2022 CHEMICAL SECURITY SUMMIT

August 23-25, 2022

#ChemicalSecurity

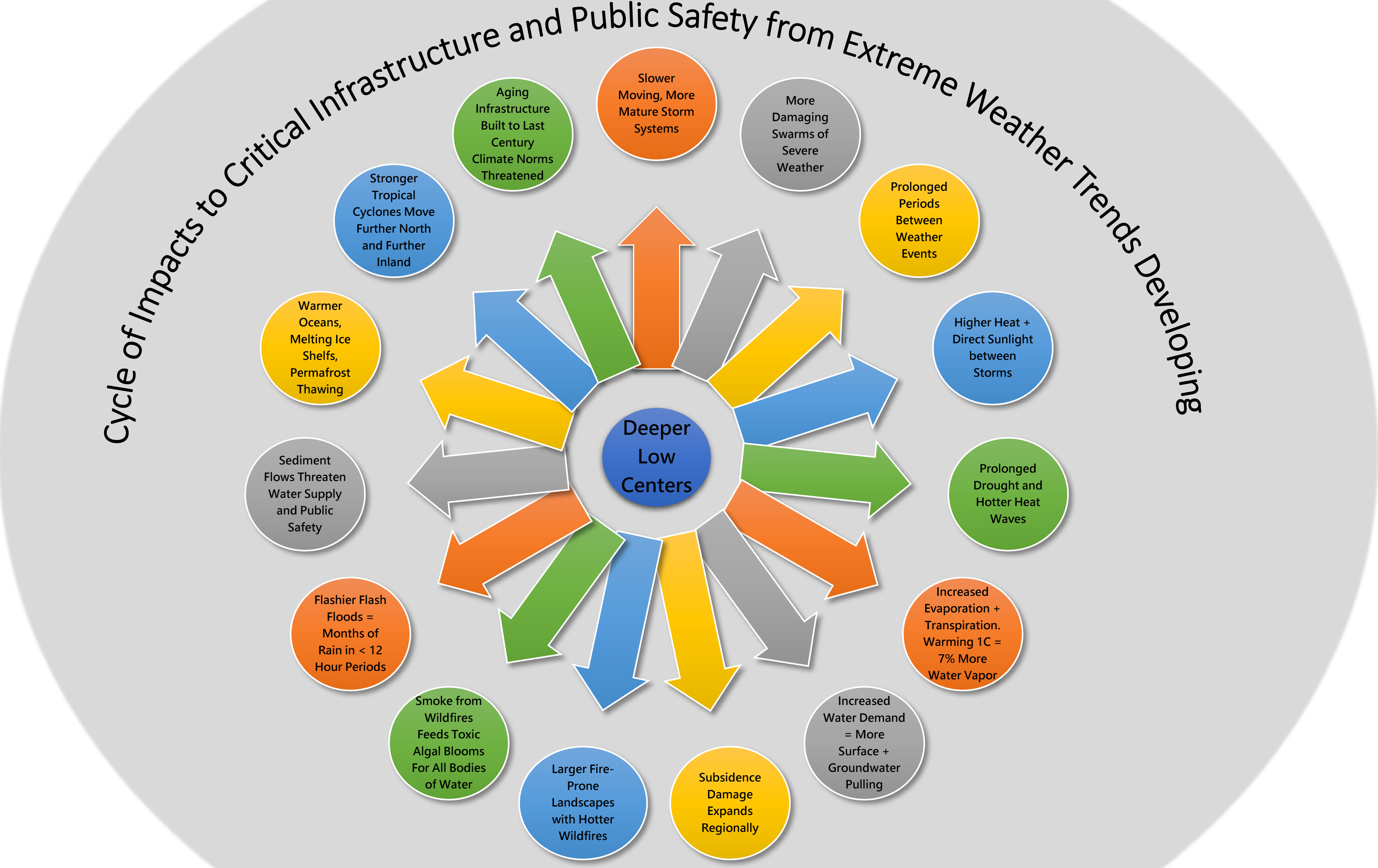
Extreme Weather Trends and Impacts

08/16/2022

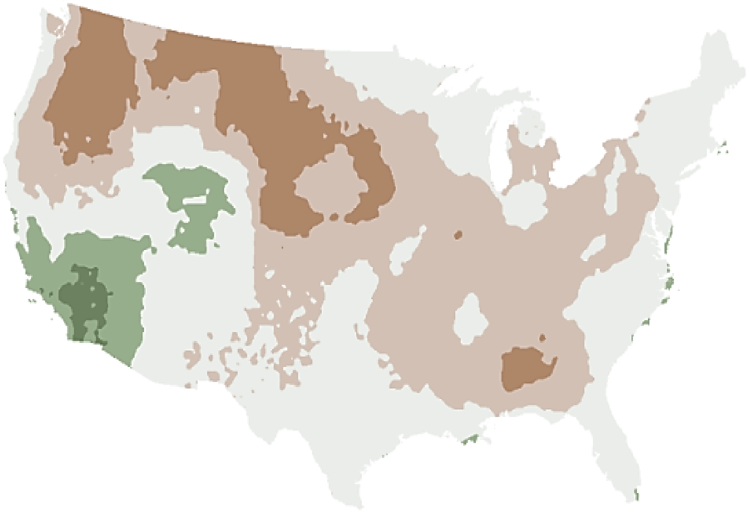
Ms. Sunny Wescott
Lead Meteorologist
ISD Collaboration Cell
202-701-4470 | Sunny.Wescott@cisa.dhs.gov

Interlinked Events

- Extreme Heat
- Prolonged Drought
- Larger Fires
- Pollution
- Agricultural Impacts
- Water Issues
- Increased Flooding
- Astronomical Threats
- Tropical Cyclones


Cycle of Impacts to Critical Infrastructure and Public Safety from Extreme Weather Trends Developing
Deeper Low Centers
Slower Moving, More Mature Storm Systems
More Damaging Swarms of Severe Weather
Prolonged Periods Between Weather Events
Higher Heat + Direct Sunlight between Storms
Prolonged Drought and Hotter Heat Waves
Increased Evaporation + Transpiration. Warming 1C = 7% More Water Vapor
Increased Water Demand = More Surface + Groundwater Pulling
Subsidence Damage Expands Regionally
Larger Fire-Prone Landscapes with Hotter Wildfires
Smoke from Wildfires Feeds Toxic Algal Blooms For All Bodies of Water
Flashier Flash Floods = Months of Rain in < 12 Hour Periods
Sediment Flows Threaten Water Supply and Public Safety
Warmer Oceans, Melting Ice Shelfs, Permafrost Thawing
Stronger Tropical Cyclones Move Further North and Further Inland
Aging Infrastructure Built to Last Century Climate Norms Threatened

RISK FACTOR



Changing humidity

An increase in temperature also leads to an increase in the rate of water evaporation, causing changes to atmospheric humidity that affect the way heat impacts communities.

Change in relative humidity in 30 years

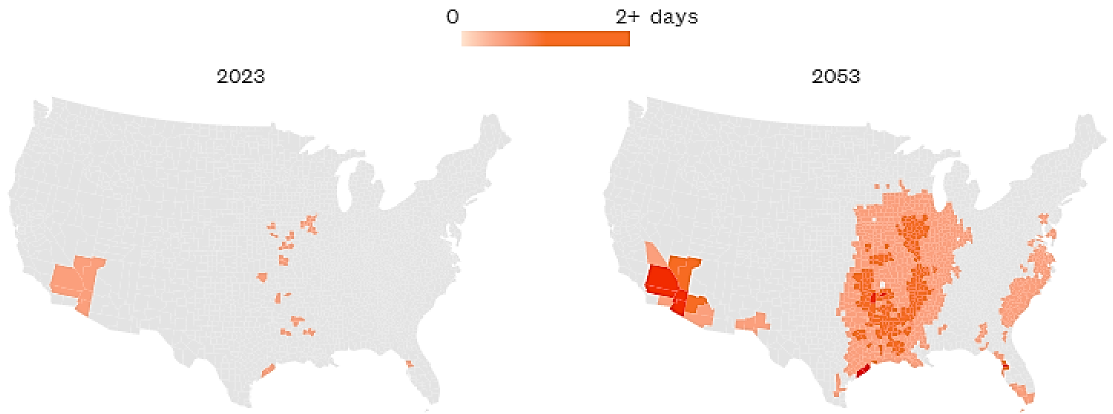
-4% -2% 0% 2% 4%

Climatology Lab MACAv2 downscaled GCM, based on historical period 1950-2005 and adjusted to future conditions using the RCP4.5 emissions scenario.

https://riskfactor.com/

Dangerous heat days

The middle of the U.S. is projected to see a rise in days with heat index temperatures above 125 degrees



Notes: Heat index temperature is the "feels like" temperature – what the temperature feels like to the human body when air temperature is combined with humidity.

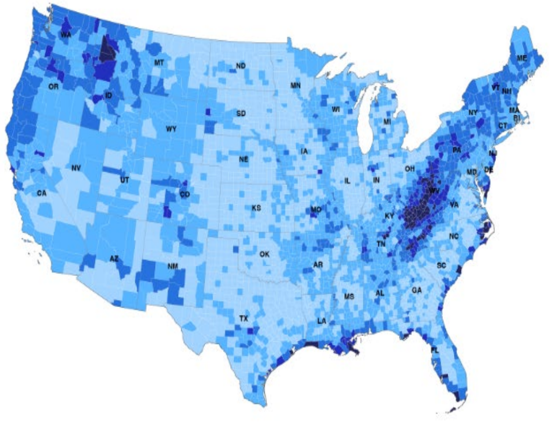
Source: First Street Foundation

Graphic: Nigel Chiwaya / NBC News

FLOOD Risk across the United States

FLOOD FACTOR | FIRE FACTOR | HEAT FACTOR

24.7 M Properties at risk today | **26 M** Properties at risk in 30 years | **5.3 %** Change in risk



Property / County

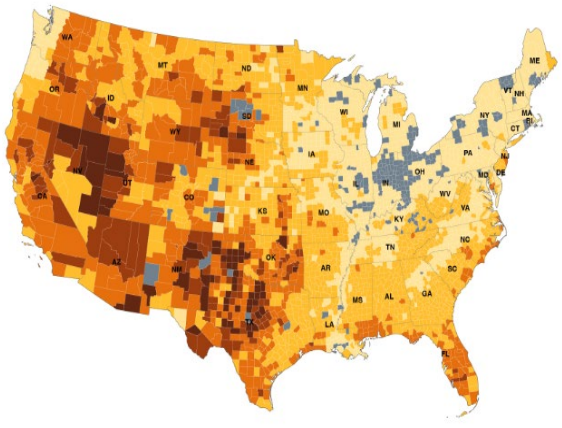
Distribution of properties at risk (145M analyzed)

- Minor - 1.3M
- Moderate - 5.4M
- Major - 7.4M
- Severe - 6.2M
- Extreme - 5.7M

FIRE Risk across the United States

FLOOD FACTOR | FIRE FACTOR | HEAT FACTOR

71.8 M Properties at risk today | **79.8 M** Properties at risk in 30 years | **11.1 %** Change in risk



Property / County

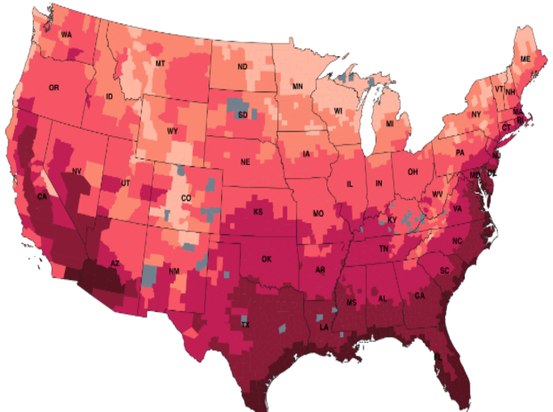
Distribution in properties at ris (145M analyzed)

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

HEAT Risk across the United States

FLOOD FACTOR | FIRE FACTOR | HEAT FACTOR

15.8 M Properties with Extreme Risk | **107 M** Population with yearly days above 125°F in 30 years | **157 %** Avg. increase in local hot days



Property / County

Distribution in properties at risk (145M analyzed)

- Minimal - 6.7M
- Minor - 15.7M
- Moderate - 39.6M
- Major - 36.4M
- Severe - 27.4M
- Extreme - 15.8M

Humans typically stay cool by sweating. As sweat droplets form on the skin, they evaporate in the heat and cool the skin, bringing down the body temperature. As the wet-bulb temperature approaches your core temperature, you lose the ability to cool down.

- Sweat can only evaporate if the air is dry enough to take up moisture. Once the relative humidity surpasses 95%, sweat will collect on the skin and increase heat.
- According to a 2020 study, wet bulb conditions are becoming increasingly common.

If the wet bulb temperature exceeds the human body's skin temperature of around 35°C, 95°F perspiration can no longer act as a cooling mechanism and the body will quickly overheat, which can result in death

- **Air conditioning removes humidity from the air and is the best solution when wet-bulb temperatures get too high**.
- Fans can help sweat evaporate more efficiently, but they're less effective. People die of heat stress at wet-bulb temperatures much lower than 95°F (35°C).

A sustained wet-bulb temperature **exceeding 35°C (95°F)** is likely to be fatal even to fit and healthy people, unclothed in the shade next to a fan; at this temperature human bodies switch from shedding heat to the environment, to gaining heat from it.

- At *wet-bulb* temperatures above 35°C, it is thought that even young, healthy people will *die* in about six hours.
- At an internal temperature of **43°C (109.4°F)** serious brain damage, continuous convulsions, shock, and death are possible results for humans. Cardio-respiratory collapse will likely occur.
- During a heat stroke the body temperature increases to over 104°F. The acute overheating causes a brain edema, that evokes symptoms such as cramps, clouding of consciousness, headache, and sickness. In the worst cases heat stroke ends with lasting brain damages or with death.
- "If there's enough moisture in the air, it's thermodynamically impossible to prevent the body from overheating, even if there is an endless supply of water available, shade, and light clothing."
- People die of heat stress at wet-bulb temperatures lower than 95°F. The wet-bulb temperature during the June 2021 Pacific Northwest heatwave was closer to 77°F.

Within 50 years, states like **Arkansas, Missouri, and Iowa** will likely hit the critical wet-bulb temperature limit (NASA). https://climate.nasa.gov/ask-nasa-climate/3151/too-hot-to-handle-how-climate-change-may-make-some-places-too-hot-to-live/

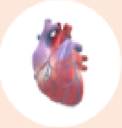
LOW-INCOME FAMILIES ARE DISPROPORTIONATELY AFFECTED BY HIGH HOME ENERGY COSTS.

16.3% OF A LOW-INCOME FAMILIES' GROSS ANNUAL INCOME IS SPENT ON HOME ENERGY COSTS

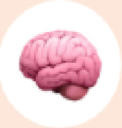
3.5% OF OTHER HOUSEHOLDS' ANNUAL INCOME IS SPENT ON HOME ENERGY COSTS COMPARATIVELY

Heat Affects Health in Many Ways

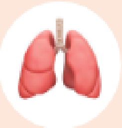
Warmer temperatures increase the risk for a diverse range of health risks. For example:



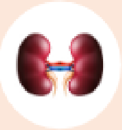
An increased risk of **hospitalization for heart disease**.



Heat exhaustion, which can lead to **heat stroke** if not treated, can cause critical illness, brain injury, and even death.

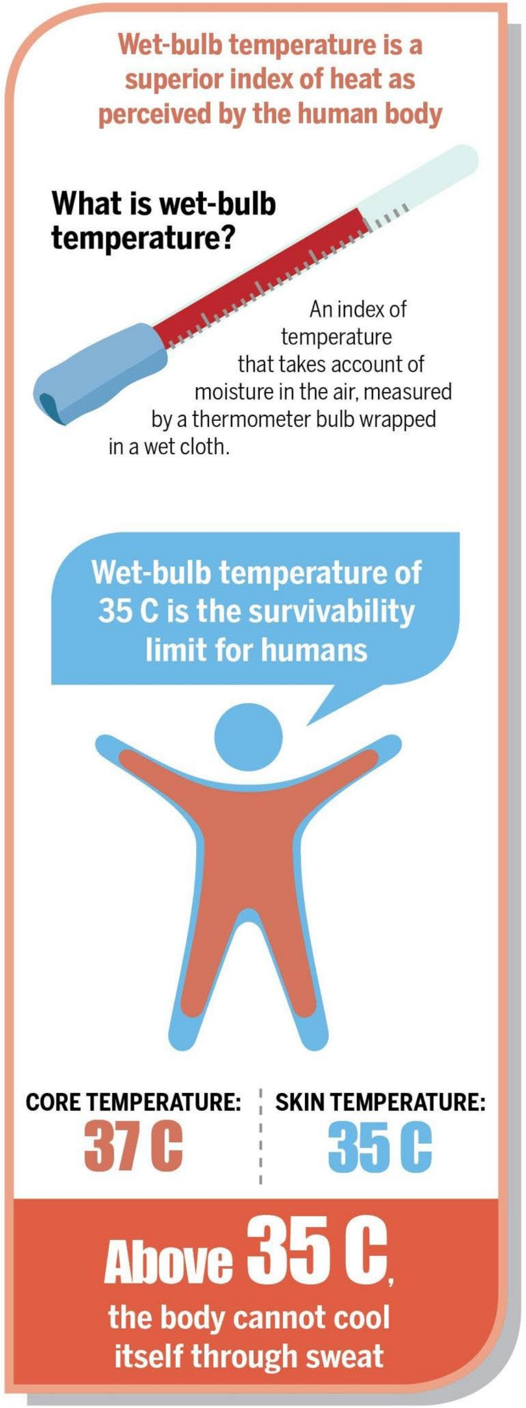


Worsening **asthma** and **chronic obstructive pulmonary disease (COPD)** as heat increases the production of ground-level ozone.



Dehydration, which can lead to **kidney injury** and blood pressure problems. Some kidney damage can become irreversible with repeated or untreated injury.

Violence, **crime**, and **suicide** may increase with temperature, adding to the rates of depression and anxiety already associated with climate change.



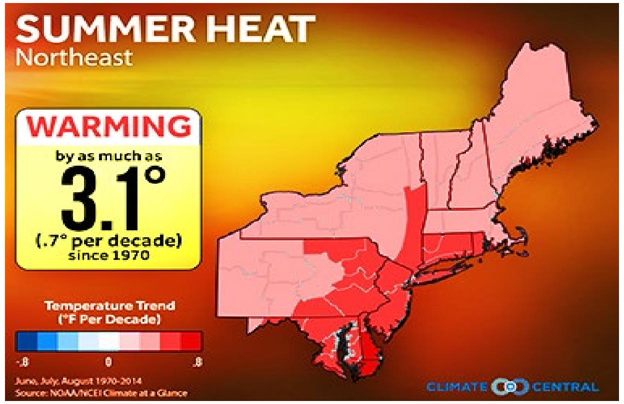
How Does This Impact CI?

