Colorado River Basin Climate and Hydrology
State of the Science

for the

Southwest Basin Roundtable
DCP/DM Workgroup

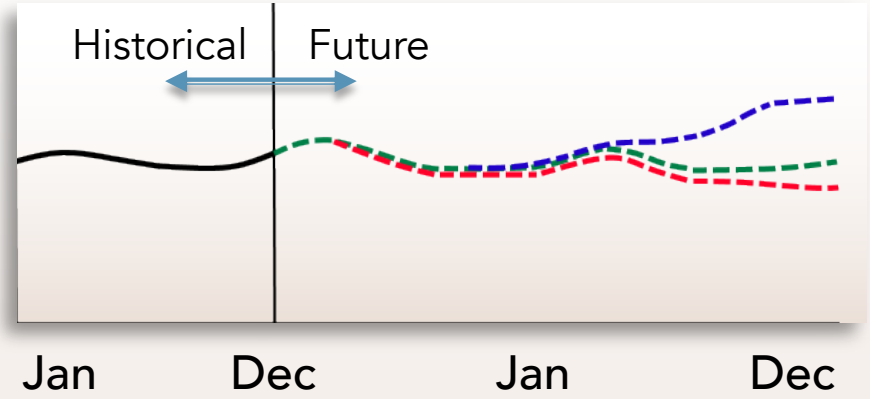
July 23, 2020

Jeff Lukas & Liz Payton

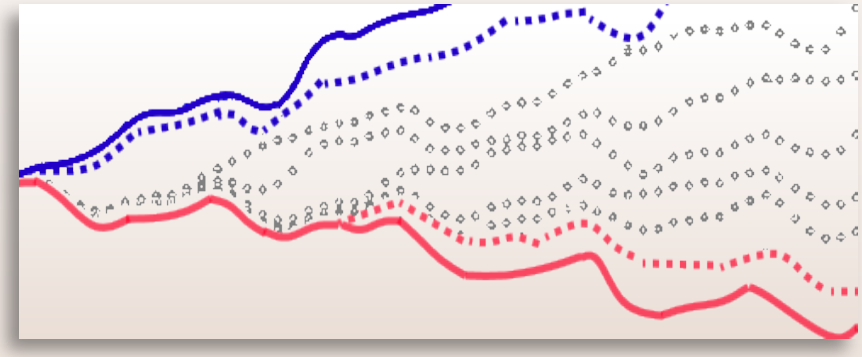
Western Water Assessment
CIRES, University of Colorado Boulder

The uncertain future

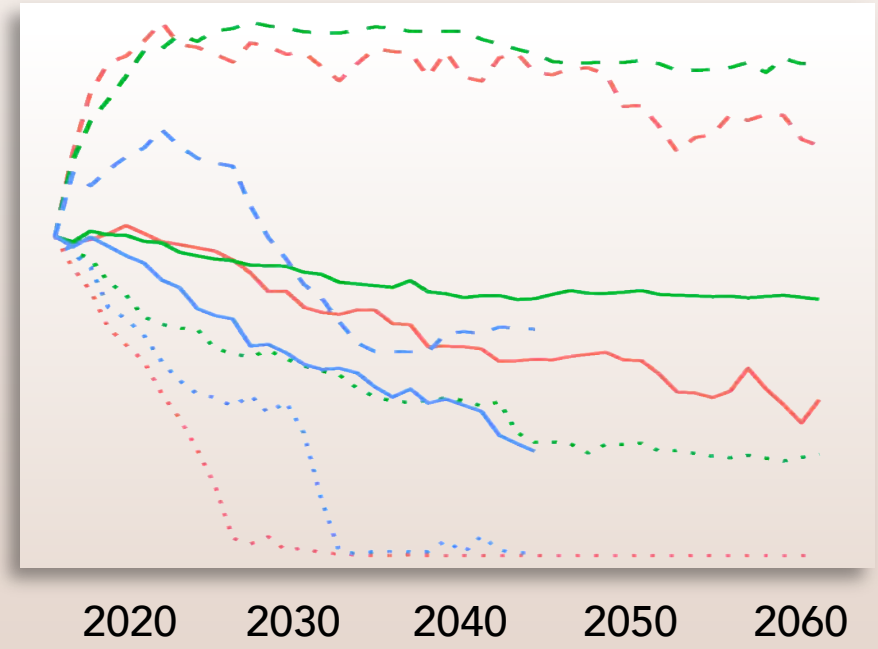
Short term (0-2 years)



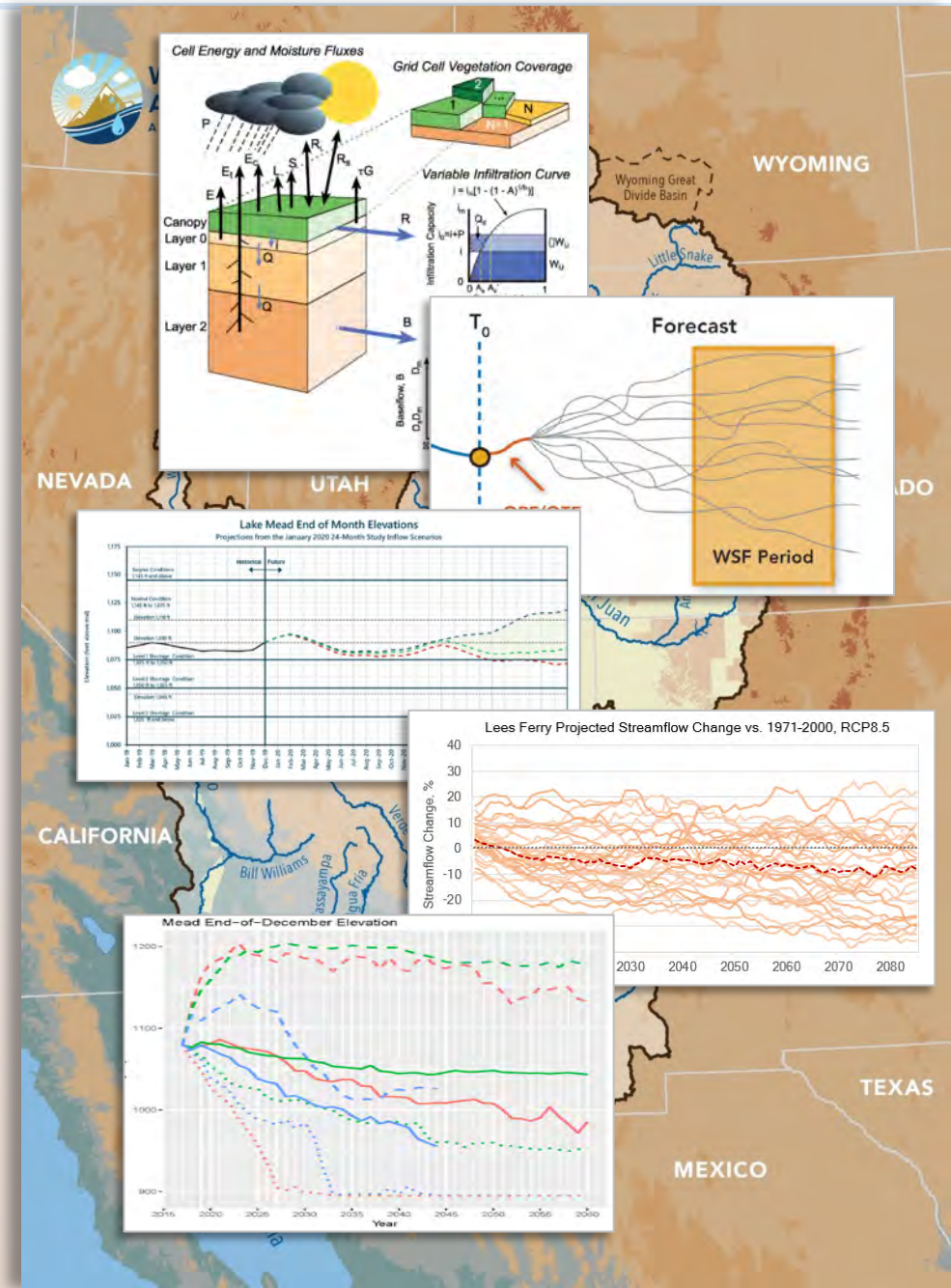
Mid-term (1-5 years)



Long-term (5-50 years)



The need for science synthesis



Sponsors

Reclamation
Arizona Department of Water Resources
California's Six Agency Committee
Central Arizona Water Conservation District
Colorado River District
Colorado Water Conservation Board
Denver Water
Metropolitan Water District of So. California
New Mexico Interstate Stream Commission
Southern Nevada Water Authority
Utah Division of Water Resources
Wyoming State Engineer's Office

Other assistance

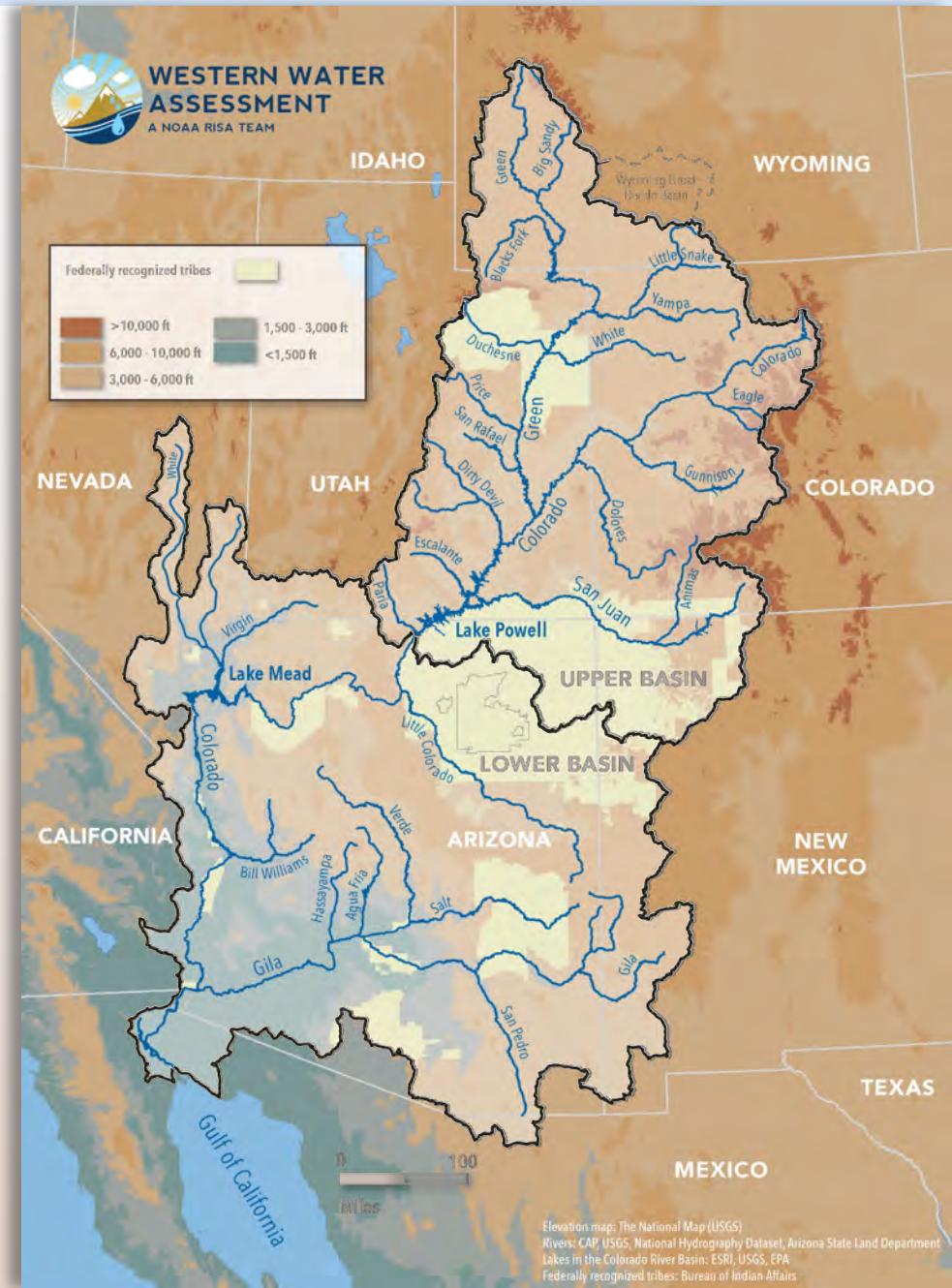
NOAA Colorado Basin River Forecast Center
U.S. Geological Survey

Objectives

- Synthesize research
- Convey knowledge gaps & uncertainties
- Prompt research ideas
- Inform funding priorities
- Describe Reclamation models
- Provide foundation for basin discussions

Boundaries

- No evaluation of water policy or management
- No explicit recommendations
- Focus on water supply



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Organization

Setting the stage

Volume I — Current understanding of the basin

Links in the modeling chain

Volume II — Primary data and models

Volume III — Short- and mid-term forecast tools

Volume IV — Long-term planning hydrology

Volume I — System models (24MS, MTOM, CRSS, et al.)

