Presentations (Pg. 9)

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Recognizing and Addressing the Potential for Long-Term Drought in California

Staff Recommendation
Receive and file.

What is drought?

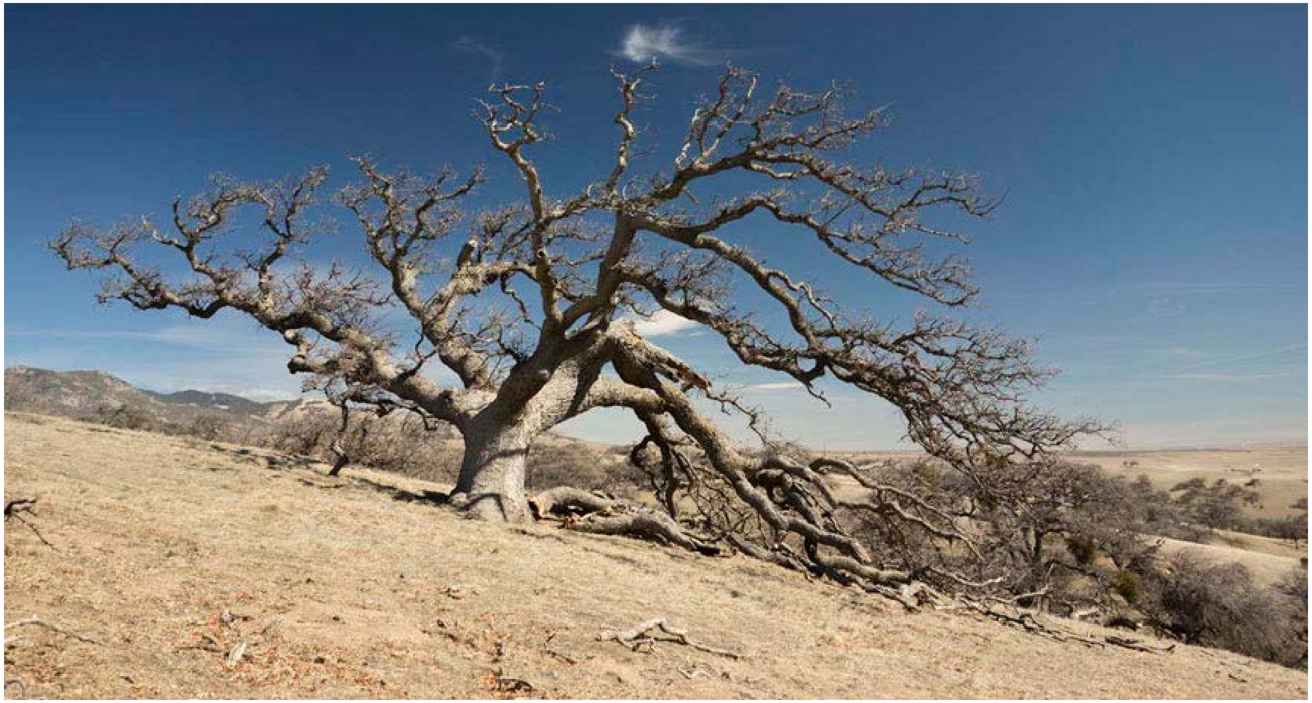


Photo Credit: D. Griffin
https://www.sciencenews.org/article/california-drought-worst-least-1200-years

We know it when we see it, right?

Folsom Lake Reservoir, 2014.
https://ca.water.usgs.gov/california-drought/

But, what are the physical conditions that indicate drought?

Drought "Bucket Model" Equation [1]

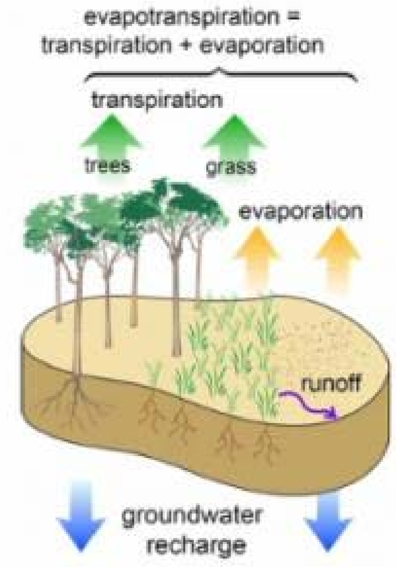
$$P - E = \frac{dS}{dt} + R_o + G_w$$

Precipitation – Evapotranspiration = Soil Moisture Storage + Runoff + Groundwater

Supply

Demand

How do we know the value of these variables in the future? Can we predict drought?



[1] Equation Credit: Fan, Y., & Van Den Dool, H. (2004). Climate Prediction Center global monthly soil moisture data set at 0.5 resolution for 1948 to present. *Journal of Geophysical Research: Atmospheres*, *109*(D10).

