Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Challenges of adoption of probabilistic hydro-meteorological forecasts for reservoir operations.

NATHALIE VOISIN, MARK WIGMOSTA, RICK SKAGGS, ANDRE COLEMAN, CINDY RAKOWSKI

Pacific Northwest National Laboratory, Richland, WA

HEPEX workshop, June 25 2014, College Park MD

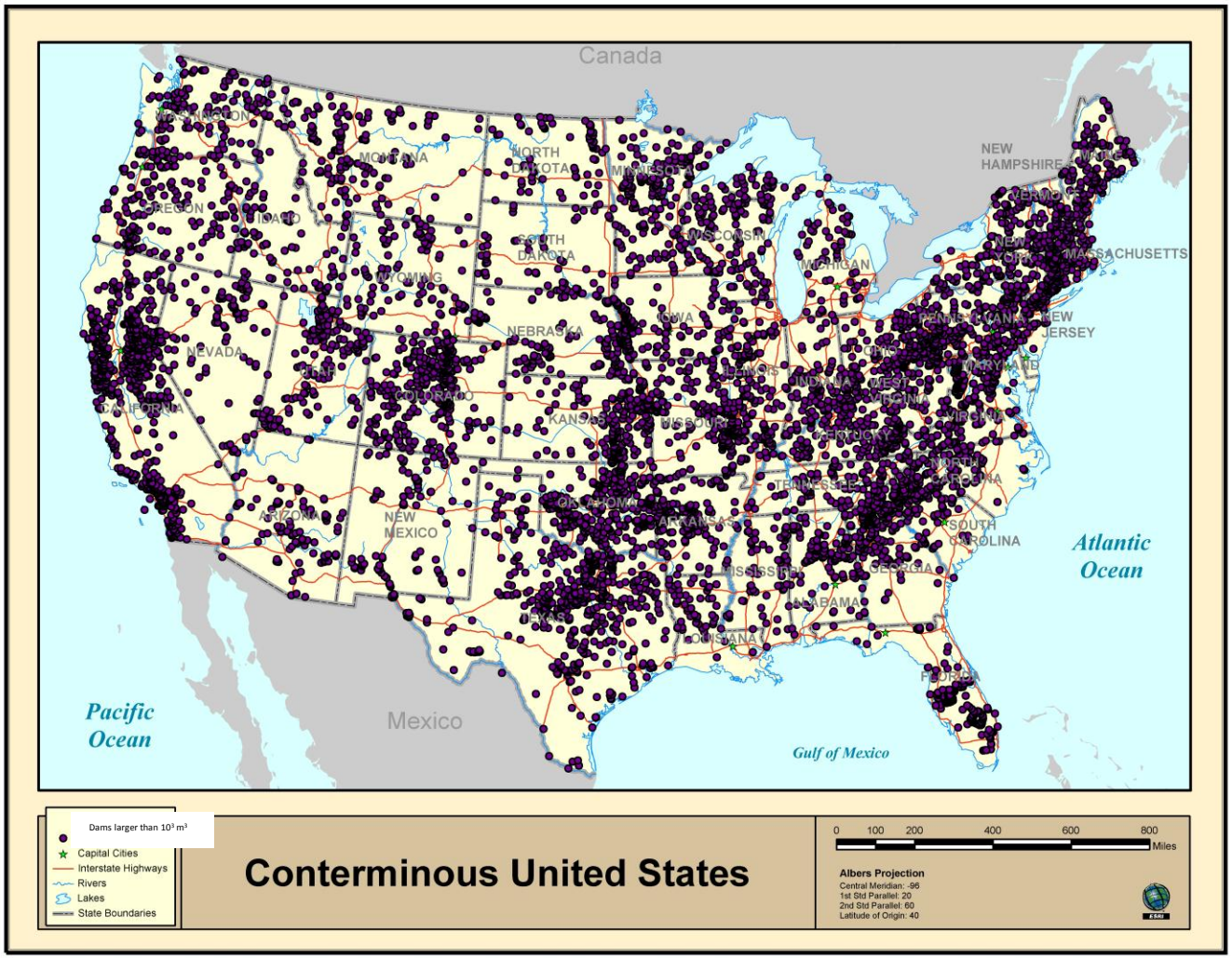
Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

How many reservoirs could benefit from ensemble hydro-meteorological forecasts, i.e. risk based approach?

