Exploring the Range of Potential Climate Change Impacts on Western Rivers: Case Studies from the Upper Yellowstone

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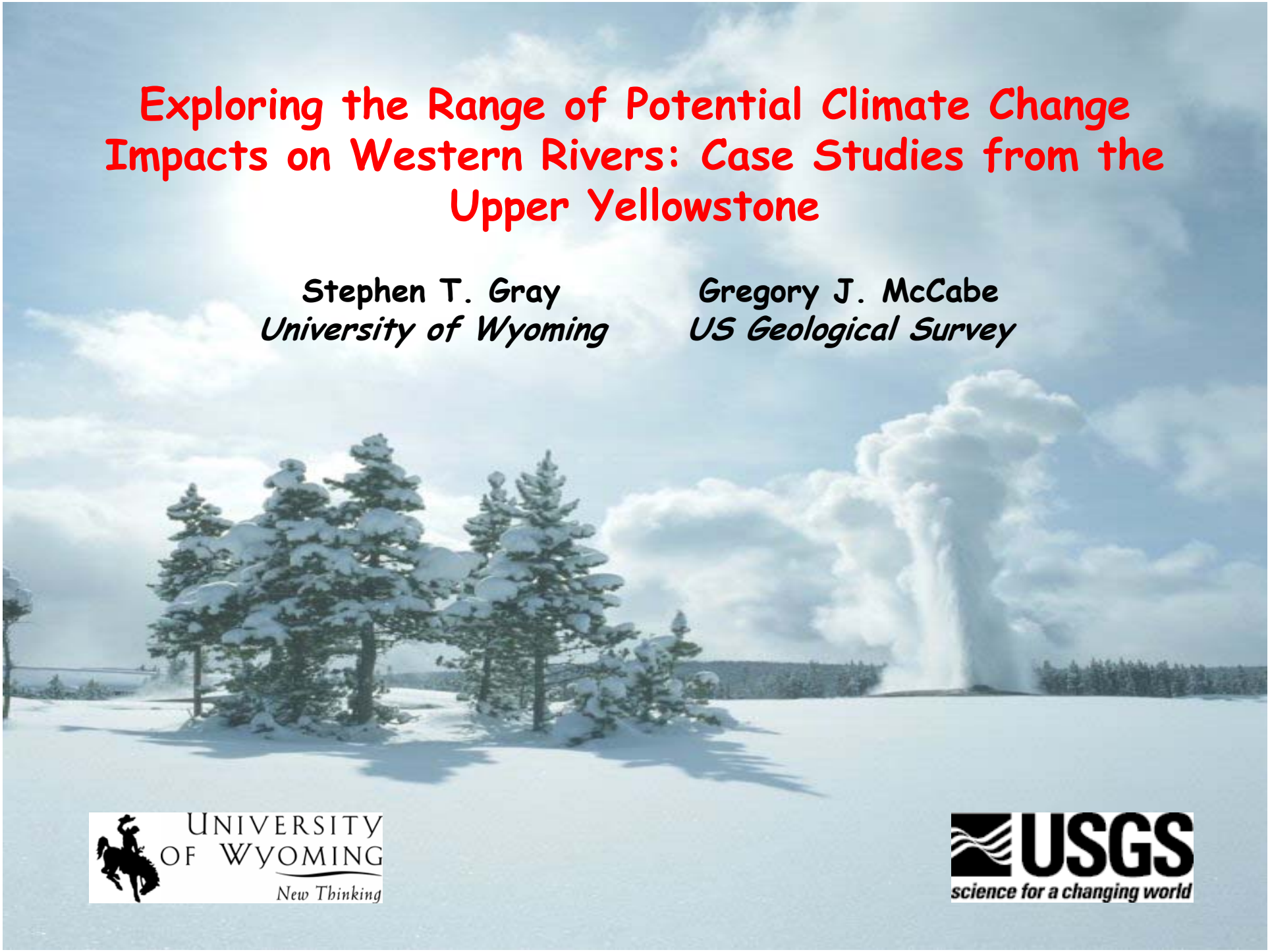
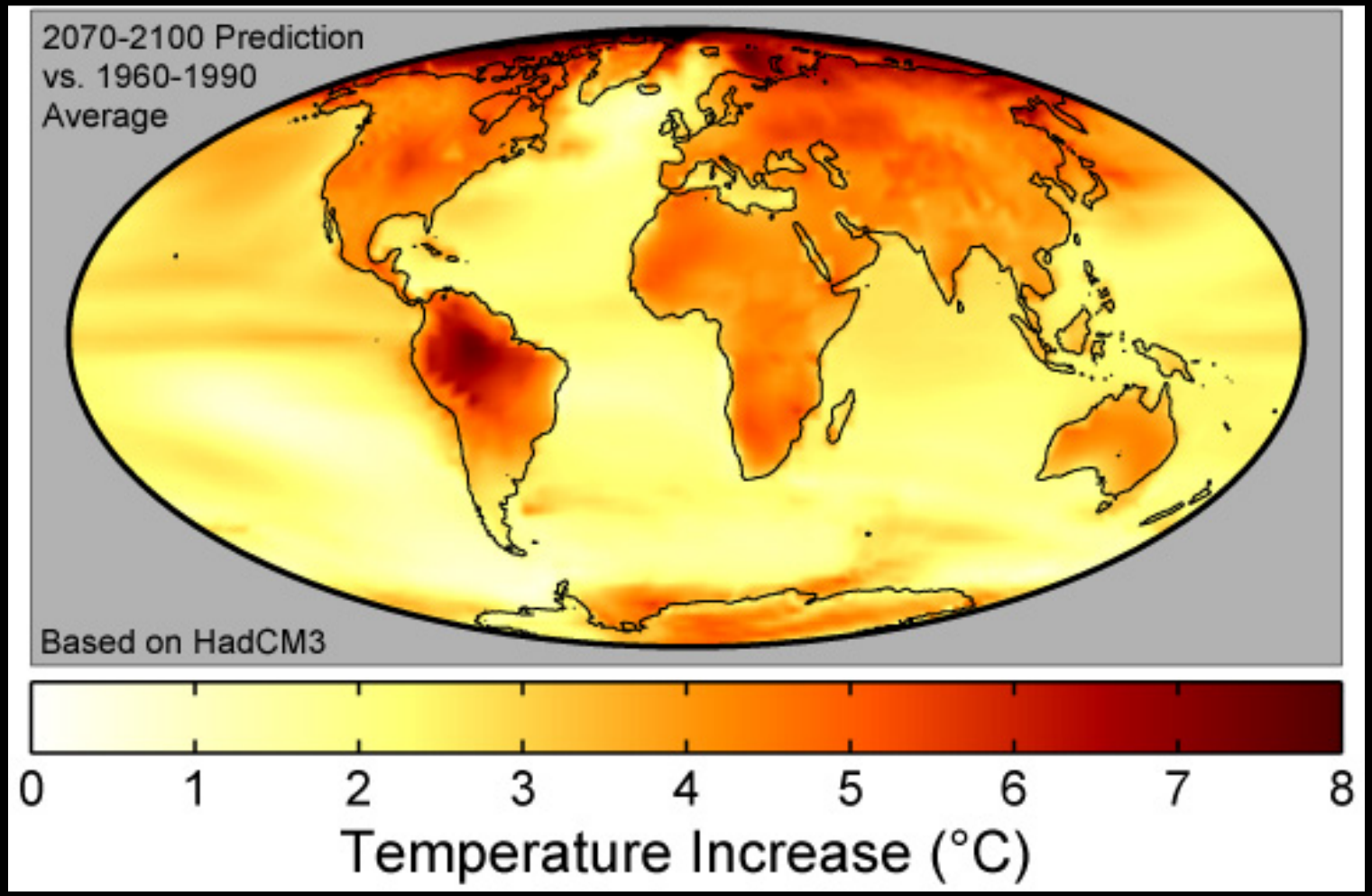


