California Extreme Weather

2023 Seasonal Outlook and Cascading Impacts

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

05/31/2023

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2022 Billion Dollar Disasters

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

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

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

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

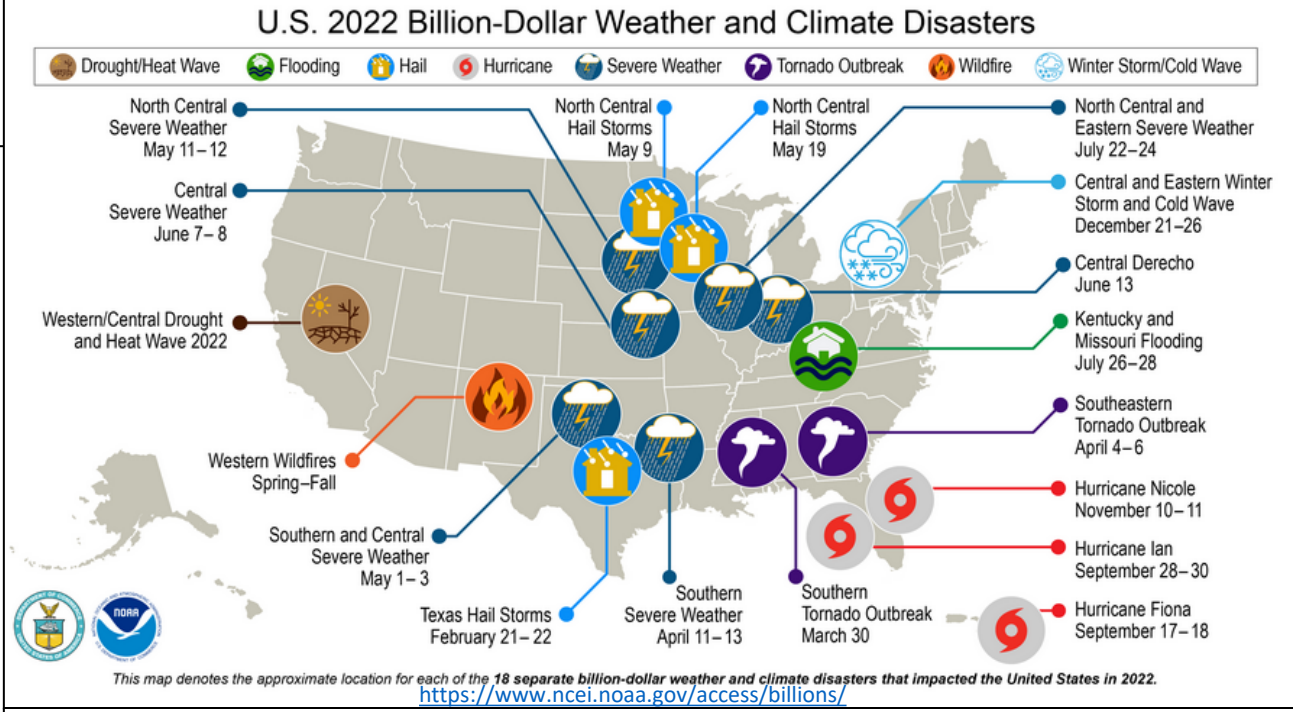
- The annual costs from billion-dollar disasters has exceeded $100 billion in five of the last six years (2017-2022) with 2019 being the only exception.
- The total cost of the last seven years (2016-2022) exceeds $1 trillion while the costs for 341 events from 1980-2022 exceeds $2.475 trillion (inflation-adjusted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

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

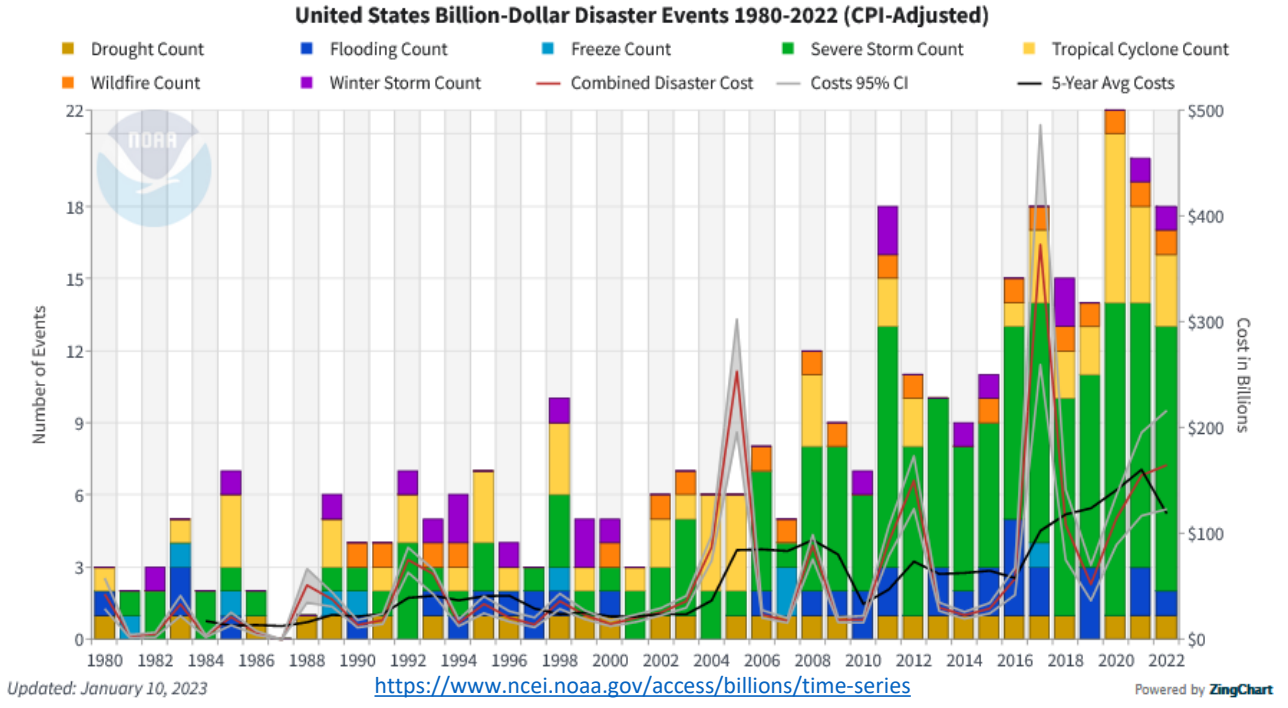
- Over the last 43 years (1980-2022), the years with 10 or more separate billion-dollar disaster events include 1998, 2008, 2011-2013, and **2015-2022**.

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

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



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



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

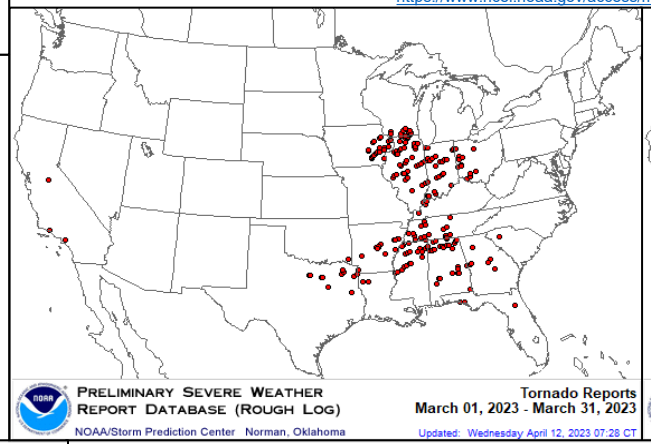
Powered by ZingChart

Anomalous Weather

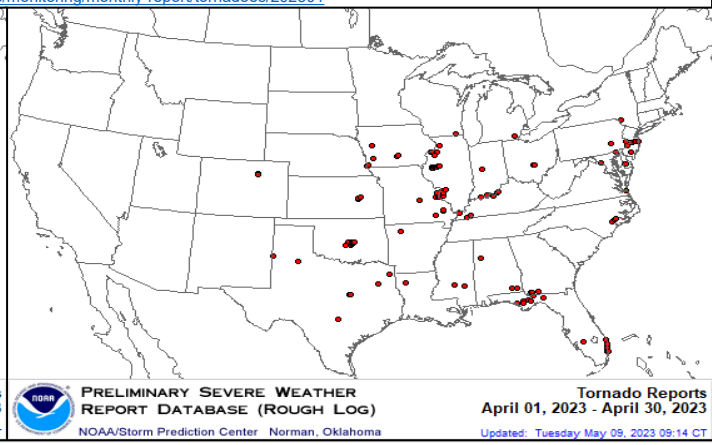
According to the California Department of Water Resources, the statewide snowpack for March was the deepest ever recorded at 237% of normal.

- California in April saw sunny conditions and several warm spells with high daytime temperatures and above-freezing nighttime temperatures spurred rapid snowmelt in Utah, California and Nevada.
- Mammoth Mountain, California, recorded their snowiest season on record with more than 870 inches on the summit.
- The Central Sierra Snow Lab surpassed 700 inches of snow for the season — the second-highest total on record since 1951.

According to data from NOAA's Storm Prediction Center, during March, there were 244 tornado reports. This is more than triple the 1991-2010 average of 80 tornadoes for the month of March. There were 55 tornado reports in February This is nearly double the 1991-2010 average of 29 tornadoes for the month of February. In January there were 168 tornadoes, five times the average of 35 tornadoes.
https://www.ncei.noaa.gov/access/monitoring/monthly-report/tornadoes/202301

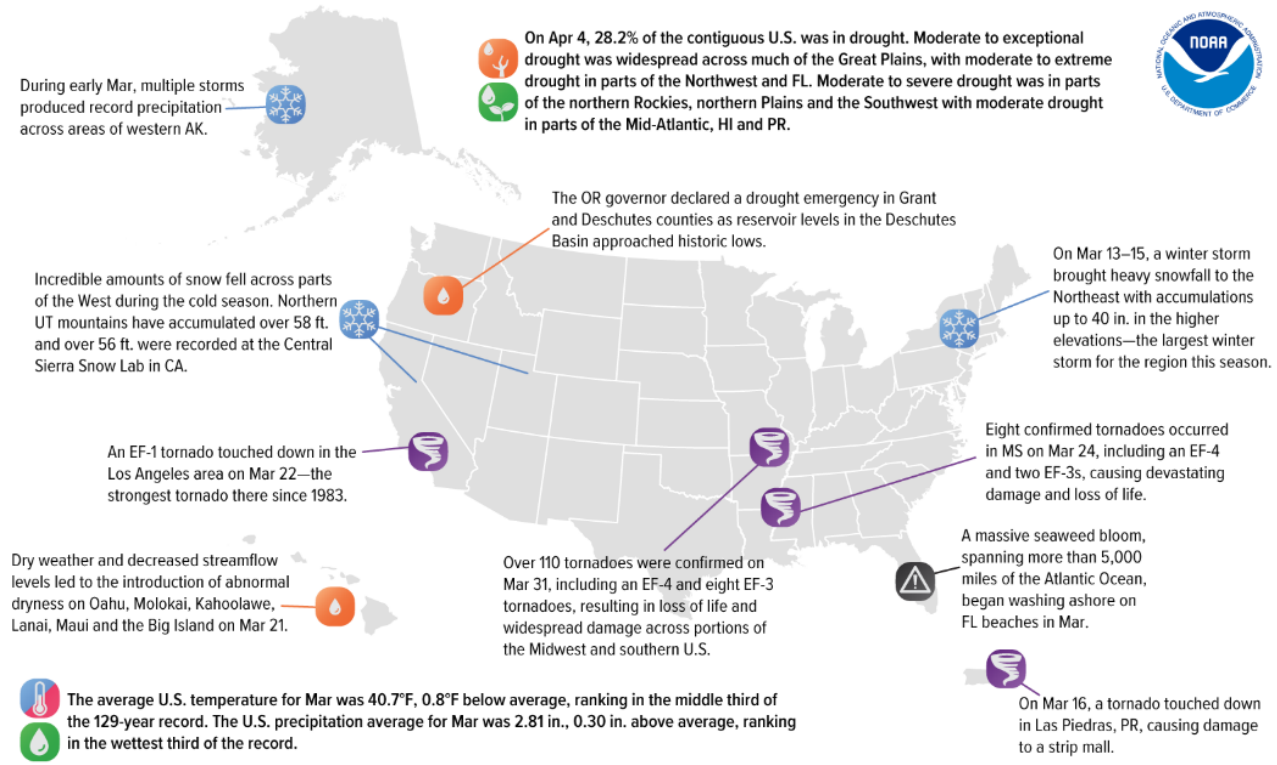


PRELIMINARY SEVERE WEATHER REPORT DATABASE (ROUGH LOG)
NOAA/Storm Prediction Center Norman, Oklahoma
Tornado Reports
March 01, 2023 - March 31, 2023
Updated: Wednesday April 12, 2023 07:28 CT



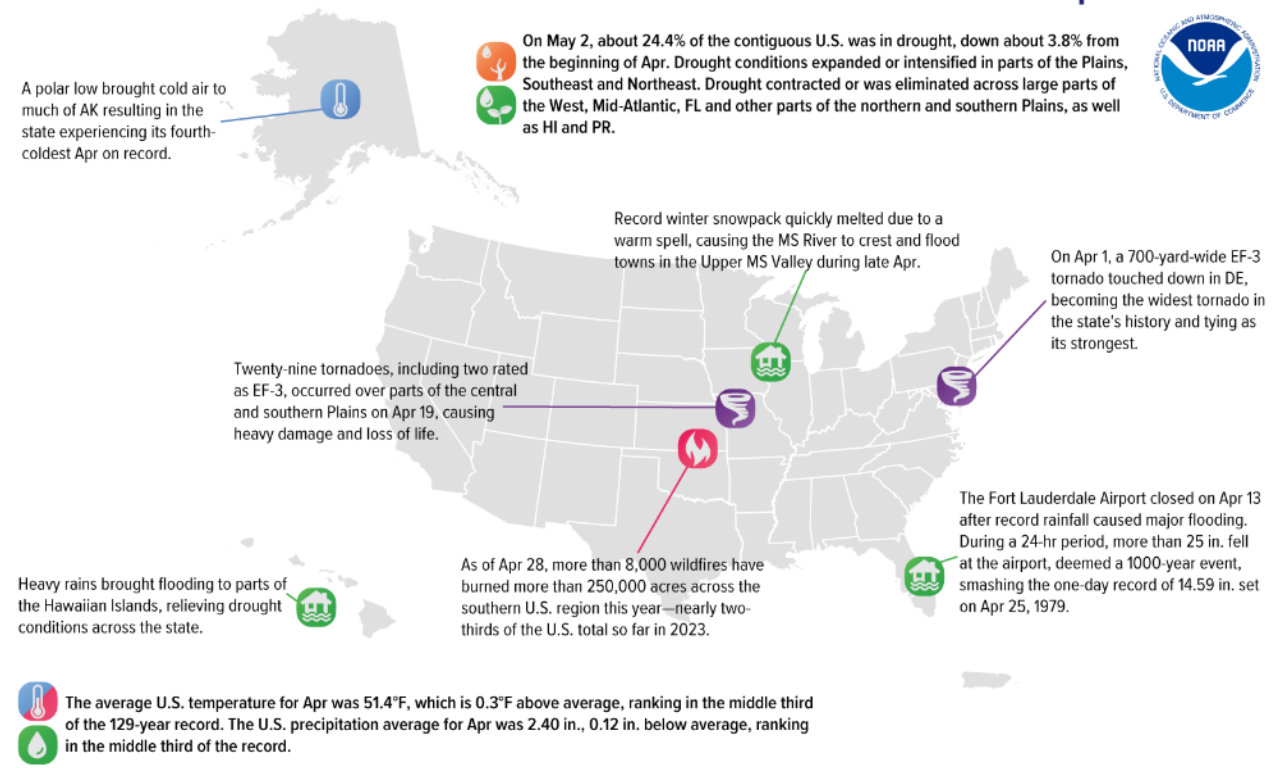
PRELIMINARY SEVERE WEATHER REPORT DATABASE (ROUGH LOG)
NOAA/Storm Prediction Center Norman, Oklahoma
Tornado Reports
April 01, 2023 - April 30, 2023
Updated: Tuesday May 09, 2023 09:14 CT

U.S. Selected Significant Climate Anomalies and Events for March 2023



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/

U.S. Selected Significant Climate Anomalies and Events for April 2023



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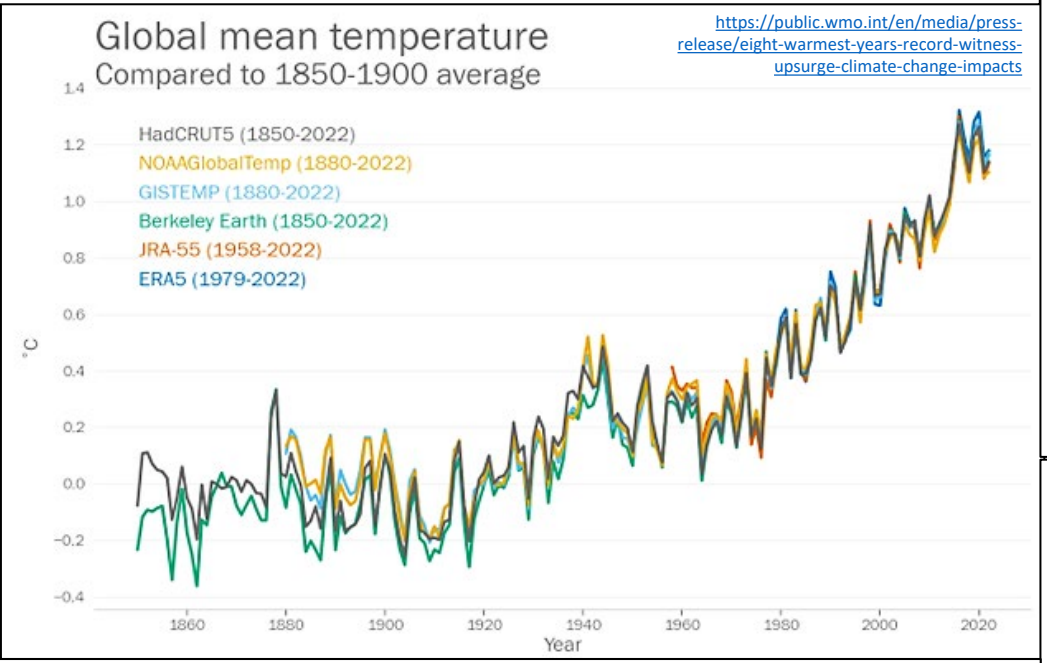
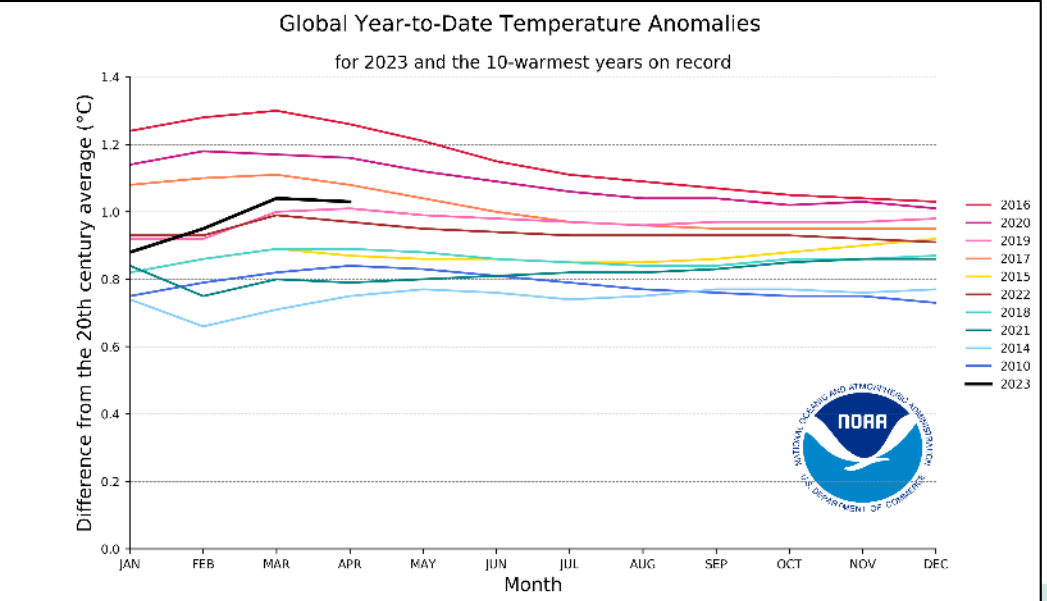
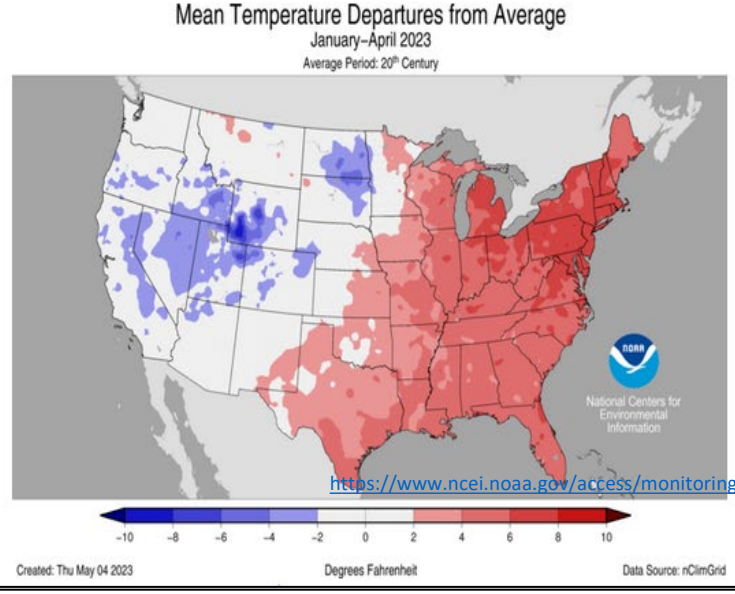
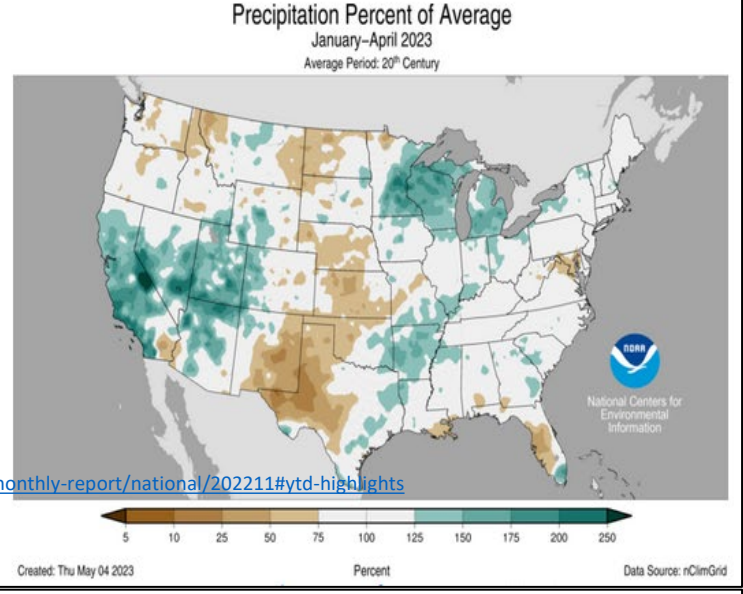
Record Setters



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







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

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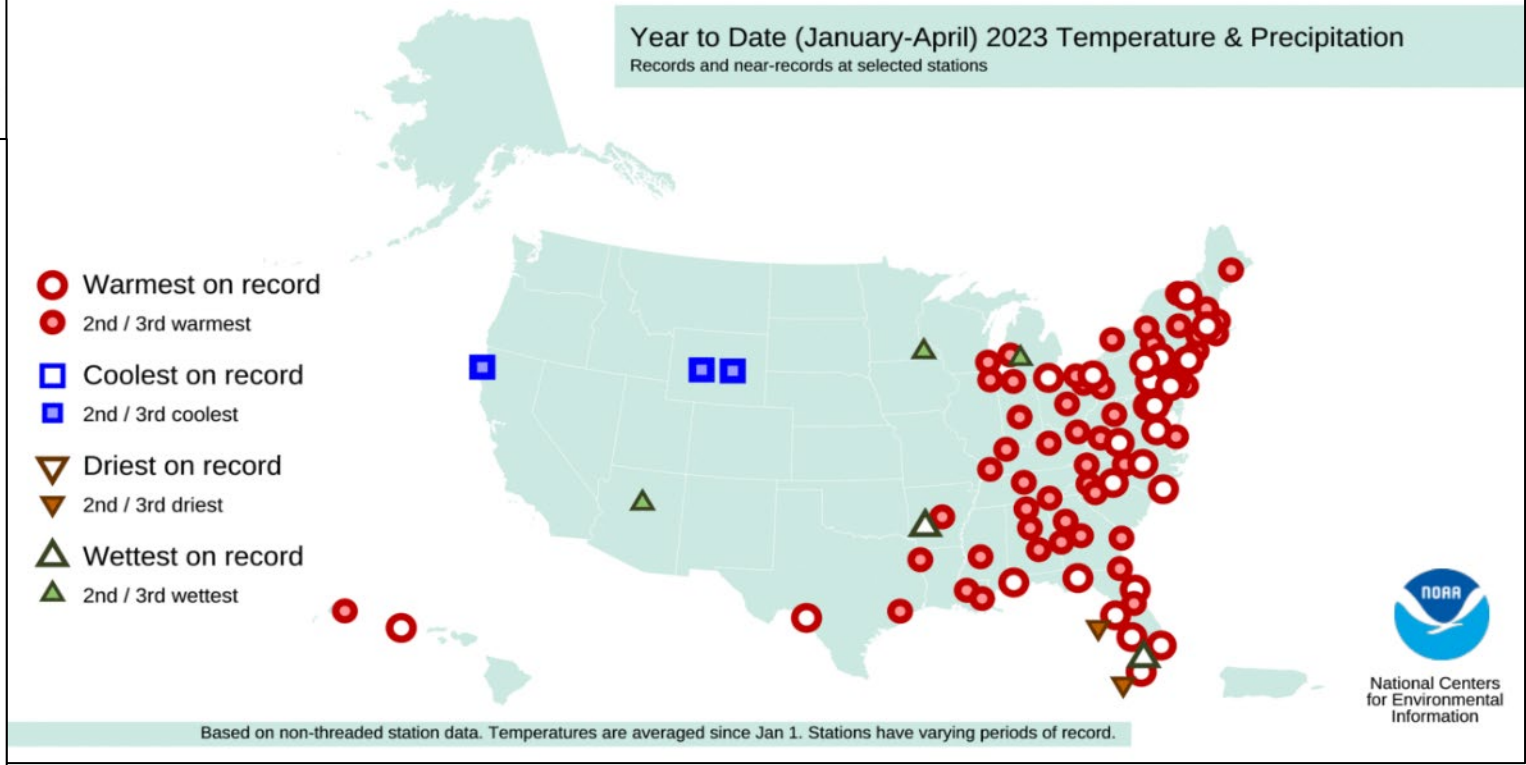
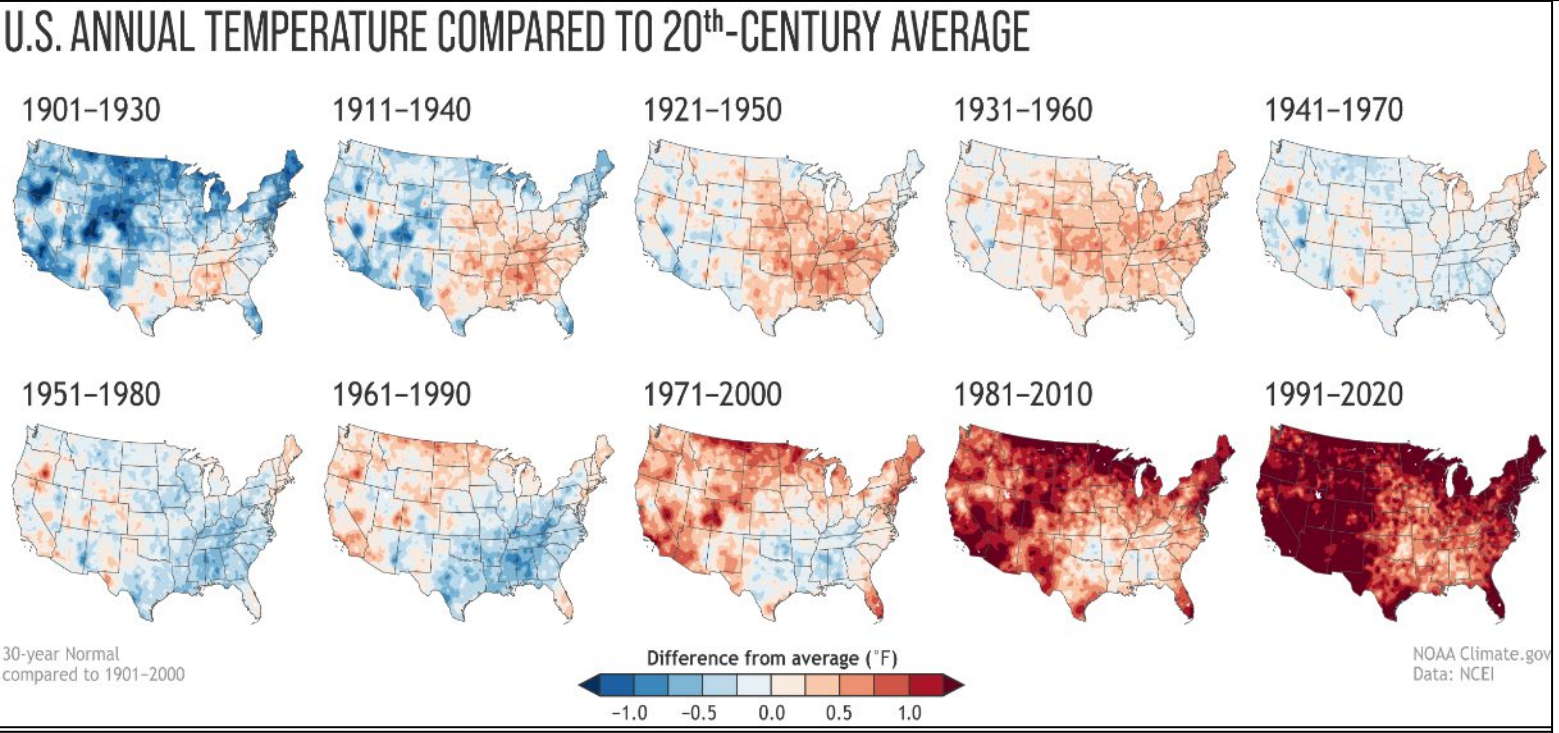
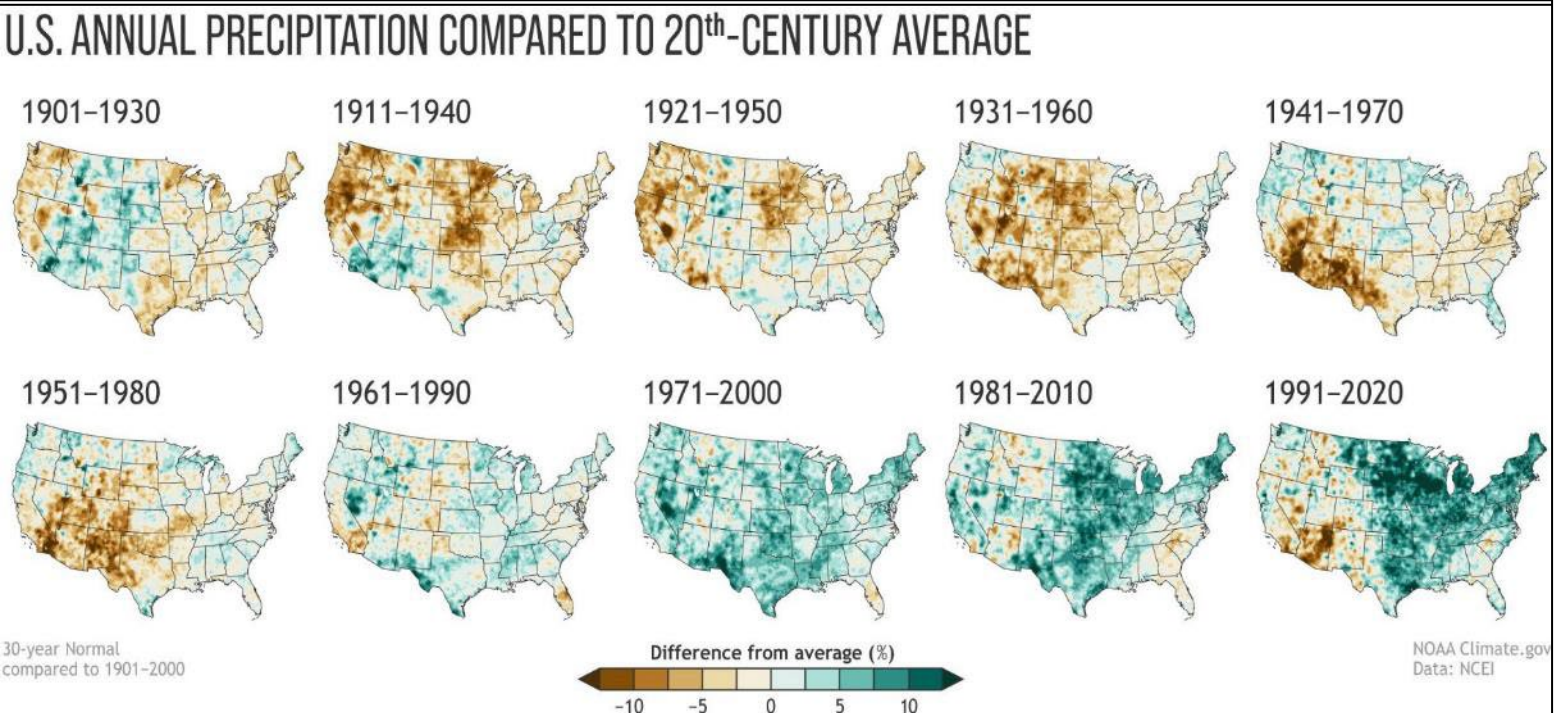






By 2050, about 63% of the US population could be forced to endure temperatures over 100°F. For areas where triple-digit temperatures are seasonal already, the baseline temperature and the frequency of high heat events will increase.

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.

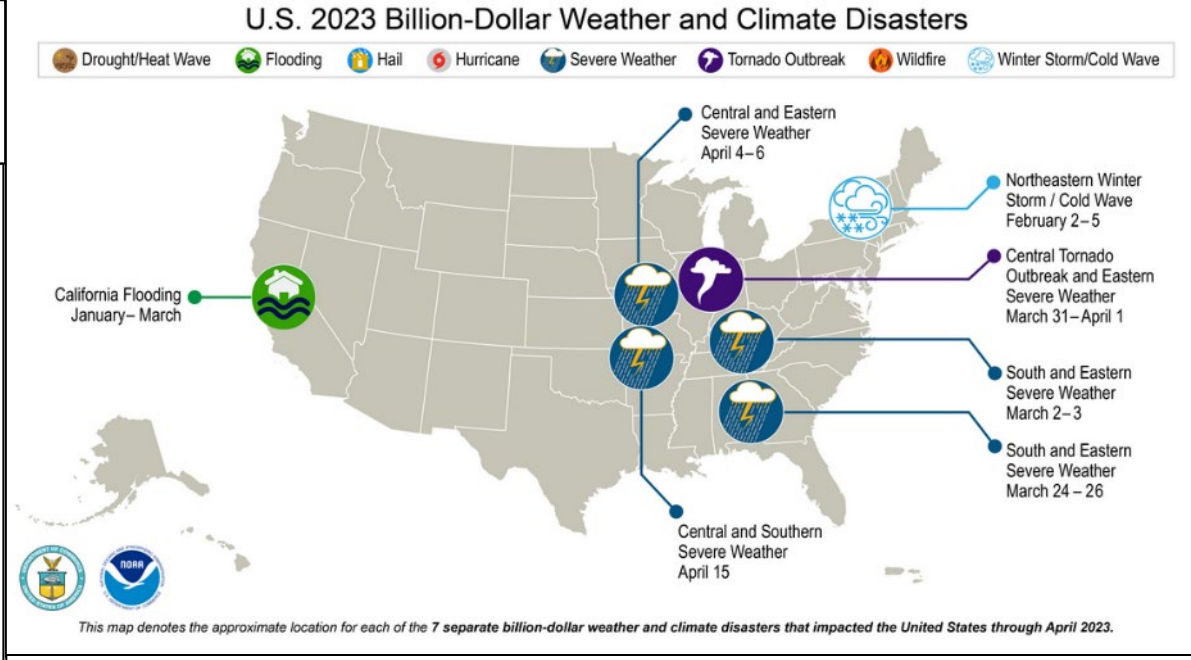
In cities, the air, surface and soil temperatures are almost always warmer than in rural areas. This effect is known as the **Urban Heat Island**.

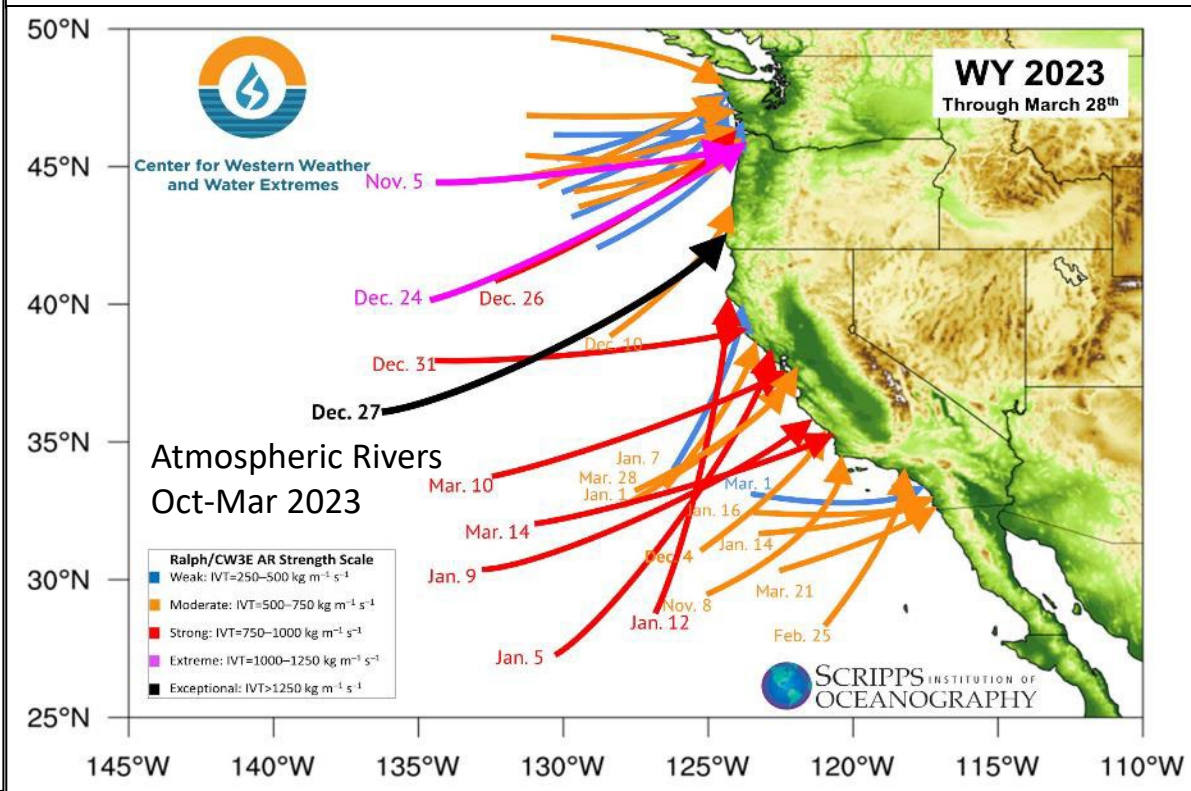
Weather Threats to Stability

Most of the contiguous U.S. experienced above-average temperatures during 2022.

So far during 2023 a few of the major headlining weather events:

- January had several notable weather systems that brought severe thunderstorms and an unusually high number of tornadoes to portions of the United States. Over 150 tornadoes have been confirmed by the National Weather Service.
- This was the first time since 2017 and only the third time since 1950 that January had more than 100 tornadoes during the month.
- February had several notable weather systems that brought severe thunderstorms and an unusually high number of tornadoes to portions of the United States.
- On March 31, nearly 28 million people were under tornado watches as a widespread and deadly tornado outbreak occurred across portions of the Midwest and southern U.S. More than 110 tornadoes, including an EF-4 and eight EF-3s, were confirmed by the National Weather Service—the largest outbreak in a 24-hour period for the month of March.
- According to the Scripps Institution of Oceanography, a total of 31 atmospheric river events, 11 weak, 13 moderate, 6 strong and 1 extreme, brought precipitation to California.
- Also, in February a rare winter storm dumped heavy snow and record rainfall on portions of Southern California, prompting the National Weather Service to issue the first blizzard warning for the region since 1989.
- According to the U.S. Drought Monitor, drought conditions in the West improved from 73.5% coverage on November 1, 2022, to 30.9% on April 4, 2023.
- On March 22, an EF-1 tornado touched down in the Los Angeles area becoming the strongest tornado to hit the area since 1983.
- In early April 2022, NCEI added an additional seven historical weather and climate events which, through inflation and review, surpassed the billion-dollar threshold.
- The U.S. has now sustained 348 weather and climate disasters since 1980 where overall damages/costs reached or exceeded $1 billion. The total cost of these 348 events exceeds $2.510 trillion.





Atmospheric River Damages

Roughly 80%of levee breaches in California's Central Valley are associated with landfalling Atmospheric rivers (UCSD - Scripps). Atmospheric rivers (or ARs) produce up to 50% of California's precipitation annually and 65% seasonally (AGU).

