SOUTH FLORIDA WATER MANAGEMENT DISTRICT

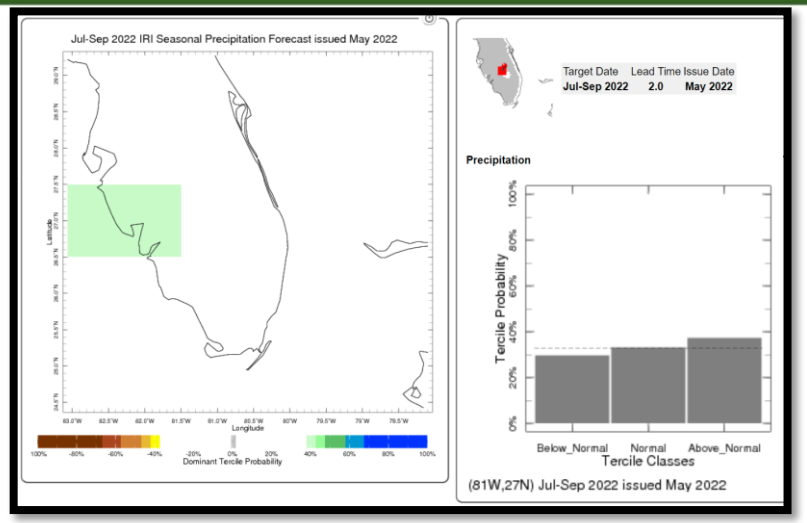
Conditional Positional Analysis (CPA) Methodology and Implementation