University of Wyoming
New Thinking

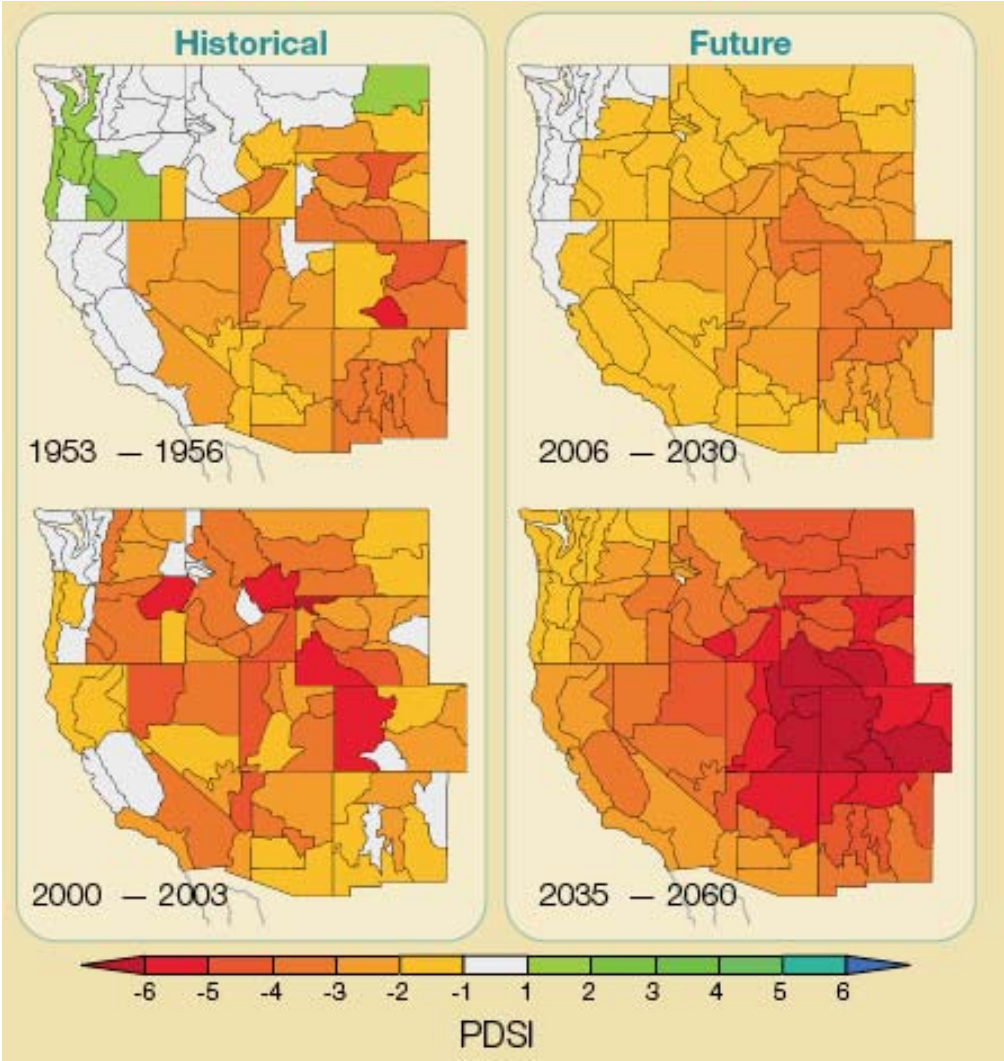
USGS
science for a changing world

The Prognosis- Temperature increases and other climatic changes will continue for many centuries to come



IPCC 2007

Warming = Perpetual Drought?



Calculated Palmer Drought Severity Index Values

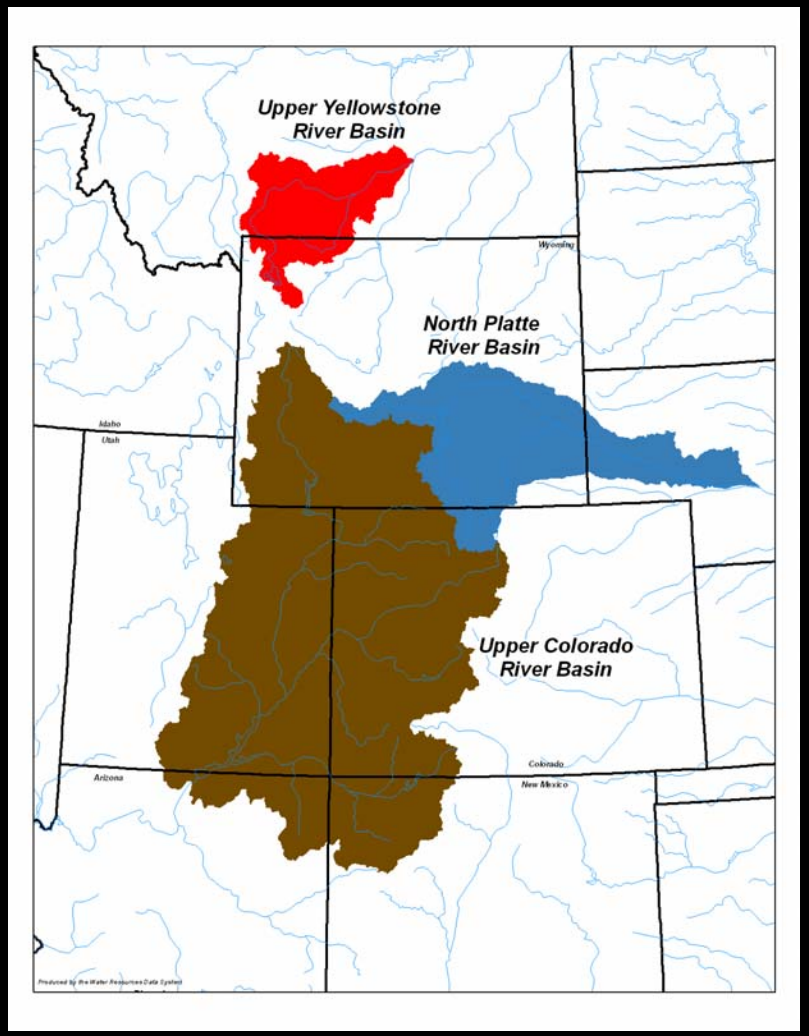
No significant change
In precipitation plus
1.4 °C temp. increase

Small increases in temperature lead to increased evaporation and decreased water yield to streams

