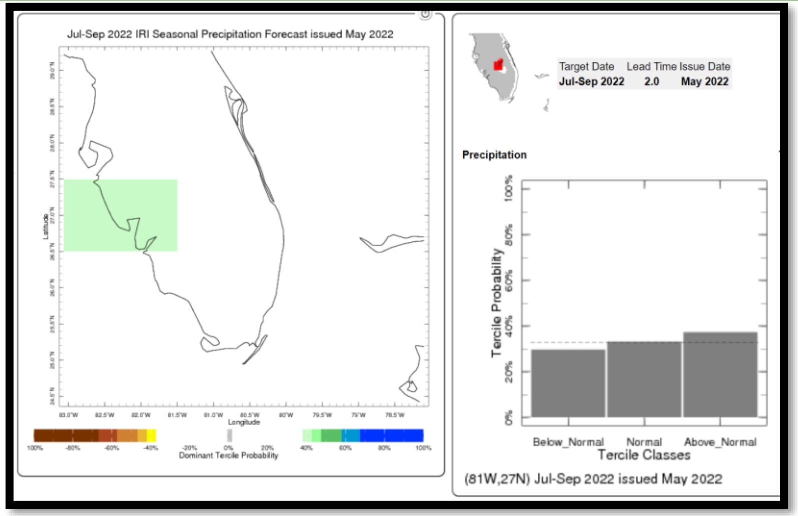
Conditional Positional Analysis (CPA) Methodology and Implementation

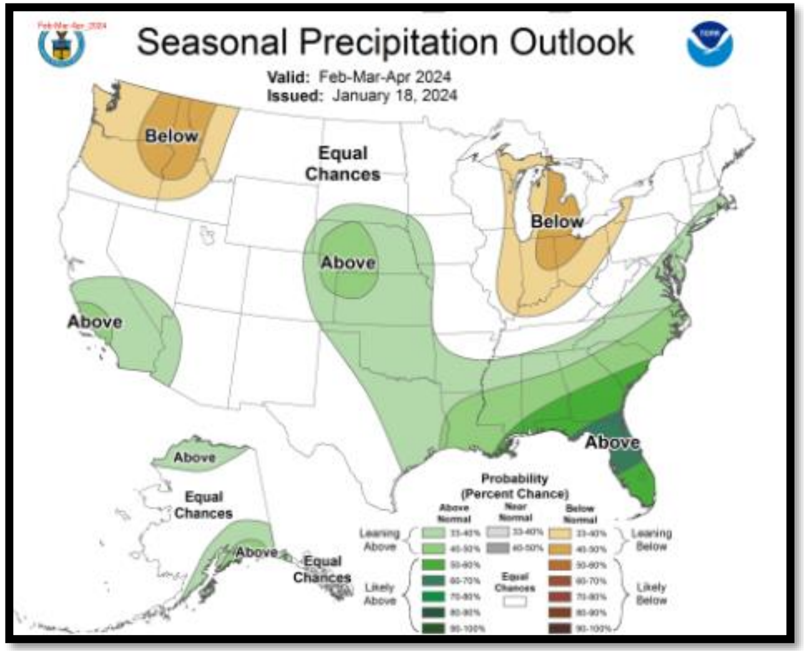
Water Resources and Systems Modeling Bureau
SFWMD

Motivation

- Stage forecasts over seasonal to annual timeframes are important for operational planning in South Florida
- Rainfall is the most important driver of water levels and other conditions in the Everglades
- Rainfall outlooks are uncertain over medium- and long-range
  - information is available in the form of tercile probabilities at 3 monthly seasonal scale
- Drawbacks of currently implemented techniques for stage forecasting
  - historical rainfall instead of rainfall outlook
  - not constrained by operational protocols



International Research Institute (IRI)

