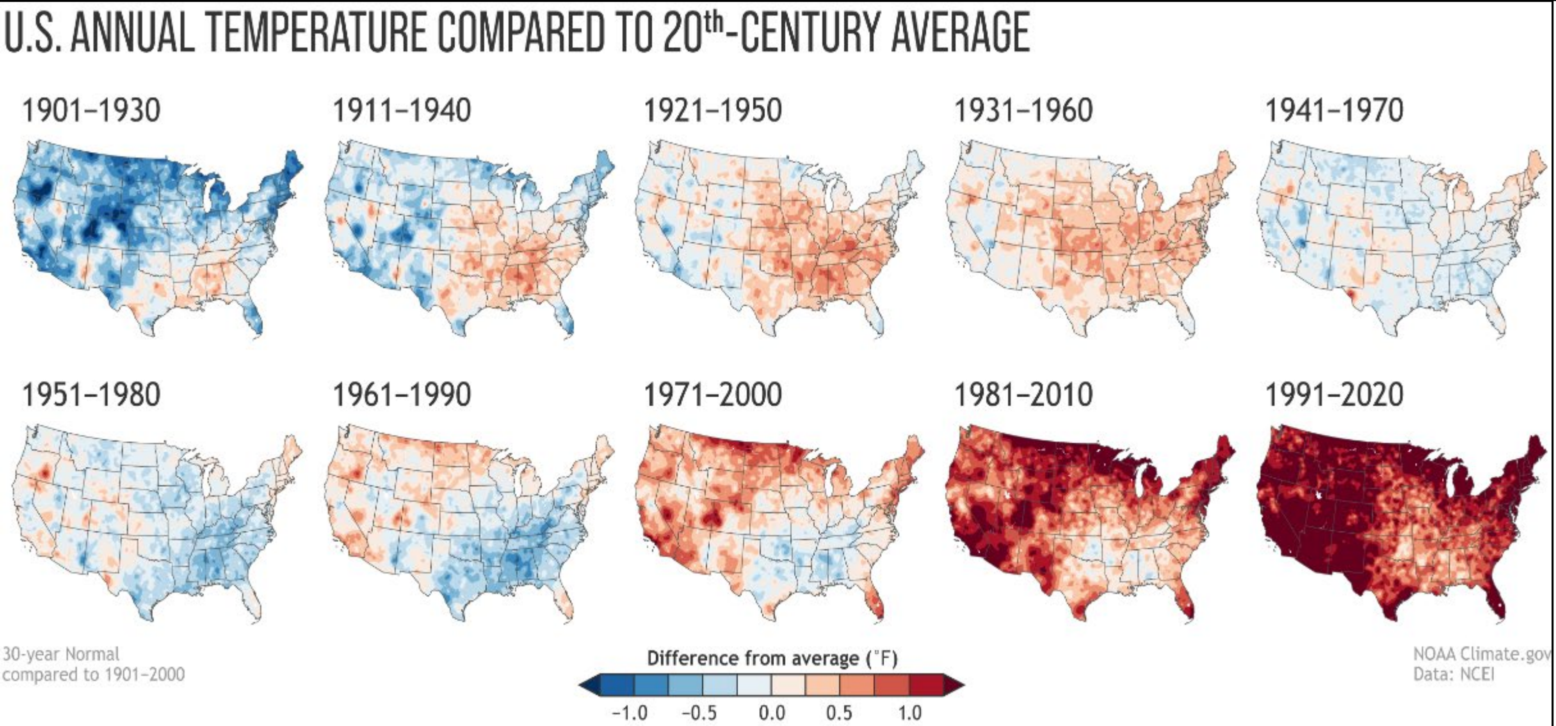


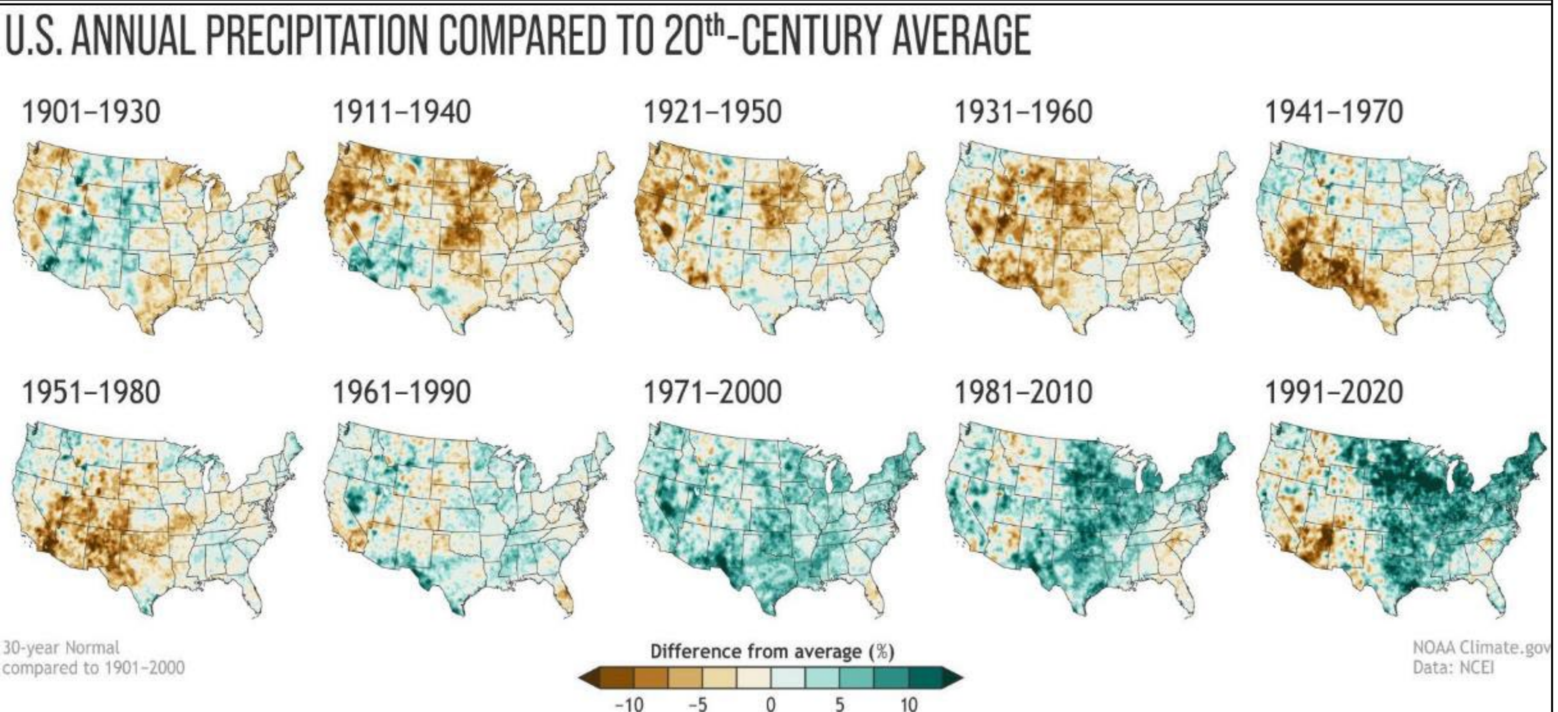
Selected Significant Climate Anomalies and Events: June 2024

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



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





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

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

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

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

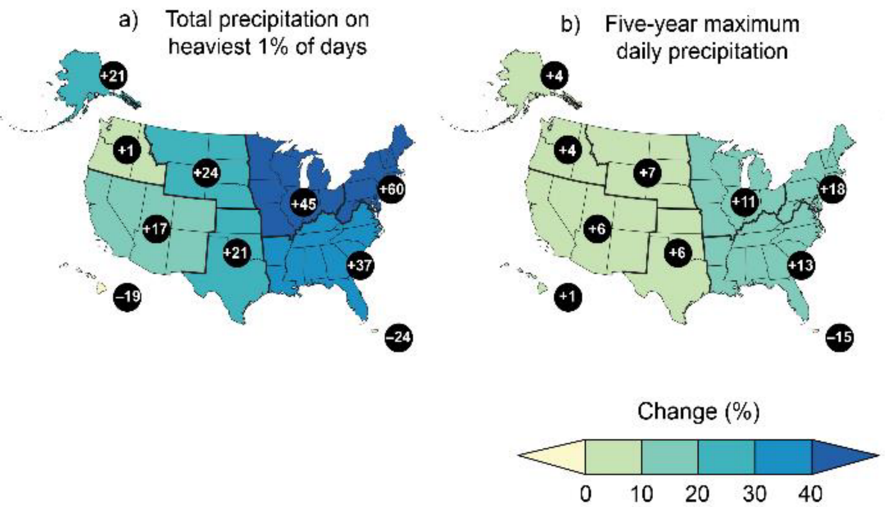
- Extreme heat and humidity are growing more common due to the growing distance between major low-pressure centers crossing the US, allowing for direct sunlight heating the surface and a larger presence of greenhouse gases trapping that heat for prolonged periods.

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

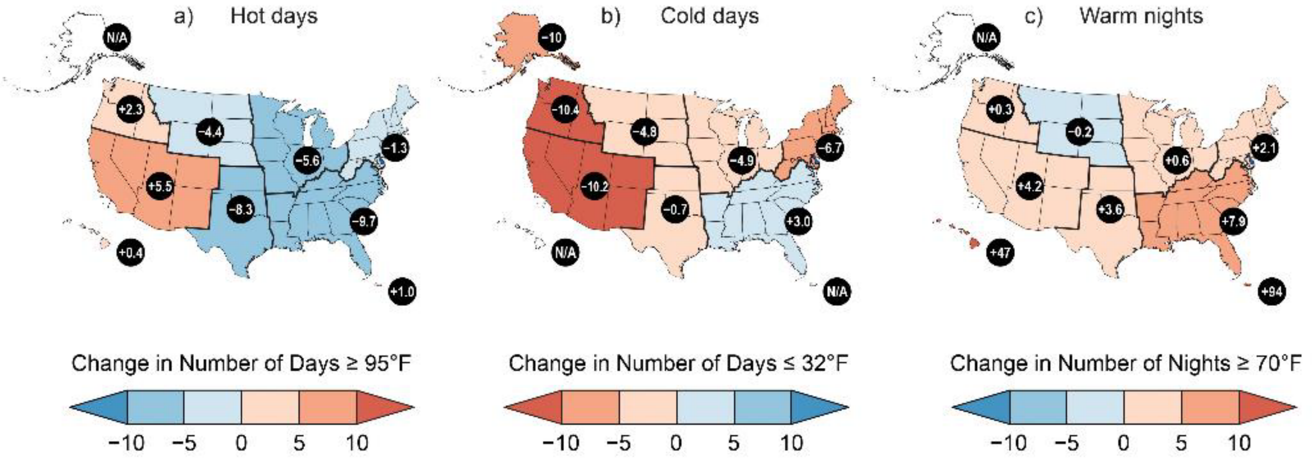
National Changes in Temperature and Precipitation Throughout the Seasons

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

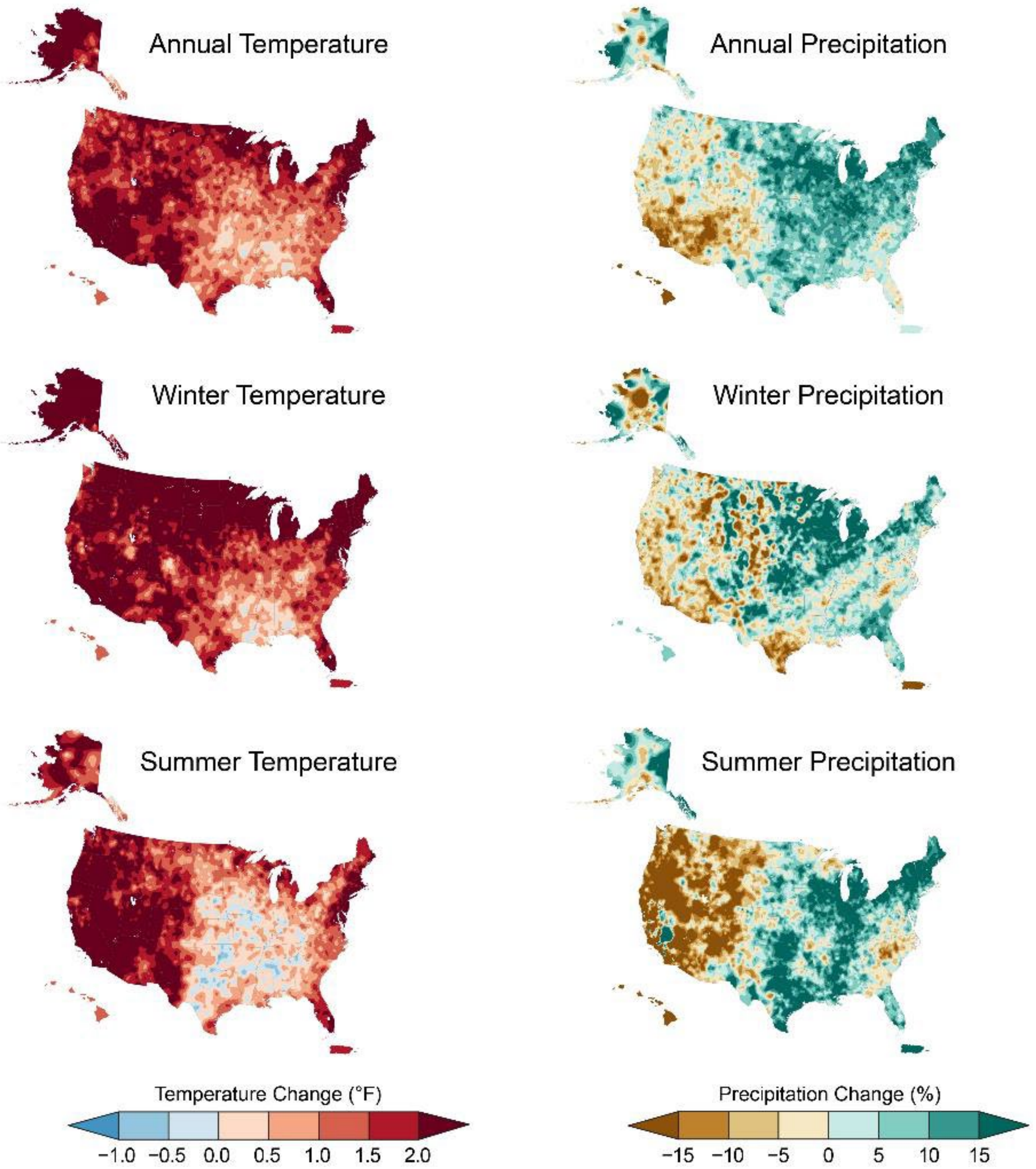
Observed Changes in the Frequency and Severity of Heavy Precipitation Events



Observed Changes in Hot and Cold Extremes



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



Radiative Heat Threats: Cities + Canals

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

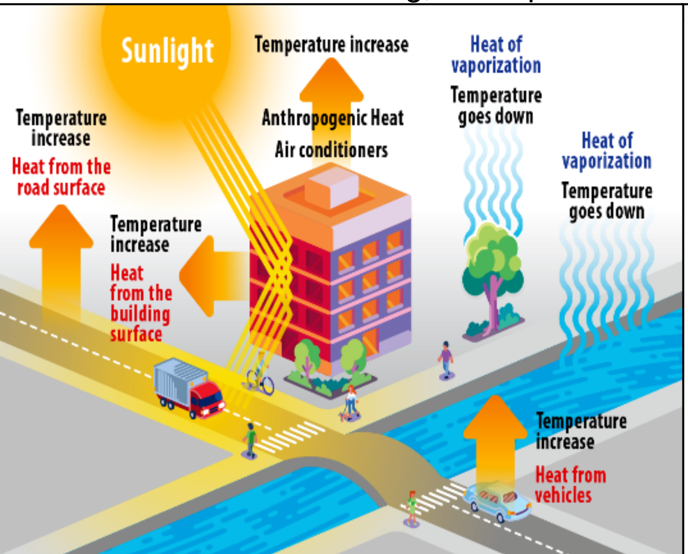
Heat transfer from a body with a high temperature to a body with a lower temperature, when bodies are not in direct physical contact with each other or when they are separated in space, is called heat radiation. Thermal radiation is one of three mechanisms which enables bodies with varying temperatures to exchange energy.

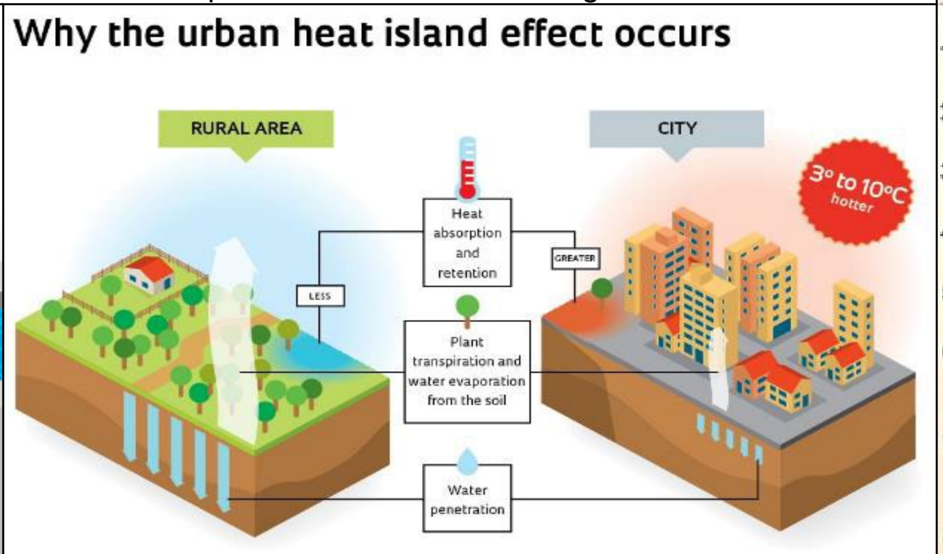
- Sunshine, or solar radiation, is thermal radiation from the extremely hot gasses of the sun, and this radiation heats the earth.
- The entire body acts as an emission source of continuous thermal radiation, and as a continuous receiver of radiation originating even from far-field bodies.
- Concrete is a great material for absorbing and storing heat from the sun, meaning it can warm to higher temperatures then most other materials and releases that heat more slowly as direct heating stops. On a hot summer day, concrete that's in the shade can easily average 70°F, however, concrete that's in direct sunlight can reach 135°F. Builders test this with a device called an infrared thermometer. Due to the higher temperature, these mixtures are at risk of expansion-triggered water incursion.
- Grass rarely exceeds 80°F, wood peaks around 90°F, composite decking about 100°F, but concrete can reach a hotter temperature and hold onto that heat longer.