No significant change
In precipitation plus
2.8 °C temp. increase

Source: Hoerling and Eischeid - SW Hydrology, 2007

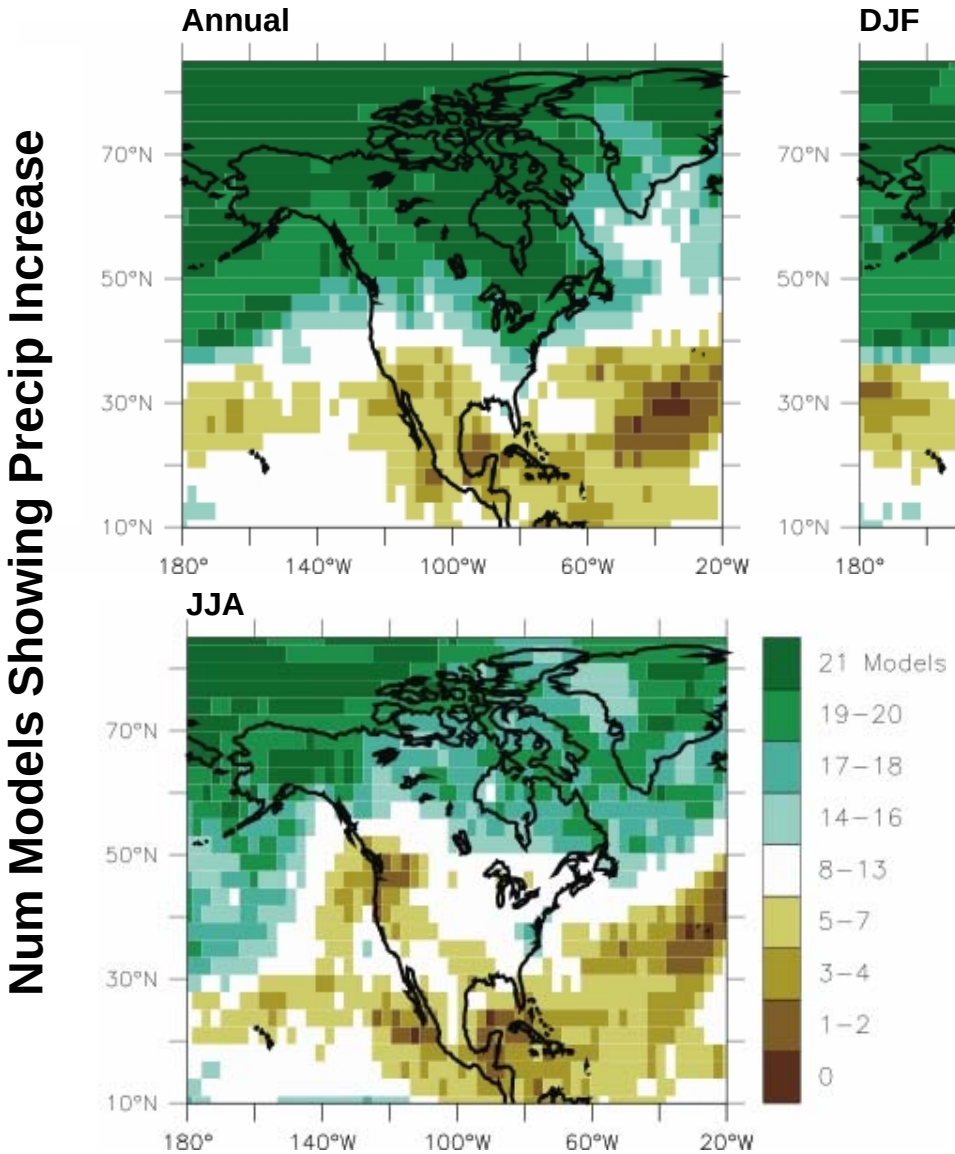
River Flow Sensitivity Studies



How will river flows change when increasing temps are combined with drought and precip change?

Gray et al. (2007), Quat. Res.
Gray and McCabe (In Review) WRR
McCabe and Gray, In Prep.

The Precipitation Forecast Dilemma

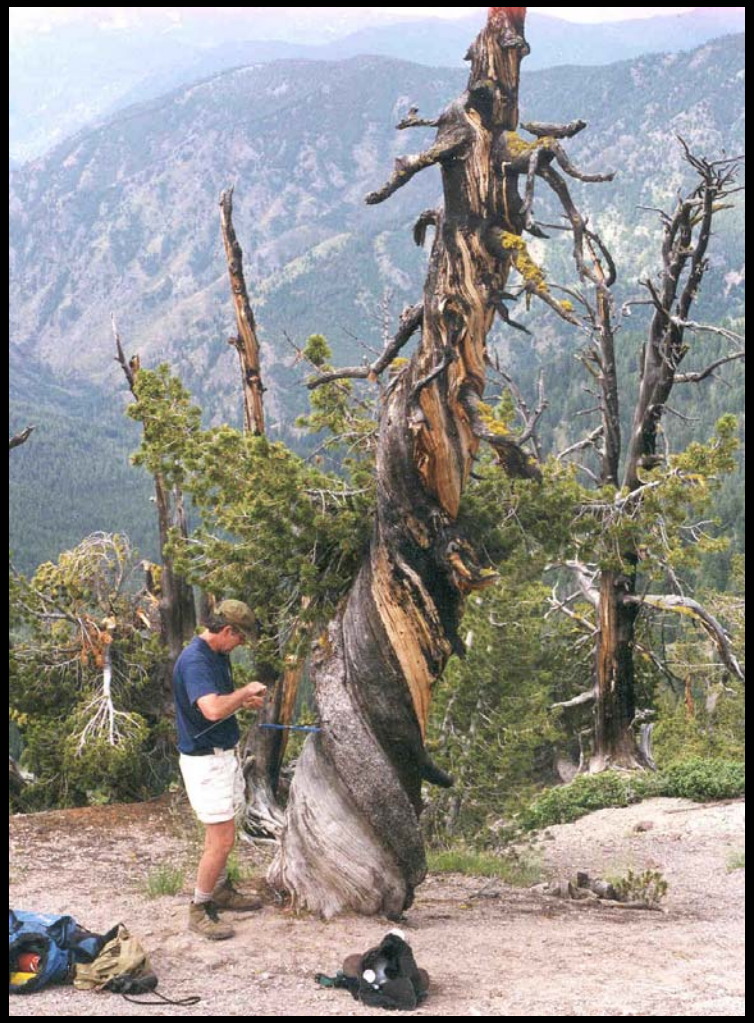


Upper Yellowstone Example

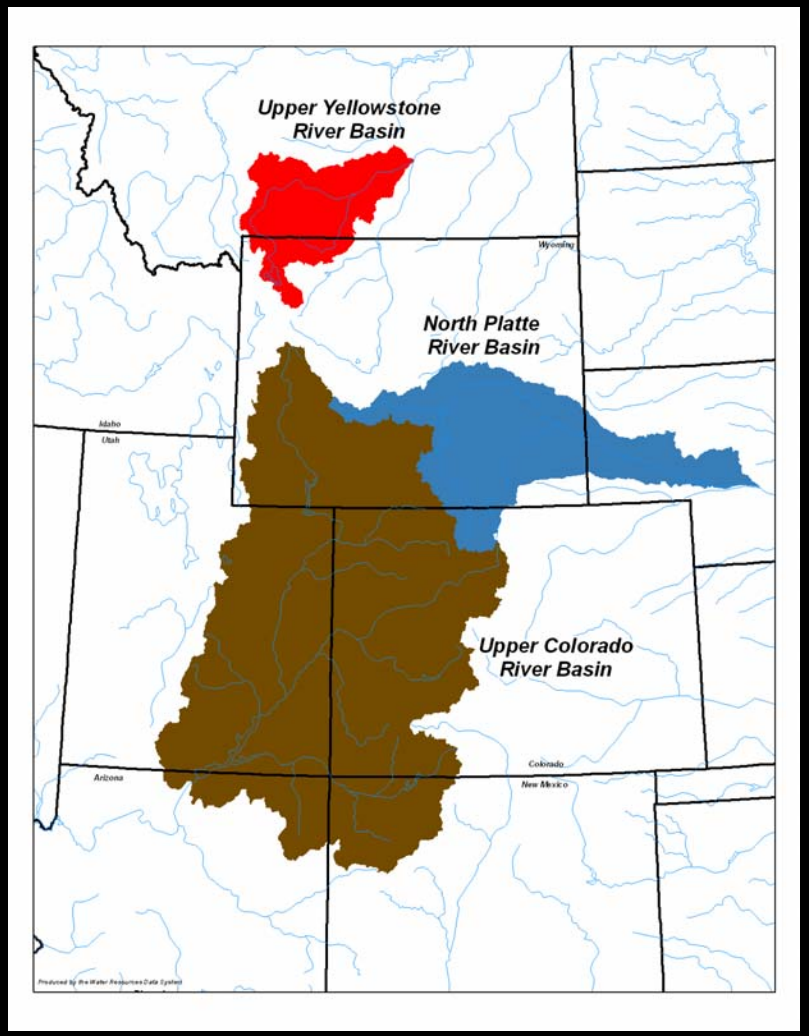
- Models are split on annual and JJA drying/wetting
- 14 of 21 models suggest wetter winters
- BUT "wetter winter" models often over-predict regional precipitation by > 200%

After IPCC 2007

Expanding the Range of Precip Scenarios



River Flow Sensitivity Studies



Tree-ring precipitation
(range of natural variability)

