Analysis of climatic conditions leading to low streamflows in the headwaters of the Colorado River

by

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Acknowledgments

- NSF/EPSCoR Fellowship Program
- College of Arts and Sciences
- Dr. J.J. Shinker- Geography
- Dr. Bryan Shuman- Geology and Geophysics
- Dr. Tom Minckley- Botany

Significance/Background

- Under “normal” conditions the Green River, located in southwestern Wyoming, runs at approximately 1,269,000 acre-feet/year (Frantz and Williams 2001).
- This contributes a substantial amount of water to the Colorado River which provides water for drinking, irrigation, and energy production for around 25 million people (Anderson, 2002).
- Low-flow years reduce the amount of water available for those needs.
- Recent population increases and warming spring temperatures are putting stress on water resources.

http://watersim.asu.edu/images/maps/ColoradoWatershed.png

Colorado River

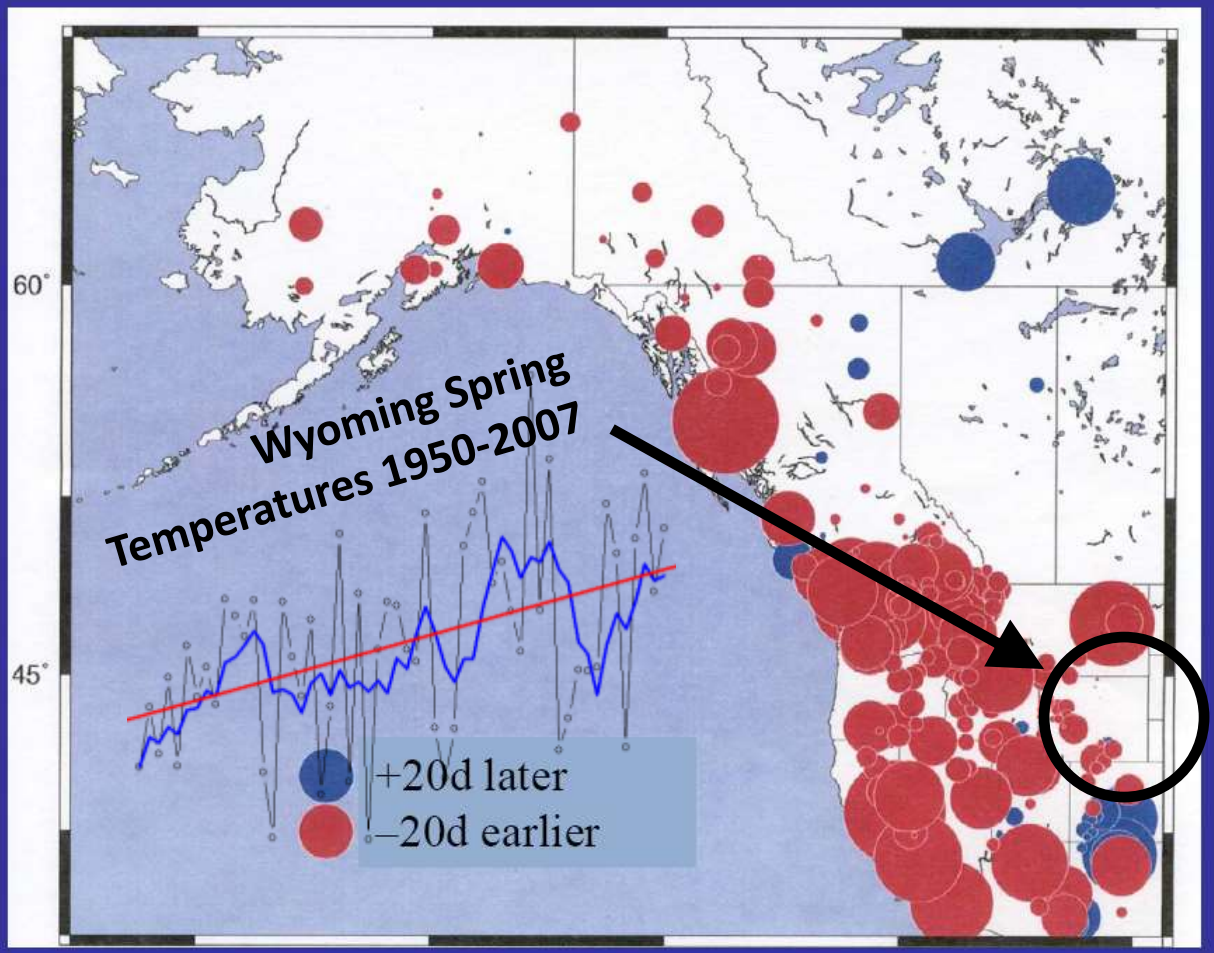
Supply: Green River Lakes, WY

Demand: Las Vegas, NV

Consequences of warming for snowmelt (a water resource)

-Faster spring run-off
-Earlier spring run-off
-Diminished late-season flow
-Increased evaporation

Trends in timing of spring snowmelt (1948-2000)



Courtesy Mike Dettinger, USGS

Stewart et al.(2004) Climatic Change 62, 217-232.

