GILA RIVER NEAR SOLOMON AZ

Basin area	7896 square miles
Gage elevation	3060 feet
Average water year flow	322747 acre feet

UPPER GILA RIVER

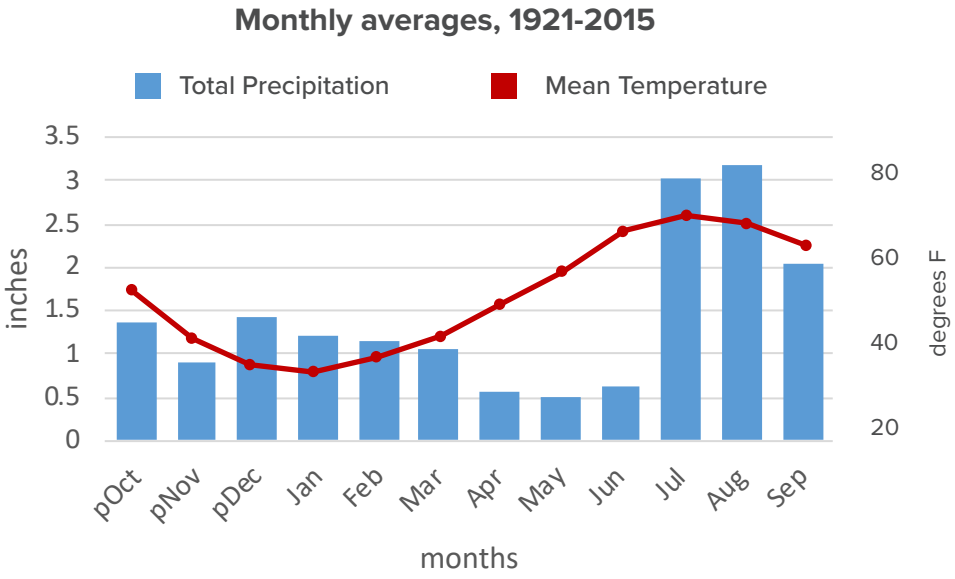
Relationships between Climate and Streamflow

Upper Gila River: Relationships between Climate and Streamflow

What are the main climatic controls on Verde River water year streamflow?

The relationship between water year streamflow and monthly or seasonal temperature and precipitation for the upper Gila River watershed examined for the years 1921-2015, along with a shorter snowpack record, to determine the most important climatic influences on streamflow (data on P. 6). After identifying the most important climate factors related to water year flow, stepwise linear regression was used to determine the variance in streamflow accounted for by specific climate variables (P. 2). Trends in streamflow and climate were then assessed (P. 3). Droughts were identified, along with the average climate conditions that occurred during the years of each multi-year drought (P. 4). Finally, years for which streamflow and climate conditions were unusual were examined in greater detail (P. 5).

The climate of the basin is characterized by two peaks in precipitation: the cool season (October-March) and the monsoon (June-September). Average temperatures range from 36F in January to 71F in July.

