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Patterns and Drivers of Flow Change in the Santa Fe River Basin, Florida

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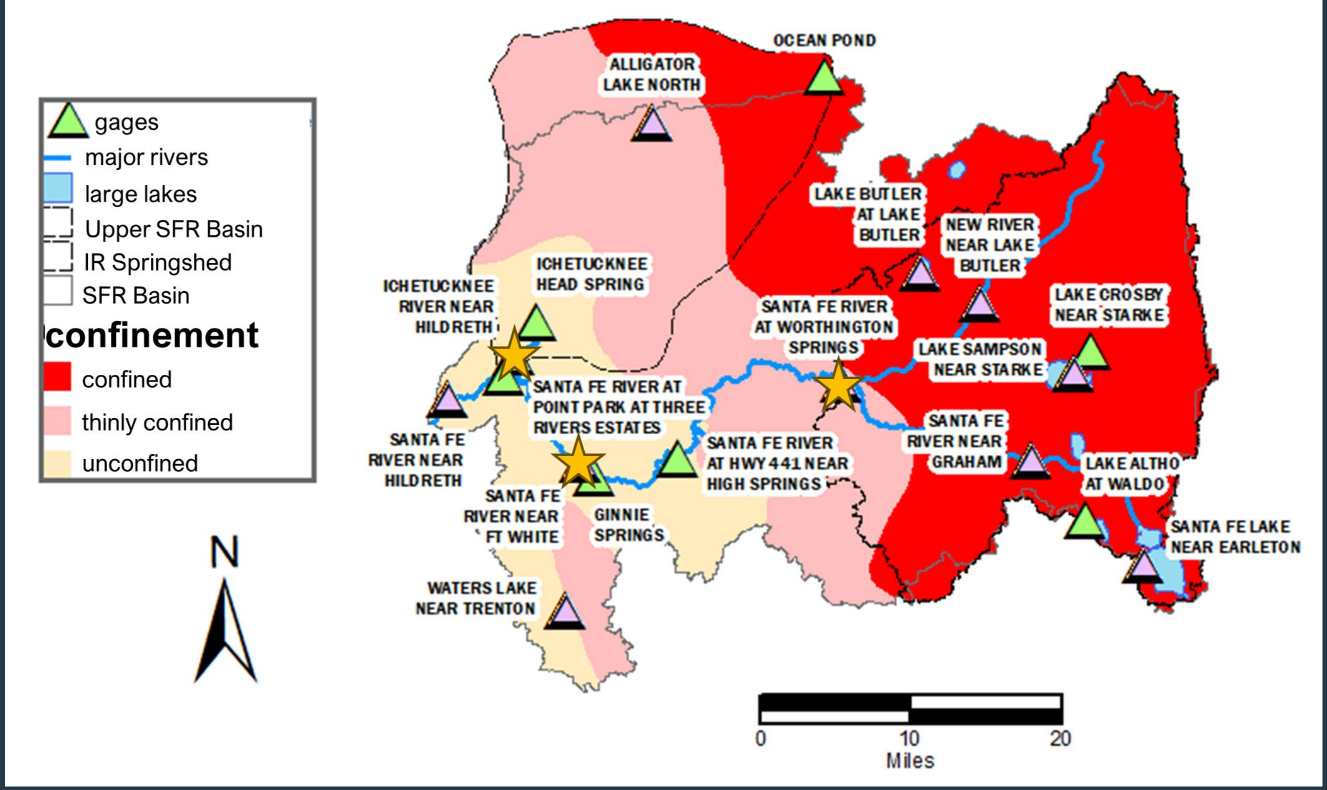
General Objective

