All the Answers to Water Supply and Demand:

Why Should We Use Climate Data in Forecasting Water Supply?

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Outline

1. Objectives
2. Background Concepts
3. Uncertainty in Hydrological Models
4. Assessment of Hydrological Uncertainty
5. Socio-Economical Value of Reliability
6. Closing Statements

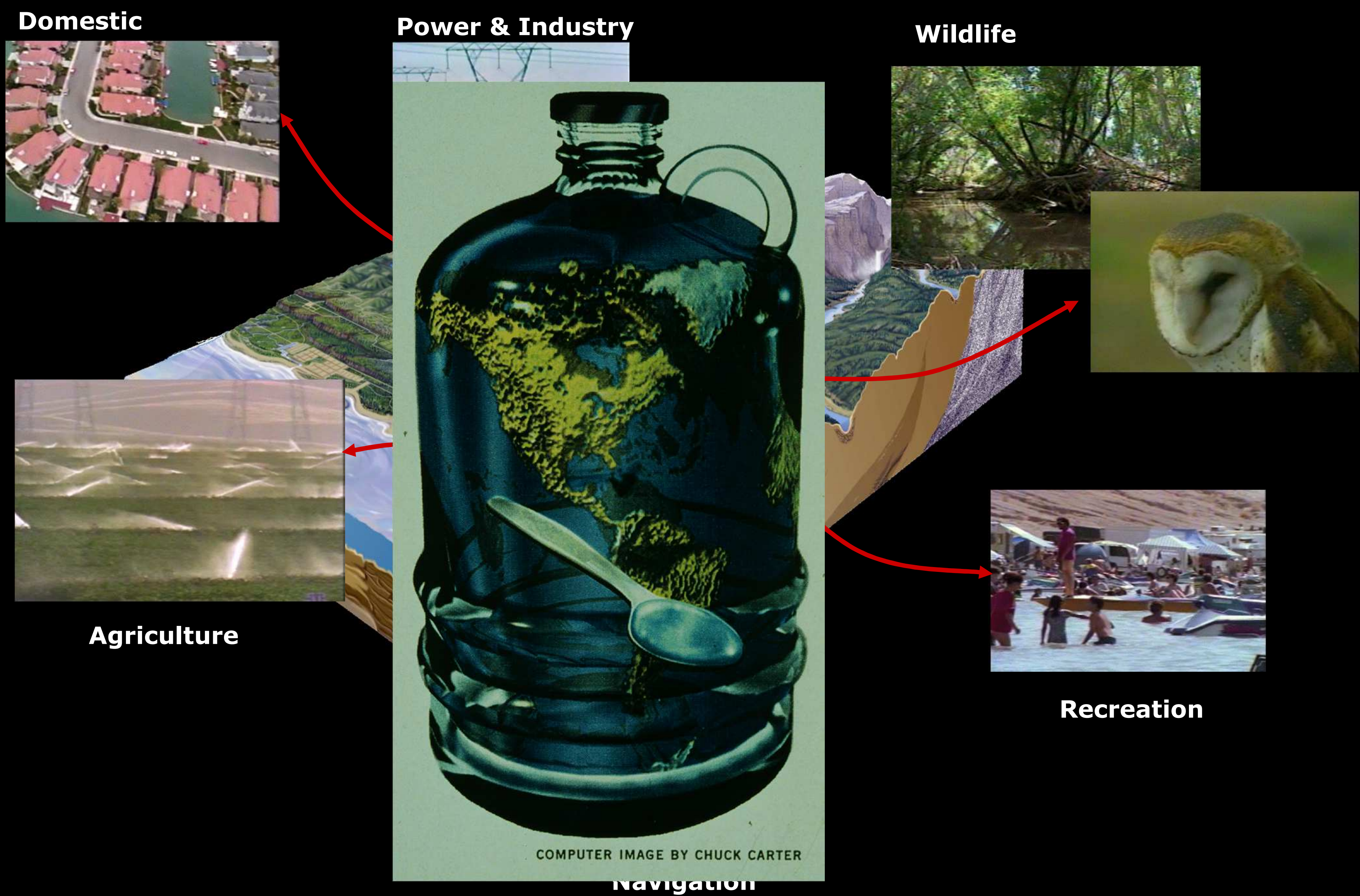
Objectives

- Quantifying system uncertainties to improve reliability.
- Economic cost/benefit of more reliable water delivery forecast.

