Incorporating Large-Scale Climate Information in Water Resources Decision Making

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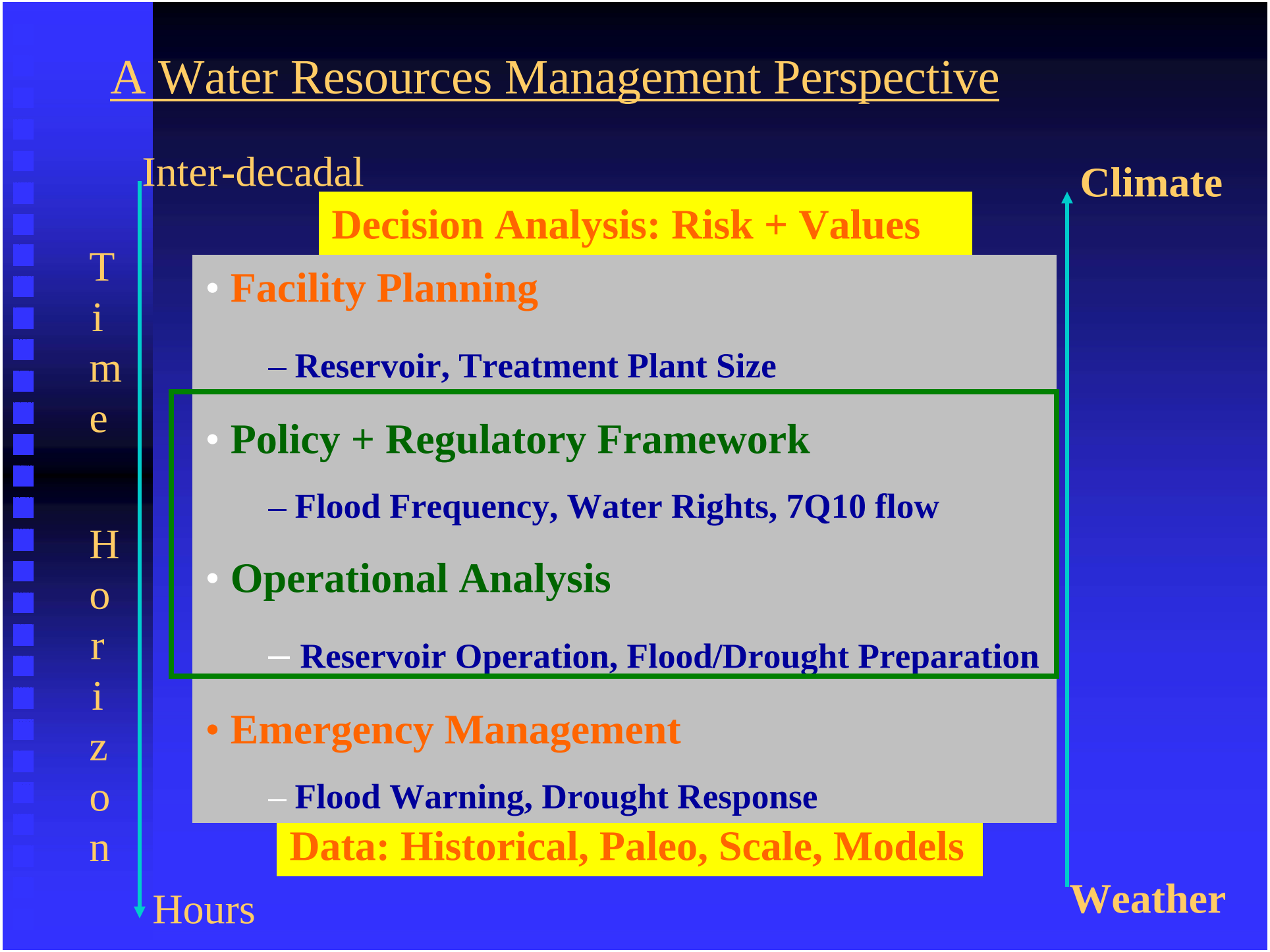
A Water Resources Management Perspective



Study Area

PYRAMID LAKE

WINNEMUCCA LAKE (dry)

CALIFORNIA

NEVADA

Nixon

Stillwater NWR

Derby Dam

TRUCKEE CANAL

STAMPEDE

Reno/Sparks

Fernley

Fallon

INDEPENDENCE

TRUCKEE RIVER

BOCA

Newlands Project

PROSSER

Truckee

Farad

MARTIS

Ft Churchill

LAHONTAN

CARSON LAKE

DONNER

Carson City

Tahoe City

CARSON RIVER

LAKE TAHOE

Motivation

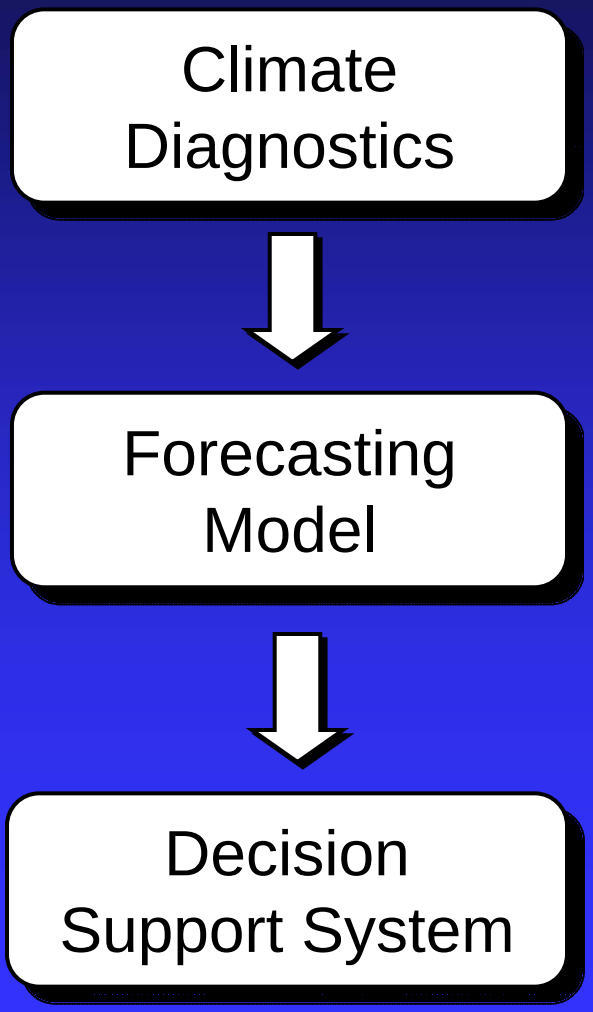
- US Bureau of Reclamation (USBR) searching for an improved forecasting model for the Truckee and Carson Rivers (accurate and with long-lead time)
- Forecasts determine reservoir releases and diversions
- Protection of listed species