Global average surface temperature has risen at an average rate of **0.17°F per decade since 1901** like the rate of warming within the contiguous 48 states.

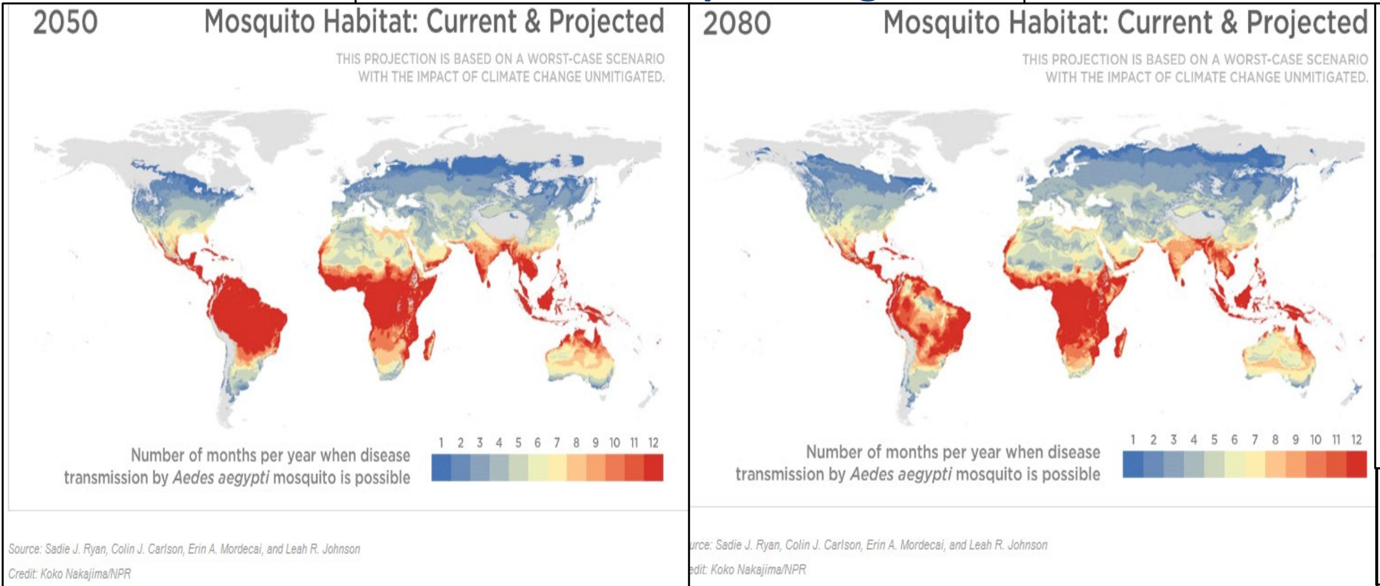
Buckling Roadways
Warping Railways
Runway Defects
Energy Infrastructure Impacts
Permanently Damaged Crops
Widespread Algal Blooms
Depleted Water Oxygen
Livestock/Fishery Deaths
Deadly Ambient Air Temperatures
Wildlife Incursions Increasing
Cement/Concrete/Tar Degradation

Building Insect Swarms
Decreased Hibernation Periods
Increasing Longevity of Insects
Migration Pattern Shifts
Wildfire Climate Growth
Flash Drought Amplification
Wet-Bulb Days Increasing
Roofing/Insulation Damage
Cast Iron Bridge Support Cracking
Decreased Surface Water
Exposed Structural Support

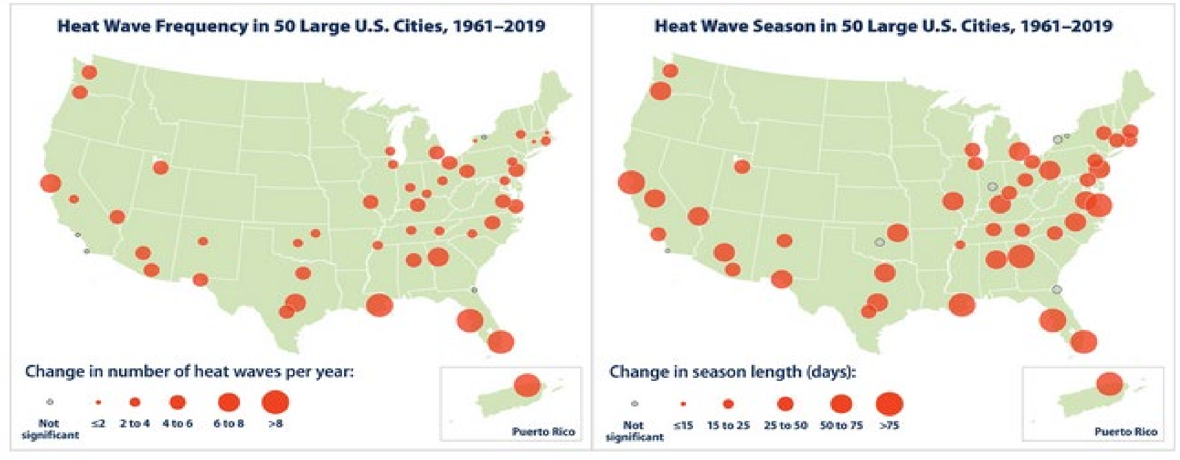
Earthen Dam Damages
Decreased Transportation
Lack of Adhesion Materials
Strain on Medical Services
Overwhelmed Morgues
Military Operations Impact
Readiness Degradation
Contaminated Water Sources
Loss or Lack of Critical Staff
Heat Creates More Ozone
Increased Human Mortality Rates



Forecasted Mosquito Migration



EPA United States Environmental Protection Agency

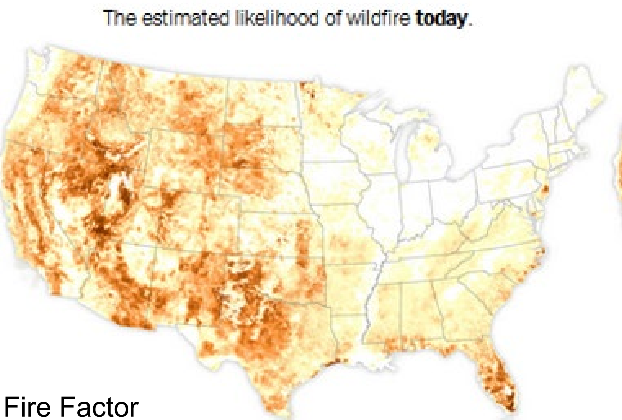


These maps represent the number of heat waves per year (frequency) and the number of days between the first and last heat wave of the year (season length) compared with the local temperature threshold for defining a heat wave across 50 U.S. metropolitan areas

FIRE WEATHER

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

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



Fire Factor

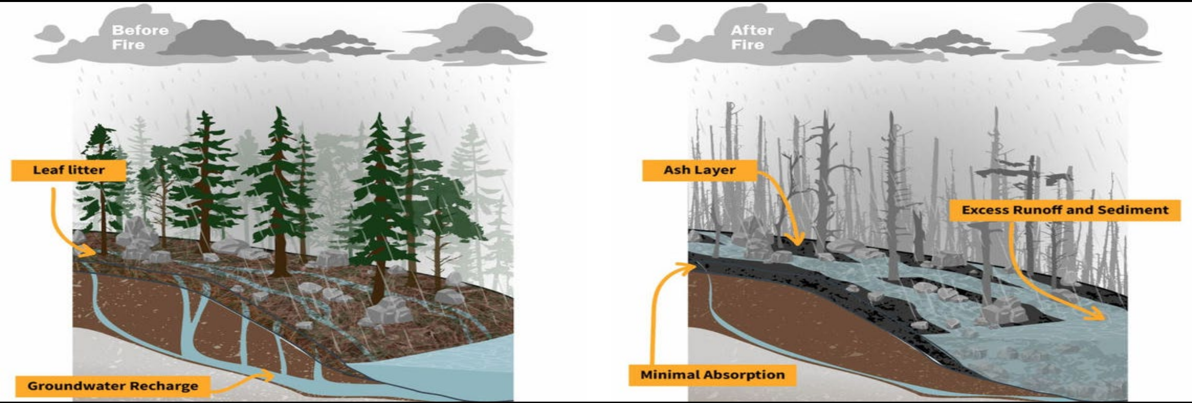
A study from the University of Colorado states wildfires have become larger, more frequent, and more widespread since the year 2000.

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

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

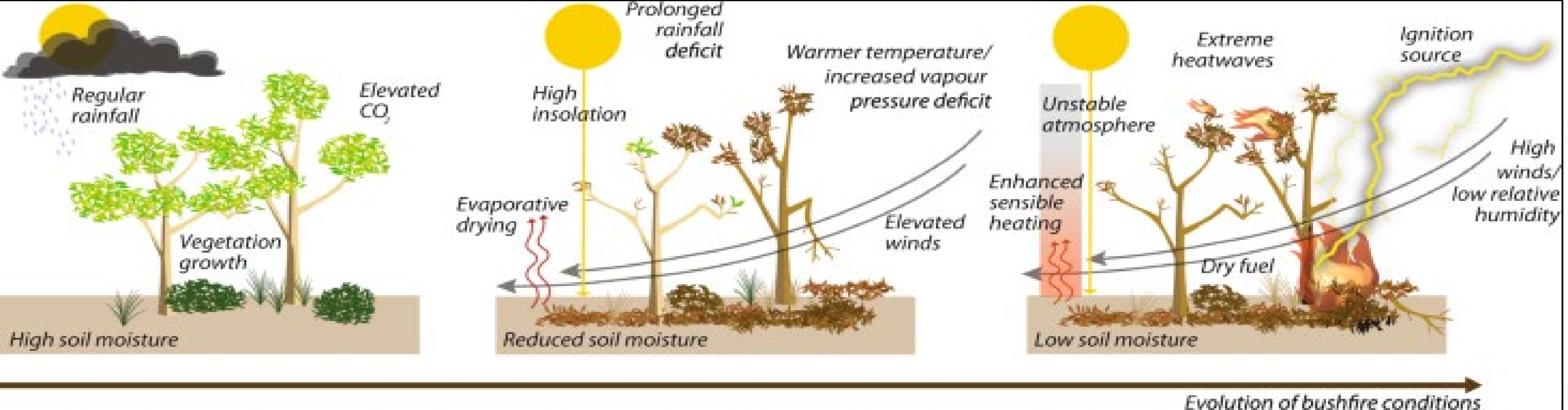
Satellite imagery and state/federal fire history records from 28,000 fires in 1984-2018 showed more fires occurred in the past 13 years than the previous 20 years. On the West and East coasts, fire frequency **doubled**. In the Great Plains, fire frequency **quadrupled**.

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

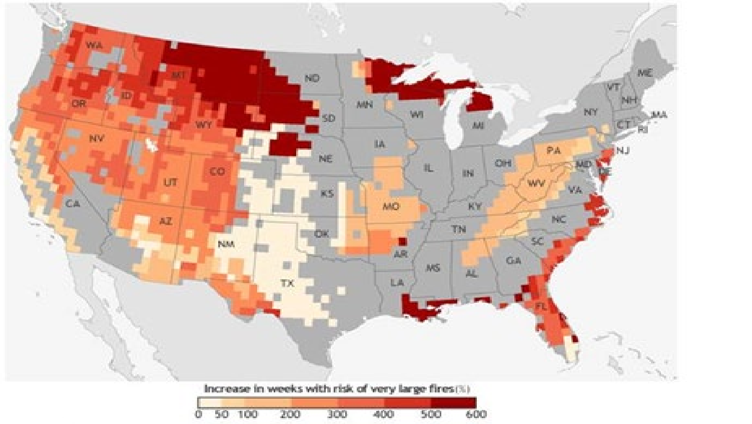


Disasters related to weather, climate, or water hazards happen five times more often now than they did in the 1970s. Droughts that may have occurred only once every decade or so now happen 70% more often.

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



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



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

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

Fire severity describes ecosystem responses to fire and is useful for conveying the effects of fire on the soil and water system. Severity reflects the amount of energy (heat) that is released by a fire and the degree that it affects the soil and water resources. It is classified according to postfire criteria on the site burned and is classified into *low*, *moderate*, and *high*.

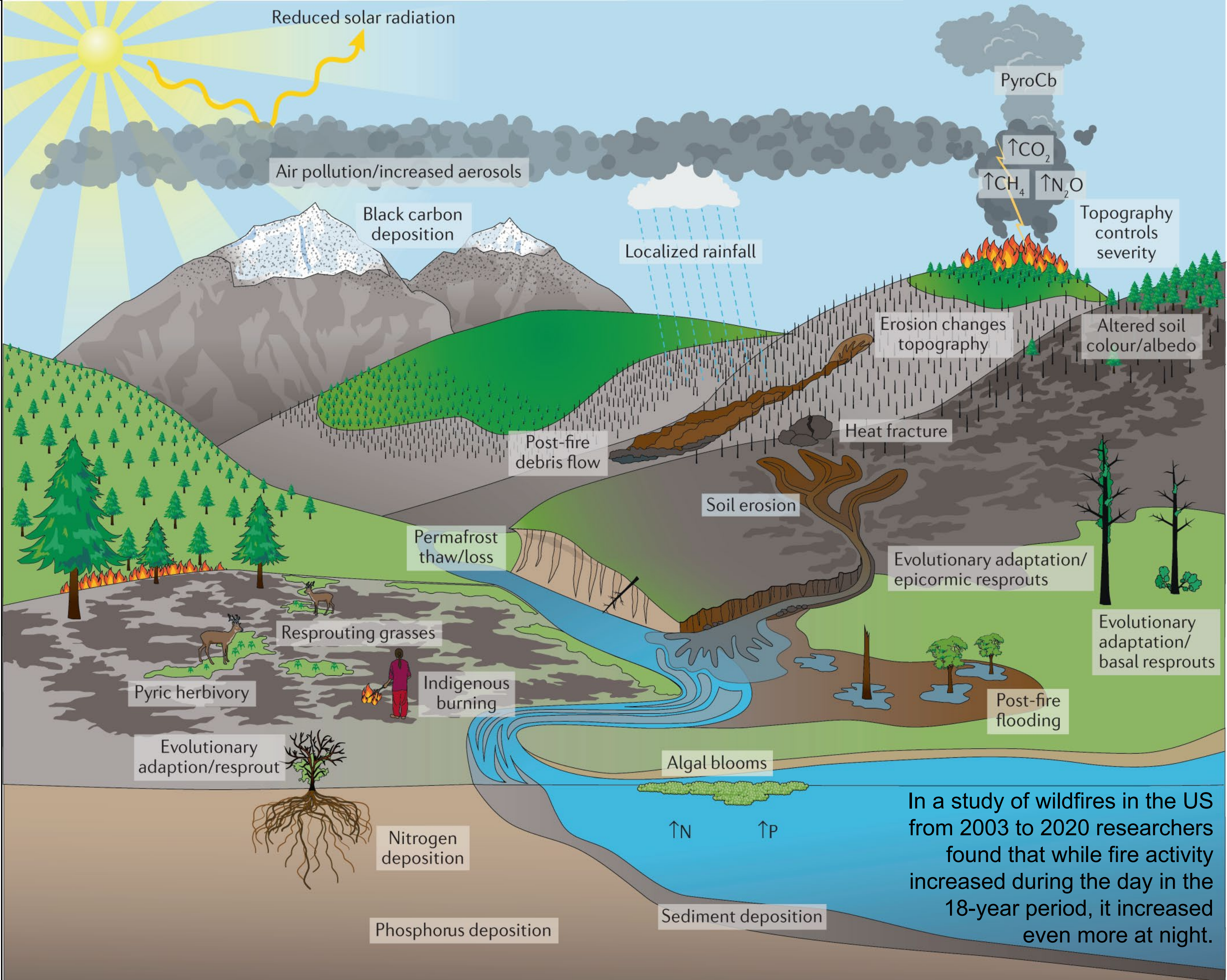
- Heat transfer in the soil during the combustion of aboveground fuels and surface organic layer.
- High intensity fires can produce high severity changes in the soil and cause water phobic layers.
- Combustion is the rapid physical-chemical destruction of organic matter that releases the large amounts of energy stored in fuels as heat.

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

- Damaged soil from heat transfer result in less fire-resistant plant retention and more scraggly brush.

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

Fires are getting larger and harder to extinguish.