Demonstration of the Problem

Managing California's Water Resources

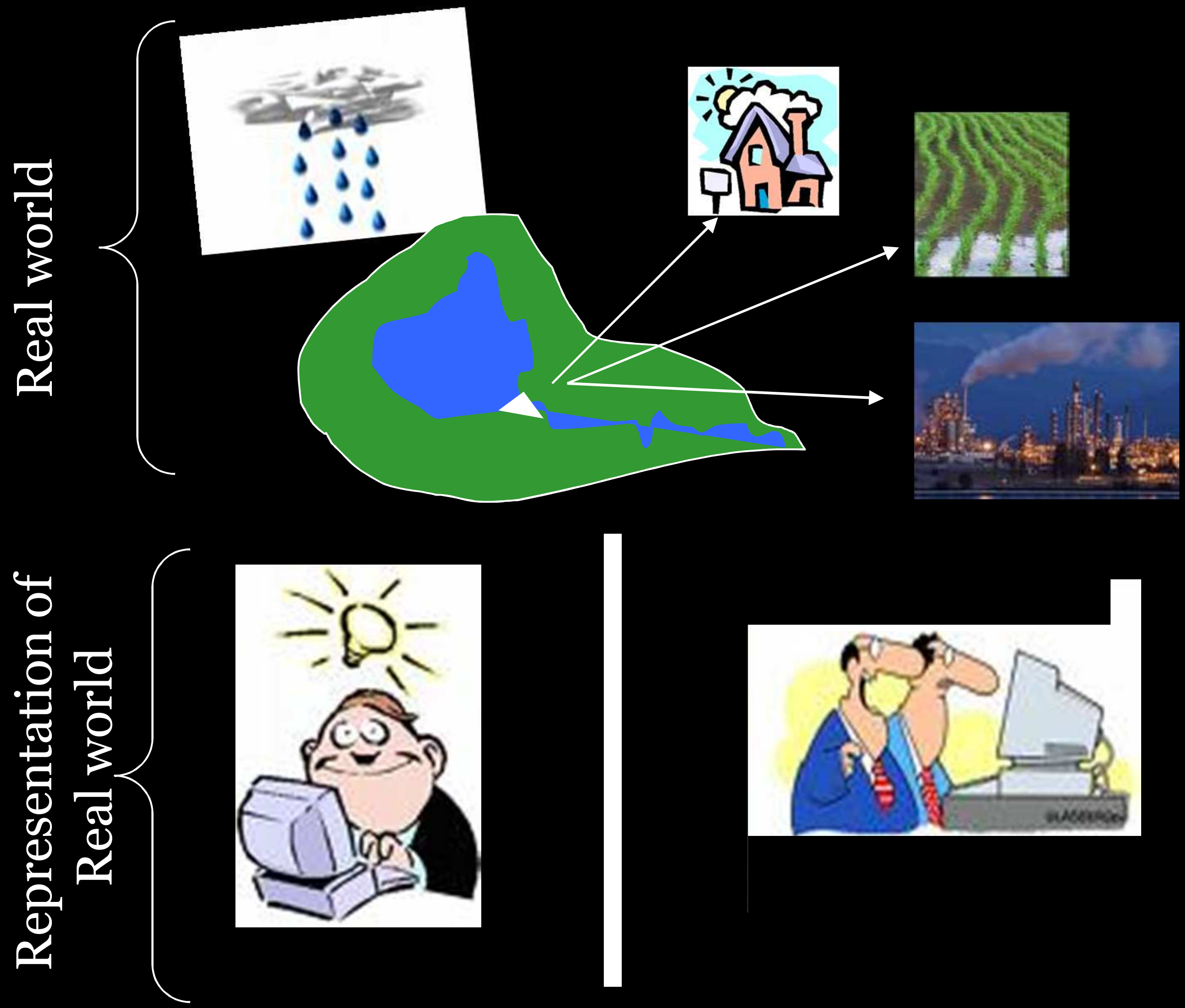
Competing Demands in California



Near Term Challenges California is Facing

This calls for an integrated, efficient and sustainable plan to management of water resources

Integrated System



Research Community

Water Resource Manager/Planners

What is Water Reliability?

- Annual amount of Water that can be expected to be delivered with certain frequency.

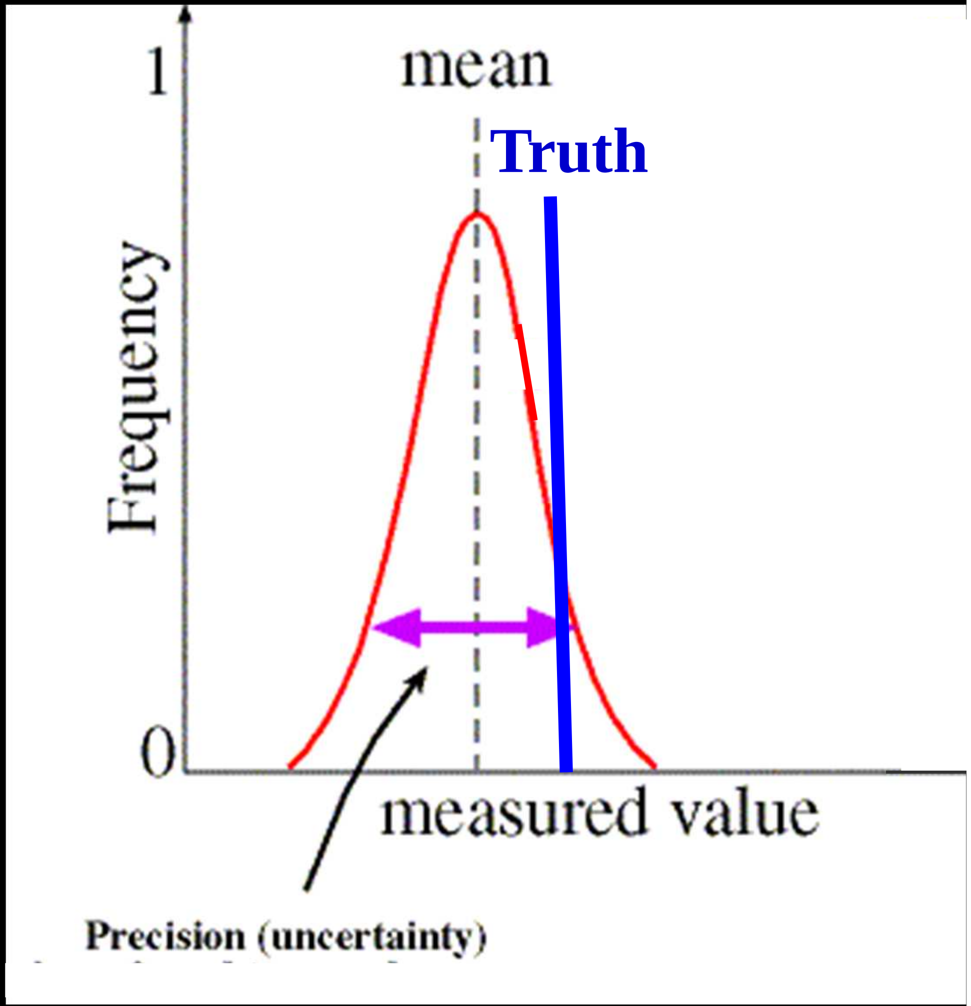
How to Improve Reliability?

Considering:

- uncertainty in future hydrologic events (e.g. impacts of climate change).
- uncertainty within the management system (e.g. modeling processes).
- disaster management issues such as exploring alternative water supply sources in case of a catastrophe.

