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Evaluating Forecasts in Reservoir Operations: The Role of Reforecast Products in Examining Extremes

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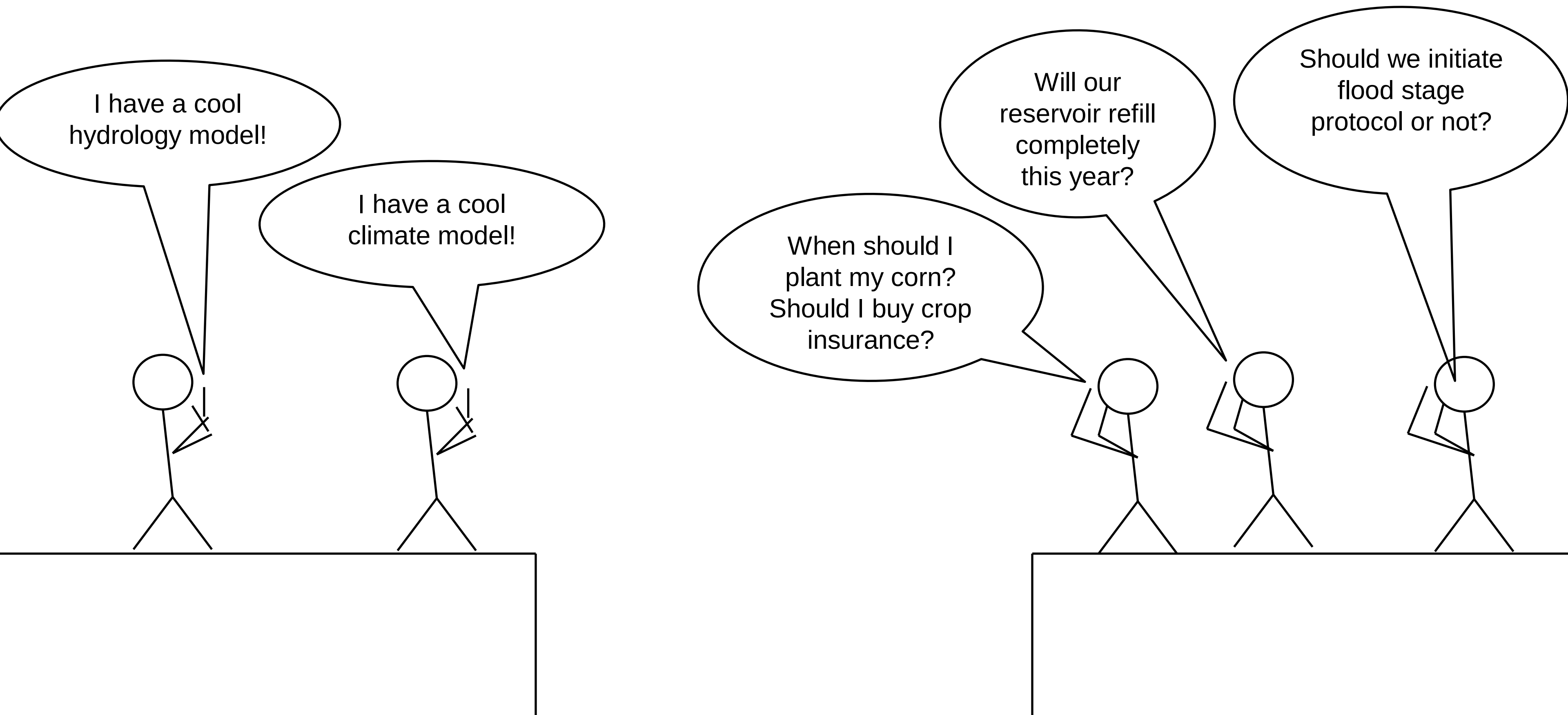
Dr. Austin Polebitski, Dr. Richard Palmer

February 26, 2014

Department of Civil and Environmental Engineering

NOAA SARP


I have a cool hydrology model!
I have a cool climate model!
When should I plant my corn? Should I buy crop insurance?
Will our reservoir refill completely this year?
Should we initiate flood stage protocol or not?

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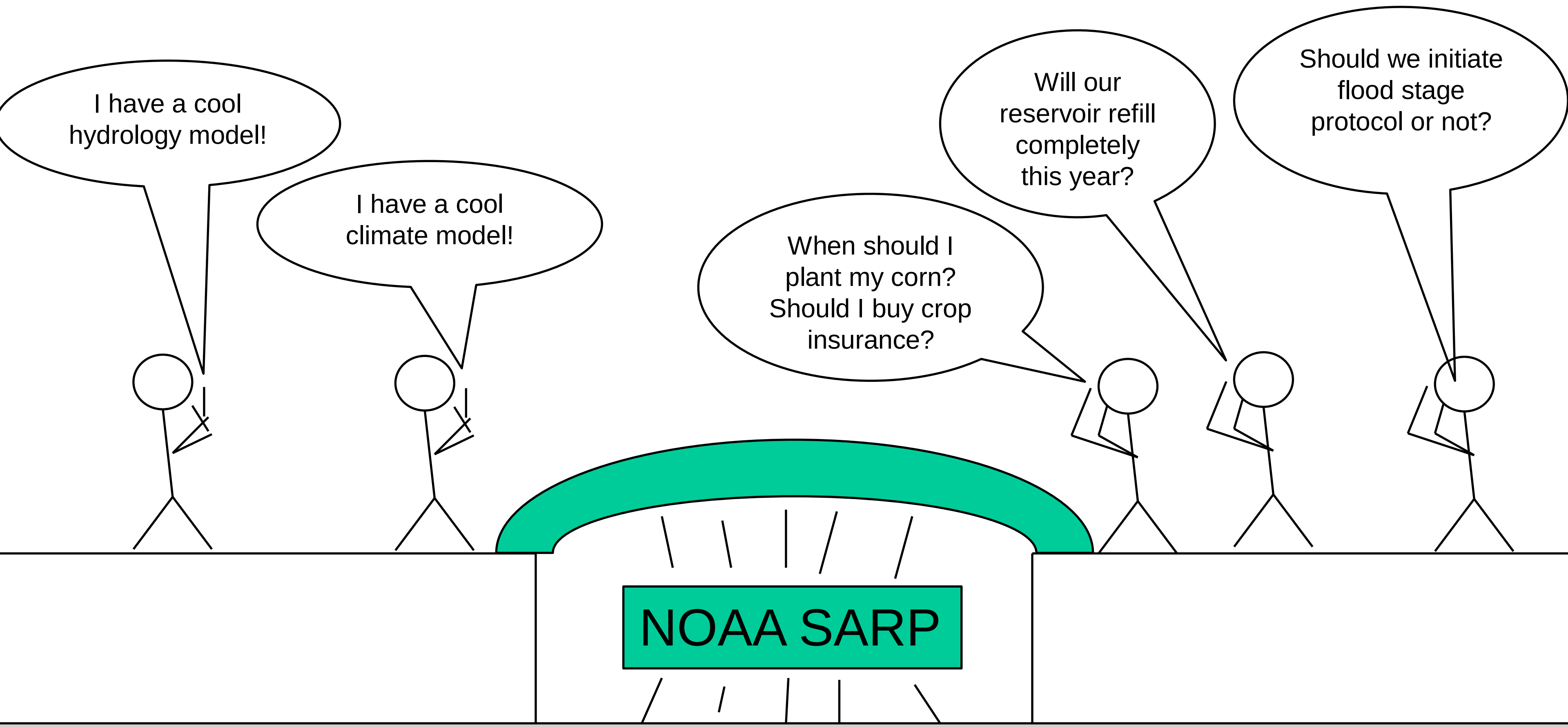
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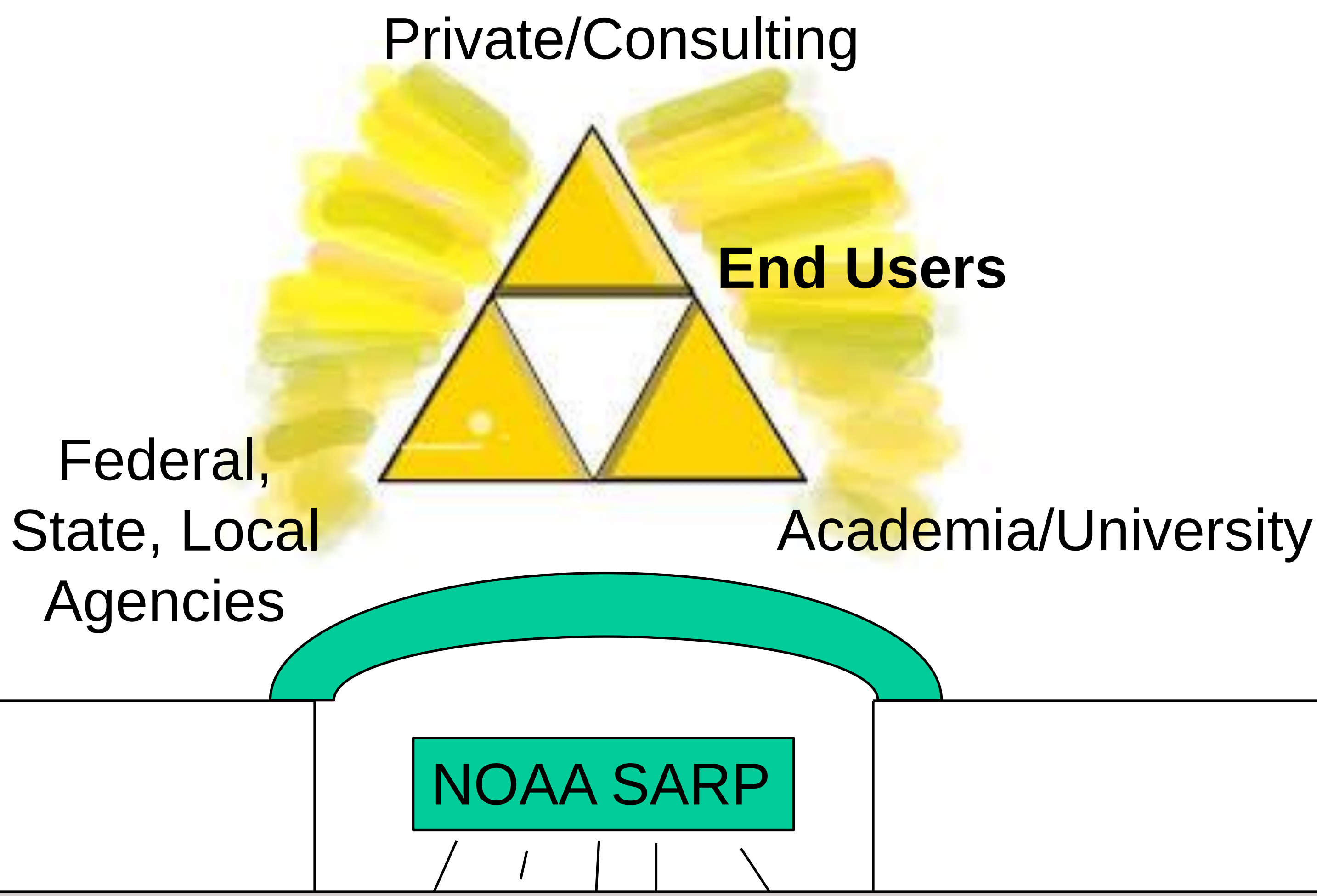

Private/Consulting
End Users
Federal, State, Local Agencies
Academia/University
NOAA SARP

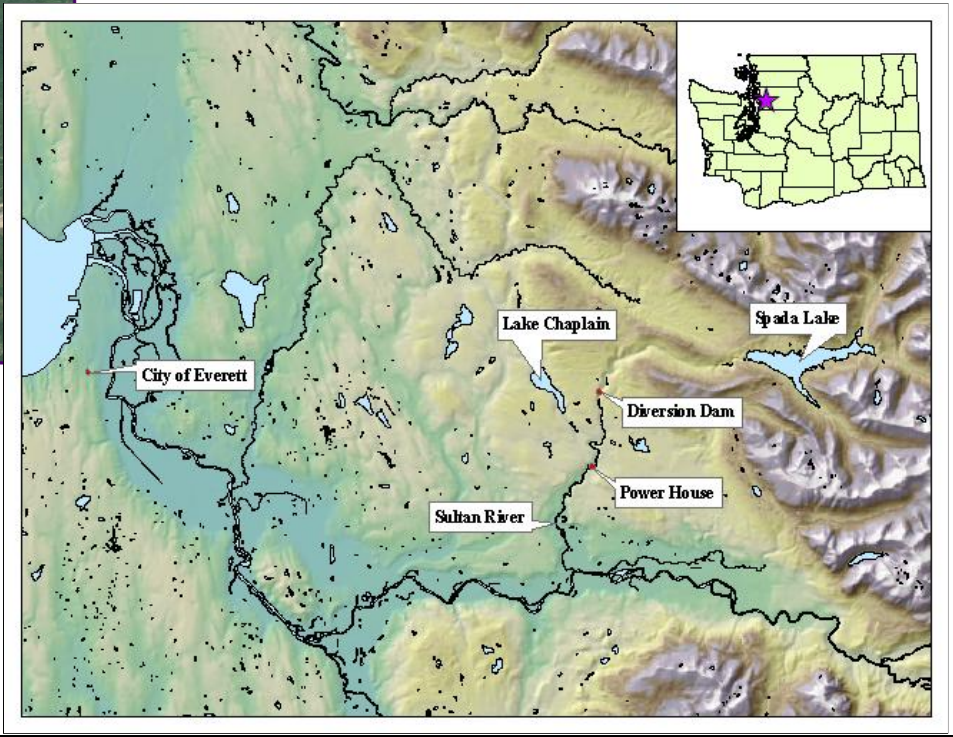
Project Goals

Demonstrate the potential usefulness of climate forecasts and create an appropriate framework for their application

- Co-generate knowledge concerning system operations between researchers and water managers
- Generate ESP streamflow using reforecasts at partner locations
- Evaluate skill of GFS and CFSv2 and corresponding streamflow in the context of decision making
- Disseminate data, case studies, and recommendations to the broader water community

Project Partners - Case Studies

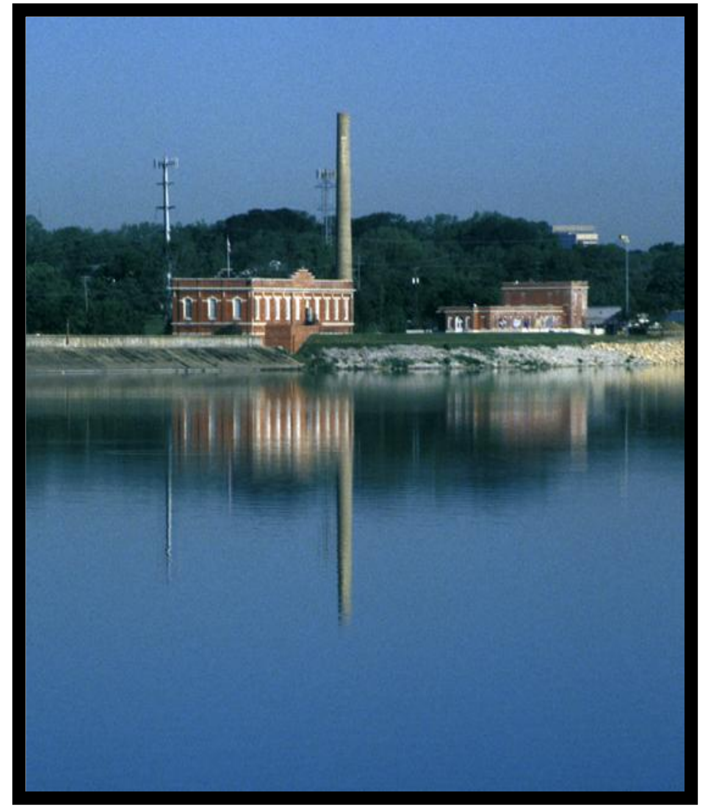
Snohomish County PUD
Jackson Hydropower System:
Multi-purpose



Salt Lake City
Parley's System:
Drinking Water, Flood Control

Project Partners - Case Studies

PacifiCorps Bear Lake:
Irrigation Supply, Flood Control



Dallas Water Utilities System:
Drinking Water

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Workshop


NATIONAL WEATHER SERVICE
Weather Forecast Office
Colorado Basin River Forecast Center
SALT LAKE CITY, UTAH

Partner	Hydropower	Water Supply	Environmental Flows
Dallas	None	• Firm yield • Frequency of instituting voluntary or mandatory restrictions • Total revenues generated • Minimum storages in reservoirs	None
PacifiCorp Bear Lake	• Energy production lost relative to baseline	• Volume of water provided to irrigation • Annual allocation of water • Accuracy of forecast of water to be allocated • Irrigation supply lost	None
Salt Lake City	• None	• Appropriate storage level at the beginning of water supply season • Balancing water sources and supplies	• Cannot divert into pipeline until >5 cfs at Lamb's Diversion
SnoPUD	• Mega-watts hours produced per year, • Total avoided costs from other purchases • Annual energy value	• Water provided to Everett • Need to implement curtailments	• Number of times fish flows are unmet • Minimizing peak releases that harm fish • Provide "flushing flows" to move fish down stream

