Deciphering tap water distribution dynamics in contrasting urban settings using isotope-based metrics

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I. Research Question

- How do water consumption, infrastructure, and climate influence tap water isotope ratios in two distinct urban settings in Gaborone (Botswana) and Arlington (Texas, USA)?

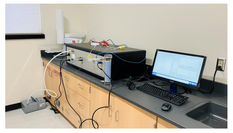
II. Hypothesis

- Greater water consumption leads to significant spatial isotopic variation, whereas lower consumption results in more consistent isotopic patterns influenced by seasonal fluctuations.

III. Methods

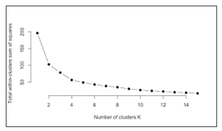
1. Tap water sampling (2022-2024) to capture isotope seasonality

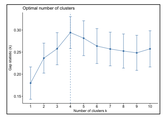
2. Water stable isotopes analysis



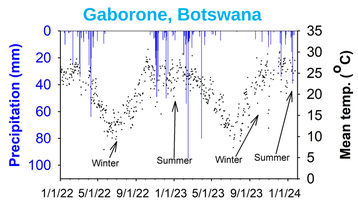
3. Clustering analysis

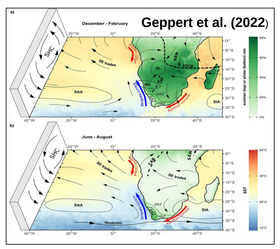
K-means: partitions data into several clusters (k) by assigning a point to the nearest centroid and updates centroids until convergence (elbow and silhouette methods)



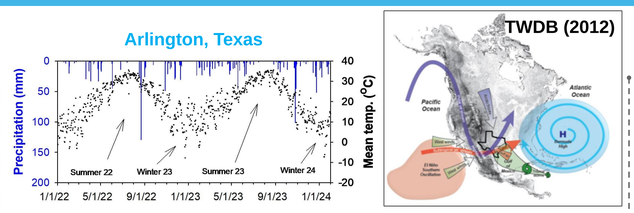


IV. Study Site



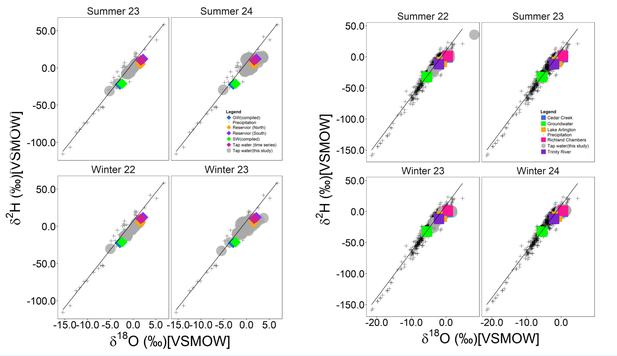


SE trade winds and the seasonal migration of the ITCZ control the isotopic variability of precipitation in southern-central Africa.

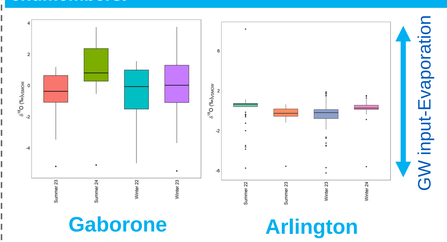


Moisture sources (Arctic cold fronts, westerlies, Gulf air, and localized convective storms play a remarkable role in controlling isotope variations across north-central Texas.

V. Results



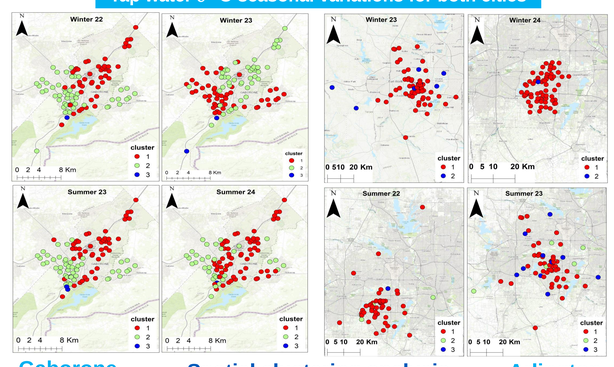
Dual-isotope space showing $\delta^{18}O$ versus $\delta^{2}H$ in tap waters and regional endmembers.



