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Ensemble Flow Forecasting for Hydropower Operations

NATHALIE VOISIN

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U.S. DEPARTMENT OF ENERGY

Objective:
Demystify Hydropower Operations with respect to Forecasting Needs

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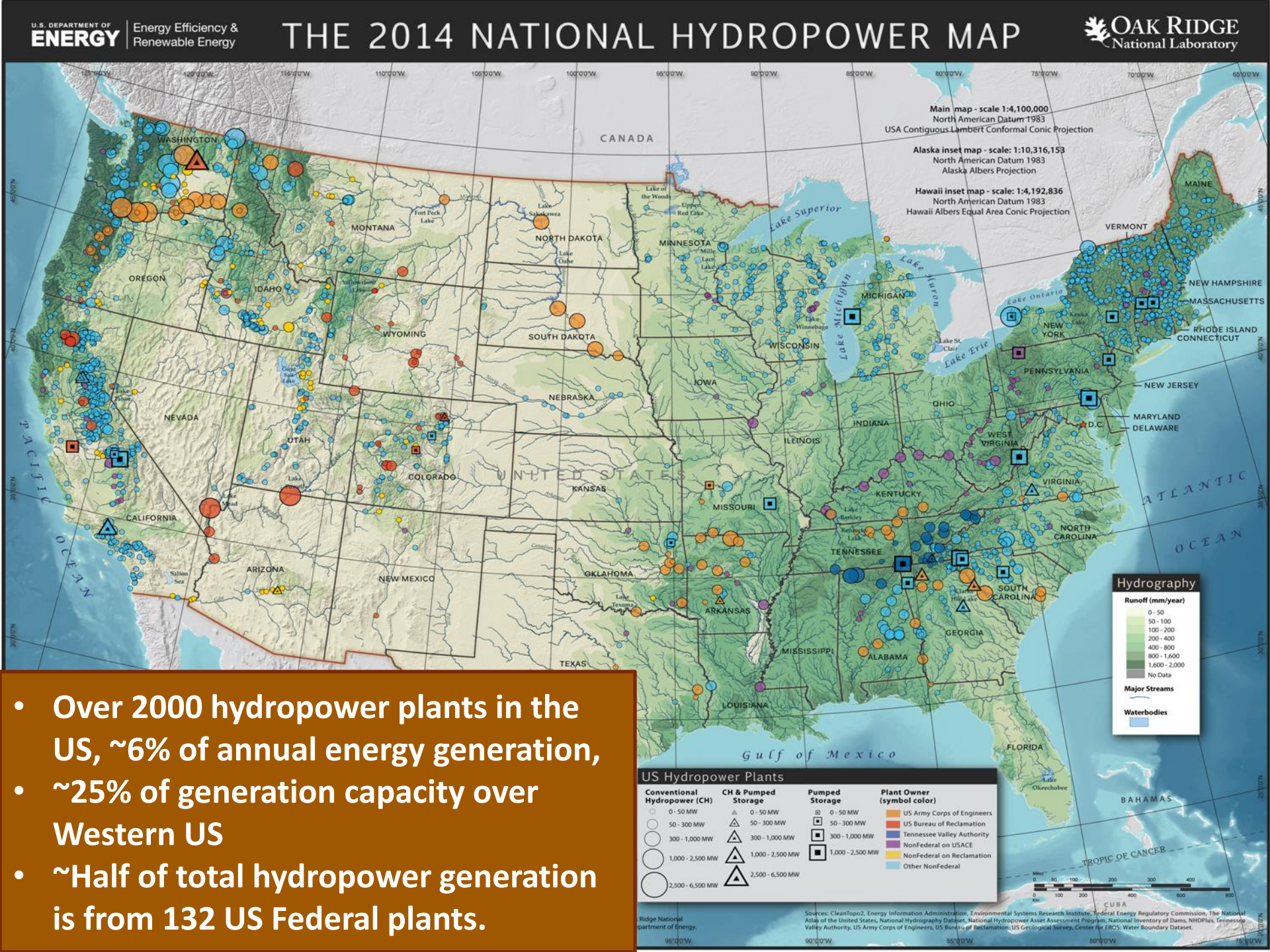
1. Diversity in hydropower operations in the US and corresponding forecast needs:
   - ❖ Plant scale
   - ❖ Grid scale
2. Roadmap to design forecasts and help transition research into operations
3. Case study on the communicating the value of forecasts: when to stop and how to go on