↓ ↓

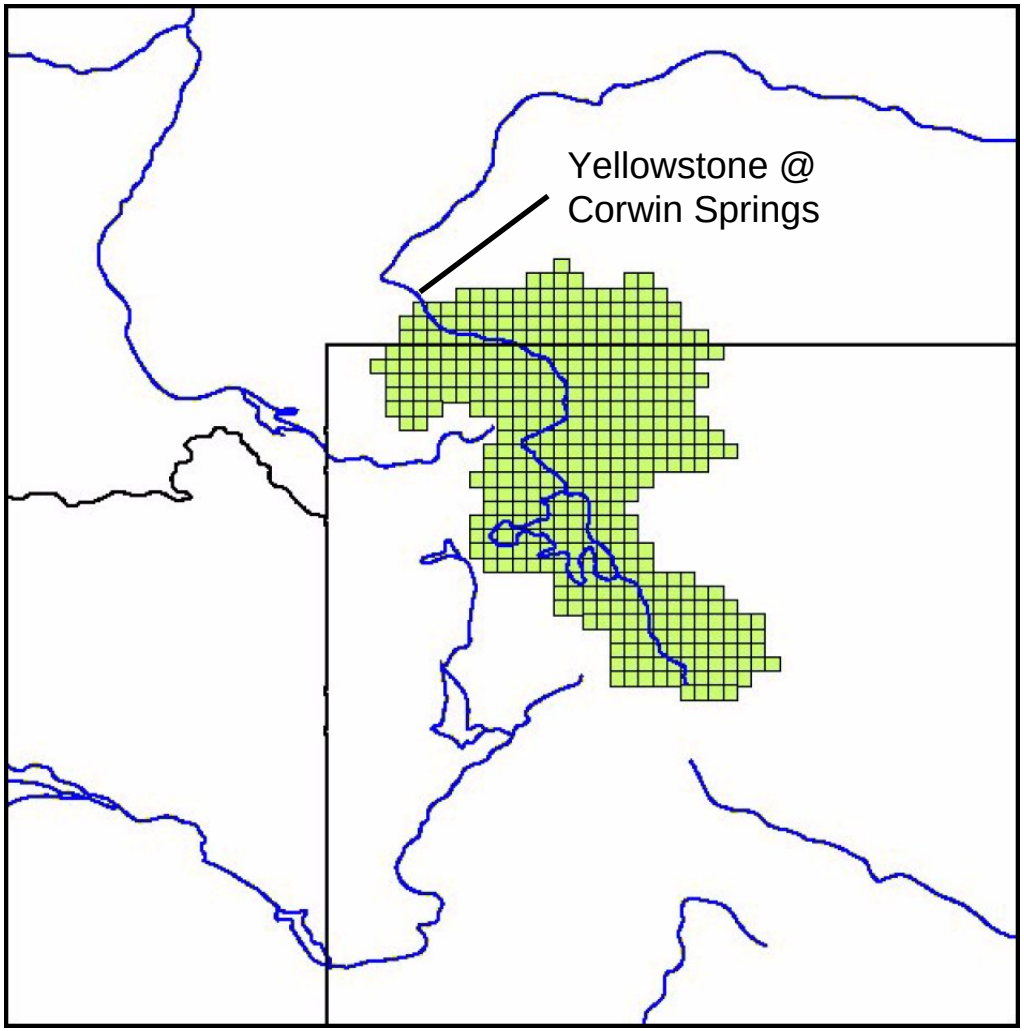
Temperature Scenarios
(Past, Present and Future)

↓ ↓

RIVER FLOW MODEL

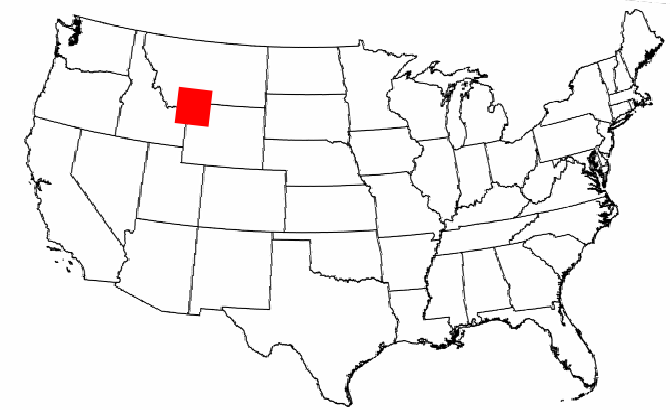
↓ ↓

Estimates of Discharge
(Flow at Key Gages)