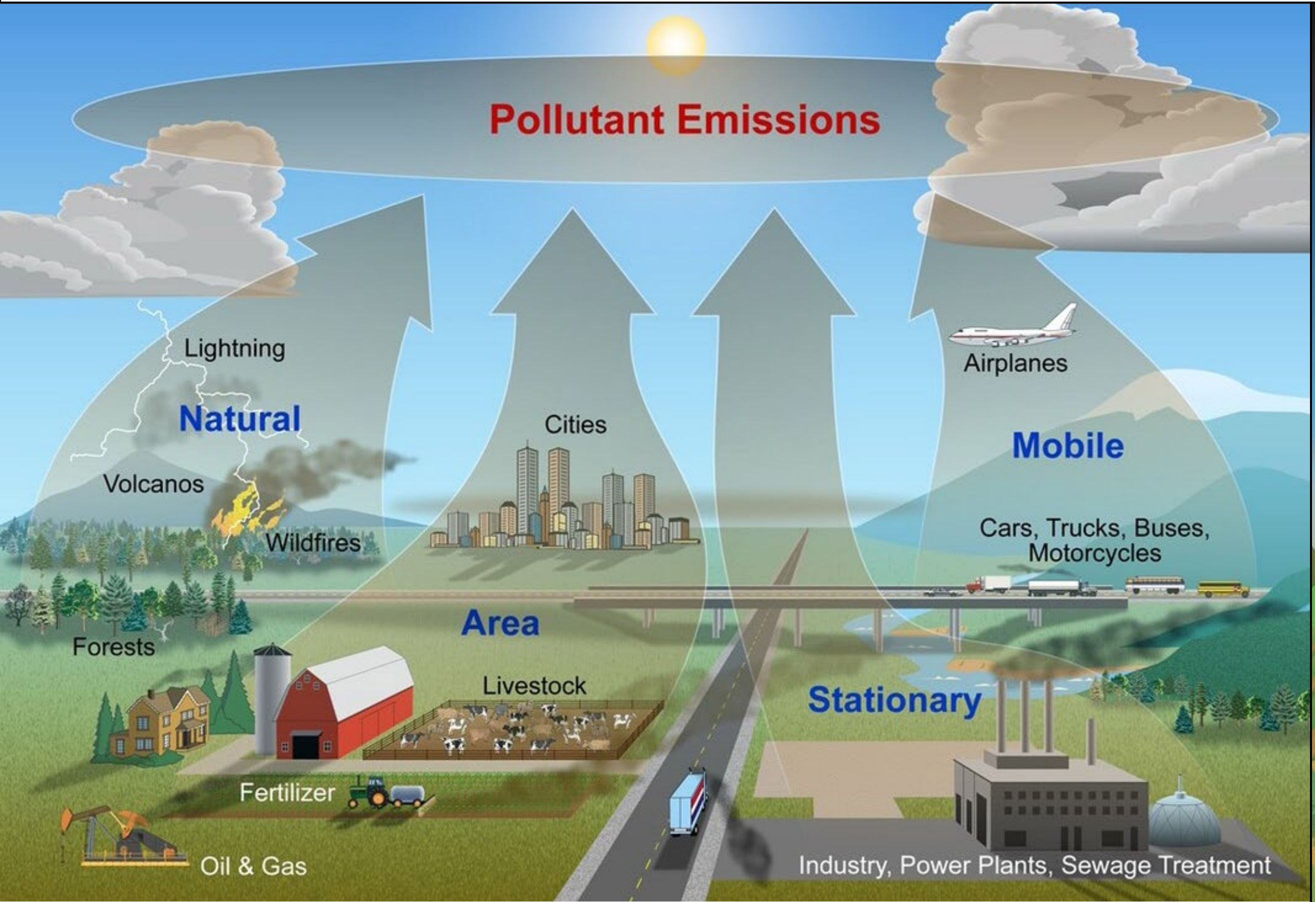
https://www.fs.fed.us/rm/pubs/rmrs_gtr042_4.pdf

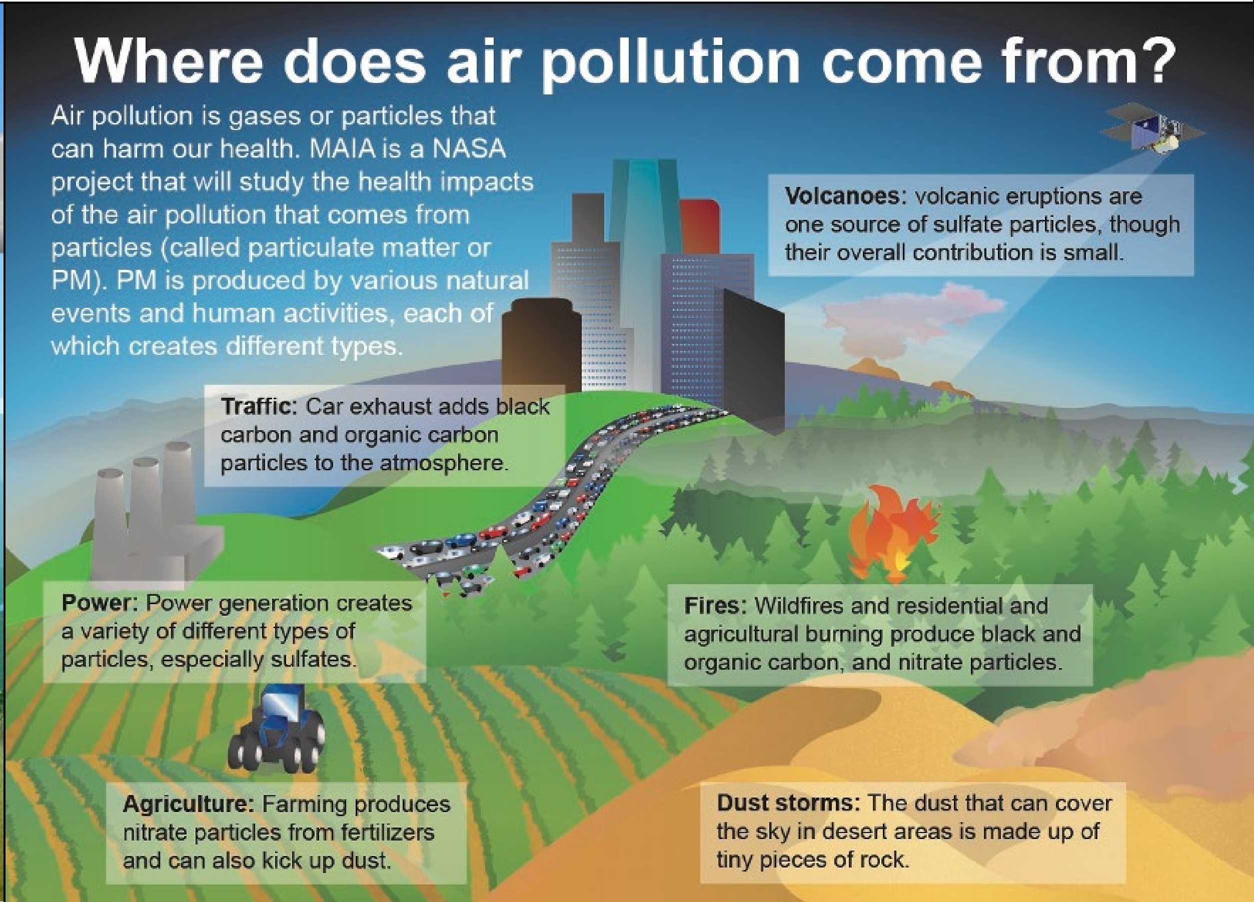
Air pollution is caused by solid and liquid particles and certain gases that are suspended in the air. These particles and gases can come from car and truck exhaust, factories, dust, pollen, mold spores, volcanoes and wildfires. The solid and liquid particles suspended in our air are called **aerosols**. (NASA)

- Any particle that gets picked up into the air or is formed from chemical reactions in the air can be an aerosol. Many aerosols enter the atmosphere when we burn fossil fuels, such as coal and petroleum, and wood. These particles can come from many sources, including car exhaust, factories and even wildfires.
- Some of the particles and gases come directly from these sources, but others form through chemical reactions in the air. Aerosols can come from other places, too, such as ash from an erupting volcano. Dust, pollen from plants and mold spores are also examples of aerosols.
- A gas called **ozone** is a major cause of air pollution. Ozone is also a greenhouse gas that can be both good and bad for our environment.

Ground-level ozone is formed when **volatile organic compounds (VOCs), also known as hydrocarbons, and nitrogen oxides (NOx)** interact in the presence of sunlight.

Sources of VOC and NOx emissions include large industry such as chemical manufacturers, and combustion sources such as power plants burning fossil fuels; small industry such as gasoline-dispensing facilities, autobody paint shops, and print shops; automobiles, trucks and buses; and off-road engines such as aircraft, locomotives, construction equipment and gasoline-powered lawn and garden equipment.



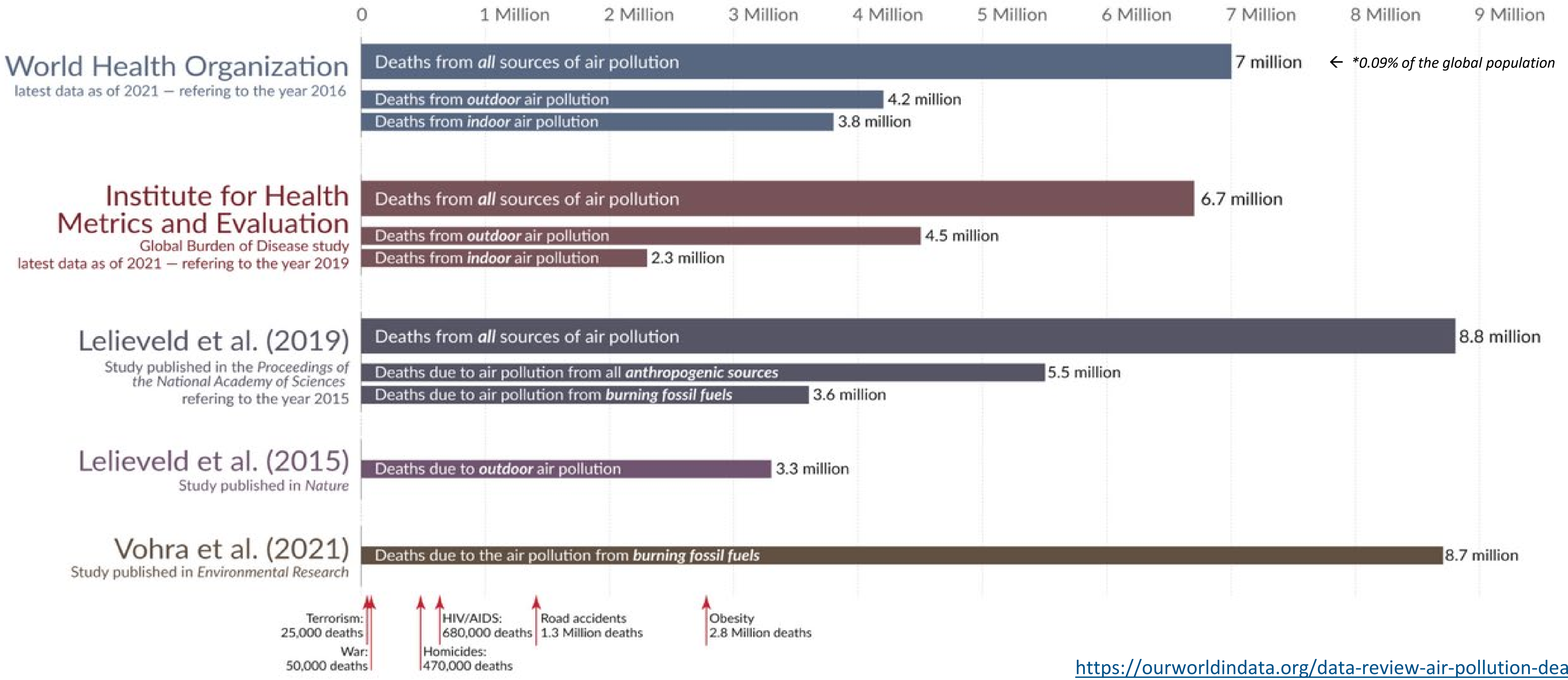


How many people die from air pollution each year?

Estimates of the global death toll from air pollution published in major recent studies

'All sources' includes both anthropogenic and natural sources:

- The largest source of natural air pollution is airborne dust in the world's deserts. Other natural sources are fires, sea spray, pollen, and volcanoes.
- Anthropogenic sources include electricity production; the burning of solid fuels for cooking and heating in poor households; agriculture; industry; and road transport.



https://ourworldindata.org/data-review-air-pollution-deaths

Data on annual death tolls from other causes is the latest data from the World Health Organization, UCDP, and Global Terrorism Database as of November 2021.

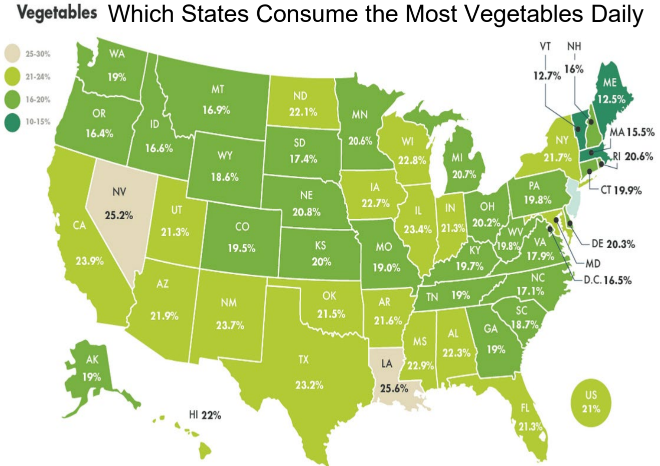
OurWorldinData.org – Research and data to make progress against the world's largest problems.

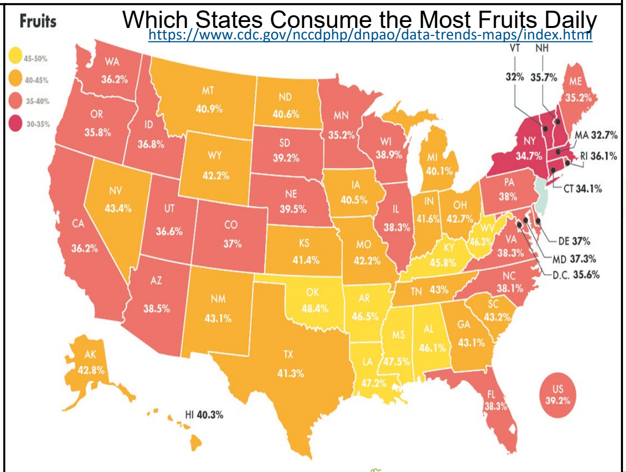
AGRICULTURAL SECTOR

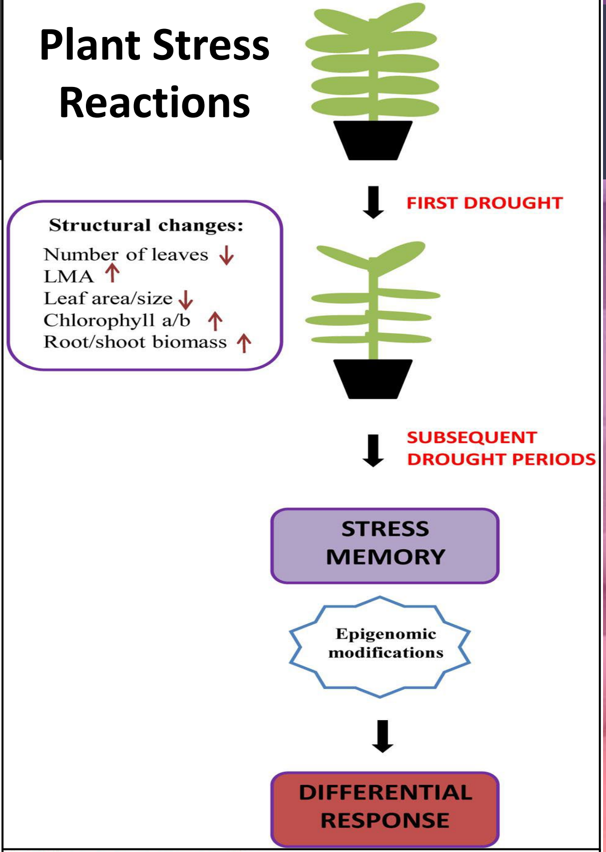
Recent studies have indicated as plants continuously are exposed to drought conditions; the quality of the plant perpetuates degradation.

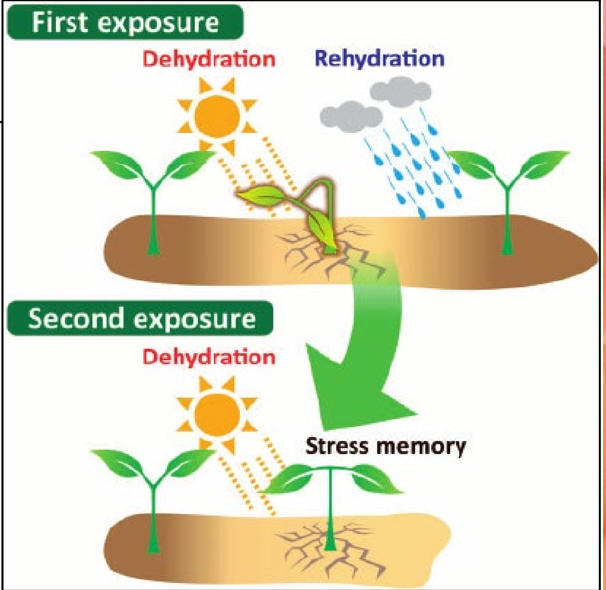
- The plant's memory retains the exposure and associated stress from the abiotic abnormal event causing the overall yield and size of the plant to permanently reduce.
- Seedlings from stressed plants can prematurely sprout as overall global temperature increases continue, meaning harvests will be more susceptible to late season frosts or annual flooding periods when plants normally would hibernate.
- Recent studies at Pennsylvania State University tracked the ability to induce stress inheritance within plants.
    - "When plants are modified epigenetically, they can modify many genes in as simple a manner as possible," Mackenzie pointed out. That includes adjusting the circadian clock, detecting light and triggering growth and reproductive phases, and modifying hormone responses to give them maximum flexibility, making them more resilient."
    - By adjusting the epigenetic architecture of a plant, researchers were able to access its resiliency network, and see how genes are expressed quickly and broadly to adjust a plant's growth to adapt to the environment.

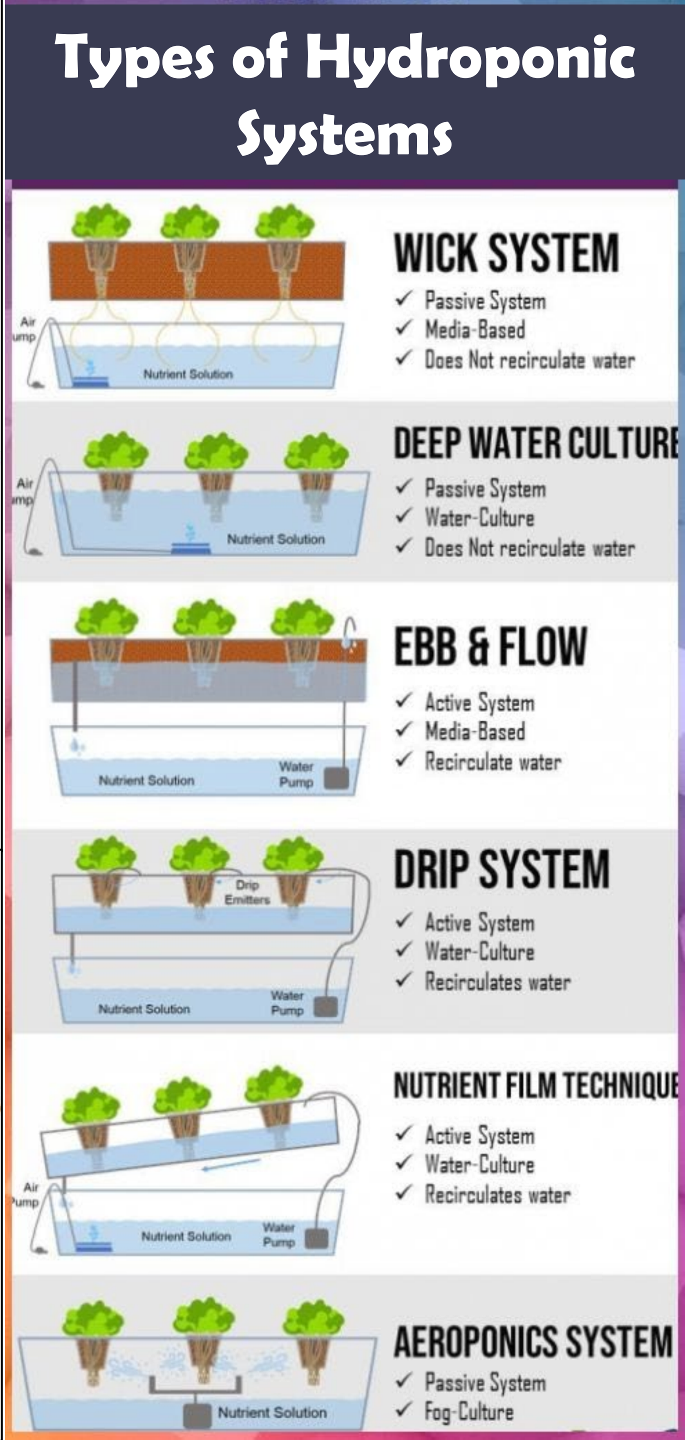
Potential Solutions: Hydroponic systems, moving plants into a covered atmosphere such as a greenhouse, shifting to vertical plant landscapes, greywater and blackwater recycling systems, drip irrigation systems, shade netting, hybrid breeding plants to be more heat and drought resistant regionally, or genetic isolation of traits for new generation of seedlings.

