75 YEARS

Sonoma Water

SERVING THE COMMUNITY SINCE 1949

In partnership with ESA

Future Rainfall Database

James Gregory, Environmental Science Associates

Sasha Ponomareva, Sonoma Water

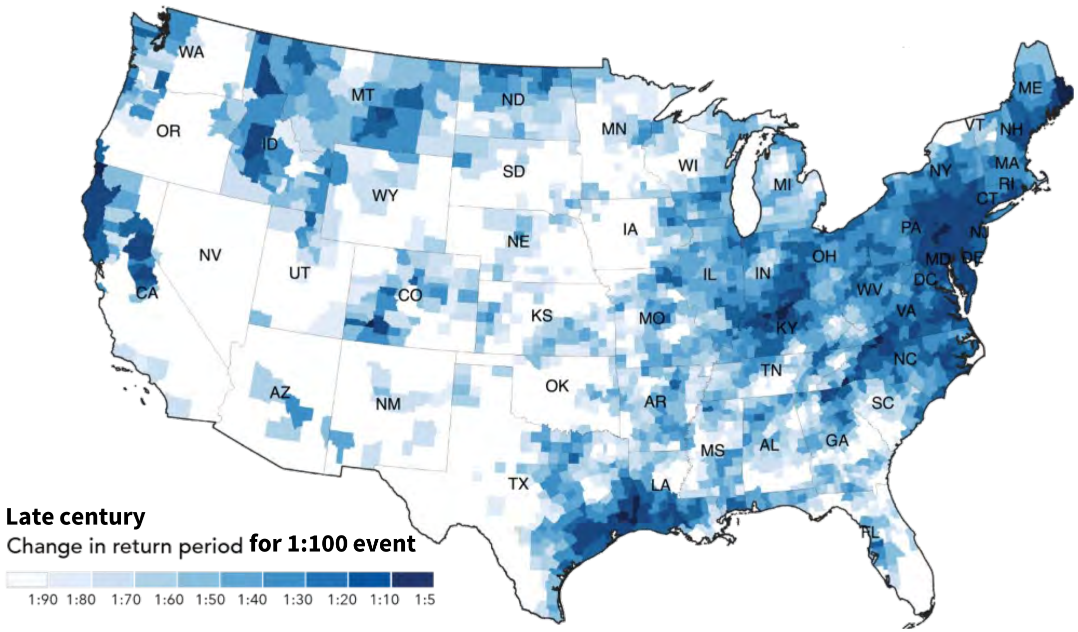
August 12, 2024

sonomawater.org

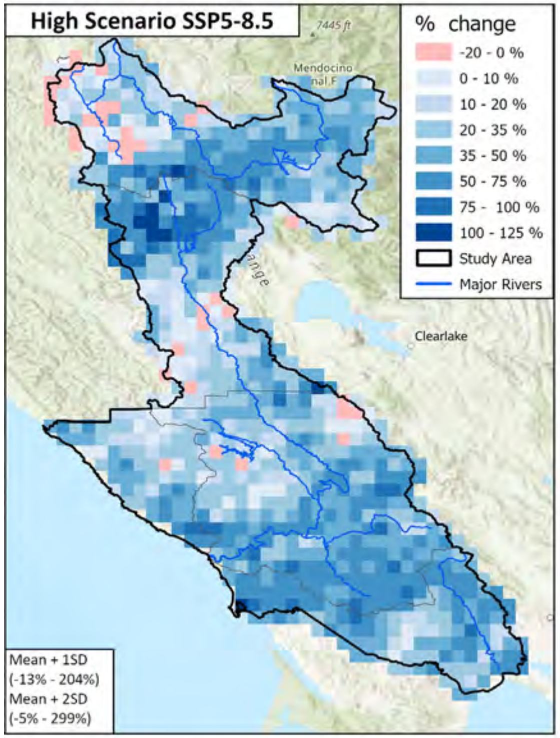
Agenda

I. Downscaling Overview (James Gregory, ESA)
II. Sonoma Water's commitment and data application (Sasha Ponomareva, Sonoma Water)
III. Questions

I. Why do we need future climate data?



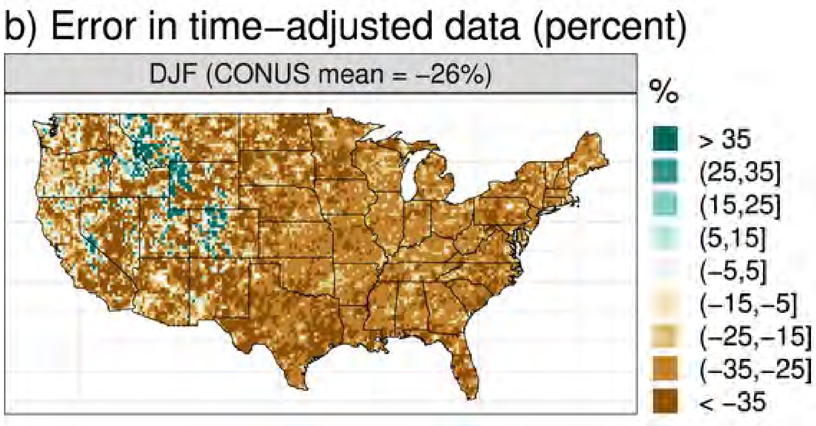
First street foundation



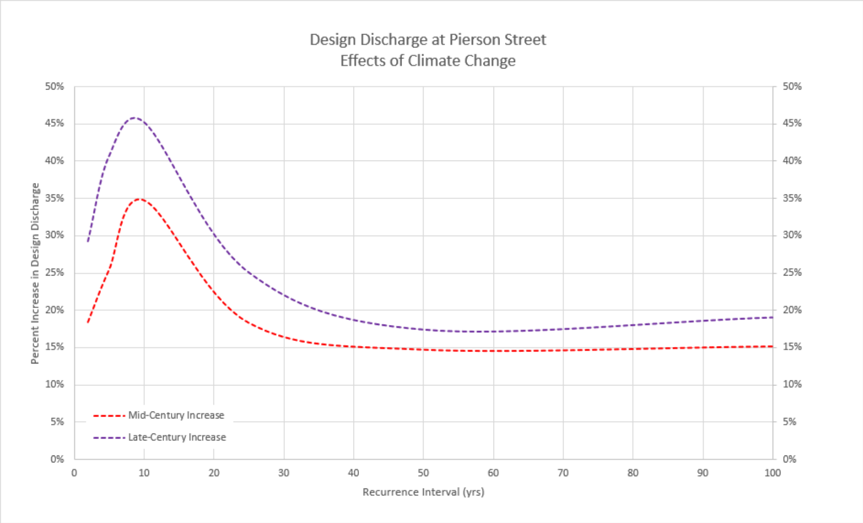
Sonoma Water Future Rainfall
Model Mean % Change in 100-year rainfall
Late Century (2100)
ESA (2018)

Past climate data applications at Sonoma Water | CSWP

- Downscaled climate data applied to flood models of the Santa Rosa Creek watershed to evaluate future flood scenarios
- 'LOCA1' downscaled data applied
    - Developed by David Pierce at Scripps Institute of Oceanography (2014)
    - 6-km grid
    - Uses older emissions scenarios (CMIP5)
- LOCA1 relied on historic dataset that underestimated extreme 24-hr rainfall by ~25-30%



Journal of Hydrometeorology 22, 7; 10.1175/JHM-D-20-0212.1



Characterization of the future climate

Shared Socioeconomic Pathways (SSPs, socioeconomics) and Representative Concentration Pathways (RCPs, emissions)

- The International Panel on Climate Change (IPCC) developed five narrative scenarios (SSPs) of global development regarding population, policy, technological progress, GDP, degree of urbanization, etc., without any contribution from mitigation strategies.
  - SSP1: Sustainability
  - SSP2: Middle of the road
  - SSP3: Regional rivalry
  - SSP4: Inequality
  - SSP5: Fossil-fueled development
- Mitigation strategies can then be linked to individual SSPs to capture emissions trajectories called Representative Concentration Pathways (RCPs).
  - RCP 1.9: <1.5° C warming
  - RCP 2.6: <2.0° C warming
  - RCP 3.4: 2.0-2.4 C warming
  - RCP 4.5: 2.5-3.0° C warming
  - RCP 6.0: 3.0-3.5° C warming
  - RCP 7.0: 4.0° C warming
  - RCP 8.5: 5.0° C warming

RCP 1.9 and RCP 2.6: Aggressive mitigation

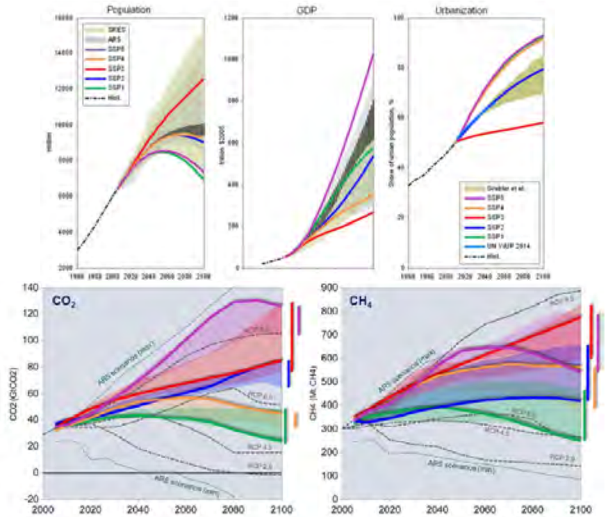
RCP 3.4 and RCP 4.5: Intermediate to moderate mitigation

RCP 6.0, RCP 7.0 and RCP 8.5: Little to no mitigation

- The combined SSP-RCP scenarios are used to drive climate models.

