

Northern California's Challenging Climate Future

Warmer, Wetter, and Drier

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Sponsors:

California Energy Commission (CEC)

California Department of Water Resources

NOAA via CNAP RISA

USGS/DOI via SW Climate Science Adaptation Ctr

U.S. Dept of Energy, Dept of Defense

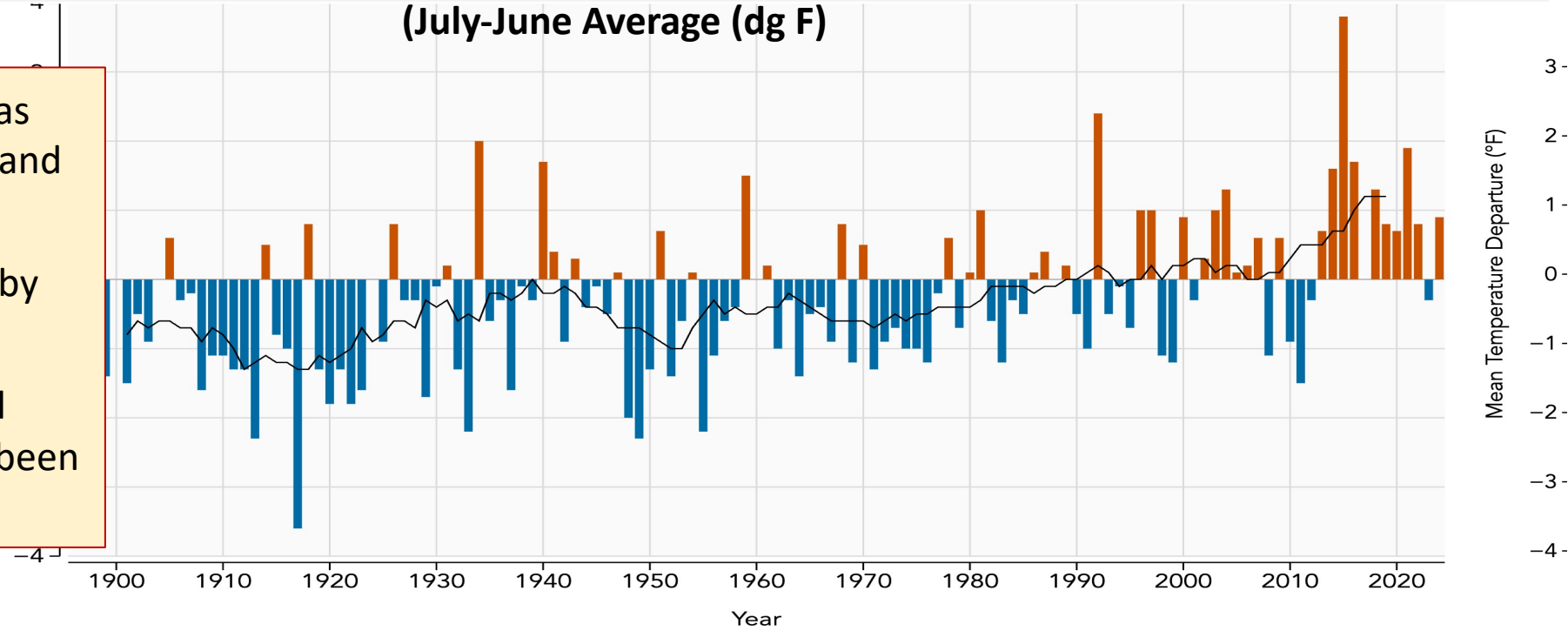
California North Coast NCEI Climate Division Temperature

(July-June Average (dg F))

California North Coast region has warmed along with western U.S. and the entire global surface,

Warming very likely reinforced by anthropogenic causes.

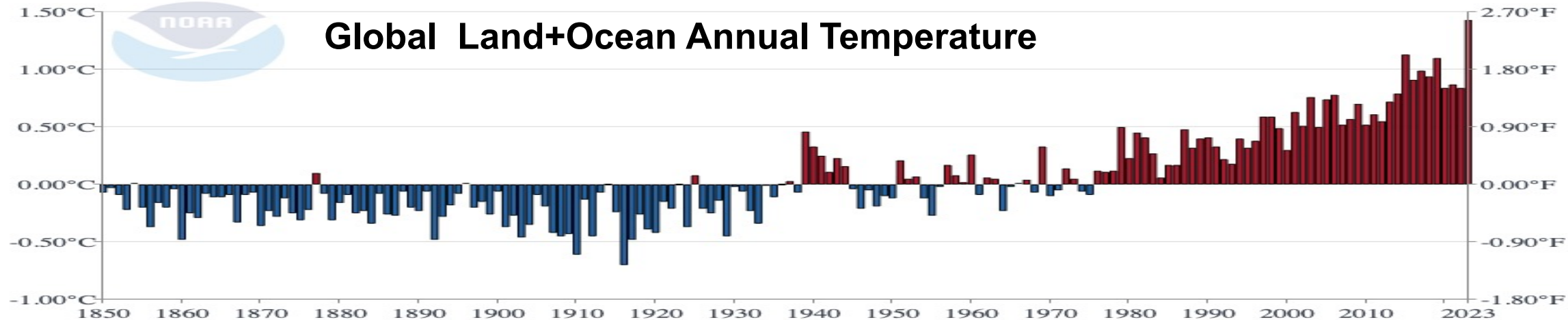
Warming has been substantial beginning ~1980. Since 2012 has been persistently warm.=