8121 Majors Reservoirs in the conterminous US

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Irrigation
- Flood Control
- Water Supply
- Hydropower
- Recreation
- Other

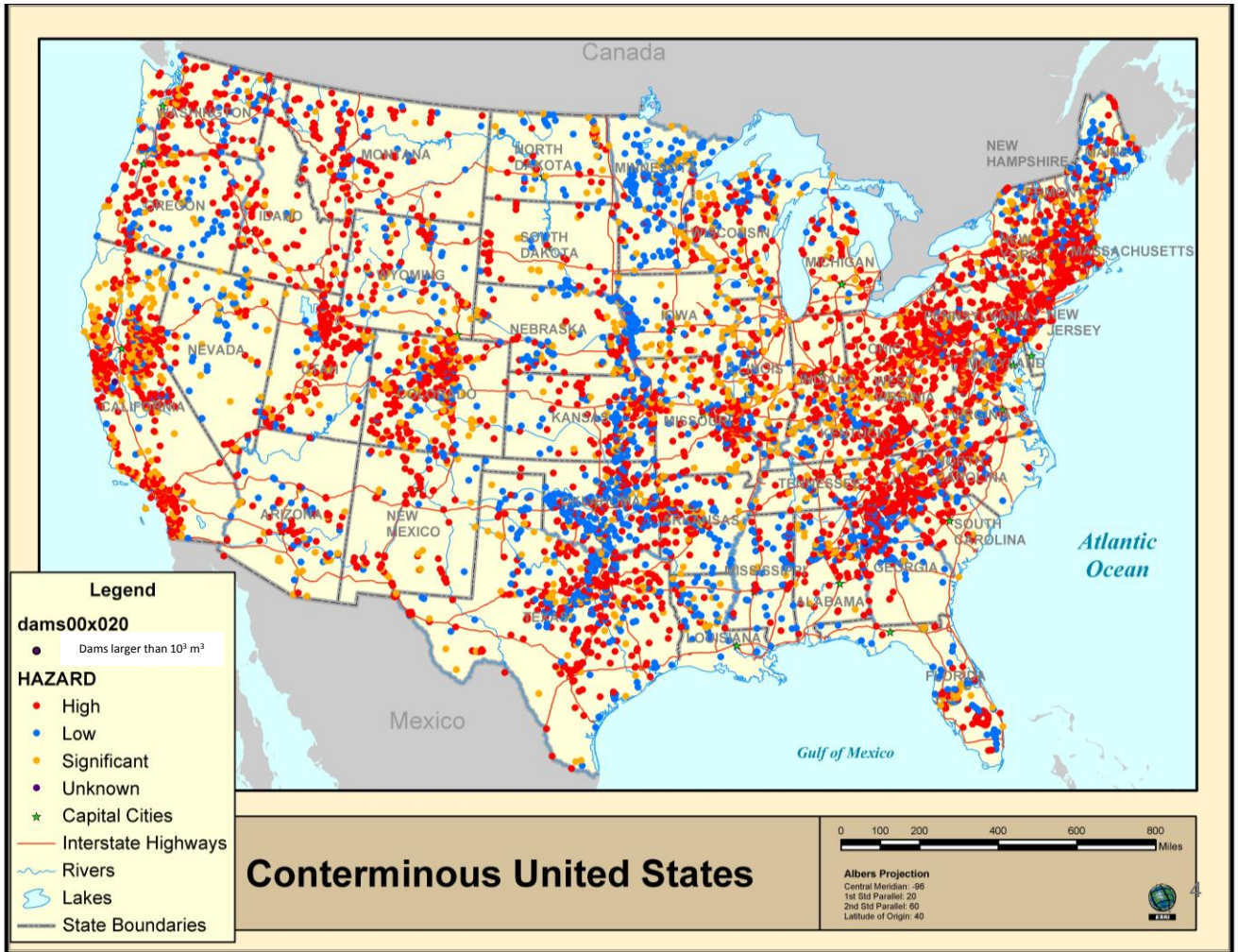


80% of all reservoirs have high to significant hazard

- Relatively, multi objective reservoirs have higher hazard than single objective reservoirs

"potential hazard to the downstream area resulting from failure or mis-operation of the dam or facilities."

High: loss of human lives
Significant: economic loss, environmental damage, structures
Low: limited to owner property, low economic and environmental loss



How many reservoirs could benefit from added value of ensemble flow forecast and risk-based information ?