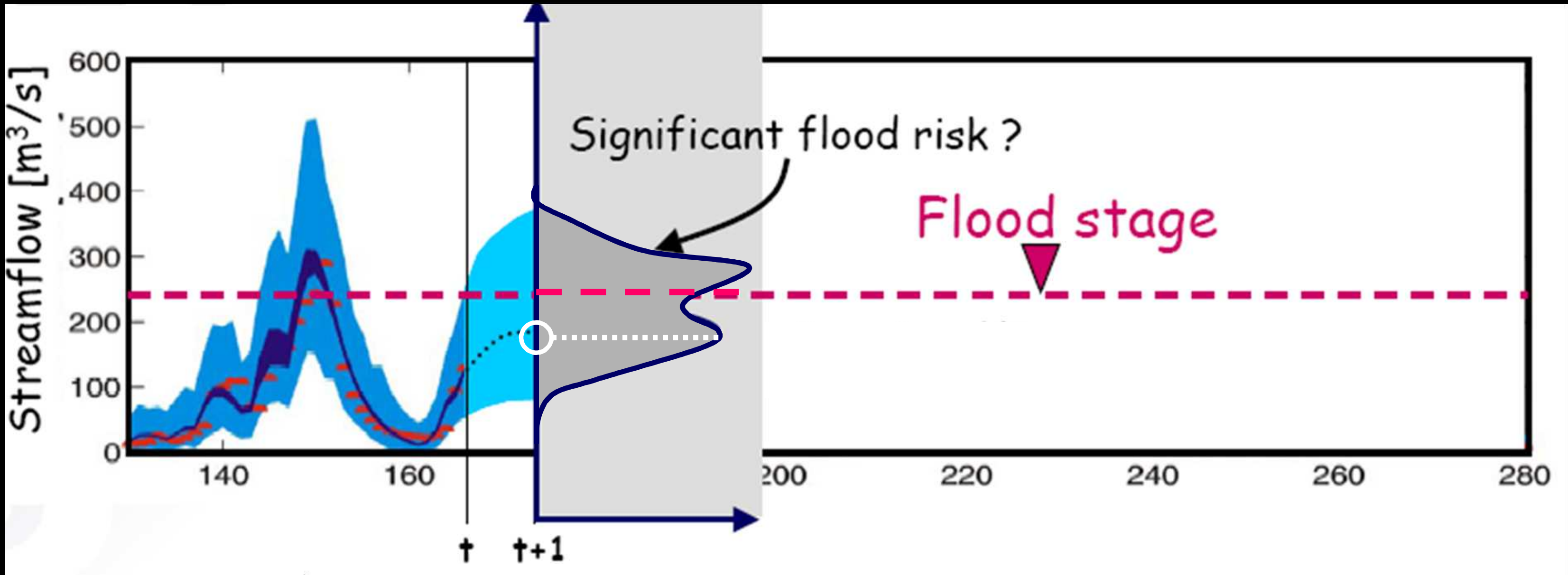
What is Uncertainty?

- The <u>uncertainty of a measurement or estimation</u> is stated by giving a range of values which are likely to enclose the true value.



Why Do We Care?

Why Uncertainty is important?

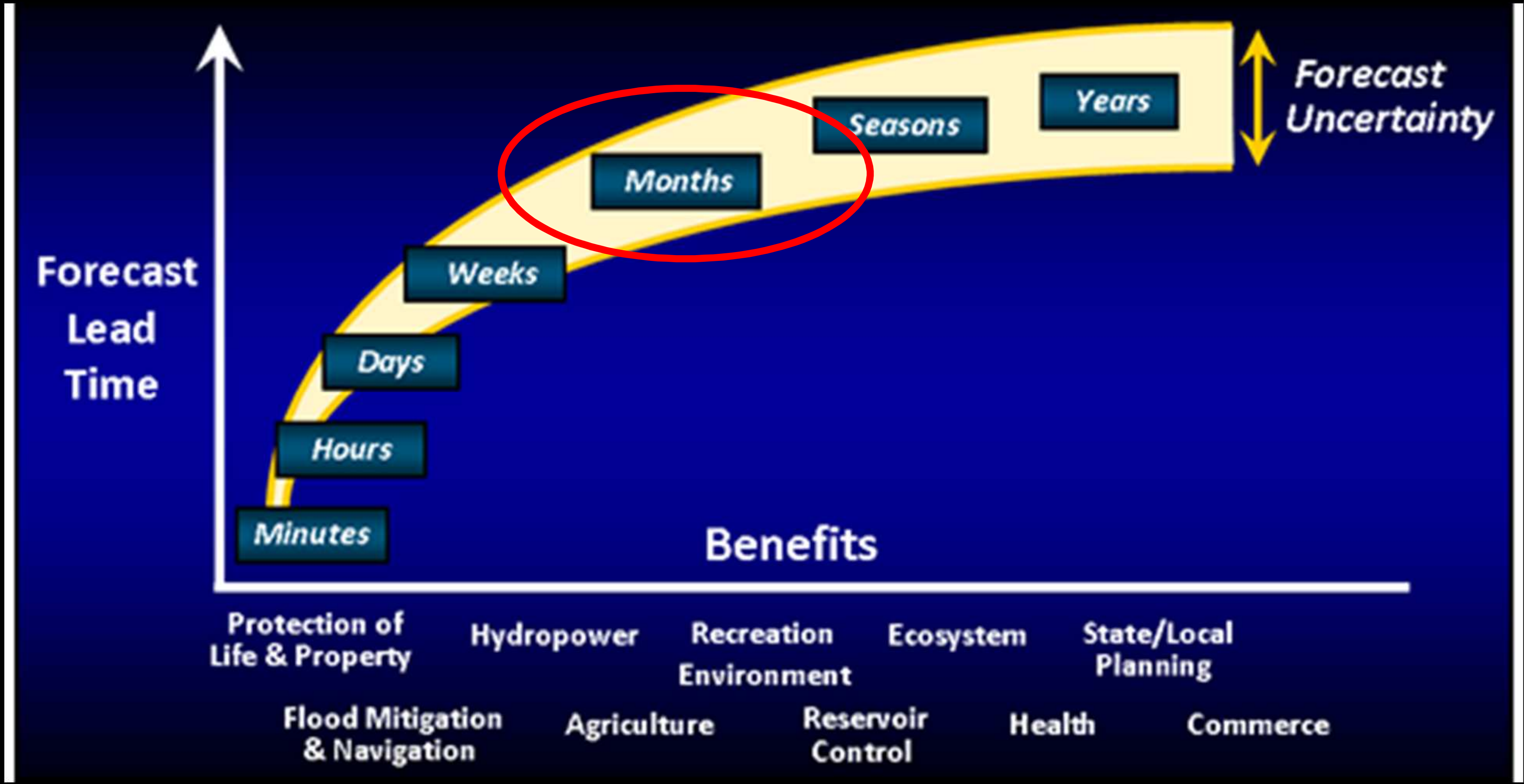


Why Reliability is Important?

More reliable forecast can:
Change our perspective of expected future extreme events such as Floods and Droughts.