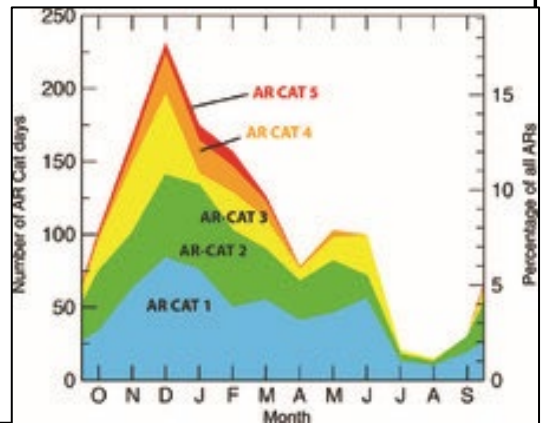
- The new impact matrix uses amounts of water vapor within an atmospheric river as its basis and a period of 24 to 48 hours as its standard measurement of duration.
- When an atmospheric river lasts in an area for less than 24 hours, it is demoted by one category, but if it lingers for more than 48 hours, it is promoted.
- This approach is based on research showing that a combination of strong water vapor transport with long duration over a location, is what causes the greatest impacts.
- Unlike the hurricane scale, unable to represent adequately the impacts of slow-moving lower-category hurricanes, the atmospheric river scale builds in duration as a fundamental factor.
- Previous analysis has shown that on the West Coast, the Oregon coast receives the most atmospheric rivers in the "extreme" range (Atmospheric River Cat 4), averaging about one per year. Washington receives extreme atmospheric rivers about every two years, the Bay Area about every three years and Los Angeles every 10 years.
- The strongest atmospheric river storms hitting the Southern California coast annually, typically fall in the "moderate" to "strong" range (AR Cat 2-3).

Scientists believe that a series of atmospheric rivers caused the Great Flood of 1862, a megaflood that left 6,000 square miles of California's Central Valley under water.

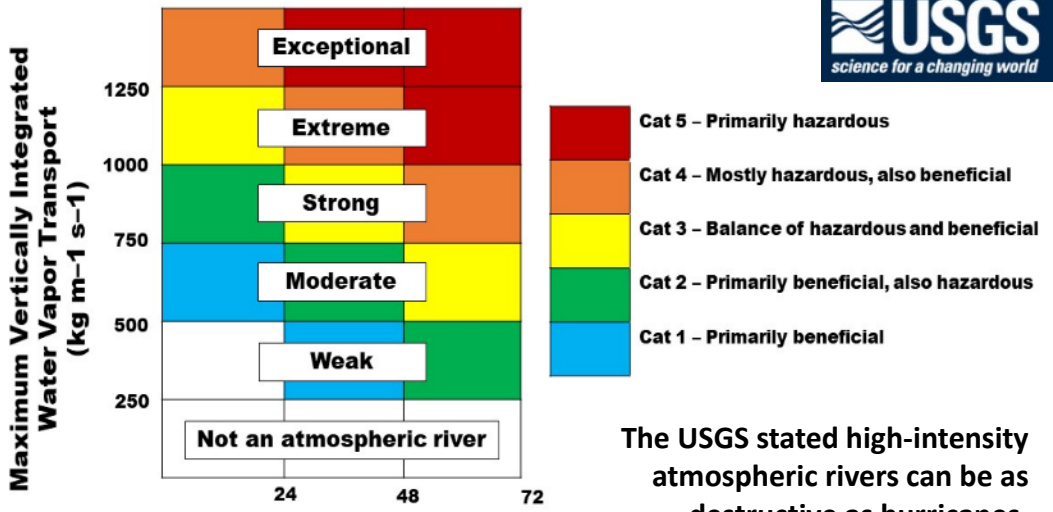
- **Atmospheric rivers cause about $1.1 billion in flood damage annually across the western United States**

The portion of California's annual precipitation that comes from atmospheric rivers is expected to increase as the climate warms.

- A typical atmospheric river can be 300 miles wide, a mile deep and more than 1,000 miles long.
- The term "Pineapple Express" refers to Atmospheric Rivers that form in tropical regions of the Pacific, often around Hawaii.
- Atmospheric Rivers likely contributed to the collapse of both spillways at Oroville Dam in February of 2017.



ARs on the West Coast…	Quantitative finding	References
Cause the heaviest rains	92% of West Coast's heaviest 3-day rain events fed by ARs	Ralph and Dettinger (2012)
Bring warmest storms (less snow, more rain)	Average >50% more precipitation and 2.5°C warmer than other storms in Sierra Nevada	Dettinger (2004); Backes et al. (2015); Guan et al. (2016)
Cause West Coast floods	40%–90% of major floods in West Coast rivers have been fed by ARs	Ralph et al. (2006); Neiman et al. (2011); Konrad and Dettinger (2017)
Cause storm surges in coastal areas	15%–50% of annual sea level maxima are associated with AR-related cyclones	Khouakhi and Villarini (2016)
Yield extreme coastal winds	20%–50% of extreme coastal-wind episodes associated with ARs	Waliser and Guan (2017)
Breach levees	81% of Central Valley levee breaks happened during ARs	Florsheim and Dettinger (2015)
Cause landslides, debris flows, and avalanches	ARs cause 68% of postfire debris flows in Southern California	Oakley et al. (2017); Young et al. (2017); Hatchett et al. (2017)
Bring cycles of wet and dry years	Account for 85% of multiyear precipitation variance in California	Dettinger and Cayan (2014)
Fill reservoirs and provide water supplies	30%–50% of California rain, snow, and streamflow from ARs	Guan et al. (2010); Dettinger et al. (2011)
End West Coast droughts	40%–75% of droughts on West Coast ended by an AR	Dettinger (2013)
Sustain wetlands, floodplains, and fisheries	77% of ecologically significant inundations of Yolo Bypass floodplain, Sacramento River, initiated by ARs	Florsheim and Dettinger (2015)
Water deserts and forests far inland, modulate wildfire risks	Statistically significant relations found between summer normalized difference vegetation index (greenness) and areas burned in parts of interior Southwest	Albano et al. (2017)
Freshen estuaries but sometimes threaten estuarine fauna	Mar 2011 ARs freshened San Francisco Bay by 60%, resulting in wild oyster kill rate of 97%–100%	Cheng et al. (2016)
Modify banks and bottom sediments, modulating aquatic fauna in mountain streams	More invertebrate densities and diversity after major AR flooding; 10 times more in predisturbed settings	Herbst and Cooper (2010)



USGS science for a changing world

The USGS stated high-intensity atmospheric rivers can be as destructive as hurricanes.

https://journals.ametsoc.org/view/journals/bams/100/2/bams-d-18-0023.1.xml

What is an ‘Atmospheric River’

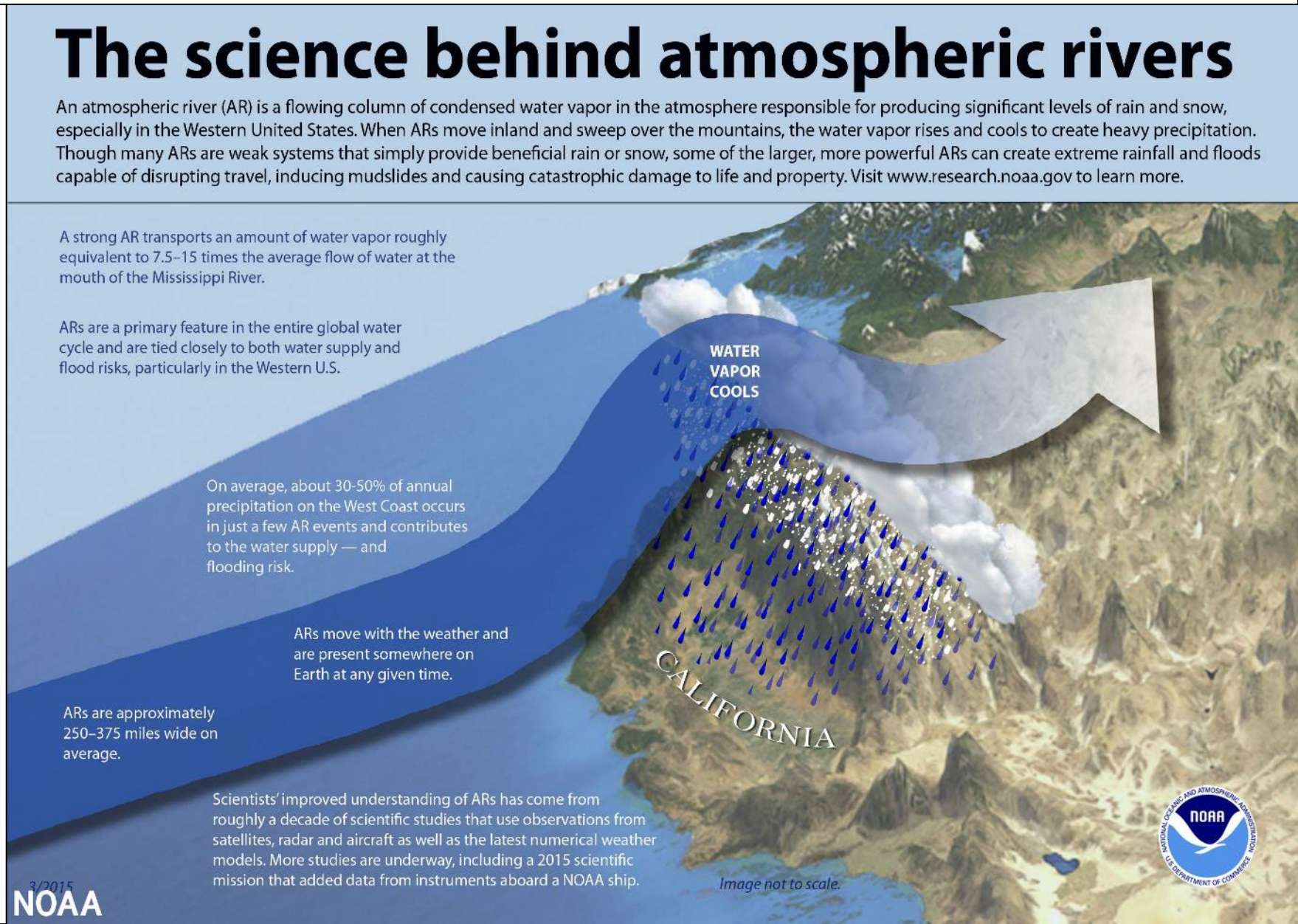
Atmospheric Rivers are relatively long, narrow regions in the atmosphere transporting water vapor from the Ocean to the Land. These columns of vapor move with the weather systems, or frontal boundaries, carrying an amount of water vapor roughly equivalent to the average flow of water at the mouth of the Mississippi River. When the atmospheric rivers make landfall, they often release this water vapor in the form of rain or snow (NOAA).

Fronts act like a conduit to channel warm, moist air northward and eastward ahead of the low-pressure system in what is called the “warm conveyor belt”.

The strongest fronts are also regions of strong winds in the lower portions of the atmosphere. The stronger the winds, the more moisture that can be transported

- Atmospheric River Portal: https://psl.noaa.gov/arportal/
- Gridded Precipitation Observations: https://psl.noaa.gov/arportal/precipitation_observations/
- Precipitation Forecasts: https://psl.noaa.gov/arportal/precipitation_forecasts/
- Satellite Imagery: https://zoom.earth/ or https://psl.noaa.gov/arportal/satellite_observations/

Like tropical cyclones, atmospheric rivers are a form of extreme weather that affects many areas of the globe. The new study estimates that, on average, at least 300 million people around the world are exposed to floods and droughts linked to atmospheric rivers each year. The percentage of Earth’s population affected by atmospheric river storms may relatively small, but the effects are significant (NASA).



Current Drought Areas

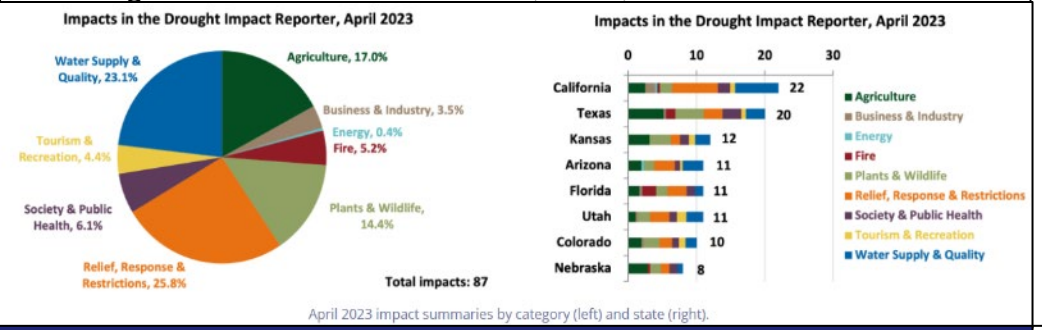
While cooler than normal temperatures are expected to persist through mid-June, current drought damages from the past two years remain prevalent as soils more slowly work to absorb runoff and scraggly brush rapidly grows in previously dried areas.

In April, The NDMC recorded 87 drought impacts in the past month, with California (22 impacts) and Texas (20 impacts) topping the list.

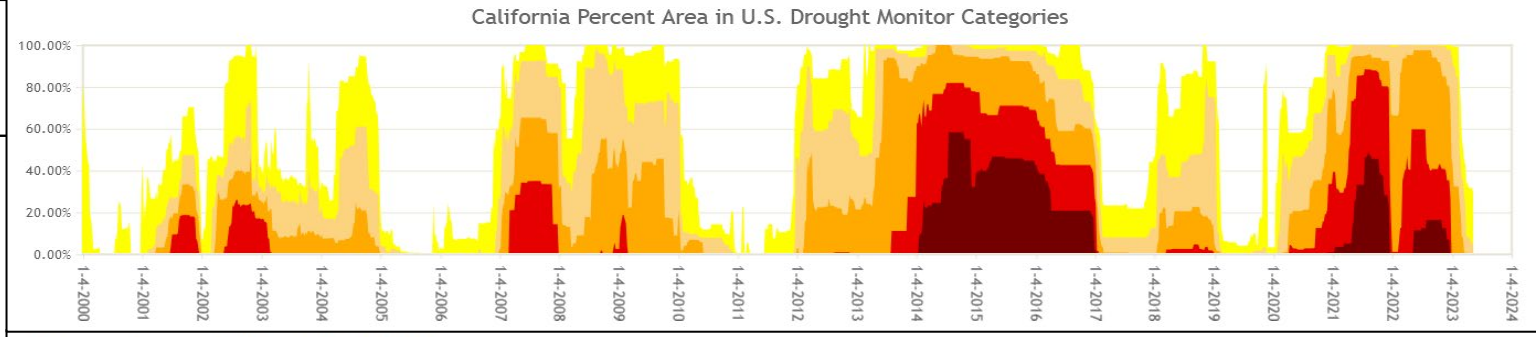
- In California, water supply issues and restrictions were the primary concerns as record snowpack and rainfall improved conditions but couldn't quite make up for years of drought.
- Nationally, the beef cow inventory reached a 60-year low at the start of 2023 with 28.9 million head, down 3.6% from 2022.
- According to the USDA's National Agricultural Statistics Service, more than 90% of those cows are in states where most of the pasture and range is rated as very poor to fair.

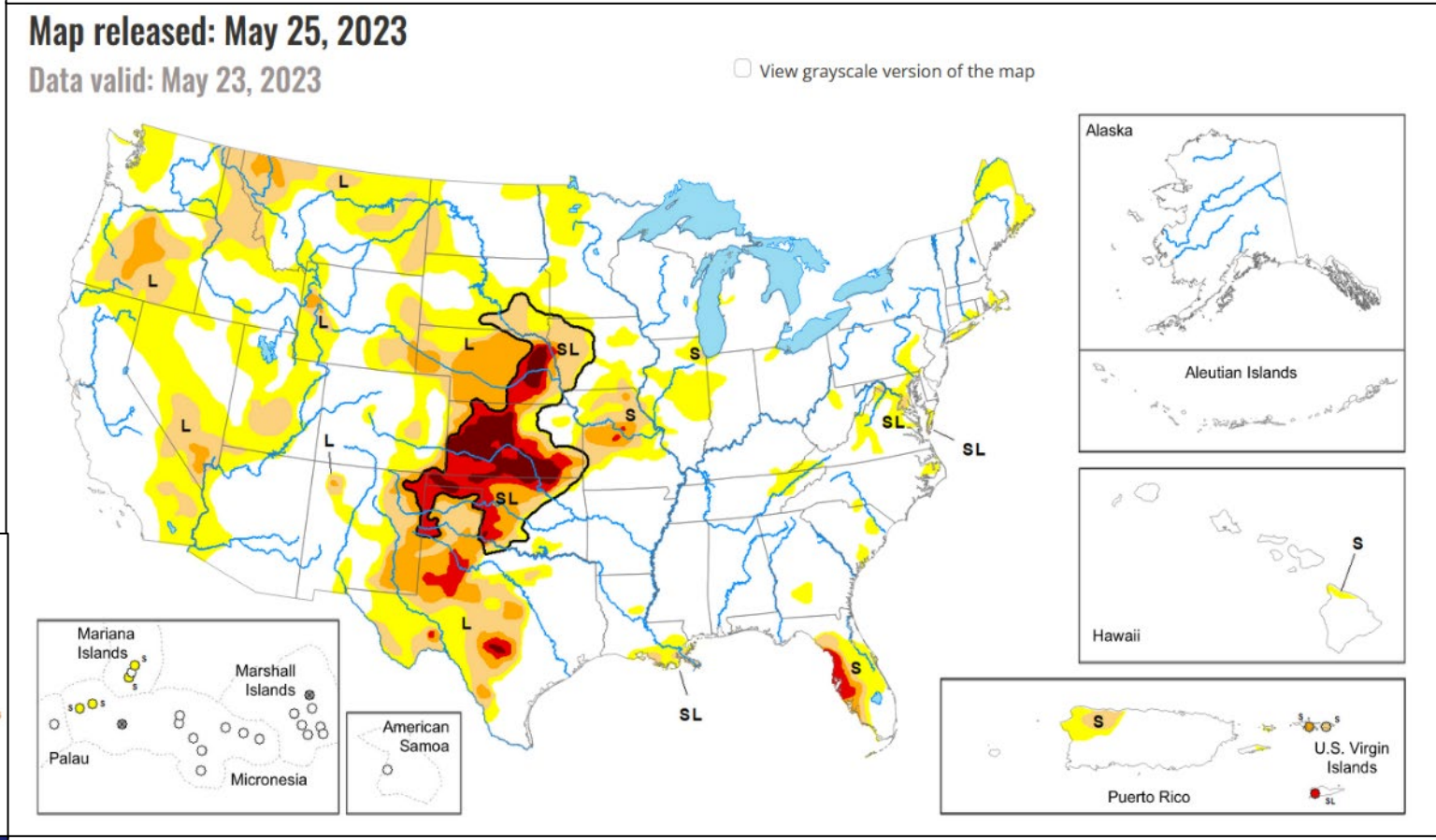
California's snowpack still stands at 254% of average for May, prompting warnings about spring flooding.

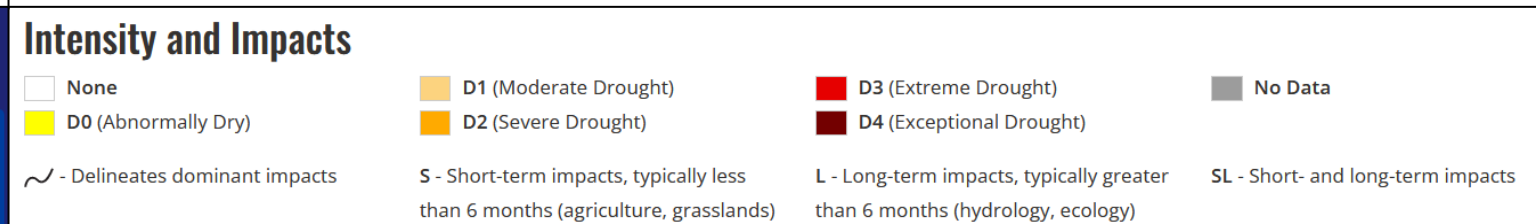
- Average snowpacks have only measured above 200% in April during the winter seasons in 1952, 1969, and 1983.



April 2023 impact summaries by category (left) and state (right).







Drought Outlook

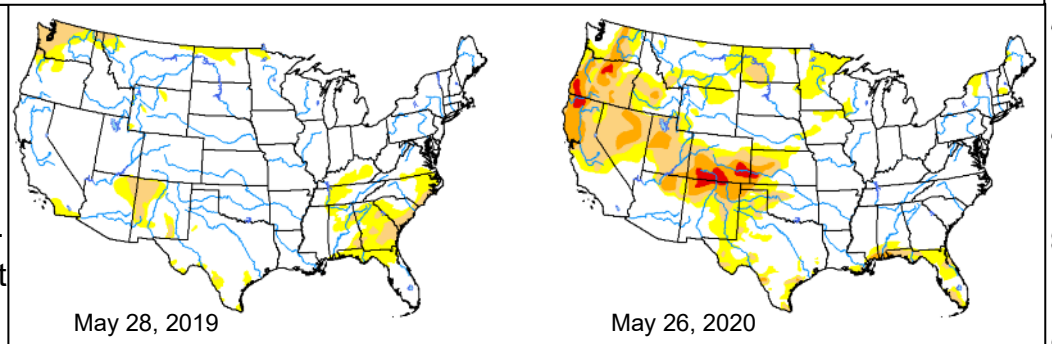
In April, California announced that for the first time since 2006 it will allocate 100% of requested water from the State Water Project.

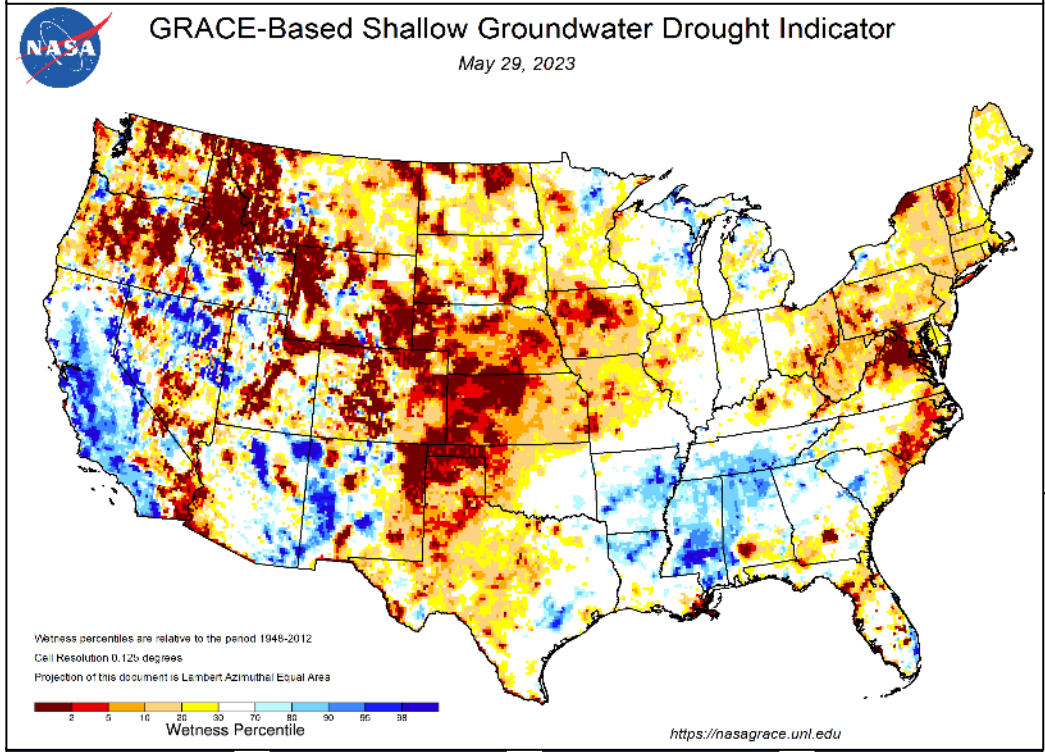
The State Water Project delivers to 29 public water agencies serving 27 million Californians and 750,000 acres of farmland.

The state says it is also maximizing the water that can be diverted toward recharging groundwater basins for future use.

The record-high snowpack has the USACE Sacramento District preparing for above-average inflows to and outflows from USACE-managed reservoirs throughout California's Central Valley, including Isabella Lake.

The cooler days may be hindering honeybees needed for pollination



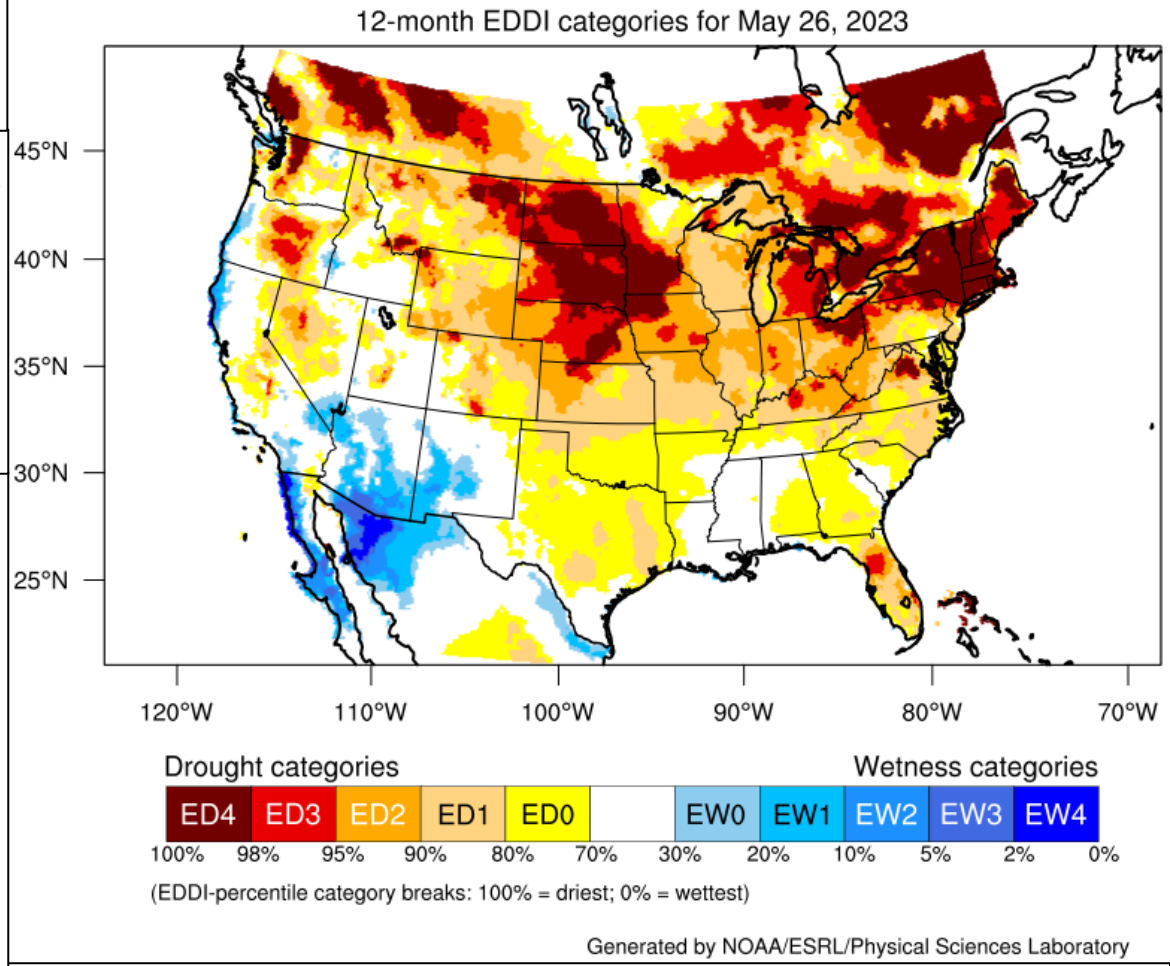


54
counties with USDA Disaster Designations (primary)
— 0 counties since last week

~704,800
California residents in areas of drought, according to the Drought Monitor
↓ 1.5% since last week

15th
driest April on record (since 1895)
0.55 in. total precipitation
↓ 1.08 in. from normal

16th
wettest January—April on record (since 1895)
19.29 in. total precipitation
↑ 6.34 in. from normal



The Evaporative Demand Drought Index (EDDI) is an experimental drought monitoring and early warning guidance tool. It examines how anomalous the atmospheric evaporative demand (also known as "the thirst of the atmosphere") is for a given location and across a time period of interest.

EDDI can offer early warning of agricultural drought, hydrologic drought, and fire-weather risk by providing near-real-time information on the emergence or persistence of anomalous evaporative demand in a region.

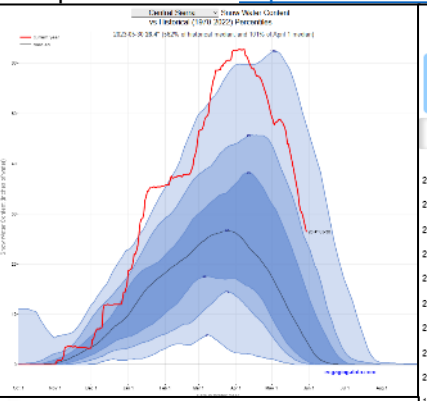
A particular strength of EDDI is in capturing the precursor signals of water stress at weekly to monthly timescales, which makes EDDI a strong tool for preparedness for both flash droughts and ongoing droughts.

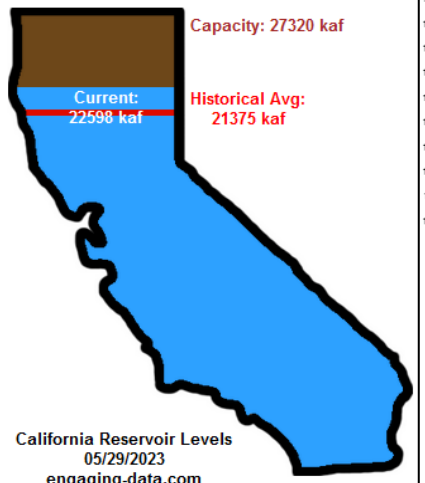
Current California Conditions

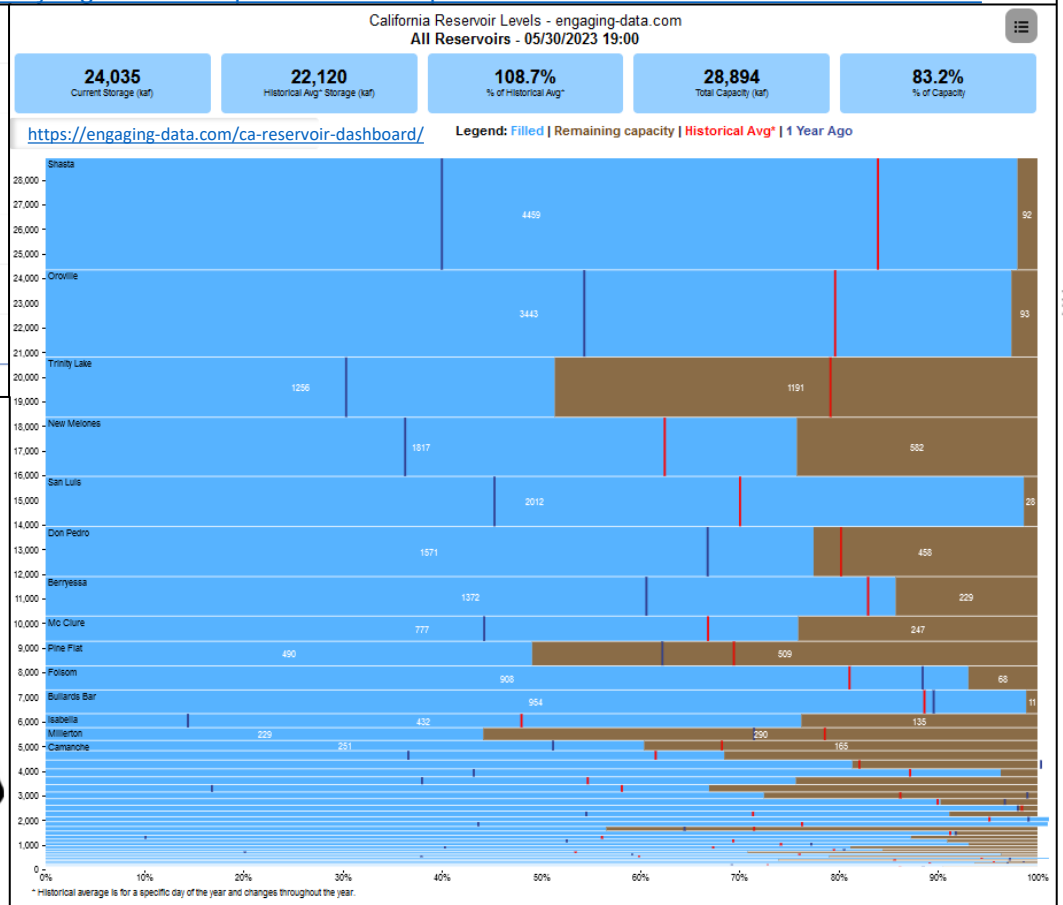
This year's spring runoff is the highest it has been in about 40 years, resulting in concerns for reservoir levels exceeding capacity during early to mid-June rainfall.

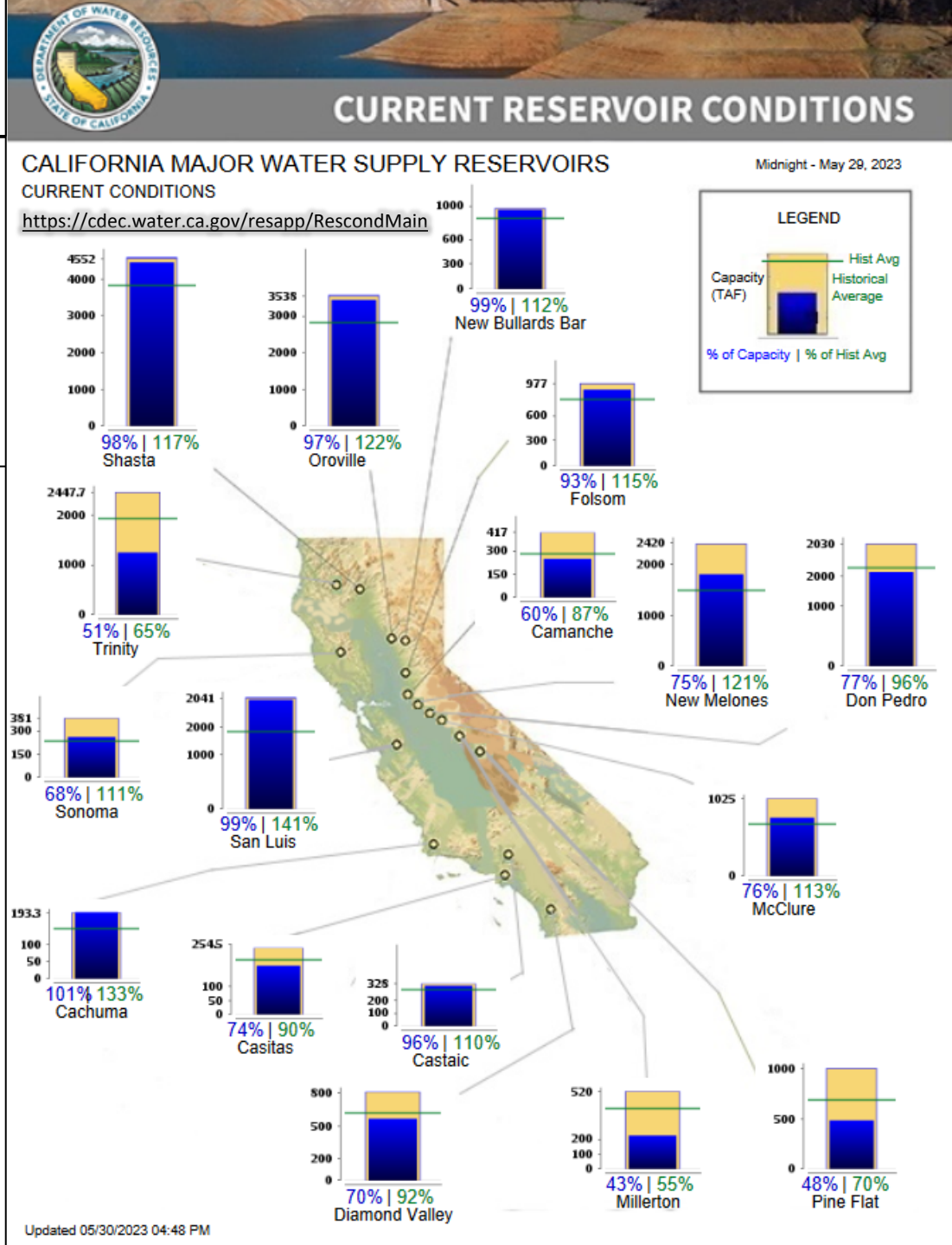
- It should be noted that Trinity reservoir in northern California remains near half of its historical average as well as Millerton and Pine Flat.
- Similar conditions existed in 2019 before major drought swings began in 2020. The same swings could re-occur in a more condensed period as warming trends may be more intense this year.
- Temperatures may be below average, but still range from 70-90 degrees over the coming weeks and building heat expanding from the Central US into the Southwest begins mid-June.

Helpful resources: https://caresiliency.org/resources/quick-links/atmospheric-rivers/#1630011503333-25961431-c97e









Climate Forecast

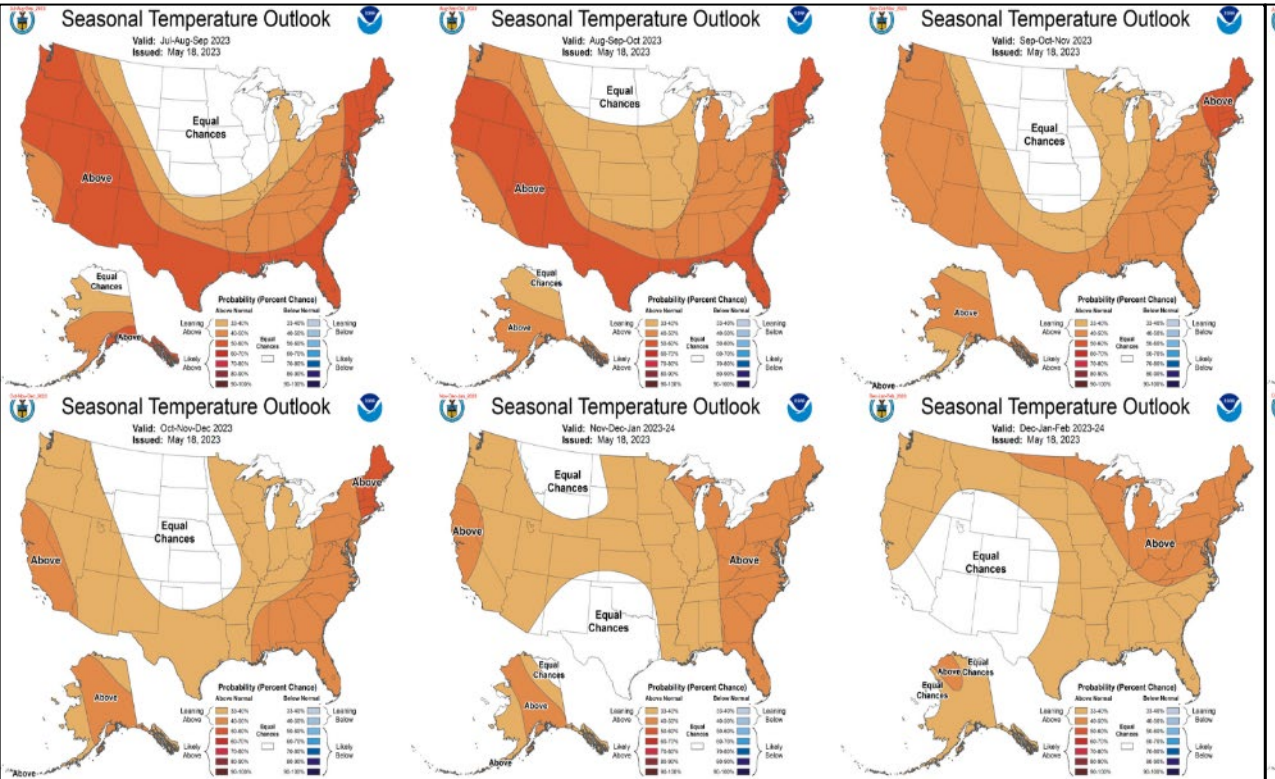
Summer – Fall/Early Winter 2023

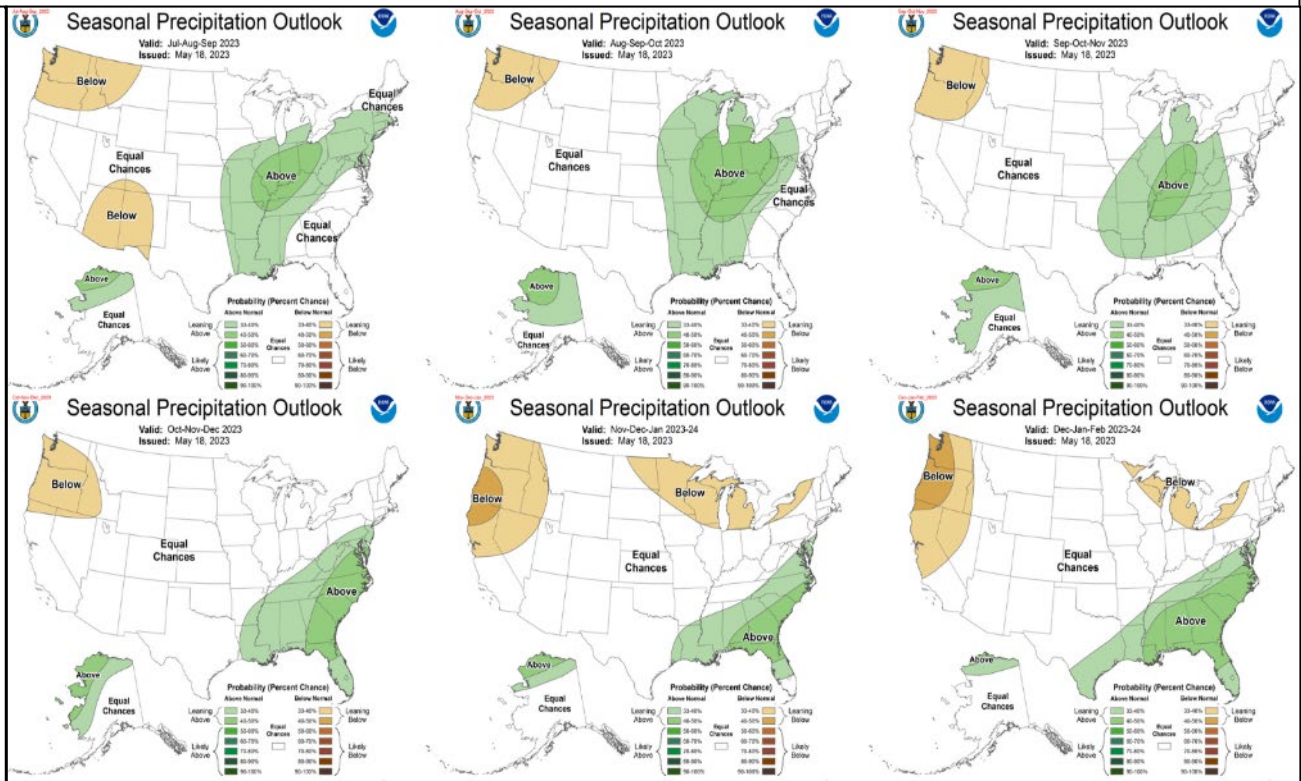
During El Niño events, the jet stream over the Pacific Ocean becomes less wavy and splits into a strengthening subtropical jet stream near the equator and a weaker polar jet stream and can result in a greater number of storms and above-average precipitation across the Southwest during winter and early spring.