Cui-ui

Lahontan Cutthroat Trout

Truckee Canal

Outline of Approach



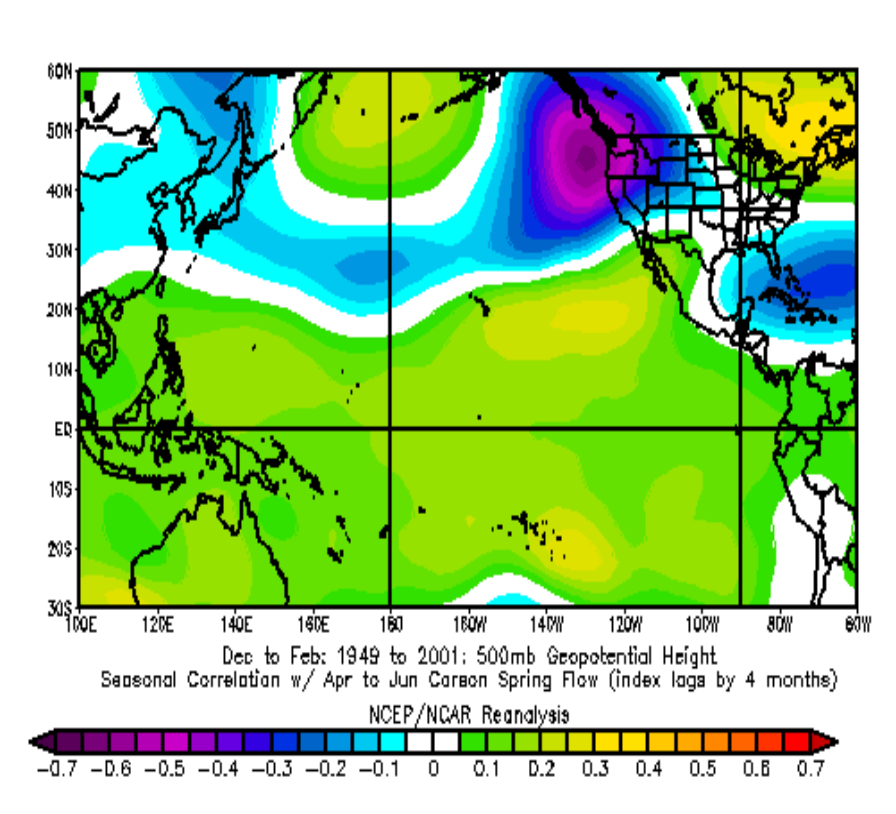
- Climate Diagnostics
  - To identify relevant predictors to spring runoff in the basins
- Forecasting Model
  - Nonparametric stochastic model conditioned on climate indices and snow water equivalent
- Decision Support System
  - Couple forecast with DSS to demonstrate utility of forecast

Data Used

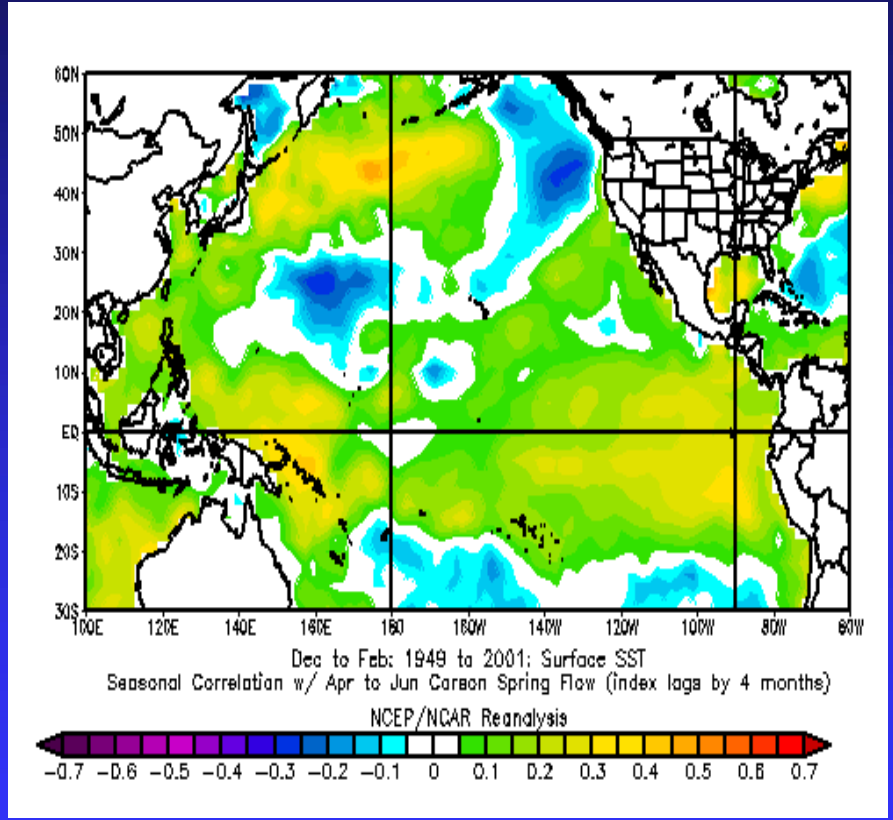
- 1949-2003 monthly data sets:
  - Natural Streamflow (Farad & Ft. Churchill gaging stations)
  - Snow Water Equivalent (SWE)- basin average
  - Large-Scale Climate Variables