- Enables the decision makers to better handle risk in decision making
- Therefore mitigate some of social, economical and environmental impacts.
- Also manage our limited water resources more efficiently under new adaptation plans

Forecast Uncertainty



Value of Reliability

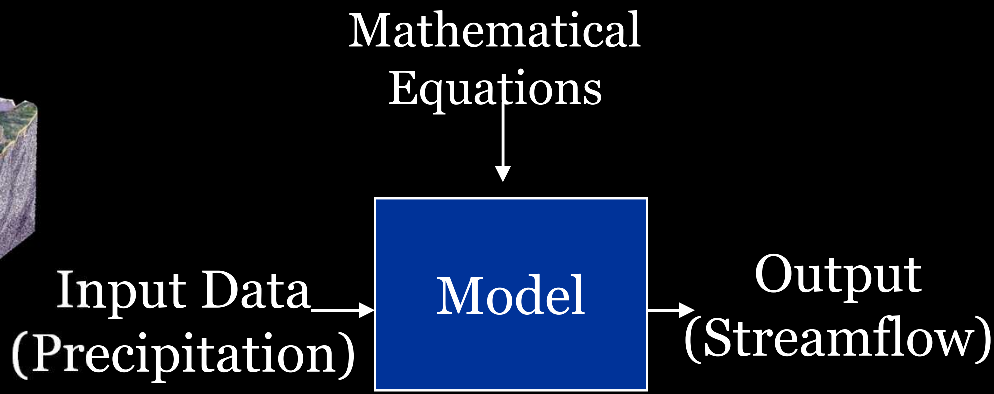
- The Value of an acre foot change in mean deliveries to the farmers is $94/acre.

- A one-unit increase in the uncertainty (Variance) of deliveries decreases expected profit $34/acre.

Models are used to
Estimate or Predict Physical Processes

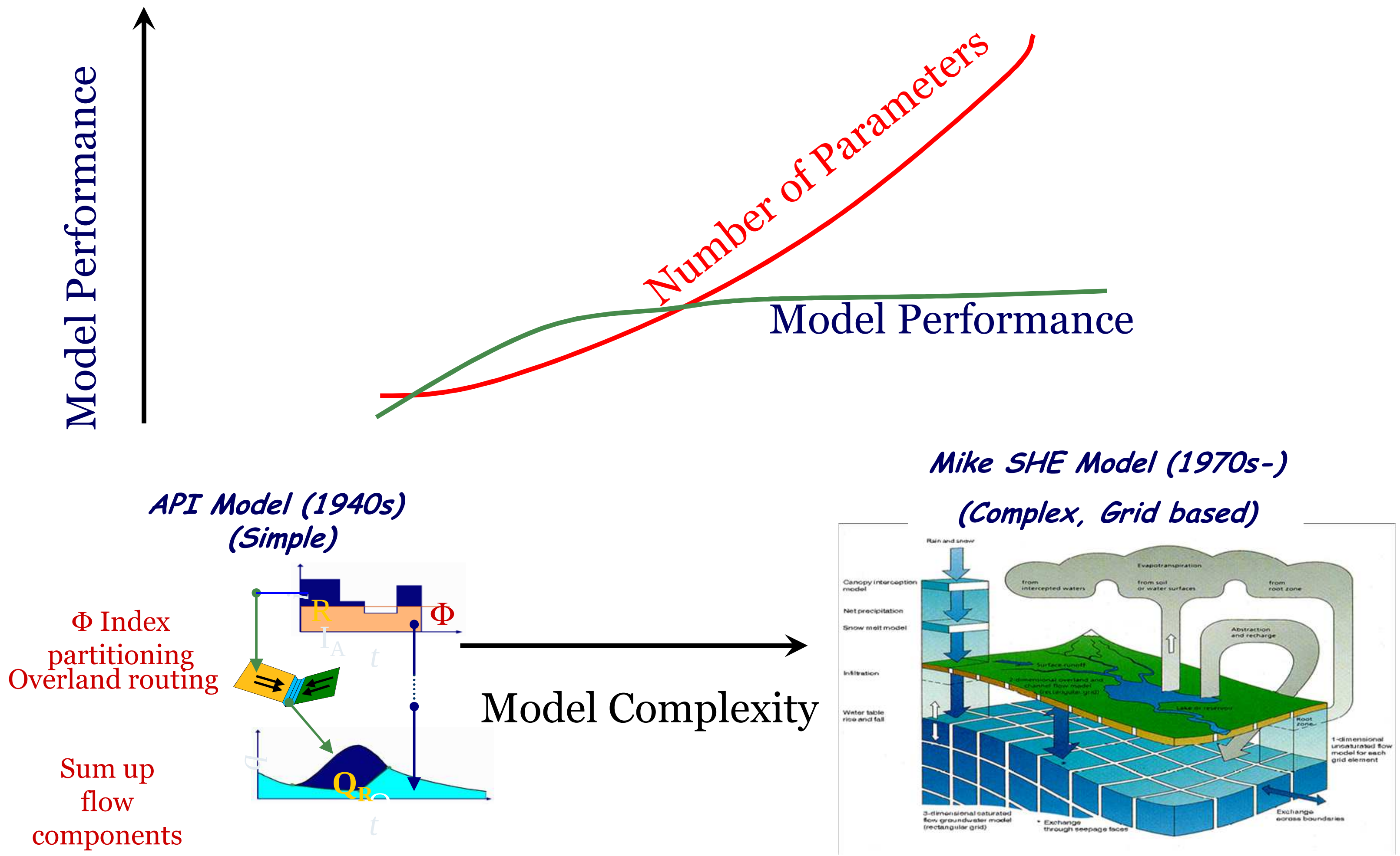
What is a Model?

- Mathematical representation of complex real world physical processes.