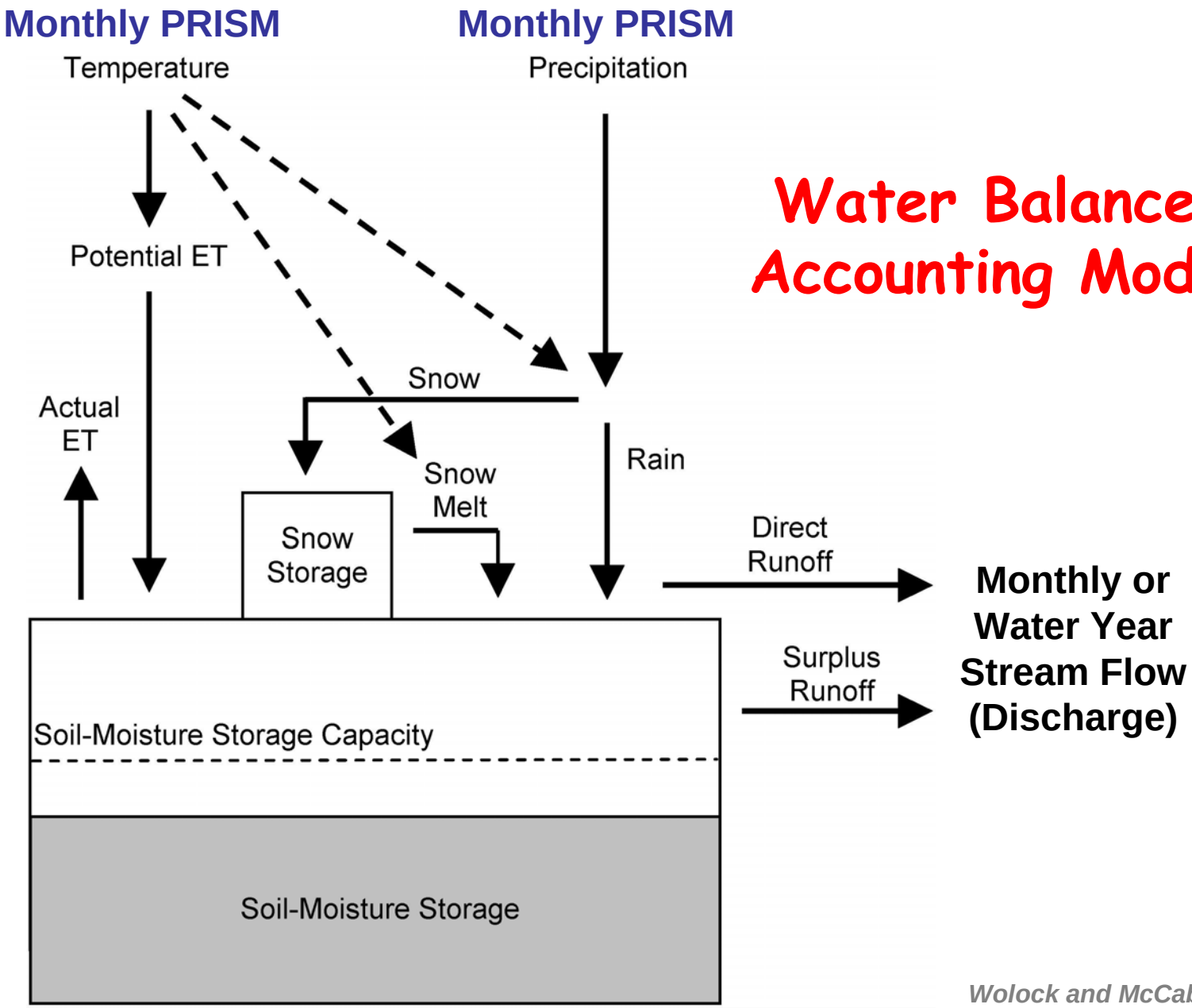


Upper Yellowstone River

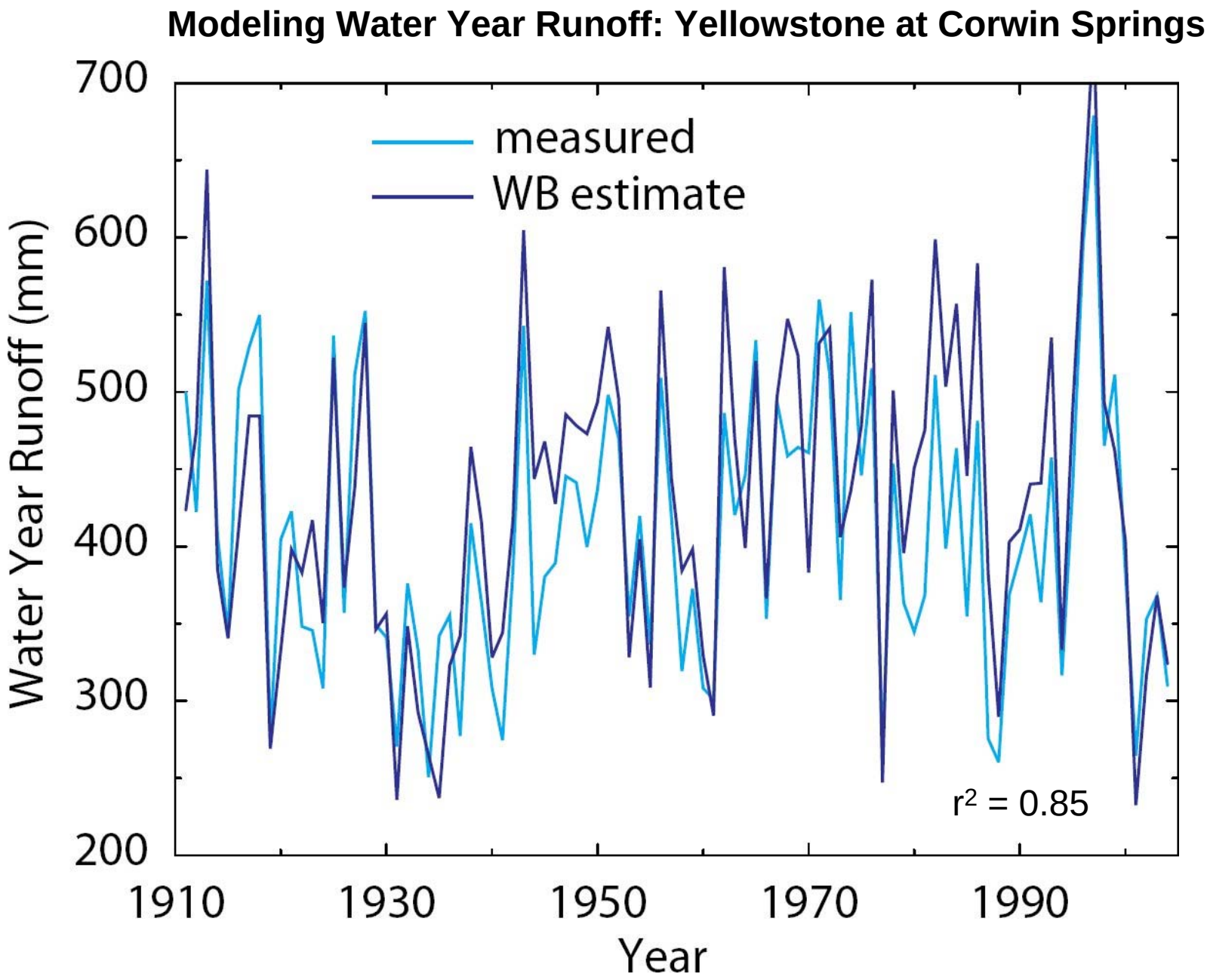
- Headwaters above Corwin Springs, Montana
- Drains approx. 6794 km^2
- Majority in Yellowstone National Park
- Unregulated flows
- Gage in continuous operation since 1911



Water Balance Accounting Model



Wolock and McCabe,1999
McCabe and Wolock, 2007


Modeling Water Year Runoff: Yellowstone at Corwin Springs
measured
WB estimate
Water Year Runoff (mm)
700
600
500
400
300
200
1910
1930
1950
1970
1990
Year
r2 = 0.85

Climate Scenarios

Temperature

- 1896-1995 Averages
- Predicted 2025, 2050 and 2100
  - IPCC AR4
  - 50th percentile A1B
- Reconstructions
  - Moberg et al. 2005
  - D'Arrigo et al. 2004

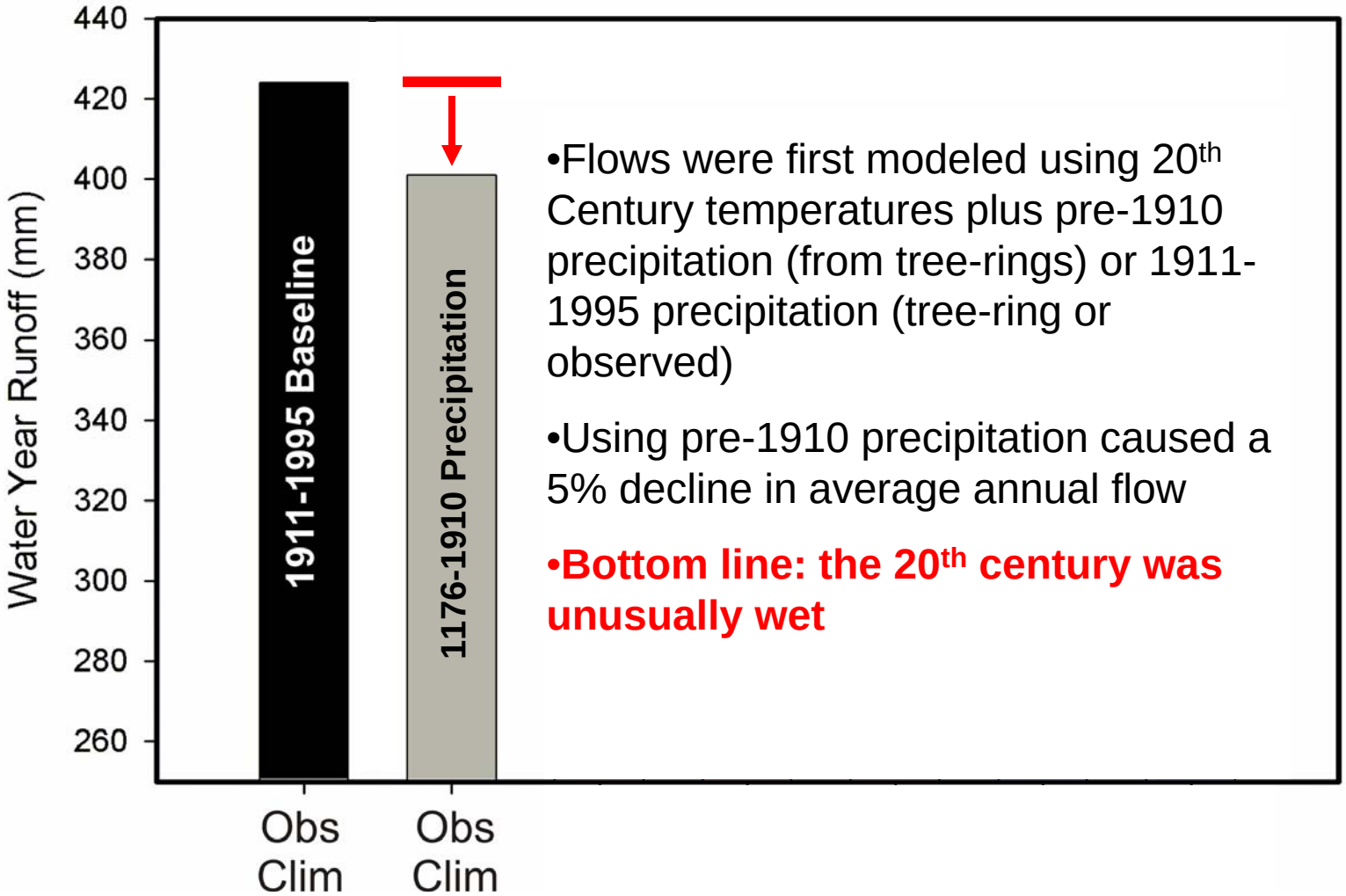
Precipitation

- 20th Century observed
- Tree-ring reconstruction
  - 1173-1996
  - Originally annual
  - Disaggregated to monthly values

Results:

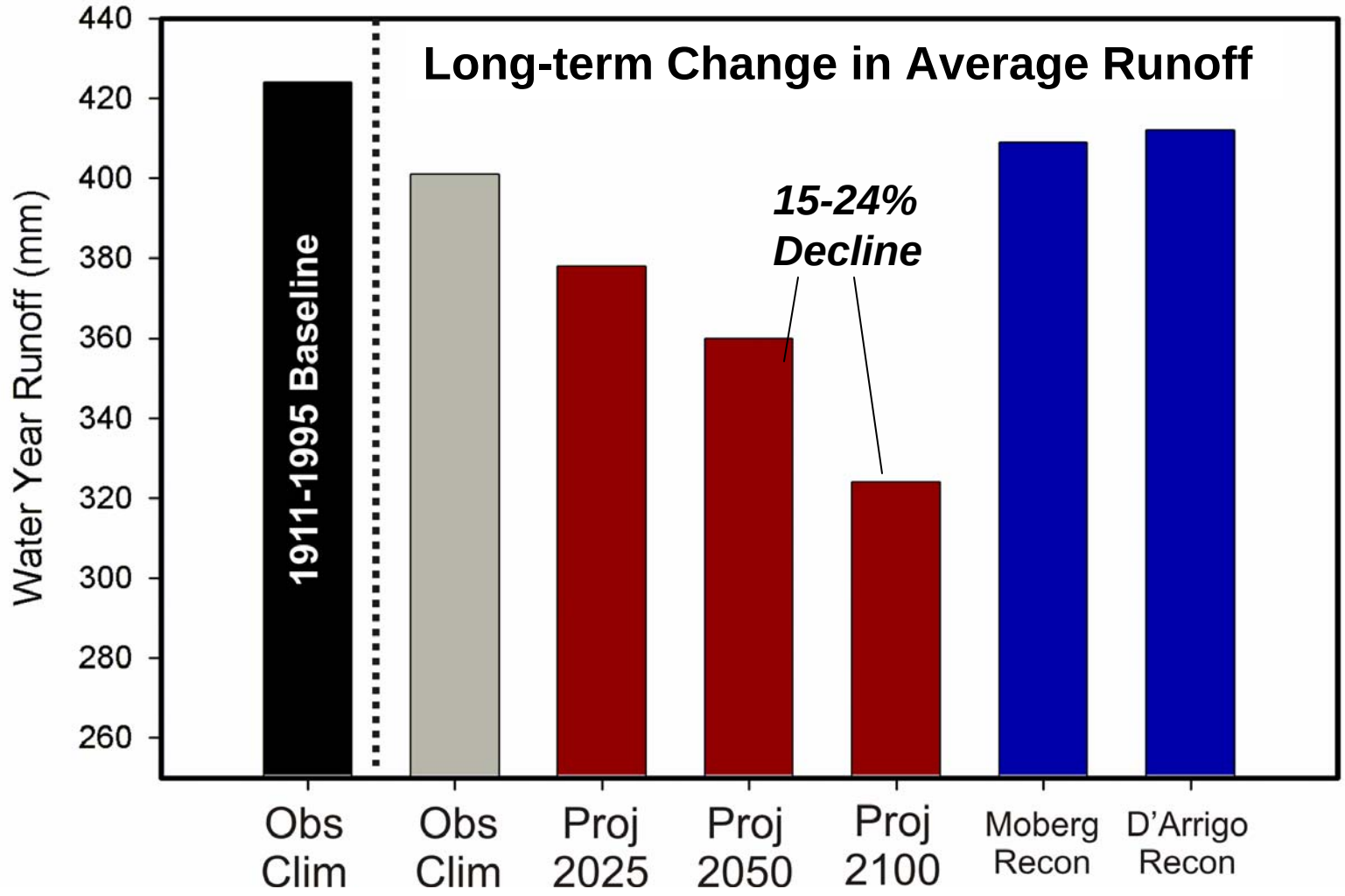
Climate Scenarios and Streamflow Modeling

Modeling Potential Impacts on the Yellowstone River



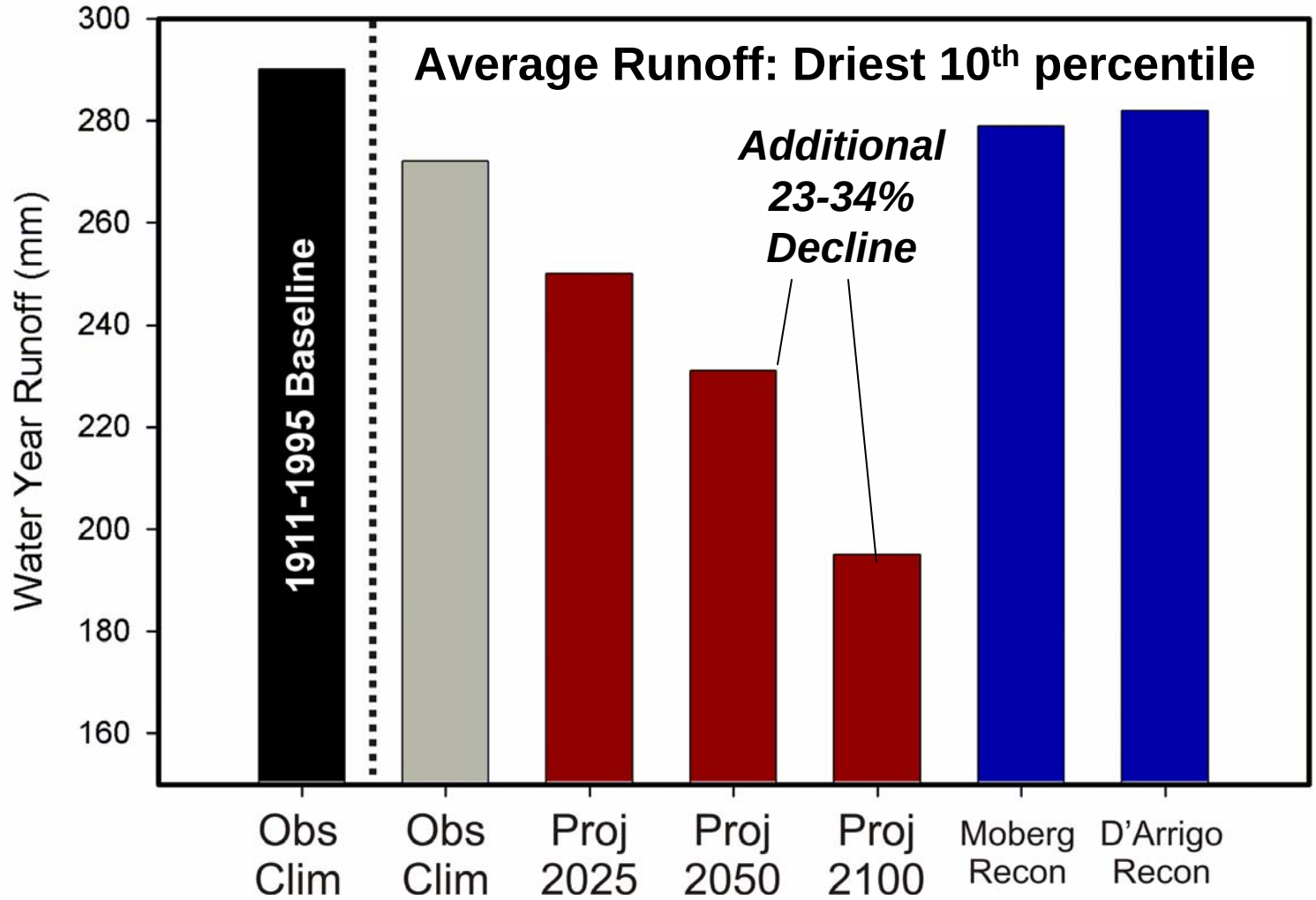
- Flows were first modeled using 20th Century temperatures plus pre-1910 precipitation (from tree-rings) or 1911-1995 precipitation (tree-ring or observed)
- Using pre-1910 precipitation caused a 5% decline in average annual flow
- **Bottom line: the 20th century was unusually wet**