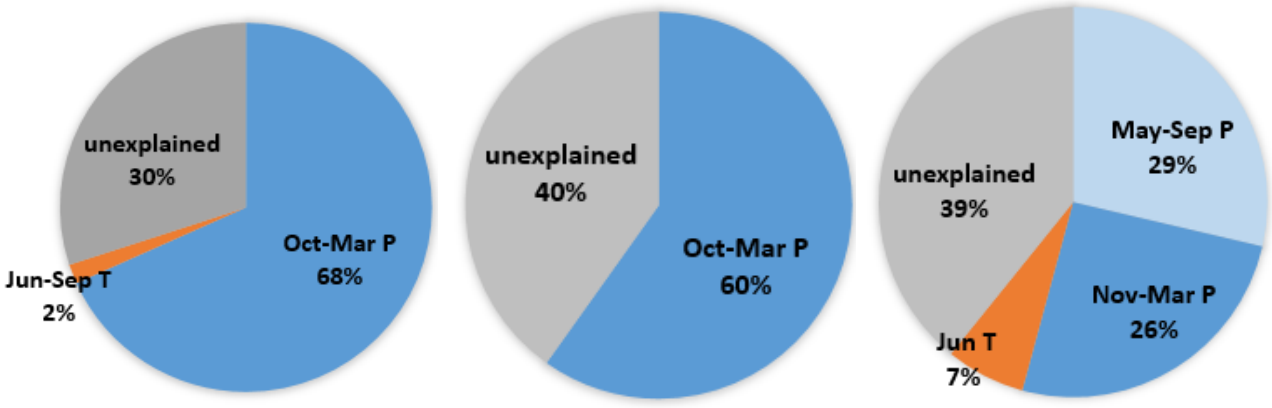


Summary of Main Findings

- When all years are considered, cool season (October-March) precipitation is the most important influence on streamflow, accounting for 68% of the variance in flow, less than for the Salt and Verde Rivers, where winters are wetter.
- In years with below median flow, monsoon precipitation accounts for slightly more of the variance in flow than cool season precipitation; June temperatures become more important, explaining 7% of the variability in flow.
- There is no evidence of long-term trends in flow, precipitation or snow, but significant warming has occurred over the past 100 years, although the increase is less in summer.
- In all streamflow droughts, flows deficits are less than cool season deficits; the monsoon always below median, so may be further reducing flows.
- During some droughts and individual years, warm temperatures maybe further exacerbating low flows, but this effect is less obvious than in other lower Colorado River sub-basins.
- Years with above median flow, with flow greater than winter precipitation (e.g., 2006) appear both early and late in the record, while more years with less flow than might be expected given precipitation (like 2004 and 1960) occurred between the 1930s and 1960.

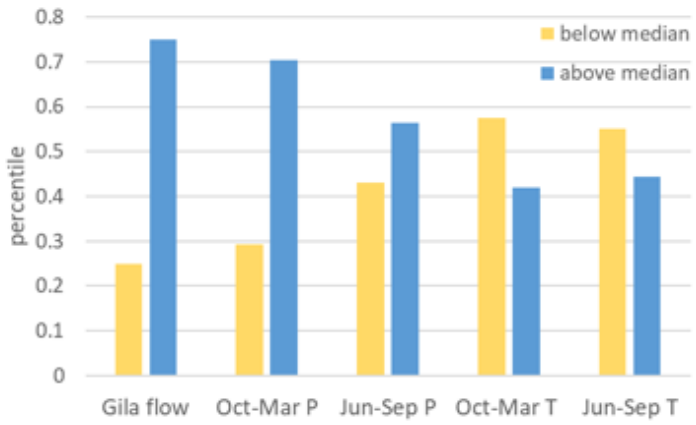
Upper Gila River: Climatic Controls on Streamflow

Pie charts below show seasonal precipitation and temperature variables that are most important for water year streamflow.

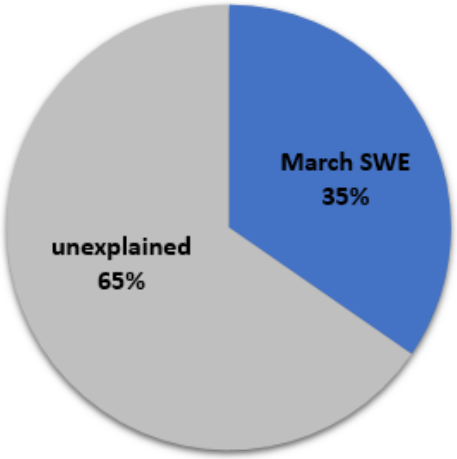


All years | Above median years (high flow) | Below median years (low flow)

Climate averages (in percentile) for streamflow years above and below the median show similar results, but add some information regarding the climate conditions that accompany these two sets of years. Lower flow years are very dry in the cool season, and warm in both spring and monsoon seasons. There is less difference in monsoon precipitation in below and above median flow years than in the cool season.



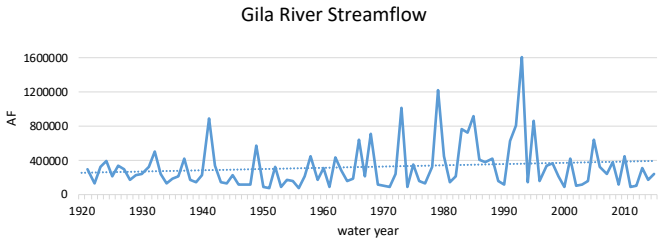
What about snow?
The snow water equivalent (SWE) snowpack on March 1 at the Coronado Trail explains just over one third of the variance in flow. Note that this is based on one snow course site, and from 1951-2015 to be consistent with other lower Colorado River basins (full record starts in 1938).