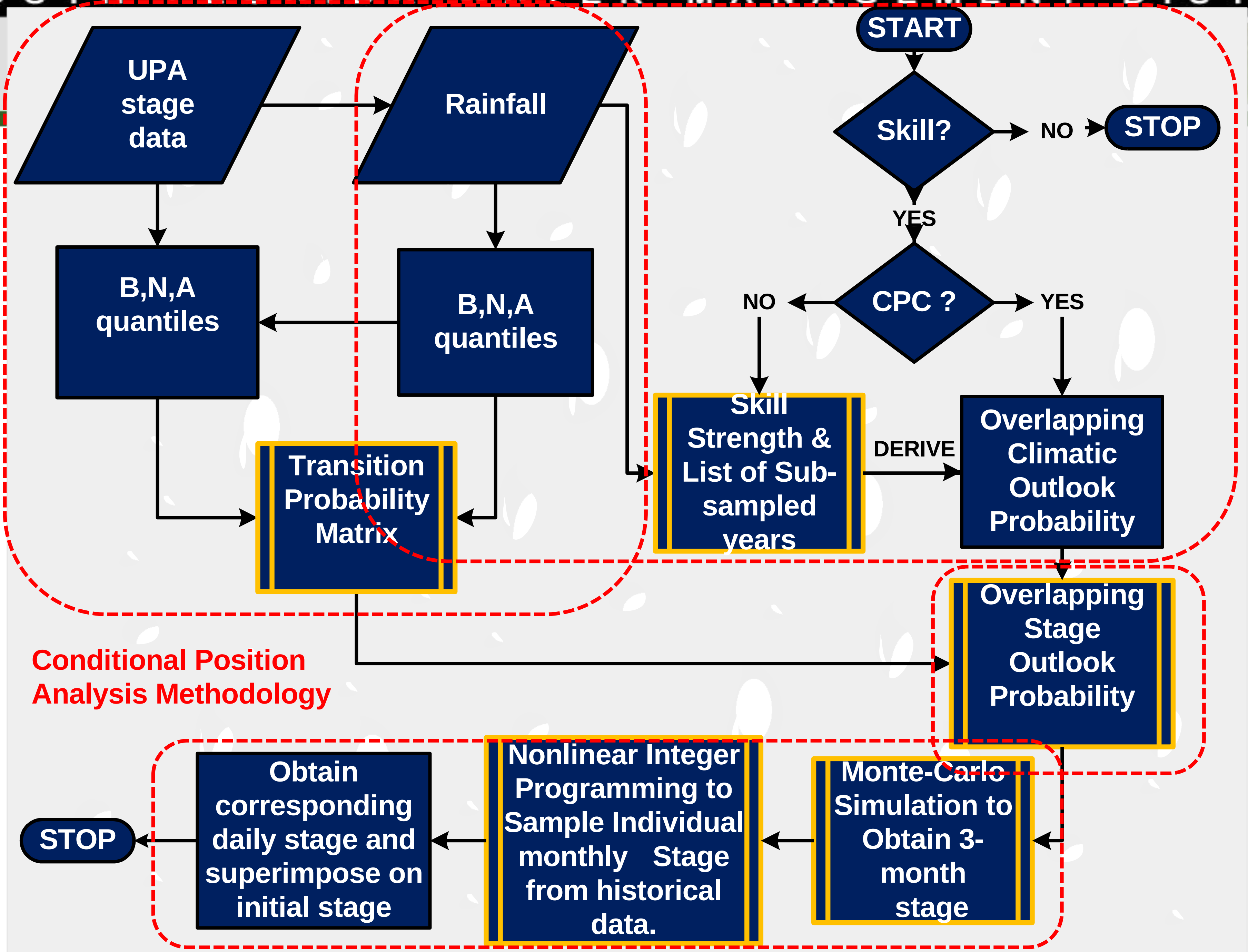


NOAA, Climate Prediction Center (CPC)

Methodology in nutshell

Dr. Alaa Ali

Conditional Position Analysis Methodology



Ali (2016)

Basis

- Change in stage and rainfall are correlated (Ali, 2009)

Step 1

- Obtain transition probability matrix (TPM) for 10 seasons (3-month periods) constituting 1 year forecast period

$$TPM\Big|_i = \begin{pmatrix} p_{dd} & p_{dn} & p_{dw} \\ p_{nd} & p_{nn} & p_{nw} \\ p_{wd} & p_{wn} & p_{ww} \end{pmatrix}$$

Pij – probability of stage change category i, given the rainfall being in the j^{th} state
i and j – dry (d), normal (n), and wet (w)

