Can We Reliably Forecast the Future without Knowing the Past? UFA Level Predictions In North Florida

(Study conducted as part of PhD research at University of South Florida)

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- Observations
- Historical Patterns
- Climate Cycles
- Has stationarity been dead or never existed?

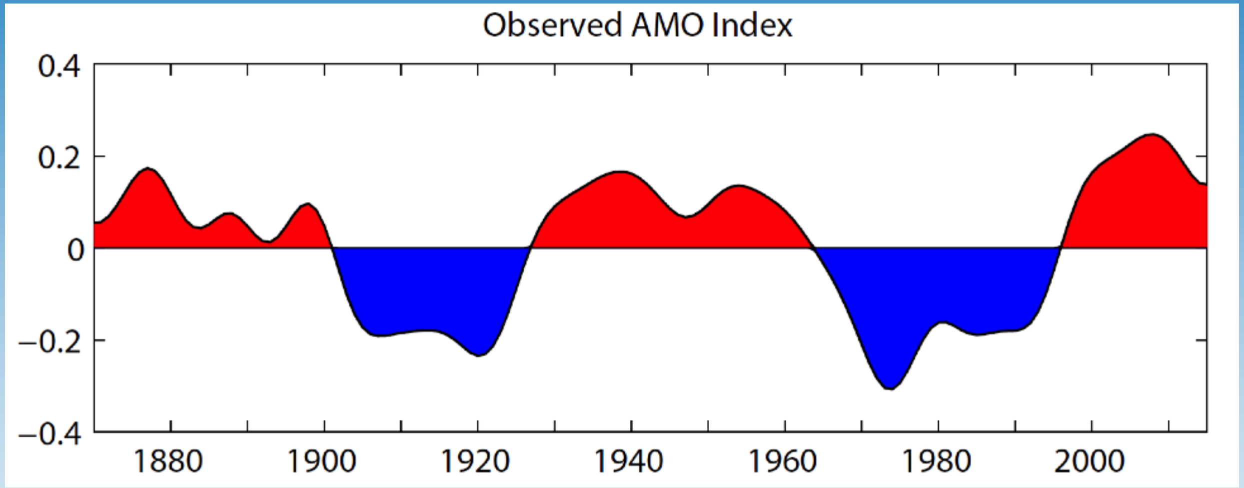
PAST

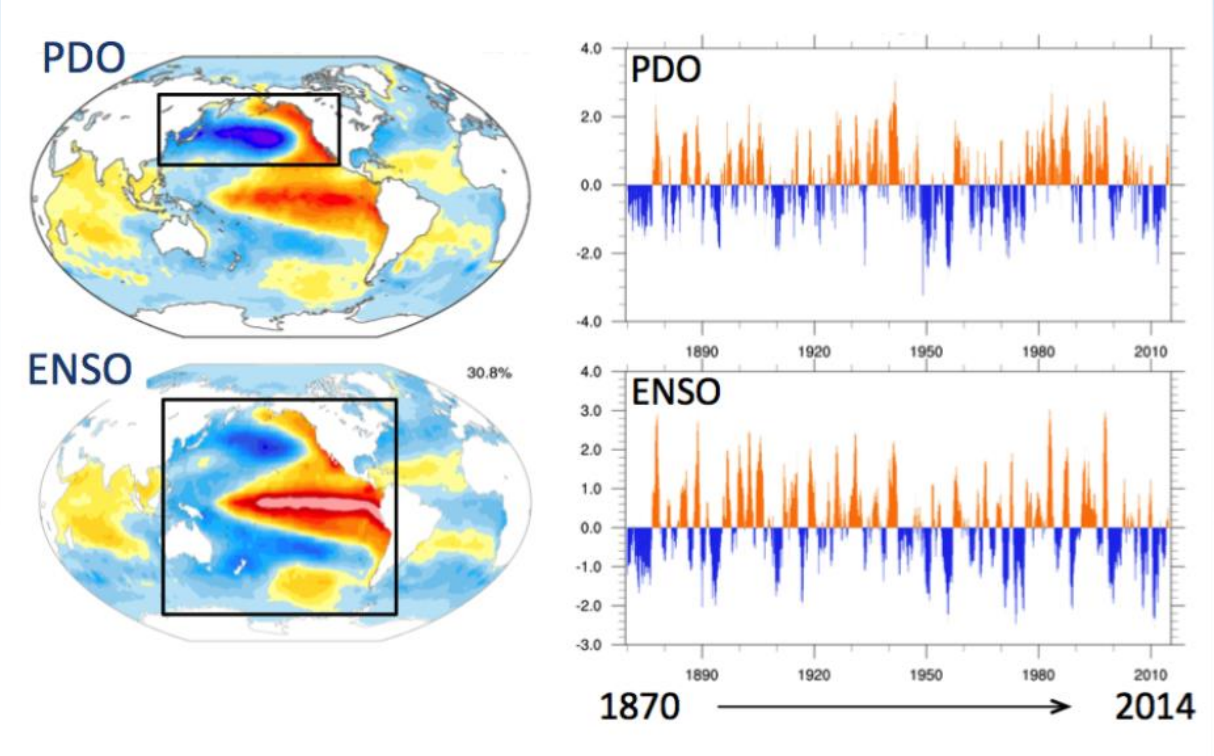
- Global Climate Models
- Rainfall/Temperature projections
- Uncertainty

