Emerging Reclamation Methods for Incorporating Climate Change into Dam Safety

National Dam Safety Program Technical Seminar | February 22, 2023

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Supporting information provided by Reclamation TSC 8210/8211 staff

FEMA

Outline

- Existing methods for developing flood load estimates for dam safety studies

- Adapting to account for effects of climate change
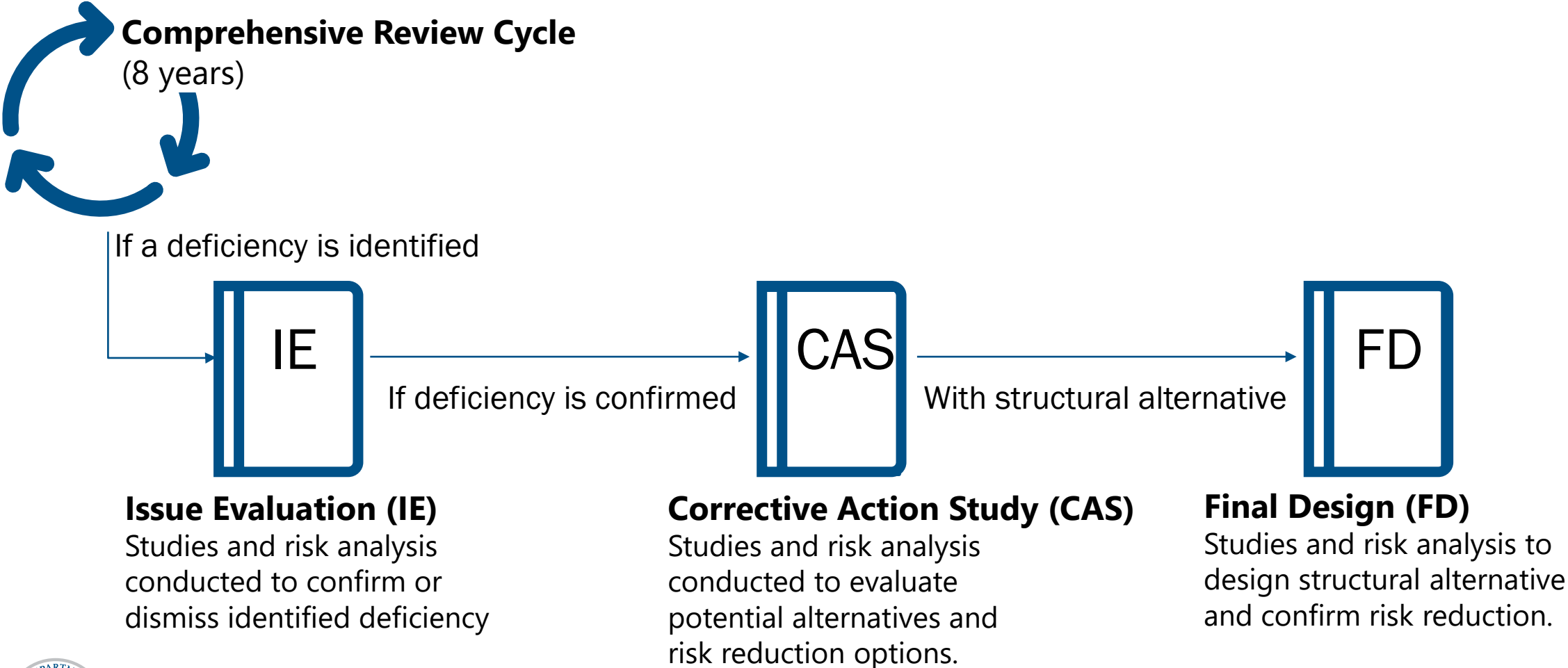
- Forecast-Informed Reservoir Operations (FIRO)

Dam Safety Flood Hazard Studies

Existing Methods
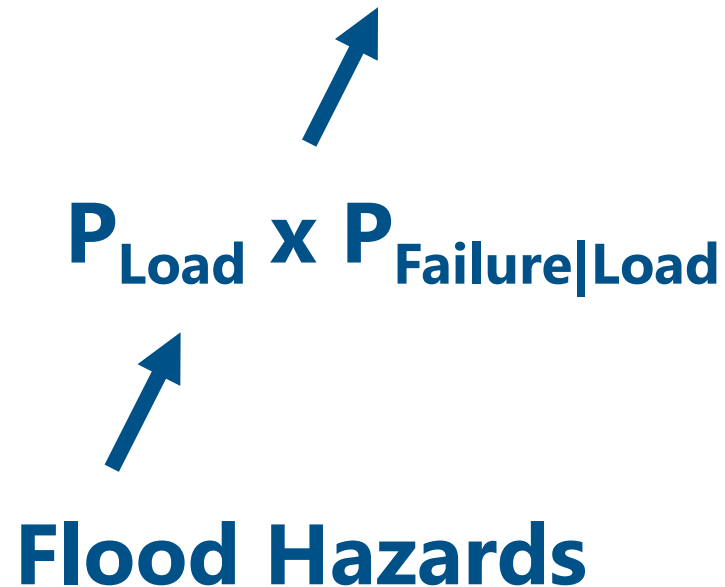
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Existing Methods to Estimate Flood Hazards