Heat islands form because of reduced natural landscapes in urban areas and increases in heat-retentive materials. Trees, vegetation, and water bodies tend to cool the air by providing shade, transpiring water from plant leaves, and evaporating surface water, respectively.

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

At the current rate of heating, the expansion buffer will not stop the material from buckling more often.





SURFACE TEMPERATURES

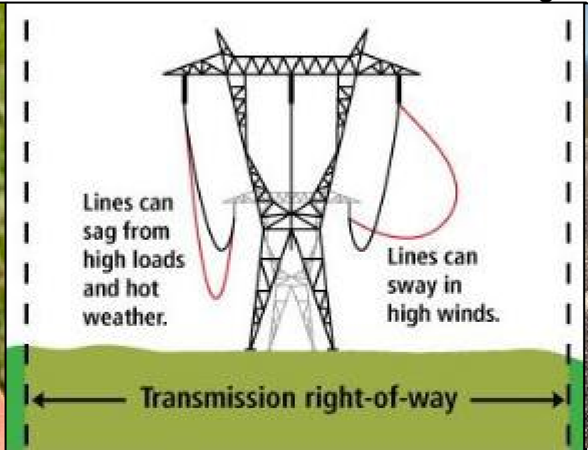
	3/4/22 10:30am	6/21/22 10:30am	6/21/22 3:30pm
AIR TEMPERATURE	52°	84°	104°
1. Concrete (sidewalk)	58°- 61.5°	110°	142°
2. Asphalt (street)	62°- 64°	125°	155°
3. Plants	65°	89°- 91°	105- 115°
4. Turf (grass)	69°- 71°	93.5°	99.5°
5. Bare Dirt	78°	119°	159°
6. Mulch	81°	120°	154°
6a. Soil under mulch	→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

Critical Infrastructure Sectors Risk from Heat

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

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

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



Subsidence Impacts to Infrastructure

The slow sinking of infrastructure, also known in some regions as “settling”, can be triggered by wells overpulling groundwater, unstable soils from extreme heat drying, aquifers overfilling from a storm after condensing during drought, limestone or coal mine degradation, sewer system leaks and subsequent soil compaction, or general gravity over time compressing rock, sand, soil, and groundwater.

As extreme weather continues to intensify, potholes have increased across numerous states as have retaining wall slips as have foundation and sidewalk heaving, impacting vehicles and homes at a greater rate.

- Extreme heat can make some materials more malleable, increasing the frequency of failure and subsequent collapse which can cause sloping issues for homes.

Aquifer over-pumping or heightened us of water systems during heatwaves could cause unexpected sinking and fissures threatening structural integrity.

- Areas may become the new lowest-lying location and become prone to increased rates of runoff flooding despite not historically being in floodplains.

Extreme heat in the cities from subways and sewers can emanate upwards, overheating materials from underneath and warping them.

Subsidence across regions can result in pipeline damages as soil displacement shifts the horizontal and vertical stability of the system.

Extreme Heat and Powerlines

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

- Heatwaves and drying winds between storms can amplify Red Flag conditions resulting in more public safety power shutoffs and subsequently amplified heat risk for city buildings, supporting infrastructure, and result in overwhelmed hospitals as residents seek locations known to maintain cooling facilities.

Transportation Impacts

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

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

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

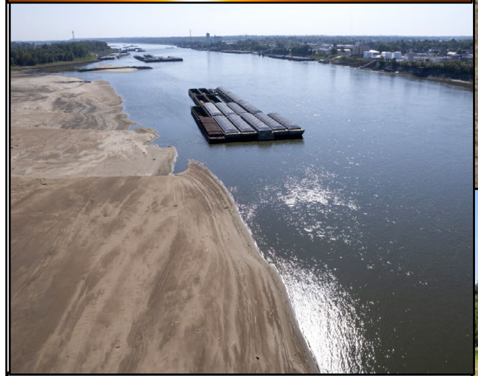
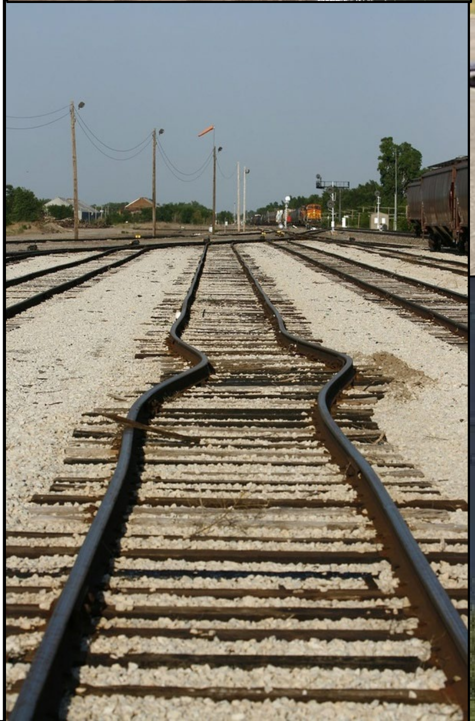
- Warped railways under direct heating may increase derailments.
  - Stalled materials in transport can overheat, damaging the products.

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

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

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

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


Severe Weather on the Rise

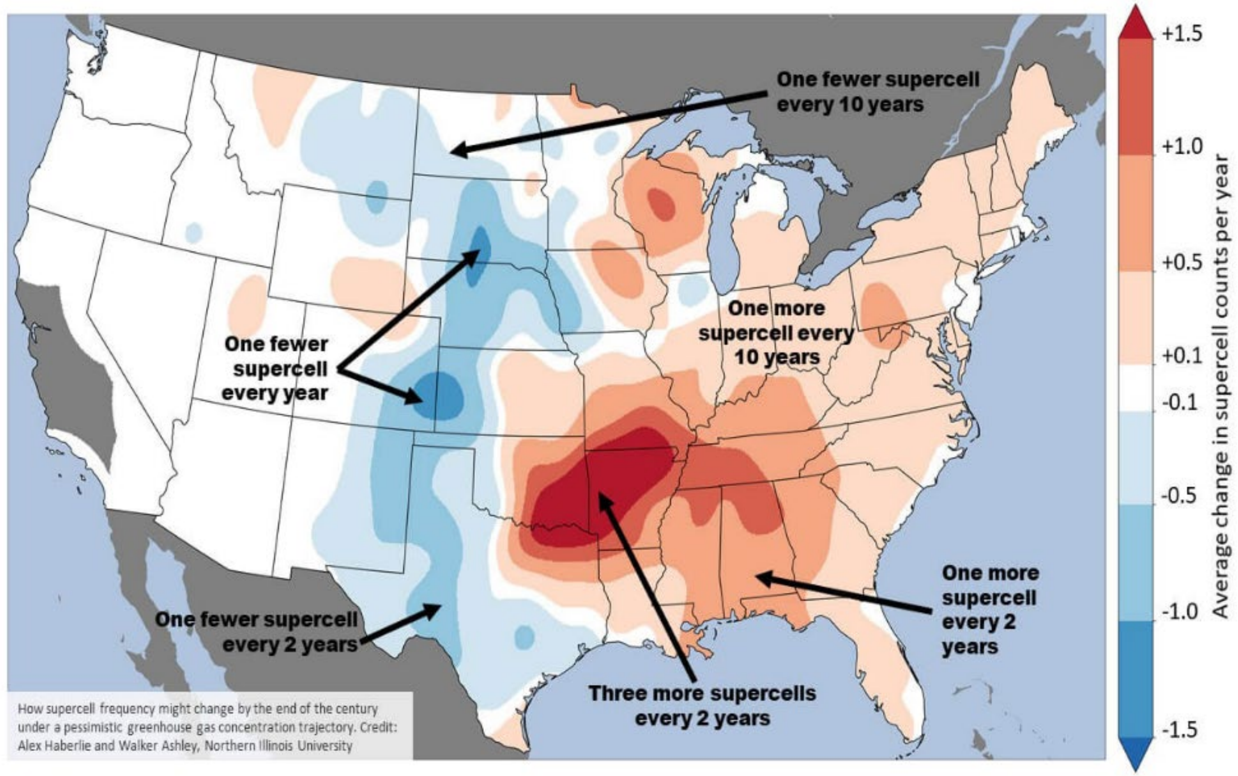
Hail events throughout the US are forecasted to intensify regarding size of the hailstones as warmer climates enable stronger updrafts for supercell storms responsible for large hail.

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

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

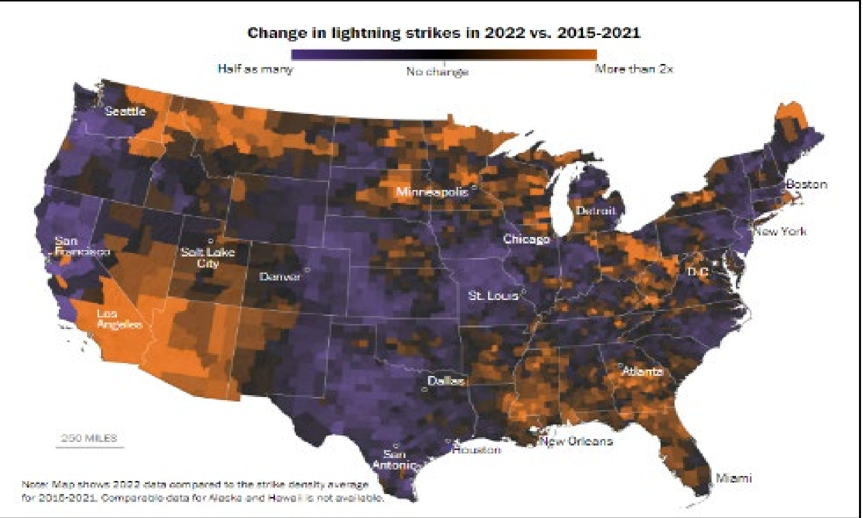
Tornado activity from 2008-2021 in comparison with 1991-2010 indicates the seasonal frequency has remained the same but the location and intensity of tornadic supercells has expanded from "Tornado Alley" to "Dixie Alley" producing larger, longer supercells. Dixie Alley includes Eastern TX, AR, LA, TN,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

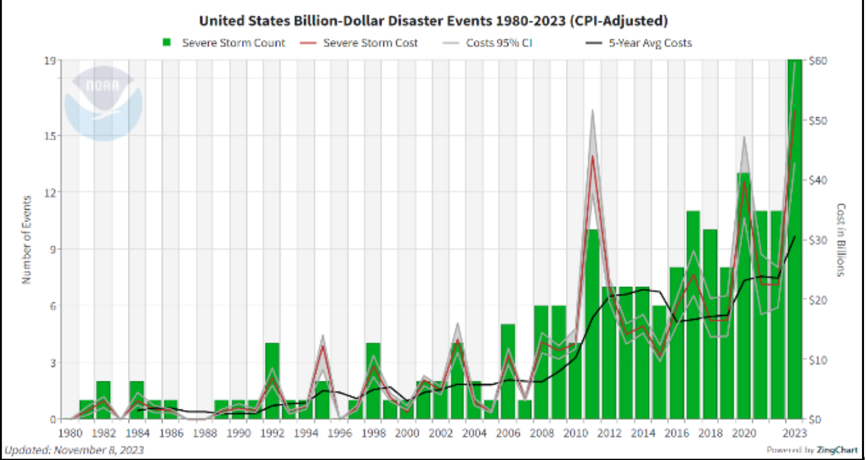
A recent study predicts a nationwide 6.6% increase in supercells and a 25.8% expansion in the area and time supercells remain over land by the year 2100. This may result in areas which do not often see tornadic activity reporting an increase in events too.

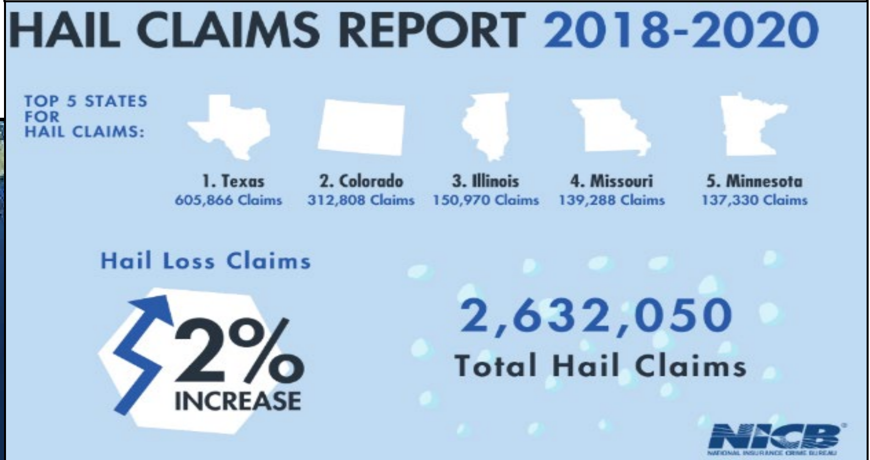


How supercell frequency might change by the end of the century under a pessimistic greenhouse gas concentration trajectory. Credit: Alex Haberlie and Walker Ashley, Northern Illinois University

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



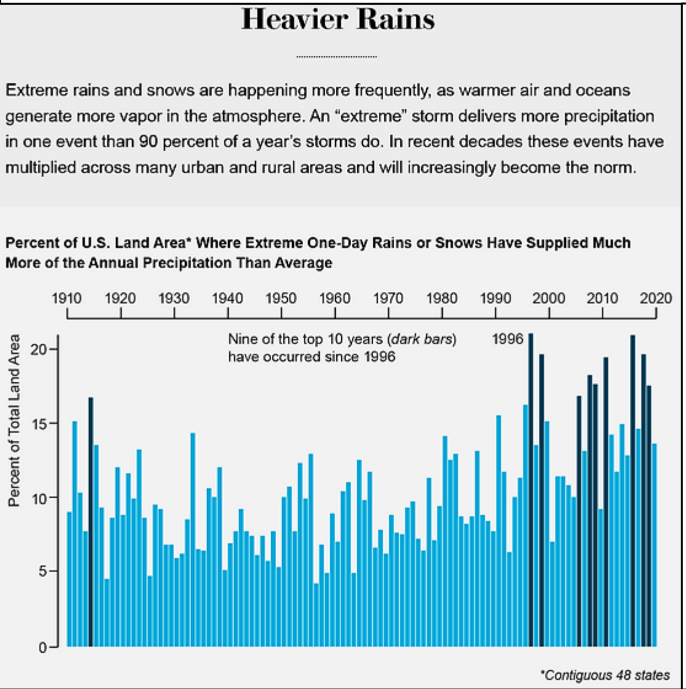




Increases in 1 Hour / 6 Hour / 24 Hour Rainfall Totals

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

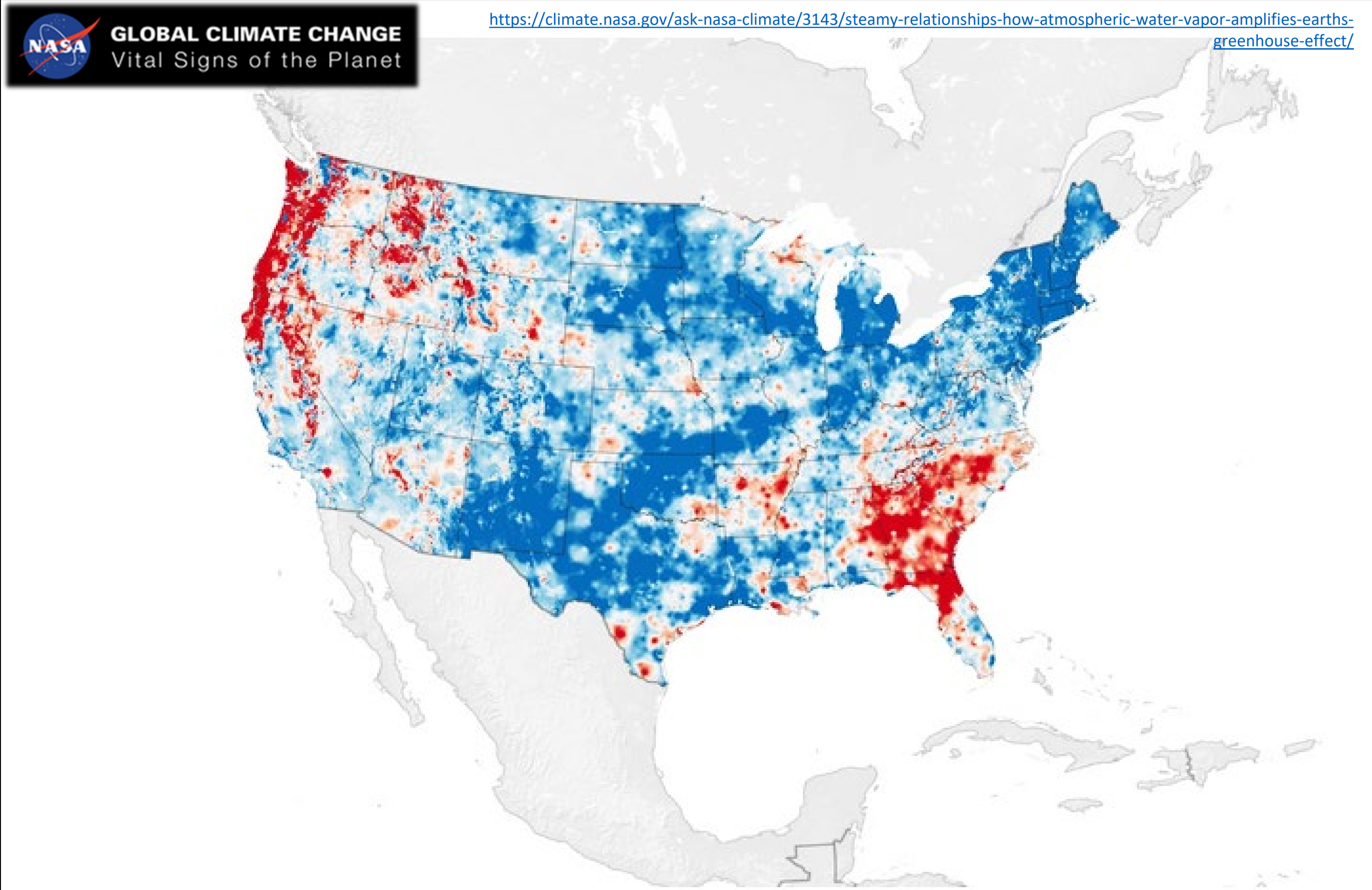
- More evaporation from the land also dries soils out. When water from intense storms falls on hard, dry ground, it runs off into rivers and streams instead of dampening soils. This increases the risk of drought and floods.



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

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

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).