FUTURE

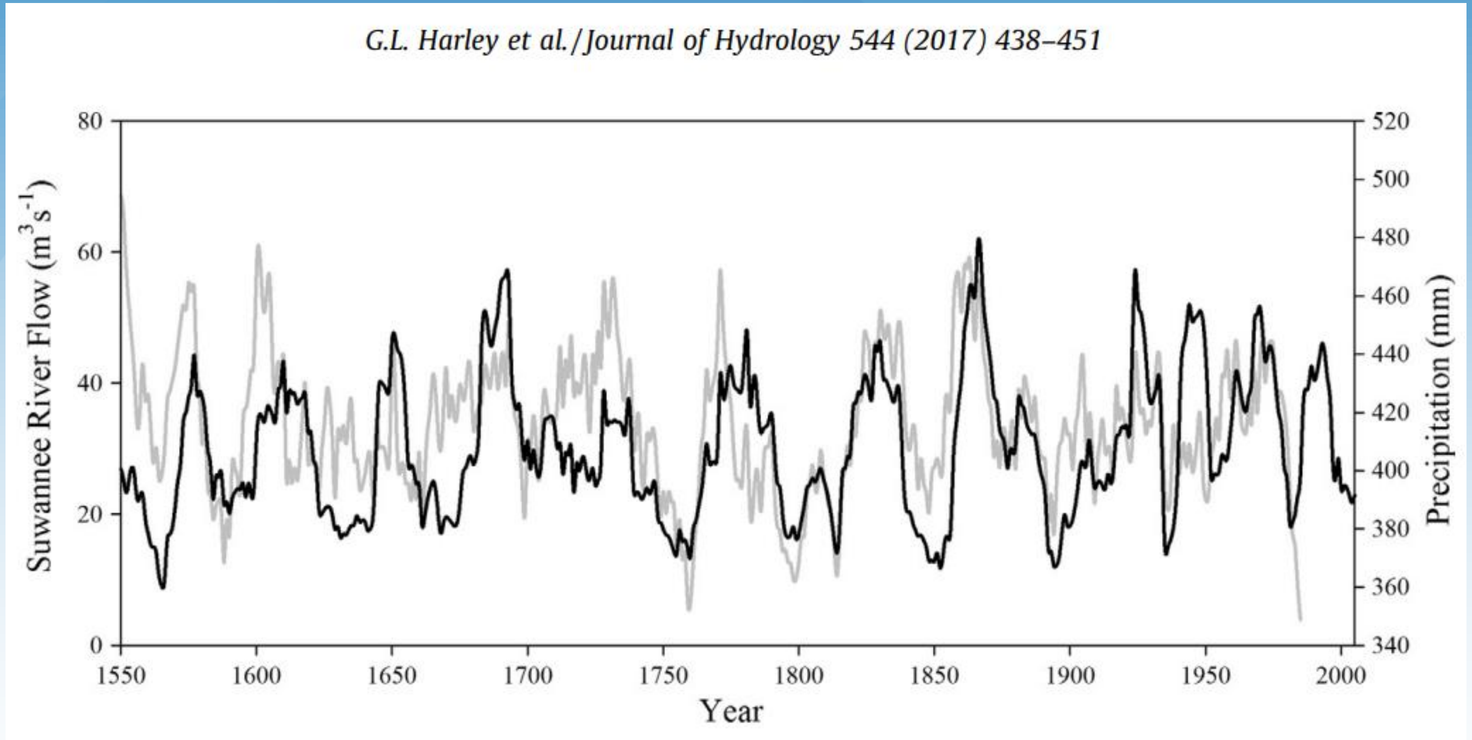
Climatic Cycles

Climate Cycle	Frequency
El Nino Southern Oscillation (ENSO)	3 – 7 years
Pacific Decadal Oscillation (PDO)	15 – 30 years
North Atlantic Oscillation (NAO)	7 – 32 years
Atlantic Multidecadal oscillations (AMO)	50 – 90 years

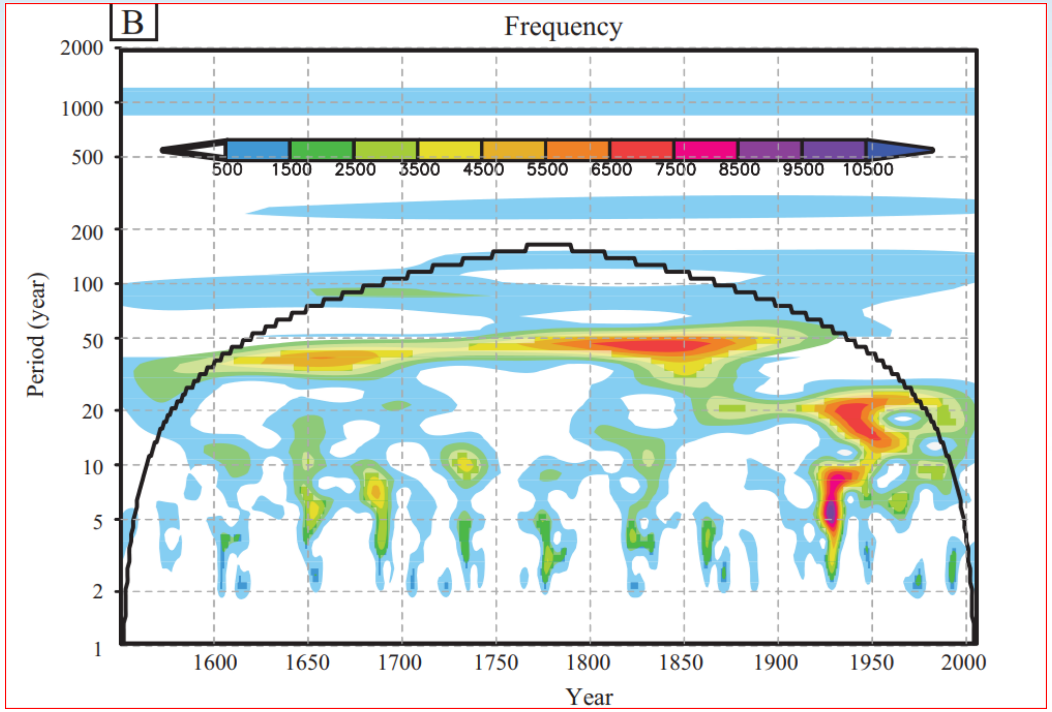




Hydrologic Responses to Climatic Cycles:



Harley, G.L., Maxwell, J.T., Larson, E., Grissino-Mayer, H.D., Henderson, J. and Huffman, J., 2017. Suwannee River flow variability 1550–2005 CE reconstructed from a multispecies tree-ring network. Journal of Hydrology, 544, pp.438-451.



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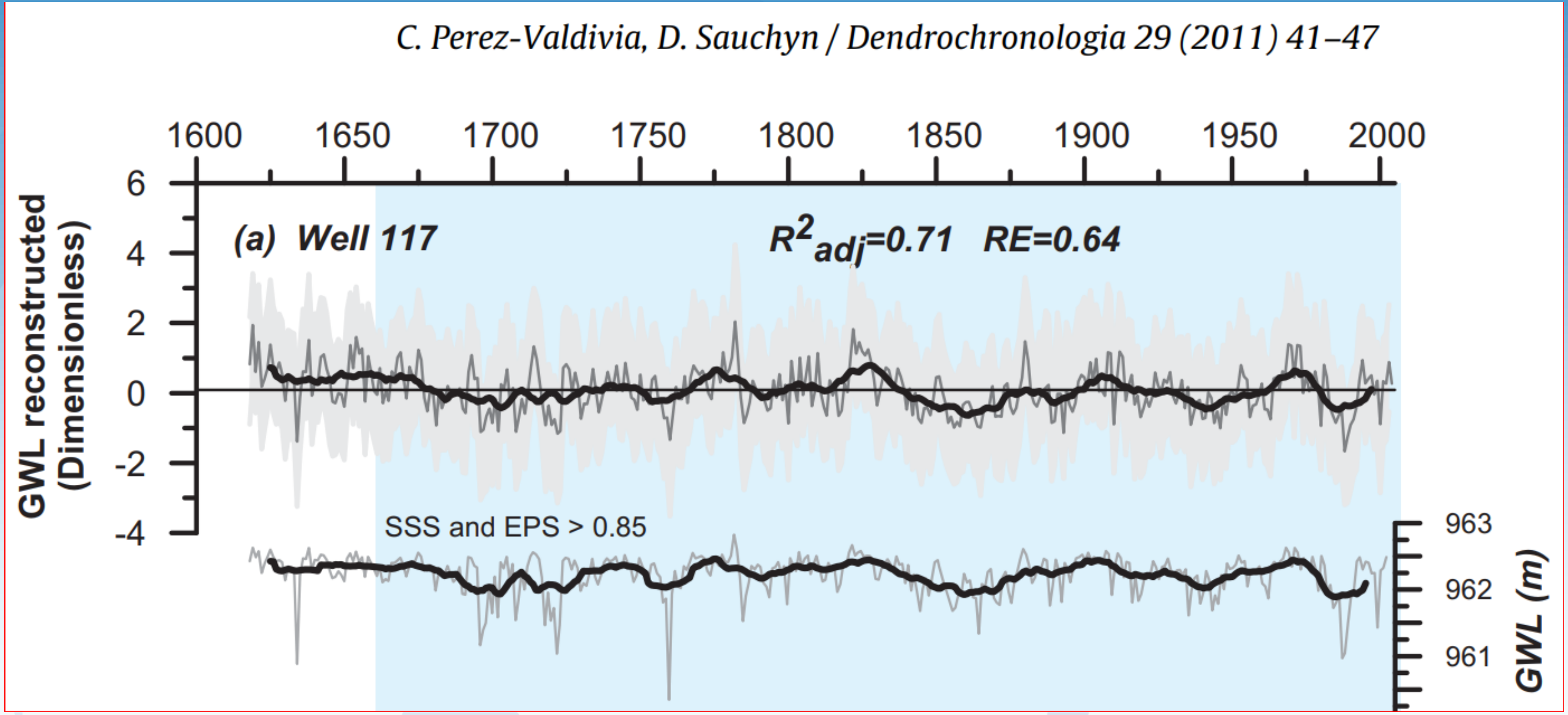
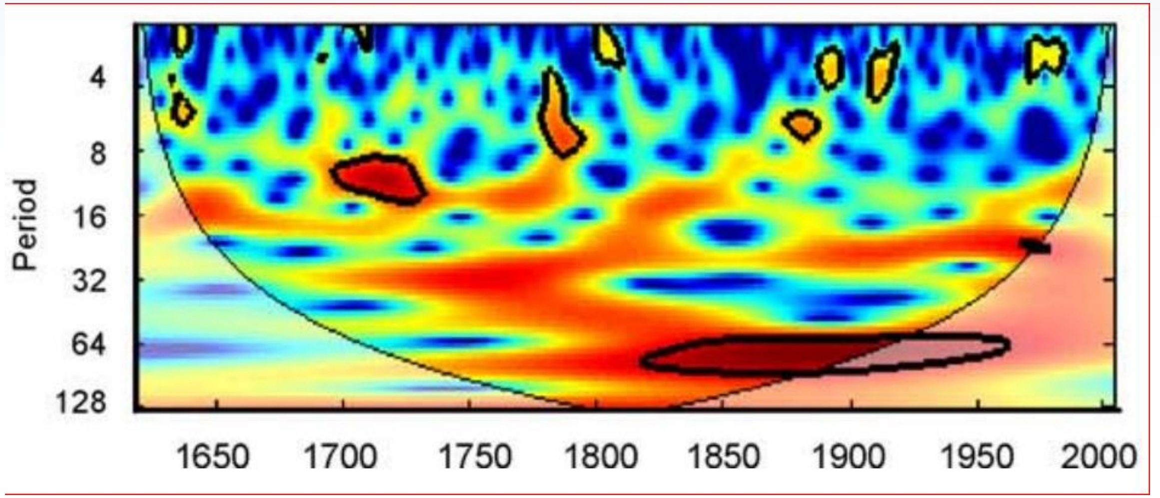
Groundwater Responses to Climatic Cycles:





Perez-Valdivia, C. and Sauchyn, D., 2011. Tree-ring reconstruction of groundwater levels in Alberta, Canada: Long term hydroclimatic variability. Dendrochronologia, 29(1), pp.41-47.

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Groundwater Level Predictions in North Florida

	UFA Levels	POR
Site 1	71 – 91 ft	1960 - present
Site 2	40 – 63 ft	1948 - present
Site 3	57 – 73 ft	1979 - present

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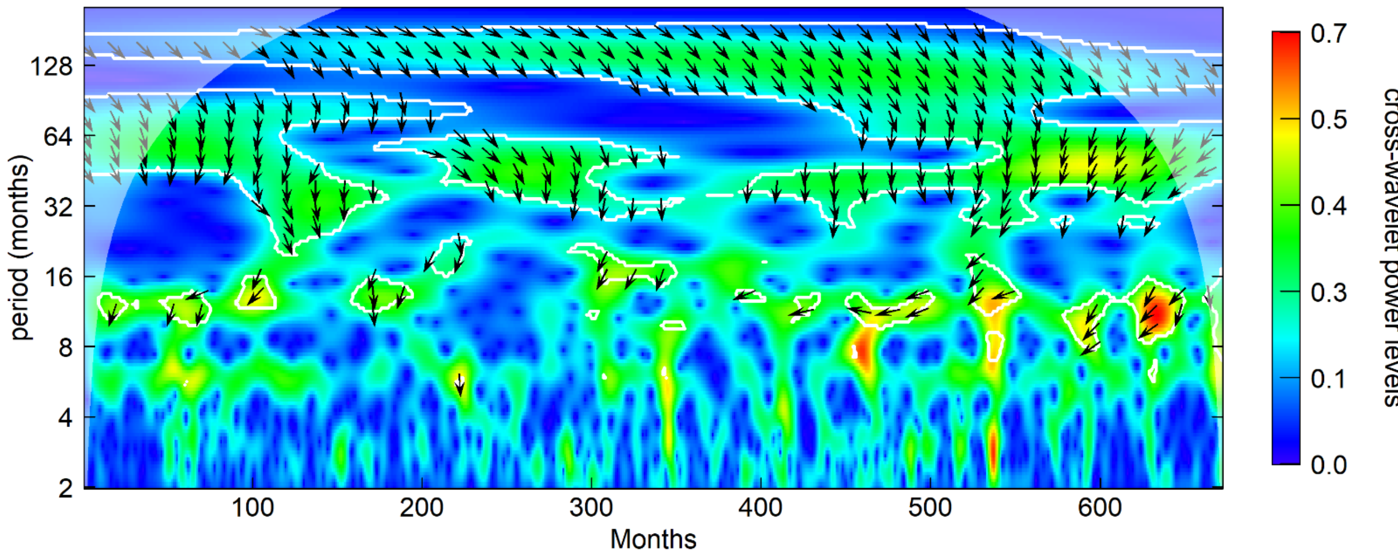
Physically constrained Wavelet-aided Statistical Model (PCWASM)

- Principle of convolution
- Wavelet analysis
- Low frequency signals
- Modified Cooper-Jacob Approximation
- Validated for hindcasting and forecasting

$$h_i = h_0 + \underbrace{\alpha \sum_{k}^{i} \lambda_{i-k} R_k}_{\text{Rainfall Term}} - \underbrace{\beta \sum_{j}^{i} \left(PET_j - \overline{PET}\right)}_{\text{ET Term}} - \underbrace{\gamma Q_i - \delta \sum_{m}^{i} \Delta Q_m \ln t_{i-m} - \emptyset \sum_{m}^{i} \frac{\Delta Q_m}{t_{i-m}}}_{\text{Pumping Term}}$$