Winter Climate Correlations

Carson Spring Flow



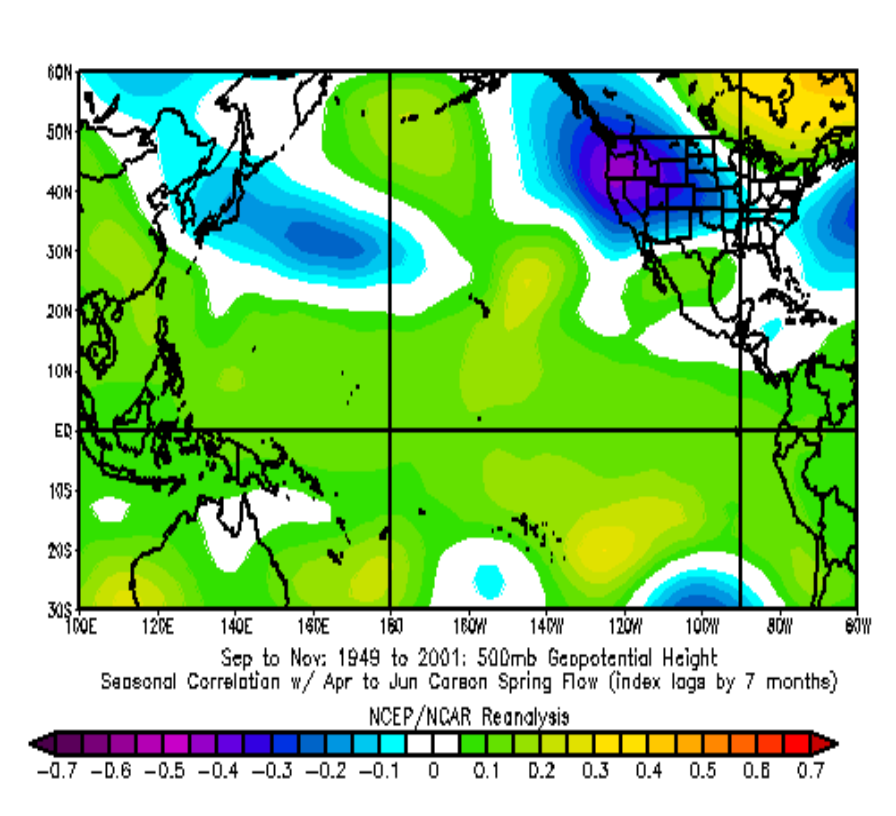
500mb Geopotential Height



Sea Surface Temperature

Fall Climate Correlations

Carson Spring Flow



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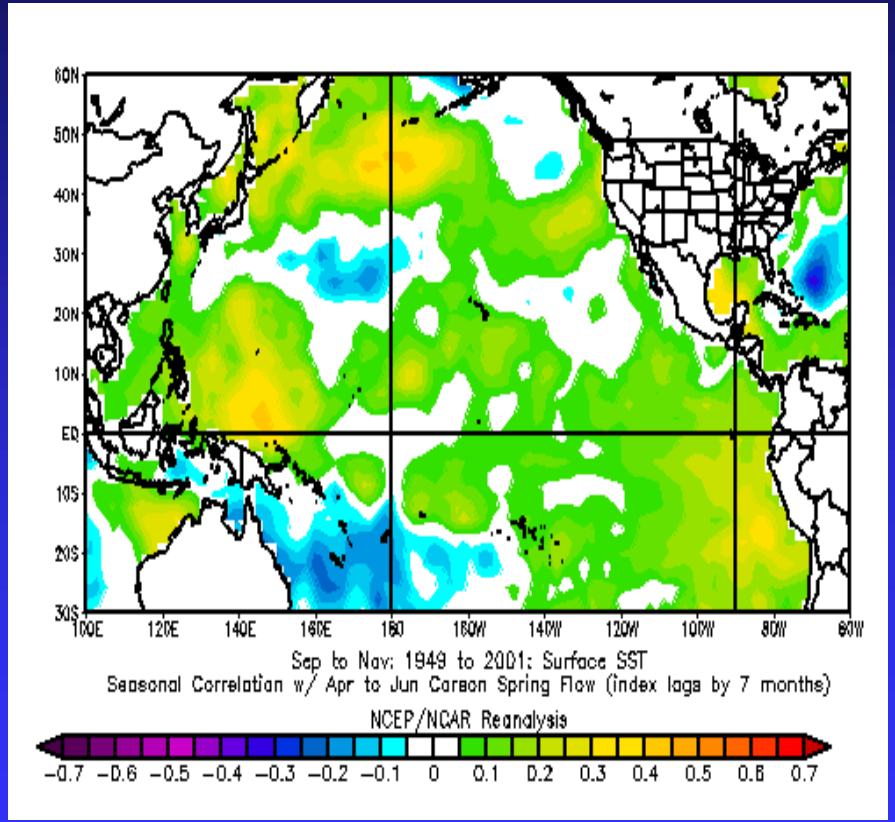
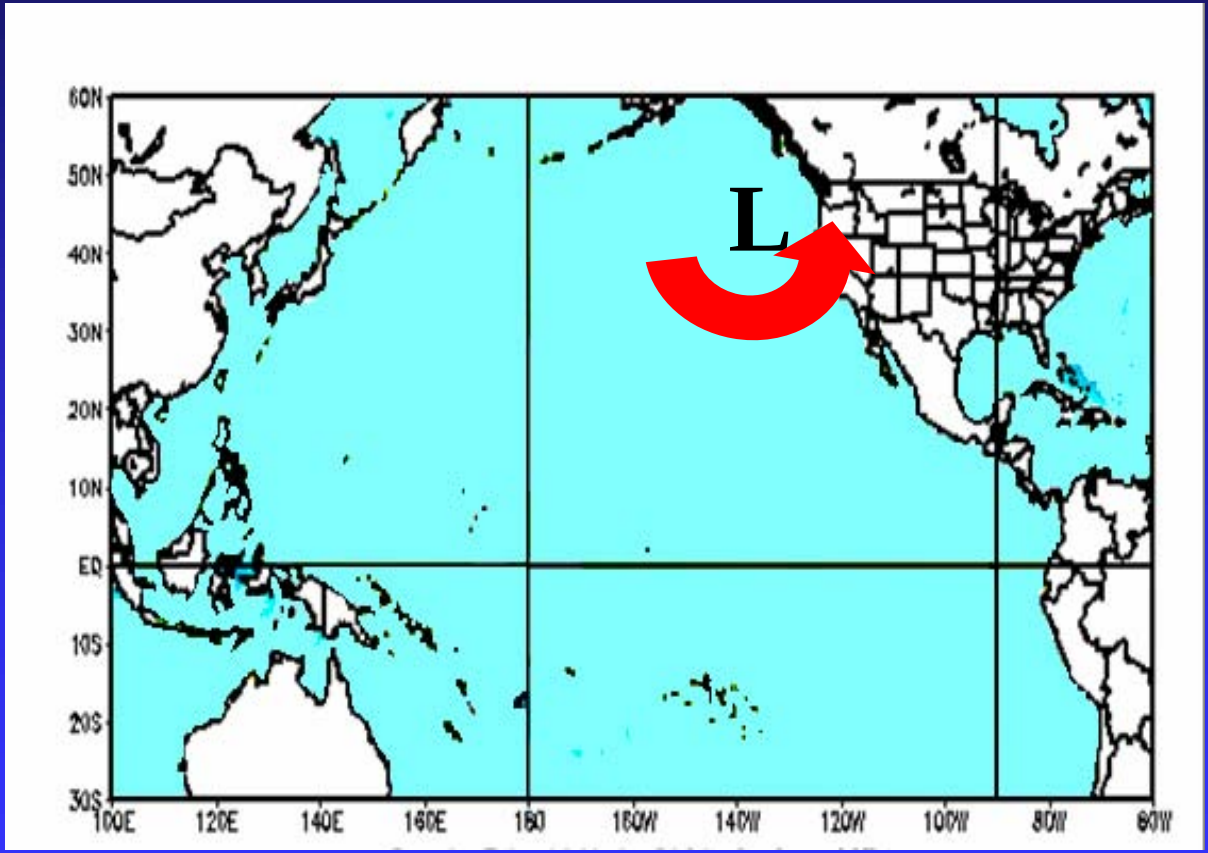