Tropical Cyclones

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

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

Recent Hurricane Season Studies

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

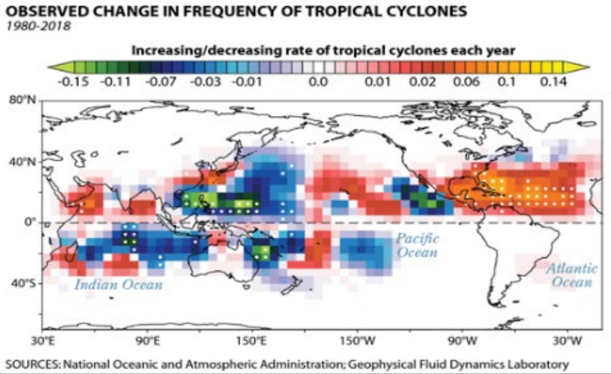
- One assessment suggests an increase in intensity, proportion of the most intense storms, and the occurrence of storms with extreme rainfall events.

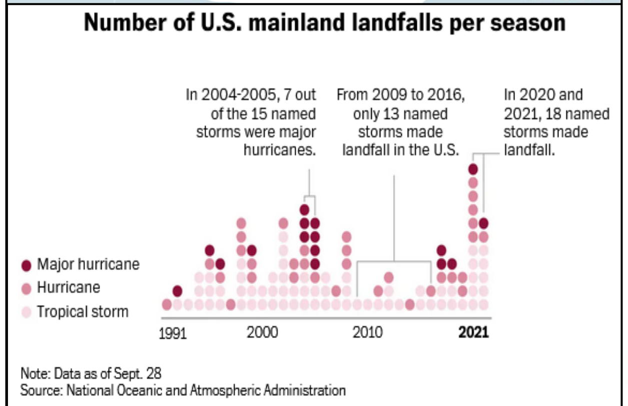
- A recent study from Yale using data from 2020’s cyclone Alpha and 2021’s cyclone Henri states the next 75 years will see an expansion of hurricanes/typhoons into mid-latitude regions, including major cities such as New York, Boston, Beijing, and Tokyo

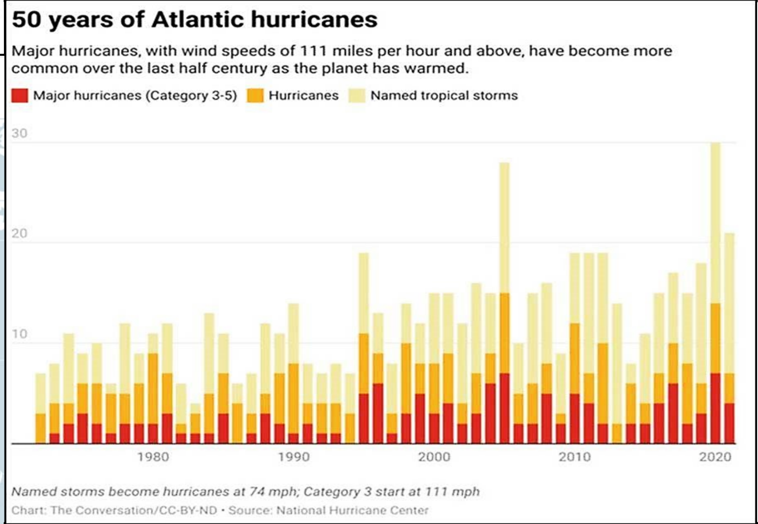
- A recent assessment indicated an increase of global tropical cyclone rainfall rates at 7% per degree of Celsius of warming with an observational finding of a 1.3% global increase in tropical cyclone rainfall rates per year since the early 1900s.

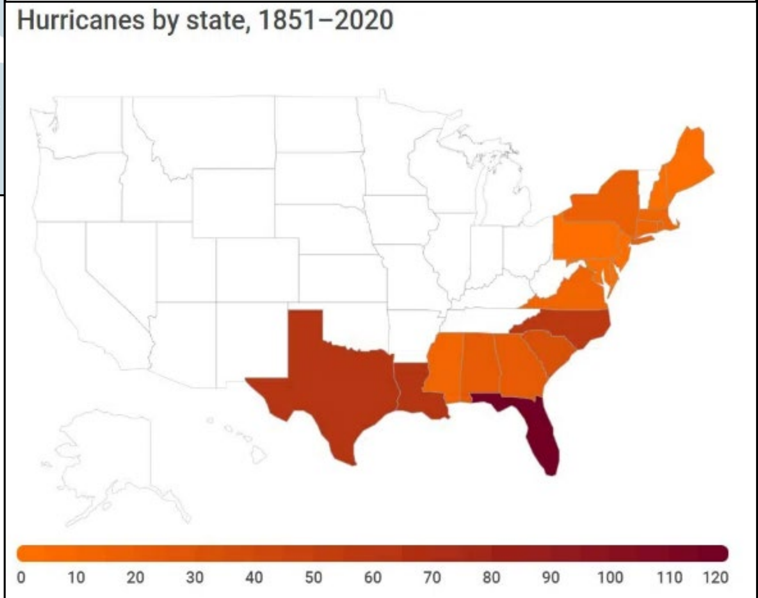
NOAA recently released a new explanatory guide: This information could be a useful guide to distribute to staff, as it succinctly covers the dangers of hurricanes and how to plan for them. 57% of fatalities during tropical cyclones have been caused by storm surge.

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





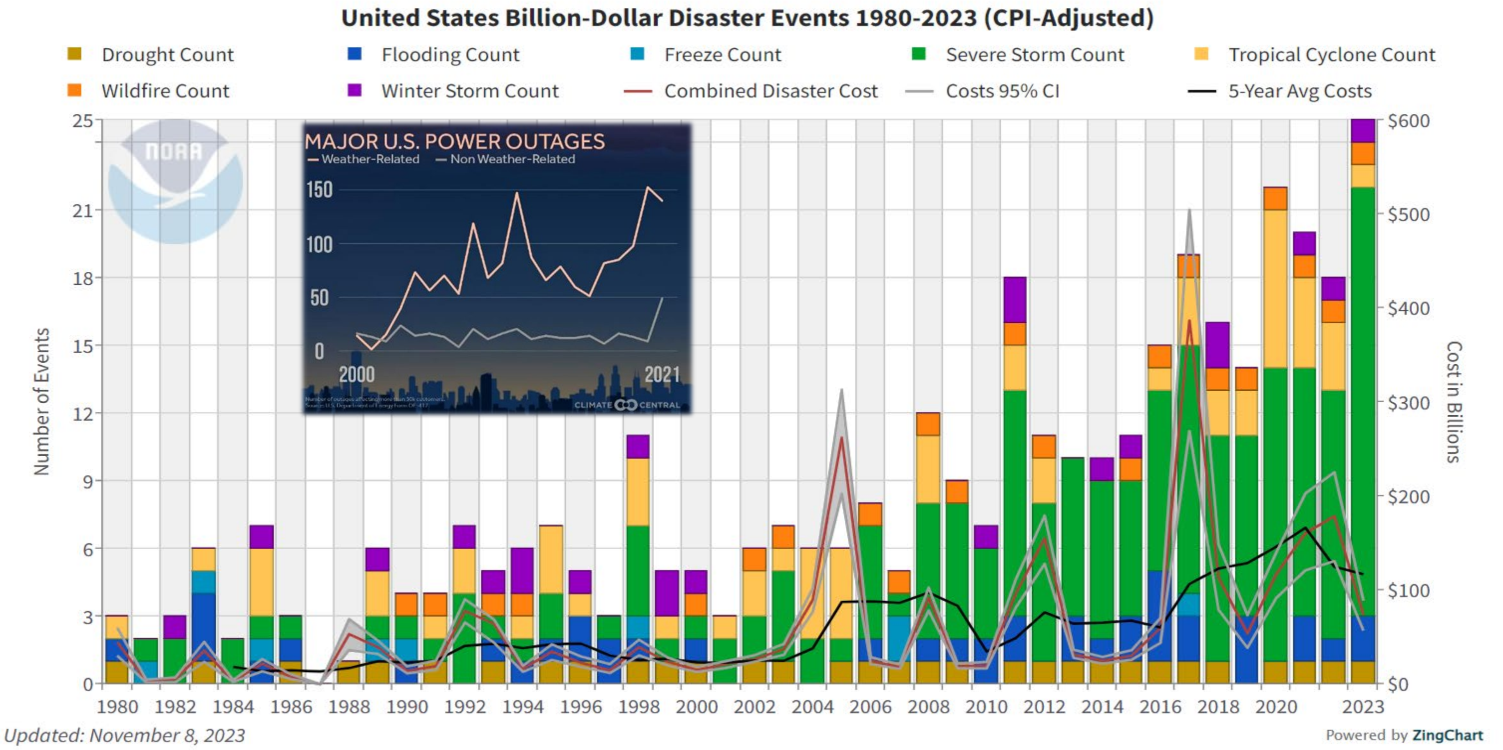


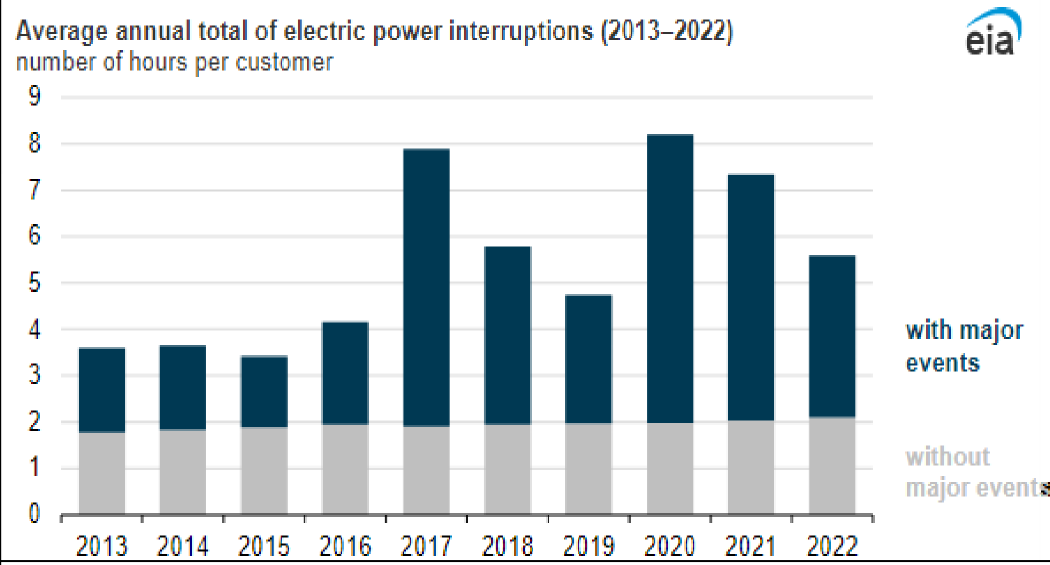


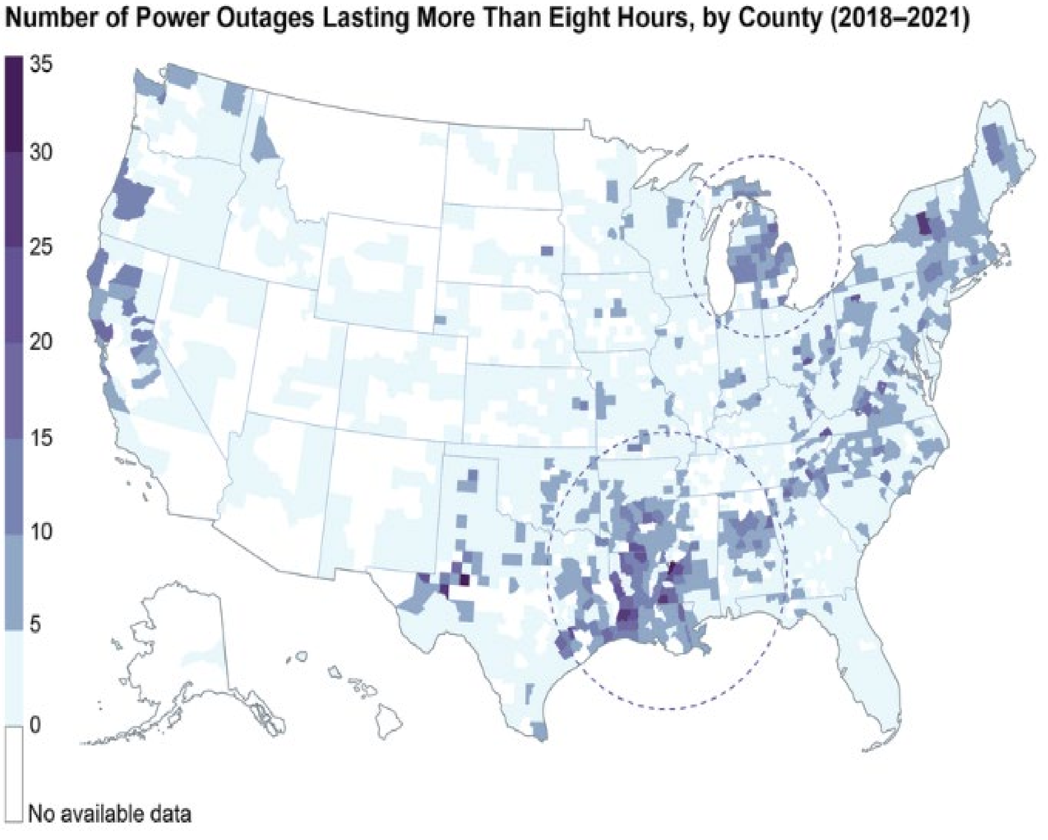
Energy Sector Loss - Weather

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.







The Role of Heat in Storm Growth

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

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

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

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

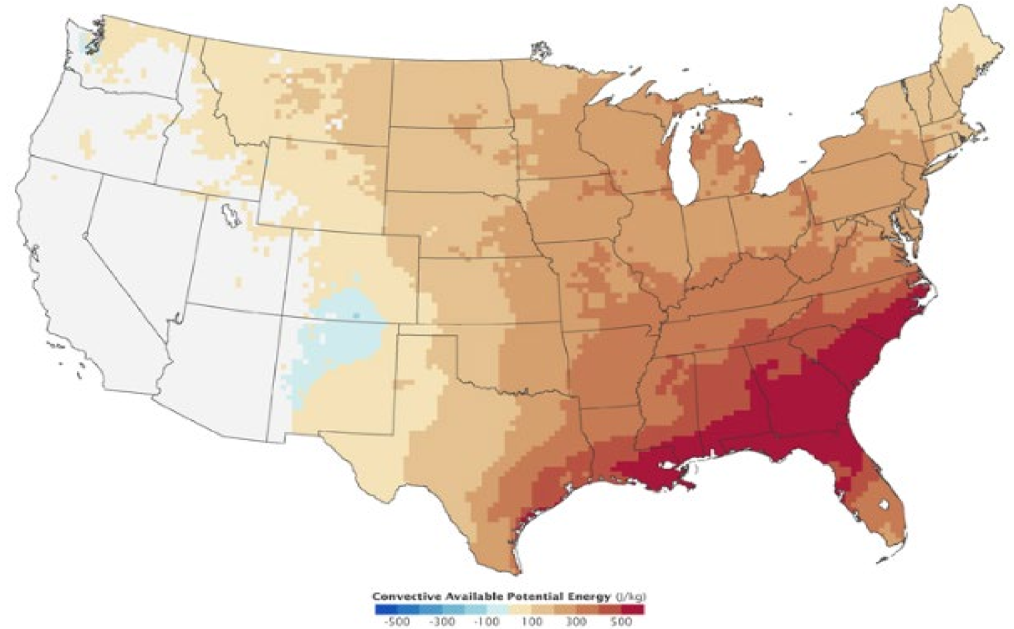
Hail: increasing temperatures and humidity could fuel larger hail and could mean smaller pellets are more likely to melt before hitting the ground.

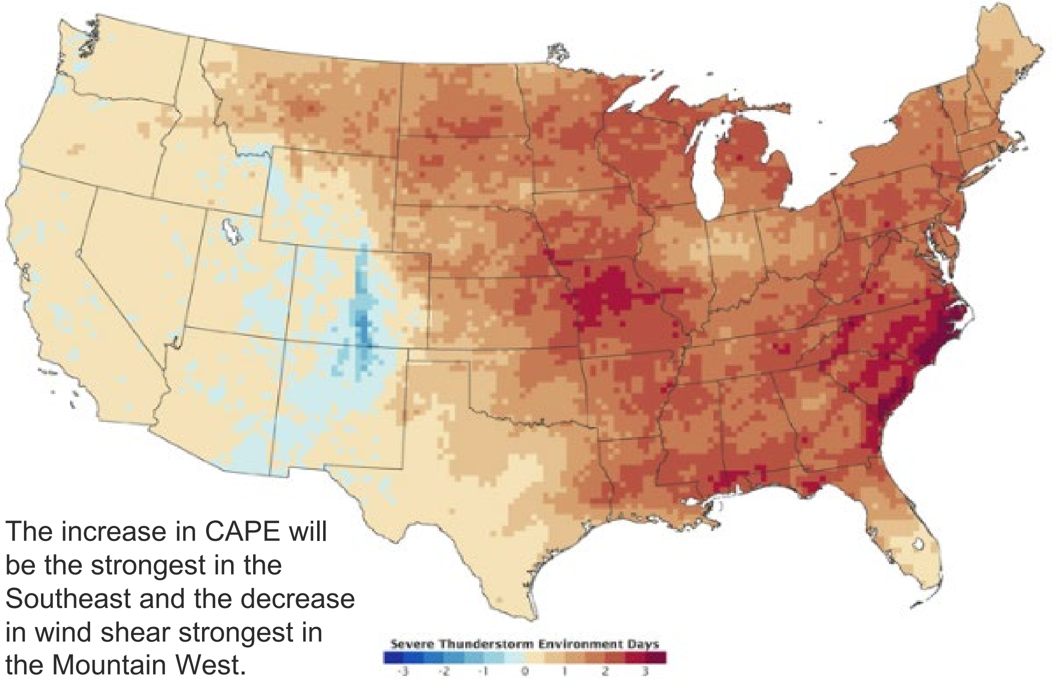
- Damage from severe thunderstorms has been inching up by about 7% annually for 30 years.
- Worldwide, thunderstorm losses were almost 90% higher than the previous five-year average of $32 billion, and more than <u>double</u> the previous 10-year average of $27 billion.

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

Severe thunderstorms and climate change

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





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

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




Community Impacts

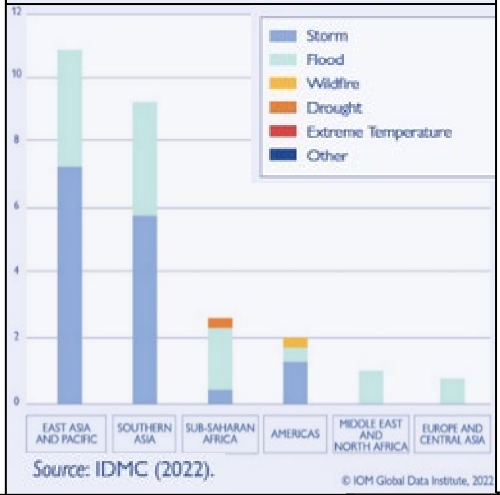
Recent studies have suggested that people who experience the impacts of hurricanes, catastrophic flooding or other severe weather events are more likely to believe in, and be concerned about, climate change post-disaster event.