Global Land and Ocean
December Temperature Anomalies



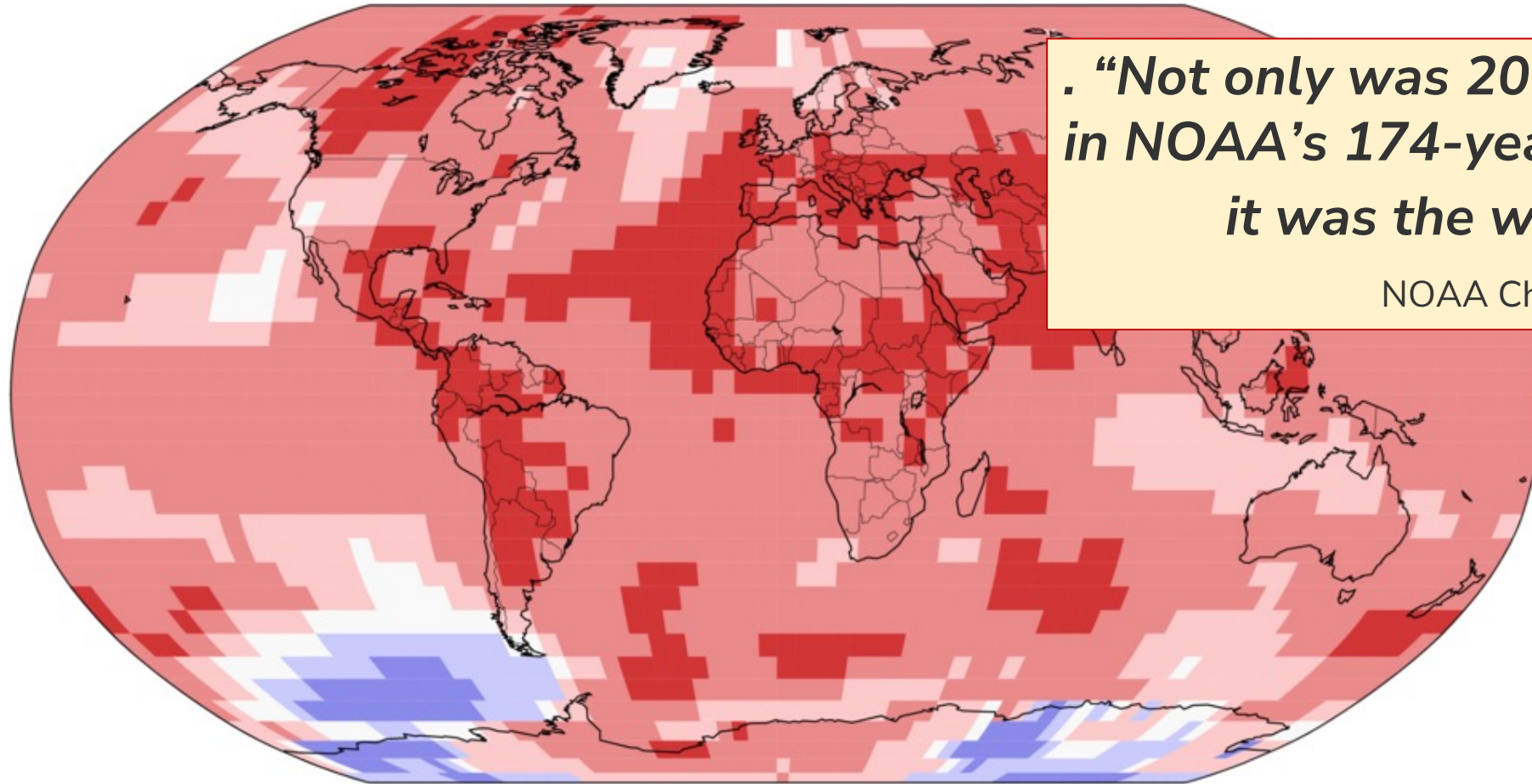
Global Land+Ocean Annual Temperature



Land & Ocean Temperature Percentiles Jan–Dec 2023

NOAA's National Centers for Environmental Information

Data Source: NOAA GlobalTemp v5.1.0–20240108




“Not only was 2023 the warmest year in NOAA’s 174-year climate record — it was the warmest by far.”


NOAA Chief Scientist Dr. Sarah Kapnick




Record
Coldest


Much
Cooler than
Average


Cooler than
Average


Near
Average


Warmer than
Average


Much
Warmer than
Average


Record
Warmest

Napa Growing Season has advanced by 4 weeks since 1950's

Napa Growing Season (GDD Cutoff: Degree Days ≥ 1400 °C)

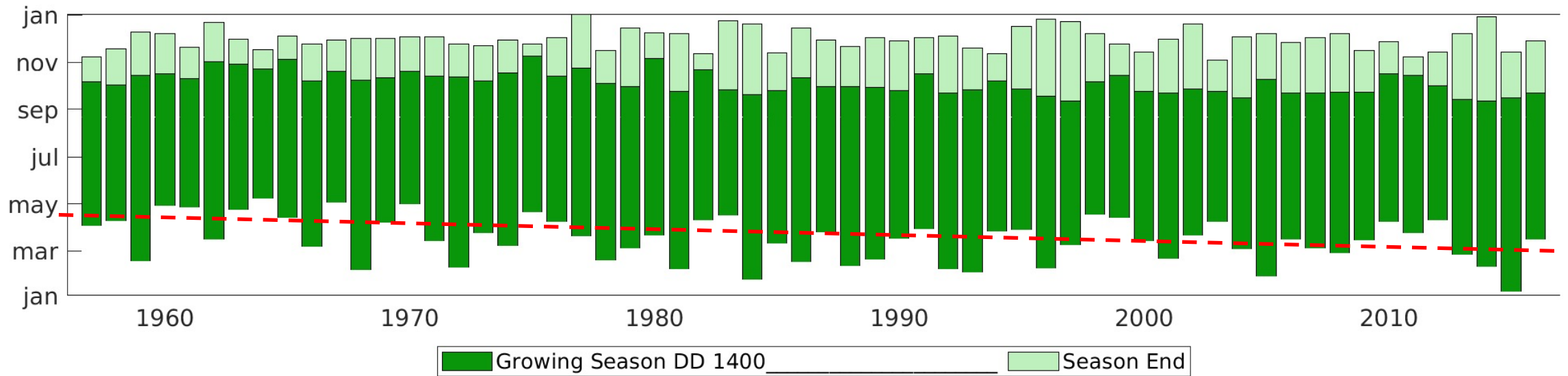
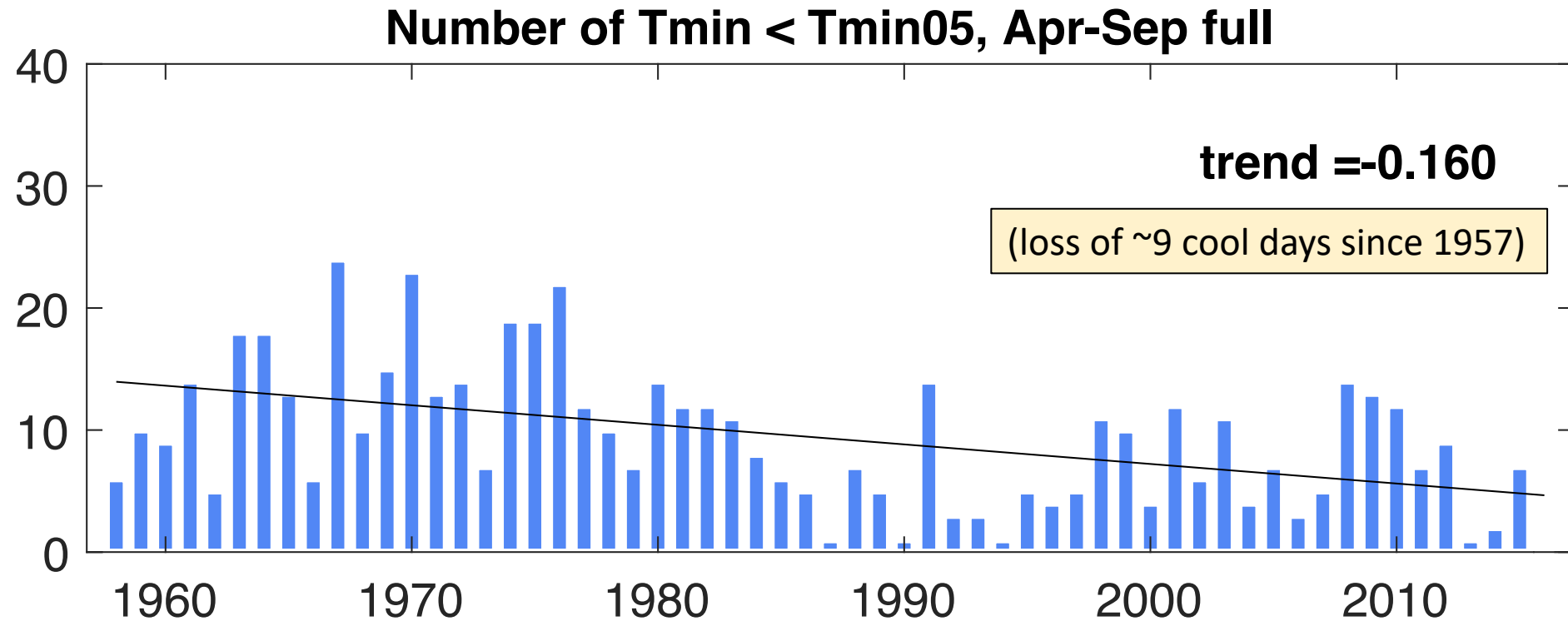


Figure 2. Each years growing season start through day when growing season reaches 1400 growing degree days (dark green) and ensuing period until growing season ends (light green). From Napa 1958-2016 USHCN data.