- **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.**

Plant Scale: Hydropower Optimization and Flow Forecast

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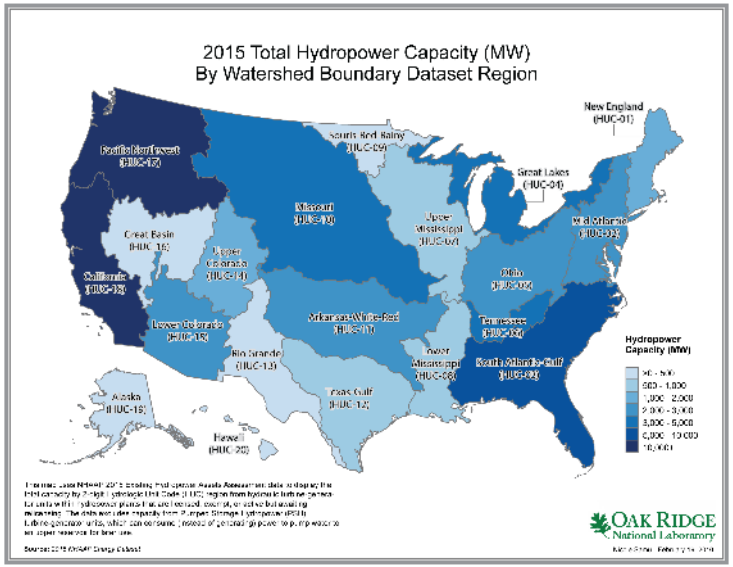
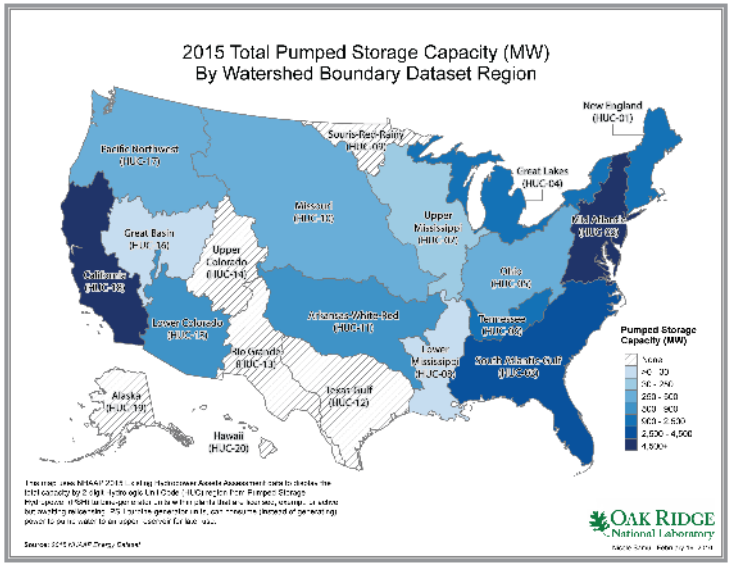
- Mode of operations:
  - Generation (firm)
  - Capacity (peak, reserve)
- Range of operations:
  - Hourly targets:
    - River routing – management of releases through a chain of run-of-the-river reservoirs,
    - Storage change constraints,
    - Downstream constraints – coordination with flood forecast
  - Day-ahead scheduling, week
  - Seasonal – business consideration
  - Inter-annual
  - Climate change