Comprehensive Review Cycle
(8 years)

If a deficiency is identified

IE → If deficiency is confirmed → CAS → With structural alternative → FD

Issue Evaluation (IE)
Studies and risk analysis conducted to confirm or dismiss identified deficiency

Corrective Action Study (CAS)
Studies and risk analysis conducted to evaluate potential alternatives and risk reduction options.

Final Design (FD)
Studies and risk analysis to design structural alternative and confirm risk reduction.

What is Flood Risk?

Flood Risk = Annual Failure Probability x Consequences

$$P_{Load} \text{ x } P_{Failure|Load}$$

Flood Hazards

FEMA

Existing Methods to Estimate Flood Hazards (2)

Deterministic Methods
Seek to define the upper bound of flood hazards

Probabilistic Methods
Seek to define flood hazards based on probabilities

Let's Compare

Deterministic Methods

- Upper bound estimate of floods (i.e. IDF or PMF)

- Maximized precipitation applied to hydrologic model to produce maximized hydrology

- Considerable subjectivity and uncertainty in methods

- Unknown probability = unknown risk

Probabilistic Methods

- Probabilities associated with flood magnitudes

- Streamflow-based and rainfall-based approaches

- Streamflow-based
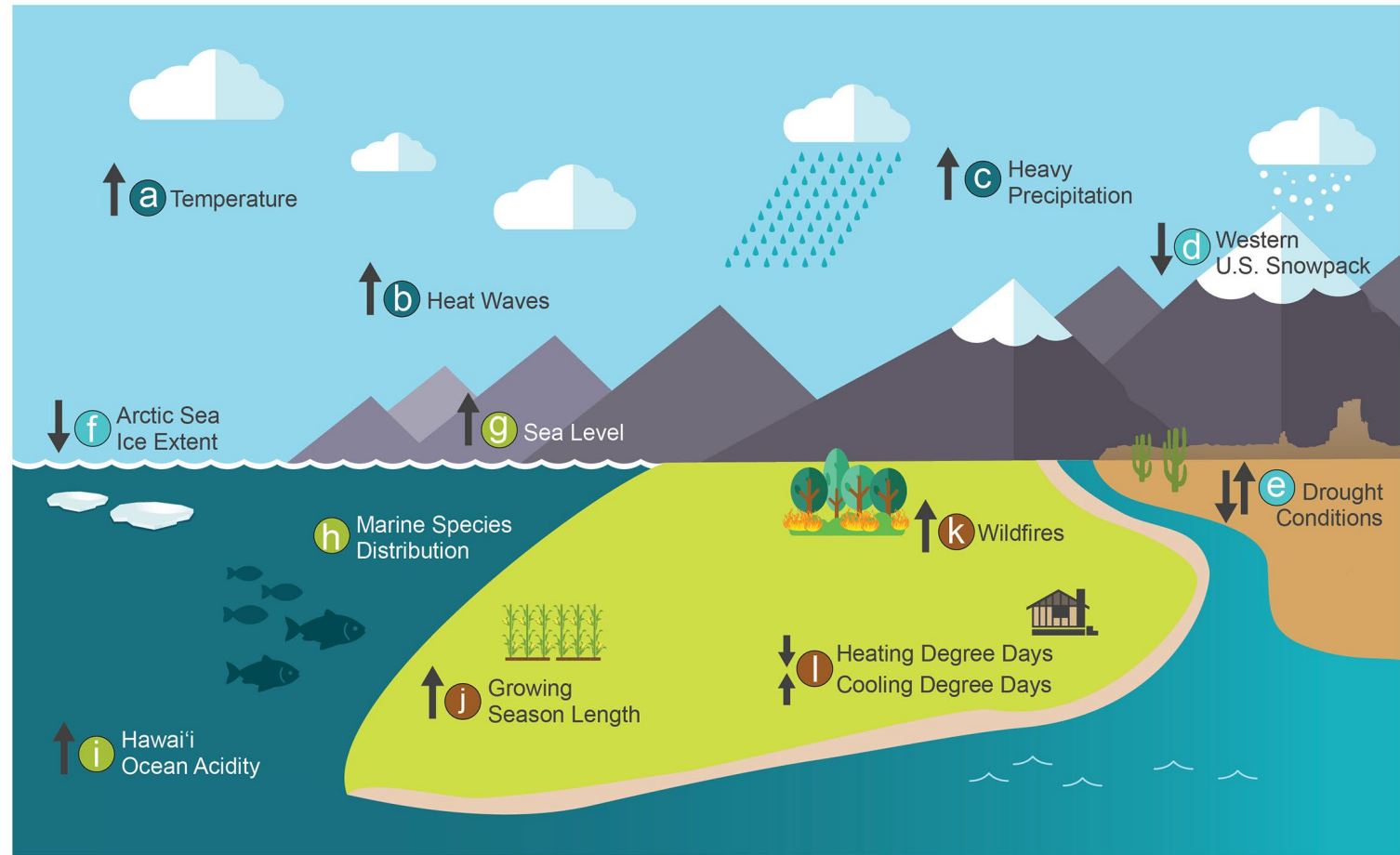 - HEC-SSP, PeakfqSA, RMC-BestFit