Objectives

1. Identify low-flow years of the Green River headwaters.

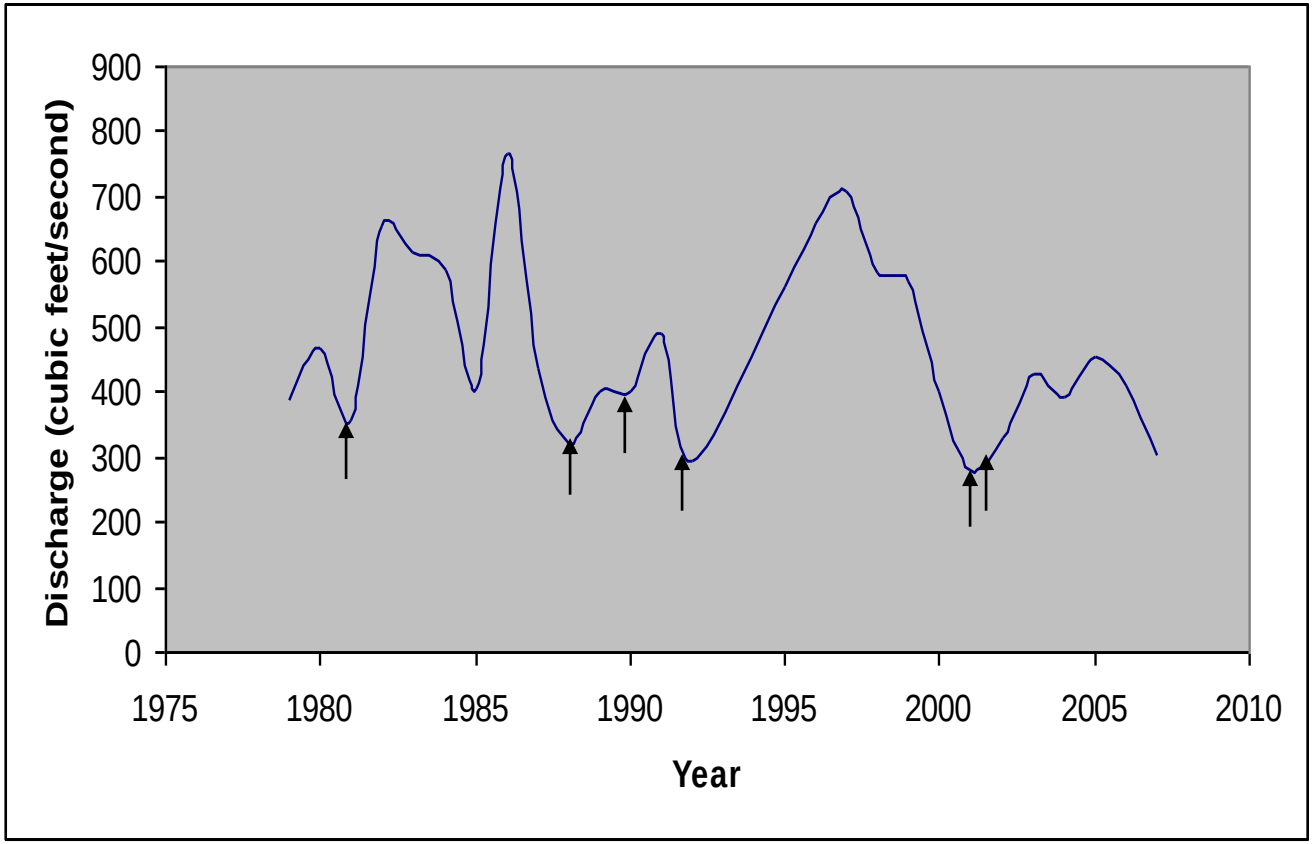
2. Create composite-anomaly maps of climatic variables related to low river flow.

3. Examine the relationship of low-flow years with selected climatic variables.

Data

Low-flow years were selected using a time series of annual runoff in the Green River Drainage Basin (time series from the USGS).

Years of low flow:
1981, 1988,1990,
1992, 2001, 2002



Methods

- Data from the North American Regional Reanalysis (NARR) were used to create composite-anomaly maps of climatic variables.

- The composite-anomaly method averages the values of a selected variable for the selected years (or seasons) of low flow and compares those values to the long-term mean from 1979-present (Yarnal et al. 2001).