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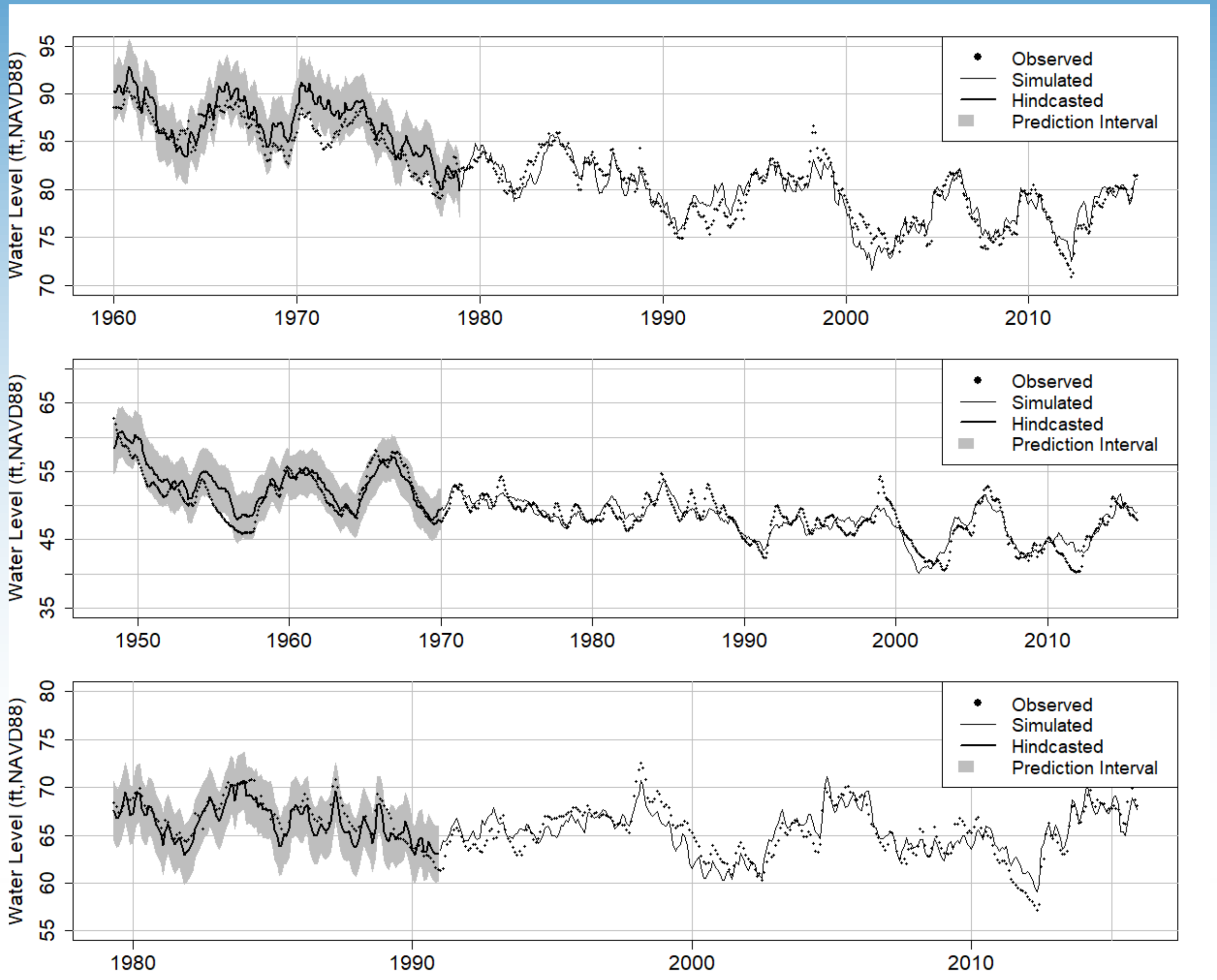
Predicting the Past

- Hindcast groundwater levels to early 1900s
- Assess the validity of the hindcasts
- Predict pumping impacts
- Analyze return periods of critical low levels



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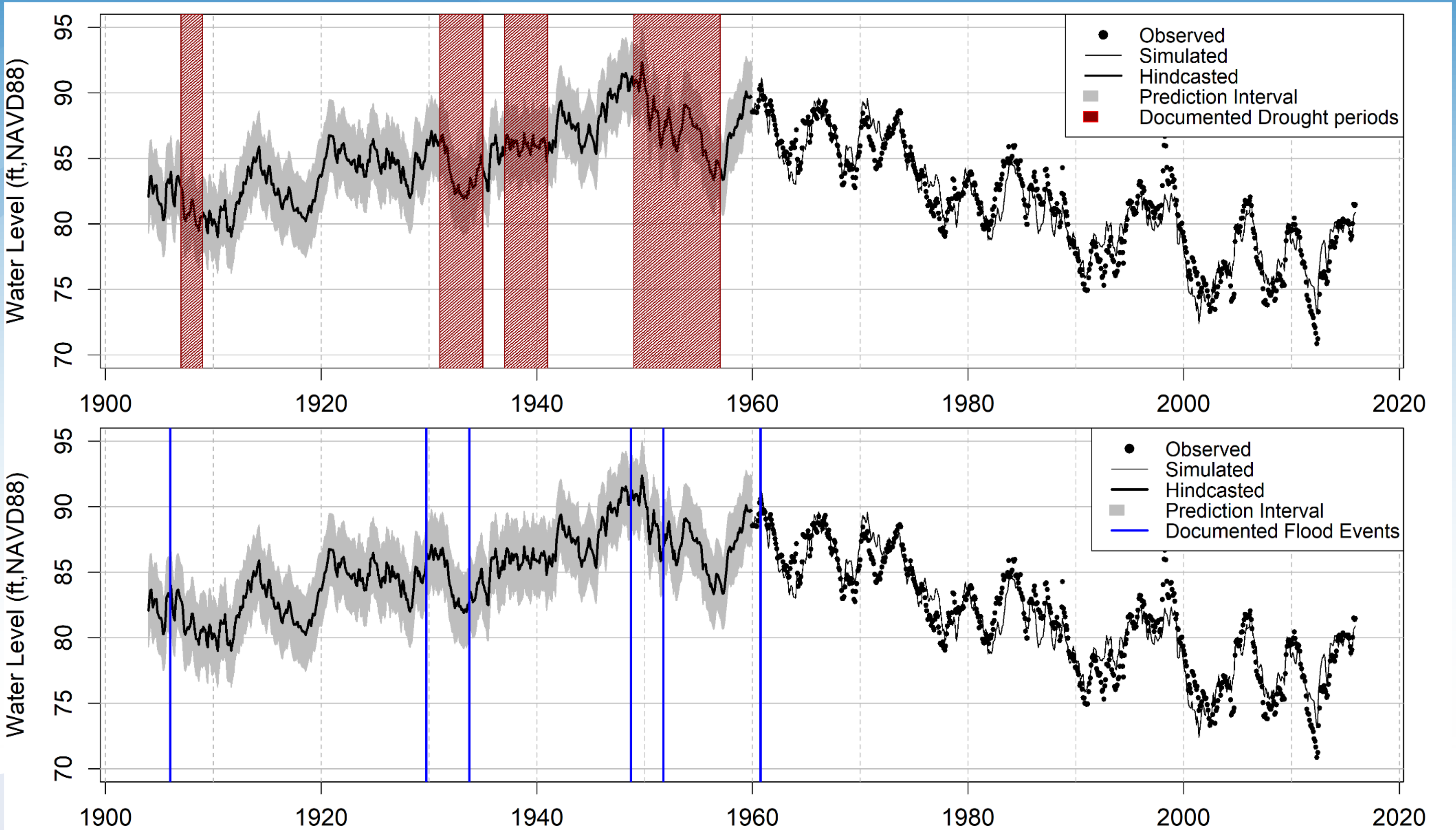
Long-term Hindcasting (Site 1)



