Operating for Hydrologic Change – Adapting to Changing Distributions

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Presentation Outline

• Water operation decision timescales
• Use of historical and forecast information in operational decisions
• Discontinuity in approaches across timescales largely due to skill
• Suggestive changes in distributions can be useful for improving decisions even at longer lead times
• Examples of adapting operations to changing distributions
Water Operations and Decision Time Scales

- Weather Forecasts
  - Skill from initial state
  - Flood Operations
  - Real-time Flood Ops
  - Emergency Management

- Seasonal Outlooks
  - Skill from climate forcing
  - Seasons
  - Months
  - Days
  - Hours
  - Minutes

- Decadal Predictions
  - Forecast Uncertainty
  - Years

- Climate Projections
  - Decades
  - Infrastructure Development
  - Operations and Resource Planning
  - Environmental Releases/Flows
  - Water Allocation Decisions
  - Hydropower Decisions
  - Emergency Management
  - Real-time Flood Ops
  - Flood Operations

Decision Timescales
Short- to Medium-Term Water Operations

- Forecast skill is derived from **initial state** (atmosphere, oceans, watersheds, etc)
- RFCs provide deterministic and ensemble information that is used in water operations modeling and decision-making
But What about Annual to Decadal Scales?

- Forecast skill is derived from mix of **initial state and forcings**
- Decadal predictions and climate projections are available and are suggestive of the “change”
- Three common approaches … based on perception of skill

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**No Confidence in Annual/Decadal Skill**

- Use of historical traces

**Partial Confidence in Annual/Decadal Skill**

- Initial state of watershed snow/moisture storage
- Models based on historical climate and deterministic forecasts

**Confidence in “Change” at Annual/Decadal Scale**

- Projection information
- Blends of projection and historical
- Change results are commonly utilized
Intersection of Need and Skill – The Goal

What is Skillful?

Global prediction
Regional/local prediction
Climate-related impact prediction

Intersection of predictive capacity with stakeholder needs
Communication of decision-relevant predictive information and uncertainties

What is Needed?

Morss et al. (2018)
Colorado River Basin Water Supply and Demand Study

• Study Objective
  - Assess future water supply and demand imbalances over the next 50 years
  - Develop and evaluate opportunities for resolving imbalances

• Study conducted by Reclamation and the Basin States (WY, CO, NM, UT, AZ, NV, and CA) in collaboration with stakeholders throughout the Basin
How will the future unfold?
Scenario Planning: Addressing an Uncertain Future

- The path of major influences on the Colorado River system is uncertain and cannot be represented by a single view.

**Water Supply Scenarios**
- Observed Resampled
- Paleo Resampled
- Paleo Conditioned
- Downscaled GCM Projected

**Water Demand Scenarios**
- Current Projected
- Slow Growth
- Rapid Growth
- Enhanced Environment
Projections of 2011-2060 Average Natural Flow at Lees Ferry

- **Observed**: 102 Traces, Mean = 15002
- **Paleo**: 1244 Traces, Mean = 14675
- **Paleo Conditioned**: 1000 Traces, Mean = 14937
- **Climate Projections**: 112 Traces, Mean = 13588

Climate Projections represent a long-term mean roughly equal to the recent multi-decadal drought (new normal?)

Box represents 25\textsuperscript{th} – 75\textsuperscript{th} percentile, whiskers represent min and max, and triangle represents mean of all traces.
Detailed Investigation of CMIP3-CMIP5 and Isolated Warming Impacts

Continuing precipitation uncertainty

Warming is Consistent and Robust
Modernizing California’s Water Systems …

Increasing Water Storage

Prop. 1 water storage projects
California water officials on Tuesday approved $2.7 billion of Proposition 1 bond money for new water storage projects.