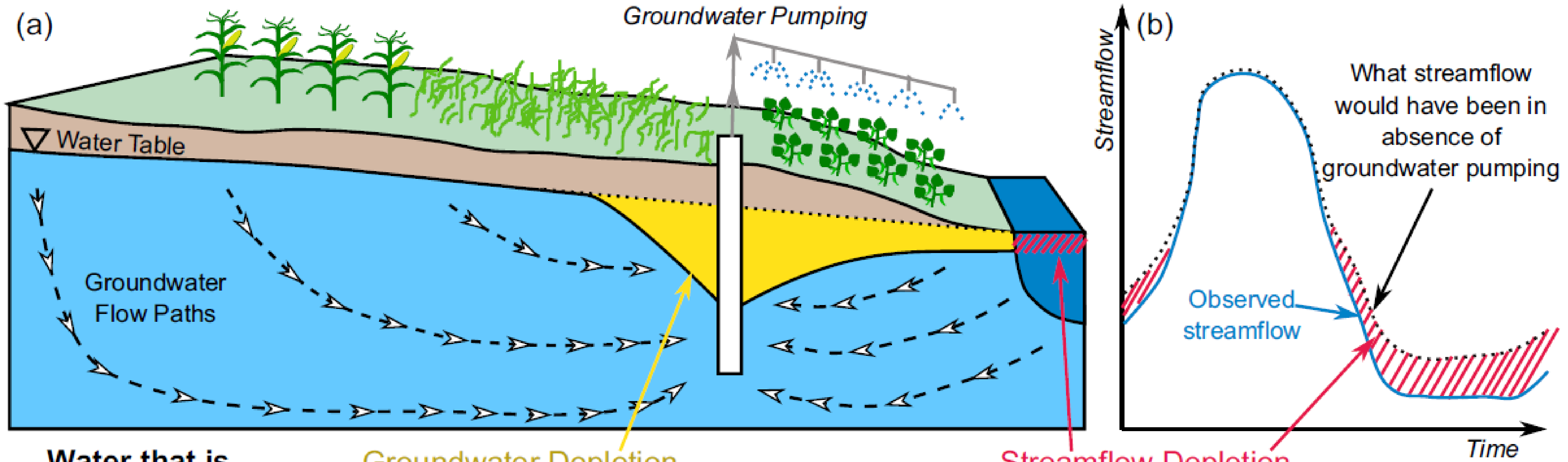
Determine the relative impact of **groundwater withdrawals** on **spring and stream flows and levels** in the Santa Fe River Basin and in relation to other drivers such as **precipitation and ET** **using a** **data-driven approach**.

Study Region
Santa Fe River Basin, FL

- Confined → Unconfined
- Runoff → Baseflow
- Analysis involved three gages (gold stars)
  - Santa Fe River at Worthington Springs (Upper Basin)
  - Santa Fe River near Ft. White (Lower Basin)
  - Ichetucknee River near Hildreth (spring-fed tributary)



Background
Flow Change Attribution



Water that is pumped from a well comes from two sources:

Groundwater Depletion
Pumping reduces groundwater storage.
This can be quantified by measuring changes in groundwater levels.

Streamflow Depletion
Pumping captures groundwater that would have flown into the stream and/or induces infiltration from the stream into the aquifer.
This cannot be directly measured and is challenging to estimate.

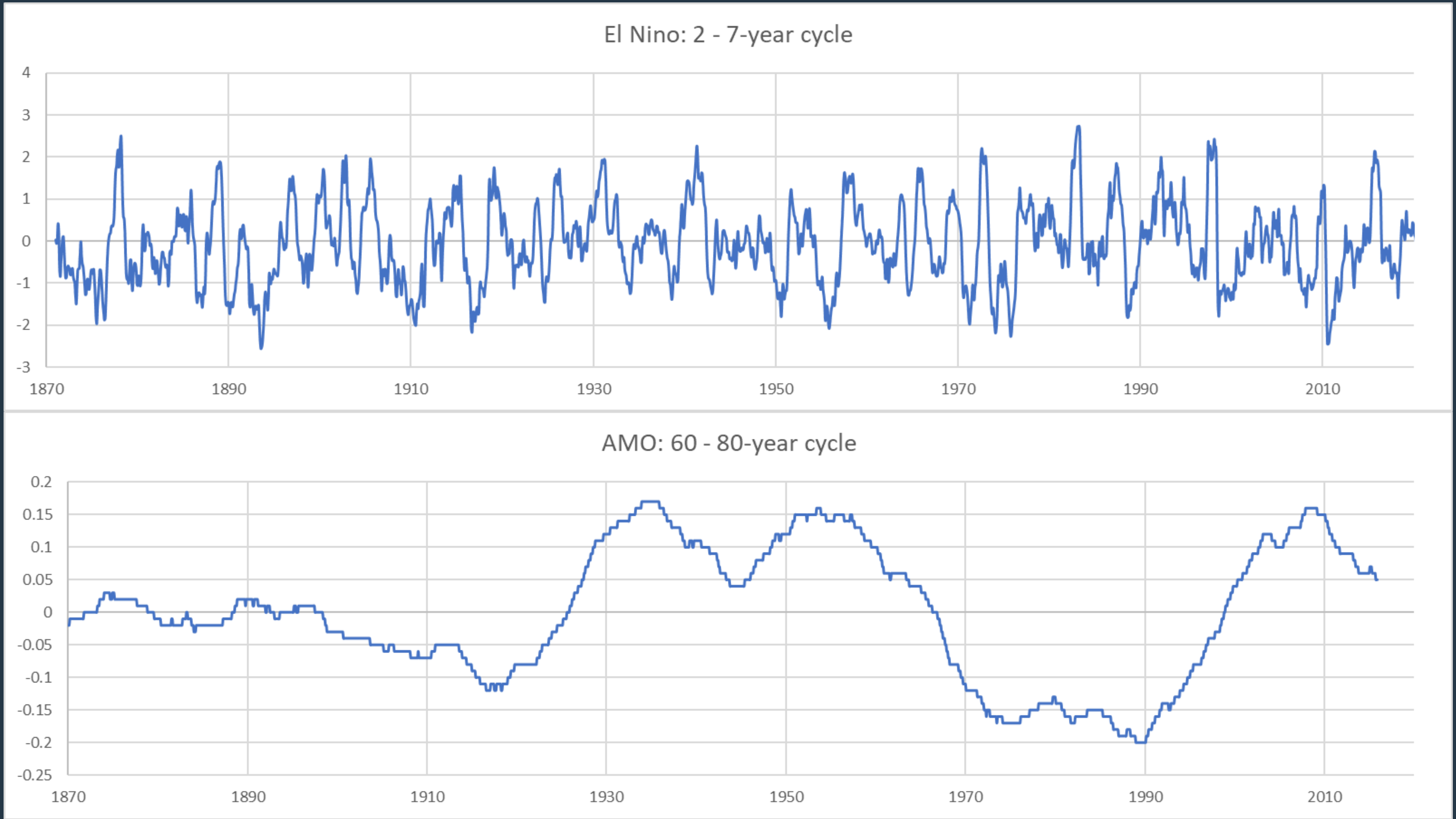
Zipper et al. (2022)