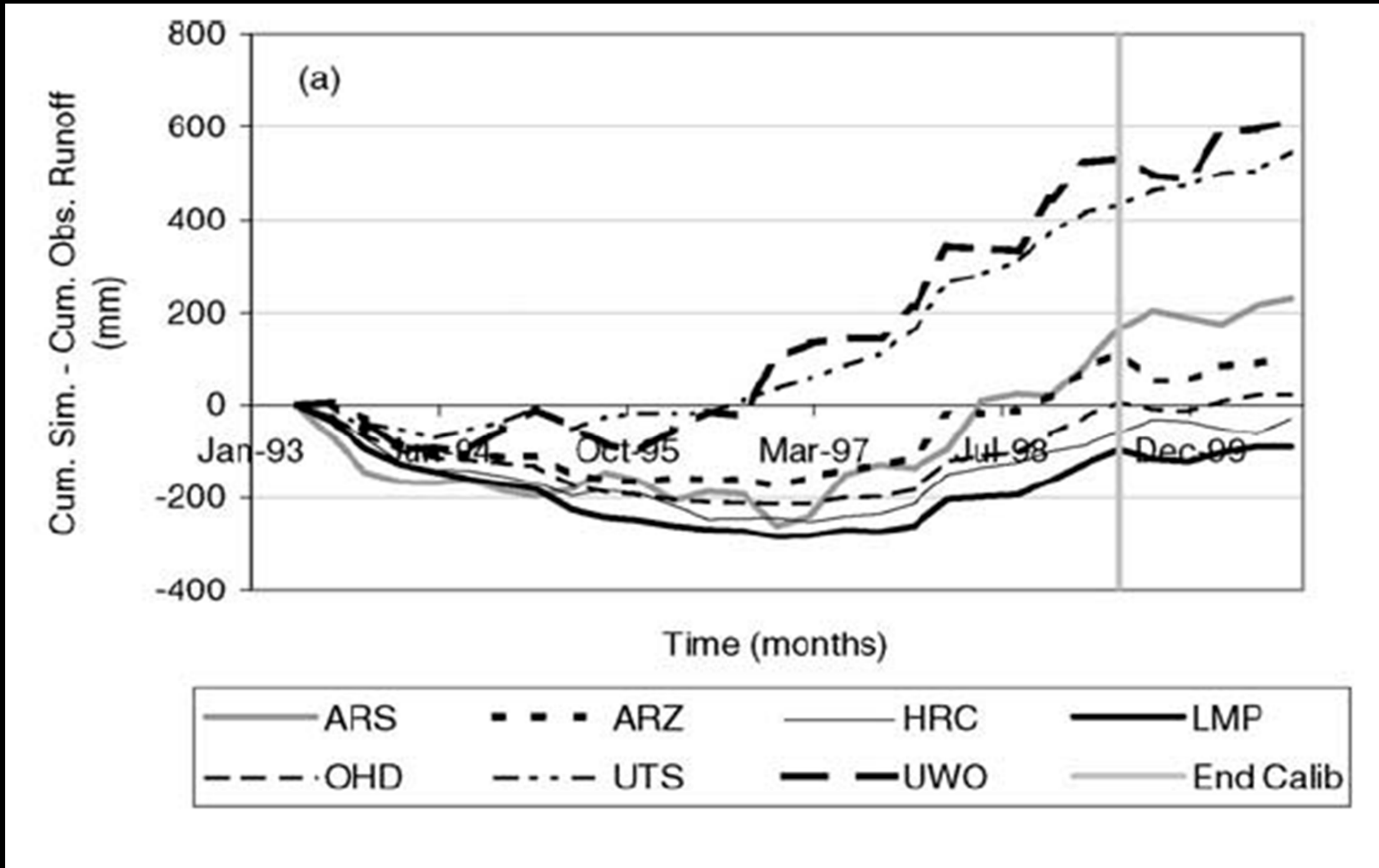


- Models help us understand and interpret the subject matter they represent such as the hydrological system.

From real world to our world



Performance of different models under the same condition



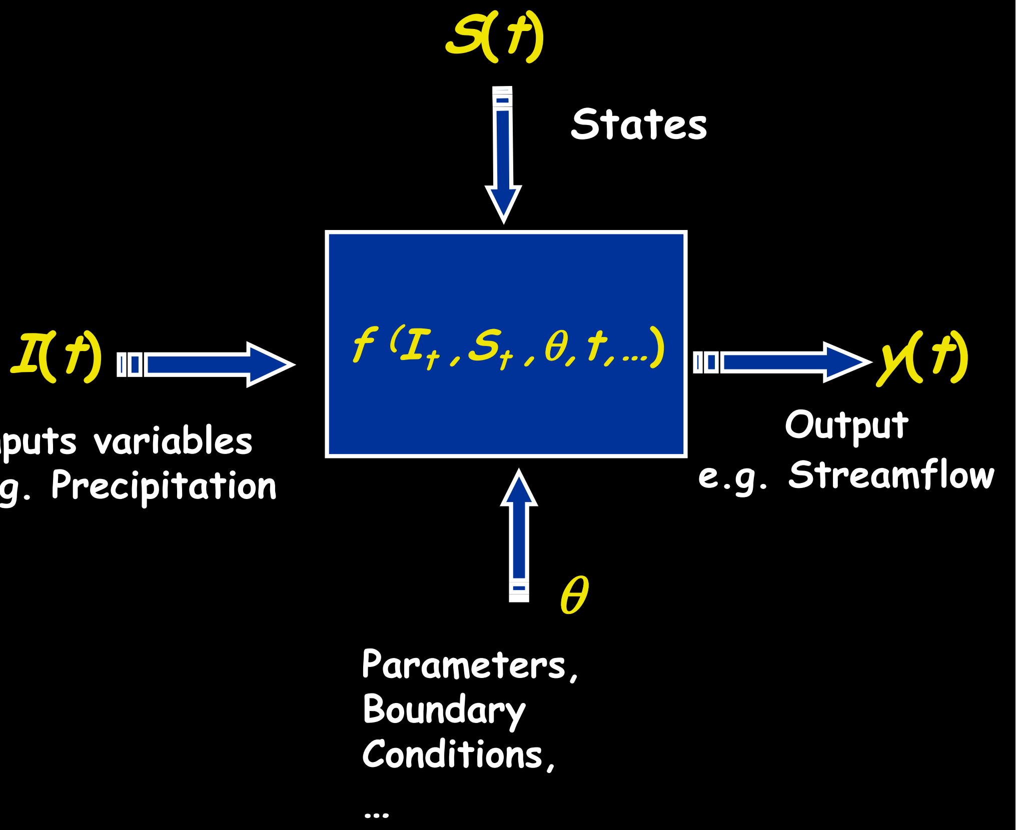
Cumulative simulation errors for calibrated hydrologic models: Illinois River basin at Watts

DMIP Results, (From Reed et al., 2004)

Why the difference?

Sources of uncertainty in hydrologic prediction

- Uncertainty exist in:
  - Inputs, I(t)
  - States, S(t)
  - Parameters, θ
  - Model equations, f
  - Outputs, y(t)



Assessment of Hydrological Uncertainties

Study Area

- Upstream of Shasta reservoir in Sacramento basin, California (including all the catchments that contribute to the inflows to Shasta).
- Monthly precipitation and temperature data from 1962-1994.
- Single aggregated demand which represents the water demand south of Shasta.

