Photo credit: John Hannon, Reclamation

CWEMF

Put Things into Perspective:
- Characterize and Communicate Uncertainty

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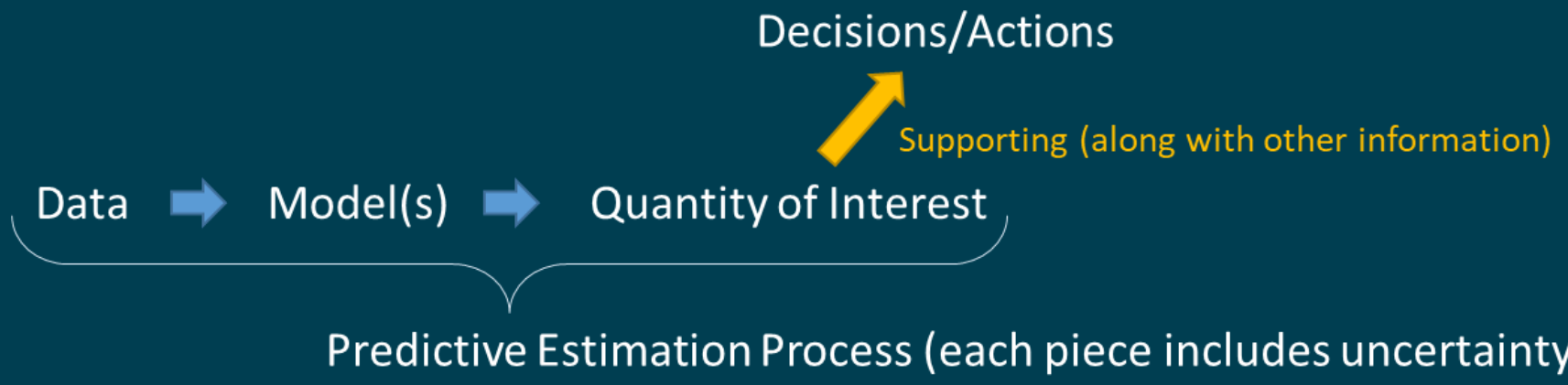
Why do We Care about Uncertainty?

- Properly informed decisions/actions require understanding of uncertainty associated with the predicted quantity of interest (for WTMP: water temperature).



Sources of Uncertainty for WTMP

Source	Where to Find it	Potential implication
Input uncertainties - calibration	Initial conditions and boundary conditions	Initial conditions and boundary conditions provided using measured data would be subject to measurement errors and uncertainties. This includes limited accuracy of the sensors, and in some cases, the time and location of measurements.
Input uncertainties - forecast	Initial conditions and boundary conditions	Initial conditions and boundary conditions provided using forecast data would be subject to the prediction/forecast errors and uncertainty from the corresponding predictive estimation process. Forecast operations are included herein.
System error or discrepancies	Results from using a mathematical representation describing a phenomenon in the model	For the WTMP this is focuses on geometric representation, parameterization or representation of unique attributes (e.g., TCD, submerged dam), and multiple models.
Parameter uncertainty	Designated parameters for the model representation	Parameter uncertainty is usually quantified through calibration using known values (or measured data) and are thus, subject to uncertainty.
Model propagation uncertainties	Inherited from upstream models, passed to downstream models	Accumulation and/or cancelation of error/uncertainty.

WTMP - Activities Developing Procedures to Address Uncertainty

- **Identify sources of uncertainty**
  (e.g., data, models)
- **Estimate and prioritize uncertainty**
  (e.g., datasets and models)
- **Characterize aggregated uncertainty of modeling results**
  (e.g., forecasts, hindcasts)
- **Communicate uncertainty**
  (e.g., forecasts for real-time operational decision-making, hindcasts for learning and strategic investment to improve long-term effectiveness in forecasting)

WTMP - Handling Uncertainty in Datasets and Models

Build Models | Test Models

- **Calibration Mode**
  - Quantification of uncertainty associated with the data and parameter estimation was included in calibration (e.g., calibration parameters)
  - Resulting predictive errors were assessed using model performance metrics to determine the fitness and acceptability of the calibrated model.
  - Only calibrated models with acceptable predictive errors are used for applications.