Modeling Potential Impacts on the Yellowstone River



No change from historic precipitation plus warming scenarios

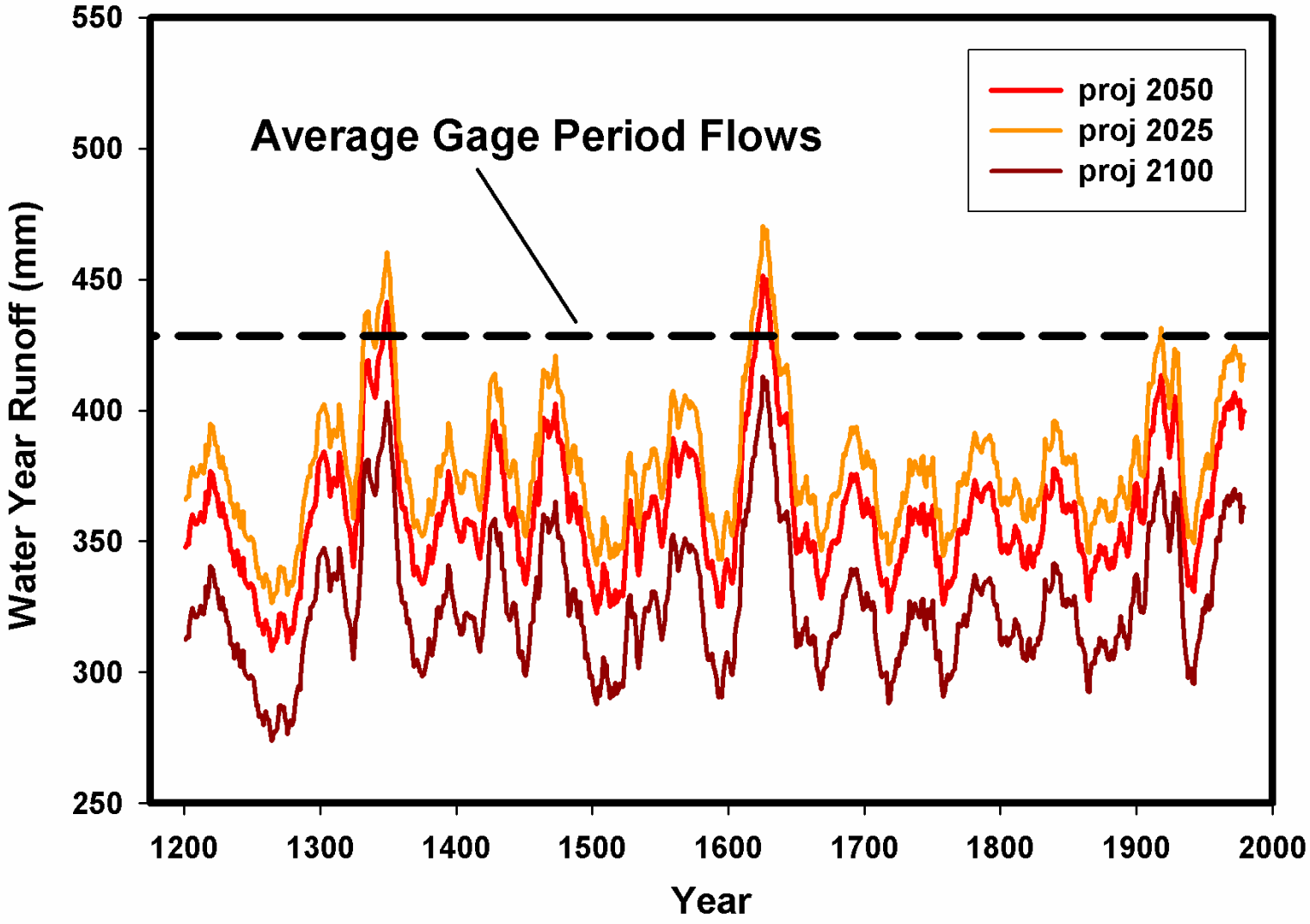
Modeling Potential Impacts on the Yellowstone River

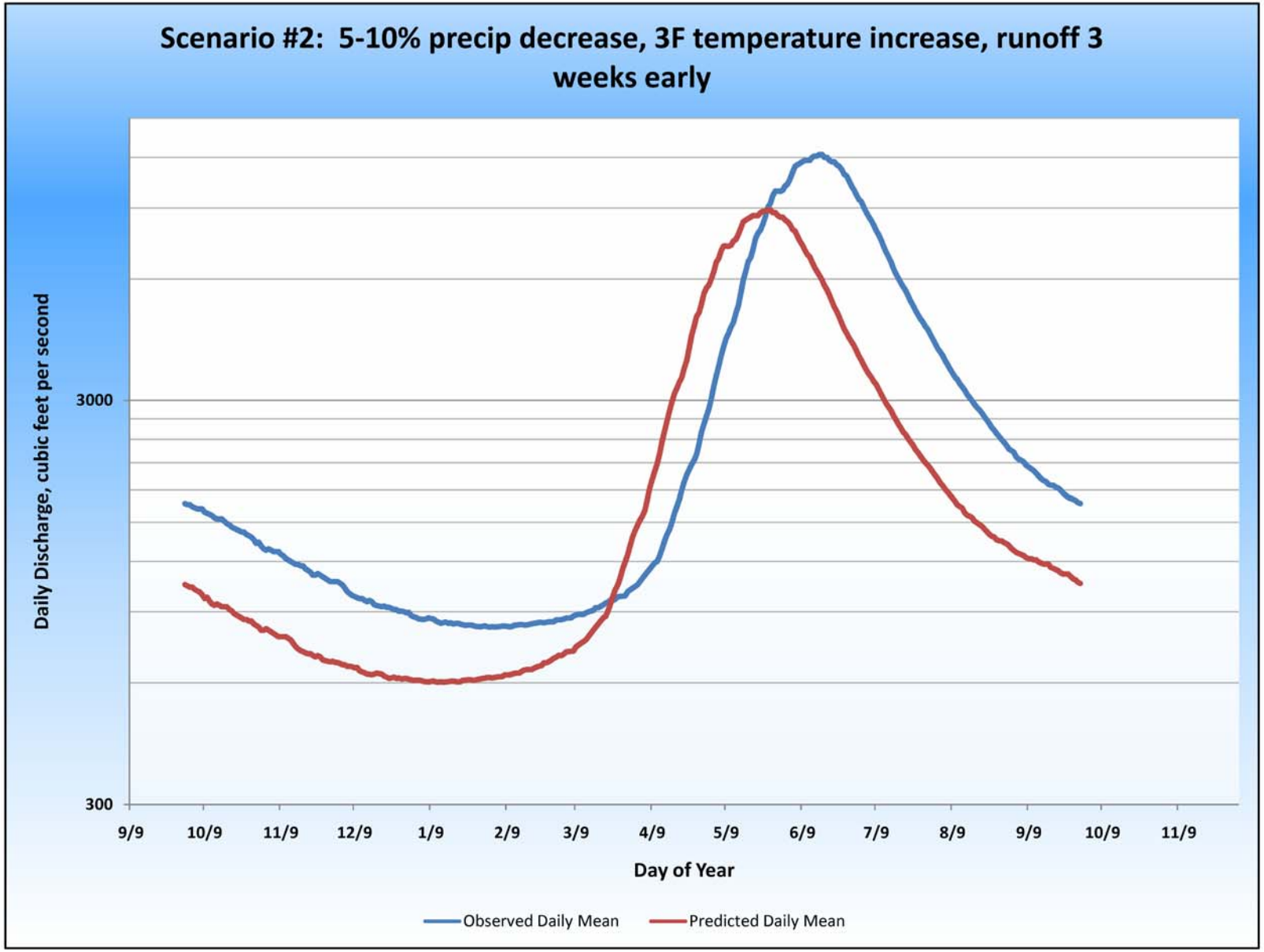


No change from historic precipitation plus warming scenarios

Could precipitation offset increasing temperatures?