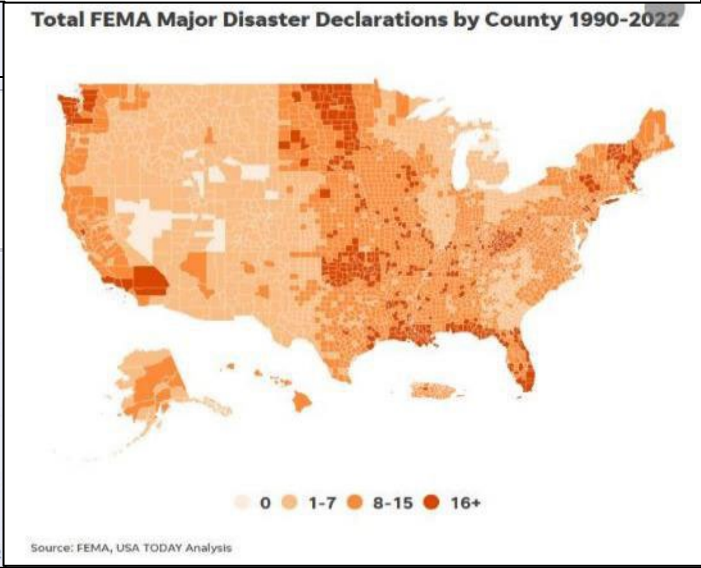
- People who perceived that damage had occurred at such a broad scale were more likely to believe that climate change is a problem, is causing harm, and were more likely to perceive a greater risk of future flooding in their community.
    - In contrast, individual losses such as damage to one's own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

A 2018 FEMA study on why residents won't evacuate in the face of disaster showed the leading barriers were insufficient money (17% of residents) or poor physical health (18%). 'Men are also more likely to ignore orders than women'.

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)

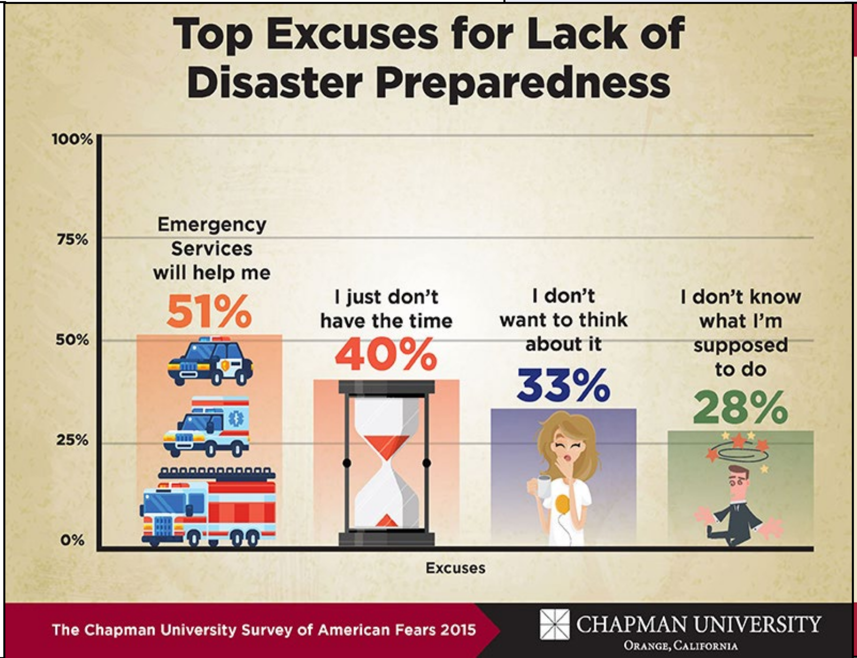




Research supported by NIEHS and others have shown that preparation, adaptation, and mitigation actions can reduce poor health outcomes and infrastructure disruption during and after an extreme weather event.

- Older residents make up a larger share of the population in warmer areas of the US.
    - 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.



Federally mentioned Options for Consideration

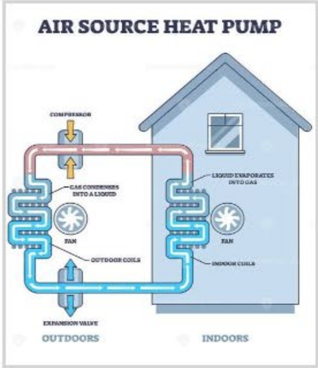
Mitigating extreme heat begins at the surface by reducing material heat absorption, reflecting solar radiation, and by insulating properties to reduce cooling needs and thereby reducing energy needs.

Many of these resiliency options can provide multi-threat benefits to other extreme weather threats such as insulating the home helps reduce energy needs in winter, green roofs can prevent snow melt and freezing rain damages to roofs, cooling vegetation can reduce wildfire threats when maintained, and improving the albedo rating of roofs, roads, and sidewalks can reduce the local heat field yielding a localized benefit to temperature gradient winds and severe storms.

Air Conditioning Systems

HVAC systems in residential and commercial buildings can lower body temperatures and keep sensitive electric equipment cool. Using smart HVAC can reduce energy use

CDC



Heat Pumps

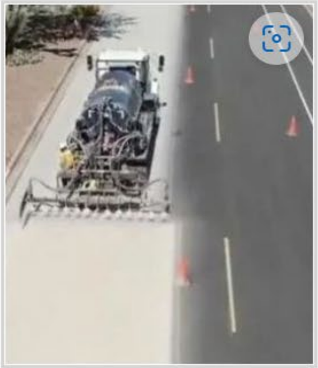
Heat pumps offer energy-efficient alternatives in all climates for to furnaces and air conditioners. These can be hybrid, geothermal, or air-source.

DOE

Sustainable Pavements

Sustainable pavement achieves engineering goals while meeting basic human needs, using resources effectively, and preserving and restoring surrounding ecosystems.

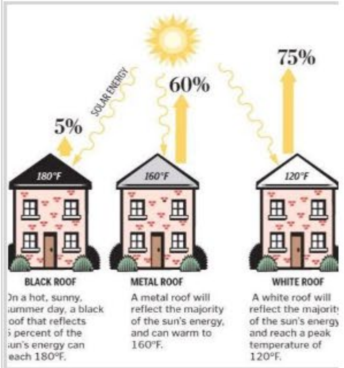
DOT



Cool Pavements

Reflective coatings along with covered areas and vegetation can reduce heat absorbed during the day. Raising the albedo of all paved surfaces can reduce city temperatures by reflecting solar radiation.

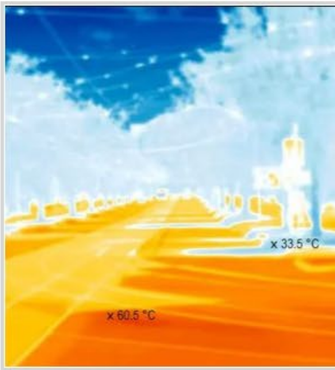
EPA



White Roofs

A white roof is 8.5% cooler than a non-white roof, reducing site temperatures by ~7°F. Solar reflective paint on low-rise buildings can save ~300 kWh in peak summer hours.

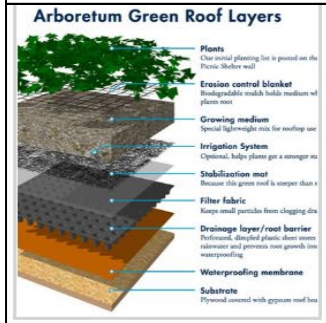
DOE



Cooling Vegetation

Trees and vegetation provide cooling through shade and evaporation of rainfall. Urban forests have temperatures that are on average 2.9°F lower than unforested urban areas. Canopies can cool sites by ~30°F

EPA



Green Roof

A green roof is a vegetative layer grown on a rooftop. Green roofs can be 30-40°F lower than a conventional roof and can reduce city-wide ambient temperatures by 5°F.

EPA

White Railways

Train tracks can be near 70°F (20°C) hotter than the air temperature. A rail painted white is 5°C to 10°C cooler than a non-painted segment. (Used in Austria, Switzerland, UK, Germany, and Spain)

IRJ

Reflective Insulation

Radiant barriers like aluminum foil insulation can block the flow of radiation. Wrapping cast iron metals susceptible to cracking, such as bridge supports, can prevent heating.

DOE

Window Heat Blockers

Sun control window films can reflect up to 80% of heat-producing infrared rays and blocks ultraviolet light. Energy efficient windows can reduce solar heat gain. This also applies to vehicles.

DOE

Backup Energy Generation

Generators, renewables, or backup batteries can prevent unplanned outages. The Resilient Power Best Practices Guide for energy resiliency methods scalable to various infrastructure types and sizes.

CISA

Cover Crops and Canal Covers

Cover crops can improve soil health and stability, prevent overheating, and enhance water availability between cash crop rotation. Covering canals from direct heating can prevent lining damage, water loss or contamination.

USDA

Thunderstorms and Mitigation

Damage from tornadoes and straight-line wind events such as outflow boundaries, derechos, or wind funneling between infrastructure can result in damage to roofs, siding, fences, high-profile vehicles, bring down trees, create projectiles, blow out windows, destroy windshields, destroy energy infrastructure, cause propane explosions, trigger energy surges, flip vehicles, collapse sheds, damage both internal and external furniture and of course result in complete destruction of personal property.

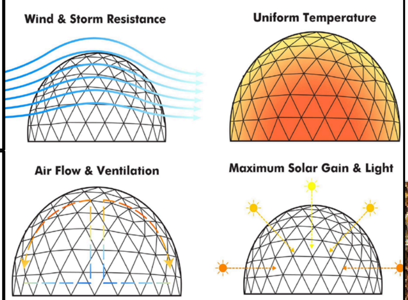
- Hail intensities have also increased in downward force as they fall due to thunderstorm updrafts building faster enabling hail to more rapidly form and reducing the amount of air trapped inside thereby making hail stones heavier.
    - Grapefruit sized hail (+5.25 inches in diameter) falling at +150 mph has been reported in seven states in the past three years and is expanding in frequency.
        - The warmer the air ahead of a storm, the greater intensity for moisture and instability to result in stronger systems.

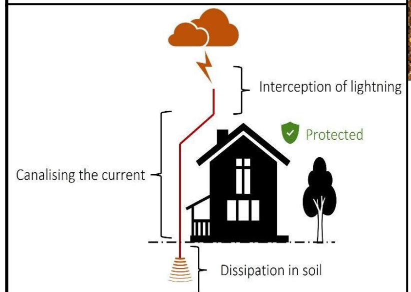
Certain building shapes, like geodesic domes, can withstand tornadic winds near EF5 (+260 mph).

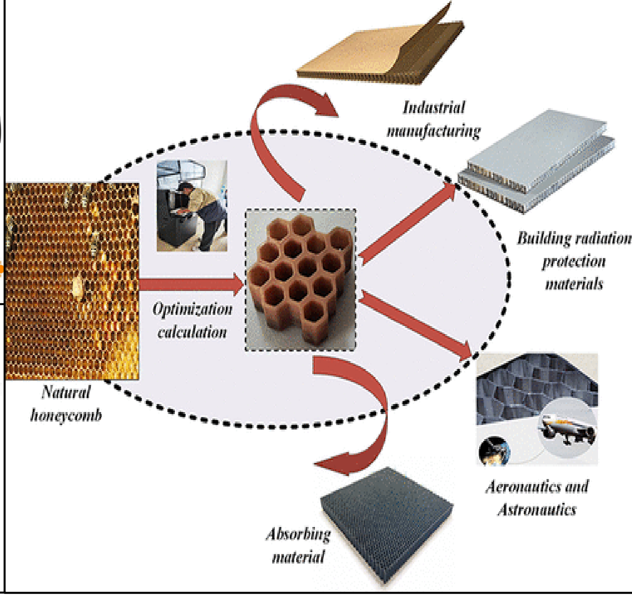
- Improving the tensile strength of roofing applications for non-dome roofs will assist in hail protection, but spray on membranes or steel can degrade over time and add significant costs to repairs on the backend of future hailstorms and severe weather.
    - Other options include adding dome or bowed material to roofs for dispersing force, 3D printed honeycomb technology to improve tensile strength, adding external bowed walls to existing home frames to improve wind and water force resilience, lightning protection systems to prevent power surges, trimming trees are all homeowner options for consideration to mitigate storm damages, and burying powerlines within communities.

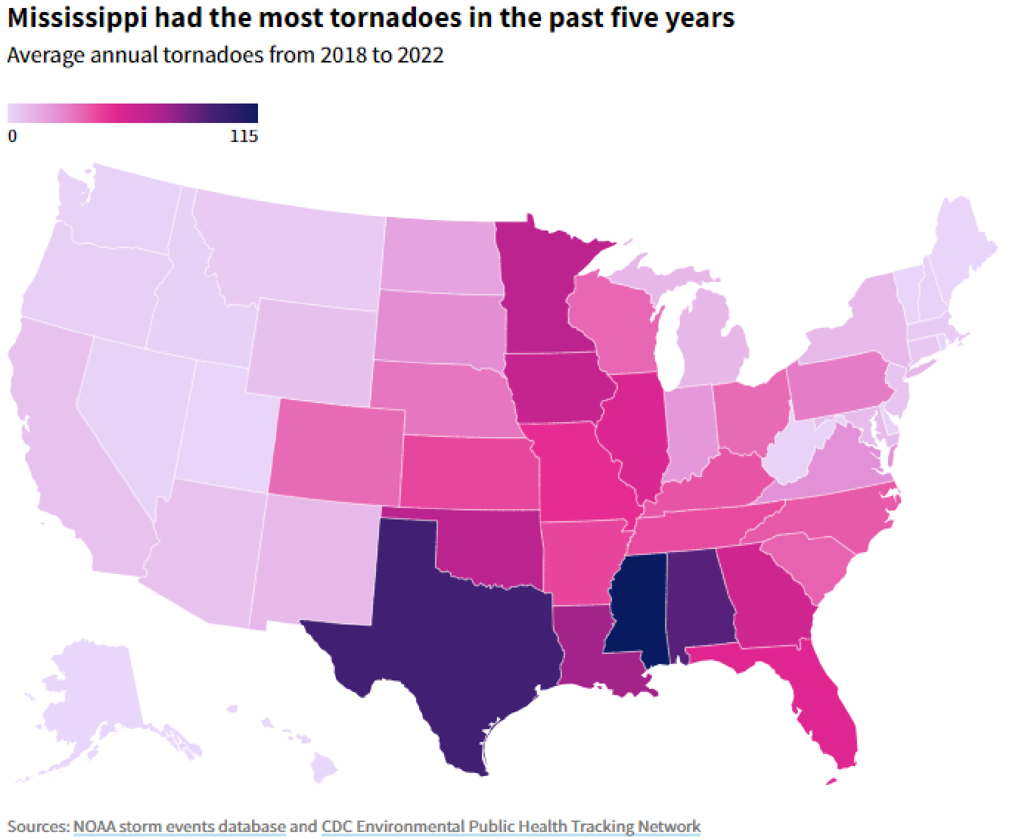
While trimming trees can help reduce fallen limbs, trees need to be evaluated for other damages from heat/drought/insect or wildlife impacts from other climate enhanced trends which could result in heightened rates of downed trees.

- An example of this threat occurred in Austin, Texas during a single storm in 2023 when the past drought and freeze events contributed to a mass tree fall event resulting in a sudden widespread loss of power and notable roadway transportation delays.
- Ensuring after leading trees fall, that the remaining trees in a community/backyard have protection from sudden heightened exposure to stronger winds, drought, wildfire, and now may fail at a faster rate.









Mitigating Local Wildfire Threats

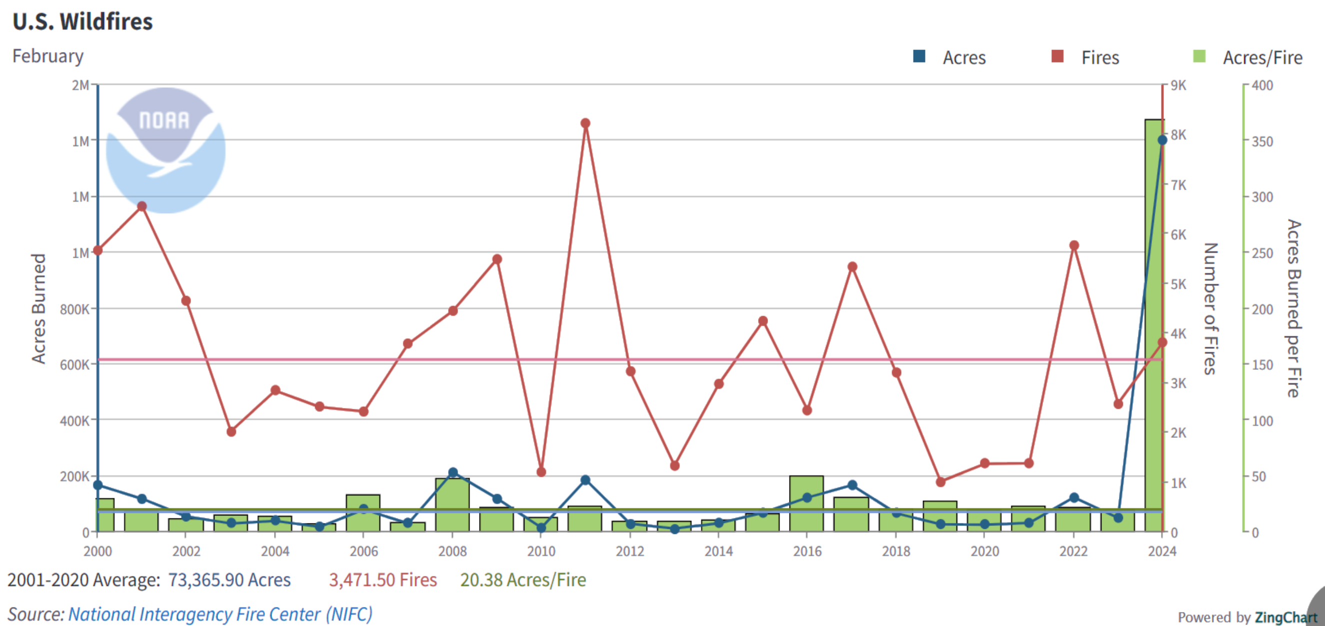
Some cities internationally have invested in a community-wide sprinkler system to keep vegetation moist while others have increased drip-irrigation systems for larger plants both of which require an increased use of surface or groundwater and may over burden that limited regional resource. Response operations after a fire has impacted a community can prevent the secondary threats from developing.