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

All. Higher challenge of adoption for reservoirs with significant to high hazard:

→ 2201 single objective reservoirs with high to significant hazard
- might be more open to adopt risk based operations.
- most of the applications so far
- represent only 10-30% of total storage managed for different purposes

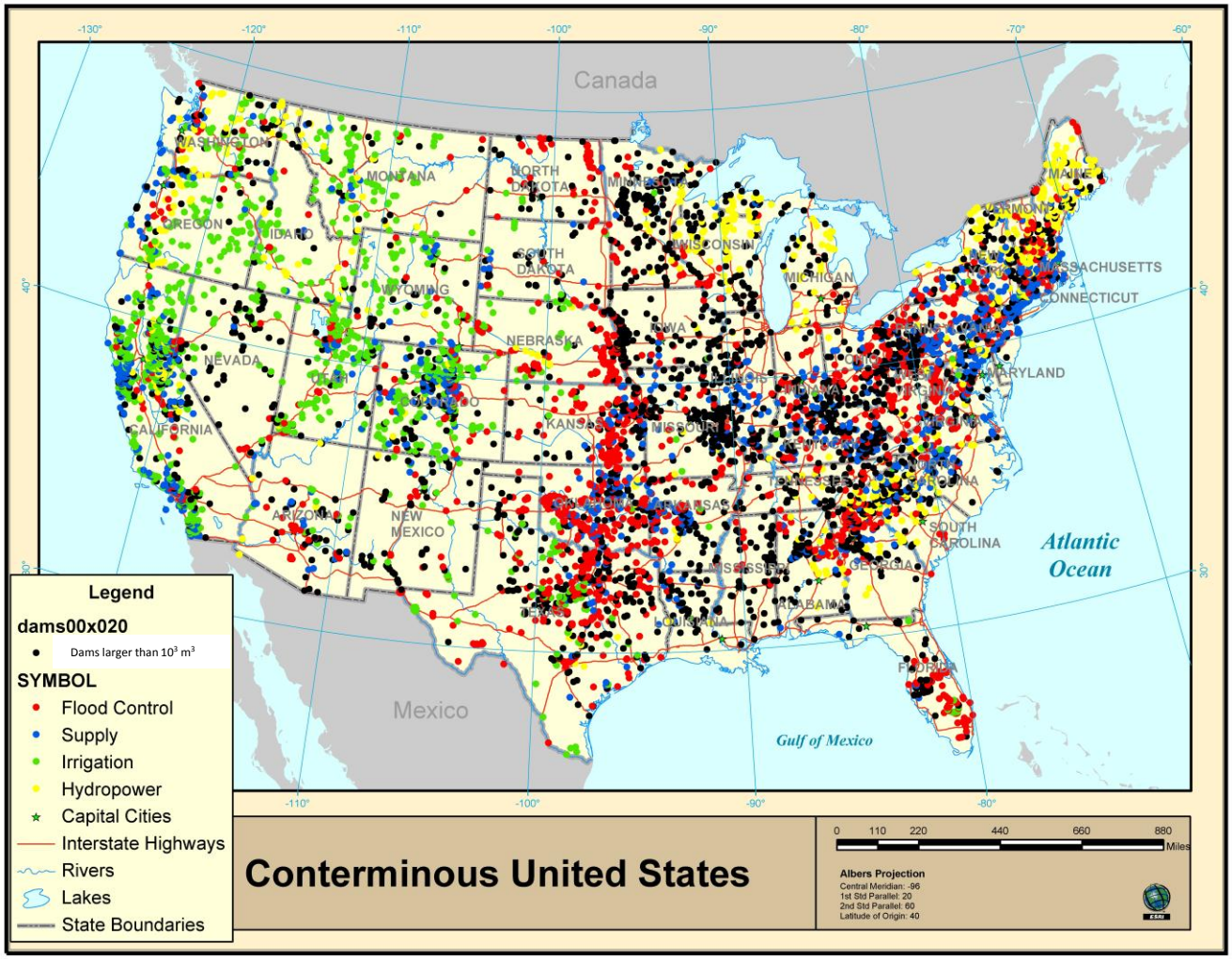
→ 467 multi objective reservoirs with high to significant hazard.
- Less of them but bigger storage.
- higher hazard than single objective
- What are those reservoirs?