Chapter 2. Current Understanding of Basin Climate and Hydrology

- Current understanding of the basin
  - Primary data and models
    - Short- and mid-term forecast tools
      - Long-term planning hydrology
        - System models

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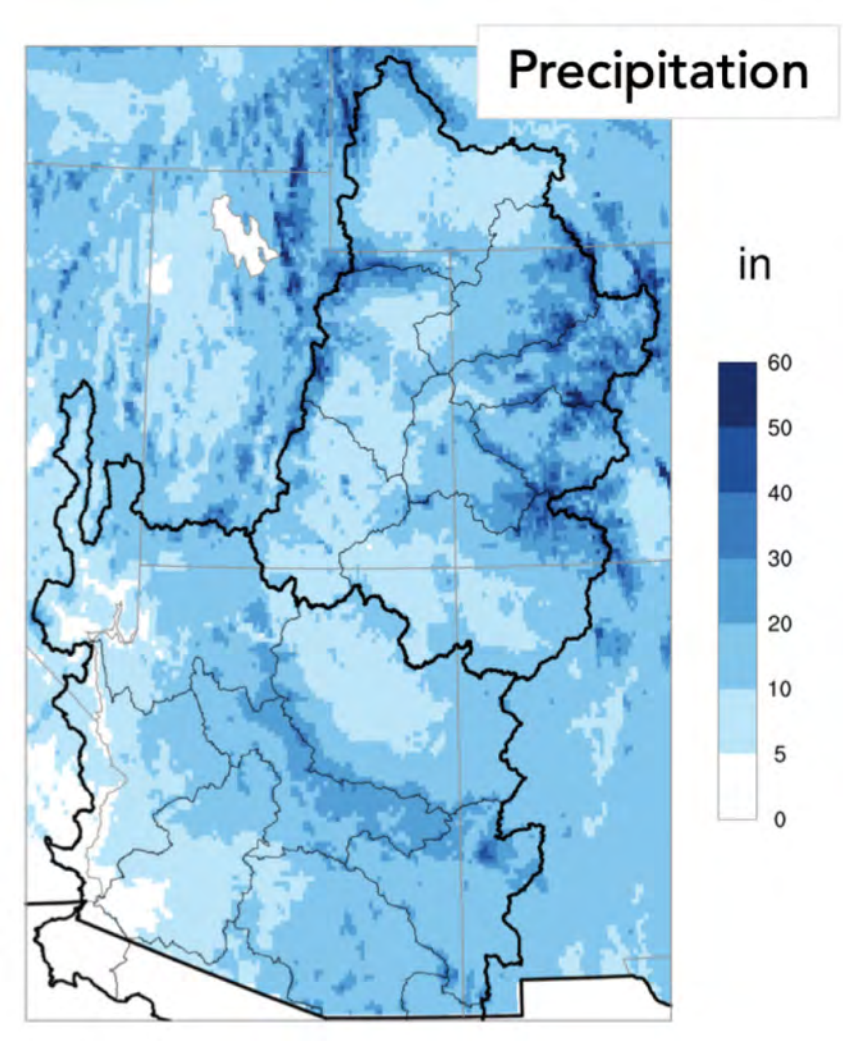
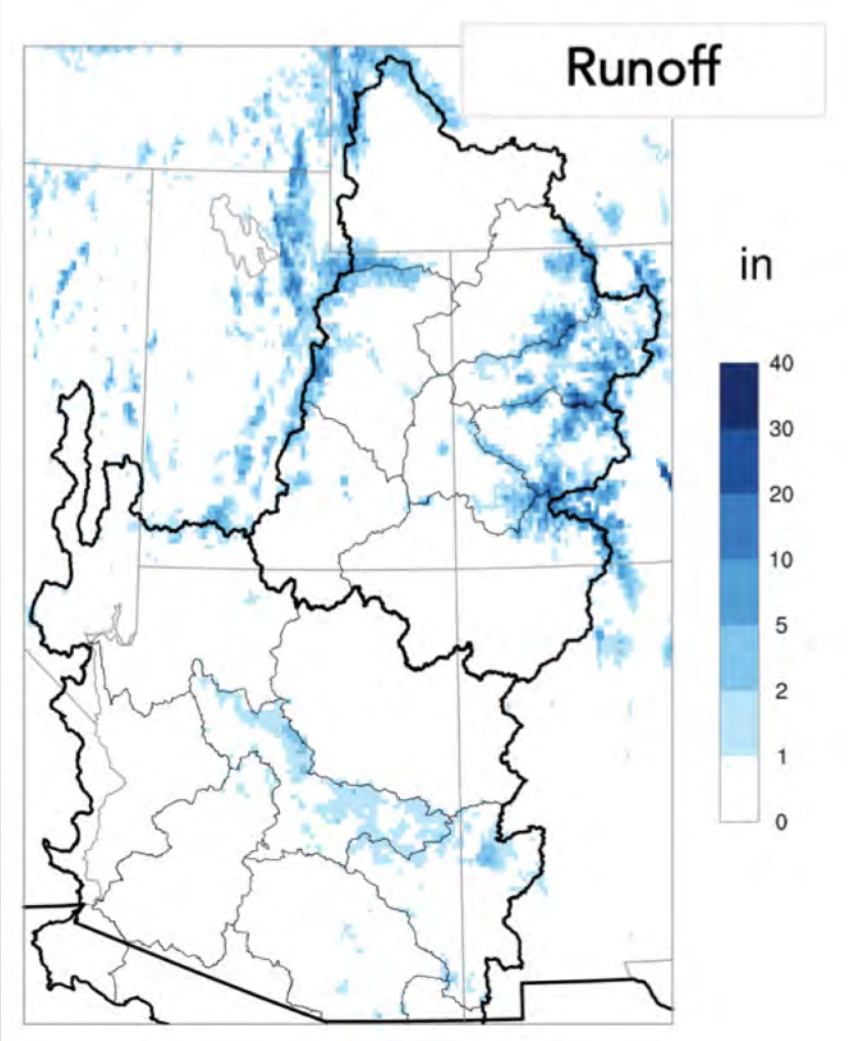
Natural Hydrology of the Upper Basin (1906-2017 average)

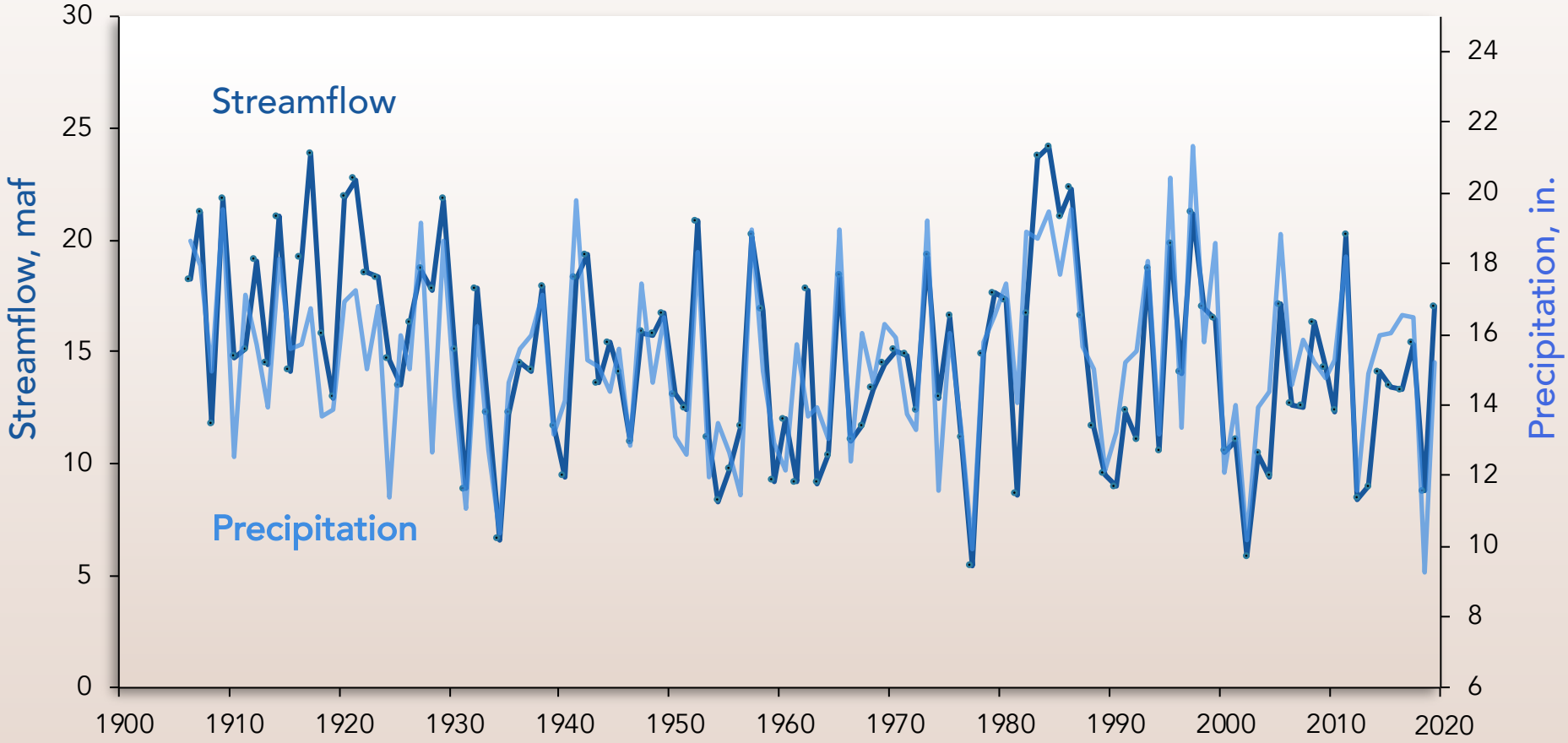
Basin or Sub-basin (gage)	Natural Streamflow (maf)	Proportion of Colorado River at Imperial Runoff (%)	Precipitation (maf)	Runoff Efficiency (%)
Green River (nr Green River, UT)	5.4	34%	92 maf Upper Basin Total	16%
Colorado River (nr Cisco, UT)	6.8	42%		
Dolores River nr Cisco	*0.8*	*5%*		
San Juan River (nr Bluff, UT)	2.1	13%		
Total Upper Basin (Colorado River at Lees Ferry)	**14.8**	**92%**		

85% of the runoff comes from 15% of the CO River Basin

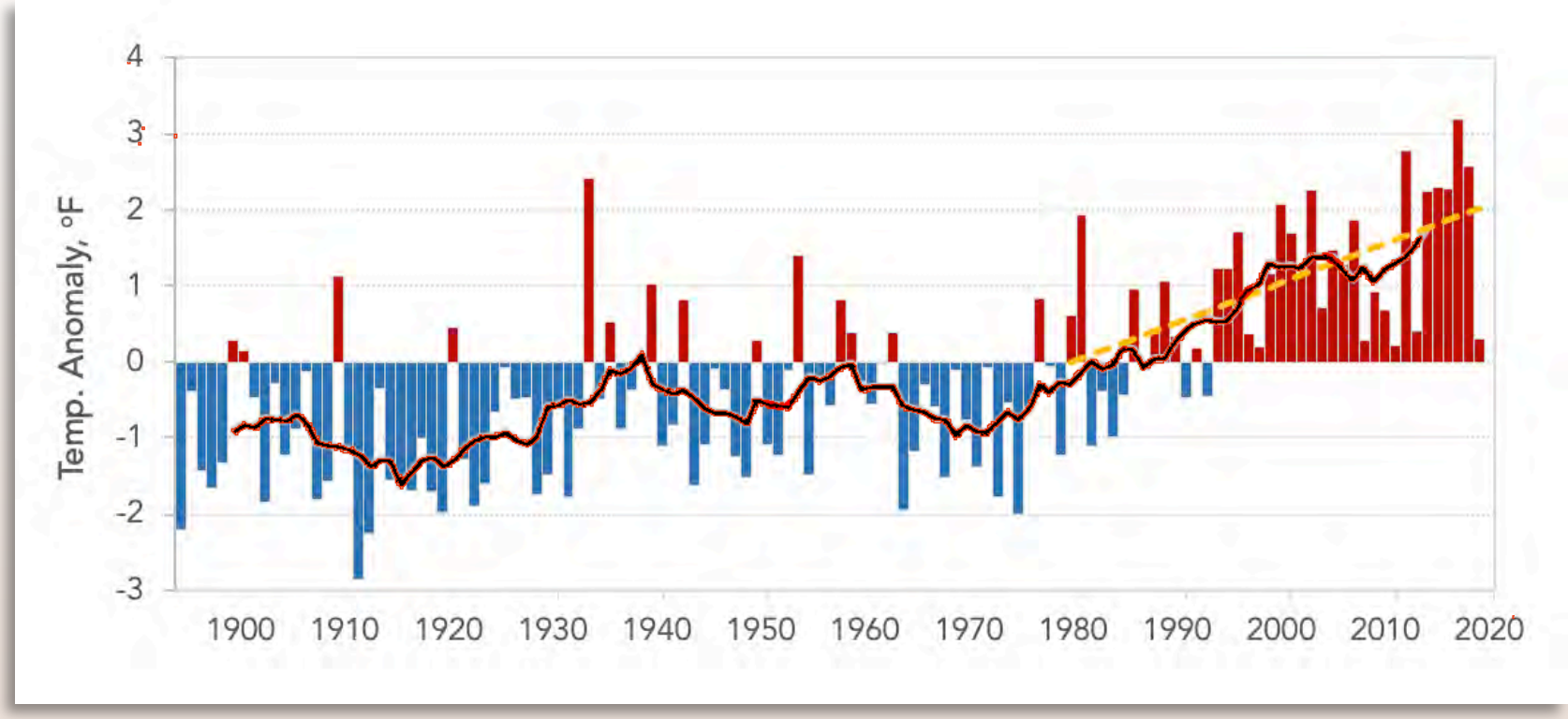




Upper Basin water-year precipitation vs. streamflow, 1906-2019



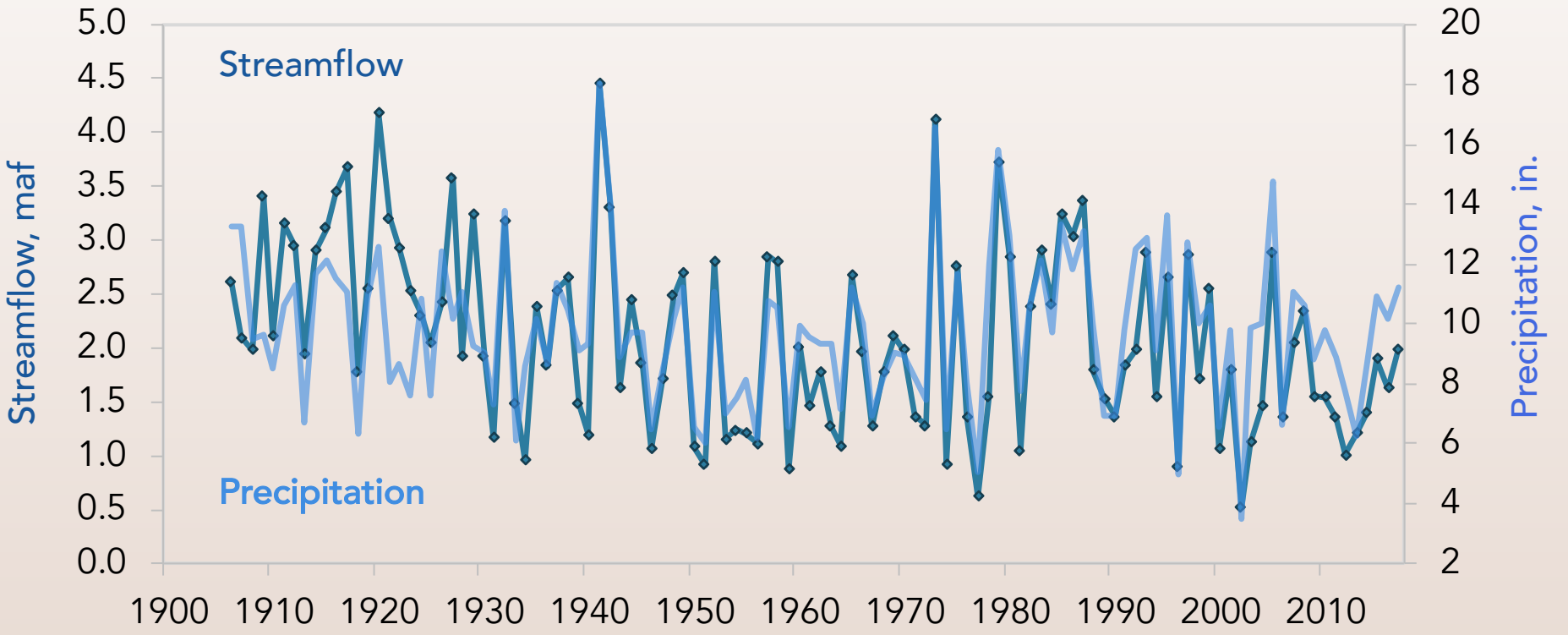
Colorado River Basin: 2°F of warming since 1980