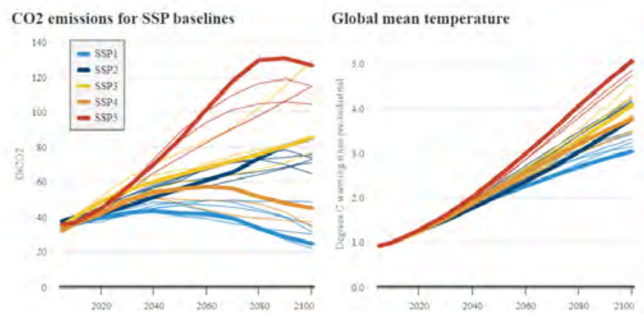
SSP Variables

RCP emissions



https://climate-scenarios.canada.ca/?page=cmip6-overview-notes

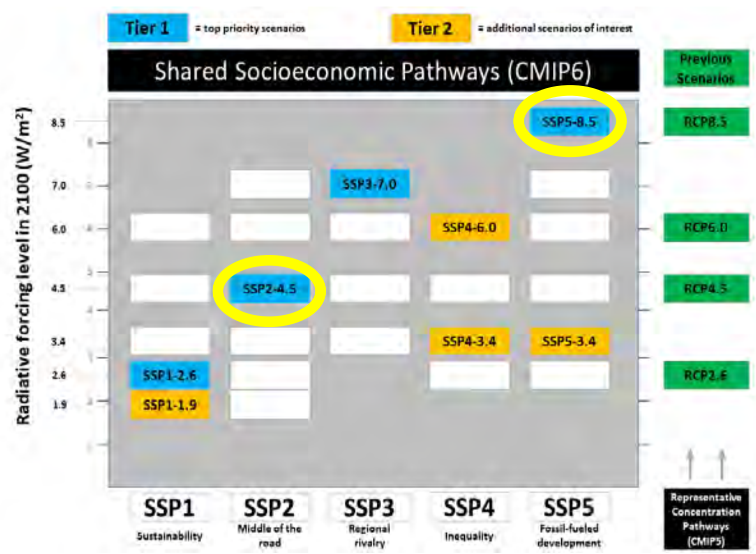
SSP-RCP outcomes



https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/

Key Scenarios for Planning

- **SSP2 Middle of the road** (medium challenges to mitigation and adaptation) **RCP4.5** (modest mitigation)
  - The world continues similar trajectory as past with uneven development and income growth across countries.
  - Global environmental degradation persists despite some improvements in sustainability efforts.
  - Population growth slows but income inequality and societal/environmental vulnerabilities remain issues.
  - Mitigation from RCP4.5 stabilizes warming potential by 2100
- **SSP5 Fossil-fueled development** (high challenges to mitigation, low challenges to adaptation) **RCP 8.5** (no mitigation)
  - Rapid innovation and technology development fueled by competitive markets and human capital investments.
  - Economic growth remains high with energy-intensive lifestyles, even as population peaks and declines.
  - Confidence in managing local and global environmental issues through geoengineering and other solutions.
- **SSP2-4.5** and **SSP5-8.5** scenarios align with most other California climate change evaluations



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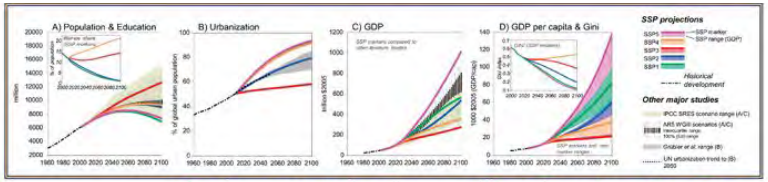
Global climate models and downscaling

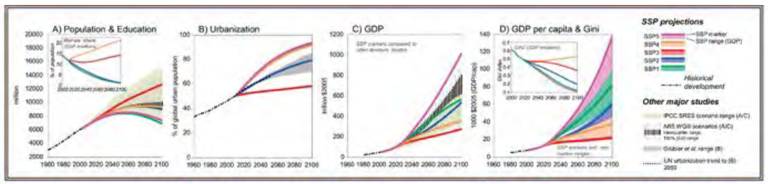
SSP-RCP variables



https://downscaling.lbl.gov/data/

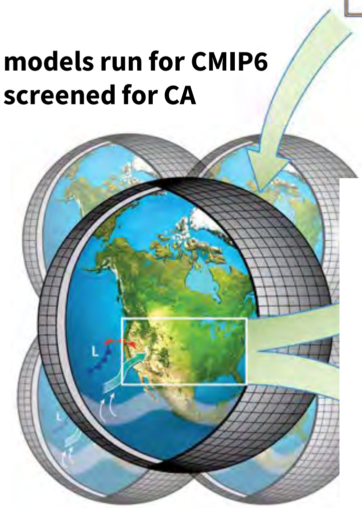
Global climate models and downscaling

SSP-RCP variables

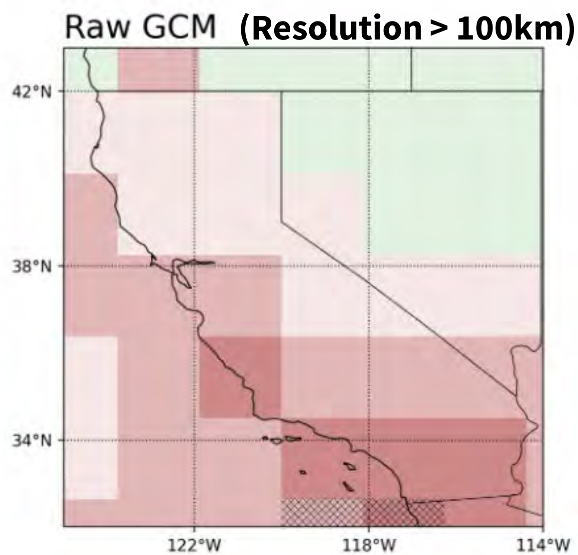


GCM

- **27 models run for CMIP6**
- **15 screened for CA**



(Resolution > 100km)



https://downscaling.lbl.gov/data/

Global climate models and downscaling

SSP-RCP variables

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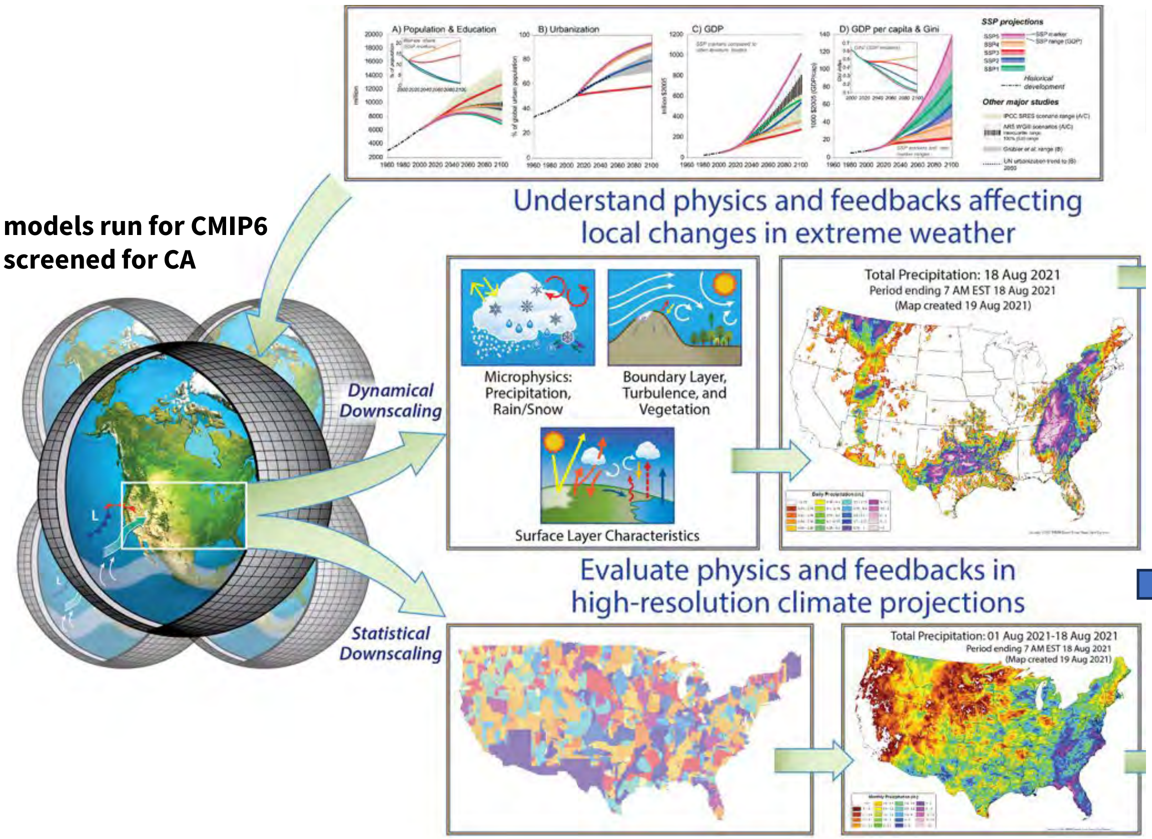
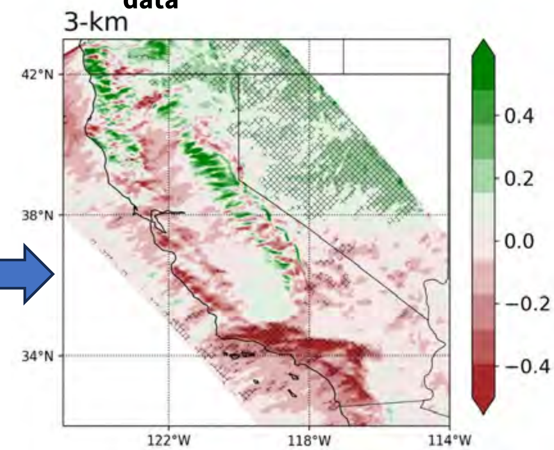


