



**WATER TOMORROW**  
**2020 Integrated Resources Plan**

# IRP Joint Workshop on Climate Change

**Metropolitan Board of Directors and  
Member Agency Managers**

May 25, 2021



# Ed Means Facilitator

- President of Means Consulting LLC
- 40 years in water in California
- Experienced facilitator on technical issues
  - Over 15 strategic plans
  - 8 scenario plans
  - Numerous expert panels
- Consultant since 1999 on numerous planning projects including scenario planning, resource plans, and strategic plans across the country
- Worked at Metropolitan from 1980-1998 including as Director of Resources during first MWD IRP



# *Workshop Logistics*

*Meeting Logistics*

*Objectives*

*Approach*

# Meeting Logistics

- Limited time – be succinct; focus on climate change issues
- Staff will consider all comments and questions as planning moves forward
- Staff will provide written guidance to process related questions
- Mute audio / turn off video unless talking
- Use the chat feature to submit questions you haven't already submitted
- The meeting is being recorded
- May also submit questions during meeting to: [MWDIRP@mwdh2o.com](mailto:MWDIRP@mwdh2o.com)

# Workshop Objectives

- Gain familiarity of climate science for water resource planning
- Opportunity for workshop participants to pose questions to the panel of climate experts
- Feedback on charge questions on drivers of climate change
- Obtain expert feedback prompted by participant questions to improve quantification of scenarios

# Workshop Approach

- Panel member discussion of charge questions related to climate change
- Panel member feedback on questions submitted by the Board and member agency managers in advance
- Panel member feedback for clarification or additional climate-related questions from Board members or member agency participants



# *Staff Presentation*

*Recap of Work Effort  
Refinement Approach  
Charge Questions for Workshop*

# Brief Recap of Work Efforts

- Preliminary scenario assumptions presented - October 2020
  - Initial assessment to illustrate potential for supply/demand ranges across scenarios and types of analytics available
- Joint Workshop on Demands - March 2021
  - Staff continuing to work with experts and incorporating feedback into the analysis
- Scenario Refinements – Ongoing
  - More robust modeling and evidence-based effort
  - Identify plausible supply/demand ranges across scenarios
  - Update “gap analysis”
  - Serves as the basis for identifying the actions needed to achieve 100 percent reliability for each scenario

# How We Are Refining the Scenarios

- Collaborative Approach
  - Scenario refinements are grouped into three areas
    - Local Supply, Imported Supply and Demands
  - Engage with experts (demand and climate)
    - Contracted to help staff with technical support
    - Expanded to include Board and Member Agencies interaction
- Today's workshop focuses on climate change
  - Introduction to climate science
  - Going from global to local
  - Regional hydrologic changes
  - Climate and water demand
  - What do we plan for?





## *Panel Introductions*

Dr. Heidi Roop

Dr. Julie Vano

Brad Udall

Heather Cooley

# Dr. Heidi Roop

- Assistant Professor at the University of Minnesota, Department of Soil, Water and Climate.
- Ph.D in Geology from Victoria University of Wellington, M.S. in Geology from Northern Arizona University, and B.A. in Geology from Mount Holyoke College.
- Works to develop innovative ways to build bridges between theory and practice of science communication.
- Participated in research around the world from Greenland and Antarctica to the mountains of Vietnam and New Zealand.
- Holds Affiliate Assistant Professorship at University of Washington School of Public Health.
- Adjunct Researcher at Center of Science and Society at Victoria University of Wellington.
- Editor for the journal *Geoscience Communication*.



# Dr. Julie Vano

- Research Director at Aspen Global Change Institute.
- Ph.D. in Civil and Environmental Engineering from University of Washington, M.S. in Land Resources from University of Wisconsin and B.A. in Biology, minors in Mathematics and Chemistry from Luther College.
- Focuses on connecting science and decision making, hydrology, water resource management, science policy, climate change adaptation, and system dynamics.
- Trainer for Water Utility Climate Alliance (WUCA) Resiliency Training to help water utilities build resilience to a changing climate.
- Lead and contributing author in reports for federal and state agencies, including Water Reliability in the West - 2021 SECURE Water Act Report.
- American Geophysical Union Science and Society Section President.



# Brad Udall

- Senior Water and Climate Research Scientist at Colorado Water Institute, Colorado State University.
- M.B.A. from Colorado State University and B.S. in Environmental Engineering from Stanford University.
- Wide-ranging background in water and climate policy issues.
- Extensive writing on the impacts of climate change on water resources in American West, including:
  - [Global Climate Change Impacts in the United States](#)
  - [Western Water Assessment's Climate Change in Colorado Report](#)
- Awarded by California Department of Water Resources for work in facilitating interactions between water managers and scientists.
- Awarded by Department of Interior for work on groundbreaking 2007 EIS on Colorado River shortages and coordinated reservoir operations.



# Heather Cooley

- Director of Research at the Pacific Institute.
- M.S. in Energy and Resources and B.S. in Molecular Environmental Biology from the University of California, Berkeley.
- Conducts and oversees research on water issues such as:
  - Sustainable water use and management
  - Connection between water and energy
  - Impacts of climate change on water resources
- Served on the California Commercial, Industrial, and Institutional Task Force.
- Currently serves on the California Urban Stakeholder Committee and the California Urban Water Conservations Council's Board of Directors.





# *Part I: Global Climate Change*

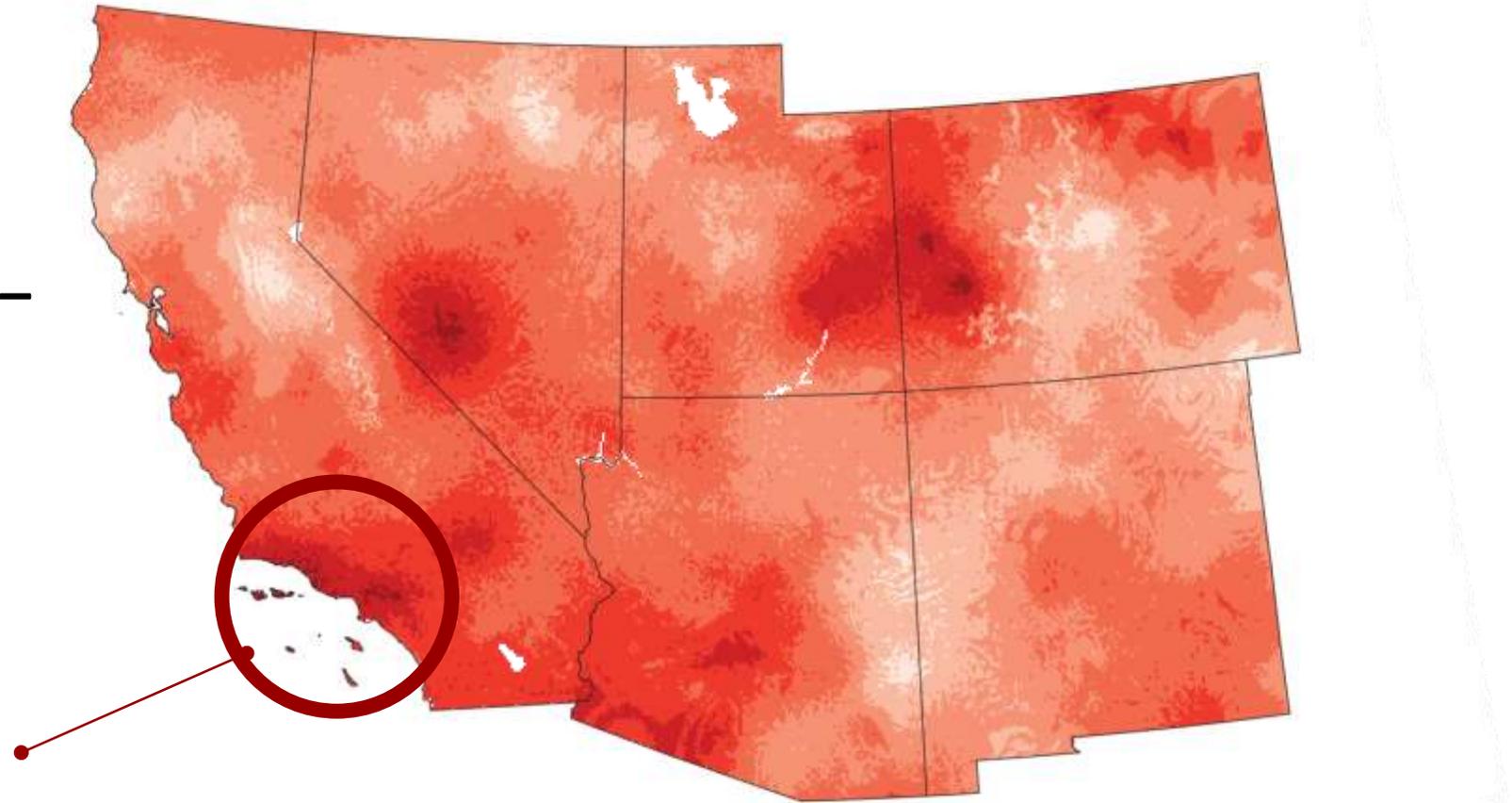
Dr. Heidi Roop

# 2.0°F of global warming since the late 1800's

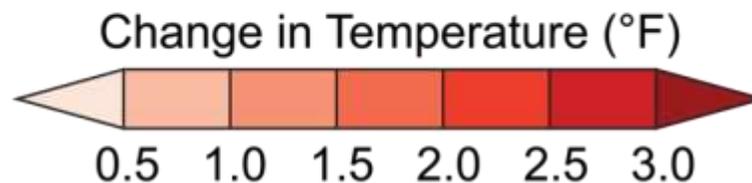


# Warming is occurring across the Western U.S.

This map shows the difference between 1986–2016 average temperature and 1901–1960 average temperature.



Southern CA has already warmed by ~3.0°F since the early 1900s.





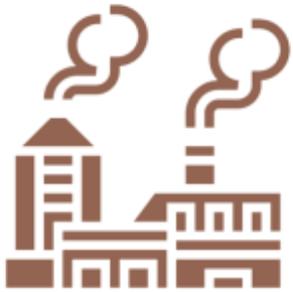
**This warming translates into impacts that matter for community well-being, ecosystems *and* water resources management.**

# Climate Change Context in CA

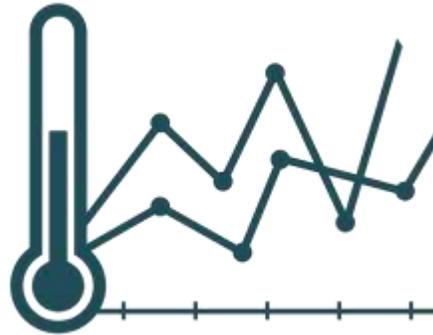
 CALIFORNIA'S FOURTH <b>CLIMATE CHANGE</b> ASSESSMENT	CLIMATE IMPACT	DIRECTION	SCIENTIFIC CONFIDENCE FOR FUTURE CHANGE
	TEMPERATURE	WARMING ↗	Very High
	SEA LEVELS	RISING ↗	Very High
	SNOWPACK	DECLINING ↘	Very High
	HEAVY PRECIPITATION EVENTS	INCREASING ↗	Medium-High
	DROUGHT	INCREASING ↗	Medium-High
	AREA BURNED BY WILDFIRE	INCREASING ↗	Medium High

# But, what is the actual range of outcomes?

Future climate impacts, and the ranges we can anticipate, are primarily determined by:



**Human  
choices**

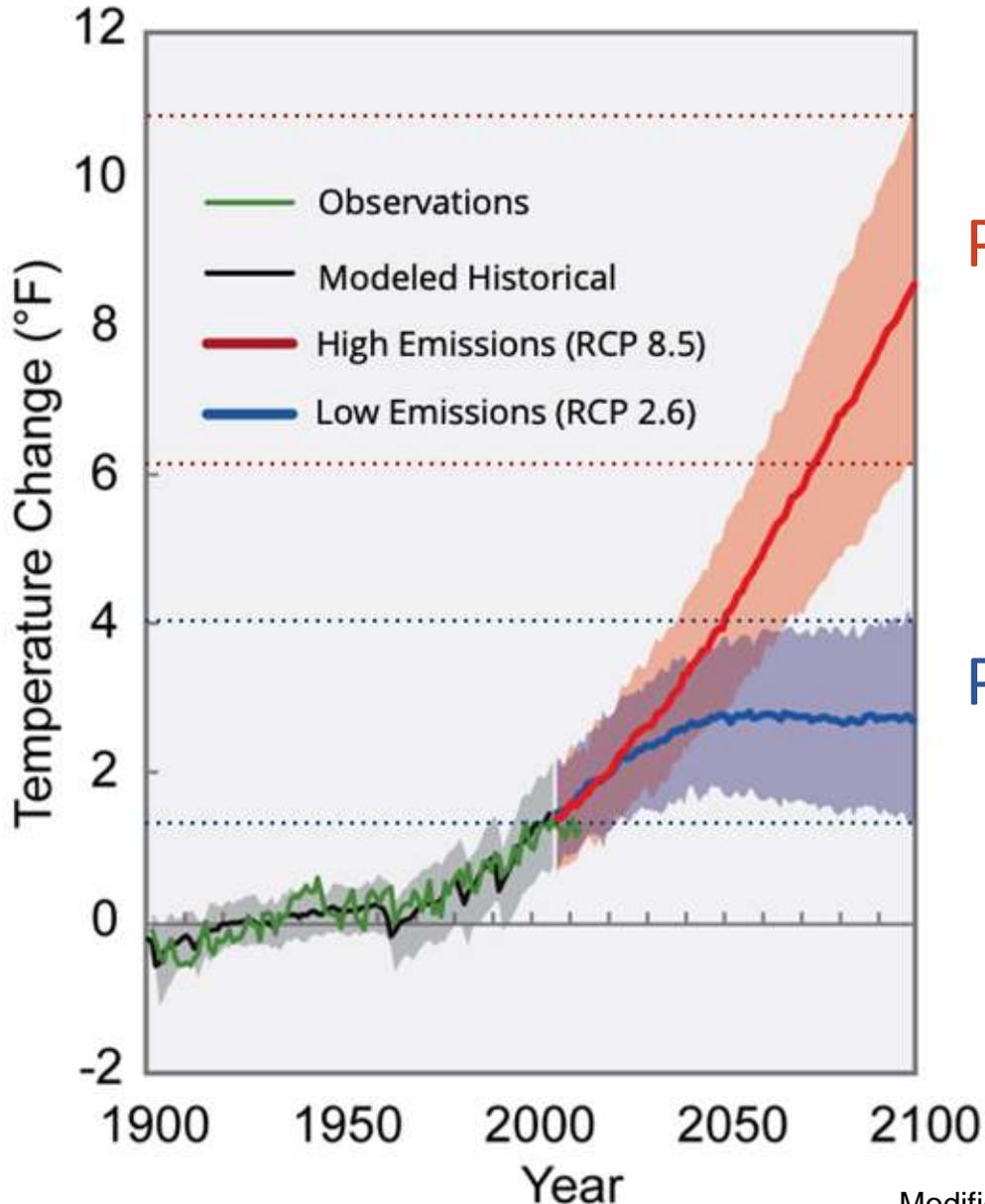


**Natural  
Variability**



**Physical process  
representations**  
(e.g. models, downscaling)

# Human Choices: the principal driver of long-term warming is total emissions of CO<sub>2</sub>



Projected warming under continued **HIGH emissions**

Projected warming under **LOW emissions**

# Different outcomes for different emissions scenarios:

## Temperature Change

If greenhouse gas emissions...	are reduced at a moderate rate...	then California will experience average daily high temperatures that are warmer than the historical average by...	<b>2.5°F</b> from 2006 to 2039.	<b>4.4°F</b> from 2040 to 2069.	<b>5.6°F</b> from 2070 to 2100.
	continue at current rates...		<b>2.7°F</b> from 2006 to 2039.	<b>5.8°F</b> from 2040 to 2069.	<b>8.8°F</b> from 2070 to 2100.

## Change in snowpack



By 2050, the average water supply from snowpack is projected to decline to **2/3** from historical levels.

with no emissions reductions



Water from snowpack could fall to less than **1/3** of historical levels by 2100.

# Human Choices: planning and preparation

**How we feel climate change depends on:**



+



How well we **prevent** further warming

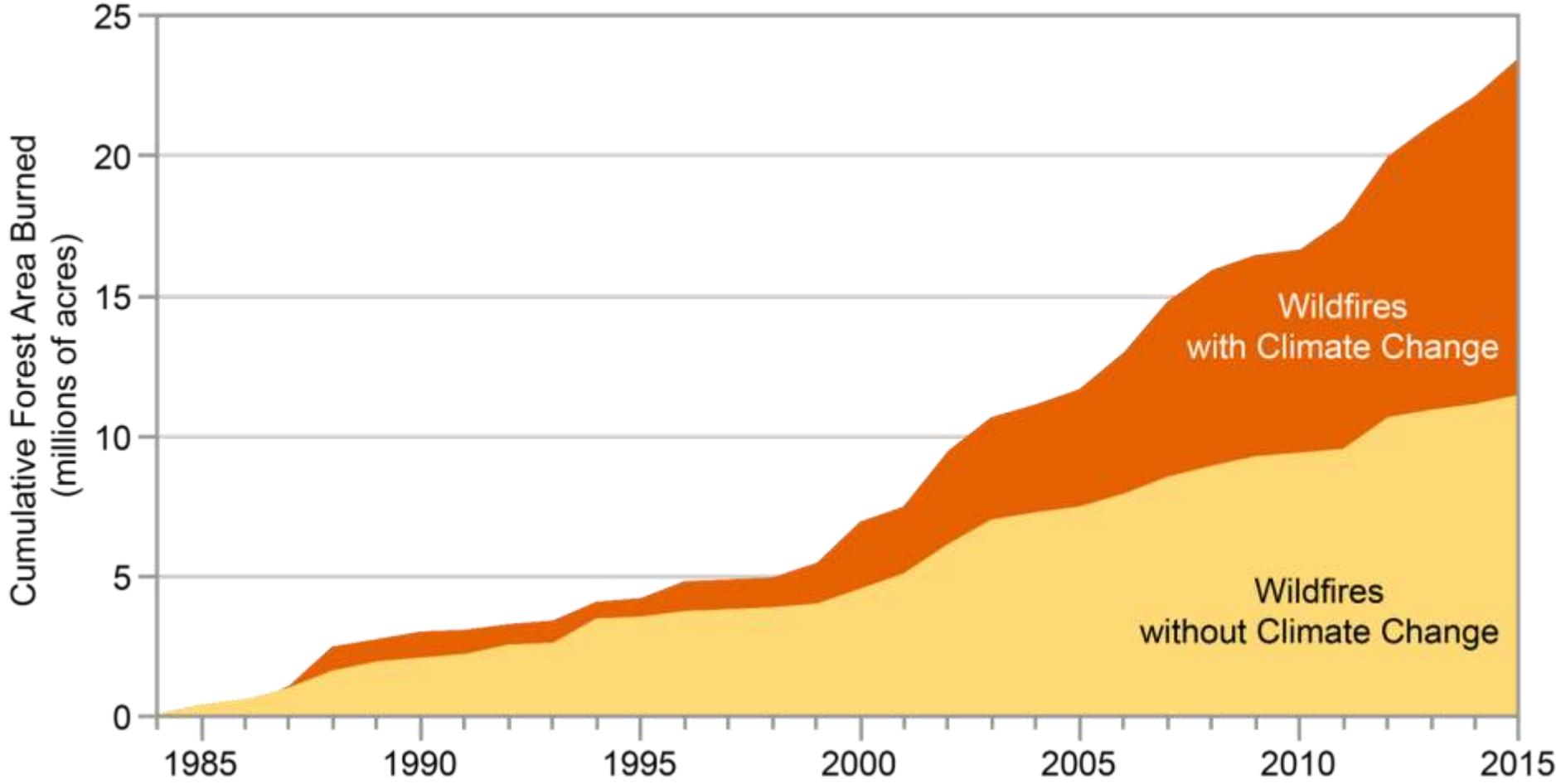
How well we **prepare** for the changes we've set in motion



**Water supply and flood management practices need to be revised to account for our changing climate future.**



# Natural Variability: Natural, Human & Climate Drivers



The cumulative forest area burned by wildfires has greatly increased between 1984 and 2015, with analyses estimating that the area burned by wildfire across the western United States over that period was **twice what would have burned had climate change not occurred.**

Source: 4th National Climate Assessment Southwest Chapter, 2018; Abatzoglou & Williams, 2016

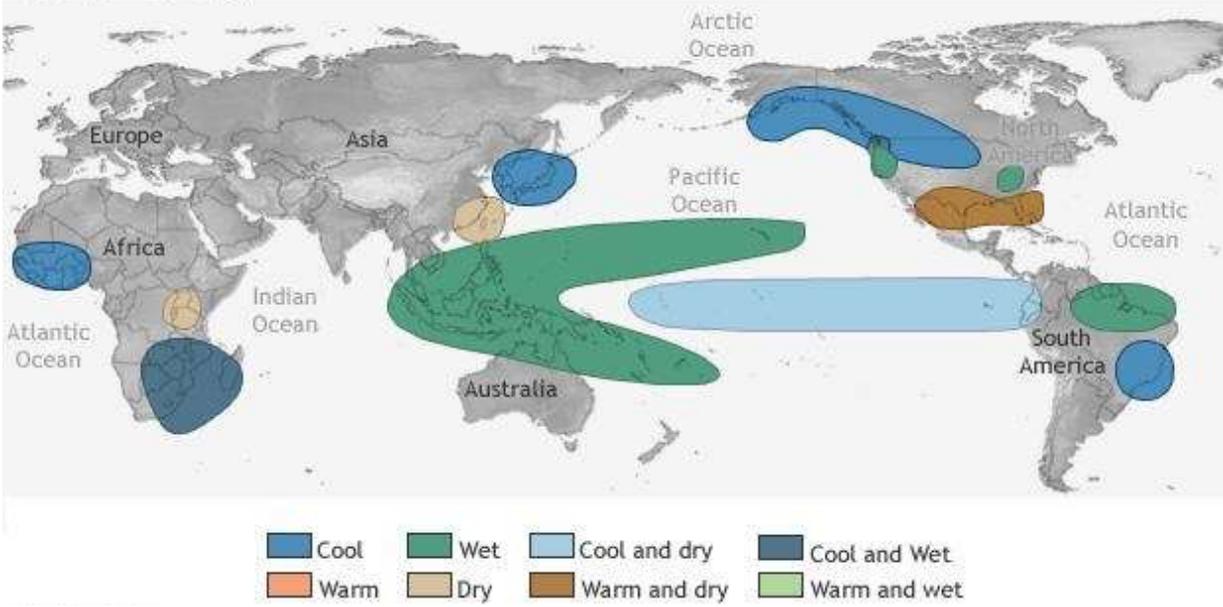
# Natural Variability:

Natural variability is also influenced by processes internal to the climate system that arise, in part, from interactions between the atmosphere and ocean, such as El Niño/La Niña events.

Sun, volcanic eruptions, and changes in the orbit of the Earth around the sun exert an external control on climate variability.