Evapotranspiration Figure Credit: Toews, M.W. 2007. Conceptual diagram of near-surface hydrology, showing evapotranspiration, evaporation, transpiration, runoff, and recharge processes.

Climate Conditions Drive Weather Patterns

- CO_2 is a greenhouse gas which means that it absorbs and radiates Heat
- Increased levels in CO_2 atmosphere increases global temperature (Heat)
- Increased Heat Causes Increased Evapotranspiration which influences Precipitation Patterns (weather) around the Globe
- Drought arises from conditions of Shortage of Precipitation (Moisture Supply) or Excess Evapotranspiration (Moisture Demand).

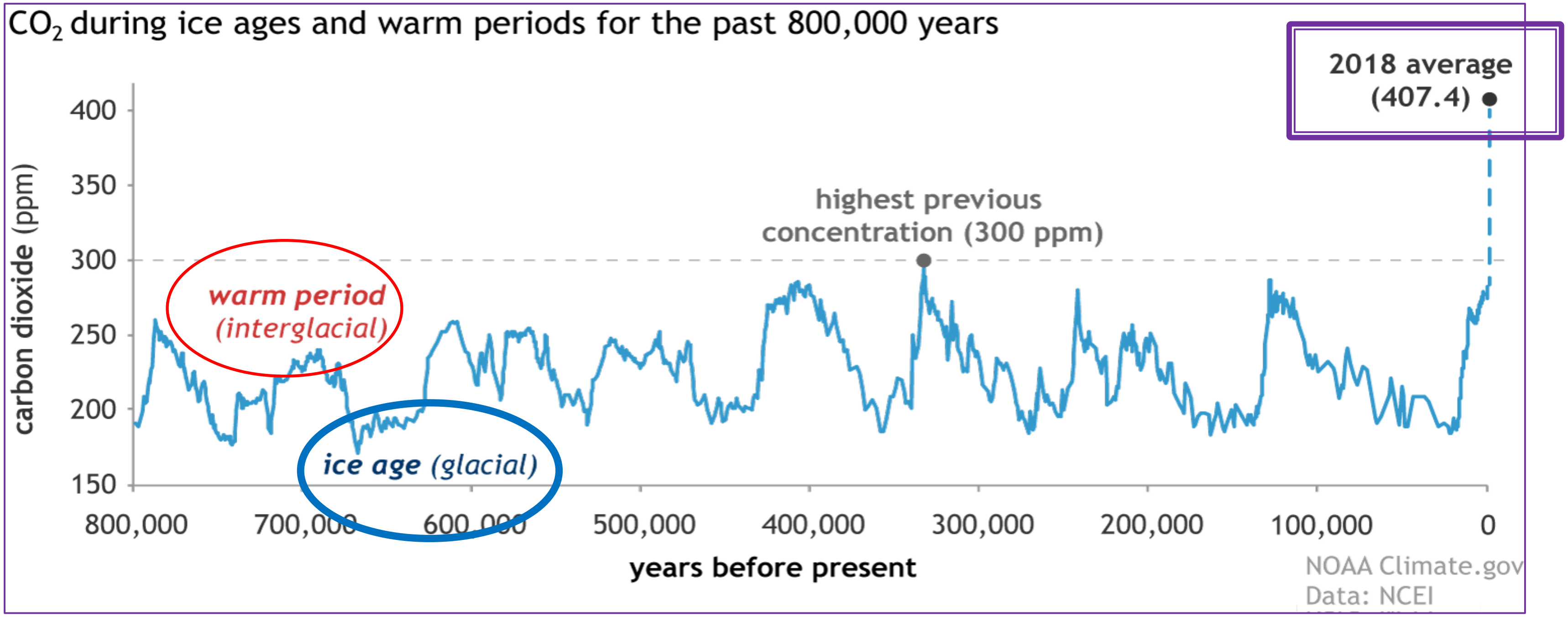


Figure Credit: NOAA, Climate.gov

- The annual rate of increase in atmospheric CO_2 over the past 60 years is about 100 times faster than previous natural increases (around the end of the last ice age 11-17k thousand years ago).