Partner	Hourly/Daily	Weekly	Monthly
PacifiCorp Bear Lake	• None	• Flood Control Decisions	• Flood Control Decisions • Irrigation Allocations • Drought
Salt Lake City	• Flood Mitigation	• Flood Mitigation • Drinking Water Deliveries	• Flood Mitigation
SnoPUD	• Hydropower Generation • Channel forming flows	• Drinking Water • Hydropower Scheduling • Flood Control • Environmental Flows	• Refill/Drafting Rates

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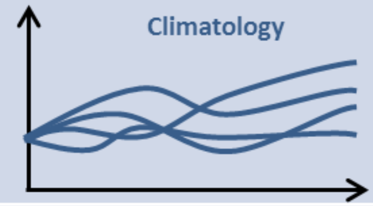
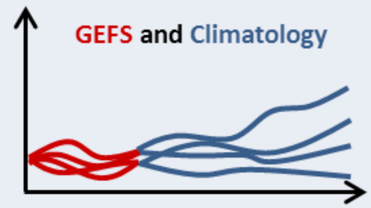
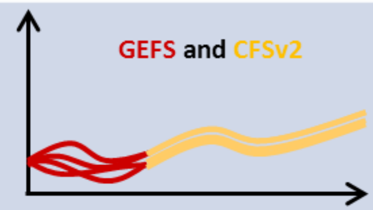
Types of Streamflow Forecasts Used

Type of Forecast	Forcings	Streamflow
ESP/Climatology	Historic	
HEFS	GEFS and Climatology	
HEFS	GEFS and CFSv2	

- ESP – Ensemble Streamflow Prediction
- HEFS – Hydrologic Ensemble Forecast System
- CFS– Climate Forecast System
- GEFS – Global Ensemble Forecast System

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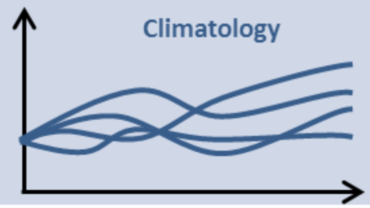
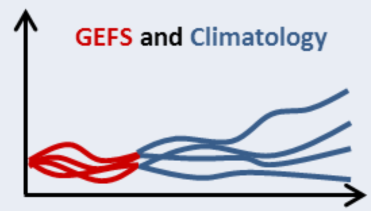
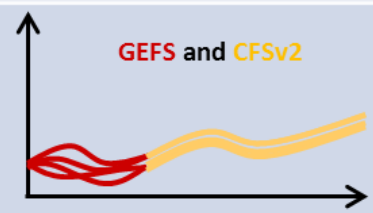
ESP/Climatology	Historic	
HEFS	GEFS and Climatology	
HEFS	GEFS and CFSv2	

Expectation: Variability decreases

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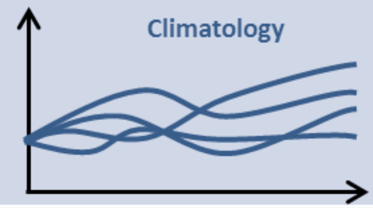
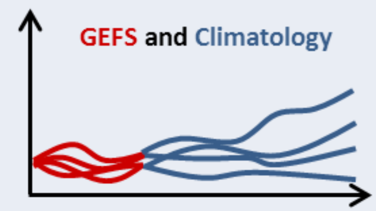
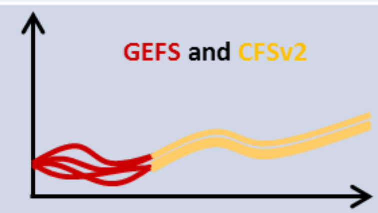
ESP/Climatology	Historic	
HEFS	GEFS and Climatology	
HEFS	GEFS and CFSv2	

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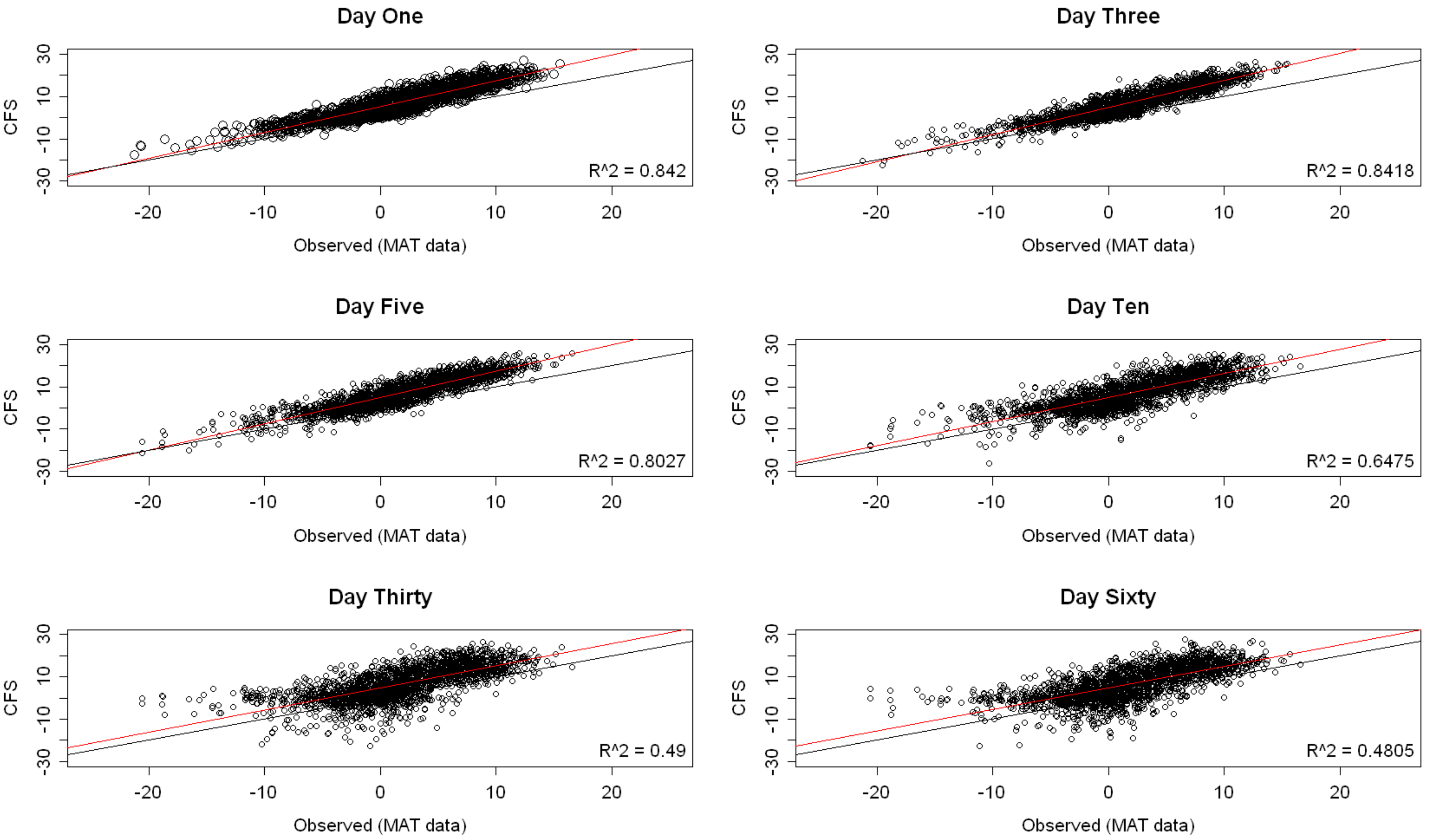
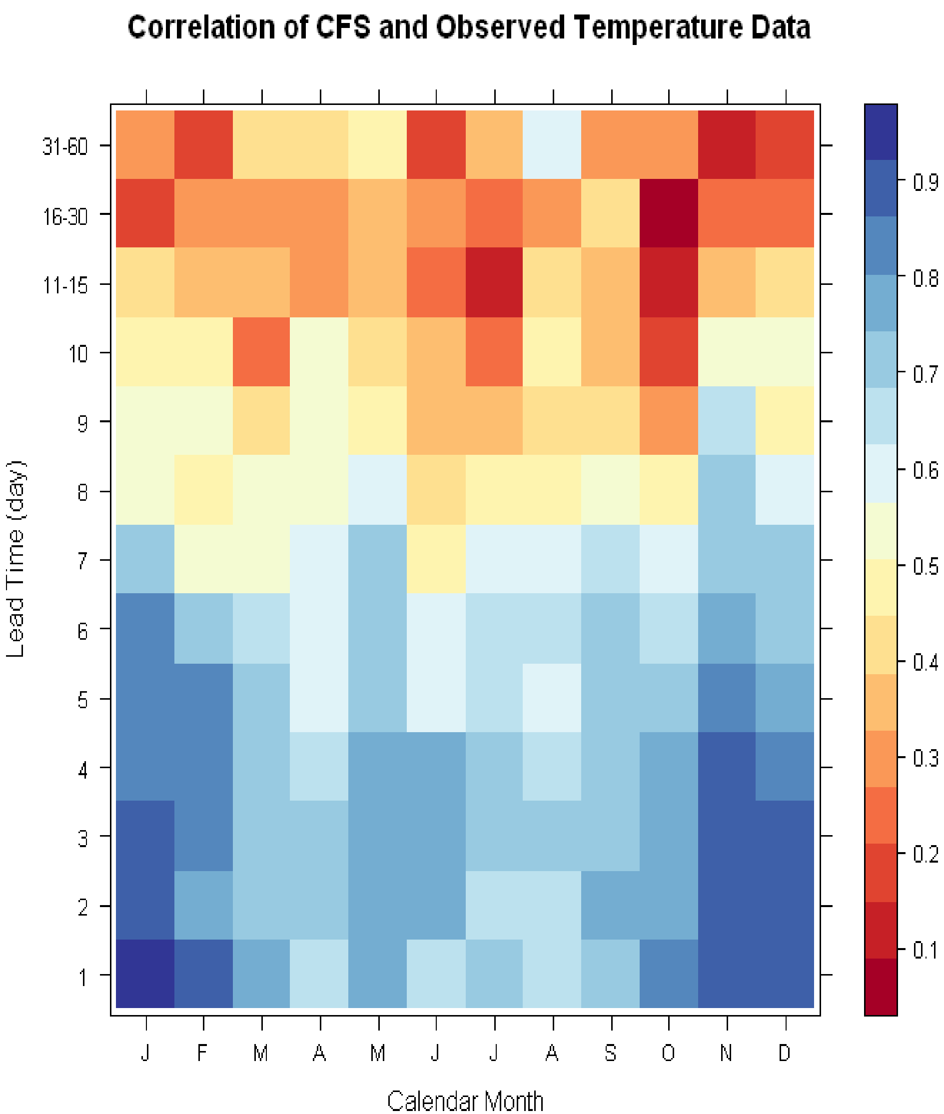
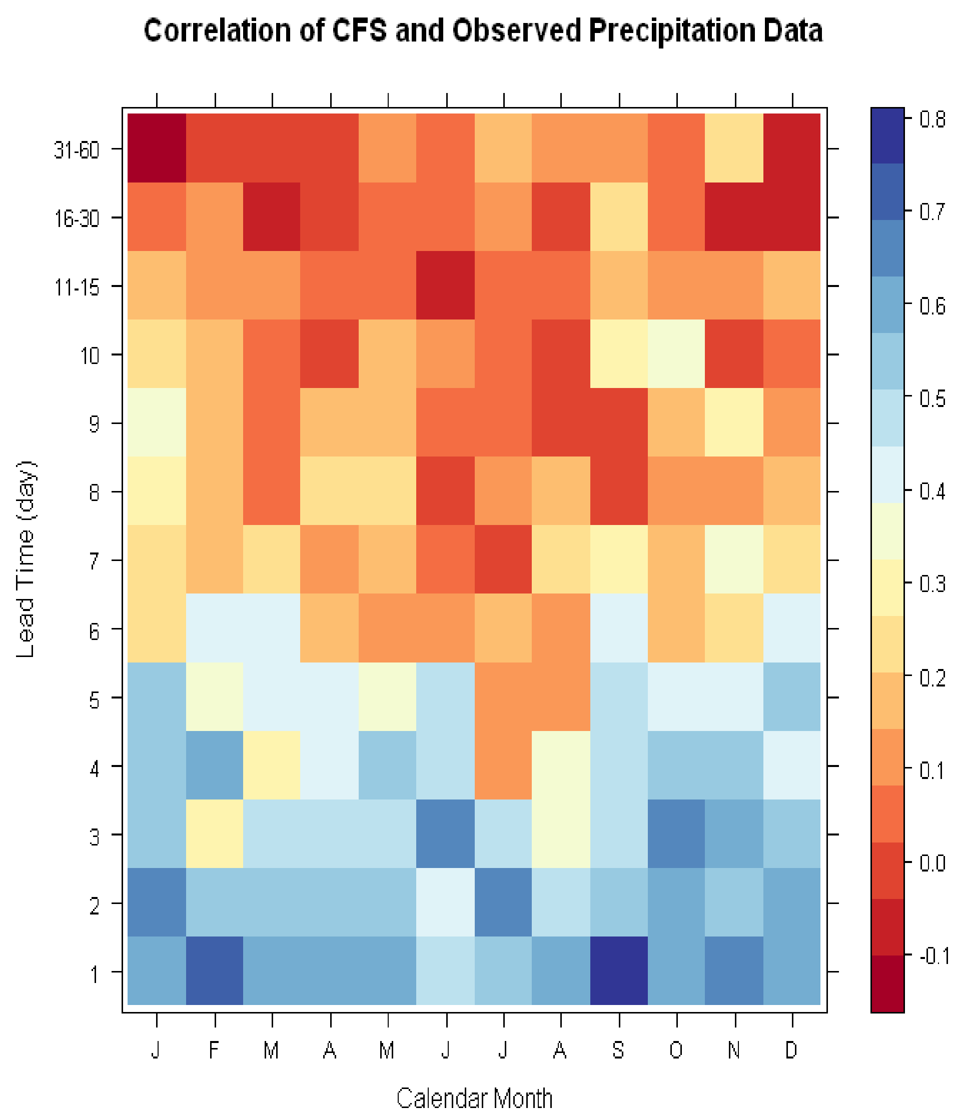
CFS Forecast vs. Observed Temperature (°C)