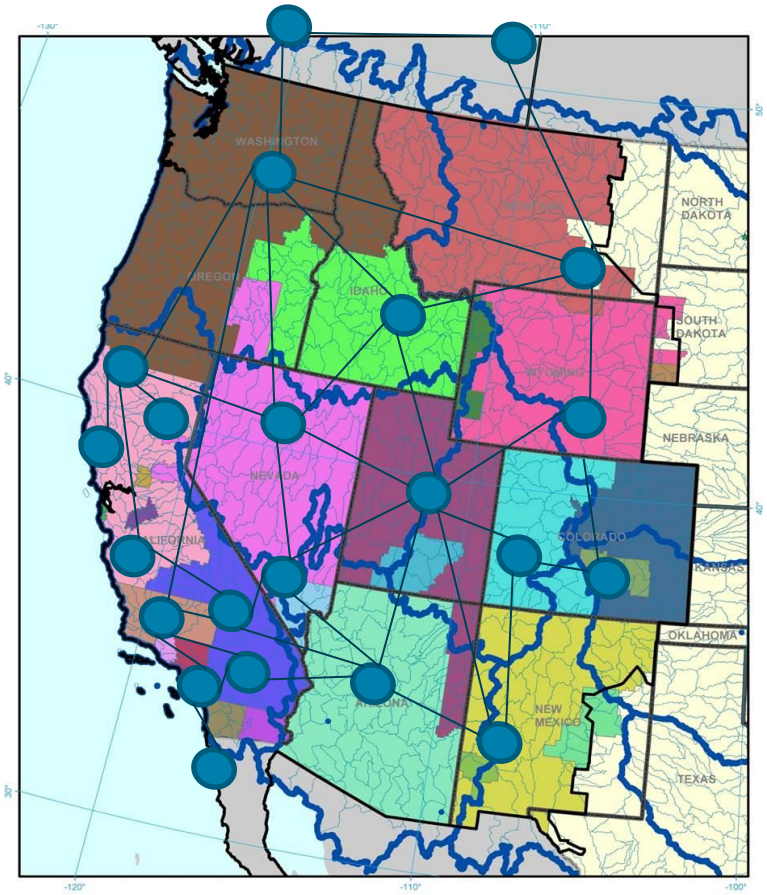


Grid Scale:
Use of Flow Forecast in Grid Modeling

- 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

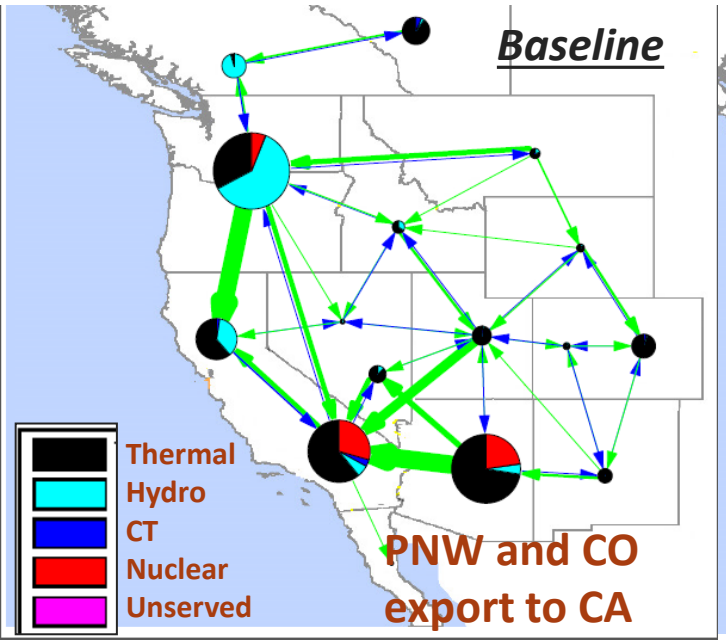
Regions of water-energy jurisdictions



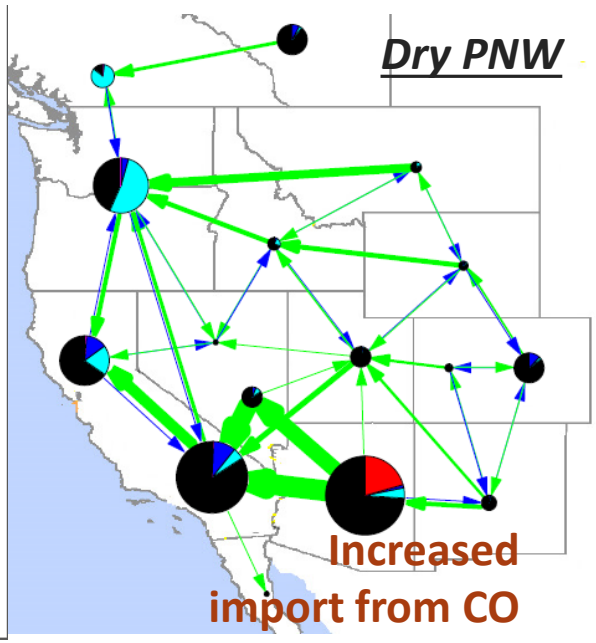
Flow forecast and production cost models: Forecasts need consistency across regions

- 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

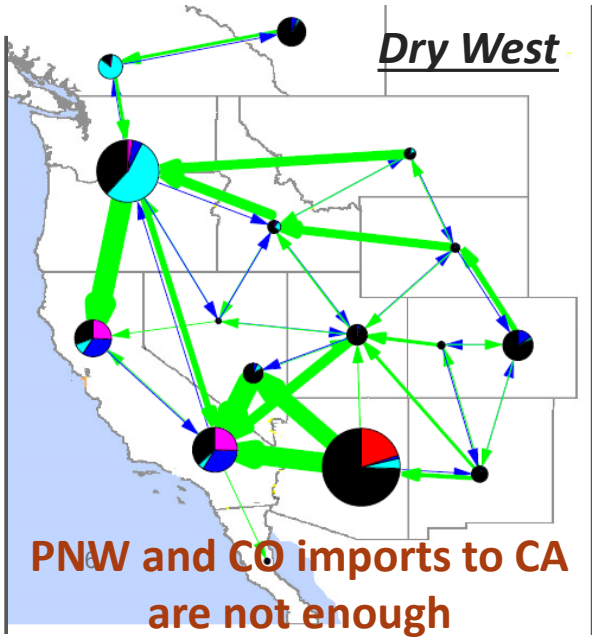
August transmission and generation mix



100% August demand met
Operating costs: $19.8 B



100% August demand met
Operating cost: $20.4 B



6% August demand NOT met

Voisin, N. et al. 2016: [in revision]