- Clear decayed organic material around the property and check community ecology health.
- Remove combustible vegetation (like eucalyptus) and encourage the growth of cover crops where possible to keep soils moist.
- Create a flow-reduction barrier system for slopes near sites to reduce debris flows and flash flooding concerns post-fire.
- Identify areas where soils face hydrophobic layering and encourage plants with deeper roots or use of worms to churn soil naturally between fires.
- Use drones to identify areas with premature yellowing in the fall or delayed blooming in the spring can identify trees likely to decay internally before wildfires. Drones can also be used for vegetation planting during wildfire recovery.
- Utilize arborists to evaluate the health of community tree lines and drone mapping to identify hotspots or powerline heat surge trends.
- Improve debris flow/runoff flows with low-lying barrier systems

Housing plans to improve resiliency for non-evacuation residents by reducing energy needs or health and safety threats: Improve home insulation, shading, and material reflectivity ratings to reduce site heating and need less energy or to prevent loss or damages during power outages while using home or community greywater recycling systems for interlinked drip irrigation and water systems.

Updating homes to new fire codes by reducing or removing grandfathering policy such as requiring sprinkler systems and external sensors in local foliage for heat and smoke which alerts local firefighters will improve response efforts and reduce loss.

- Sensors for wells pulling groundwater will help flag pollutants immediately versus annual testing, reducing the risk of contaminated water threats.



Mitigating Surface Flooding Threats

Since 1965, large floods have become more frequent across the Northeast, Pacific Northwest, and Northern Great Plains (EPA).

- Just one inch of floodwater can cause up to $25,000 in damage (FEMA).
- 12 inches of flowing water can carry away most vehicles, presenting a secondary threat to infrastructure in debris.
- Vehicles parked on larger flat surfaces like car dealerships or parking garages could see heightened flood risks due to a lack of drainage during flash floods.

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

- The national floodplains are expected to grow by approximately 45% by 2100.

Flood resiliency in homes can come in multiple forms, from elevating power outlets to reducing leaks through improved sealant to raising HVAC and backup generators.

- Homes can install deployable flood gates/fences and inflatable barriers to prevent inflow from nearby threatened drainage paths at sites and communities if kept with emergency equipment.
- New property developments in New Jersey have required outlets be installed at least 3 feet above the ground in first floors.
- Storing boxes and electronics in the basement should be shifted to attics.
- Waterproof compounds can be applied to walls in lower elevations to prevent water incursion and damages.
- Sump pumps in flood prone locations may need additional sump pumps or drainage paths installed which could yield greater runoff rates downstream.
- Clearing gutters and drains around homes can prevent overflows and reducing water using in the home can reduce water backflows from over inundates sewers.

Sea Level Rise Planning

Individuals selling their homes to relocate inland for safety may sell at a loss due to damage/risk while those seeking beachfront properties may willingly move to the higher risk area due to drop in pricing, unaware of the potential loss.

Warehouses along the coast, used to store materials ahead of loading container at docks face risks of coastal flooding damaging or destroying items. Additional losses to the supply chain capabilities from drought reducing the availability of timber and subsequently driving prices up.

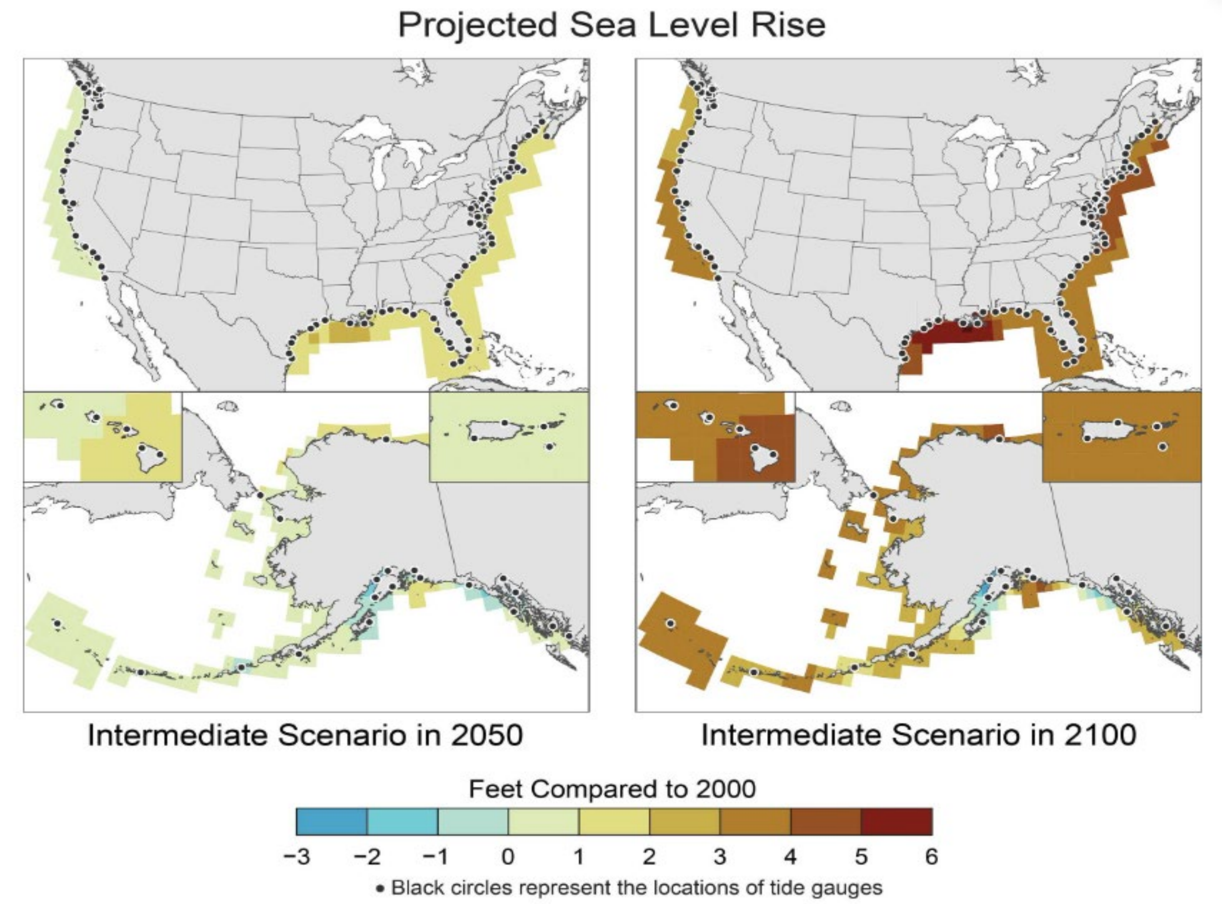
- Timber farmers are expected to lose $96 million after droughts killed more than 12 million pine trees in Mississippi."
- There were record tree die offs reported in Oregon last year as well as California which reported over 129 million trees died in the severe droughts over the past decade. Lumber prices have more than tripled from 2019 to 2021
- Hurricanes can also result in saltwater inundation for vegetation resulting in die offs along the entire eastern coastline, with storm surge amplified by sea level rise along with decreased drainage from river systems amplifying riverine floods.

Impacts to homes can range from sinking, flooding, dislodging from their foundations, or septic backflow problems.

- Coastal homes are highly sought after despite the rising threats of floods and erosion resulting in property loss or significant repair costs.

Mitigation: According to [Climate Central, NOAA, FEMA, and USGS], by 2030, storm-driven floods reaching 4 feet above the high-tide line will occur twice as often as today. Planning for the loss of homes along the all of our coastlines will include organized retreat and implementing tidal flow options.

- Improve coastal barrier systems such as floating flood gates, taller flood walls, more drainage canals, and increase flow breaks like artificial reefs.
- Breakwaters and jetties can be constructed along beach access points as an additional wave barrier system.
- Seawalls bring temporary wave relief but end up causing leading-edge erosion on the ocean-facing side of the wall, triggering wall damages.
- Seagrass and other natural vegetation can provide filtration of certain particulates and hold sands and soils in place during storms and waves.
- Homes may need to retreat further inland to allow natural vegetation to reclaim coastlines and prevent cliff or beach collapse into the ocean.



Tropical Cyclone Resiliency

While NOAA has stated there is no intent to increase the Saffir Simpson Scale to include Category 6 winds due to the recent increases in storm intensities, it should be noted that multiple tropical cyclones last year produced wind gusts over 200 mph with one gust reaching 216 mph on shore in Taiwan before the sensor broke.

- Homes experiencing winds over 192 mph can sustain damage even if cement, steel, and impact resistant glass are used in construction if the shape of the home is not aerodynamic or provides a flat side surface which would see various force damages.

Vehicle Resiliency: elevating parking structures above flood threat levels to include driveways may be too intensive but deployable flood barriers can work in most locations.

- More permeable roadways and sidewalks can reduce standing floodwater presence and remove vehicle flooding risks during drives. Sealant applications for doors and undercarriages could reduce water damage to vehicles sitting in flooded parking lots.
- Camera sensors for intentional driving into floodwaters could reduce claim payout needs.

Home Resiliency: Preventing wind damage, flood water force damage, hail and debris falls, and tornadic activity coupled with lightning strike risk requires a change in structure design.

- The dome home can withstand winds topping 200 mph and coupling with wind generators and solar or battery backup generation can provide energy resilience with on-site water recycling reducing community impacts in full outside of road/vehicle flood threat.
- Some domes built with inset windows and lower profiles can withstand winds of 250 mph.
- Due to the dome shape, hail stones and tree debris disperse force more evenly across the surface resulting in less damage than a traditional roof.
- The rounded walls at the base of structure encourage water passing to the sides and are less likely to cave in or crack in comparison to standard rectangular home wall designs.
- Rebuilding old homes is not necessary, a dome exoskeleton can encapsulate typical homes and be installed as an attachment to the current structure to improve resilience.

'Hurricane proof' dome home hits the market near Charleston

PROPERTY I BY JAMIE ROBINSON

Courtesy Michael Royal / Pareto Group

Virginia Changes in Climate

An extremely hot day in Virginia is about 93ºF. This is based on historical maximum temperatures on the top 2% of days in an average year.

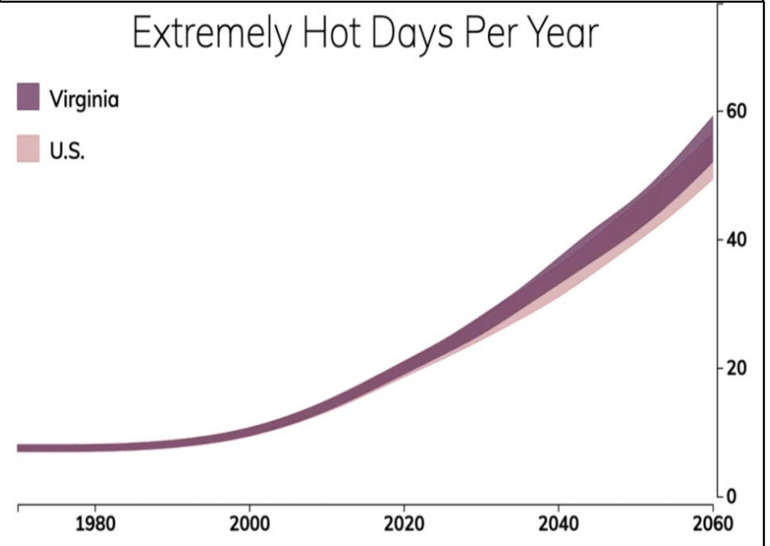
The frequency of very hot days is increasing. On average, someone in Virginia will experience about 43 extremely hot days in 2050.

Historically, Charlottesville experienced an average of 1.6 inches of rain about 11 times per year. In 2050, it is projected to experience an average of 1.5 inches of rain about 14 times per year.

Historically, Alexandria experienced an average of 1.6 inches of rain about 10 times per year. In 2050, it is projected to experience an average of 1.5 inches of rain about 13 times per year.

Since the beginning of the 20th century, temperatures have risen more than 1.5°F in Virginia

Summer average temperatures in the most recent 16 years (2005–2020) exceeded early 1930s.

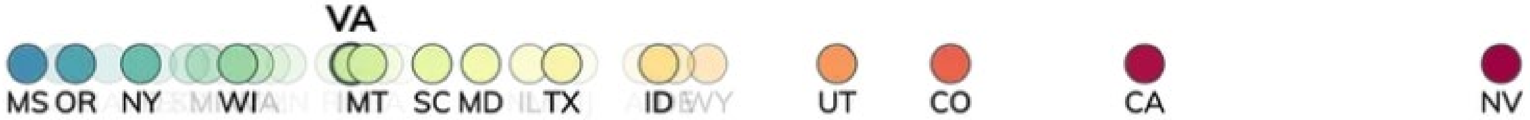


Heat

Virginia ranks #14 for highest heat risk

Drought

Virginia ranks #22 for highest drought risk



Precipitation

Virginia ranks #24 for highest precipitation risk

Flood

Virginia ranks #24 for highest flood risk

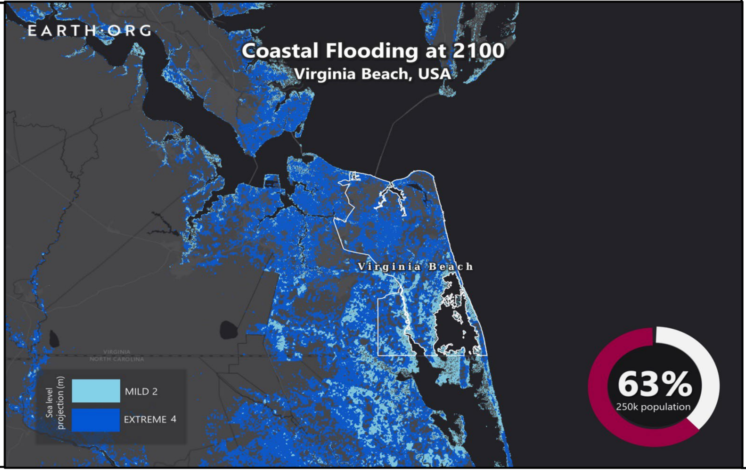
Fire

Virginia ranks #28 for highest fire risk

Virginia Sea Level Rise Risk

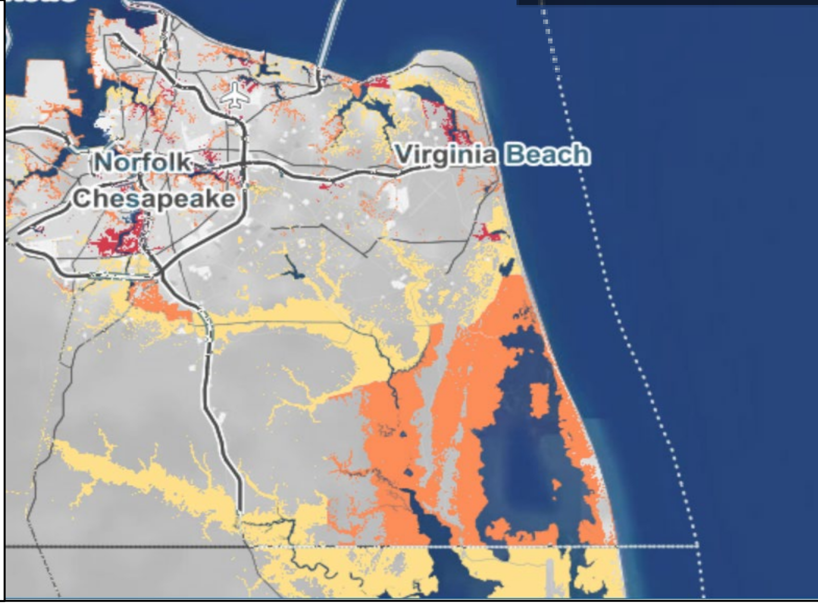
Phase II of the Coastal Resilience Master Plan is currently in development and will be released by December 2024.

- This phase of work will build on the Phase I plan and incorporate all major flood hazards, including precipitation-driven flooding; update the project inventory; and update the impacts of exposure.



A *39%* risk of at least one flood over *5 ft* taking place between now and 2050 in the Virginia area.
Virginia Beach city, a highly affected area in Virginia.

Land below 5 ft is colored yellow through red to denote populations with low through high social vulnerability. Social vulnerability can compound coastal risk. Maroon lines are levees.



The sea level around Hampton Roads is up to 14 inches higher than it was in 1950.

This increase is mostly due to Virginia's sinking land, and it's causing major issues. Hampton roads is second only to New Orleans as the largest population center at risk from sea level rise in the country.

There are already over 45,000 properties at risk from tidal flooding in Virginia.

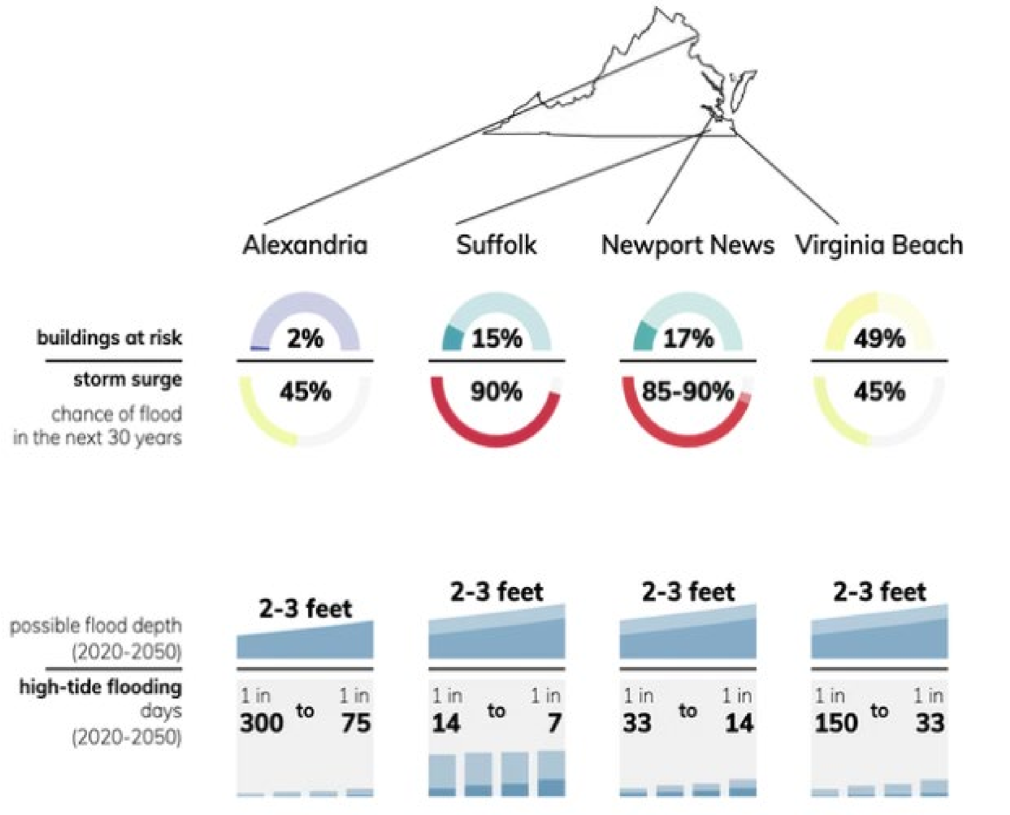
The state is planning over $4 billion in sea level rise solutions, which include stormwater and sewage system protection projects.