1. Sites project: $816 million
   New $2 billion off-stream reservoir tapping the Sacramento River.
2. South Sacramento Co. conjunctive use program: $281 million
   New $355 million effort to bank treated wastewater underground.
3. Los Vaqueros Reservoir expansion: $489 million
   Additional $90 million enlargement of off-stream reservoir.
4. Pacheco Reservoir expansion: $485 million
   New $90 million reservoir enlargement.
5. Tempanales Plan: $171 million
   New $3 billion reservoir on the San Joaquin River.
6. Kern Farm: $68 million
   $17 million ground water bank.
7. Willow Springs water bank: $95 million
   $33 million expansion of ground water bank.
8. Chino Basin conjunctive program: $207 million
   $45 million to bank treated wastewater underground.

Delta Conveyance

Central Valley Flood Protection Plan
2017 Update

Flood Protection
Characterizing Climate Change Impacts – Atmosphere to Ocean: Supporting infrastructure adaptation, operations planning, resource protection

1. Emissions Scenario
   - Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003

2. Climate Simulations
   - IPCC emission scenarios
   - CMIP3 & CMIP5 simulations
   - Statistically downscaled

3. Spatial Downscaling
   - VIC hydrologic model

4. Hydrologic Models
   - CALSIM II hydrology and operations model, water temperature models, salmonid life cycle and mortality models, hydropower generation, etc.

5. Operations Models

6. Bay-Delta Models
   - UNTRIM, RMA, DSM2 estuary models

Sea level change

Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003
California Resources Agency/California Water Commission

Statewide climate scenarios and data products for water planning
Projected Changes in Hydrograph Characteristics

American River at Folsom

- Peak flows are projected to occur significantly earlier in the year
- Maximum annual 1-day and 3-day flows are projected to increase
- Storm durations are projected to decrease in all major watersheds

Merced River at Lake McClure
Central Valley Flood Protection Plan (2017 Update)
Understanding Changing Flood Risks in the California Central Valley under Climate Change

- Future climate different from historical climate
  - Warmer temperatures
  - Increasing precipitation extremes
  - Sea level rise

- Flood planning, long-term resiliency

- Watersheds with high sensitivity to warming

- Adaptation measures
  - Improve storage operations
  - Flood bypass expansion
  - Levee protection and upsizing
  - Managing land uses
Understanding Decision-Climate Interactions on Decadal Scales

Decadal Prediction

Climate Change Projection
Temperature is Skillful

Better than a guess
Worse than a guess

Years 1-5

Years 5-9
Precipitation is not very skillful . . . yet

Years 1-5

Years 5-9

Better than a guess

Worse than a guess

DRAFT
Decadal Streamflows Predictions

Sacramento and San Joaquin Eight River Basins

Pilot Study in Central Valley

- Utilizing decadal predicted anomalies in T and P for future years 1 - 9
- Adjusting the historical 100-year distribution for predicted anomalies
- Resampling distribution to develop ensembles of future years 1 - 9
Decadal Predictions Supporting Hydrological Indices

Historical Hydrology
Decadal Predictions Supporting Hydrological Indices

Eight River Index

Year 1-9

Statistics for SAC_4R1_OBS_DPMOD
- Mn..1% / 99%. Max
- 1% .5% / 95% .99%
- 25% .35% / 65% .75%
- 35% .45% / 55% .65%
- 5% .15% / 85% .95%
- 45% .55%
- 15% .25% / 75% .85%
- 50%
Reconstructed Streamflow (Example only)

Historical Reconstructed (1921 - 2010)

Decadal Prediction (2017 - 2025)

- 90th Percentile
- Median
- Min
- Max
Operationalizing Decadal-Scale Predictions?

**History as Indicator of Future**

**Decadal Predictions as Predictor**

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The graphs illustrate the CVP North of Delta Storage over time, with green lines representing all realizations and red lines indicating specific predictions.
In Closing

• Methods for use of higher absolute skill forecasts (days to weeks) are commonly used in water operations applications

• Long-range climate projections are commonly applied to understand future “changes”

• Seasonal to decadal scale predictions suffer from lack of robust predictive skill, but anomalies may still be suggestive of future trends

• Methods developed from use of decadal-scale prediction information blends approaches to change the distributions
Questions?

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