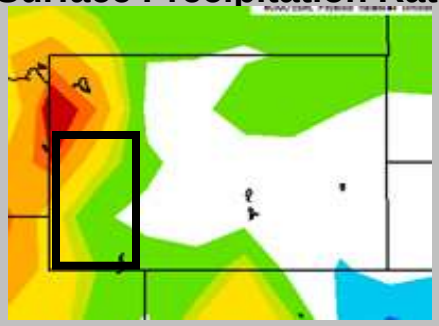
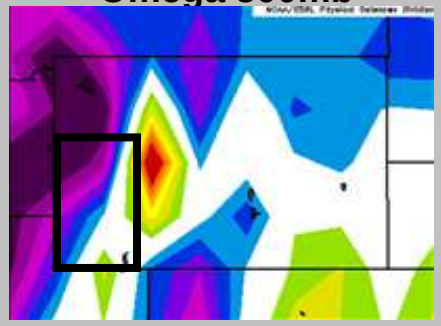
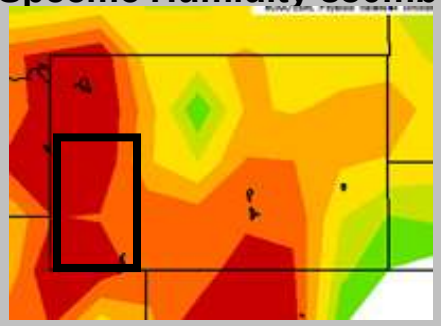
Climatic Variables Examined

- **Precipitation Rate at the Surface**: surface moisture availability.
- **Omega (Vertical Velocity) at 500mb**: mechanisms that enhance (through rising motions) and suppress (through sinking motions) precipitation.
- **Specific Humidity at 850mb**: atmospheric moisture availability.
- **Air Temperature at the Surface**: surface condition.

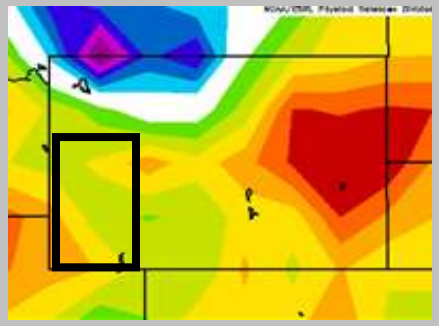
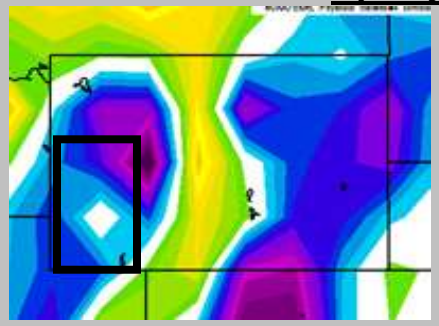
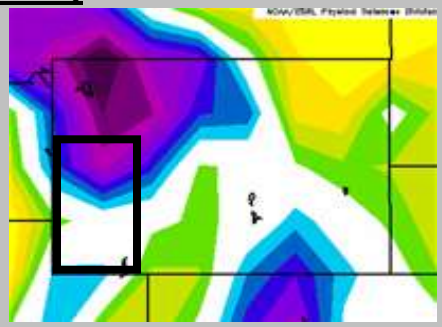
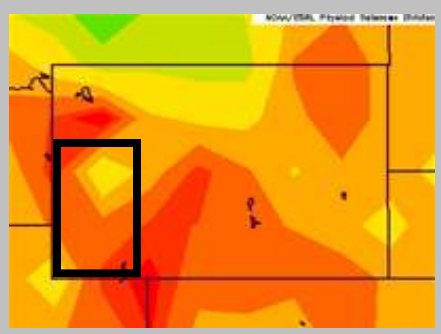
Results/Maps

Winter (JFM)

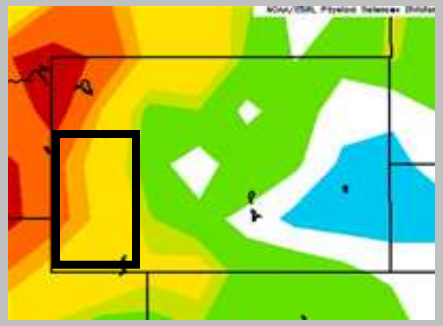
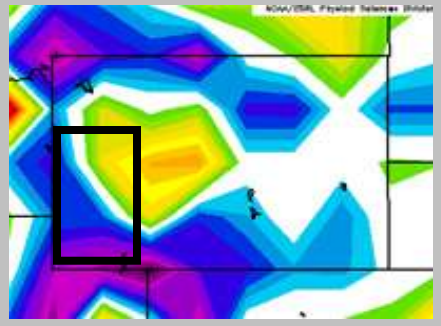
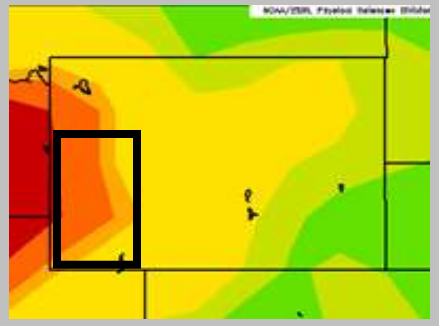
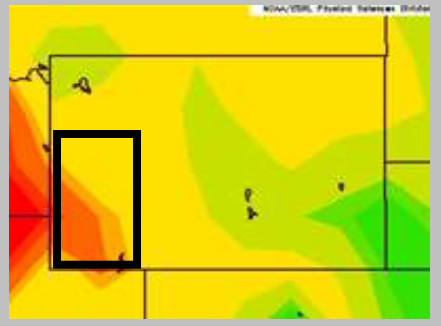
Surface Precipitation Rate | Omega 500mb | Specific Humidity 850mb | Surface Air Temperature