Roadmap for Use/Design of Forecast in Hydropower Operations

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

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

How To Improve Forecasts and When to Stop?

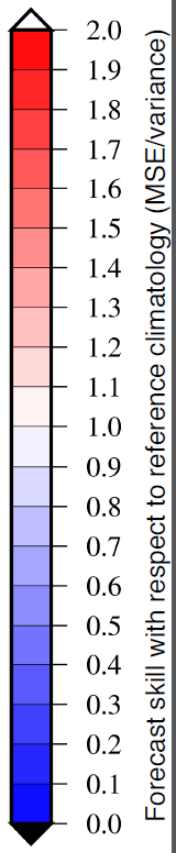
- Seasonal Flow Forecasts for Reservoir Operations Optimization at Oroville, CA.

What the optimization system expects : Perfect forecast

Low boundary for forecast skill

Communicating expectations – when to stop improving the forecasts

What the forecaster knows about the skill of the forecast



Anghileri D, N Voisin, AF Castelletti, F Pianosi, B Nijssen, and DP Lettenmaier. 2016. "Value of long-term streamflow forecast to reservoir operations for water supply in snow-dominated catchments." Water Resources Research. doi:10.1002/2015WR017864

How To Improve Forecasts and When to Stop?

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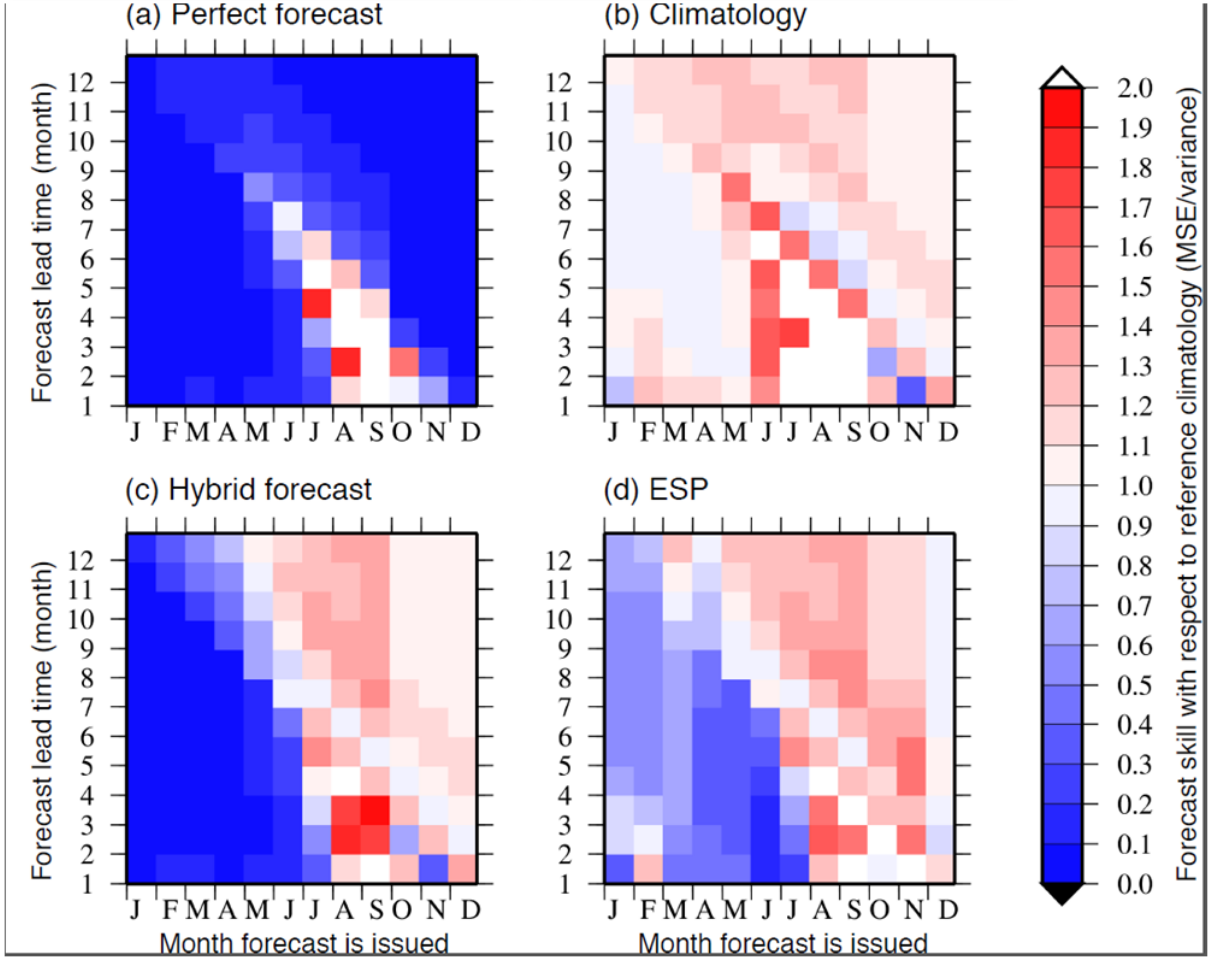