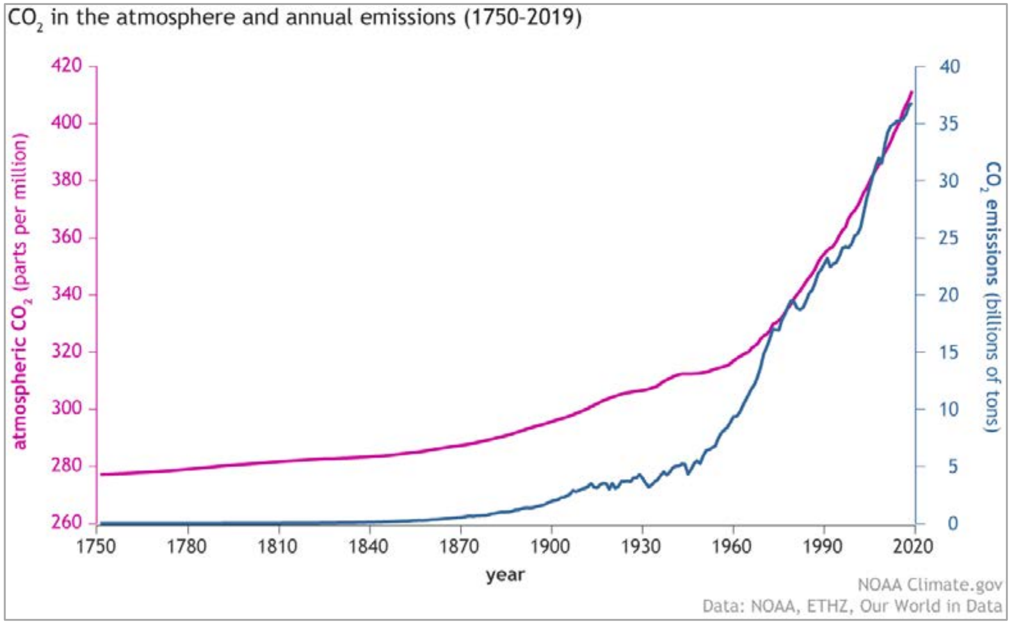


Figure Credit: NOAA, Climate.gov

How do we know?

Photo Credit: NASA's Goddard Space Flight Center/Ludovic Brucker.

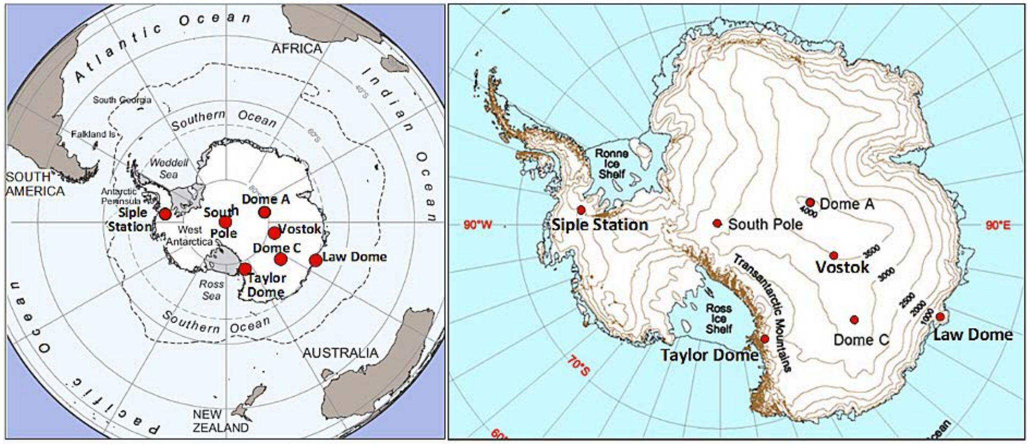


Figure Credit: Luthi et al. 2008

- The last time atmospheric CO_2 levels were this high was more than 3 million years ago

- Earth's temperature was 2°–3°C, or about 4° - 5° F, warmer.

Lüthi, D., et al. 2008. EPICA Dome C Ice Core 800KYr Carbon Dioxide Data. IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2008-055. NOAA/NCDC Paleoclimatology Program, Boulder CO, USA. Accessed from the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy")

CO_2 levels are High and Rising.

Q: What does this mean for humans?   A: Weather will become more extreme and variable.

- Increased intensity and duration of heat waves
- Longer, drier, periods in some areas with longer wet periods in others
- Increased frequency and intensity of wildfire
- Increased duration and frequency of hurricanes and monsoons
- Increased ocean temperature, which influences weather patterns
- Melting polar ice, sea level rise

Image from https://climate.nasa.gov/effects
Photo Credit: VladisChern/Shutterstock.com

Image from https://climate.nasa.gov/effects/ Photos Bottom Left - Mellimage/Shutterstock.com, center - Montree Hanlue/Shutterstock.com

Weather vs. Climate

- Weather refers to atmospheric conditions that occur locally over short periods of time. Ex: rain, snow, clouds, winds, floods or thunderstorms.
- Climate refers to the long-term regional or even global average of temperature, humidity and rainfall patterns over seasons, years or decades.
- Climate and ocean conditions are driver of global weather patterns.