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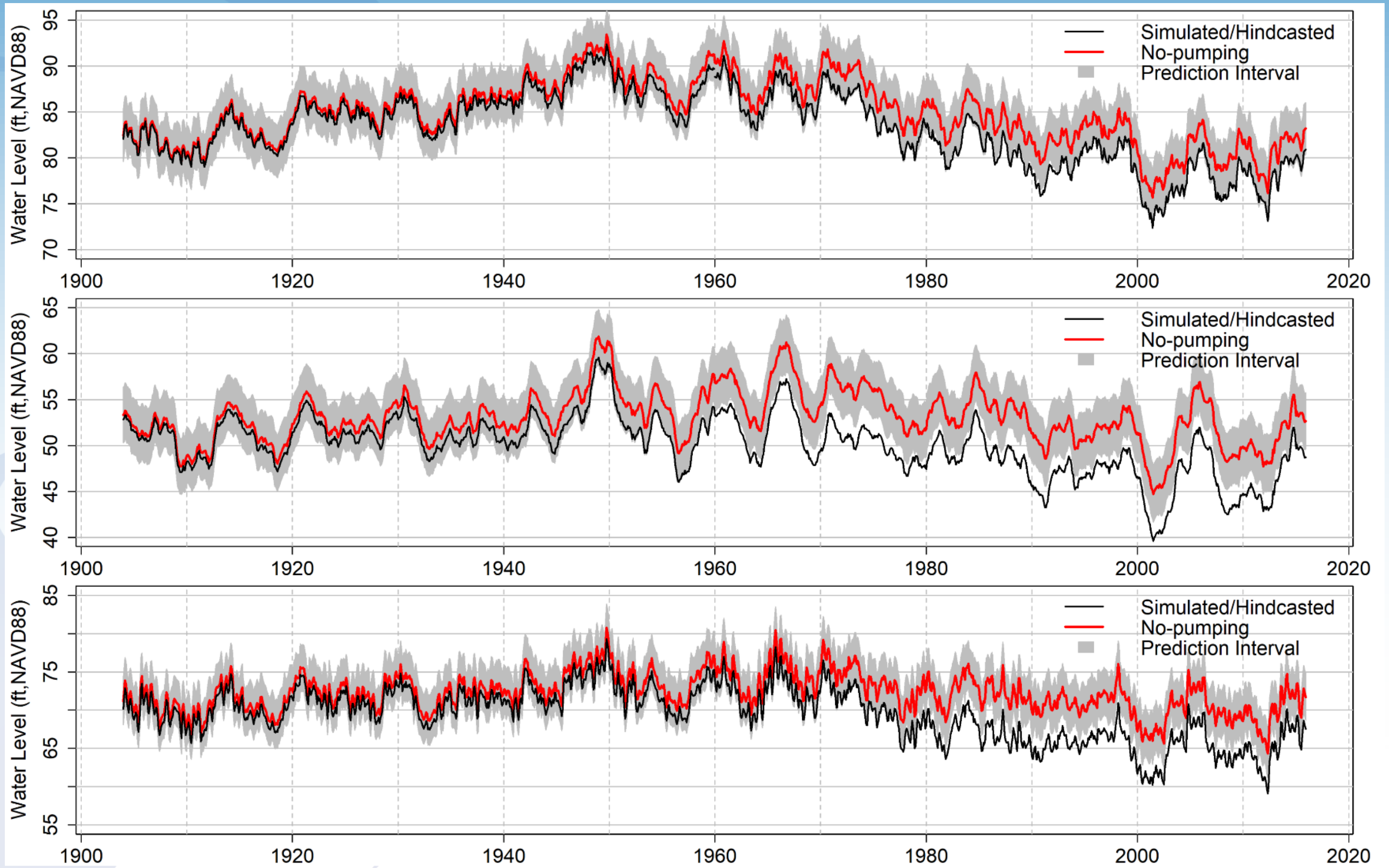
Predicting groundwater levels in the absence of pumping impacts



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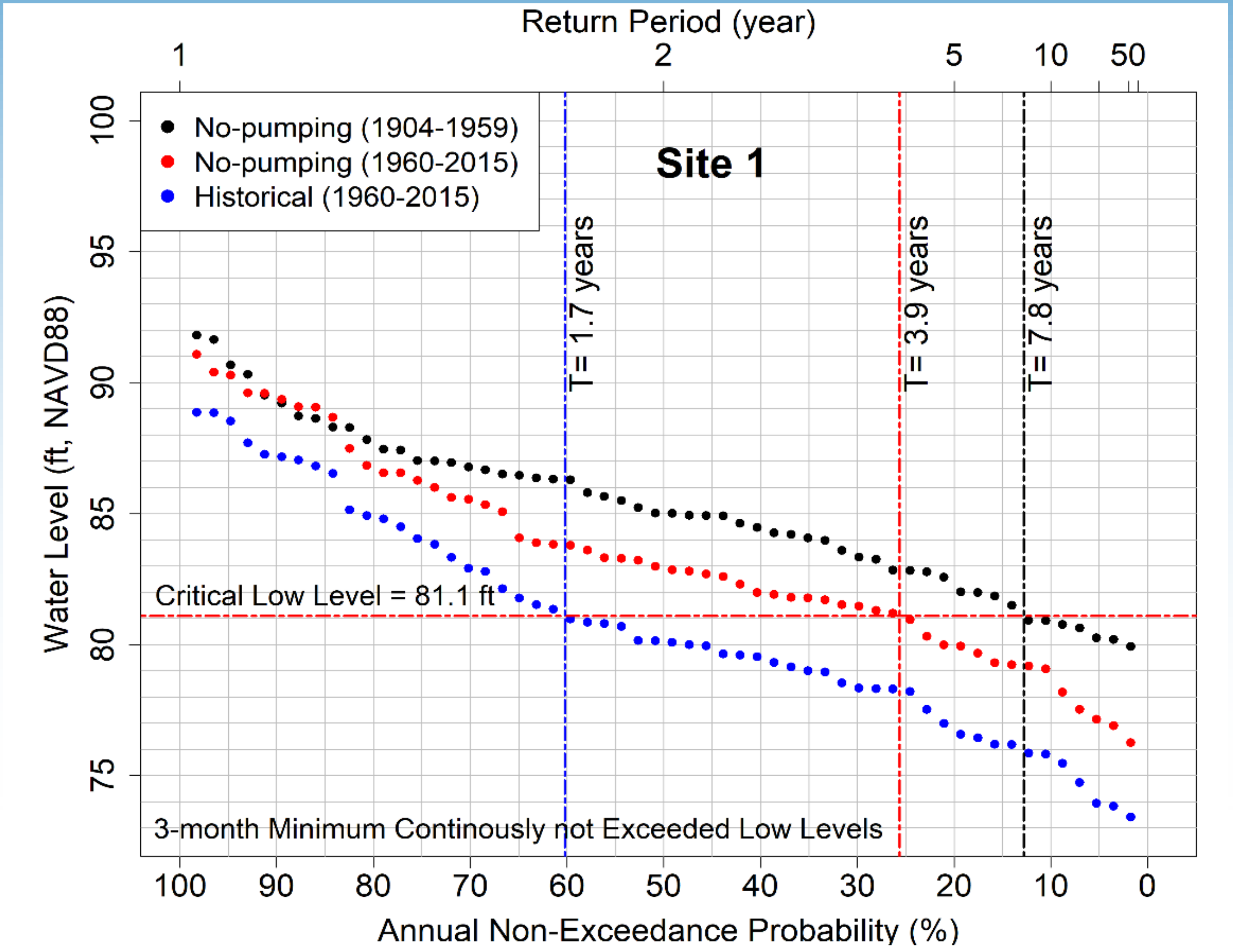
Critical Low-level Frequency Analysis

Site	Critical Low Level (ft) not exceeded for 3 months	Return Period in years		
		No-pumping (1904-1959)	No-pumping (1960-2015)	Historical (1960-2015)
Site 1	81.1	7.8	3.9	1.7
Site 2	48.6	14.4	8.8	1.7
Site 3	68.4	16.4	9.6	1.5



A critical low-level condition was assumed to occur when water levels dropped below the 10th percentile for three consecutive months