Analysis: 800 yr tree-ring record plus future temps



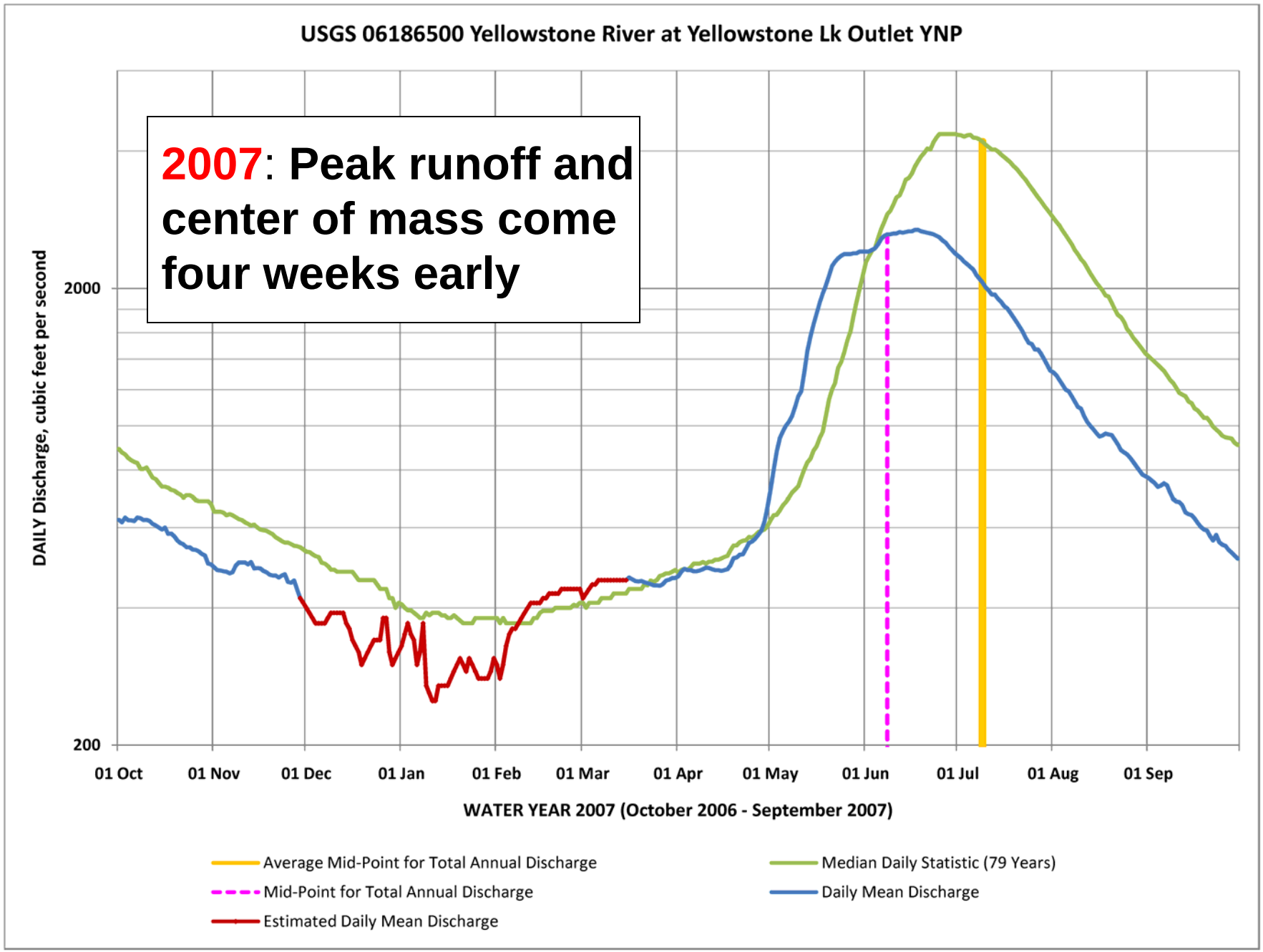

Scenario #2: 5-10% precip decrease, 3F temperature increase, runoff 3 weeks early
Daily Discharge, cubic feet per second
3000
300
9/9
10/9
11/9
12/9
1/9
2/9
3/9
4/9
5/9
6/9
7/9
8/9
9/9
10/9
11/9
Day of Year
Observed Daily Mean
Predicted Daily Mean

Impact on Late Season Flows:

Estimated CFS August 1

	Scenario #1 +3F & Same P	Scenario #2 +3F & -7% P	Scenario #3 +3F & +7% P
Predicted Mean	2320	1993	2620
10th Percentile	1232	1040	1424
90th Percentile	3289	2825	3715

Observed Mean for August 1: 4260 cfs
Lowest Observed Flow (1919): 1550 cfs

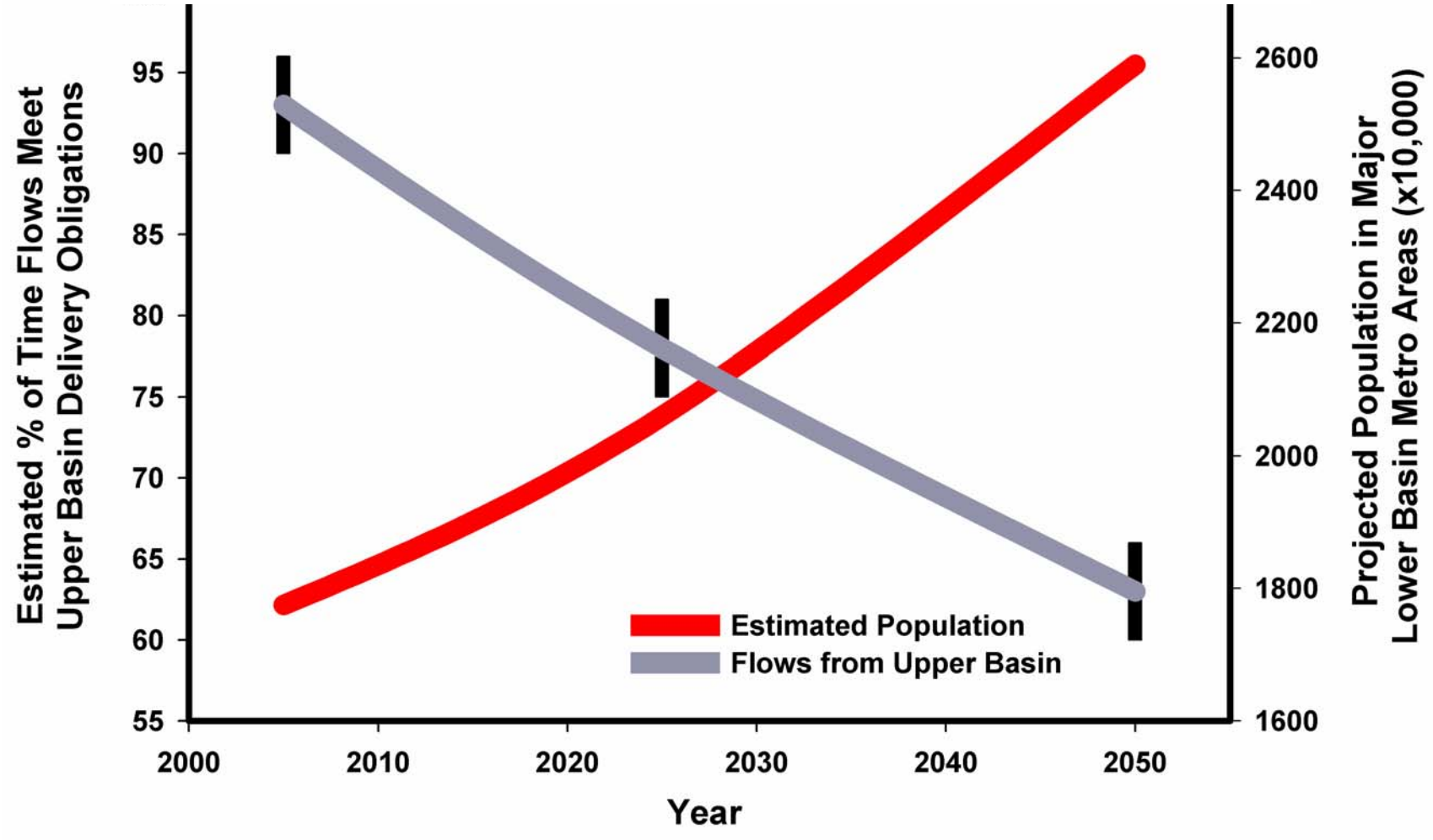

USGS 06186500 Yellowstone River at Yellowstone Lk Outlet YNP
2007: Peak runoff and center of mass come four weeks early
DAILY Discharge, cubic feet per second
2000
200
01 Oct
01 Nov
01 Dec
01 Jan
01 Feb
01 Mar
01 Apr
01 May
01 Jun
01 Jul
01 Aug
01 Sep
WATER YEAR 2007 (October 2006 - September 2007)
Average Mid-Point for Total Annual Discharge
Mid-Point for Total Annual Discharge
Estimated Daily Mean Discharge
Median Daily Statistic (79 Years)
Daily Mean Discharge

Summary of Results

- 20th Century (our "baseline") was unusually wet
- Potential for extended low-flow periods *even in the absence of additional warming*
- Small amounts of warming would greatly intensify the impact of droughts
- Potential precipitation increases not likely to offset temperature-driven drying
- Greatest impacts in late summer(?)

The Western Rivers Problem

Projected Upper Colorado Flows vs. Population Growth



Source: McCabe and Wolock 2007

Thanks!