- Rainfall-based
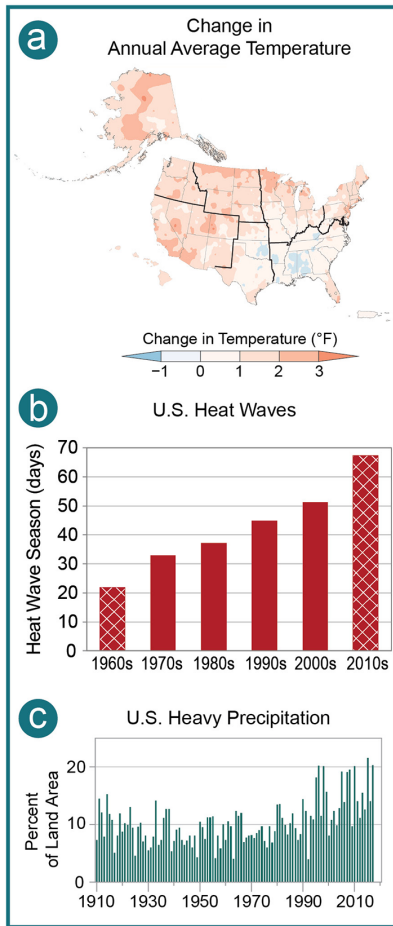 - AEP-neutral
  - Stochastic

Dam Safety Flood Hazard Studies (2)