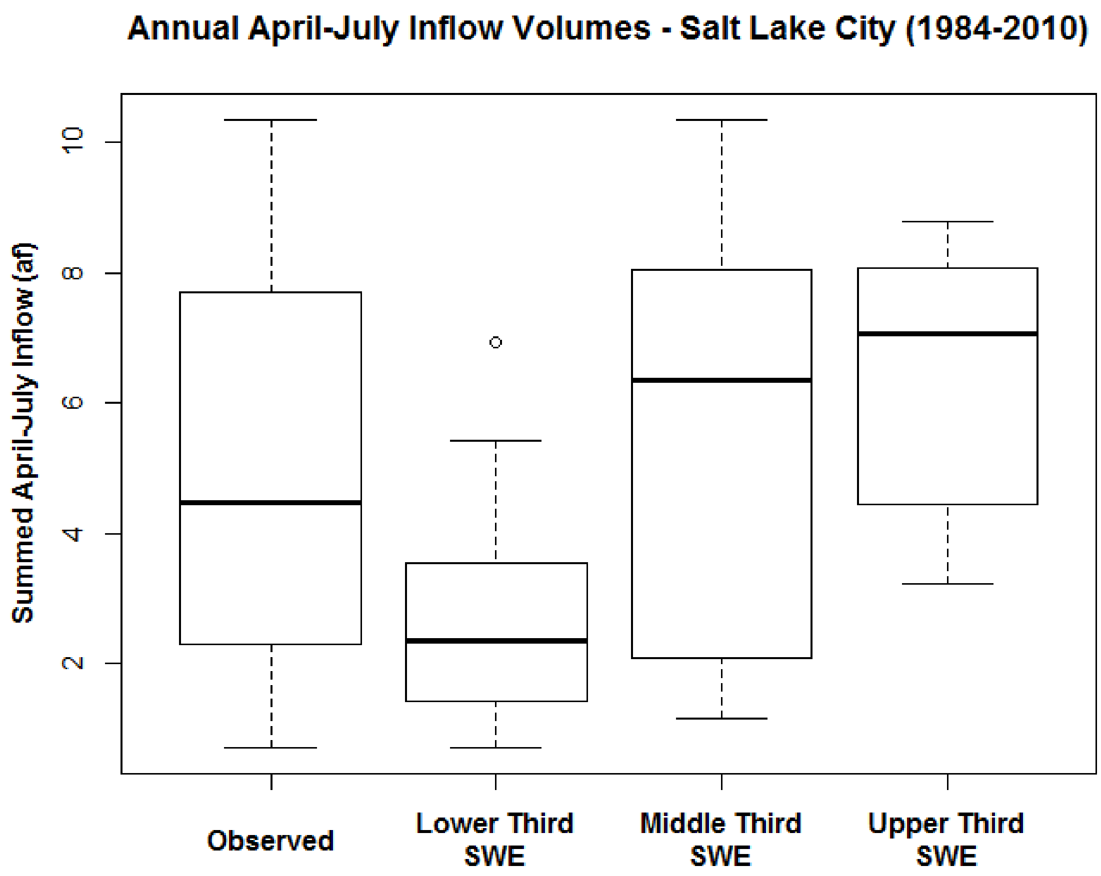


CFS Correlations by Lead Day

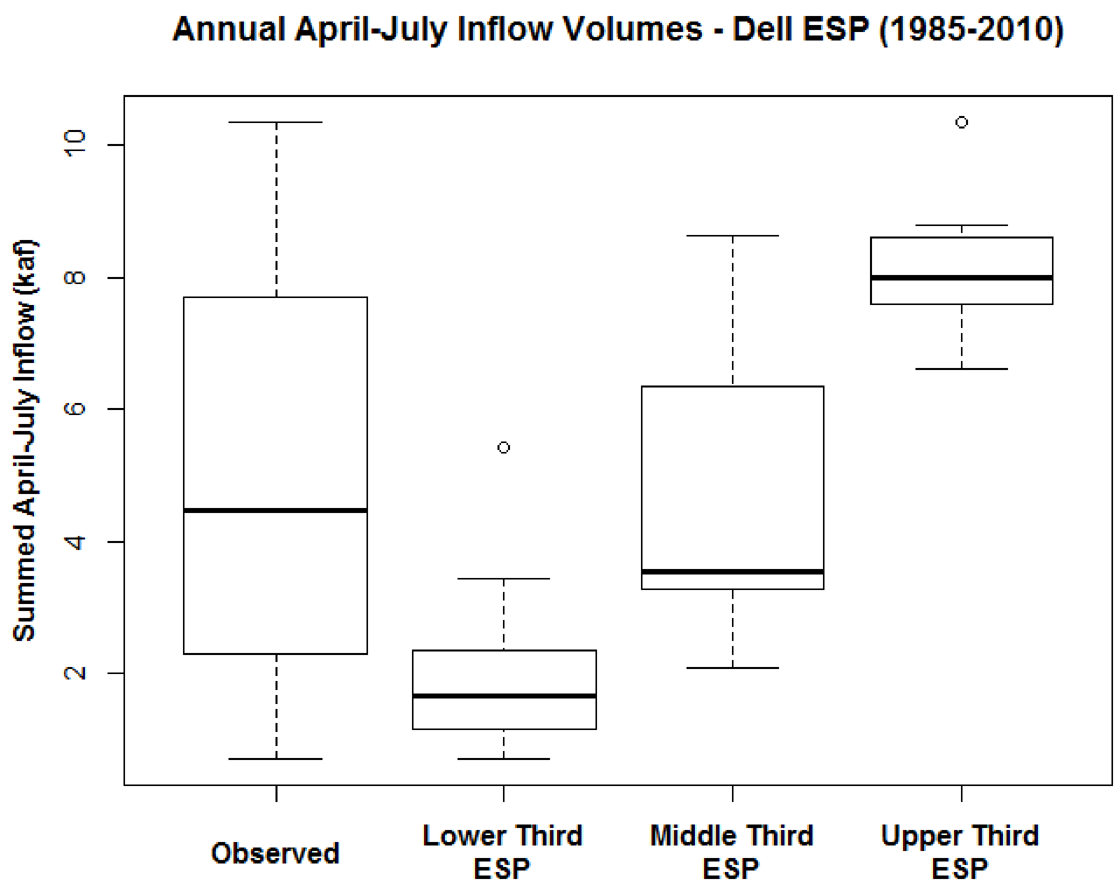




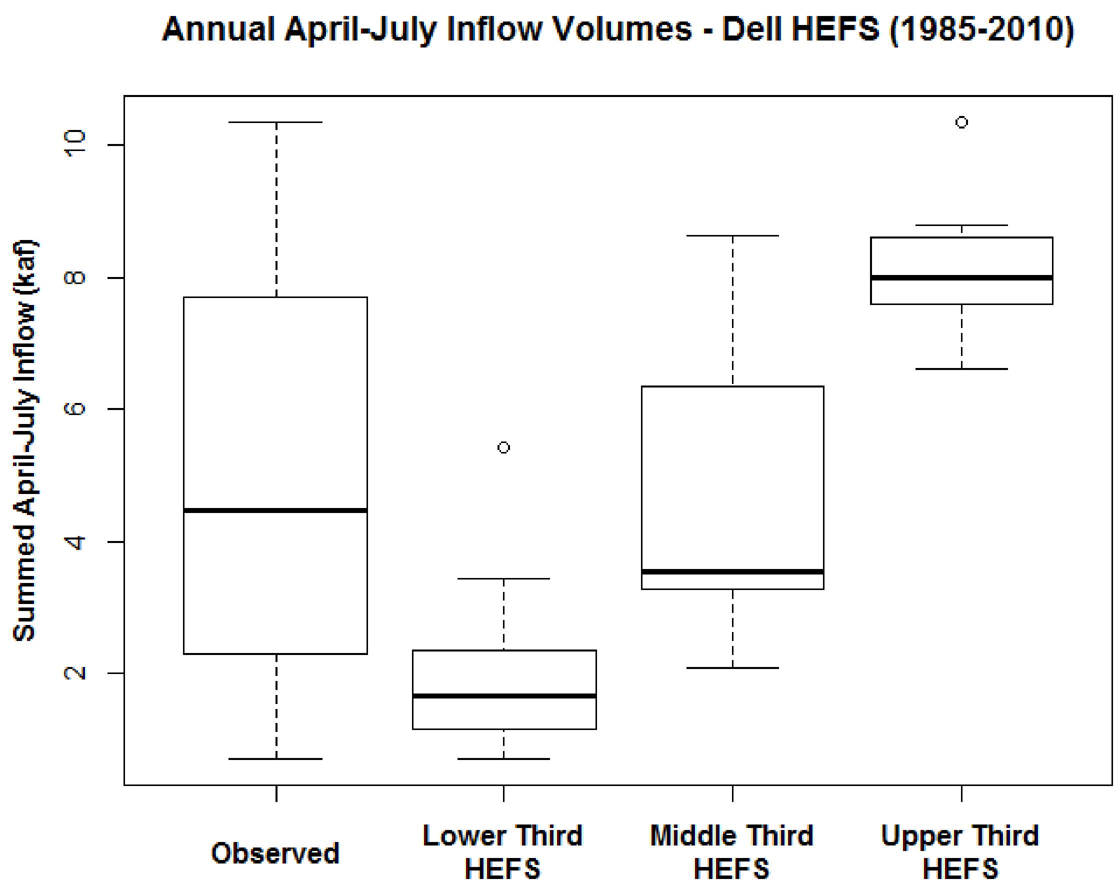
Snowpack as a Crude Forecasting Method: SLC



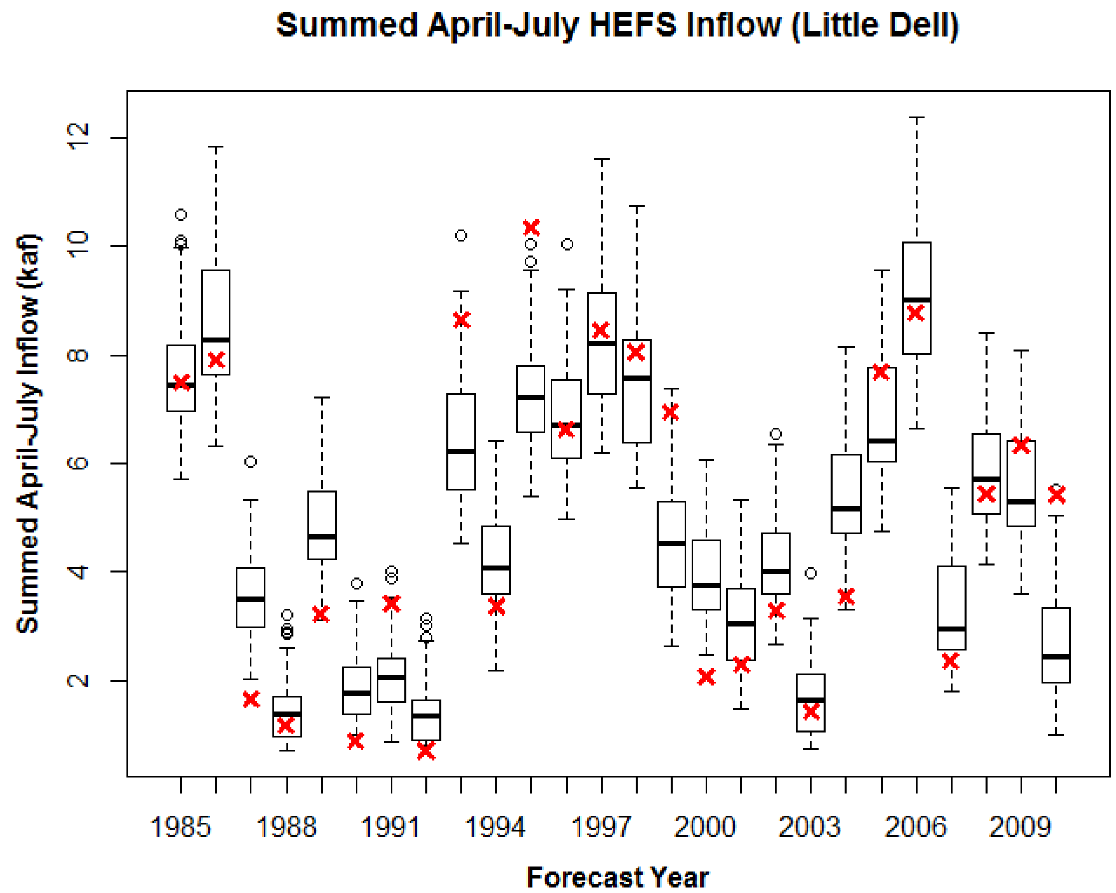
Additional skill when using ESP forecast



Additional skill when using HEFS forecast



HEFS DELL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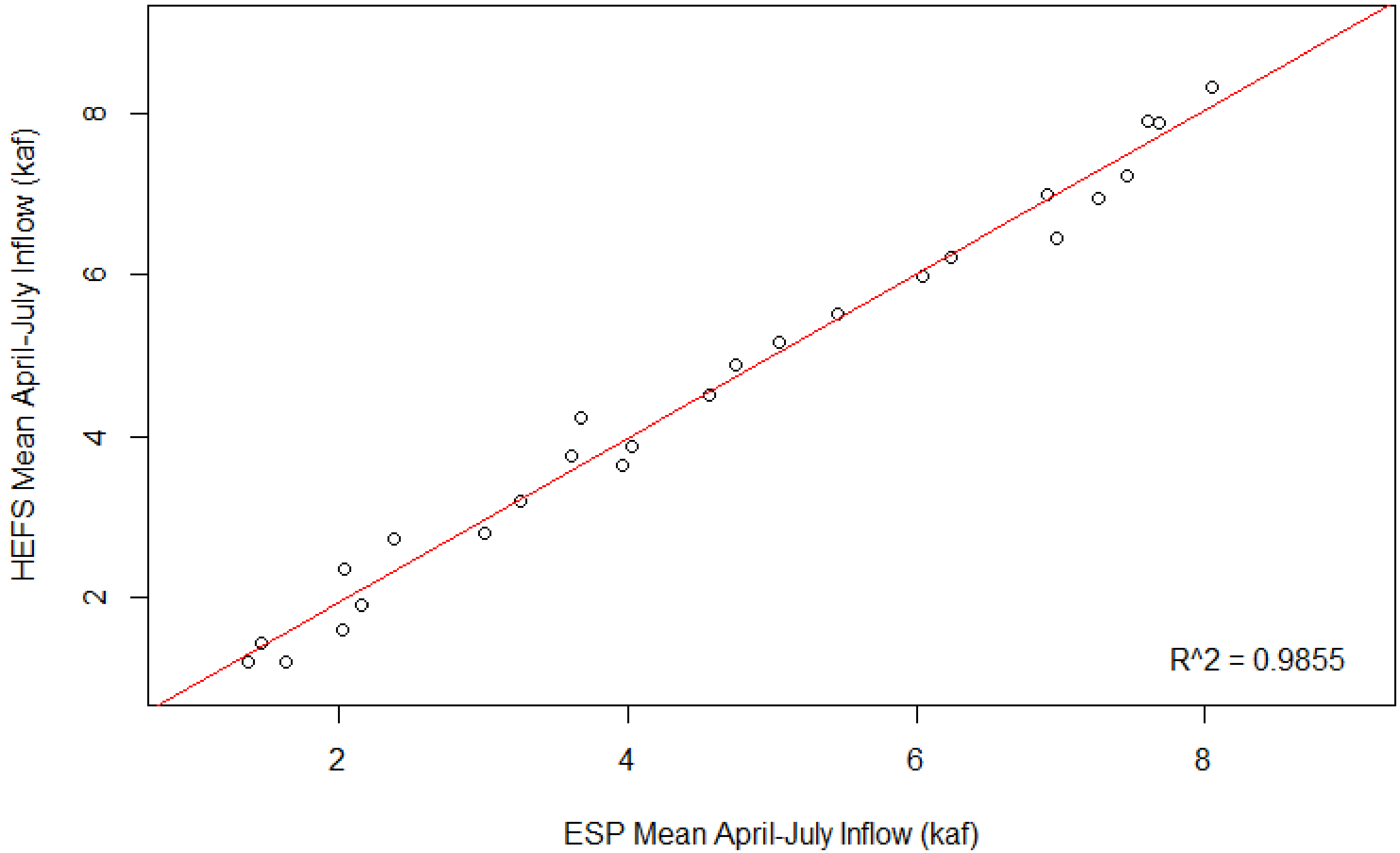
Forecast Year

Means of ESP and HEFS (kaf)



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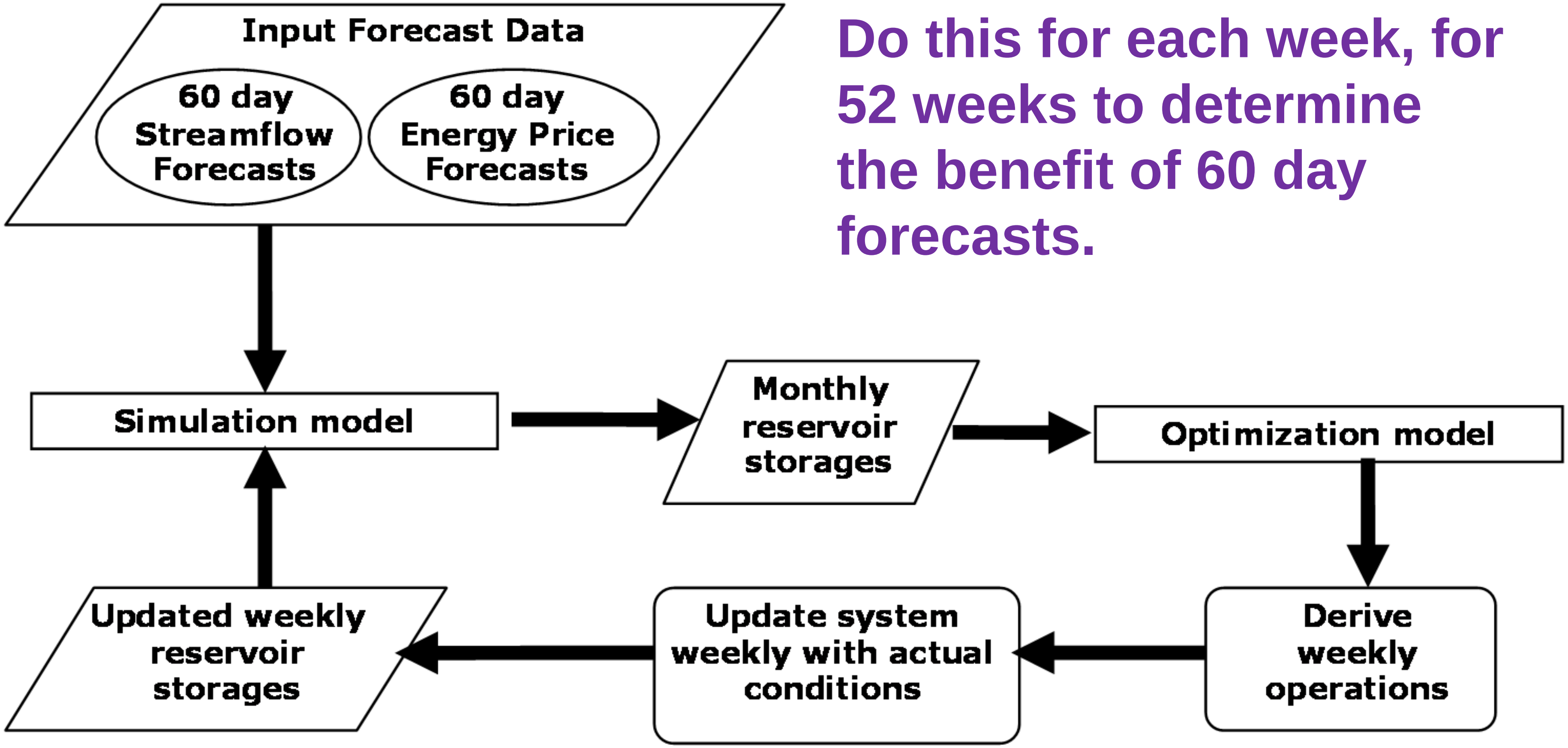
Proof of Concept - Method