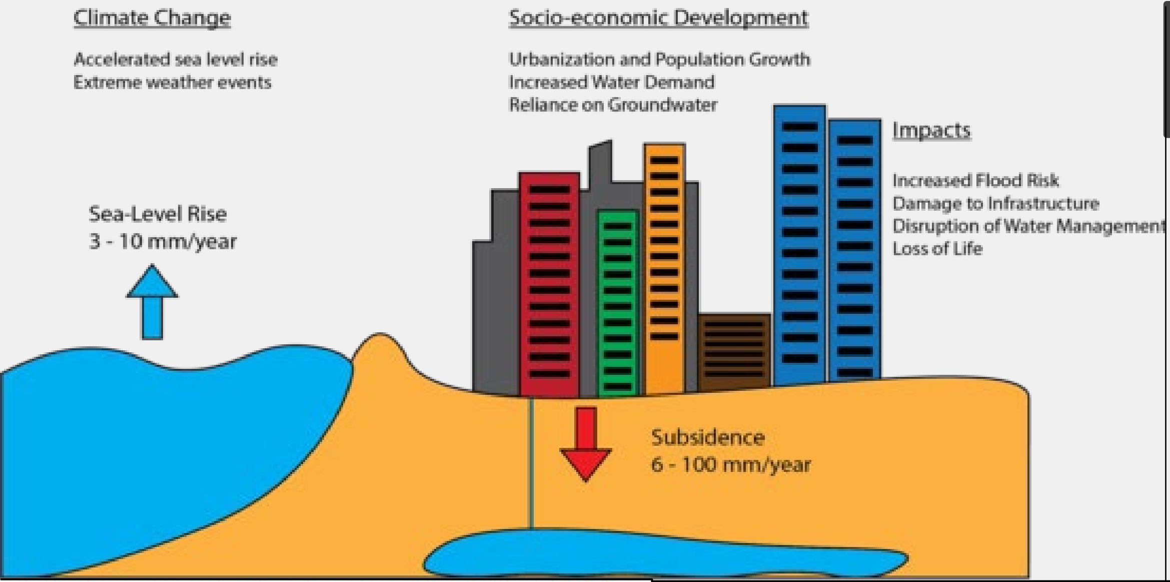












STUDYING SUBSIDENCE

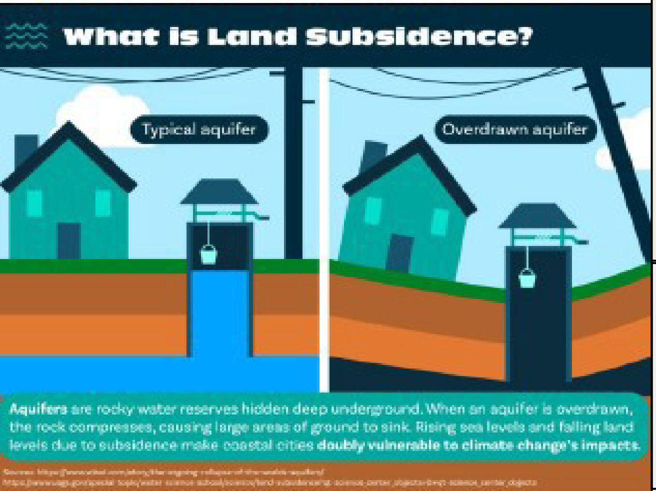
Subsidence has been recorded in the US at a rate of nearly 2-feet over three years for some aqueducts.

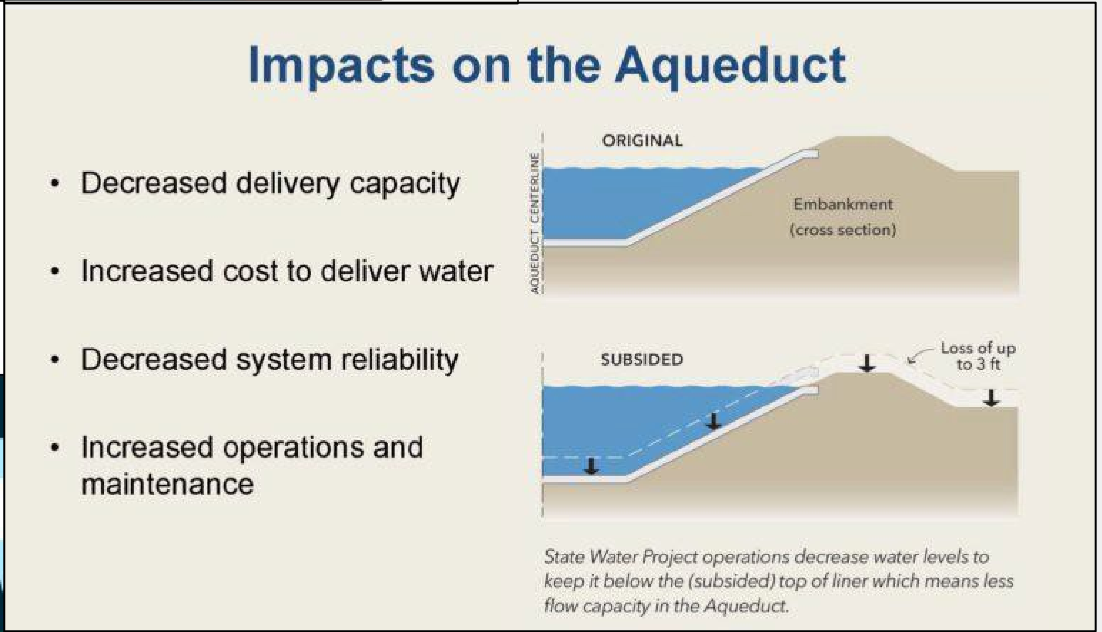
- Utilizing aqueducts to channel water from one area to another, pulling from wells at a faster rate, digging new wells to pull from the underground aquifers, pumping water from lakes/rivers, and creating supplementary channels along canals to siphon water from set provisions has compounded the upstream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

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

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

"The removal of water from aquifers without incoming rainfall or replenishment at the same or greater rate is causing the water table to lower beyond reach of wells and aqueducts which is resulting in deeper wells and more digging, further compounding the loss of water within the aquifer. The soil at that point loses the underneath saturation and begins to condense, known as compacting, and as the weight of the surface infrastructure in the area compounds the soil further, the region along the dried aquifer experiences subsidence (sinking) and the potential collapse the cavernous aquifer left without water to fill the volume. Mexico City, Tehran, rural Iraq, China, Turkey, Texas, and various parts of California have radar-confirmed studies linking subsidence to this issue with lasting damage to the structural integrity of various types of infrastructure considered to be imminent and potentially deadly if not mitigated." – Sunny Wescott, Meteorologist





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

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

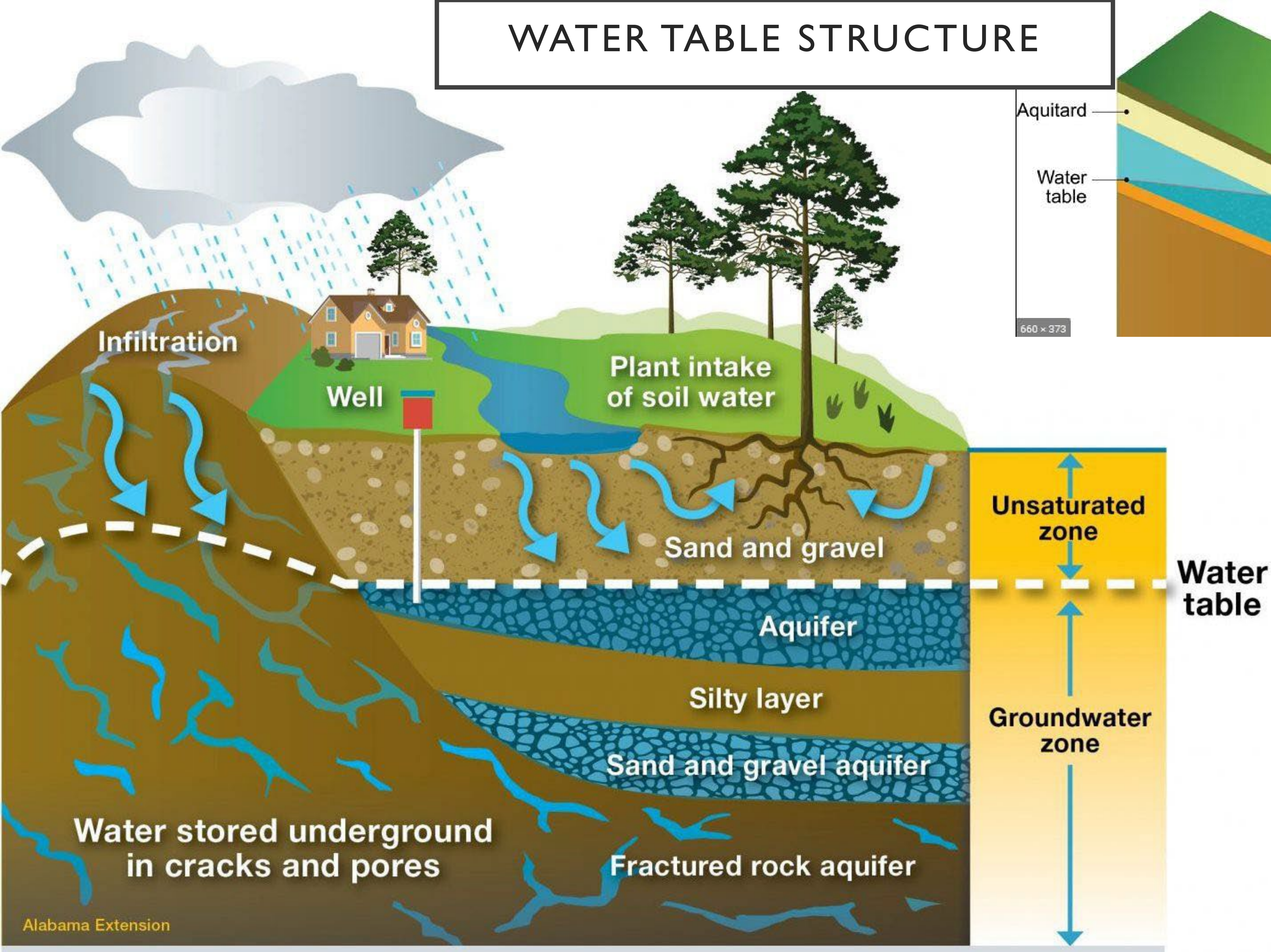
It takes about two years for rainwater drought to become groundwater drought, though in some cases it takes up to 15 years if rainfall persists below average throughout a region.

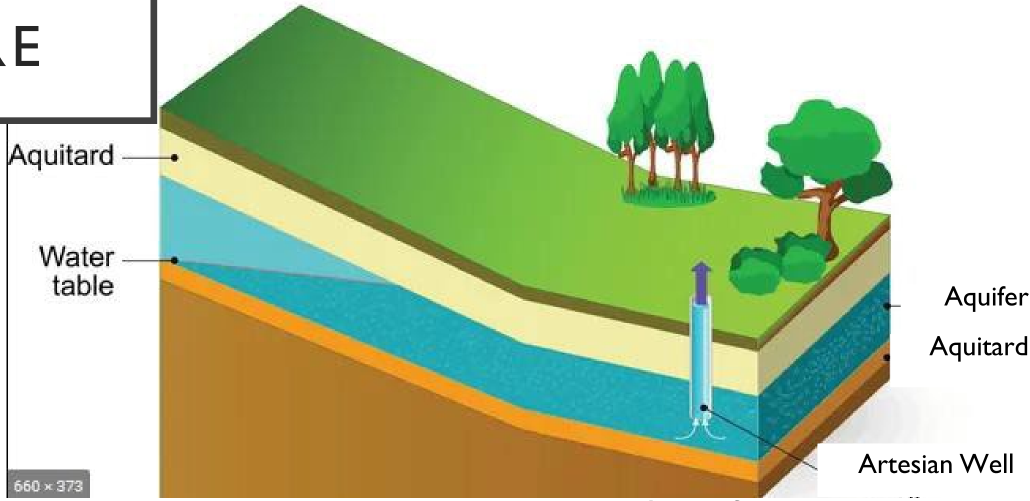
- Subsidence in the United States has directly affected more than 17,000 square miles in 45 states, and associated annual costs are estimated to be over $125 million.
- The principal causes of subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydro compaction, natural compaction, sinkholes, and thawing permafrost (National Research Council, 1991).
- As the ground drops across the state due to the compacting soils, the varying rates of sinking will increase flash flood total accumulation as water pools in the lowest lying points.
    - Subsidence may cause areas which were not previously the lowest-lying area to take on more water than previous flood plans accounted for.

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

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

WATER TABLE STRUCTURE





What is an Aquifer:

An underground layer of water-bearing permeable rock, rock fractures, or unconsolidated materials (gravel, sand, or silt).

What is an Aqueduct:

An artificial channel for conveying water, typically in the form of a bridge across a valley or other gap.

What is a Well:

A hole drilled into the ground to access water contained in an aquifer by digging, driving, or drilling. A pipe and pump are used to pull water out.

What is an Aquitard:

A geologic formation/stratum that lies adjacent to an aquifer which allows only a small amount of liquid to pass.

FLOODING CHANGES AND SEA LEVEL RISE

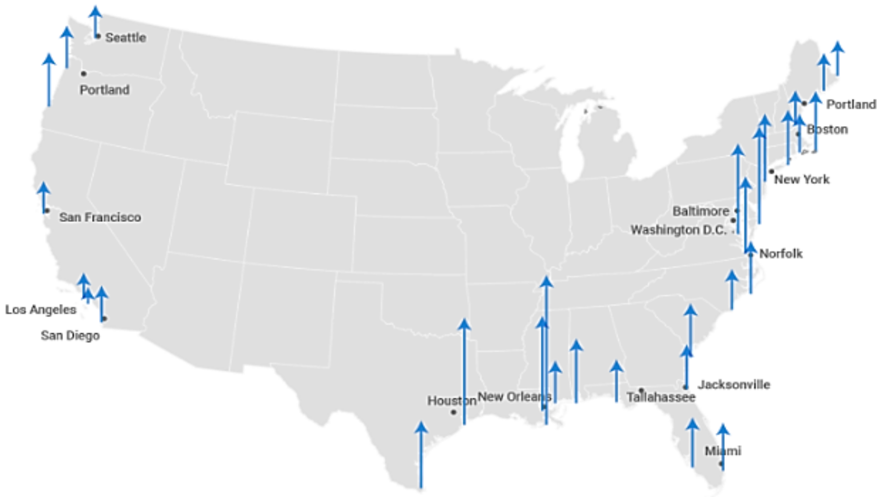
Floods are the most common natural disaster in the US and about 41 million U.S. residents are at risk from flooding along rivers and streams.

- River flooding can result from heavy rainfall, rapid snow melt, or ice jams.
- Urban flooding refers to flooding that occurs when rainfall overwhelms the local stormwater drainage capacity of a densely populated area.
- Over 8.6 million Americans live in areas susceptible to coastal flooding, which happens when winds from a coastal storm, such as a hurricane or nor'easter, push a surge of water from the ocean onto land.
- High tide floods (also known as "sunny day" floods) occur when the sea washes up and over roads and into storm drains as the daily tides roll in.

Extreme flooding will continue to be concentrated in regions where humans have built on floodplains or low-lying coastal regions.

- As extreme weather events increase, risks will extend into new areas.

1000-year flood events will occur more often due to increased land use and heavier precipitation. The term "1,000-year flood" means a flood of that magnitude (or greater) has a 1 in 1,000 chance of occurring in any given year.



Rise in inches, compared to 1980-2010 average.

+5 in.

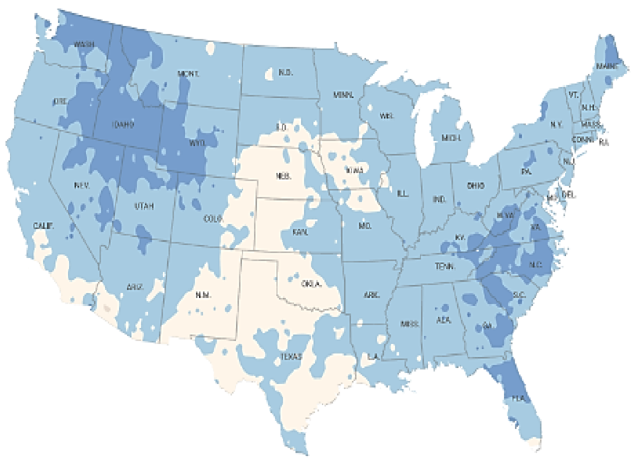
Place with highest sea level rise (inches)

14.4	Grand Isle, LA
10.3	Galveston Pier 21, TX
9.4	Ocean City Inlet, MD
9.1	New Canal Station, LA
8.7	Lewisetta, VA

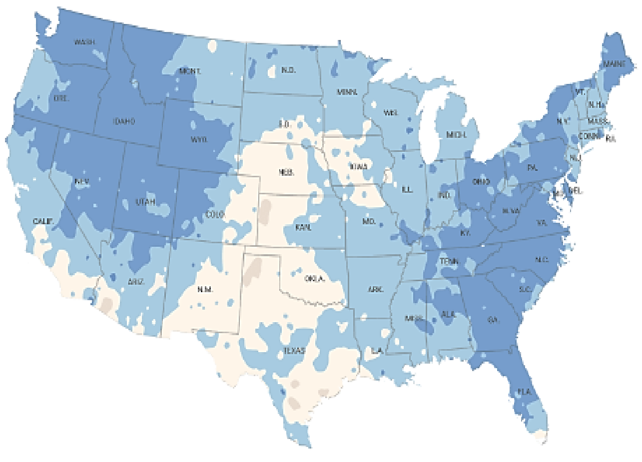
Source: Kopp et al, 2017. Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections.