Adapting for Climate Change

Indicators of Climate Change

Fourth National Climate Assessment (2018) – US Global Change Research Program
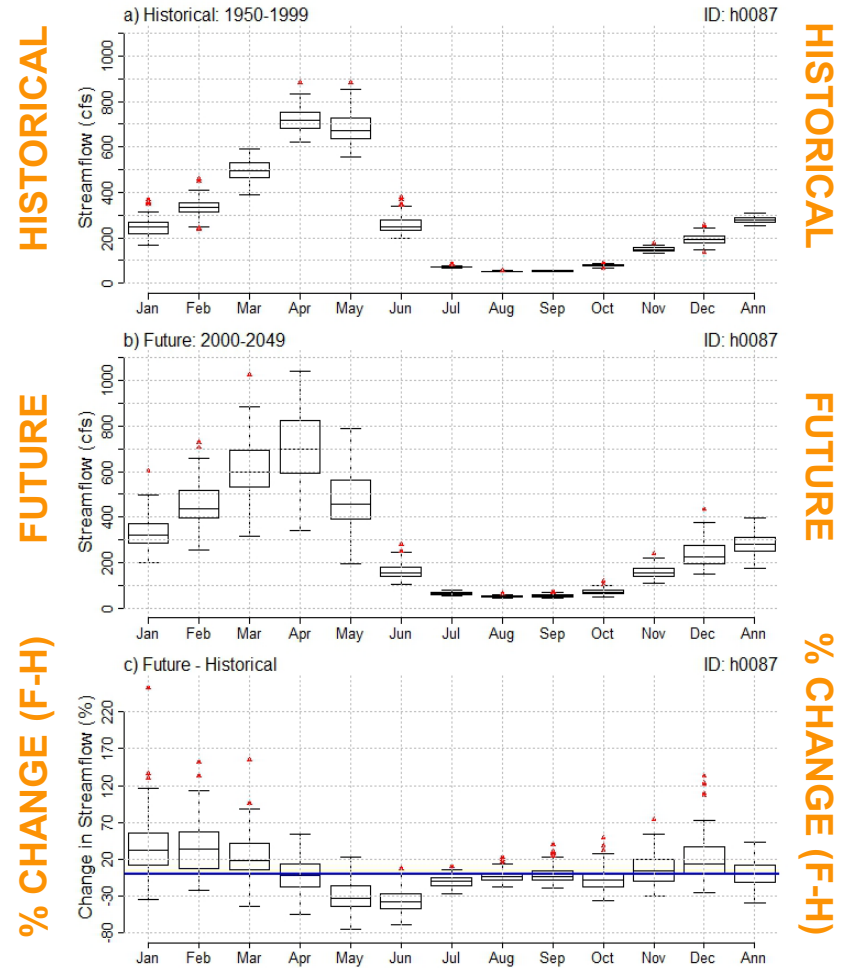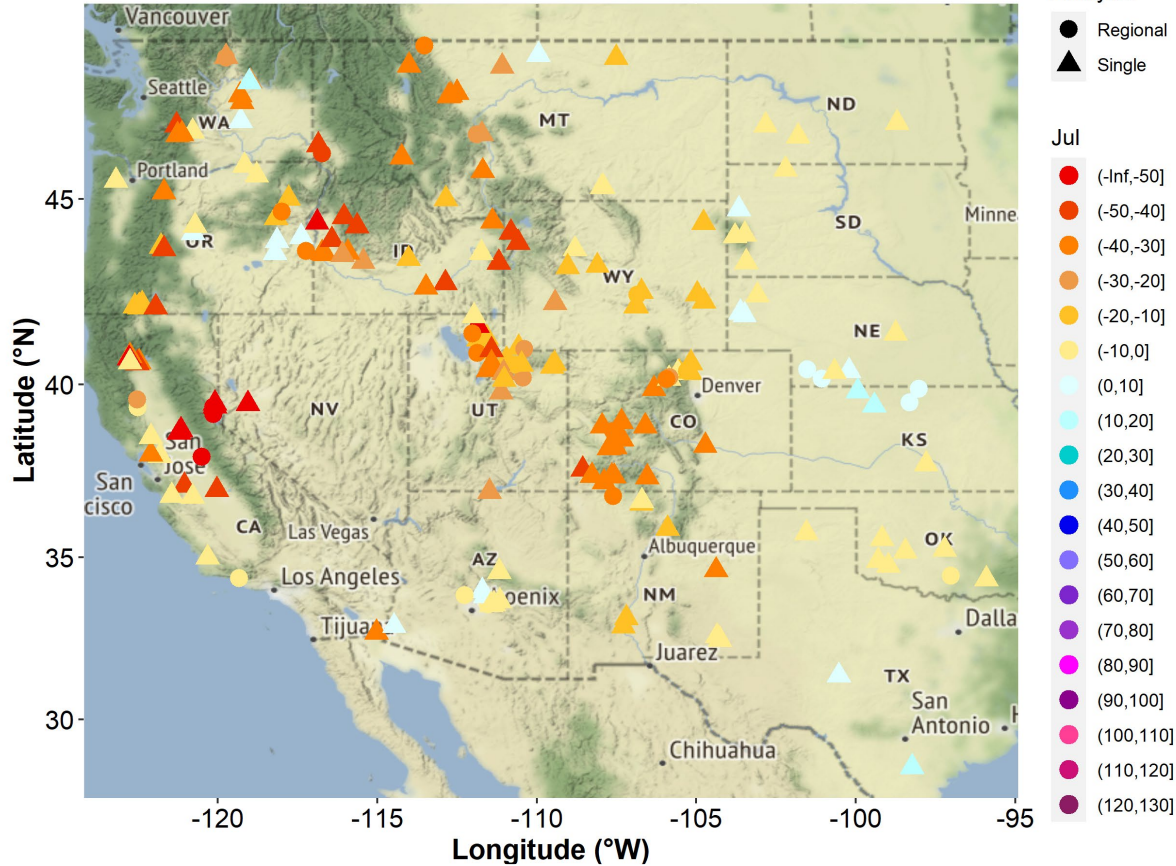
Incorporating Climate Change in Risk Framework

- Climate Change in Flood Hazard Analysis

  - How to select climate projections that appropriately represent extreme storm drivers

  - How to project streamflow (e.g., whether to directly use streamflow projections or use climate forcings to project streamflow)

  - What time horizons should be considered (e.g., 50 years: 2070?)