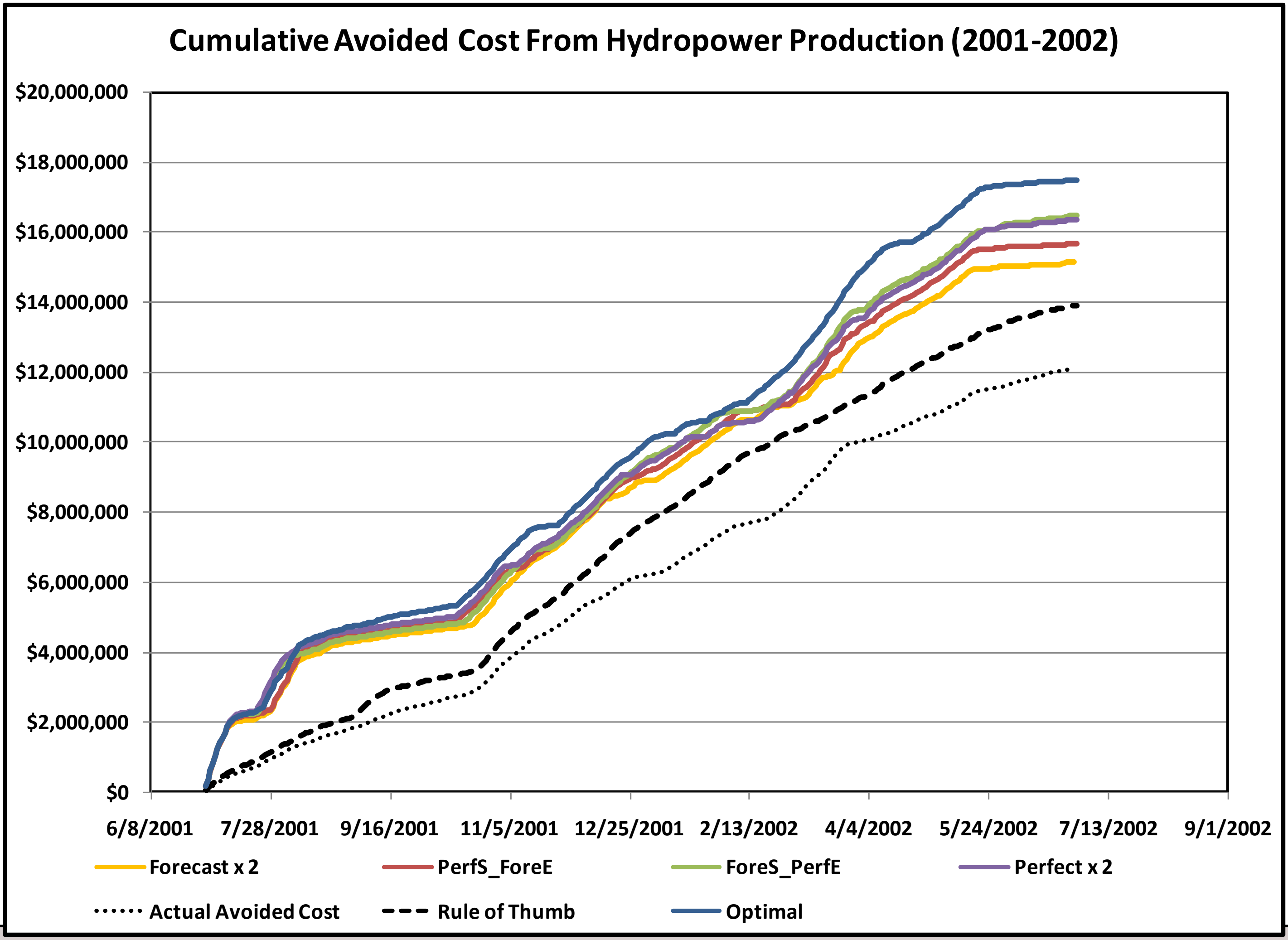
Do this for each week, for 52 weeks to determine the benefit of 60 day forecasts.

Proof of Concept - Results

- Use DSS to evaluate revenue gains in three hydrologically different years
- Compare the use of forecast information against ‘perfect knowledge’

	Annual Inflow (AF)	Average Energy Price	Standard Deviation In Energy Prices
2001-2002	697,800	$25.93	$13.44
2002-2003	522,489	$31.07	$13.29
2003-2004	554,374	$39.49	$6.70

Proof of Concept - Results



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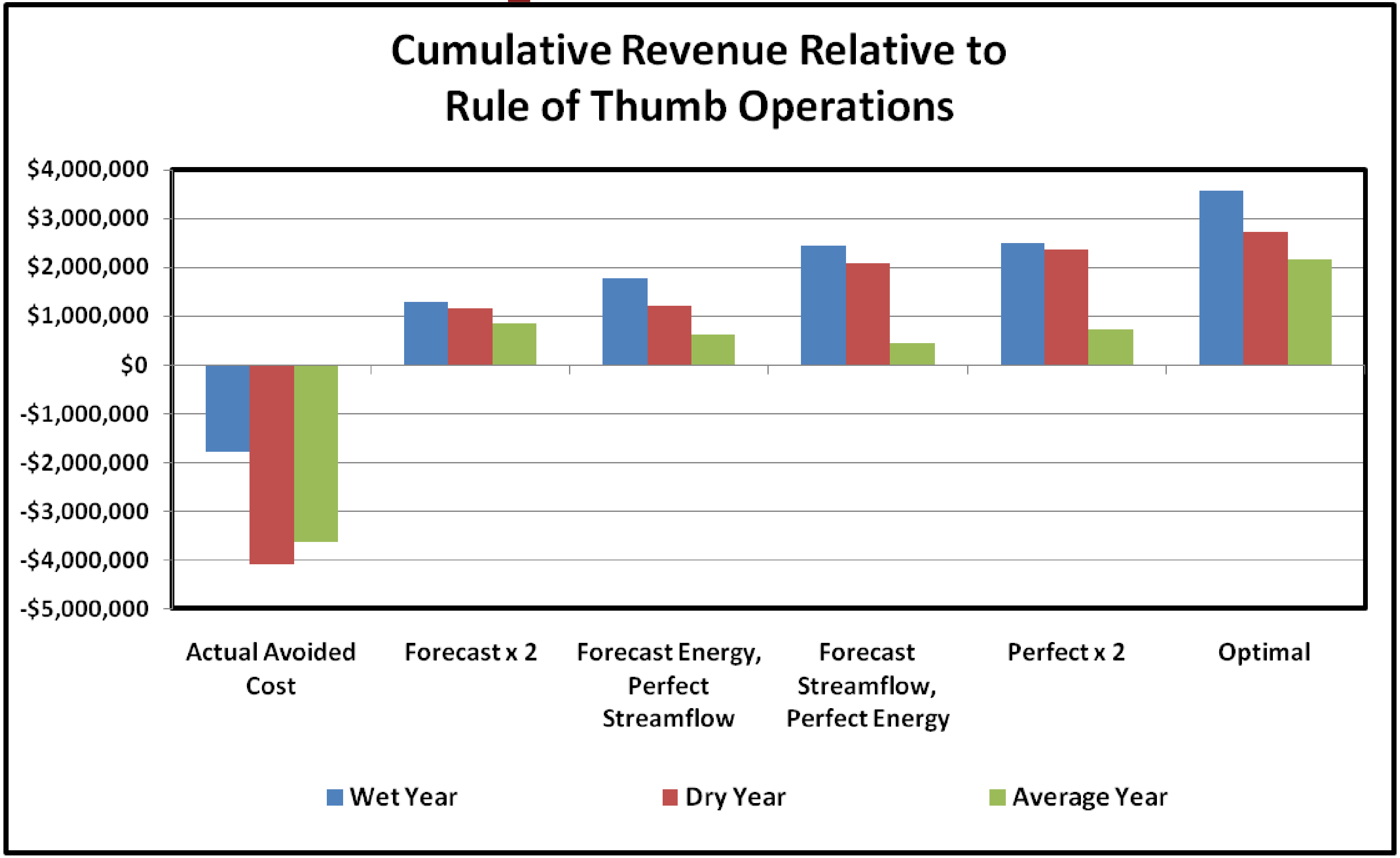
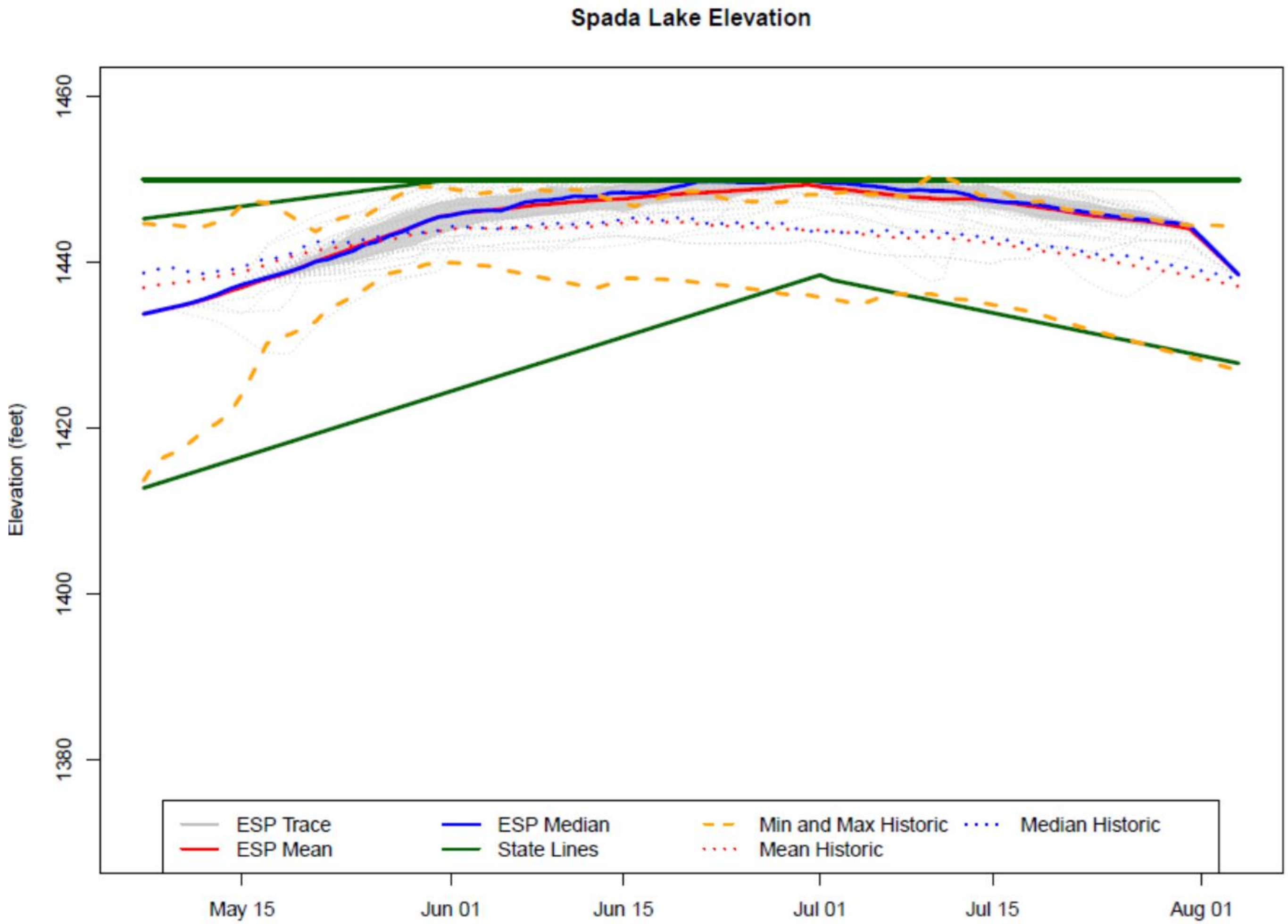


Current Operations and Forecast Use



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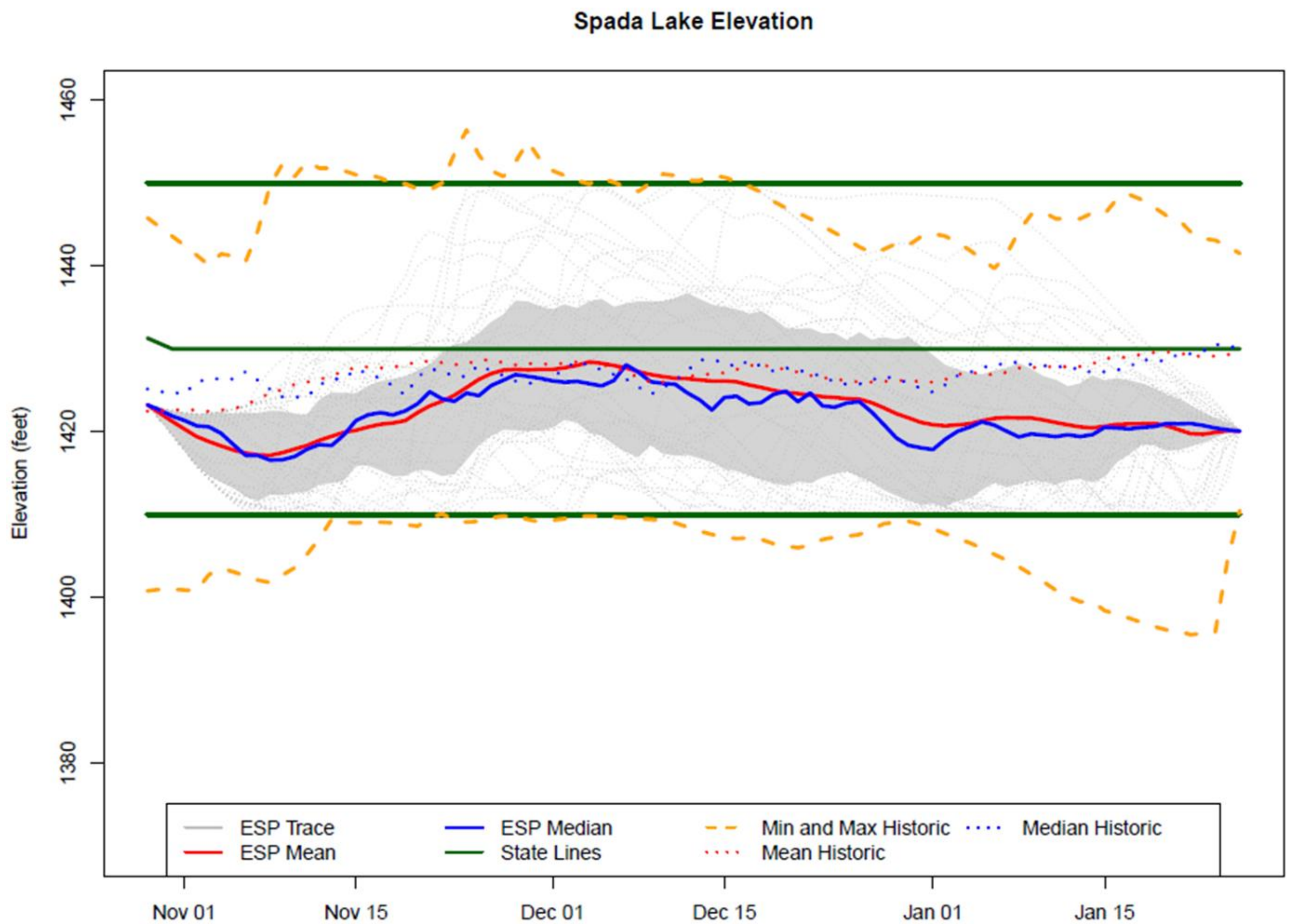
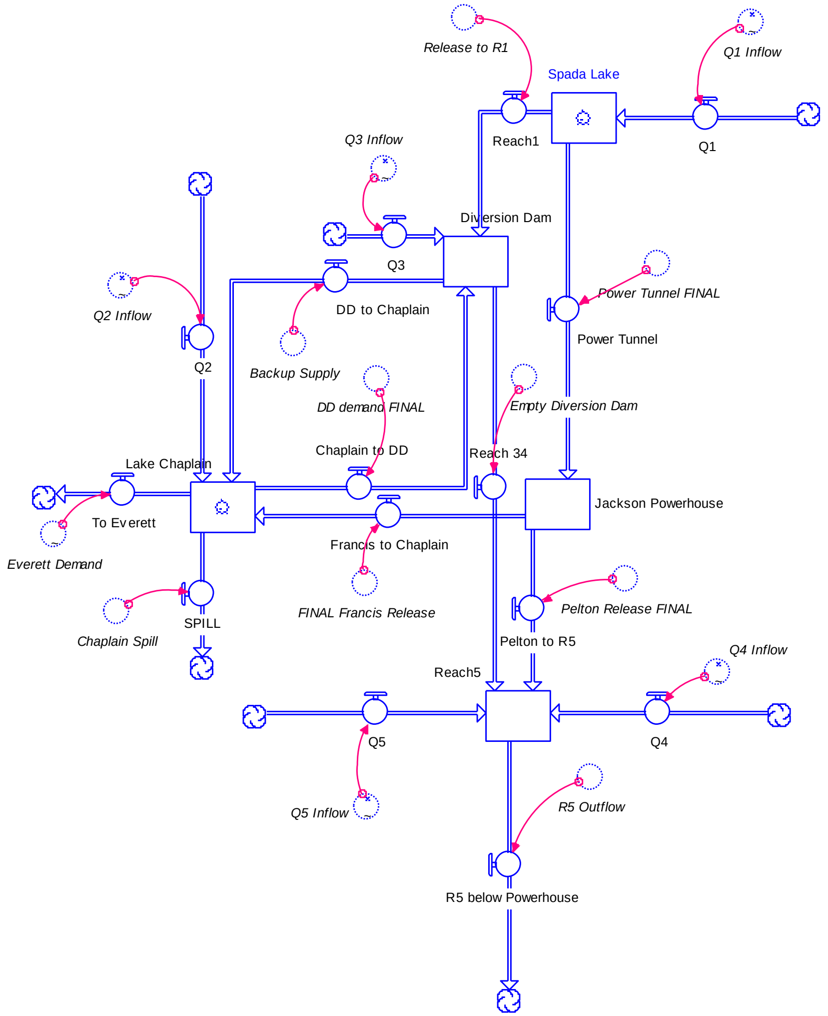