Sea Surface Temperature

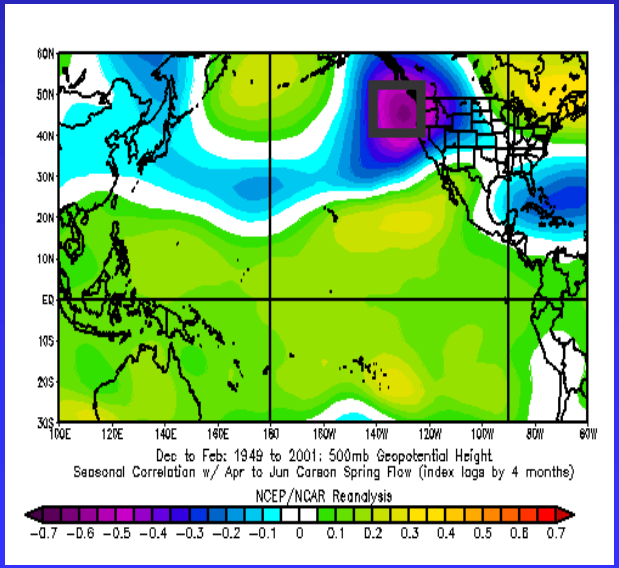
Physical Mechanism



- Winds rotate counter-clockwise around area of low pressure bringing warm, moist air to mountains in Western US

Climate Indices

- Use areas of highest correlation to develop indices to be used as predictors in the forecasting model
- Area averages of geopotential height and SST



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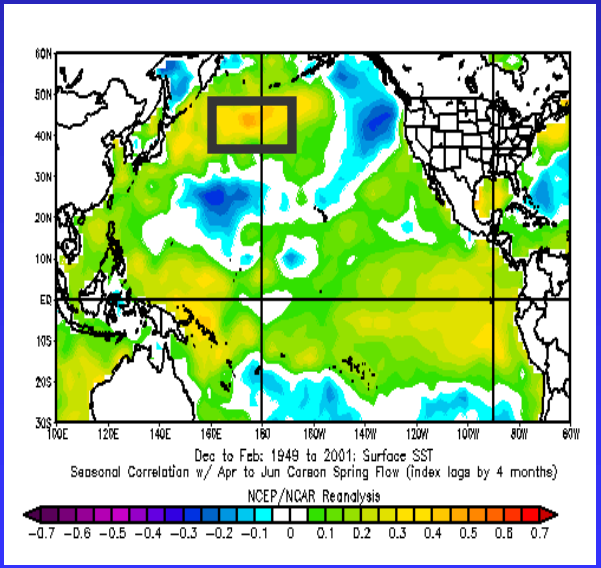
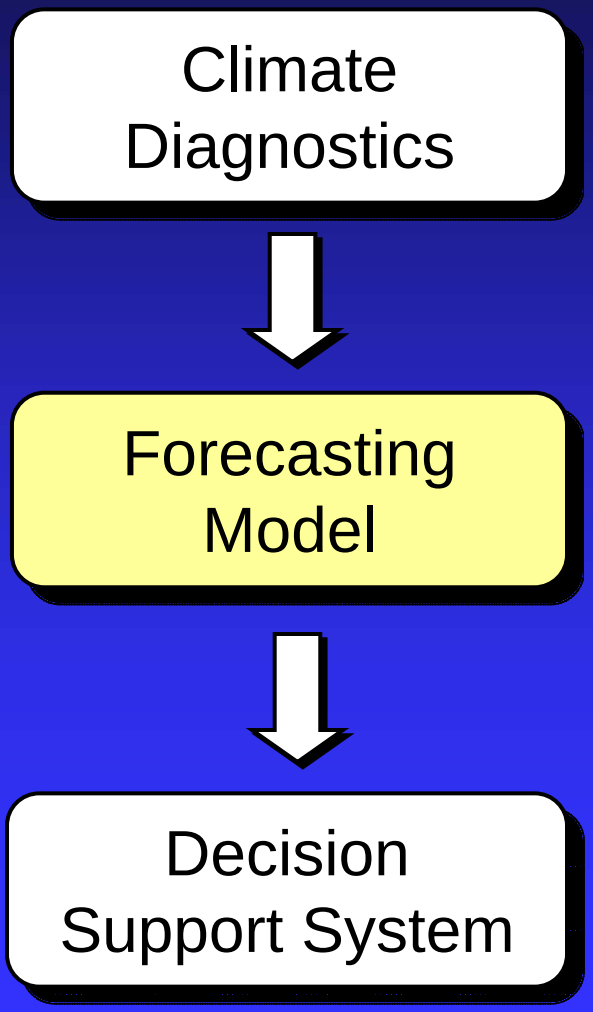