The sea level around Sewells Point, Virginia, has risen by 14 inches since 1950. Its speed of rise has accelerated over the last ten years and it's now rising by one inch every 4 years

In places like Sewells Point, king tides are typically nearly a foot and a half higher than normal. Add that to the 14 inches of sea level rise since 1950, and you end up with flooding even on sunny days.

- Hampton Roads is experiencing the highest rates of sea level rise along the entire East Coast.
- In the last decade, the speed at which Virginia's sea level is rising has increased and is now rising by as much as 1 inch every 4 years.
- round Hampton Roads, it took around 26 years for the sea level to rise 6 inches.
- Scientists now forecast that in just the next 13 years, the sea level will have risen by another 6 inches.

In a third of 55 coastal sites studied throughout the US, 100-year storm surges will be 10-year or more frequent events by 2050



DC Additional Maps of Note

District of Columbia, District of Columbia

Total Population 692,683

Flooding

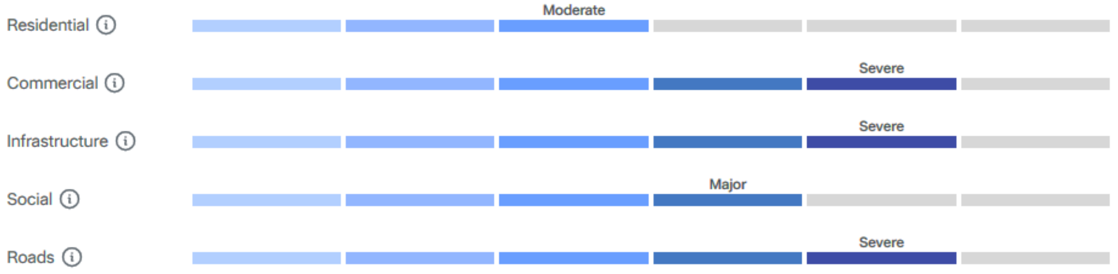
Future Climate Indicators

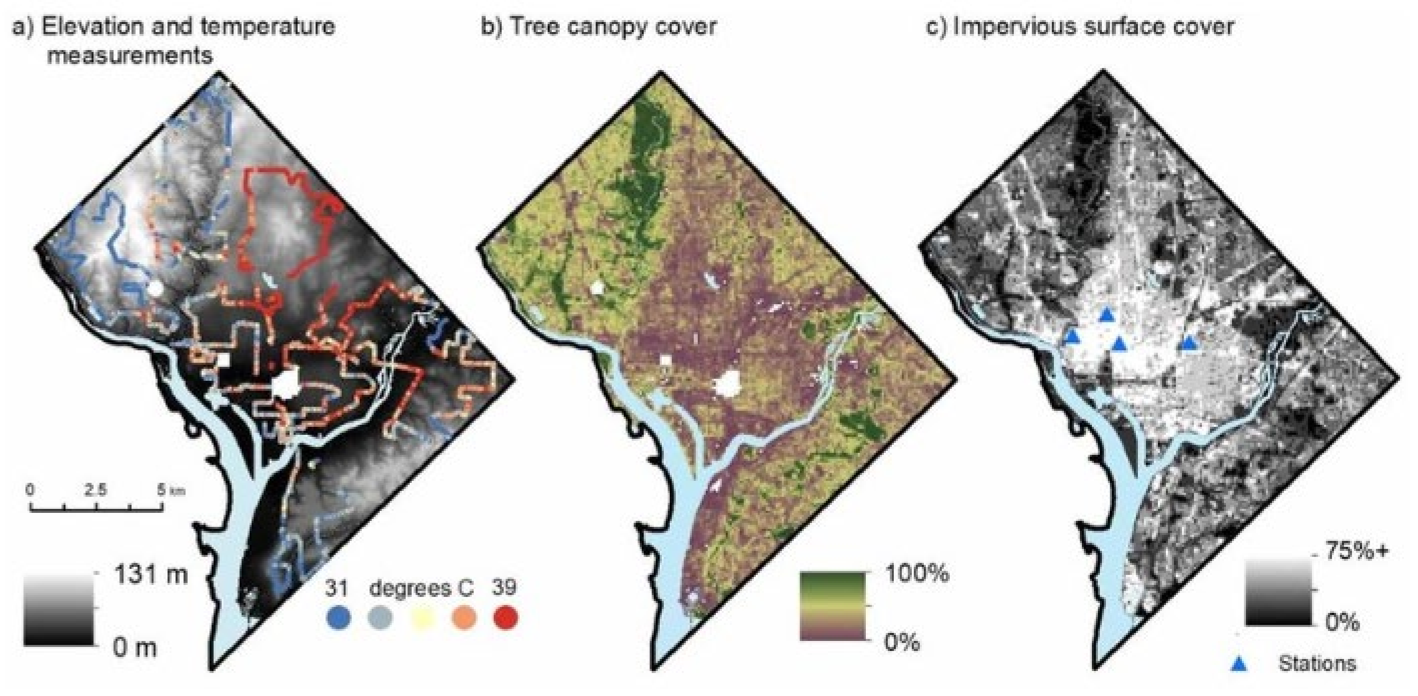
Indicator	Modeled History (1976 - 2005)	Early Century (2015 - 2044)		Mid Century (2035 - 2064)		Late Century (2070 - 2099)	
		Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions
	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max
Precipitation:							
Annual average total precipitation	43" 41 - 45	44" 41 - 49	45" 42 - 50	45" 42 - 50	46" 42 - 50	46" 42 - 52	48" 42 - 52
Days per year with precipitation (wet days)	172 days 164 - 177	172 days 155 - 183	172 days 155 - 184	172 days 152 - 187	171 days 151 - 185	172 days 153 - 189	170 days 145 - 195
Maximum period of consecutive wet days	11 days 10 - 12	11 days 10 - 13	11 days 10 - 13	11 days 9 - 14	11 days 10 - 14	12 days 10 - 14	12 days 9 - 15
Annual days with:							
Annual days with total precipitation > 1inch	6 days 5 - 6	6 days 5 - 8	7 days 5 - 8	7 days 6 - 8	7 days 5 - 9	7 days 6 - 9	8 days 6 - 10
Annual days with total precipitation > 2 inches	1 days 0 - 1	1 days 0 - 1	1 days 1 - 1	1 days 1 - 1	1 days 1 - 1	1 days 1 - 1	1 days 1 - 2
Annual days with total precipitation > 3 inches	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 1
Annual days that exceed 99th percentile precipitation	6 days 6 - 8	7 days 7 - 9	8 days 7 - 9	8 days 7 - 9	8 days 7 - 10	8 days 8 - 10	10 days 9 - 12
Days with maximum temperature below 32 °F	8 days 6 - 9	4 days 1 - 7	4 days 1 - 7	3 days 1 - 6	2 days 1 - 5	2 days 0 - 4	1 days 0 - 2

N/A = Data Not Available for the selected area

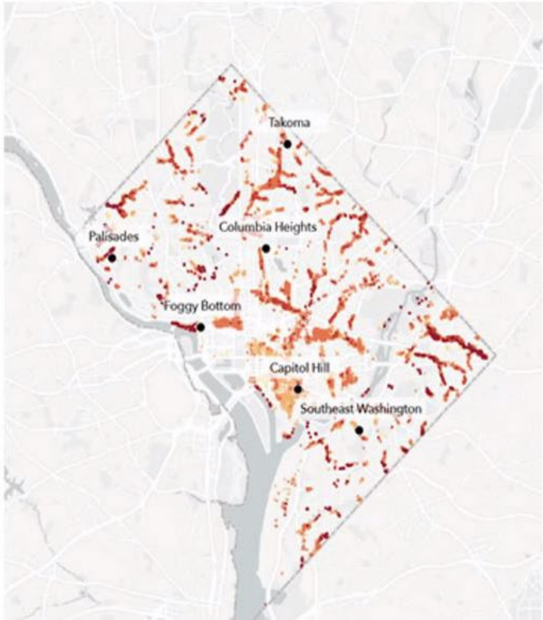
Community Impact from Flooding in Washington

In addition to property damage, flooding can cut off access to utilities, emergency services, transportation, and may impact the overall economic well-being of an area. Overall, the city of **Washington** has a **major risk from flooding**. This is based on the level of risk the properties face rather than the proportion of properties with risk. To determine community impact from flooding, the operational risk for today and in 30 years is calculated for all properties in the community based on the property use and flooding depth. This includes special calculations for hospitals, power stations, police stations, fire stations, airport, roads, and other critical infrastructure.

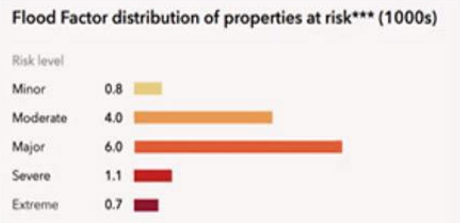




DC Integrated Flood Model (IFM)



Right now, the district does not know where there is interior flood risk. The exception is areas that have been flooded recently. That means some residents are vulnerable to flooding and might not know it. This happens because interior flooding is not mapped. With a completed IFM, the district will protect life safety by making residents aware of interior flood risk. The IFM will also help the district plan and test proposed flood risk reduction measures. These include blue-green infrastructure that DOEE hopes to build. These measures cannot be built without the IFM to map interior flood risk.



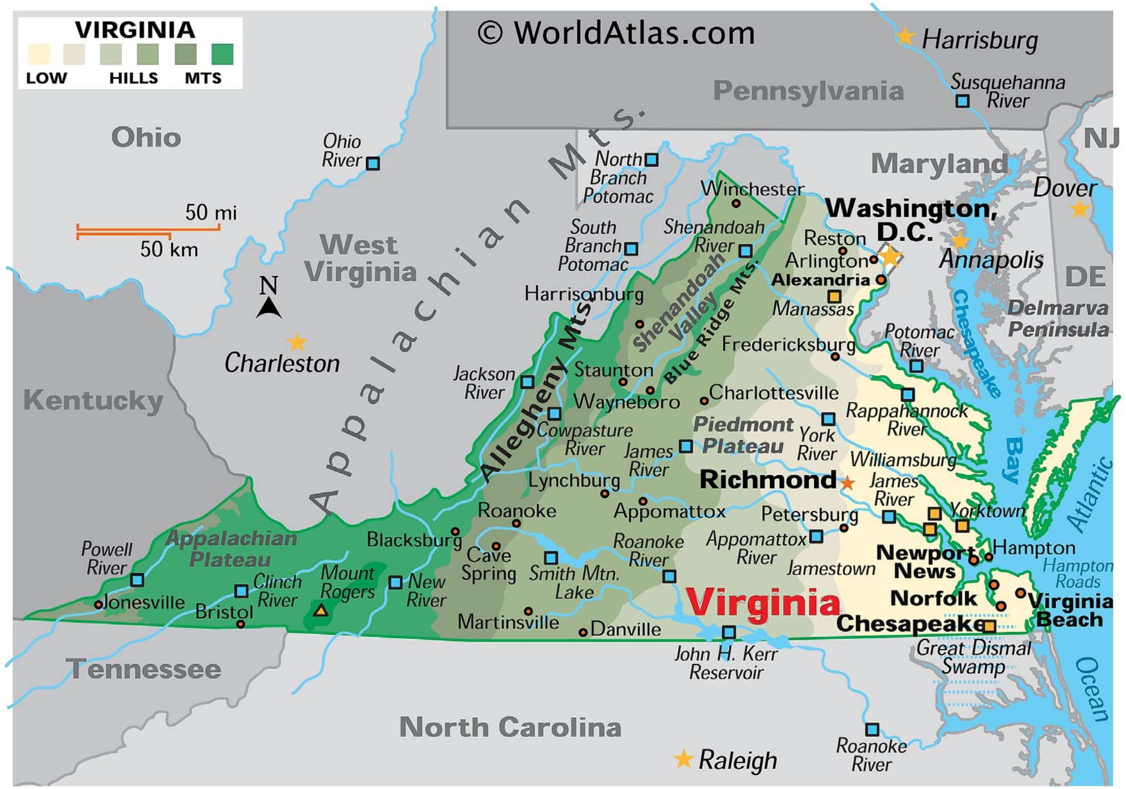
Virginia Climate Statistics

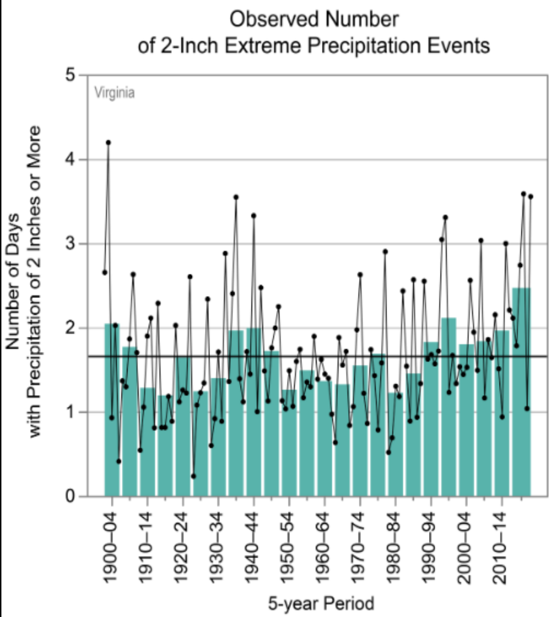
Since the beginning of the 20th century, temperatures have risen more than 1.5°F in VA. A winter warming trend is reflected in a below average number of very cold nights since 1990.

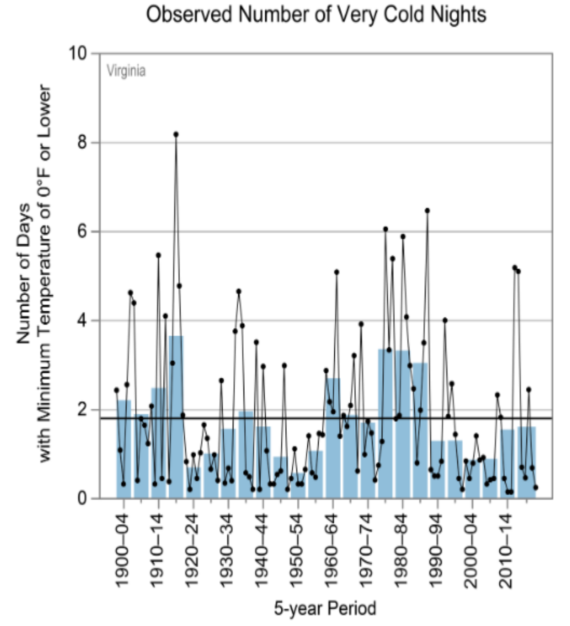
- Summer average temperatures in the most recent 16 years (2005–2020) exceeded those in the early 1930s.
- Total annual precipitation in Virginia shows a small upward trend (Figure 2c), with multiyear values mostly above average since 1995.

Since 1990, the number of 2-inch extreme precipitation events has been trending upward, with the 2015–2020 period surpassing the previous high of the late 1990s

- The wettest year on record was 2018 (statewide total of 63.5 inches), and 2020 was the third wettest (61.4 inches).







Arlington County, Virginia **Flooding**

Future Climate Indicators

Indicator	Modeled History (1976 - 2005)	Early Century (2015 - 2044)		Mid Century (2035 - 2064)		Late Century (2070 - 2099)	
		Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions
	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max
Precipitation:							
Annual average total precipitation	42" 40 - 44	44" 41 - 49	45" 41 - 50	45" 42 - 50	46" 42 - 50	46" 41 - 52	48" 42 - 53
Days per year with precipitation (wet days)	170 days 163 - 176	170 days 154 - 180	170 days 154 - 181	170 days 151 - 184	169 days 150 - 183	170 days 151 - 186	168 days 144 - 193
Maximum period of consecutive wet days	11 days 10 - 12	11 days 10 - 12	11 days 9 - 13	11 days 9 - 13	11 days 10 - 14	11 days 10 - 14	11 days 9 - 14
Annual days with:							
Annual days with total precipitation > 1inch	6 days 6 - 7	7 days 6 - 9	7 days 6 - 10	8 days 6 - 9	8 days 6 - 10	8 days 6 - 9	9 days 7 - 10
Annual days with total precipitation > 2 inches	1 days 1 - 1	1 days 1 - 1	1 days 1 - 1	1 days 0 - 1	1 days 1 - 2	1 days 1 - 2	1 days 1 - 2
Annual days with total precipitation > 3 inches	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0
Annual days that exceed 99th percentile precipitation	7 days 7 - 7	8 days 8 - 8	8 days 8 - 8	8 days 8 - 8	9 days 9 - 9	9 days 9 - 9	10 days 10 - 10
Days with maximum temperature below 32 °F	7 days 6 - 9	4 days 1 - 7	4 days 1 - 7	3 days 1 - 6	2 days 1 - 5	2 days 0 - 4	1 days 0 - 2

N/A = Data Not Available for the selected area

Washington DC Statistics

Historic snowfall totals – Regan Airport and NWS certified

- 24 hours: +21" – January 1922
- 48 hours: +26" – January 1922
- 72 hours: +28" – January 1922

