Multi-Objective Evolutionary Algorithm Model for Water Supply Sources Allocation

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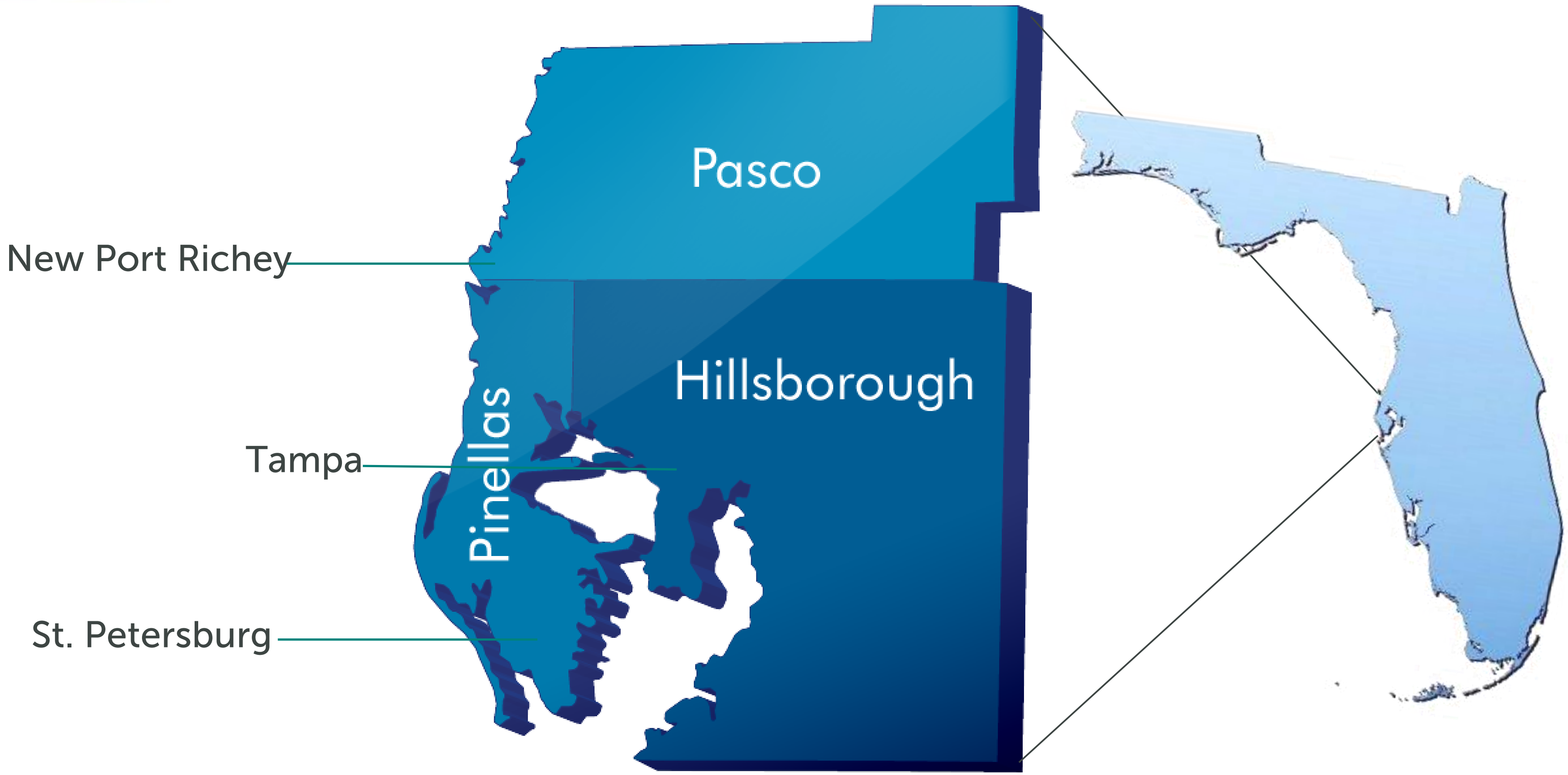
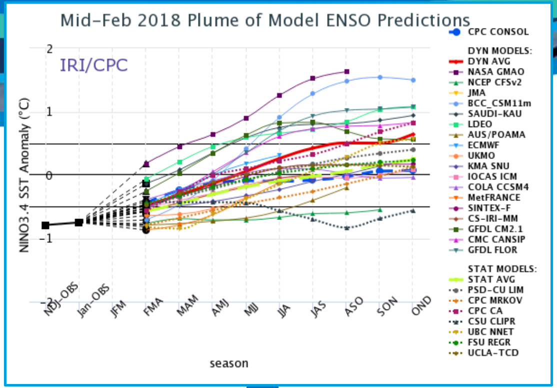
Tampa Bay Water's Member Governments

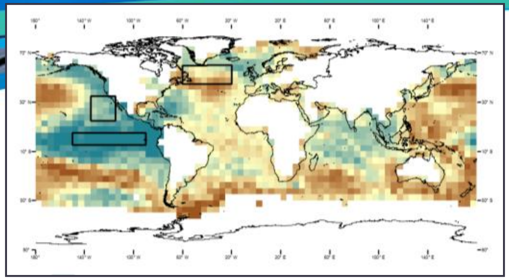


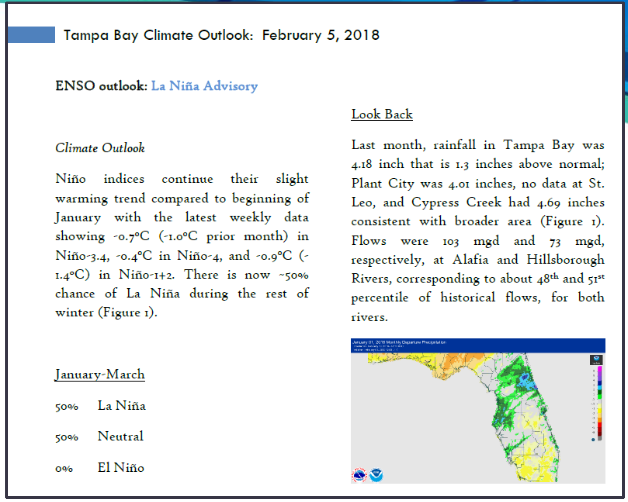
Tampa Bay Water's Supply System

- Integrated drought-resistant supply system
  - 13 wellfields
  - 8 groundwater treatment facilities
  - Surface Water Treatment Plant
  - Desalination Treatment Plant
  - 9 pump stations
  - 270 miles of transmission mains