El Niño events can delay the onset of the monsoon in Southern California, Arizona, and New Mexico by weakening and repositioning the subtropical high that guides moisture into the Southwest. El Niño events also influence development and strength of tropical storms in the eastern Pacific Ocean, and moisture associated with these storms has the potential to deliver above-average rain to the region, typically in late summer or early fall.

ENSO and the Monsoonal Flow and Seasonal Maps*:*

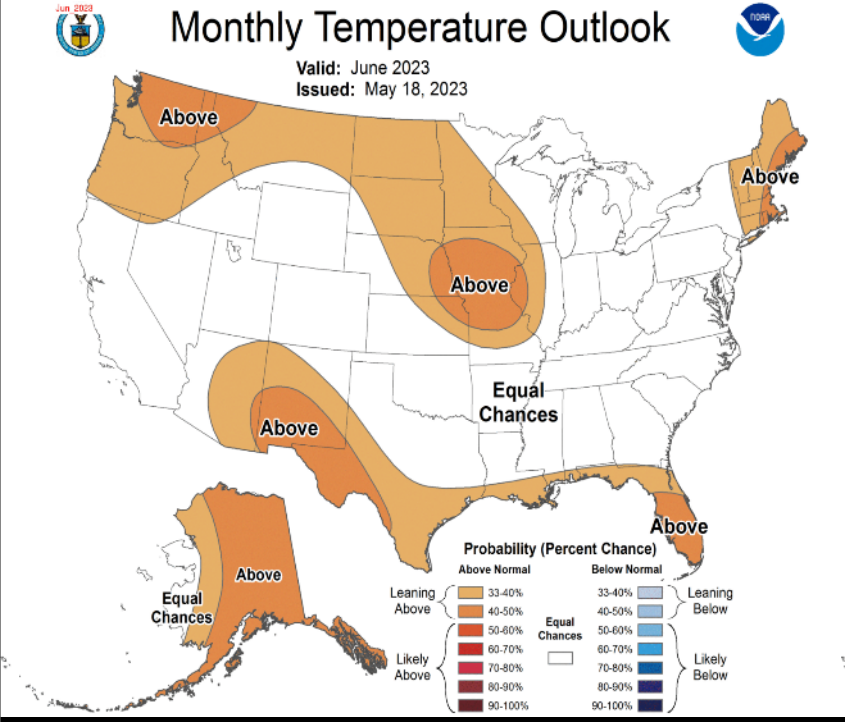
https://climas.arizona.edu/sw-climate/el-ni%C3%B1o-southern-oscillation/faq and https://www.cpc.ncep.noaa.gov/products/predictions/90day/





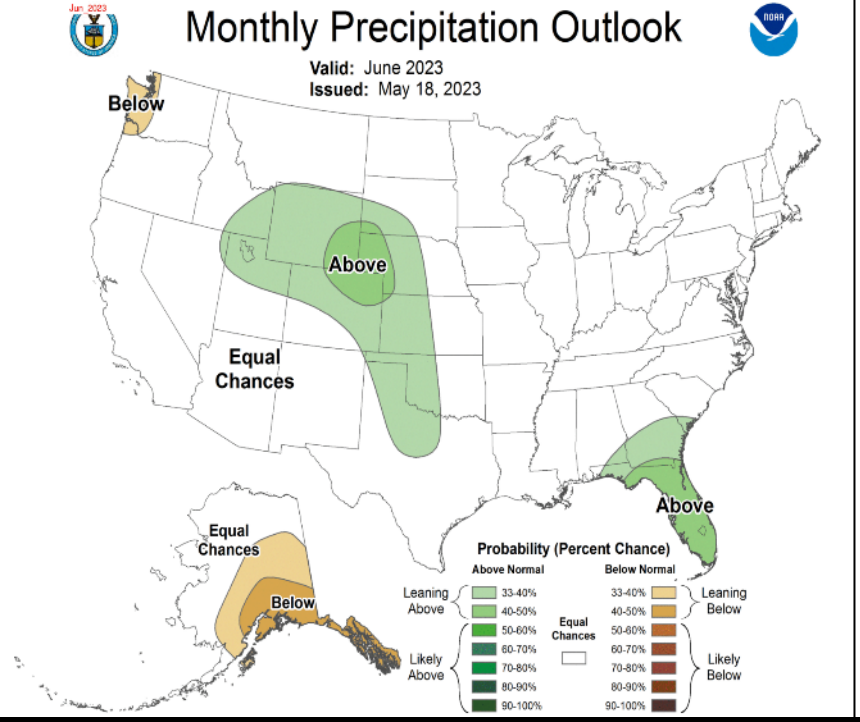
Monthly Temperature Outlook

Valid: June 2023
Issued: May 18, 2023



Monthly Precipitation Outlook

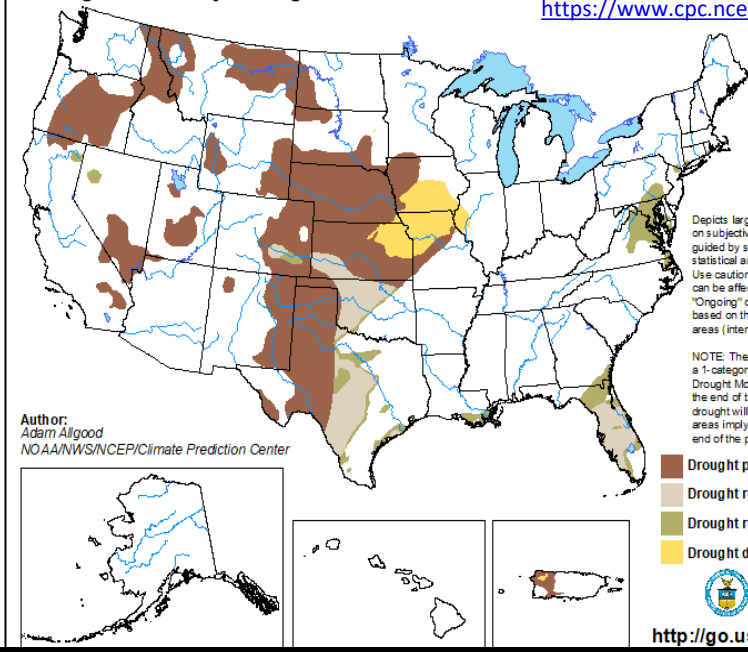
Valid: June 2023
Issued: May 18, 2023



U.S. Monthly Drought Outlook

Drought Tendency During the Valid Period

Valid for May 2023
Released April 30, 2023
https://www.cpc.ncep.noaa.gov/



Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Use caution for applications that can be affected by short lived events. "Ongoing" drought areas are based on the U.S. Drought Monitor areas (intensities of D1 to D4).

NOTE: The tan areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period, although drought will remain. The green areas imply drought removal by the end of the period (D0 or none).

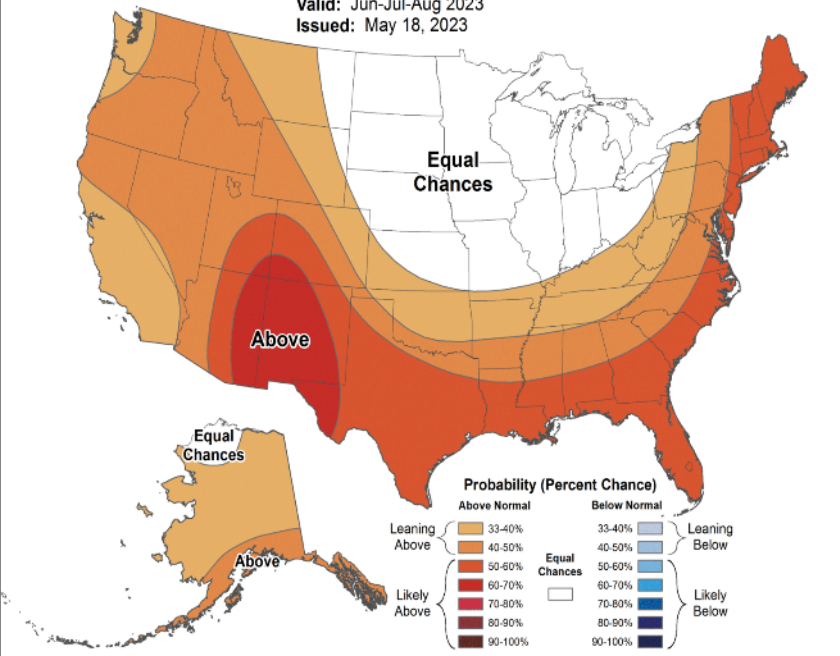
Drought persists
Drought remains but improves
Drought removal likely
Drought development likely

Author:
Adam Allgood
NOAA/NWS/NCEP/Climate Prediction Center

http://go.usa.gov/3eZGd

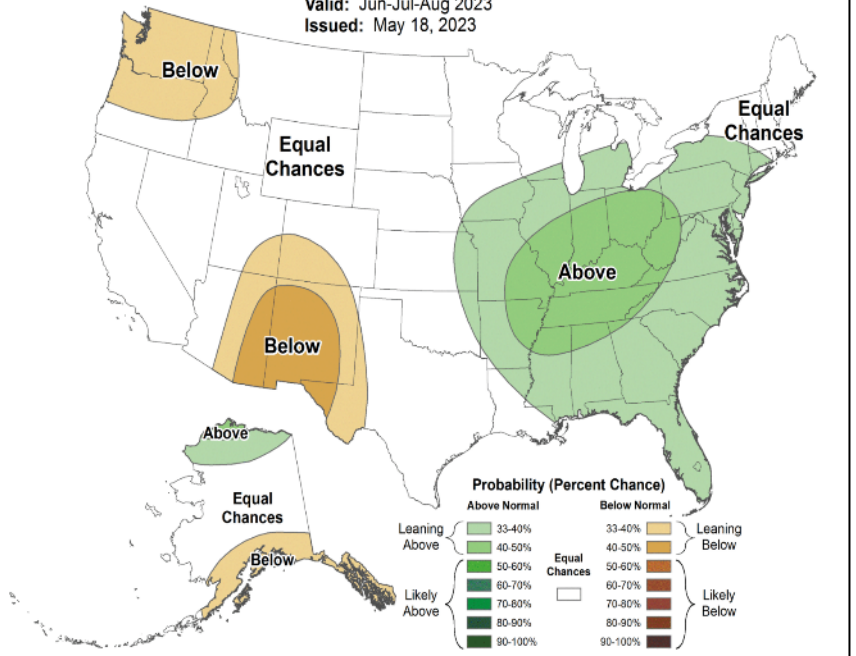
Seasonal Temperature Outlook

Valid: Jun-Jul-Aug 2023
Issued: May 18, 2023



Seasonal Precipitation Outlook

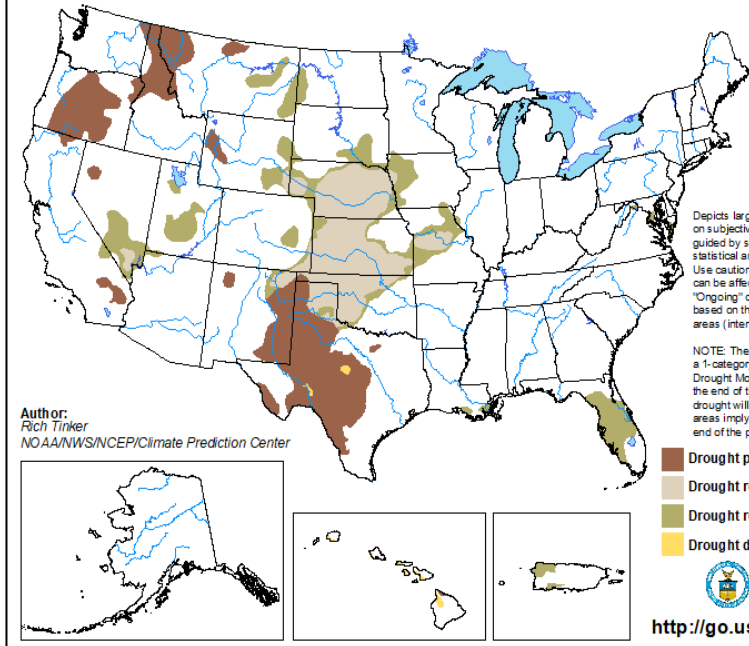
Valid: Jun-Jul-Aug 2023
Issued: May 18, 2023



U.S. Seasonal Drought Outlook

Drought Tendency During the Valid Period

Valid for May 18 - August 31, 2023
Released May 18



Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Use caution for applications that can be affected by short lived events. "Ongoing" drought areas are based on the U.S. Drought Monitor areas (intensities of D1 to D4).

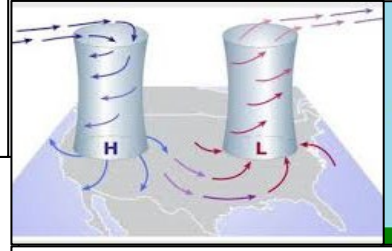
NOTE: The tan areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period, although drought will remain. The green areas imply drought removal by the end of the period (D0 or none).

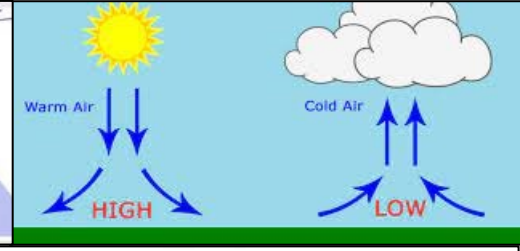
Drought persists
Drought remains but improves
Drought removal likely
Drought development likely

Author:
Rich Tinker
NOAA/NWS/NCEP/Climate Prediction Center

http://go.usa.gov/3eZ73

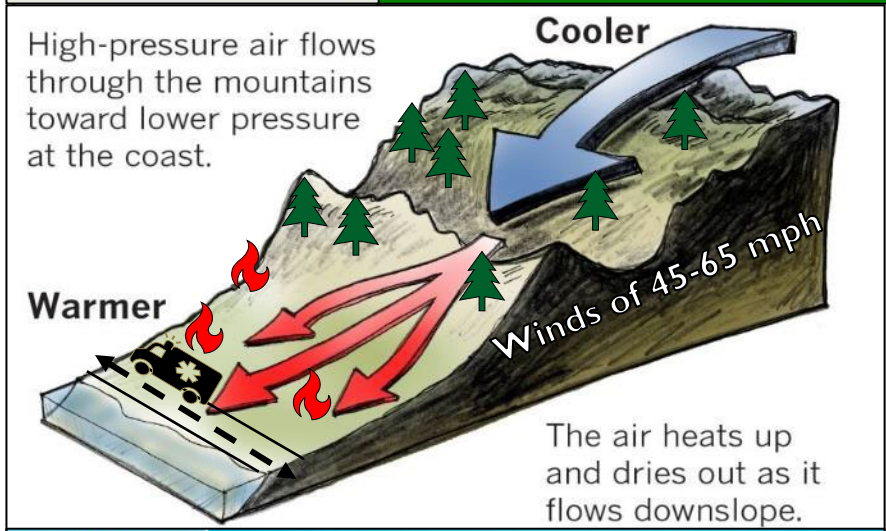
Increased Surface Winds Due to Heat

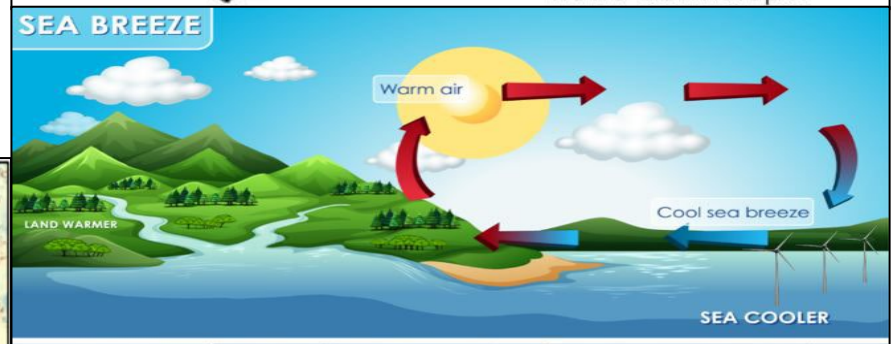


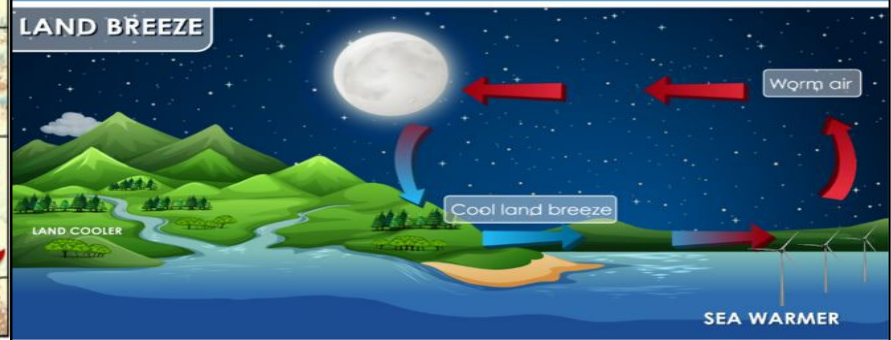


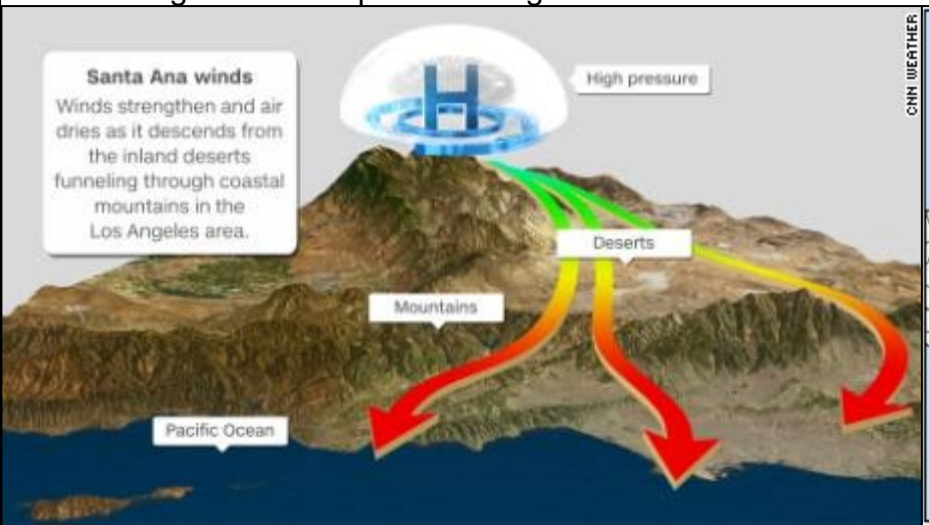
Santa Ana Winds: When a high-pressure center moves into the Desert Southwest, air is forced downslope which compresses and warms it at a rate of about 29F per mile of descent. As its temperature rises, the relative humidity drops; the air starts out dry and winds up at sea level much drier still. The air picks up speed as it is channeled through passes and canyons and can cause gusts of 45-60 mph with peak gusts around 70-90 mph. The winds can also bring areas of exceptionally warm air into southern California increasing the regions daily highs to over 30 degrees above average. Extreme Santa Ana wind events have increased slightly in general over the last 60 years.

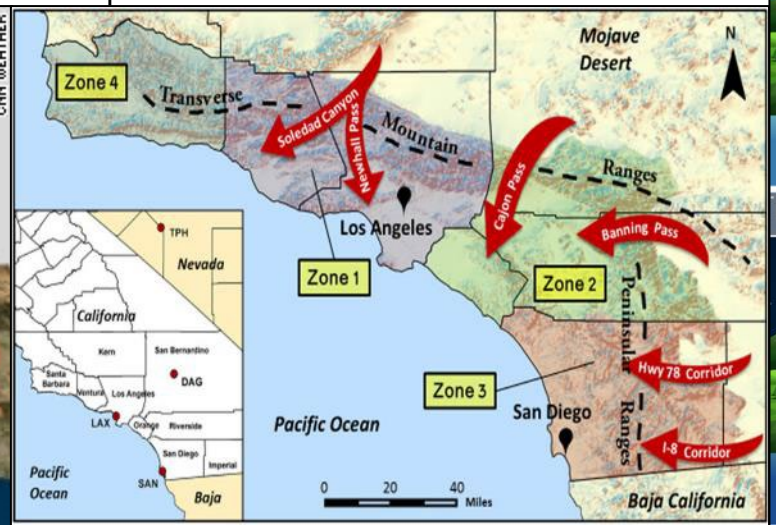
- A study from 2015 showed Santa Ana wind events are stronger during El Niño years when they're also combined with warm sea surface temperatures in the North Pacific Ocean, known as positive Pacific Decadal Oscillation. The study indicates fewer events, but longer duration per event during warm months, and fewer events in winter.
- Damages: Power line damage, downed trees and tree limbs, mountain pass and valley wind hazards to high-profile vehicles, rapid wildfire spreads, increased surface drought conditions, higher levels of evapotranspiration for plants, and wide areas of heat advisories.
- The diurnal sea breeze/land breeze circulation is a common and long-studied within the Los Angeles Basin. During daytime, a strong sea breeze brings air from the Pacific coast inland and transports the pollutants from downtown Los Angeles east into the basin. A front bringing a sea breeze can temporarily increase fire intensity.
- During nighttime, a weaker land breeze moves urban emissions from the Los Angeles Basin over Santa Monica Bay. During late spring and summer, the land breeze begins around midnight and continues until mid-morning, resulting in a 6-hour period during when urban air masses are transported over water.











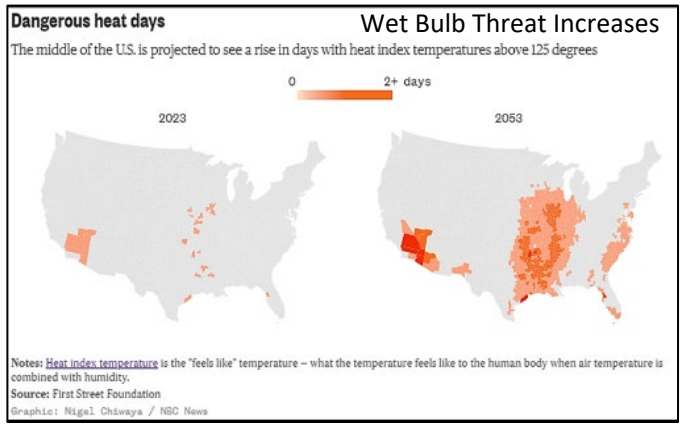
Heat Impacts to Infrastructure

Global average surface temperature has risen at an average rate of **0.17°F per decade since 1901**, comparable to the rate of warming within the US.

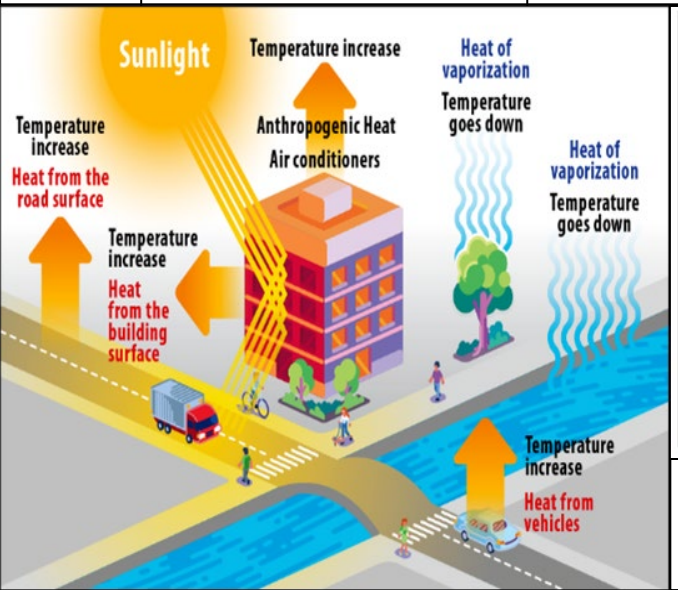
Buckling Roadways
Warping Railways
Runway Defects
Energy Infrastructure Impacts
Permanently Damaged Crops
Widespread Algal Blooms
Depleted Water Oxygen
Livestock/Fishery Deaths
Deadly Ambient Air Temperatures
Wildlife Incursions Increasing
Cement/Concrete/Tar Degradation

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

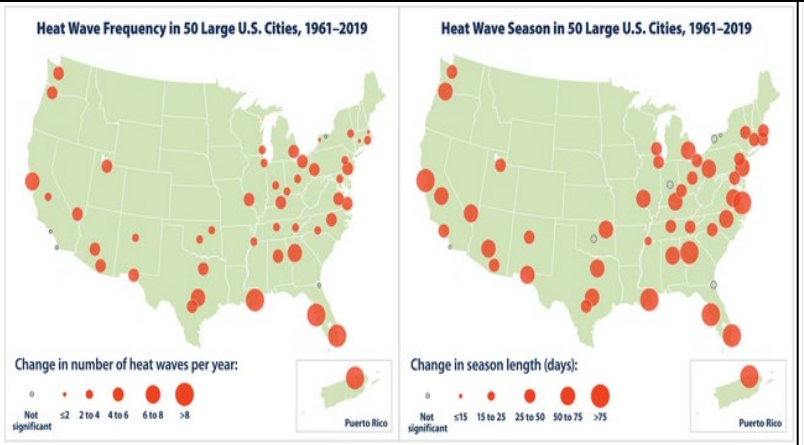
Earthen Dam Damages
Decreased Transportation
Lack of Adhesion Materials
Strain on Medical Services
Overwhelmed Morgues
Military Operations Impact
Readiness Degradation
Contaminated Water Sources
Loss or Lack of Critical Staff
Heat Creates More Ozone
Increased Human Mortality Rates



Heat and Cities

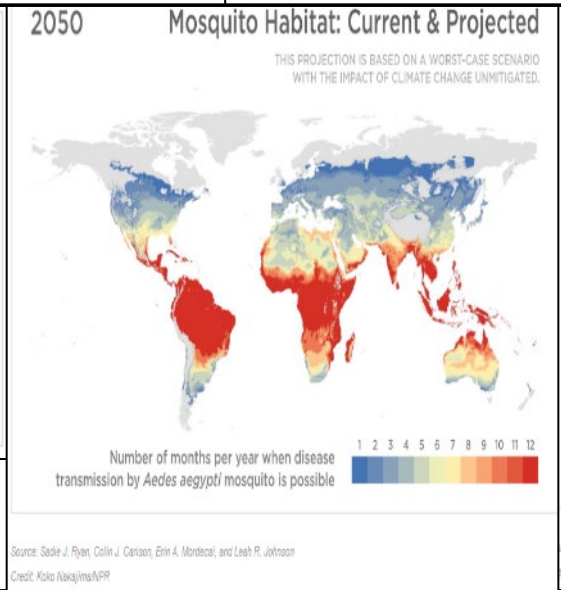


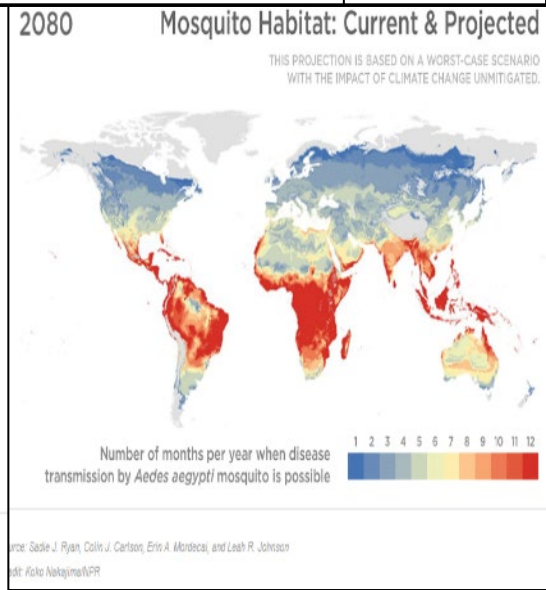
EPA United States Environmental Protection Agency



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

Forecasted Mosquito Migration





Infrastructure Risk Across the US

By 2053, a third of the country could experience at least one day with a heat index above 125°F. The World Meteorological Organization released its own outlook, which found that in the next five years, worldwide temperatures are likely to surpass record levels due to heat-trapping greenhouse gases and the incoming El Niño.

- As ambient air temperatures continue to rise, overheating equipment can threaten power grid stability.
- Concrete degradation from direct sunlight and heat can cause cracks, dimpling of the material, expansion within the structure which allows moisture to infiltrate and break down the stability of the foundation/supporting structures.
- The loss of cooling abilities due to power outages during high heat events could mean sites will need to shut down or reduce operations to prevent overheating threatening server bays and equipment storage.
- Local dams, levees, and other water retention structures could see loss in efficiency as cracks, breaks, and elevation shifts from subsidence expand across regions from the stressors of heat and overpulling.
- Damage/ supply chain delays are possible from warped railways, buckling roadways, and depressed runways. Pipelines can see breakage from overstressed materials during intense heat domes. Crop decay and increased livestock mortality rates are expected due to worsening heat impacting the agricultural sector heavily.

The Pacific Northwest 2021 heat wave cost $8.9 billion in damages as 221,000 acres of forest were damaged by temperatures ranging from 116-118°F, power cables reportedly sagged or melted, state roads saw upheaval and buckling, electricity demand surged resulting in power outages, and caused outages in Sacramento's data center.

California Specific

In 2022 the Santa Clara Valley Medical Center and O'Connor Hospital in California reported a blackout for four hours due to temperatures over 109°F causing substations and site generators to fail. During Public Safety Power Shutoffs (PSPS), infrastructure owners face the risk of inoperable facilities across the county with degraded emergency services.

According to Climate Central's "Climate Shift Index," human-caused climate change has made the warm overnight low temperatures in the West, including California, five times more likely to occur than they would in the absence of added greenhouse gases.

- Extreme heat last year set in during early September resulting in significant grid concerns and requests for residents to pre-cool homes and reduce use during the day.
- September 4th: Gov. Gavin Newsom (D) declared a state of emergency to free up state resources to address the extreme heat. The proclamation notes that energy demand could exceed 48,000 megawatts, the greatest load of the year.
- Heat in 2014-2016 (the last El Niño period of comparison) provided record-breaking warmth each year with threats to the grid repeating year over year and 2015-2016 lacking significant rainfall despite pre-indicators for a soggy season. Sea levels also tend to be higher during El Niño years, indicating that periodic coastal inundations from high tides will be amplified due to rising seas
- El Niño's agricultural effects in the state are usually most evident during winter, when warmer temperatures — especially warmer minimum temperatures — can negatively affect crops that require a higher chill during winter dormancy, such as pistachios, cherries and pears
- To avoid blackouts during heat waves, Newsom and the state Legislature spent $3.3 billion to create a "strategic reliability reserve." State officials used the money to extend the life of some gas-fired power plants that were scheduled to retire and to purchase large diesel-powered generators

Radiative Heat Threats

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.

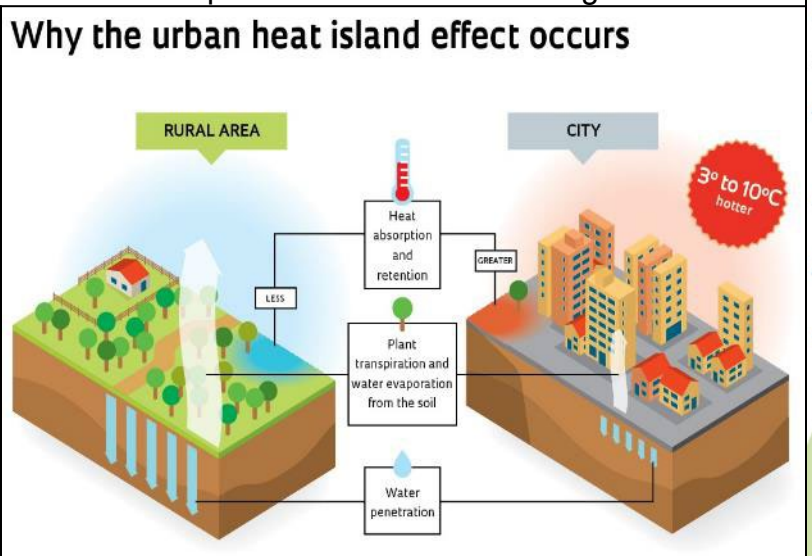
Heat transfer from a body with a high temperature to a body with a lower temperature, when bodies are not in direct physical contact with each other or when they are separated in space, is called heat radiation. Thermal radiation is one of three mechanisms which enables bodies with varying temperatures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

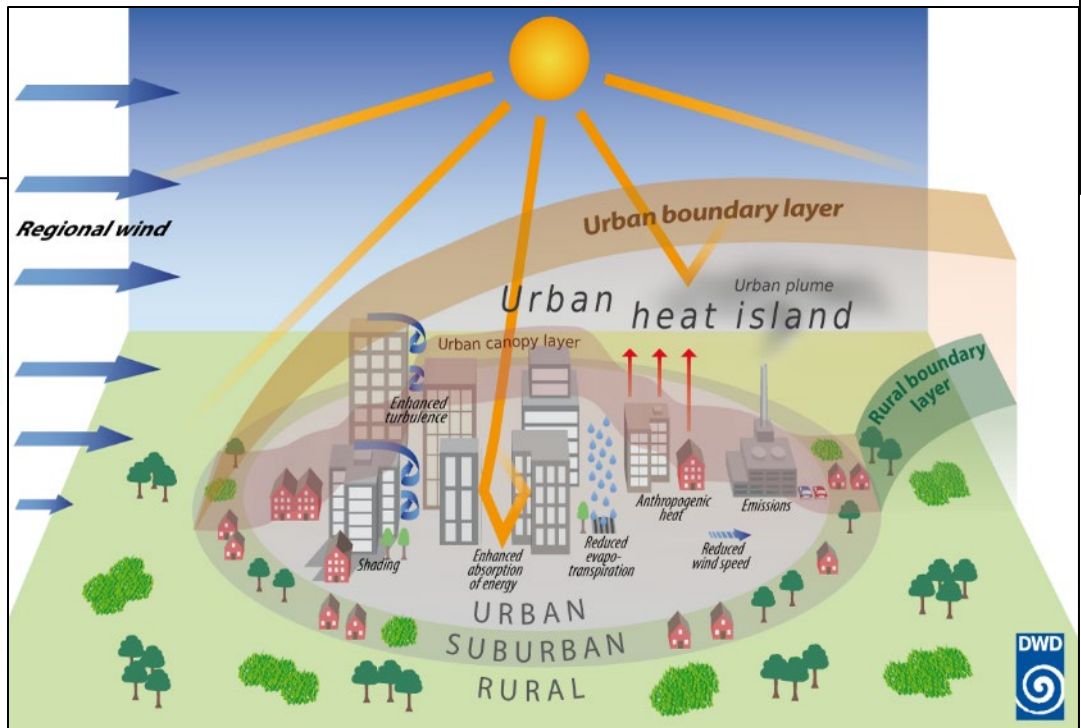
- Sunshine, or solar radiation, is thermal radiation from the extremely hot gasses of the sun, and this radiation heats the earth.
- The entire body acts as an emission source of continuous thermal radiation, and as a continuous receiver of radiation originating even from far-field bodies.
- Concrete 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. Concrete **has a very high heat capacity.**
- 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 as a result 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.





La Niña vs Neutral vs El Niño

The next ENSO Diagnostics Discussion is scheduled for 08 June 2023.

The Current ENSO Index Forecast: The IRI plume also indicates El Niño is likely to form during the May-July season and persist into the winter (90% chance) with a ~55% chance of a strong El Niño developing.

- El Niño years can produce further northward moving Pacific Ocean tropical cyclones.

El Niño refers to the above-average sea-surface temperatures that periodically develop across the east-central equatorial Pacific, represents the warm phase of the ENSO cycle and can amplify tropical systems in the Pacific.

- El Niño events can delay the onset of the monsoon in the Southwest by weakening and repositioning the subtropical high that guides moisture into the region but could contribute to more continental systems entering California, amplifying landslide risks from floods.

Major California events during the last Neutral ENSO Index period

2017: Billion Dollar Disaster: February floods, Northern October fires

- Most of the precipitation fell over San Diego County on February 17 (1.07 inches at Lindbergh Field) and record-setting precipitation (2.34 inches at Lindbergh Field) on Feb. 27. The combination of the wet January and February 2017 ranked the wettest "Jan + Feb" on record for the northern Sierra (8 Station Index - 97 years) and for the San Joaquin River basin (5 Station Index - 113 years) and second wettest for the Tulare basin (6 Station Index - 96 years).
- 2017 was the most destructive wildfire season on record in California at the time. Throughout 2017, the fires destroyed or damaged more than 10,000 structures in the state (destroyed 9,470, damaged 810), a higher tally than the previous nine years combined. In total 9,133 fires burned 1,248,606 acres.

2018: Billion Dollar Disaster: California Firestorm Summer-Fall

- The 2018 wildfire season was the deadliest and most destructive wildfire season on record in California, with a total of over 7,500 fires burning an area of over 1,670,000 acres, the largest area of burned acreage recorded in a fire season.

2019: Billion Dollar Disaster: Drought and Heatwave

- Widespread power outages occurred in June due to a historic heatwave across the entire state of California. The Bay Area Rapid Transit reported significant delays as a result of the weather. Fire danger is high, and air quality is poor.

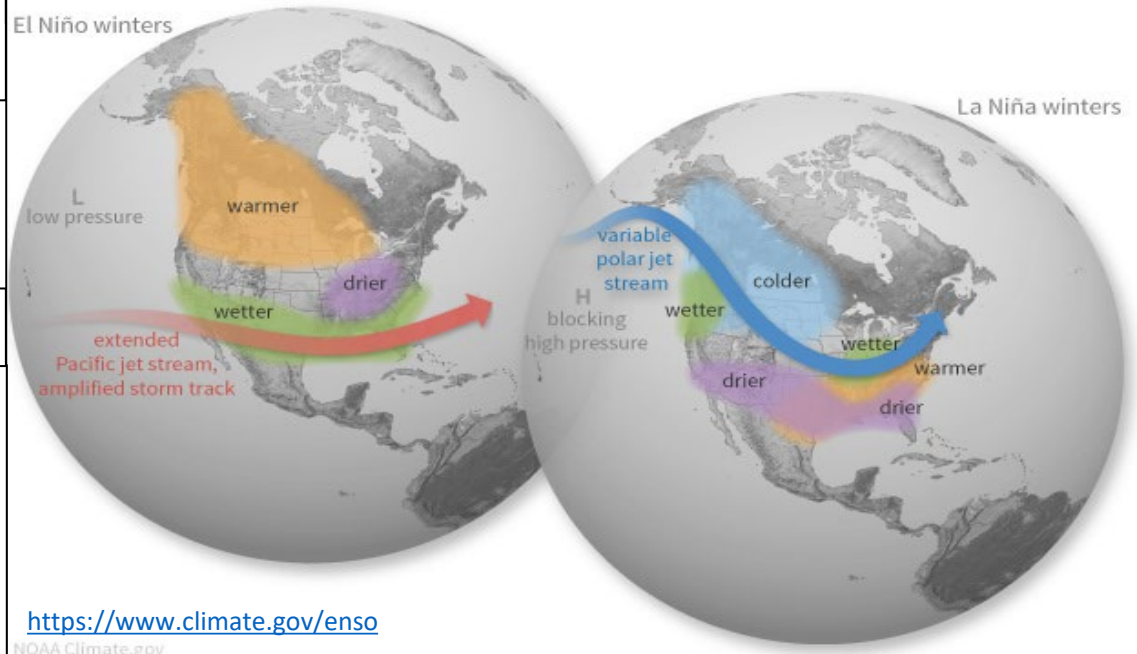
2020: Billion Dollar Disaster: The 2020 California Wildfire season

- As of the end of the year, nearly 10,000 fires had burned over 4.2 million acres, more than 4% of the state's roughly 100 million acres of land, making 2020 the largest wildfire season recorded in California's modern history.

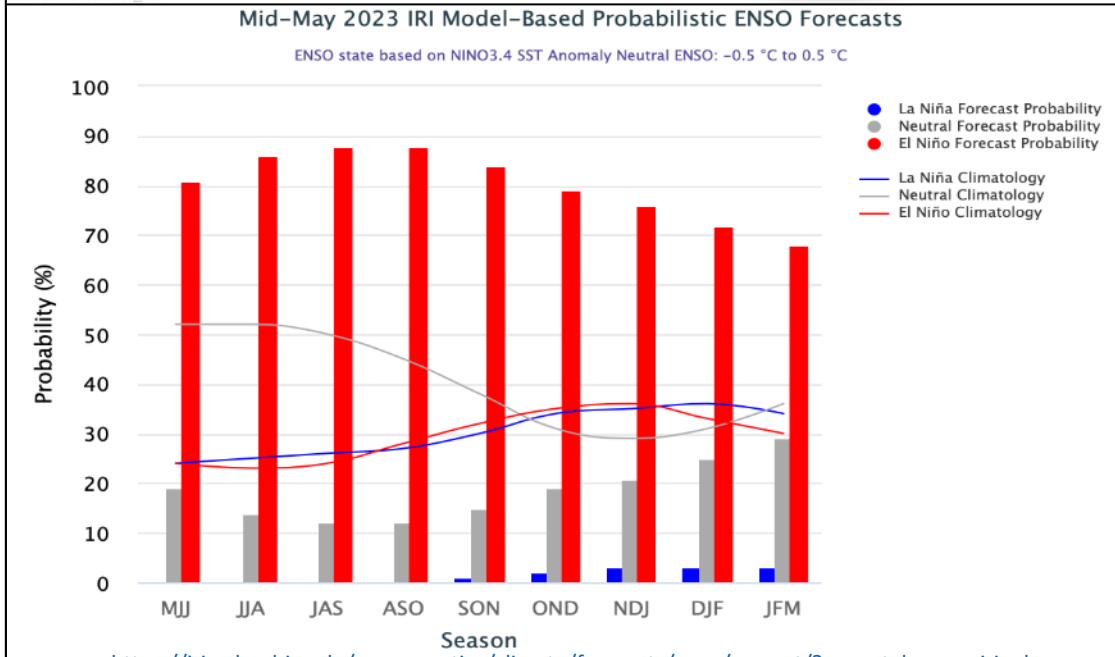
ENSO-neutral refers to those periods when neither El Niño nor La Niña is present.