There is more variation in the beginning of the growing season than the end of the growing season

Decreasing cool extremes April- September

5th percentile daily Tmin half as many 2000's as in 1950's-60's

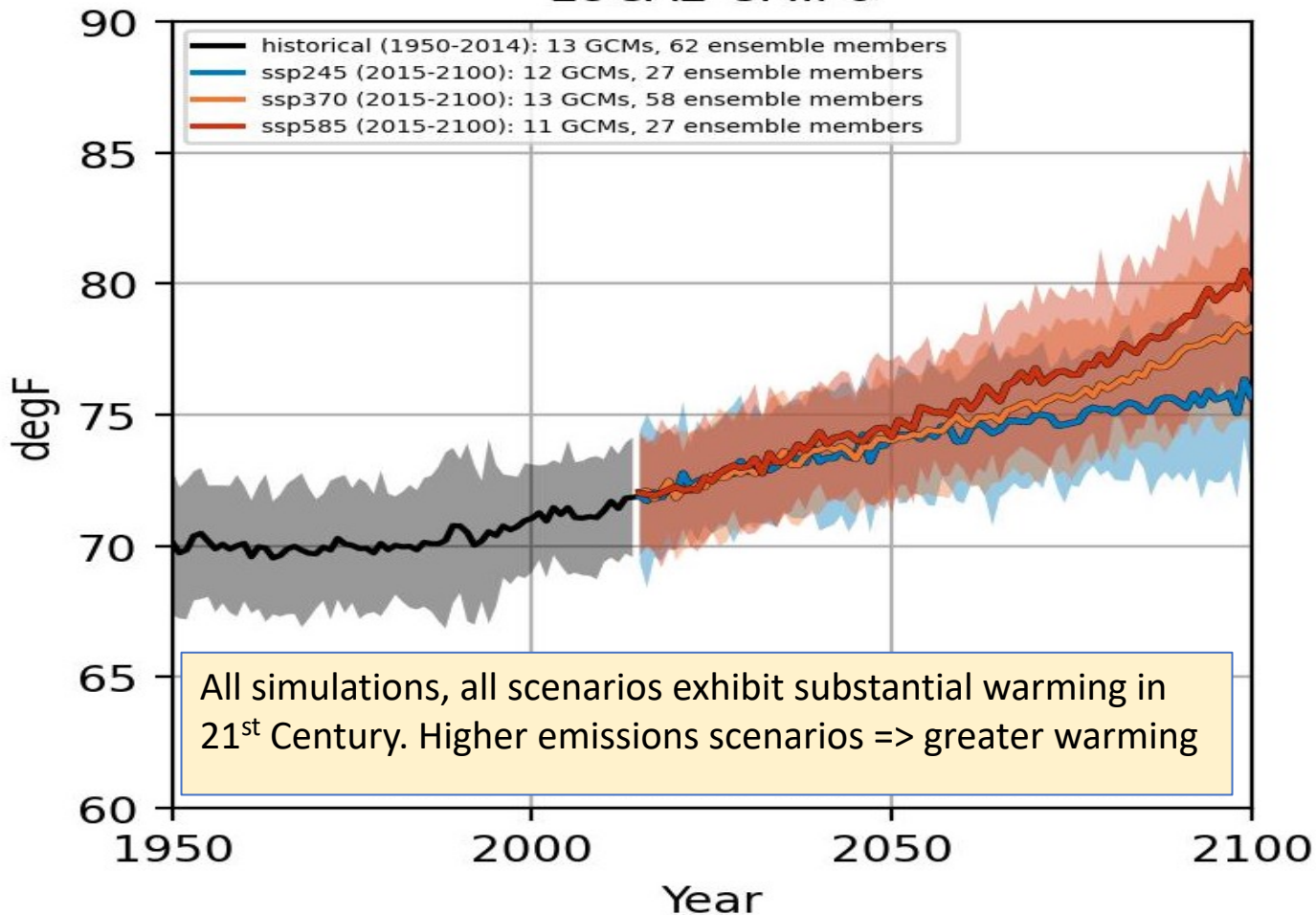


Additional warming predicted +2°F by 2045

Russian and Napa Watersheds Projected Annual Tmax downscaled CMIP6 Global Climate Models

LOCA CA Annual Average Maximum Daily Temperature
Russian River and Napa River Watersheds