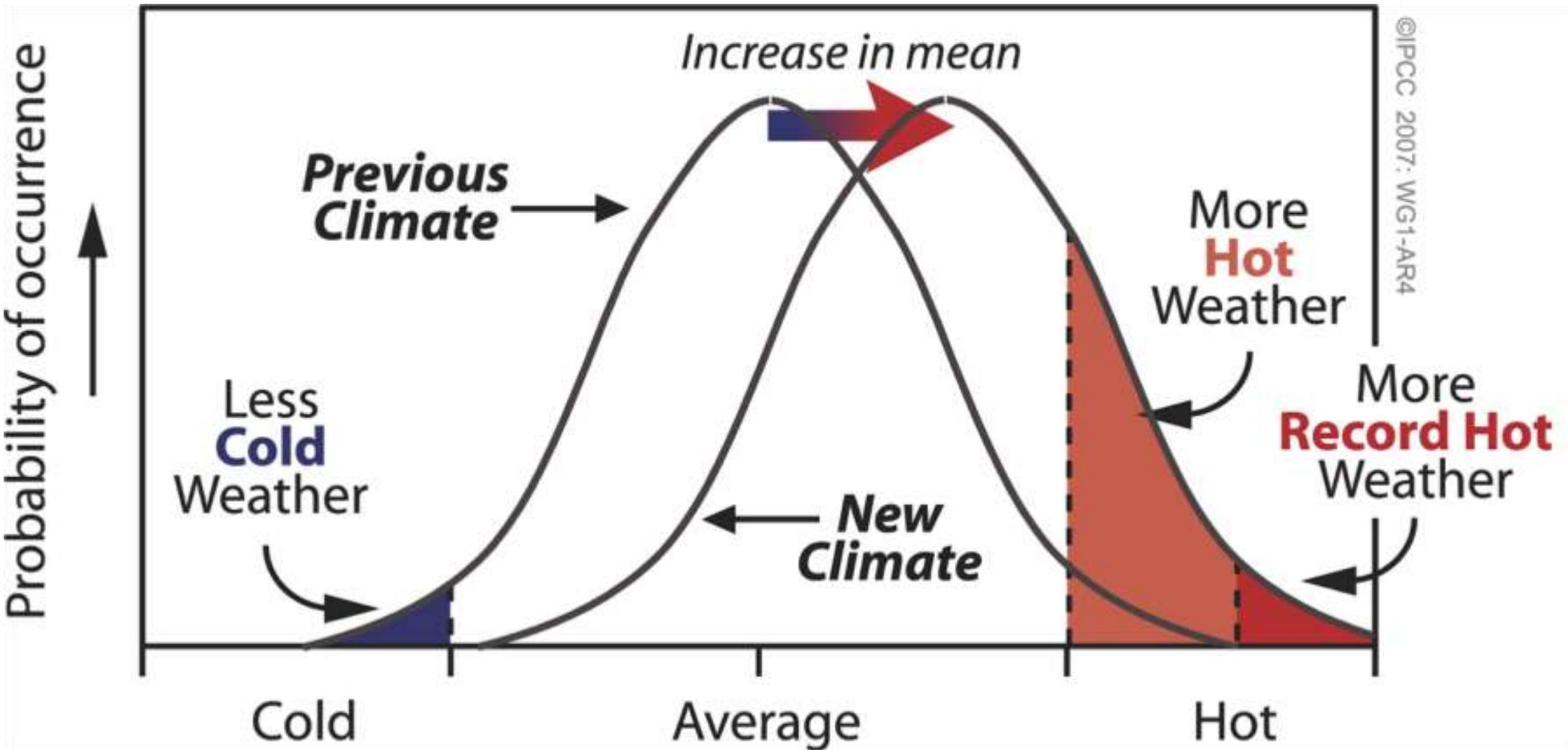
## LA NIÑA CLIMATE IMPACTS

December-February



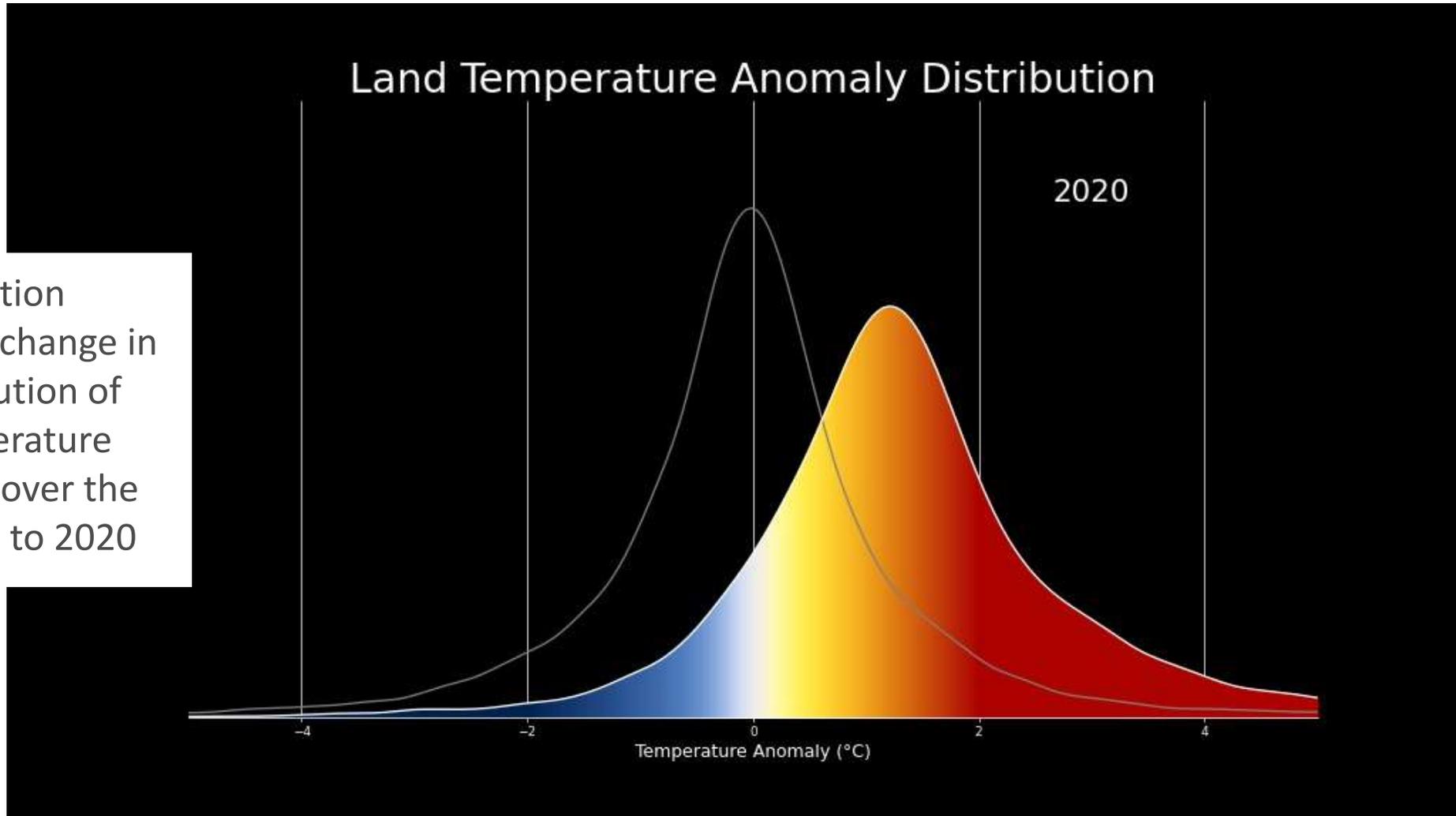
Source: climate.gov; Roesch et al., 2006)

# Climate change induces a shift in means & extremes



# NASA Animation

This animation shows the change in the distribution of land temperature anomalies over the years 1951 to 2020



# Physical Process Representations-

*Do climate (and other) models actually “work”?*

*We don't have a crystal ball...*



*but, we do have useful tools in our toolbox...*

# Climate models provide critical information about our future climate

## Climate Models

- Are the **best source of information** we have to understand future climate;
- Provide **projections**, not predictions;
- Have important **limitations & uncertainty**.

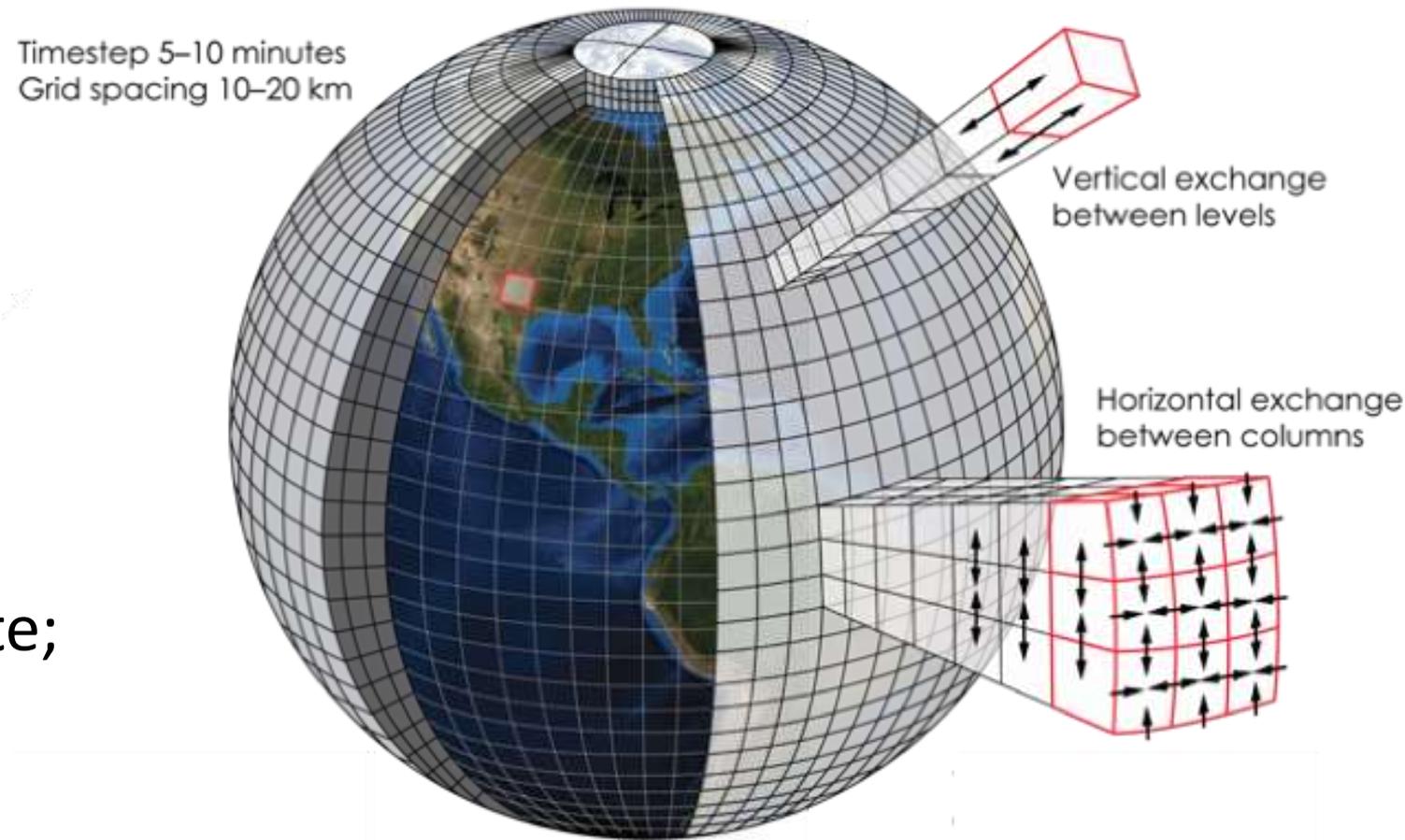


Image Modified from K. Cantner, AGI

# Models can produce information at a range of scales and for different time periods & emissions scenarios.

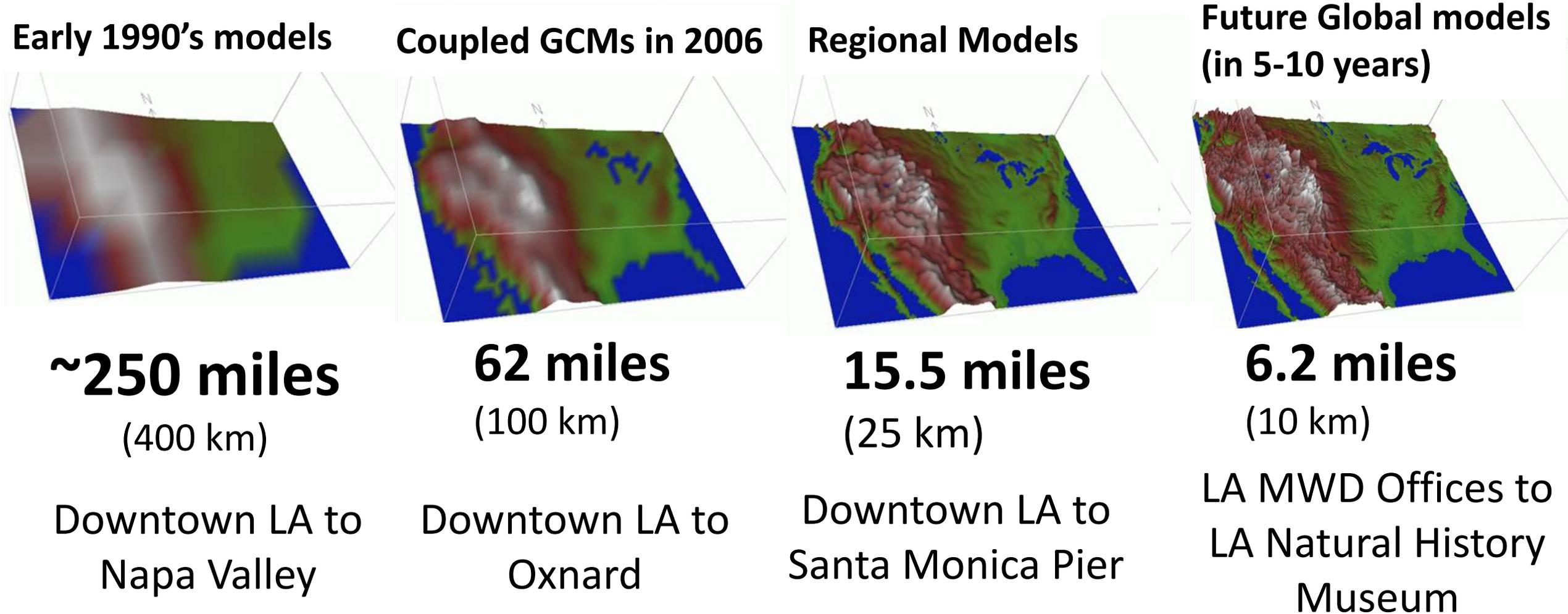
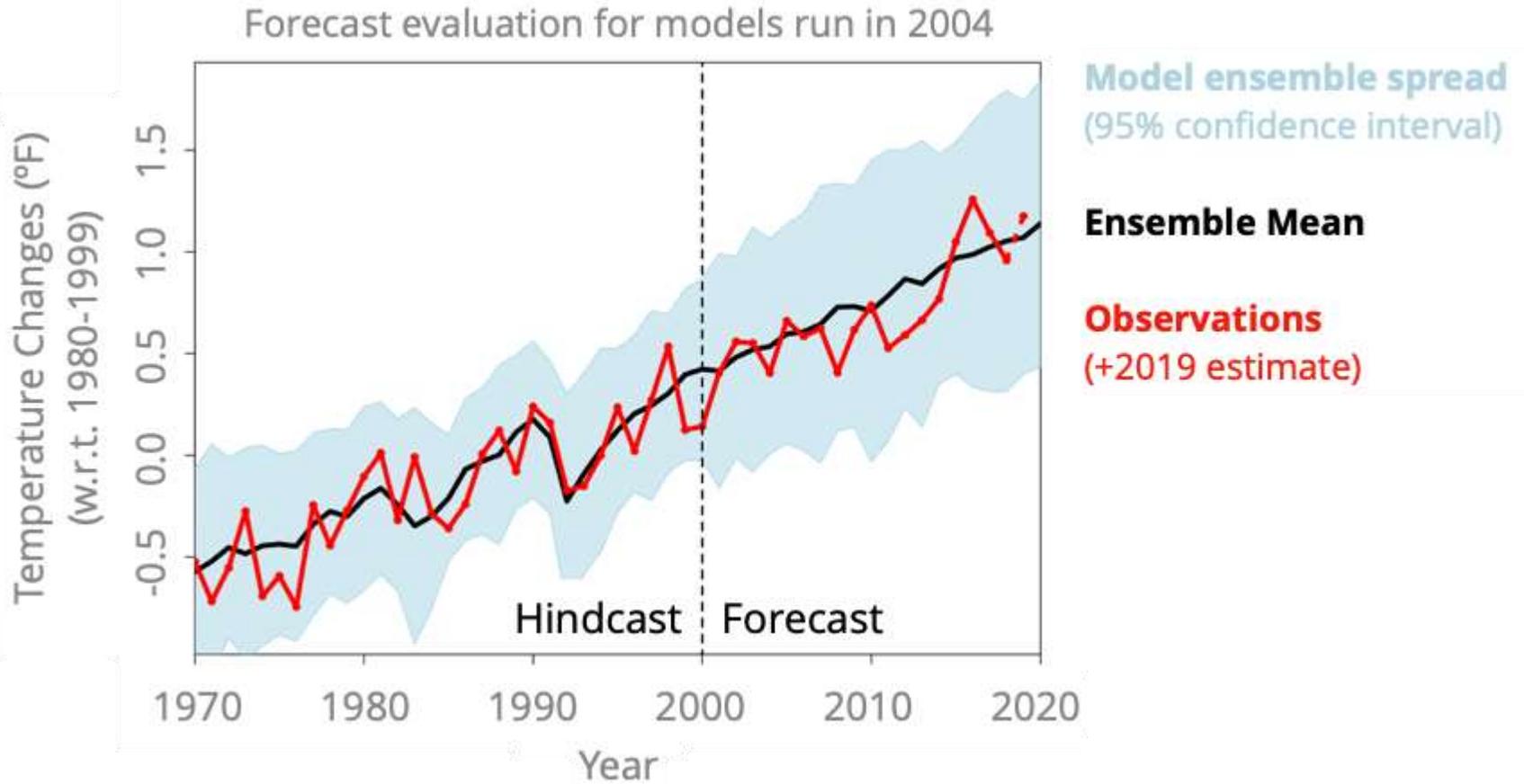