  - How to quantify and reduce uncertainty

- Population Growth in PAR

  - How to include population growth and settlement density

  - How climate related impacts may change settlement areas
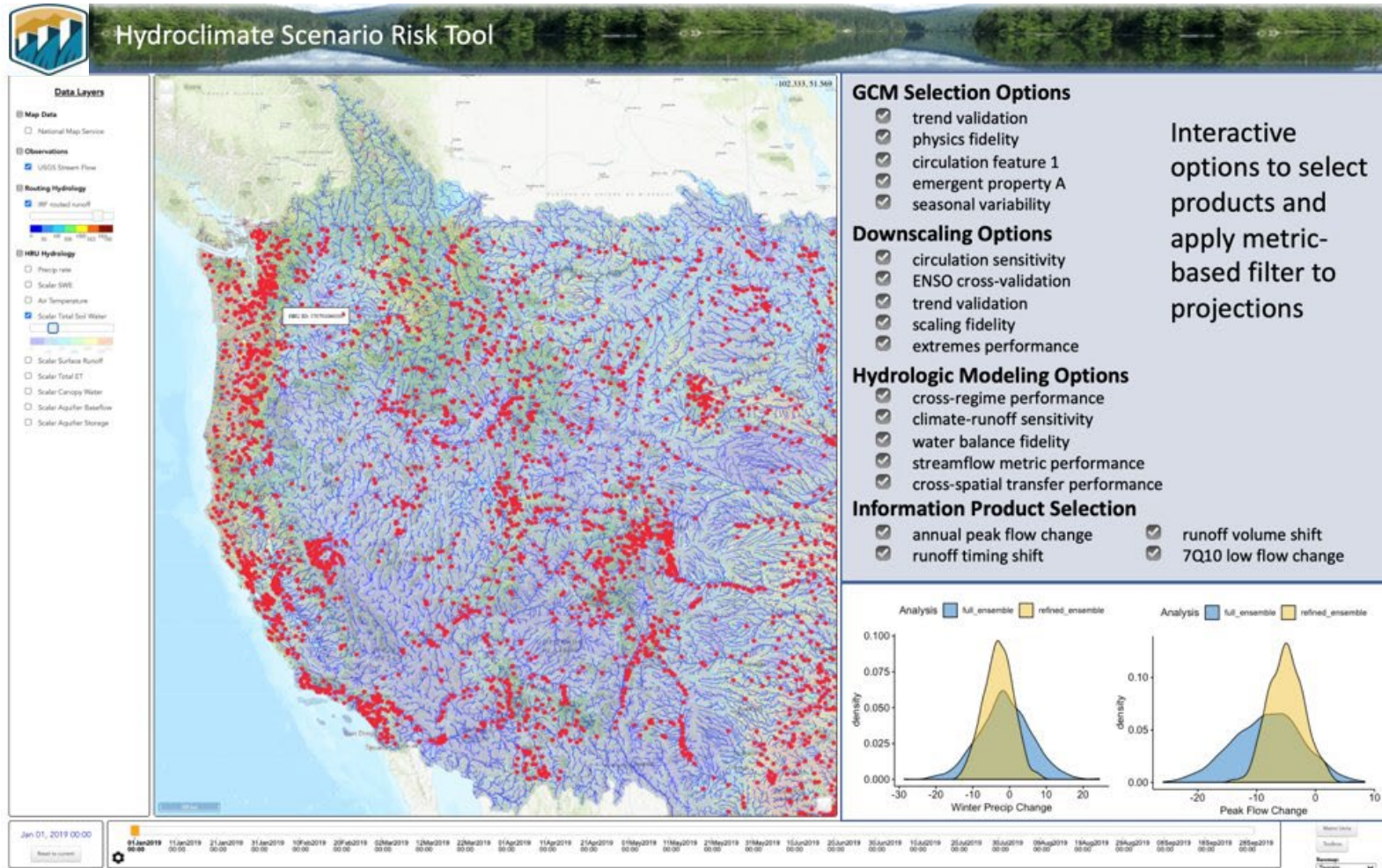
  - How to account for secondary effects

# Supporting Dam Safety: BCSD5 Data

July Percent Changes

Incorporating Climate Change in CRs

[Andy Newman, NCAR]

Incorporating Climate Change in IEs

- Stochastic storm transposition

  - Randomly "moving" storm events within predefined transposition domain

- Combing outputs with process-based hydrologic models to develop future flood frequency estimates

  - WRF-Hydro

[Dan Wright, UW-Madison]
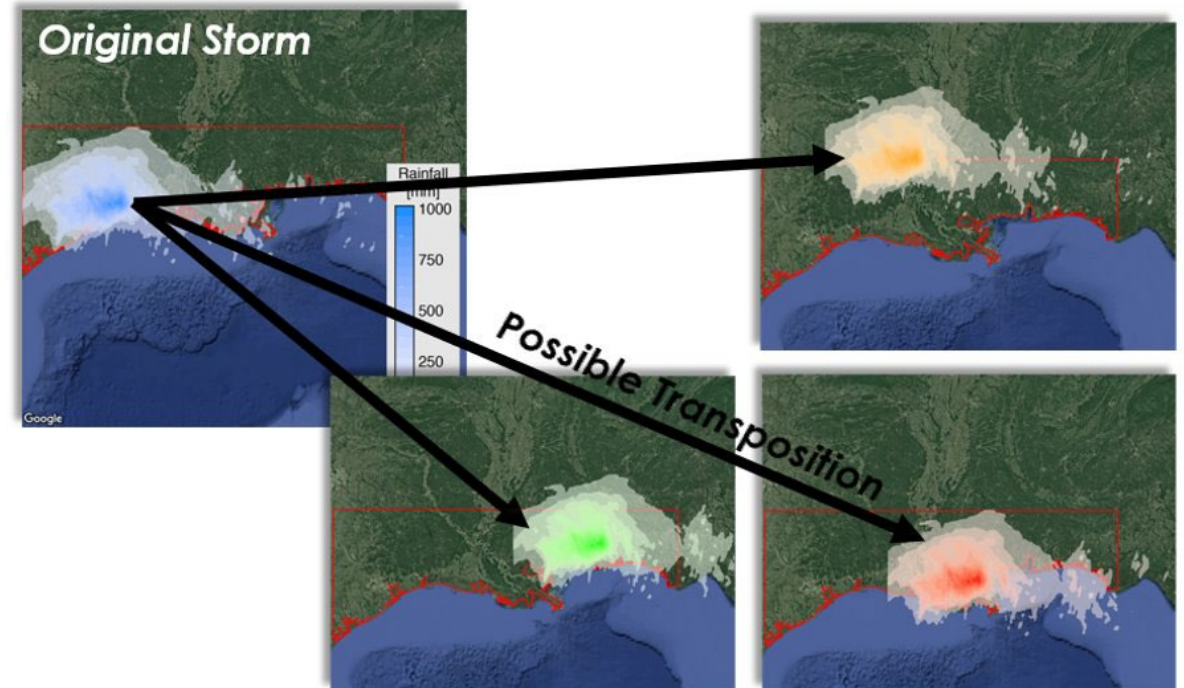
Incorporating Climate Change in Precipitation-Frequency (2)