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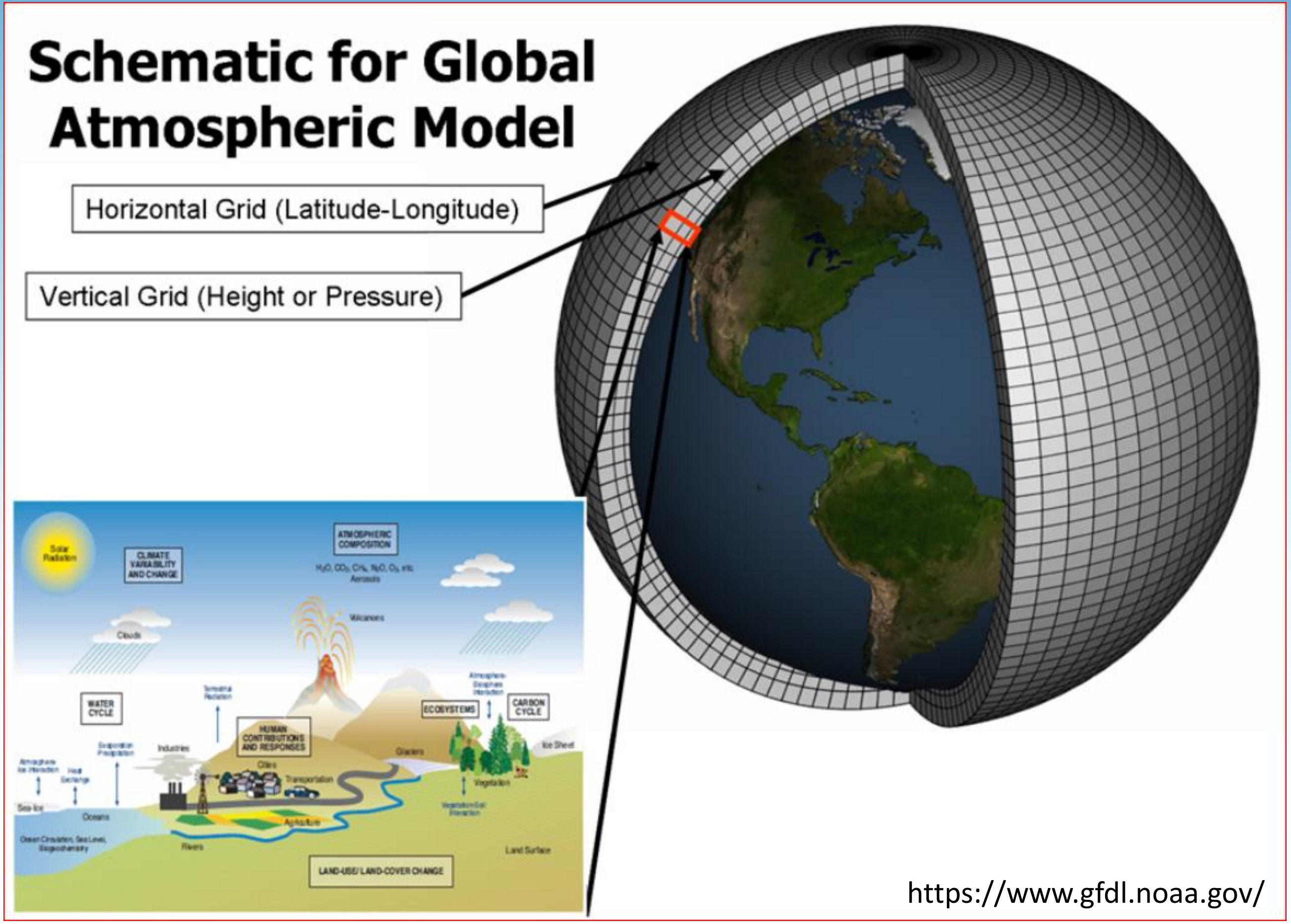
Forecasting the Future

- Utilize 42 downscaled Global Climate Model datasets (CMIP5)
- Forecast groundwater levels to 2100 under low and medium emission scenarios
- Evaluate GCM performance
- Evaluate the discrete effect of each driver separately



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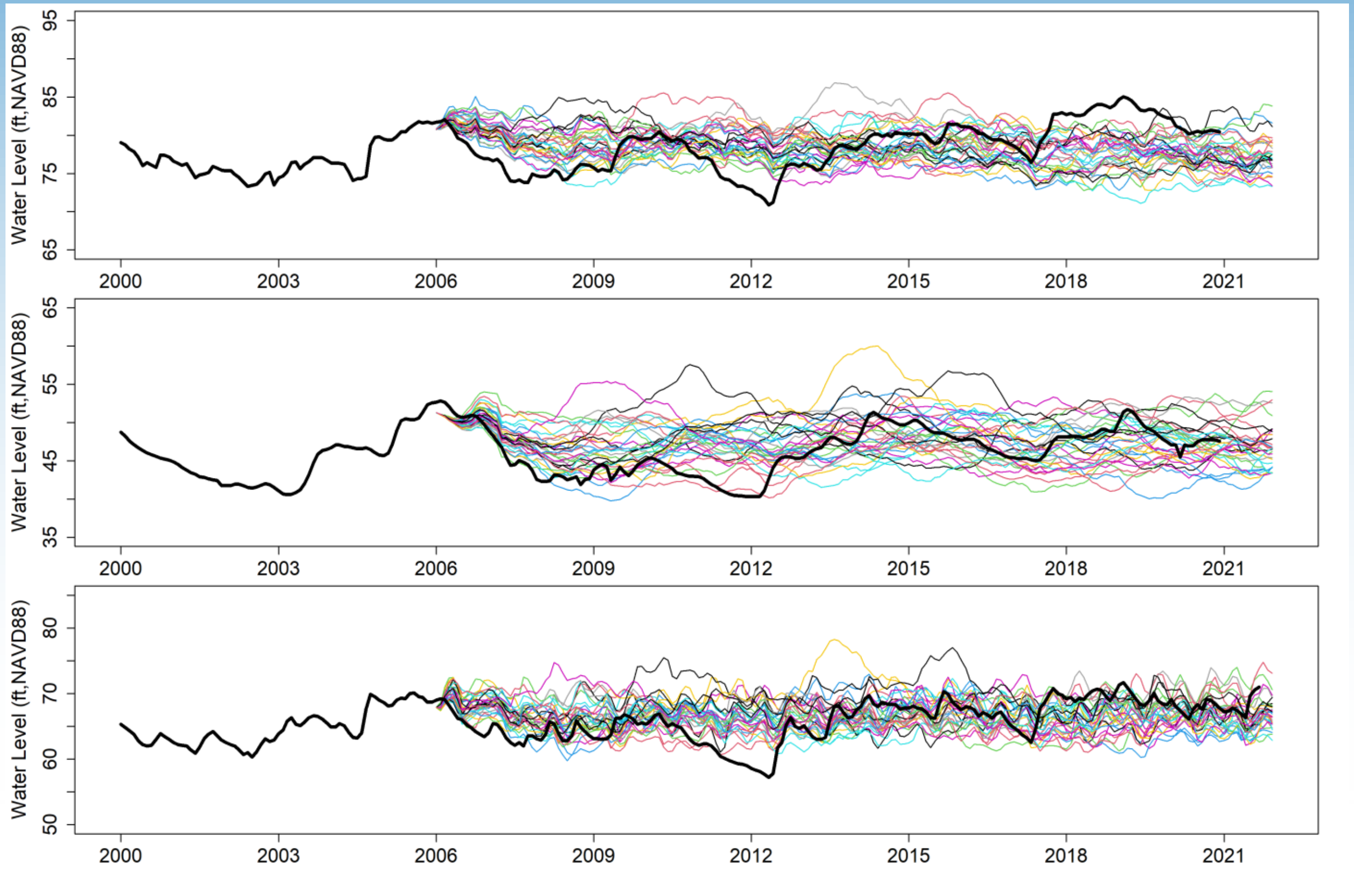
Performance of GCM projections Observed vs Forecasted