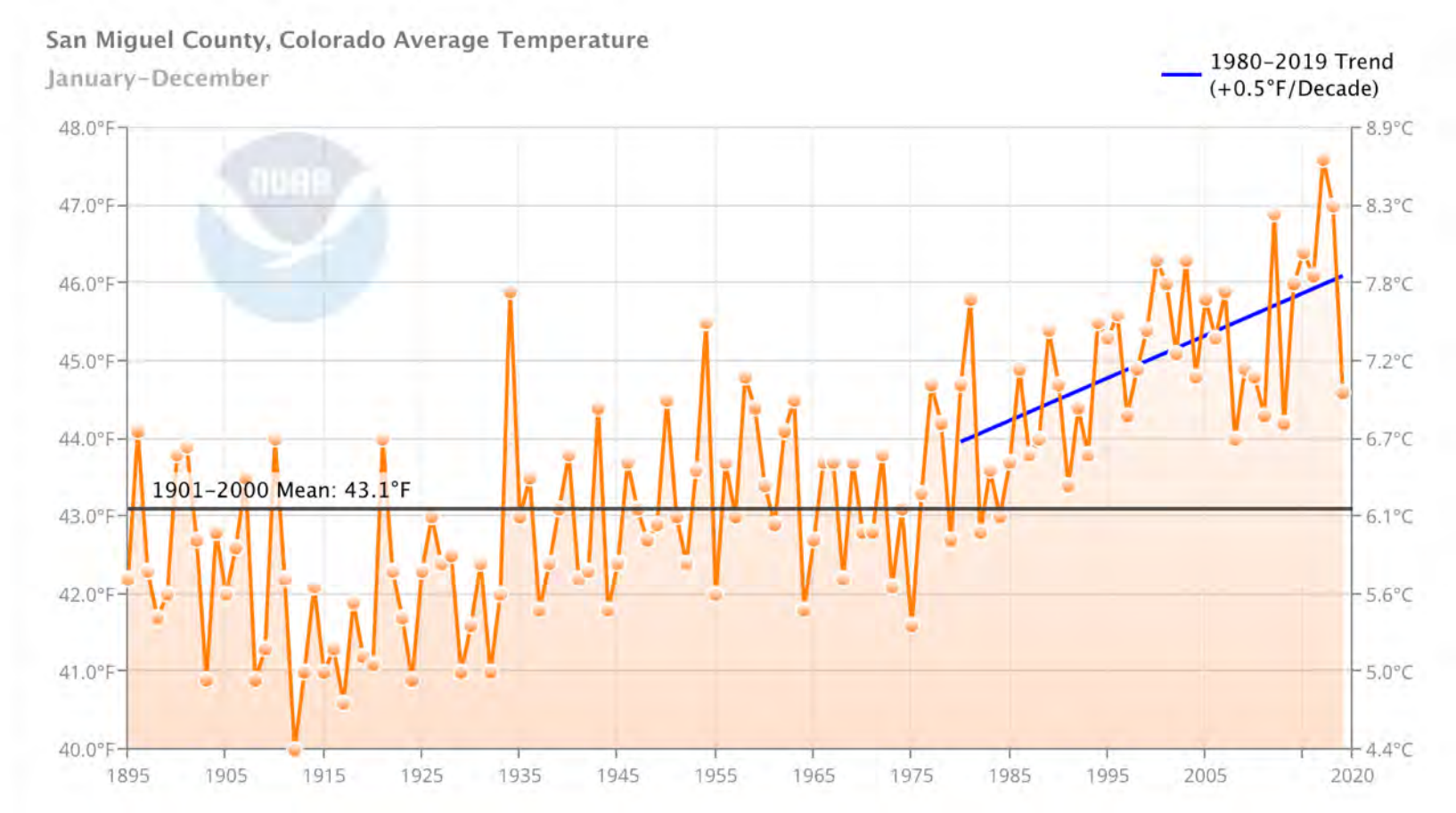
Report findings: Upper Basin streamflow change

- Over the 2000-2019 period, compared to 1906-2019:
  - *Temperatures 2ºF higher*
  - *Precipitation 5% lower*
  - *Lees Ferry streamflow 15% lower*
- Lower precipitation can't explain all of the decrease in runoff
- Warming temperatures are responsible for 20-50% of the runoff decrease
- Warming alone decreases runoff by 2% to 6% per 1ºF

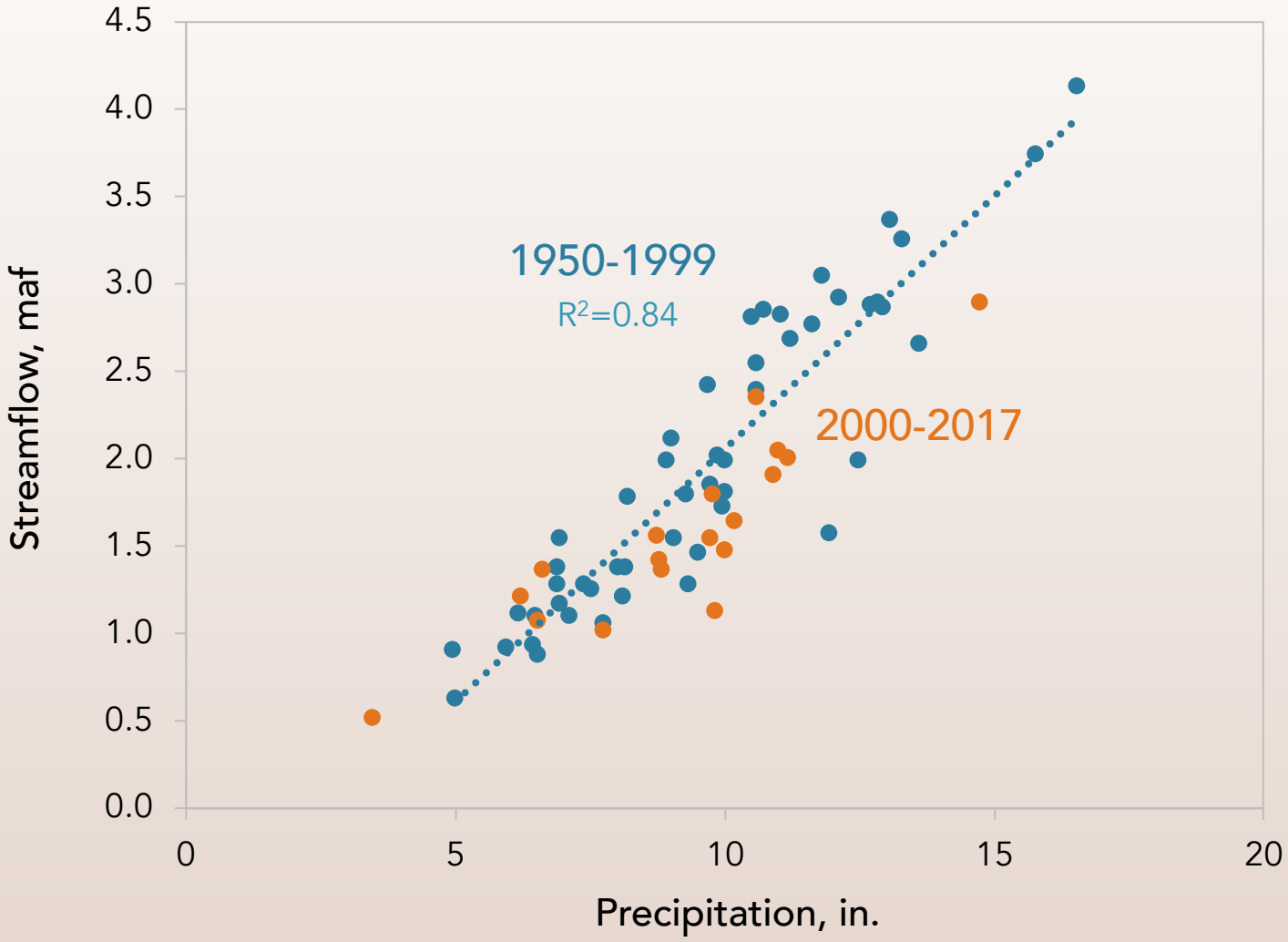
San Juan Basin - **Sep-May** precipitation vs. water-year streamflow nr Bluff, UT, 1906-2017



Southwest CO: 2°F of warming since 1980



San Juan Basin - Sep-May precipitation vs. water-year streamflow



Chapter 3. Primary Planning Tools

- Current understanding of the basin
- Primary data and models
  - Short- and mid-term forecast tools
    - Long-term planning hydrology
      - System models

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Chapter 4. Observations—Weather and Climate

- Current understanding of the basin
- Primary data and models — YOU ARE HERE
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Chapter 5. Observations—Hydrology

Current understanding of the basin

Primary data and models

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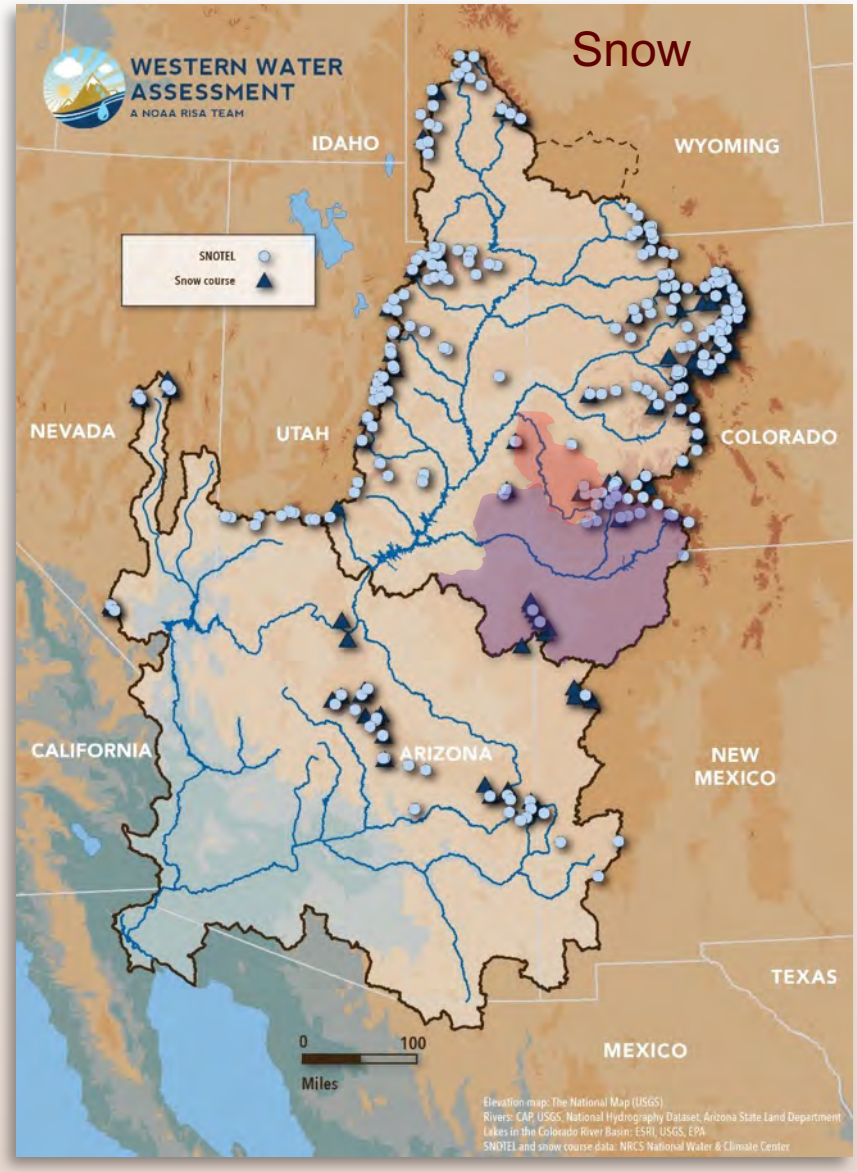
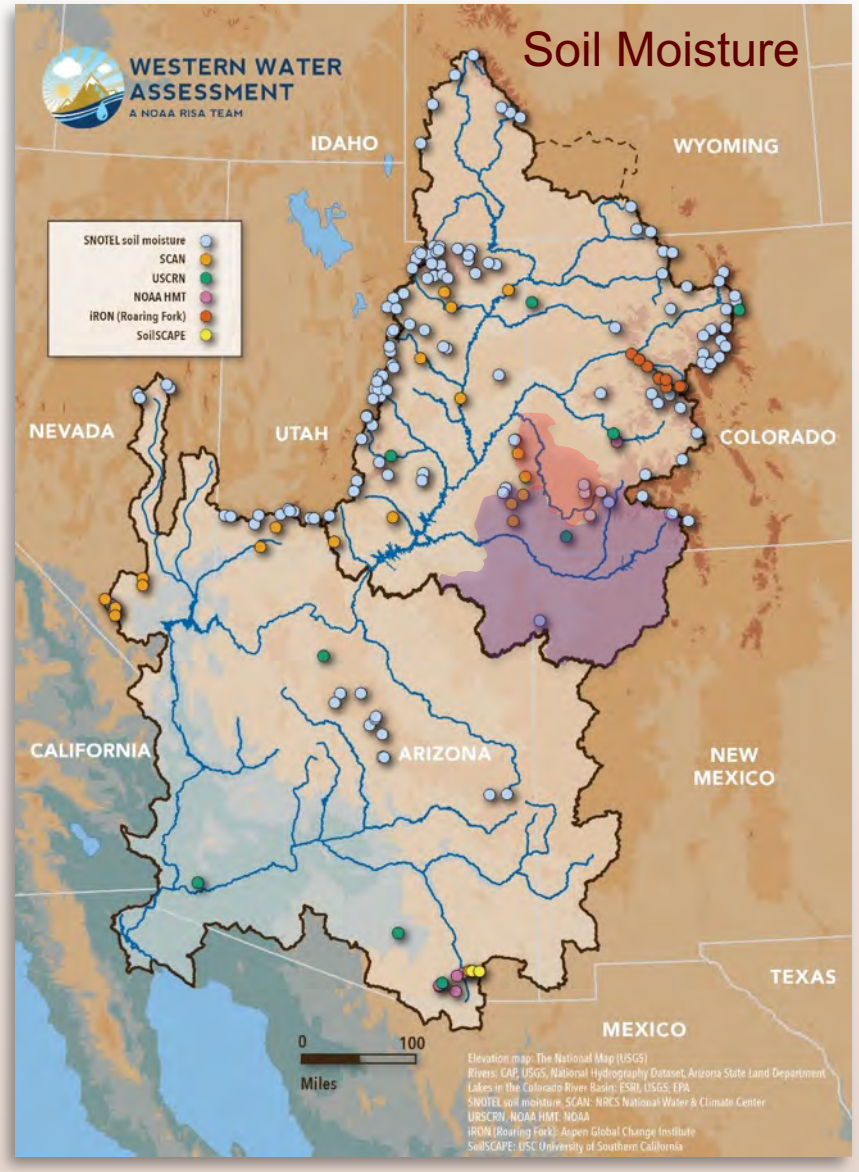
Short- and mid-term fo tools