Spring (AMJ)

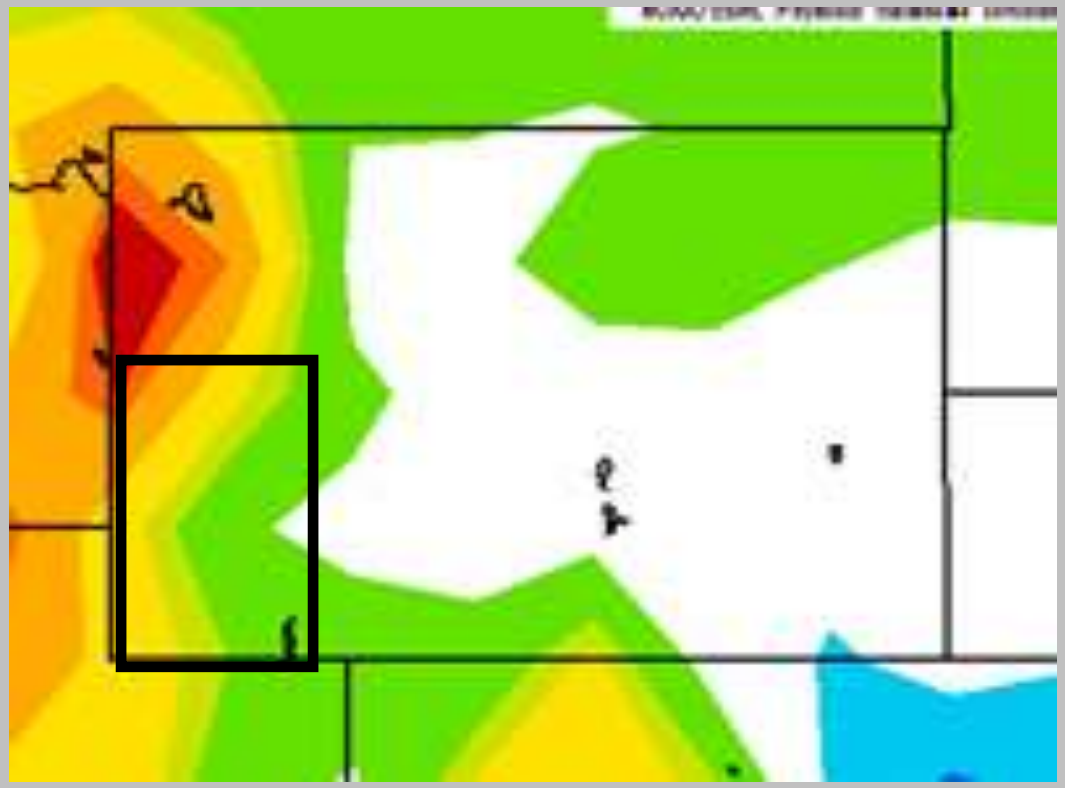
Summer/Fall (JAS)

For all maps: green, yellow, orange, and red colors indicate below-average conditions; blue and purple colors indicate above-average conditions; and white indicates average conditions.

Results

Winter (JFM) precipitation was below average for every year—1981 being the exception with an average precipitation rate.