Methodology

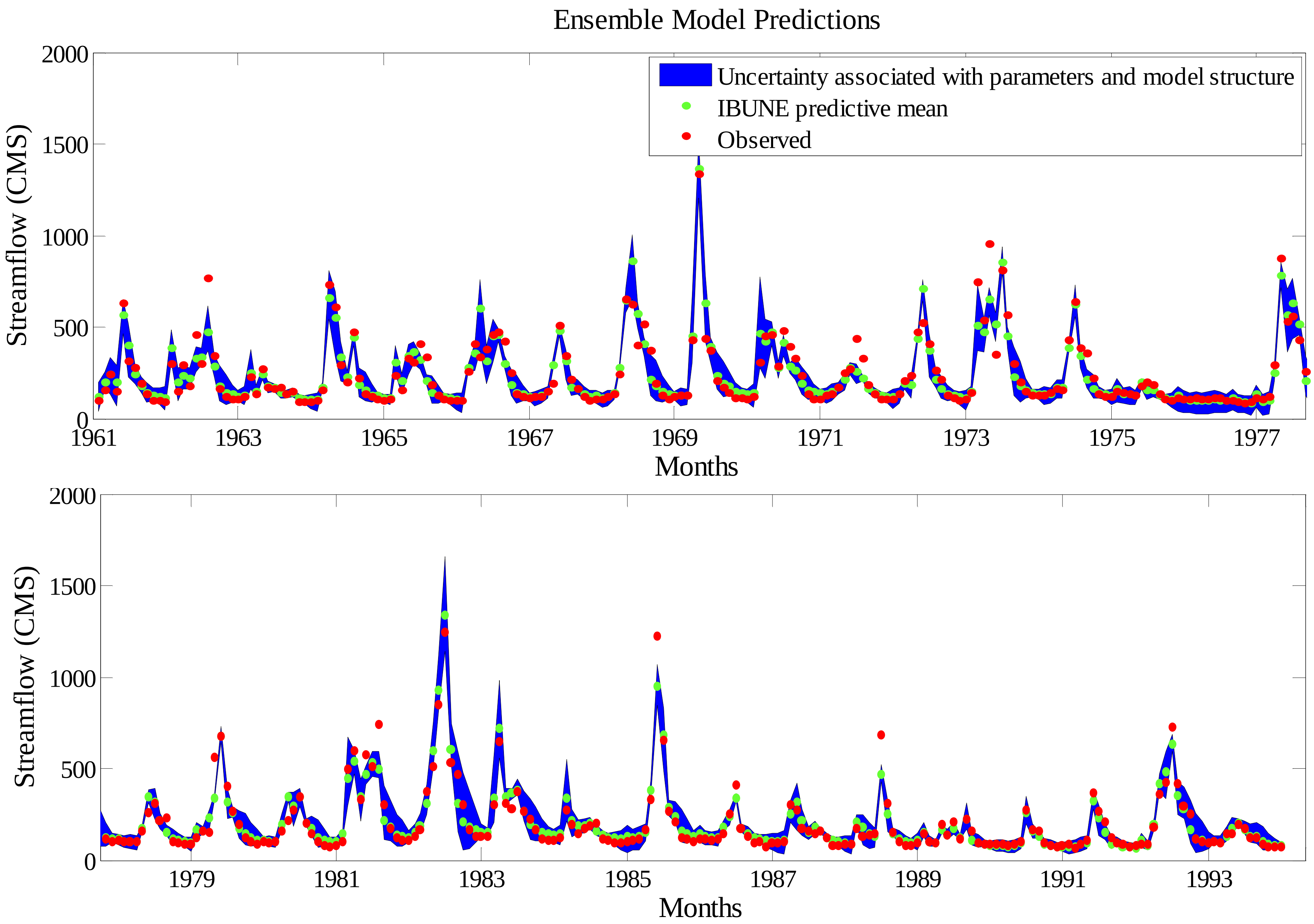
- Hydrological Uncertainty:
  - Monte Carlo techniques
  - Bayesian Theory
- Two uncertainty assessment scenarios:
  - One Model

    versus
  - Ensemble Forecast (IBUNE)
- Split sample approach :
  - Calibration:1962-1989
  - Validation: 1990-1993

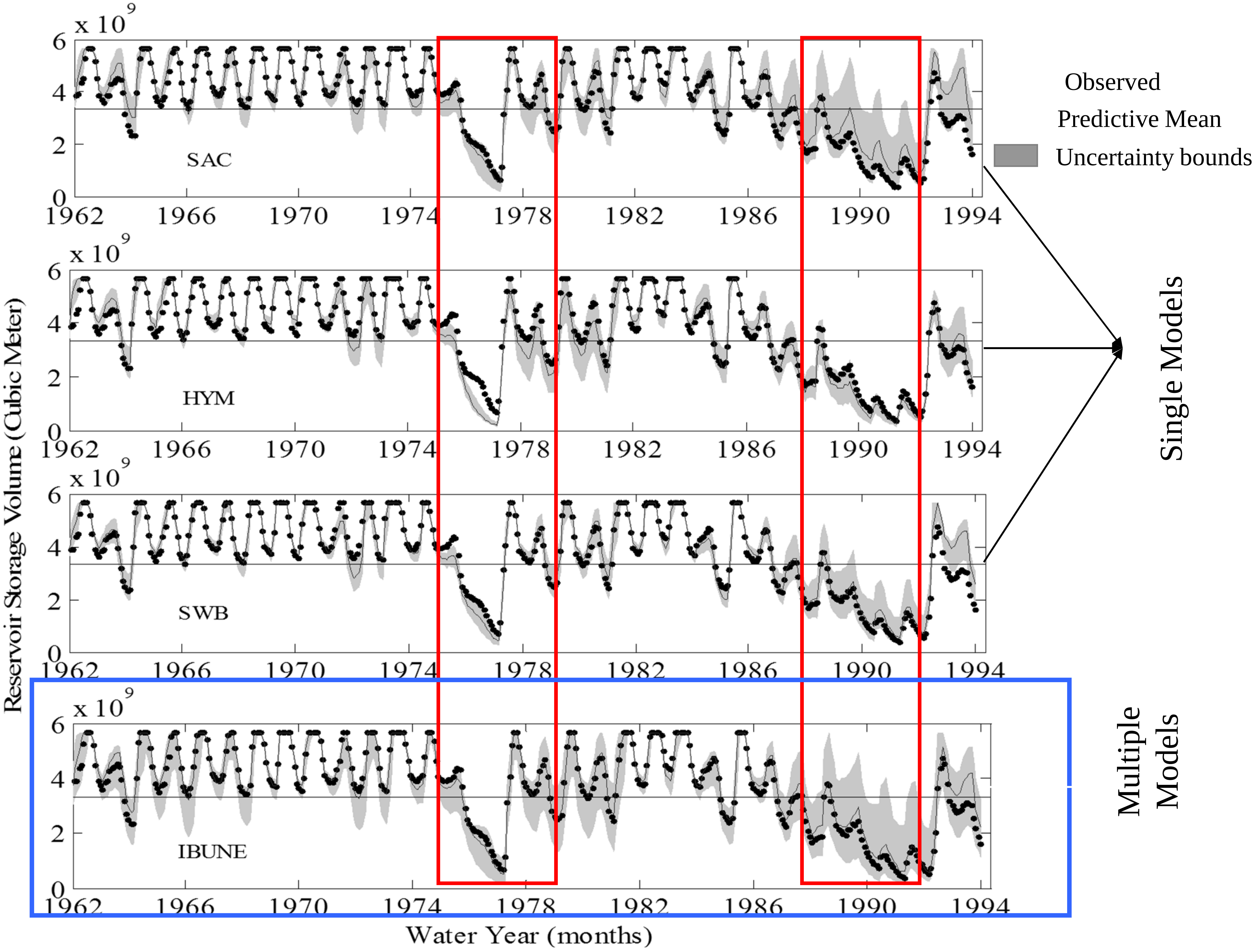
Methodology

- Three hydrologic models to generate streamflow ensembles.
  - Hydrologic MODel (HYMOD,5 parameters)
  - Simple Water Balance model (SWB, 5 parameter)
  - SACramento Soil Moisture Accounting (SAC-SMA) Model (13 parameter)