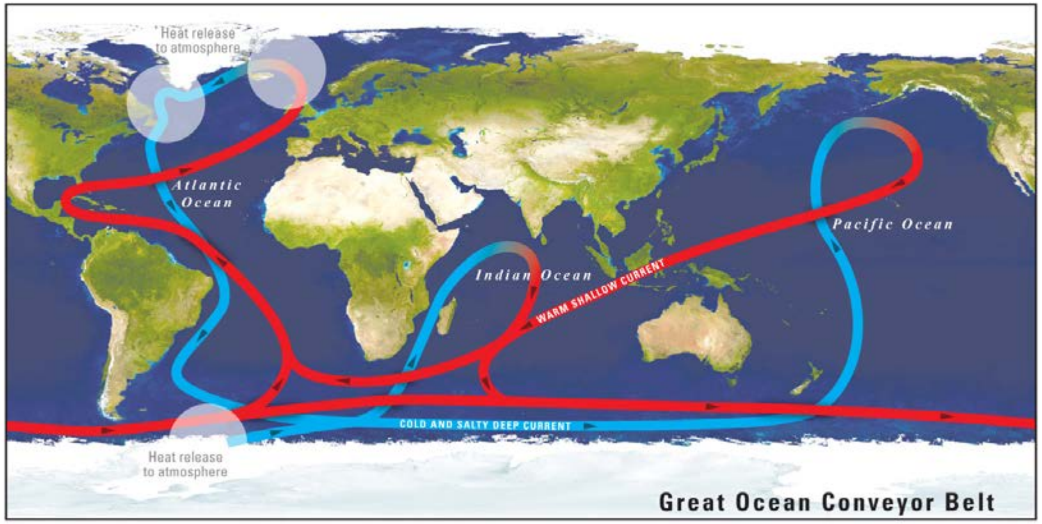


Figure Credit: USGS. https://pubs.usgs.gov/pp/p1386a/gallery2-fig31.html

Changes in Precipitation Patterns

- General circulation of atmosphere delivers moisture from the oceans to land.
- Large atmospheric disruptions caused by ocean temperatures and currents (e.g. El Niño, La Niña)
- Hotter temperatures demand more from land surface
- Drought indices depict unprecedented drying throughout much of US
- Megadrought Lasting Decades Is 99% Certain in American Southwest

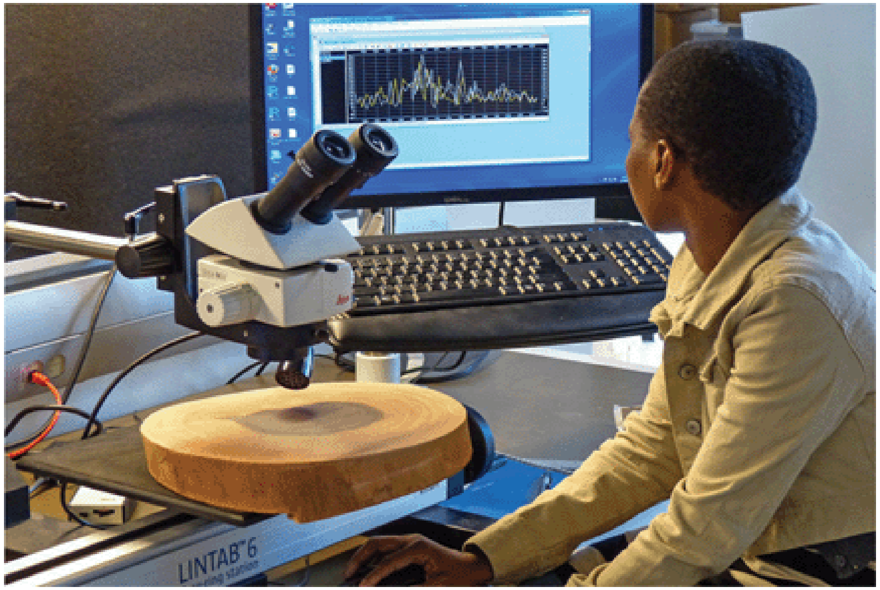
Photo Credit: AP/Jae C. Hong

Image from https://climate.nasa.gov/effects/

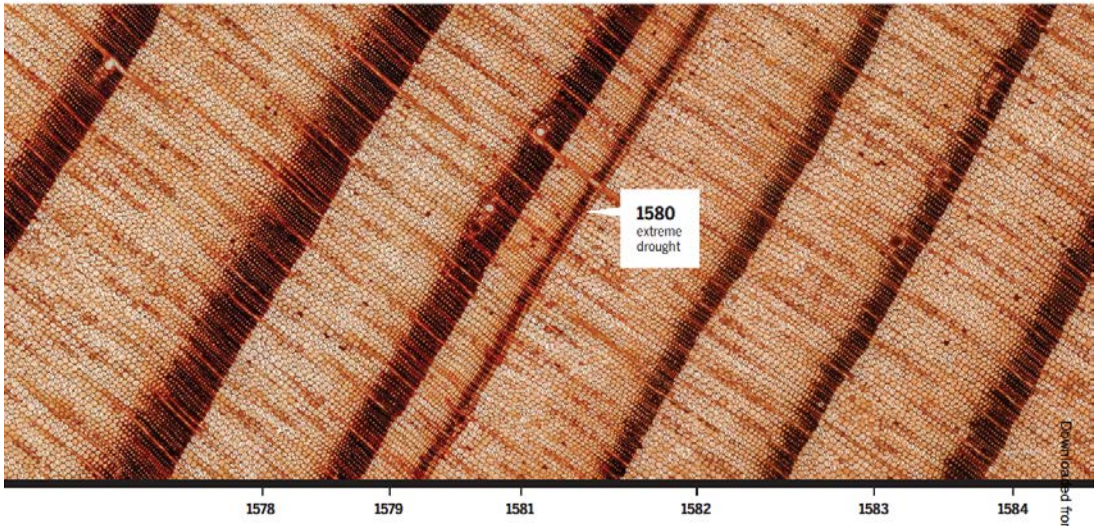
In the April Issue of Science, David W. Stahle described Megadrought in his article, ***Anthropogenic megadrought:*** *Human-driven climate warming worsens an otherwise moderate drought.*