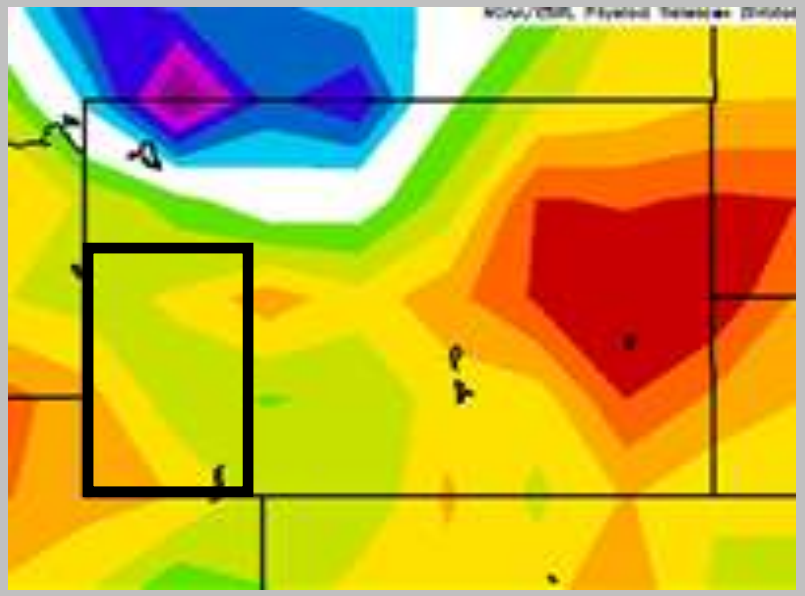


Composite-anomaly map of winter precipitation rate at the surface for 1981, 1988, 1990, 1992, 2001, and 2002 combined.

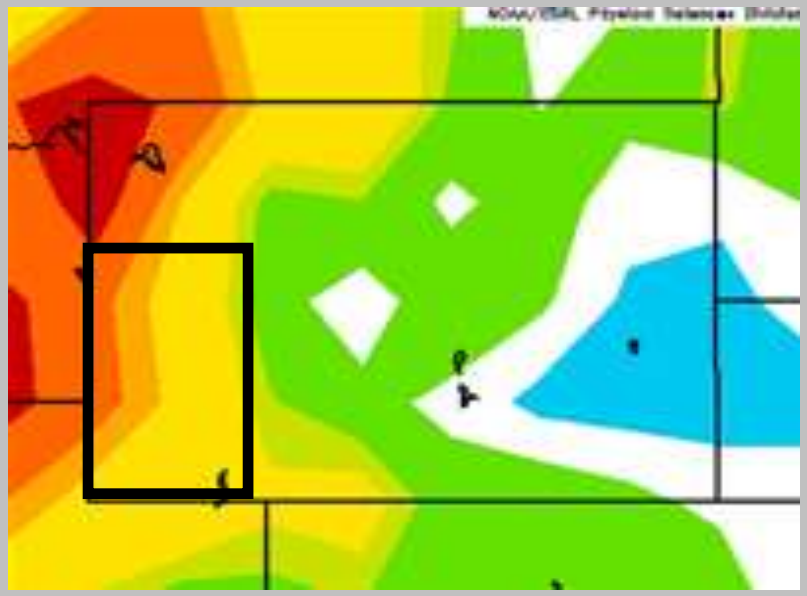
Results (cont.)

These dry conditions persisted through spring (AMJ) and summer/fall (JAS).

Spring



Summer/Fall

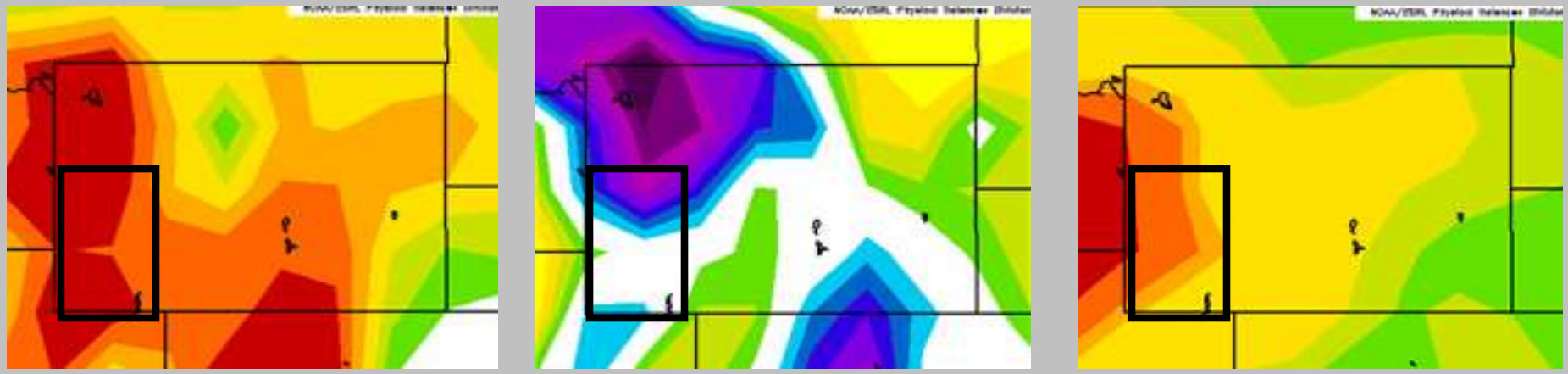


Composite-anomaly maps of spring (left) and summer/fall (right) precipitation rate at the surface for 1981, 1988, 1990, 1992, 2001, and 2002 combined.