50% of reservoirs operated for hydropower are multi objective

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Irrigation, supply and flood control: >= 90% are single-objective reservoirs

- Irrigation in the West
- Flood control in the East
- Water supply and hydropower across the US



Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Adoption of Innovation in a multi-objective operating system

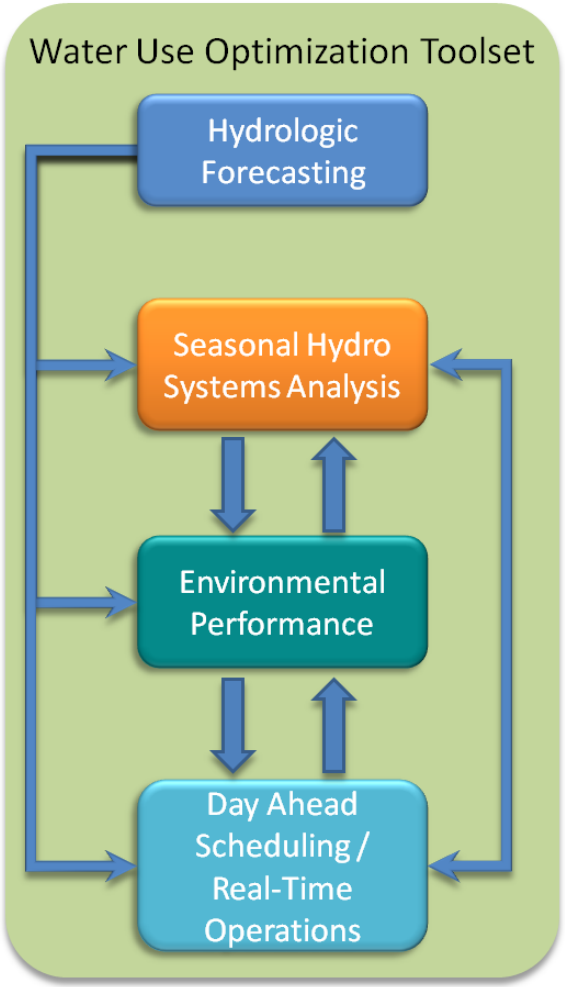
the
US Department of Energy
Water Use Optimization Toolset
(WUOT)

Water Use Optimization Toolset

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Challenge: How to operate conventional hydropower plants in an increasingly uncertain and competitive water-constrained environment
  - increasingly complex electricity markets
  - environmental constraints
  - water supply restrictions

- Objective of the toolset: to link water supply, power generation, ancillary services and environmental performance for planning and operations that:
  - increases energy and grid services from available water
  - enhances environmental benefits from improved hydropower operations and planning.