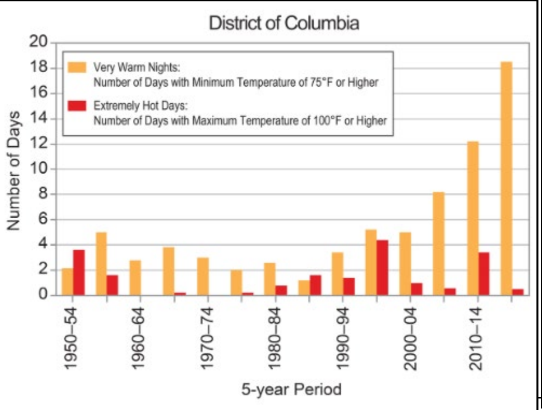
Major impacts from winter weather

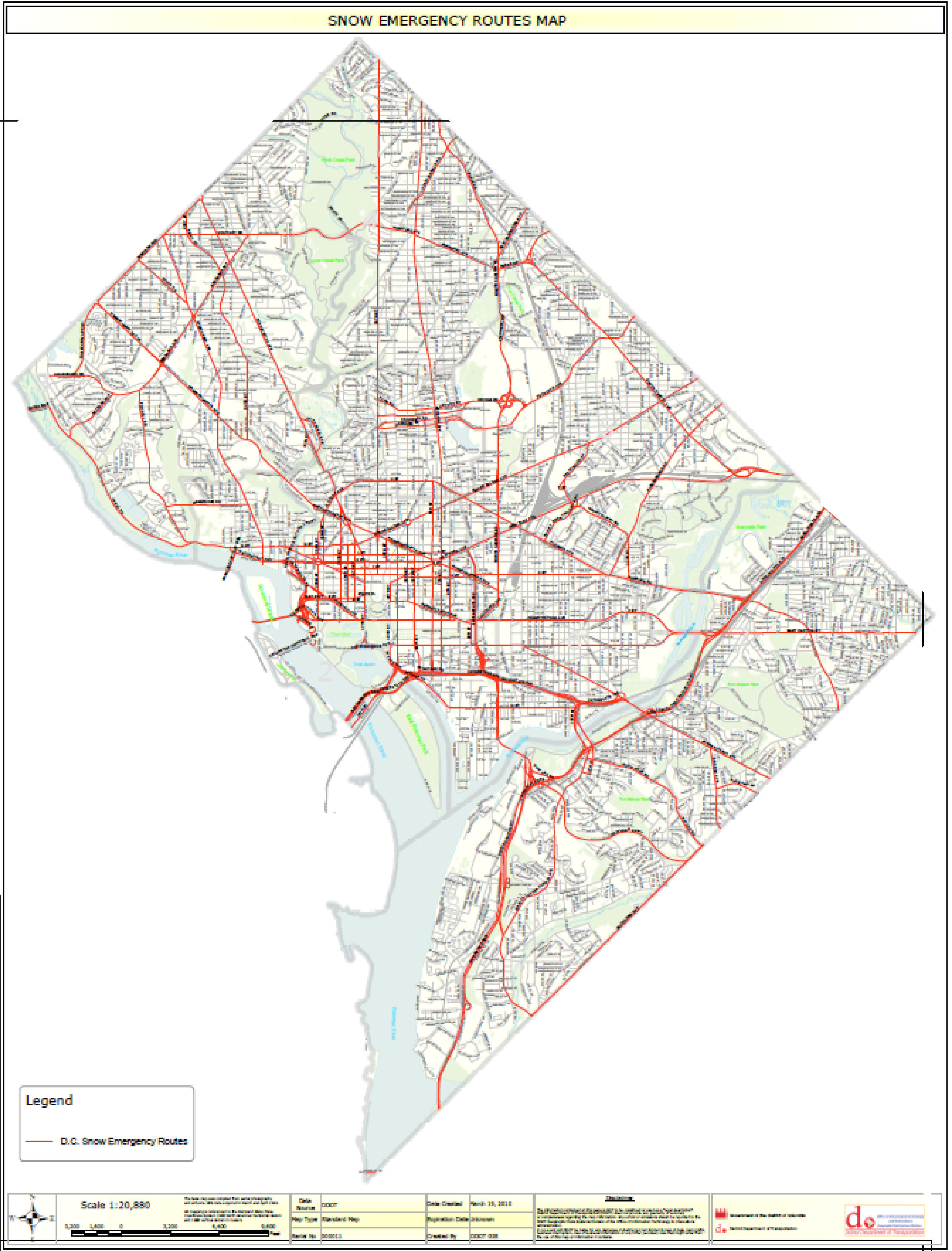
- Roadway Impacts: Ice, snow, sleet, snow drifts, surface glaze
    - School closures, delayed openings, closed sites, crashes
- Railway Impacts: Snow accumulation over 3 inches, icing
    - Snow plans suspend some routes, delays, detours
- Airport Impacts: Ice, snow cover, deicing requirements
    - Ground stops, delays, cancellations, rerouting
- Barge Impacts: Snow, sleet, ice threats for multiple states
    - Regional delays, Georgetown coastal flooding threat
- In the greater DC area, there were no ≥ 8" snowfalls between 1900-08, '09-17, '42-57, '67-78, and '88-95.

Washington (Reagan National), Virginia

Year-to-Date Precipitation — Wettest years

Year-to-Date	Precipitation
January-December 2018	66.30"
January-December 2003	60.85"
January-December 1948	57.57"
January-December 2020	57.37"
January-December 1972	51.97"

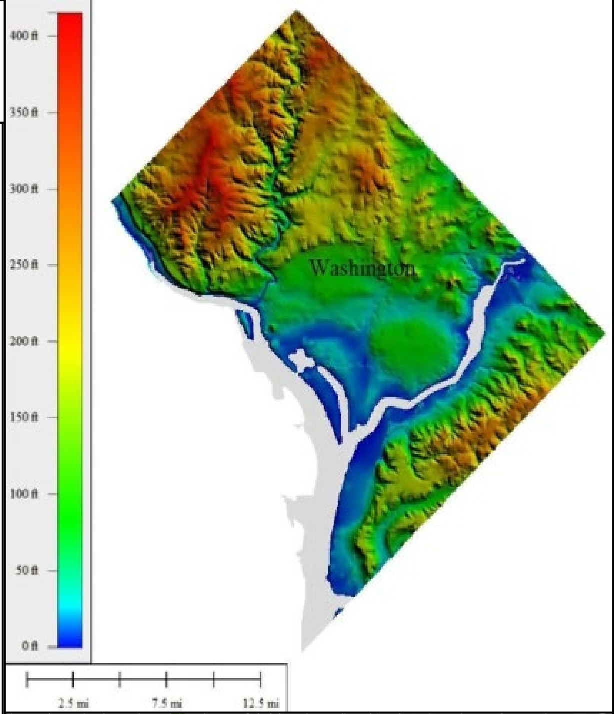




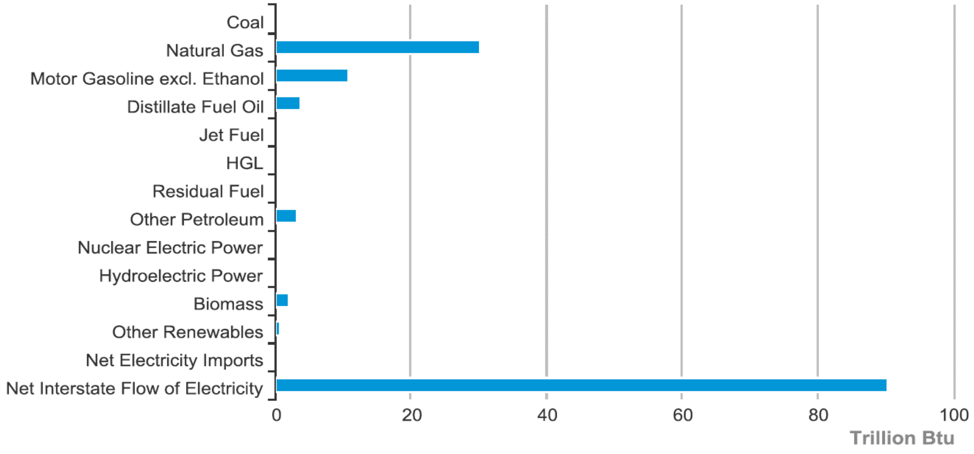
DC Critical Infrastructure and Energy Portfolio

The loss of continuous, health rains across the region have resulted in increased presence of algal blooms and bacteria, threatening drinking water, while needs are increasing for the river to supply water for cooling for such as for the Kennedy Center and powerplants.

- The commercial sector accounts for around three-fifths of total energy consumption in the District of Columbia, a higher share for that sector than in any state.
- The District's Renewable Portfolio Standard requires that 100% of the electricity sold in the city be from renewable sources by 2032, including at least 5.5% from solar energy.
- In 2022, solar energy generated 59% of the total small-scale and utility-scale electricity within the District, natural gas accounted for 24%, and biomass provided 17% of the city's generation.
- The District has more than three times as many public electric vehicle charging locations, about 310 in total, than it does motor gasoline stations, and the city's per capita gasoline expenditures are lower than those of any state.
- The District consumed less electricity in 2022 than all but four states, but its per capita total electricity use is the 13th highest compared to the states. About 98% of the electricity consumed in the city is generated in other states.
- DC imports upwards of 90% of its electricity, while most of what is generated in the District is from rooftop solar resources.
- The average age of sewer mains has increased from 84 years in 2016 to over 90 years in 2020, moving closer to their expected service life of 110 to 120 years.

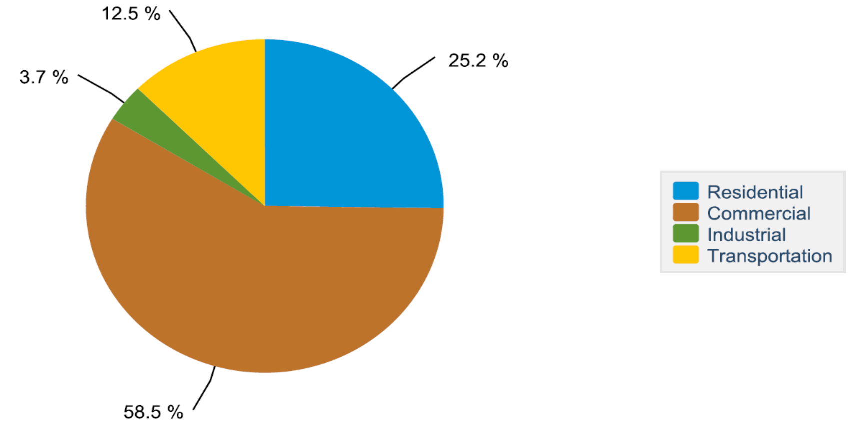


District of Columbia Energy Consumption Estimates, 2022

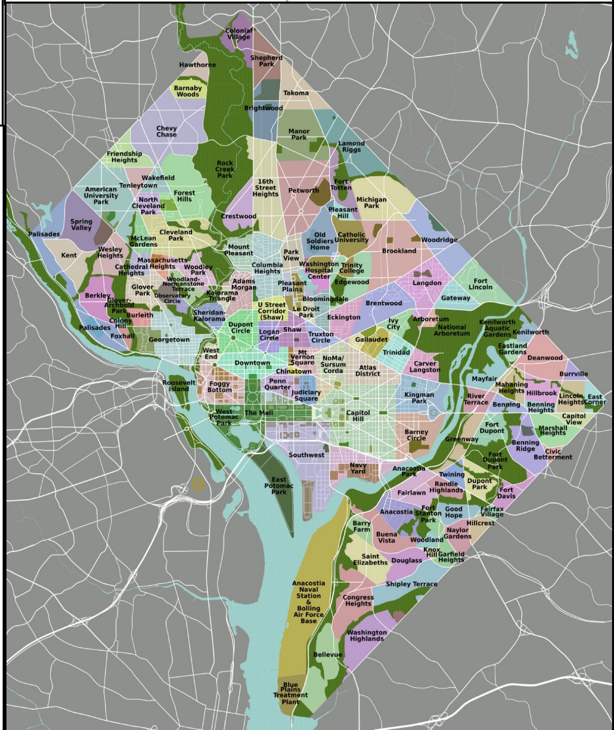


eia Source: Energy Information Administration, State Energy Data System

District of Columbia Energy Consumption by End-Use Sector, 2022



eia Source: Energy Information Administration, State Energy Data System



The Infrastructure Report Card for DC provides the following information: Metropolitan Washington Council of Governments (MWCOG) forecasts that D.C.'s population will grow from 672,200 in 2015 to 987,200 in 2045.

Currently, 70% of the District's bridges have at least one major component listed in fair condition.

- Overall, about 30% of D.C.'s bridges were either built or rehabilitated before 1980. With an average life span of bridge structures at 50 years, these bridges will likely need a major rehabilitation or replacement in the next 10 years, unless there is a robust preventive maintenance program implemented.
- more than 100 D.C. bridges have substandard conditions of their deck geometry, vertical and horizontal clearances, water flow adequacy or approach roadway alignment. Without updates, these structures can lead to unsafe situations for the travelling public, add to mounting congestion problems in the District.
- With an average age of 62 years, D.C. bridges are significantly older than the national average of 44 years.

D.C.'s drinking water comes from the Potomac River, is conveyed by the U.S. Army Corps of Engineers (USACE)-owned Washington Aqueduct and is purchased and delivered to users by the D.C. Water and Sewer Authority (D.C. Water).

- The District's drinking water infrastructure also includes four pumping stations, five reservoirs, three elevated water storage tanks, and 9,300 fire hydrants. Current projections show capacity is sufficient to meet demands through 2030.
    - The median age of the drinking water pipes is 77 years and leaks at over twice the rate of the industry's average.
- In an average year, there are typically 400 to 550 water main breaks in D.C. primarily due to age and deteriorating conditions.

The National Levee Database shows that the District of Columbia has two levee systems: The District of Columbia Levee System (DCLS) and the District of Columbia Anacostia Levee (DCAN), totaling 3.41 miles in length.

- D.C. is susceptible to three types of flooding: riverine flooding from the Potomac and Anacostia Rivers, interior flooding, and coastal storm surge. In addition, the watershed that contributes to Anacostia River flooding originates in Bladensburg, MD, is highly urbanized, and quickly generates large volumes of stormwater during rain events.
- The current system does not provide adequate capacity to reduce the risk of flooding to D.C.
- Within the District of Columba, rail includes 75 track miles, four rail yards, and two passenger stations. Between 223 and 233 trains pass through, depart, or arrive in D.C. on a typical weekday.
- Most of the existing rail infrastructure in D.C. was initially built roughly 120 years ago and in need of upgrades and/ or hardening against prolonged wear and tear – mechanical wear due to length of time in service, train volumes and tonnages - intense weather, including extreme high and low temperatures and flooding.

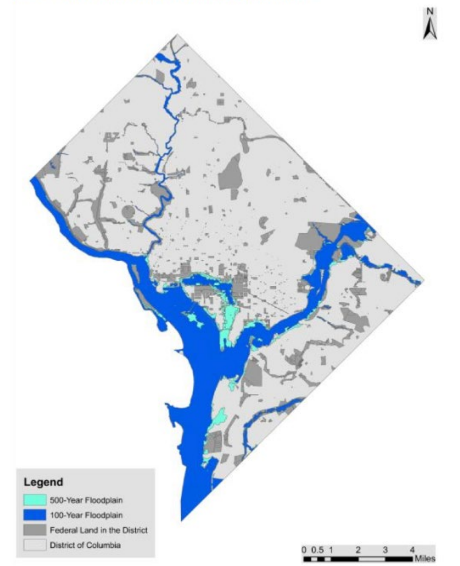
Since Washington, D.C. does not generate any energy within its boundaries from coal, oil, or gas, the District does not have any transmission pipelines or storage facilities. Washington Gas is the sole distributor of natural gas, utilizing approximately 1,392 miles of pipeline in the District.

The District FIRM, shown in Figure 1 (right), was updated in 2010 and shows the SFHA and the extent of the 500-year floodplain.

FEMA FIRMs tend not to depict flood hazards from intense rainfall events, so they do not show all sources of flood risk.

They also may not have the most up-to-date data, particularly in areas where flood risk is changing rapidly from climate changes and/or development.

Figure 1. Special Flood Hazard Areas in Washington, DC



Maryland Statistics

Historic snowfall totals for Baltimore:

- 24 hours: 25.5” – January 2016
- 48 hours: 29.2” – January 2016
- 72 hours: 26.8” – February 2003

Major impacts from winter weather:

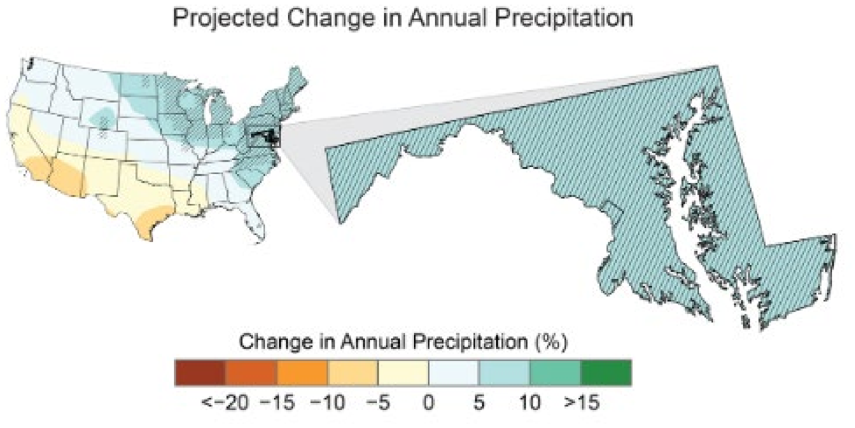
- Over the past decade, Baltimore City has had several strong winter storms that have disrupted regular activities, resulted in auto accidents, and caused power outages.
- Delays in cargo handling in ports and airports likely.

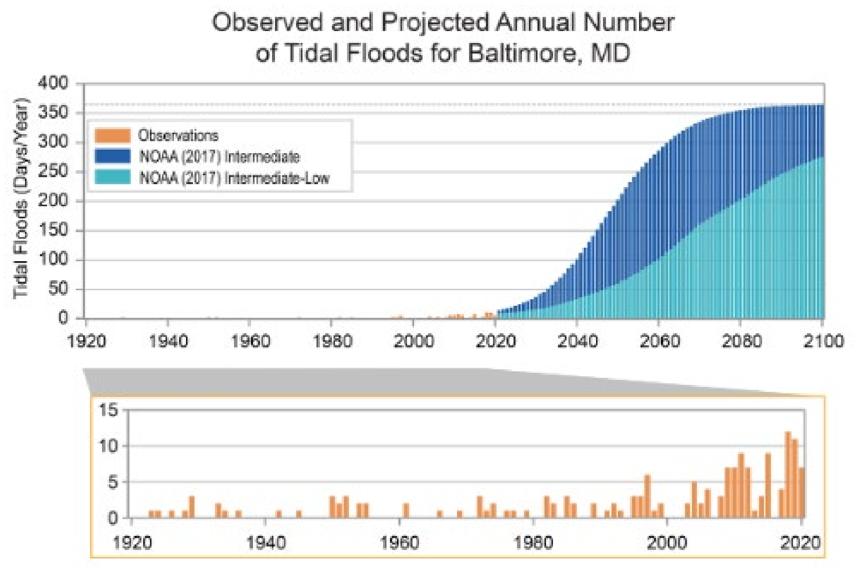
Baltimore receives approximately 21.1 inches of snowfall on average annually.