Long-term planning hydrology

System models

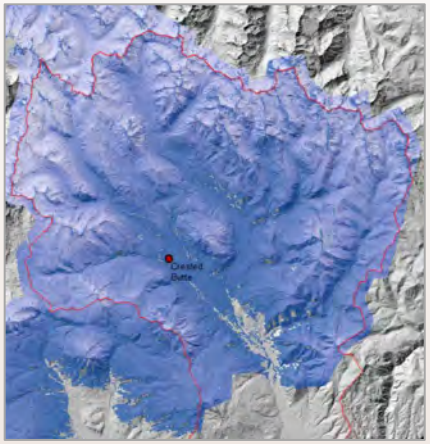
Snow and soil moisture observation sites

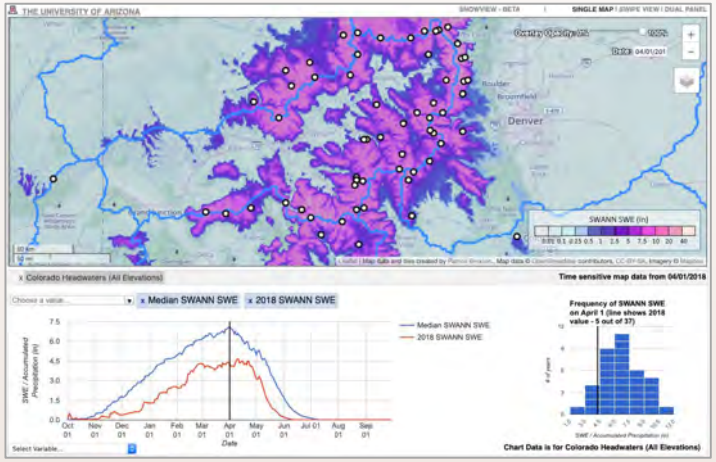


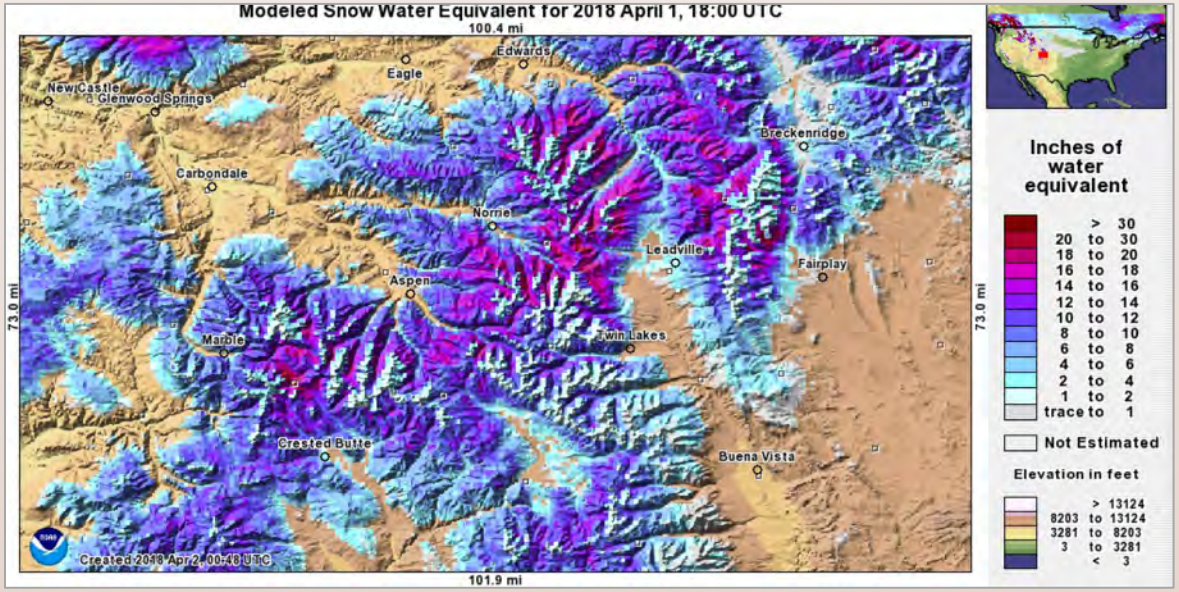


Spatially distributed products

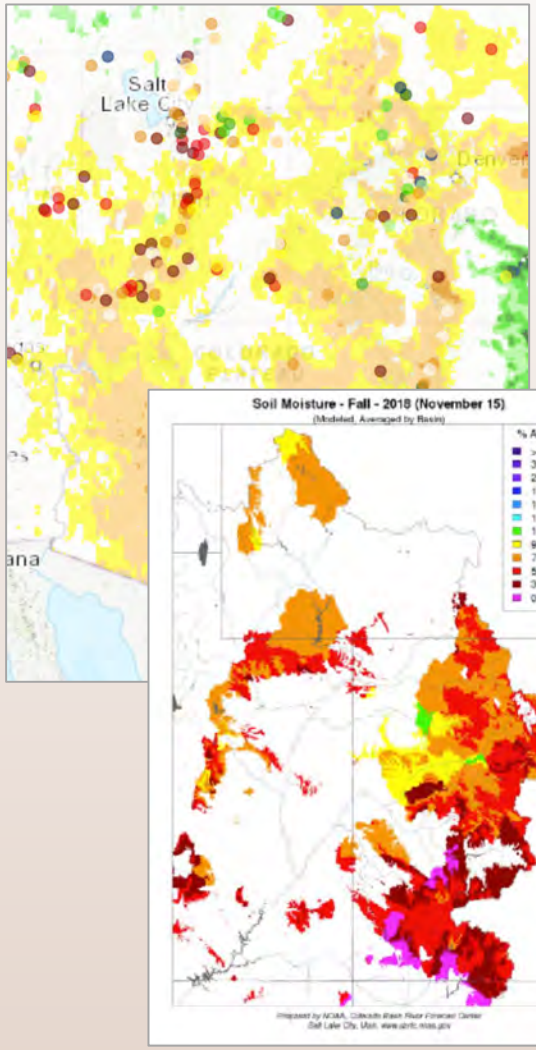
Snow







Soil Moisture



Chapter 6. Hydrologic Models

- Current understanding of th
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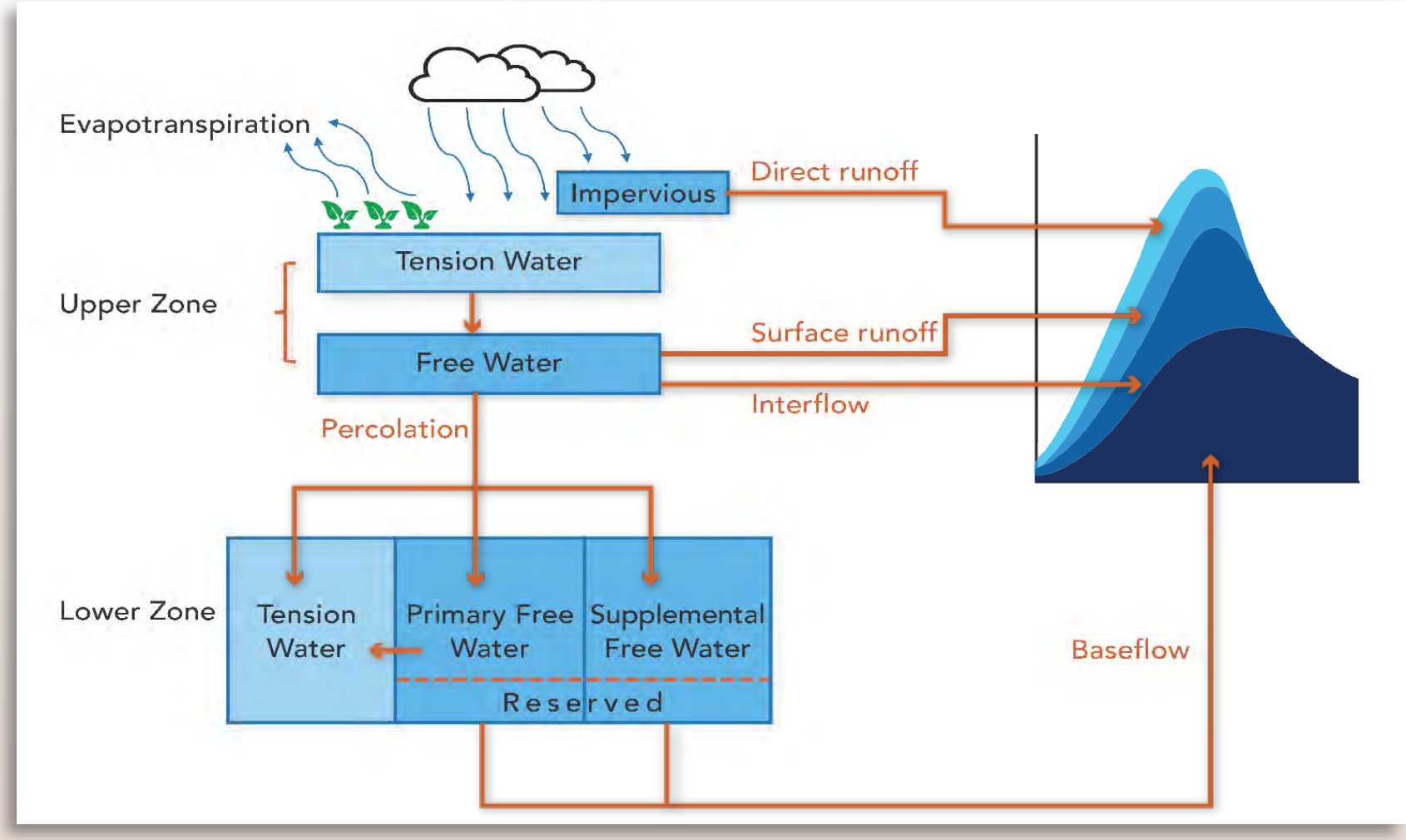
Schematic of Sac-SMA model used by CBRFC



Chapter 7. Weather and Climate Forecasting

- Current understanding of the basin
- Primary data and models
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- Long-term planning hydrology
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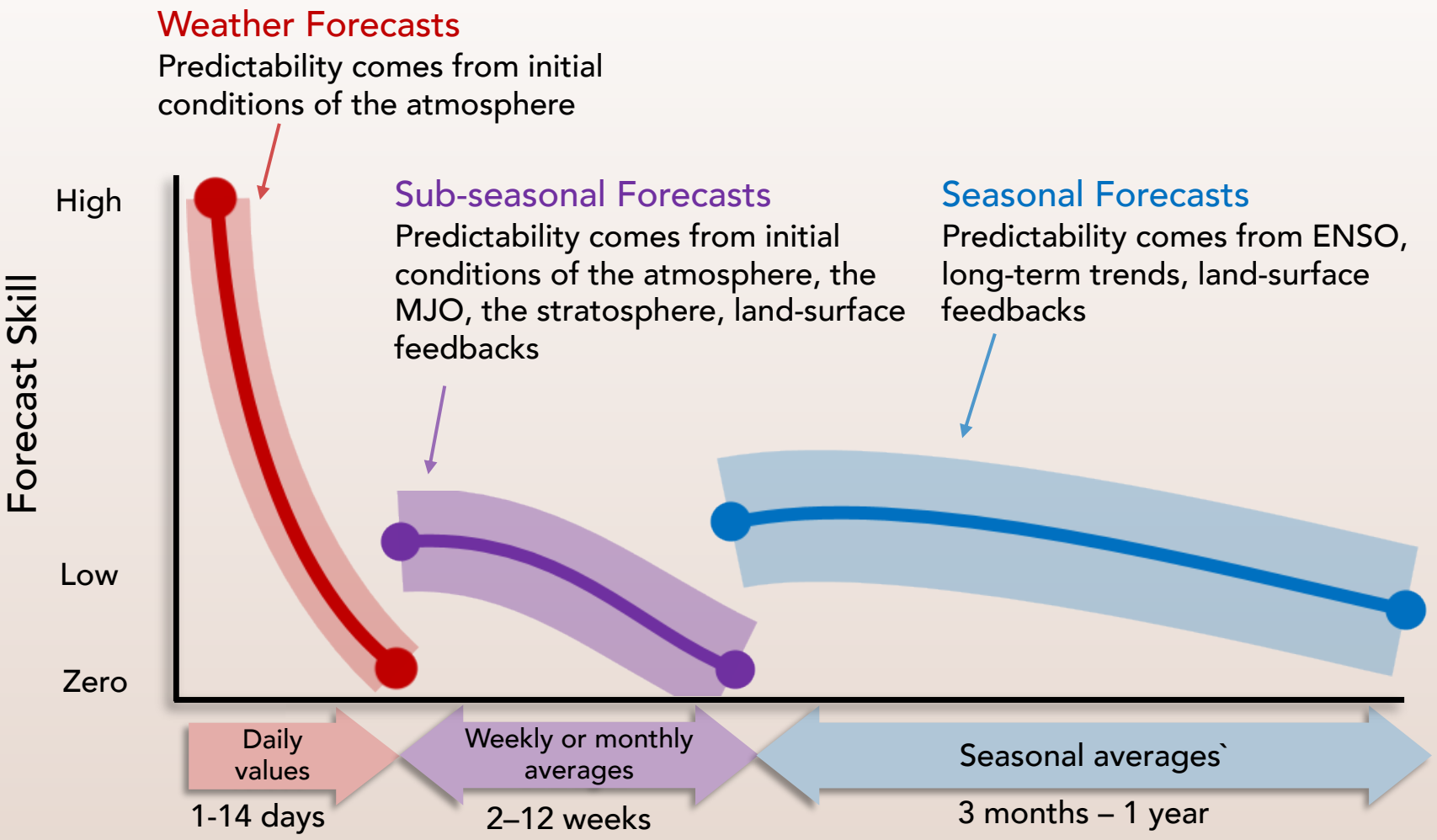
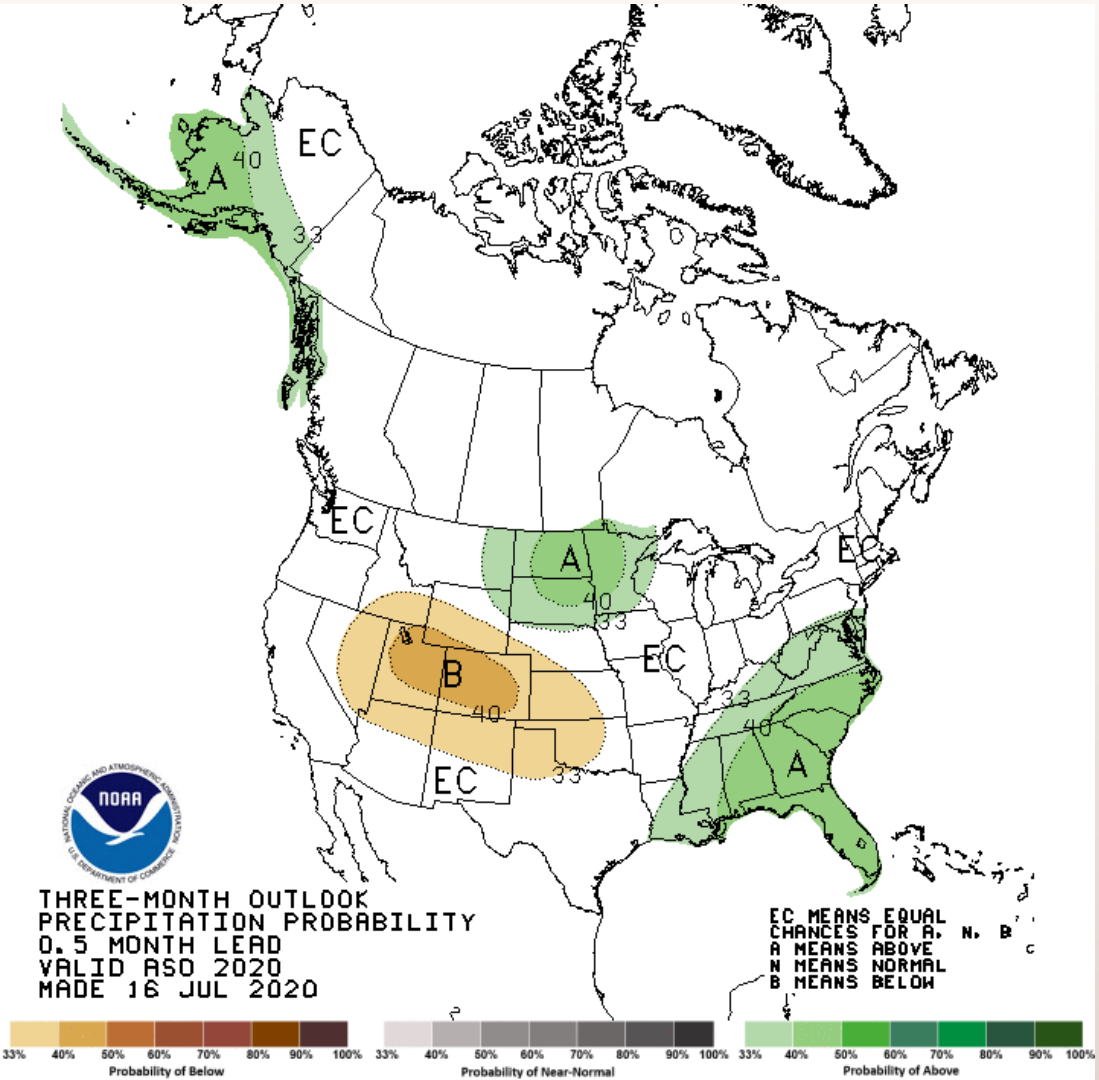
Forecast skill vs. time horizon