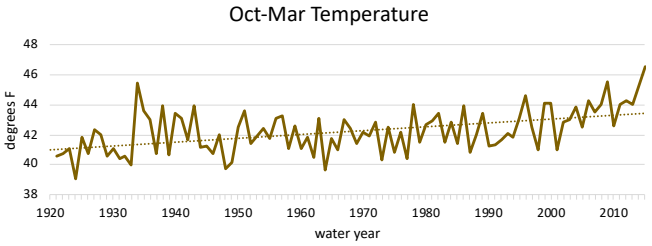


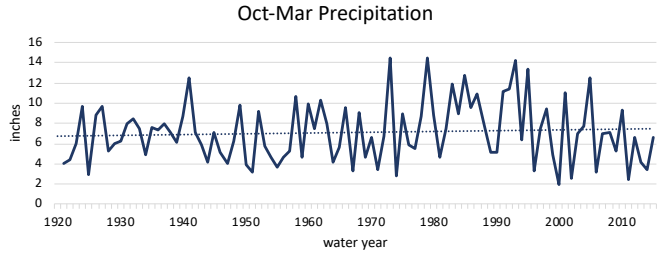
Main findings

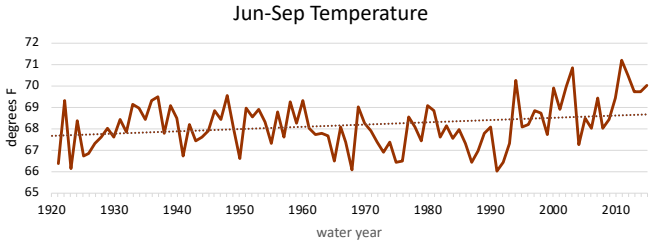
All years: cool season precipitation explains most of the variance, with just 2% explained by warm season temperatures.
Above median flow years: cool season precipitation is the only climate variable that explains a significant amount of streamflow variability.
Below median flow years: warm season precipitation explains a greater proportion of the variance in low flow years than does cool season precipitation, and June temperatures add an additional 7%.

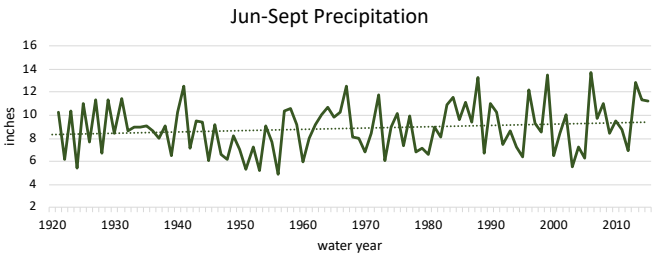
Upper Gila Streamflow and Climate: Trends Over Time



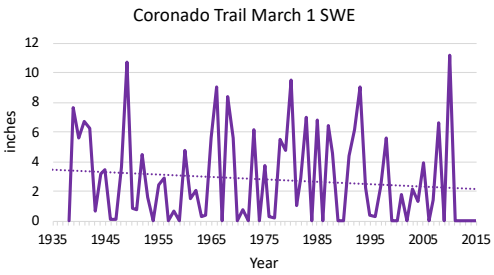


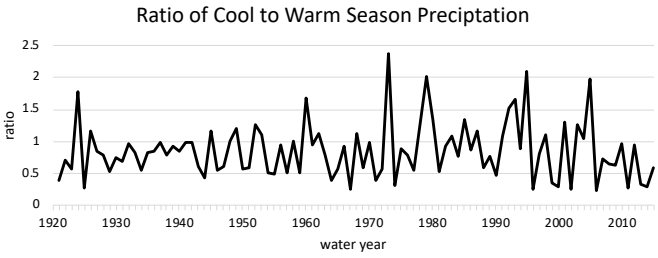






The ratio of cool season precipitation to monsoon precipitation contains no trend. Ratios are quite variable, ranging from 0.23 (2006) to almost 2.4 (1973), with an average of 0.85.