Figure modified from NCAR

# Have climate model projections been reliable?

**Hindcasts:** compare model predictions to recorded climate observations. If climate models are able to successfully *hindcast* past climate variables (e.g. temperature), this gives us more confidence in the model. *The physics of the model drive the change, rather than the historical data.*

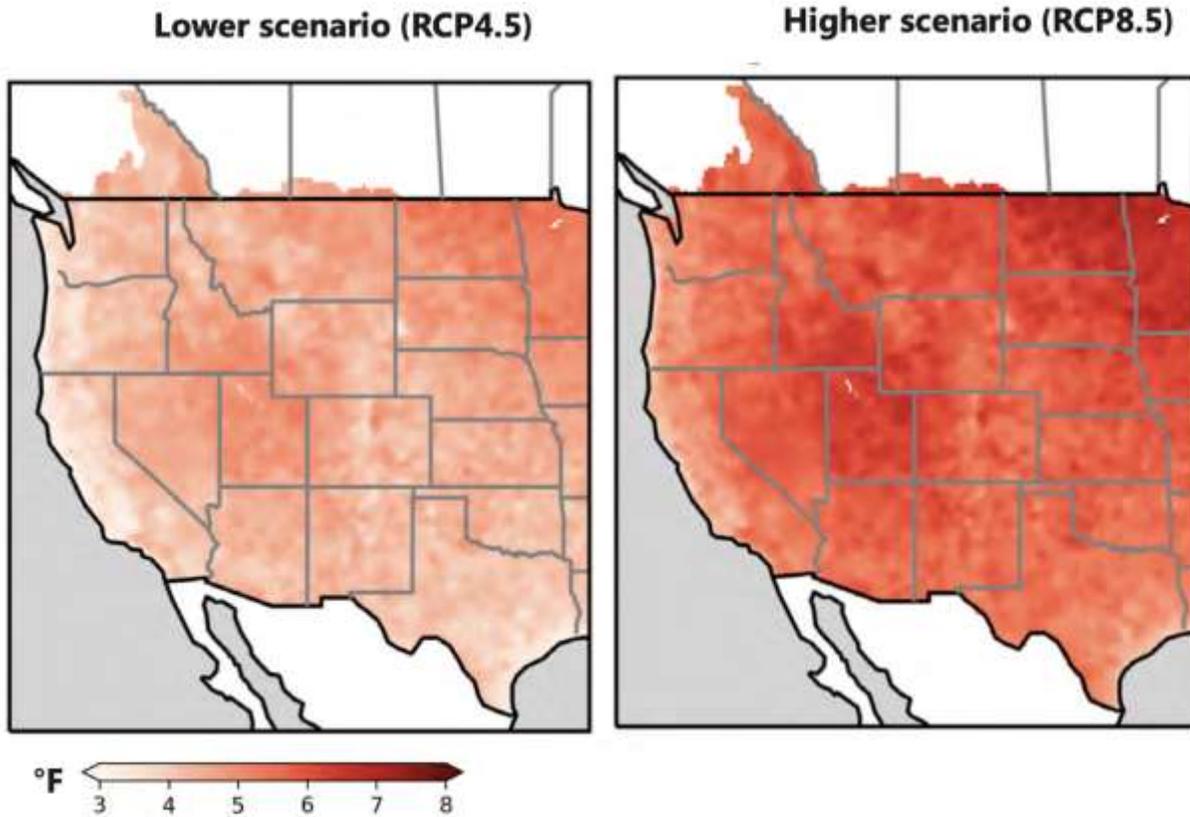


IPCC model projections from 2004 **compare well** with observed temperature change from 2004-2019

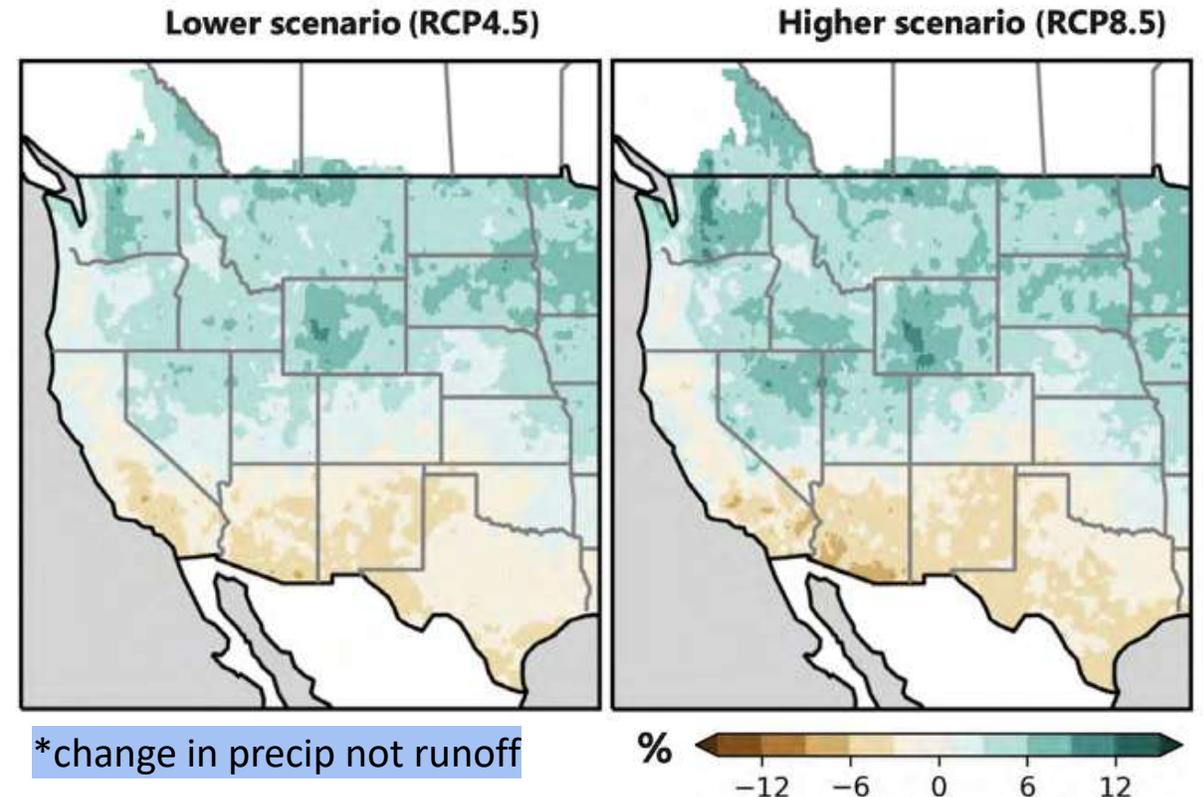
From NASA: <https://climate.nasa.gov/news/2943/study-confirms-climate-models-are-getting-future-warming-projections-right/>

# Examples of projection data for 2040-2069

## Temperature Projections



## Precipitation Projections\*



Maps show average change in temperature and precipitation across a two emissions scenarios for the period 2040 - 2069 relative to 1970 - 1999 using the **LO**calized **C**onstructed **A**nalogs (LOCA) downscaling approach.

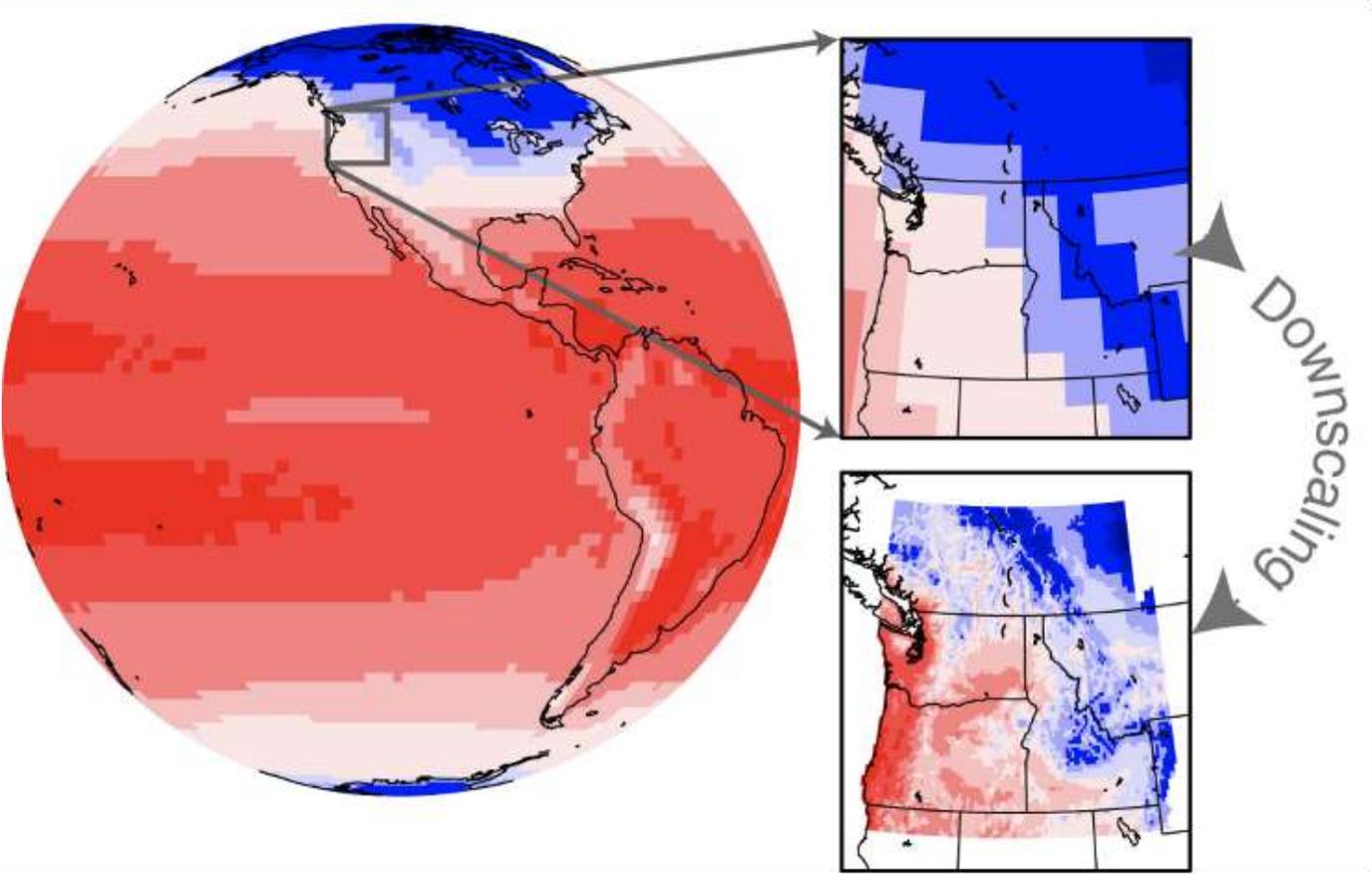
**These maps convey an average across 32 global climate models.**