Streamflow Input to the Reservoir



Reservoir Storage


x 10^9
SAC
HYM
SWB
IBUNE
Observed
Predictive Mean
Uncertainty bounds
Single Models
Multiple Models
Reservoir Storage Volume (Cubic Meter)
Water Year (months)
1962
1966
1970
1974
1978
1982
1986
1990
1994

Socio-Economical Value of Reliability

About 500,000 acre feet of land in the San Luis & Delta-Mendota region is being irrigated by the 10% of the water from Shasta reservoir.

Time line

- November - December: Farmers decide on their crops and also financing
- January- March: Secure water resources and prepare for cropping
- April 1st: Based on the Snowpack in the Feather River Watershed and the storage in Lake Oroville SWP deliveries are estimated.

Economic Model

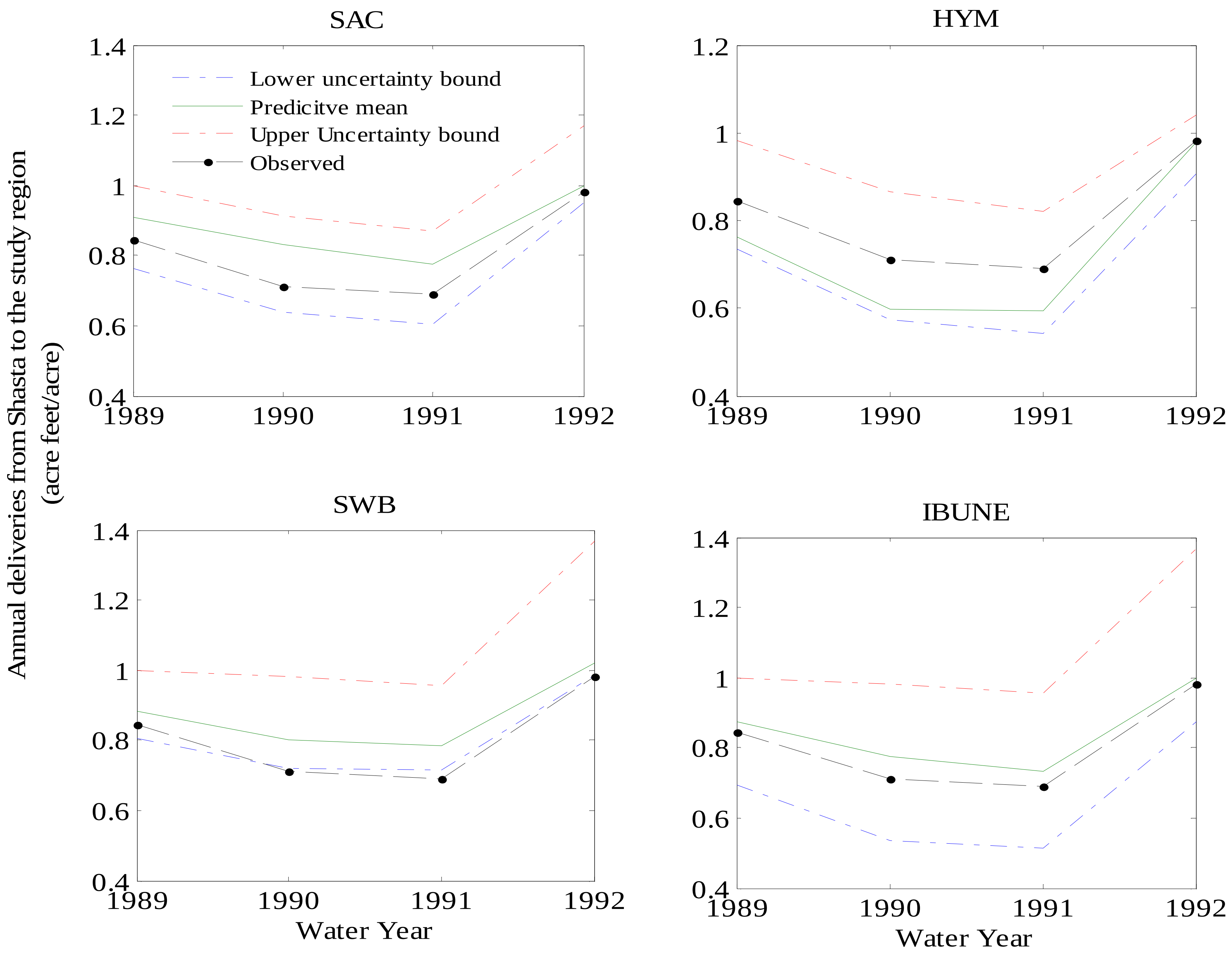
- Value of one unit change in mean deliveries

  $94/acre

- Cost of one unit change in uncertainty of deliveries

  $34/acre

- Numbers represent the cost of decisions by farmers to supplement water from Shasta (i.e groundwater pumping, spot water purchasing) or to plant less water intensive (or cheaper) crops.


SAC
HYM
SWB
IBUNE
Lower uncertainty bound
Predicitve mean
Upper Uncertainty bound
Observed
Annual deliveries from Shasta to the study region
(acre feet/acre)
Water Year
Water Year
1989
1990
1991
1992
0.4
0.6
0.8
1
1.2
1.4

Economic Benefit

- Economic benefit/cost of more reliable prediction:
  - Improving predictive mean using IBUNE:
    - 70's drought (1975-1977): $2.27-$17.3 million
    - 90's drought (1989-1992): $7.65-$10.5 million
  - More accurate uncertainty assessment:
    - 70's drought (1975-1977): -$1.08 million
    - 90's drought (1989-1992): -$3.03 million

- Farmers in the San Luis & Delta-Mendota region could have benefited between $1 to $11 per acre per year during the 70's drought and between $2.5 and $4 per acre per year during the 90's drought.