- Climate history can be found in tree-ring chronologies.
- Narrow rings in trees of semiarid climates indicate hot, dry summers.
- Megadroughts were extremely rare and found to historically occur only occurring only once or twice every thousand years.
- Megadrought of 1580s worst drought in 1200 years
- Second worst event???

2000 – 2018 in American SW!



Dendrochronologist Zakia Hassan Khamisi measures tree-ring widths
PHOTO: VALERIE TROUET

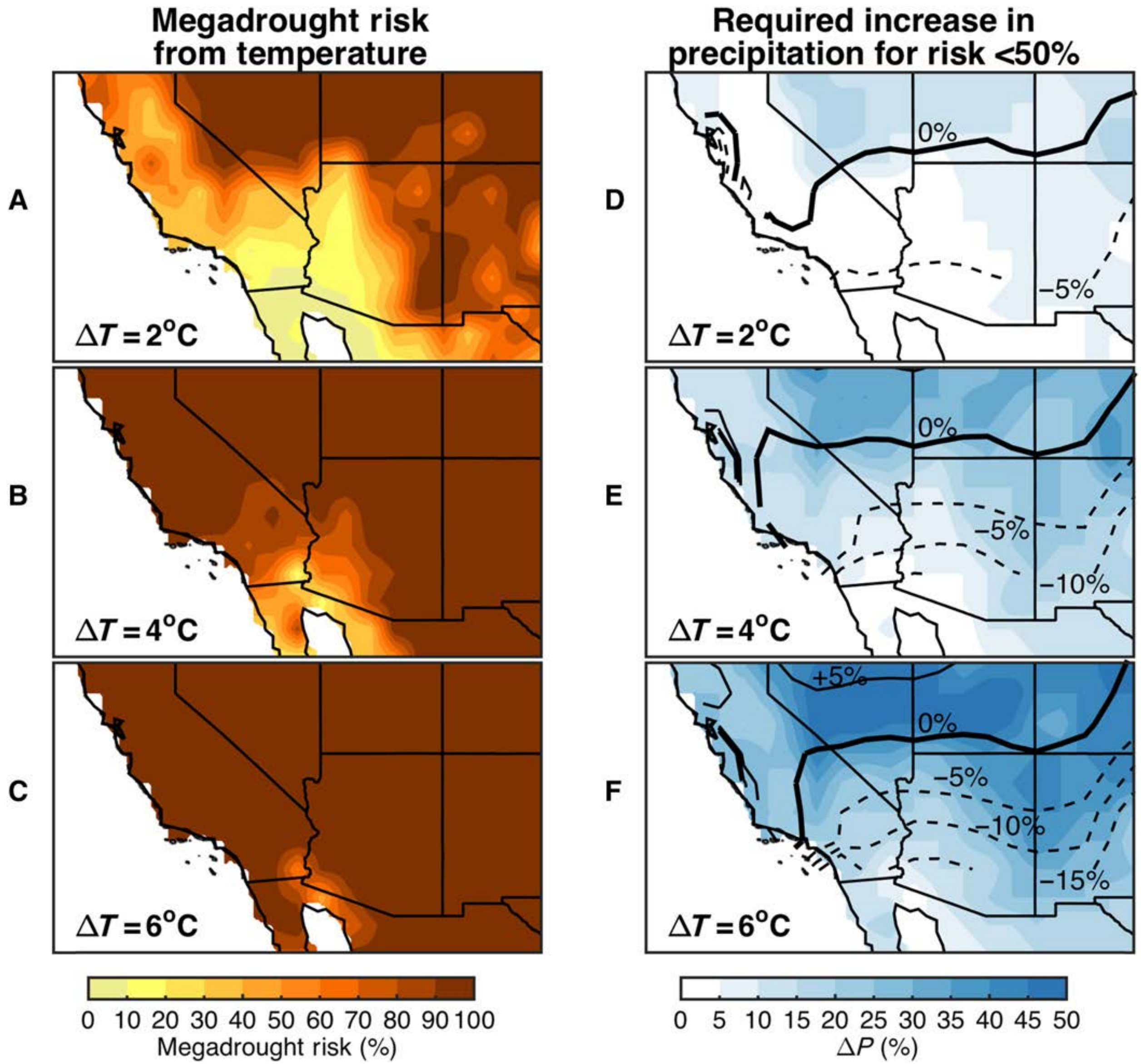


Annual tree-ring sequence reveals reduced growth of a Douglas fir in California during the late 16th-century megadrought.