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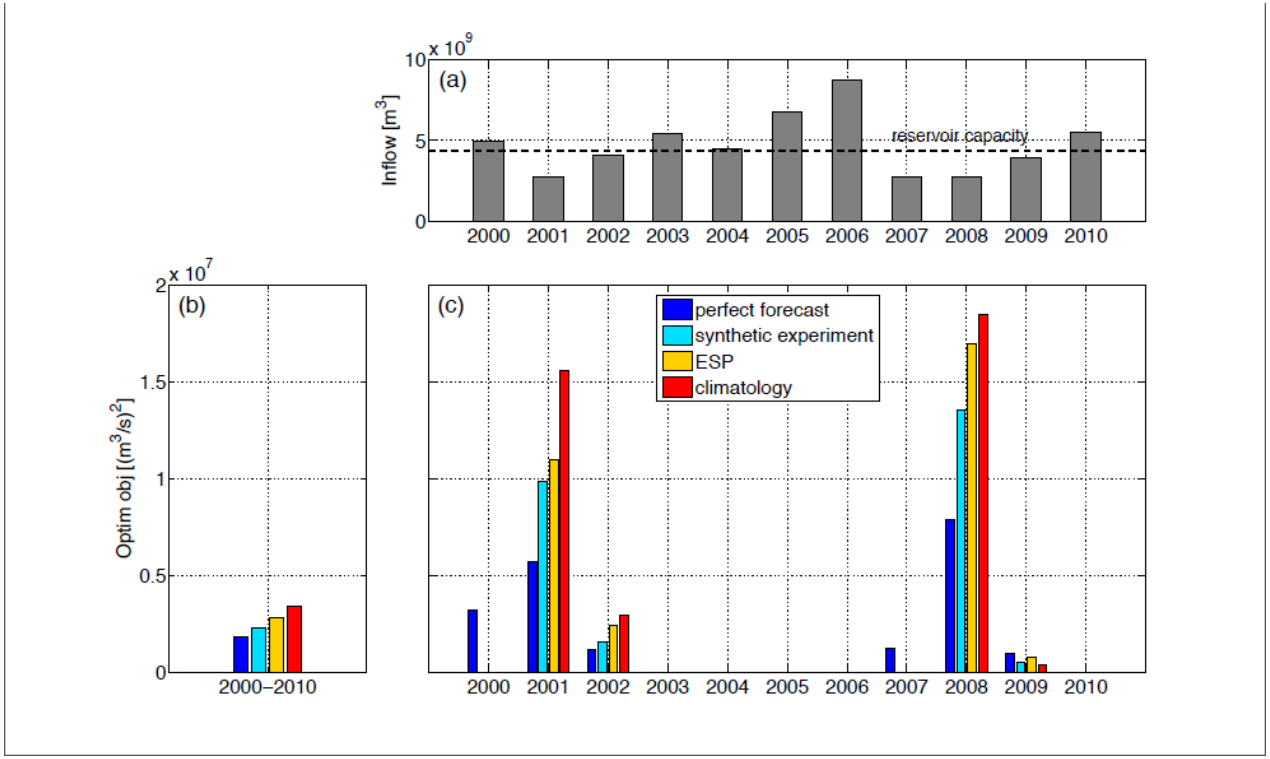
Communicating Skill of Forecasts

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



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

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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

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Thank you

DEPARTMENT OF ENERGY "WATER USE OPTIMIZATION TOOLSET" PROJECT

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