Sea Surface Temperature

Outline of Approach



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➢ Forecasting Model
  - Nonparametric stochastic model conditioned on climate indices and SWE

- Decision Support System
  - Couple forecast with DSS to demonstrate utility of forecast

The Ensemble Forecast Problem

- Ensemble Forecast/Stochastic Simulation /Scenarios generation – all of them are *conditional probability density function problems*

$$f\left(y_t \middle| y_{t-1}, y_{t-2}, \ldots, y_{t-p} \right) = \frac{f(y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-p})}{\int f(y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-p})\, dy_t}$$

- Estimate conditional *PDF* and simulate (Monte Carlo, or Bootstrap)

- K-NN Approach is Used

Model Validation & Skill Measure

- Cross-validation: drop one year from the model and forecast the "unknown" value

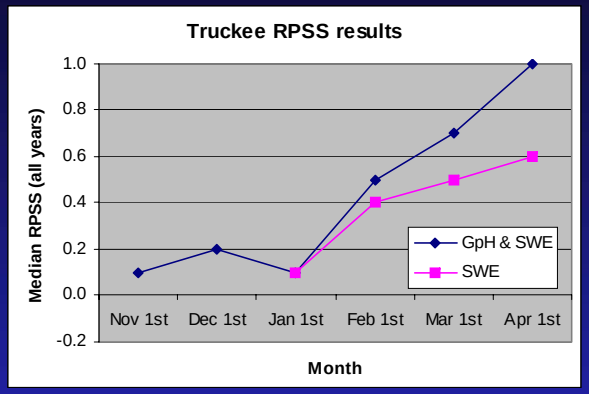
- Compare median of forecasted vs. observed (obtain "r" value)
- Rank Probability Skill Score

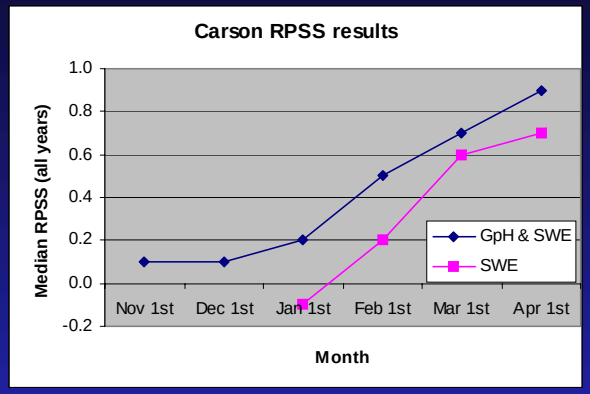
$$RPS(p,d) = \frac{1}{k-1}\left[\sum_{j=1}^{k}\left(\sum_{n=1}^{i} P_n - \sum_{n=1}^{i} d_n\right)\right] \quad \Rightarrow \quad \mathrm{RPSS} = 1 - \frac{\mathrm{RPS(forecast)}}{\mathrm{RPS(climatology)}}$$

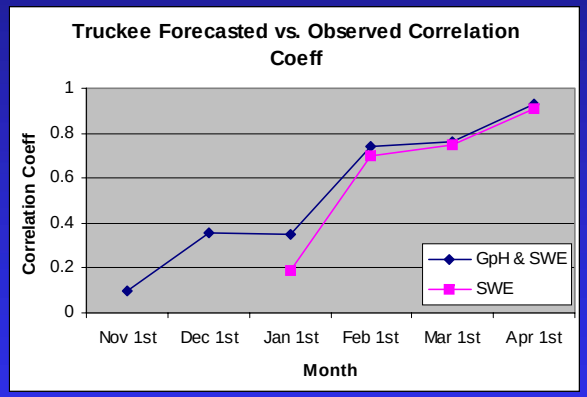
- Likelihood Skill Score

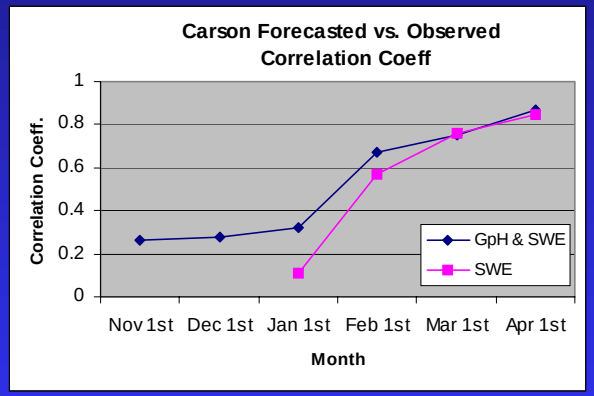
$$L = \left(\frac{\prod_{t=1}^{N} P_{j,i}}{\prod_{t=1}^{N} P_{c_{j,i}}}\right)^{\frac{1}{N}}$$