Apply (Calibrated) Models

- **Forecasting Mode**
  - Uncertainty of the calibrated model is accepted as is for contributing the overall uncertainty of model results.
  - Initial and boundary conditions (i.e., data) are the focus for examining uncertainty of the predictive/ forecasting estimates

WTMP – Approach to Characterize Uncertainty of Model Results

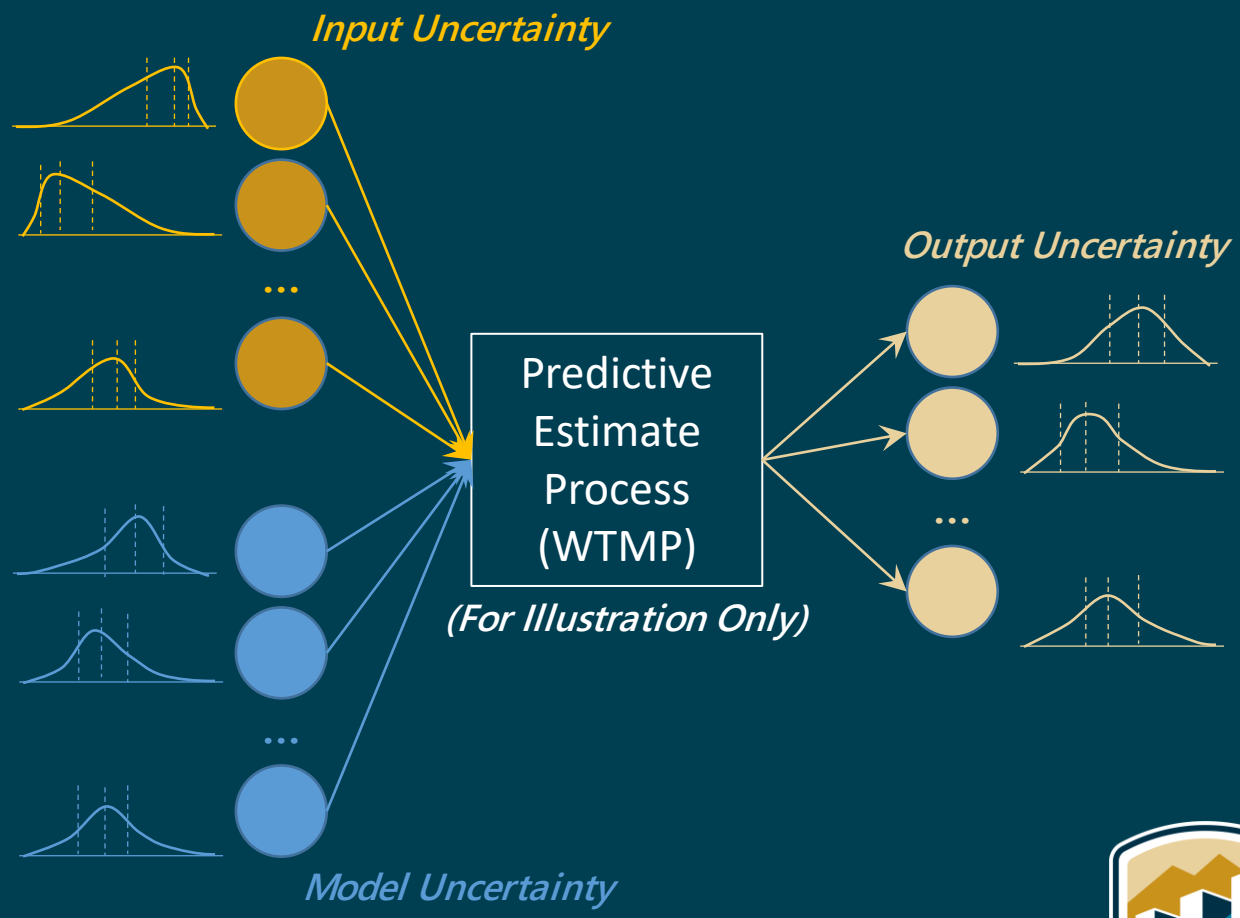
- **Active** development area for the WTMP team