*Part II:  
Going from Global  
to Local*

Dr. Julie Vano

# Going from Global to Local

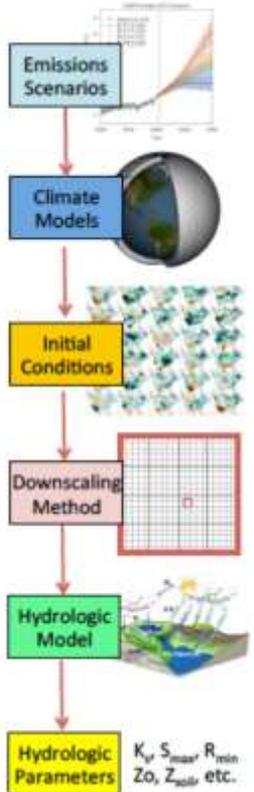


Translating global information for regional water management

*Figure courtesy of UW Climate Impacts Group*

# Multiple Ways to Evaluate Future Changes

## Climate impacts modeling chain



Clark et al. 2016; connect models in a chain

## Stochastic hydrology

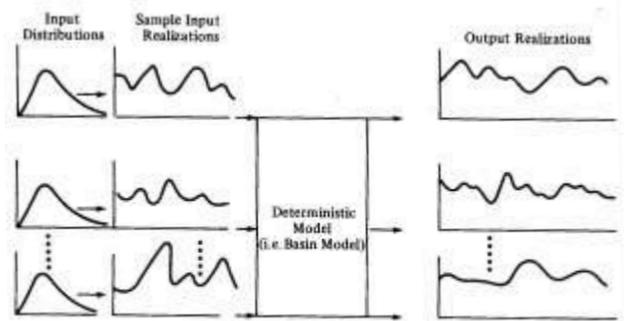
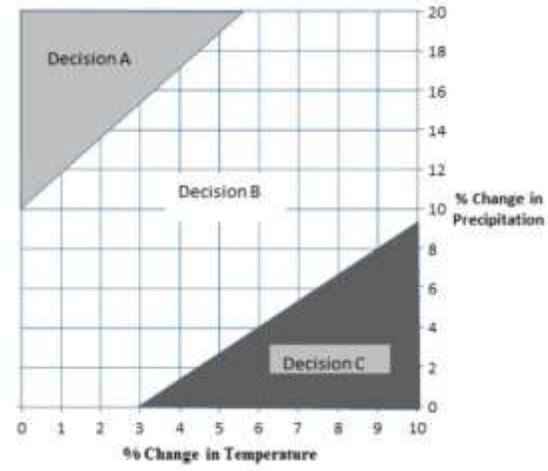


Figure 1.3 Concept of Monte Carlo experiments. Bras and Rodriguez-Iturbe, 1985; generate synthetic timeseries using statistics from the past

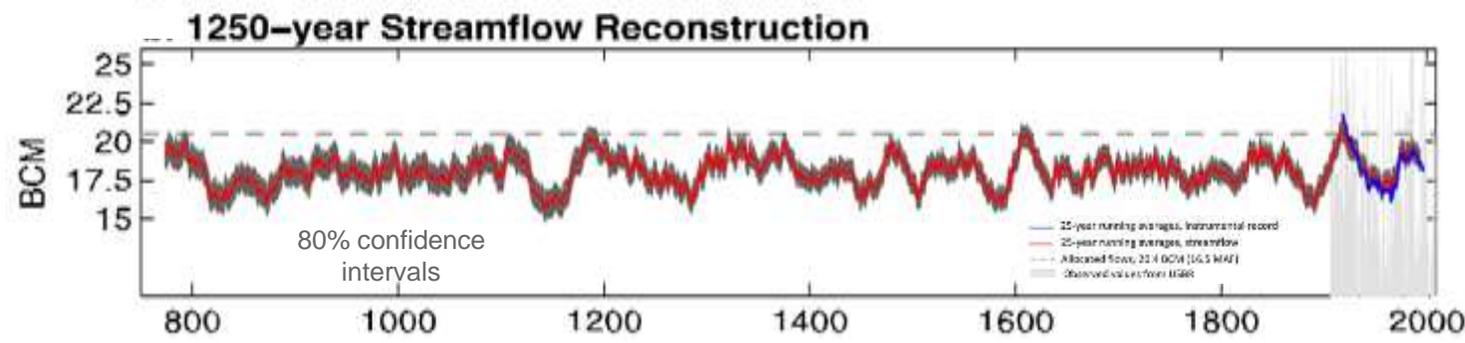
## Climate-informed vulnerability analysis



Brown et al., WRR, 2016; explore system vulnerabilities with perturbations

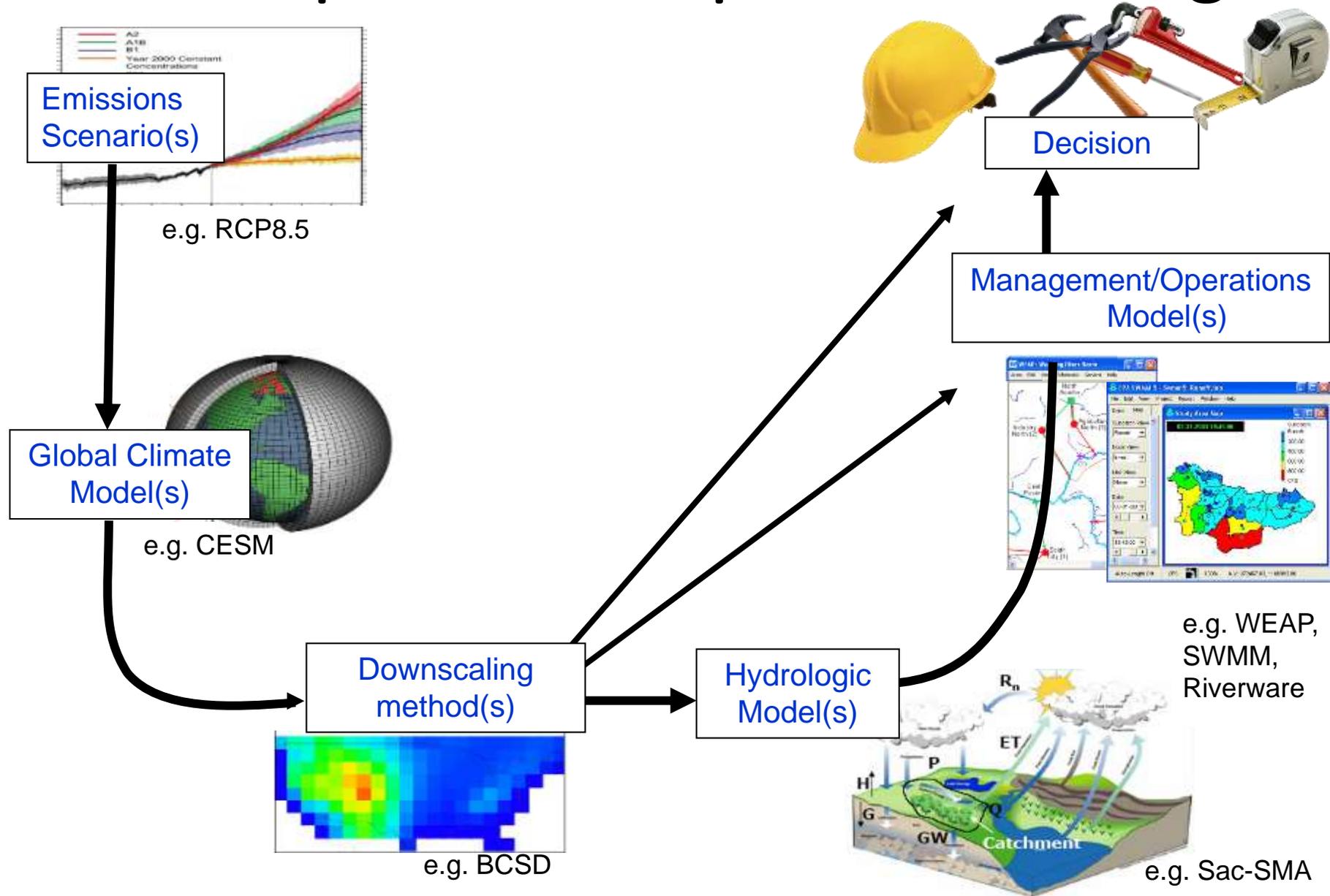
**\*and others**

## Paleoclimate studies



Vano et al., BAMS, 2016; generate timeseries using reconstructions of the distant past

# Classic “Top-down” Impacts Modeling Chain



# Downscaling methods

Ways to make global climate information more locally relevant



statistical methods  
(computationally  
efficient)

hybrid  
techniques



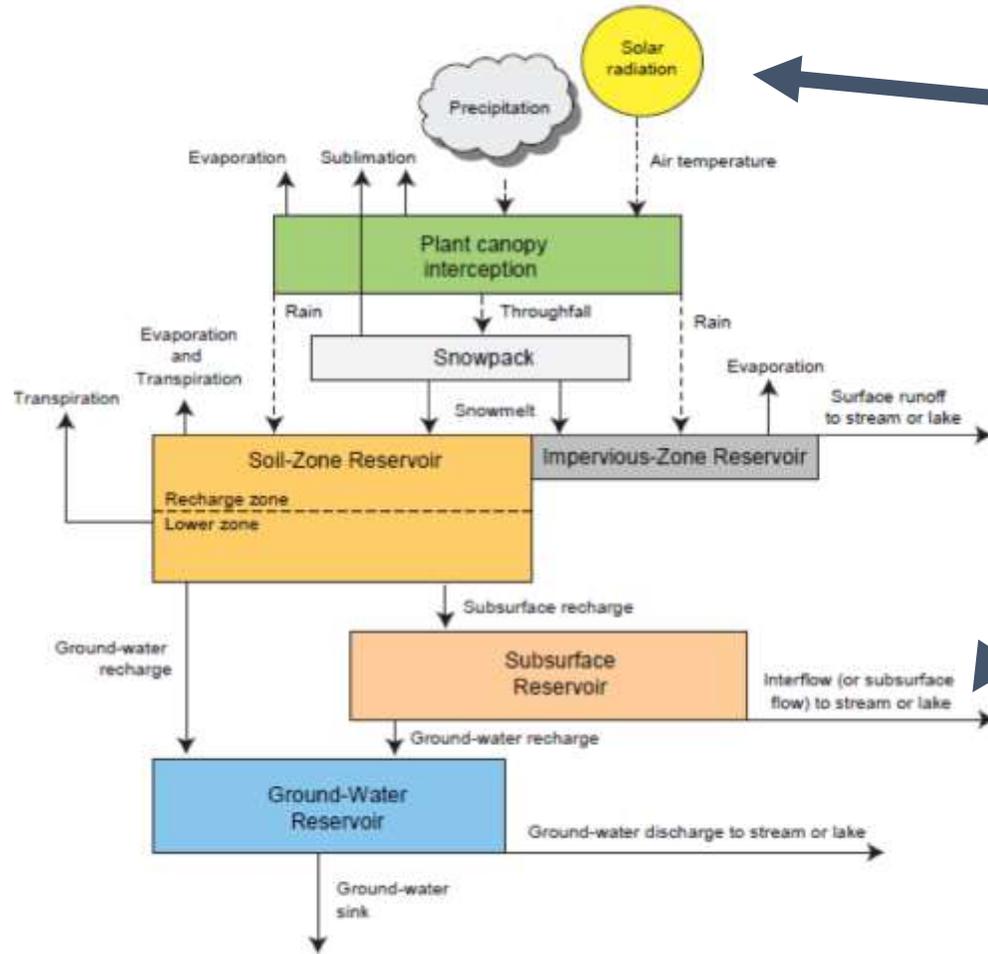
high-resolution regional  
climate models  
(captures local dynamics)

## Tradeoffs:

- Physical realism vs. computational cost
- Single realization vs. ensemble
- Explicit physics/feedbacks vs. simplicity