Seasonal flow forecasting system






Tampa Bay Climate Outlook: February 5, 2018

ENSO outlook: La Niña Advisory

Climate Outlook

Niño indices continue their slight warming trend compared to beginning of January with the latest weekly data showing -0.7°C (-1.0°C prior month) in Niño-3.4, -0.4°C in Niño-4, and -0.9°C (-1.4°C) in Niño-1+2. There is now ~50% chance of La Niña during the rest of winter (Figure 1).

January-March

50%	La Niña
50%	Neutral
0%	El Niño

Look Back

Last month, rainfall in Tampa Bay was 4.18 inch that is 1.3 inches above normal; Plant City was 4.01 inches, no data at St. Leo, and Cypress Creek had 4.69 inches consistent with broader area (Figure 1). Flows were 103 mgd and 73 mgd, respectively, at Alafia and Hillsborough Rivers, corresponding to about 48th and 51st percentile of historical flows, for both rivers.

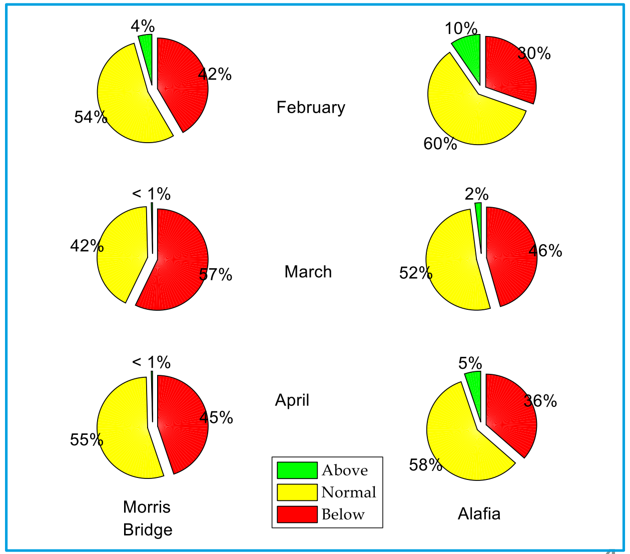
Contingency Table

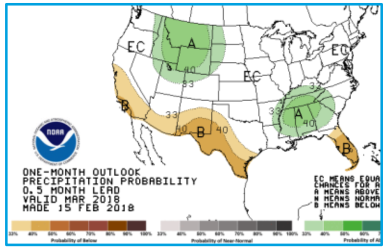
Climate Outlook

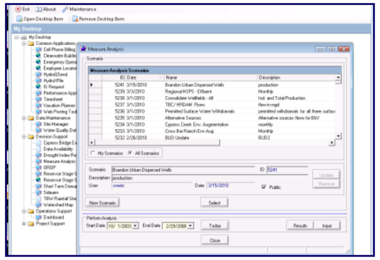
&

Observation

Weather-based Rainfall Model

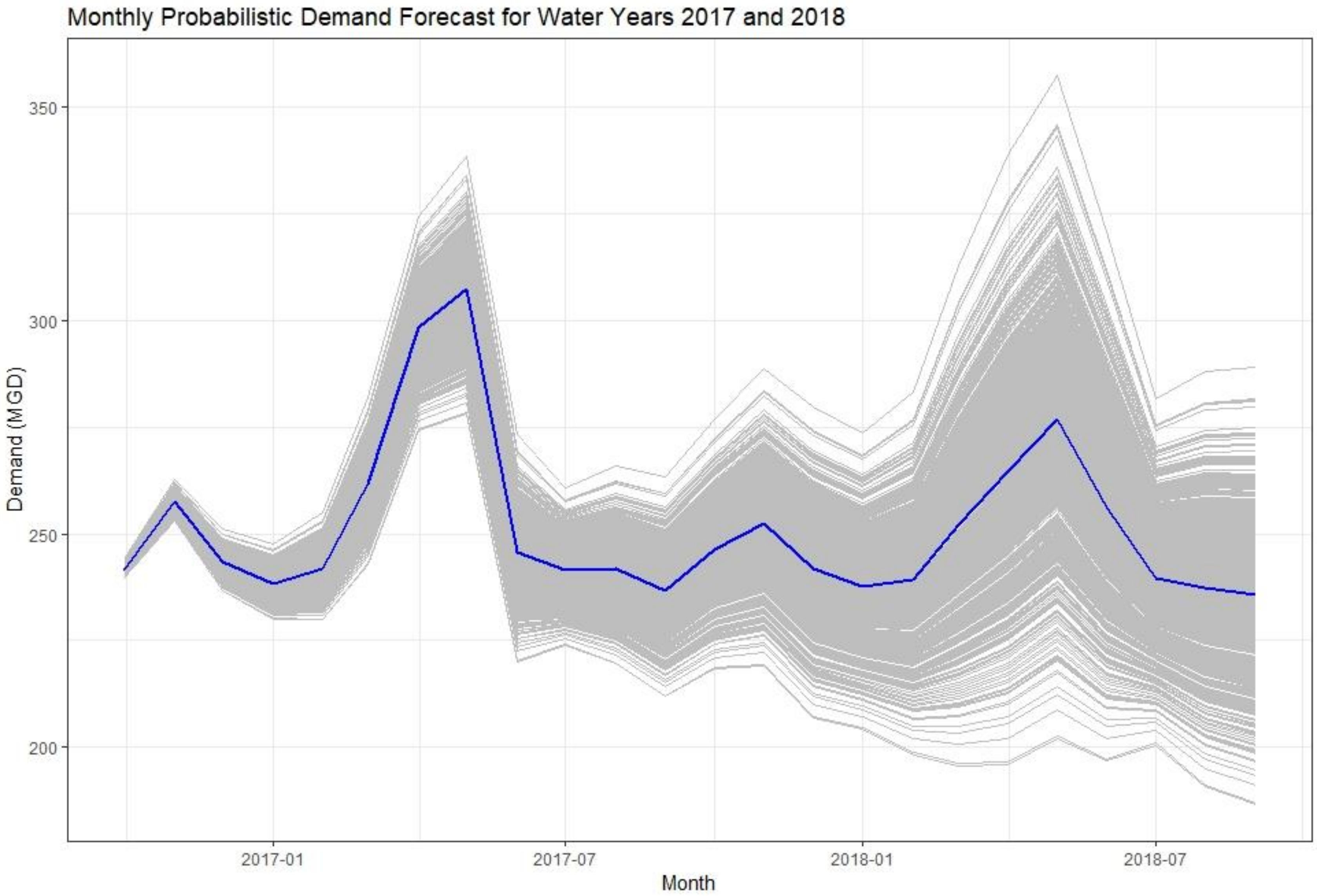






Rainfall/Runoff Model

Seasonal demand forecast



Four Objectives defined

Minimize:

- deviation from annual budget (in mgd)
- total cost of water production (in relative monetary values)
- Under-Utilization of groundwater use
- Over-Utilization of groundwater use

Examples of Operating Constraints:

- Keep reservoir storage full at the end of water year
- surface water treatment operation efficiency

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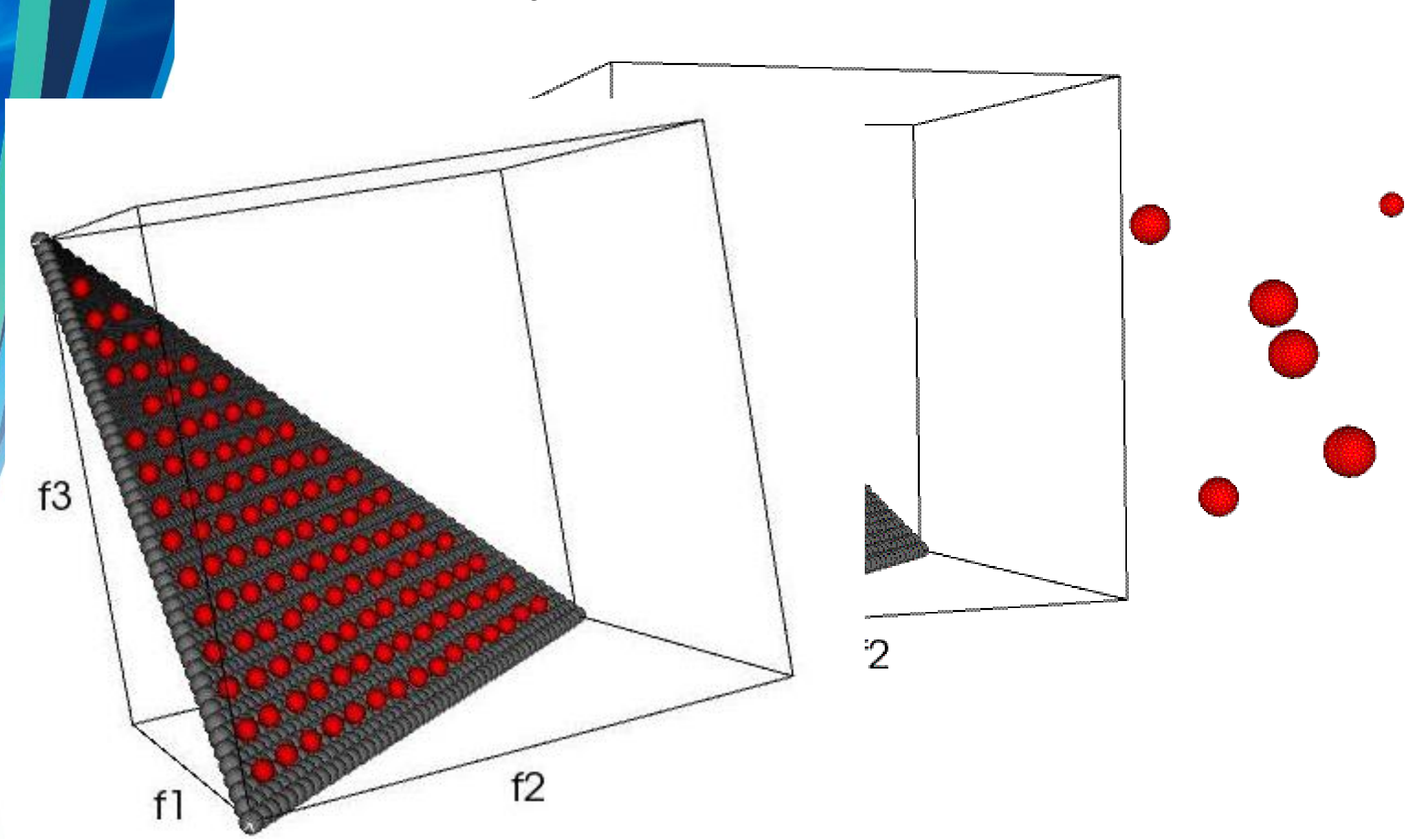
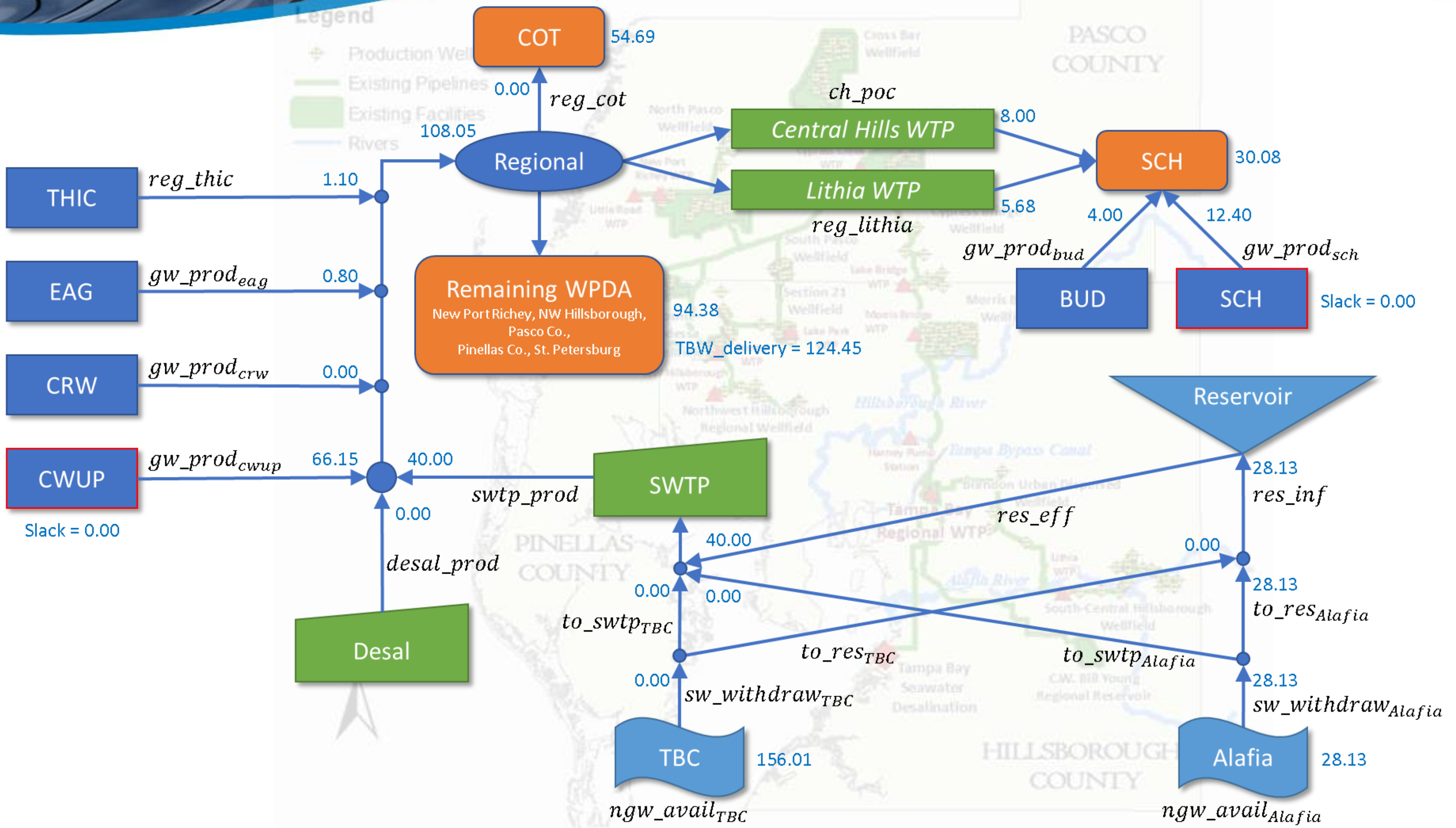
Three-objective Test Problem



