Ensemble Flow Forecasting for Hydropower Operations

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Objective:
Demystify Hydropower Operations with respect to Forecasting Needs

1. Diversity in hydropower operations in the US and corresponding forecast needs:
   - Plant scale
   - Grid scale

2. Roadmap to design forecasts and help transition research into operations

3. Case study on the communicating the value of forecasts: when to stop and how to go on
• Over 2000 hydropower plants in the US, ~6% of annual energy generation,
• ~25% of generation capacity over Western US
• ~Half of total hydropower generation is from 132 US Federal plants.
Mode of operations:
- Generation (firm)
- Capacity (peak, reserve)

Range of operations:
- Hourly targets:
  - River routing – management of releases through a chain of run-of-the-river reservoirs,
  - Storage change constraints,
  - Downstream constraints – coordination with flood forecast
- Day-ahead scheduling, week
- Seasonal – business consideration
- Inter-annual
- Climate change
Grid Scale: Use of Flow Forecast in Grid Modeling

- Multi-objective water resources: reservoir operations optimization

- Multi-sector operations (water-energy):
  - Regression model for generation; On-site planning
  - Unit dispatch optimization; Market based, maintenance
  - Power flow models; Reliability analysis
  - Production Cost models; Operations
  - Expansion models; Investment

Regions of water-energy jurisdictions
Flow forecast and production cost models: Forecasts need consistency across regions

- Some drought spatial patterns trigger vulnerabilities in the WECC power system operations
- Role of hydropower in mitigating droughts varies regionally and is function of other regions’ generation portfolio and of transmission constraints

August transmission and generation mix

Baseline

PNW and CO export to CA
100% August demand met
Operating costs: $19.8 B

Dry PNW

Increased import from CO
100% August demand met
Operating cost: $20.4 B

Dry West

PNW and CO imports to CA are not enough
6% August demand NOT met

Voisin, N. et al. 2016: [in revision]
Roadmap for Use/Design of Forecast in Hydropower Operations

<table>
<thead>
<tr>
<th>Attributes of management flexibility</th>
<th>Attributes of operational flexibility</th>
<th>Attributes of basin characteristics</th>
<th>Attributes of optimization (generation vs capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single objective</td>
<td>Annual Runoff/storage capacity &lt; 1</td>
<td>snowmelt</td>
<td>Local consumption</td>
</tr>
<tr>
<td>Multi-objective and assigned pool</td>
<td>Seasonal Runoff/storage capacity &lt; 1</td>
<td>rain</td>
<td>Coordination with other plants and/or technologies to provide for utility load</td>
</tr>
<tr>
<td>By-product</td>
<td>Low storage – run-of-the-river</td>
<td>Transition snow-rain</td>
<td>market</td>
</tr>
</tbody>
</table>

What fraction of the forecast volume can be used?

How does it translate in uncertainty quantification?

What type of forecast products, blending of forecast products?

Sources of uncertainties?

Source of forecast skill and skill per horizon

Competition with other types of uncertainties for optimization
Seasonal Flow Forecasts for Reservoir Operations Optimization at Oroville, CA.

What the optimization system expects:
- Perfect forecast

Communicating expectations – when to stop improving the forecasts

Low boundary for forecast skill

What the forecaster knows about the skill of the forecast

Forecast skill with respect to reference climatology (MSE/ Variance)

How To Improve Forecasts and When to Stop?

Seasonal Flow Forecasts for Reservoir Operations Optimization at Oroville, CA.

What the optimization system expects:
- Perfect forecast
- Communicating expectations
- When to stop improving forecasts

What the forecaster knows about the skill:
Communicating Skill of Forecasts

- Use end-to-end systems
- Interpretations:
  - Optimization under uncertainty
  - Optimization under different forecast skills over different time horizons

Conclusion: End-to-end System and Role of Forecasts

Work ahead:

- Hydropower operators would like to increase the value of forecasting:
  - Increase communication of the needs
  - Develop boundaries of operational opportunities and flexibility.
  - Collaboration with forecasters

- HEPEX (Hydrological Ensemble Prediction Experiment):
  - Collaboration for understand flexibility of systems and risk management:
    - Understand horizons of electricity generation management
    - Understand other players at the table: wind, solar, market, energy demand
  - Support design forecast:
    - Combine forecast products
    - Clear roadmaps for post processing approaches / use of forecast products
Thank you

DEPARTMENT OF ENERGY “WATER USE OPTIMIZATION TOOLSET" PROJECT