*Increasing methodological complexity in downscaling methods*

# Hydrologic models



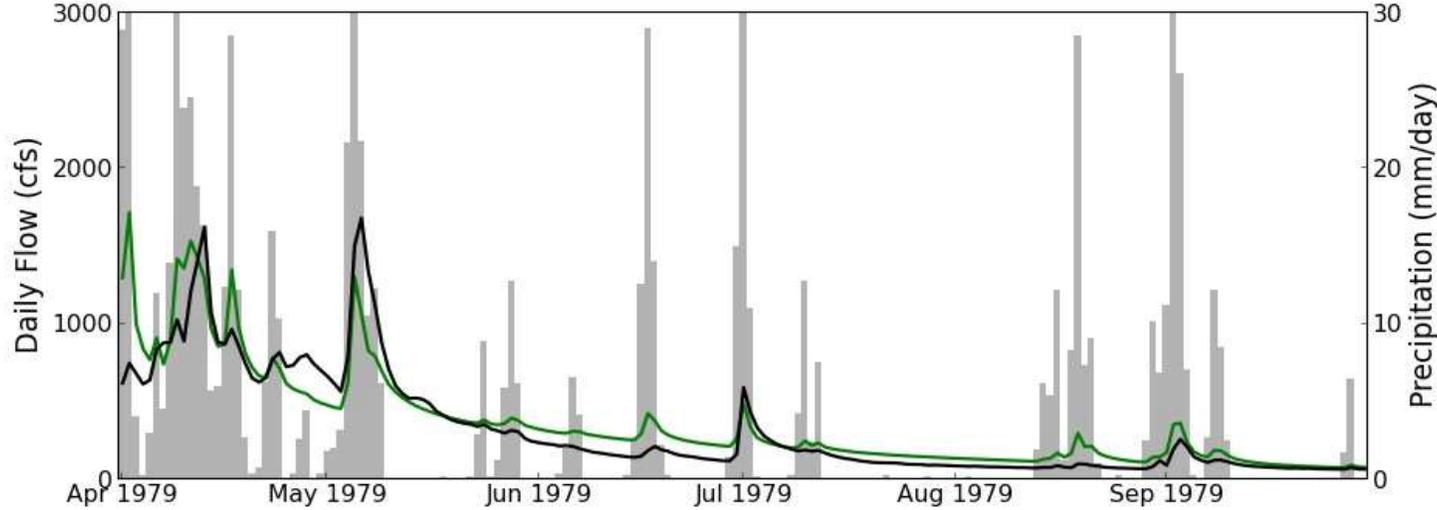
**We have:** precipitation, temperature, other atmospheric values

**We want:** streamflow (highs, lows), water demand from vegetation, water temperature

Hydrology models represent energy and water fluxes in watersheds, encapsulate our best understanding

Fill gaps since measurements unavailable in most places

# Hydrologic models



**Without hydrologic model:**  
only had gray bars  
(precipitation values) to  
estimate streamflow

**With hydrologic model:**  
able to use precipitation  
values to estimate streamflow,  
particular useful to  
understand future projections





# No model is perfect

*“The accuracy of streamflow simulations in natural catchments will always be limited by simplified model representations of the real world as well as the availability and quality of hydrologic measurements.” (Clark et al., WRR, 2008)*

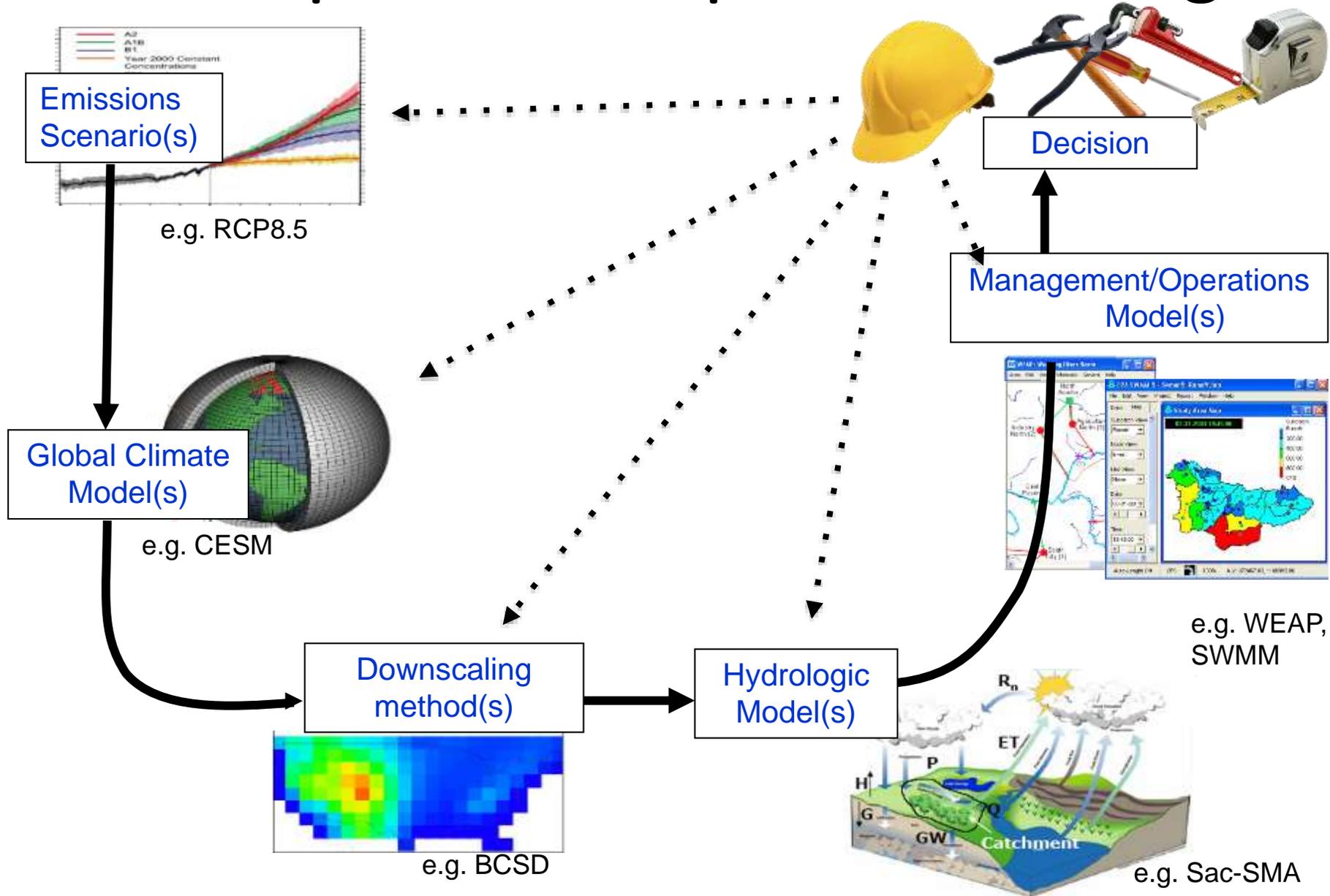
## **Do not expect perfect results,**

- Not prediction, but a tool to test how system responds (what if scenarios)

## **BUT we can make better choices...**

- Seek simple yet defensible (do not need a Cadillac)
- Be aware of models' shortcomings
- Use a range, not a single model outcome

# Revised “Top-down” Impacts Modeling Chain



# Questions to determine an appropriate models



- Where is the area of interest?
- How large of an area?
- What is the impact of interest?
- When in the future?
- Does event sequencing matter?
- What type of climate uncertainty is important?
- What is available?

Different impacts often require different approaches

Figure source: Courtney Mendar (<http://www.courtney-mendard.com>)



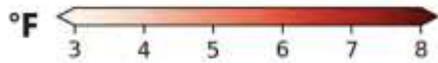
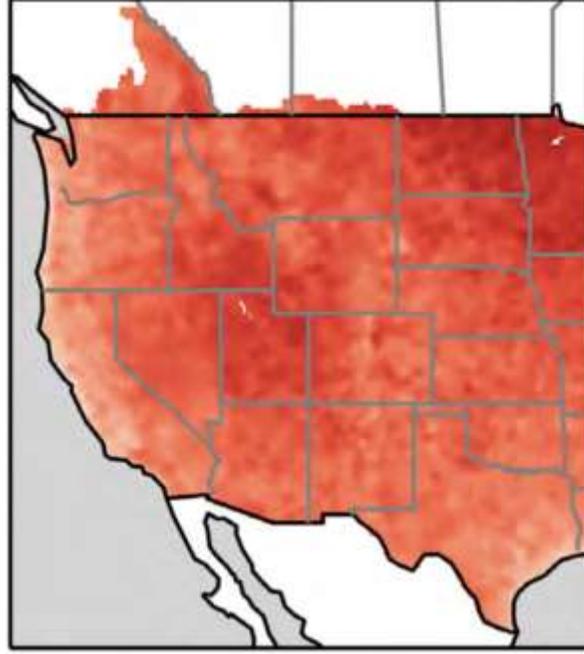
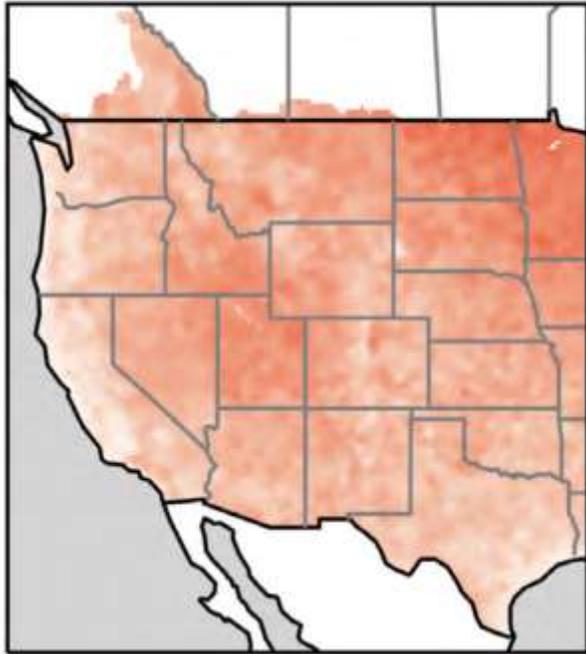
# Regional Hydrologic Changes

## Temperature Projections

## Precipitation Projections\*

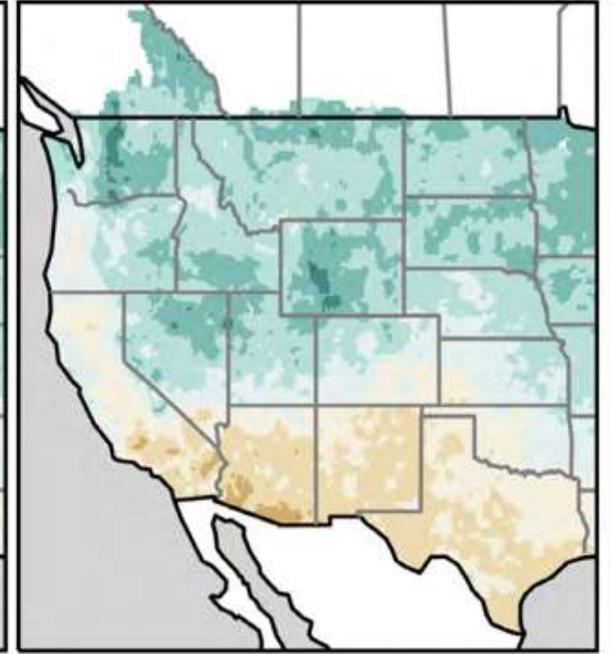
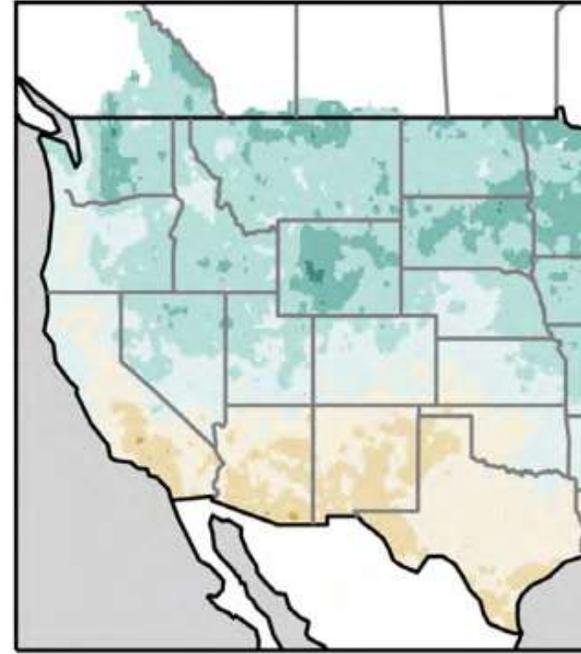
Lower scenario (RCP4.5)

Higher scenario (RCP8.5)

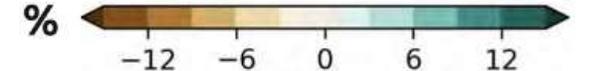


Lower scenario (RCP4.5)

Higher scenario (RCP8.5)



\*change in precip not runoff



Maps show average change in temperature and precipitation across a two emissions scenarios for the period 2040 - 2069 relative to 1970 - 1999 using the **LO**calized **C**onstructed **A**nalogs (LOCA) downscaling approach.