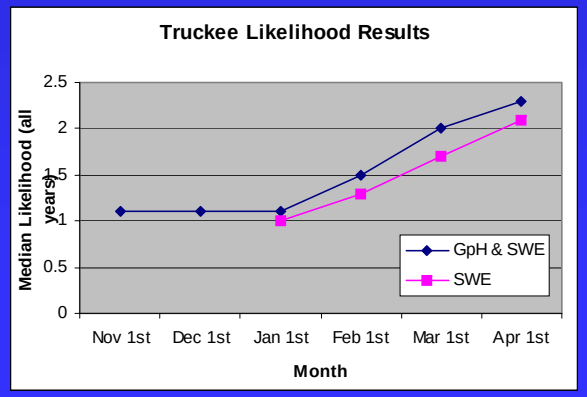
Forecasting Results

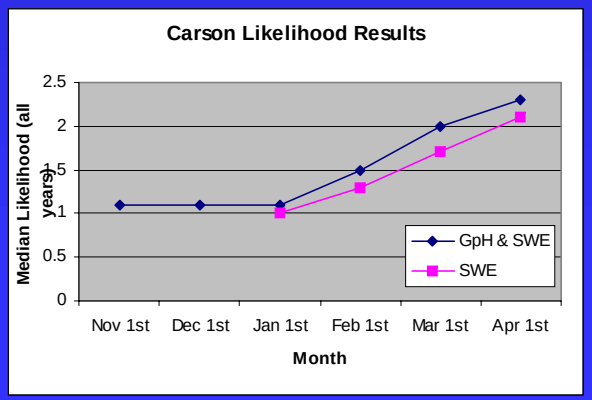




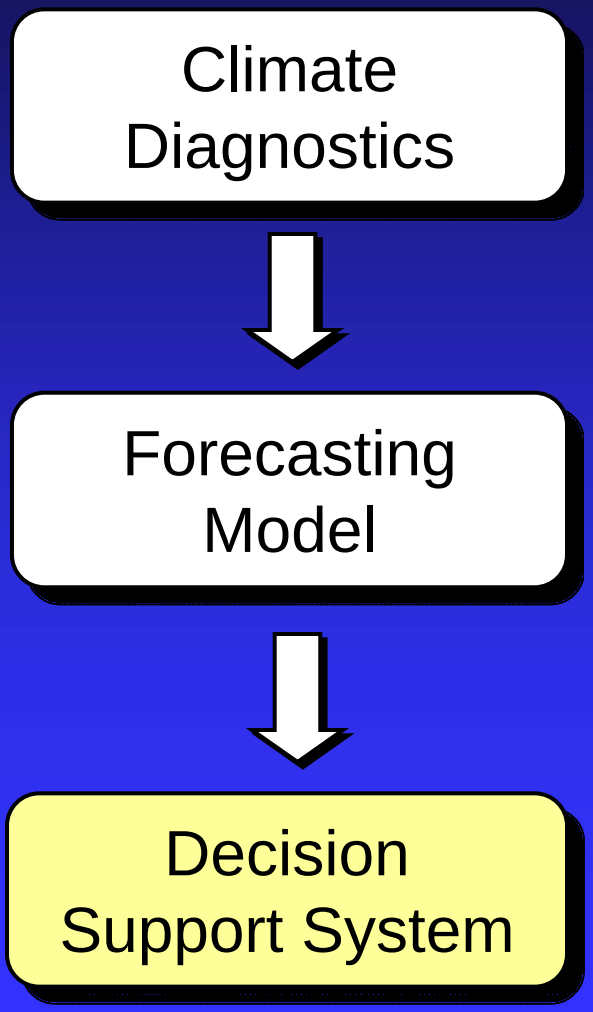








Outline of Approach



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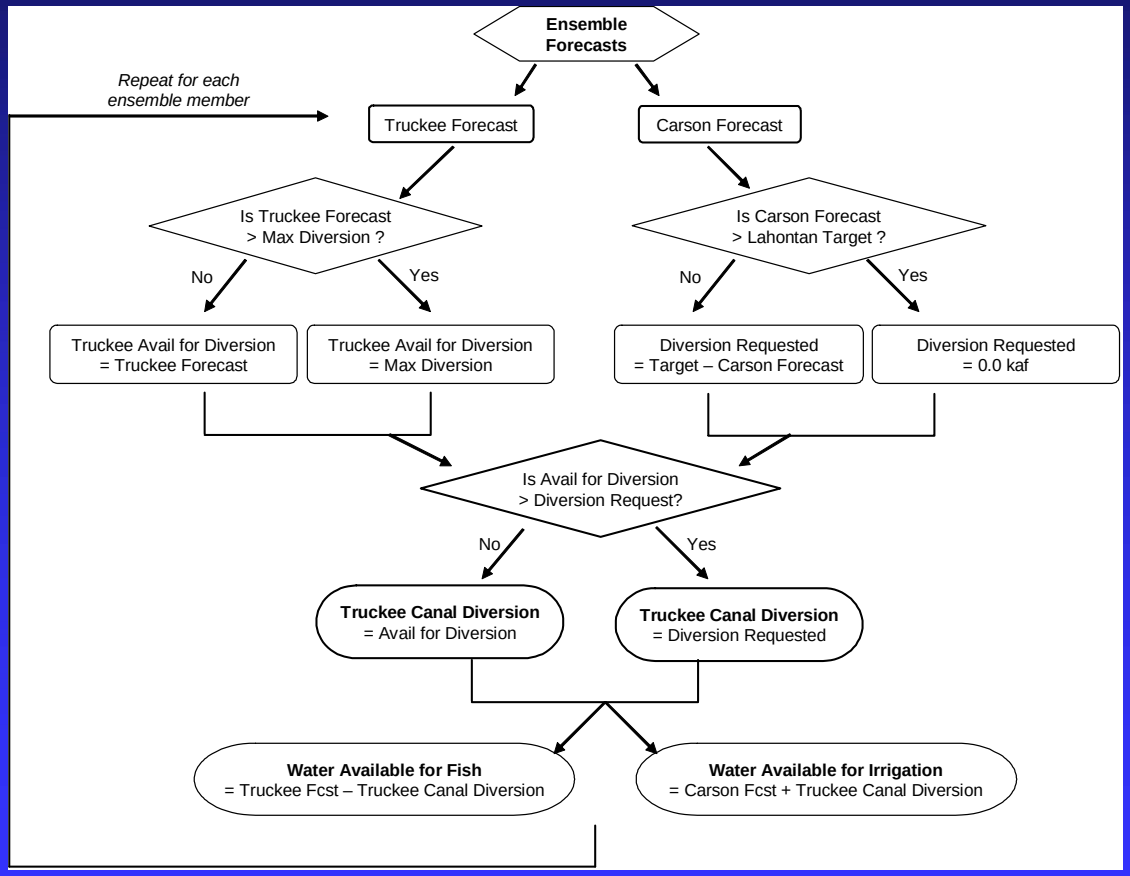
Seasonal Decision Support System

- Method to test the utility of the forecasts and the role they play in decision making
- Model implements major policies in lower basin (Newlands Project OCAP)
- Seasonal time step

Seasonal Model Policies

- Use Carson water first
- Max canal diversions: 164 kaf
- Storage targets on Lahontan Reservoir: 2/3 of historical April-July runoff volume
- No minimum fish flows (release from upstream reservoir to combat low flows)