Background
Flow Change Attribution Methods

- Analytical methods (math)
  - Pros: Theoretically rigorous, low data requirement, computationally efficient.
  - Cons: Many simplifying assumptions, limited applications
- Numerical methods (modeling)
  - Pros: Flexible, accurate scenario predictions, broad applications
  - Cons: High data requirement, computationally intensive, systematic error
- Statistical methods (data-driven)
  - Pros: Less computationally intensive, flexible, many standard methods
  - Cons: Lack of causality, inability to extrapolate, high data requirement

Zipper et al. (2022)

Background
Climate Indices



General Objective

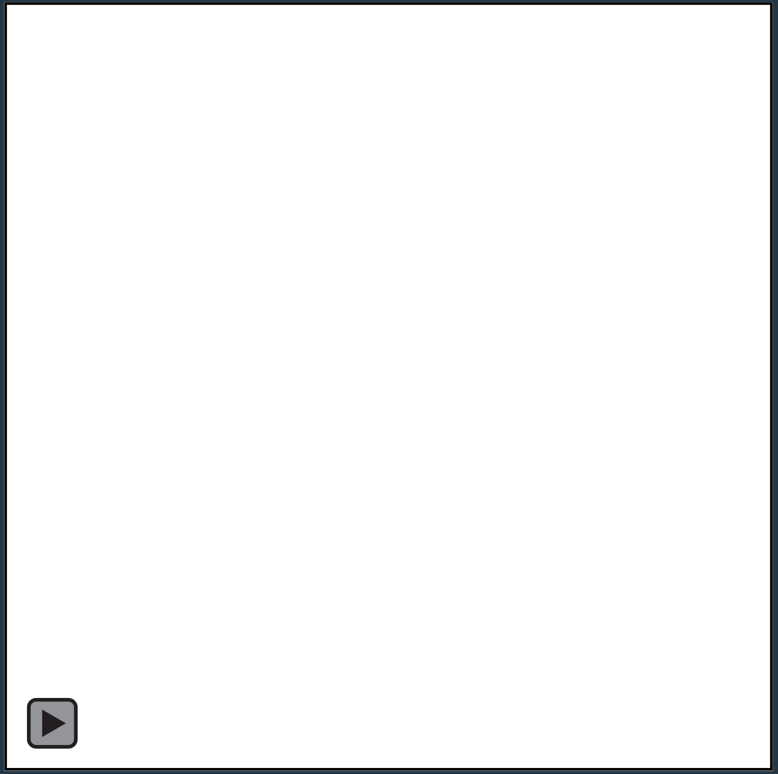
Determine the relative impact of **groundwater withdrawals** on **spring and stream flows and levels** in the Santa Fe River Basin and in relation to other drivers such as **precipitation and ET using a data-driven approach**.