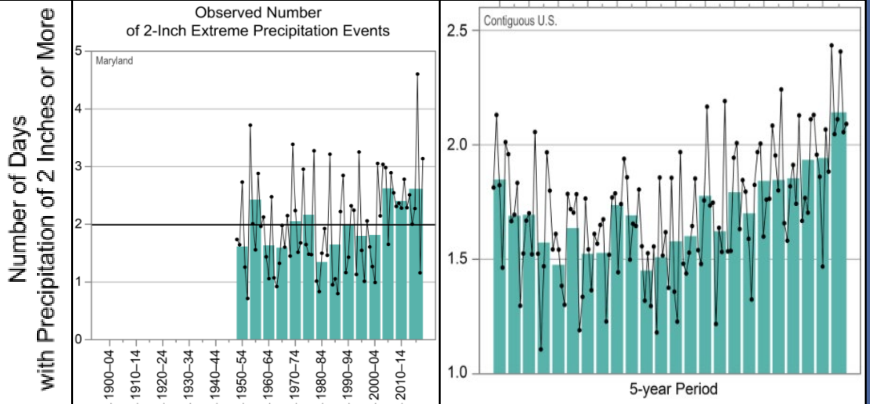
- Snow flurries can be reported as early as September on the Allegheny Plateau, and in October in extreme eastern portions of the State.
- The last snowfall in eastern portions usually occurs in April and on the Allegheny Plateau in May.

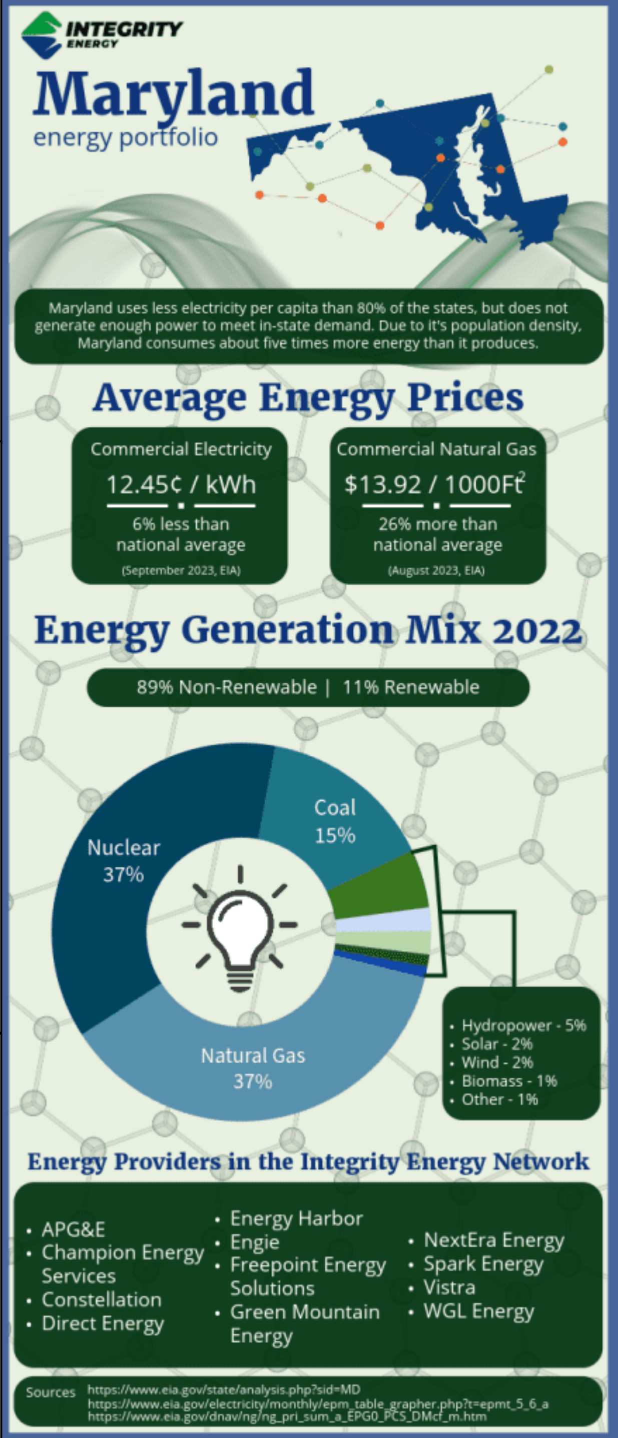
Trends over the past 5 Years indicate winter storms are condensing in intensities, meaning storms which used to take place over 2-3 days are occurring within 48 hours or less for snowfall accumulations, damaging winds, icing events as warming trends persist, and even severe weather longer throughout the year.

The Chesapeake Bay area is the third most vulnerable area of the United States to sea level rise (SLR), behind Louisiana and South Florida.









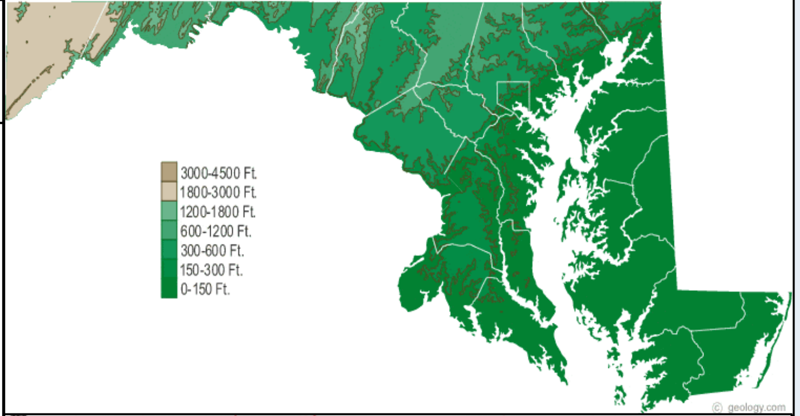
Maryland Weather Data

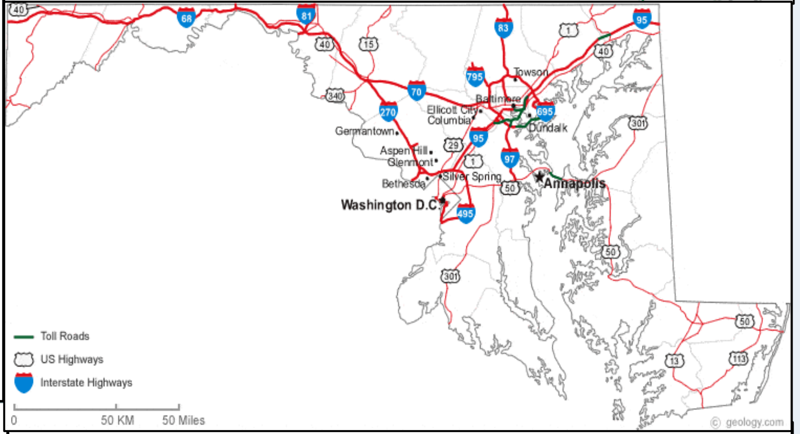
Temperatures in Maryland have risen about 2.5°F since the beginning of the 20th century, and temperatures in this century have been warmer than in any other period.

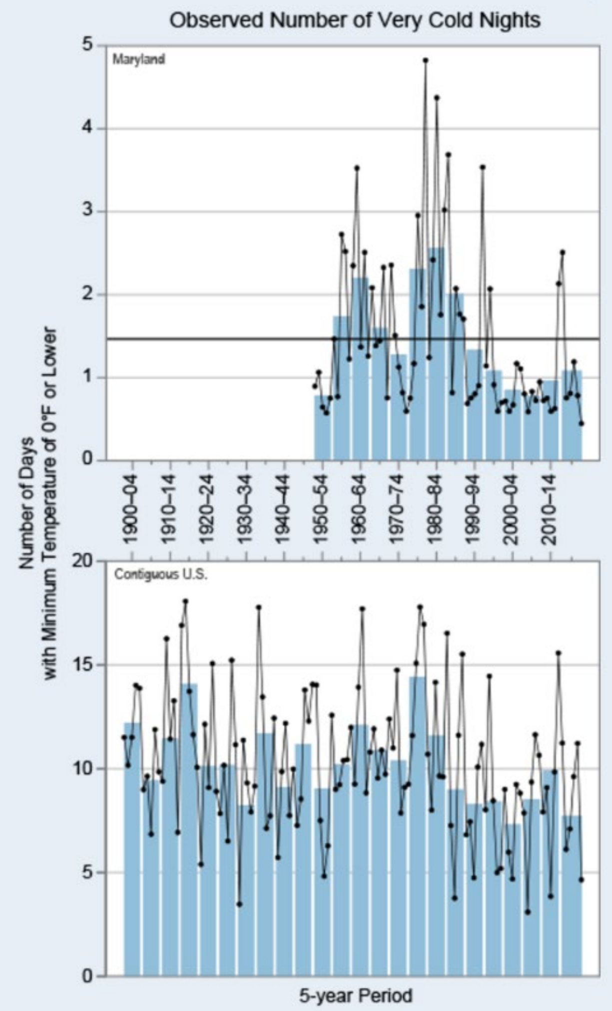
Annual average precipitation in Maryland varies from about 40 inches in the Appalachian Mountain region to about 50 inches in the western and eastern areas of the state.

- Total annual precipitation has been above the long-term average for the last 26 years (1995–2020).
- The annual number of 2-inch extreme precipitation events averaged 2.5 days per year during the 2005–2020 interval, compared to 1.8 days per year during the 1950–2004 interval.

Given recent trends in abnormal warming over winter, there are larger swings in extreme winter events too. This year's winter will develop under La Niña conditions







Prince George's County, MD Flooding

Future Climate Indicators

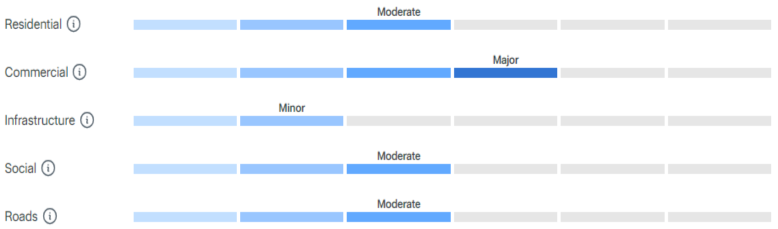
Indicator	Modeled History (1976 - 2005)	Early Century (2015 - 2044)		Mid Century (2035 - 2064)		Late Century (2070 - 2099)	
		Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions
	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max
Precipitation:							
Annual average total precipitation	**42"** 40 - 44	**44"** 41 - 49	**45"** 42 - 50	**45"** 42 - 50	**45"** 42 - 49	**46"** 42 - 51	**47"** 41 - 52
Days per year with precipitation (wet days)	**176 days** 168 - 181	**176 days** 159 - 187	**175 days** 158 - 186	**176 days** 156 - 191	**174 days** 155 - 188	**176 days** 156 - 192	**173 days** 147 - 198
Maximum period of consecutive wet days	**11 days** 10 - 12	**11 days** 10 - 13	**12 days** 10 - 13	**12 days** 10 - 14	**12 days** 10 - 14	**12 days** 10 - 14	**12 days** 10 - 15
Annual days with:							
Annual days with total precipitation > 1inch	**5 days** 5 - 6	**6 days** 4 - 7	**6 days** 5 - 8	**6 days** 5 - 8	**7 days** 5 - 8	**7 days** 5 - 8	**8 days** 5 - 9
Annual days with total precipitation > 2 inches	**0 days** 0 - 1	**1 days** 0 - 1	**1 days** 0 - 1	**1 days** 0 - 1	**1 days** 0 - 1	**1 days** 0 - 1	**1 days** 0 - 1
Annual days with total precipitation > 3 inches	**0 days** 0 - 0	**0 days** 0 - 0	**0 days** 0 - 0	**0 days** 0 - 0	**0 days** 0 - 0	**0 days** 0 - 0	**0 days** 0 - 0
Annual days that exceed 99th percentile precipitation	**6 days** 5 - 7	**7 days** 6 - 8	**7 days** 7 - 8	**7 days** 7 - 8	**8 days** 7 - 9	**8 days** 7 - 9	**9 days** 8 - 11
Days with maximum temperature below 32 °F	**8 days** 6 - 10	**5 days** 1 - 7	**4 days** 2 - 8	**3 days** 1 - 6	**3 days** 1 - 6	**2 days** 0 - 5	**1 days** 0 - 2

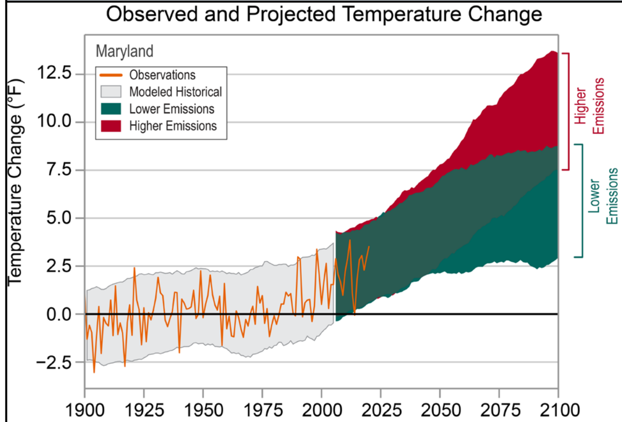
N/A = Data Not Available for the selected area

College Park, MD has moderate risk from flooding. There are 1,239 properties in College Park at risk of flooding over the next 30 years.

Community Impact from Flooding in College Park

In addition to property damage, flooding can cut off access to utilities, emergency services, transportation, and may impact the overall economic well-being of an area. Overall, the city of **College Park** has a **moderate risk from flooding.** This is based on the level of risk the properties face rather than the proportion of properties with risk. To determine community impact from flooding, the operational risk for today and in 30 years is calculated for all properties in the community based on the property use and flooding depth. This includes special calculations for hospitals, power stations, police stations, fire stations, airport, roads, and other critical infrastructure.





Maryland Energy Profile

In 2022, nuclear energy and natural gas generated 75% of Maryland's total in-state electricity, with each supplying almost equal amounts of the power supply.

- Maryland's only nuclear power plant—the two-reactor Calvert Cliffs power plant located on the western shore of the Chesapeake Bay—accounted for about 39% of the state's total net generation.
- Natural gas-fired generation has more than tripled since 2015, as nearly 2,600 megawatts of new natural gas-fired generating capacity came online. Natural gas accounted for about 36% of in-state electricity generation in 2022.
- Coal-fired generating plants historically supplied more than half the state's net generation, but coal's share has been below 50% since 2012 and was at 12% in 2022.

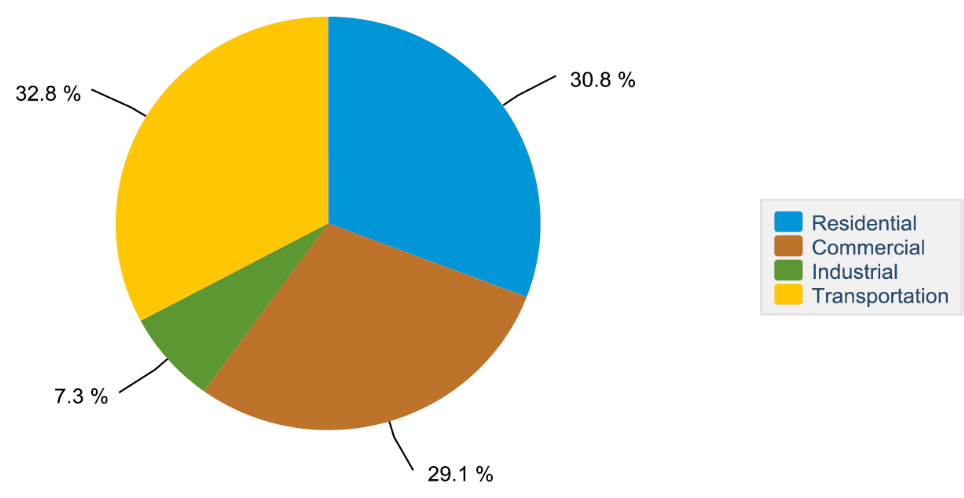
As of mid-2023, there were four generating units at Maryland's three remaining coal-fired power plants with a combined generating capacity of nearly 1,800 megawatts.

- The two largest power plants intend to stop burning coal by 2025 and the smallest plant will end its coal use in mid-2024.
- Solar energy, hydropower, wind, and biomass accounted for most of the state's remaining net generation in 2022. Since 2015, almost all the state's new generating capacity has been natural gas-fired or solar-powered.
- Maryland uses 40% more electricity than it generates with the extra supply being delivered to the state over the regional grid.
- The industrial sector accounts for 6% of the state’s electricity consumption.

Solar powered-generation more than quadrupled from 2015 to 2022.

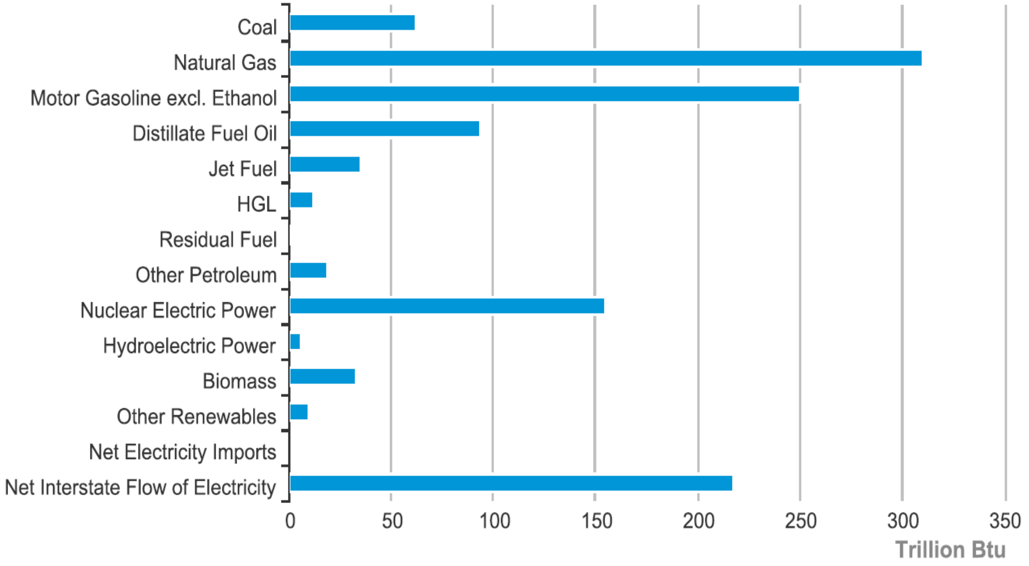
- Nearly two-thirds of the state's solar generation came from small-scale, customer-sited solar photovoltaics (PV), such as rooftop solar panels.

Maryland Energy Consumption by End-Use Sector, 2022



Source: Energy Information Administration, State Energy Data System

Maryland Energy Consumption Estimates, 2022



Source: Energy Information Administration, State Energy Data System

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

Weekly National-International Climate Summary:

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

Bi-Weekly CISA Extreme Weather Working Group:

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

For Questions Contact:

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DHS – CISA – ISD ACOS
202-701-4470 | Sunny.Wescott@cisa.dhs.gov