Incorporating Forecasts

Simulation Model – Stella or R

- Simulates system operations
- Calculates how water is routed through the system



Incorporating ESP Forecasts: Parley's System

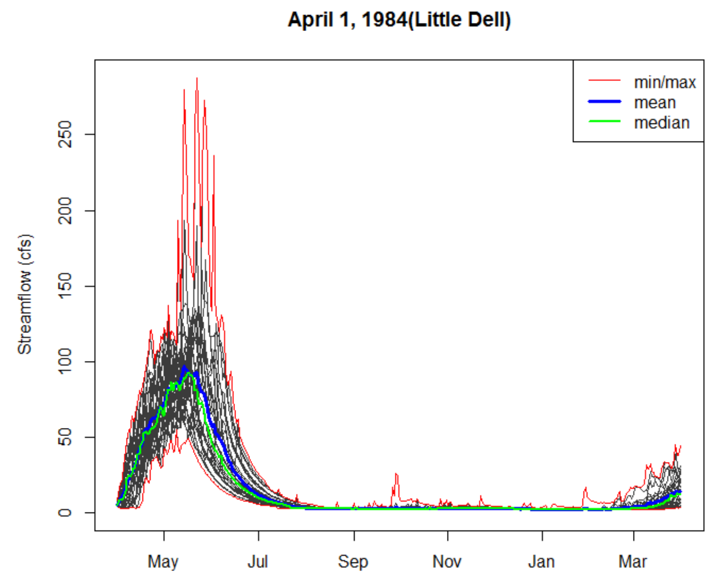
- Operated by Salt Lake City
- Releases to supply drinking water
- Releases for flood management

Incorporating Forecasts: Salt Lake City

For today's example:

1. ESP traces used as inflow to the model

2. Static Rule Curve based on the median historic storage determines how releases are made

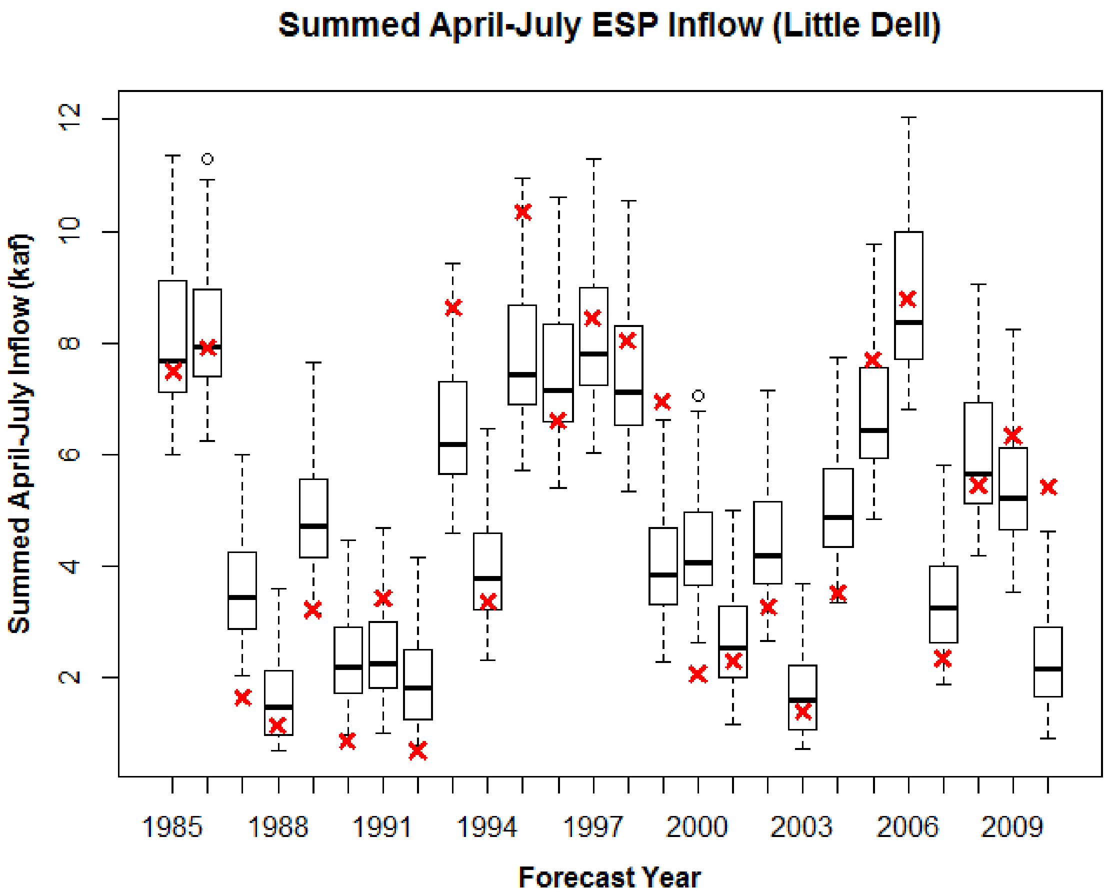


Inflows → Reservoir Storage → Releases

Potential Benefits of Using Forecast

Critical Period	Concern	Value
Low inflow or low pool elevation	Not providing enough water	How much releases should be reduced
High inflows or high pool elevation	Spilling, flooding	Chance of spilling, potential peak inflows

ESP DELL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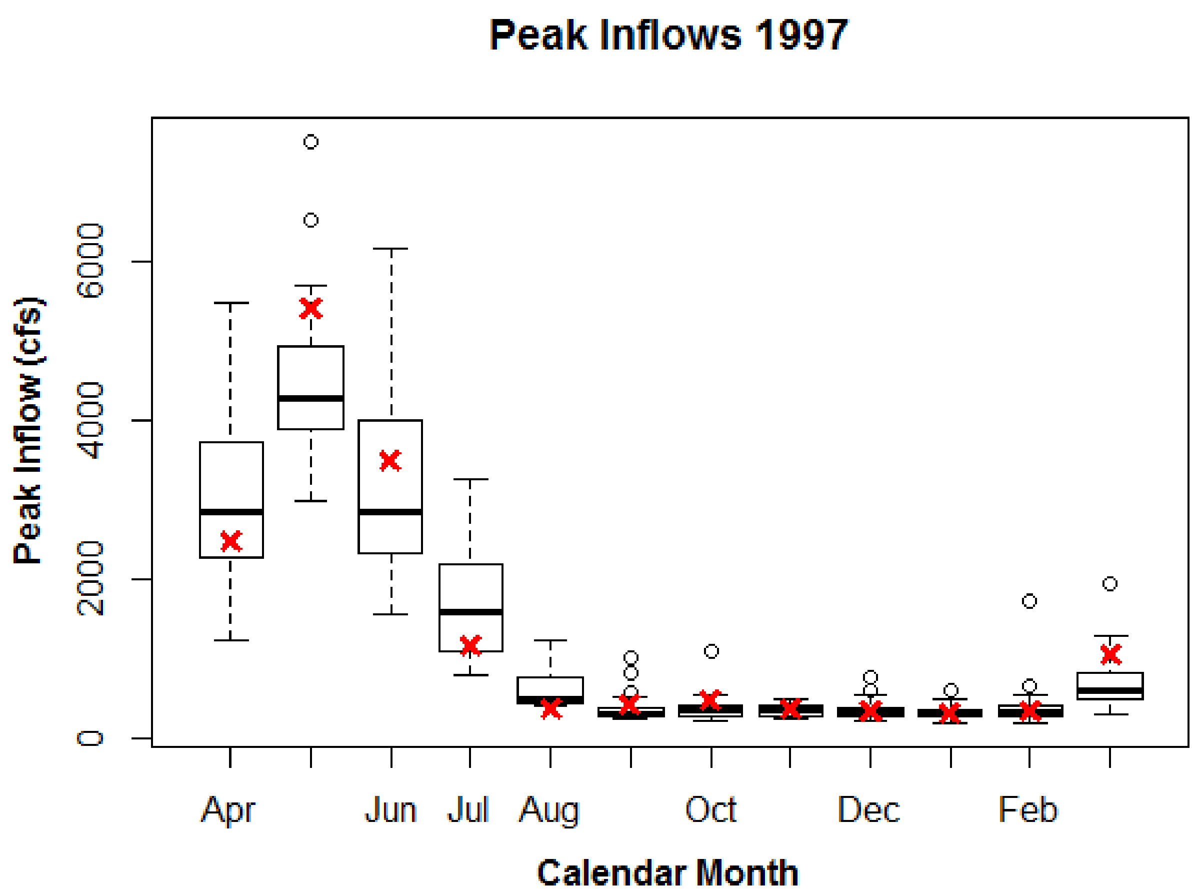
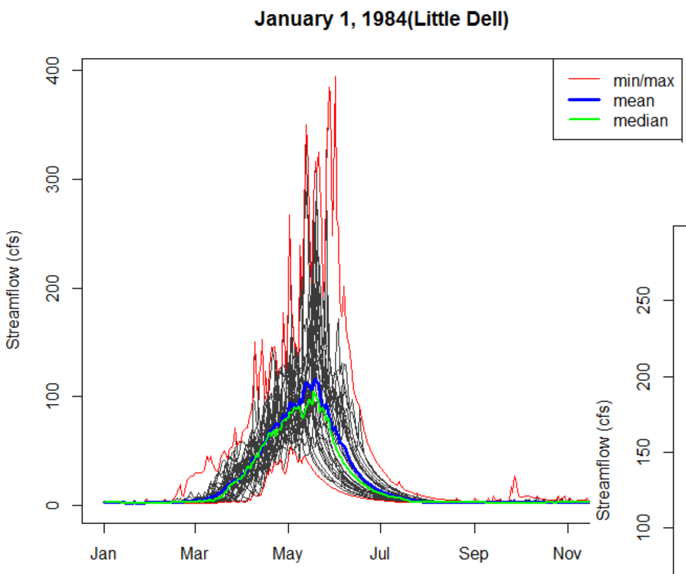
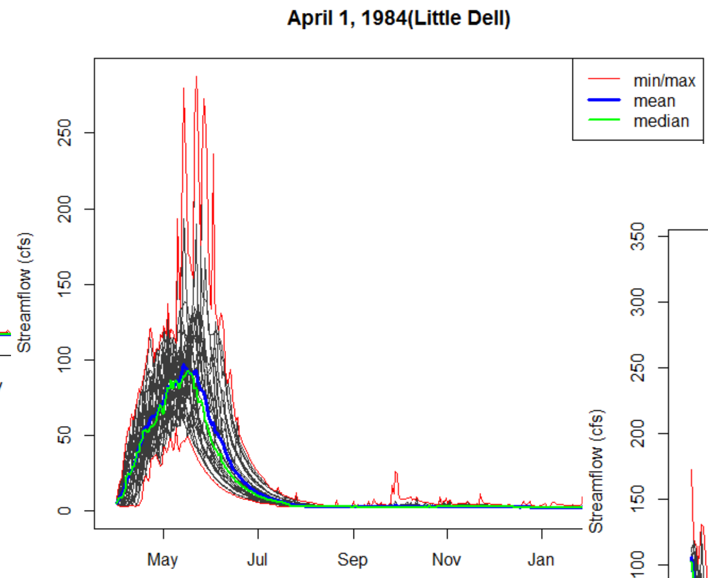
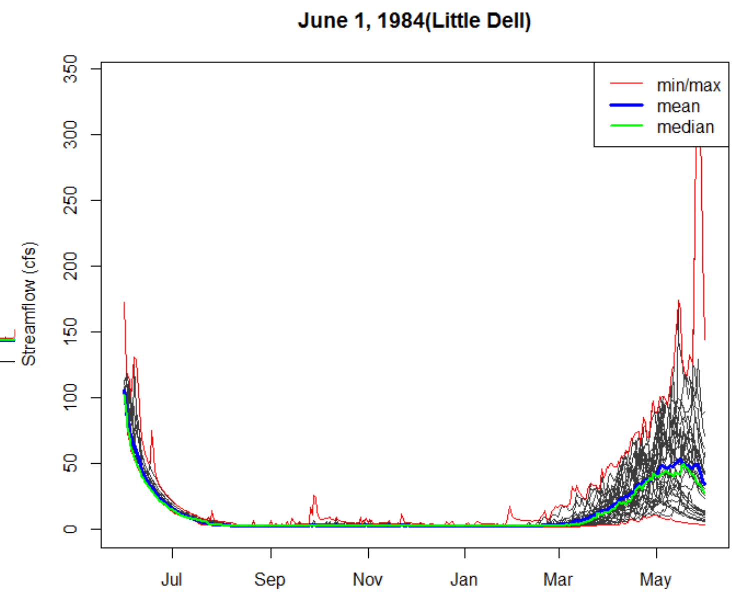
Example of Results: High Flow Year