From http://science.sciencemag.org/ 17 APRIL 2020 • VOL 368 ISSUE 6488

- Left Figure: Risk of Megadrought increases as temperature increases

- Right Figure: Increased precipitation that would be needed in order to reduce risk of megadrought to less than 50%.



From: Relative impacts of mitigation, temperature, and precipitation on 21st-century megadrought risk in the American Southwest
BY TOBY R. AULT, JUSTIN S. MANKIN, BENJAMIN I. COOK, JASON E. SMERDON
SCIENCE ADVANCES 05 OCT 2016 :

In his article, *Essentials of Drought,* published in this special issue of Science, author Toby Ault explains,

Climate change alters the balance of moisture throughout the world.

"If you are a water resource manager and you remember just one thing from this review, it should be this -- cutting CO_2 emissions reduces drought risk."

-Toby Ault

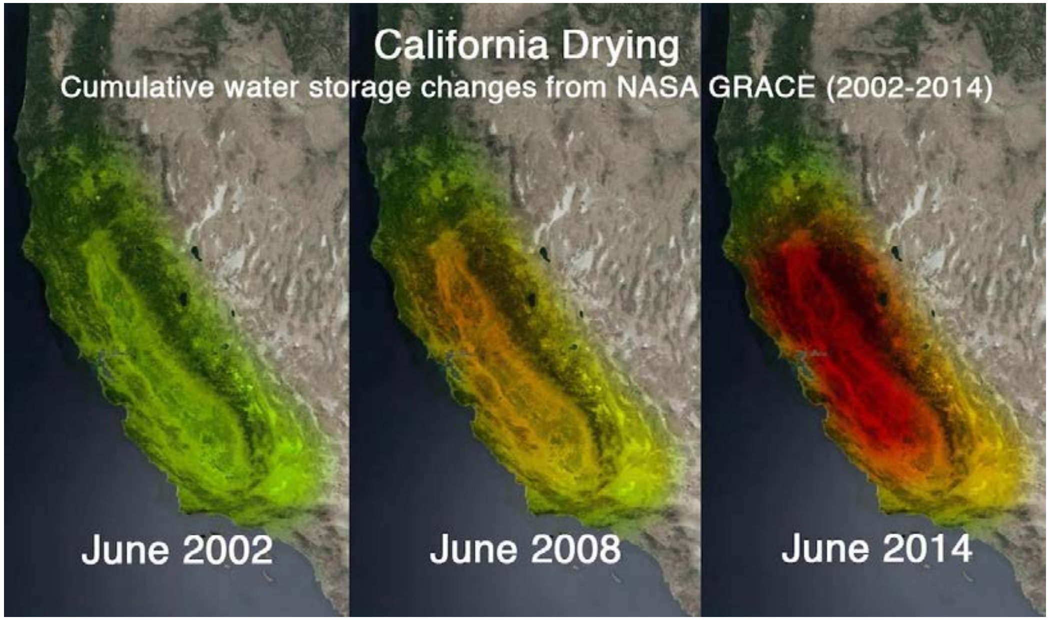
April 2020 - The American Association for the Advancement of Science (AAAS) Puts the Issue Front and Center:

Credit: Science. Vol 368, Issue 6488, 17 April 2020

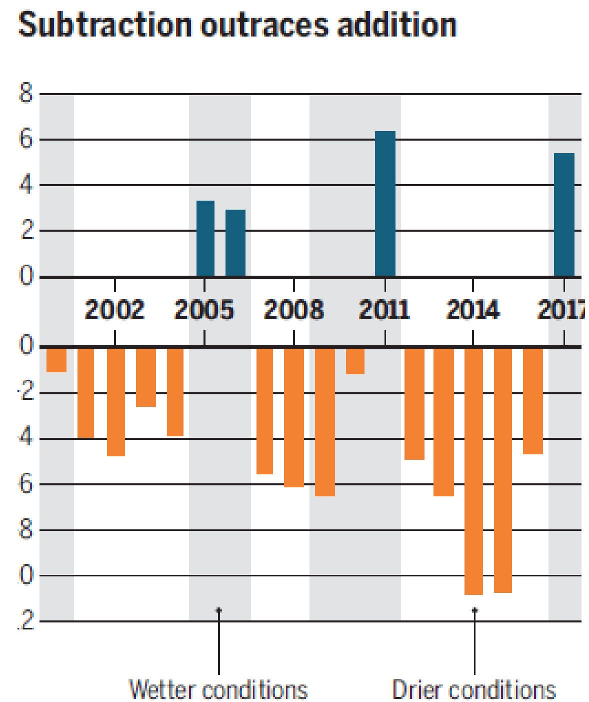
As California Water Managers,

How will we Respond?