TPM is calculated based on historical observed stage and rainfall timeseries

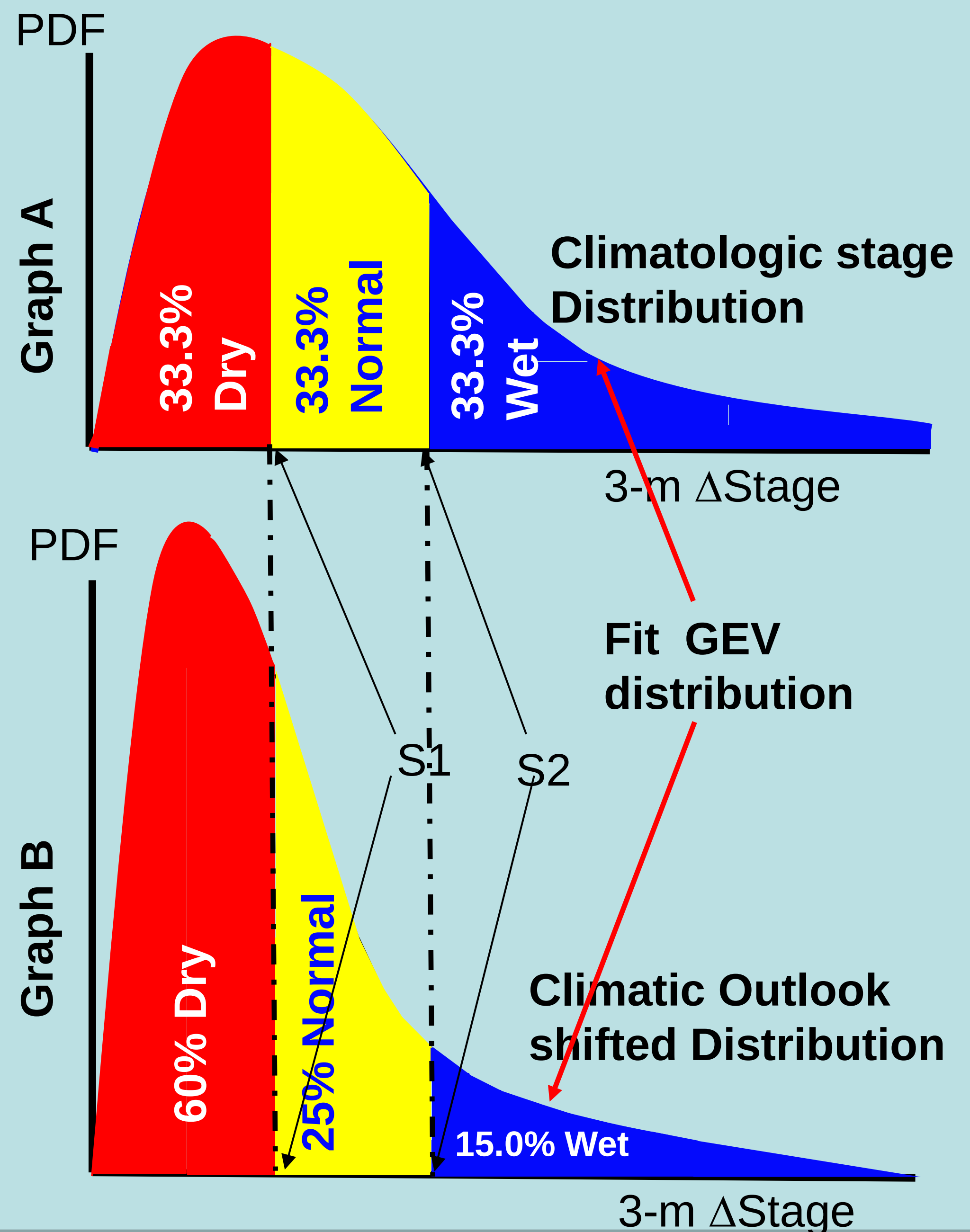
Step 2: Change in stage outlook for a given rainfall scenario