- Capture the range of observed levels
- Fail to replicate the timing of high and low extremes
- Fail to capture the timing of climatic cycles, controlling hydrologic memory



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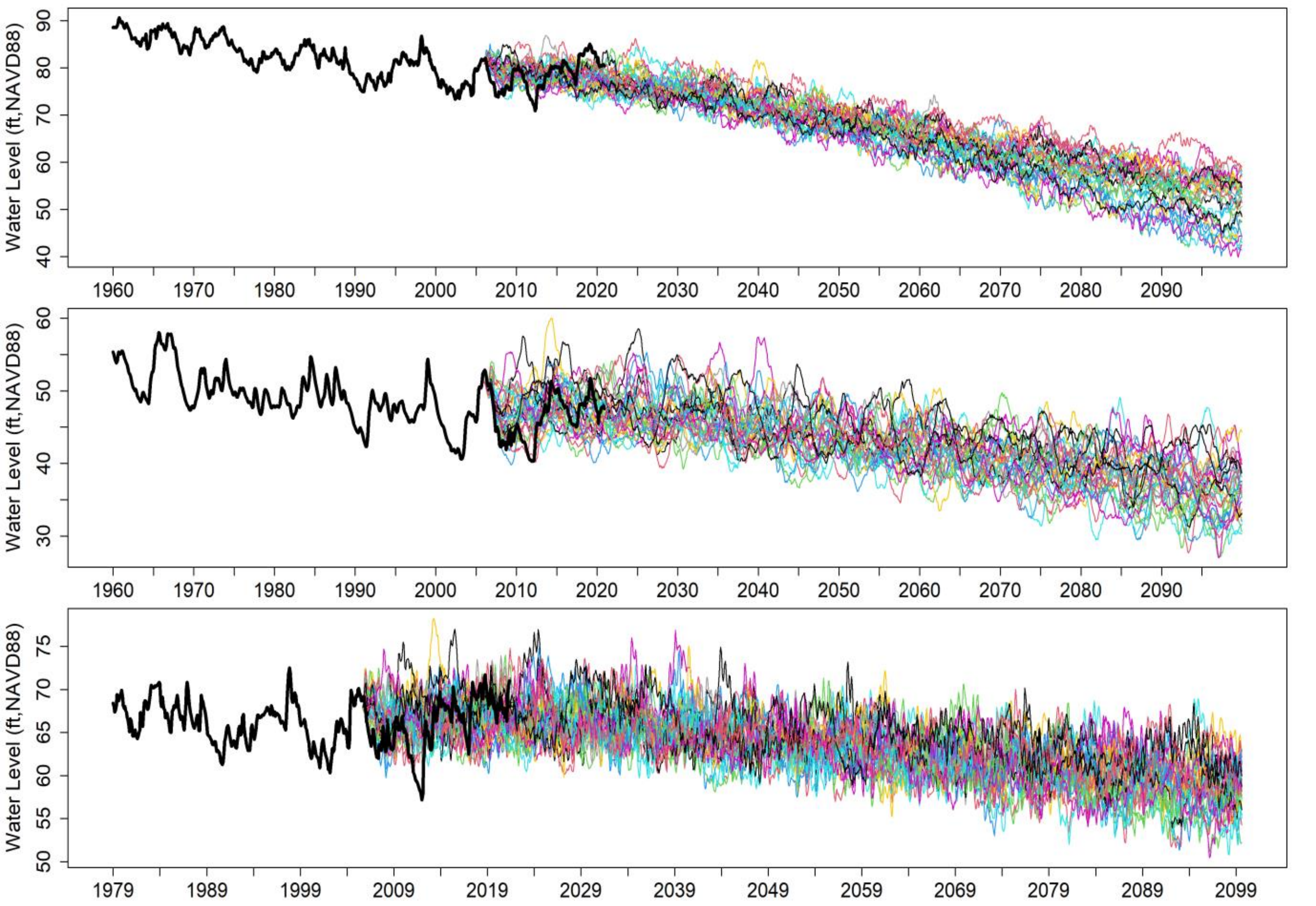
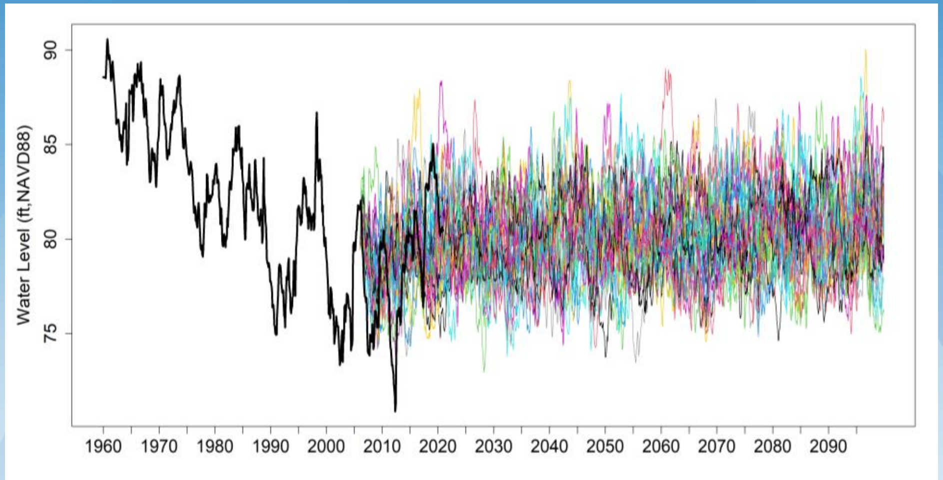
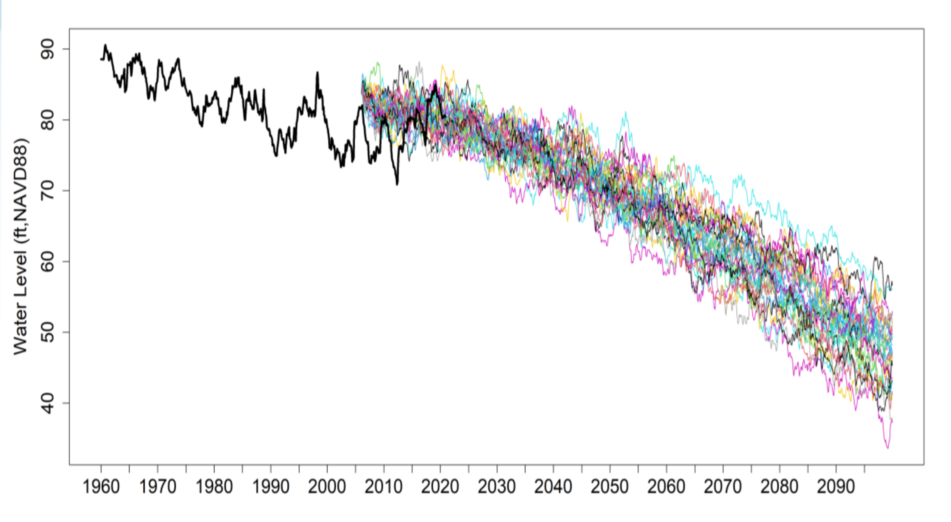
Groundwater Level Forecasts

