

The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future

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Key Partners: Bo Svoma (Salt River Project); Erin Young (Flagstaff Water Services)

End Users: Flagstaff Water Services, Central Arizona Project, U.S. Forest Service, Salt River Project, Ron Doba Management Services LLC

Project Dates: 2017 – 2022

Summary of Impact

Generating scientific results for water resource management: This project produced meaningful scientific results that were useful for decision-makers in the Lower Colorado River Basin (LCRB). Through collaboration with regional resource managers, the CLIMAS team developed a research agenda that addressed their concerns about the roles of temperature and monsoon patterns on water resources in the Salt, Gila, and Verde River basins.

Understanding climate impact on water availability: This research resulted in online fact sheets and peer-reviewed publications that clarified the roles of temperature and the monsoon on streamflow and surface water availability. Connections made through this work led to a more extensive collaboration with City of Flagstaff's Water Services about the role of climate on their city's main source of surface water.

Value of peer-reviewed research: This project equipped end-users with quantitative data and peer-reviewed research that supported their observations, enabling them to communicate more confidently with their constituents, agencies, and customers about climate and water resources.

Problem Statement

Warming temperatures have an increasingly important effect on streamflow and surface water supplies. In the three major tributaries of the Lower Colorado River Basin (LCRB) – the Salt, Verde, and Gila Rivers – temperature may play a more significant role in mediating how much precipitation ends up as streamflow. However, before this project, studies had not yet investigated the impact of temperatures on streamflow in this basin.

Research Focus

The initial project focused on understanding the role of temperature on streamflow in the LCRB. Another focus investigated the role of the monsoon's contribution to streamflow in the LCRB, and how warming temperatures may affect the monsoon's contribution.

A spin-off project was later designed for the City of Flagstaff to evaluate the influence of climate on Lake Mary water supplies, which is Flagstaff's main source of surface water. The Flagstaff Water director and resource manager attended a project-related presentation in 2019 and connected with the CLIMAS team to conduct specific analyses for them.

Project Activities

2018 Workshop: CLIMAS researchers invited 8 resource managers in the LCRB to an initial workshop to co-develop the research focus and aims of the project.

Data Analysis: CLIMAS conducted analyses based on the expressed interests of resource managers.

2019 Workshop: A subset of resources managers attended a follow-up workshop in 2019 and webinar to show results for one watershed of interest. Resource managers provided feedback the analyses and suggested additional types of analysis. The CLIMAS team provided a fact sheet draft and solicited feedback.

Flagstaff Water Analysis: CLIMAS researchers met with City of Flagstaff personnel to discuss how one of their main water supplies, Upper Lake Mary, responded to climatic conditions in the Rio de Flag and Walnut Creek watersheds. The CLIMAS team delivered findings via a report and presentation, led by graduate student Talia Anderson. CLIMAS also shared the climatic data used for these analyses.

Project Outputs

Peer-reviewed Publications:

Woodhouse, C.A., B. Udall. 2022. Upper Gila, Salt and Verde Rivers: Arid Land Rivers in a Changing Climate. *Earth Interactions* 1:1-14. <https://doi.org/10.1175/EI-D-21-0014.1>

Gerlak, A.K., S. Karambelkar, D.B. Ferguson. 2021. Knowledge Governance and Learning: Examining Challenges and Opportunities in the Colorado River Basin. *Environmental Science & Policy* 125:219-230. <https://doi.org/10.1016/j.envsci.2021.08.026>

Karambelkar, S., A.K. Gerlak. 2020. Collaborative Governance and Stakeholder Participation in the Colorado River Basin: An Examination of Patterns of Inclusion and Exclusion. *Journal of Natural Resources* 60:1. <https://www.jstor.org/stable/26912770>

Reports:

[Lower Colorado River Basin Fact Sheets](#) – One fact sheet for each of the Gila, Salt/Tonto, and Verde River basins were developed regarding a) streamflow and climate relationships, b) trends in key climatic variables, and c) the role of climate during multi-year droughts.

Anderson, T.G., C.A. Woodhouse, D.B. Ferguson. 2020. *Upper Lake Mary Lake Level Response to Climate Variability*. Final Report to Flagstaff Water Services.

Presentations:

Science to Support Decision Making: The Influence of Climate on Lower Colorado Streamflow Variability: Project kick-off meeting 2018.

Relationships between Climate and Verde River Streamflow. 2019. Flagstaff, AZ, Joint Meeting of Coconino Plateau Water Advisory Council and Coconino Plateau Watershed Partnership.

Engaged Research to Advance Scientific Goals: A Case Study from the Lower Colorado River Basin. 2019. American Geophysical Union.

Upper Lake Mary: Lake Level Response to Climate Variability. 2020. Presentation of results to Flagstaff Water Commission.

Upper Lake Mary: Lake Level Response to Climate Variability. 2020. Presentation of results to Flagstaff Water Services.

Climate and Streamflow in the Upper Gila, Salt, and Verde Rivers: Relationships and Trends. 2022. Phoenix Chapter of the Arizona Hydrological Society.

Selected Scientific Findings:

Temperature and Streamflow:

Unlike the Upper Colorado River, the upper Gila River and major Gila River tributaries do not yet reflect significant declines in annual streamflow, despite warming trends (Figure1).

While statistically significant trends in annual streamflow are not evident, decreases in autumn and spring streamflow reflect warming temperatures and some decreases in spring precipitation.