Data Retrieval and Processing

Variable	*Source/Description*	*Treatment*
Precipitation (P)	PRISM, high-resolution, spatially distributed, monthly.	Subsets based on GIS, spatial and temporal aggregation.
Potential Evapotranspiration (PET)	Derived from PRISM temp. data using Blaney-Criddle equation calibrated to Penman-Monteith estimates derived from FAWN, monthly.	Subsets based on GIS, derivation, calibration, spatial and temporal aggregation
Groundwater Levels (GW)	Well data from SRWMD, gap-filled, spatially distributed, monthly.	Subsets based on GIS, spatial and temporal aggregation, PCA analysis.
Water Use (WU)	Approximate regional use from SRWMD, annual. Public supply use from FDEP, monthly. Agricultural use from SRWMD, monthly.	Subsets based on GIS, spatial and temporal aggregation, gap-filling.
Baseflow (BF)	Derived from streamflow from USGS and SRWMD using Eckhardt filter calibrated to Stewart method, daily.	Separated by gage, derivation, calibration, temporal aggregation, gap-filling.
Climate Indices (AMO and ENSO)	Retrieved from NOAA, monthly.	Temporal subsets based on overlap with other variables.

Data Analysis

- Nonlinear Time Series Analysis
  - Decomposition and characterization using singular spectrum analysis
    - Phase space reconstruction
  - Causality testing using convergent cross-mapping