- Very wide range of groundwater level projections
- Weighted average annual declines from 2020 to 2099 are 24 feet at site 1, 10 feet at site 2 and 8 feet at site 3 under medium emission scenario
- Declines accelerated after 2040s



Influence of each driver on future trends

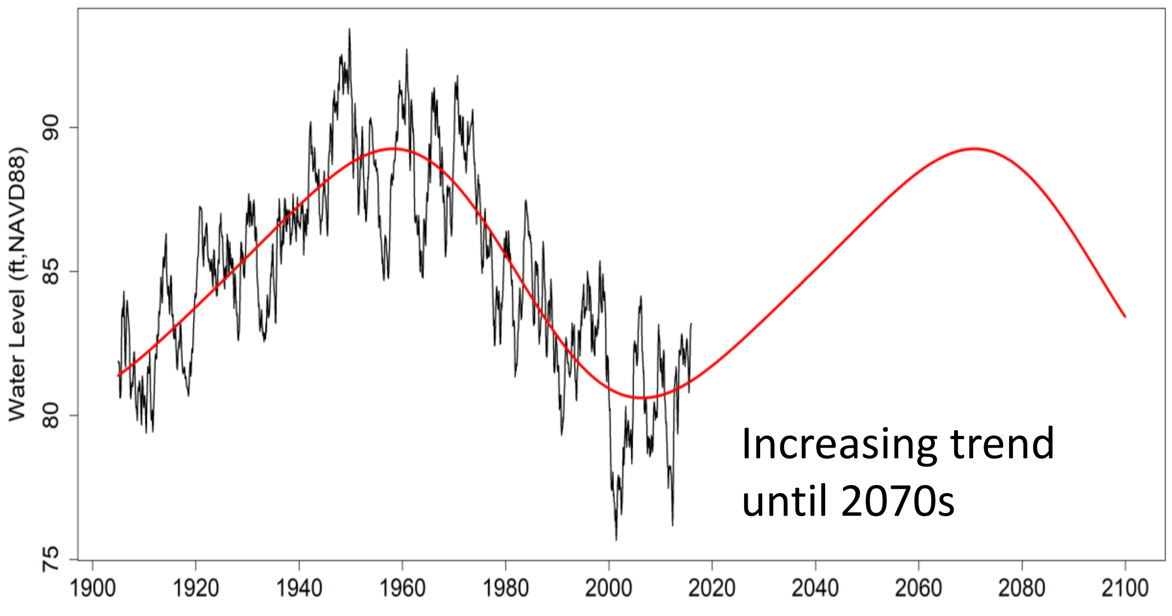


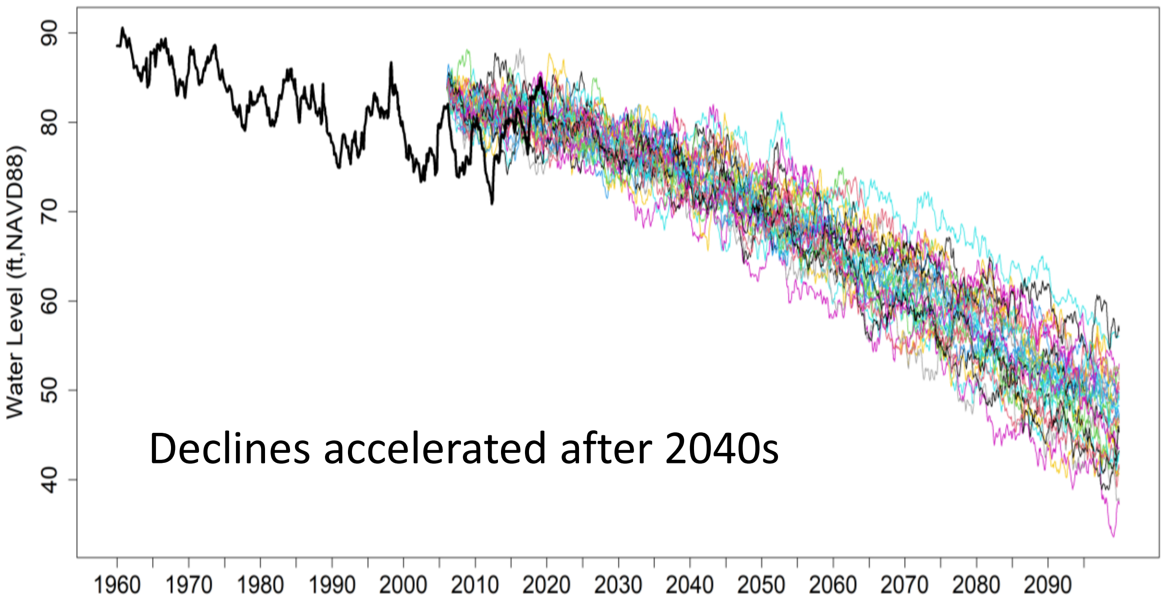


Rainfall-only-forecasts show increase in groundwater levels

Future declines primarily due to pumping impact and rising temperature

Past vs Future





Historical Harmonic Trend

Forecasts based on historical hydroclimatic patterns

GCMs projections

Forecasts based on projected rainfall and temperature

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Summary of Findings

- Frequencies of critical low levels increase significantly in the 1960-2015 period when compared to the 1904-1959 period due to climate change and pumping
- Future long-term rainfall trend might lead to rising groundwater levels, which might be overshadowed by global warming and increased groundwater pumping, hence, causing declines
- Centennial cyclic trends may exist in groundwater levels, critical for future predictions
- Further investigation is needed to better understand the effect of centennial cycles on future groundwater levels and how these cycles can be incorporated into the downscaling methods.

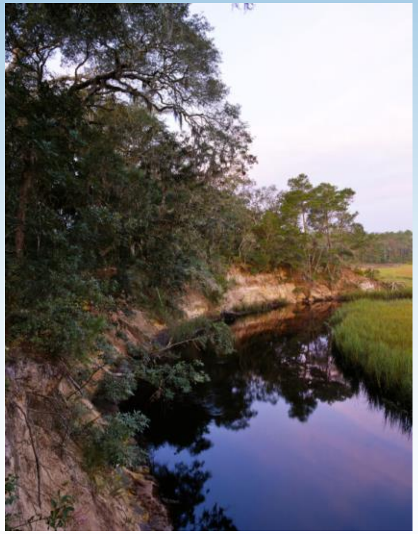
Can we reliably predict the future without knowing the past?

GCM-based forecasts are recommended to be cautiously utilized for groundwater resource planning when significantly departing from historical long-term cyclic patterns

For more information

- Gordu, F. and Nachabe, M.H., 2021. A physically constrained wavelet-aided statistical model for multi-decadal groundwater dynamics predictions. Hydrological Processes, 35(8), p.e14308.
- Gordu, F. and Nachabe, M.H., 2021. Hindcasting multidecadal predevelopment groundwater levels in the Floridan aquifer. Groundwater, 59(4), pp.524-536.
- Gordu, F. and Nachabe, M.H., 2023. Inferences of Groundwater Response to Projected Hydroclimatic Changes in North Florida. Journal of Hydrologic Engineering, 28(4), p.04023001.

Questions

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