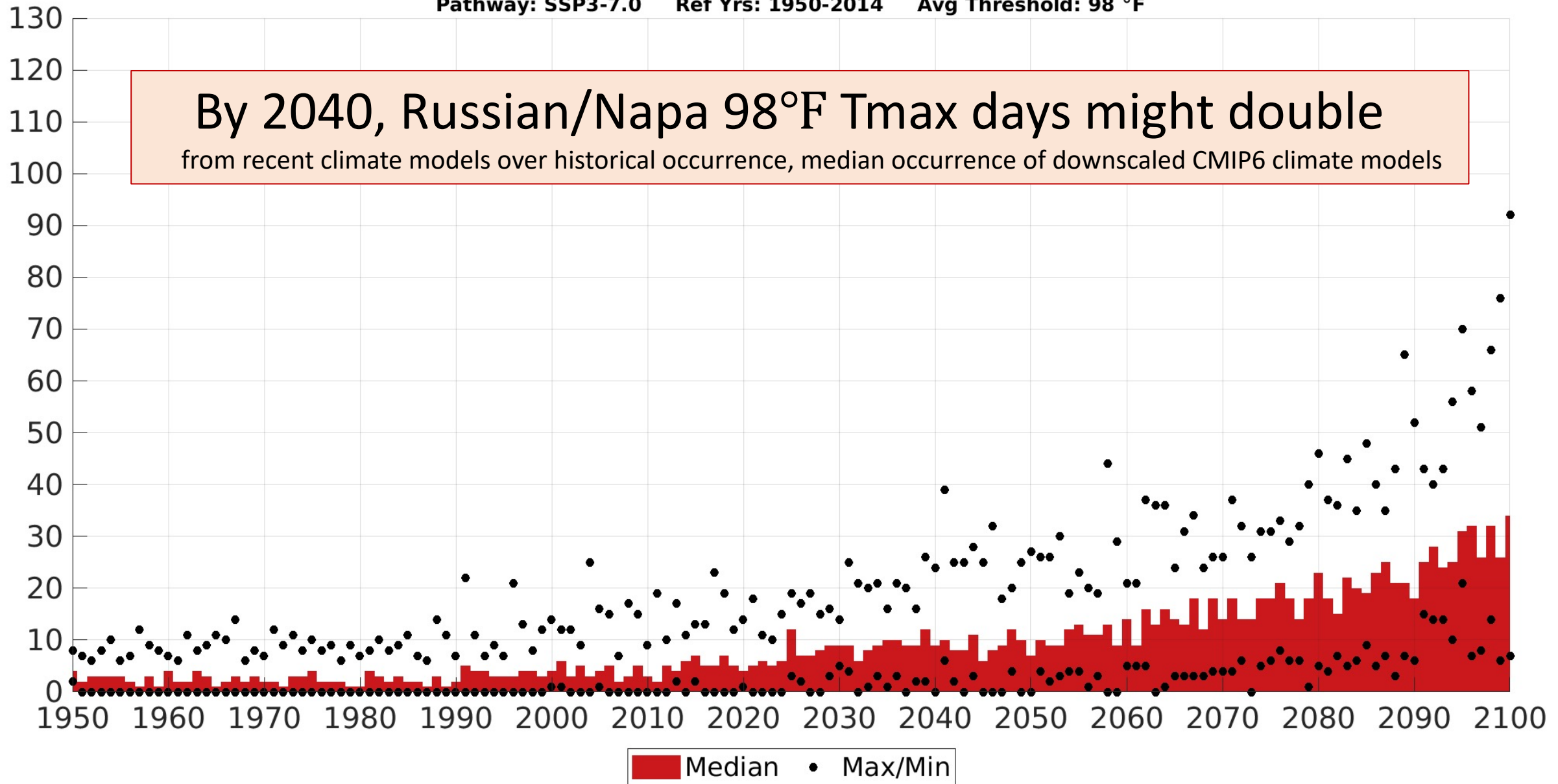
LOCA2 CMIP6



Russian + Napa Watersheds

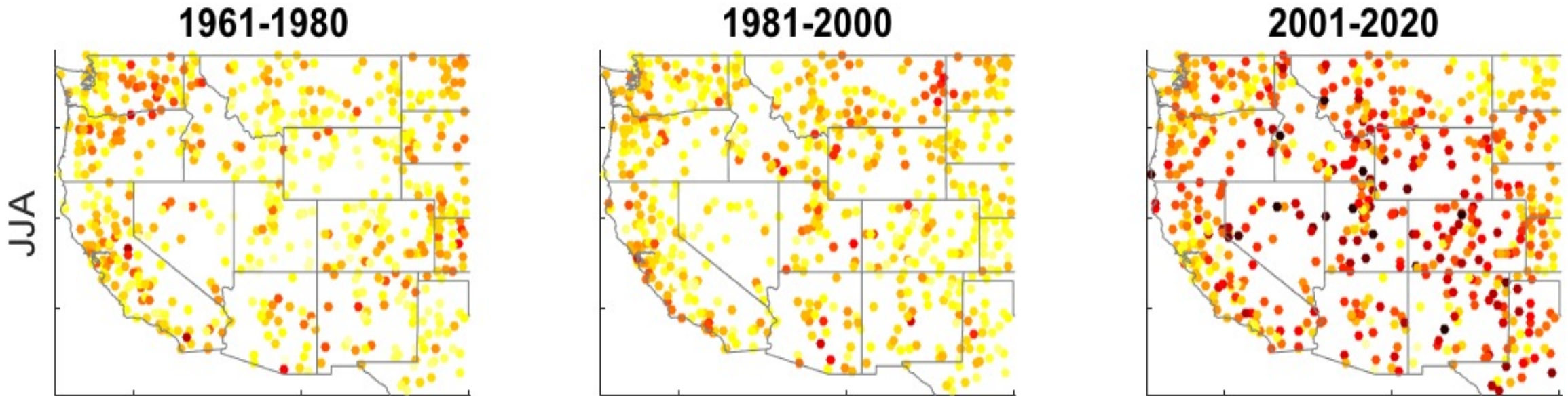


Russian-Napa: T_{\max} Extremes Exceeding 99th Percentile Within Each Model
models: ACCESS-CM2, CESM2-LENS, CNRM-ESM2-1, EC-Earth3, FGOALS-g3, GFDL-ESM4, INM-CM5-0, IPSL-CM6A-LR
KACE-1-0-G, MIROC6, MPI-ESM1-2-HR, MRI-ESM2-0, TaiESM1
Pathway: SSP3-7.0 Ref Yrs: 1950-2014 Avg Threshold: 98 °F



Increasing Hot Spells last 6 decades

daily Tmax >95th percentile June-August



Fraction (%) of Tmax 95 percentile extremes in each 20 yr period

Santa Rosa sets new heat record, at 115 degrees, as Sonoma County sizzles in extreme heat wave

[MARTIN ESPINOZA](#) THE PRESS DEMOCRAT, September 6, 2022

Santa Rosa hit its hottest-ever recorded temperature Tuesday as a blistering, weeklong heat wave sent people scrambling for indoor cover and overtaxed the state's power grid, again raising the specter of a more dangerous climate era five years after a historic firestorm in the region did much the same.

The official temperature in Santa Rosa reached 115 degrees in downtown, breaking the previous record of 113 set July 11, 1913, according to the National Weather Service.

Tuesday's record also set a new threshold for the hottest daily temperature and the hottest September day, re-topping more than a century of local heat marks.

California has exceptional Highly Variable Annual Precipitation

Coefficient of Variation of Annual Precipitation from COOP records, WY 1951-2008

COEFFICIENTS OF VARIATION OF
TOTAL PRECIPITATION, WY 1951-2008



Western U.S. has high
year-to-year variability
especially in the Southwest

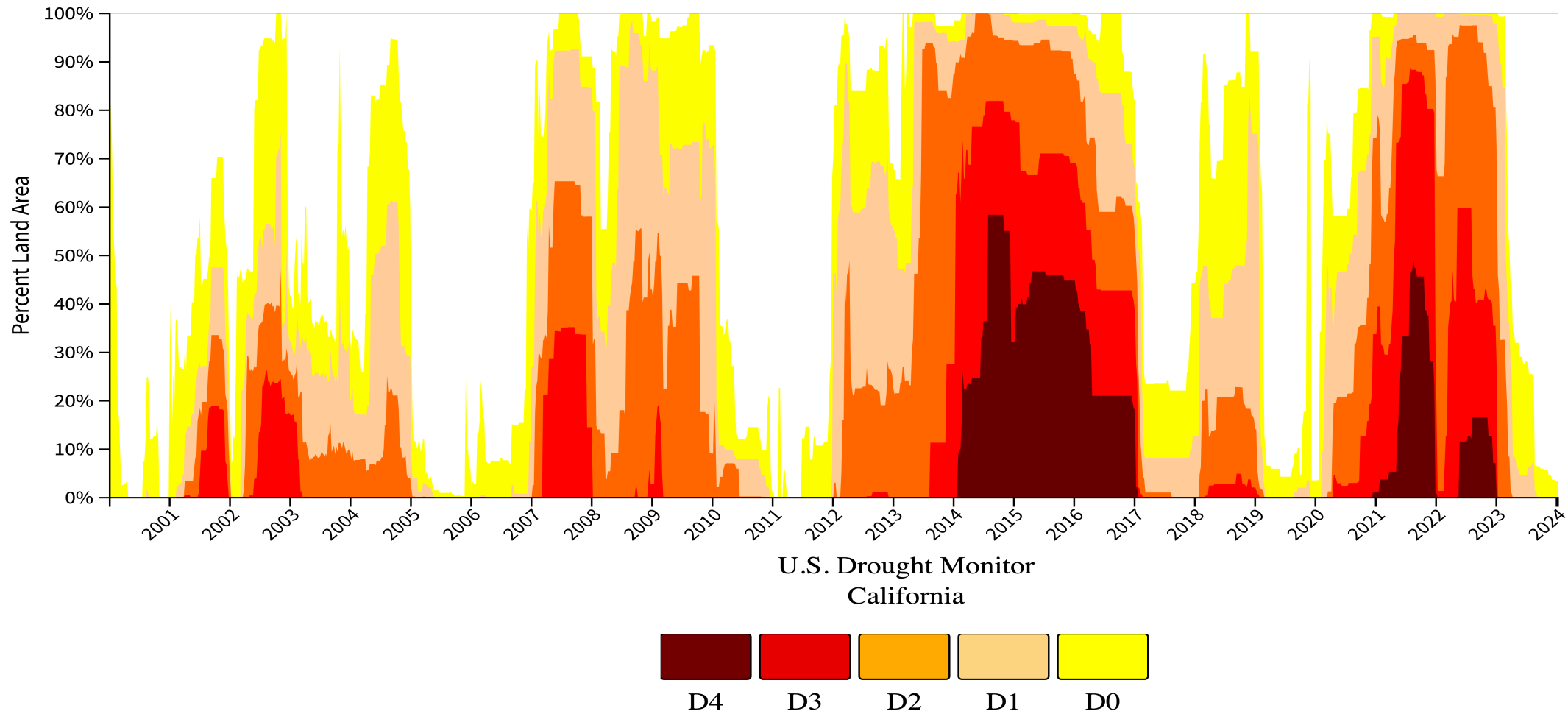
fraction



Drought occurs frequently in California

California Statewide Drought Intensity 1979-2019

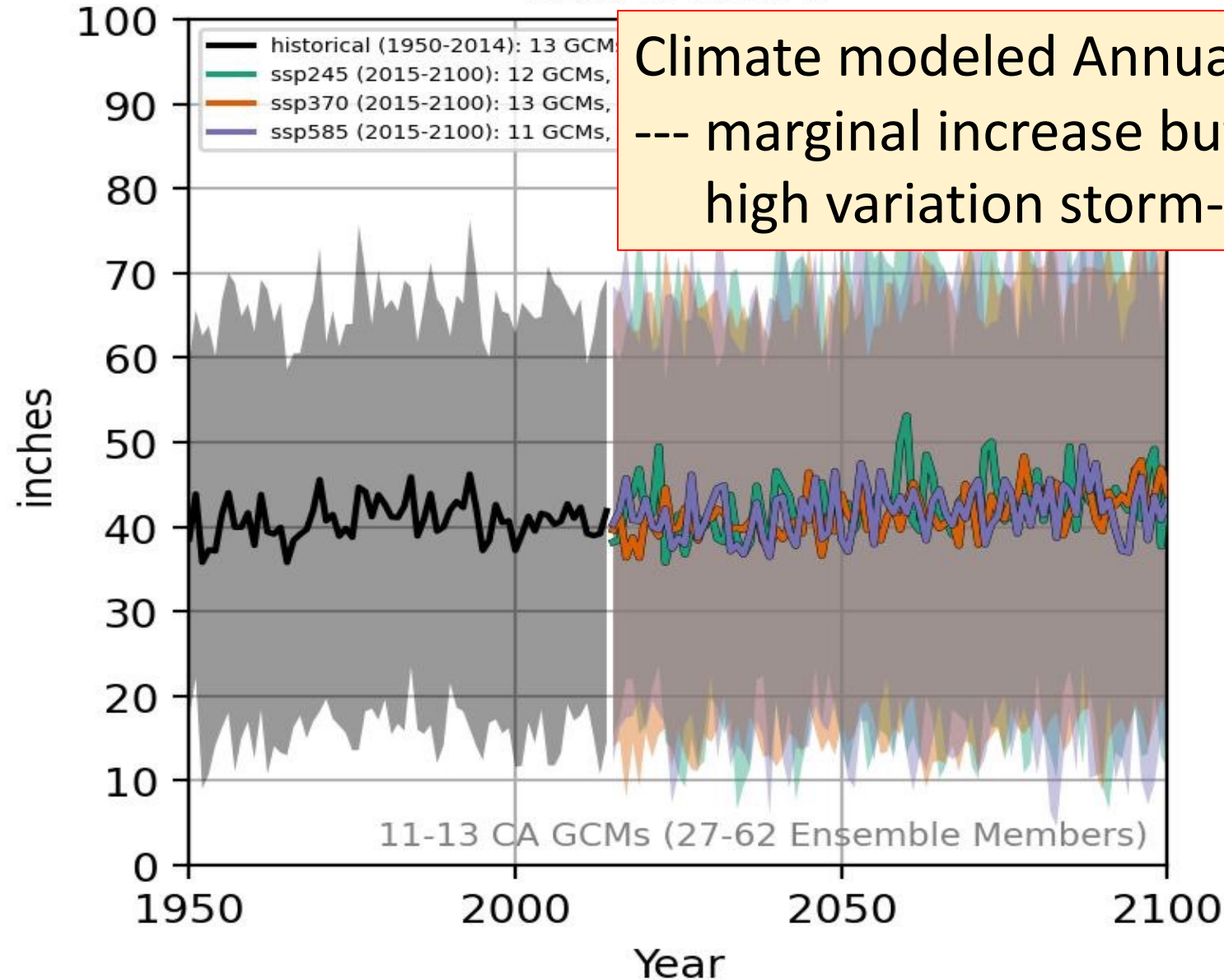
US Drought Monitor <https://www.drought.gov/states/california>