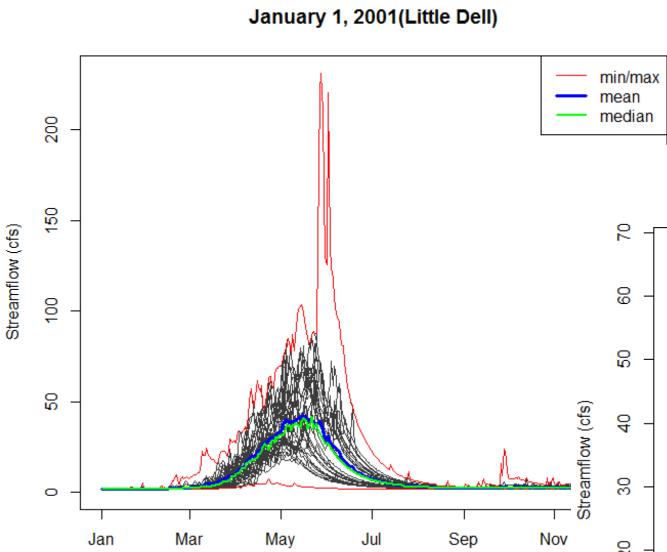
ESP Streamflow – High Inflow Year

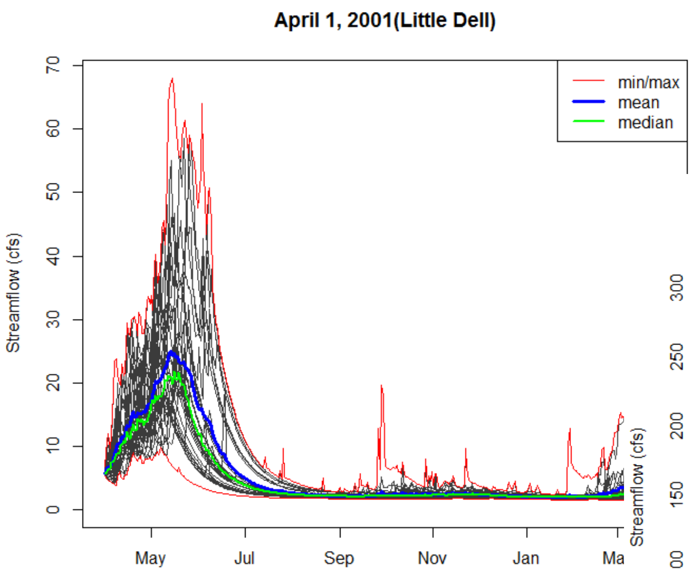


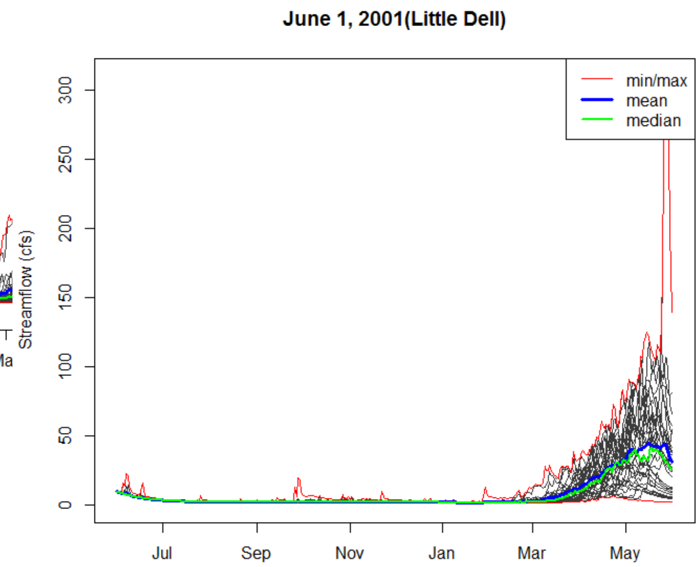




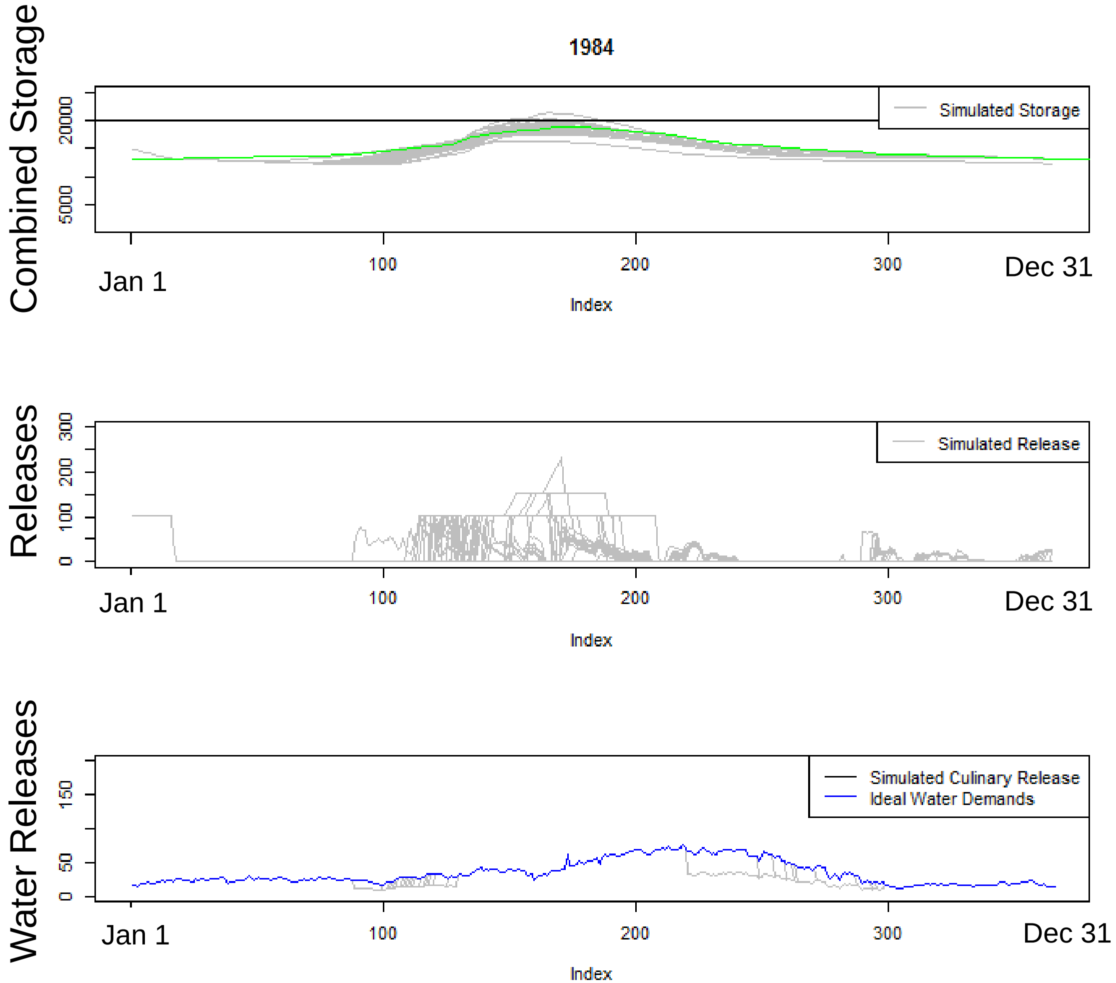
ESP Streamflow – Low Inflow Year



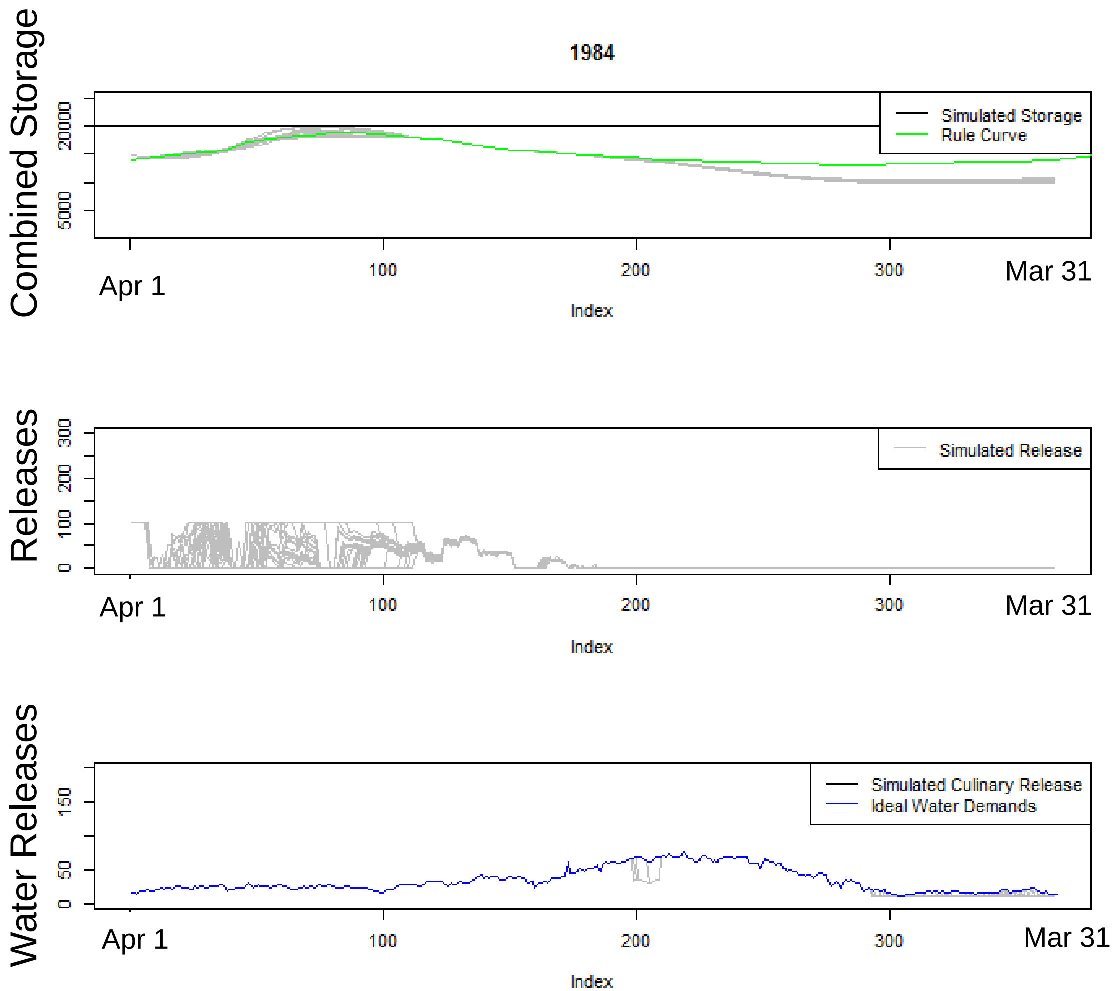




January ESP – Operational Output (af)



April ESP - Operational Output (af)



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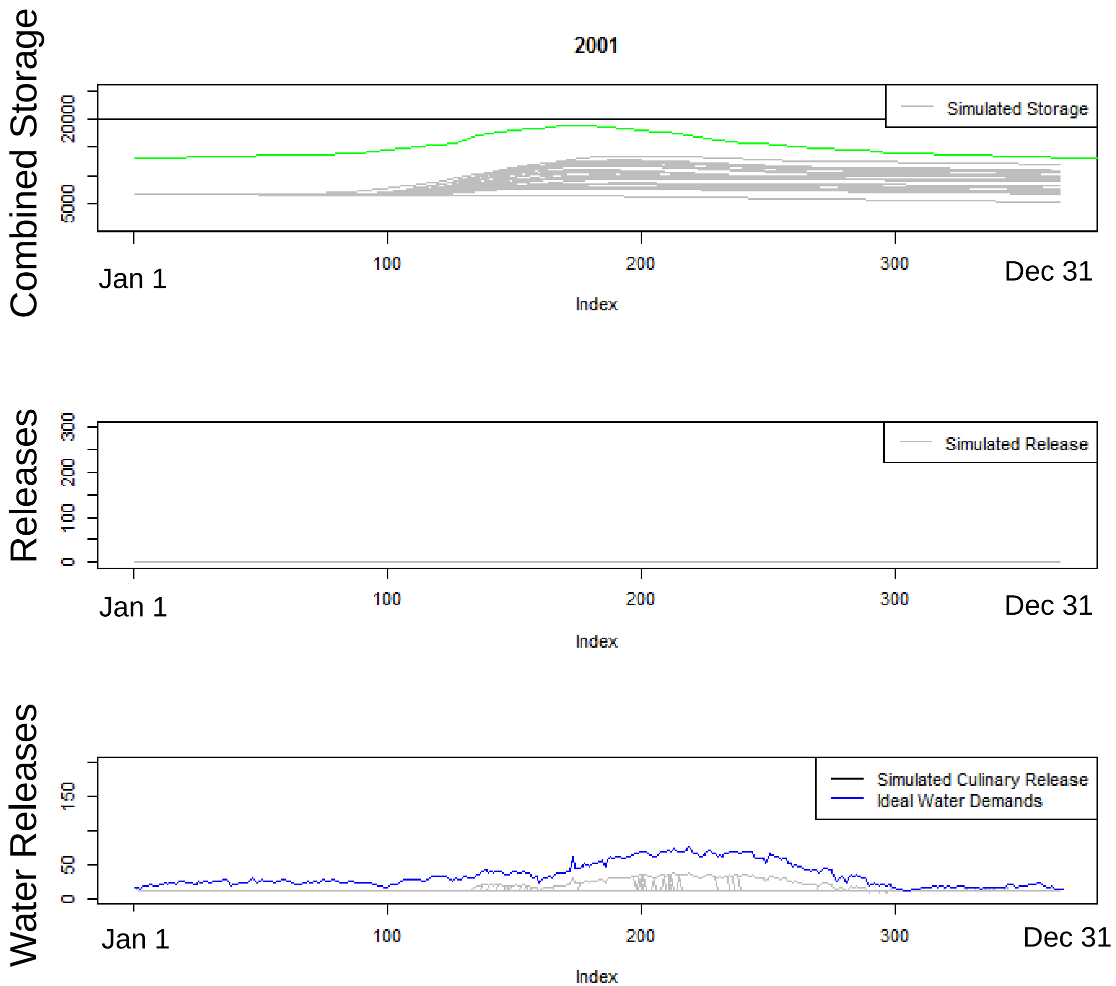

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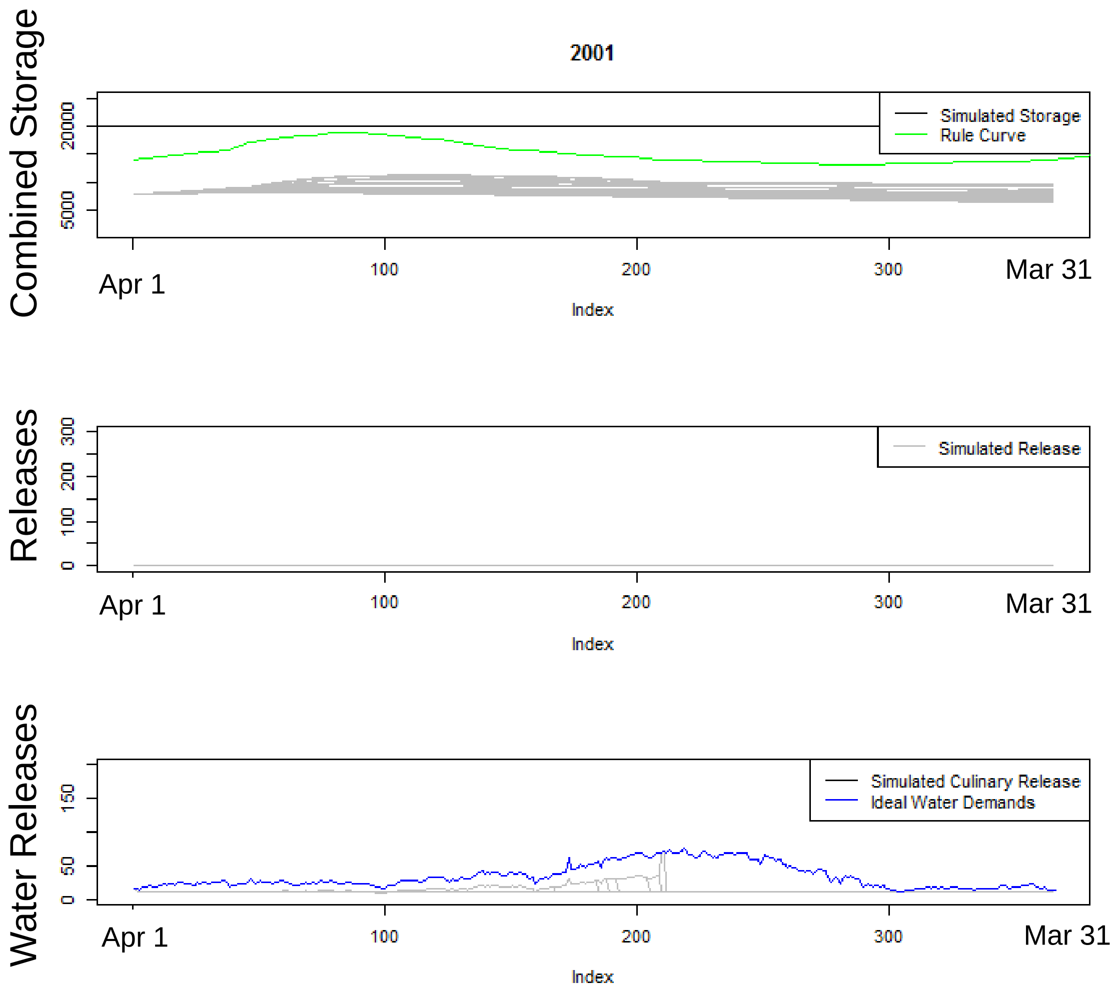
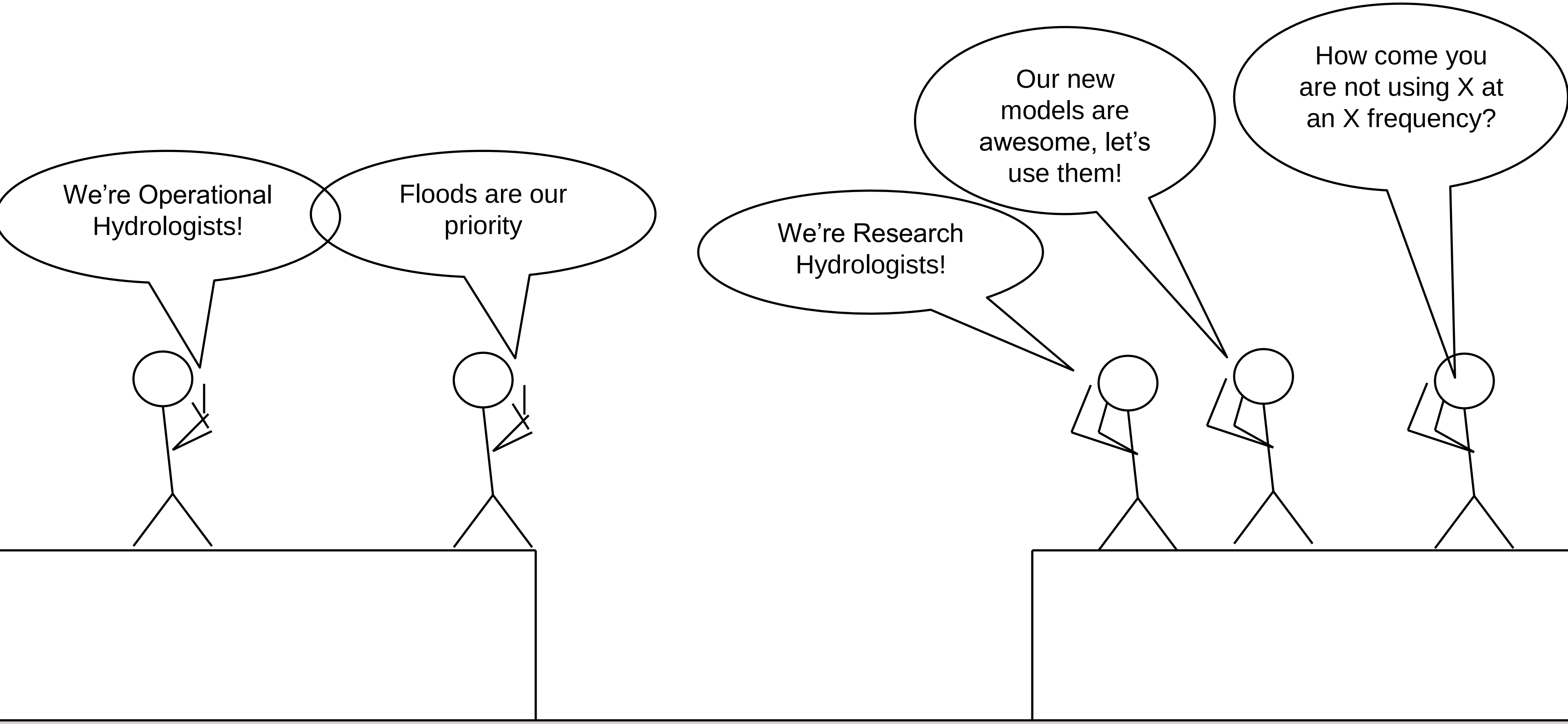