Oceans are about 7-8 inches higher than they were in 1900 (3 inches were added since 1993). The rate of rise this past century was greater than any other century in the past 2,000 years. The IPCC predicts seas globally will rise around 1-4 feet above 2000 levels by 2100. NOAA's projects that, due to regional factors such as ocean currents, coastlines like the East Coast could see seas up to 9.8 feet higher by 2100.

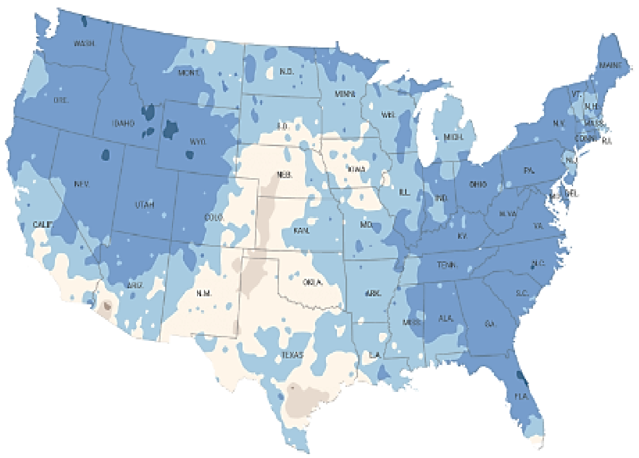
Select year of projection | **This year** | In 15 years | In 30 years



Select year of projection | This year | **In 15 years** | In 30 years



Select year of projection | This year | In 15 years | **In 30 years**



Change in extreme rain events compared to 1980-2010 average.

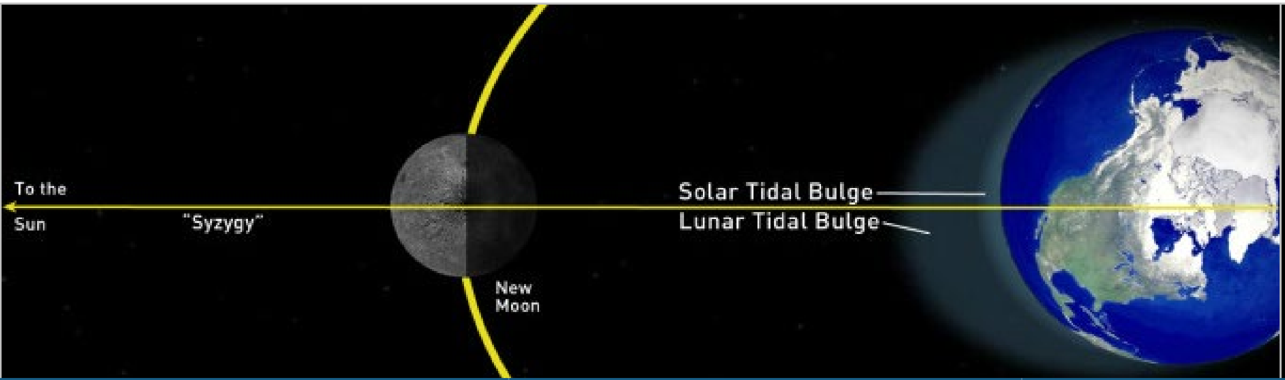
←LIGHTER HEAVIER→

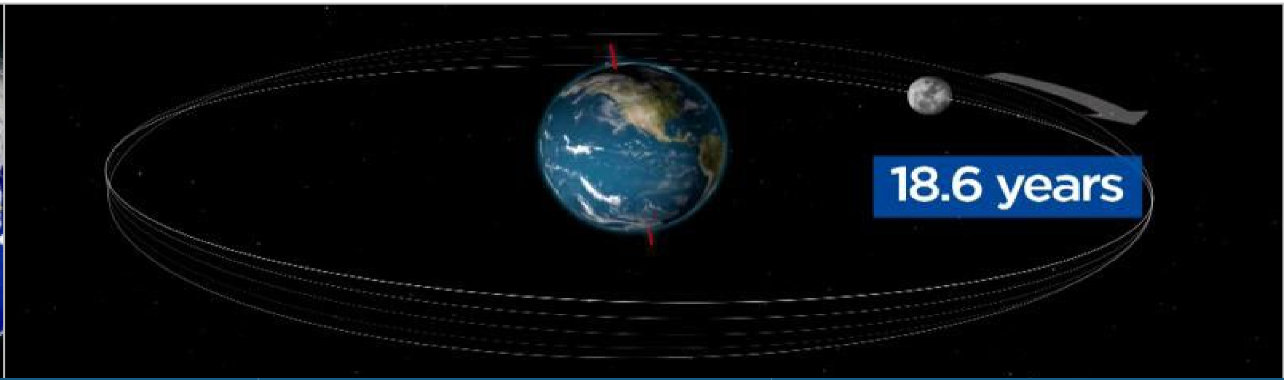
-10% -5% 0% 5% 10%

Source: NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP).

Moon Wobble

- As part of the 18.6-year lunar nodal cycle, the moon orbits around the Earth on a plane that is tilted about 5 degrees relative to the Earth's orbit around the sun, known as the ecliptic plane. **When the moon intersects with Earth's orbit at the two nodes, it wobbles.** This event was first reported in 1728 and fluctuates the Moon's gravitational pull on the tidal events across the globe.
- The tilt can either suppress or amplify tides. High tides could become lower than normal, and low tides could become higher than normal. Thereby, half of the 18.6-year lunar cycle counteracts the effect of sea level rise on high tides, and the other half increases the effect.
- Nasa has predicted in a new study that the next moon wobble will directly impact American coastlines in the **mid-2030s.**
  - "The higher seas, amplified by the lunar cycle, will cause a leap in flood numbers on almost all U.S. mainland coastlines, Hawaii, and Guam. Only far northern coastlines, including Alaska's, will be spared for another decade or longer because these land areas are rising due to long-term geological processes."
    - Why does this matter to you? Planning: Understanding that all your flooding events are clustered in a particular month, or you might have more severe flooding in the second half of a year than the first – that's useful information. Example: King Tide increases into areas which flood a handful of times a year may see floods a handful of times per season. 'Sunny Day' flooding events are already being amplified by the expanding sea levels from glacier melt and ocean surface heating.
    - Puget Sound saw its lowest tide in more than a decade mid-June 2022, 4 feet lower than the average daily low tide. The wobble in the moon's orbit is nearing its peak, making the tides roll in and out more powerfully than usual in the past 13 years.
  - **NASA says most US coastlines will see a three to four times increase in high tides for at least a decade**, according to the study.
    - https://www.nasa.gov/feature/jpl/study-projects-a-surge-in-coastal-flooding-starting-in-2030s/
  - A hub of resources for climate tools and sea level change, the seal level rise tool can be used for coastal flooding planning: https://sealevel.nasa.gov/
  - The Virtual Earth System Laboratory includes simulations related to glaciers, ice sheets, sea level, and solid earth: https://sealevel.nasa.gov/data_tools/2





GLOBAL MEAN SEA LEVEL	OCEAN MASS	STERIC HEIGHT	GREENLAND ICE MASS CHANGE	ANTARCTICA ICE MASS CHANGE
↑ 3.4 ± 0.4 mm/yr	↑ 2 ± 0.3 mm/yr	↑ 1.2 ± 0.2 mm/yr	↓ 274 ± 21 Gt/yr	↓ 152 ± 39 Gt/yr

NHC FORECAST - ATLANTIC BASIN

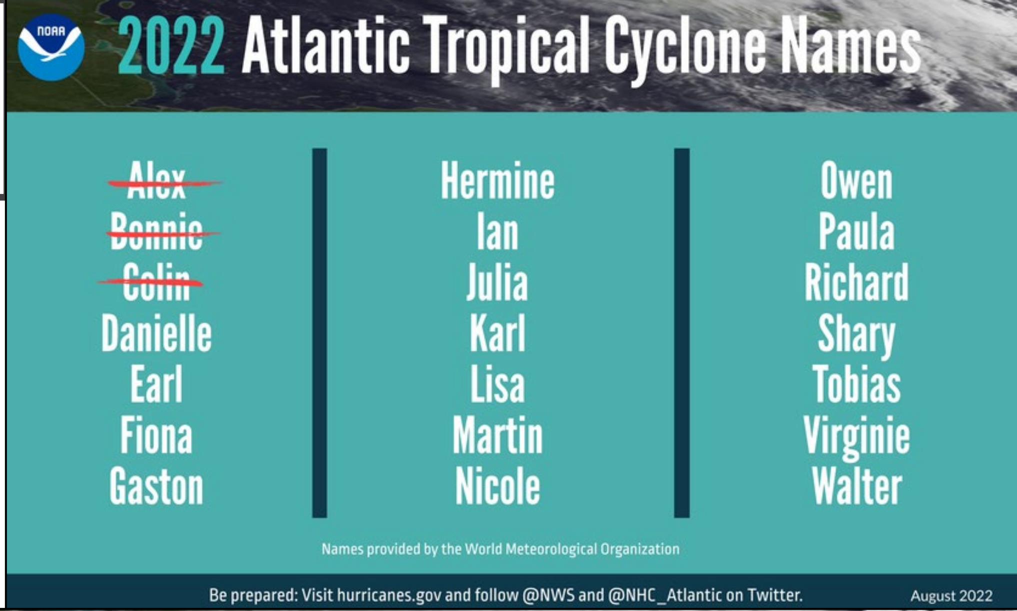
The increased activity expected this hurricane season is attributed to several climate factors, including the ongoing La Niña expected to persist through the hurricane season into winter, warmer-than-average sea surface temperatures in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, weaker Atlantic trade winds, and an enhanced west African monsoon.

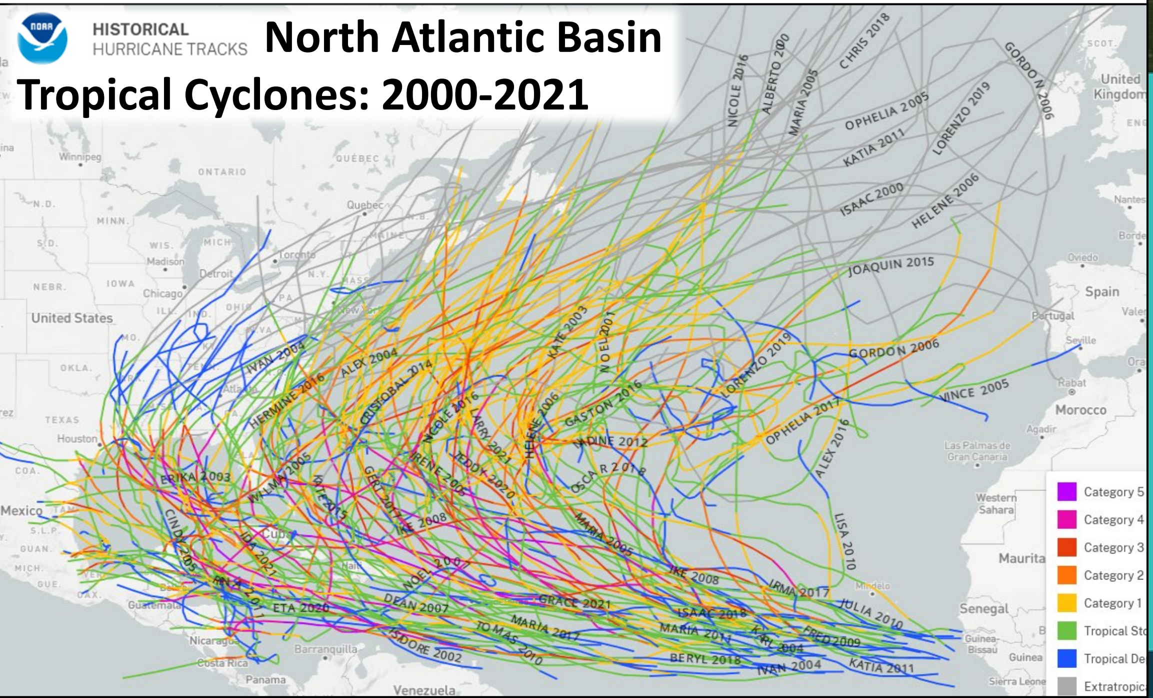
An enhanced west African monsoon supports stronger African Easterly Waves, which seed many of the strongest and longest-lived hurricanes during most seasons.

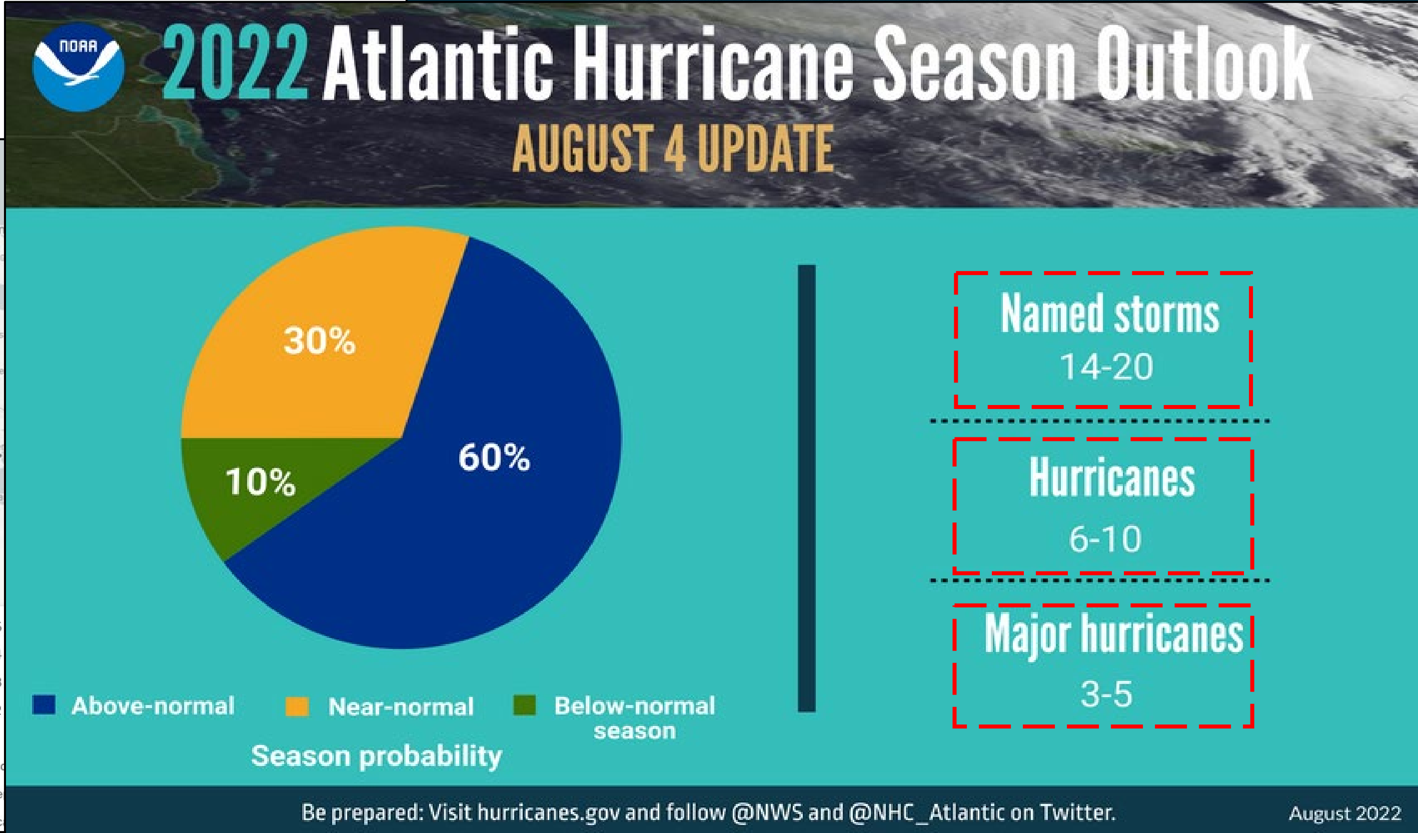
The Excessive Rainfall Outlook (ERO) has been experimentally extended from three to five days of lead time, giving more notice of rainfall-related flash flooding risks from tropical storms and hurricanes.

- The ERO forecasts and maps the probability of intense rainfall that could lead to flash flooding within 25 miles. https://www.wpc.ncep.noaa.gov/qpf/excessive_rainfall_outlook_ero.php

In June, NOAA enhanced an experimental graphic that depicts the Peak Storm Surge Forecast when storm surge watches or warnings are in effect.