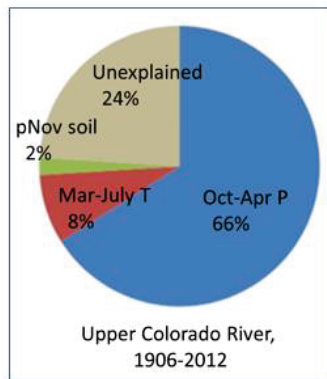
Given relationships between observed climate and streamflow, current trends in hydroclimate, and projections for the future, it would be reasonable to expect declines in Gila River water supplies in the coming decades.

On the need for peer-reviewed research:

Connie's research suggests results that we were expecting, but there wasn't a lot of peer reviewed literature to support it before this project. The way we communicate to the U.S. Bureau of Reclamation and to customers about water resiliency projects is heavily informed by this CLIMAS research.

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Bo Svoma, Salt River Project

Climate variables explaining water year streamflow (1914/1921-2015)



Verde

Salt/Tonto

Gila

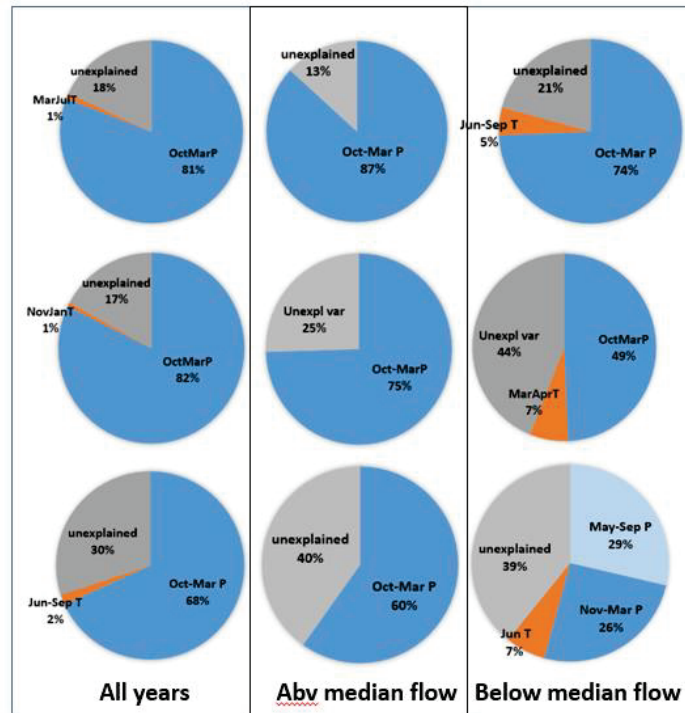


Figure 1. Climate variables explaining water year streamflow for the Verde, Salt/Tonto, and Gila River basins, with comparison to the Upper Colorado River basin.

Monsoon Influence:

Annual streamflow is dominated by cool-season precipitation, but the monsoon influence is discernable as well. The monsoon is variable across the basin and complicated by an inverse relationship with cool-season precipitation in the Salt and Verde River basins.

Major multiyear streamflow droughts in the Salt and Verde River basins are often accompanied by wet monsoons, suggesting that monsoon precipitation may partially offset the impacts of a dry cool season.

Societal Impacts by Category

Connectivity:

- The Flagstaff Water director and water resource manager attended a project-related presentation in 2019 and connected with the CLIMAS team to conduct a specific analysis about the influence of climate on Lake Mary water supplies, Flagstaff's main source of water.
- Connections made through this project led to ongoing conversations with Salt River Project and invitations to present findings to additional interested groups, such as the Arizona Hydrological Society.

Conceptual:

- Findings from this project confirmed what water managers thought was happening regarding the influence of increasing temperatures on streamflow. However, before this project, they did not have scientific data that demonstrated this influence. Findings published in peer-reviewed academic journals provided water resource managers with credible information that they could cite when communicating with agencies like Bureau of Reclamation and with water utility customers.
- Flagstaff Water asked for spreadsheets of climate data to do further analysis on a longer lake level record that their technician had generated. This suggests that this collaboration had an impact of increased learning – a better understanding of the climatic controls on their only surface water supply – in the form of shared hydroclimatic data.

On understanding local water supply:

We've known how important it is to understand the nuances of how climate influences lake levels in terms of long-term reliability as climate shifts but at the same time overall the lake has been reliable and cyclical enough that we've been mostly okay since 1941. We've ridden out some tough times, but the community still had water. We knew this was an area we needed to solicit for a project and Connie and Daniel offered us this project at no cost to the city. Their student, Talia Anderson, completed the analysis, issued a report and given several presentations on her research to staff.

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Erin Young, Flagstaff Water

On CLIMAS expertise:

Their research put some data behind what our operators have been qualitatively saying for years. But we'd never quantified or characterized the seasonality of those changes. Having the expertise of CLIMAS working on the project - that data weighs more when we talk to our sustainability team. When I provide a CLIMAS report it has more clout than if we did something ourselves.

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Erin Young, Flagstaff Water

Capacity Building:

- Three graduate students gained experience with collaborative and community-based research. One student conducted data collection and analysis; one did the analyses for Flagstaff Water Services, presented results, and generated the final report; and a third co-authored two academic publications.
- Flagstaff Water serves the City of Flagstaff, with a population around 75,000, and provides over 8000 acre-feet of water per year. Surface water makes up about 26% of that total, most of which comes from upper Lake Mary. Study results enabled Flagstaff Water to communicate to their clients about the impacts of climate on water supply and how surface water varies in response to climate. This information will also be used for water resource planning and thinking about probabilities and impacts of drought.