**These maps convey an average across 32 global climate models.**

Source: [Reclamation's 2021 SECURE Water Act](#)



## *Part III: Regional Hydrologic Changes*

Brad Udall

**Additional slides may be added**

# Climate Change is Water Change

Earth's Climate and its Water Cycle are intimately connected  
Heat-Driven Water Cycle will change in profound ways

More Evaporation + More Precipitation

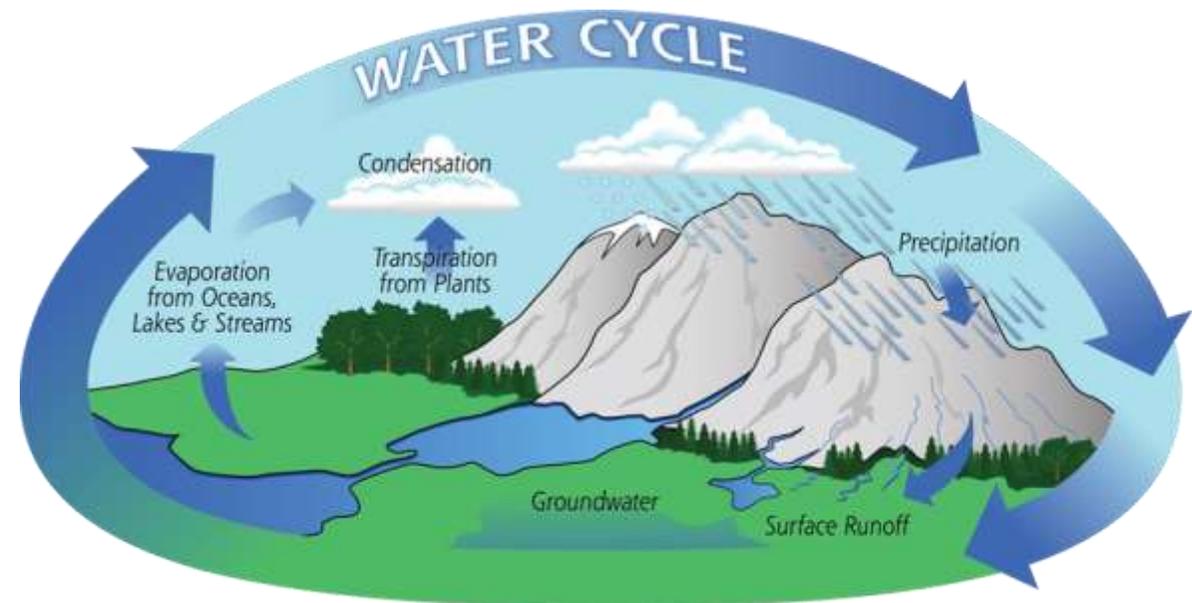
More Intense Precipitation (when it does)

More Floods + More Droughts

Snow Dependent Basin Changes

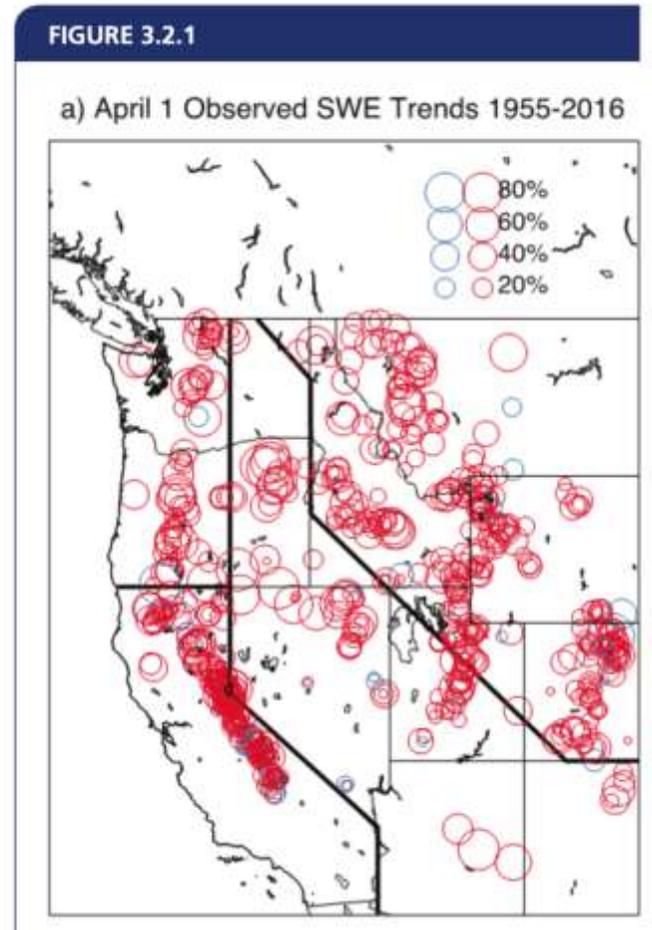
Regional Winners and Losers

Water Quality Declines



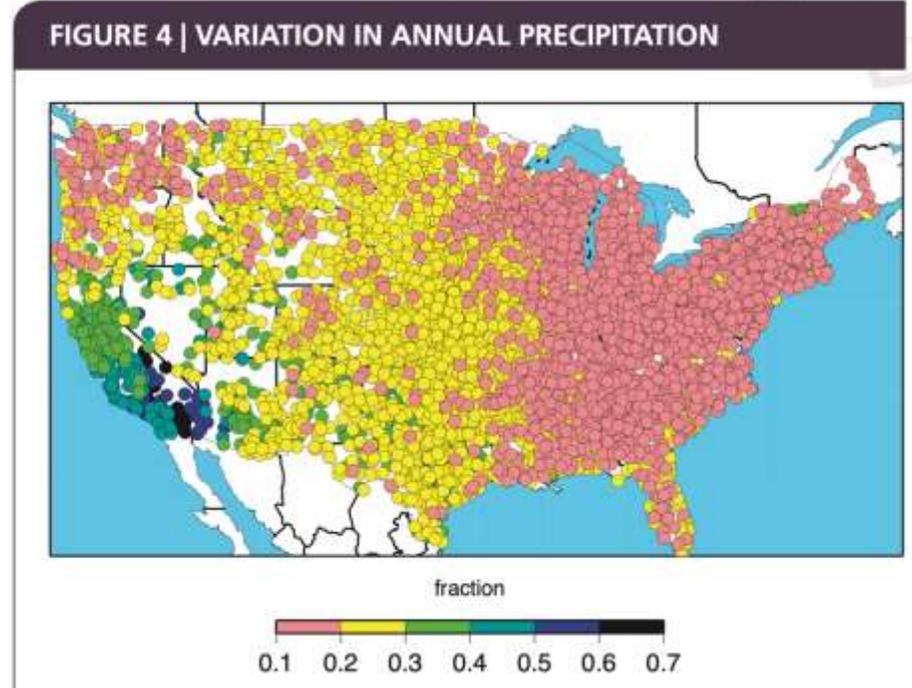
# Common CA+CRB Hydrologic Changes

- Earlier Runoff
- More Rain, Less Snow
- Declining April 1 Snow Water Content
- Lower Late Season Flow
- Declining Water Quality
- More Year-to-Year Variability
- Wide Range of Future Annual Flow Volumes



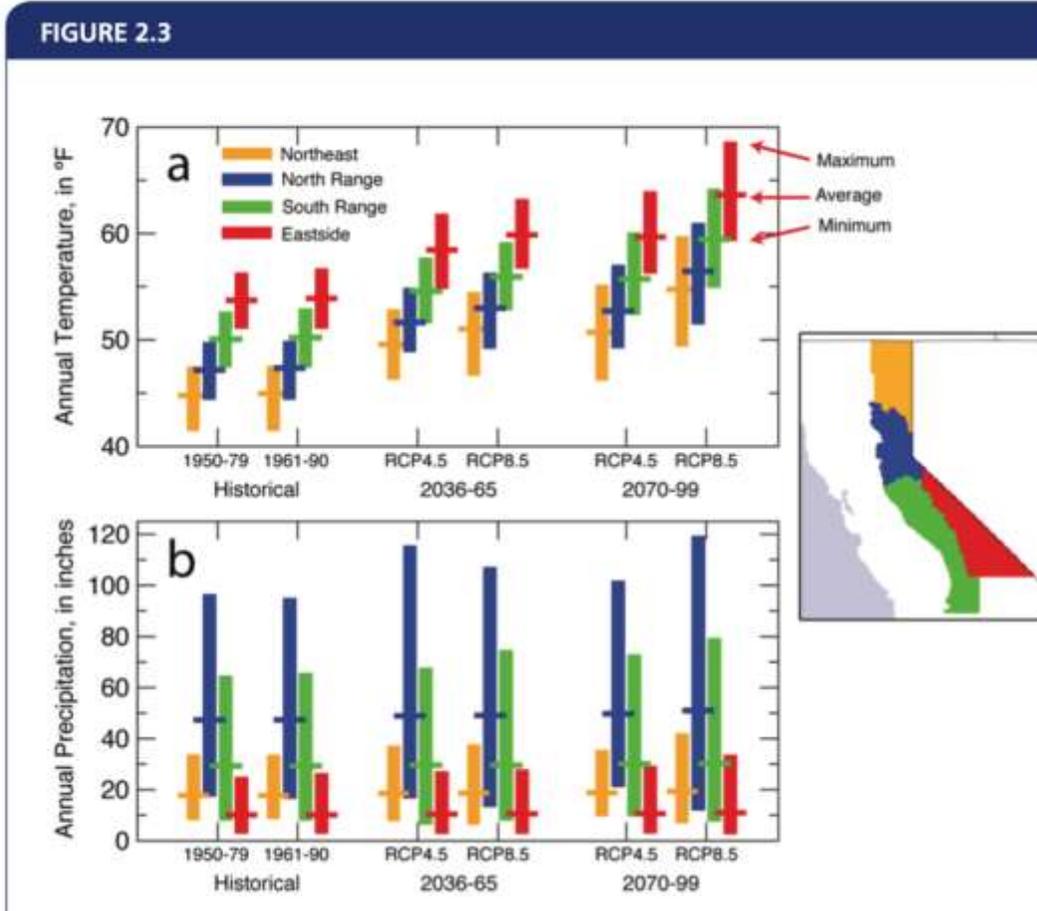
# California Specific Issues

- Climate Issues
  - Mediterranean Climate
  - Atmospheric Rivers
- Policy / Management Issues
  - Flood Control vs Conservation Storage
  - Bay Delta

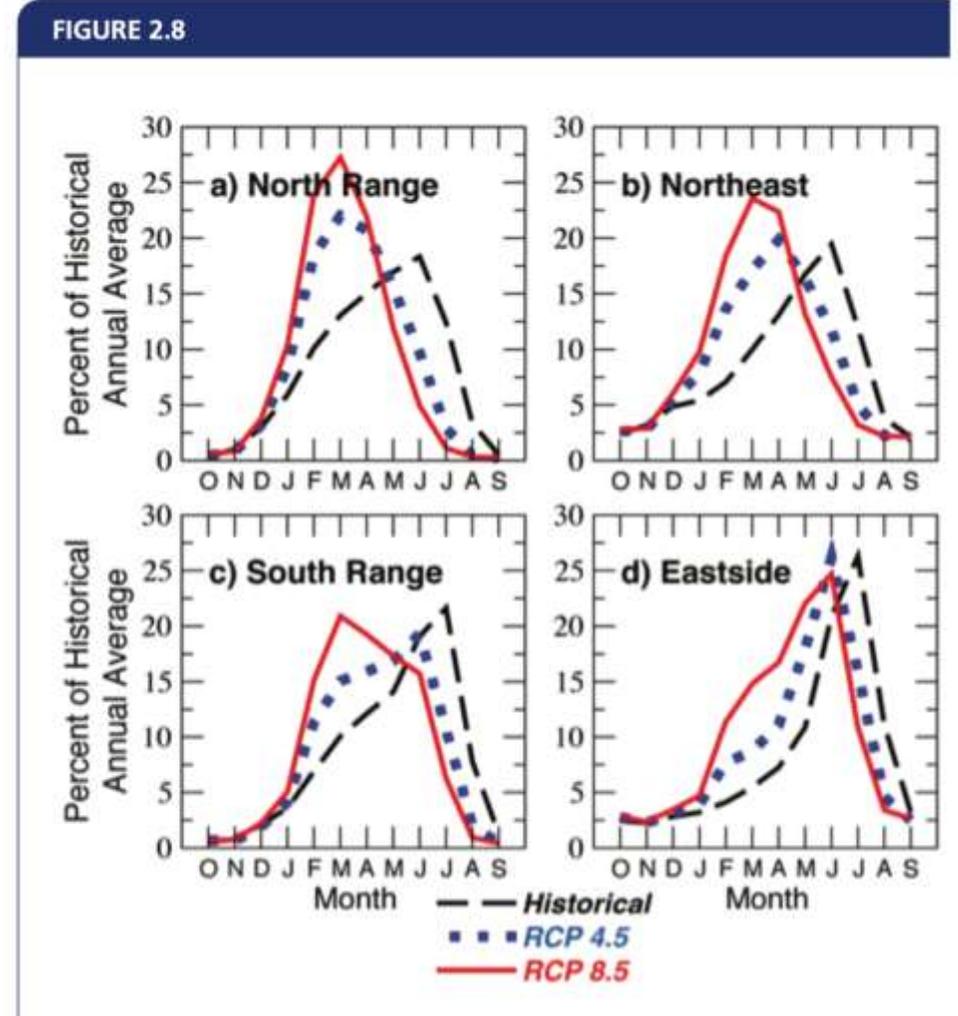


Nationally, California has the most variable precipitation. Years range from ~50% to 200% of normal unlike 10-20% of normal elsewhere.