- Heuristic method: flexibility for stochastic problems with unknown gradients
- Search balances convergence and diversity
- Borg MOEA: efficient, reliable performance broad range of applications

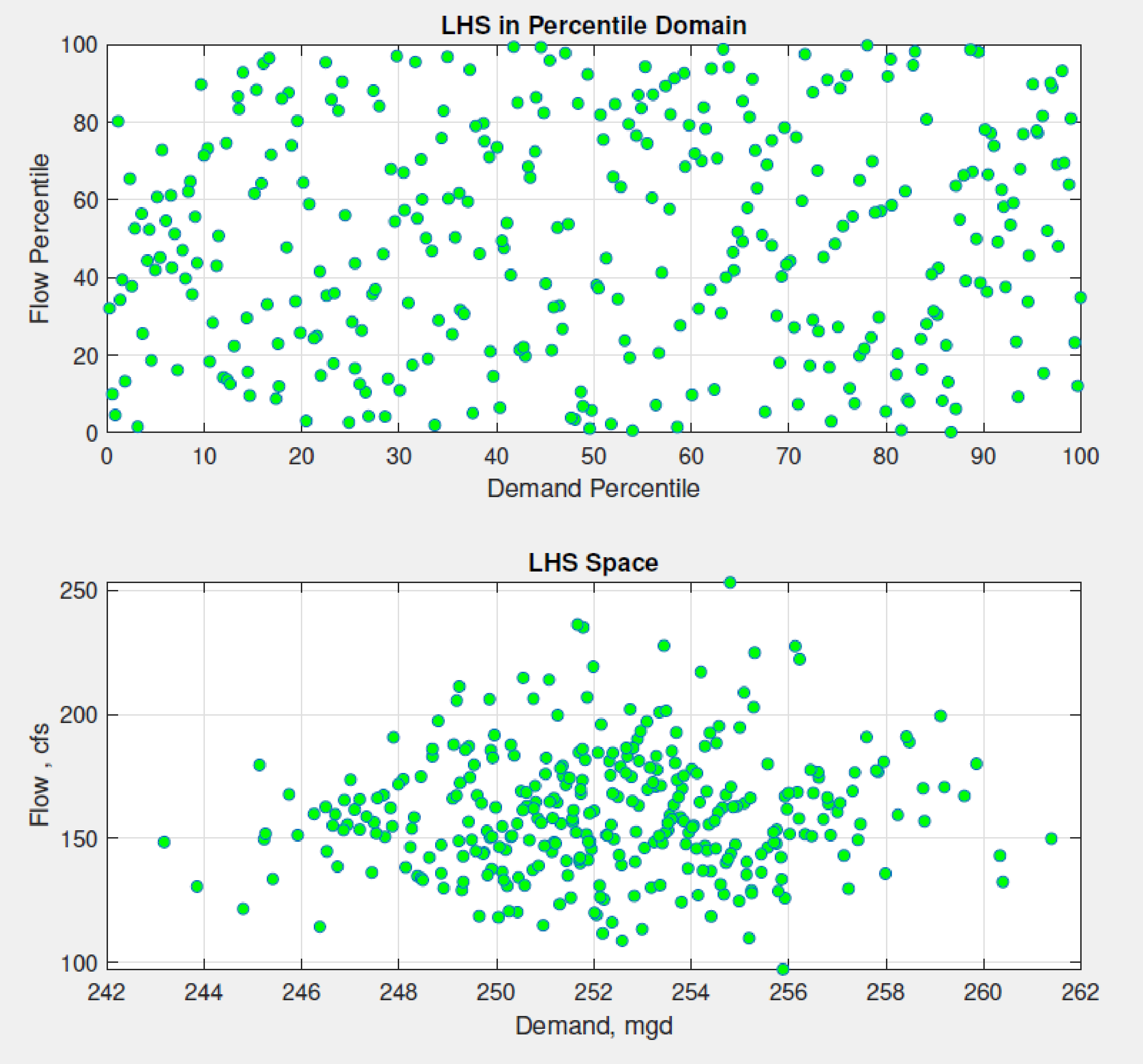
Reed, P.M., D. Hadka, J.D. Herman, J.R. Kasprzyk, and J.B. Kollat. 2013. Evolutionary Multiobjective Optimization in Water Resources: The Past, Present, and Future. *Advances in Water Resources*, 51, 438–456. [Invited Submission for 35th Anniversary Issue].