Decision Model Flowchart



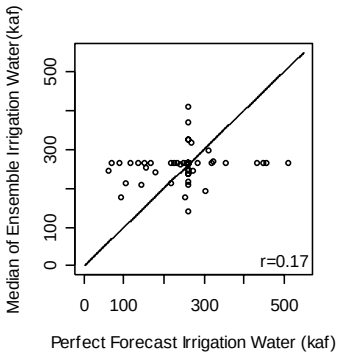
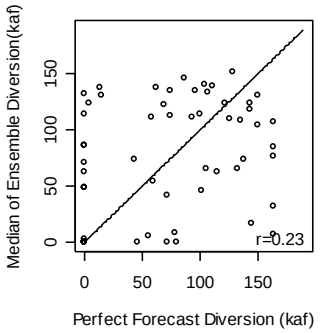
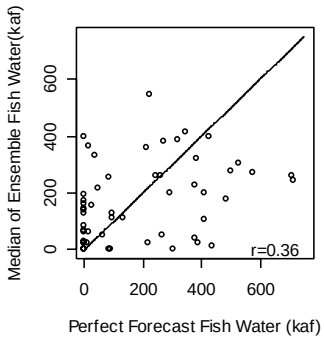
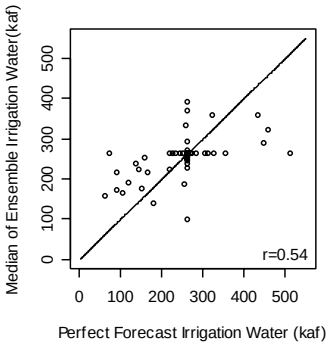
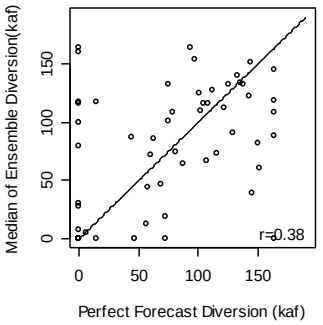
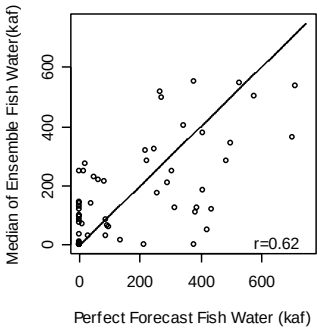
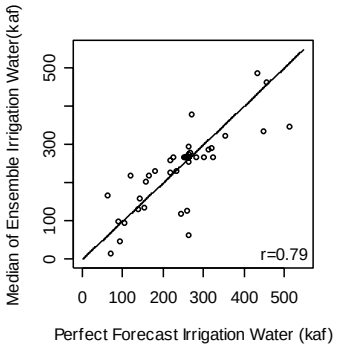
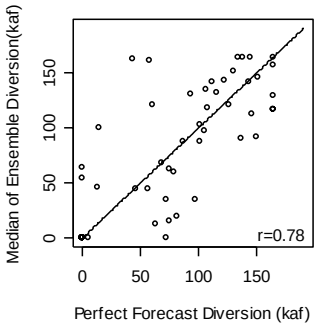
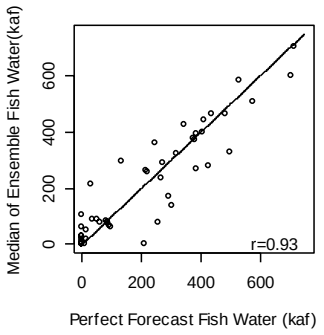
Decision Variables

- Lahontan Storage Available for Irrigation

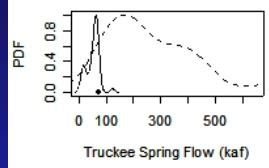
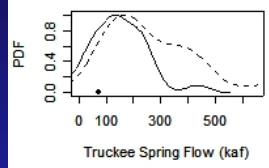
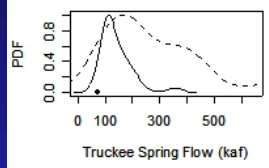
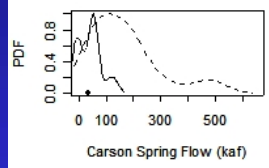
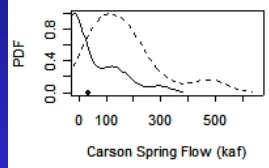
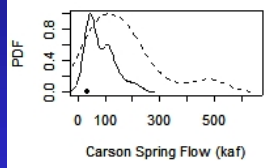
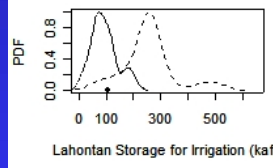
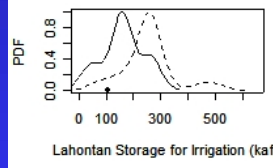
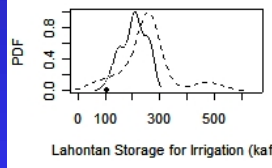
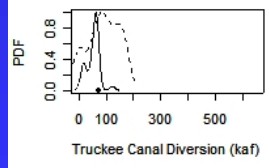
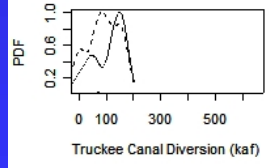
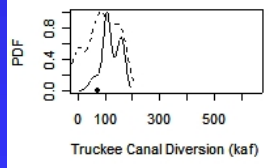
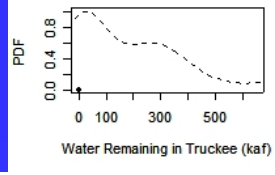
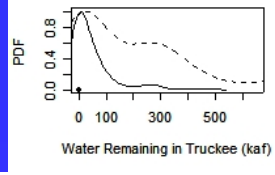
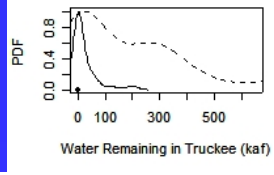
- Truckee River Water Available for Fish