Stage Outlook **TPM** **Rainfall Outlook**

$$\begin{pmatrix} p(\Delta stage)_d \\ p(\Delta stage)_n \\ p(\Delta stage)_w \end{pmatrix}_i = \begin{pmatrix} p_{dd} & p_{dn} & p_{dw} \\ p_{nd} & p_{nn} & p_{nw} \\ p_{wd} & p_{wn} & p_{ww} \end{pmatrix}_i \begin{pmatrix} p(rain)_d \\ p(rain)_n \\ p(rain)_w \end{pmatrix}_i$$

Step 3: Fit Distributions to delta stage outlook

- Based on stage outlook values, fit probability distributions for all 10 3-month windows using Monte Carlo Simulations



- Generate random number (rand) between 0-1,select stage from graph A

0 0.6 0.85 1

- 0<rand<0.6 , select dry stage at random from Graph A
- 0.6<rand<0.85, select normal stage at random Graph A
- 0.85<rand<1, select wet stage at random Graph A

Ali (2016)

Step 4.1: Optimized delta stage timeseries

- MCS approach to run n simulations
- For each of n simulations
  - generate delta stage timeseries based on rainfall scenario by sampling delta stage probability distributions in Step 3
  - Disaggregate 3-month delta stage values to monthly delta stage values – minimize the following objective function
  - $\sum_{i=1}^{10}\left(\sum_{j=i}^{i+2} \Delta\text{stage}_j - \Delta 3\text{stage}_i\right)^2$ → Objective Function
  - Genetic Algorithm (GA) is used for a Non-Linear Integer Programming framework for optimization
  - Monthly delta stage values are sampled from delta stage values obtained historic data

Step 4.2: Stage realizations

- Combine daily delta stage values for optimized monthly stages to form daily delta stage timeseries
- Superimpose daily delta stage timeseries on initial stage to calculate stage realizations
- Repeat above two steps for all n monthly delta stage timeseries to get n stage realizations
- Assembly of stage realizations is constrained by upper and lower regulation schedule bounds:
- $lower(i) < stage(i) < upper(i)$ → Bound constraint for month i. Constraints are soft rather than strictly enforced to allow flexibility under extreme or unforeseen weather scenarios.