- L-moments using extreme precip from climate models (unlikely)

- Scale at-site mean precip by some factor based on future forcing mechanisms

- Scale parameters of a statistical distribution based on future forcing mechanisms

- Determine changes in seasonality from climate model output
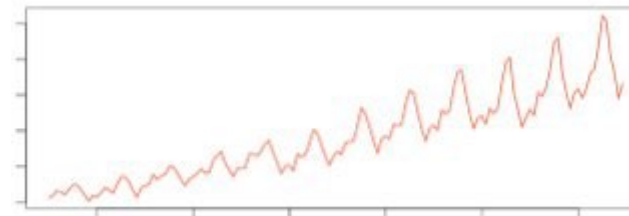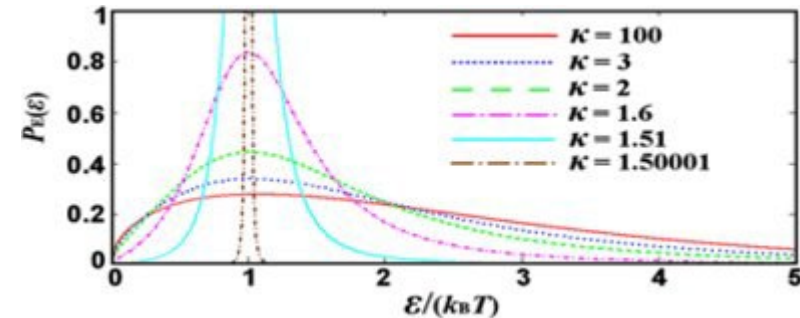
Forecast-Informed Reservoir Operations