Latest California coverage for downscaled data



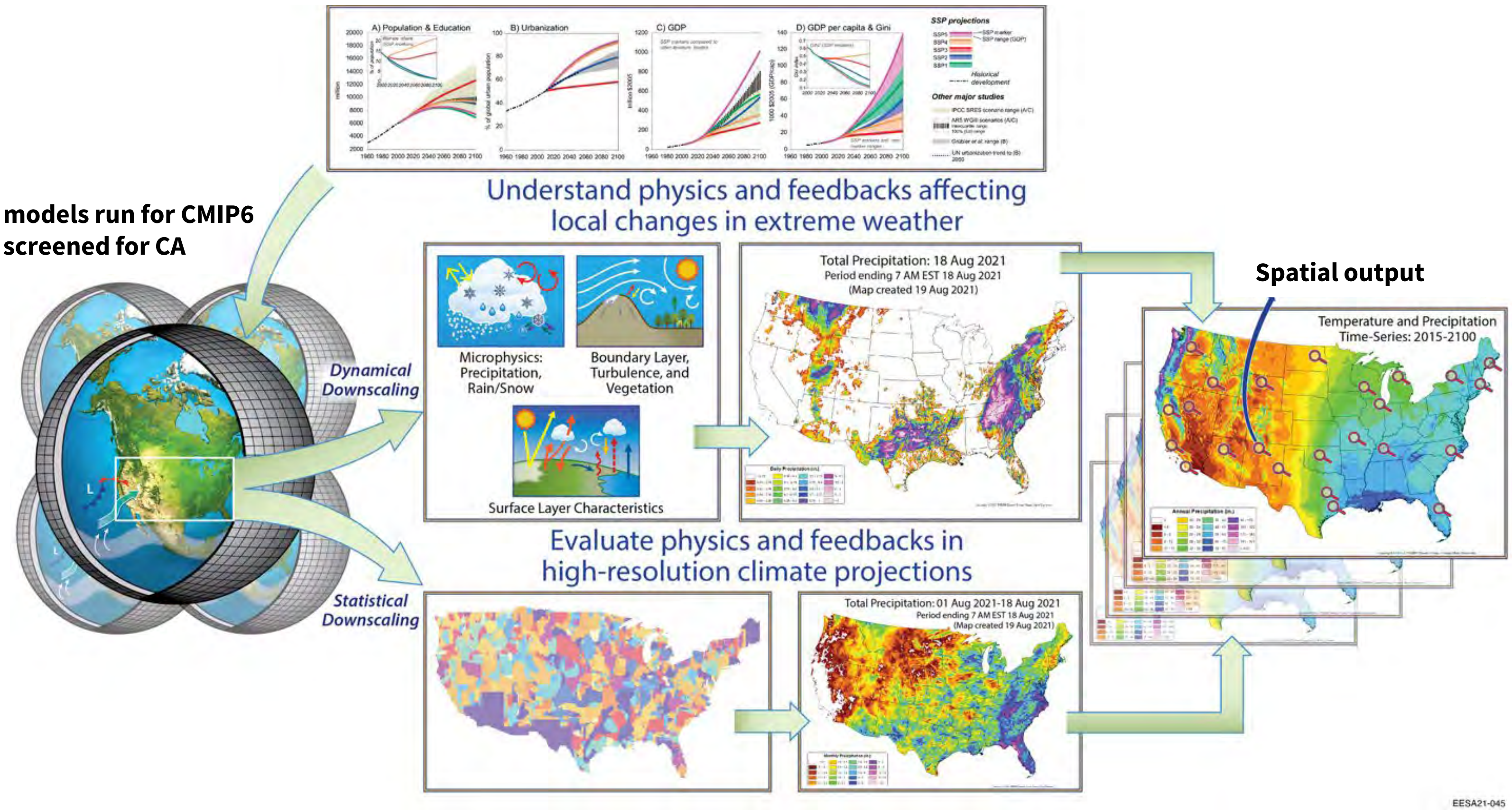
https://downscaling.lbl.gov/data/

Global climate models and downscaling

SSP-RCP variables

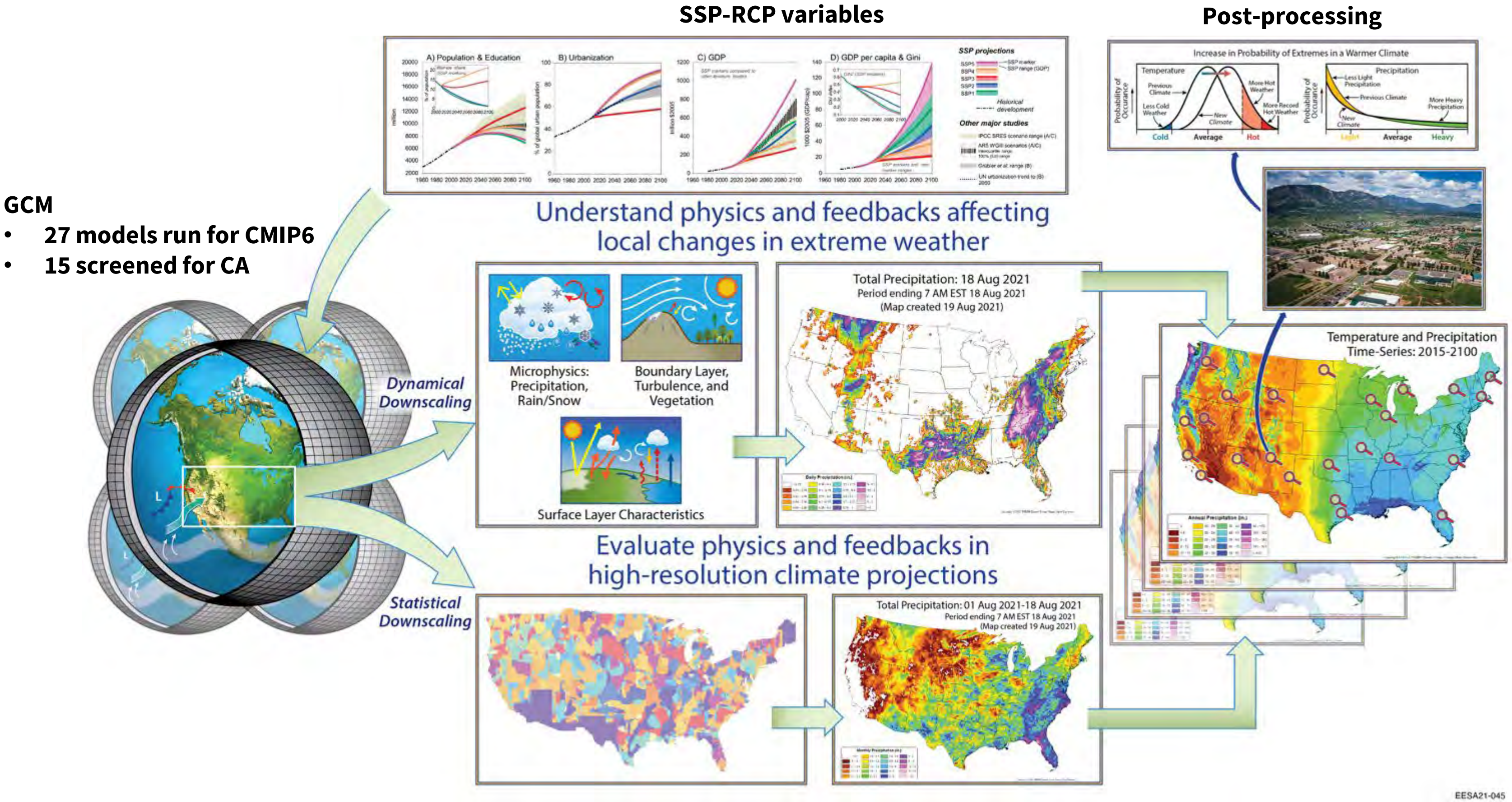
GCM
- **27 models run for CMIP6**
- **15 screened for CA**