Past ENSO Years

El Niño	Neutral	La Niña
	1896	
1897	1898-1899	1904
1900	1901-1902	1909
1903	1905	1910
1906	1907-1908	1911
1915	1912-1914	1917
1919	1916	1918
1926	1920-1924	1925
1931	1927-1930	1934
1941	1932-1933	1939
1942	1935-1938	1943
1958	1940	1950
1966	1944-1949	1951
1973	1952-1954	1955
1978	1957	1956
1980	1959-1961	1962
1983	1963-1965	1971
1987	1967-1970	1974
1988	1972	1976
1992	1975	1989
1995	1977	1999
1998	1979	2000
2003	1981-1982	2008
2007	1984-1986	2011
2010	1990-1991	2012
2016	1993-1994	2021
	1996-1997	2022
	2001-2002	
	2004-2006	
	2009	
	2013-2015	
	2017-2020	



https://www.climate.gov/enso



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

Past Strong El Nino years

The 1982-83 El Niño contributed to an estimated $4.1 trillion in global income losses in the five years that followed, and the 1997-98 El Niño contributed to an estimated $5.7 trillion in losses, according to a study published Thursday in the journal Science.

- Median losses from the incoming El Niño event could be at least $3 trillion by 2029.
- The costs are much larger than previous estimates and reflect the ways in which economies endure persistent depressions for several years after El Niño events.
- Insurance losses will be high, and changes in banking and interest rates in response to those effects are possible.

Triple-dip La Niña's recorded since 1950 spanned the years 1954-1956, 1973-1976, and 1998-2001. Neutral Enso Index typically correlates with a significant swing in severe weather for California when shifting towards El Niño conditions.

- For California, years with 10+ tornadic events were: 2015 (10), 2012 (12), 2005 (30), 2004 (10), 1998 (25), 1997 (17), 1996 (22), 1993 (12), 1992 (20), 1991 (16), 1983 (10), 1982 (14), 1978 (14), 1958 (10).

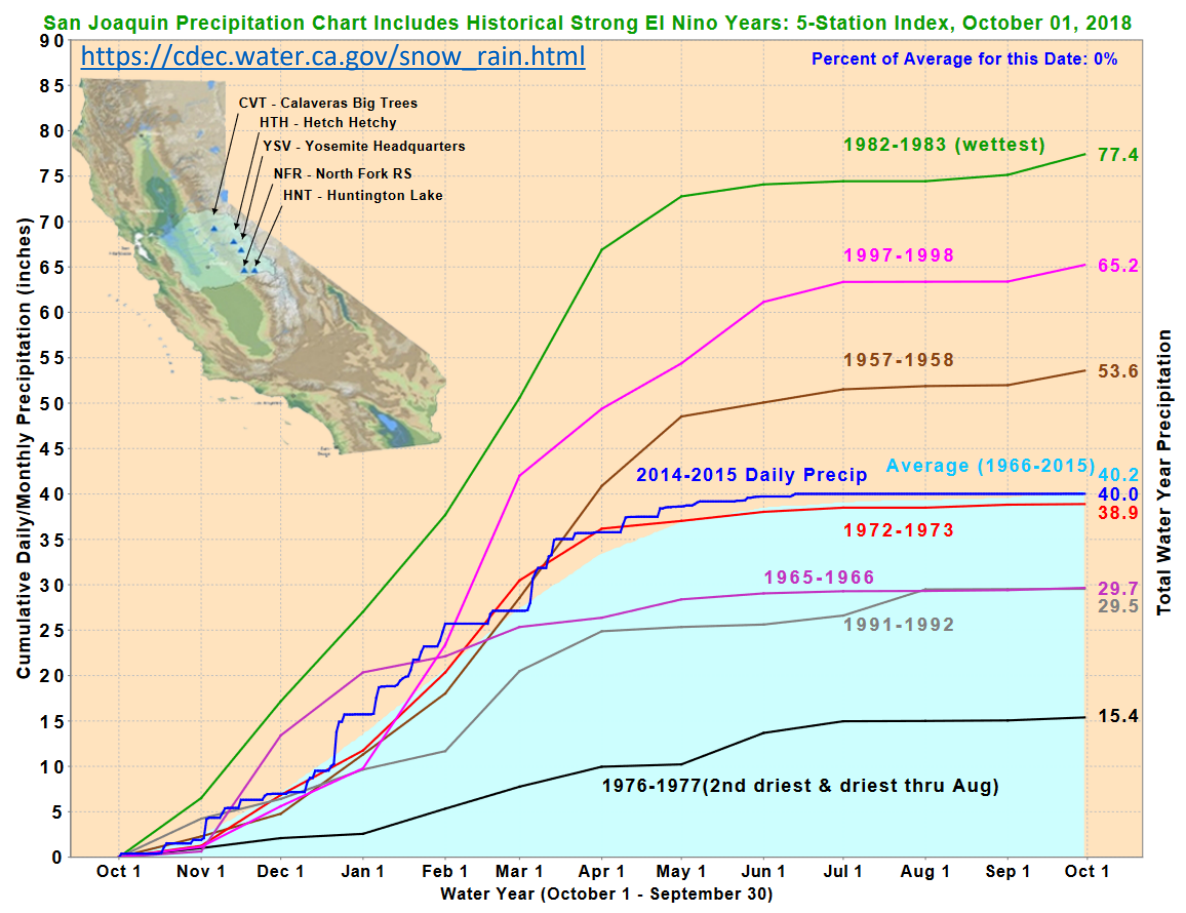
Precipitation shifts during winter associated with strong El Nino years can vary significantly as depicted in the bottom corner graphic.

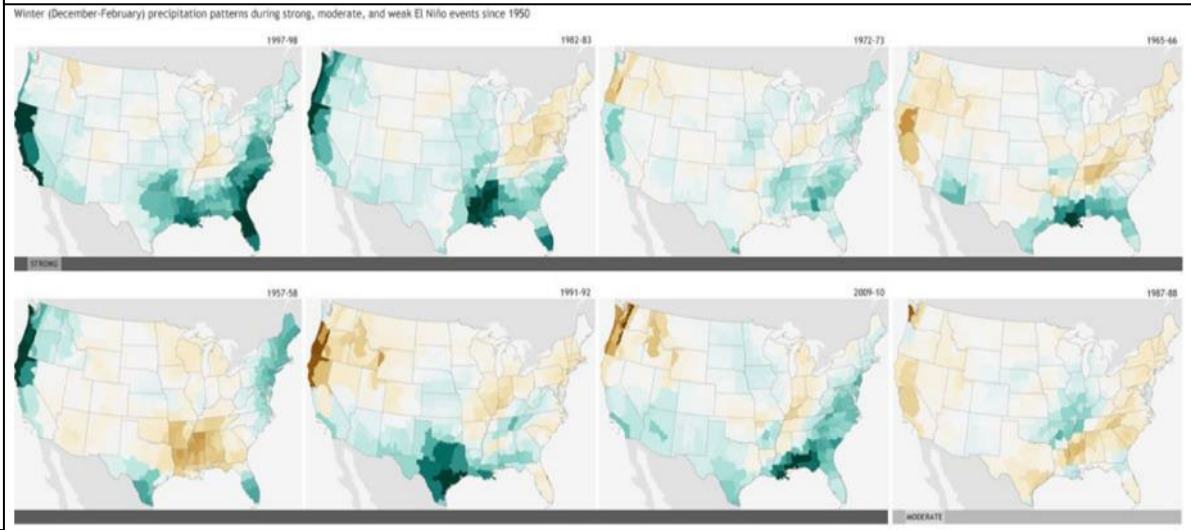
- The graphic in the upper corner, consolidated in 2018, depicts the shift in the San Joaquin basin during strong El Niño years also highlighting the significant variance in averages.

The Great Flood of 1862 in California was caused by storms developing over the abnormally warm Pacific Ocean causing 43 days of rain/snow reaching near 10 feet of accumulation. The event in began in November-December and persisted into the New Year (1861-1862).

Coming off Triple Dip La Niña:

- The winter season of 1997-1998 with a very strong El Niño occurring was one of the wettest on record across California, with typically double the normal amount of rainfall and about $850 million in flood and storm damage statewide.
- The winter season of 2002-2003 produced heavy rainfall across most of the Western US resulting in widespread power outages reaching over 1.1 million outages and torrents of floodwater causing damage. In coastal areas some sites saw 6 inches of rain in less than 24 hours while mountains saw heavy snowfall.





Tropical Cyclones Changes

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 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.

On average 2-4 hurricanes make landfall per season with 11 storms having made landfall in 2020 and eight storms making landfall in 2021. 2020 broke the previous record of nine landfalls set in 1916.

Recent Hurricane Season Studies

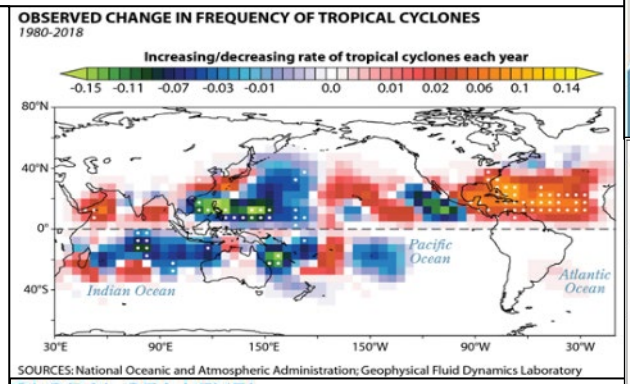
- A study analyzing the 2020 North Atlantic hurricane season found that hourly hurricane rainfall totals were around 10% higher compared to hurricanes recorded in the pre-industrial (1850s) era.

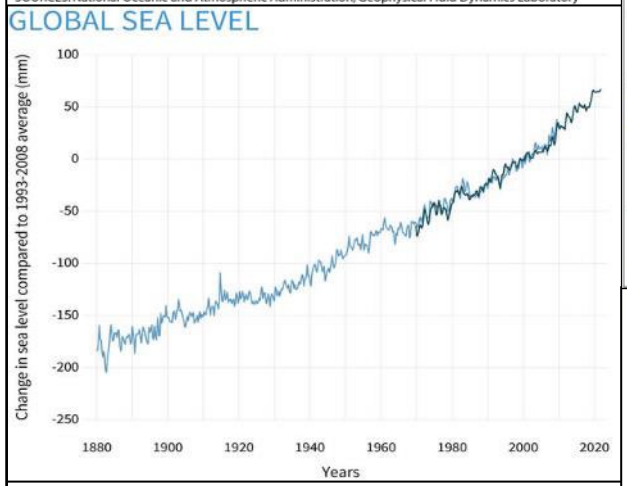
- A recent assessment suggests an increase in intensity, proportion of the most intense storms, and the occurrence of storms with extreme rainfall events.*18 tropical storms (7 hurricanes) have made landfall in the past two years in the eastern United States.*

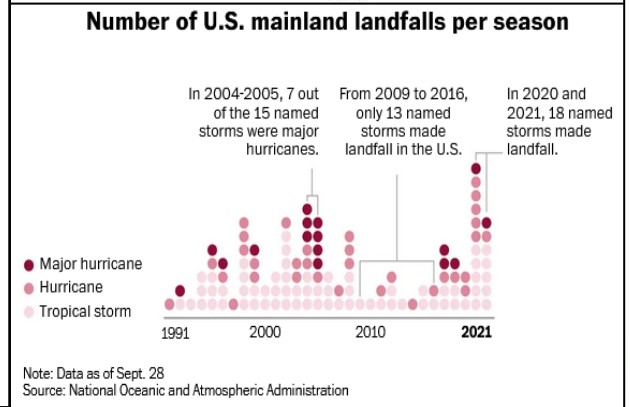
- A recent study from Yale using data from 2020’s cyclone Alpha and 2021’s cyclone Henri states the next 75 years will see an expansion of hurricanes/typhoons into mid-latitude regions, including major cities such as New York, Boston, Beijing, and Tokyo

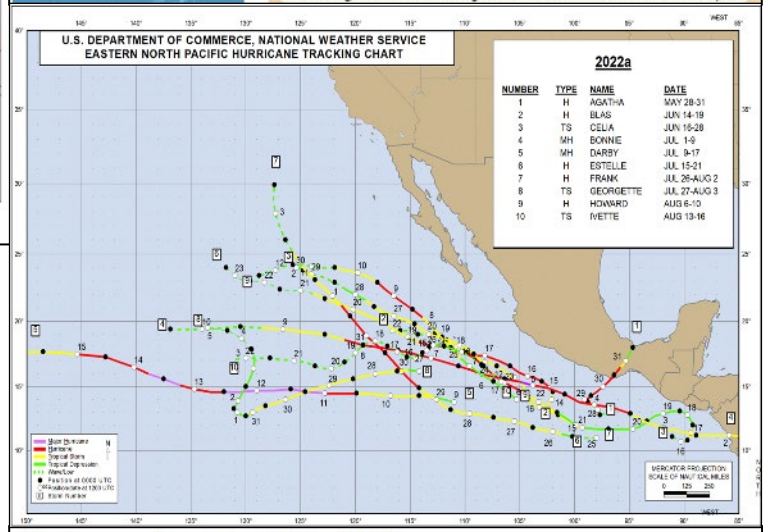
- A recent assessment indicated an increase of global tropical cyclone rainfall rates at 7% per degree of Celsius of warming with an observational finding of a 1.3% global increase in tropical cyclone rainfall rates per year since the early 1900s.

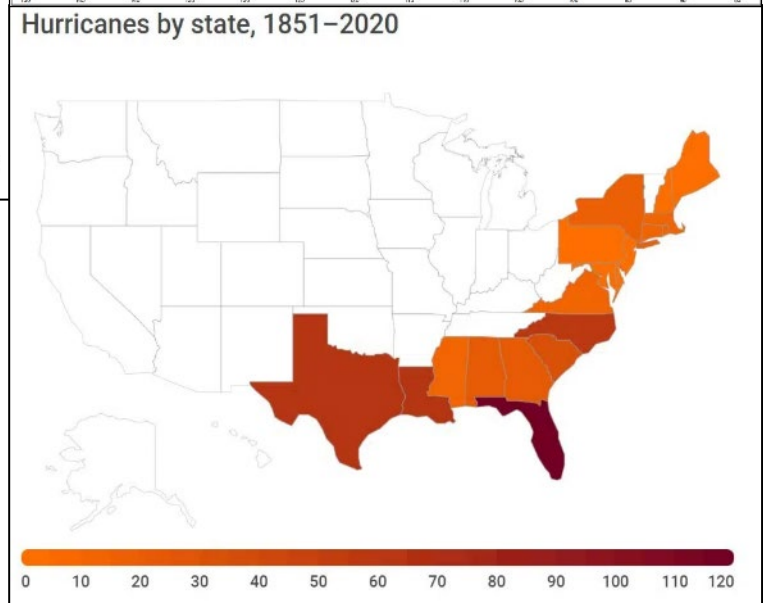
- The IPCC 6th assessment states with high confidence that the global proportion of tropical cyclones that reach very intense (category 4-5) levels, peak winds, and rainfall rates are all expected to increase annually.











California Tropical Cyclones

For the 2023 season, 4 to 7 tropical cyclones are predicted for the Central Pacific hurricane region. A near-normal season has 4 or 5 tropical cyclones.

California Landfall: In 1858 a hurricane came ashore near Long Beach.

The Central Pacific Hurricane Center will extend the forecast range of the Tropical Weather Outlook from five to seven days this season.

- The seven-day outlook will provide emergency managers and communities with more time to prepare for tropical activity and creates a seamless suite of products when combined with the two-week Global Tropical Hazards Outlook from the Climate Prediction Center.

This summer, NOAA will increase its supercomputing capacity by 20%, allowing for more detailed, higher-resolution forecast models, advanced physics and improved data assimilation.

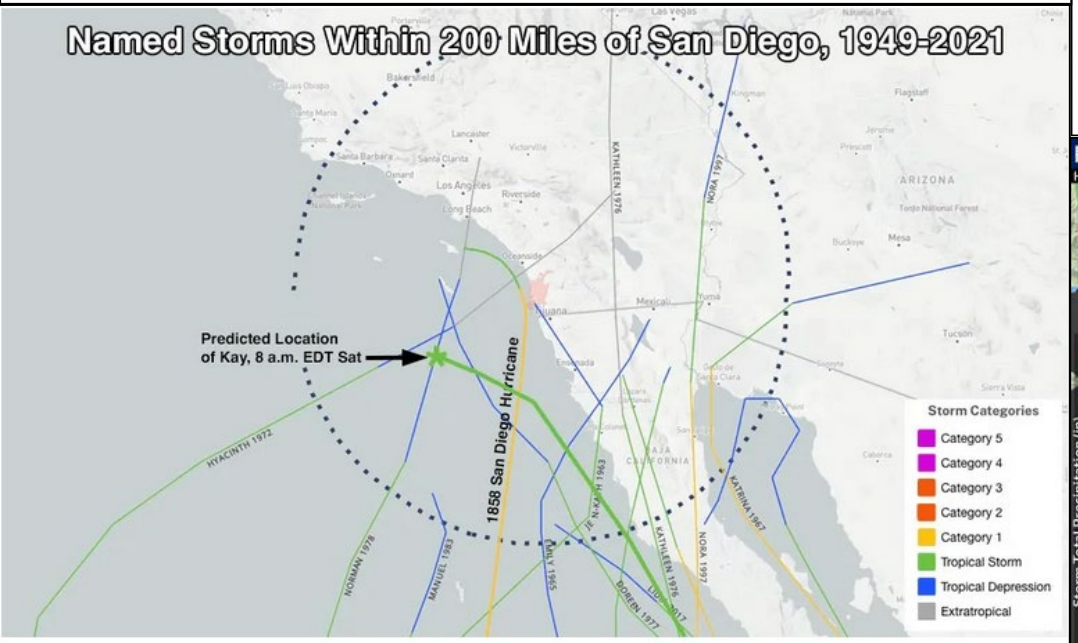
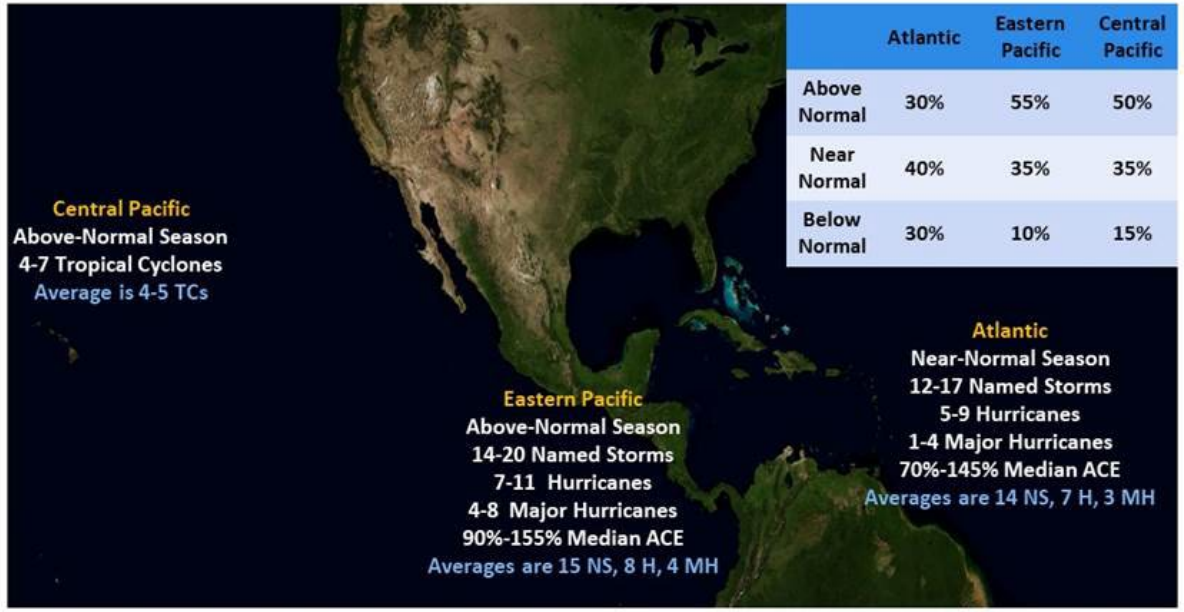


Figure 2. The 11 a.m. EDT Thursday NHC forecast: Kay is predicted to go where few tropical cyclones have ever gone. The presumed track of the 1858 San Diego Hurricane is taken from Chenoweth and Landsea, 2004. (Image credit: modified from NOAA Historical Hurricane Tracks website)

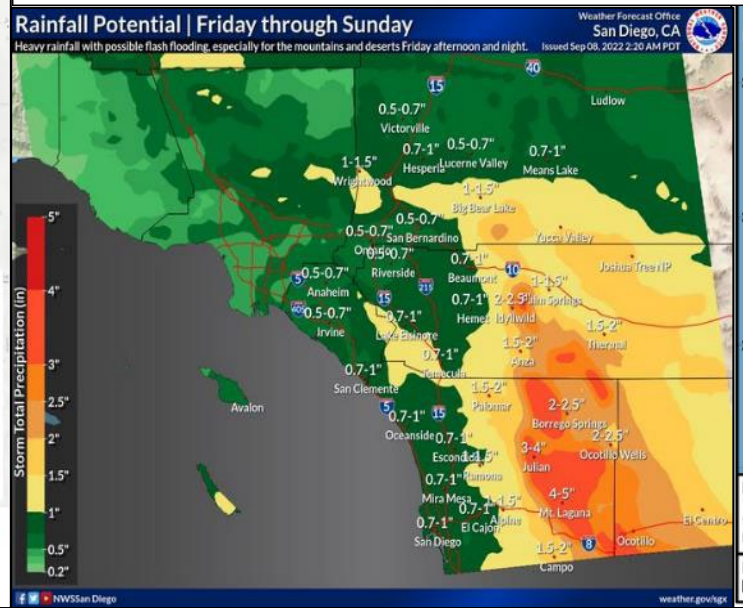
NOAA's 2023 Hurricane Season Outlooks

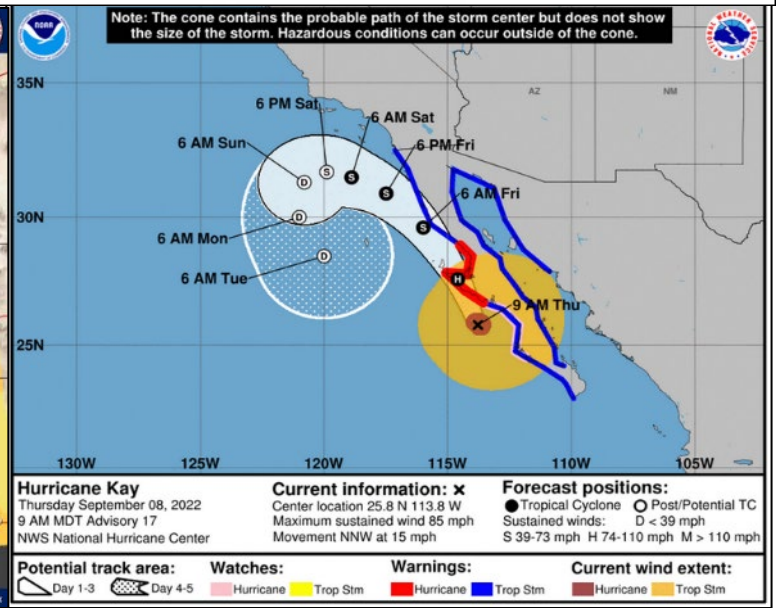


	Atlantic	Eastern Pacific	Central Pacific
Above Normal	30%	55%	50%
Near Normal	40%	35%	35%
Below Normal	30%	10%	15%

For the Eastern Pacific hurricane region, the outlooks indicate a 55% chance of an above-normal season, a 35% chance of a near-normal season, and a 10% chance of an above-normal season. The odds for the Central Pacific are 50% for an above-normal season, 35% for a near-normal season, and 15% for a below-normal season.

These outlooks are for the overall seasonal activity. They are not a hurricane landfall forecast.





California's Historic Records: Cycle of Drought to Floods

Historic Records

- California's Record Rainfall for a 24-hour period was **25.83 inches**, occurring January 22-23, 1943, at Hoegee's Camp in the San Gabriel Mountains, Los Angeles County.

2020

- The 2020-21 water years combined rank as the two driest years in California's statewide precipitation record. Drought and Precipitation Historic Reports: https://www.ncdc.noaa.gov/sotc/drought/202211

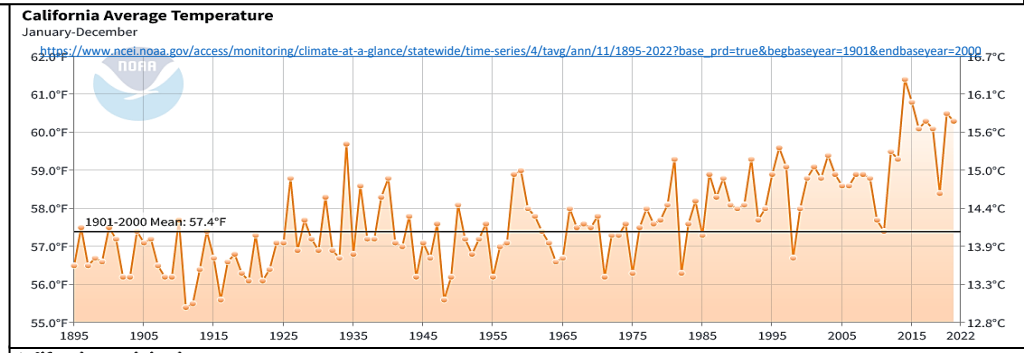
2021

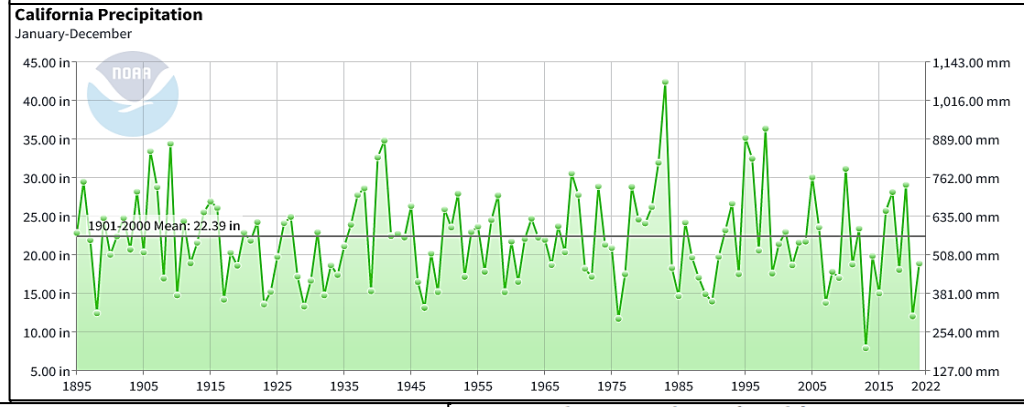
- Drought conditions had improved significantly at the end of 2021 as California received record snowfall in the Sierra. In October 2021 Downtown Sacramento reported an all-time record 24-hour rainfall total of 5.44 inches, surpassing a mark set in 1880. San Francisco also reported the 'wettest day ever' at 4.02 inches. The state received more precipitation in the final three months of 2021 than in the previous 12 months with record-breaking snowfall in multiple areas for December.

2022

- According to NOAA, the first 6-months of 2022 was California's record driest year. California: driest 11-month SPEI; the corresponding SPI tied with 2013 as the driest on record, but the value for the SPEI (-1.98) was more extreme than the value for the SPI (NCDC). Statewide record rainfall November 2022.

Tracking California's Records: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/rankings/CA-001/pcp/202211



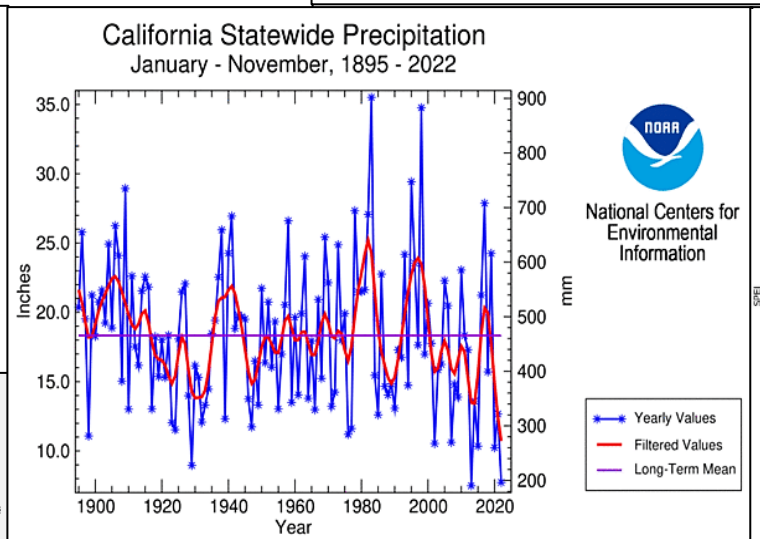


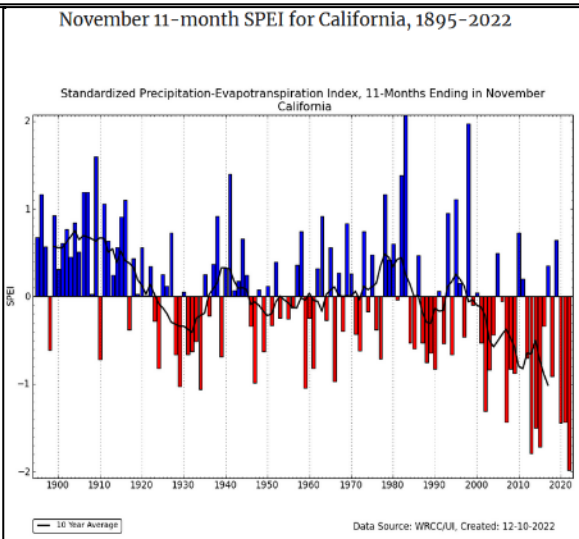
Record rainfall was reported in: November 2022 - California

- Sandberg with 3.62 inches, breaking the record of 0.43 inches in 2002,
- Los Angeles Airport with 1.31 inches, breaking the record of 1.3 inches set in 1998,
- Bob Hope Airport in Burbank with 0.98 inches, breaking the record of 0.66 inches set in 1979,
- Lancaster with 0.51 inches, breaking the record of 0.4 inches in 2002,
- Palmdale Airport with 0.31 inches, breaking the record of 0.22 inches set in 1979.
- San Diego with 0.64 inches, breaking the record of 0.52 inches in 1946,
- Oceanside Harbor with 0.91 inches, breaking the record of 0.64 inches in 1979,
- Lake Elsinore with 0.70 inches, breaking the record of 0.6 inches set in 1905,
- San Jacinto with 0.64 inches, breaking the record of 0.32 inches set in in 1979,
- Escondido with 0.91 inches, breaking the record of 0.56 inches set in 1893,
- Ramona with 0.92 inches, breaking the record of 0.51 inches set in 1998,
- 2.65 inches in Big Bear, breaking a record of 1.91 inches set in 2020,
- 2.39 inches in Idyllwild, breaking a previous record of 1.4 inches set in 2002.

Seventeen states had a precipitation rank in the driest third of the 1895-2022 record for January-November, including two in the top ten driest category — California (second driest) and Nebraska (fourth driest).

Monthly runoff data for California is provided by the USGS Water Watch website.





Flooding Changes: Flashier Flash Floods

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

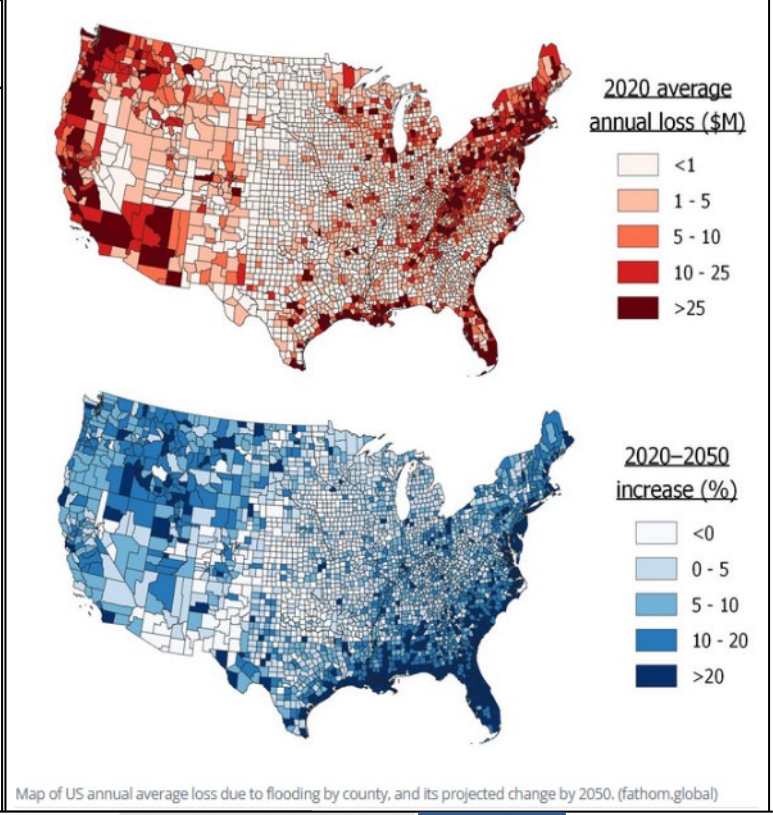
- River flooding can result from heavy rainfall, rapid snow melt, or ice jams thawing resulting in riverbank damages.
- Urban flooding refers to flooding that occurs when rainfall overwhelms the local stormwater drainage capacity of a densely populated area causing water to continue to overflow into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

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

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

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

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

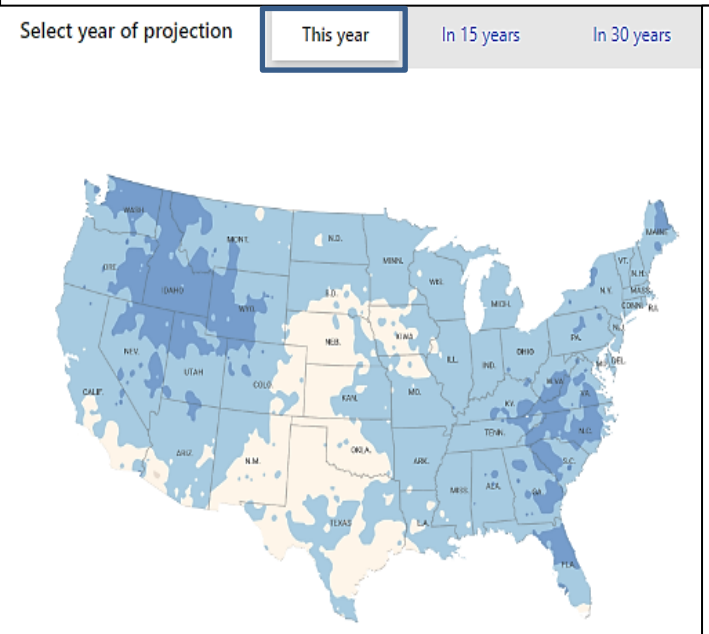


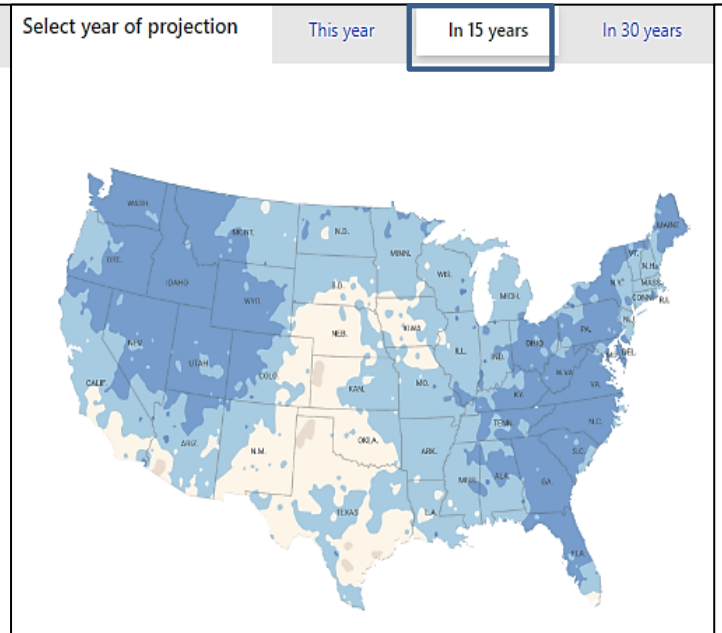
Map of US annual average loss due to flooding by county, and its projected change by 2050. (fathom.global)

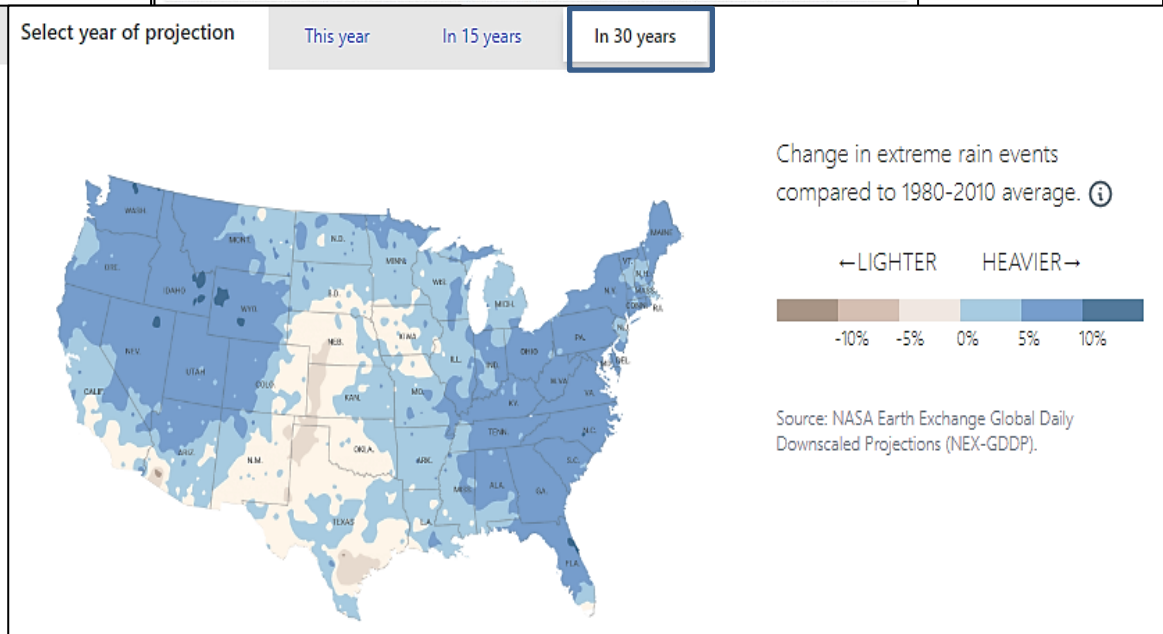
A 2021 study indicated the average annual flood losses are forecast to increase by 26% by 2050, from $32 billion to $40.6 billion, based on 2021-dollar values.

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

A flood can impact anyone.