Seasonal precipitation forecasts:
Overall very low skill for SW CO* and the Upper Basin



*But moderate skill for SW CO during ENSO events, in late winter/spring

Chapter 8. Streamflow Forecasting

- Current understanding of the basin
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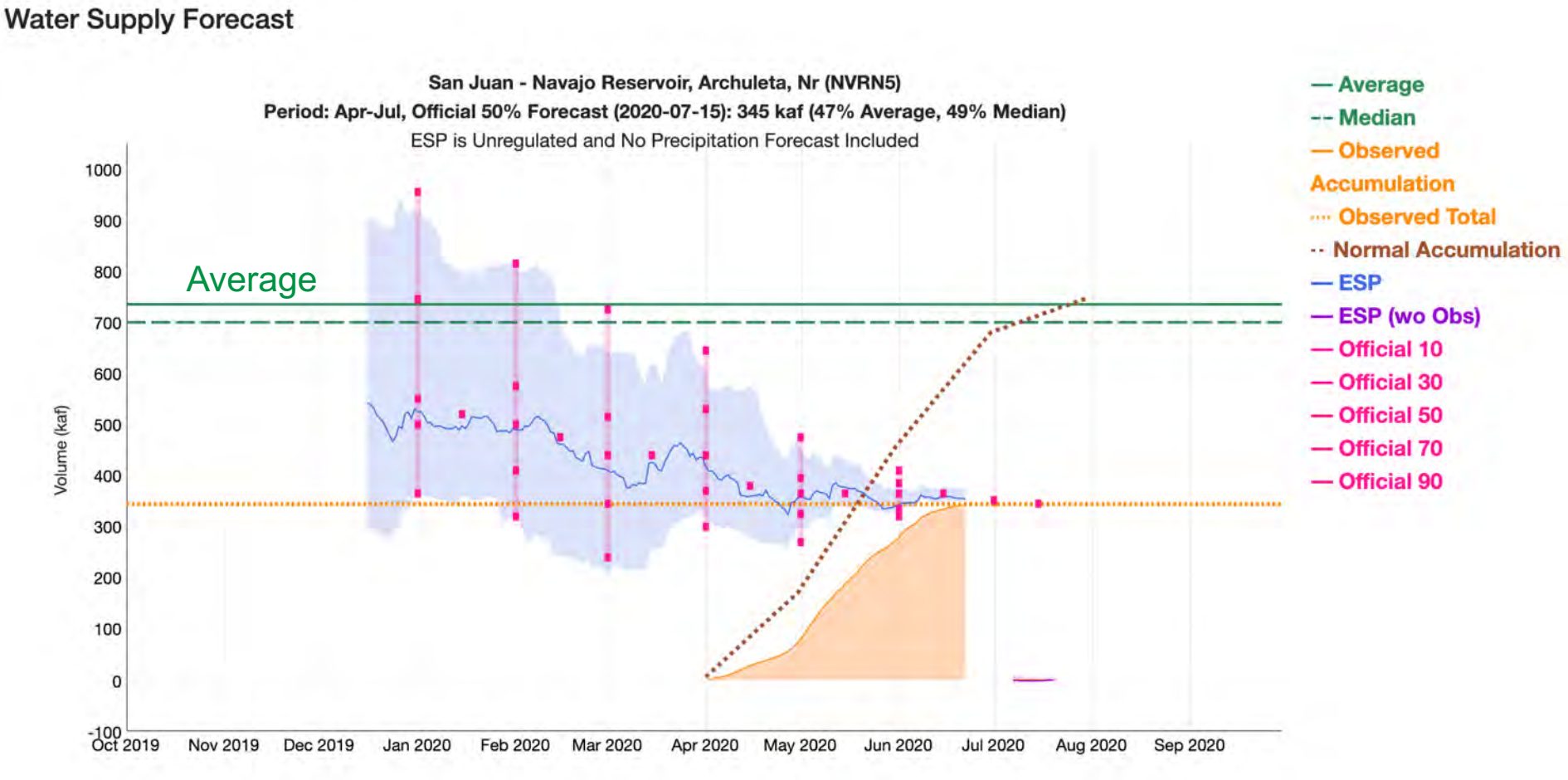
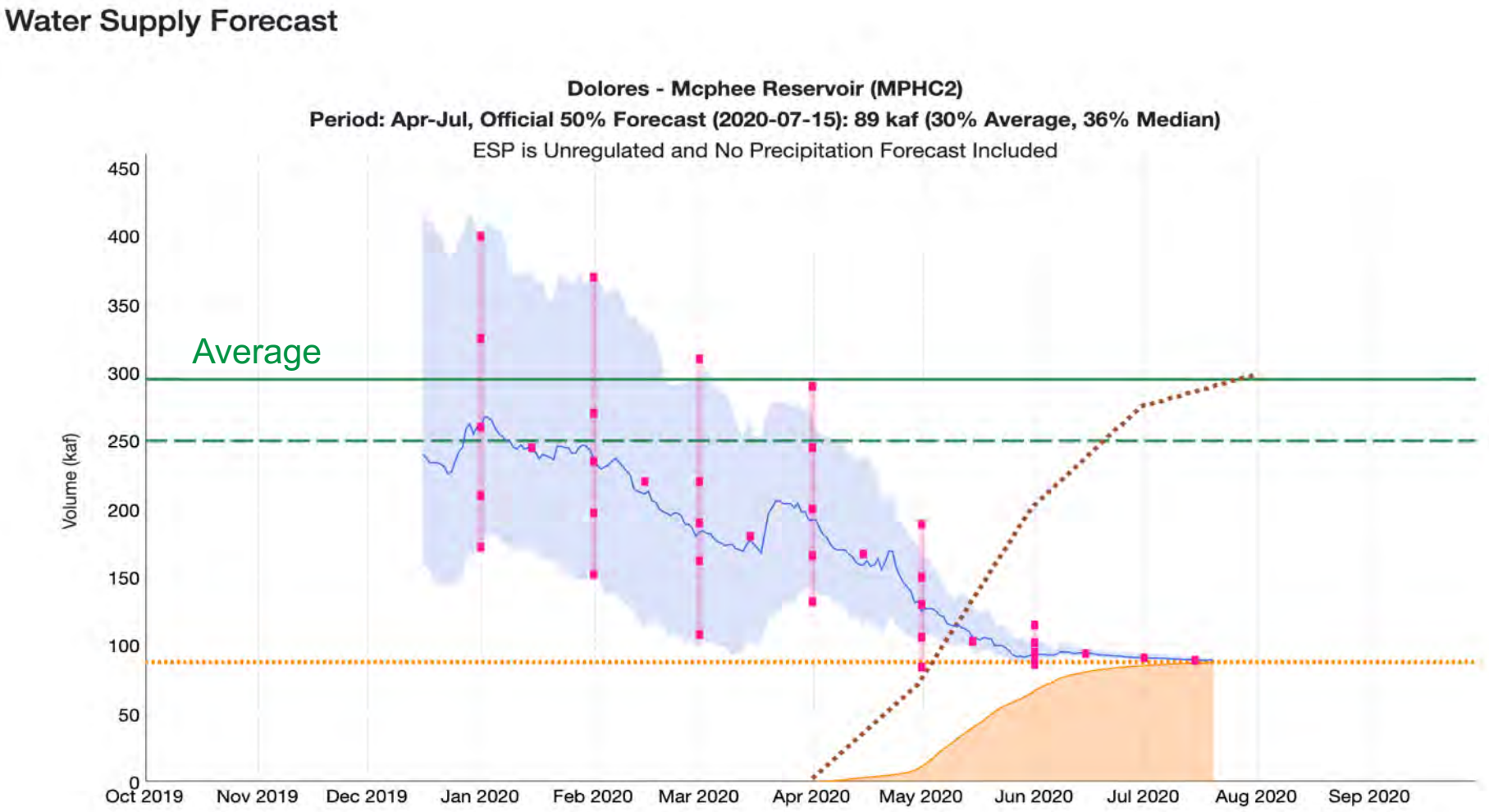
2020 CBRFC forecast evolution plot – San Juan-Navajo



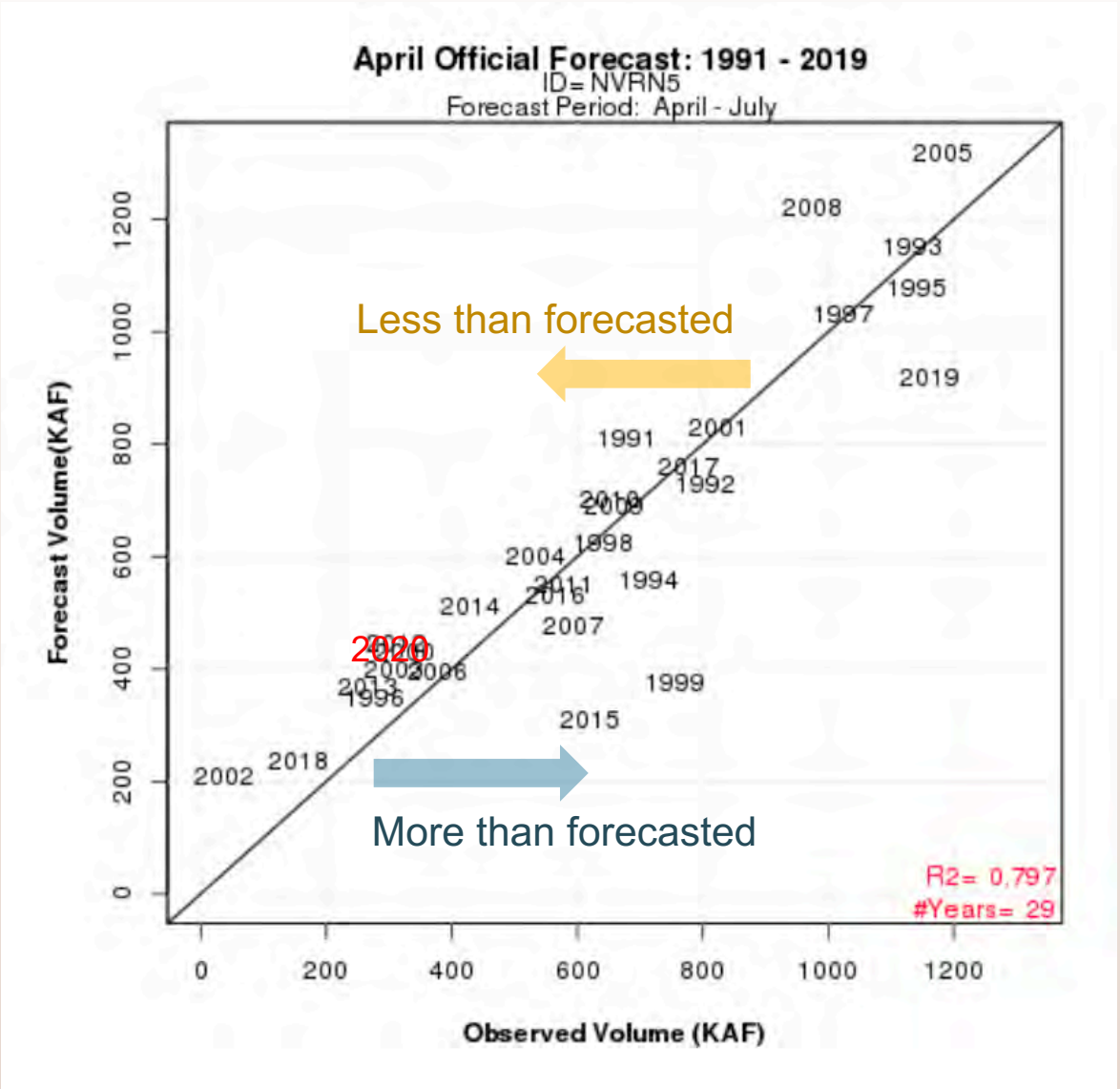
Source: https://www.cbrfc.noaa.gov/wsup/