Results (cont.)

Specific humidity during all seasons ranged from much lower than average to above average.

Winter **Spring** **Summer/Fall**

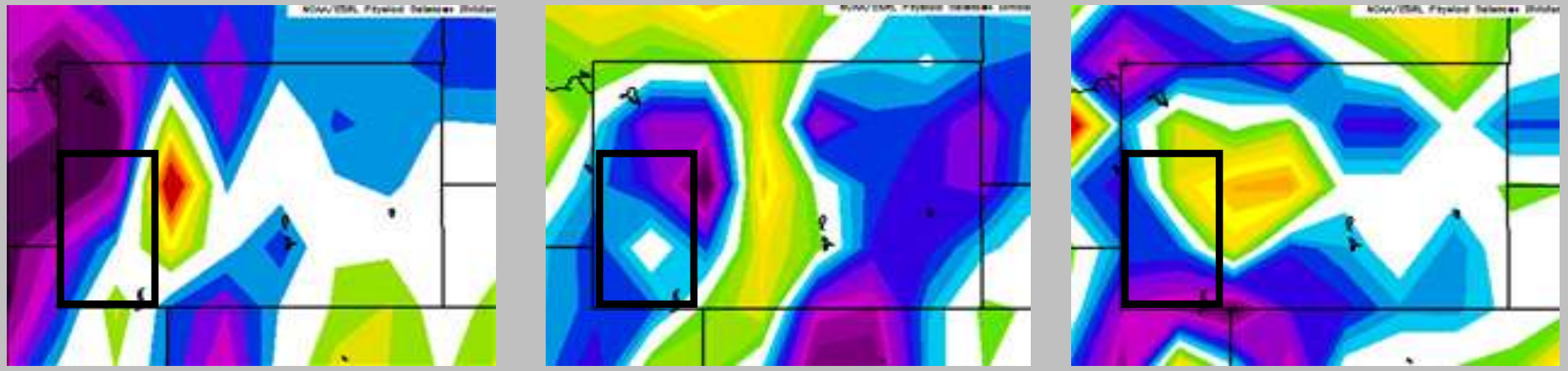


Composite-anomaly maps of winter (left), spring (center), and summer/fall (right) specific humidity at 850mb for 1981, 1988, 1990, 1992, 2001, and 2002 combined.

Results (cont.)

When there was sufficient moisture (high specific humidity) available in the atmosphere to allow for precipitation, sinking motions were dominant and suppressed precipitation; and when rising motions were dominant there was not enough moisture (low specific humidity) in the atmosphere to allow for precipitation.