Recent dry spells have been unusually warm!

LOCA CA Annual Average Precipitation Russian River and Napa River Watersheds

LOCA2 CMIP6

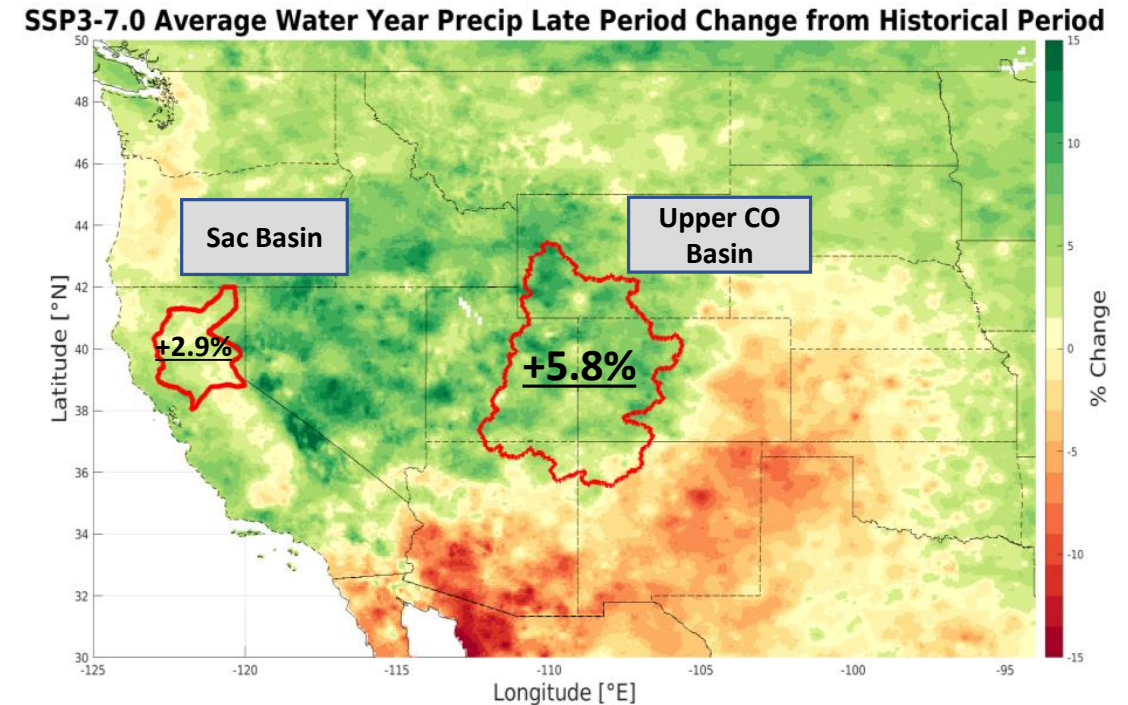
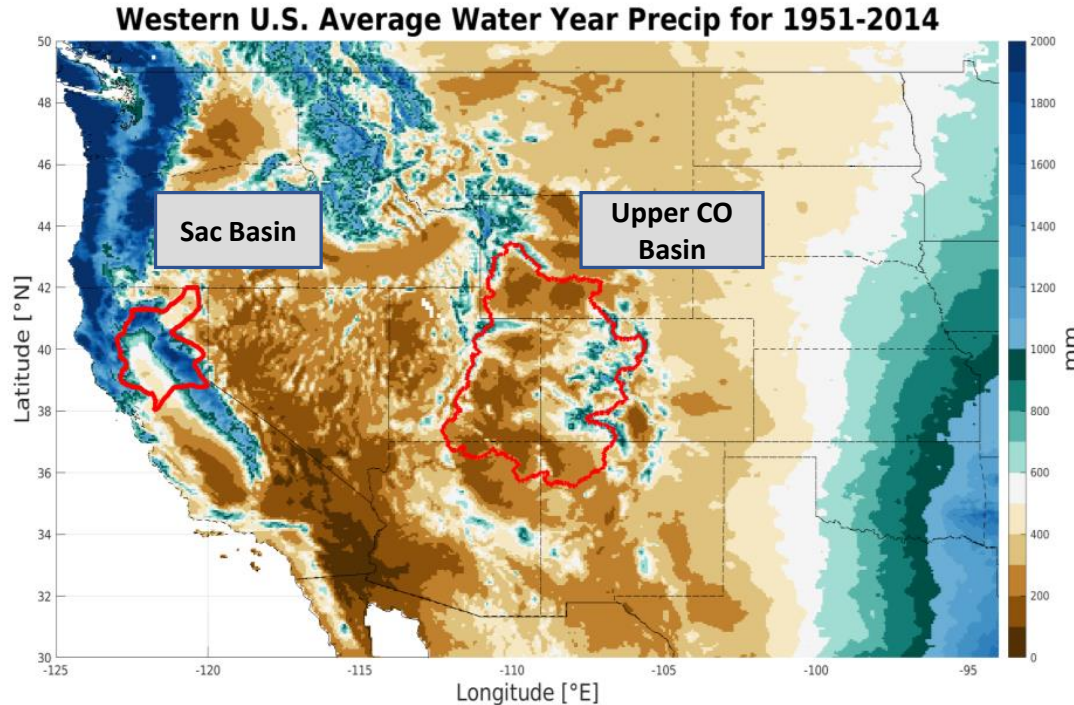


Climate modeled Annual Precipitation Russian / Napa
--- marginal increase but uncertain
high variation storm-multiyear scales



Slightly Wetter late -21st Century?