Colorado State University (Aug 4th Update) Atlantic Seasonal Hurricane Forecast 2022

Forecast for 2022 Hurricane Activity

Forecast Parameters	CSU Forecast for 2022*	Average for 1991-2020
Named Storms	18	14.4
Named Storm Days	85	69.4
Hurricanes	8	7.2
Hurricane Days	30	27.0
Major Hurricanes	4	3.2
Major Hurricane Days	8	7.4
Accumulated Cyclone Energy+	150	123

+A measure of a named storm's potential for wind and storm surge destruction defined as the sum of the square of a named storm's maximum wind speed (in 10^4 $knots^2$) for each 6-hour period of its existence.

https://tropical.colostate.edu/forecasting.html

1 or more Major Hurricane (Category 3-5) landfall probability -- *(100-year average)*

Caribbean: 57% *(+15% average and -7% from July 7th)*

Entire CONUS Coastline: 68% *(+16% average and -7% from July 7th)*

East Coastline (+Florida peninsula): 43% *(+12% average and -7% from July 7th)*

Gulf Coast (Florida panhandle westward): 43% *(+13% average and -6% from July 7th)*

Atlantic Basin Tropical Cyclone Name List: 2022	Pacific Basin Tropical Cyclone Name List: 2022
Alex	Agatha
Bonnie	Blas
Colin	Celia
Danielle	Darby
Earl	Estelle
Fiona	Frank
Gaston	Georgette
Hermine	Howard
Ian	Ivette
Julia	Javier
Karl	Kay
Lisa	Lester
Martin	Madeline
Nicole	Newton
Owen	Orlene
Paula	Paine
Richard	Roslyn
Shary	Seymour
Tobias	Tina
Virginie	Virgil
Walter	Winifred
	Xavier
	Yolanda
	Zeke

*The Atlantic Basin supplemental name list remains unchanged from 2021

Tropical names are recycled every six years, name lists are maintained by the WMO

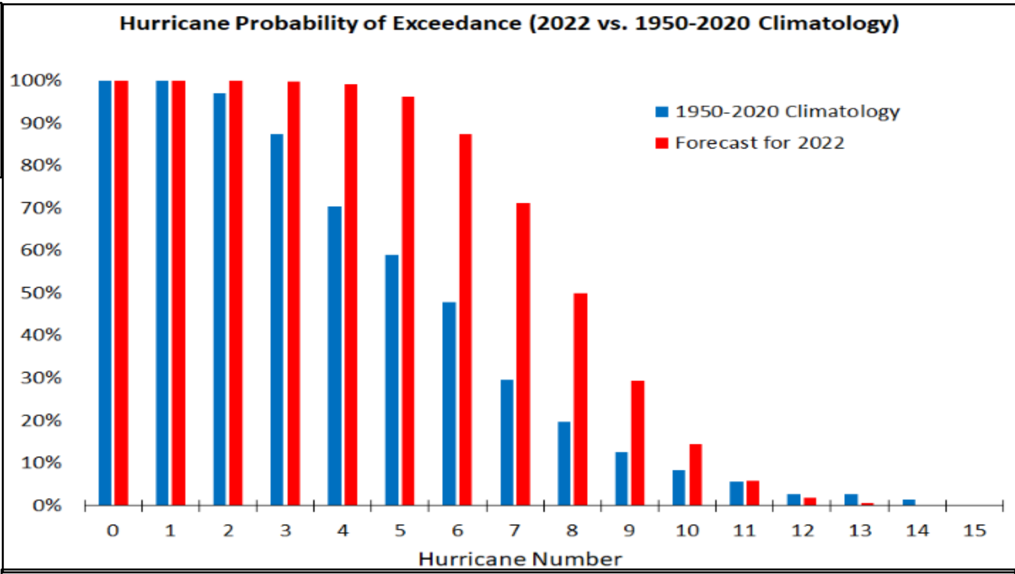
Recent Hurricane Season Studies

- 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.

- A recent assessment suggests an increase in intensity, proportion of the most intense storms, and the occurrence of storms with extreme rainfall events. *18 tropical storms (7 hurricanes) have made landfall in the past two years in the eastern United States.*

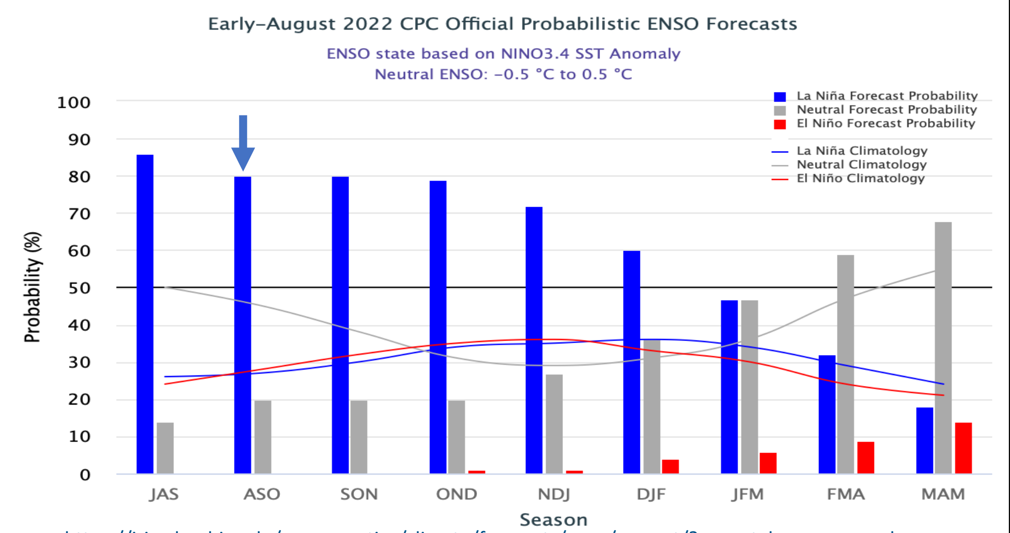
- A new study from Yale using data from 2020's cyclone Alpha and 2021's cyclone Henri states the next 75 years will see an expansion of hurricanes/typhoons into mid-latitude regions, including major cities such as New York, Boston, Beijing, and Tokyo

- 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.



The sea surface temperature in the Gulf of Mexico and the Atlantic Ocean indicate the 2022 Hurricane Season could see La Niña remain through Winter 2022-23. Climatology studies indicate high potential for ***another over- active hurricane season, above-average probability for major hurricane landfall along the continental US Coast to the Caribbean, and more cyclone development closer to US coastlines than typical.***

The IPCC 6th assessment states with high confidence that the global proportion of tropical cyclones that reach very intense (category 4-5) levels, peak winds, and rainfall rates are all expected to increase annually.



https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-cpc_plume

ATLANTIC HURRICANE ACTIVITY SUMMARY

The increase in hurricane activity is attributed to the warm phase of the Atlantic Multi-Decadal Oscillation (AMO) which began in 1995 and has favored more, stronger, and longer-lasting storms since that time.

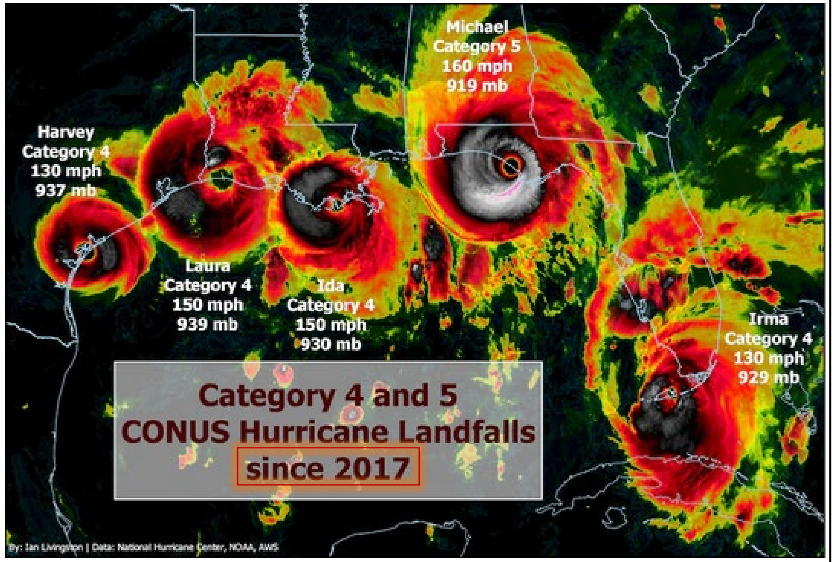
Before 2017, the nation recorded a 10-year landfall drought. 2006-2016 was the longest interval on record without a Category 3 hurricane or stronger making landfall in the US.

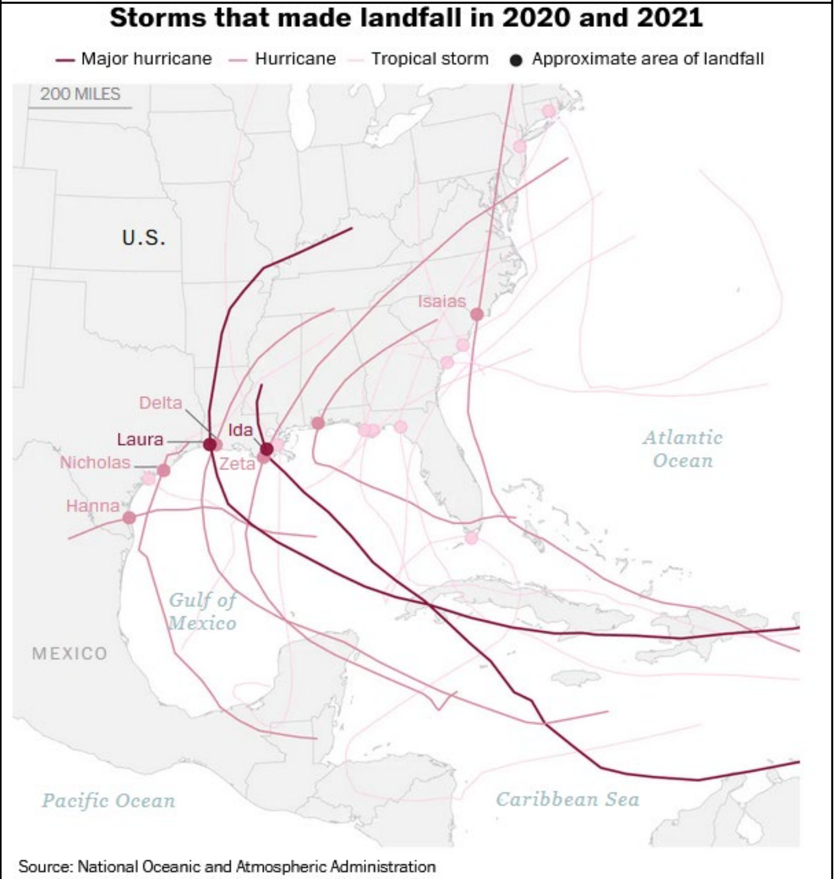
- 53 named storms have formed in the Atlantic since the start of the 2020 Hurricane Season.
    - From 2009 to 2016, over the course of eight years, 13 named storms came ashore.
    - 18 storms, including seven hurricanes have made landfall in the past two years in the eastern United States.

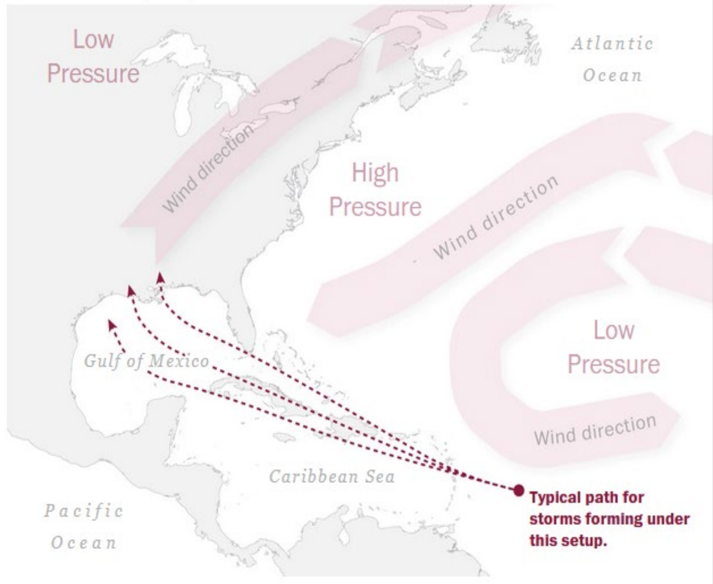
A recent assessment by hurricane experts correlates an increase in intensity and the proportion of the most intense storms, as well as increase in the occurrence of storms resulting in extreme rainfall rates over 3-hour timeframes which increased by 10% while 3-day total rainfall accumulations increased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

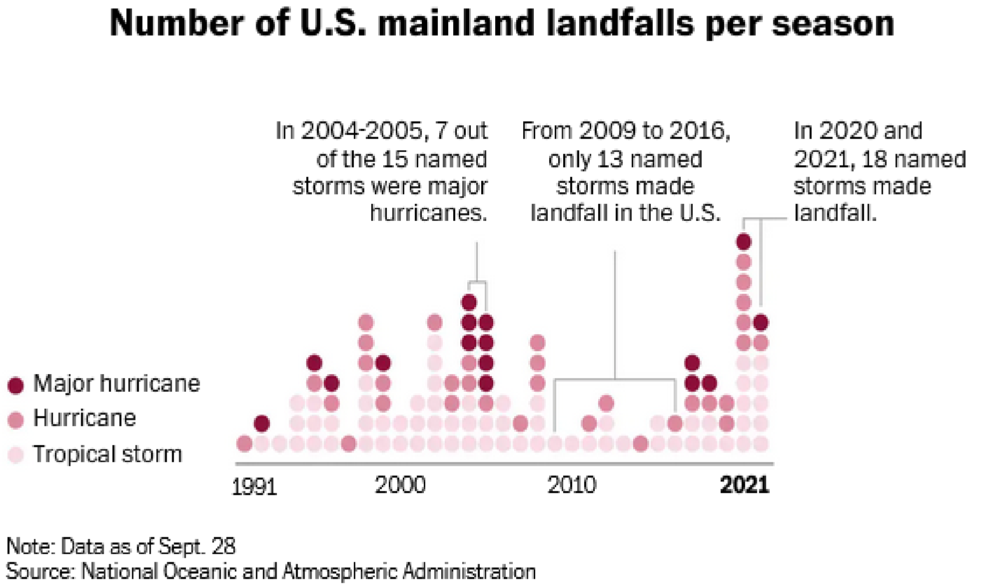
- Extreme rainfall rates when focusing on *hurricane strength only* saw increases for 3-hourly rainfall rates of 11% and 3-day total accumulated rainfall by 8%. Damaging winds associated with tropical low centers are also expected to increase.
- A study revised in February 2022 stated “Extreme Atlantic 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.

A total of 1,789 Tropical Cyclones were examined in the period from 1998 to 2016 by the Tropical Rainfall Measuring Mission and the Global Precipitation Measurement mission: “The resulting radial profiles show that major hurricanes in the Atlantic basin exhibit significantly heavier inner-core rainfall rates than those in any other basins”.









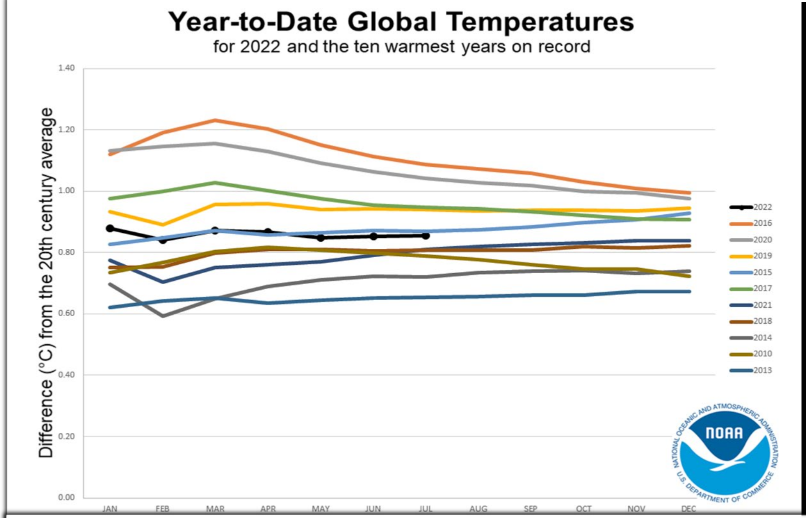
July 2022 Global Climate Report

The July 2022 global surface temperature departure was the sixth highest for July in the 143-year record at 0.87°C (1.57°F) above the 20th century average of 15.8°C (60.4°F).

The five warmest Julys on record have all occurred since 2016. July 2022 also marked the 46th consecutive July and the 451st consecutive month with temperatures, at least nominally, above the 20th century average.

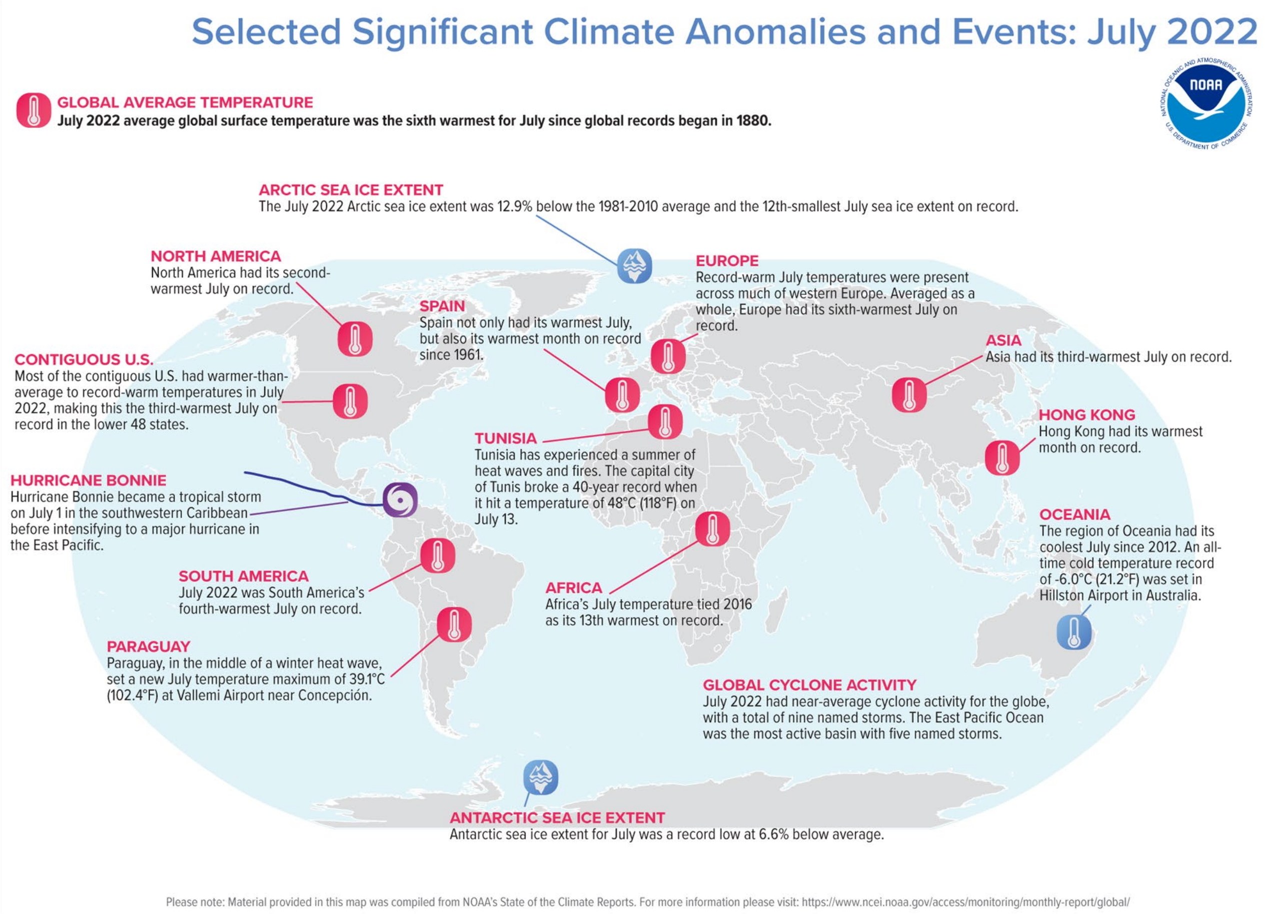
Regionally, July 2022 was among the top ten warmest Julys on record for several continents. North America had its second-warmest July on record at 1.41°C (2.54°F) above average. Europe had its sixth-warmest July.