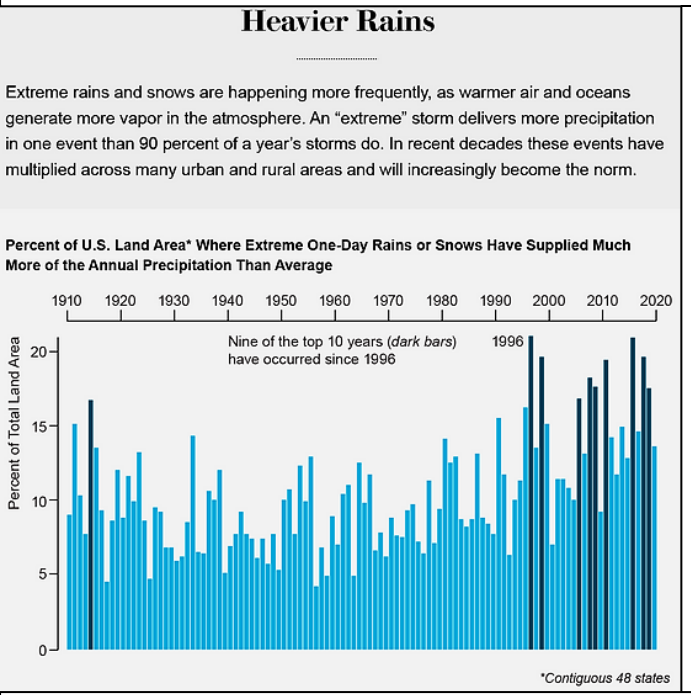




Increases in 1 Hour / 6 Hour / 24 Hour Rainfall Totals

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

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

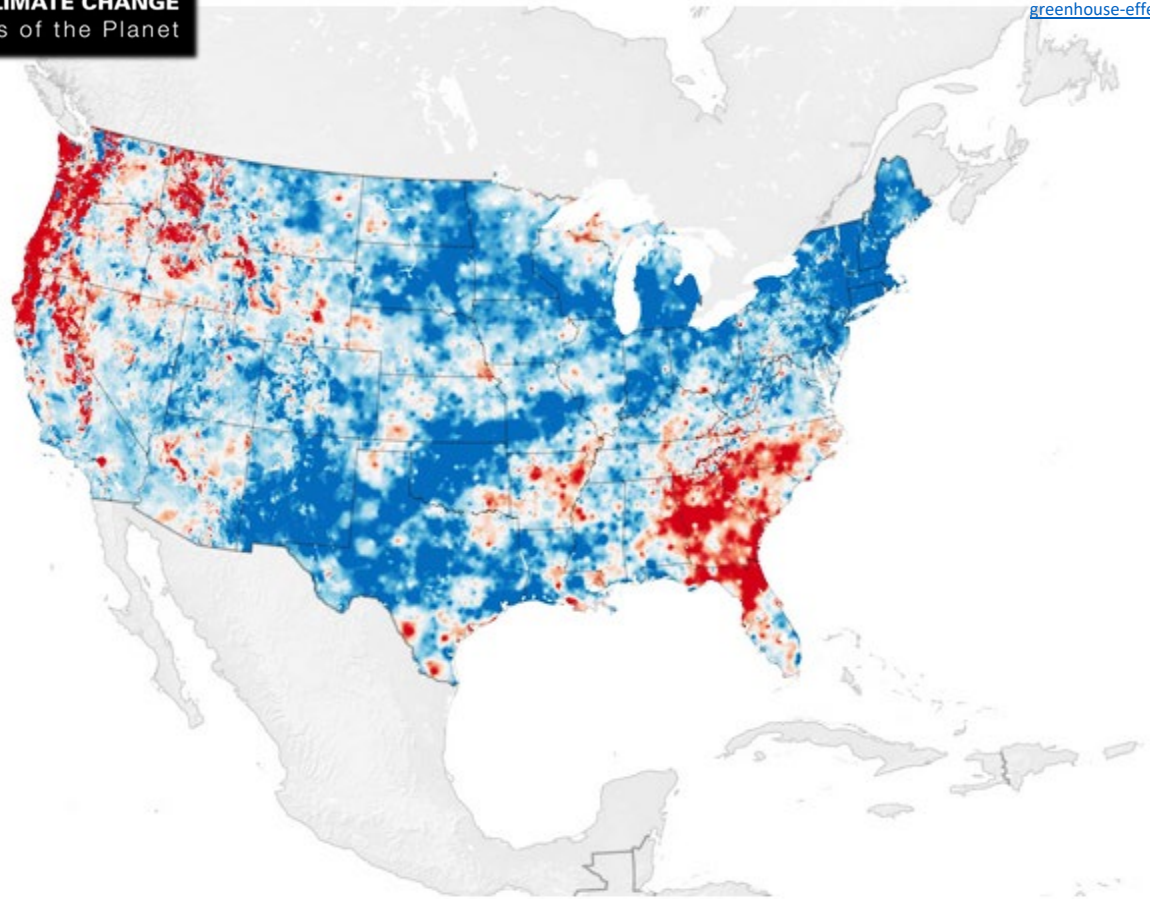


- The average change in hourly rainfall intensity across all 150 stations from 1970 to 2021 was +13%.
- 63% (95/150) of stations had an increase in hourly rainfall intensity of +10% or more (Climate Central).
- 90% of the 150 locations analyzed now experience more average rainfall per hour than in 1970.
- 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.

GLOBAL CLIMATE CHANGE
Vital Signs of the Planet

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



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

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

Severe Storm Records

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

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

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

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

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

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

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

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

Top Ten Active Days of 2022

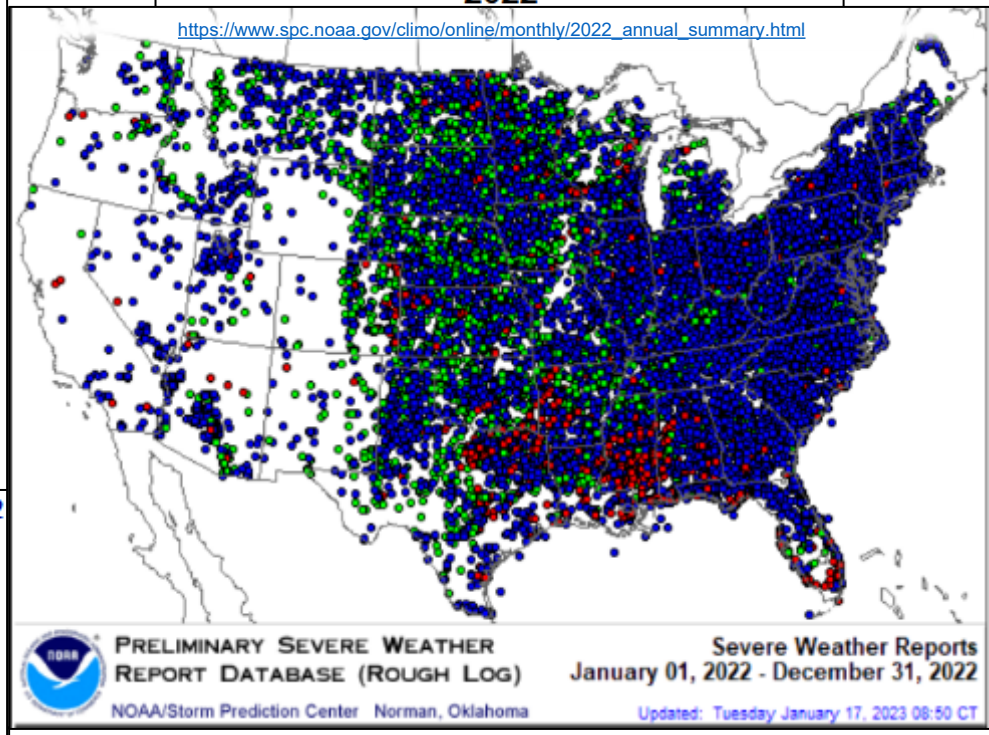
Rank	Date	Total Reports
1	06/17/22	496
2	06/13/22	439
3	06/16/22	432
4	05/12/22	421
5	07/23/22	394
6	07/12/22	348
7	04/13/22	341
8	05/06/22	315
9	06/07/22	314
10	03/30/22	311

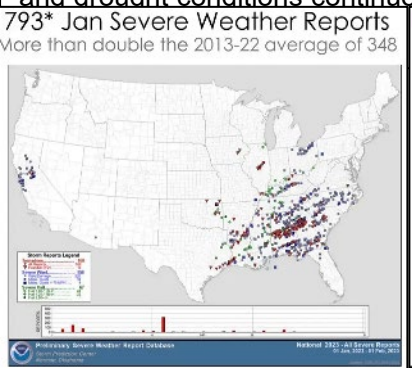
Top Ten Tornado Days of 2022

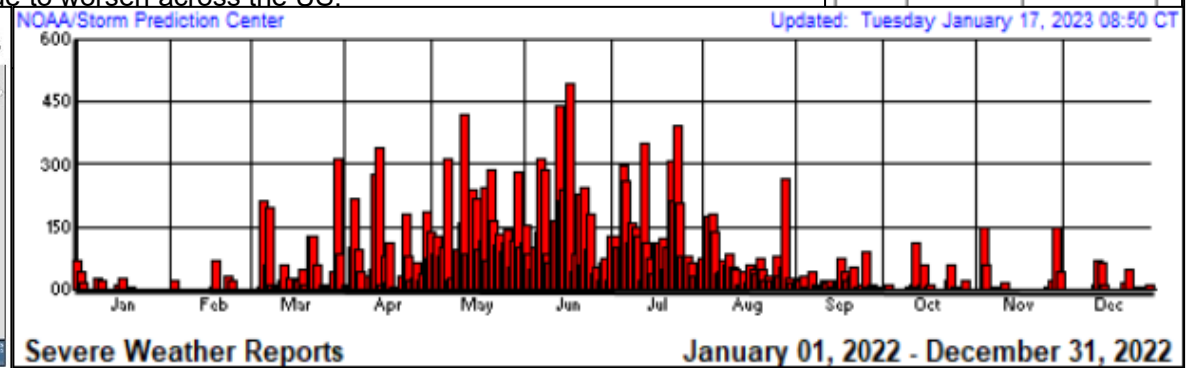
Rank	Date	Tornadoes
1	03/30/22	84
2	04/05/22	76
3	11/04/22	62
4	03/22/22	56
5	03/21/22	52
6	11/29/22	45
7	12/14/22	44
8	03/05/22	43
9	12/13/22	41
10	04/13/22	40

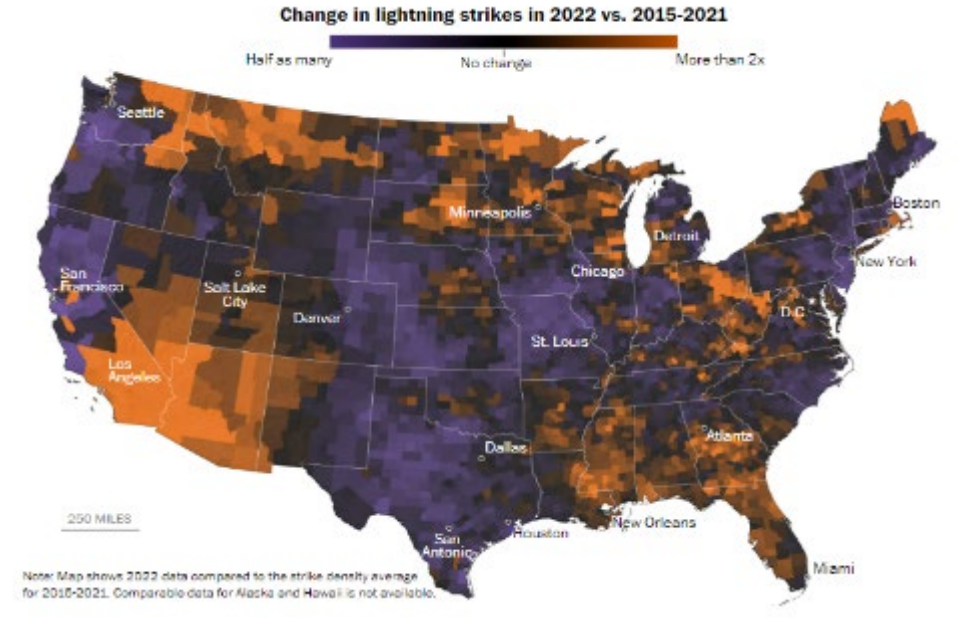
Annual Severe Weather Report Summary 2022

https://www.spc.noaa.gov/climo/online/monthly/2022_annual_summary.html









Severe Weather in California

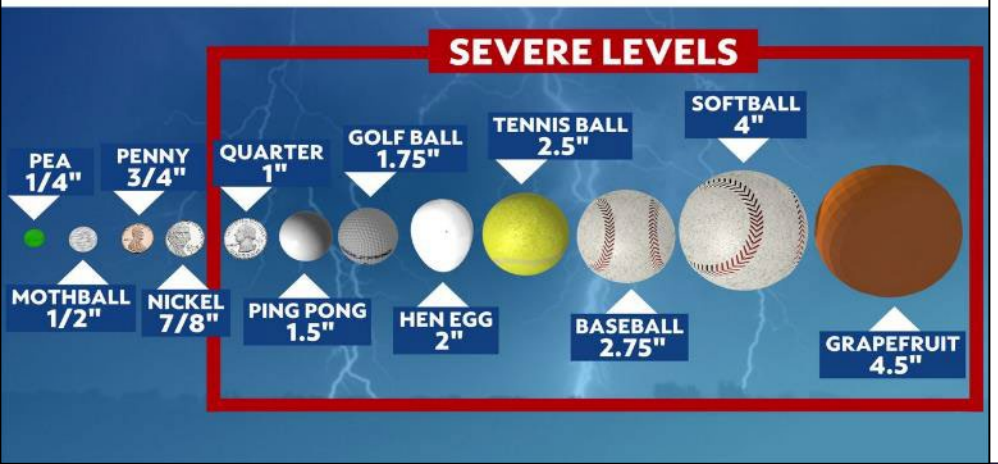
Hail events throughout the US are forecasted to intensify regarding size of the hailstones this year as warmer climates enable stronger updrafts for supercell storms responsible for large hail.

- The most damaging hail events are in downbursts, driven by powerful downdrafts. Downbursts are typically only a few miles across and last a few minutes but can have vertical windspeeds of 156-179 mph with large, destructive hail.
- Earlier this month (May), there were **12,046** estimated impacted properties by hail of 1.00 inch or larger in California.

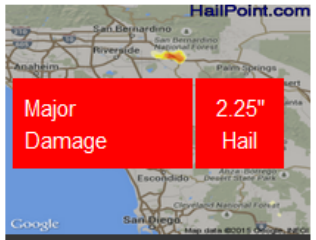
The heaviest hailstone ever recorded fell in Gopalganj district of Bangladesh in 1986, weighing 2.25lbs. South Dakota holds the US record at 18.6 inches in diameter and 1.9lbs creating a 10-inch pit.

- Insured U.S. hail losses average $8 billion - $14 billion per year, or $80-140 billion per decade, as noted by the Insurance Information Institute. **US Hail Damage averages over $10 Billion annually.**

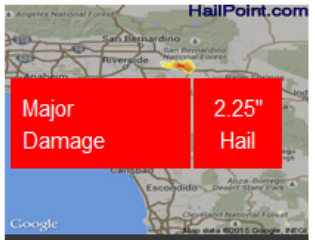
HAIL SIZE COMPARISON



Hail Maps

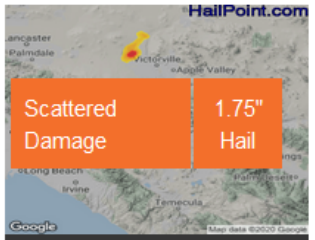


Temecula, CA
July 30, 2015
1"+ Hail Impacts
Population: 37,752
Homes: 13,864

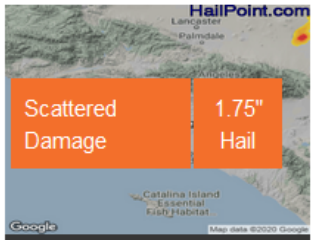


Murrieta, CA
July 30, 2015
1"+ Hail Impacts
Population: 37,752
Homes: 13,864

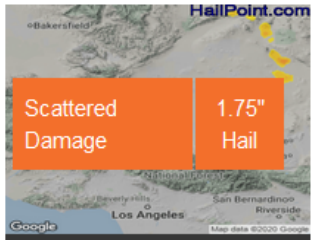
San Bernardino, CA
July 30, 2015
1"+ Hail Impacts
Population: 38,816
Homes: 14,319



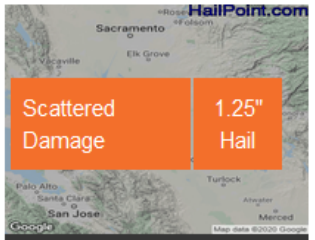
San Bernardino, CA
May 21, 2023
1"+ Hail Impacts
Population: 978
Homes: 337



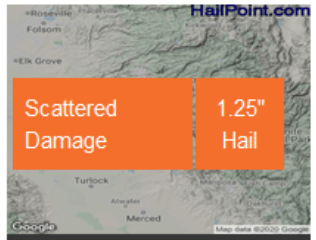
Los Angeles, CA
May 21, 2023
1"+ Hail Impacts
Population: 978
Homes: 337



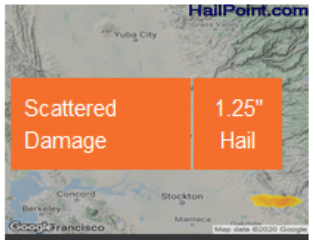
Lancaster, CA
May 21, 2023
1"+ Hail Impacts
Population: 978
Homes: 337



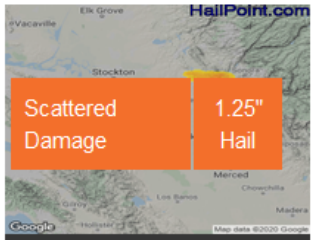
Stockton, CA
March 11, 2023
1"+ Hail Impacts
Population: 403
Homes: 209



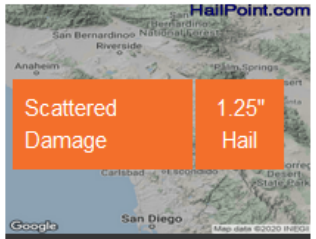
Sonora, CA
March 11, 2023
1"+ Hail Impacts
Population: 403
Homes: 209



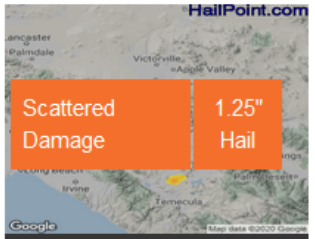
Sacramento, CA
March 11, 2023
1"+ Hail Impacts
Population: 403
Homes: 209



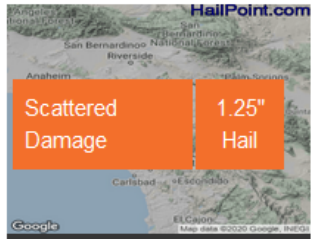
Modesto, CA
March 11, 2023
1"+ Hail Impacts
Population: 403
Homes: 209



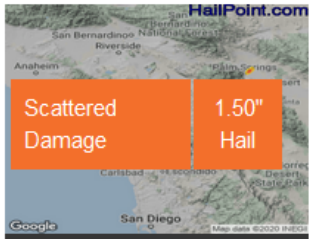
Temecula, CA
October 08, 2022
1"+ Hail Impacts
Population: 1,517
Homes: 490



San Bernardino, CA
October 08, 2022
1"+ Hail Impacts
Population: 1,517
Homes: 490



Murrieta, CA
October 08, 2022
1"+ Hail Impacts
Population: 1,517
Homes: 490



Temecula, CA
October 06, 2022
1"+ Hail Impacts
Population: 3,052
Homes: 1,745

San Bernardino, CA
October 06, 2022
1"+ Hail Impacts
Population: 3,052
Homes: 1,745

Fire Weather

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

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

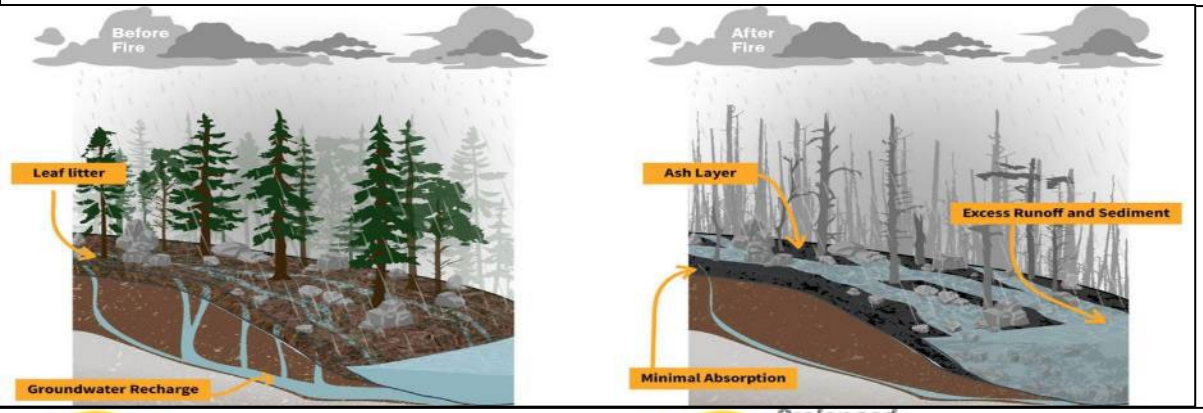
A study from the University of Colorado states wildfires have become larger, more frequent, and more widespread since the year 2000.

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

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

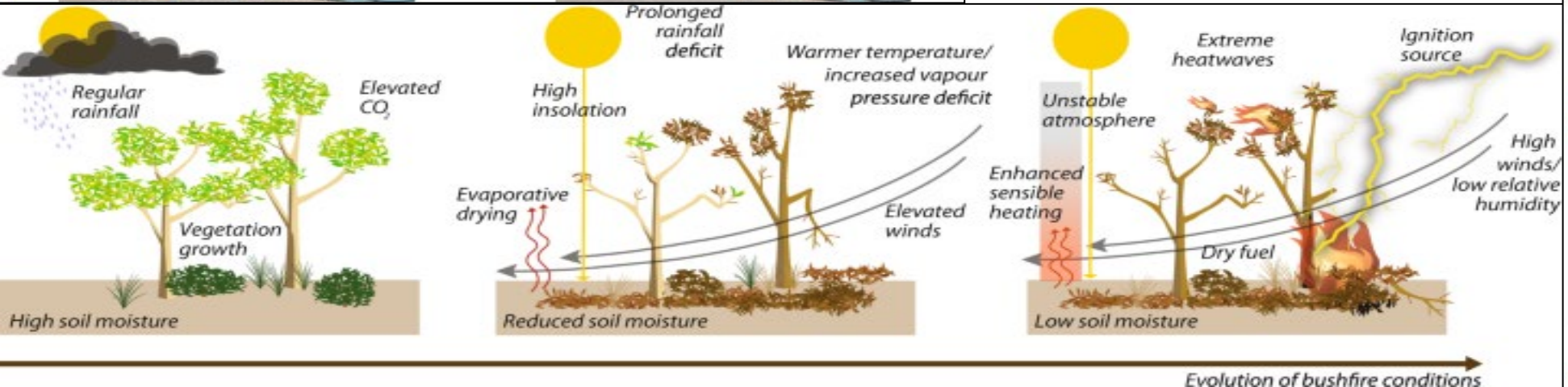
Satellite imagery and state/federal fire history records from 28,000 fires in 1984-2018 showed more fires occurred in the past 13 years than the previous 20 years. On the West and East coasts, fire frequency **doubled**. In the Great Plains, fire frequency **quadrupled**.

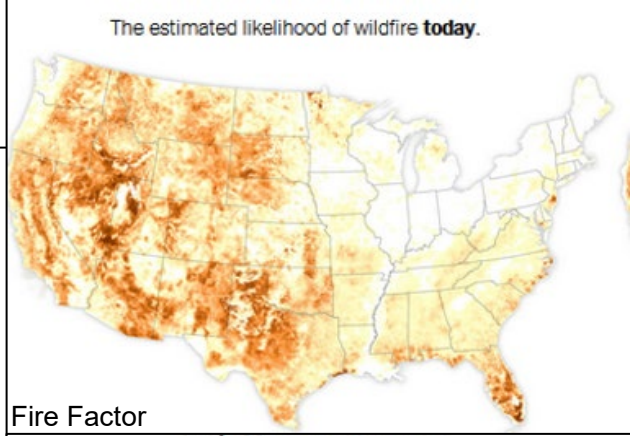
Burned vegetation and charred soil form a water repellent layer which blocks water absorption along with compacted soil from months to years of drought which also inhibits water absorption regionally. These soil changes cause short rainfall events to be less beneficial for long term recovery.



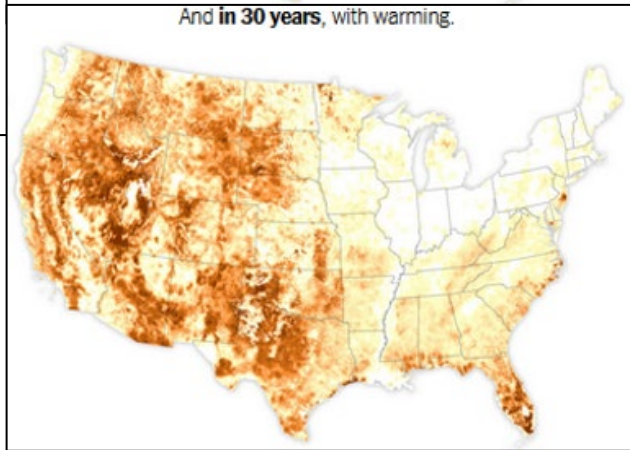
Disasters related to weather, climate, or water hazards happen five times more often now than they did in the 1970s. Droughts that may have occurred only once every decade or so now happen 70% more often.

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

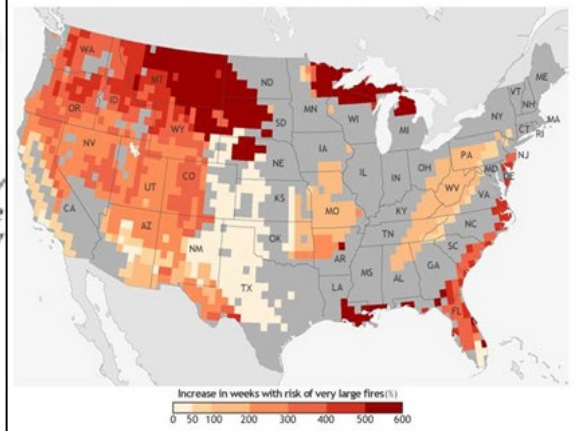




Fire Factor



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 Weather Updates

There are **7,540,239** properties in **California** that have some risk of being affected by wildfire over the next 30 years. This represents **66%** of all properties in California.

- So far in California for the month of May, 985 wildfires have burned over 1,024 acres while 1,205 fires have burned 1,233 acres this year.
- In Northern California, forecasters are calling for below-normal significant large fire potential in the Sacramento Valley foothills and lower elevations of the Bay Area until June into August.

7-Day Significant Fire Potential Forecast Page: https://fsapps.nwcg.gov/psp/npsg/forecast/#/outlooks?state=sideBySide&gaccId=10

Daily report updates: https://www.nifc.gov/nicc/sitreprt.pdf

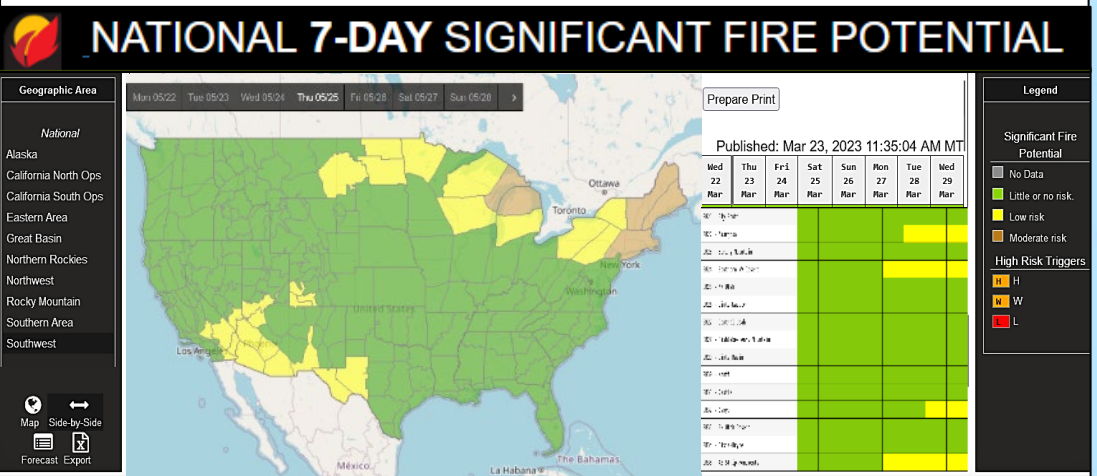
Daily situational awareness dashboard: https://gacc.nifc.gov/swcc/predictive/intelligence/intelligence.htm

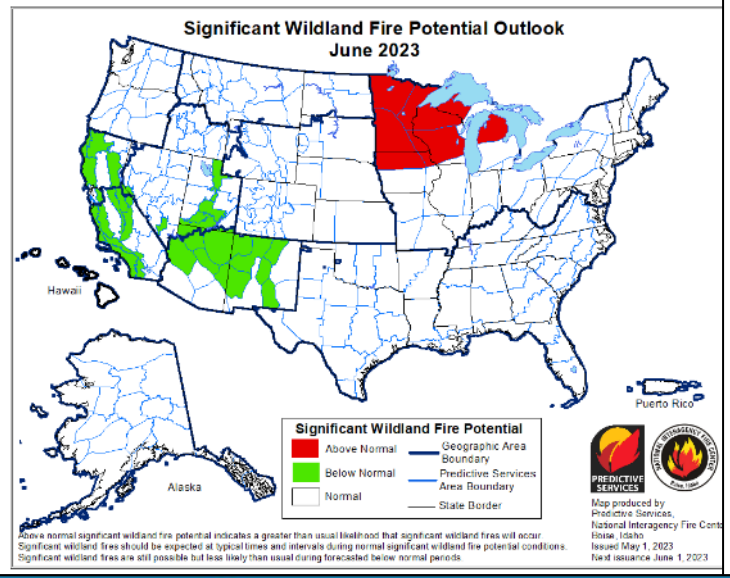
Fire and Smoke Map: https://fire.airnow.gov/

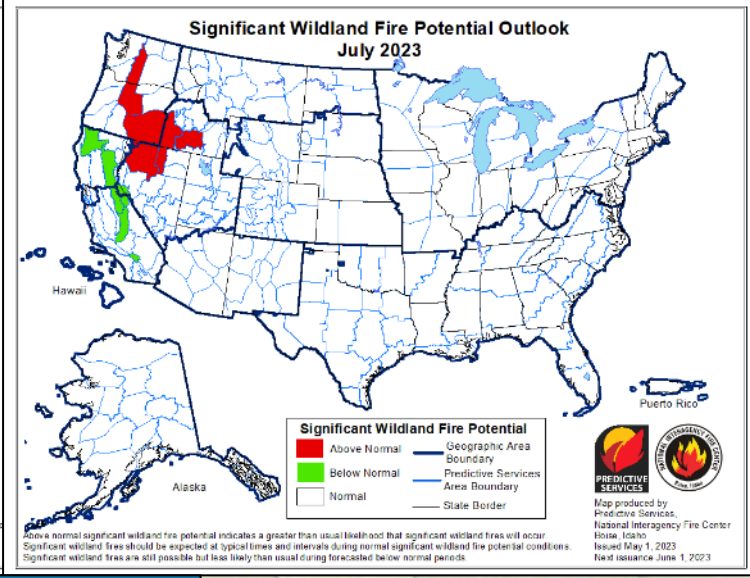
10-hour Dead Fuel Moisture: https://www.wfas.net/images/firedanger/fm_10.png

Smoke Forecast from the HRR Model: https://www.weather.gov/mfr/wildfire

Santa Ana Wildfire Threat Index: https://fsapps.nwcg.gov/psp/sawti







Peak of Fire Activity

Highly flammable plants include ornamental juniper, Leyland cypress, Italian cypress, rosemary, arborvitae, eucalyptus, and ornamental grass. There are 11 species of cypress in CA and 5 species of Eucalyptus.

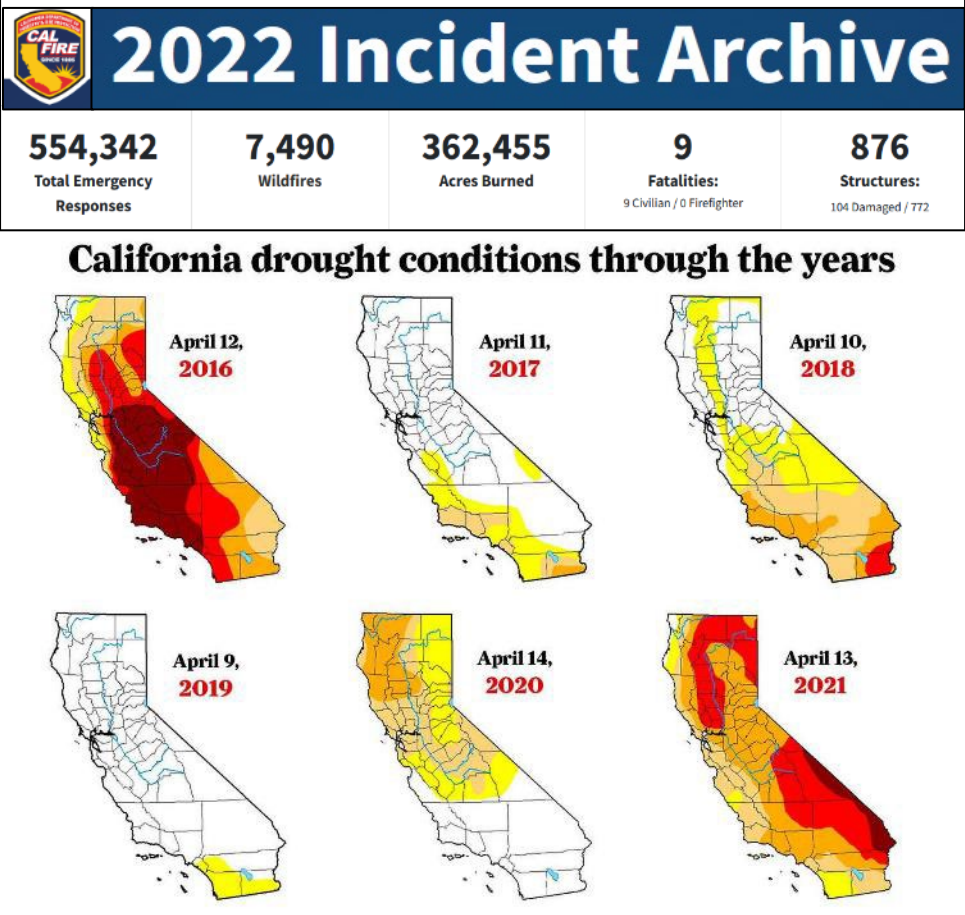
- Eucalyptus was brought into the state from Australia and is invasive with more than 50,000 acres of eucalyptus planted in 60 years. Once established, Eucalyptus can regrow even after removal.

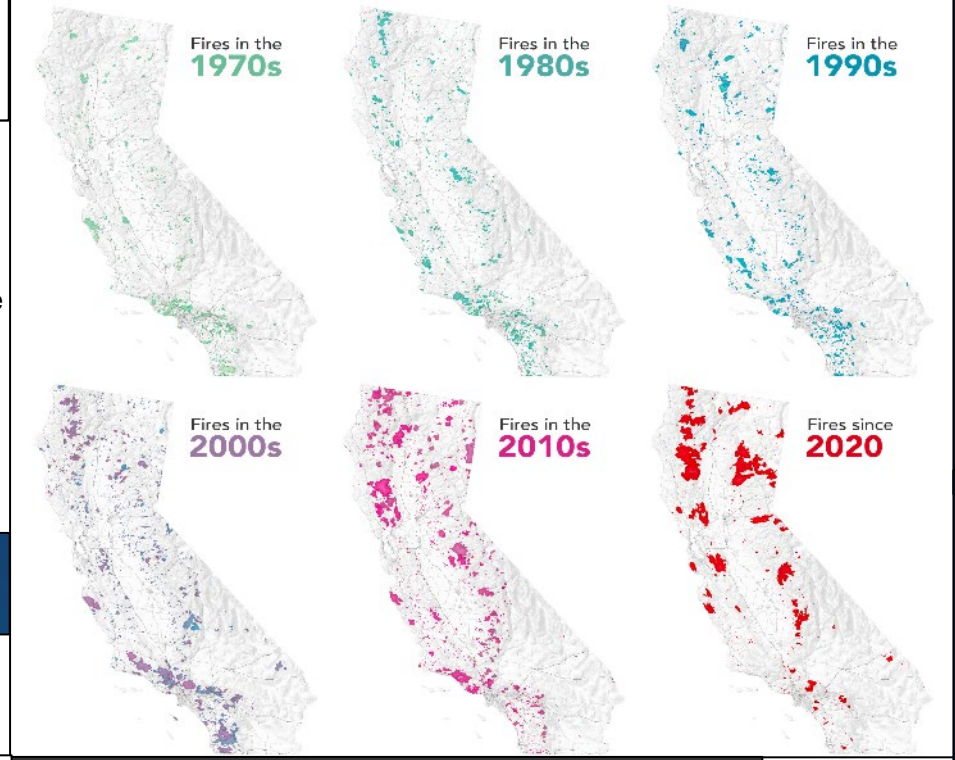
California has an estimated 2.04 million properties at risk of **Extreme** Wildfire Activity, or 15% of the state's properties.

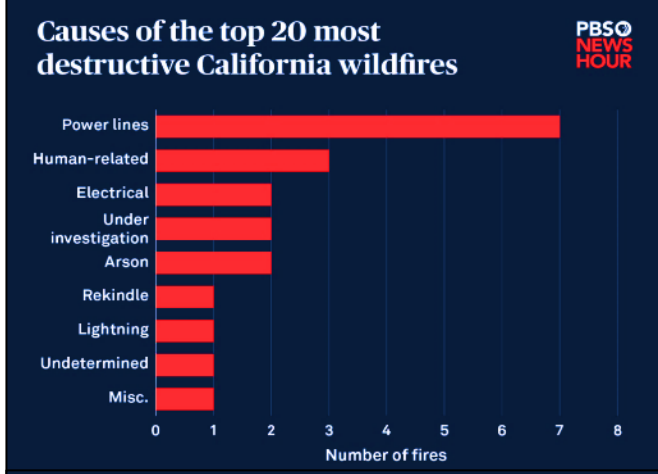
While the number of fires in 2022 was only slightly below the 5-year average, the total acreage burned was well below the 5-year average.

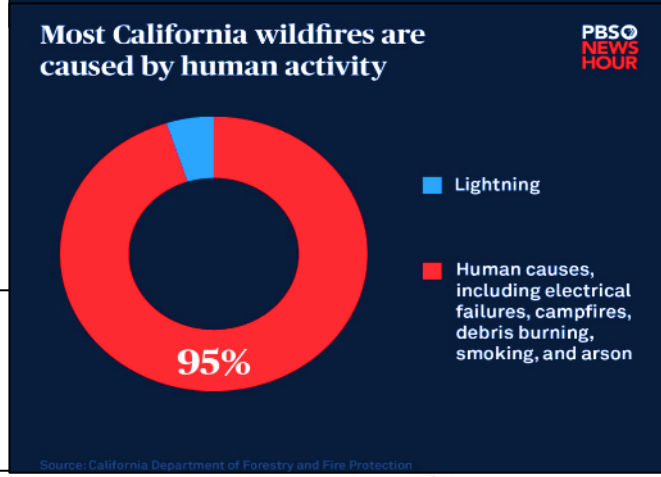
2022 Incident Archive

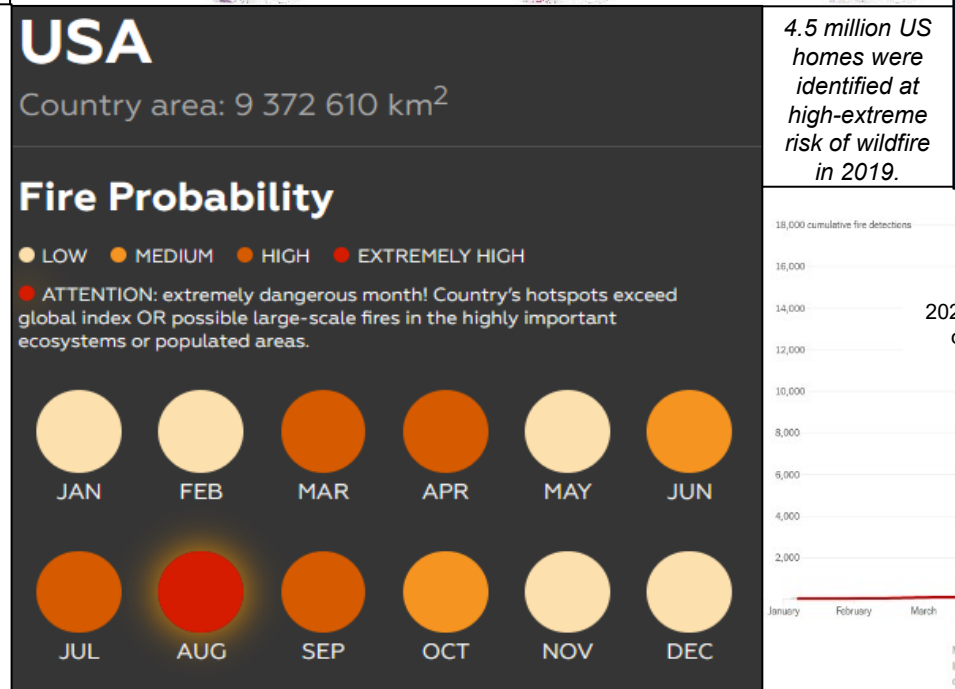
554,342	7,490	362,455	9	876
Total Emergency Responses	Wildfires	Acres Burned	Fatalities: 9 Civilian / 0 Firefighter	Structures: 104 Damaged / 772



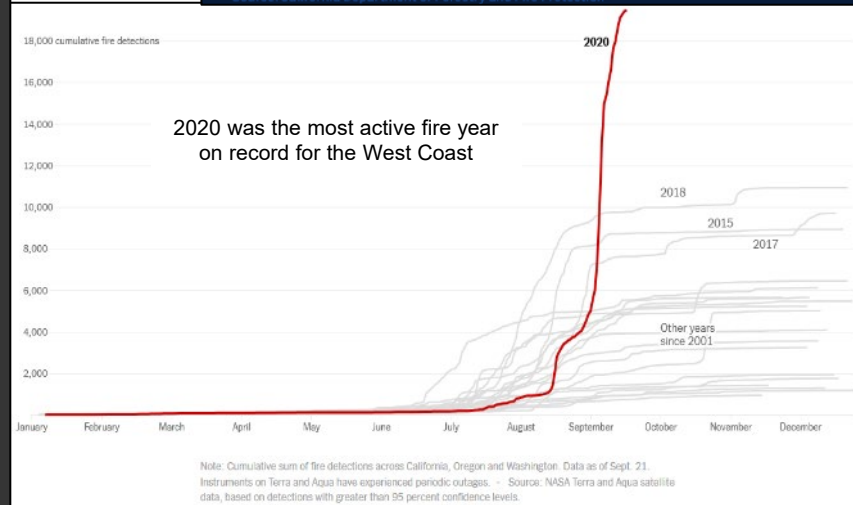








4.5 million US homes were identified at high-extreme risk of wildfire in 2019.



California Fires: A Growing Trend

In 2021, fires burned over 3,075 square miles and destroyed more than 3,000 homes commercial properties, and other structures. California experienced the most fires.