CMIP6 Precipitation 10-member CMIP6 SSP-3.70 single ensemble Subset



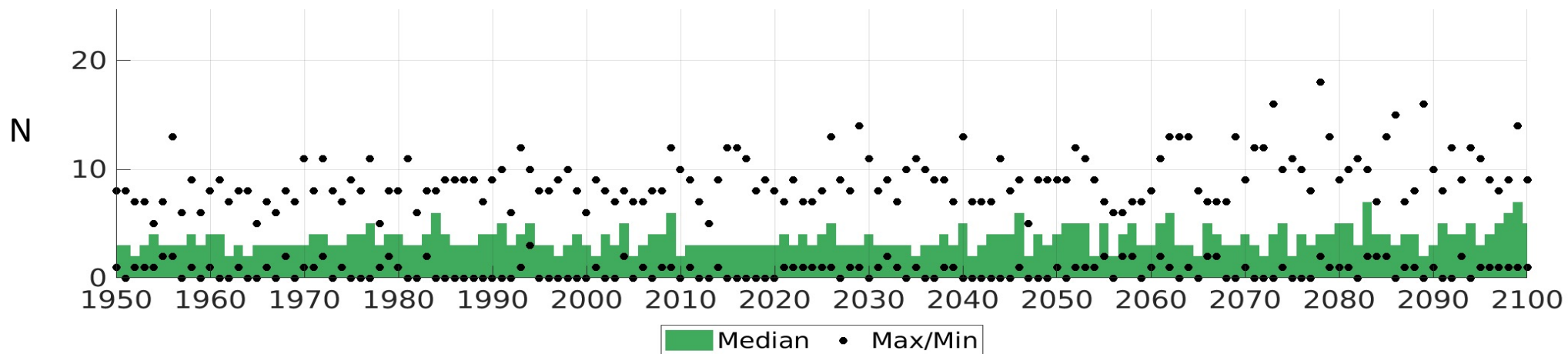
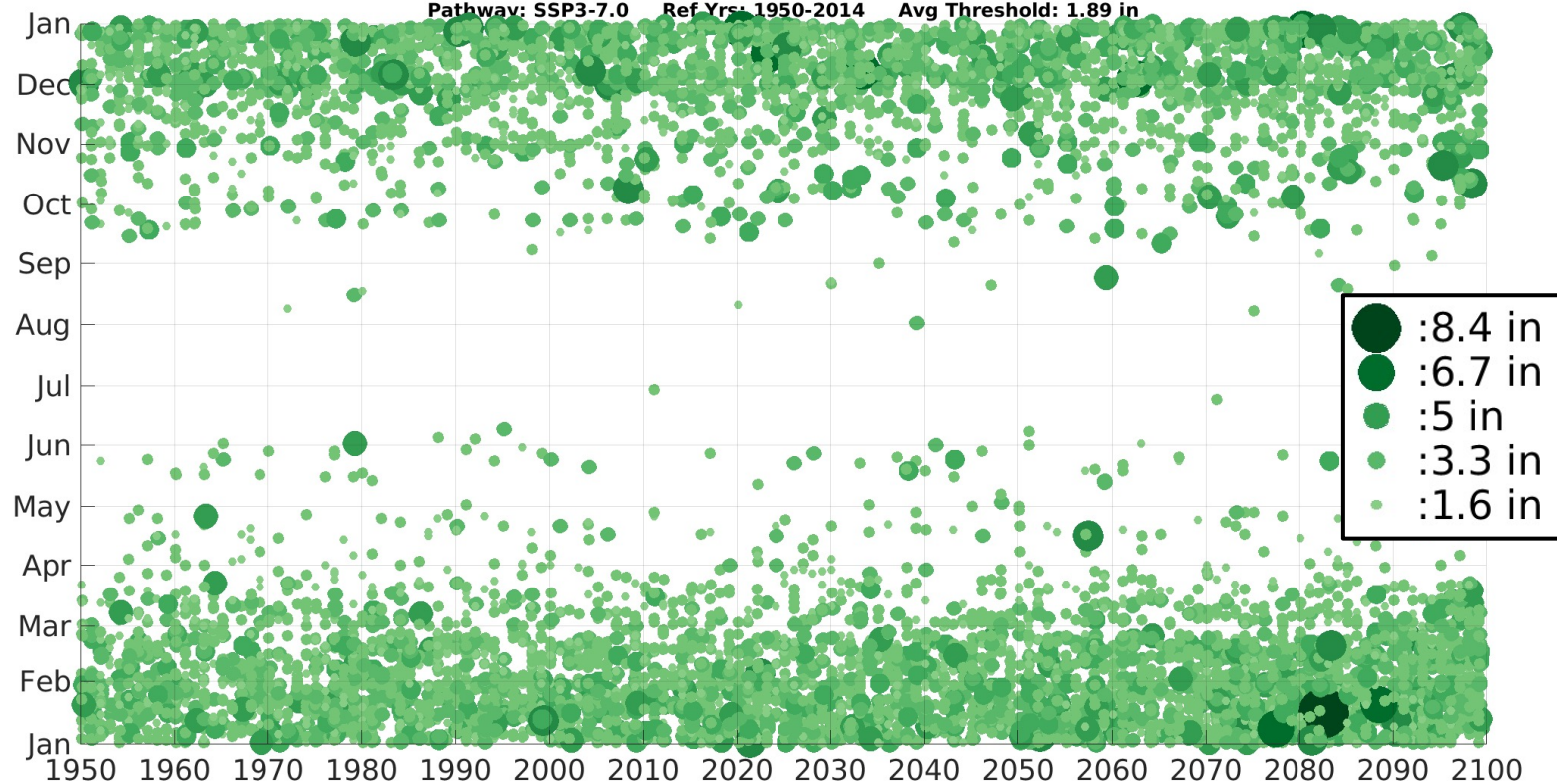
10 CMIP6 GCMs

ACCESS-CM2, ACCESS-ESM1-5, CNRM-ESM2-1 (1 EM), EC-Earth3, EC-Earth3-Veg, FGOALS-g3, IPSL-CM6A-LR, MIROC6, MPI-ESM1-2-HR, MPI-ESM1-2-LR

**Heavy precipitation days (99th percentile)
rise incrementally in frequency and intensity**

Russian / Napa watershed avg
98th percentile
daily precip = 1.86"
from 12 CMIP6 GCMs

Russian-Napa: T_{max} Extremes Exceeding 99th Percentile Within Each Model
models: ACCESS-CM2, CESM2-LENS, CNRM-ESM2-1, EC-Earth3, FGOALS-g3, GFDL-ESM4, INM-CM5-0, IPSL-CM6A-LR
KACE-1-0-G, MIROC6, MPI-ESM1-2-HR, MRI-ESM2-0, TaiESM1
Pathway: SSP3-7.0 Ref Yrs: 1950-2014 Avg Threshold: 1.89 in



California Spring Snow Pack will diminish markedly as climate warms

Strong model consensus:
California is confronted with substantial loss of spring snowpack as climate warms