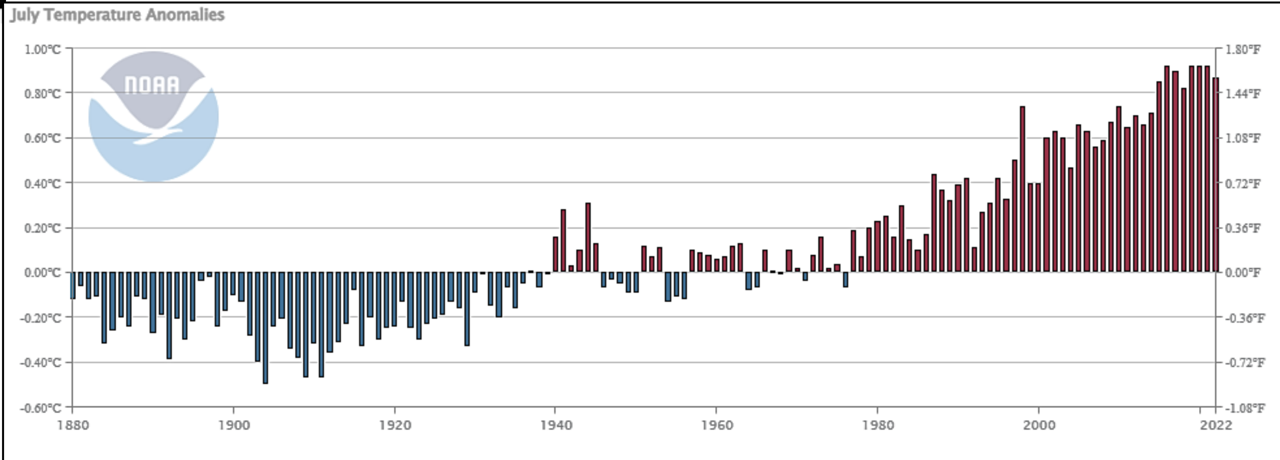
July 2022 was the third-warmest July on record for the U.S.

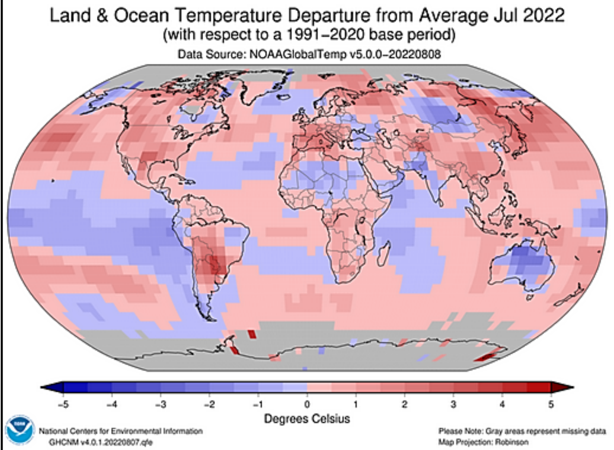


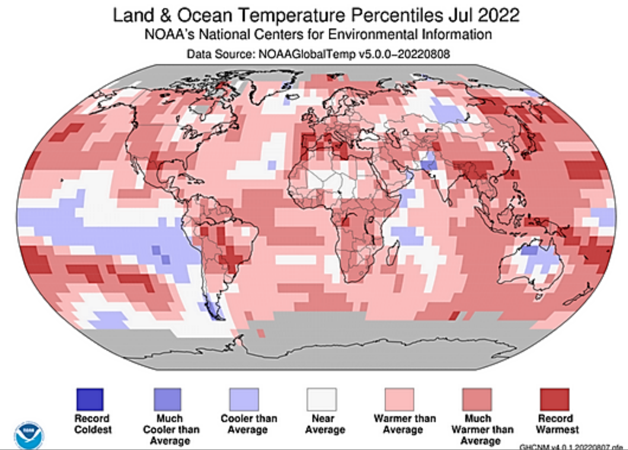
The year-to-date temperature anomalies for 2022 (black line) and the 10 warmest years on record: 2016 (1st), 2020 (2nd), 2019 (3rd), 2015 (4th), 2017 (5th), 2021 (6th), 2018 (7th), 2014 (8th), 2010 (9th), 2013 (10th), and 2005 (10th).

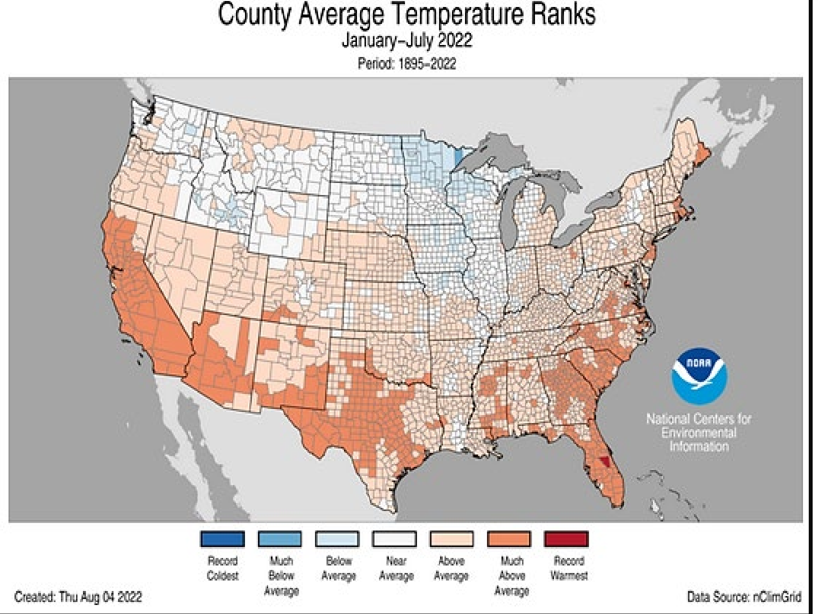
The average global land and ocean surface temperature for January–July 2022 was 0.86°C (1.55°F) above the 20th century average of 13.8°C (56.9°F), the sixth-warmest January–July period in the 143-year global record.



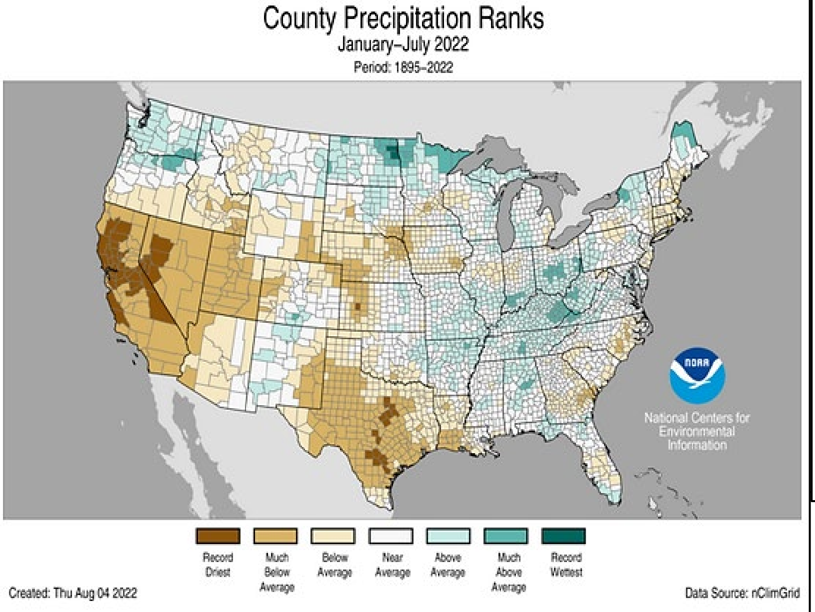


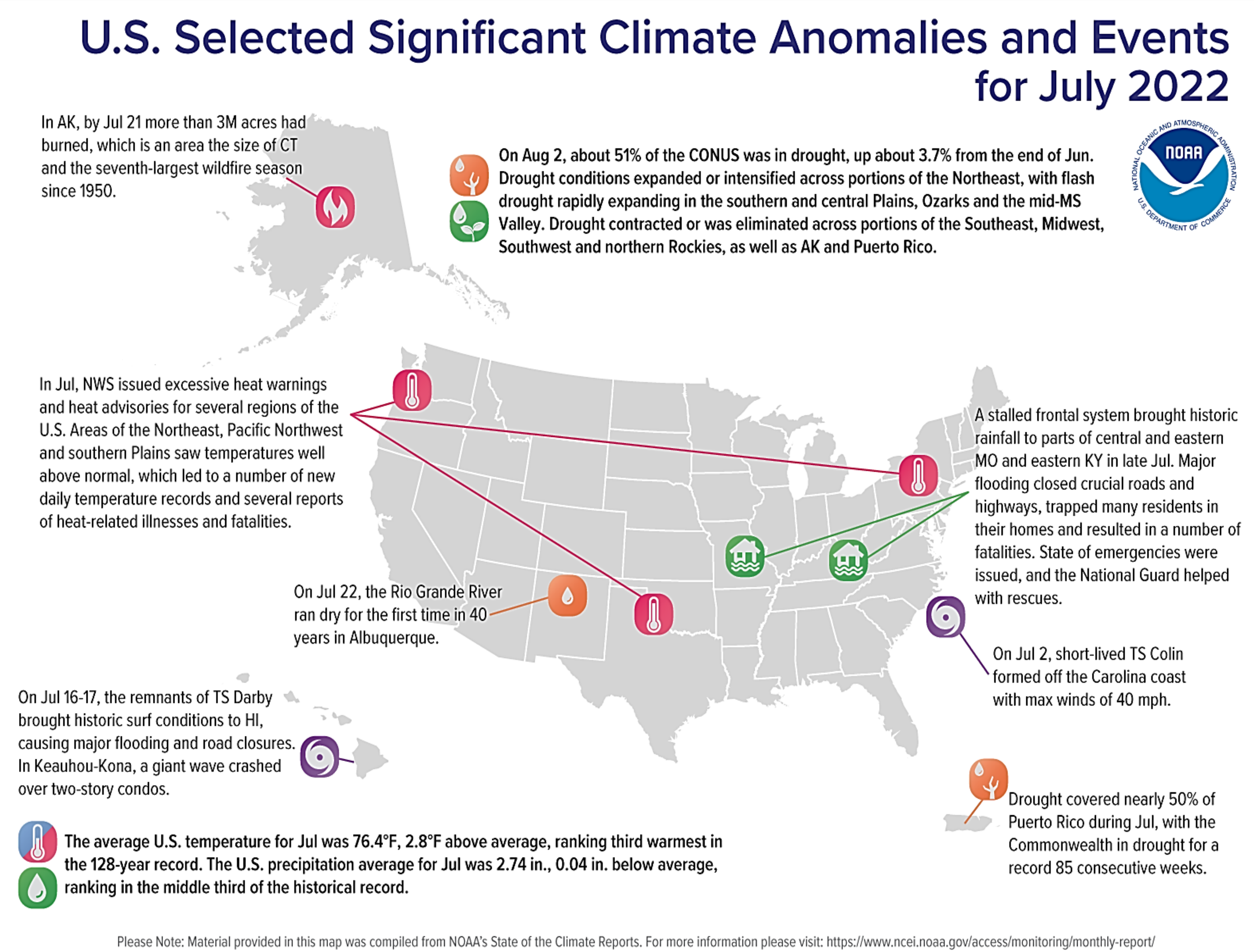






Based on [NOAA's Residential Energy Demand Temperature Index (REDTI)](), the contiguous U.S. temperature-related energy demand during July was 211% of average and the fifth-highest value in the 128-year period of record.

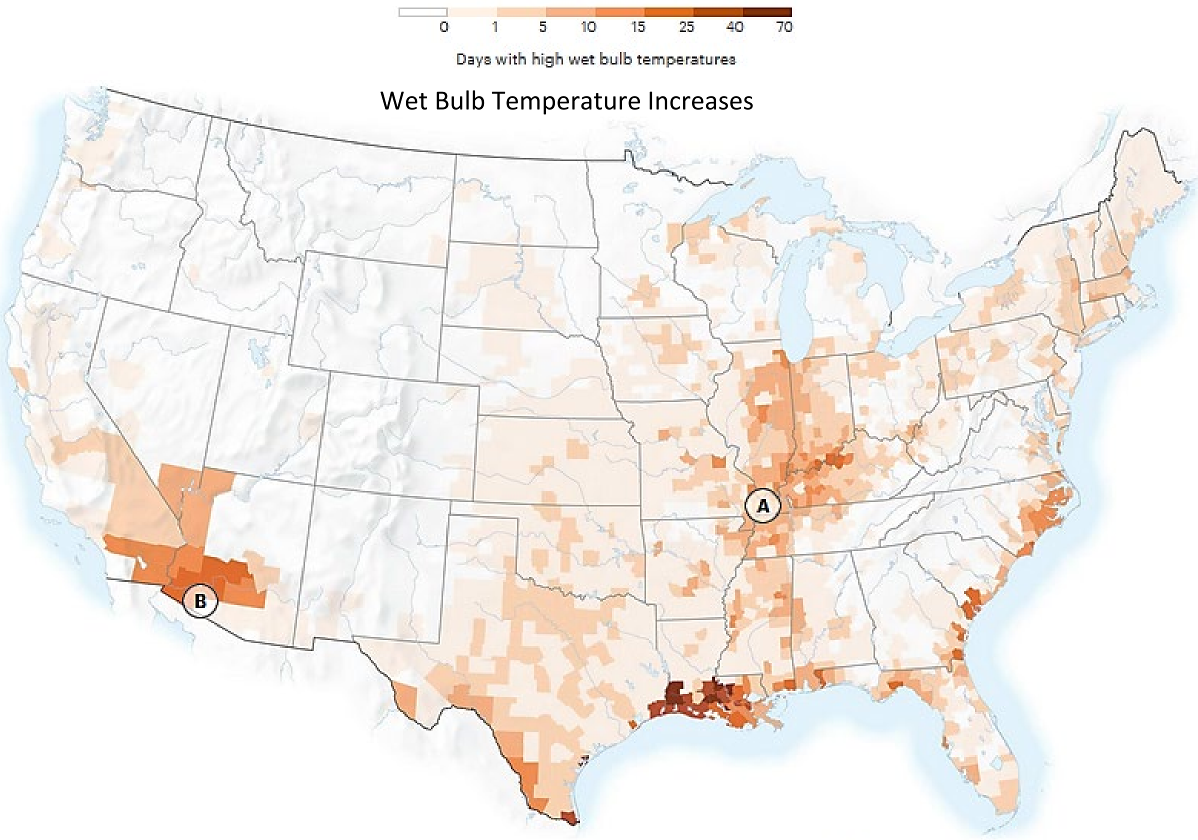




The [U.S. Climate Extremes Index (USCEI)]() for the year-to-date period was 20% above average and ranked in the highest one-third of the 113-year period of record. The USCEI is an index that tracks extremes (occurring in the upper or lower 10% of the record) in temperature, precipitation and drought across the contiguous United States (NOAA NCEI).

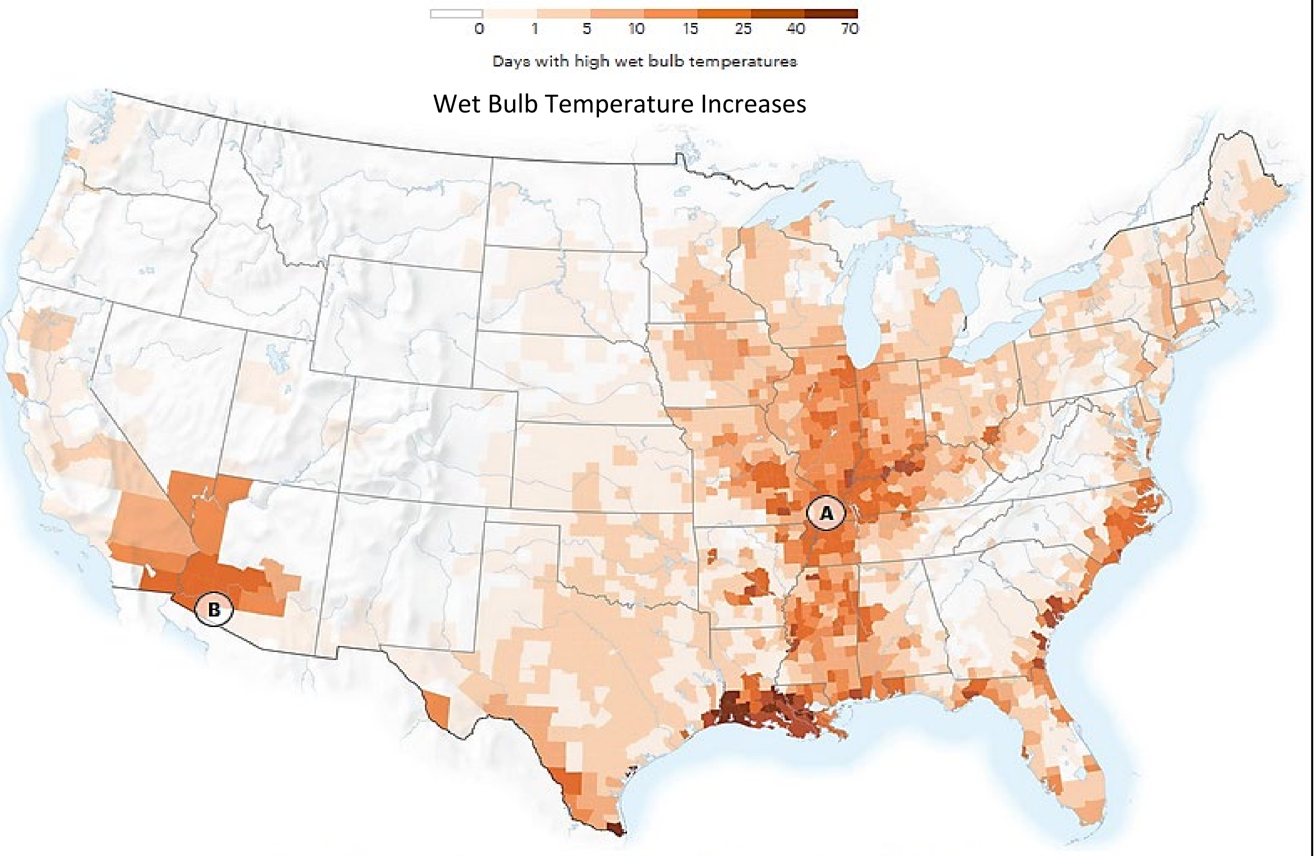
https://nca2014.globalchange.gov/highlights/overview/climate-trends

High Emissions | Moderate Emissions



By midcentury, heat and humidity in Missouri (A) will feel like Louisiana does today, while some areas we don't usually think of as humid, like southwestern Arizona (B), will see soaring wet bulb temperatures because of factors like sun angle, wind speed and cloud cover reacting to high temperatures, according to Hannah Hess of the Rhodium Group.