- Diversion through the Truckee Canal

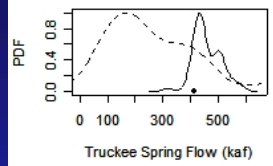
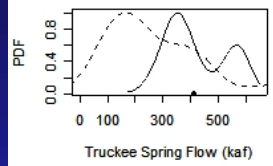
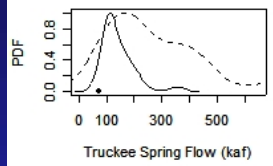
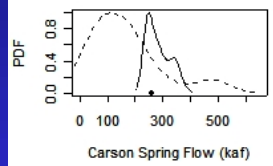
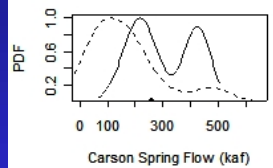
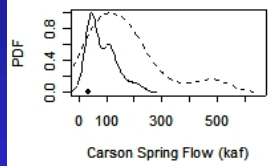
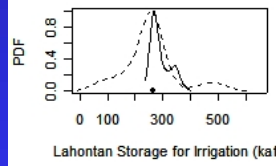
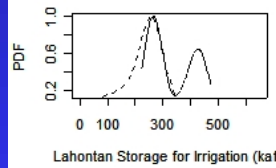
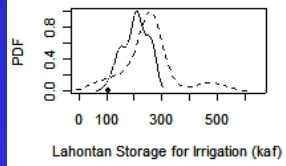
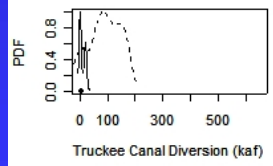
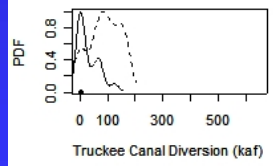
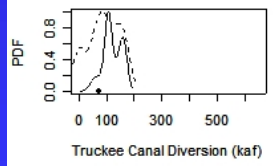
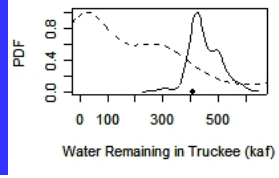
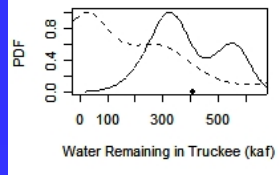
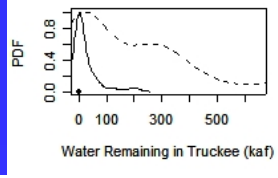
Decision Model Results

	Irrigation Water	Canal Diversion	Water for Fish
Dec 1st Forecast			
Feb 1st Forecast			
Apr 1st Forecast			

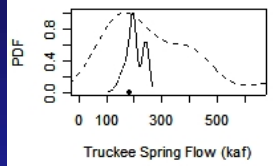
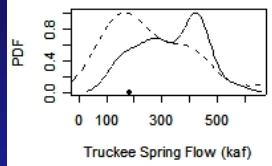
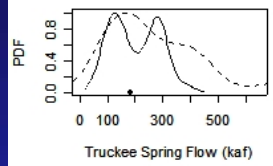
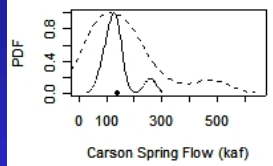
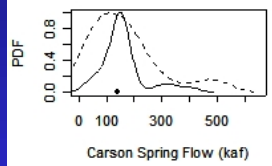
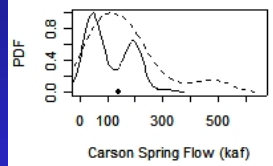
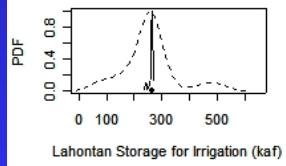
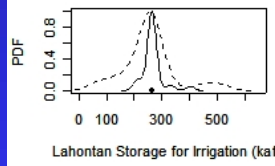
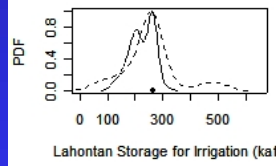
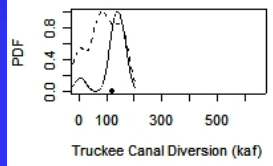
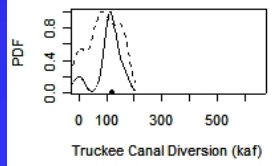
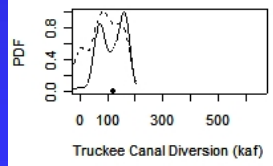
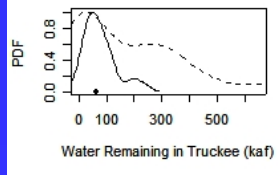
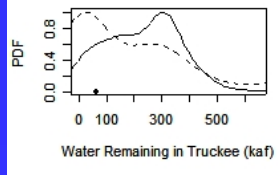
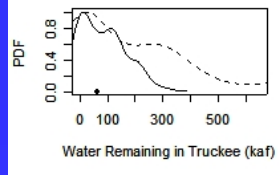
Dry Year: 1994

April 1st	February 1st	December 1st	
			Truckee Forecast
			Carson Forecast
			Storage for Irrigation
			Canal Diversion
			Water for Fish

Wet Year: 1993

April 1st	February 1st	December 1st	
			Truckee Forecast
			Carson Forecast
			Storage for Irrigation
			Canal Diversion
			Water for Fish

Normal Year: 2003

April 1st	February 1st	December 1st	
			Truckee Forecast
			Carson Forecast
			Storage for Irrigation
			Canal Diversion
			Water for Fish

Exceedance Probabilities

1994 (Dry Year)	Apr 1st	Feb 1st	Dec 1st	Historical
Irrigation Water mean value (kaf)	94	161	214	264
264 kaf Irrigation Water exceedance probability	4%	14%	18%	50%
Fish Flow mean value (kaf)	0	42	39	199
60.5 kaf Fish Flow exceedance probability	0%	57%	58%	87%
Canal Diversion mean value (kaf)	52	107	121	84

1993 (Wet Year)	Apr 1st	Feb 1st	Dec 1st	Historical
Irrigation Water mean value (kaf)	291	332	246	264
264 kaf Irrigation Water exceedance probability	73%	73%	31%	50%
Fish Flow mean value (kaf)	452	391	138	199
60.5 kaf Fish Flow exceedance probability	100%	99%	81%	87%
Canal Diversion mean value (kaf)	8	29	101	84

2003 (Normal Year)	Apr 1st	Feb 1st	Dec 1st	Historical
Irrigation Water mean value (kaf)	261	268	225	264
264 kaf Irrigation Water exceedance probability	40%	49%	26%	50%
Fish Flow mean value (kaf)	76	223	71	199
60.5 kaf Fish Flow exceedance probability	61%	91%	69%	87%
Canal Diversion mean value (kaf)	126	106	108	84

Summary & Conclusions

- Climate indicators improve forecasts and offer longer lead time
- Water managers can utilize the improved forecasts in operations and seasonal planning

Grantz et al. (2005) – submitted to BAMS

Grantz et al. (2005) – accepted in Water Resources Research.

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- CIRES and the Innovative Research Project
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