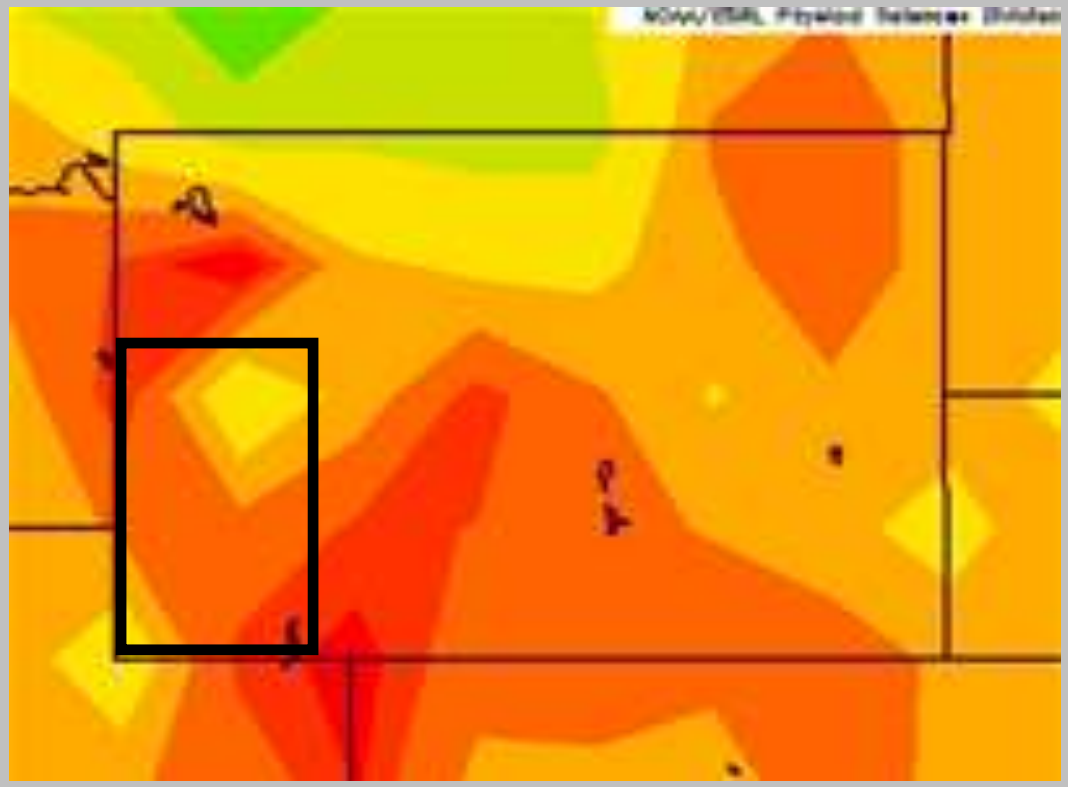
Winter **Spring** **Summer/Fall**



Composite-anomaly maps of winter (left), spring (center), and summer/fall (right) Omega at 500mb for 1981, 1988, 1990, 1992, 2001, and 2002 combined.

Results (cont.)

In addition to the climate dynamics causing persistent dry conditions, higher-than-average temperatures in spring likely led to earlier and faster spring snowmelt, resulting in reduced streamflows.



Composite-anomaly map of spring temperature at the surface for 1981, 1988, 1990, 1992, 2001, and 2002 combined.

Discussion

Lower-than-normal streamflows for 1981, 1988, 1990, 1992, 2001, and 2002 were the result of the following:

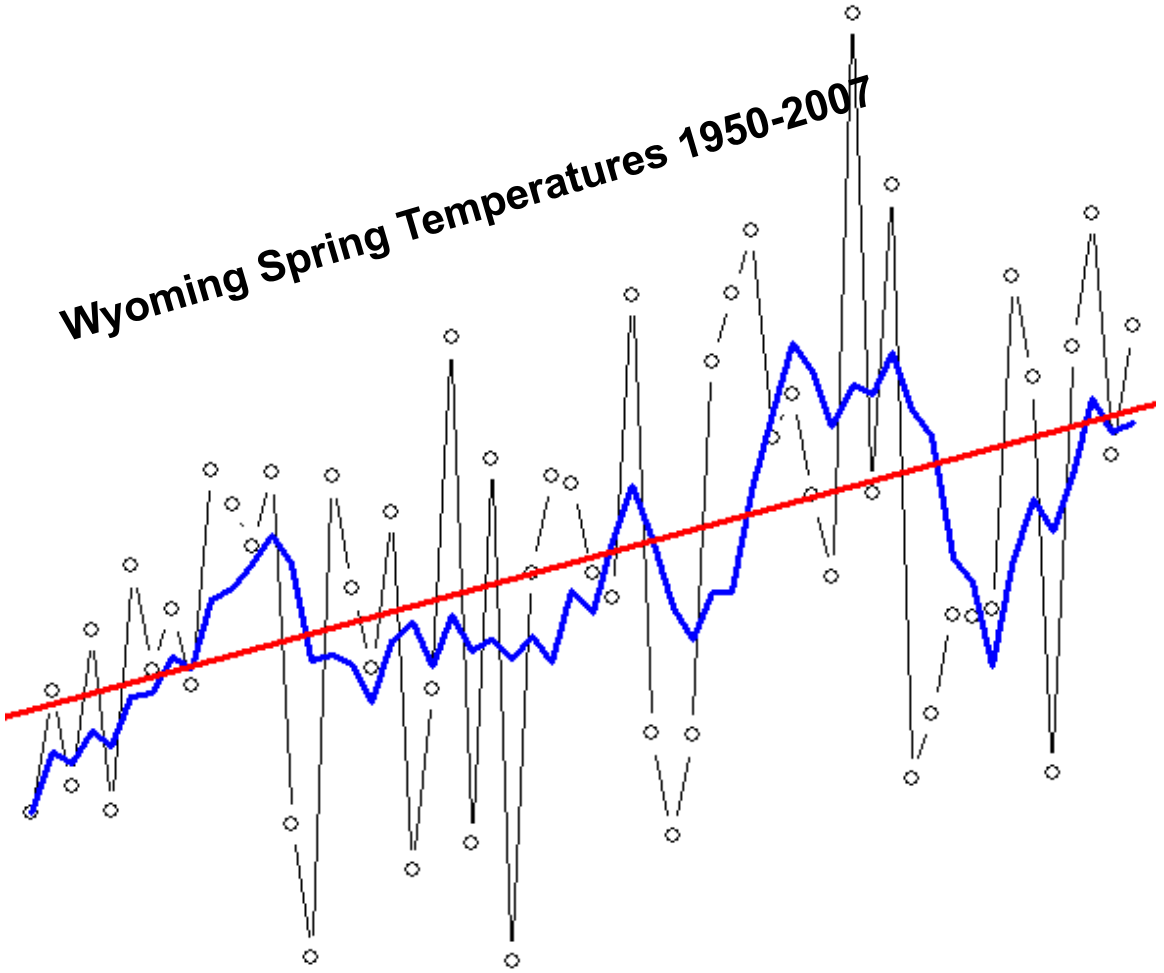
1. Dry conditions that began in winter (JFM) and persisted through the remainder of the year

and/or

2. Warmer-than-normal spring (AMJ) temperatures that reduced streamflows as a result of earlier and faster spring snowmelt.