2020 CBRFC forecast evolution plot – Dolores-McPhee

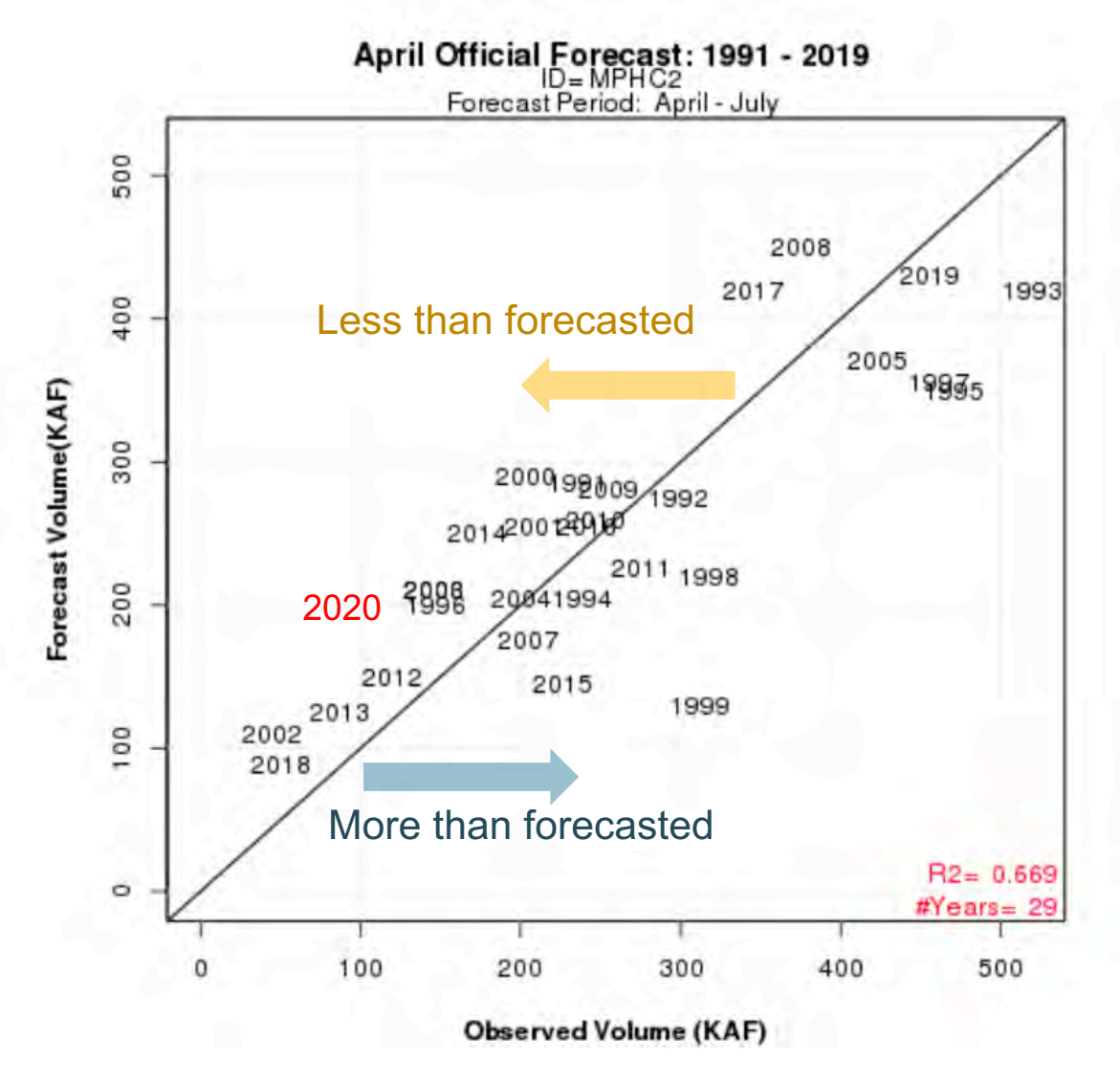


Source: https://www.cbrfc.noaa.gov/wsup/

San Juan-Navajo April 1st forecast verification, 1991-2019

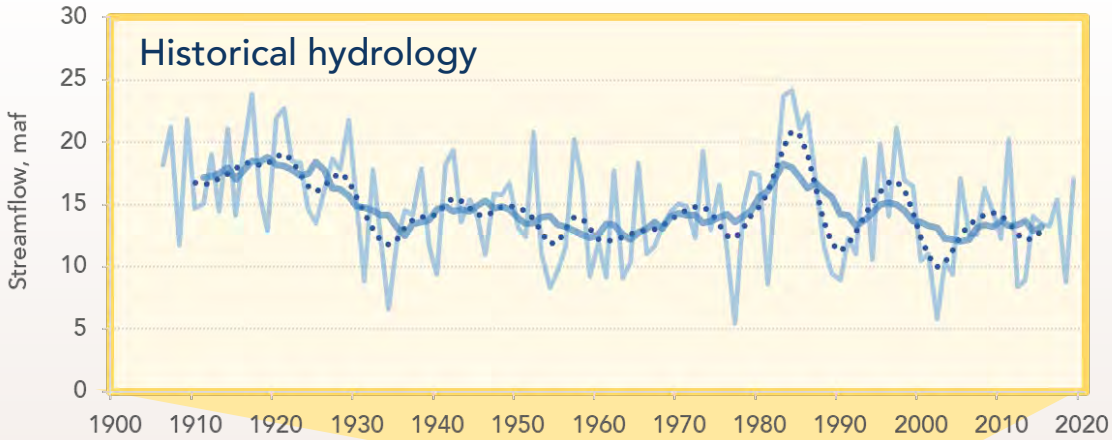


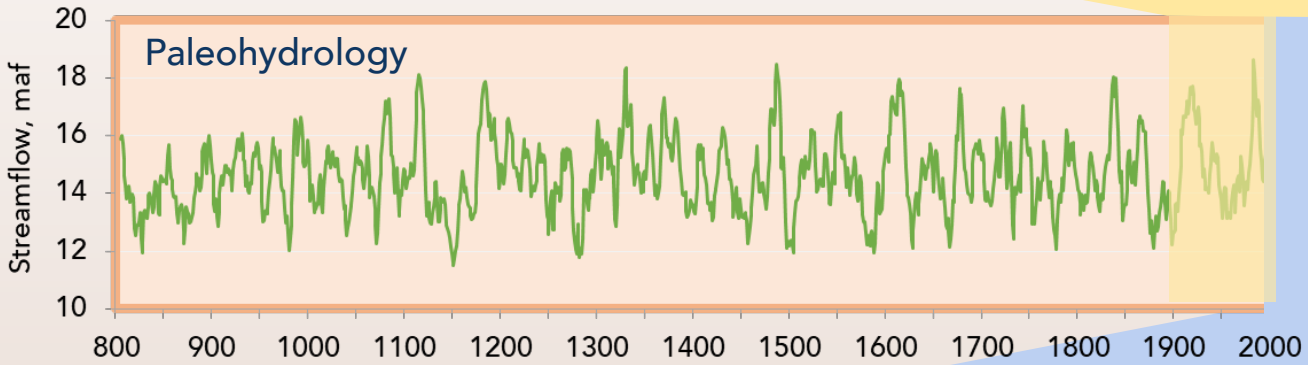
Dolores-McPhee April 1st forecast verification, 1991-2019

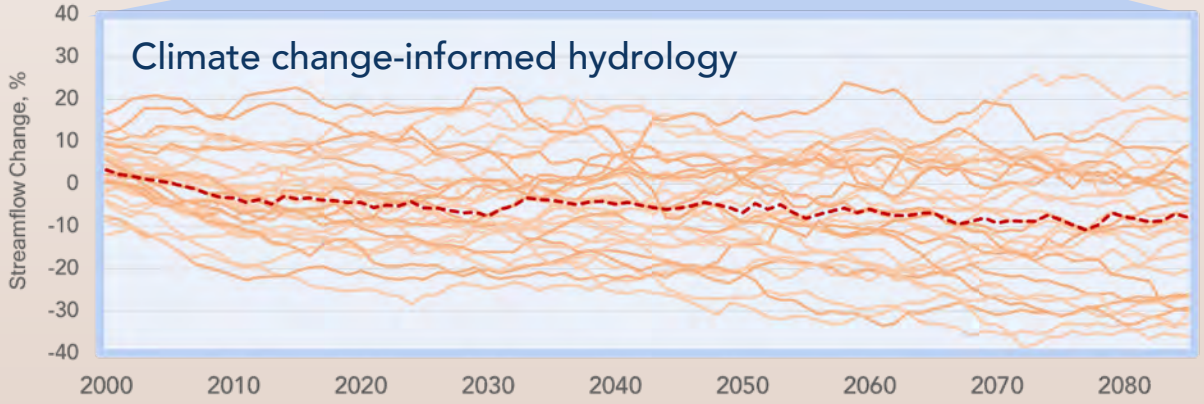


Volume IV

The long-term time horizon







Chapter 9. Historical Hydrology

- Current understanding of the basin
- Primary data and models
- Short- and mid-term forecast tools
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- System models

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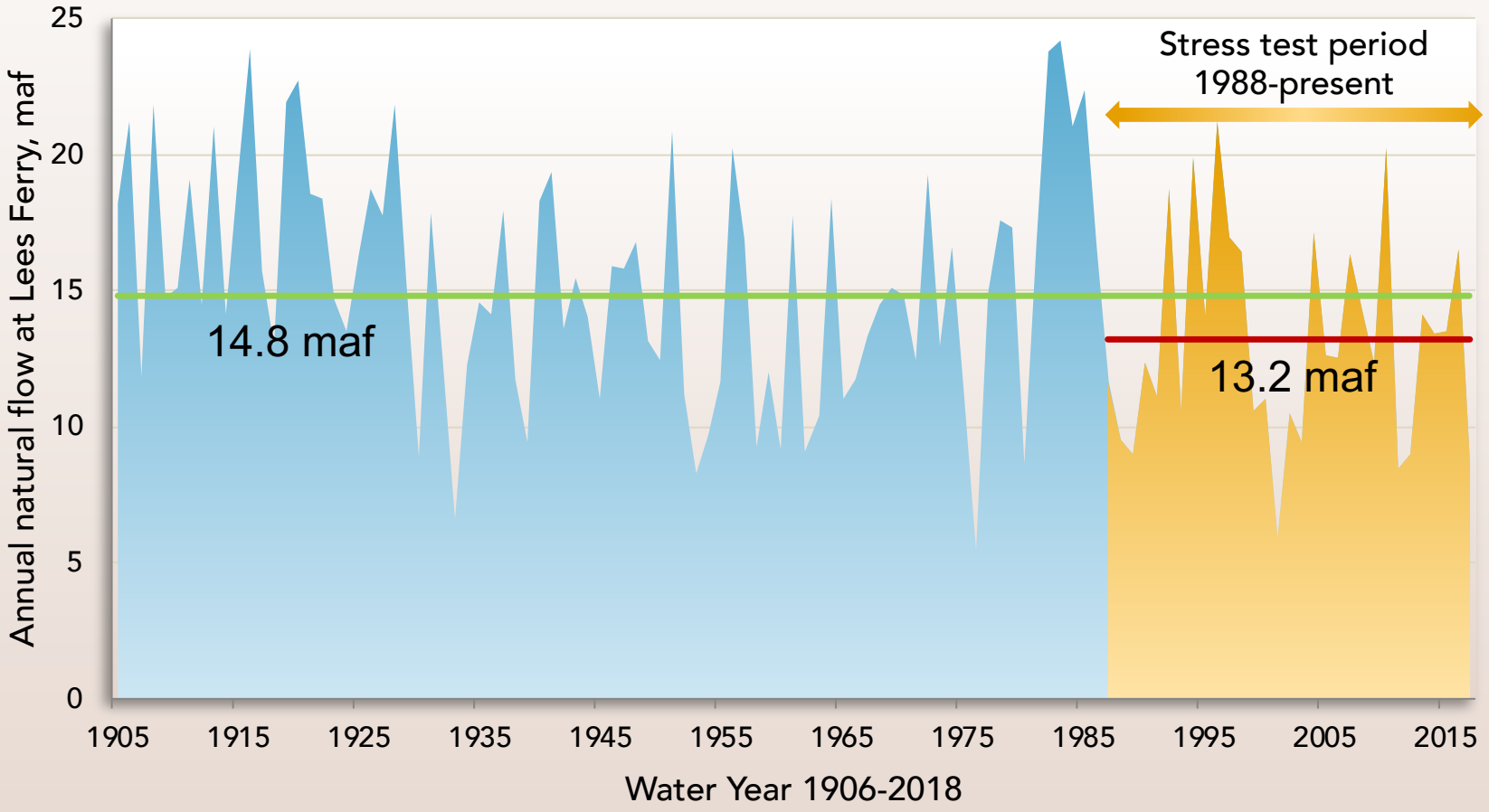
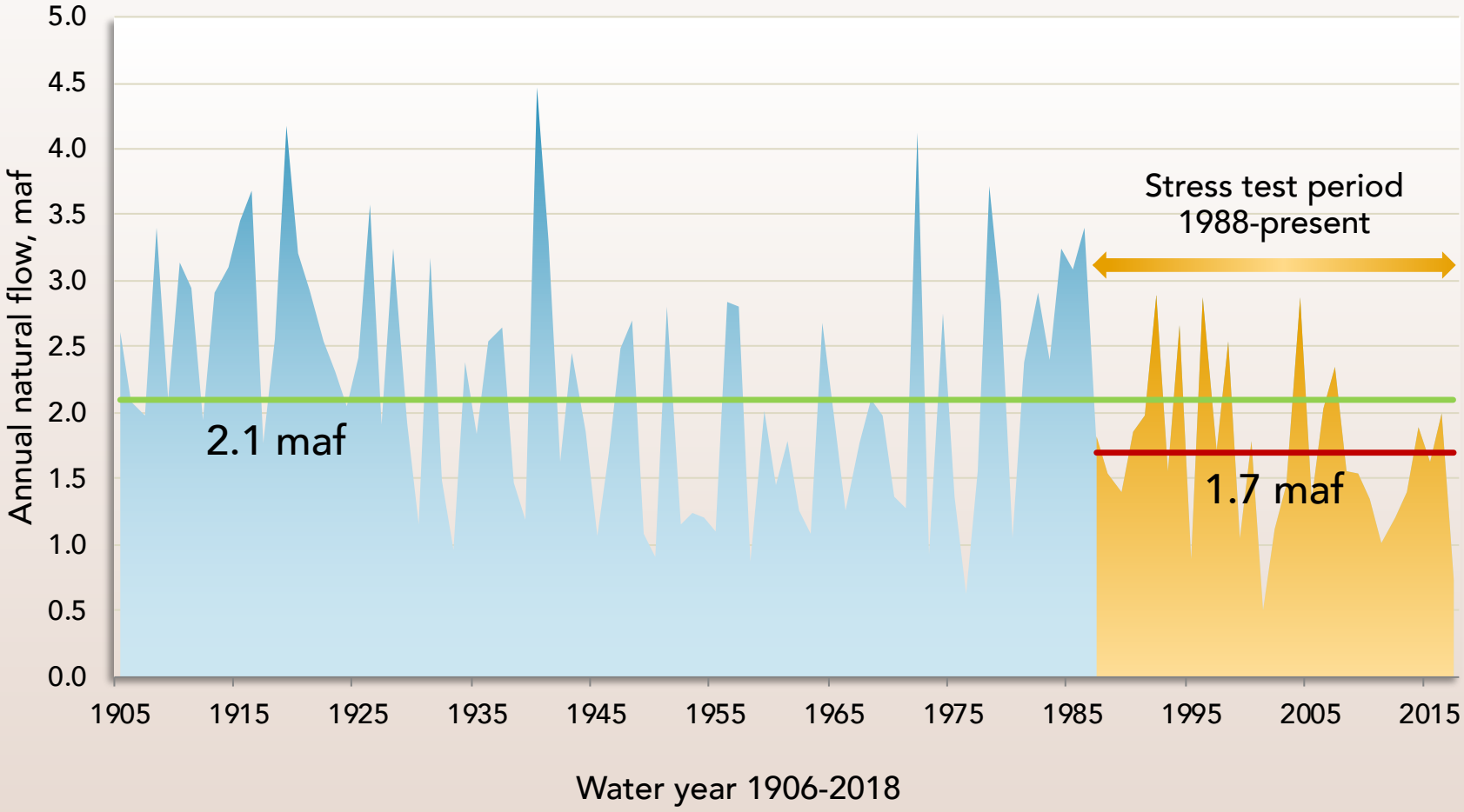
Full historical hydrology vs. Stress test