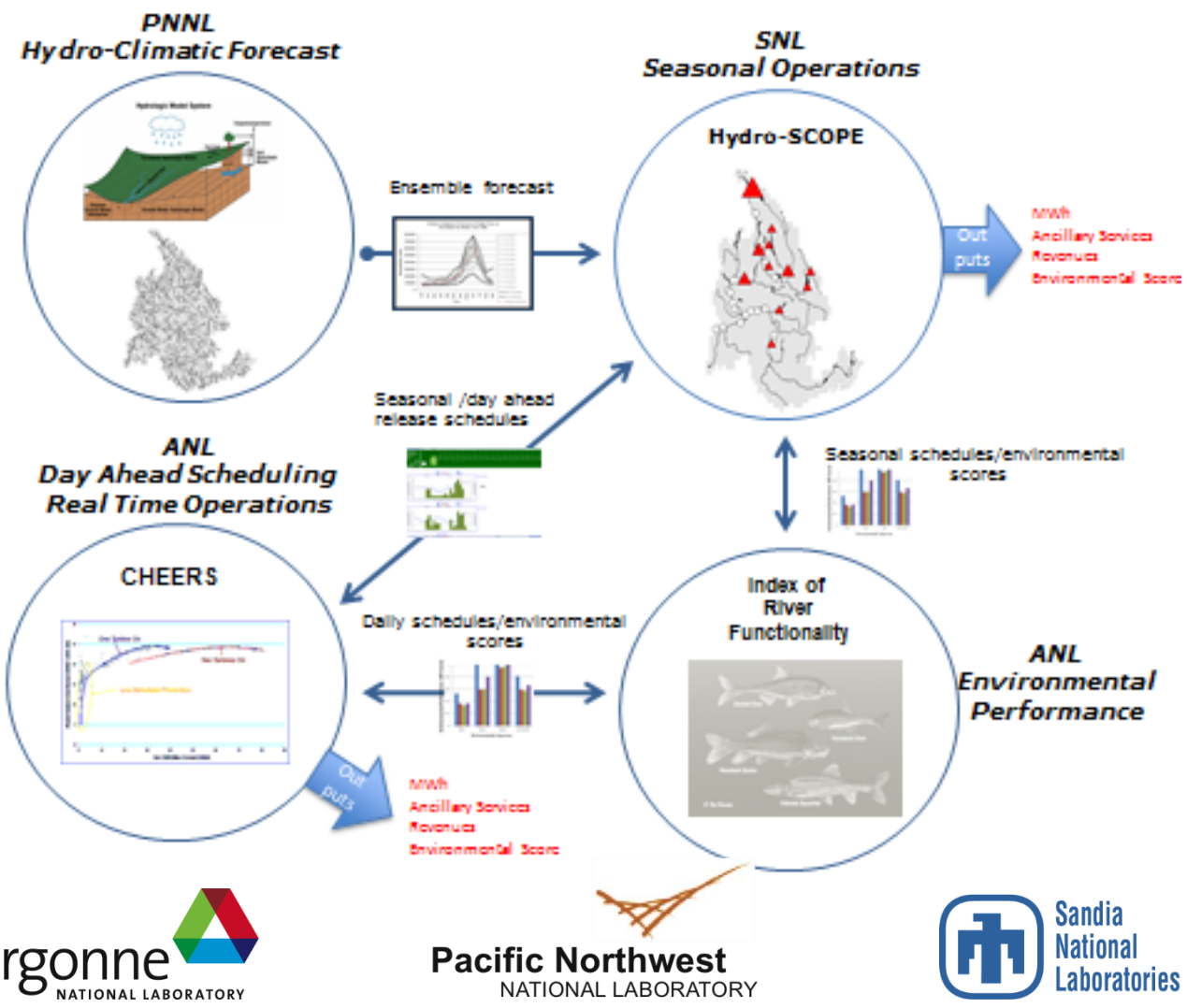


Argonne NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

Sandia National Laboratories

Water Use Optimization Toolset



4 demonstration basins:

Aspinal Unit (Gunnison R., Colorado),

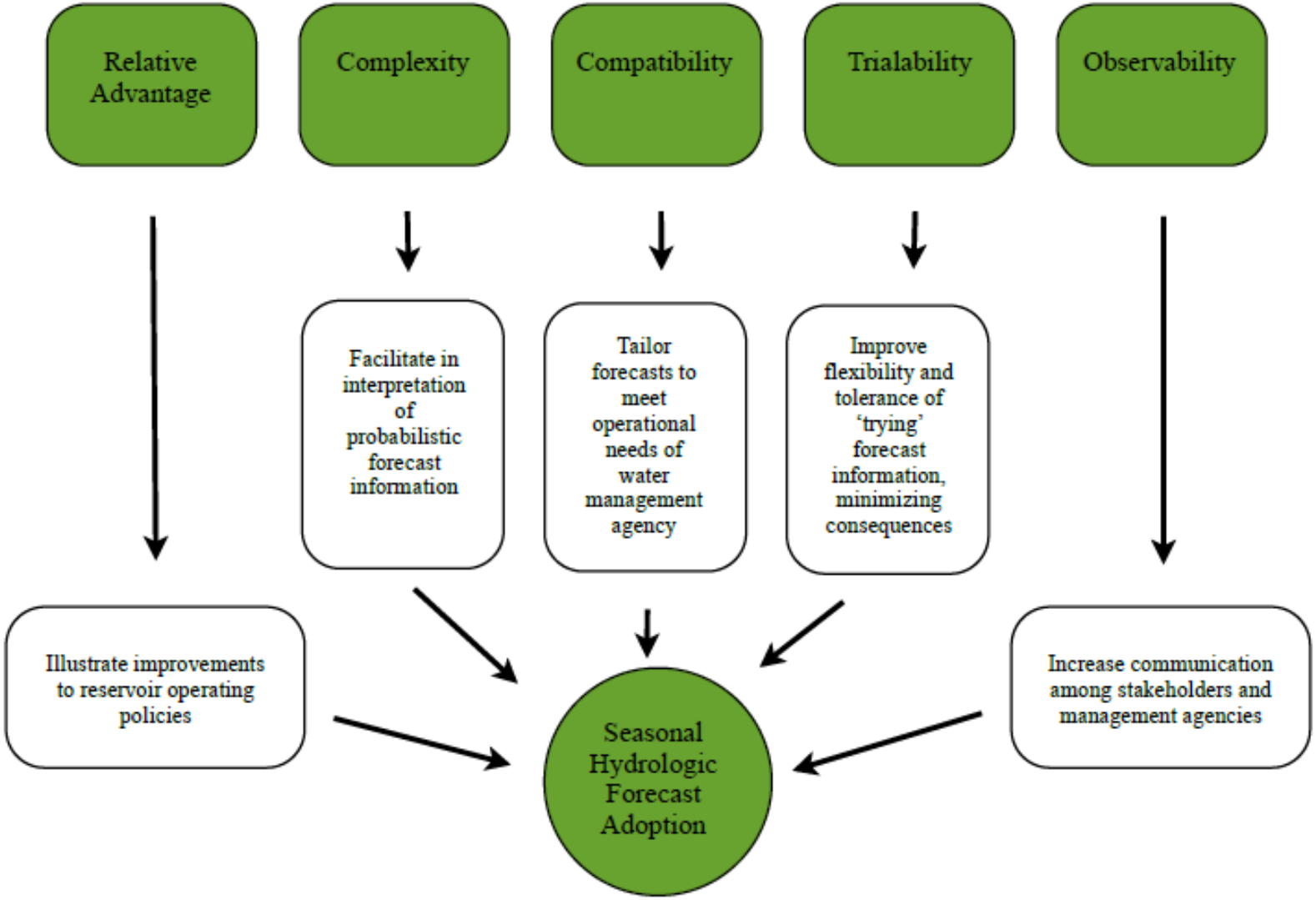
Oroville – Thermalito (Feather R., California),