$\delta^{18}O$ seasonal variation provides insights into climate patterns and hydrological processes

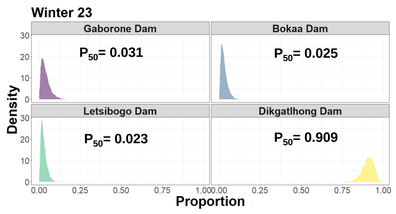
Gaborone Arlington

Tap water $\delta^{18}O$ seasonal variations for both cities



Gaborone **Spatial clustering analysis** Arlington

Water blending: Bayesian mixing analysis



Gaborone:

- Winter 2023: dominated by Dikgatlhong Dam water source.

Summer 22: ~90% from Lake Arlington (65%) and Richland Chambers (25%).
Summer 23: ~74% from Cedar Creek.
Winter 23: ~91% from Cedar Creek (31% and Richland Chambers (60%)
Winter 24: ~90% from Richland Chambers.

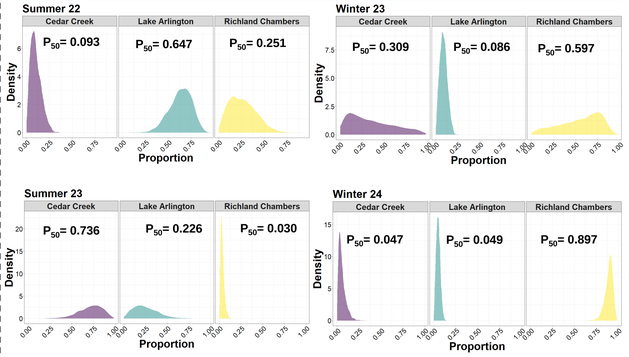
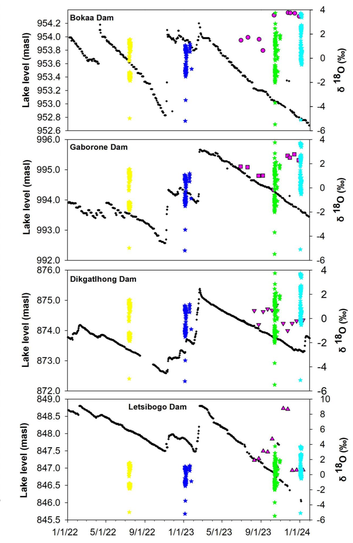


Illustration depicting the relationship between hydrometric data, isotopic compositions of reservoirs, and seasonal snapshots of tap water from Gaborone

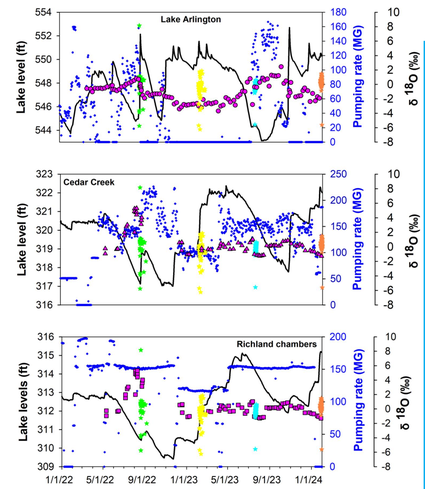


Gaborone

Sampling challenges are characterized by site remoteness and seasonal accessibility, weather, **and hydrometric data availability.**

Further sampling is needed to generate endmember time series.

Yellow, blue, green, and cyan colors represent the seasonal tap water snapshots (Winter 22-Summer 23-24)



Arlington

A notable relationship emerges between lake levels and isotopic data, with **enrichment patterns during summer and low-level periods** aligning closely with **elevated pumping and greater evaporation rates.**

Green, yellow, cyan, and orange dots, denote seasonal tap water snapshots. Pink dots represent the lake time series.

Illustration depicting hydrometric data, reservoir isotopic compositions, and seasonal snapshots of tap water from Arlington

VI. Conclusion

- In Gaborone, three (3) distinct clusters were identified across all seasons, whereas Arlington exhibited two (2) clusters during winters and three (3) during summers.
- Our results show the high sensitivity of water isotopes to detect tap water engineering practices (e.g., water blending and sourcing) and pose a new paradigm for drinking water quality monitoring during extreme flooding events.

Acknowledgments

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