Seasonal Resource Allocation Model



Addressing uncertainty in flow and demand forecasts

334 realizations of flow and demand for each MOEA run.



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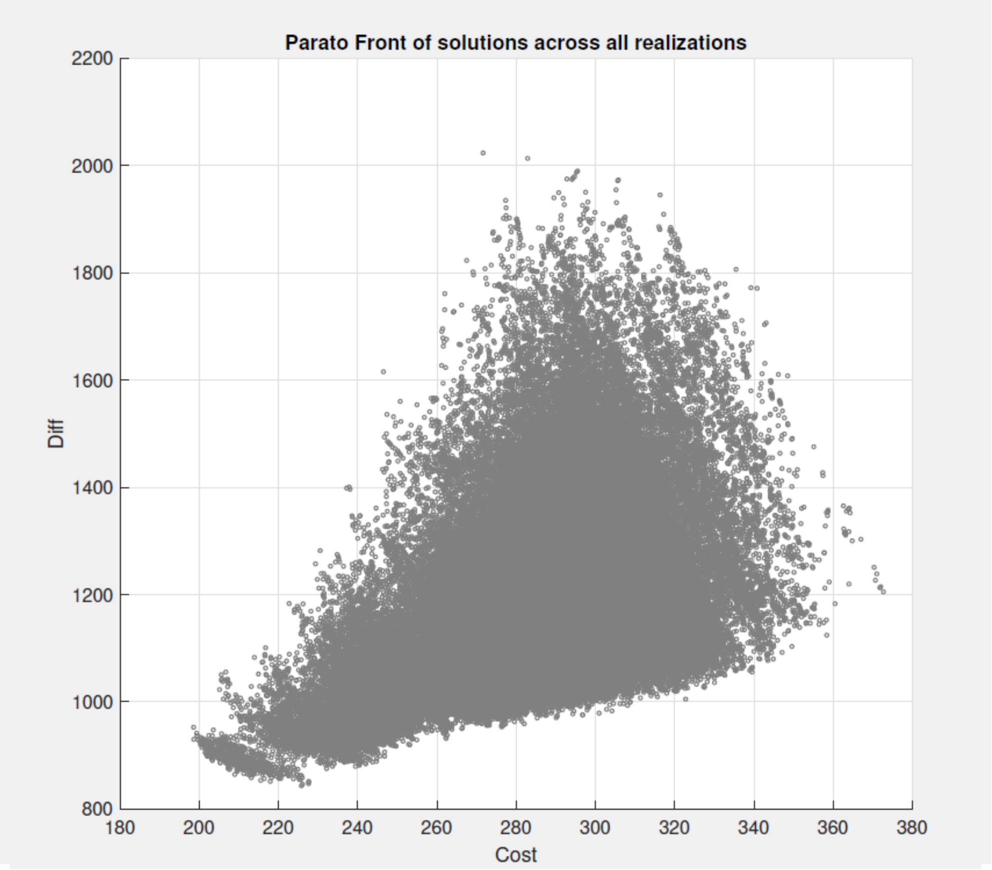
An illustrative example using retrospective analysis for October 2016

A set of solutions, corresponding to a Parato front, are obtained for each realization.

The figure shows Parato front for three realizations with different combinations of flow and demand.

All solutions from 334 realizations can be mapped to the same space for further analysis