FIRO

Adaptation Strategies

Long-term

- Programmatic Changes to Risk Analyses

- Trend Analysis

- Stochastic Hydrology
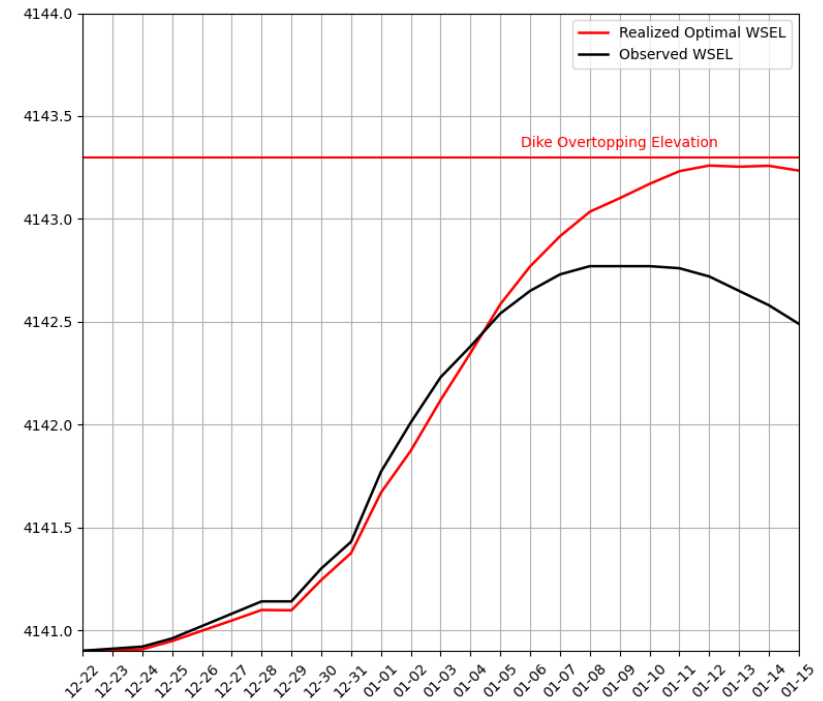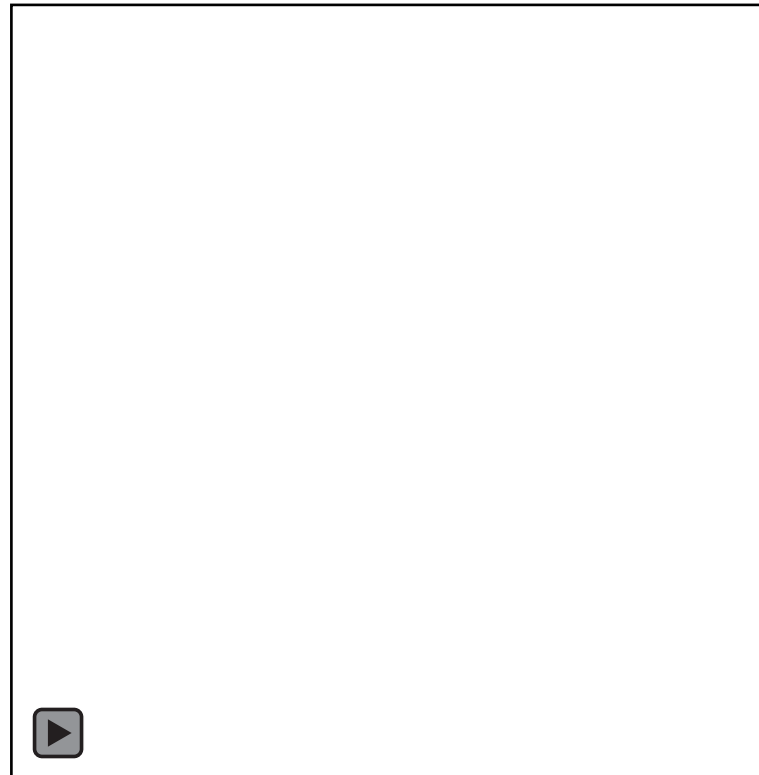
- Hydrologic Projections

Short-term

- Forecasting

- Operations Changes

FIRO

- Integrated Water Resources Planning

FIRO and Dam Safety

- Historically focused on water management

- Provides dam safety benefit when using risk-based framework

Types of FIRO

- First Kind – Informal

  □ Forecasts are used to inform operator expert judgement

- Second Kind – Reanalysis

  □ Hindcasts are used to evaluate operation guidelines for changes

- Third Kind – Real-time Operations

  □ Forecasts are coupled with hydrologic/hydraulic/decision models to calculate real time optimal solutions

- -

- Extension – Climate Adaption

  □ Climate projections are used to evaluate operations guidelines

Stages of FIRO

Precipitation Forecast Skill + Hydrologic Model Skill + Operational Benefit = FIRO
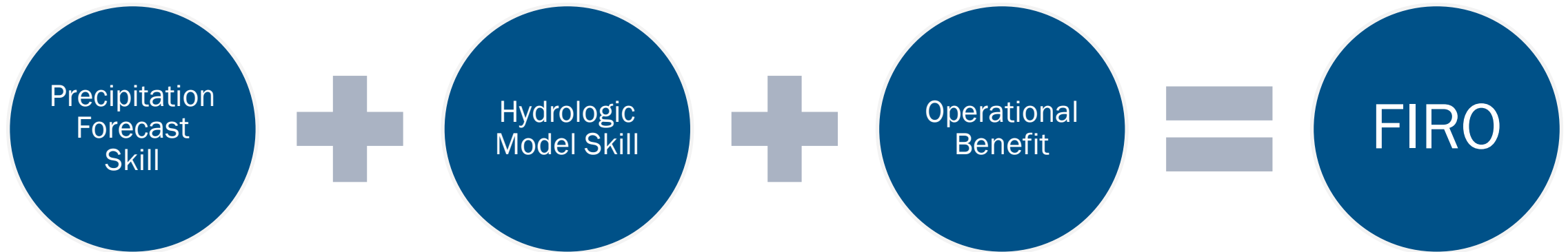
Forecast Metrics

- **Accuracy**
  - □ Error

- **Reliability**
  - □ Average agreement

- **Discrimination**
  - □ Greater prediction frequency

- **Resolution**
  - □ Magnitude differences

Correlation	Pearson Correlation
	Spearman Correlation
	p Value
Distance	MAE
	ME
	MSE
	RMSE
Probabilistic	Brier Score
	CRPS
	CRPSS
	Discrimination
	Rank Histogram
Contingent	Hit Rate
	Miss Rate
	False Alarm Rate
	Success Ratio
	Relative Operation Characteristic