Systems Modeling Unit
SFWMD

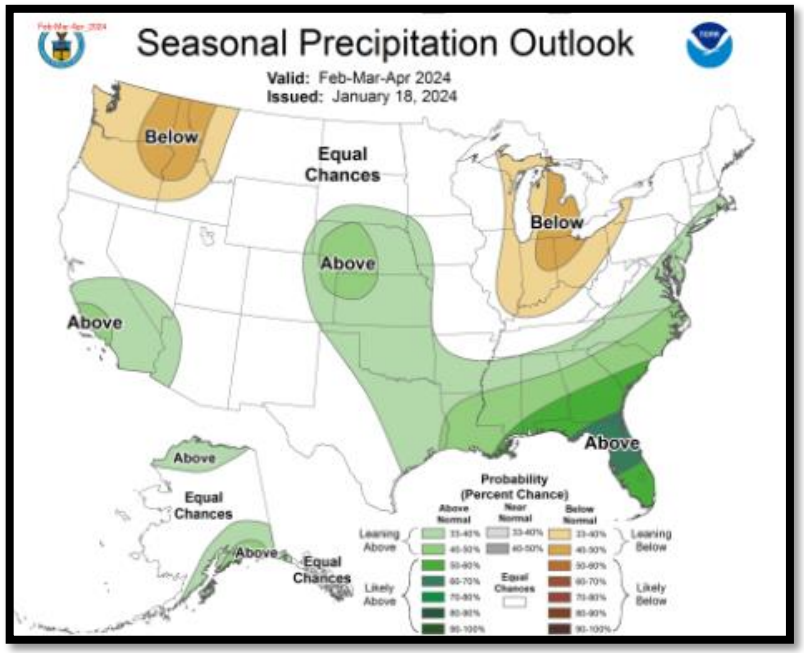
sfwmd.gov

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

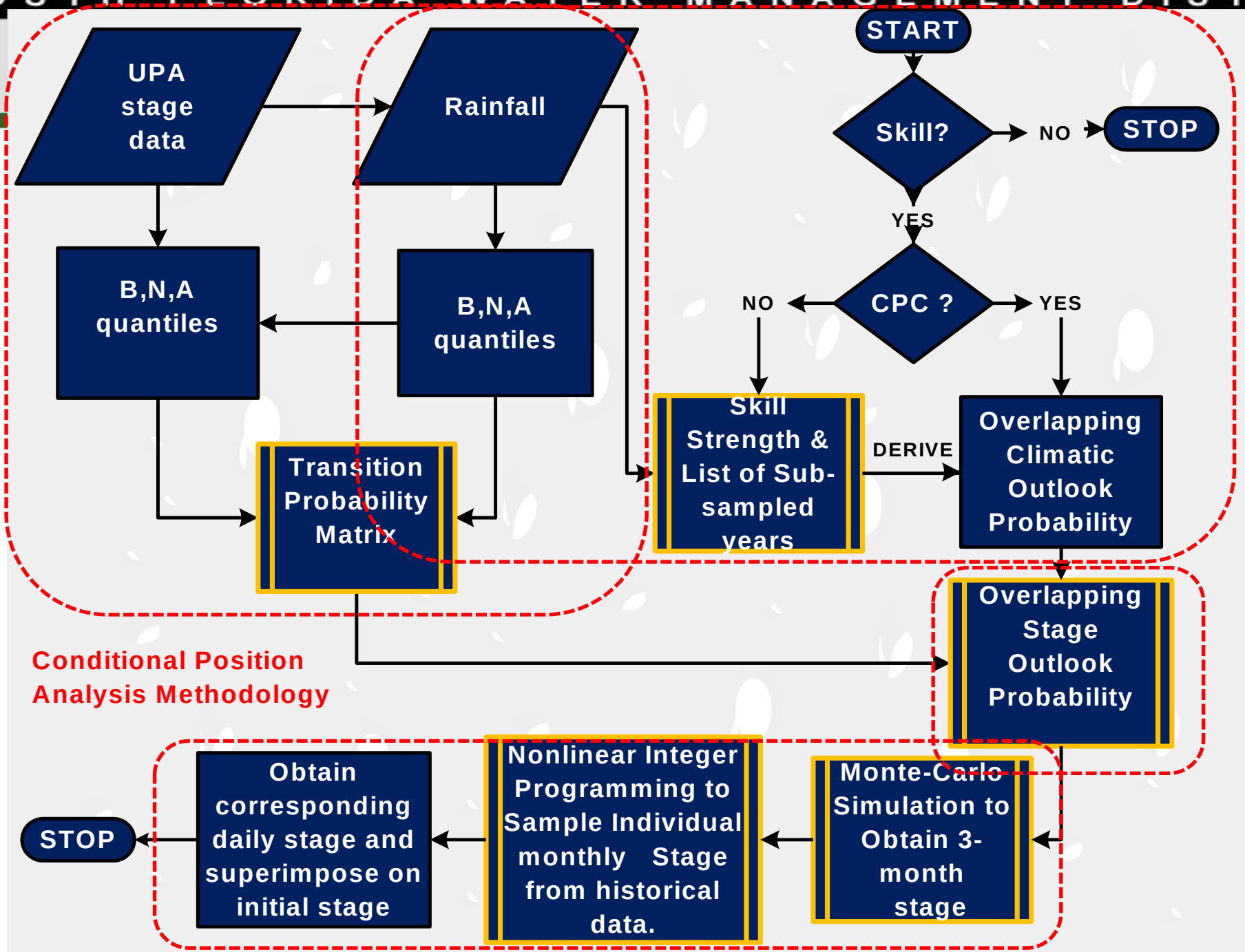


International Research Institute (IRI)



NOAA, Climate Prediction Center (CPC)

Methodology in nutshell


UPA stage data
Rainfall
B,N,A quantiles
B,N,A quantiles
Transition Probability Matrix
START
Skill?
NO
STOP
YES
CPC ?
NO
YES
Skill Strength & List of Sub-sampled years
DERIVE
Overlapping Climatic Outlook Probability
Overlapping Stage Outlook Probability
Monte-Carlo Simulation to Obtain 3-month stage
Nonlinear Integer Programming to Sample Individual monthly Stage from historical data.
Obtain corresponding daily stage and superimpose on initial stage
STOP
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