Focused Area	Specific Targeted Data/Input	Considerations of Investments (ongoing, planned, and potential) for Reducing Uncertainty
Initial conditions	Reservoir storage and stage Reservoir water temperature profile	Measurement technology, frequency, locations and other techniques
Boundary conditions	Meteorological conditions Hydrological conditions Inflow water temperature	Research and model development for predicting various boundary conditions (e.g., Reclamation's active project with NCAR for forecasting meteorological conditions of the Sacramento/Trinity system.

Availability of these improved data and their associated uncertainty would affect how we may characterize uncertainty of WTMP model results.

WTMP – Approach to Characterize Uncertainty of Model Results (cont'd)

- **Propagation of uncertainty** is real and a challenging topic (an active research area)
  - model uncertainty (inherited from accepted calibrated models)
  - Input uncertainty (from initial conditions and boundary conditions), which is further subject to the uncertainty for generating these data.



WTMP – Approach to Characterize Uncertainty of Model Results (cont'd)

- WTMP's Anticipation:
  - Focus on the global uncertainty for model results for practical use, but not the theoretical derivation of how error accumulation, cancellation, and even correction happen throughout the predictive estimation process.

- Implications for assessing water temperature conditions using model results may be different depending on the following:
  - Sizes of reservoir
  - Conditions of river reaches
  - Other localized factors
  - More importantly, what is the purpose of these model applications and what are the decision points (i.e., WHY?)

Communication of characterized uncertainty needs to fit the purpose.

WTMP – Approach to Characterize Uncertainty of Model Results (cont'd)

- A range of approaches under consideration

Single Scenario Forecast	Selective Scenario Forecasts	Ensemble forecasts	Multi-model Ensemble forecasts
One representative realization of the future scenario (representative…hopefully)	Currently used multiple but selective exceedance points (e.g., 50%, 75%, 90%, 95%, 99%) for hydrologic and meteorological conditions, with paired water temperature boundary conditions. Scenarios are not considered equally possible.	A large number of scenarios with a representative range and probability of hydrologic and meteorological conditions. All scenarios are considered equally possible.	Using different models in the predictive estimation process for ensemble forecast.
Not used as it provides insufficient information for modern decision making, but implementable in the WTMP	To be implemented in WTMP. Results can be used to bracket possible outcomes with risk consideration, but no formal risk assessment can be done. Not probabilistic.	Could be implemented in WTMP in the future [the platform can accommodate it].	Same as ensemble forecasts. Potential for future inclusion in WTMP driven by the needs and benefits of using different models.