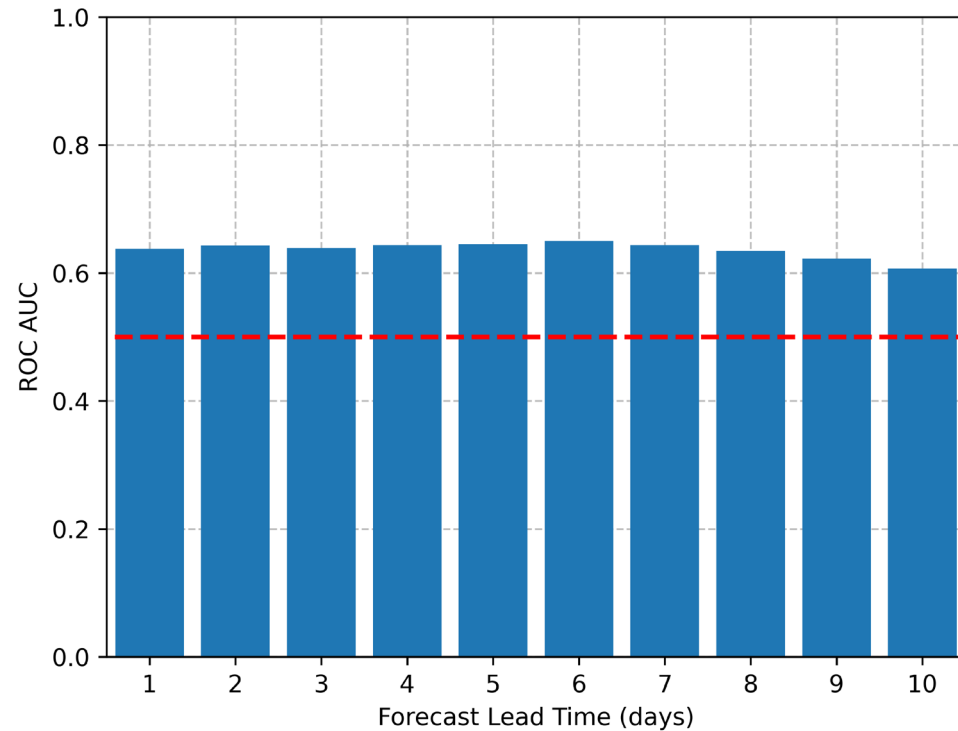# Relative Operation Characteristic - Precipitation
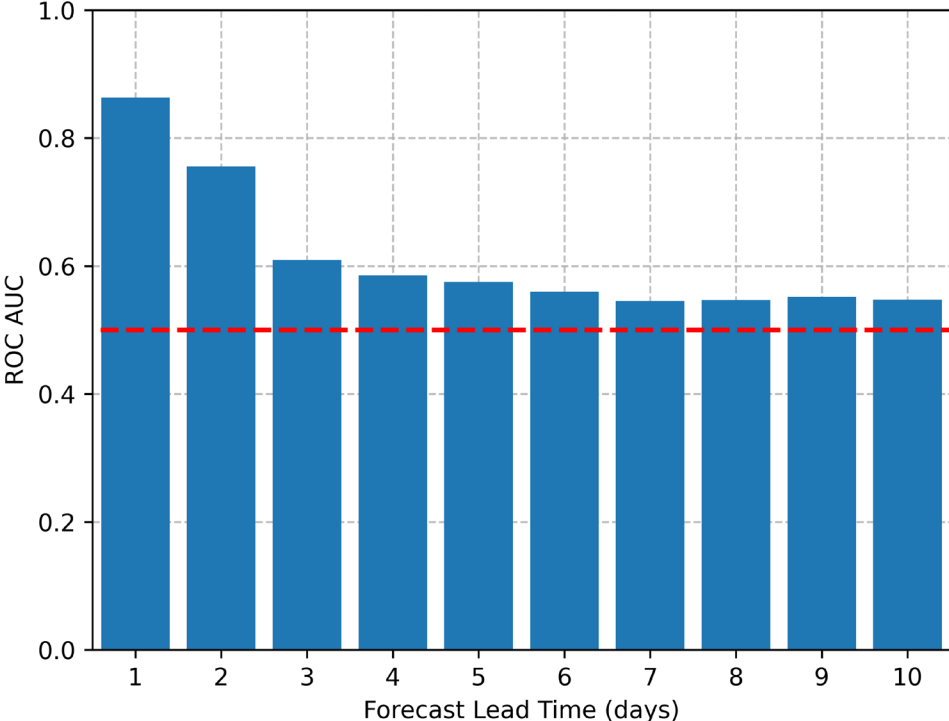
- How well can the forecast discriminate between events and non-events?

Relative Operation Characteristic - Streamflow

- How well can the forecast predict streamflow?

Thank You

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