The Effects of Temperature on Colorado River Drought over Past Centuries Inferred from a Runoff Efficiency Reconstruction

Connie Woodhouse*
School of Geography and Development, and Laboratory of Tree-Ring Research, University of Arizona

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*Co-authors: Greg Pederson (USGS), Steph McAfee (Univ. of Nevada, Reno), Greg McCabe (USGS-Denver), and Kiyomi Morino (University of Arizona) in collaboration with a number of water resource professionals. Funded by USGS Southwest Climate Science Center grant G14AP00152 and the NOAA RISA program.
“A case study across timescales”
While tree ring records have annual resolution, they probably cannot capture flash droughts.

However, they may document the impact of a flash drought.

And they can provide context.
Colorado River at Lees Ferry: Flash droughts embedded in multi-year drought*

*Consecutive below average years broken by no more than 1 above average year.
Flash droughts could be embedded in longer periods of below or above average flow.

Colorado River at Lees Ferry water year streamflow, 762-2005

% of mean = 1906-2004 observed mean
Returning to the idea that drought is not just about precipitation deficits.......
Runoff efficiency (RE): the relationship between runoff and precipitation

- flow/precipitation (in volume, for a given area, usually for the water year)

- an alternative definition: flow – precipitation (using standardized series)
Runoff efficiency is negatively associated with temperature in the UCRB

**Important caveat:** temperature is not the only factor that influences RE; dust on snow, base flows, soil moisture, and in this study, spring precipitation can also impact RE.
For this study:

\[ RE = \text{Water year streamflow} - \text{cool season precipitation} \]
2 Flavors Runoff Efficiency During Drought:

+ RE with < average flow (e.g., 1953) - cool temperatures

- RE with < average flow (e.g., 2004) - warm temperatures
Focus here: below average years with the largest* runoff efficiency values

* > +/- 1 standard deviation from the mean difference
Observed and Reconstructed RE, 1906-1997

Dotted lines = +/- one standard deviation

Again, our focus is on the extreme RE years

More details in Woodhouse and Pederson 2018
Colorado River Basin Runoff Efficiency 
below average flow years, 1569-1997

[Diagram showing years 1550 to 2000 with blue and red bars indicating + and - Runoff Efficiency, respectively.]
Colorado River Basin Runoff Efficiency: counts of extreme years by half century, 1569-1997
Colorado River Streamflow with Large RE Droughts
1569-1997

* = Average RE is > +/- 1 standard deviation from the mean
Horizontal line = ½ a standard deviation from the mean RE
Reconstructed runoff efficiency and late runoff season (May-July) UCRB temperature, 1569-1993

20-year running mean of runoff efficiency values for anomaly years only plotted on middle year
May-July temperature smoothed with a 20-year spline
Reconstructed runoff efficiency and late runoff season (May-July) temperature, with streamflow, 1569-1993
Summary

• Large departure in annual flow could result from flash drought conditions.

• These years may be embedded in ongoing droughts, or occur during decadal periods that are wetter or drier overall.

• Runoff efficiency influences drought in streamflow in both positive and negative ways.

• Positive runoff efficiency years are often imbedded in a multi-year drought, moderating the impacts of precipitation deficits, through the 20\textsuperscript{th} century.