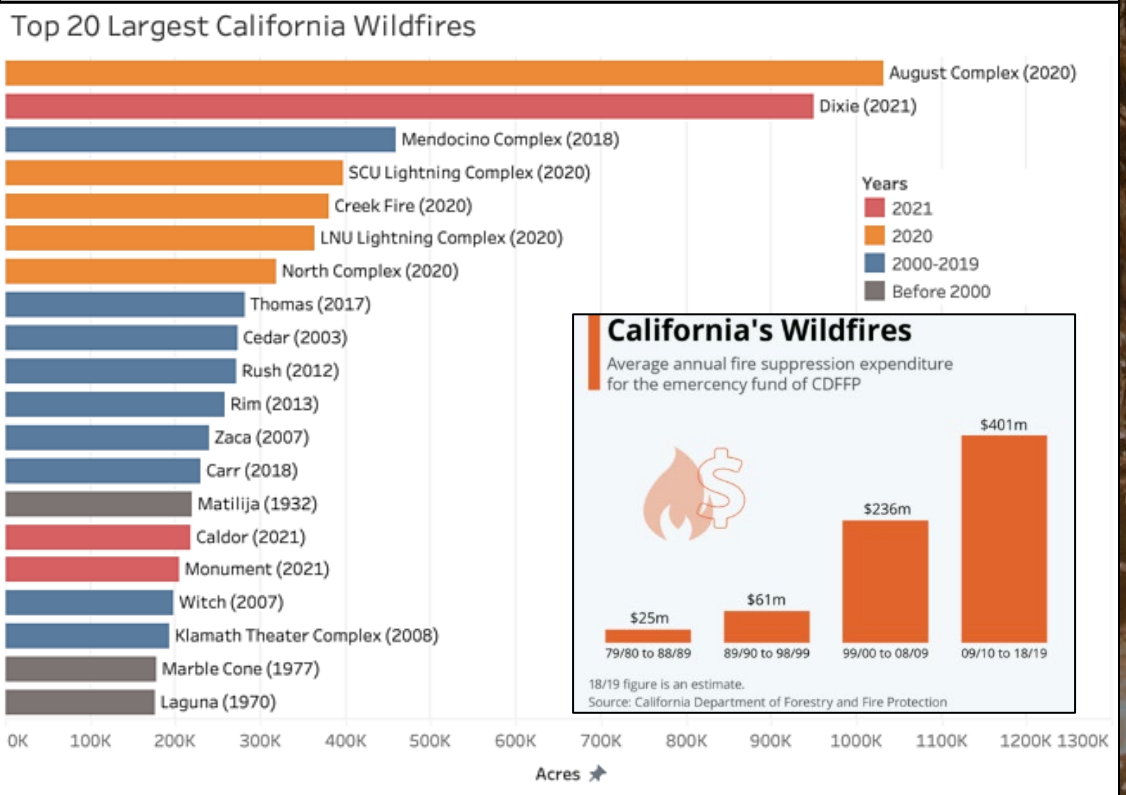
- Total damage estimates for 2021 are expected to be between $70-90 billion $45 billion to $55 billion of those damages to California alone.

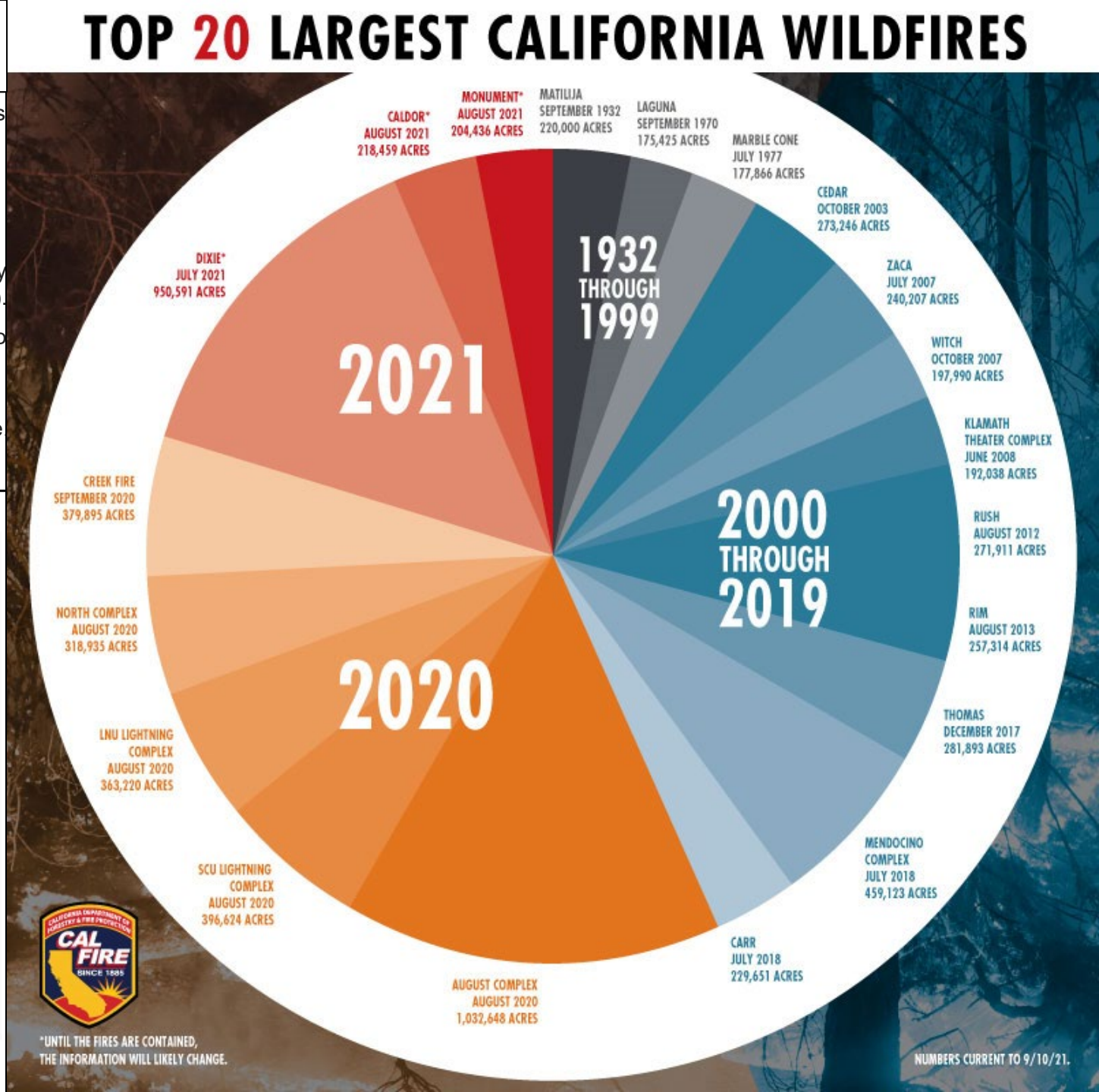
“It is no longer uncommon for a fire to burn 20,000 acres in a single day, in the past that would have typically taken two weeks. These rapid spreads are happening every year now” (Battalion Chief, California Department of Forestry - Fire Protection, 2021).

According to Verisk, in California, there were more than 2 million properties at high to extreme wildfire risk in 2021, the largest number of properties of any U.S. state.

California’s Top 10 Most Destructive Wildfires have all occurred in the last 20 years with 1991’s Tunnel Fire as the only exception ranked as the second most destructive

- The largest wildfires have all occurred in the last 18 years for the state.





Landslides/Mudslides/Debris Flows/ Rockslides

Landslides affect all 50 states and U.S. territories, where they cause 25 to 50 deaths and more than $1 billion in damages each year. As drought, wildfire, and flood events increase, so do threats of landslips.

- A major landslide in Big Sur, California in 2017 covered a quarter-mile of Highway 1 and repair estimates exceeded $40 million.
- Wildfire triggered events: wildfires leave the ground charred, barren, and unable to absorb water, creating conditions ripe for flash flooding and mudflow.
    - The USGS conducts post-fire debris-flow hazard assessments for select fires in the Western U.S.
    - Flood risk remains significantly higher until vegetation is restored—up to 5 years after a wildfire.
- Mudflows are rivers of liquid and flowing mud on the surface of normally dry land, often caused by a combination of brush loss and subsequent heavy rains.
    - Mudflows can develop when water saturates the ground, such as from rapid snowmelt or heavy or long periods of rainfall, causing a thick, liquid, downhill flow of earth.
    - Mudflows are covered by flood insurance but are different from other non-covered earth movements where there is not a flowing characteristic—such as landslides or slope failures.

For data on definitions and event types: https://www.conservation.ca.gov/cgs/landslides

Historic Landslides: https://maps.conservation.ca.gov/cgs/informationwarehouse/index.html?map=landslides

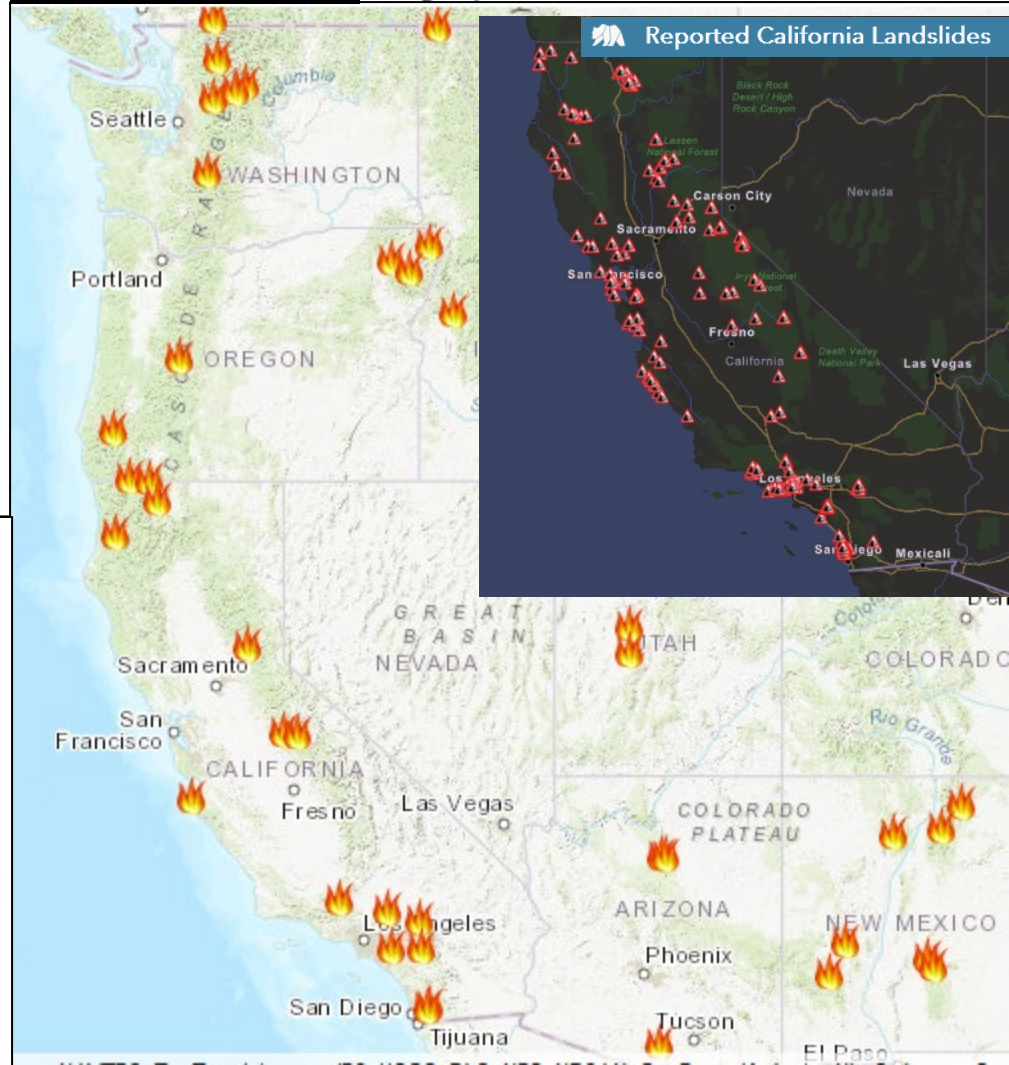
Recent Landslide Reports: https://cadoc.maps.arcgis.com/apps/webappviewer/index.html?id=bc48ad40e3504134a1fc8f3909659041

The Aquifer Risk Map prioritizes areas where domestic wells / state small water systems may be accessing groundwater that does not meet primary drinking water standards.

USGS science for a changing world

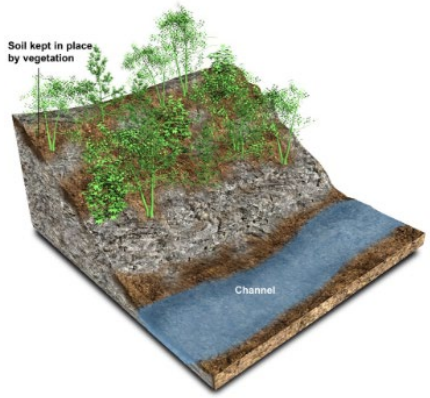
The maps below depict the likelihood of debris-flow generation and estimates of flow magnitude in locations where debris flows initiate. The models do not predict downstream impacts, potential debris-flow runout paths, and the areal extent of debris-flow or flood inundation.

Emergency Assessment of Post-Fire Debris-Flow Hazards



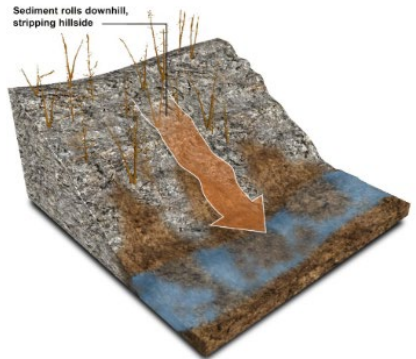
Before fire and rain

Soil is trapped on steep rocky hills by vegetation.



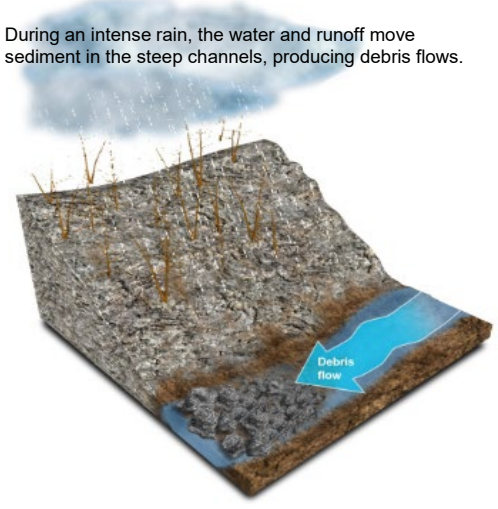
After fire

During summer's fire season, vegetation is burned, causing sediment to roll down steep hills. Within a few hours or days, channel bottoms are loaded with loose sediment.



Rain and runoff

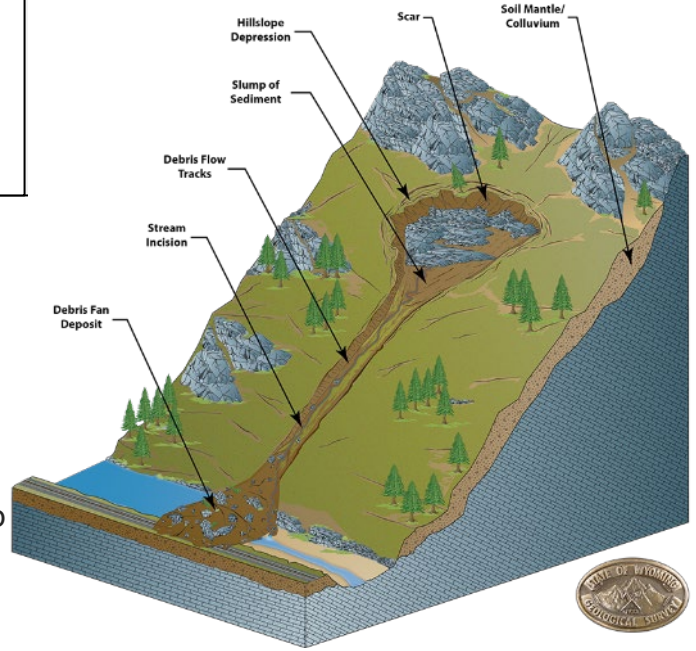
During an intense rain, the water and runoff move sediment in the steep channels, producing debris flows.

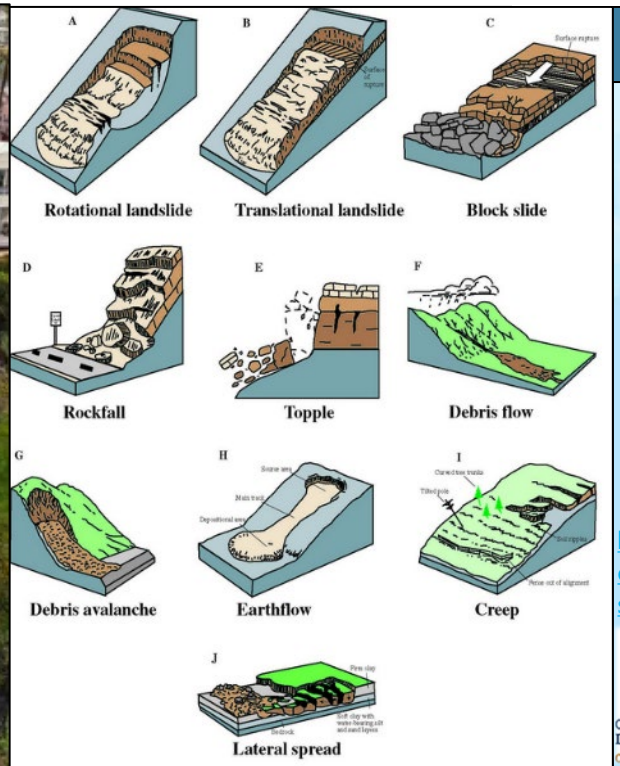


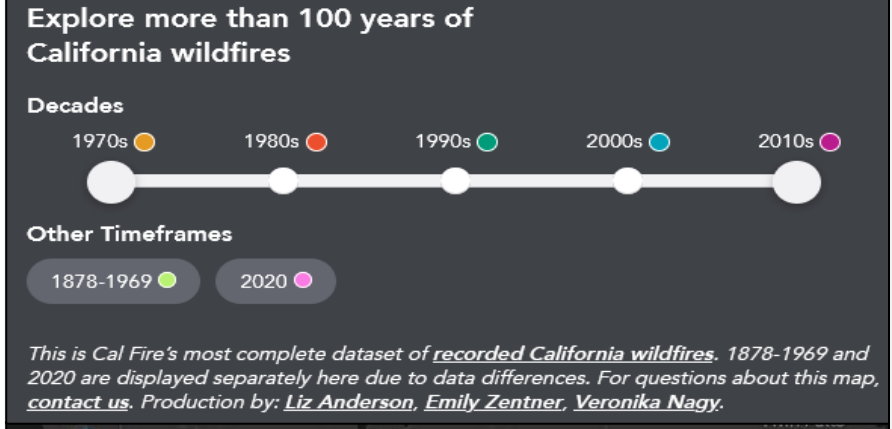
Mudslide Threat Increase

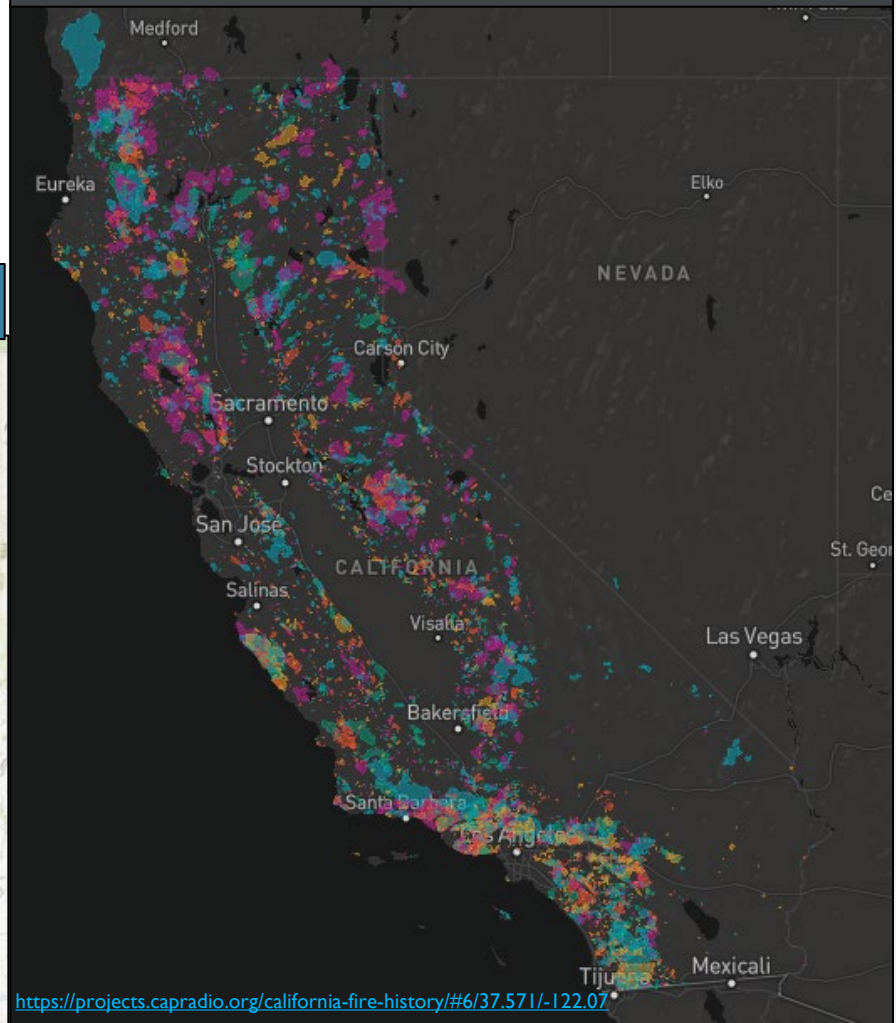
The USGS has created a mapping profile from the 2020 wildfire season satellite imagery to identify areas of tan and brown landscape where no vegetation is left, and soil is more susceptible to slippage: https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=300

- In general, the debris-flow hazard remains elevated for 2-5 years after a wildfire.
- The California Geological Survey is in the process of digitizing maps of landslides and has prepared a statewide landslide map database that is available online.
- The database shows many of the landslides mapped by CGS and others over the past 50 years.



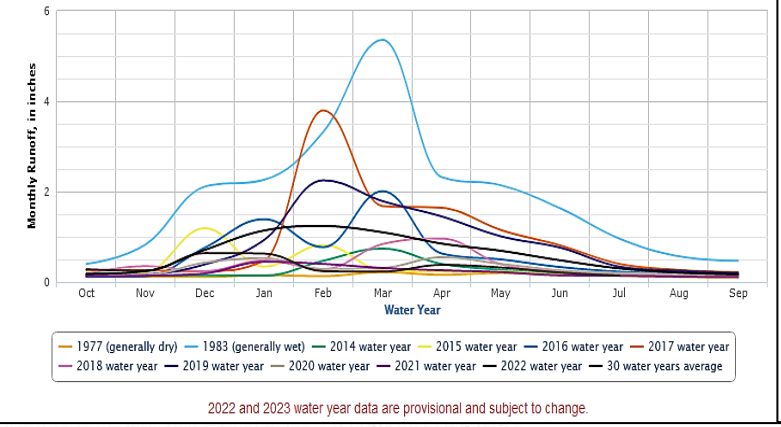




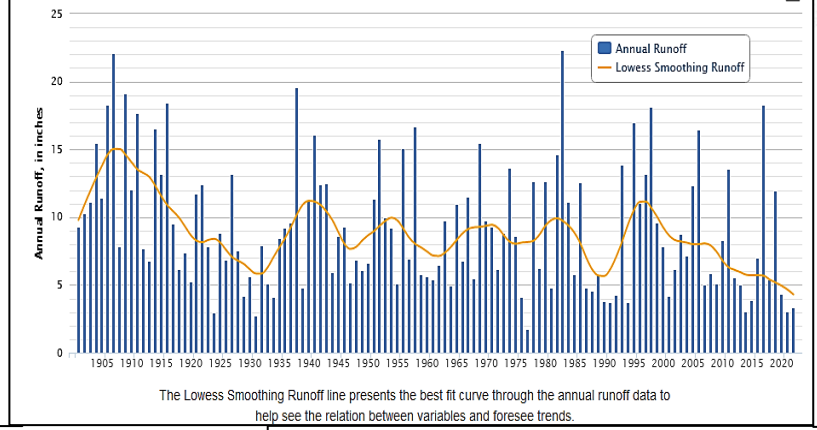


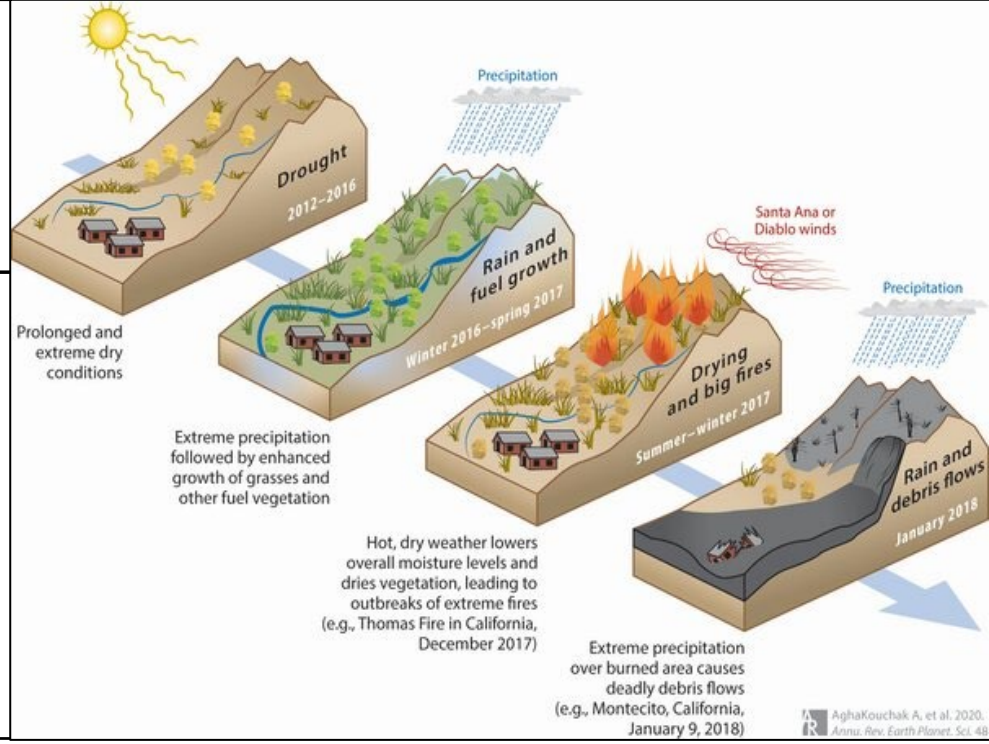
Peak Runoff Season and Soil Condition Concerns - Landslides

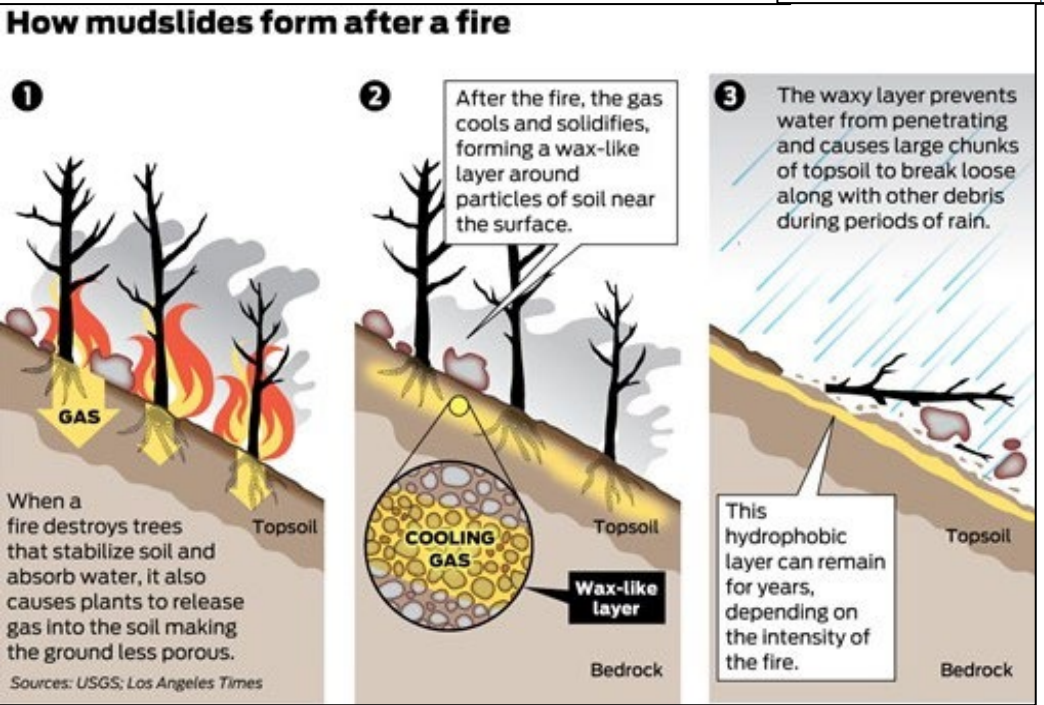
https://waterwatch.usgs.gov/



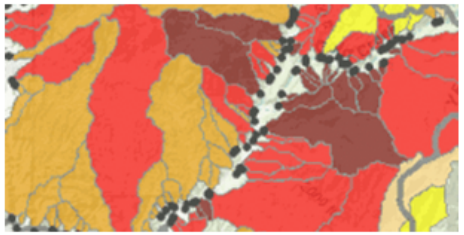
https://ca.water.usgs.gov/california-drought/california-drought-runoff.html







Post-Fire Debris-Flow Hazards



Estimates of the probability and volume of debris flows that may be produced by a storm in a recently burned area, using a model with characteristics related to basin shape, burn severity, soil properties, and rainfall.

More Info and Maps

U.S. Landslide Inventory and Interactive Map

A web-based interactive map with a consistent set of landslide data. The searchable map includes contributions from many local, state, and federal agencies and provides links to the original digital inventory files for further information.

View Map

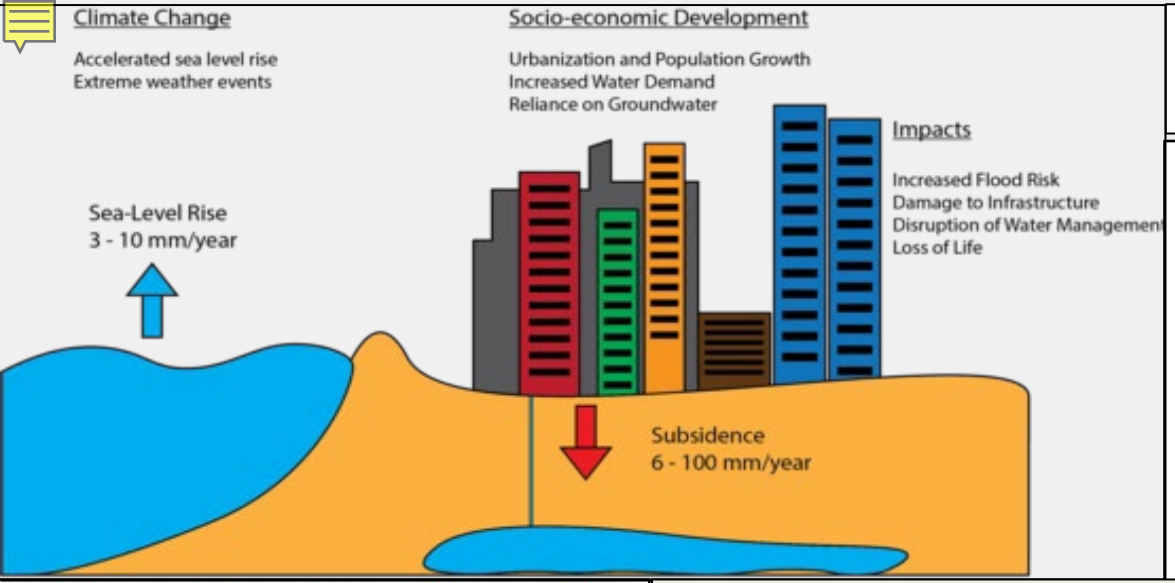
Earthquake-Triggered Ground-Failure

A web-based interactive map showing earthquake-triggered ground-failure, such as landsliding and liquefaction.

View Map

https://www.usgs.gov/programs/landslide-hazards/maps

Regional Subsidence Threat



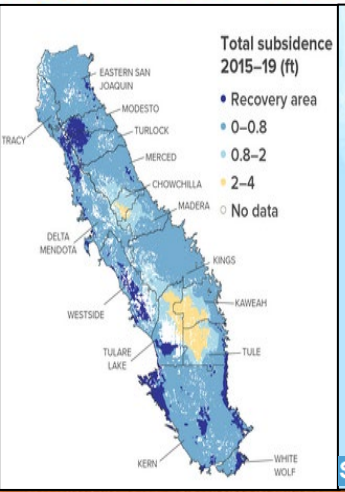
Subsidence has been recorded in the US at a rate of nearly 2-feet over three years for some aqueducts.

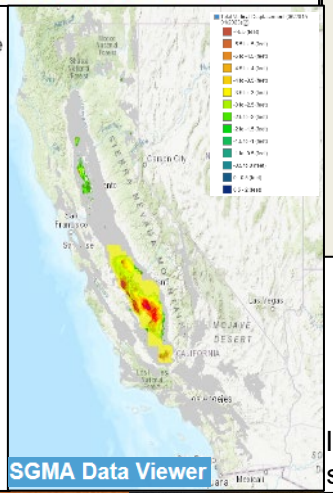
- Utilizing aqueducts to channel water from one area to another, pulling from wells at a faster rate, digging new wells to pull from the underground aquifers, pumping water from lakes/rivers, and creating supplementary channels along canals to siphon water from set provisions has compounded the upstream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

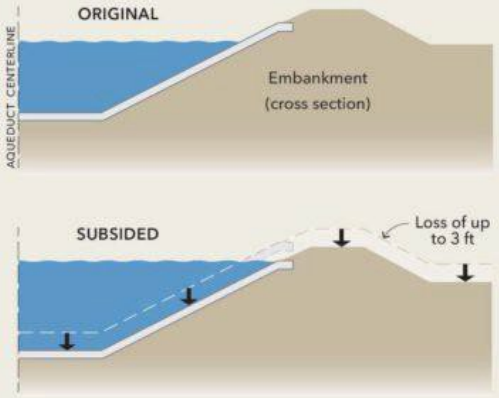
"The removal of water from aquifers without incoming rainfall or replenishment at the same or greater rate is causing the water table to lower beyond reach of wells and aqueducts which is resulting in deeper wells and more digging, further compounding the loss of water within the aquifer. The soil at 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





Impacts on the Aqueduct

- Decreased delivery capacity
- Increased cost to deliver water
- Decreased system reliability
- Increased operations and maintenance



State Water Project operations decrease water levels to keep it below the (subsided) top of liner which means less flow capacity in the Aqueduct.

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 impacted site.

Even minimal subsidence can threaten critical infrastructure

Land subsidence in flooding prone area could lead to expanded coverage and deeper water depth of flooded (inundated) areas.

- In coastal areas affected by subsidence, sea level rise and high tide will usually worsen the situation.
- California valleys and coasts are at risk.

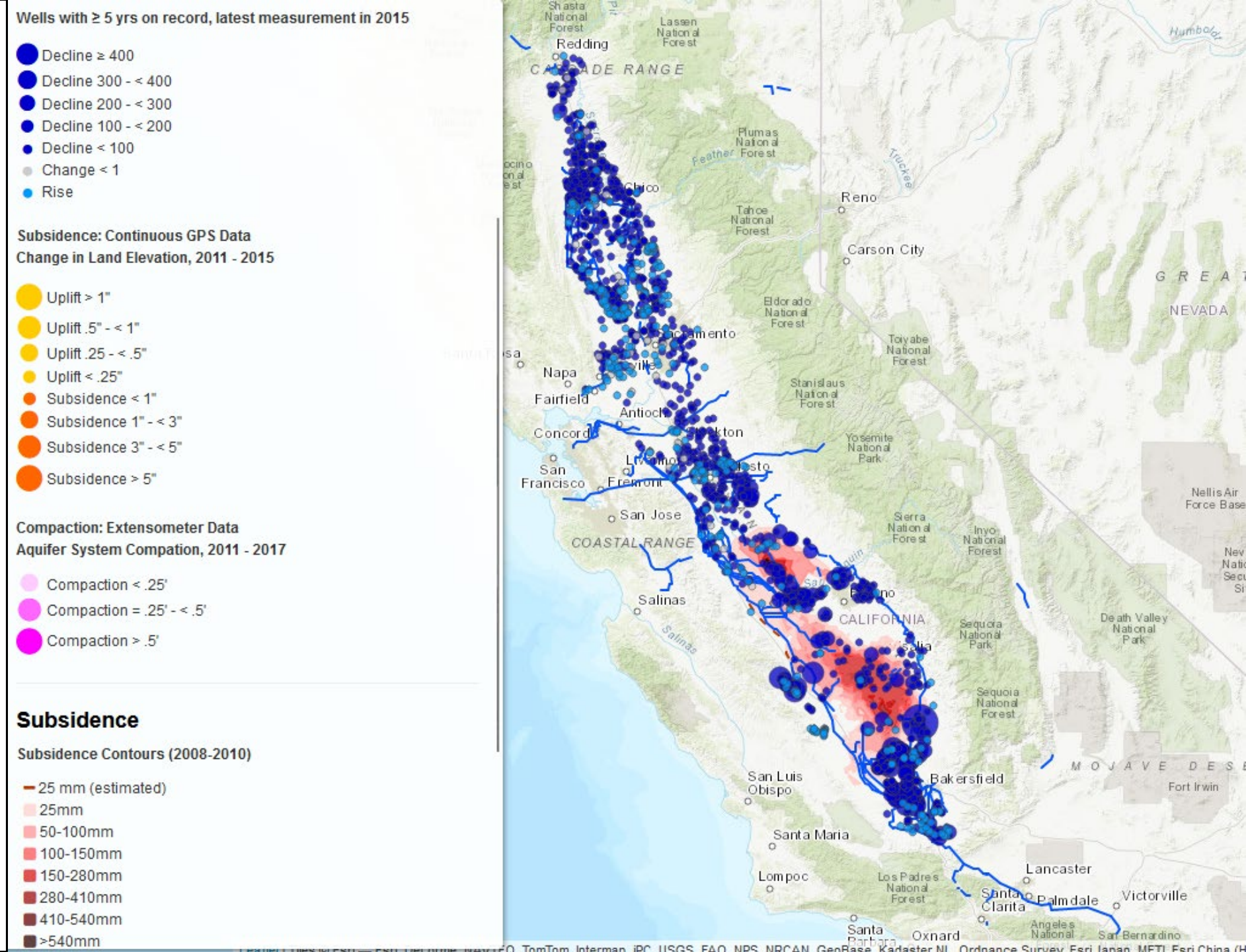
California Impacts from Subsidence

Changes of water flow pattern in drainage, canal and river systems passing the subsidence area, may also affect flooding system in the respected area.

- The Corcoran Valley levee built in 1983 stood at 195 feet but by 2017 it dropped to 188 feet and had to be raised to 192 feet.
- In 2023 it is reported to be around 188 feet again and needs to be raised to prevent issues during spring runoff in that the risk for overtopping was a sudden issue.

For the Friant-Kern Canal, subsidence, which causes the ground of the canal to sink, was brought on by groundwater overdraft conditions that occurred during the California 2011-2019 drought.

- According to a FWA 2019 report, the area most impacted by subsidence is between the Tule River and Lake Woollomes, particularly in the area of Deer Creek.
- Since the canal's construction in 1951, more than 50% of its original conveyance capacity in the middle reach has been lost due to land subsidence.
- Siphon structures completed early 2023.



Warming Surface Water Can Cause:

Harmful Algal Blooms (HABs)

E. Coli

Cholera

Ameba's

Harmful algal blooms release toxins that contaminate drinking water, causing illnesses for animals and humans.

- Natural reservoirs without wastewater treatment can cause mats of HABs and present a threat to anything consuming the water directly.

Bacteria are common single-celled organisms and are a natural component of lakes, rivers, and streams.

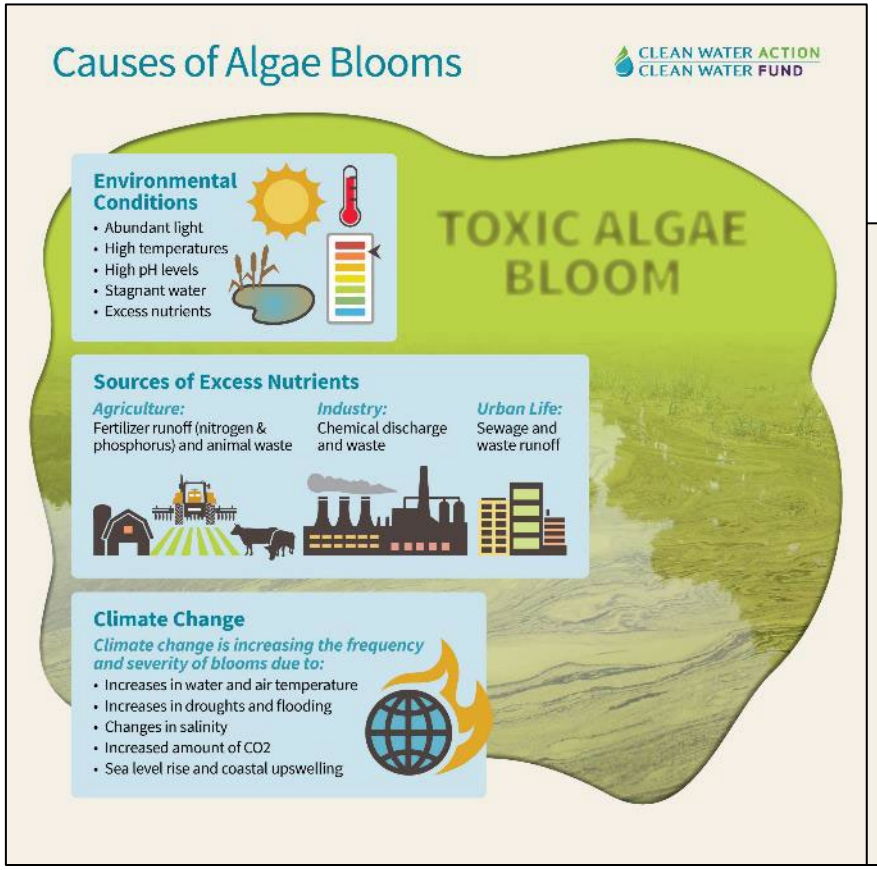
- Escherichia coli (abbreviated as E. coli) are bacteria found in the environment, foods, and intestines of people and animals. E. coli are a large and diverse group of bacteria.