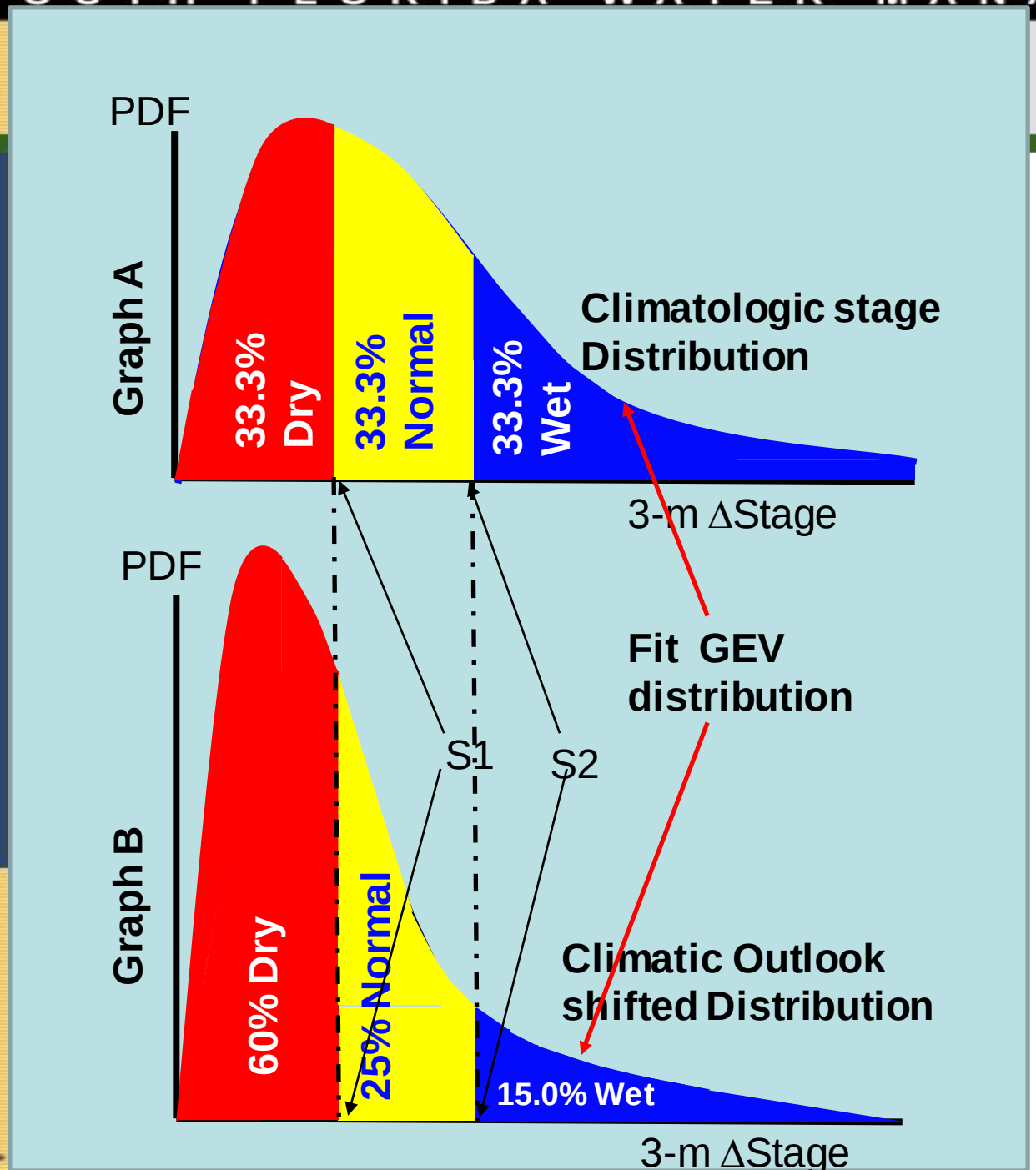
Step 2: Change in stage outlook for a given rainfall scenario

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<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 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
  - $\sum_{i=1}^{10}\left(\sum_{j=i}^{i+2}\Delta\text{stage}_j - \Delta 3\text{stage}_i\right)^2$
  - Genetic Algorithm (GA) is used for optimization
  - Monthly delta stage values are sampled from delta stage values obtained historic data

Step 4.2: Stage realizations

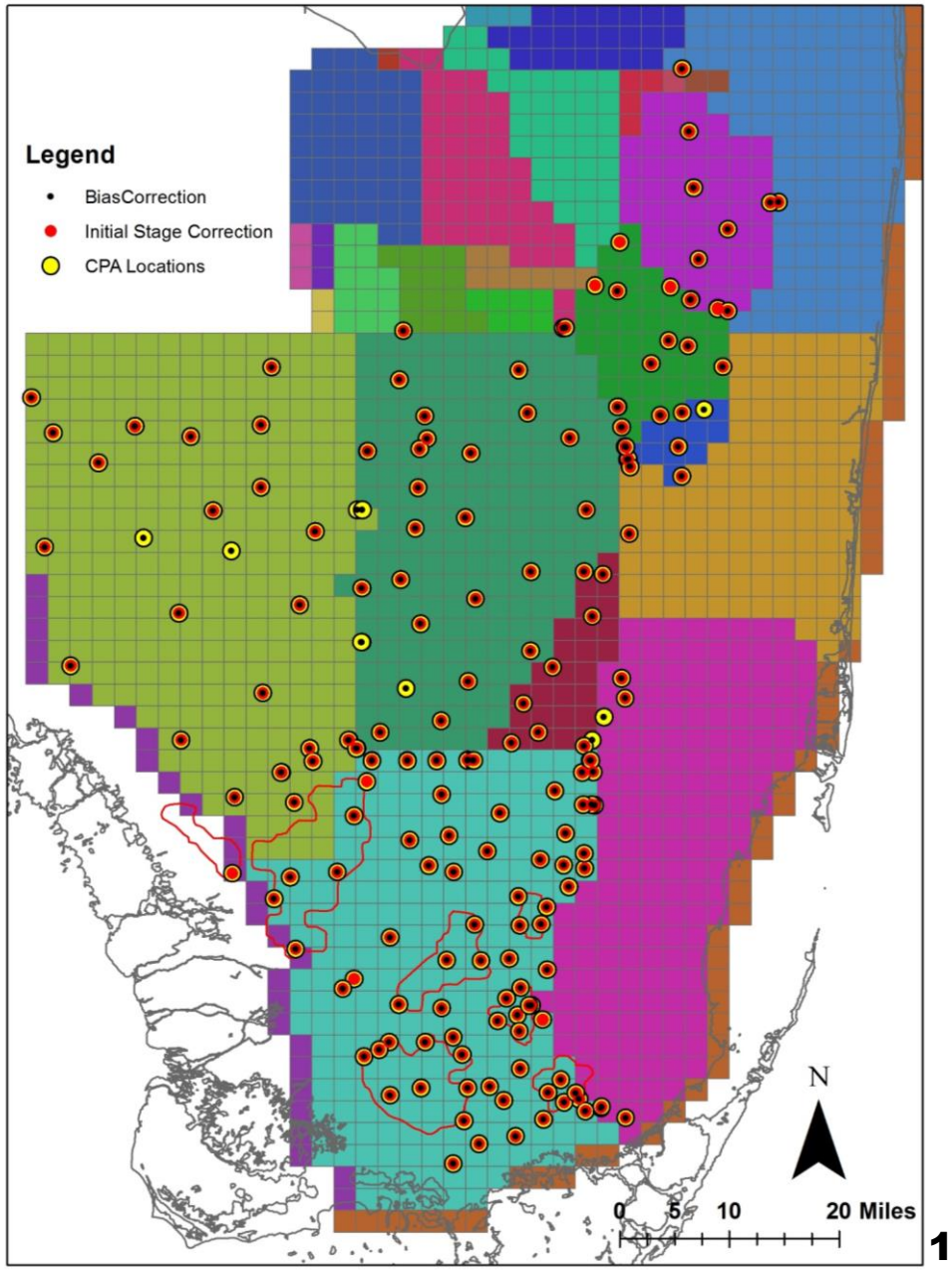
- Combine daily delta stage values for optimized monthly stages to form daily delta stage timeseries
- Superimpose daily delta stage timeseries on initial stage to calculate stage realizations
- Repeat above two steps for all n monthly delta stage timeseries to get n stage realizations