Spatial output



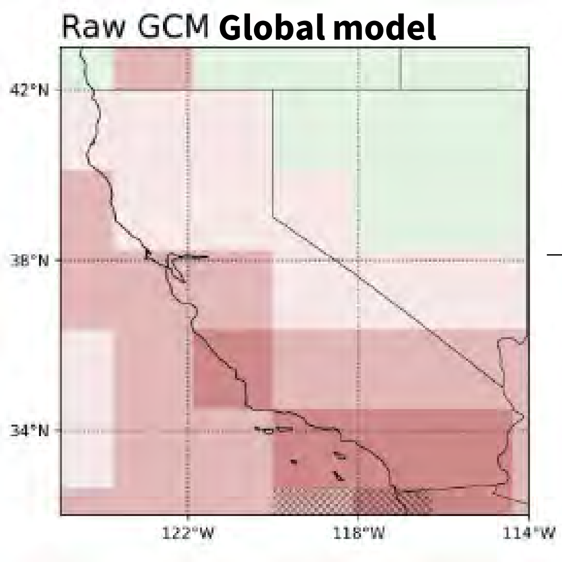
https://downscaling.lbl.gov/data/

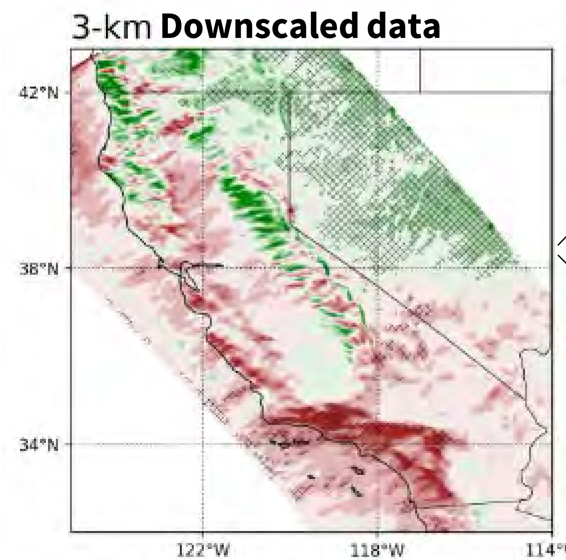
Global climate models and downscaling



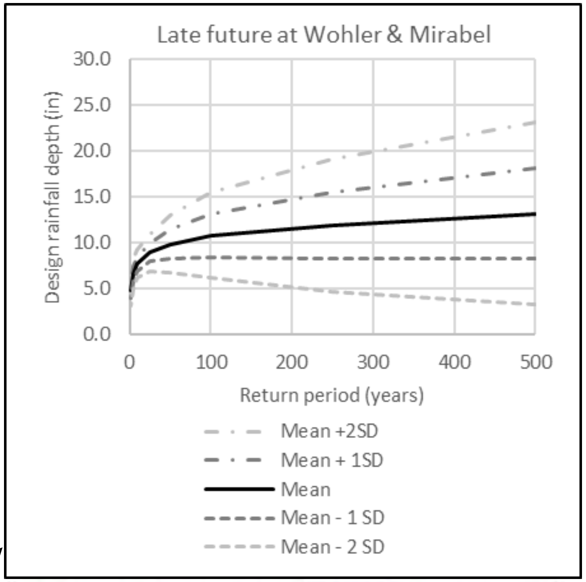
https://downscaling.lbl.gov/data/

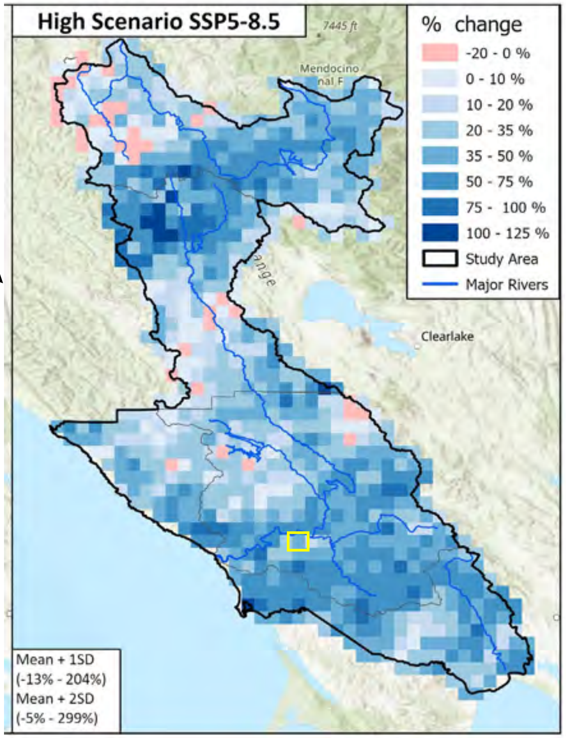
From global models to local climate data





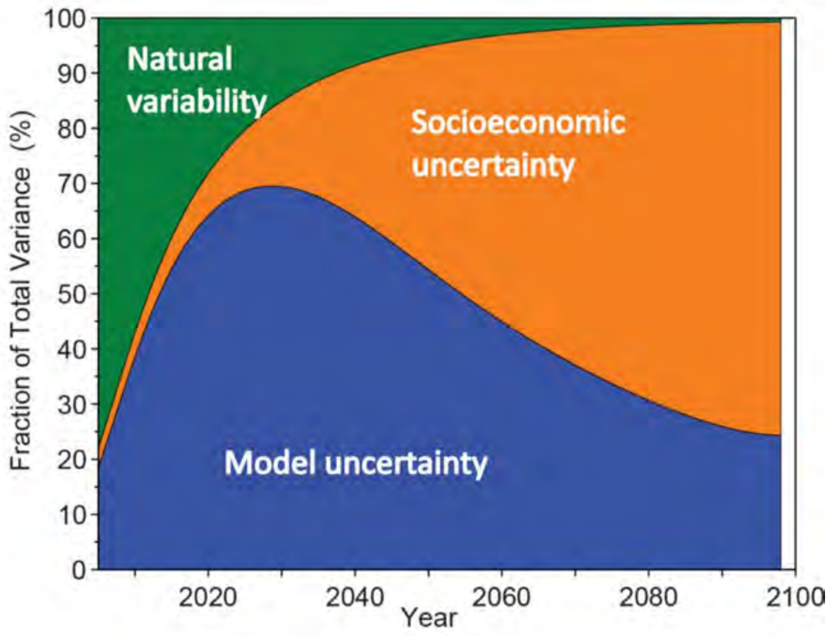
Processed output





Uncertainty: sources and considerations

- **Projection uncertainty**: Uncertainties in how future socioeconomics, politics, and technology will evolve and what paths humanity will take create inherent uncertainty in the projections.
- **Model and method uncertainty**: Model assumptions, physical model configurations, downscaling methods, temporal resolution, and frequency fitting methods, all contribute uncertainty to the climate models.
- **Natural variability:** Internal cycles (like El Niño) and external factors (such as volcanic activity), introduce unpredictable fluctuations that complicate climate projections, especially in the short term.

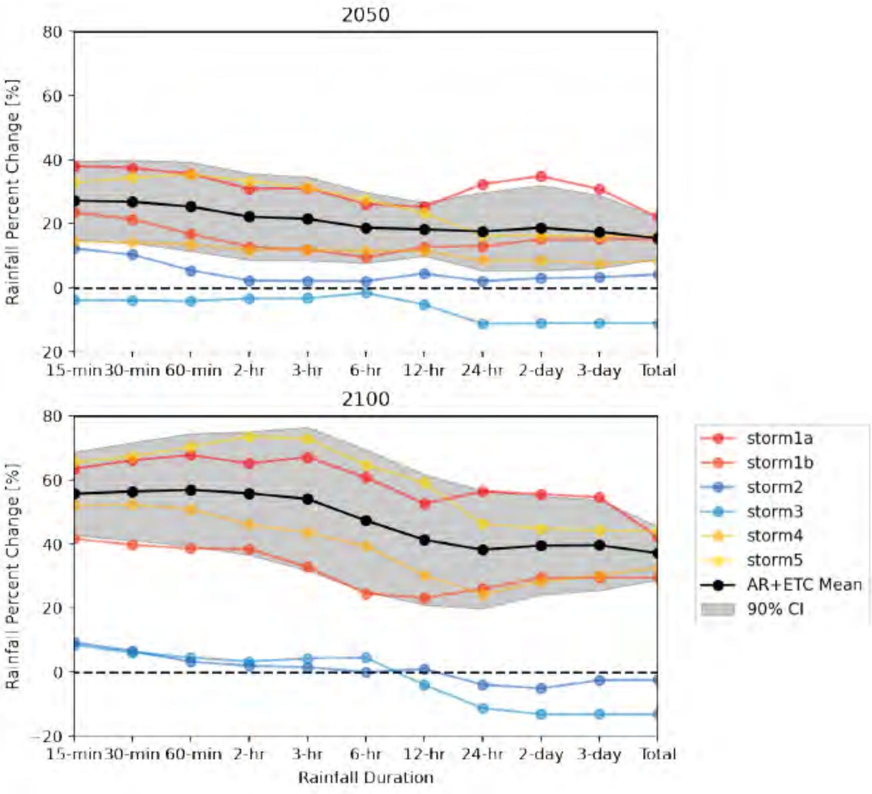


https://www.gyclimate.org/ch4

- Near term, model uncertainty and natural variability make up most of the uncertainty.
- Longer term, uncertainty in the characterization of the projections dominates.