Implementation

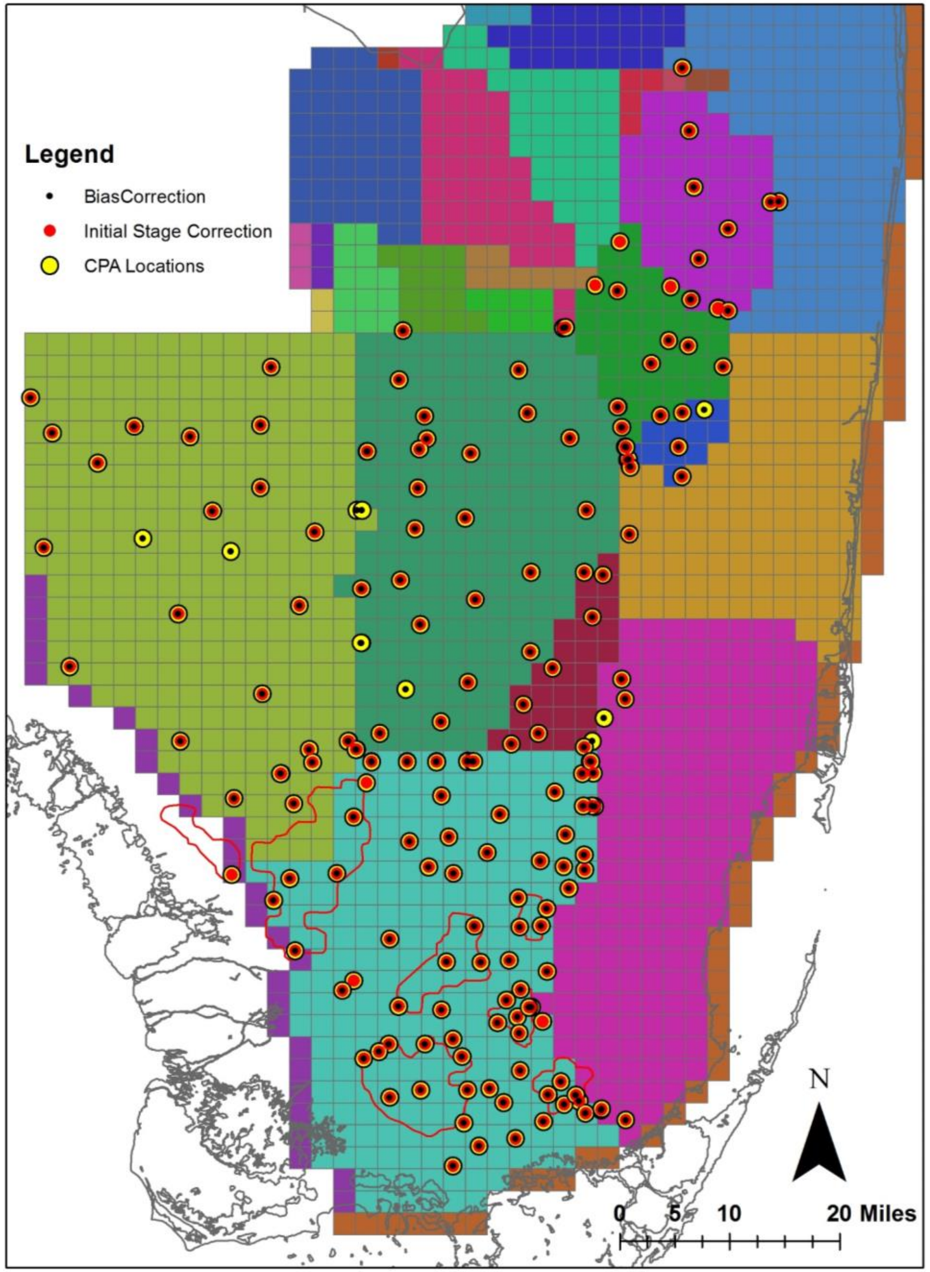
Major Contributor: Dr. Yogesh Khare

Supporting Contributor: Veerabhadra Karri, Rutambara Sonawane, Jason Godin, Walter Wilcox

CPA Implementation

- MATLAB based
- Originally developed for Lake Okeechobee
- DPA based on SFWMMv7.3.3 with POR 1965-2016
- DPA results are starting point for CPA
- Expanded to 199 locations in the Everglades (consistent with Ever Forecast), WCA1_Avg (avg of Site 7, Site 8T, and Site 9) and WCA3A_Avg (avg of Site 63, Site 64, and Site 65)
- 3 rainfall outlooks (climatological, CPC, and Preferred Scenario)

Everforecast Gages for CPA



CPA Implementation: Workflow

Step 1
- Create Rainfall Outlook (i.e., Tercile Probability) Scenario Files for Climatological, CPC, and Preferred Scenario

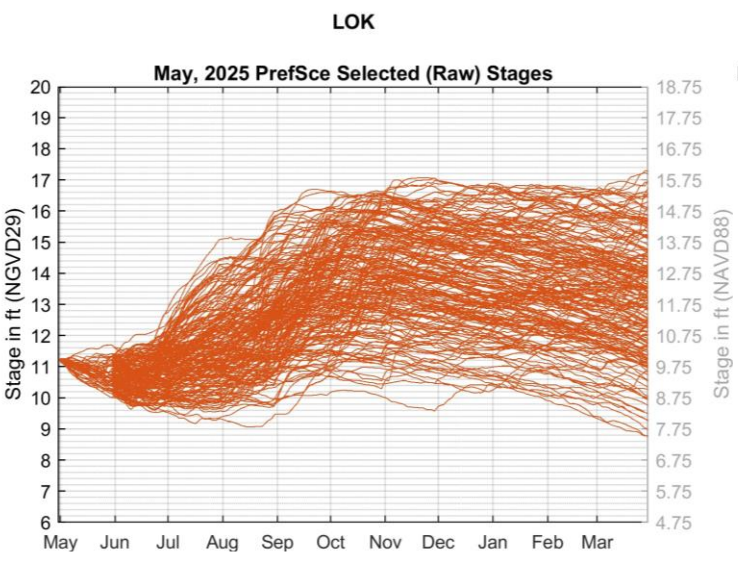
Step 2
- DPA stages extraction for the desired Operational Scenario Protocol