IMPLEMENTATION

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 EverForecast), 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

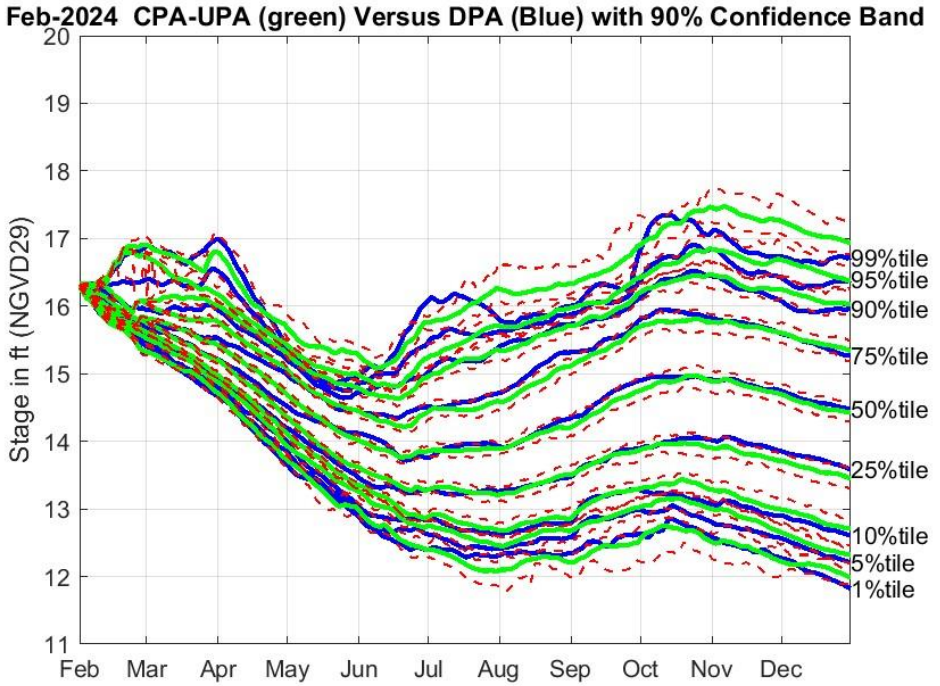
Step 3
- Process stage information (correction for known biases and initial stages) to generate inputs for CPA

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’ scenario are first collapsed on DPA stage percentiles. Corresponding adjustments are then applied to stage percentile lines for all other rainfall outlook scenarios.



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 soon to be implemented operational protocols
- Flexible to simulate any hypothetical rainfall outlook
- CPA may generate raw stage traces that do not appear realistic w.r.t. practical considerations
- Currently, efforts are underway to develop mechanism to further constrain CPA generated stages such that even extreme stages would conform to practically possible stages under current operational protocols