Cholera is an acute diarrheal illness caused by infection of the intestine with Vibrio cholerae bacteria.

- People can get sick when they swallow food or water contaminated with cholera bacteria. The infection is often mild or without symptoms but can sometimes be severe and life-threatening.

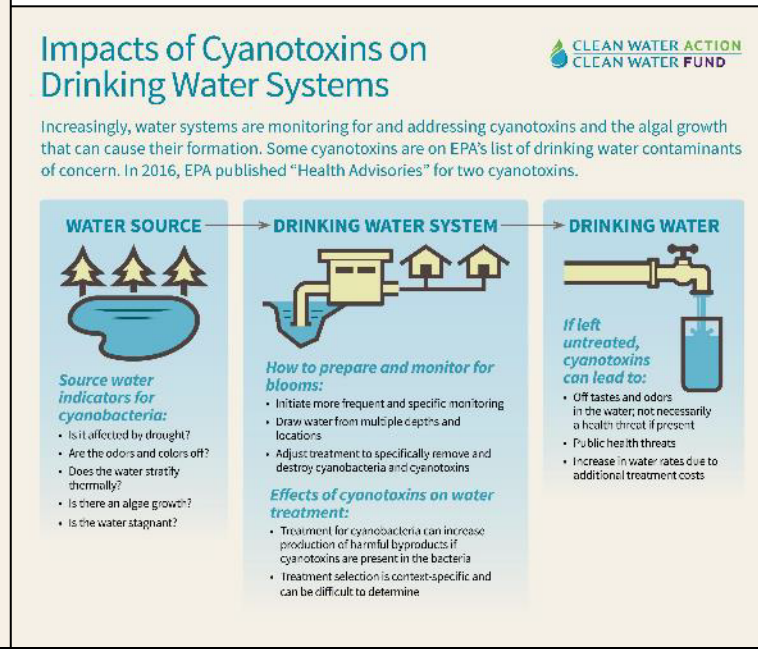
An **Ameba** named *Naegleria* is a single-celled living organism commonly found in warm freshwater (lakes, rivers, etc.) and soil. Only one type of *Naegleria* infects people: *Naegleria fowleri*.

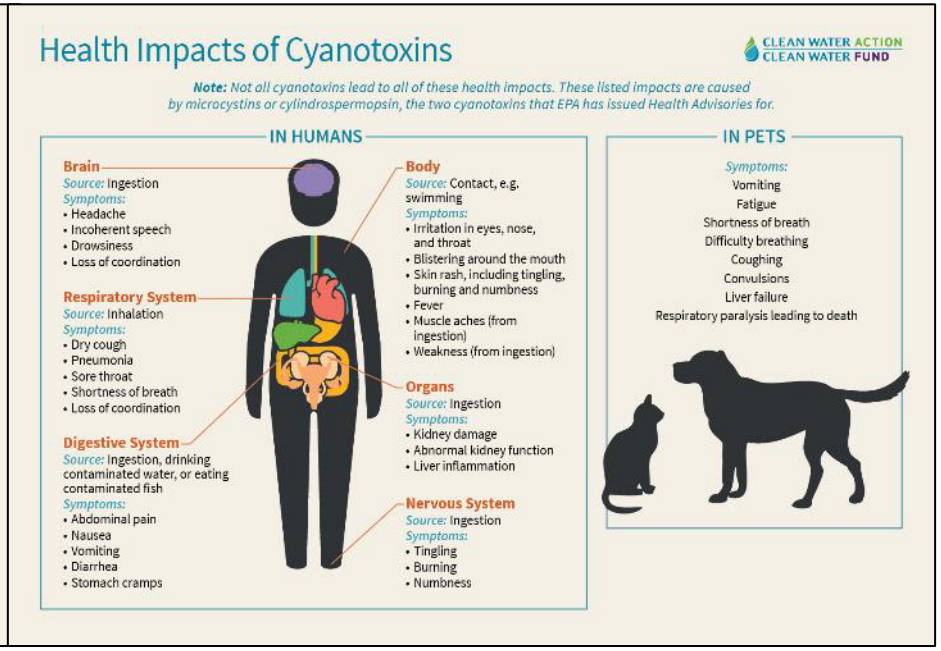
- In the United States, most infections have been caused by *Naegleria fowleri* from freshwater located in southern-tier states.



Harmful algal blooms (HABs) occur when algae — simple photosynthetic organisms that live in the sea and freshwater — grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals, and birds.

Warming Waters, Changes in Salinity, Additional Fuels (Carbon Dioxide), Higher Rainfall Rates and Excessive Runoff, Sea Level Rise Increasing Coastal Waters, and Coastal Upwelling can all play a role in HAB movements.





Increased Flooding Contributes to More Algal Blooms

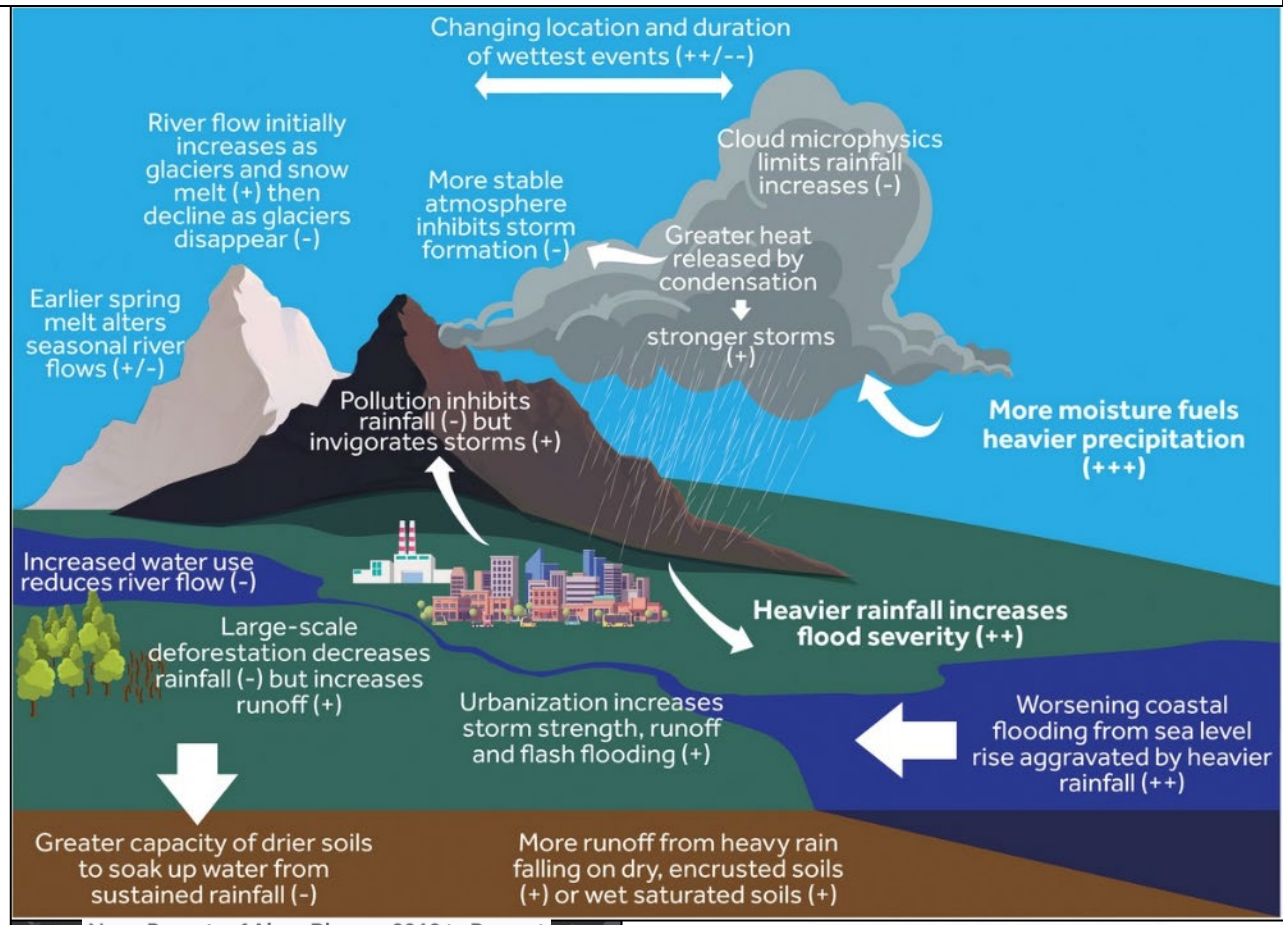
Stormwater runoff, which often includes pollutants like heavy metals, pesticides, nitrogen, and phosphorus, can end up in lakes, streams, and bays.

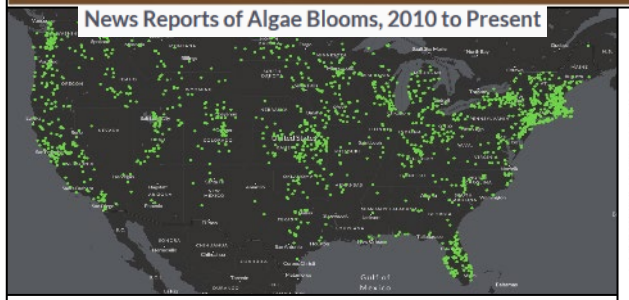
Nitrous oxide (N2O) is a potent greenhouse gas, with a warming potential of approximately 300 times that of carbon dioxide. From fertilizer runoff in farm fields, an increasing load of nitrogen is washing into rivers and streams.

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

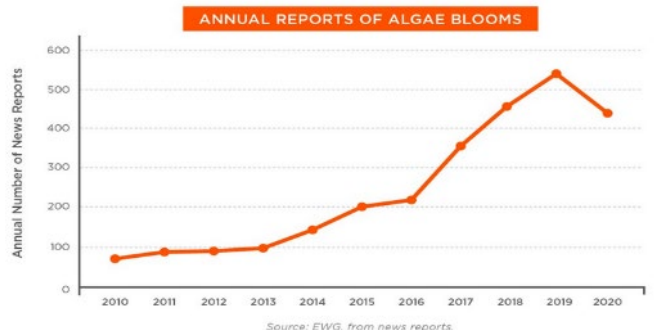
Approximately 80% of the freshwater resources in the U.S. originate on forested land, and more than 3,400 public drinking-water systems are in watersheds containing national forest lands (USDA, 2006).

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





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



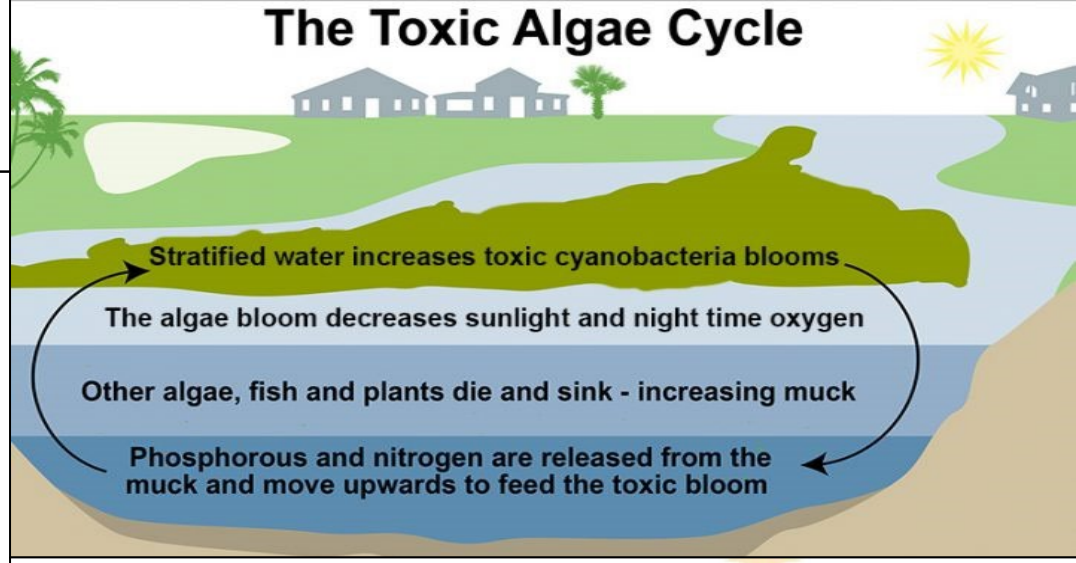
Cell Resiliency and Adaptation

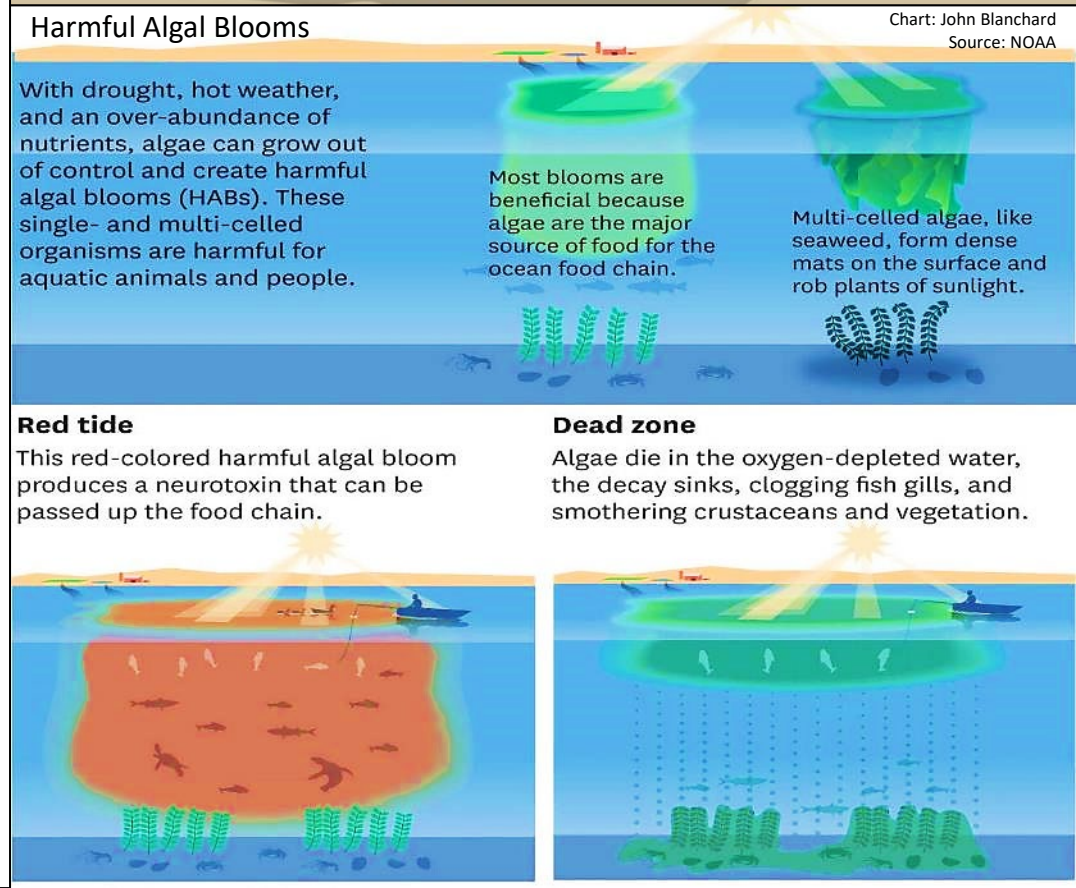
Algal blooms sometimes are natural phenomena, but their frequency, duration and intensity are increased by nutrient pollution and the blooms are becoming a regional hazard across the US.

- Algae can multiply quickly in waterways with an overabundance of nitrogen and phosphorus, particularly when the water is warm, and the weather is calm.
- “Cyanobacteria are bacteria that, like plants, use solar energy and carbon dioxide to grow (photosynthesis). Cyanobacteria occur naturally in both freshwater and marine (salt) water bodies. Blooms also can be caused by dinoflagellates (single cell microorganisms [phytoflagellates] that include luminescent forms) in marine or estuarine water bodies (red tides are an example of a dinoflagellate bloom)” St. Johns River Water Management District.

During a low-light situation most algal types go dormant, packing their cells with carbon and nitrogen as if hibernating, but in high-light (direct sunlight such as under a high pressure) the cells increased in population but decreased in carbon and nitrogen levels (Kathryn Coyne, 2021).

- Algal cells have been proven to adapt to higher temperatures than historically had been compatible for growth, some cells are now able to survive near 90 degrees.
- Higher temperatures may not constrain growth of the cells anymore and may reduce the consumption rate by organisms which consume the blooms due to the reduction of nutrients within the cell.
    - As bloom mats get thicker and wider due to increasing growth and sustainability conditions, the mats have uneven decay rates during unfavorable conditions. This allows the outer edges to act as insulation for the inner portion of the bloom and may be able to retain dormancy throughout harsh, unfavorable conditions until conditions shift back to favorable.
    - This would mean periods of decreased blooms would require active efforts to remove prior mats to prevent rapid spread once a seasonal shift occurs.
        - As the outer edges of the bloom’s mat decays, it will use oxygen from the surrounding water and still produce methane (a harmful greenhouse gas) and hydrogen sulfide, while the overall density of the mat could reduce surface access for marine life, choke various aspects of the ecology, and block sunlight.
- While algal blooms typically decay within the season they develop in, new studies indicate the impacts are becoming longer lasting and that the nutrients available to sustain them are more readily available year-round. The damage to ecology from a long-lasting bloom can be permanent.





Warming Currents Shifting Hazards

Climate change might lead to more droughts, which makes freshwater saltier. This can cause marine algae to invade freshwater ecosystems

- Algae need carbon dioxide to survive and higher levels of carbon dioxide in the air / water can lead to rapid growth of algae, especially toxic blue-green algae that can float to the surface.
- Climate change might affect rainfall patterns, leading to alternating periods of drought and intense storms. This can cause more nutrient runoff into waterbodies, feeding more algal blooms.
    - Scientists predict that sea level could rise to one meter by the year 2100. This would create more shallow and stable coastal water, conditions that are perfect for the growth of algae.
- Coastal upwelling is the process by which winds push surface water offshore and deep water moves towards the coast, bringing nutrients from the ocean floor to the surface. Climate change is expected to alter the timing and intensity of coastal upwelling.

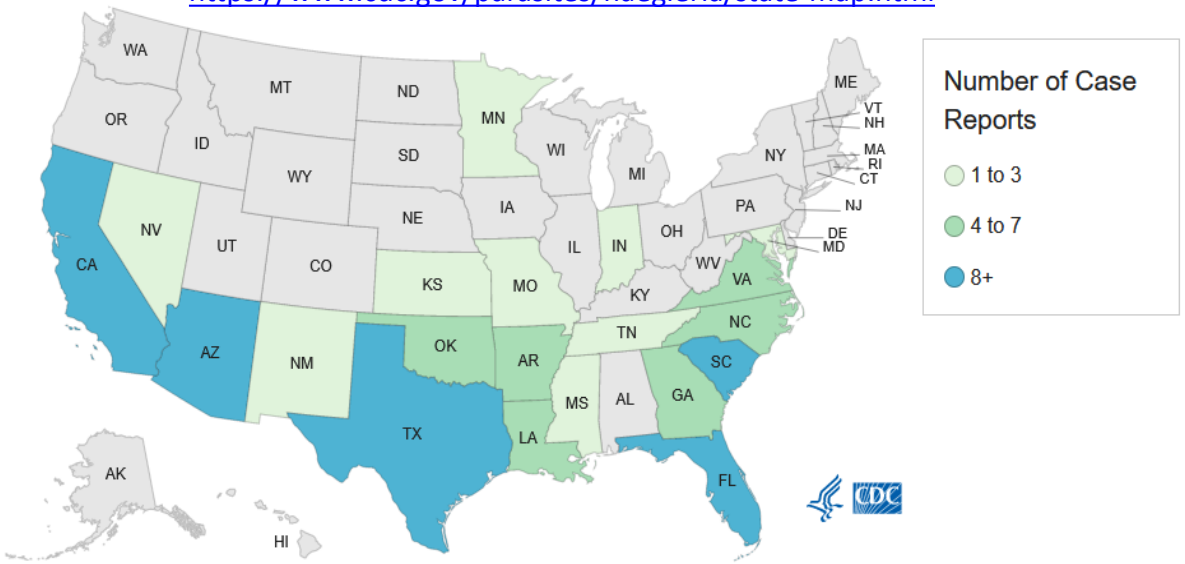
Good News: higher global temperatures will decrease the chance of most vector-borne disease spreading in places that are currently relatively warm as waters will become too hot. Bad News: warming will increase the chance that all diseases spread in places that are currently relatively cold as waters become more hospitable to growth rates.

Warmer temperatures increase transmission of vector-borne disease up to an optimum temperature or “turn-over point,” above which transmission slows. Different mosquitoes are adapted to a range of temperatures. For example, malaria is most likely to spread at 25°C (78°F) while the risk of zika is highest at 29°C (84°F). Cholera increases can be traced along warm currents.

Case Reports by State of Exposure

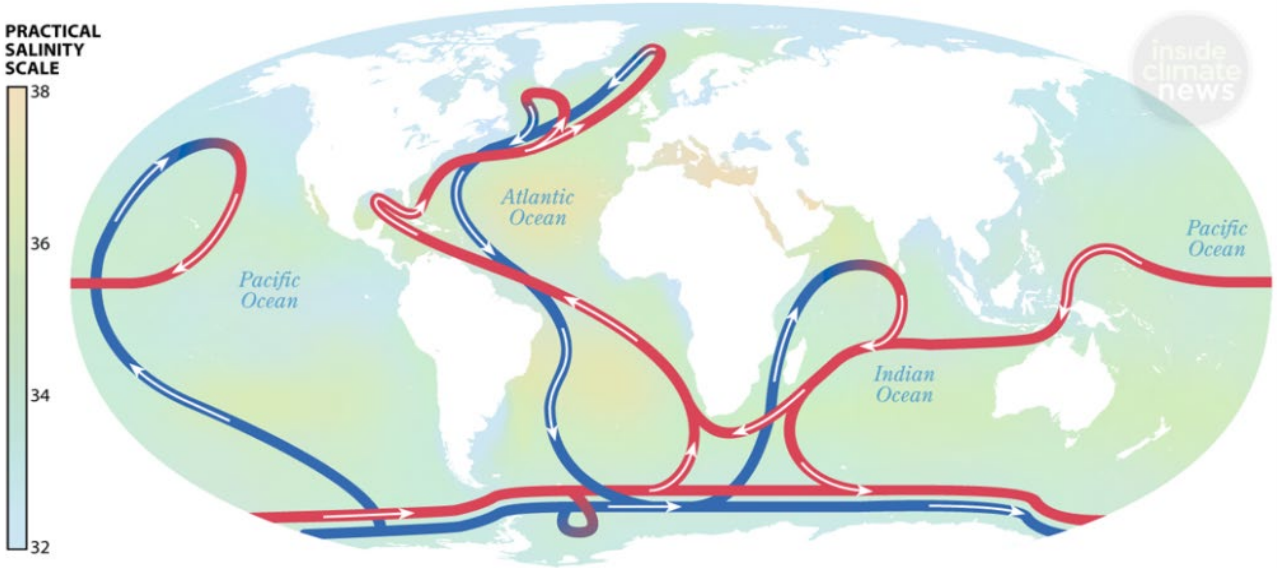
Number of Case-reports of Primary Amebic Meningoencephalitis Caused by Naegleria fowleri (N=154) by State of Exposure*— United States, 1962–2021

https://www.cdc.gov/parasites/naegleria/state-map.html



Thermohaline Circulation: The Great Ocean Conveyor Belt

Currents circulate water through the world’s oceans like a giant conveyor belt, carrying heat from the tropics toward the poles and sending colder water back in deep ocean currents. Wind, temperature and salinity help drive them. This simplified map shows the pattern.



SOURCE: NASA

PAUL HORN / InsideClimate News

Valley fever, also called coccidioidomycosis, is an infection caused by the fungus *Coccidioides*. The fungus is known to live in the soil in the southwestern United States and parts of Mexico and Central and South America.

Coccidioides spores circulate in the air after contaminated soil and dust are disturbed by humans, animals, or the weather. The spores are too small to see without a microscope. When people breathe in the spores, they can develop Valley fever. The fungus was originally discovered in 1892 in Buenos Aires and San Joaquin Valley.

- The fungus was also recently found in south-central Washington. People can get Valley fever by breathing in the microscopic fungal spores from the air, although most people who breathe in the spores don't get sick. Usually, people who get sick with Valley fever will get better on their own within weeks to months, but some people will need antifungal medication.
- *Coccidioides* lives in dust and soil in some areas in the southwestern United States, Mexico, and South America. In the United States, *Coccidioides* lives in Arizona, California, Nevada, New Mexico, Texas, and Utah.

Coccidioides is thought to grow best in soil after heavy rainfall and then disperse into the air most effectively during hot, dry conditions. There are about 15 thousand cases of Valley fever in the U.S. each year, and approximately 200 deaths, according to the U.S. CDC. Only 40% of people infected have symptoms, and 8% of those go to the hospital. https://www.nasa.gov/feature/dust-storms-and-valley-fever-in-the-american-west

"***There's no vaccine*** – the fungus lives with you for the rest of your life. Those infected are paying about US $50,000 per hospital visit, and a quarter of those people must go ten times or more" (NASA Research Team and the CDC).

Pregnant people, immunocompromised, African Americans, and Filipinos are especially at risk.

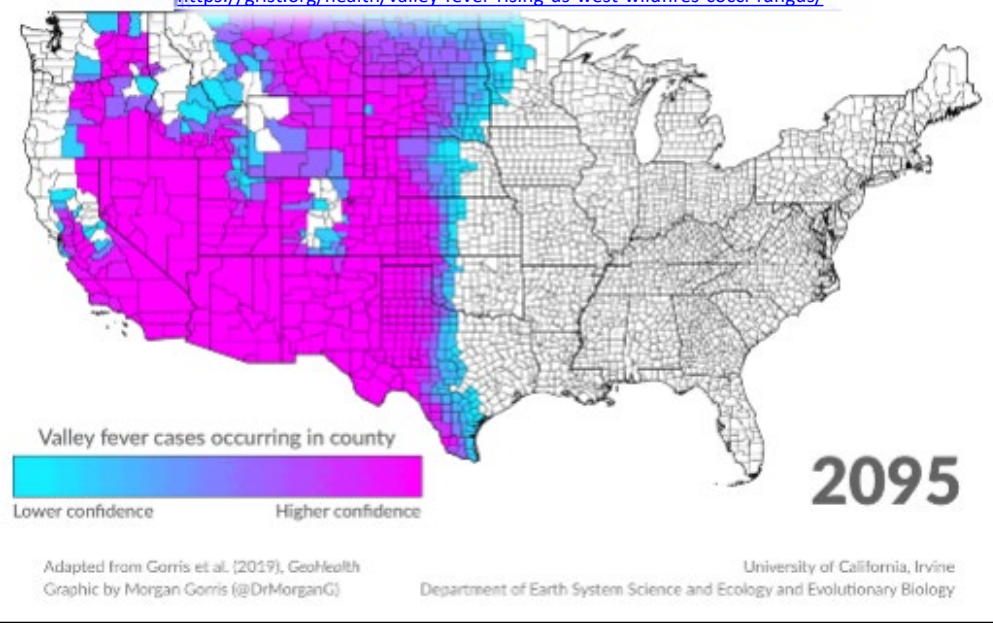
The CDC estimates that 150,000 cases of Valley fever go undiagnosed annually.

Valley fever cases in the US increased 32% between 2016-2018. Cases in California rose *800%* from 2000-2018.

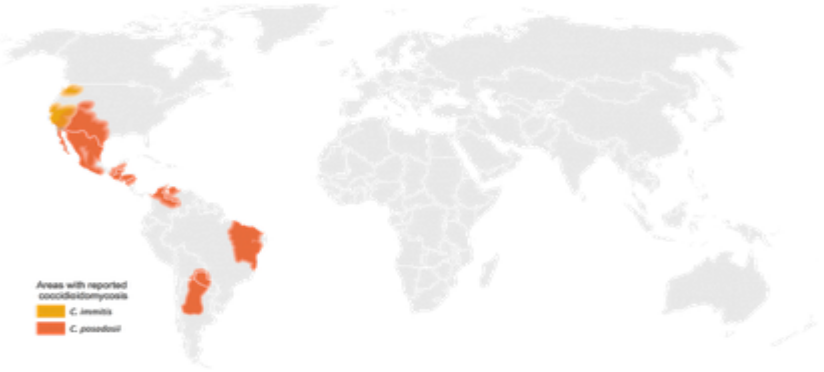
The disease's **morbidity rate** in the endemic region is comparable to **polio, measles, and chicken pox**

Expansion of Valley fever in the western US in response to high climate warming (RCP8.5)

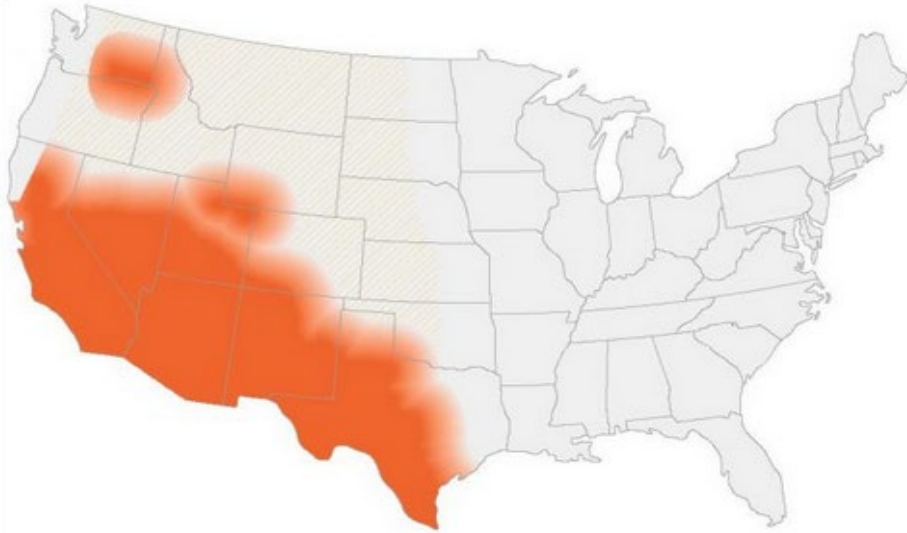
https://grist.org/health/valley-fever-rising-us-west-wildfires-cocci-fungus/



Valley Fever Estimated Presence



Estimated areas with coccidioidomycosis (Valley fever) worldwide



Estimated areas with coccidioidomycosis (Valley fever) in the United States

Drought and Seismic Activity

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

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

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

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

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

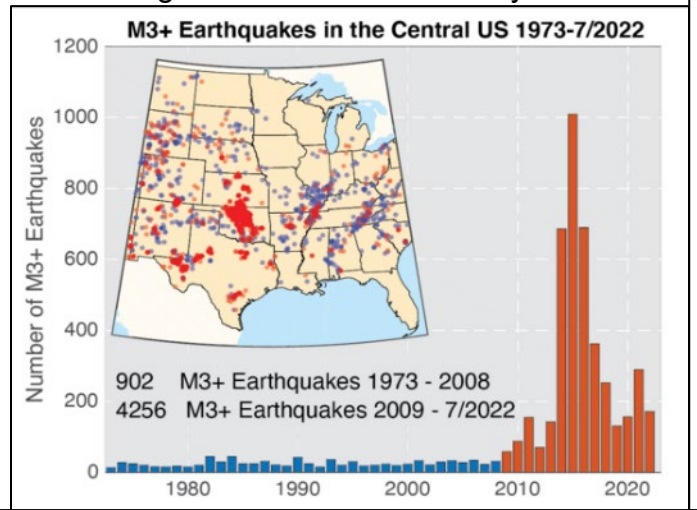
The areas around fault lines have valleys where the plates meet and are at their weakest point. Due to the lower elevations around these topography features, water tends to pool at the lowest elevation and thereby river systems were naturally located in the weaker spots of the fault line.

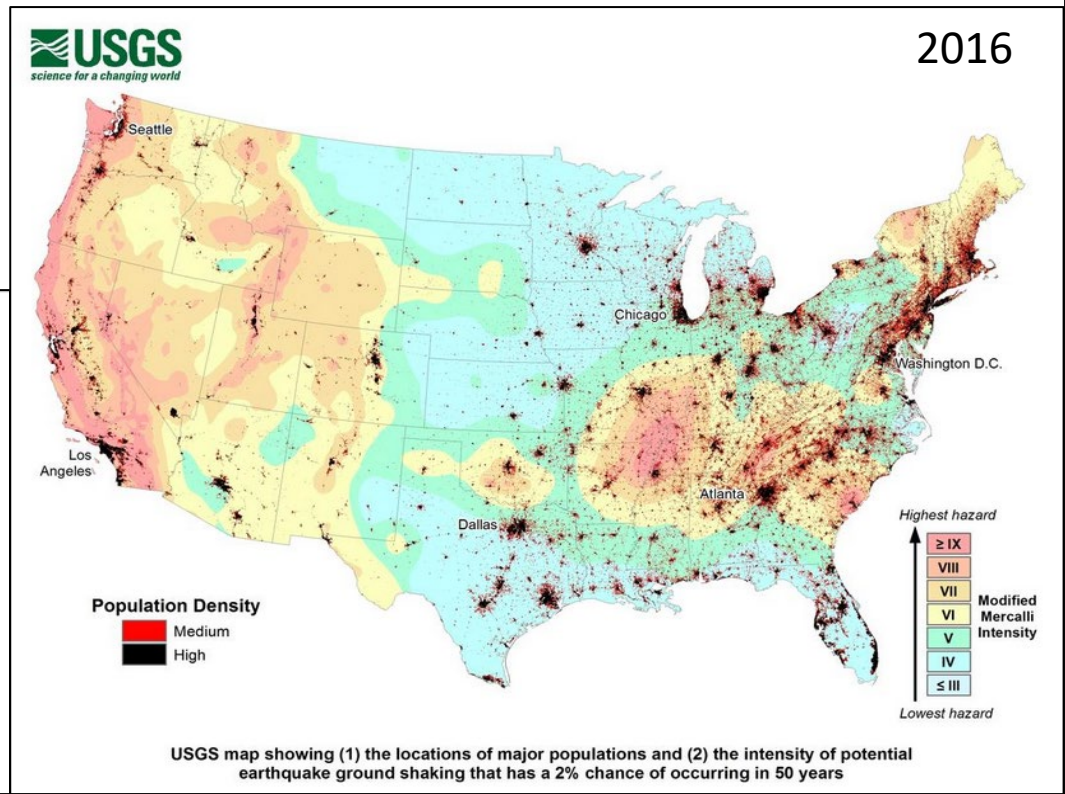
- Damming up the river system resulted in compounding water in different areas than were natural along some faults. As dams were installed, an increase in seismic activity was reported and subsequently as drought has developed, activity has increased again near the river/dam systems.

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

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

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



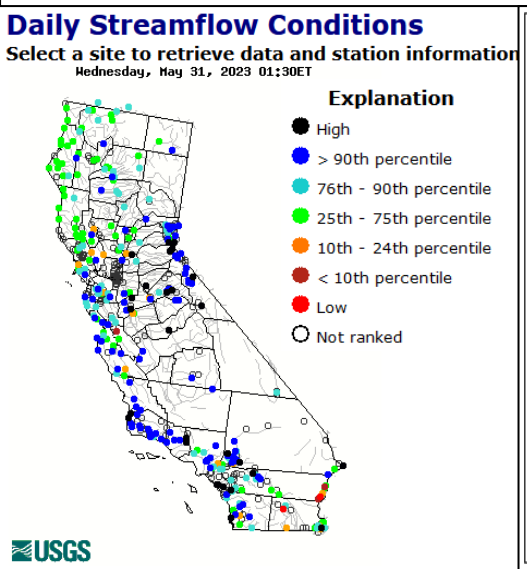


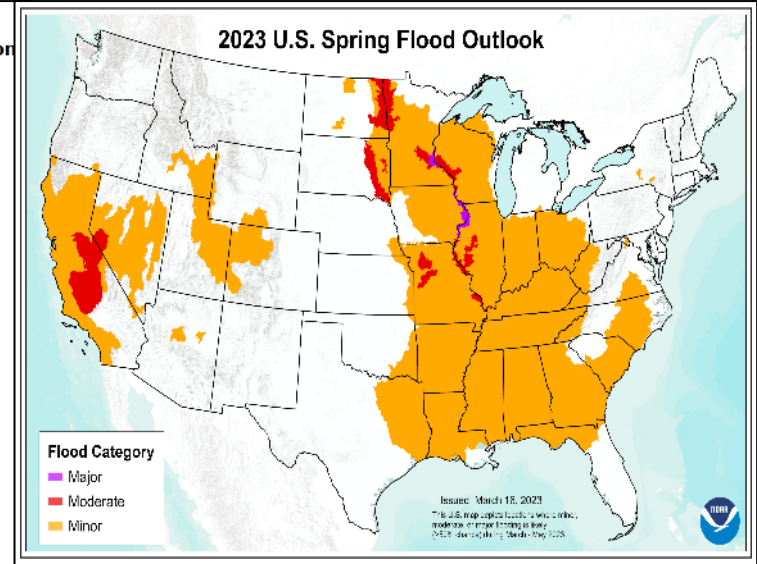
USGS map showing (1) the locations of major populations and (2) the intensity of potential earthquake ground shaking that has a 2% chance of occurring in 50 years

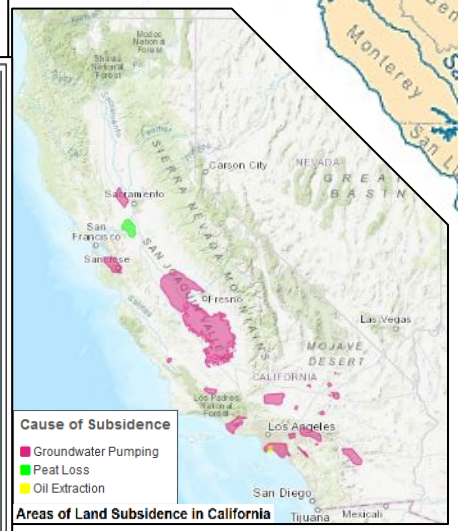
Hydrologic Outlook

Useful weather links to track observations and forecasts for impacts:

- California Stream Gauge: https://www.cnrfc.noaa.gov/river_data.php
- Sacramento Observations: https://water.weather.gov/ahps2/index.php?wfo=sto
- Region 9 Centric Forecasts: https://resreg.spl.usace.army.mil/cgi-bin/listWxProd.cgi?wxProd.in
- River Observations: https://water.weather.gov/ahps/
- NWS Operations Center Products: https://www.weather.gov/owp/operations
- River Flood Outlook: https://www.cnrfc.noaa.gov/flood_outlook.php
- River Forecasts: https://water.weather.gov/ahps/forecasts.php
- Long Range River Risk: https://water.weather.gov/ahps/forecasts.php
- Flood Zone Maps by First Street Foundation: https://riskfactor.com/?utm_source=floodfactor







https://ca.water.usgs.gov/land_subsidence/california-subsidence-areas.html

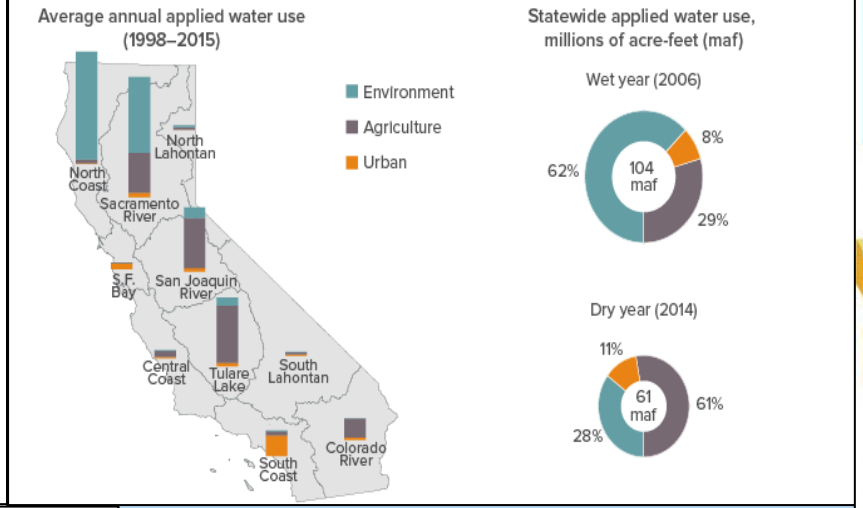
California Water Use

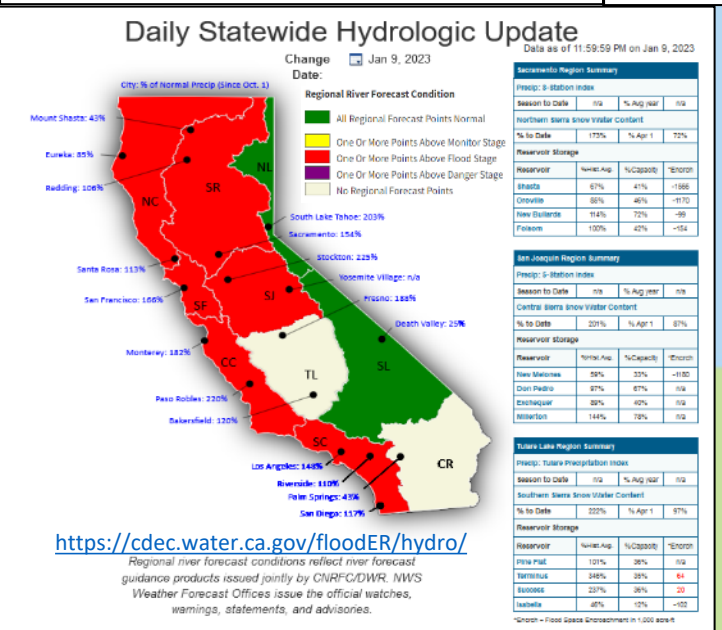
Every hydrological region in California except for one saw higher water use between March 2020-2022. The largest increases were seen in Southern California and the desert region. Water use includes residential, commercial, industrial and institutional users.