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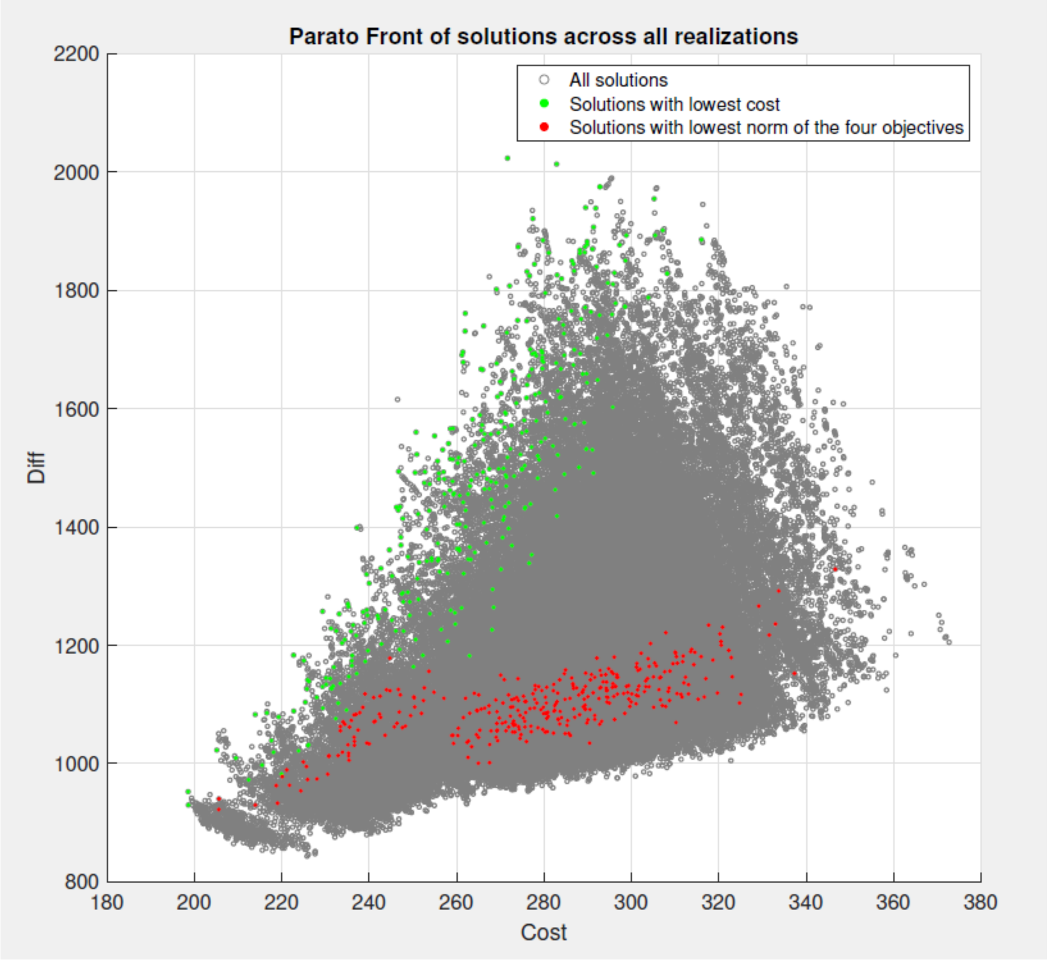
Criteria to select one solution from each Prato Front

- The following two criteria were tested to select one solution for each input realization
  - ❑ Minimum cost in each set of solutions
  - ❑ Minimum norm of the four objectives in each set of solutions

- Specific criteria used for this purpose can be different depending on operational considerations.



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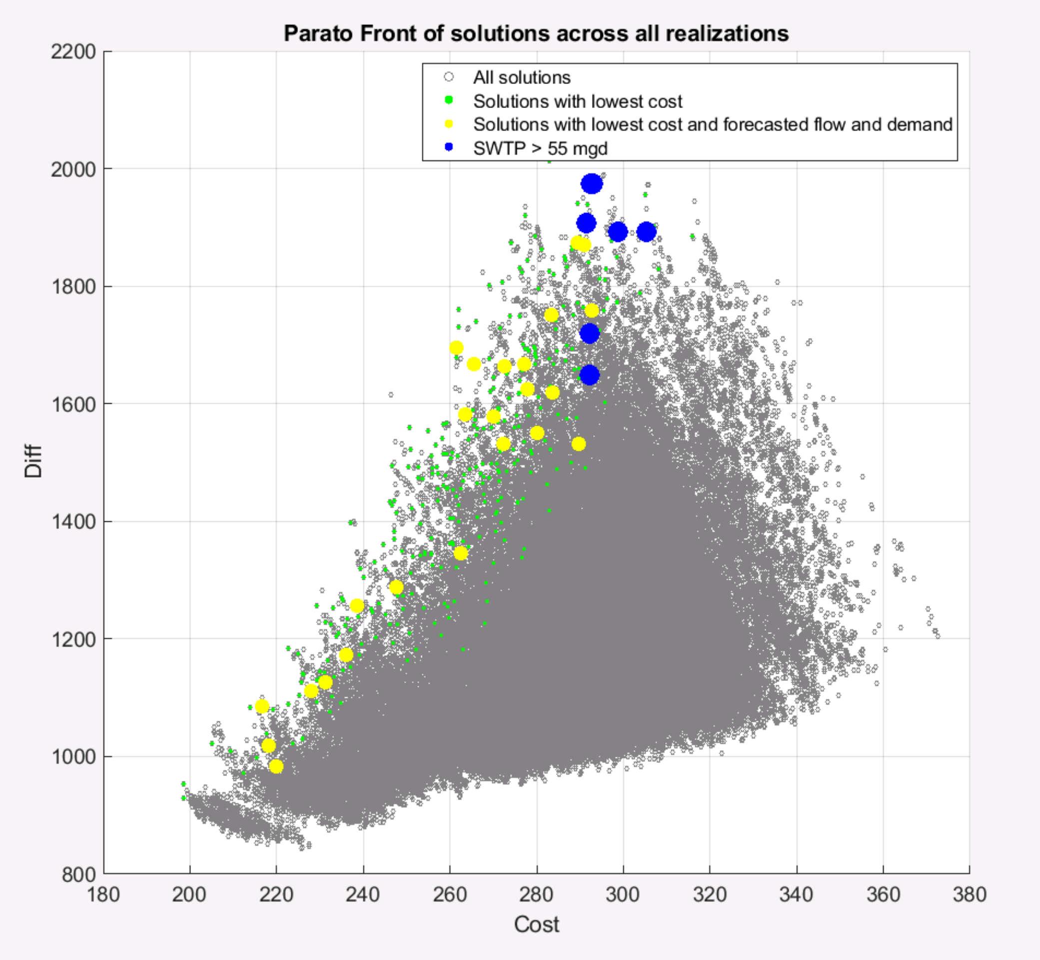
Additional criteria to filter selected solutions

- ➢ Still, a decent number of solutions (334) to be considered for decision making at this point.
- ➢ Additional criterial can be used to further filter MOEA results.
  - ❑ First filtering: Flow and demand conditions: both are normal (between 34th and 67th percentile), shown as large yellow dots
  - ❑ Second filtering: Seasonal surface water treatment production (over Oct, Nov and Dec 2016) is greater than 55 mgd
- ➢ The number of solutions reduces from 334 to 33 after 1st filtering and reduces to 6 after 2nd filtering.