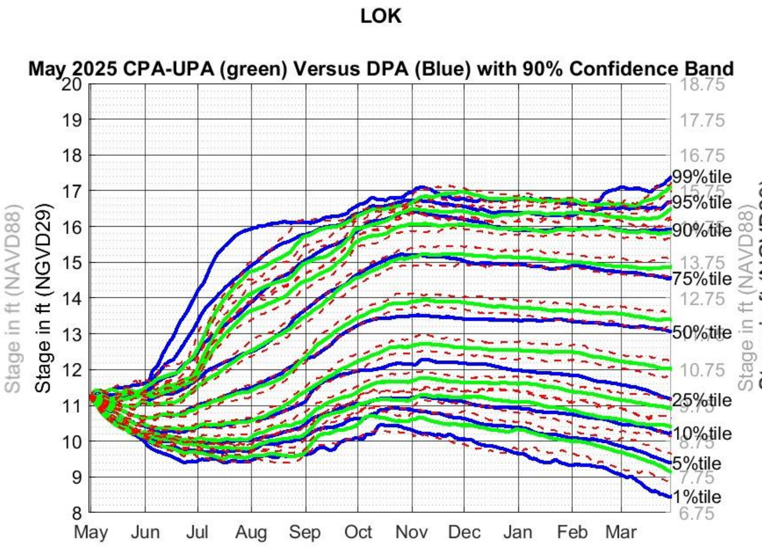
Step 3
- Process stage information (correction for known biases and initial stages) to generate inputs for CPA

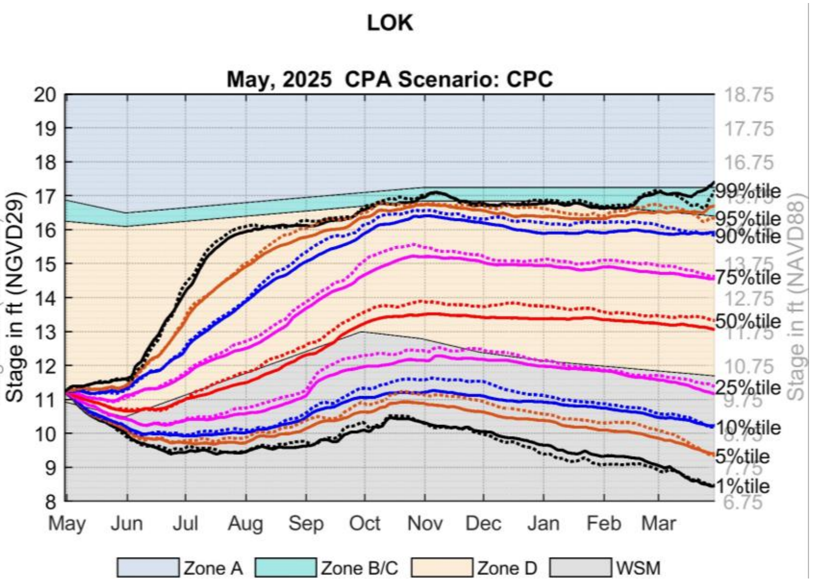
Step 4
- Run CPA on windows server in parallel mode

Step 5
- Post-process stage traces (graphics and stage outputs)

CPA Results







- Raw stage traces obtained from CPA are processed further (bootstrapped) to calculate percentile lines.
- CPA forecasted stage percentiles from “Climatological/CPA-UPA” scenario are first collapsed on DPA stage percentiles. Corresponding adjustments are then applied to stage percentile lines for all other rainfall outlook scenarios.
- Results shows DPA lines (Solid) and CPA lines (dotted) under selected rainfall scenario.

Summary

- CPA methodology transforms DPA forecasted stages based on rainfall outlook, providing a more realistic perspective to water managers on the state of the system
- Monte Carlo Simulation technique with non-linear integer programming to generate stage traces
- Incorporates currently implemented and alternative operational protocols
- Flexible to simulate any hypothetical rainfall outlook