Iterative Process Getting New Tech Into Ops



Iterative Process Getting New Tech Into Ops

Final Thoughts and Future Work

- ESP and HEFS/CFSv2 traces applied in operational framework will provide benefits,
  - we are finishing evaluating at what scales and for what decisions, final evaluations completed by September
- Generating hindcast data for evaluating system in existing framework is iterative process
  - generating data, processing through system, trouble shooting…
- Matching End User needs (update frequency, forecast length, etc.) must be priority in beginning of process

Acknowledgements

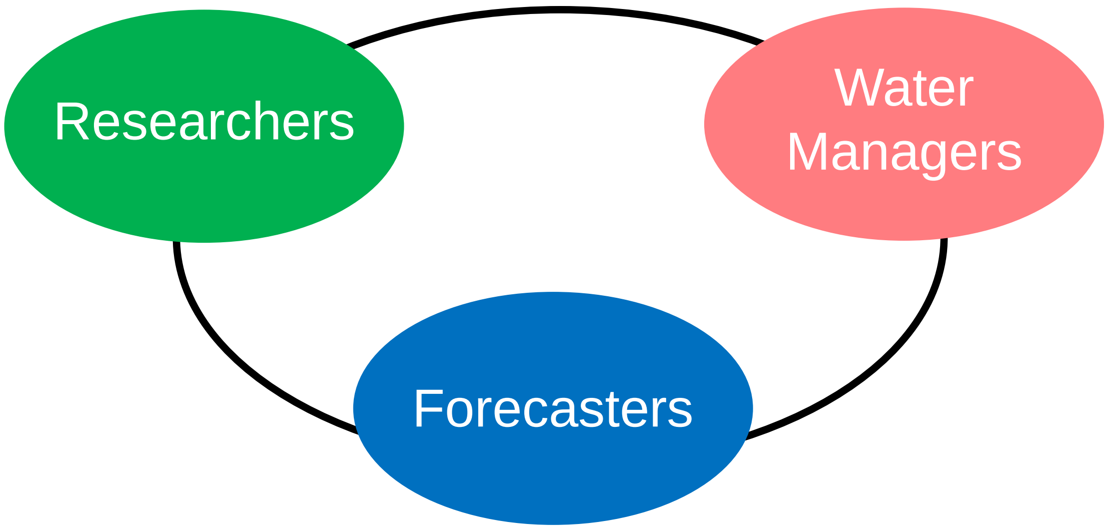
- NOAA SARP – Nancy Beller-Simms
- Advisors: Dr. Austin Polebitski,
  Dr. Richard Palmer
- CBRFC: Kevin Werner, Ashley Nielson
- Dr. Andy Wood
- Case Study Partners: Bruce Meaker, Connely Baldwin, Jeff Niermeyer, Tracie Kirkham, Denis Qualls

Thank You!

Questions?

Project Goals

- Analyze the quality of climate forecast products,
- Work with study partners to develop ways to use products in reservoir operations.



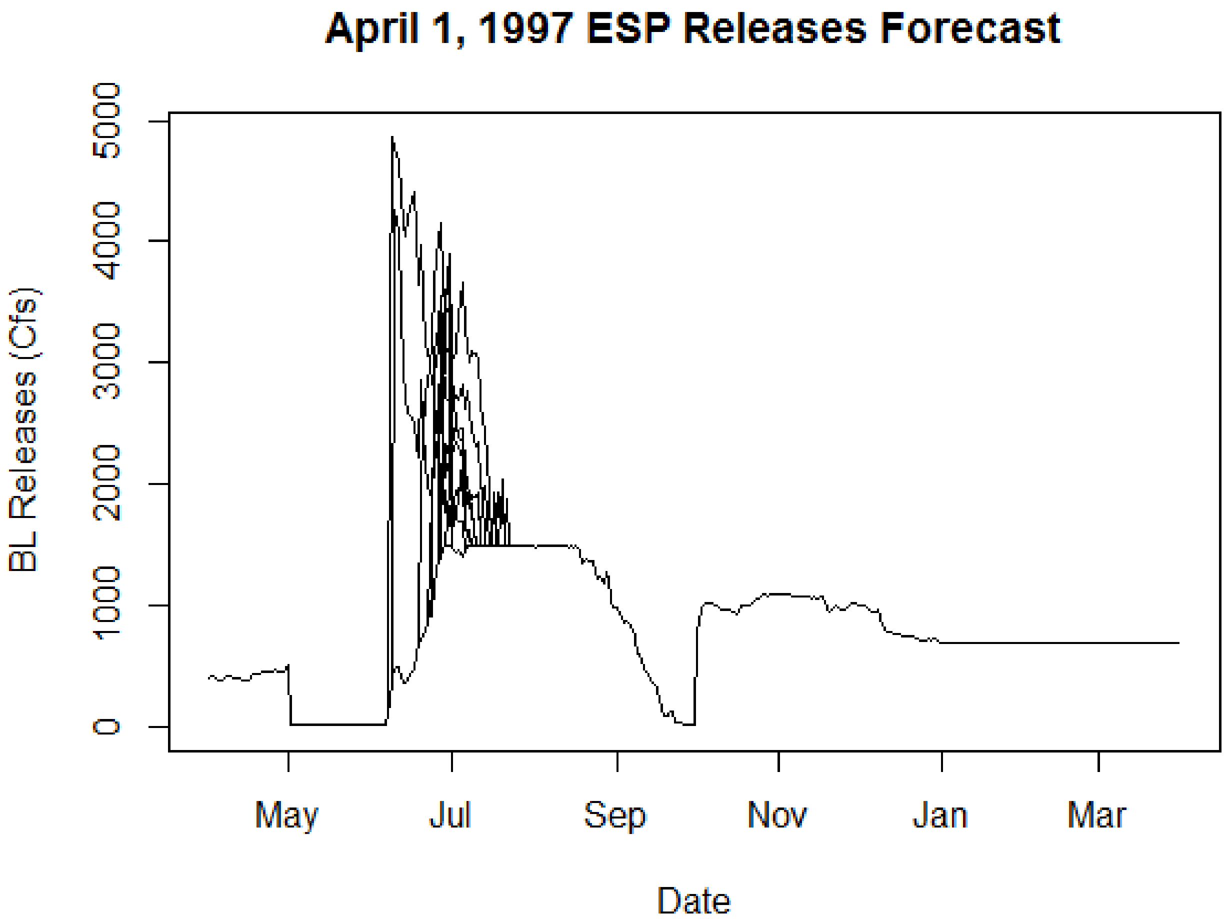
Future Work

- Quantitatively compare the results against perfect forecast information

- Is this a useful seasonal prediction tool?
  - Does including the GEFS forecast improve the regular ESP forecast?
  - What benefits do CFS model provide?

CONCLUSION: Preliminary analysis of these data suggest that climatological skill between the ESP and CFS are similar. More work is needed as the data are still very new.

Example of Results: High Flow Year



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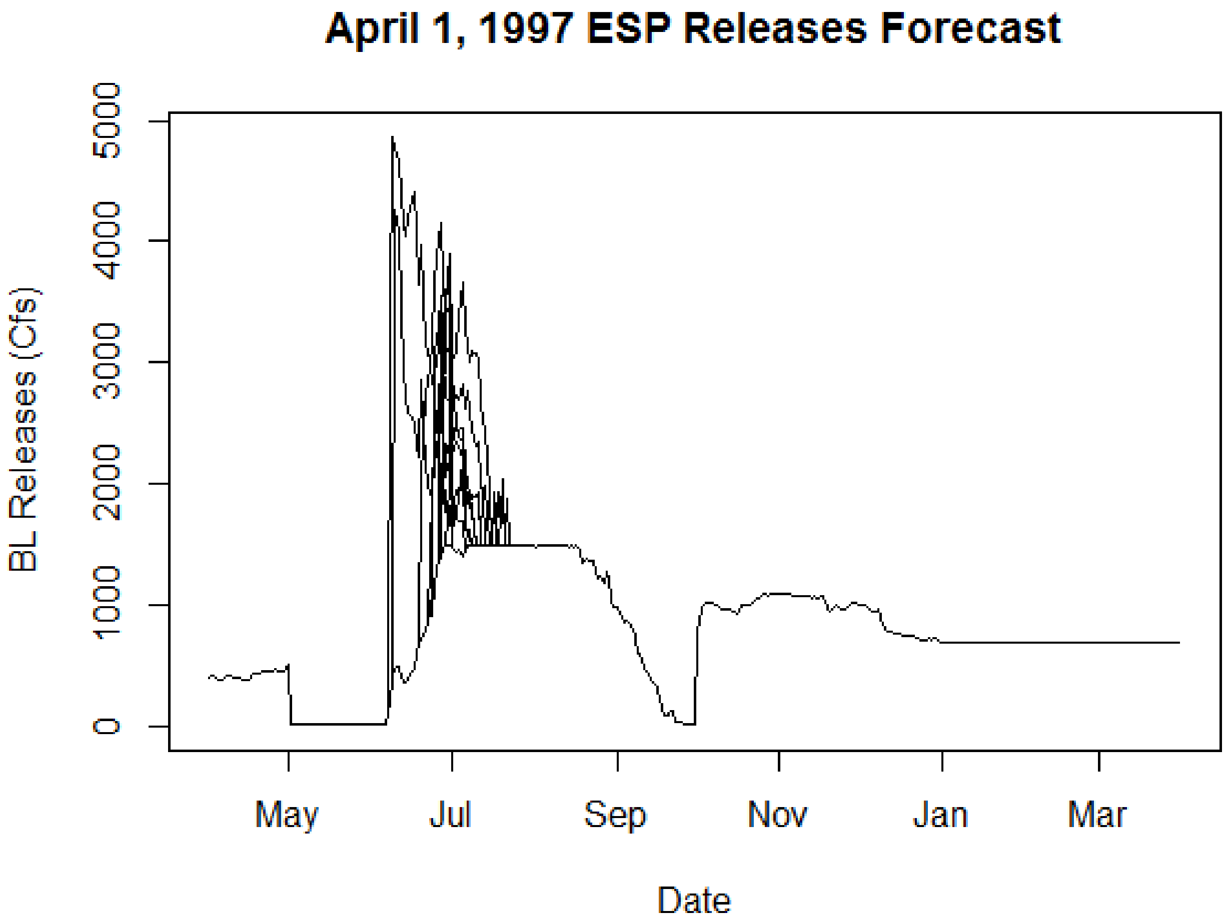
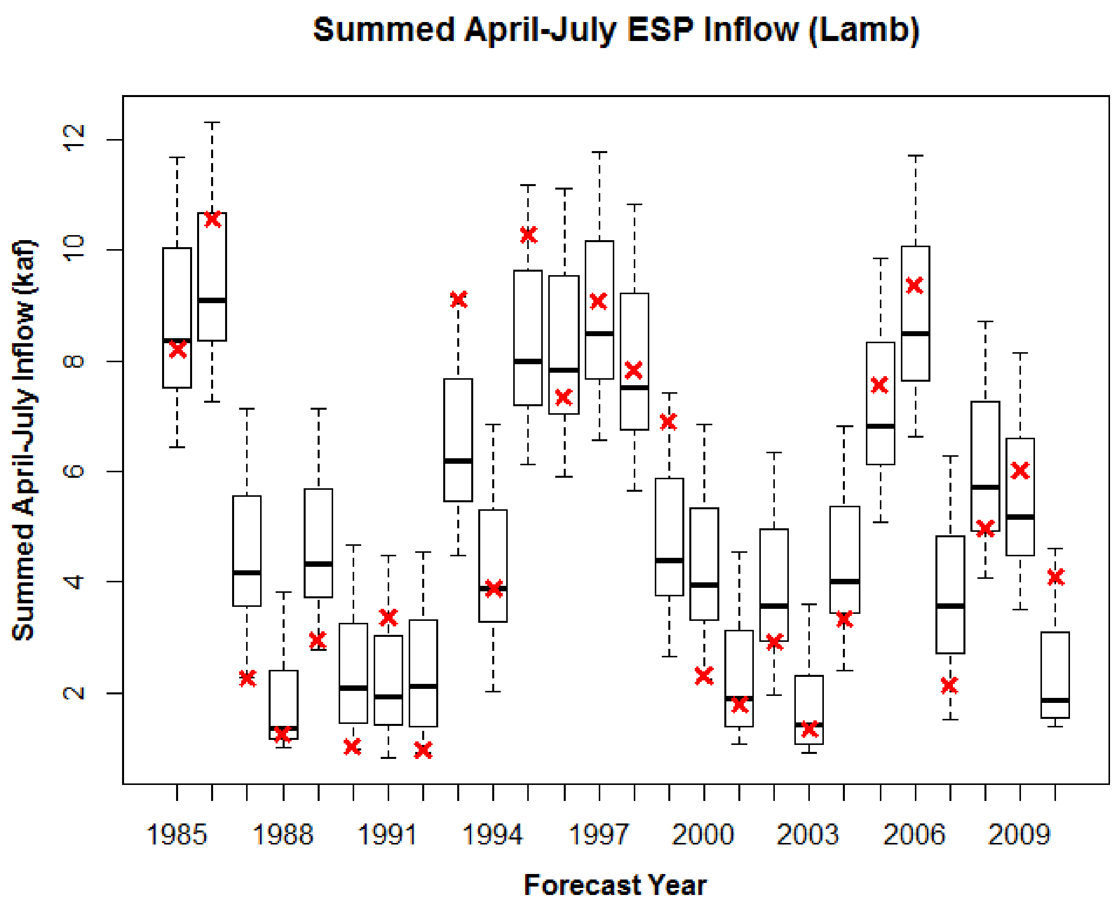