Uncertainty in temporal resolution

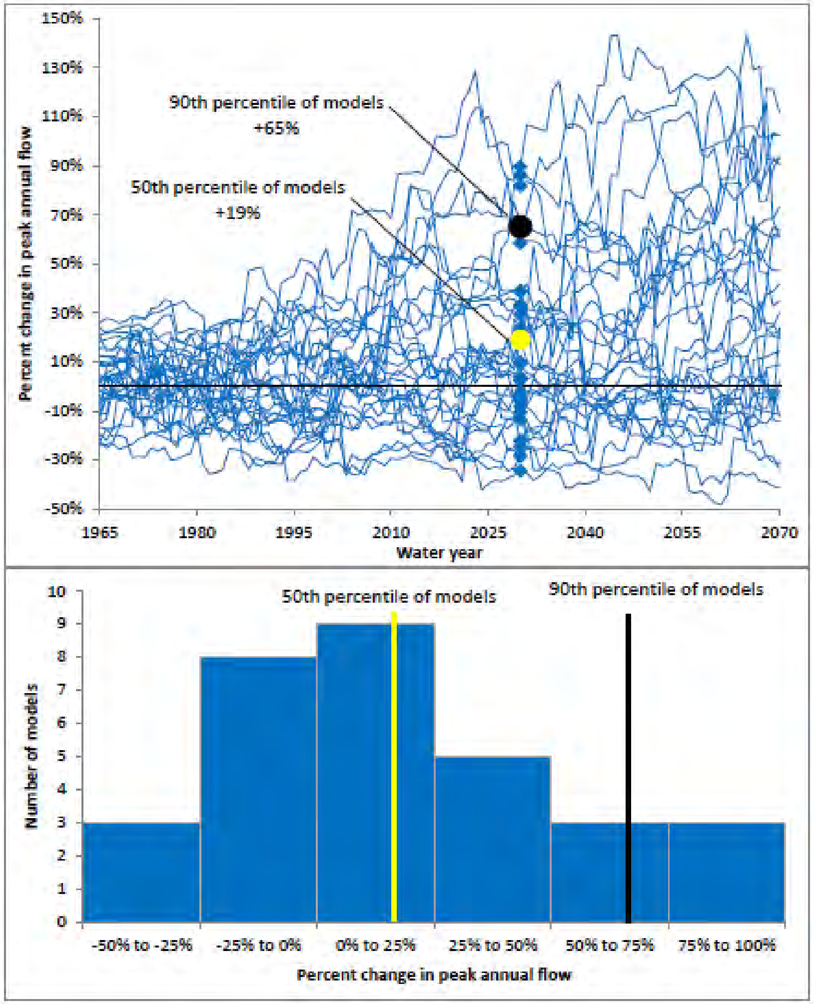
- Analyses for the Sonoma Water database used 24-hour totals
- Durations less than 24 hours may have variable future changes
- This could be investigated with future analyses applying other data sources such as the Weather Research and Forecasting (WRF) dynamical downscaling model



Mak M, Neher J, May CL, Finzi Hart J, Wehner M. 2023. San Francisco Bay Area Precipitation in a Warmer World. Volume 2: Future Precipitation Intensity, Duration, and Frequency. Prepared for the City and County of San Francisco

Uncertainty implications for risk and scenario selection

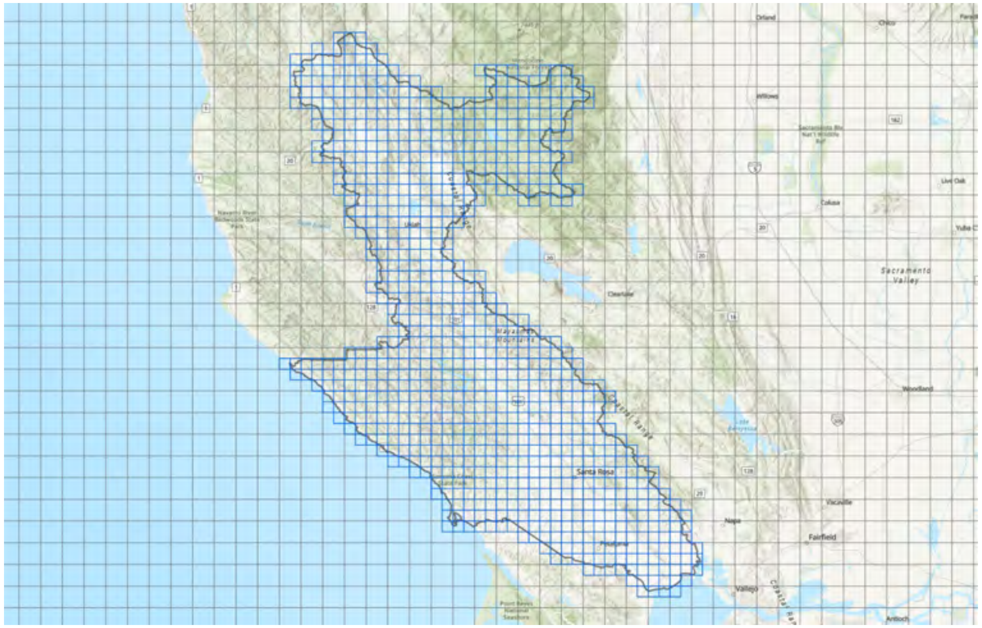
- Due to model method uncertainty, the climate models show a range in results
- Selecting the median for high emissions scenarios could underrepresent potential changes
- **Higher percentile scenario is prudent to characterize high-risk scenarios**



New California downscaled data (LOCA2)

- For CA 5th climate assessment, Scripps downscaled climate model data
- In 2021, researchers identified error in historic training data that caused LOCA1 to underpredict extreme rainfall
- In May 2022, LOCA2 was released with a 3km resolution for California
- Data contains daily precipitation and temperature for historic (1950-2015) and projected periods (2015-2100)
- Models were screened for 15 that perform best for CA climate
    - Only 13 had model runs for our selected SSPs

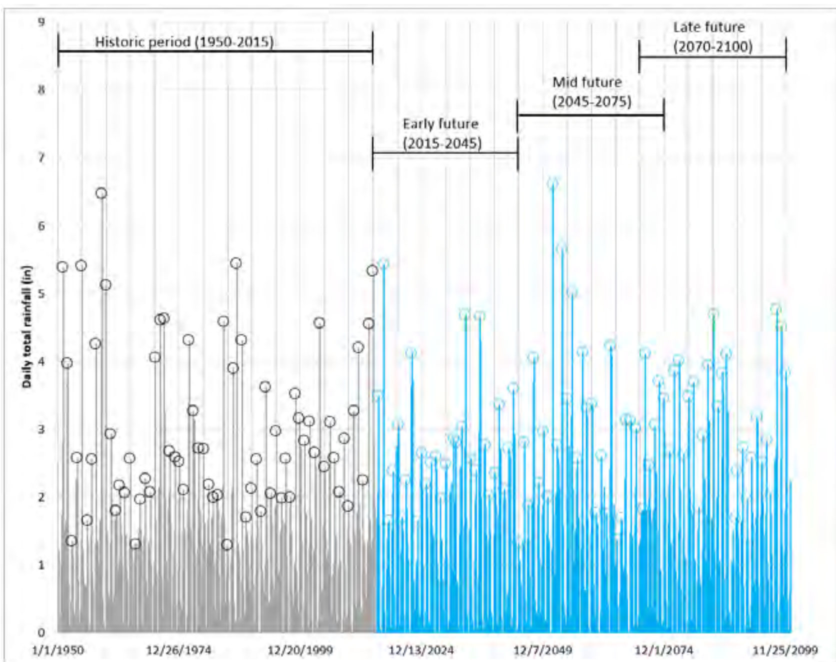
6km LOCA1 (grey) and 3km LOCA2 (blue) over Sonoma Water database domain



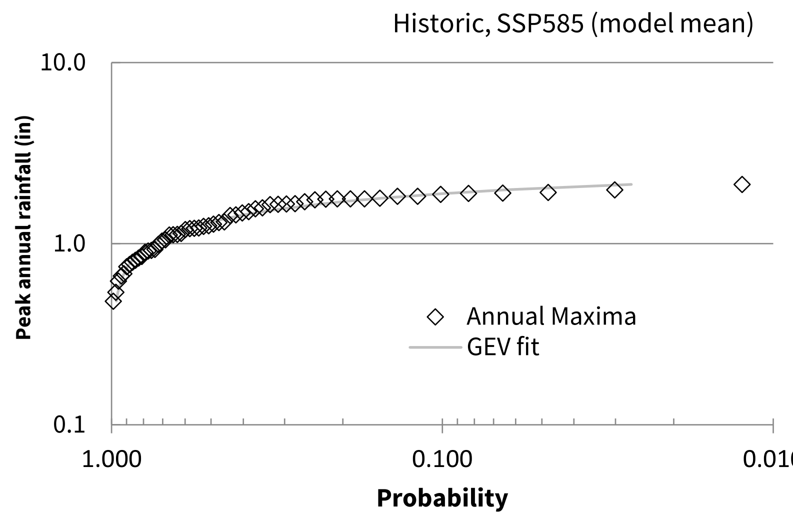
Methods – future design rainfall

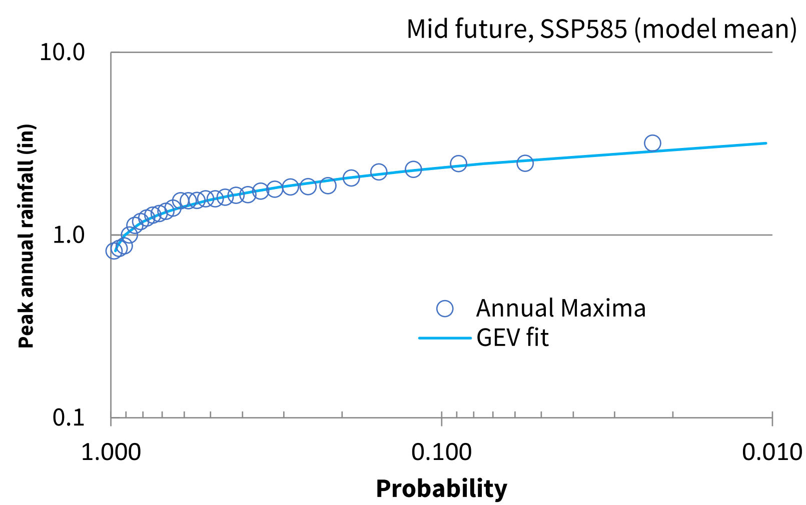
- Daily rainfall time series extracted at each cell
- Annual maxima computed for water years 1950-2100
- Future climate periods separated into 30-year blocks