Conowingo (Susquehanna, North East),

Seattle City Light (North Cascades)

Criteria to facilitate Adoption for Innovation

- Seasonal Hydroclimatic Forecasts as Innovations and the Challenges of Adoption by Water Managers (Whateley, Palmer and Brown, J. Wat. Res. Plan. Mgnt, 2014)



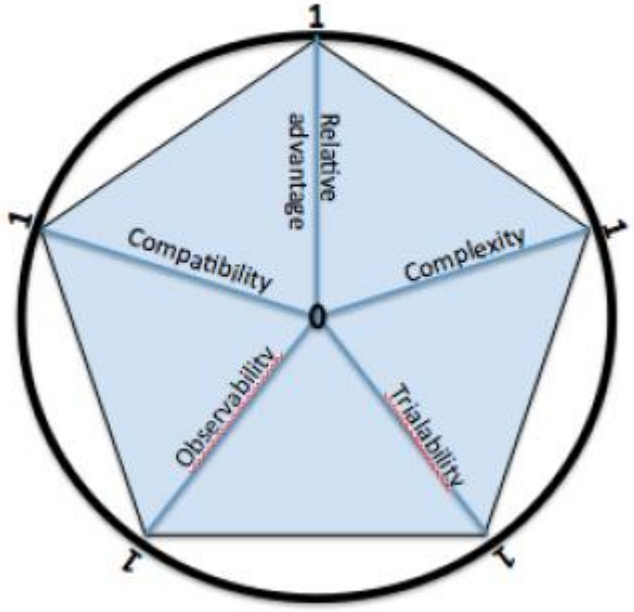
Quantifying Challenges of Adoption for Innovation in hydro-meteorological forecasts

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Seasonal Hydroclimatic Forecasts as Innovations and the Challenges of Adoption by Water Managers (Whateley, Palmer and Brown, J. Wat. Res. Plan. Mgnt, 2014)