# California Future Temp, Precip, Flows



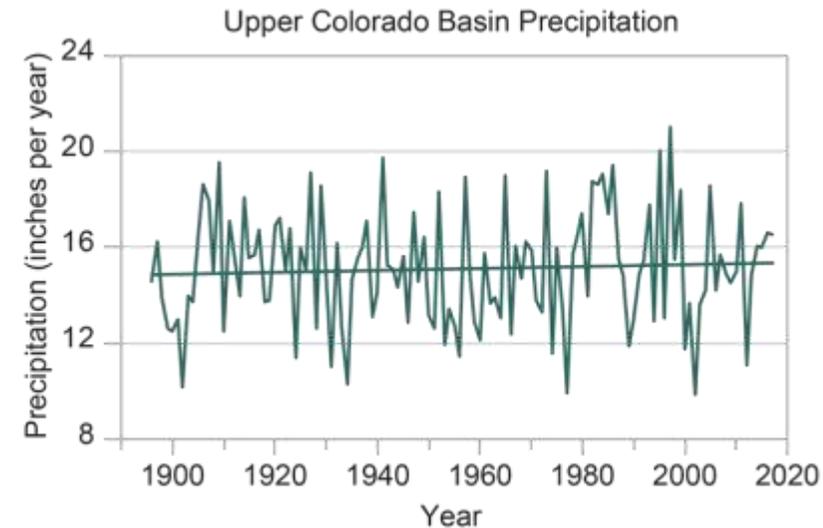
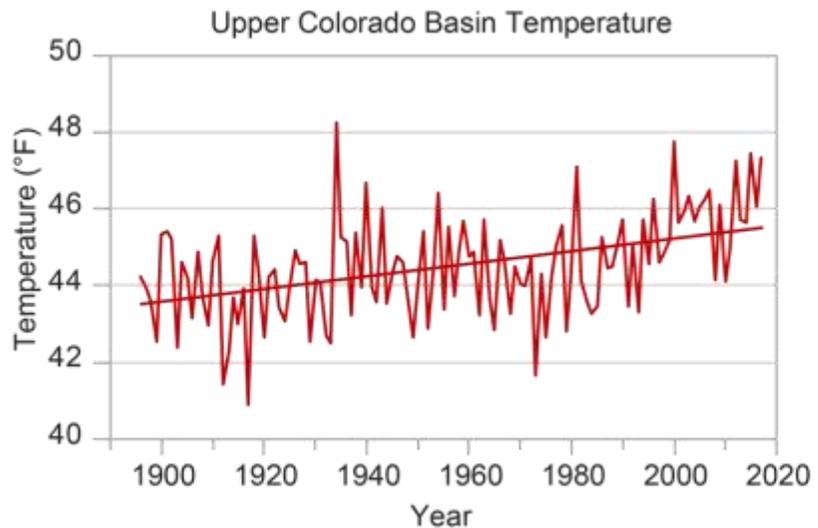
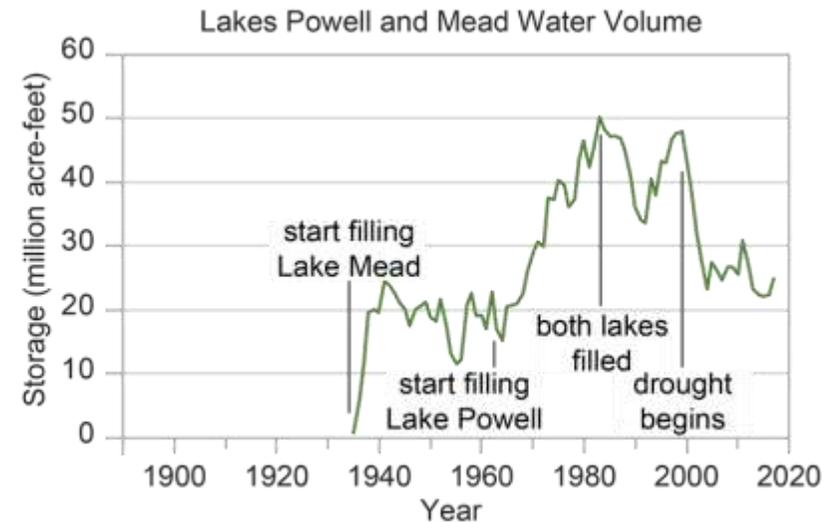
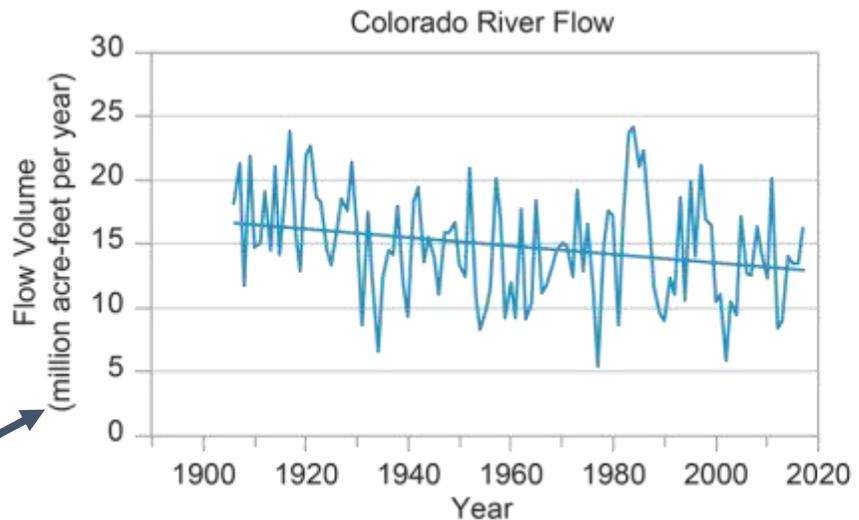
Changes Temperature and Precipitation for Sierra Regions



Changes in Annual Hydrographs for Sierra Regions

# Colorado River 1900 - 2020

Since 2000, drought that was intensified by long-term trends of higher temperatures due to climate change has reduced the flow in the Colorado River



Source: 4th National Climate Assessment Southwest Chapter, 2018

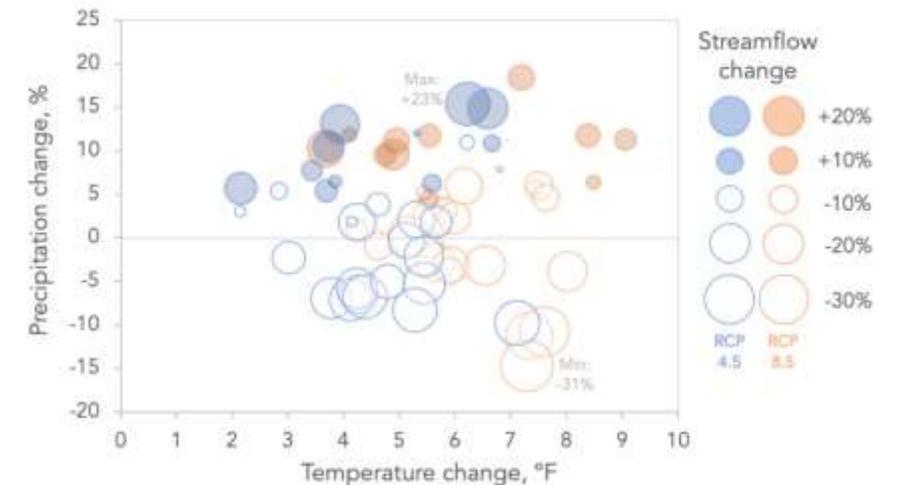
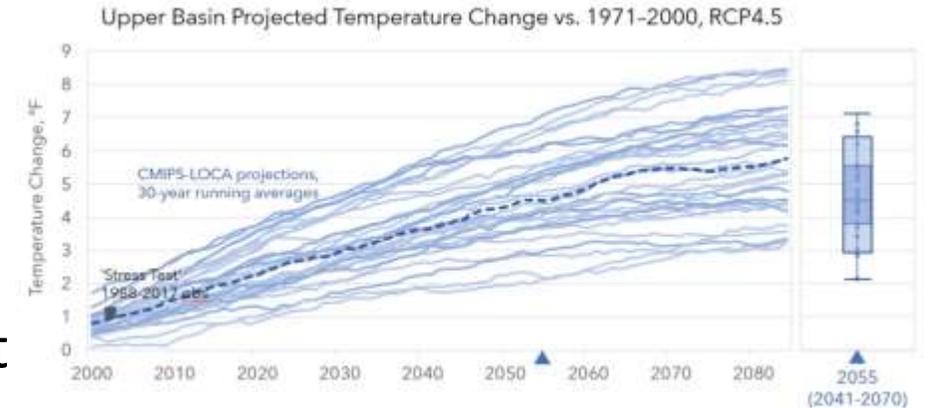
# Colorado River Specific Issues

- Climate Issues

- Temperature-induced Flow Declines
- Ongoing 20-year Drought (-20% flow)
- Projected North - South Precipitation Gradient
- Uncertain Future Precipitation
- Megadrought Potential

- Policy / Management Issues

- Colorado River Compact Interpretations
- 2026 Interim Guidelines Negotiations
- Salton Sea



Future Colorado River Streamflow Change at mid-century. Two-thirds show declines



## *Part IV: Climate Change and Water Demand*

Heather Cooley

**Additional slides may be added**

# Climate Change and Water Demand

## Climate Drivers



Direct



Direct



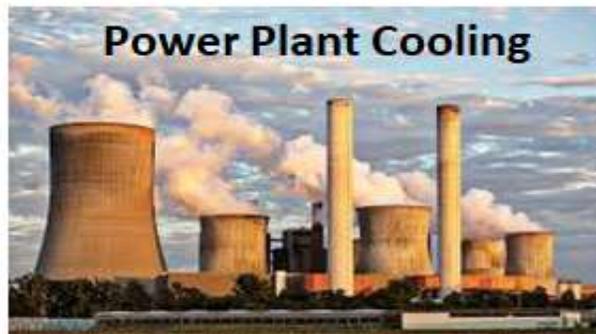
Direct



Direct & Indirect



## End Uses of Water

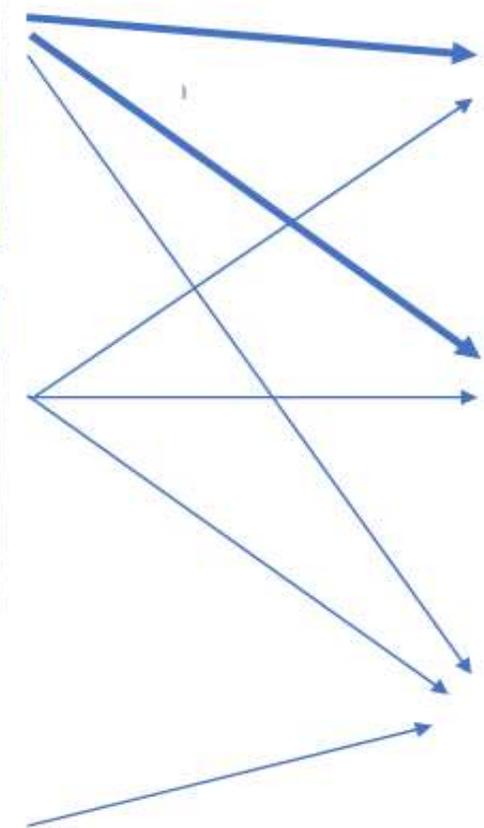


## Water Demand Sectors

Single-Family Residential

Multi-Family Residential

Commercial, Industrial, and Institutional





*Part V:  
What Do We Plan  
For?*

Brad Udall

# Prudent Planning and “Reasonable Worst Case Future”

What should we be modeling for?

- Ultimately a political / policy decision, informed by science
- Our idea: “Reasonable Worst Case Future”
- Definition: Future that is both politically possible to plan for, and climatologically possible without being on the extreme tail

What science should inform that decision?

Known Science

- Past 21 years of flows, precipitation, and temperature
- Temperature impacts on flow
- Future temperature projections
- All point to declining flows

Unknow Science – mostly precipitation

- Low confidence in models that suggest increases
- Might save the day, but is it prudent to count on this?
- Could also go down – see Hoerling et al, 2019

Ultimately a Policy Decision of What is Prudent and Possible to Plan For

Balancing of Politically Possible and Climatologically Problematic

- Some futures too hard to plan for politically and too uncertain climatologically
- Prudence dictates modeling using flows less than last 21 years but how much less?



# *Questions*

*Questions submitted prior to the workshop pertaining to charge questions*



## *Other Questions*

*Submit questions through chat (preferred) or raised hand function*



## *Conclusion*

*Facilitator summary*

*Staff Wrap up and next steps*





## *Expert Statement: Question 1*

*What major components contribute to the range of future climate outcomes?*



## *Expert Statement: Question 2*

*How do we apply global climate model outputs that examine climate change over a long timeframe to the shorter 25-year IRP planning horizon?*



## *Expert Statement: Question 3*

*What approaches or methodologies do you recommend for quantifying how climate change (e.g., changing temperatures and precipitation) affect Southern California and its imported supply watersheds?*



## *Expert Statement: Question 4*

*What models and downscaling techniques are available and appropriate for the relevant regions?*



## *Expert Statement: Question 5*

*If the models and downscaling techniques differ for each region, how do we ensure internal consistency within the analysis?*



## *Expert Statement: Question 6*

*What hydrologic changes are anticipated for the relevant regions?*



## *Expert Statement: Question 7*

*What are the important underlying climate change drivers that influence demands, and how do they affect demands in each of the three major demand sectors (single family residential, multi-family residential, commercial/industrial)?*



## *Expert Statement: Question 8*

*What other recommendations do you have for our planning?*