- Probability frequency curve fitted to annual maxima for historic and future periods and % change calculated for each future period and emissions scenario at each climate cell

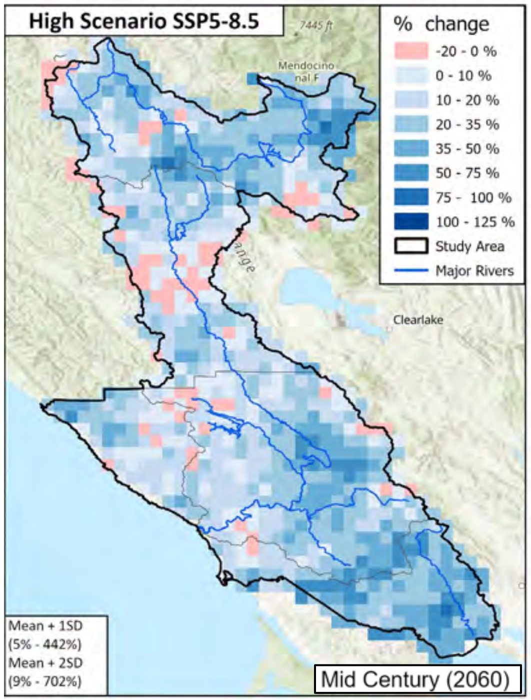


Time series for single climate model





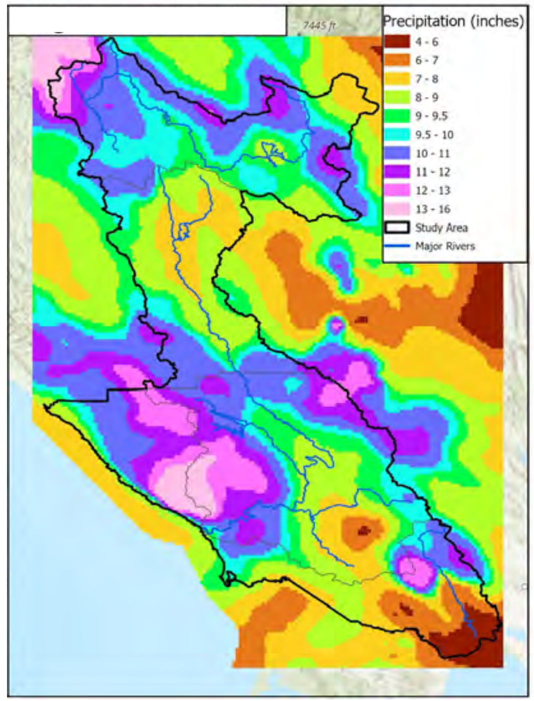
Methods – Design rainfall rasters



LOCA2 Scalar Raster

Future 100-yr rainfall % change

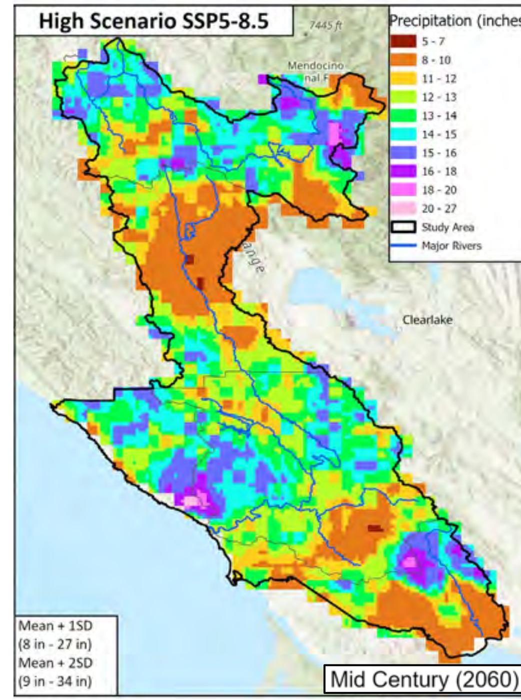
X



NOAA Atlas 14 Raster

Existing 100-Yr 24-hr rainfall depth

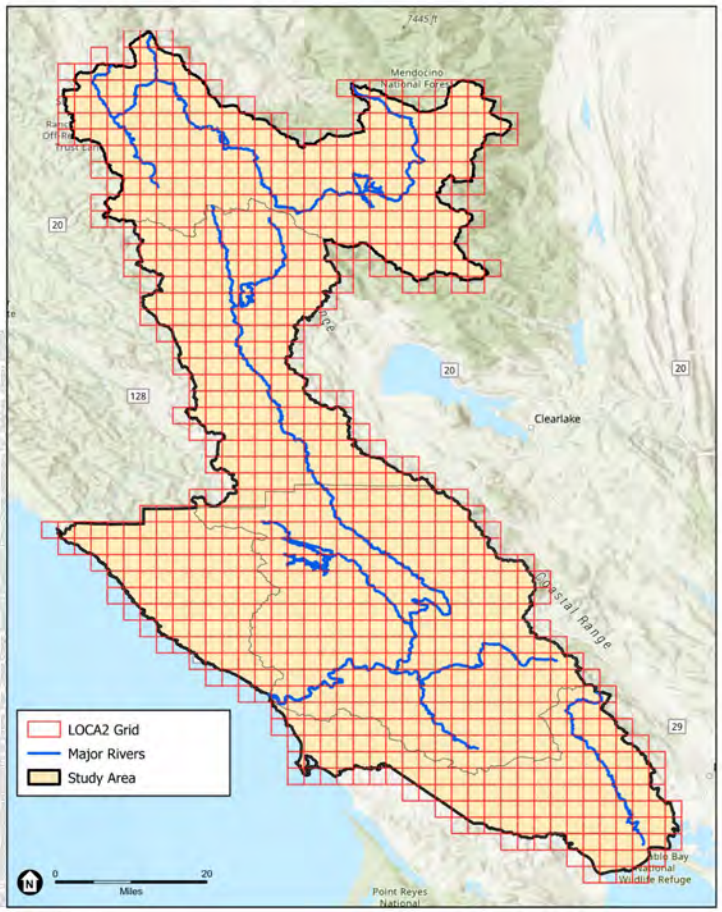
=



Scaled Design Rainfall Raster

Future 100-Yr 24-hr rainfall depth

Geodatabase



SOURCE: ESA, 2024

Sonoma Water Future Rainfall
Figure 1
Map of Study Area

TABLE 1. FUTURE RAINFALL DATABASE CONTENTS

Data type	Time Period	Emissions scenario	Variable	Climate model ensemble statistic
Geospatial Rasters (3km square scalars, 800m design depths)	Early century (2016-2045 basis, 2030 midpoint)	Medium-high (SSP2-4.5) High (SSP5-8.5)	24-hour depth for 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods* Mean Annual Precipitation	Mean Mean + 1SD Mean + 2SD
	Mid century (2046-2075 basis, 2060 midpoint)	Medium-high (SSP2-4.5) High (SSP5-8.5)	24-hour depth for 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods Mean Annual Precipitation	Mean Mean + 1SD Mean + 2SD
	Late century (2070-2099 basis, 2085 midpoint)	Medium-high (SSP2-4.5) High (SSP5-8.5)	24-hour depth for 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods Mean Annual Precipitation	Mean Mean + 1SD Mean + 2SD

*Scalar rasters at 3km resolution and raw design depth rasters at 800m resolution provided for all return periods.

*In addition to the spatial data, daily time series data at each cell for each climate model also provided to Sonoma Water