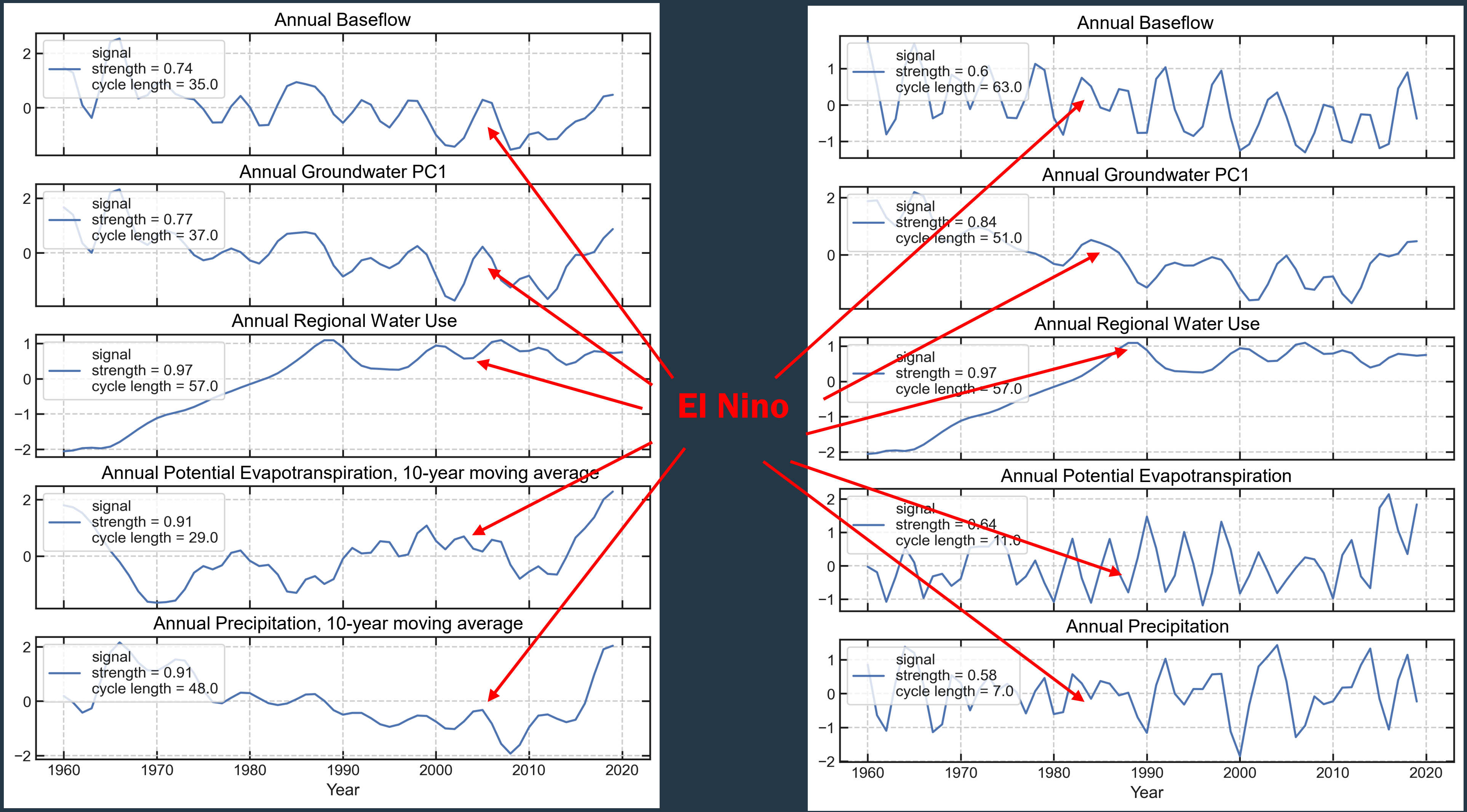


Worthington Springs monthly baseflow (1932 – 2022) in phase space.