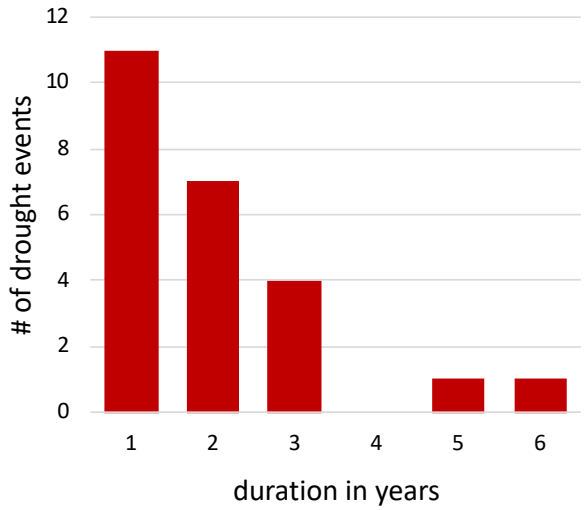




Main findings

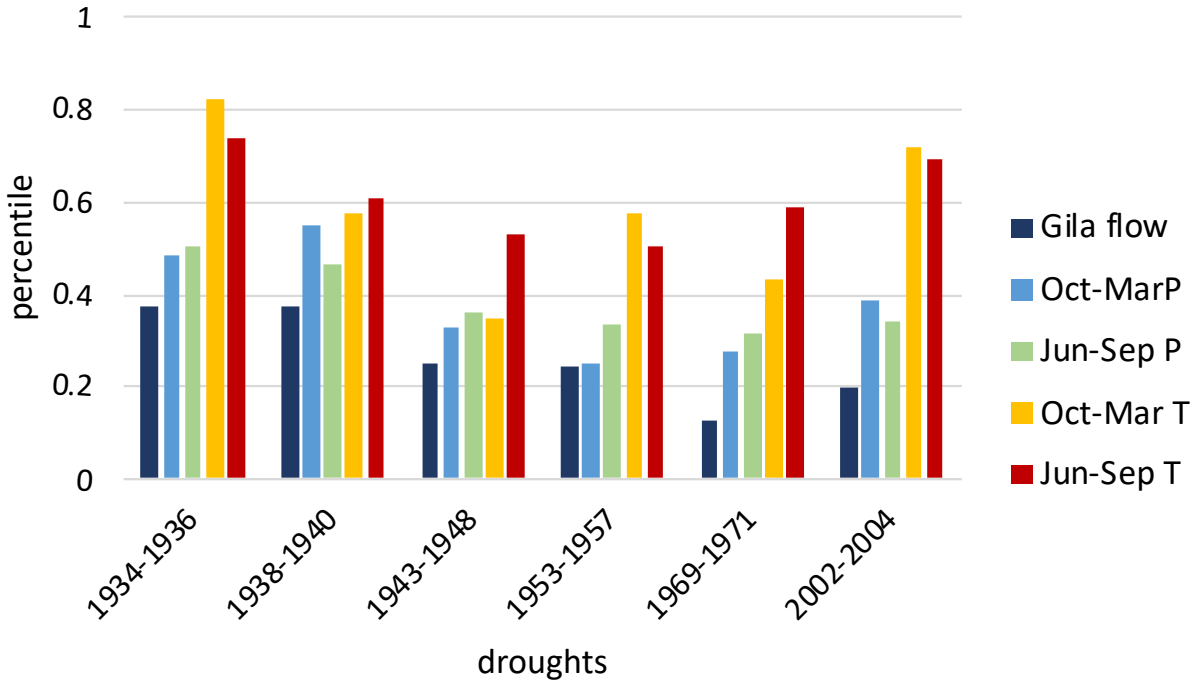
- **Streamflow and seasonal precipitation:** No significant trends
- **March 1 snow water equivalent (SWE):** No statistically significant trend in this shorter record (starts in 1938) yet, although a non-significant decreasing SWE trend is visible.
- **Seasonal temperature:** Positive and statistically significant (> 99%) warming trends in both spring and monsoon season temperatures (warming about 0.26°F/decade in the cool season and 0.11°F/decade in summer).

Upper Gila River Streamflow and Climate: Drought



Droughts (in table, left) are defined as single or consecutive years below the median water year flow.

The **major climate drivers of the six drought events that last three or more years are examined in the graph** (below). Flow is averaged over the course of the drought years, along with corresponding cool and monsoon season temperature and precipitation. Values are in percentile.



Main findings

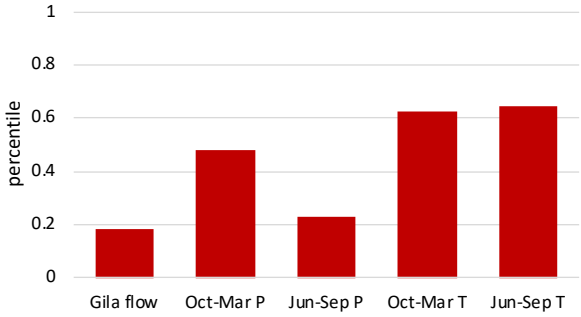
- **Droughts typically last** 1-2 years. The longest drought is a 6-year event, 1943-1948.
- Multi-year (3 yrs or more) droughts are mostly clustered between the 1930s and 1950s.
- Streamflow deficits are always less than cool season precipitation deficits.
- During these droughts, monsoon precipitation is always at or below the median; cool season precipitation is above median in one event.
- The monsoon may play a role in reducing flows, relative to cool season precipitation.
- The warmest drought was in the 1930s (it was also one of the least dry), followed by the most recent drought, 2002-2004.