II. Sonoma Water's commitment and data application

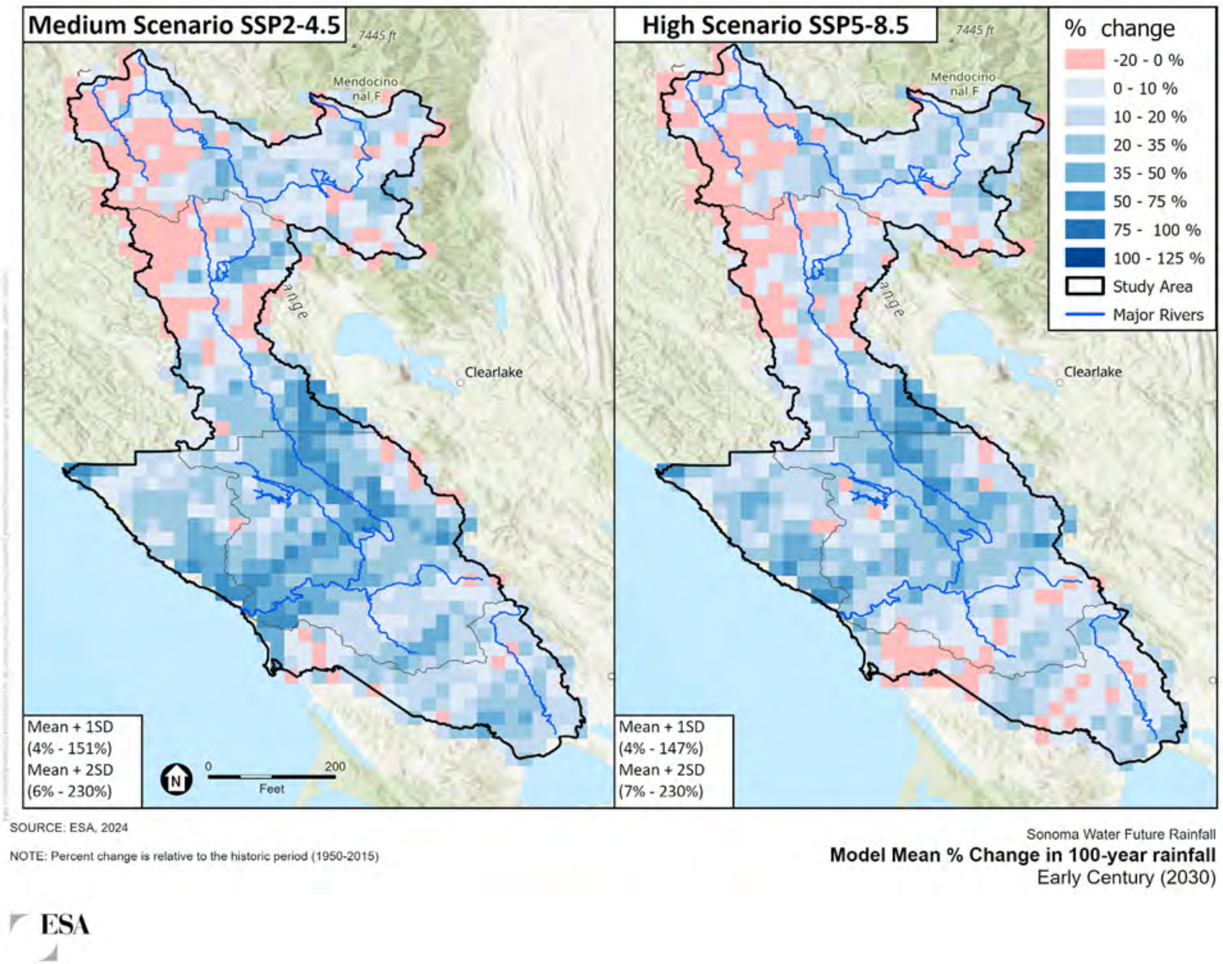
- Geodatabase
- Technical Methods Memo
- User Guidance Report

Sonoma Water's commitment

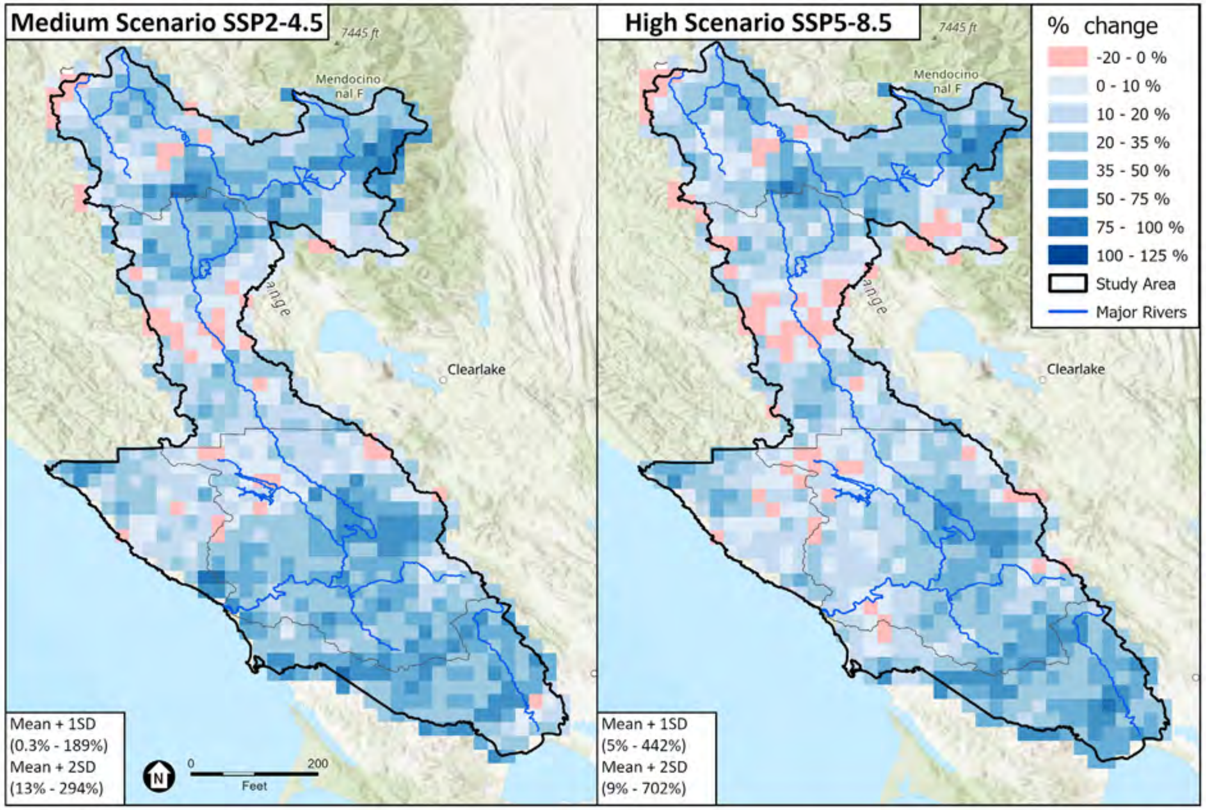
(User Guidance Report, Section 2. Background and Purpose)

In recognition of California's rapidly changing climate and at the direction of Sonoma Water's Energy and Climate Resiliency Policy (2023) and Climate Adaptation Plan (Sonoma Water, 2021), Sonoma Water has committed to incorporating future climate data into studies, planning, design, and construction projects conducted by Sonoma Water **to the extent feasible and relevant**.

100-year rainfall – Early century scalars



100-year rainfall – Mid century scalars



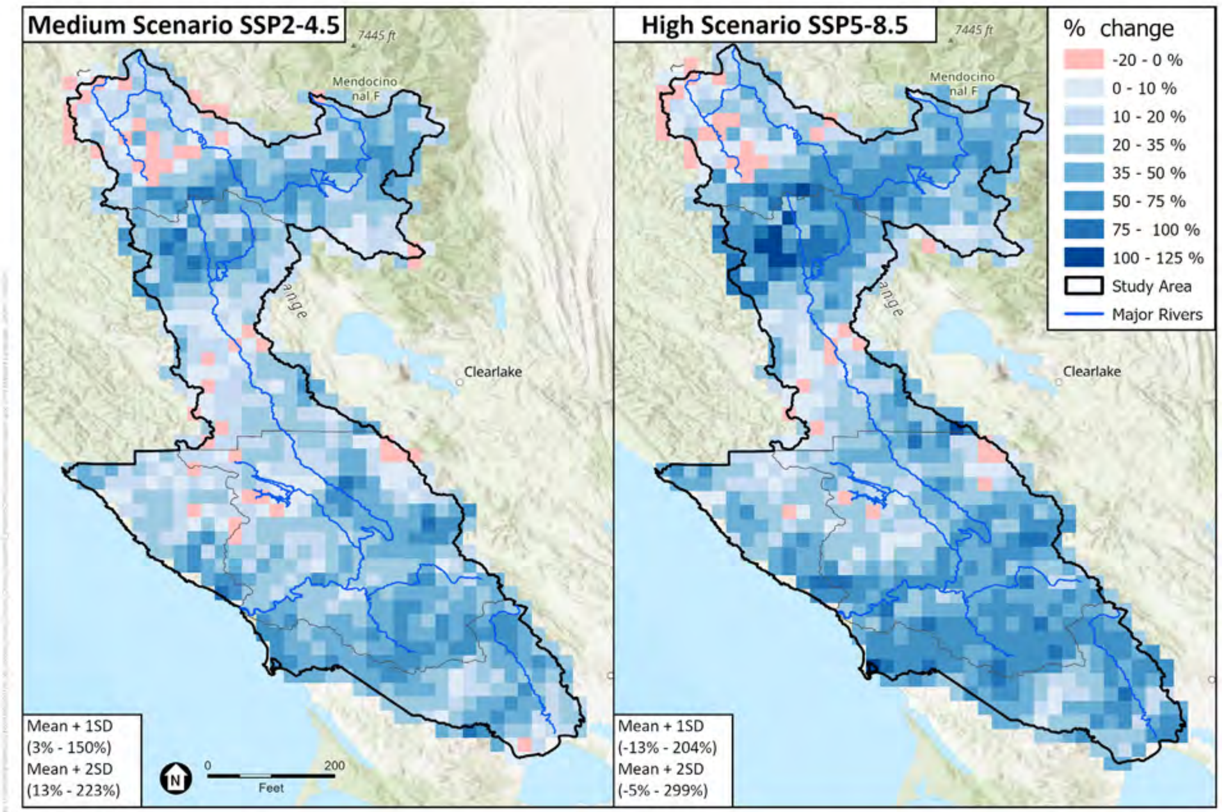
SOURCE: ESA, 2024

NOTE: Percent change is relative to the historic period (1950-2015)

Sonoma Water Future Rainfall
Model Mean % Change in 100-year rainfall
Mid Century (2060)