High Emissions | Moderate Emissions



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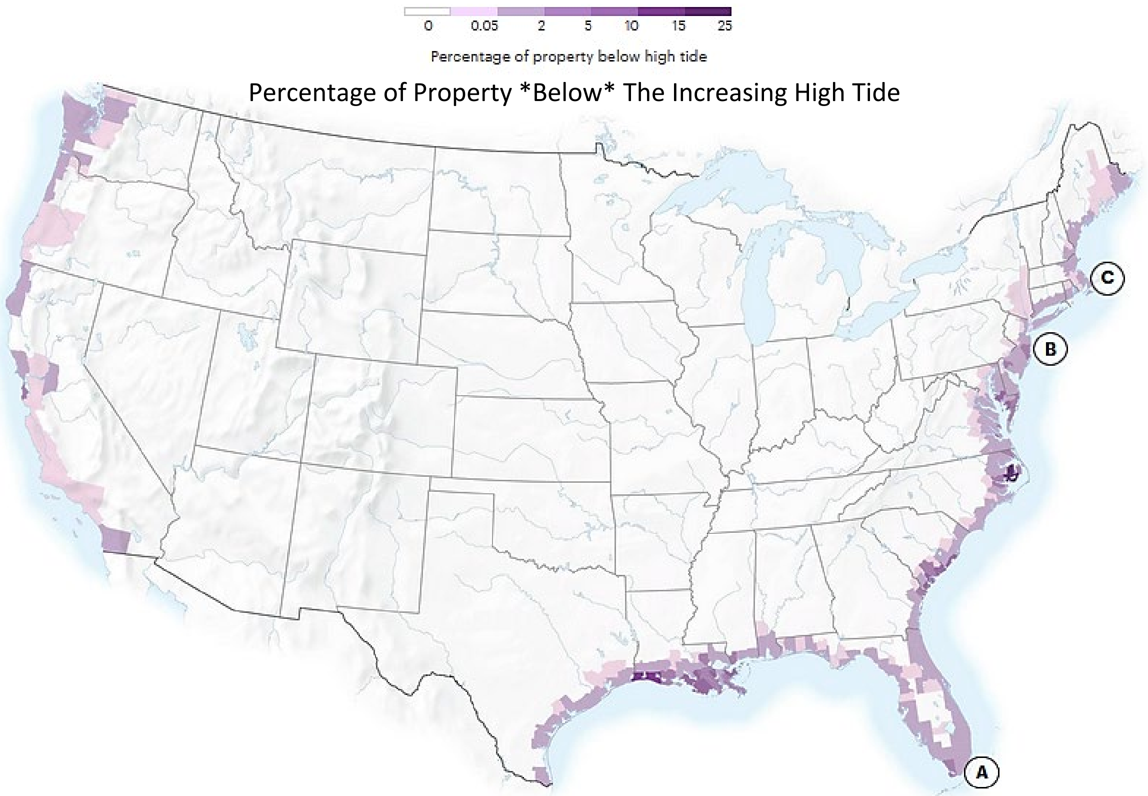
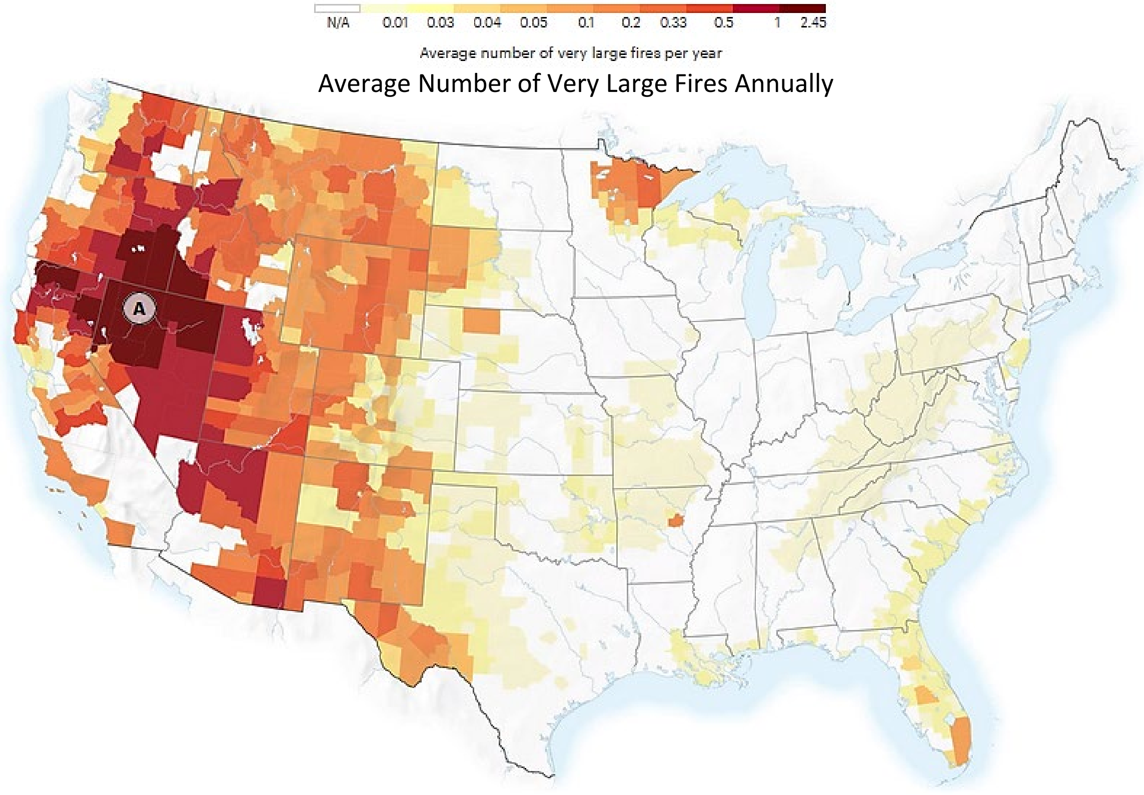


Some 50 million Americans live in eight of the largest U.S. metro areas — Miami (A), New York (B) and Boston (C) among them — which all lie in some of the most affected counties in the U.S. 13 million people could be forced to relocate due to rising sea levels by 2100.



By midcentury, the northern Great Basin, though not a densely forested region, will become the epicenter of large wildfires (A). These large, remote counties in Nevada and Oregon see cycles of wet and dry weather that turn the grassland into the fuel for fires that can easily rip through 10,000 acres a day with strong winds, said John Abatzoglou, one of the authors of the study.

https://nca2018.globalchange.gov/chapter/2/

Figure 2.5: Observed and Projected Change in Seasonal Precipitation

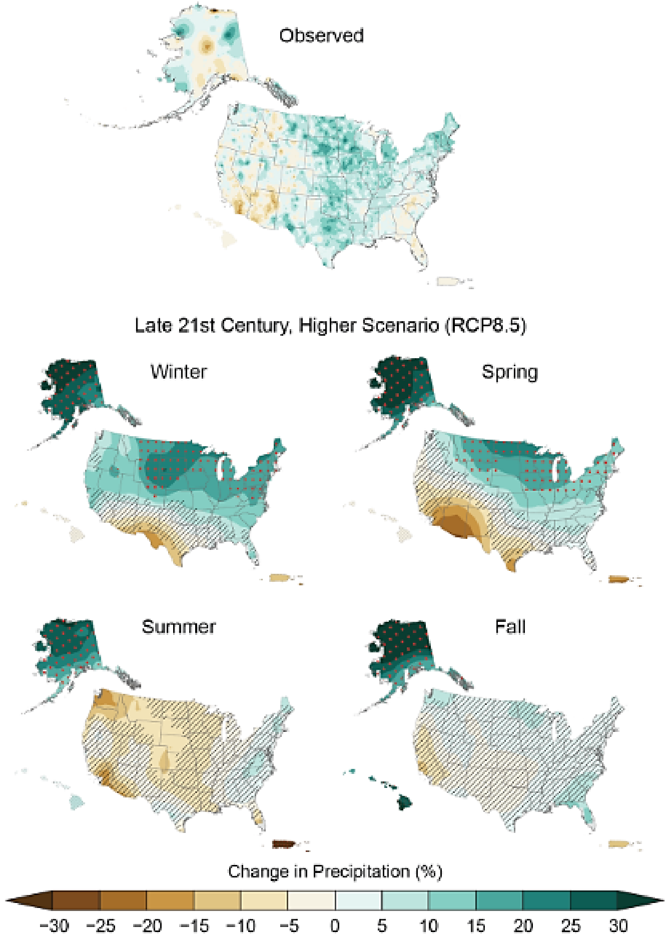


Figure 2.4: Observed and Projected Changes in Annual Average Temperature

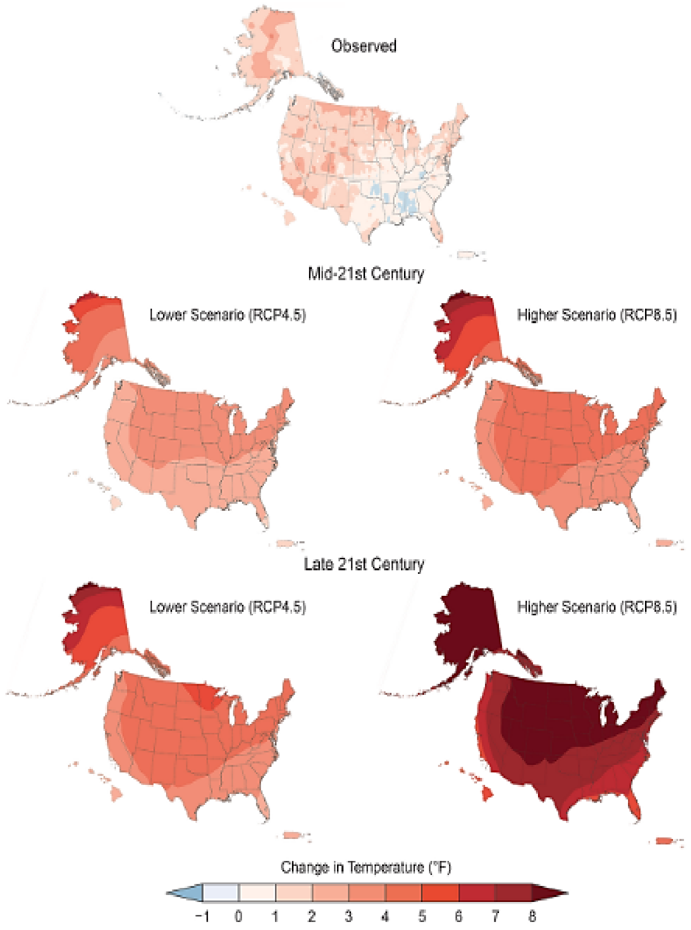
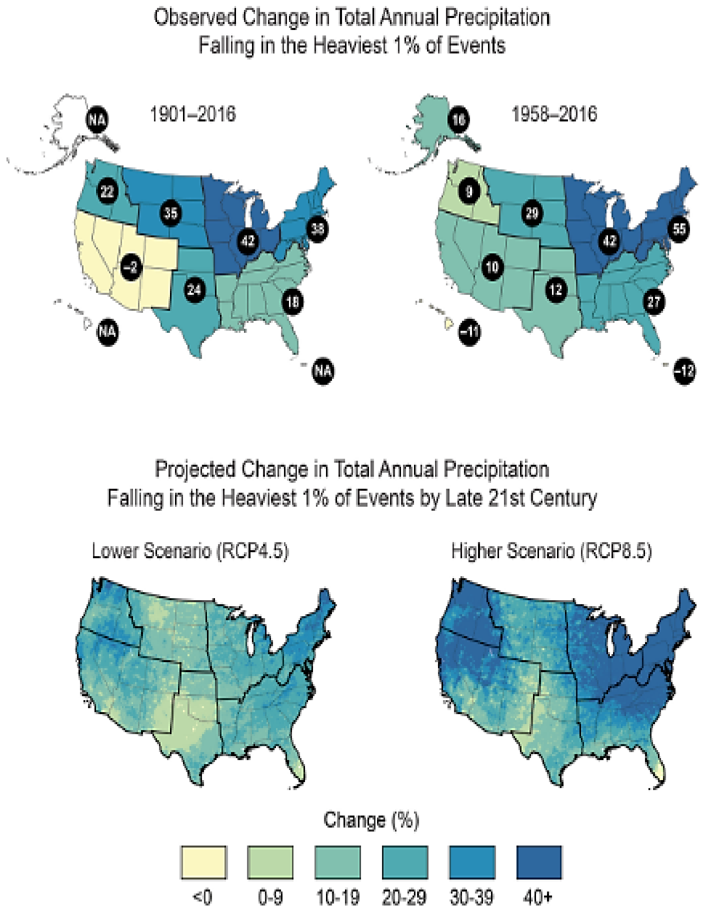


Figure 2.6: Observed and Projected Change in Heavy Precipitation



Climate Summaries:

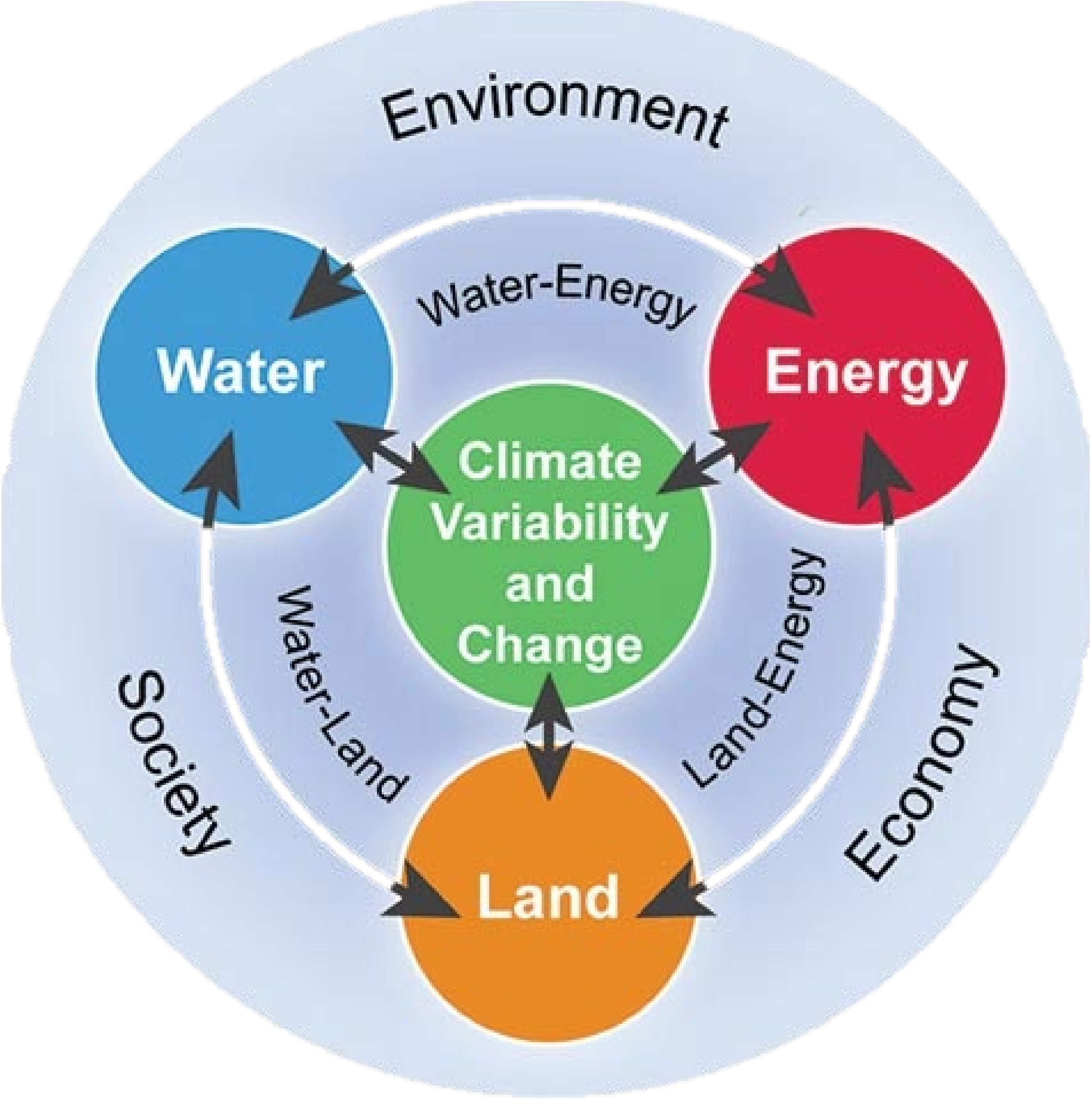
Abnormal Weather Events, Climate Headlines, Forecasted Threats, Global Impacts, Wildfire and Tropical Summaries, and Graphics for Use.

Working Group:

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

To join the distribution list for weekly National-International Climate Summaries **or** to join the Working Group please contact Sunny Wescott

Sunny.Wescott@cisa.dhs.gov



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

“Climate change affects the natural, built, and social systems relied on individually and through connections to one another. These interconnected systems are increasingly vulnerable to cascading impacts, often difficult to predict, threatening essential services within and beyond the Nation’s borders.

Our Nation’s aging and deteriorating infrastructure is further stressed by increases in heavy precipitation events, coastal flooding, heat, wildfires, and other extreme events, as well as changes to average precipitation and temperature. Without adaptation, climate change will continue to degrade infrastructure performance over the rest of the century, with the potential for cascading impacts that threaten our economy, national security, essential services, and health and well-being.” (Fourth National Climate Assessment)

For Questions Contact:

Ms. Sunny Wescott
ISD Lead Meteorologist
202-701-4470 | Sunny.Wescott@cisa.dhs.gov