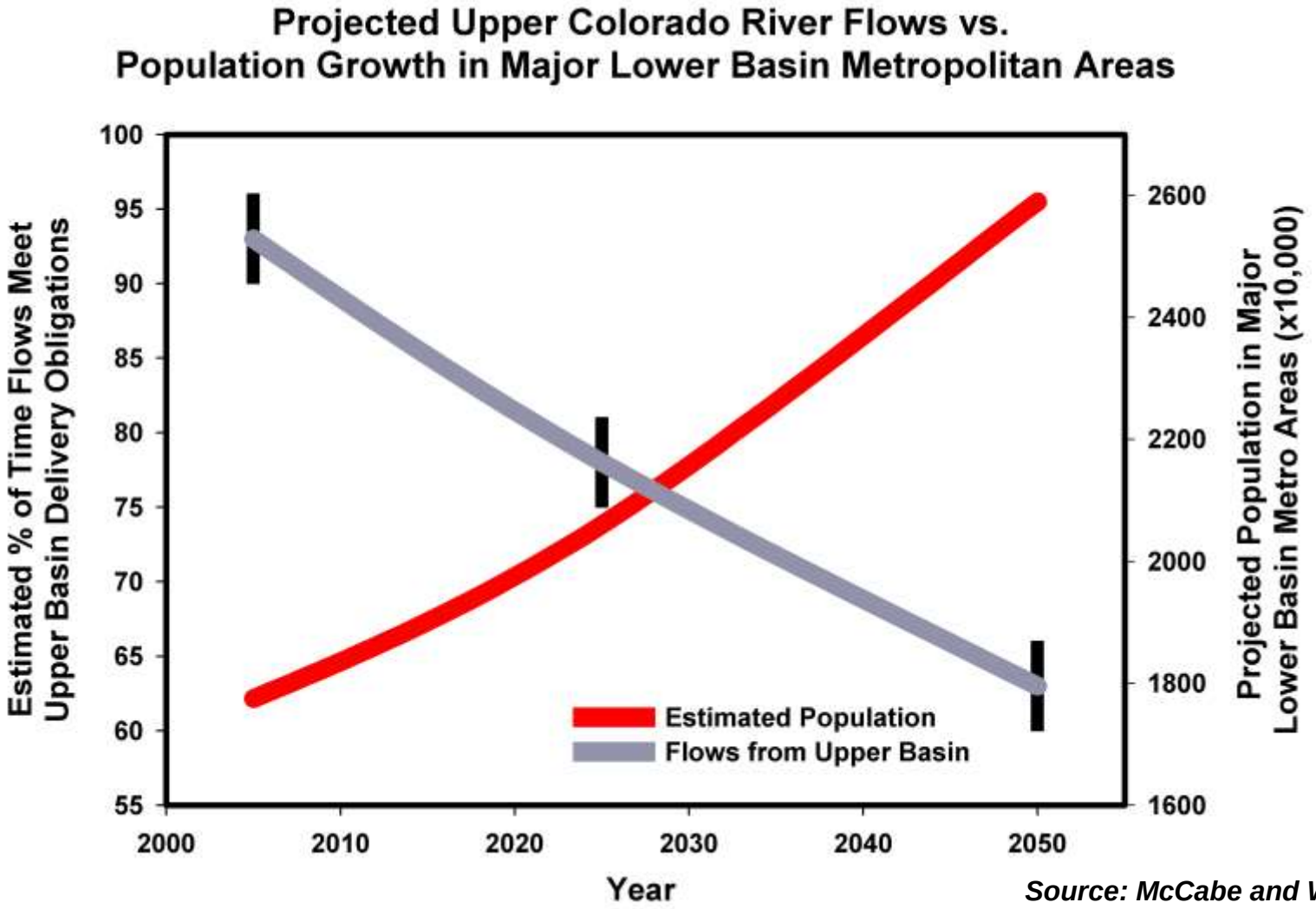
Implications

1. Further increase in spring temperatures indicates continuation of years with faster and earlier-than-normal spring snowmelt leading to more low streamflows.



Implications (cont.)

2. Increased stress on a limited and possibly decreasing water supply in conjunction with rapid population increase.



Source: McCabe and Wolock 2007

Future Research

- Further examination of regional headwaters hydroclimatology.
- Assess upper versus lower basin climatic drivers of drought.

Thank you

Questions?