ESA

100-year rainfall – Late century scalars

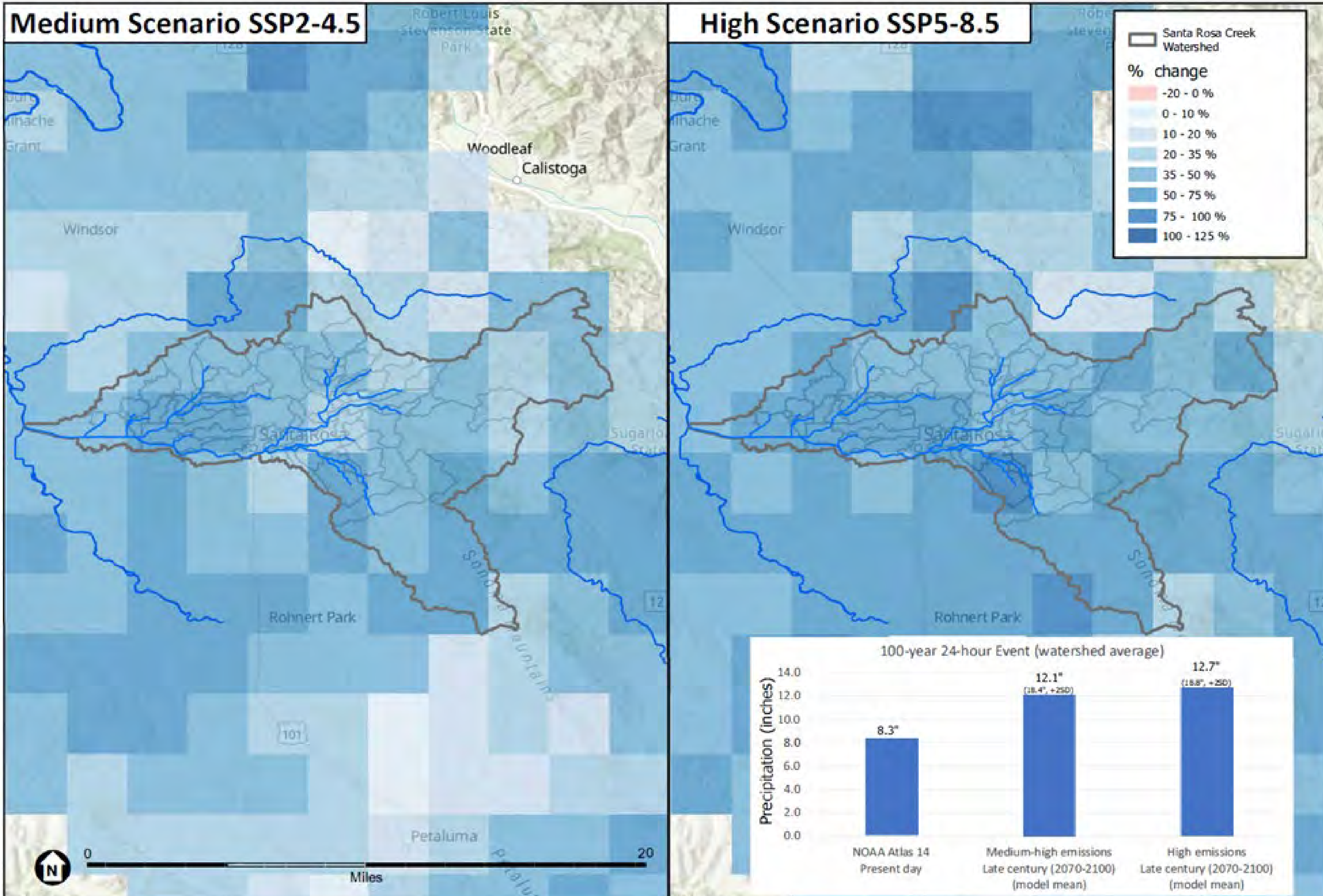


SOURCE: ESA, 2024

NOTE: Percent change is relative to the historic period (1950-2015)

Sonoma Water Future Rainfall
Model Mean % Change in 100-year rainfall
Late Century (2100)

ESA



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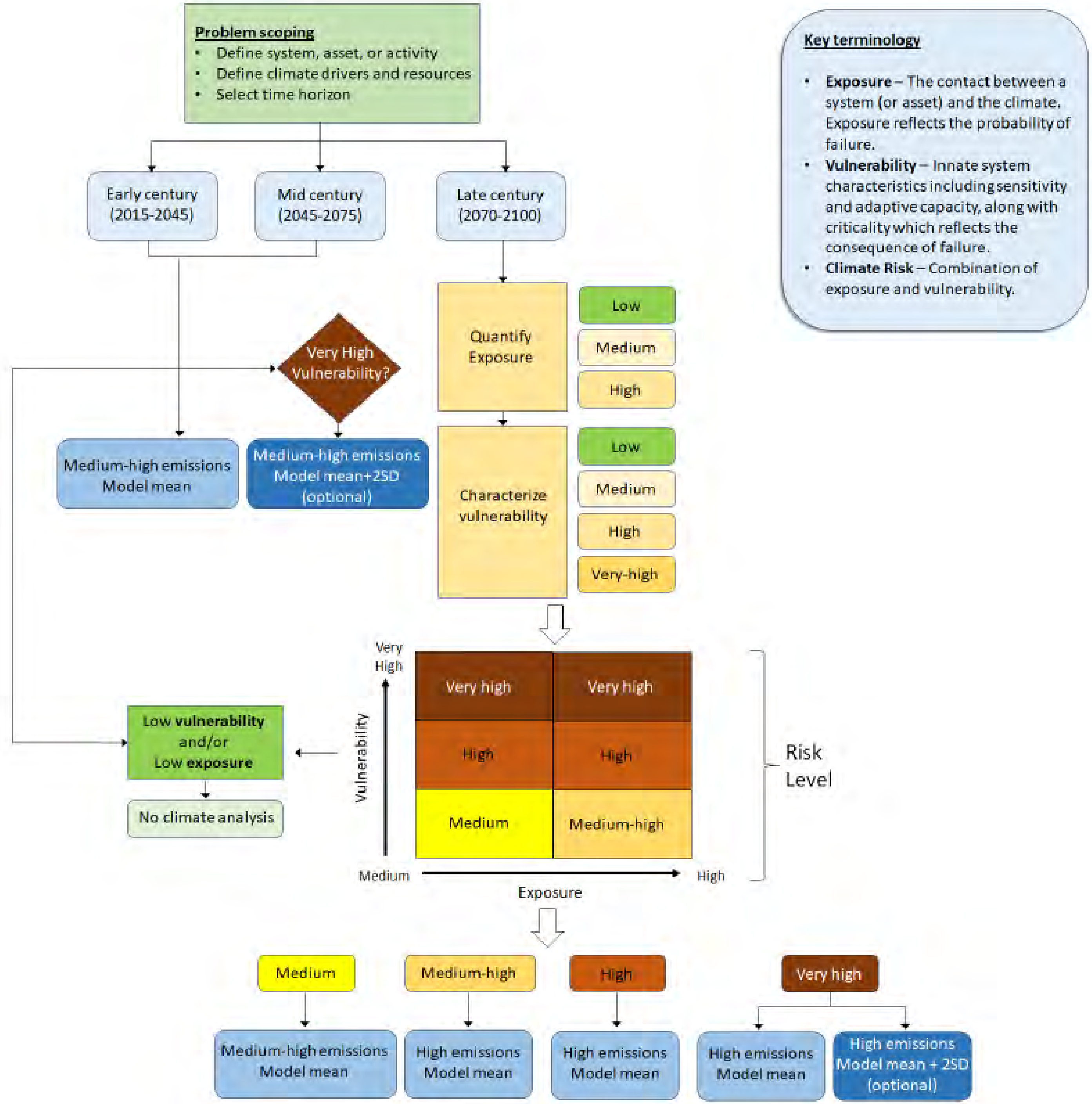

Problem scoping
Define system, asset, or activity
Define climate drivers and resources
Select time horizon
Early century (2015-2045)
Mid century (2045-2075)
Late century (2070-2100)
Very High Vulnerability?
Medium-high emissions Model mean
Medium-high emissions Model mean+2SD (optional)
Quantify Exposure
Low
Medium
High
Characterize vulnerability
Low
Medium
High
Very-high
Very High
Very high
Very high
High
High
Medium
Medium-high
Vulnerability
Medium
Exposure
High
Risk Level
Low vulnerability and/or Low exposure
No climate analysis
Medium
Medium-high
High
Very high
Medium-high emissions Model mean
High emissions Model mean
High emissions Model mean
High emissions Model mean
High emissions Model mean + 2SD (optional)
Key terminology
Exposure – The contact between a system (or asset) and the climate. Exposure reflects the probability of failure.
Vulnerability – Innate system characteristics including sensitivity and adaptive capacity, along with criticality which reflects the consequence of failure.
Climate Risk – Combination of exposure and vulnerability.

Future data needs

- Multi-day events
- Sub 24-hour events
- Temperature
- How do we apply the data where we don't have local hydraulic models/modeling capacity?

Learning as we go

- We are just getting started
- Best practice from analog agencies: retain flexibility and learn as you go
- Requirement to *study* future conditions, but maintenance and capital investment decisions always require careful evaluation of multiple criteria, including risk, cost, and level of service.

Questions?

For more information, please contact:

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Molly Oshun molly.oshun@scwa.ca.gov

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