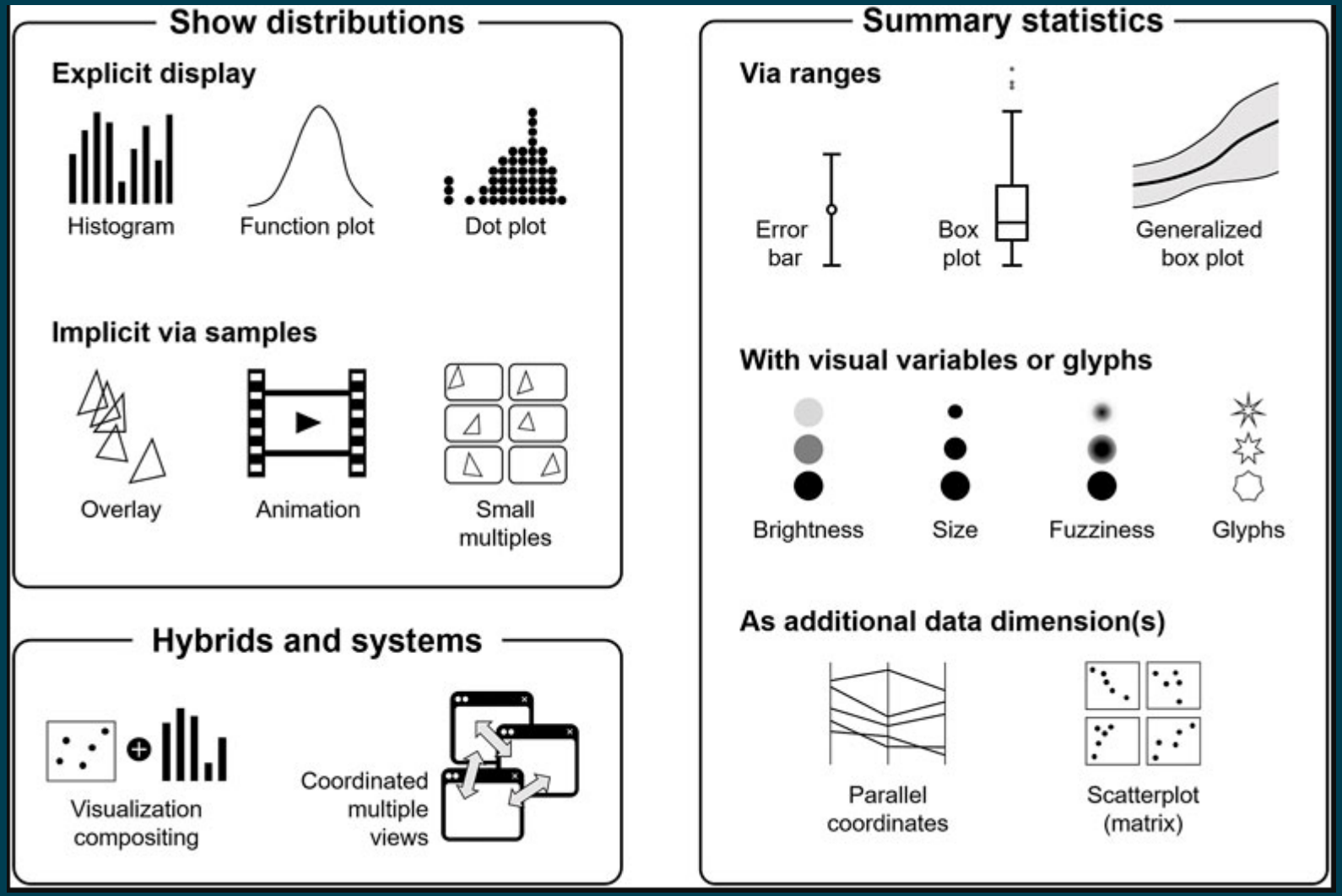
- Others (e.g., position analysis, Monte Carlo analysis)

The capacity and flexibility of the platform can accommodate most of the above, if not all. This provides opportunities for a focused initial implementation with subsequent upgrades as products of other investments become available.

Communicating Uncertainty

- Wide range of options
  - Tabular
  - Graphical
  - Other
- Reporting

Communication of characterized uncertainty needs to fit the purpose and avoid misleading inferences.



https://www.frontiersin.org/articles/10.3389/fbinf.2022.793819/full

WTMP Activities on Uncertainty - Summary

Activity	Status
Develop procedures for estimating and prioritizing uncertainty of identified sources for WTMP implementation	
Develop approaches for characterizing aggregated uncertainty of modeling results	
Develop protocols for communicating uncertainty for intended purposes	

Follow us in the future Modeling Technical Committee meetings on July 6, 2023, and October 5, 2023.