Characteristics of Innovation

RECIPE FOR SUCCESS



Characteristics of Innovation in CRB

ACTUAL
Varies by basin

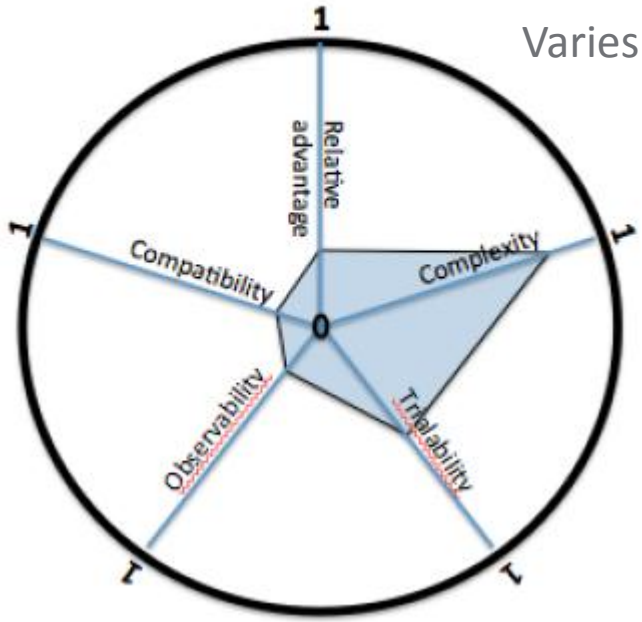
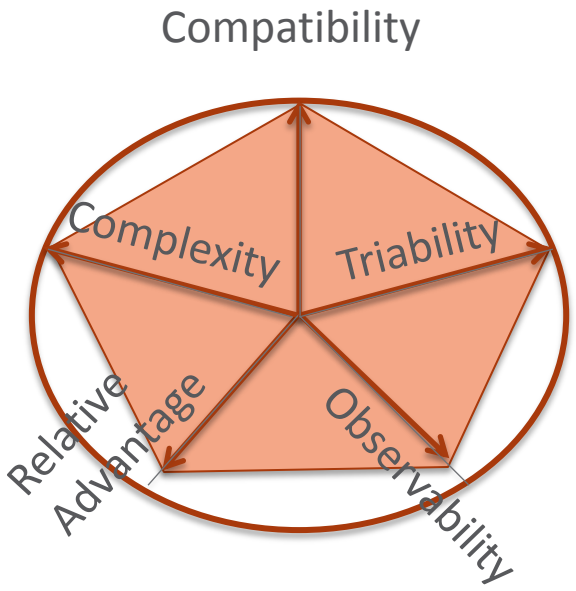


Figure 10. Characteristics of Innovation: understanding the influence of Rogers' five innovation attributes on adoption.

Challenge of Innovation in a multi-objective integrated system

- Complexity: High, but user interface
- Compatibility: possibly limited with existing operational system, but toolset ensures compatibility across multi scales and between objectives and new policies
- Triability: independent system, can be run in parallel with existing system
- Relative Advantage: based on hindcast, need business sensitive data from partners over a representative period
- Observability: multi scale and multi objective approach is meant to bring high observability between multiple stakeholders.



Focus on the hydro-meteorological forecast tool

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Observations: SWE, river flow, NLDAS precip, temperature, wind

Weather Forecasts GEFS, ESP

Pre-processor: Calibration and merging

Ensemble met forecasts

Data assimilation, particle filter

Hydrology model

Ensemble flow forecasts

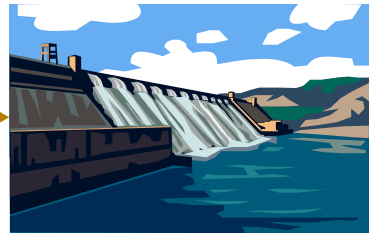
Post processor

Ensemble NATURAL flow forecasts

Users

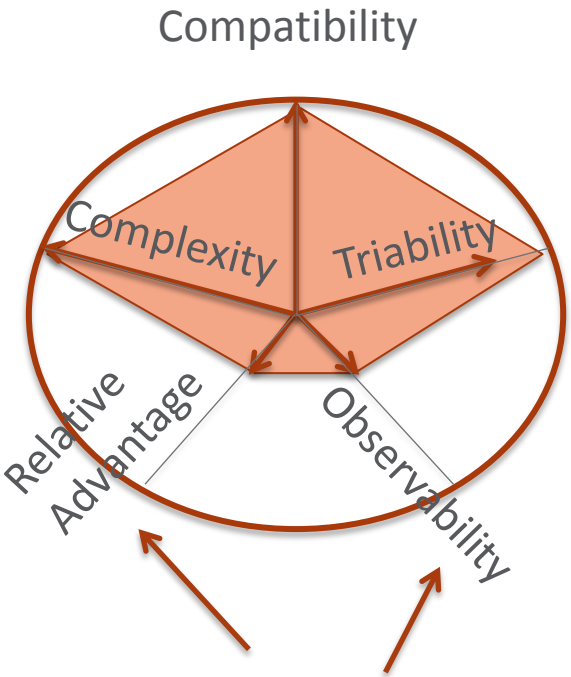
Forecaster role

Flow Forecast verification



Challenge of innovation for individual tools: Hydro-forecasting system

- Complexity: High but use own database for upload
- Compatibility: Very high – customized for all locations and forecast products required by other tools.
- Triability: operated by third party.
- Relative Advantage: based on hindcast, ensemble forecast verification. But ultimately, is through the toolset.
- Observability: multi scale and multi objective approach is meant to bring high observability between multiple stakeholders. See T. Veselka and T. Lowry's presentations.