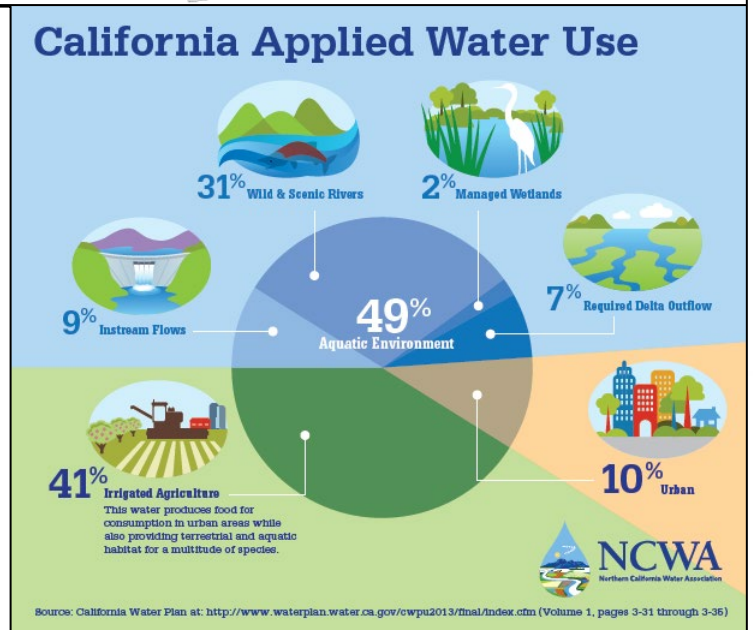
More than nine million acres of farmland in California are irrigated, representing roughly 80% of all water used for businesses and homes.

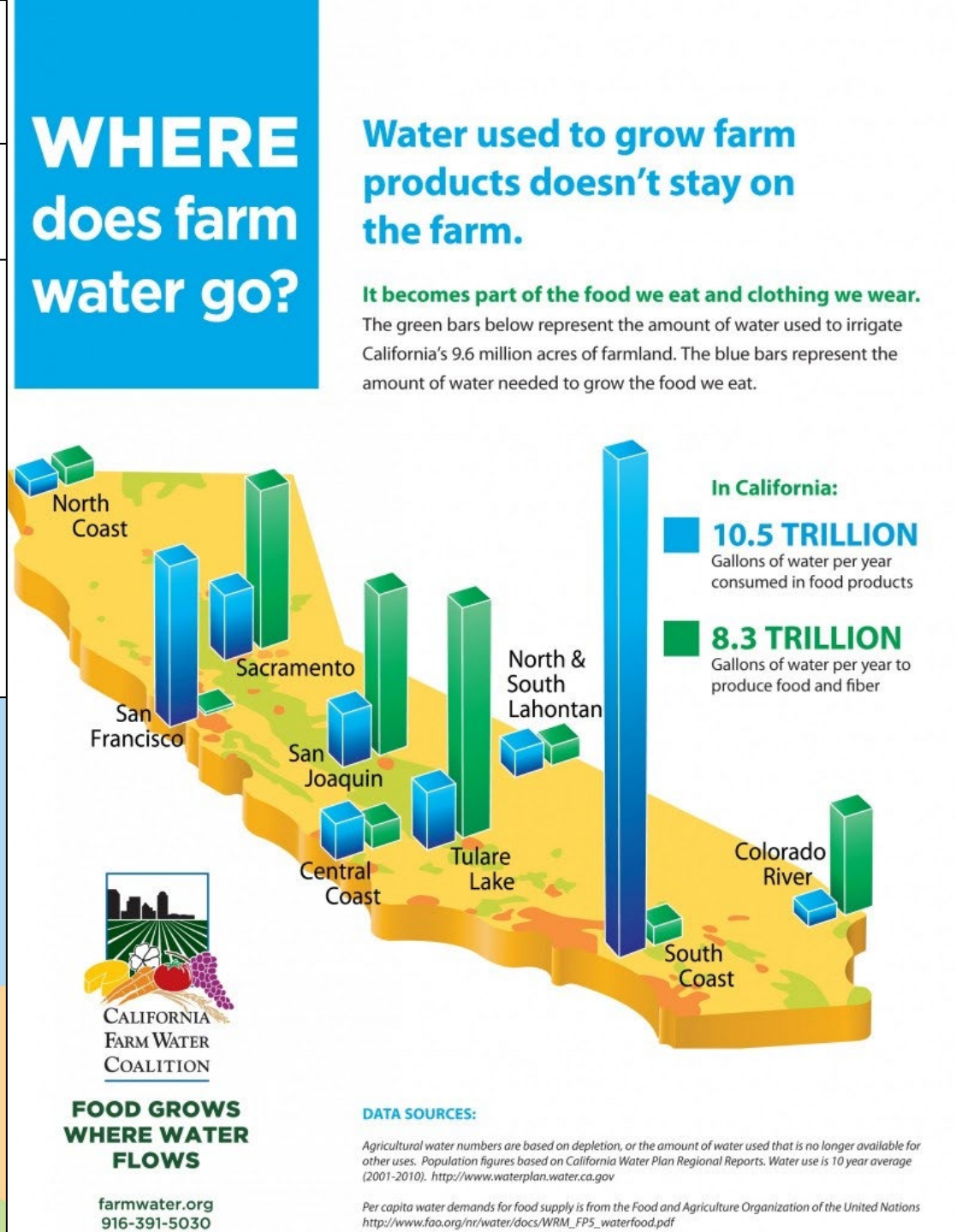
Higher-revenue perennial crops—nuts, grapes, and other fruit—have increased as a share of irrigated acreage.

75% of California's annual precipitation, made up of rain, snow, and hail, falls from November through March – mainly in the winter months (CA DWR).





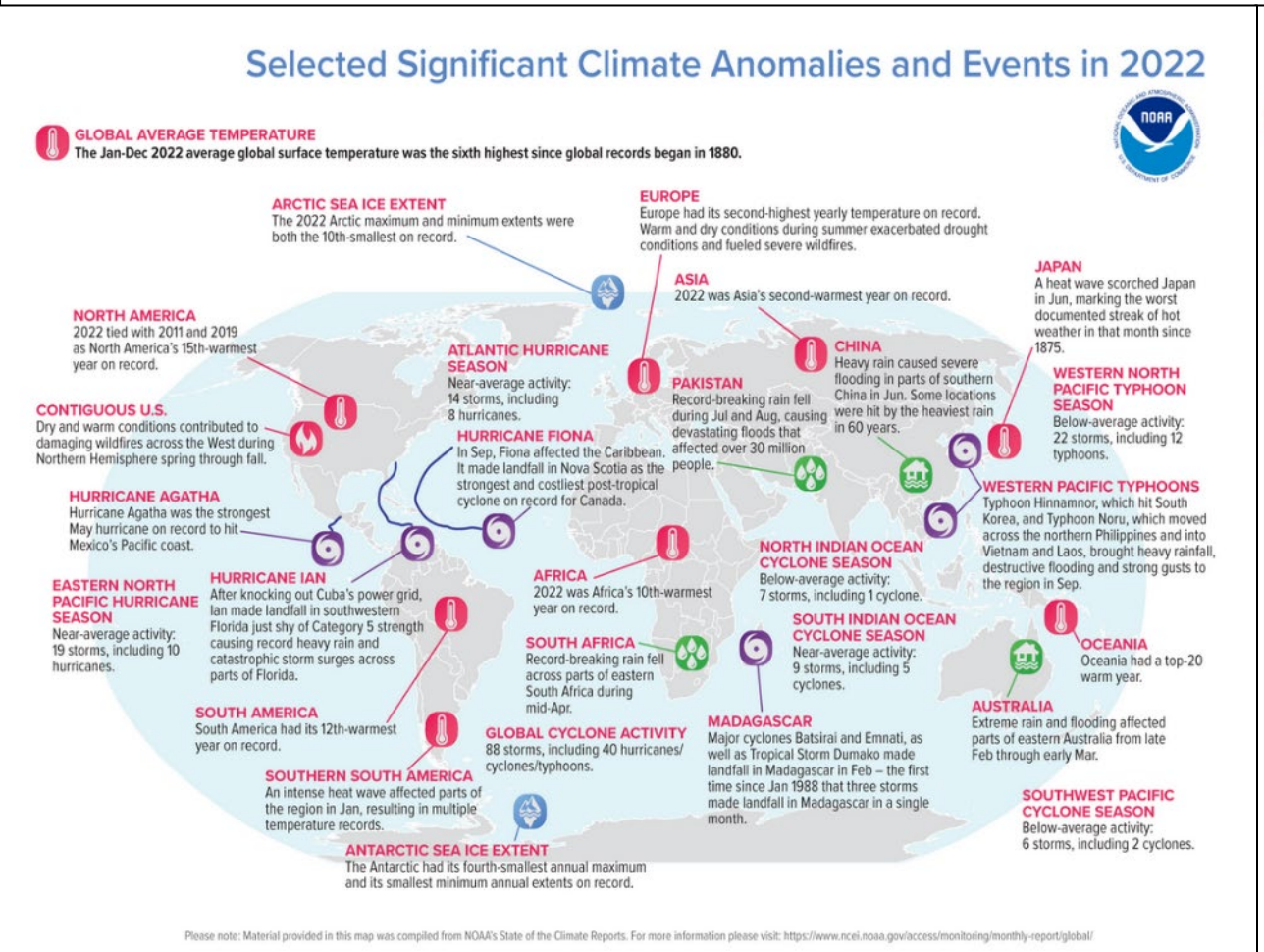


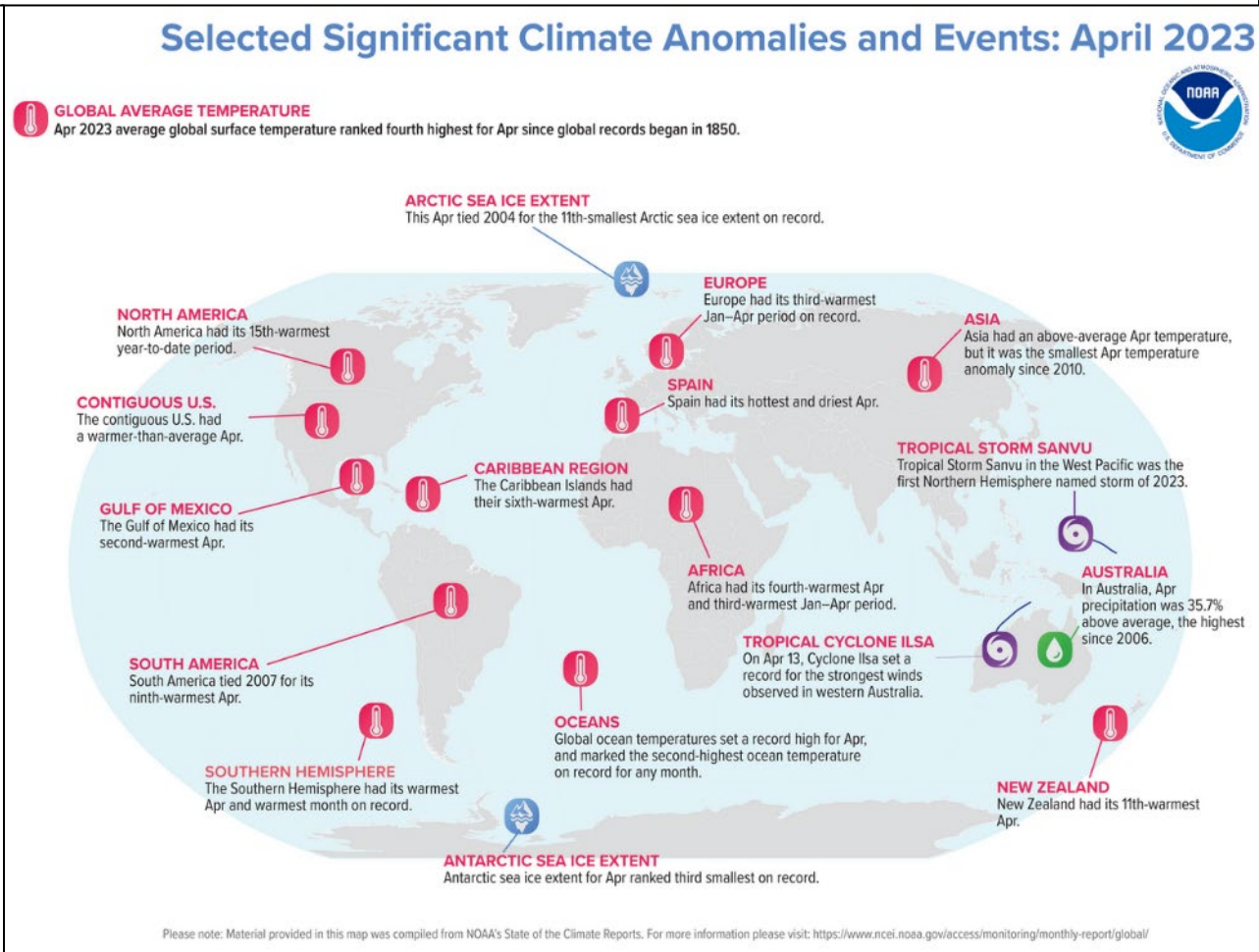


Global Impacts from Extreme Weather

The year 2022 was the sixth warmest year since global records began in 1880 at 0.86°C (1.55°F) above the 20th century average of 13.9°C (57.0°F). This value is 0.13°C (0.23°F) less than the record set in 2016 and it is only 0.02°C (0.04°F) higher than the last year's (2021) value, which now ranks as the seventh highest.

- Global ocean temperatures set a record high for April at 0.86°C (1.55°F) above the long-term average. This marked the second-highest monthly ocean temperature for any month on record, just 0.01°C (0.02°F) shy of the record-warm ocean temperatures set in January 2016.
- In recent years, manufacturers relying on the Rhine River in Germany have increasingly faced shipping capacity reductions that disrupted both inbound raw material and outbound product delivery flows as a result of drought. The same applies for the Parana River in South America, the Po River in Italy, the Mississippi River in the US, and more.





Global Heat Damages

UK: Impacts from the heatwave of 2022 in the UK: London's subway mandated temporary speed limits and reduced services as rails could bend or buckle. Network Rail closed all locations during rush hours due to the heat as temperatures rose over 104.5°F

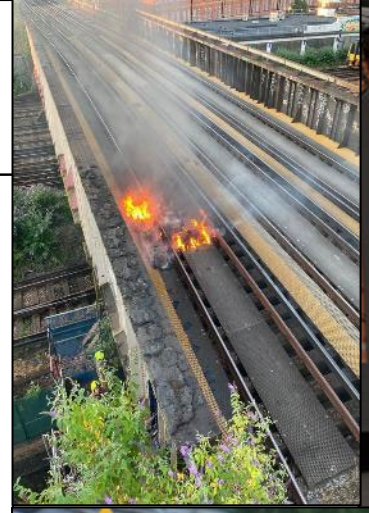
- Rail lines expand when they heat up, and they can warp and buckle if they are exposed to temperatures they weren't designed for.
- Hot temperatures can cause heavy equipment, like aircraft tires, to sink into the pavement. During periods of high heat, many planes also have performance restrictions due to a need for longer runway lengths and reduction in refueling capabilities.
- The Royal Air Force stated it halted flights at Brize Norton air base, its largest air station, because of high temperatures but that there "is no impact on RAF operations," as planes are using alternative airfields.
- Britain's Luton airport suspended flights on Monday after a runway defect was discovered during high temperatures across the country.
- Lorries were deployed to sprinkle sand on roads in a bid to stop them melting and sinking.
- Datacenters in London reported cooling related failures resulting in shutdown of services.
- Cast iron bridge supports cracked during the heatwave of 2020 and were wrapped in foil.

China: The major financial/commercial capital of Shanghai and 86 other Chinese cities reported temperatures over 104°F causing construction and outdoor work to halt.

- In a town in the southern province of Jiangxi province, a section of a road arched up 6 inches because of the heat.
- Metro stations were ordered to dim lights and adjust temperature systems on platforms and trains to save electricity.
- Roof tiles for the memorial hall in Chongqing melted and slid off as the underlying tar dissolved due to the heat, causing the site to close.
- Heat from the sun burned holes in curtains of a high-rise apartment in Chongqing.
- Rolling power outages across China's manufacturing hubs caused
- Heat damaged wheat and pig feed, pork prices rose 50%.

India: Heatwaves killed more than 22,000 people between 1992 and 2015. India saw a 55% rise in deaths due to extreme heat between 2000-2004 and 2017-2021.

Globally: Water restrictions during major heatwave events can result in additional deaths and forcing at-risk populations to access potentially contaminated open-water sources nearby.



International Climate Impacts to Manufacturing Operations

2021 Heat Wave

Manufacturing: Sichuan is rich in mineral resources like lithium and polysilicon, key raw materials in the solar photovoltaic and electronics industry. Many international semiconductor companies have plants in Sichuan, including Texas Instruments, Intel, Onsemi, and Foxconn. Chinese lithium battery giant CATL, which supplies batteries to Tesla, also has a factory in the region.

- Officials from the manufacturing hub of Chongqing notified factories August of 2022 that mandated power cuts in the municipality were extended until further notice, affecting both PC and Apple suppliers. Relocation was widely communicated.

Agri/Food: Affected by the continuous high temperature in many places, the price of fresh vegetables rose by 12.9% year-on-year, which was significantly higher than the same period in previous years

Hong Kong (CNN Business) — China's Sichuan province has ordered all factories to shut down for six days to ease a power shortage in the region as a scorching heat wave sweeps across the country.

Sichuan is a key manufacturing location for the semiconductor and solar panel industries and the power rationing will hit factories belonging to some of the world's biggest electronics companies, including Apple (AAPL) supplier Foxconn and Intel (INTC).

The province is also China's lithium mining hub — a key component of electric car batteries — and the shutdown may push up the cost of the raw material, analysts said.

China is facing its fiercest heat wave in six decades, with temperatures crossing 40 degrees Celsius (104 degrees Fahrenheit) in dozens of cities. The extreme heat has caused a spike in demand for air conditioning in offices and homes, putting pressure on the power grid. The drought has also depleted river water levels, reducing the amount of electricity produced at hydropower plants.

Sichuan, one of China's largest provinces with 84 million people, told 19 out of 21 cities in the region to suspend production at all factories from Monday to Saturday, according to an "urgent notice" issued on Sunday by the provincial government and the state grid.

For the third day this week, air quality in the city passed the "severe" threshold, reaching 445 on Friday, India's Ministry of Earth Sciences said. The figure is 10 times the target level established in the World Health Organization's 2021 air quality guidelines, which advises a 24-hour mean of 45.

As the smog descended on Delhi and the surrounding areas, officials on Friday ordered schools, factories and construction sites closed and banned diesel trucks from bringing nonessential goods to the capital. About half of the city's government employees were urged to work from home.

Los Angeles Times

Twitter's data center knocked out by extreme heat in California

As climate change continues to heat the planet, Twitter's outage underscores how extreme weather can incapacitate the online systems we all...

Sep 12, 2022

Data Center Dynamics

Twitter data center brought down by California's extreme heat wave

A Twitter data center was brought offline by California's extreme heat wave, as equipment shut down during record temperatures.

Sep 13, 2022

ZDNET

Record-breaking heatwave causes cloud-computing problems

The two major cloud providers on Tuesday reported cooling-related failures at their London-based data centers as a result of the sweltering...

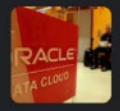
Jul 19, 2022

PC Gamer

Google, Oracle datacenters melt down in extreme European heatwave

A punishing heat wave currently gripping the UK and other parts of Europe is wreaking havoc on Google and Oracle cloud servers,...

Jul 19, 2022



Community Impacts

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

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

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

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

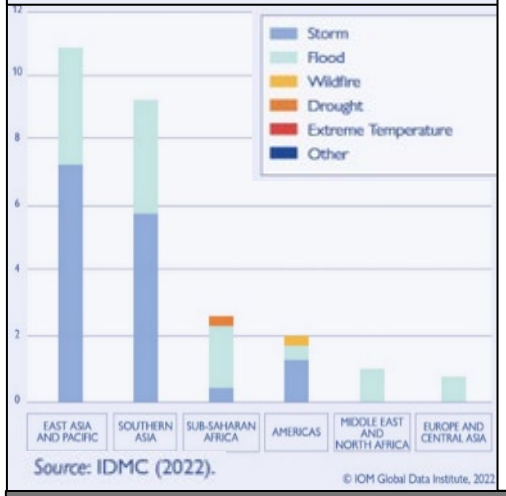
- People who perceived that damage had occurred at such a broad scale were more likely to believe that climate change is a problem and is causing harm, they were also more likely to perceive a greater risk of future flooding in their community.
- In contrast, individual losses such as damage to one's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

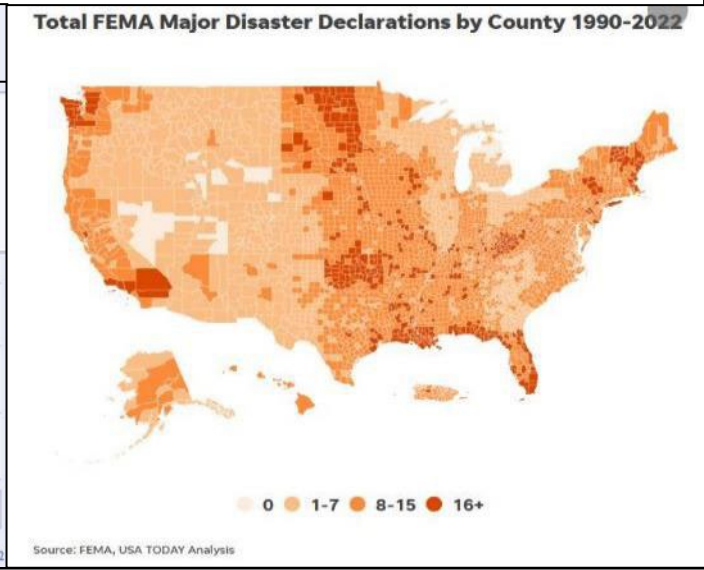
Research supported by NIEHS and others have shown that preparation, adaptation, and mitigation actions can reduce poor health outcomes and infrastructure disruption during and after an extreme weather event.
https://www.niehs.nih.gov/research/programs/climatechange/health_impacts/weather_related_morbidity/index.cfm

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

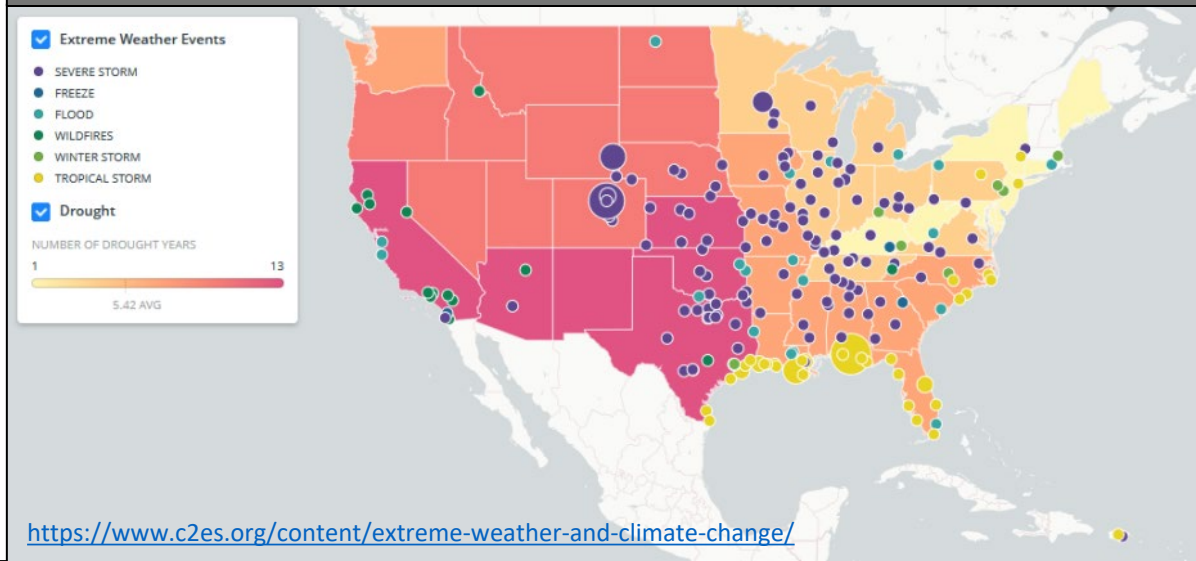
According to UNHCR, the UN’s refugee agency, an annual average of 21.5 million people have been forcibly displaced by weather-related events – such as floods, storms, wildfires and extreme temperatures – since 2008. These numbers are expected to surge in coming decades with forecasts from international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

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





Billion-Dollar Extreme Weather Events, 2000-2021



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

Climate Migration Patterns

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

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

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

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

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

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

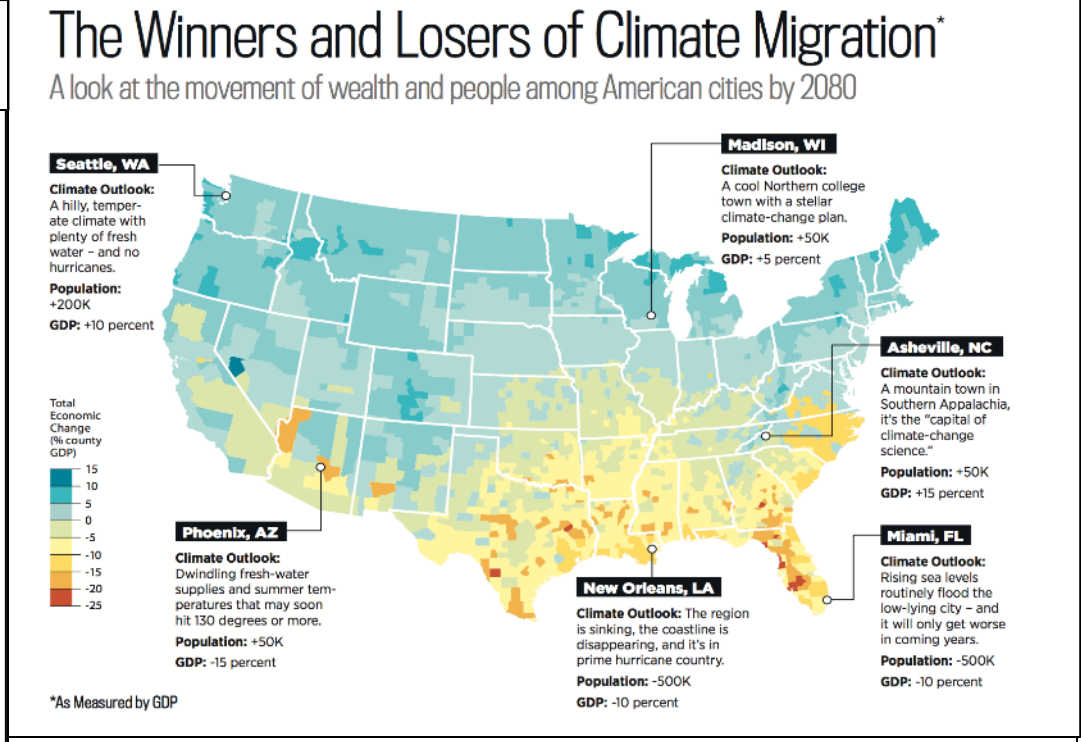
Climate change related-migration, as used in this report, is an umbrella term describing the spectrum of climate change’s relationship with human mobility—including the circumstances of “trapped populations” for whom migration is not an option despite exposure to climate-related threats. Even in the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

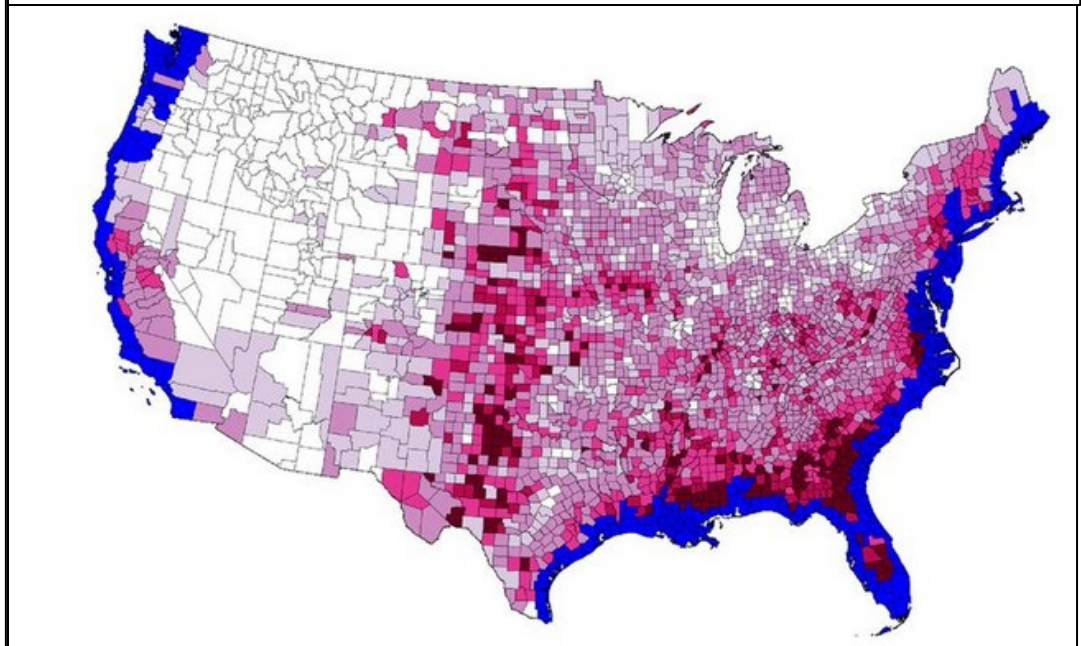
https://www.whitehouse.gov/wp-content/uploads/2021/10/Report-on-the-Impact-of-Climate-Change-on-Migration.pdf

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

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

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





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

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

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

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

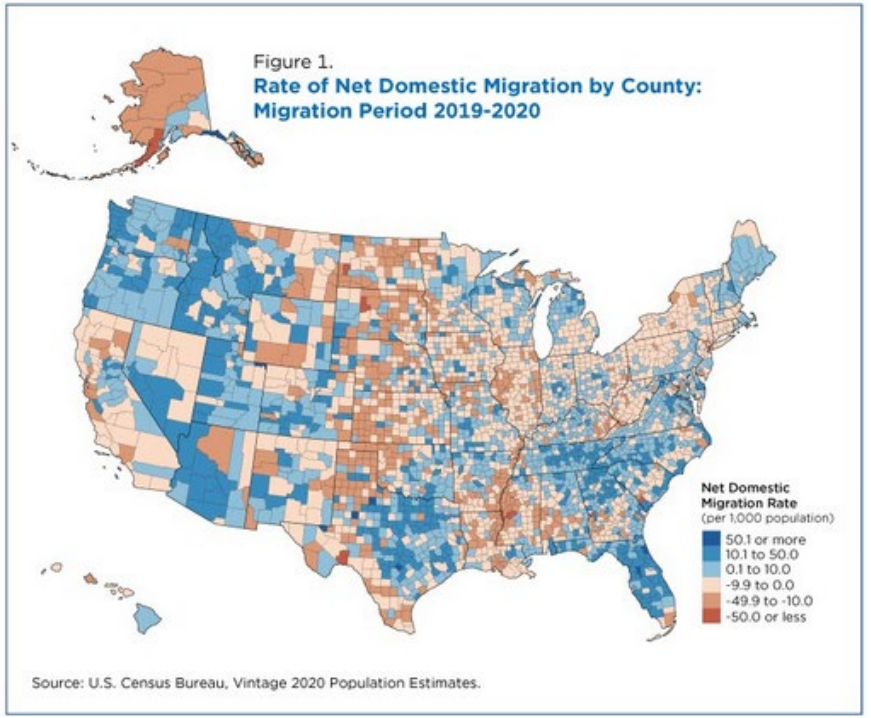
<u>Where people live influences their vulnerability to climate change:</u>

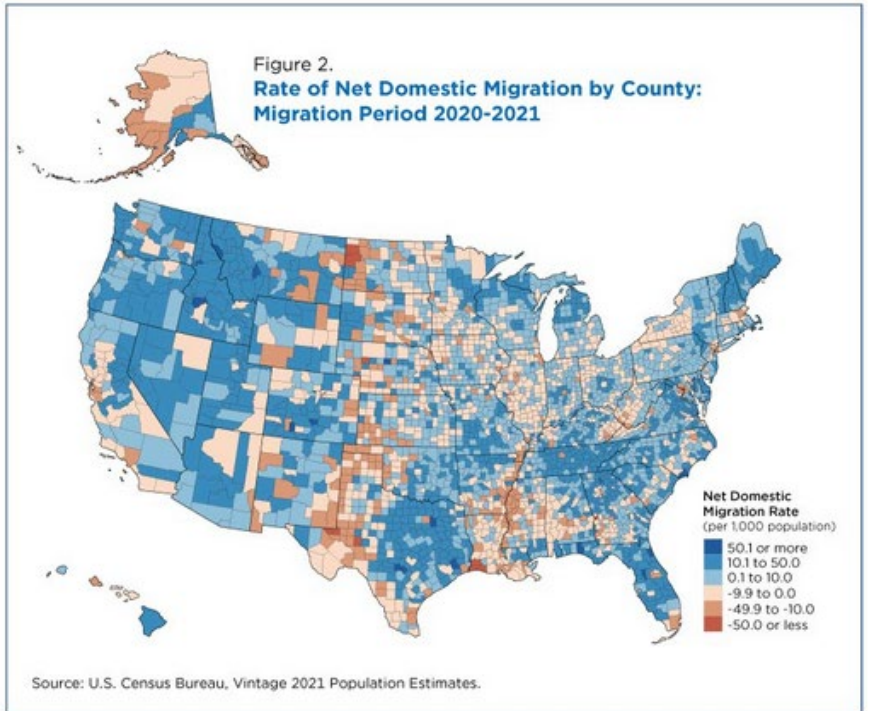
About 80% of the U.S. population lives in urban areas. As a result, increases in heat waves, drought, or violent storms in cities would affect a larger number of people than in suburban or rural areas

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

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

- **The states that had the largest growth rates were Utah, Texas, California, Arizona and Florida.** The county that added the most residents was Maricopa County in Arizona, which contains the state's biggest city, Phoenix, adding around 58,000 residents. Utah County came in at the 10th spot on the list by adding just under 22,000 residents to bring its population to around 685,000 people.
- With over 39 million people, California is the nation’s most populous state—its population is much larger than that of Texas (30 million) and Florida (22 million), but the numbers are trending down. Nearly half of Americans who plan to move say natural disasters and extreme temperatures factored into their decision to relocate.
- Climate change can impact the health and well-being of indigenous tribes by making it harder for tribes to access safe and nutritious food including traditional foods important to many tribes’ cultural practices. Many tribes lack access to safe drinking water and wastewater treatment in their communities. This could increase health risks associated with water quality problems like contamination and may reduce availability of water during droughts.





Climate Mapping Tool for Projections and Action Planning

Climate Risk & Resilience Portal (ClimRR)

CENTER FOR CLIMATE RESILIENCE AND DECISION SCIENCE
Argonne National Laboratory

https://disgeoportal.egs.anl.gov/ClimRR/

Average Annual Maximum Temperature
Historical: 71.08 (F)
RCP4.5 Mid-Century: 73.36 (F)
RCP8.5 Mid-Century: 74.29 (F)

Average Annual Minimum Temperature
Historical: 51.92 (F)
RCP4.5 Mid-Century: 53.14 (F)
RCP8.5 Mid-Century: 54.42 (F)

Total Annual Precipitation
Historical: 16.54 (inches)
RCP4.5 Mid-Century: 15.33 (inches)
RCP8.5 Mid-Century: 17.30 (inches)

Average Seasonal Maximum Temperature
Winter - Historical: 50.39 (F)
Winter - RCP 8.5 Mid-Century: 56.83 (F)
Spring - Historical: 69.53 (F)
Spring - RCP 8.5 Mid-Century: 74.65 (F)
Summer - Historical: 93.59 (F)
Summer - RCP 8.5 Mid-Century: 99.77 (F)
Autumn - Historical: 75.75 (F)
Autumn - RCP 8.5 Mid-Century: 80.08 (F)

Average Seasonal Minimum Temperature
Winter - Historical: 35.46 (F)
Winter - RCP 8.5 Mid-Century: 39.27 (F)
Spring - Historical: 49.27 (F)
Spring - RCP 8.5 Mid-Century: 52.81 (F)
Summer - Historical: 70.96 (F)
Summer - RCP 8.5 Mid-Century: 75.97 (F)
Autumn - Historical: 55.81 (F)
Autumn - RCP 8.5 Mid-Century: 59.43 (F)

Daily Precipitation Maximum Seasonal
Winter - Historical: 0.772 (inches)
Winter - RCP 8.5 Mid-Century: 0.883 (inches)
Spring - Historical: 0.657 (inches)
Spring - RCP 8.5 Mid-Century: 0.739 (inches)
Summer - Historical: 0.529 (inches)
Summer - RCP 8.5 Mid-Century: 0.443 (inches)
Autumn - Historical: 0.764 (inches)
Autumn - RCP 8.5 Mid-Century: 1.128 (inches)

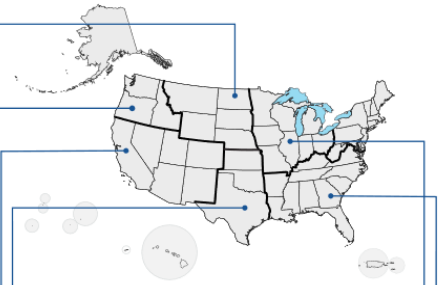
OASH | Office of Climate Change and Health Equity

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

Climate and Health Outlook

ISSUED MAY 2023

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



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

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

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

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

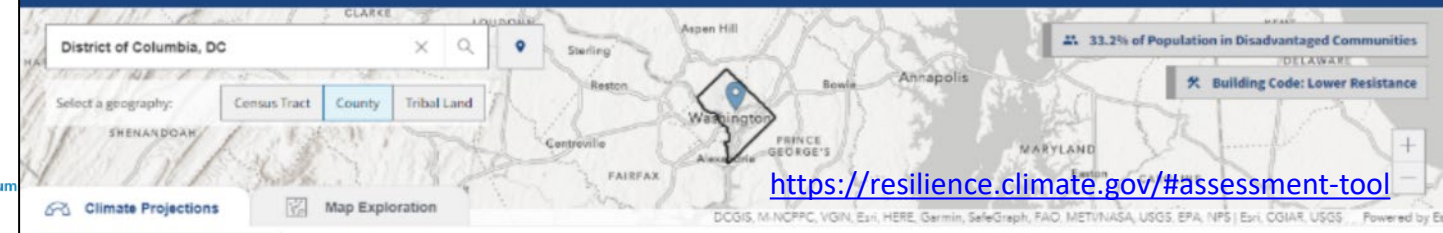
Midwest: Major spring flooding is ongoing along the mainstem of the Mississippi River from the Twin Cities, Minnesota to Keokuk, Iowa. Moderate flooding is also possible along portions of the Mississippi River mainstem from Keokuk, Iowa to St. Louis, Missouri. Minor to moderate flooding is possible across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

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

Drought Wildfire Flooding Heat

Climate Mapping For Resilience and Adaptation v1.1.a.4

CMRA | User Guide | Get Complete Report



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

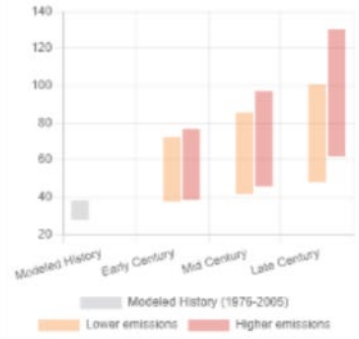
Climate Hazards
- Extreme Heat
- Drought
- Wildfire
- Flooding
- Coastal Inundation

Climate Projections for Early Century (2015–2044) | Lower emissions | Higher emissions

	Lower emissions	Higher emissions
Annual days with maximum temperature > 90°F	55.6 Days (+22.8 since 1976-2005)	57.6 Days (+24.8 since 1976-2005)
Annual days with maximum temperature > 95°F	20.0 Days (+12.8 since 1976-2005)	21.8 Days (+14.6 since 1976-2005)
Annual days with maximum temperature > 100°F	4.1 Days (+3.4 since 1976-2005)	4.8 Days (+4.2 since 1976-2005)
Annual days with maximum temperature > 105°F	0.4 Days (+0.4 since 1976-2005)	0.6 Days (+0.6 since 1976-2005)
Annual single highest maximum temperature	102.1 °F (+3.4 since 1976-2005)	102.4 °F (+3.7 since 1976-2005)
Annual highest maximum temperature averaged over a 5-day period	97.3 °F	97.7 °F

Indicator Details | Chart | Table

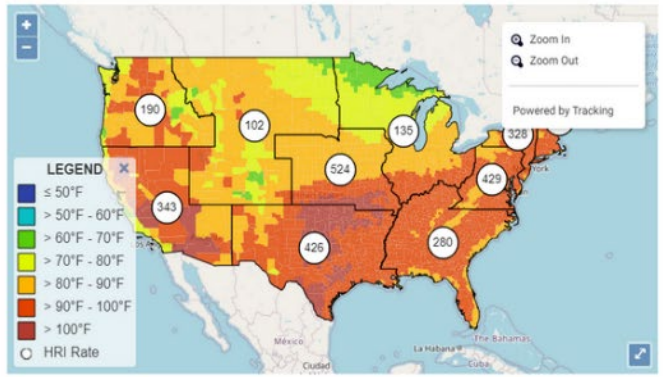
Annual days with maximum temperature > 90°F



Featured Tools

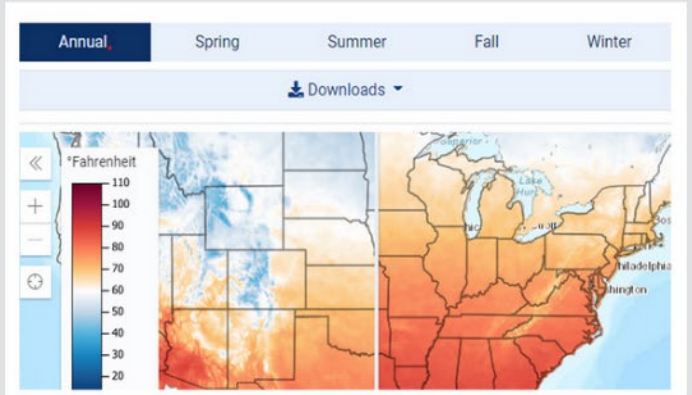
https://www.heat.gov/

Heat & Health Tracker



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

The Climate Explorer



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

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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CISA ISD ACOS – Collaboration Cell
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