Colorado River at Lees Ferry



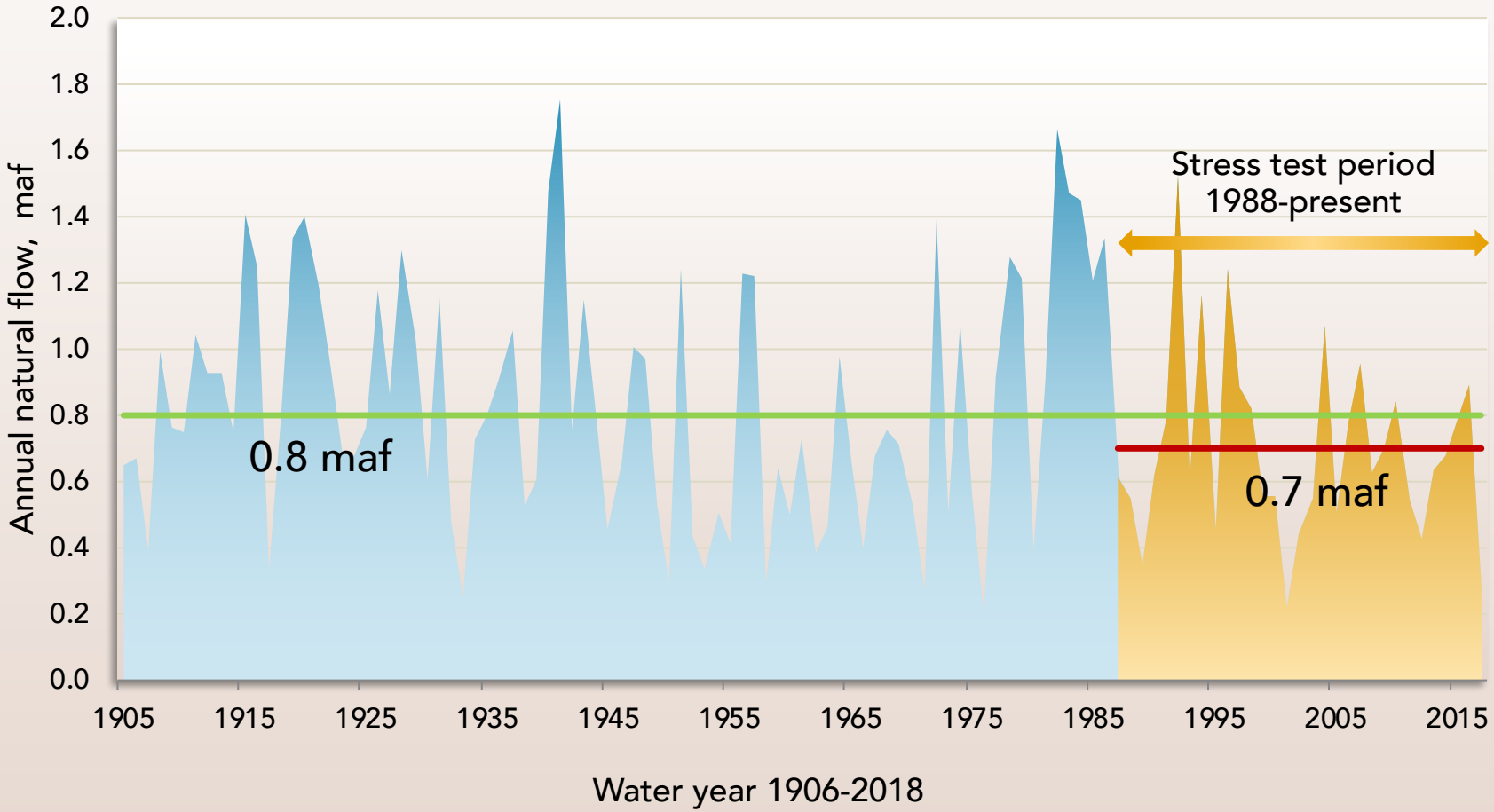
Full historical hydrology vs. Stress test

San Juan nr Bluff, UT



Full historical hydrology vs. Stress test

Dolores nr Cisco, UT



Chapter 10. Paleohydrology

- Current understanding of the basin
- Primary data and models
- Short- and mid-term forecast tools
- Long-term planning hydrology
- System models

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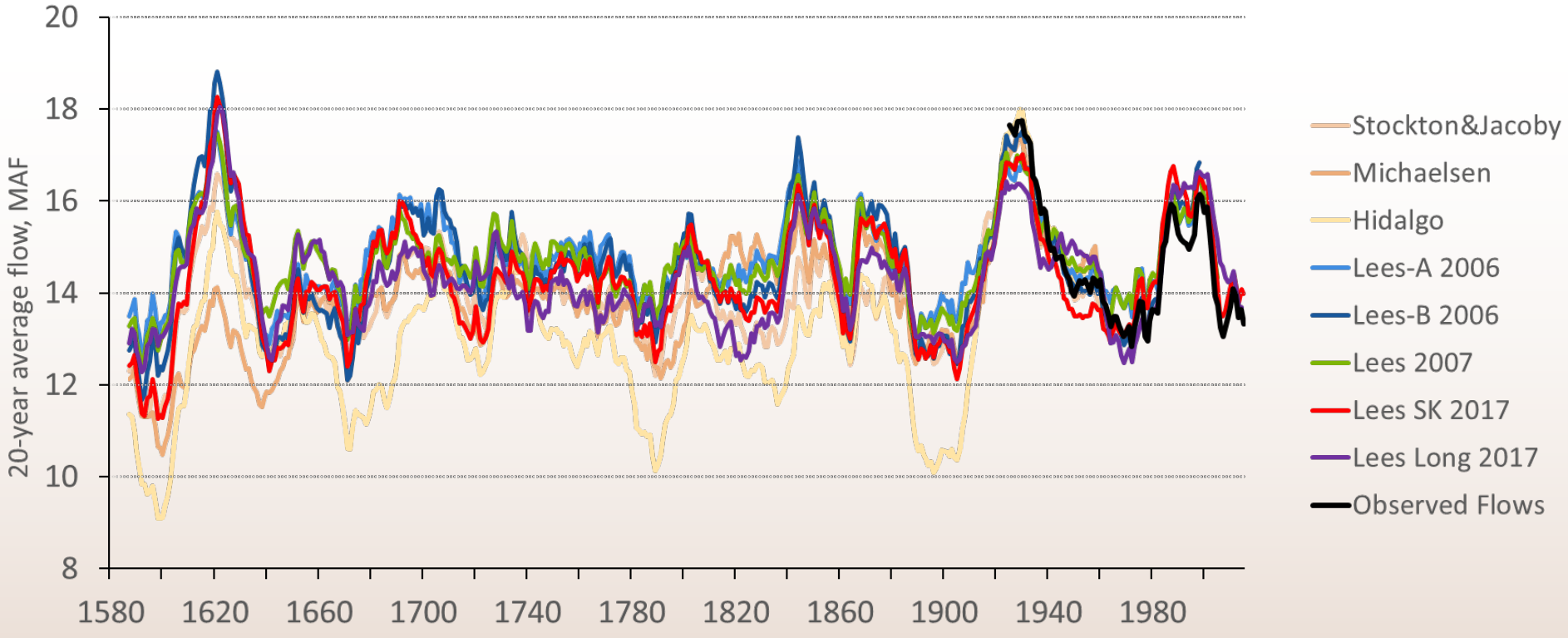
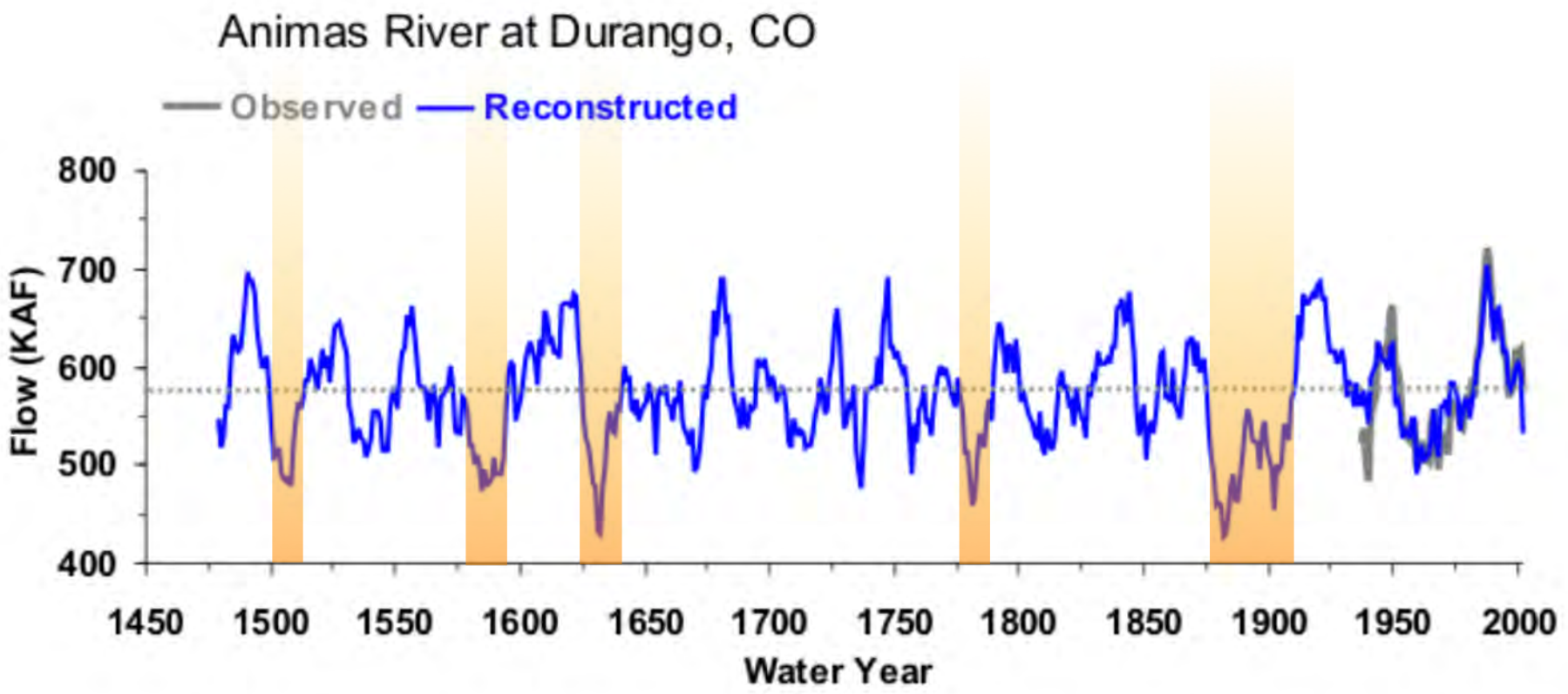
Tree-ring reconstructions of Lees Ferry annual flow, 20-year running averages