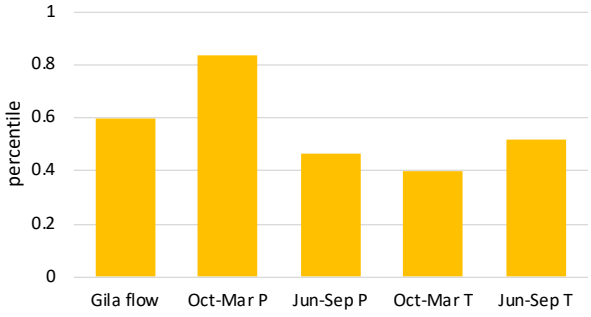
Upper Gila Streamflow and Climate: Unusual Years

2004: wettish warm winter; dry but cool monsoon

1960: very wet, cool winter; very dry, warm monsoon

Flow < precipitation

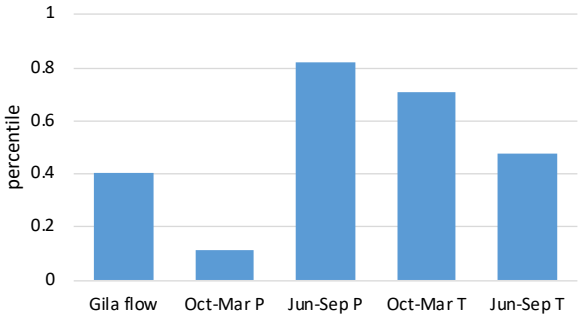


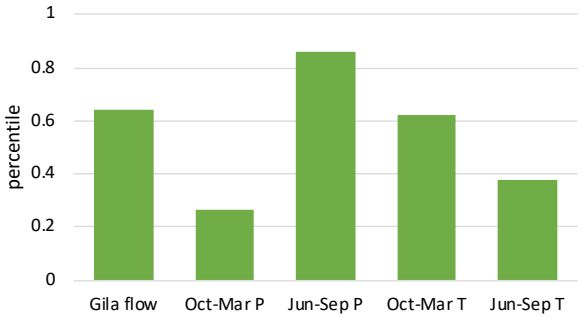


2014: dry very warm winter; very wet, hot monsoon

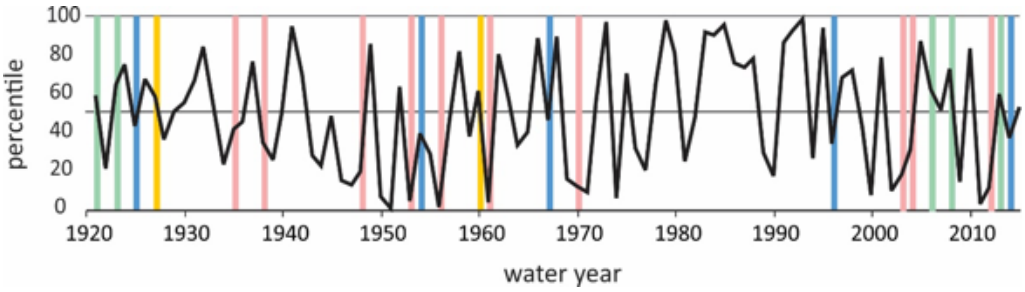
206: very dry, warm winter; super wet, cool monsoon

Flow > precipitation





All years in which the difference between water year flow and cool season precipitation is greater than one standard deviation from the mean difference are show below, in vertical bars color-coded to match the year types shown above. While each year is unique in terms of the climate conditions that cause flow to be less or more than expected given precipitation, more years with above median flow and flow greater than precipitation (like 2006, green bars) appear both early and late in the record, while more years with less flow than might be expected given precipitation (like 2004 and 1960, pink and yellow bars) occurred between the 1930s and 1960, mostly.



Main findings

While streamflow closely tracks cool season precipitation in most years, a few years have larger differences between these two variables. In these years, climate factors other than cool season precipitation may play a more important role with respect to water year streamflow. Four examples of such years are 1960, 2004, 2006 and 2014. In these years, the monsoon may be playing a larger role, along with temperature, to some extent.

DATA USED IN THESE ANALYSES

Water Year Streamflow Gila River at head of Safford Valley, near Solomon (USGS Gage 09448500)*	1921-2015
March 1 snow water equivalent (SWE) Coronado Trail snow course site	1938-2015
Monthly precipitation & temperature PRISM gridded data, area abv gage	1921-2015

*a few missing values were estimated using Gila near Redrock and San Francisco R near Glenwood

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