Need integrated system to fully evaluate and facilitate adoption

Status of ensemble hydro-meteorological forecast systems for single objective systems

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

How close are we to generalize adoption of ensemble forecasts operationally?

Relative Advantage High

Complexity expected but ease-of-use , access AND understanding

Compatibility High

Trialability Medium

Observability Management of risk among one operator communication with responsible agencies

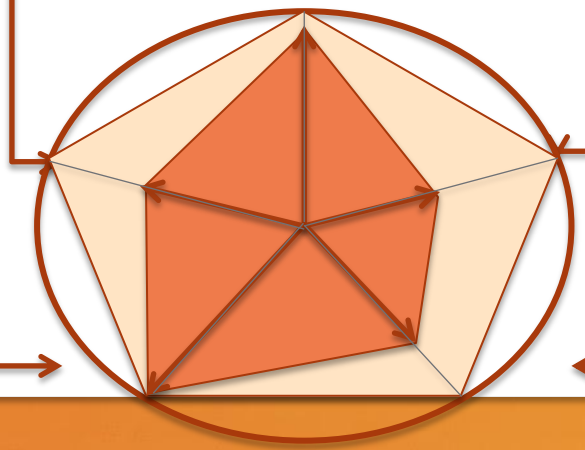
Facilitate in interpretation of probabilistic forecast information

Tailor forecasts to meet operational needs of water management agency

Improve flexibility and tolerance of 'trying' forecast information, minimizing consequences

Illustrate improvements to reservoir operating policies

Increase communication among stakeholders and management agencies



Status of ensemble hydro-meteorological forecast systems for multi objective systems

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

How close are we to generalize adoption of ensemble forecasts operationally?
Need more work

Relative Advantage
Need more applications

Complexity
expected but ease-of-use , access AND understanding

Compatibility High

Trialability Medium

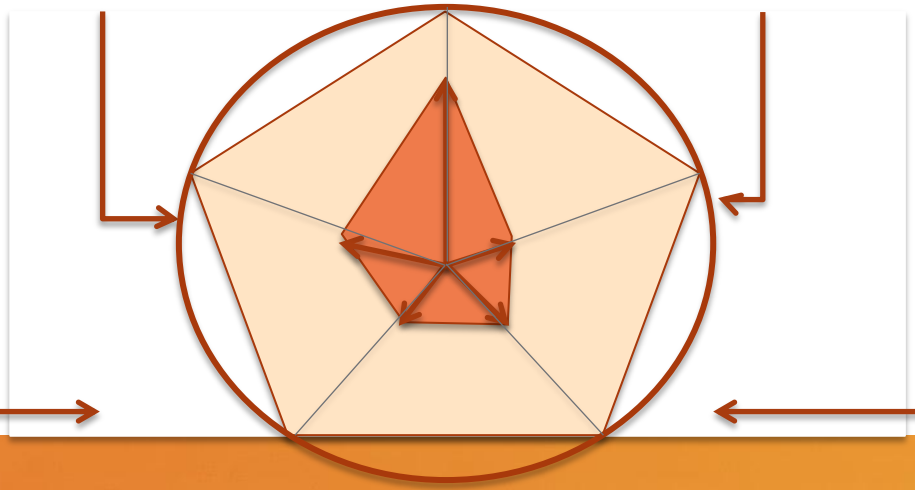
Observability
Management of risk among stakeholders – multi-objective
Need more application & research

Facilitate in interpretation of probabilistic forecast information

Tailor forecasts to meet operational needs of water management agency

Improve flexibility and tolerance of 'trying' forecast information, minimizing consequences

Illustrate improvements to reservoir operating policies



Increase communication among stakeholders and management agencies

Conclusion

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Science Implementation Plan:
  Transition toward multi objective applications and end users
  - Decision support system
  - Across temporal and spatial scales
  - Develop a standard approach for the adoption of innovation in order to address end-user challenges and direct research efforts: observability and relative advantage.

Thank you

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Contact: Nathalie.voisin@pnnl.gov
- Supported by the Department of Energy Waterpower Program, Water Use Optimization Toolset.