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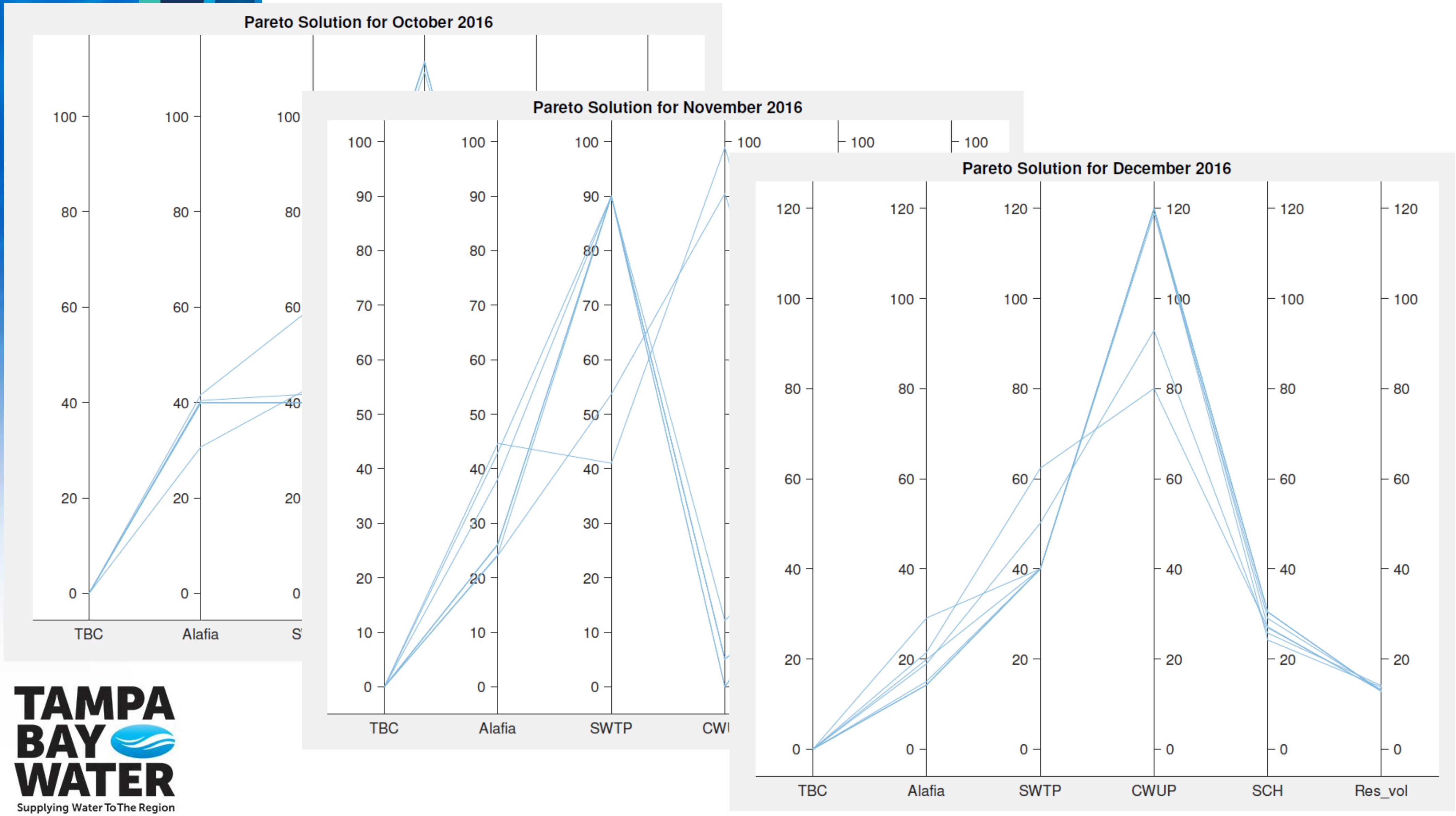
Seasonal resource allocation



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Next step in the MOEA decision tool

- Data mining to determine final decisions on allocation would based on

- Communicating uncertainty/risk

- Assessing the value of improved supply and demand forecasts (NASA project)

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Contributors

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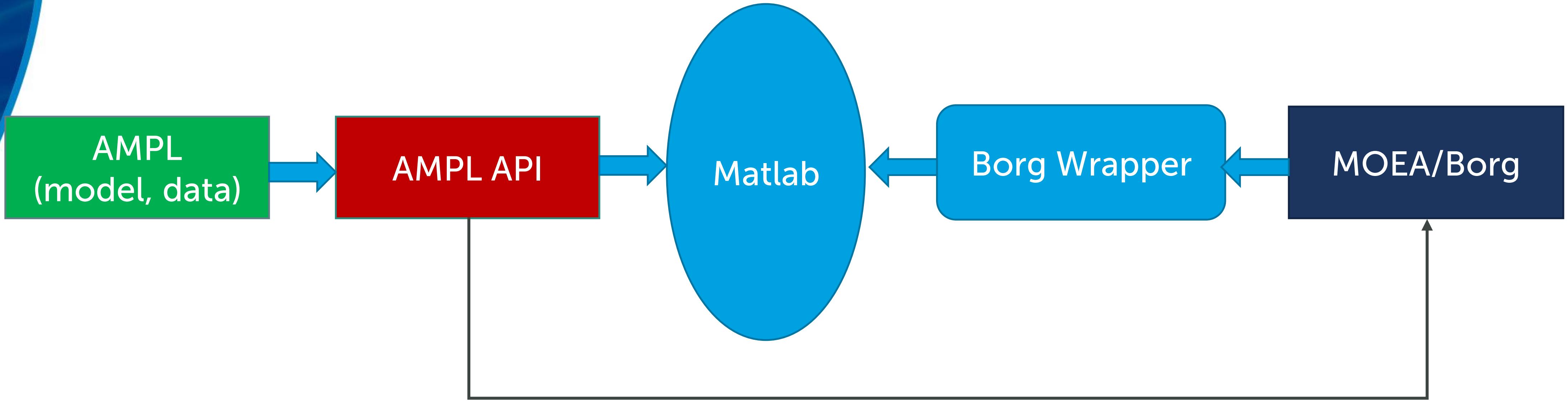
Questions