Results

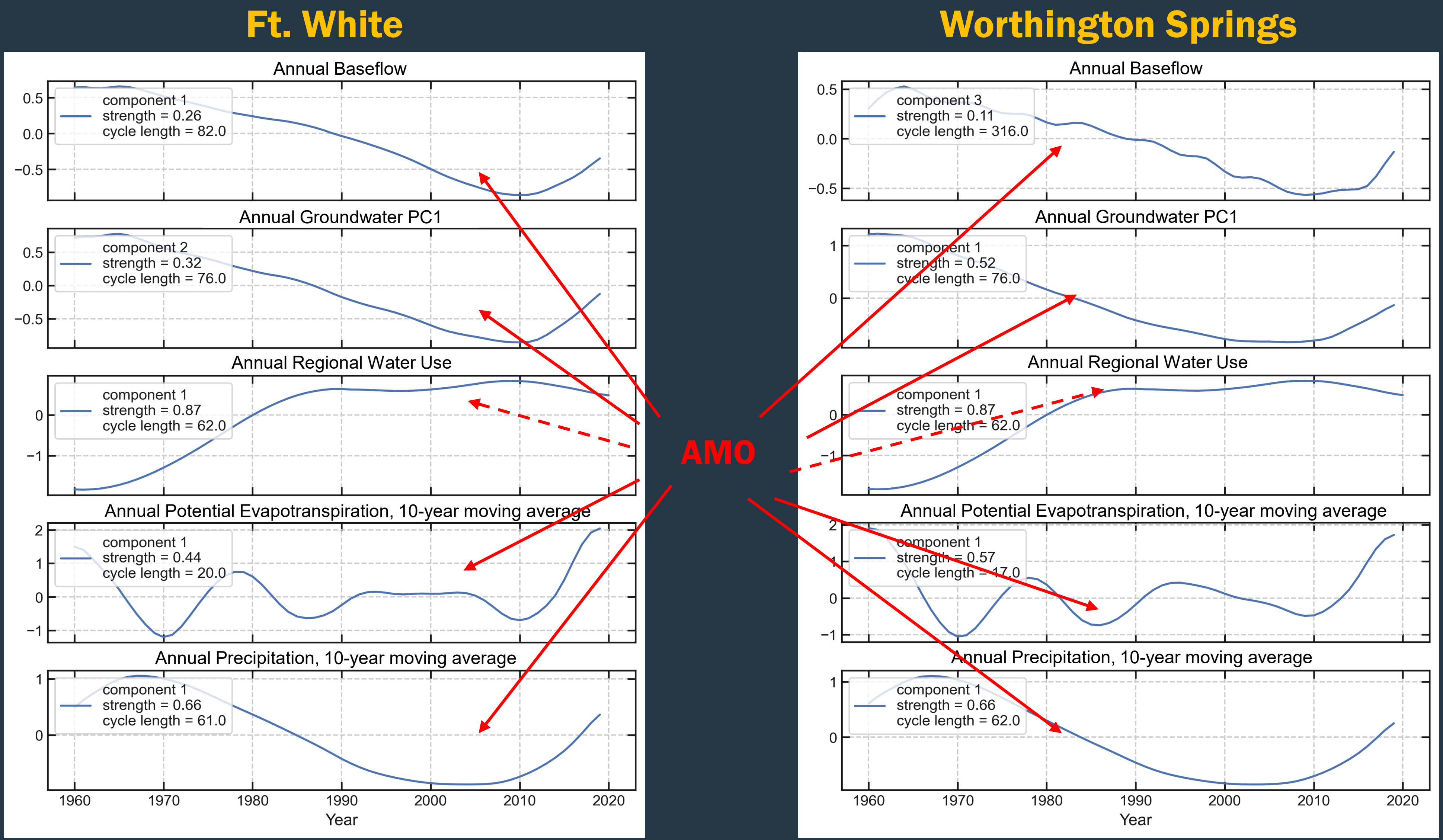
SSA – Long-term Annual Signals

Ft. White | **Worthington Springs**



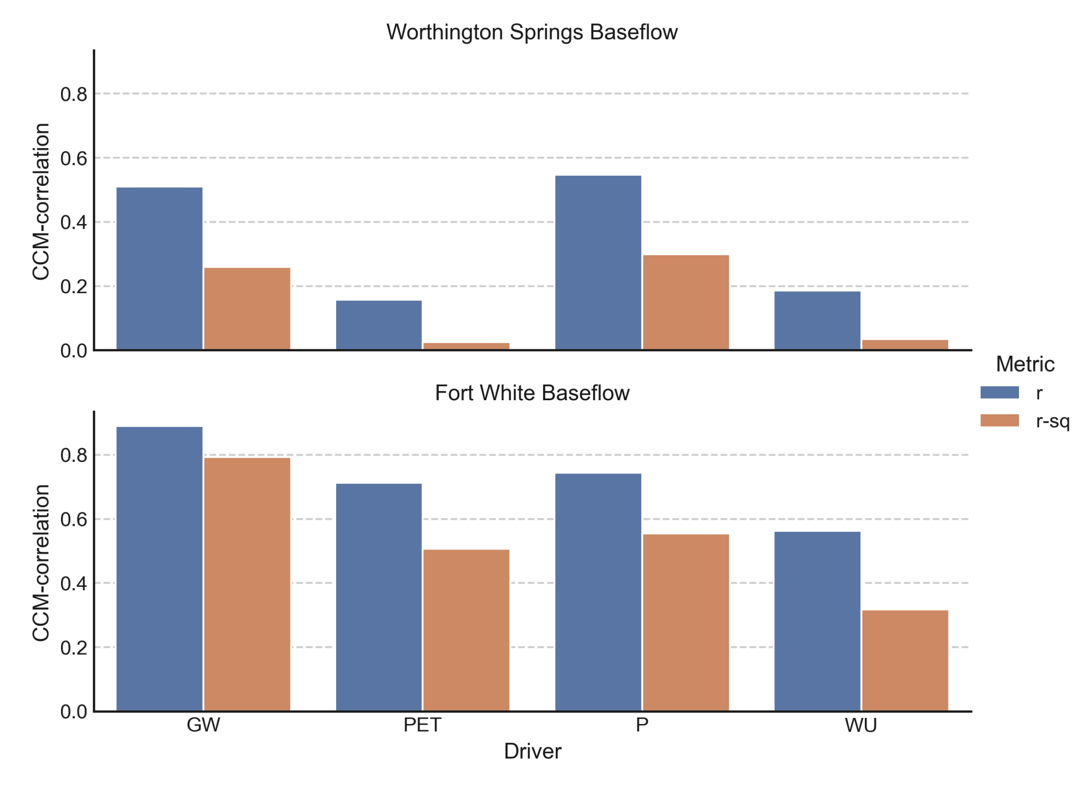
Results

SSA – Long-term Annual Signal Components



Results

CCM – Long-term Annual Relationships



- P and PET smoothed using moving sum/averages.
- Worthington had lower CCM-correlations, in general.
- GW and P are predominant drivers.
- Effects of PET and WU are similar in magnitude.

Conclusions

- Groundwater levels and precipitation are the primary drivers of baseflow at Worthington Springs and Ft. White gages.
- Baseflow at Worthington Springs exhibits higher-frequency and more stochastic variation compared to Ft. White.
- Higher level of correspondence between drivers and baseflow at Ft. White compared to Worthington Springs.
- Co-dependence and synchronicity of baseflow and water use with precipitation complicates isolating the effects of water use on baseflow.

References

Zipper, S. C., Farmer, W. H., Brookfield, A., Ajami, H., Reeves, H. W., Wardropper, C., ... & Deines, J. M. (2022). Quantifying streamflow depletion from groundwater pumping: a practical review of past and emerging approaches for water management. *JAWRA Journal of the American Water Resources Association*, *58*(2), 289-312.

Naked Spring at Ruth B. Kirby Gilchrist Blue Springs State Park