Closing Statements

- It is crucial to account for various sources of hydrological uncertainty in order to insure more reliable water supply forecasts.
- End-to-end uncertainty assessment is more evident and critical during drought spells
  - the competing demands (Ag users versus Delta Smelt)
- Connecting Scientists, policy makers and practitioners in order to have a more integrated approach.
- Maximizing the yield of our water resources by:
  - Conjunctive use
  - Integrated Water Resource Management Platform (North + South)

Thanks

Questions?

Man is a complex being; he makes the deserts bloom and lakes die. (Gil Stern)

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Characteristics of an Integrated System

- This integrated system will include an open and flexible platform that connects all California's water systems.

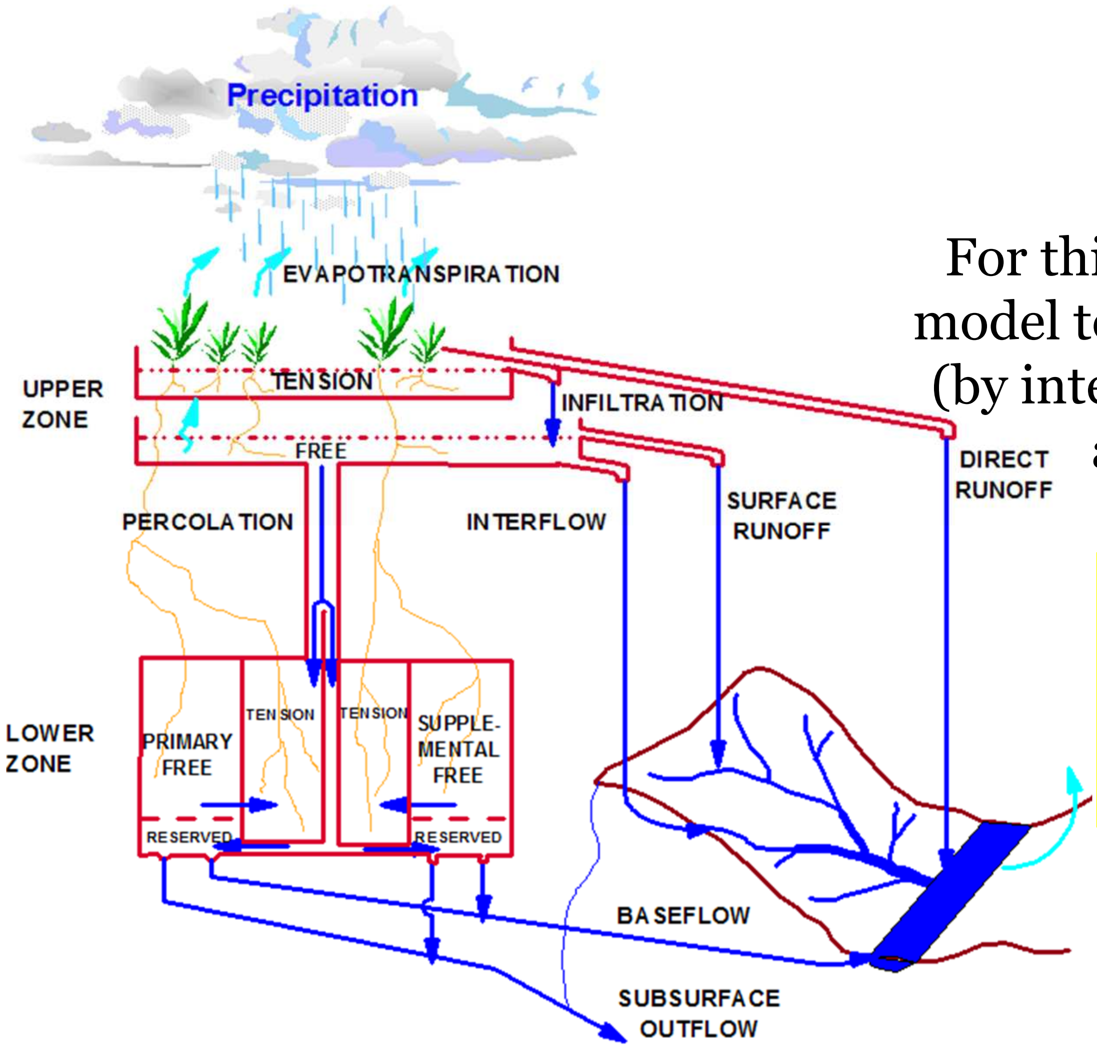
- Why an open platform?
  - More efficient resource management

    by allowing decision makers to test different possible coordinated operation scenarios.
  - Improved system reliability in term of water supply

Water Delivery

- Water Delivery Reliability:
- Annual amount of Water that can be expected to be delivered with certain frequency
- Uses computer simulation model (CALSIMII) based on 82 years of historical runoff.
- Water deliveries are directly impacted by:
- Amount of rainfall, snow pack, runoff.

SACramento Soil Moisture Accounting model
(SAC-SMA; *Burnash et al.*, 1973)



Includes 13 par
and
6 state variables

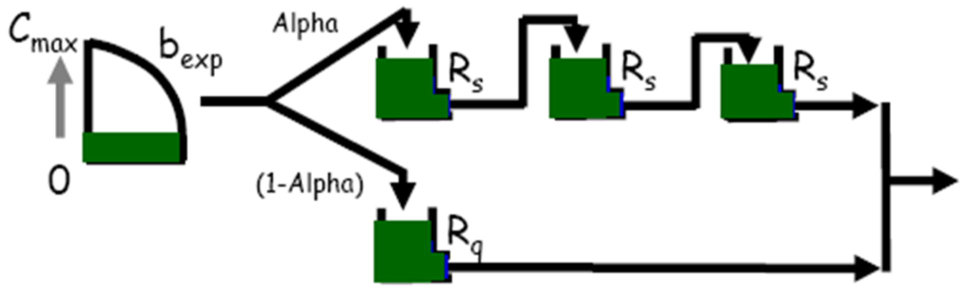
For this study we simplified this model to include just 5 parameters (by inter-relating some of the par and fixing the rest).

Complex and conceptual

Inputs:

Precipitation

HYdrologic MODel (HYMOD; *Boyle*, 2000)



Includes 5 parameters

Both simple and conceptual

Inputs:

Precipitation

Simple Water Balance Model (SWB; *Schaake et al.*, 1996)

Includes 6 parameter,
it is being used as an operational model in the Nile River forecast center