Configuration of the model: Framework



MIP fixed variables – MOEA/Borg decision variables (groundwater production from two major supply sources)

MIP decision variables – allocation from other sources

Setup MIP in AMPL as Simulation

- MIP problem – 24-month source allocation to satisfy monthly demands for a given water availability (to be withdrawn from TBC and Alafia river)
- MIP objective as optimizing preferential operation via penalty functions
- MIP constraints – operating rules, facility capacity, water distribution balance, etc.
- MIP equality constraints – evaluation of multi-objectives for MOEA/Borg

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Retrospective analysis using MOEA

- Water year 2017 with an extreme dry spring
- Retrospective forecast of demand and flow at beginning of each month
- Define data set by “RunDate” for each month
- Interim criteria to select one Pareto solution per realization

Overarching question: For each month in WY2017, how much improvement in source allocation if MOEA was used?

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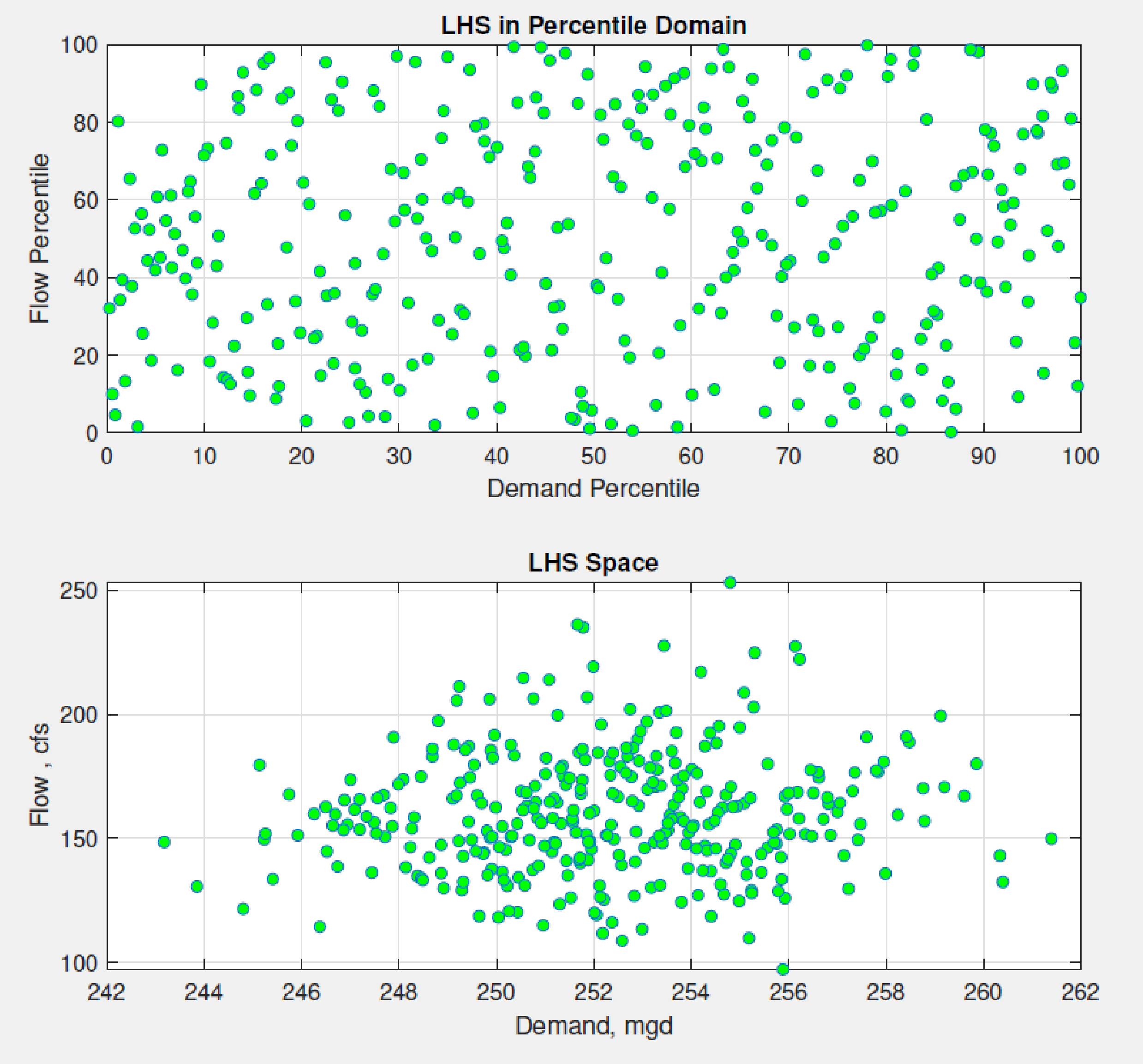
Addressing uncertainty in seasonally updated flow and demand forecasts

Latin Hypercube Sampling (LHS) applied to obtain 334 realizations of flow and demand for each MOEA run.



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Computation of MOEA

~ One RunDate takes three hours on our cluster

- 334 realizations of flow and demand
- Matlab parallel computing toolbox
- Six virtual machines each with 20 cores and 512GB RAM
- 5,000 MOEA function evaluation (MIP) calls

How long it takes to run on a single desktop with 4 cores? (~ 90 hours)

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