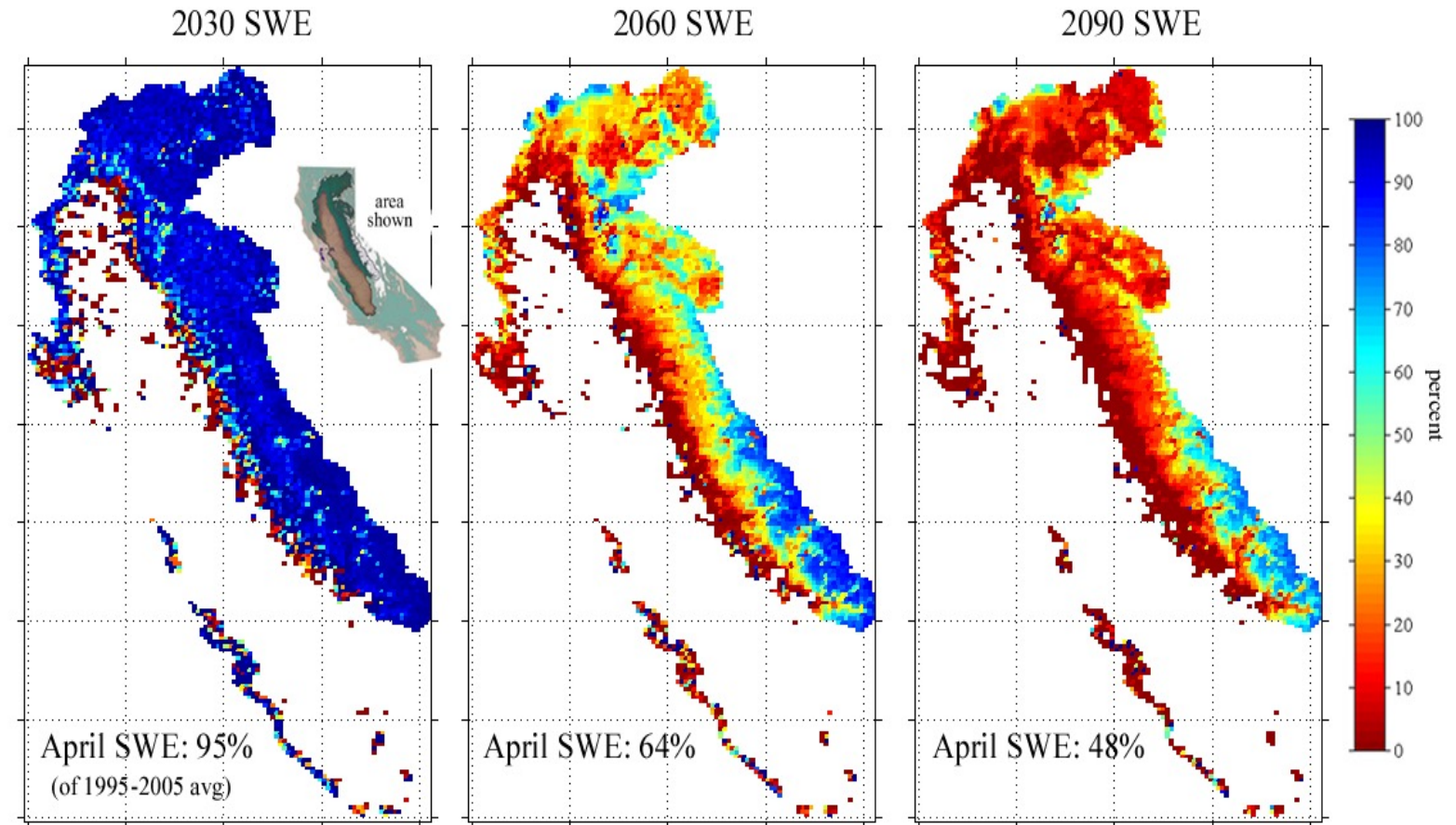
Less snow, more rain

Low and middle elevations
vulnerable to greatest snow loss

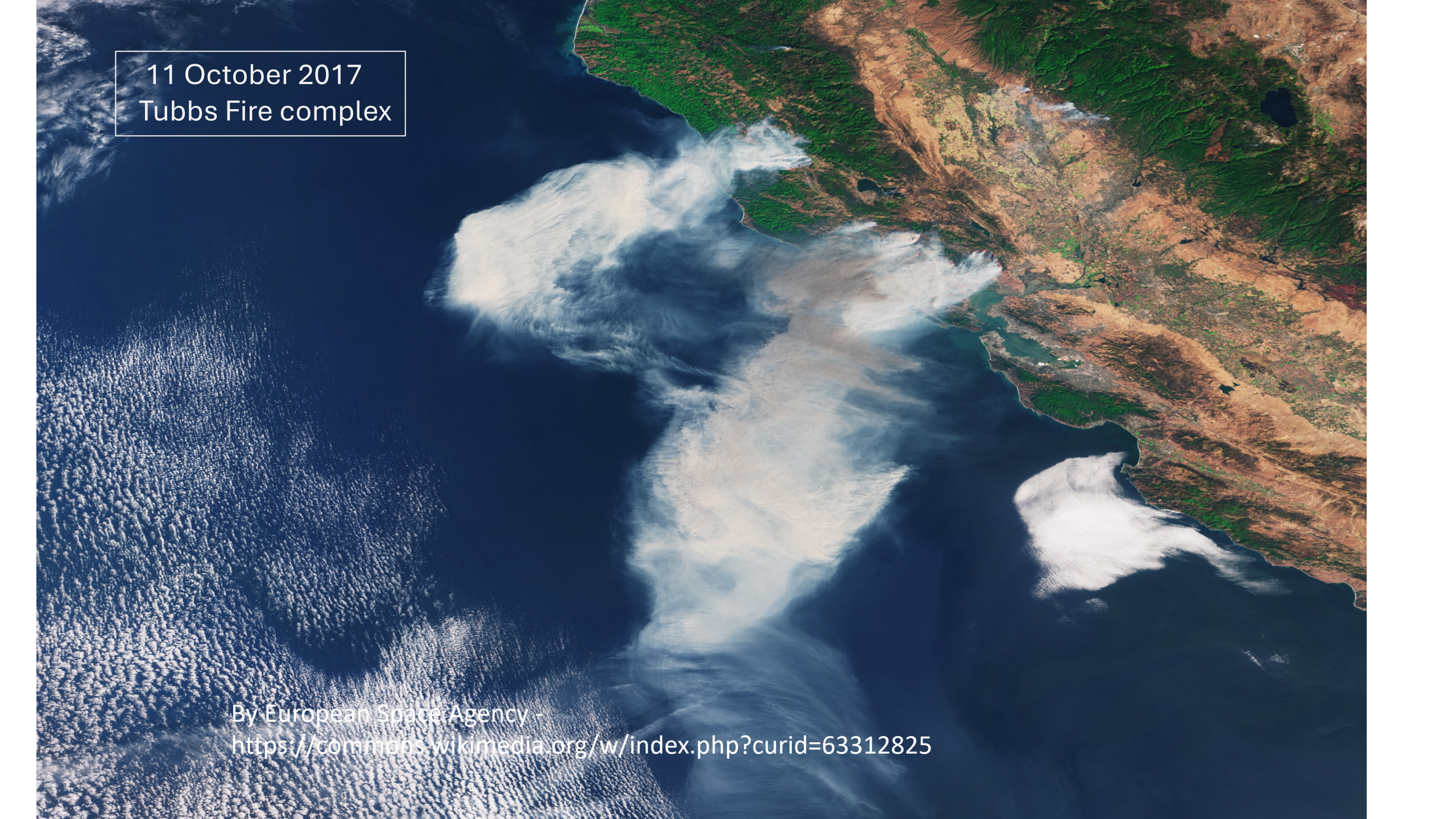
Earlier run-off

Higher floods

Potentially, less stored water



By the end of the century California could lose more than half of its spring snow pack due to climate warming. This simulation by Noah Knowles and Dan Cayan is guided by relatively moderate warming scenario, approximately $+2.1^{\circ}\text{C}$ by 2090 from PCM's Business-as-usual climate simulation. (a middle of the road greenhouse gas emissions scenario)

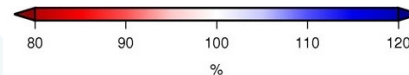
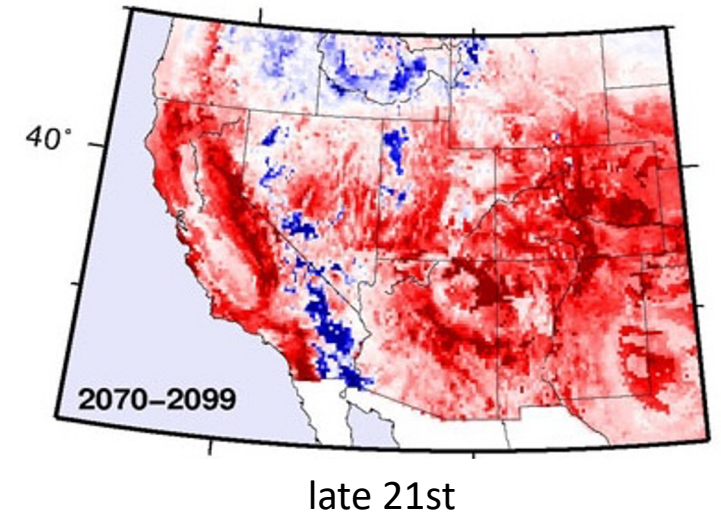
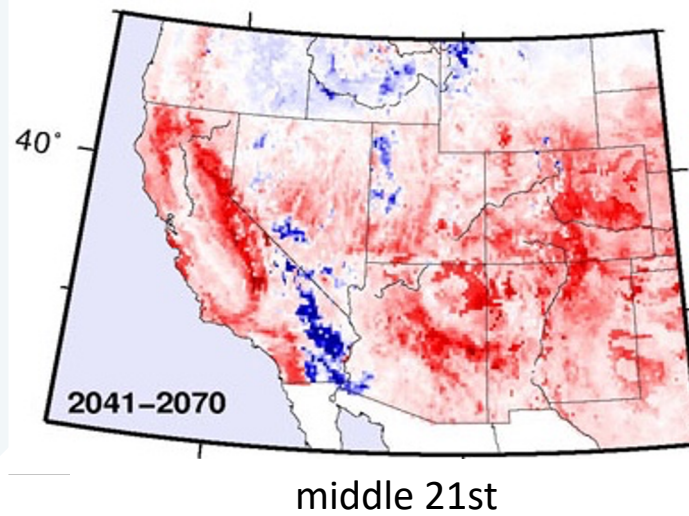
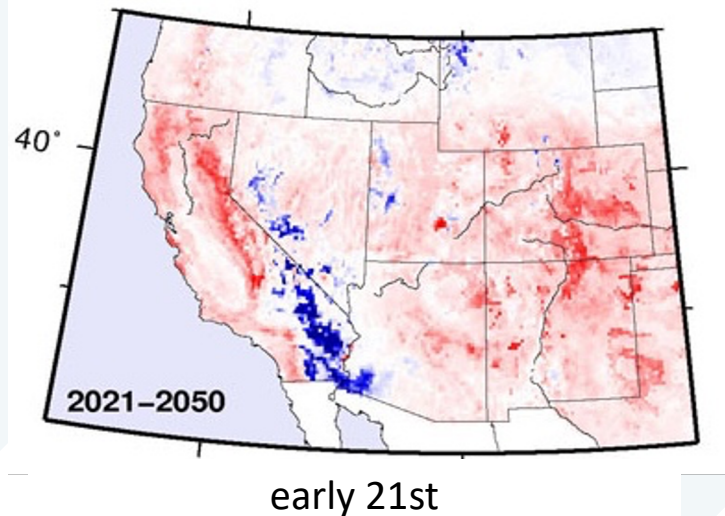
A satellite image showing a large fire complex over a coastal region. The fire is visible as a bright, irregular white and yellow area on the land, with thick plumes of white smoke rising and drifting over the ocean. The land is a mix of green vegetation and brown, arid terrain. The ocean is a deep blue with visible wave patterns.