1. Be a Steward of our Groundwater:



NASA's GRACE satellite shows California groundwater loss from space. Credit: Jay Familglietti, NASA/Cal Tech Jet Propulsion Laboratory, GRACE-FO, UC Irvine.



CREDITS: (GRAPHICS) N. DESAI/*SCIENCE*; (DATA) CALIFORNIA DEPARTMENT OF WATER RESOURCES; PPIC

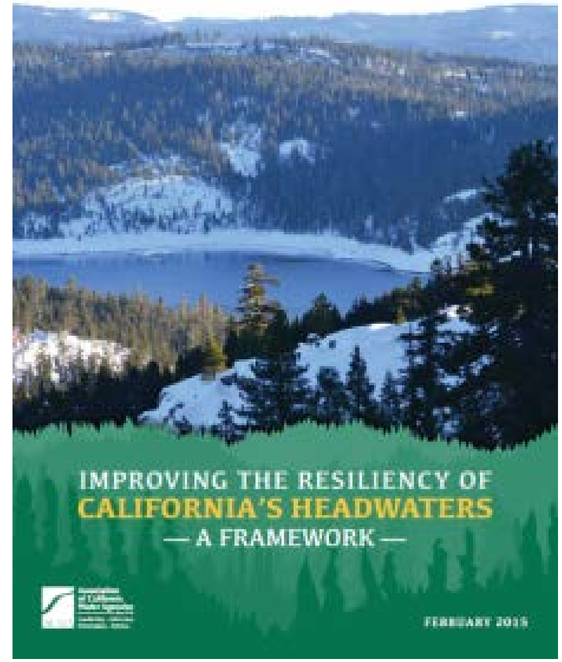
- Maintaining and restoring groundwater levels are becoming even more important as surface flow from precipitation and snow melt become less dependable with climate change.
  - Recharge is only one part of the equation and is variable due to weather patterns (in both Northern and Southern California)
  - Reduced demand (groundwater pumping) must be part of the solution.
  - Innovation and progressive whole-basin management is key.

II. Protect our Headwater Supply:

- Forests provide water to 90 per cent of the world's most populous cities

- Forests also provide other ecosystem services like flood control, hydroelectricity, fishing and recreational opportunities, and species habitat

- When rainstorms follow large and severe wildfires, they tend to flush ash, nutrients, heavy metals and toxins, and sediments into streams and rivers.



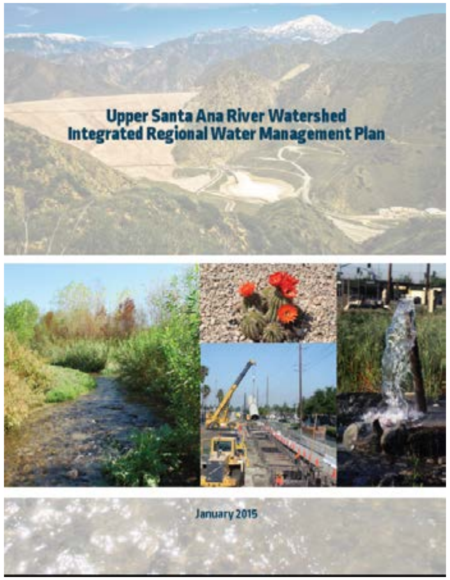
From Assoc. of California of Water Agencies. https://www.acwa.com/our-work/protecting-water-at-its-source/

Photo: USGS,/John A. Moody

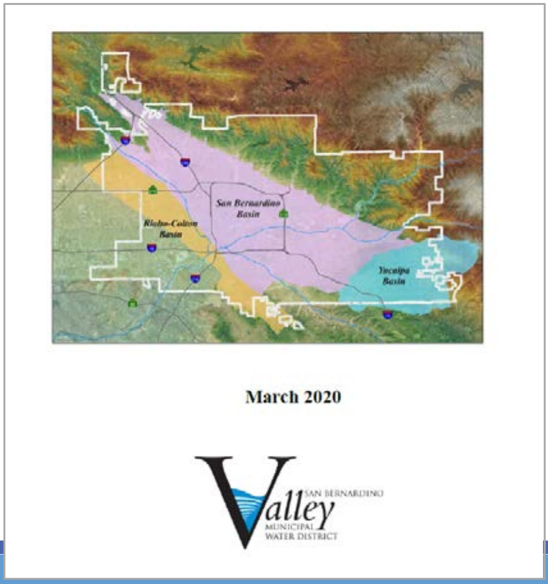
III. Invest in Science & Planning:

RAND STUDY:

- Part I: Estimated Future Demand in 2018 Study
  - Evaluated drivers of demand (population, water use, behavior etc.)
  - If temperature and population growth increase to high end of estimated range then demand could reach estimated supply
  - If WUE is not included, plausible demand could slightly exceed current supply projection with our “Reliability Factor”, in abnormal (i.e. dry) years.