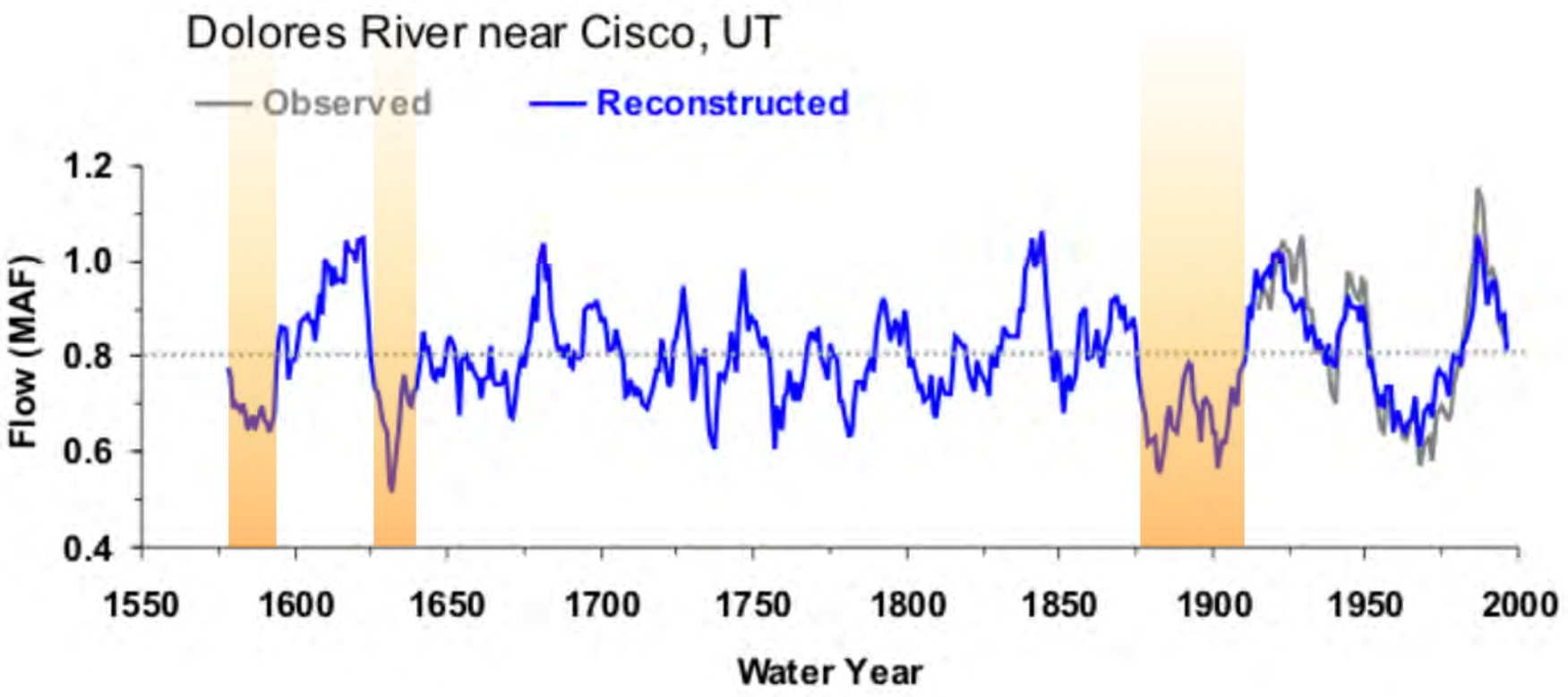


Reconstruction of Animas River flow, 1470-2002



Source: https://treeflow.info

Reconstruction of Dolores River flow, 1569-1997



Source: https://treeflow.info

Megadroughts in the Colorado River Basin since 800 AD

Chapter 11. Climate Change-Informed Hydrology

Current understanding of the basin

Primary data and models

Short- and mid-term forecast tools

Long-term planning hydrology

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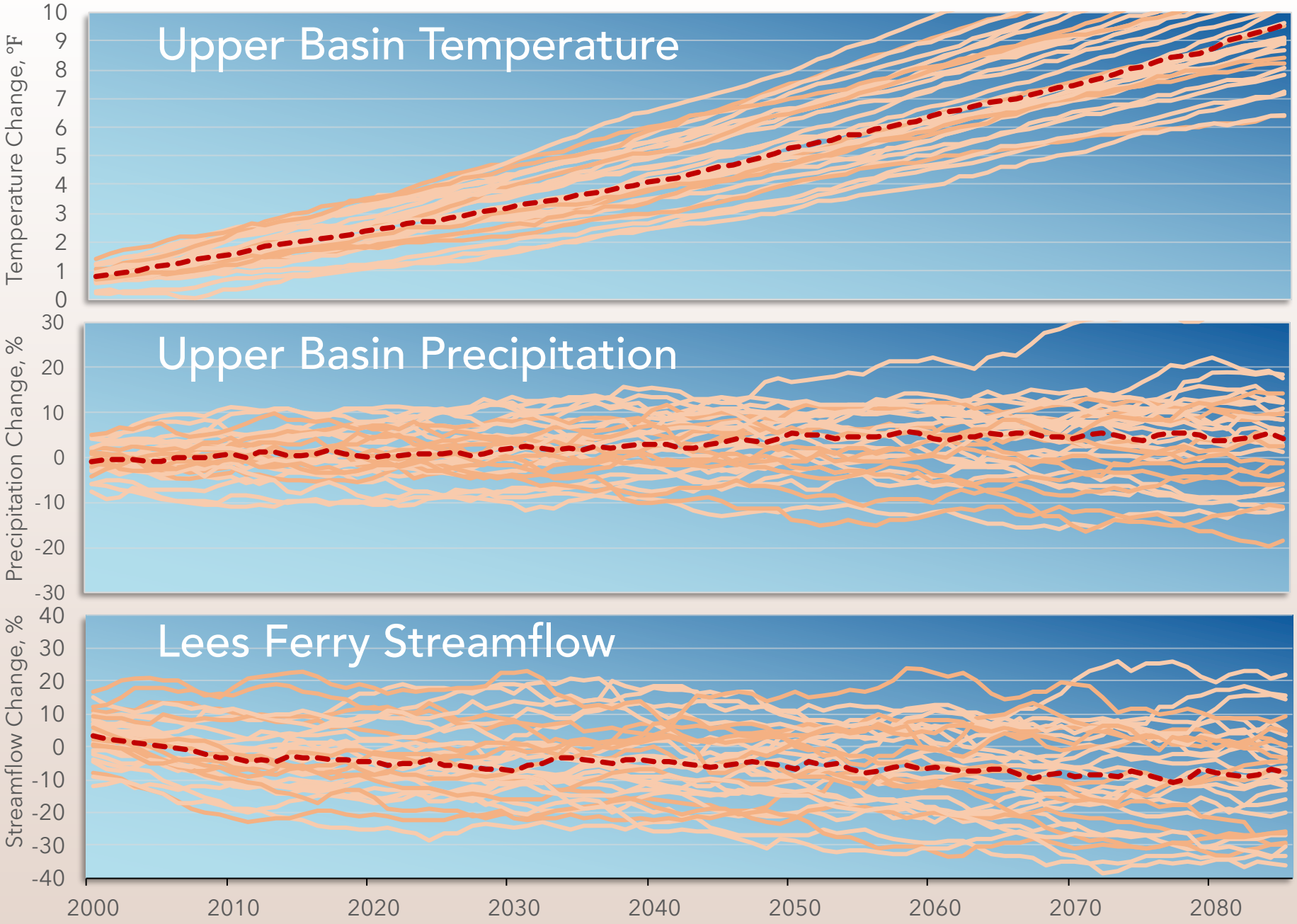
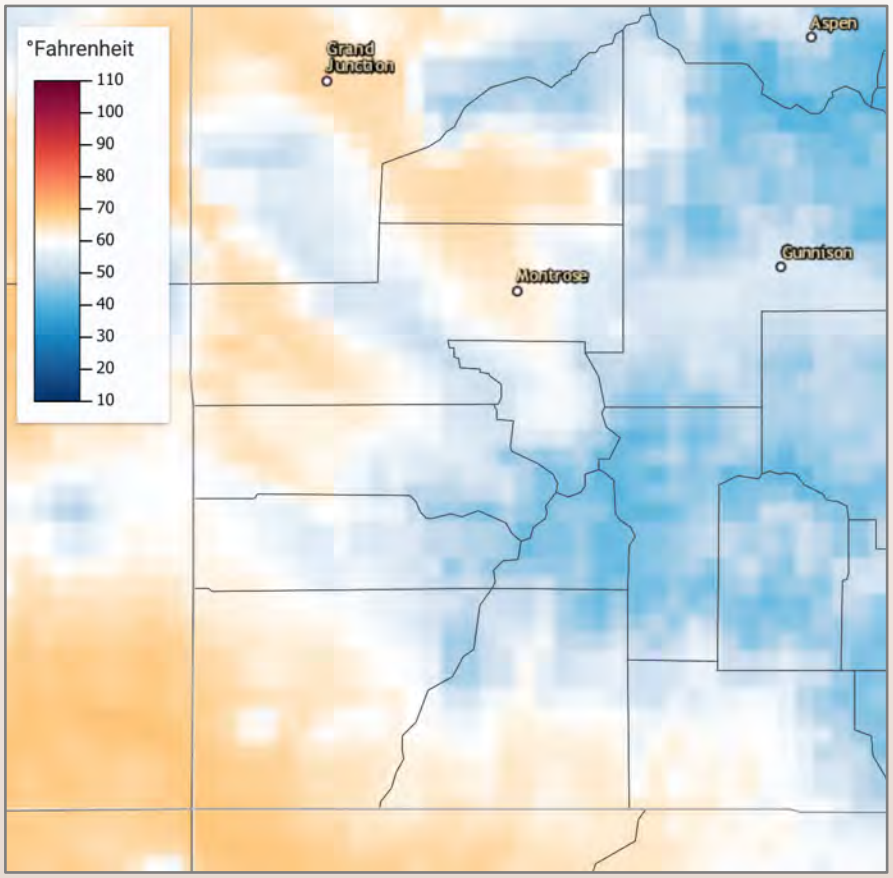
System models

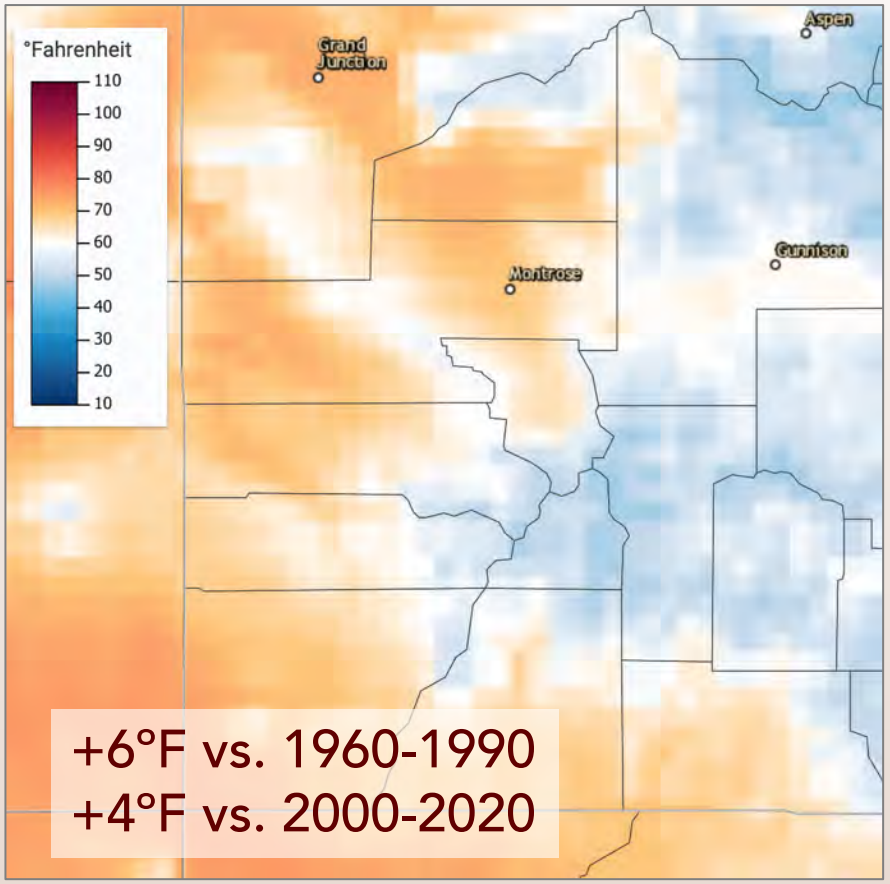

Upper Basin Temperature
Temperature Change, °F
10
9
8
7
6
5
4
3
2
1
0
Upper Basin Precipitation
Precipitation Change, %
30
20
10
0
-10
-20
-30
Lees Ferry Streamflow
Streamflow Change, %
40
30
20
10
0
-10
-20
-30
-40
2000
2010
2020
2030
2040
2050
2060
2070
2080

SW Colorado - Annual average daily max temperatures

1960-1990, Observed



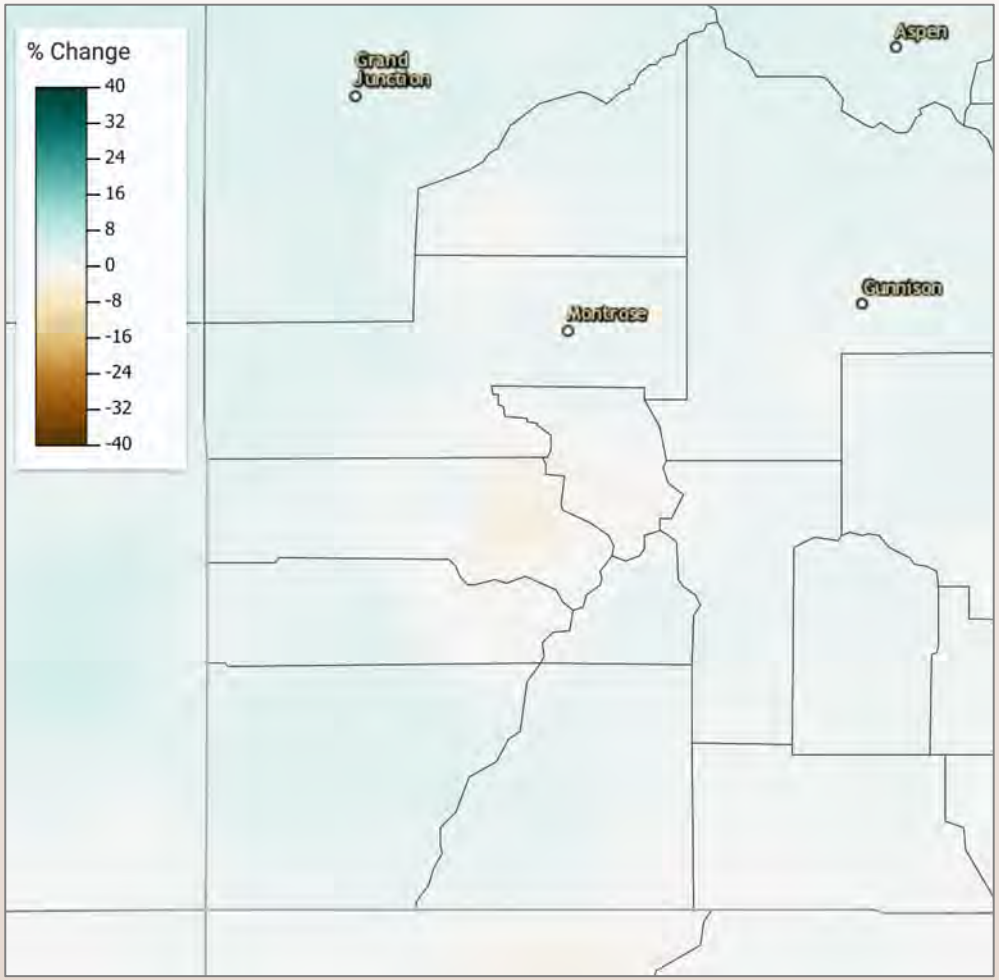
2050s, Projected (Avg of 20 models)



Source: NOAA Climate Explorer; https://crt-climate-explorer.nemac.org

SW Colorado, % *Change* in annual precipitation

2050s, Projected change (Average of 20 models)



SW CO: Unclear how annual precip will change

Source: NOAA Climate Explorer; https://crt-climate-explorer.nemac.org

Projected streamflow change for San Juan & Dolores

2020 **Colorado River Basin** report

"…studies…indicate a stronger tendency toward decreased runoff for the southern parts of the Upper Basin, including the San Juan River [compared to the Upper Basin overall]"

2014 **Climate Change in Colorado** report

"The San Juan basin shows drier outcomes than the Gunnison or the Colorado Headwaters…"

Why?

- Slightly drier range for future precipitation for SJ & D
- SJ & D hydrology more sensitive to warming

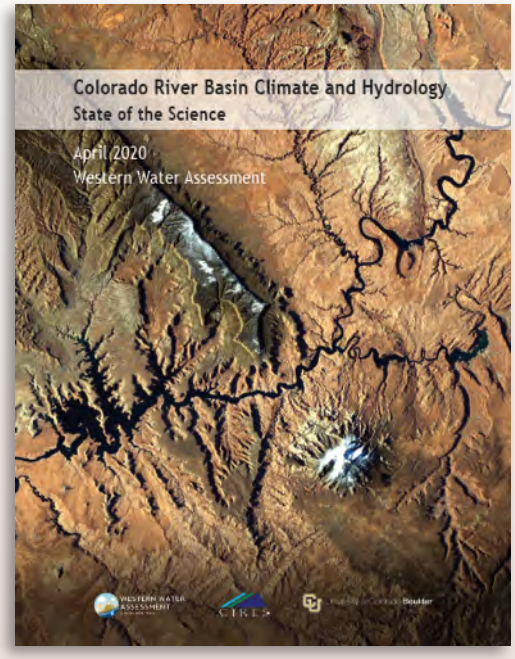
Summary: Projected changes for SW Colorado

- **Temperature – Much** warmer than now

- **Annual Precipitation –** Up? Down? Likely increase in variability.

- **Annual Streamflow, San Juan & Dolores -** Strongly tilted towards lower flows
  - *Range of models :* +5% to -35% by 2050s

Q & A



To download the full report:
https://wwa.colorado.edu/CRBreport/

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