*9/30 expected releases would exceed 1500 cfs for an average of 19 days

ESP LAMB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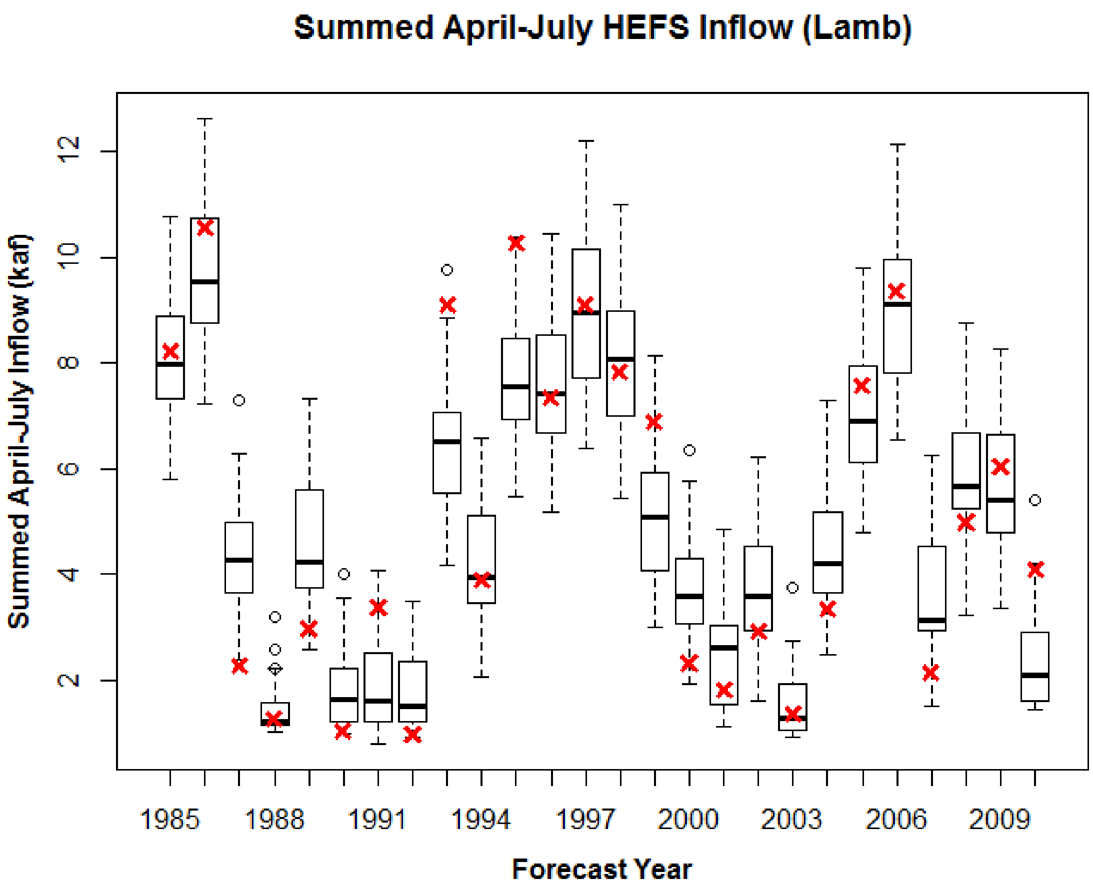
HEFS LAMB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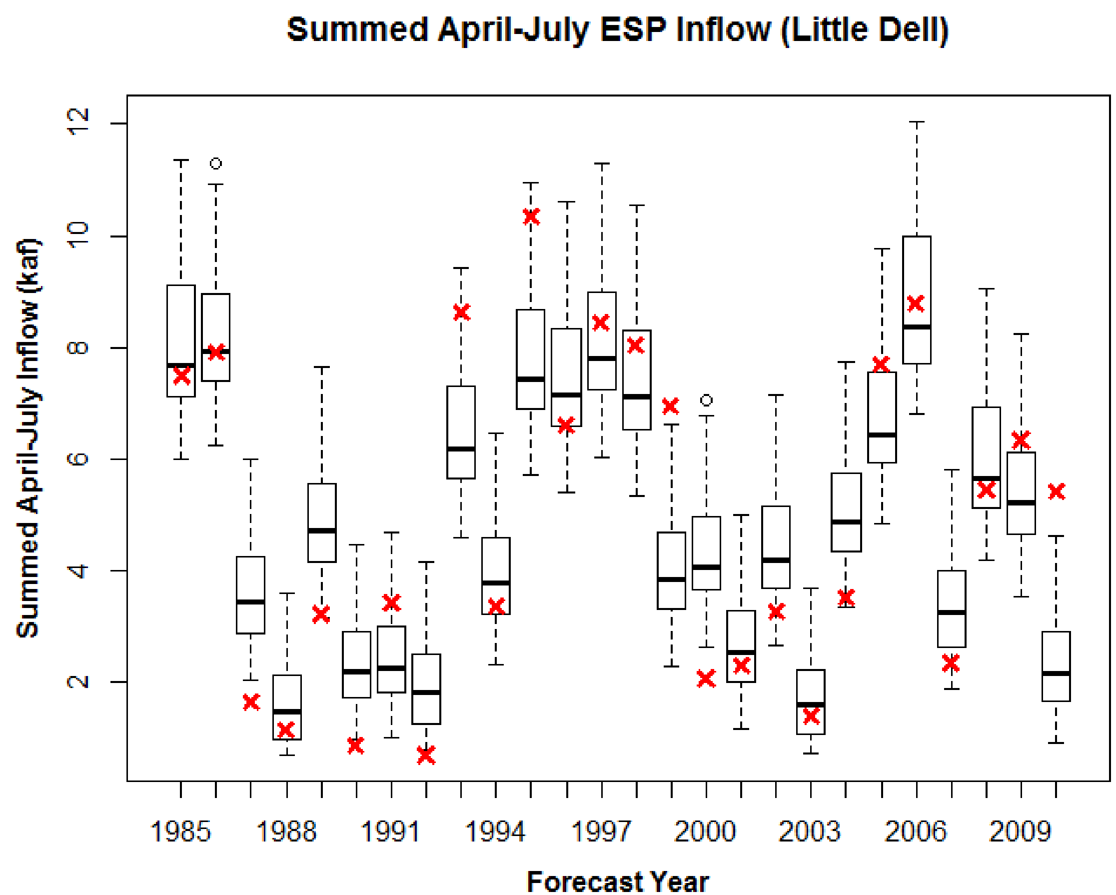
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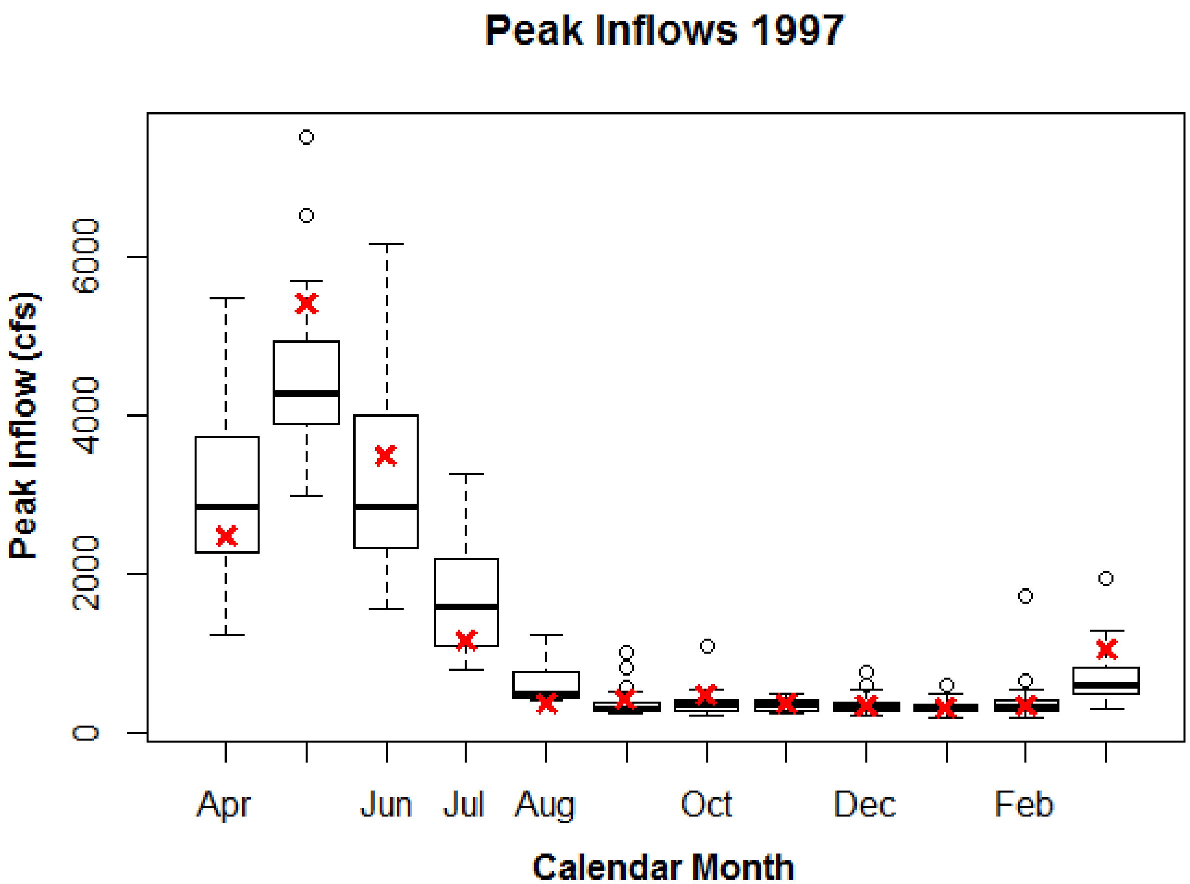

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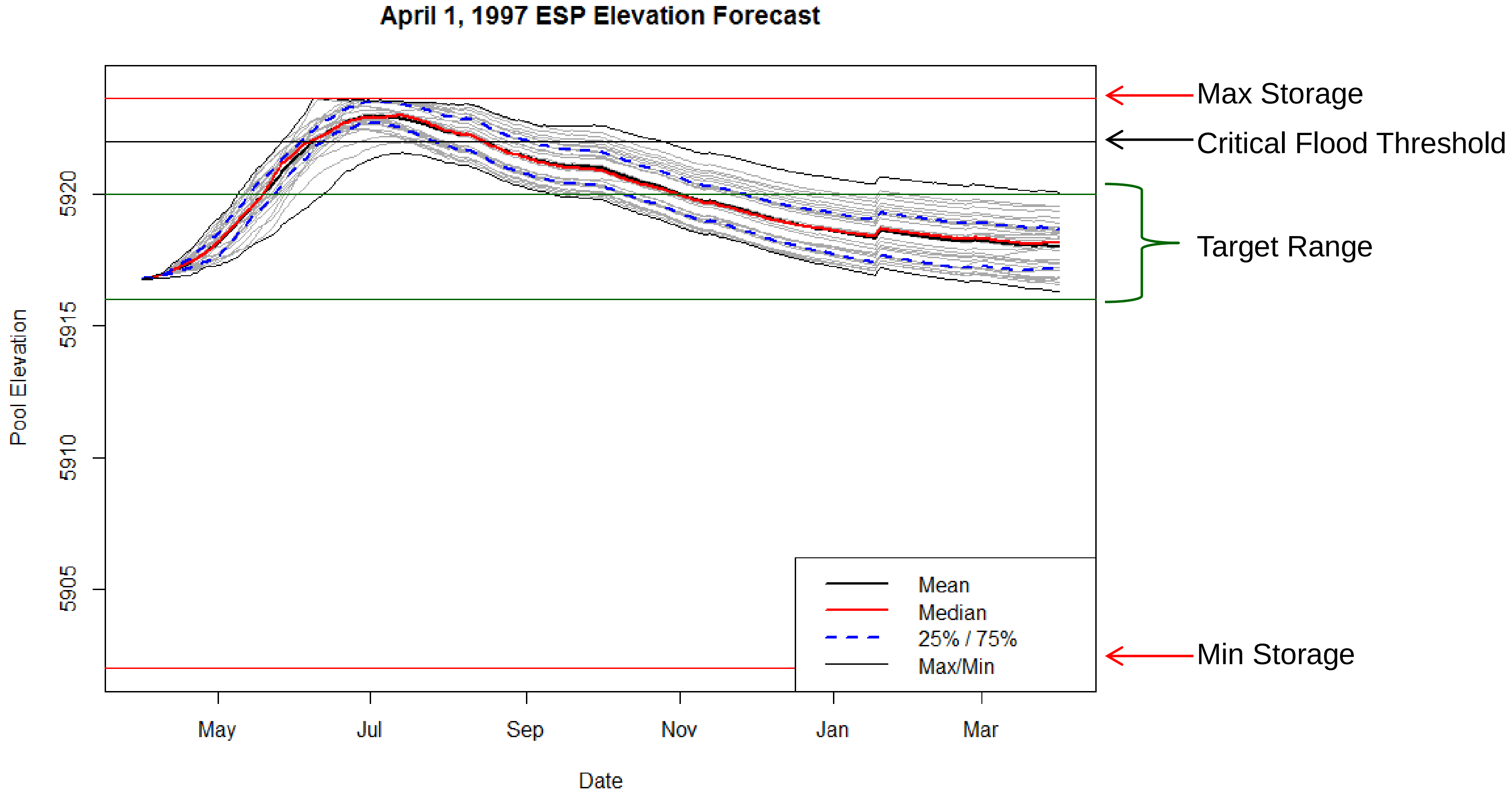

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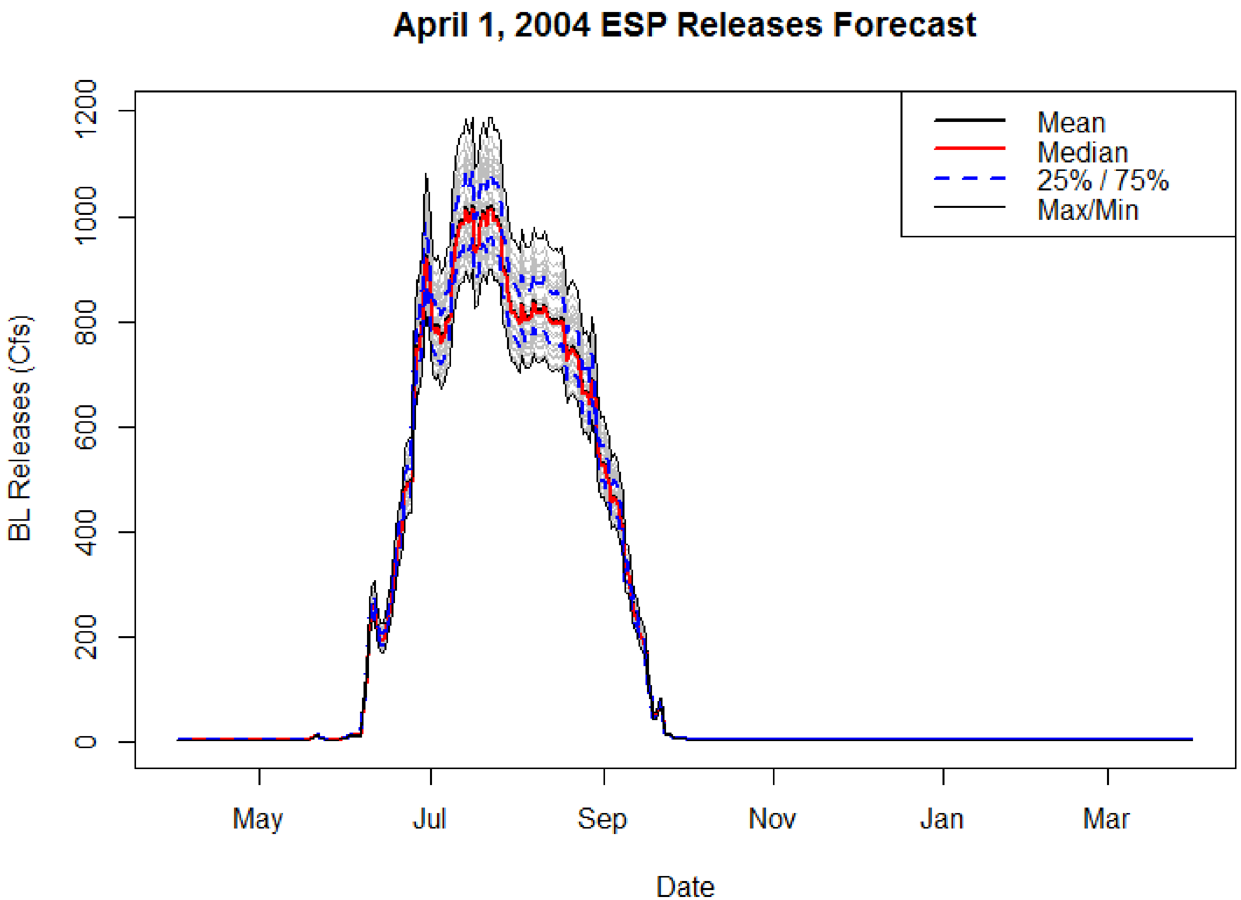

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