- Part II: Examining Supplies incorporating Climate Change
  - Exaggerating historical droughts to increase their duration and intensity.
  - Modeling a 10-year drought, 20-year drought, and a 30-year drought.
  - Applying change factors from climate models to the drought periods to scale them up and down in terms of intensity



Statewide Strategies & Collaboration :

- Climate pressures affect all aspects of California water management:
  - warming temperatures,
  - shrinking snowpack,
  - shorter and more intense wet seasons
  - volatile precipitation
  - rising seas.
- The water grid is not prepared to handle a more volatile climate.
- Strategic investments can reduce the impacts from droughts and floods (increased storage and transmission facilities)
- Rethinking infrastructure operations can also help reduce climate change impacts.
- Reliable sources of funding are needed to make the water system climate-ready

PPIC

Water

CALIFORNIA'S FUTURE

JANUARY 2020

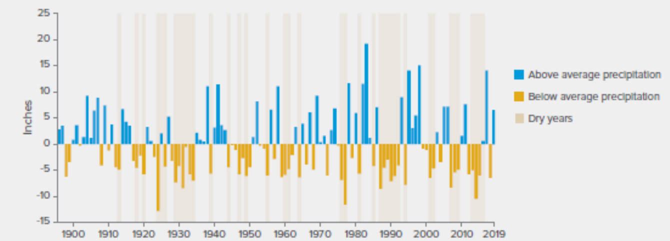
California faces growing water management challenges

Water management in California has always been challenging. The state's variable climate is marked by long droughts and severe floods, with stark regional differences in water availability and demand. California's "water grid"—the network of surface and groundwater storage and conveyance systems that connects most water use in the state—was designed to move water to population and farming centers in the Bay Area, the San Joaquin Valley, and Southern California, while also protecting residents from floods.

As the state has changed, its water challenges have intensified. The Sacramento–San Joaquin Delta is an increasingly fragile link in the water grid. California's extensive network of dams is aging. Agricultural demand is becoming less flexible, as farmers increase tree crops (especially nuts), which must be watered every year. Some poor—mostly rural—communities lack safe drinking water. Conflicts are growing between human water use and water needed for fish and other wildlife. And the latest cycle of droughts and floods highlights the growing threat of climate change.

Climate pressures are making it harder to simultaneously store water for droughts, manage flood risk, and protect freshwater ecosystems. But leaders across the state are addressing the challenges of a more volatile climate, and the Newsom administration is developing a water resilience portfolio to adapt all aspects of water management to the "new normal."

CALIFORNIA'S VARIABLE CLIMATE LEADS TO DROUGHTS AND FLOODS



SOURCE: Western Regional Climate Center.

NOTES: Bars show inches above and below the long-term California statewide average precipitation level of 23.62 inches since 1896, based on water years (October–September). Dry years are those classified as critical or dry in the Sacramento Valley. Because this classification factors in the water stored in reservoirs from the previous year, a single below-average year is often not classified as dry.

Climate extremes reveal strengths and weaknesses in California's water system

The 2012–16 drought set records for lowest river flows, smallest snowpack, and highest temperatures. Then 2017 brought near-record precipitation that stressed dams and other flood infrastructure. These extremes offer key lessons.

- **Managing demand and investing in diversified water supplies pays dividends during droughts.** During the latest drought, cities and suburbs reduced water use by nearly 25 percent. Yet the economy remained strong. This is because most urban areas—responsible for 98 percent of the state's gross domestic product—reduced less-essential uses, such as landscape watering. They also benefited from past investments in supplies.
- **Wet years create opportunities to recharge groundwater, California's main drought reserve.** During droughts, farmers rely on groundwater to make up for reduced surface water. But unsustainable pumping makes groundwater less reliable and causes sinking lands (which damage infrastructure) and reduced river flows

From PPIC 2020: Water https://www.ppic.org/wp-content/uploads/californias-future-climate-change-january-2020.pdf

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- Public Policy Institute of California. 2018. *Managing Drought in a Changing Climate. Four Essential Reforms.*
- RAND Corporation. 2018. *Estimating Future Water Demand for San Bernardino Valley Municipal Water District.*
- Stahl, D.W. 2020. *Anthropogenic Megadrought.* Science:368(6488), 238-239.
- Stokstad, E. 2020. *Deep Deficit.* Science:368(6488), 230-233.

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