11 October 2017
Tubbs Fire complex

By European Space Agency -
<https://commons.wikimedia.org/w/index.php?curid=63312825>

DRIER SUMMER LANDSCAPES

Increased warming and diminished snow causes successively greater summer soil drying during 21st Century
(this picture could change somewhat under more recent CMIP5 simulations)

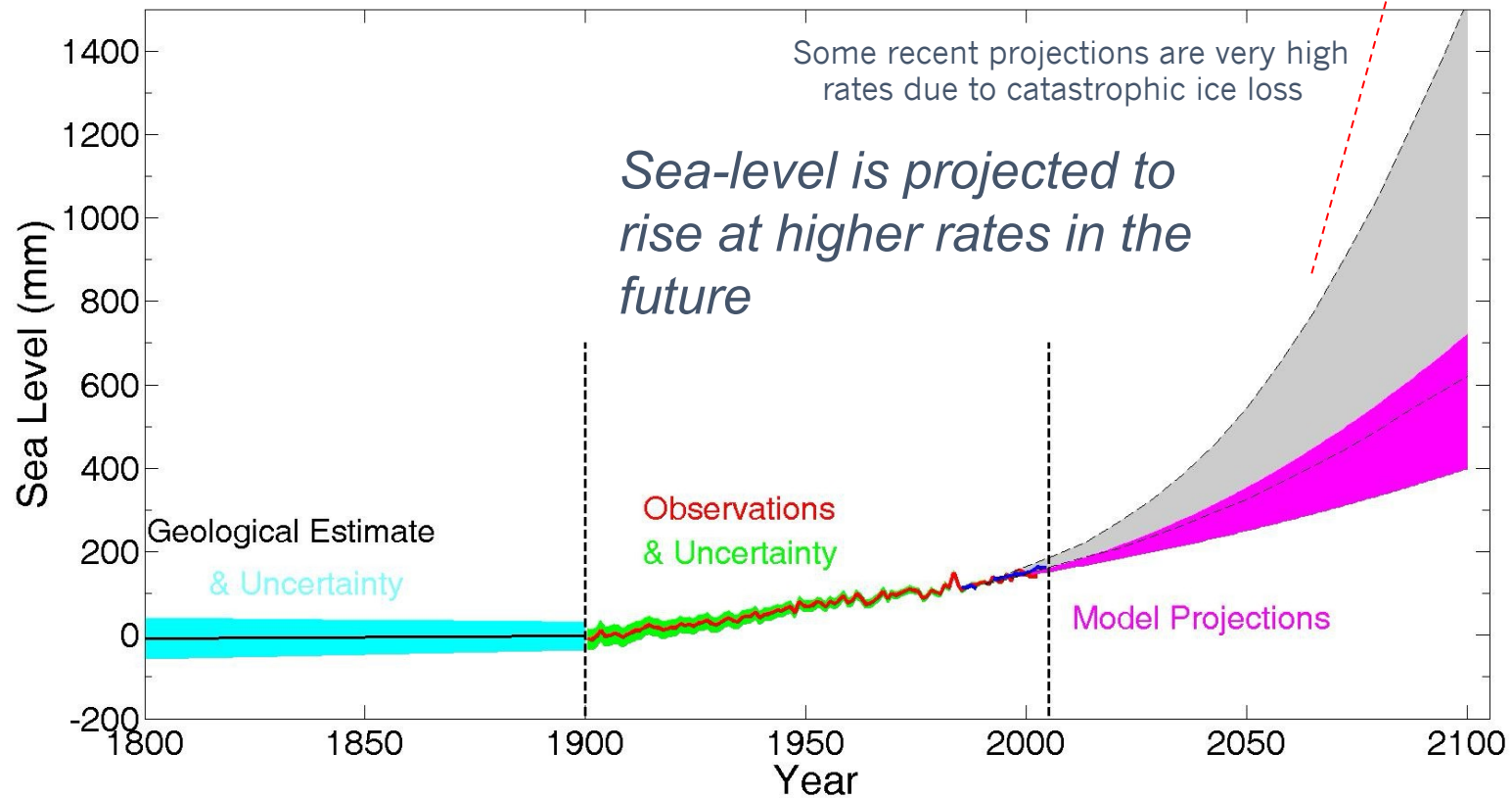


Median June 1 soil moisture
percent of historical (1971-2000) BCSD 16 SRESA2

Global sea-level is rising primarily because land ice is melting and ocean water expands as it warms.

1.7 mm per year over 20th century (from tide gages)

3.1 mm per year since 1993 (from satellites & tide gages)



Summary

Warming to continue due to anthropogenic change

warming during last 60 years about $.3^{\circ}\text{C}$ / decade

+2°F additional warming predicted by 2050

Warming has shifted Napa growing season earlier 1958-2016 *temperature reckoned (not grapes)*

Daytime and nighttime warming

Extreme Warm days increase in frequency, intensity and duration

Extreme Cool days declined

Precipitation may increase marginally, but in sporadic fashion as characteristic of California

high volatility continues

drought can occur

heaviest storm amounts may increase

Summer and early Autumn drying intensifies

wildfire risk still present

diablo winds ??

Observations are vital to track and understand climate variation and changes—

long continuous records vital; e.g. sustain Napa State Hospital and Oakville CIMIS but broader network very useful

grape phenology, wine quality records greatly important

Lower degree of warming is predicted for coast than inland

will valley climate in Sonoma Napa more closely track coastal temperature regime or inland? Influence of marine layer?

Sea Level will Rise substantially

Further Information

California Fourth Climate Change Assessment

<http://www.climateassessment.ca.gov/>

Fourth National Climate Change Assessment

<https://nca2018.globalchange.gov/>

Water Utilities Climate Alliance

<https://www.wucaonline.org/>

RISAs <http://cnap.ucsd.edu> Climate Adaptation and Science Centers . <https://www.swcasc.arizona.edu/>

CalAdapt <https://cal-adapt.org/>

Napa Warming ayan, D.R., DeHaan, Tyree, & Nicholas, (2023). A 4-week advance in the growing season in Napa Valley, California, USA. *International Journal of Climatology*, 43, 5586 - 5603.

Heat Waves Gershunov, A, Guirguis K. 2012. California heat waves present & future. *Geophys Res Letters*. 39 [10.1029/2012gl052979](https://doi.org/10.1029/2012gl052979)

Atmospheric Rivers: Ralph, FM, Dettinger MD. 2012. ...perspectives on extreme West Coast precipitation associated with Atmospheric rivers. *Bulletin of the Amer Met Society*. 93:783-790. [10.1175/bams-d-11-00188.1](https://doi.org/10.1175/bams-d-11-00188.1)

Rising Seas in California an update on sea level rise science

<http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf>