Improving basin-specific hydrologic predictability incorporating large-scale climate information

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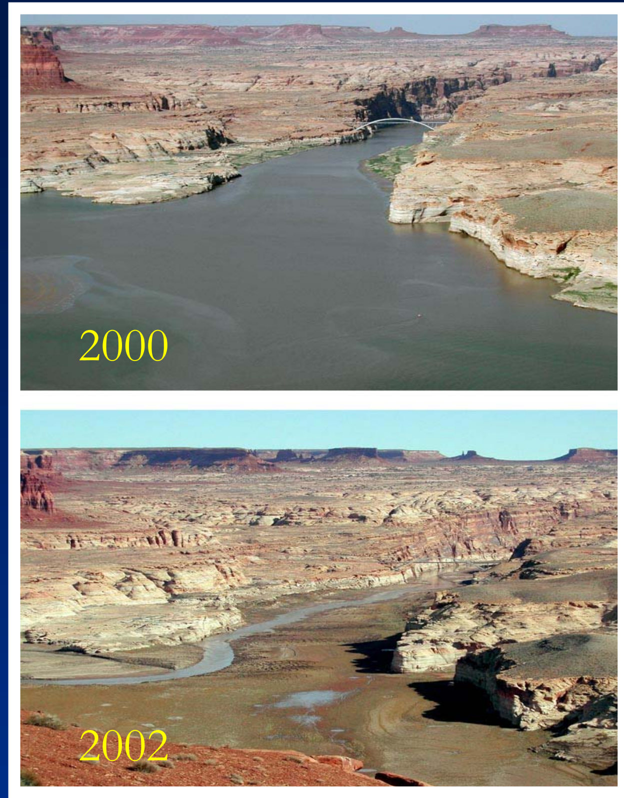
Enhancing Water Supply Reliability

An Interdisciplinary Project to Improve Predictive Capacity in the Lower Colorado River Basin

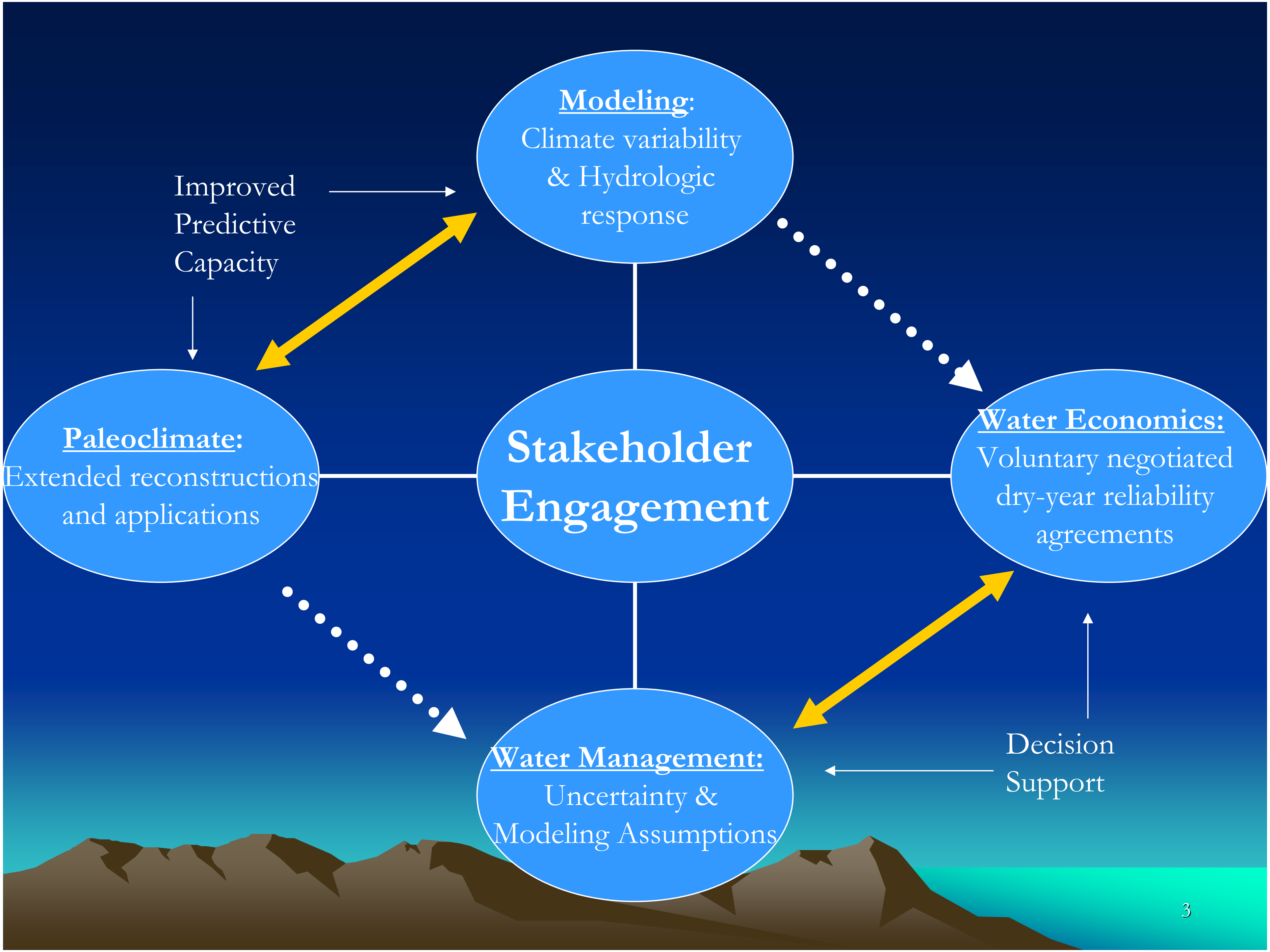


Courtesy USGS

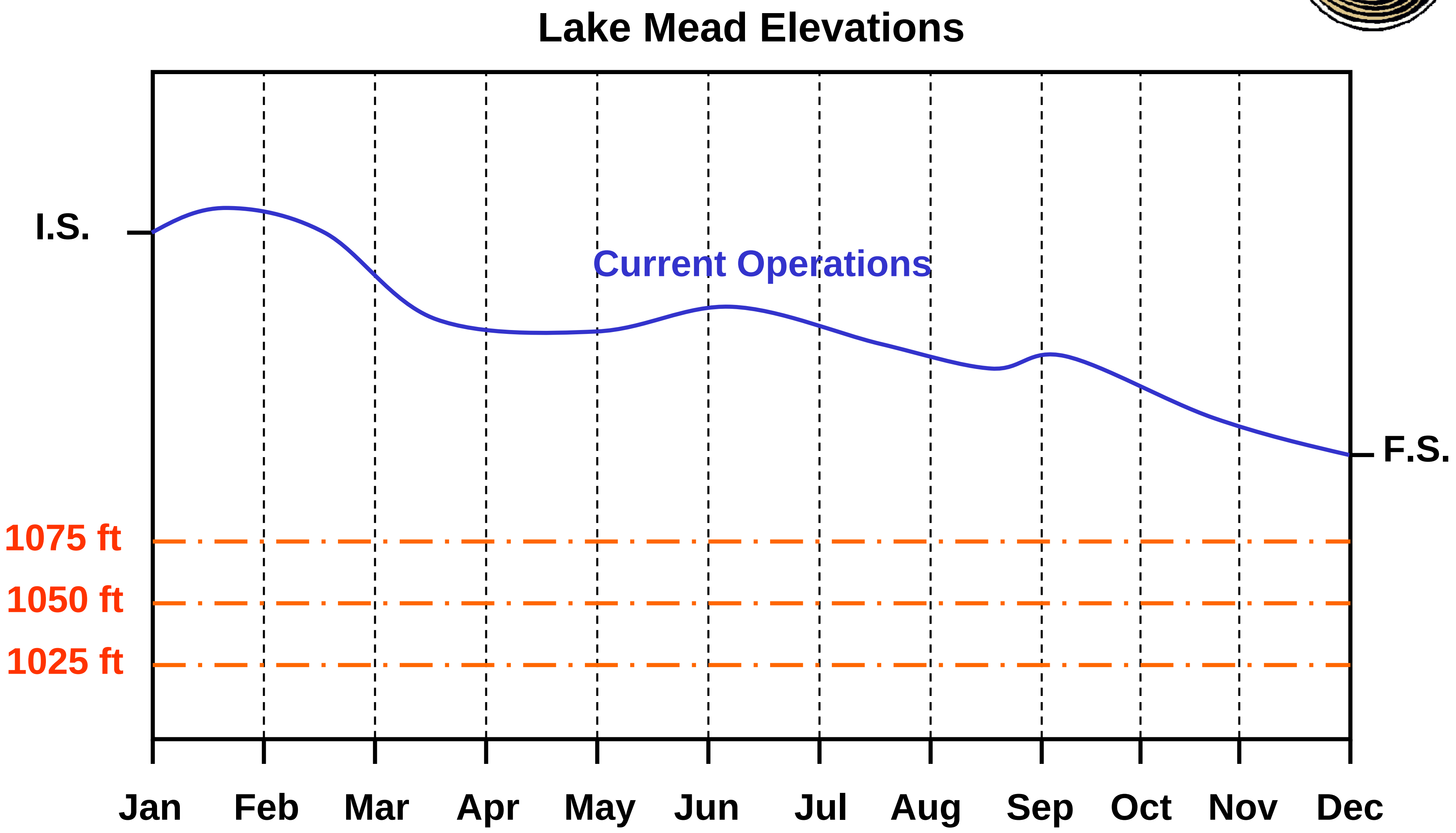
Water Sustainability
The University of Arizona

Water Resources Research Center

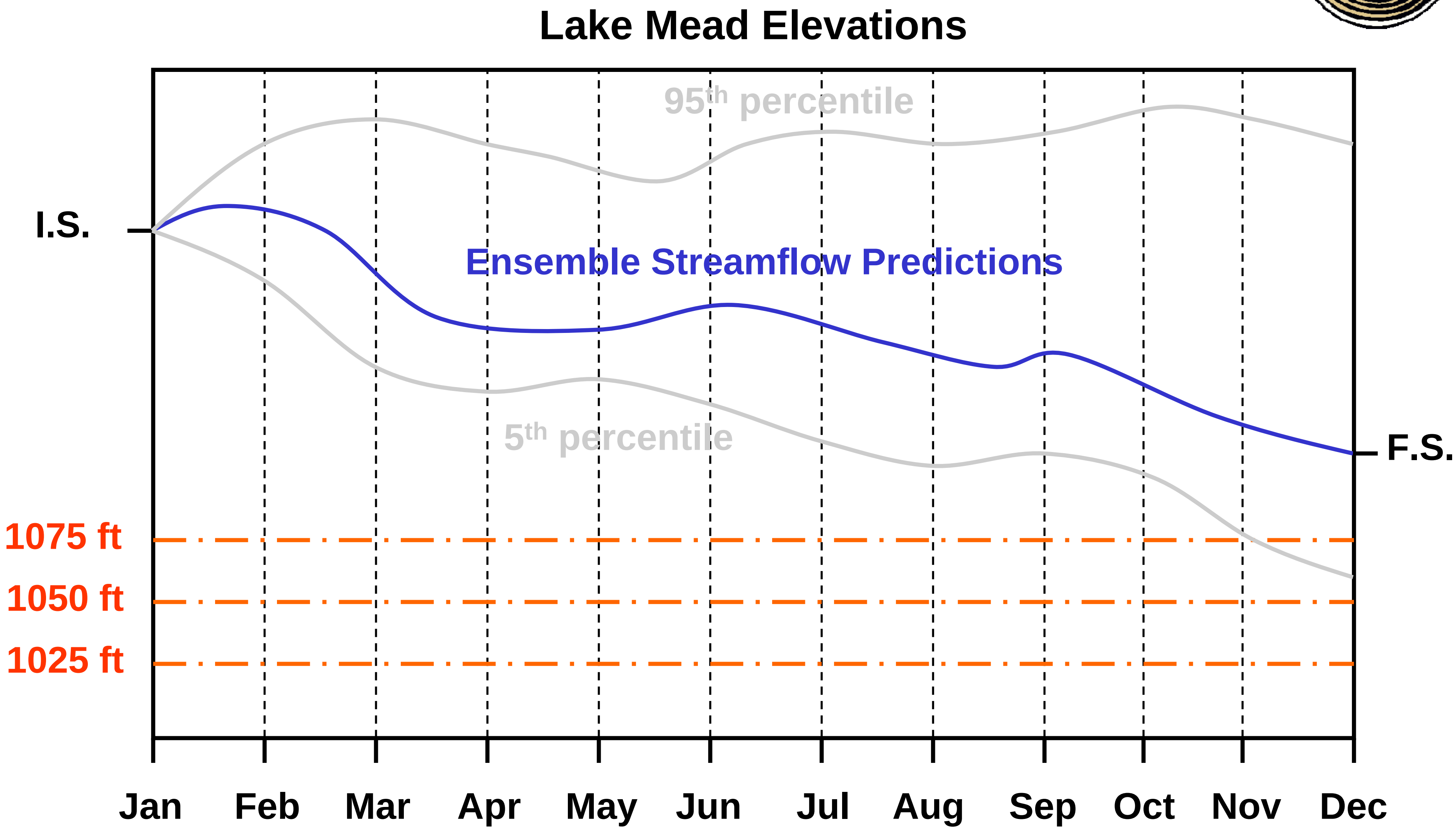
U.S. Department of the Interior
Bureau of Reclamation


Modeling:
Climate variability & Hydrologic response
Improved Predictive Capacity
Paleoclimate:
Extended reconstructions and applications
Stakeholder Engagement
Water Economics:
Voluntary negotiated dry-year reliability agreements
Water Management:
Uncertainty & Modeling Assumptions
Decision Support
3

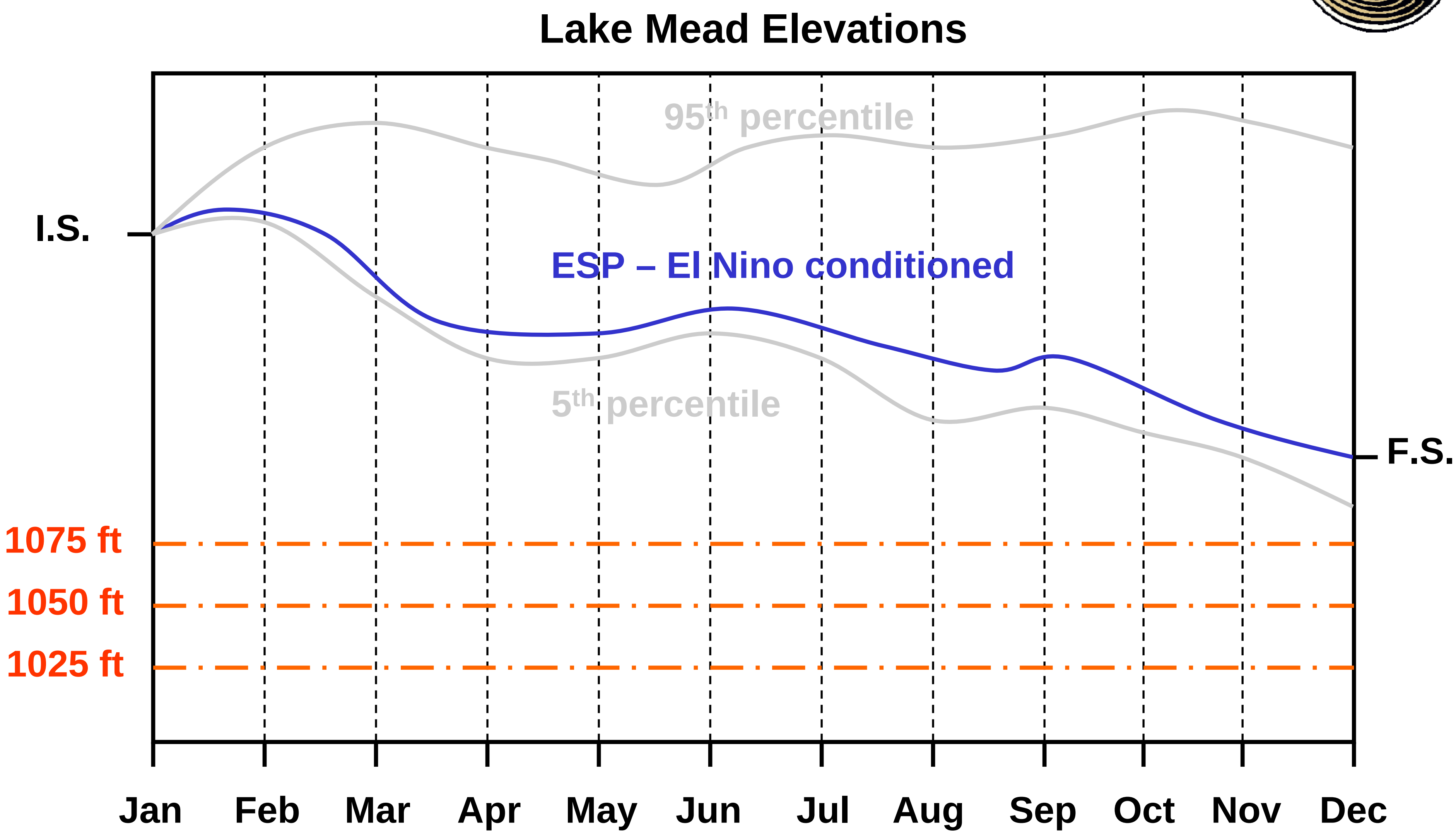
Seasonal (annual) predictability



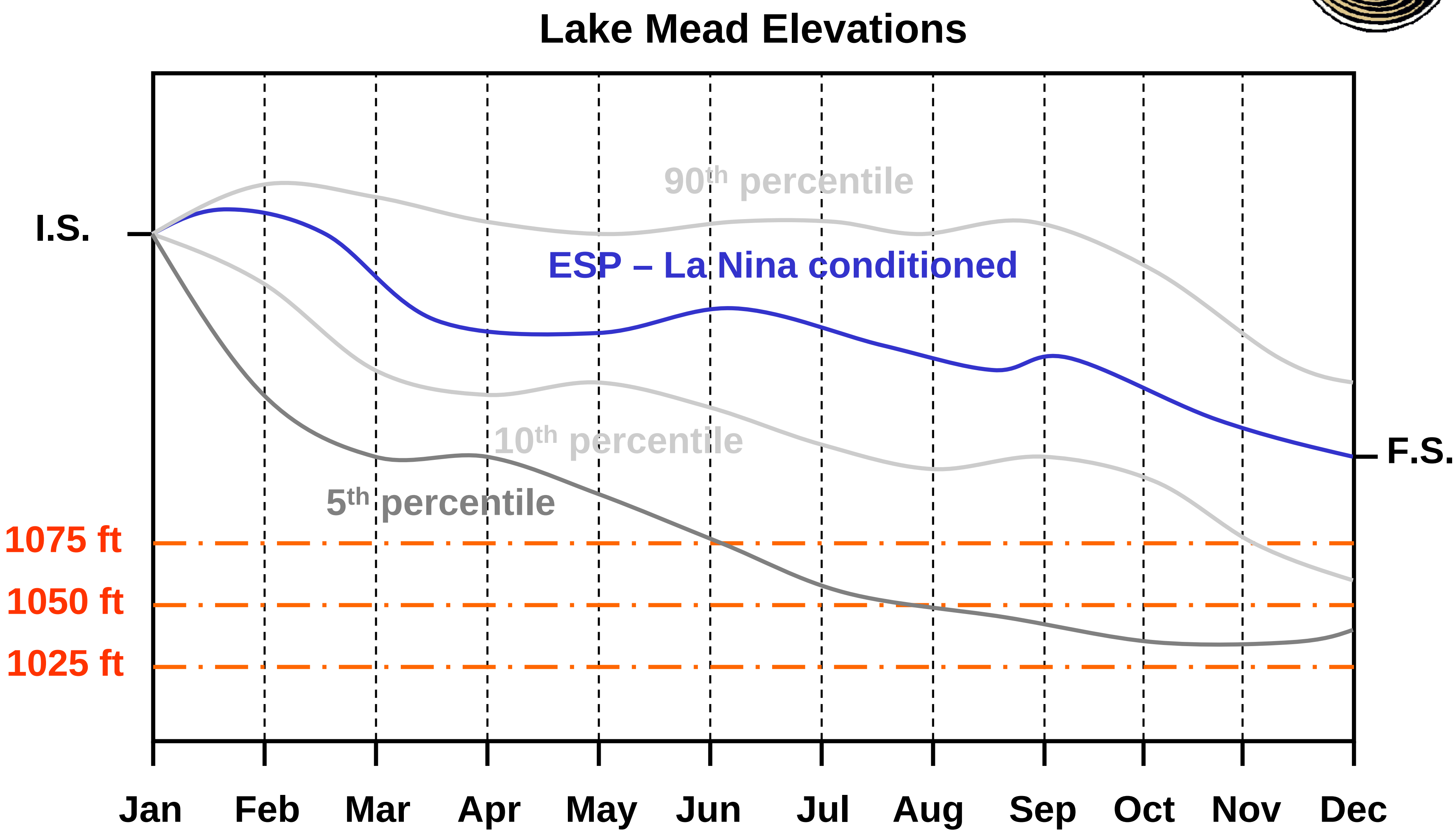
Seasonal (annual) predictability



Seasonal (annual) predictability



Seasonal (annual) predictability



Moisture source to Colorado River Basin

Research question

- Can we confidently predict at seasonal to annual time scale the available water amount in the Lower Colorado River basin based on ocean-atmosphere-land links?
- More specifically, can we do this for the Little Colorado River catchment (69,400 km^2; Annual average water yield: 1.98*10^8 m^3/year (161,000 acre*ft/year)

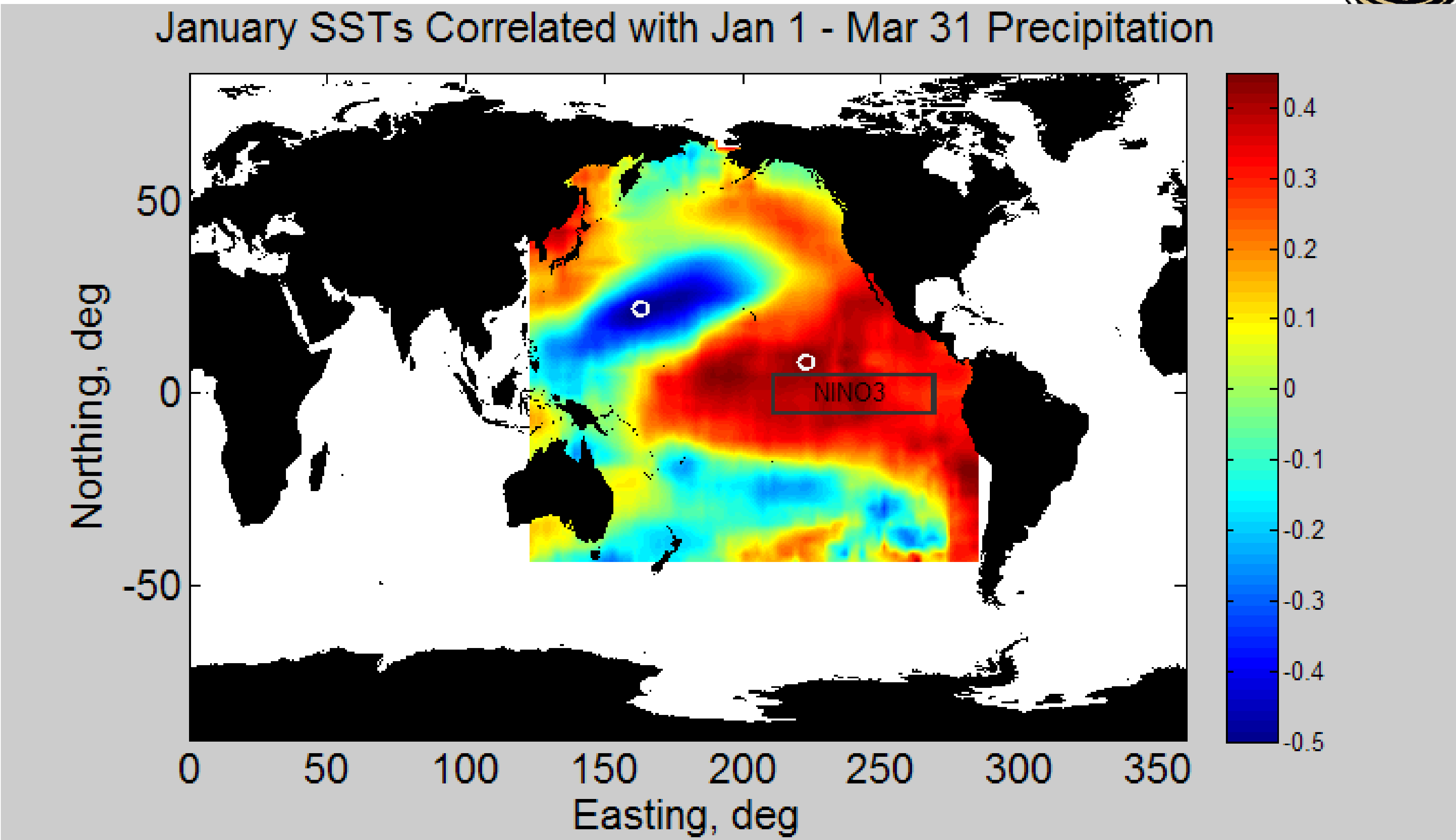
Data

- Temperature and Precipitation
  - University of Washington
  - 1/8º interpolated data set for the contiguous US
  - 505 grid cells in the Little Colorado
- Discharge
  - USGS – Cameron station (contribution area very close to total basin area)
- Sea Surface Temperature
  - International Comprehensive Ocean Atmosphere Data Set
  - 2º resolution at a monthly time step
- Used daily basin (spatial) averages of temperature, precipitation and discharge to obtain
  - Monthly average temperatures
  - Monthly sums of precipitation and discharge
- Monthly SSTs were spatially averaged over 20° longitude by 10° latitude windows
  - Initially smooth the data and help fill places and times with no data

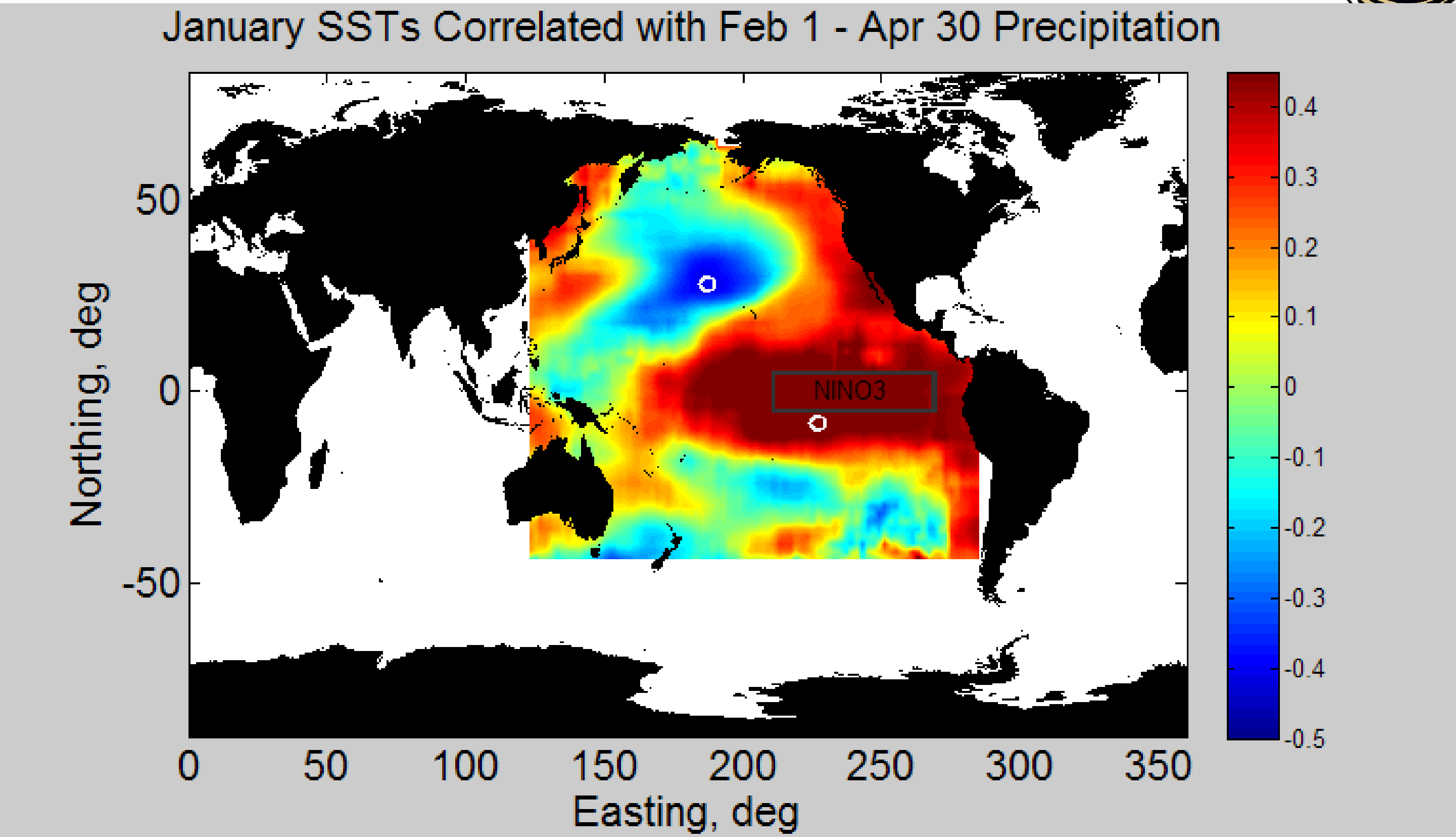
Methods

- Monthly SSTs were correlated at each point in the Pacific with 3-month average temperatures and 3-months sums of precipitation and discharge, with increasing temporal lags:
  - For example, January SSTs were correlated with Jan-Mar, Feb-Apr, … Jun-Aug basin variables (temperature, precipitation, discharge)
- Find the most correlated points in the Pacific with the Little Colorado climate and hydrology variables;
- Test significance of conditioned versus unconditioned pdf shifts in temperature, precipitation and discharge;
- Identify observation kernels, linking SST anomalies to basin-specific climate and hydrologic response, using Gaussian Mixture models (Parzen densities);
- Develop seasonal to annual prediction tool to provide most likely value (mean of normalized variable), as well as pdf to reflect uncertainty (for ensemble simulations, e.g.)

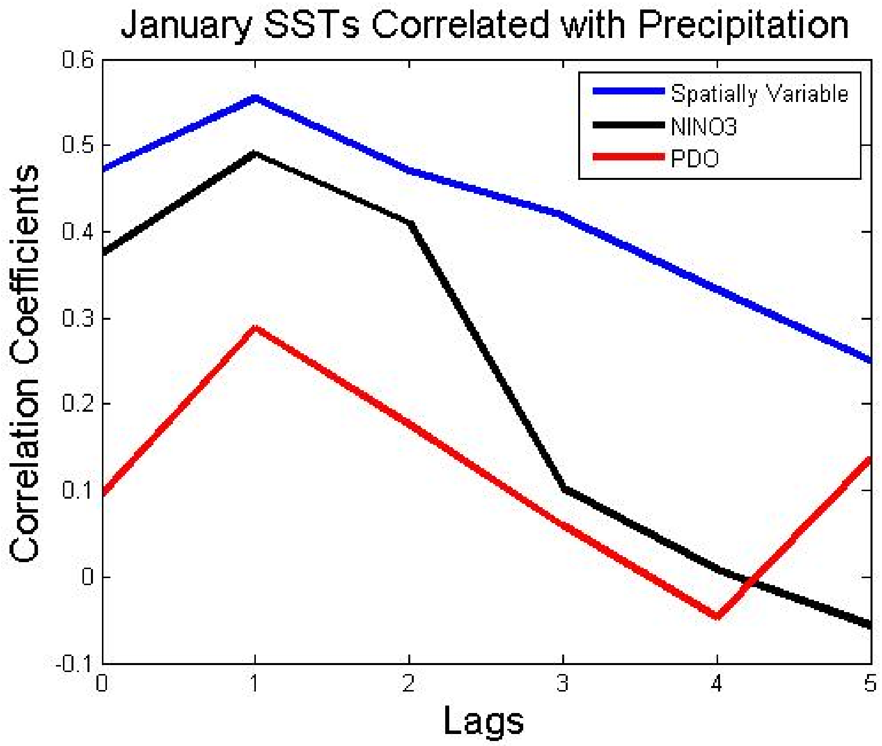
Results: correlation coefficients for different lags

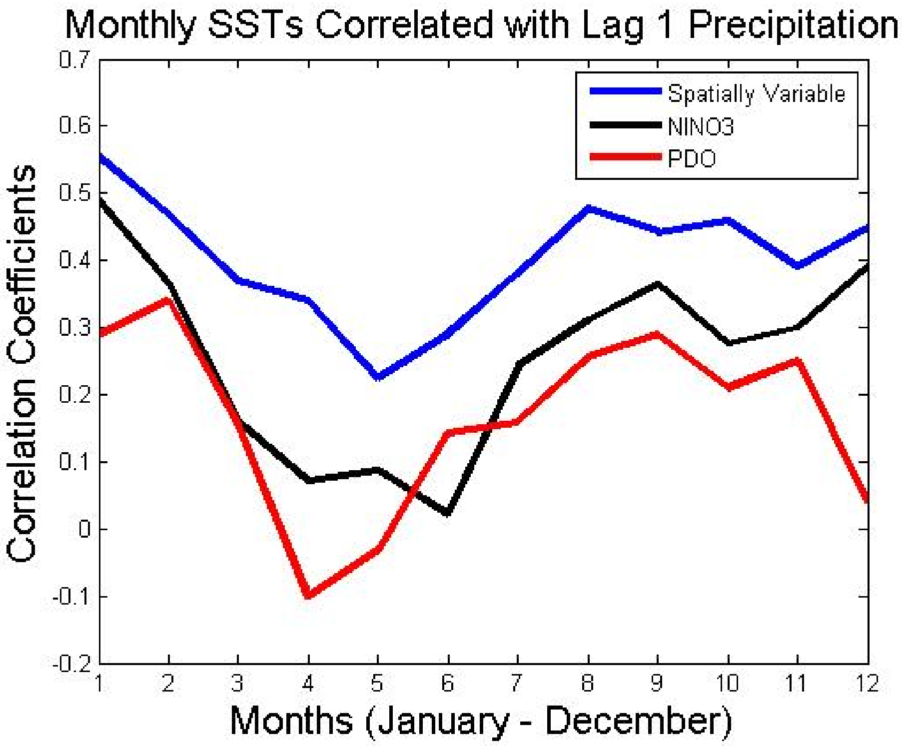


Results: correlation coefficients for different seasons

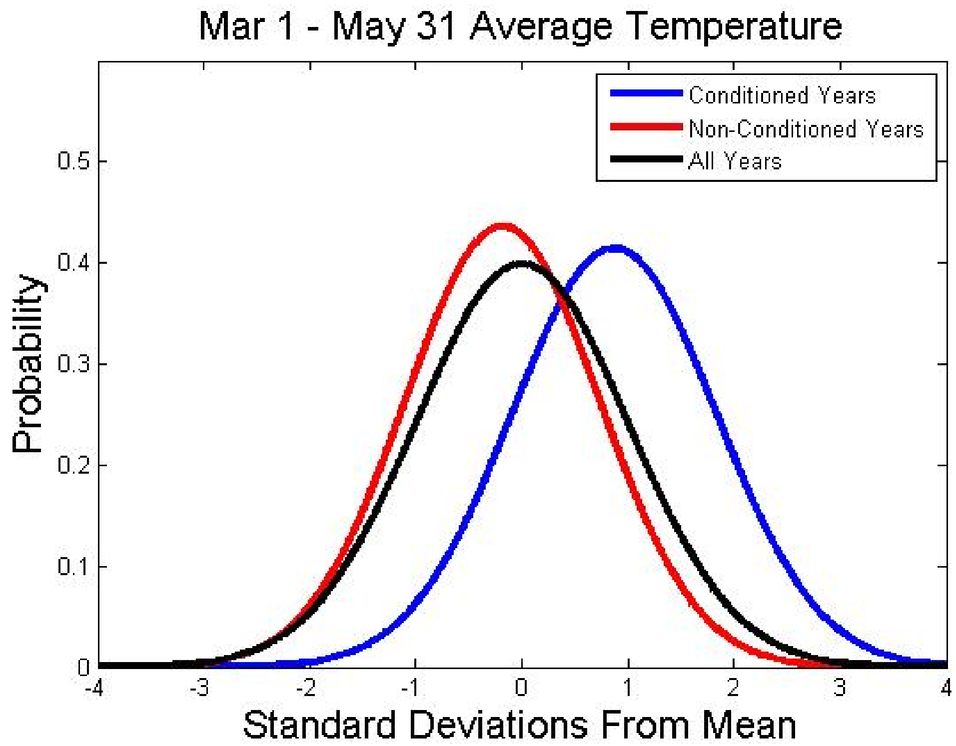


Stacking it up against ENSO and PDO



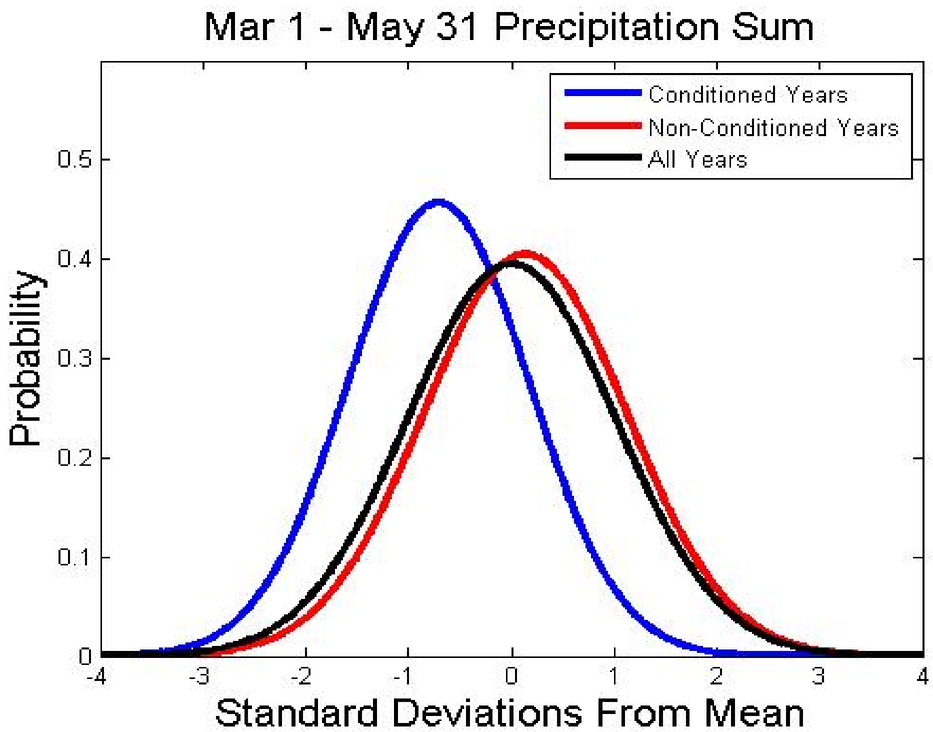


Does SST state defines significant shifts in climate variability?



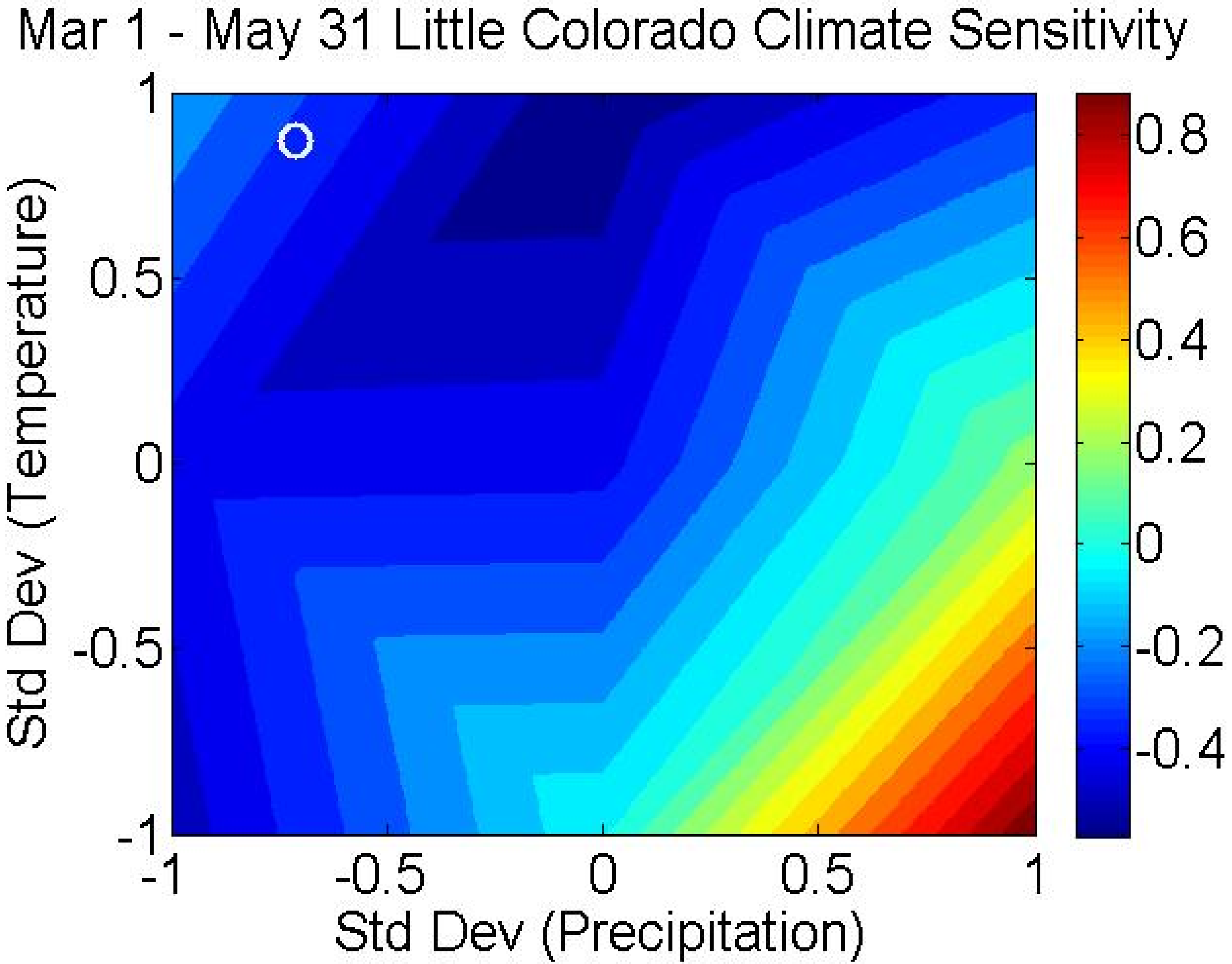
	All (std dev)	All (°C)	Conditioned (std dev)	Conditioned (°C)
25%	-.68	8.61	.22	9.56
50%	0	9.33	.87	10.25
75%	.68	10.05	1.52	10.94

Does SST state defines significant shifts in climate variability?

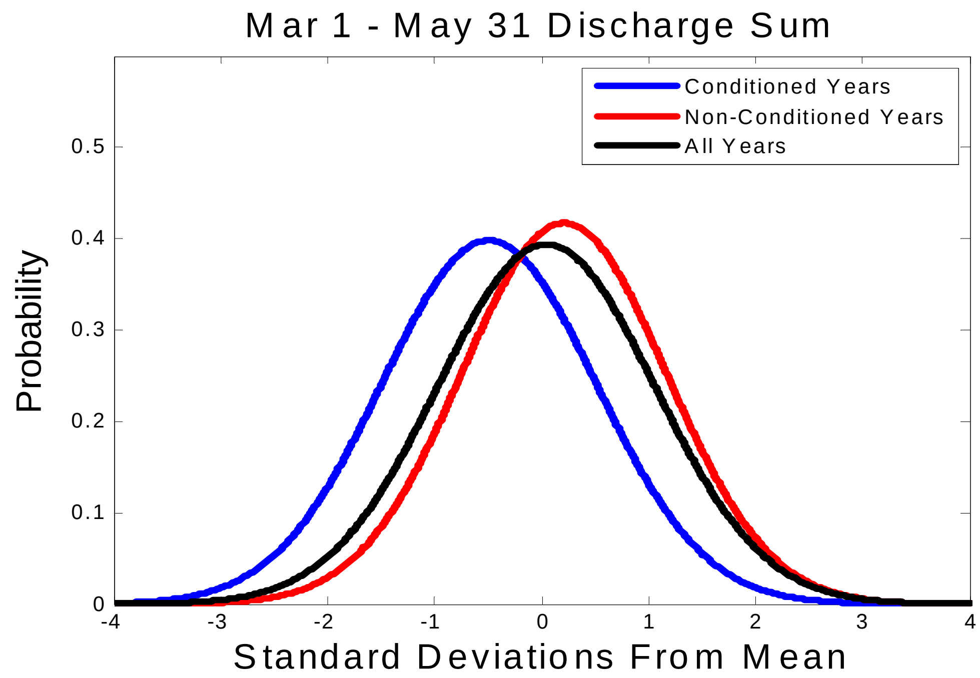


	All (std dev)	All (mm)	Conditioned (std dev)	Conditioned (mm)
25%	-.68	30.22	-1.29	19.95
50%	0	45.49	-.71	29.65
75%	.68	65.24	-.13	42.23

Little Colorado climate sensitivity (elasticity)



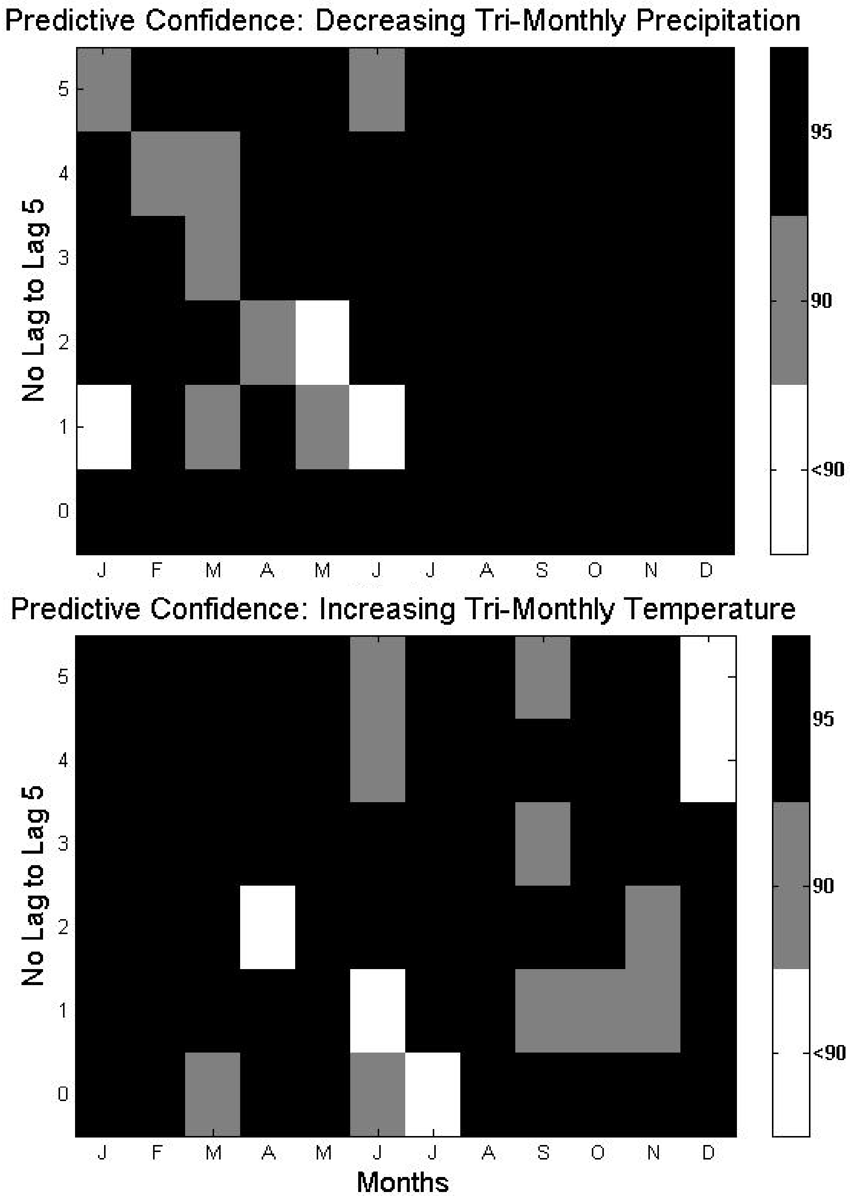
Does SST state defines also significant shifts in hydrologic response?



	All (std dev)	All (mm)	Conditioned (std dev)	Conditioned (mm)
25%	-.68	.077	-1.16	.013
50%	0	.452	-.49	.135
75%	.68	1.529	.18	.653

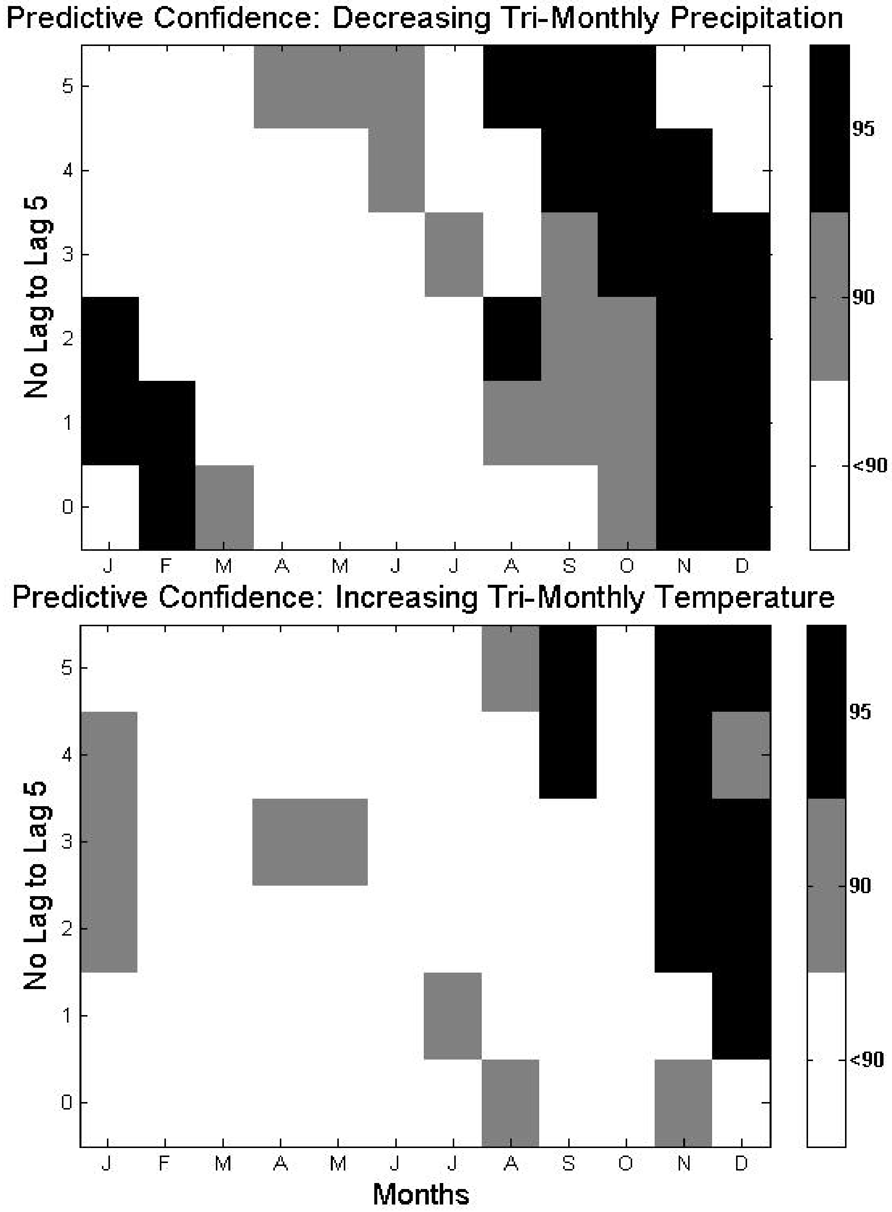
Predictive confidence SST states

- Precipitation
- Temperature

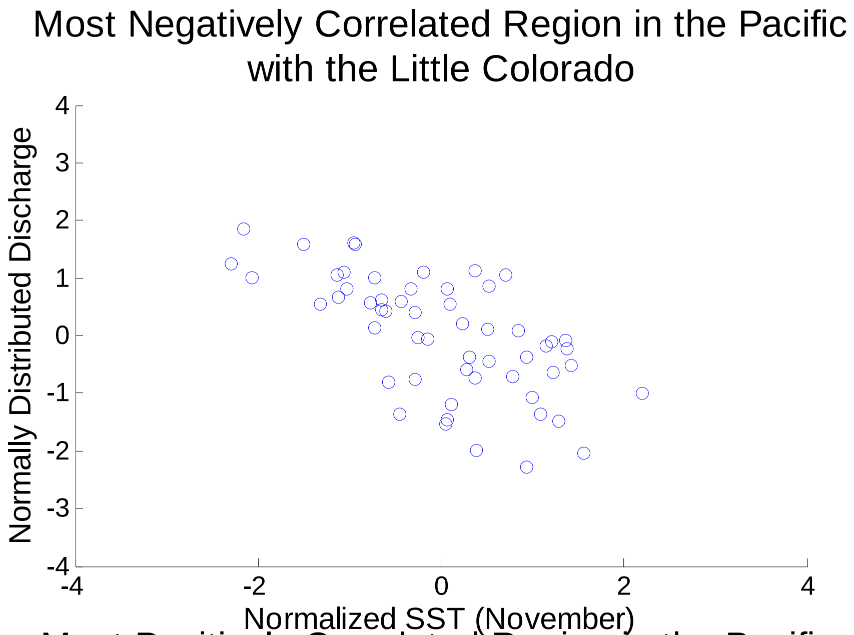


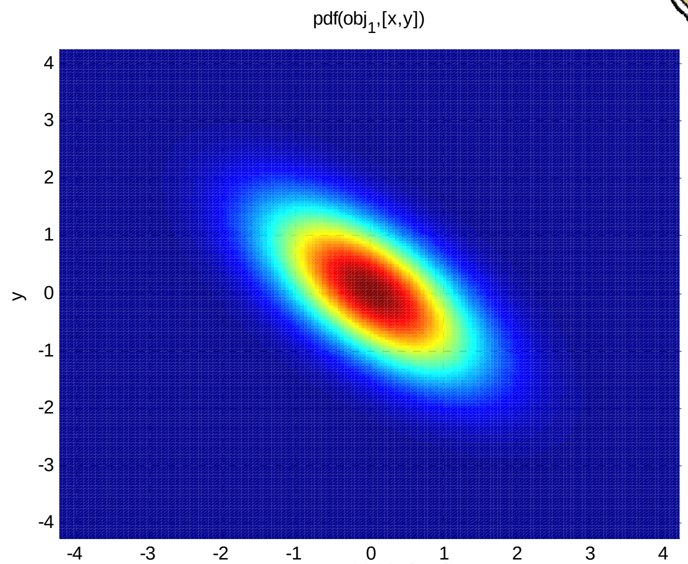
Predictive confidence SST indices

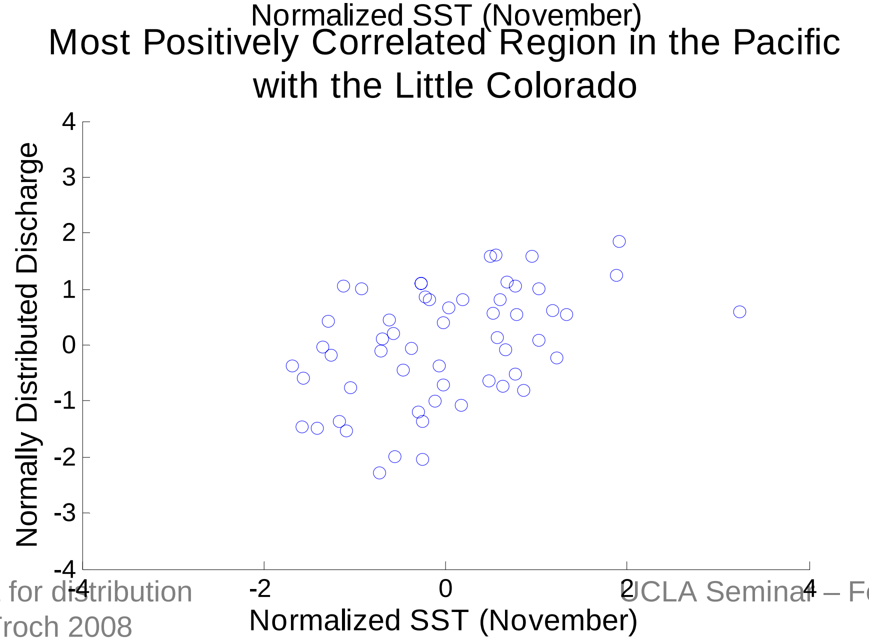
- Precipitation
- Temperature

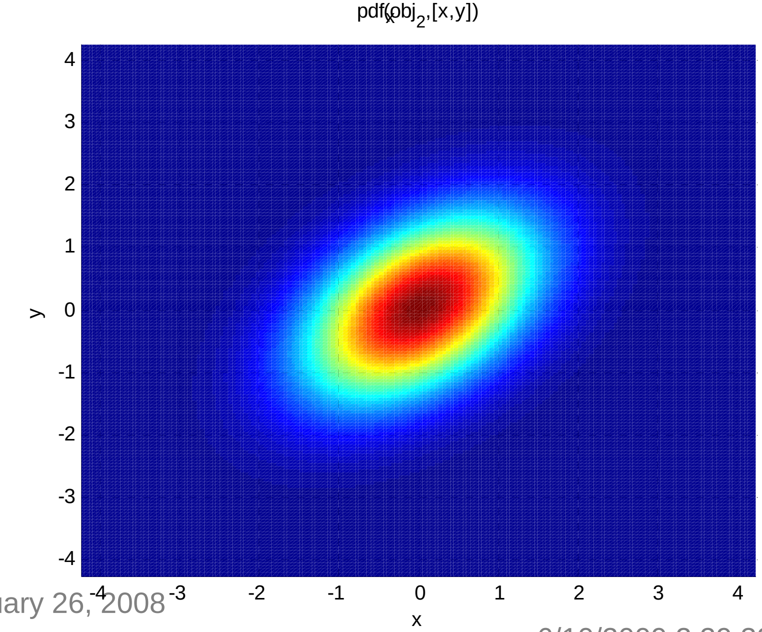


Observation kernels



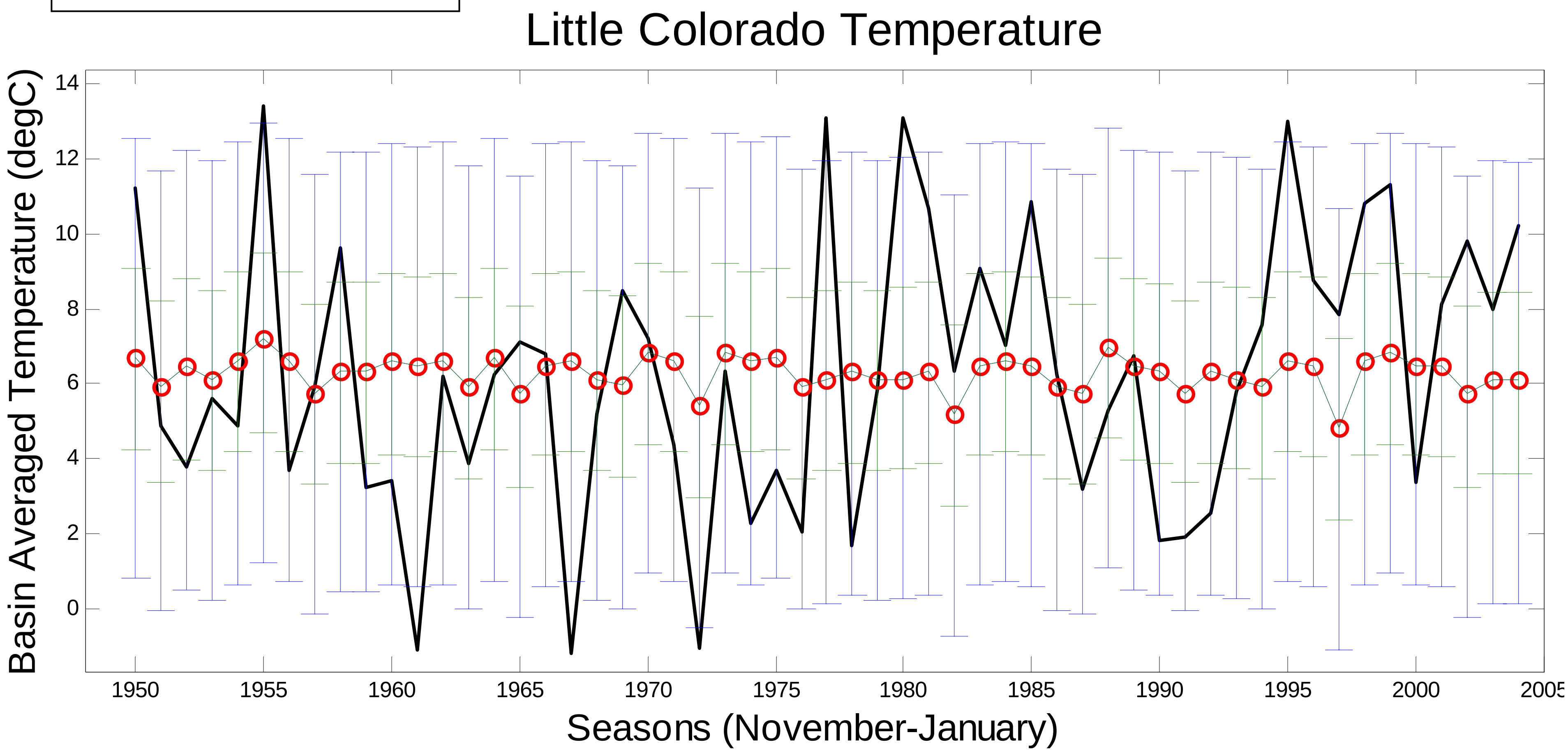






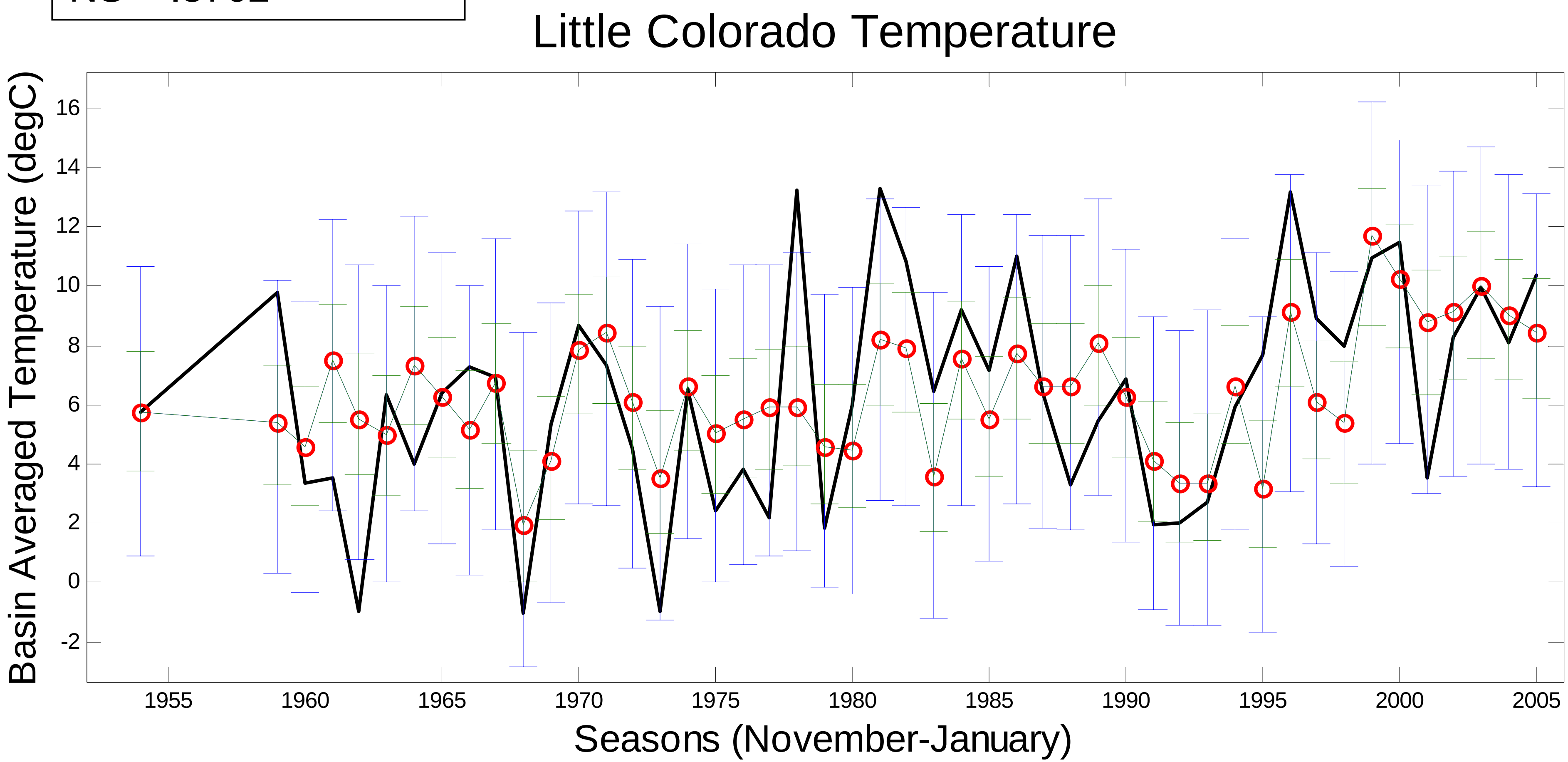
Seasonal prediction of Temperature: NINO3

CORRCOEF = .14
RMSE = 5.15
NS = .0186



Seasonal prediction of Temperature: SST states

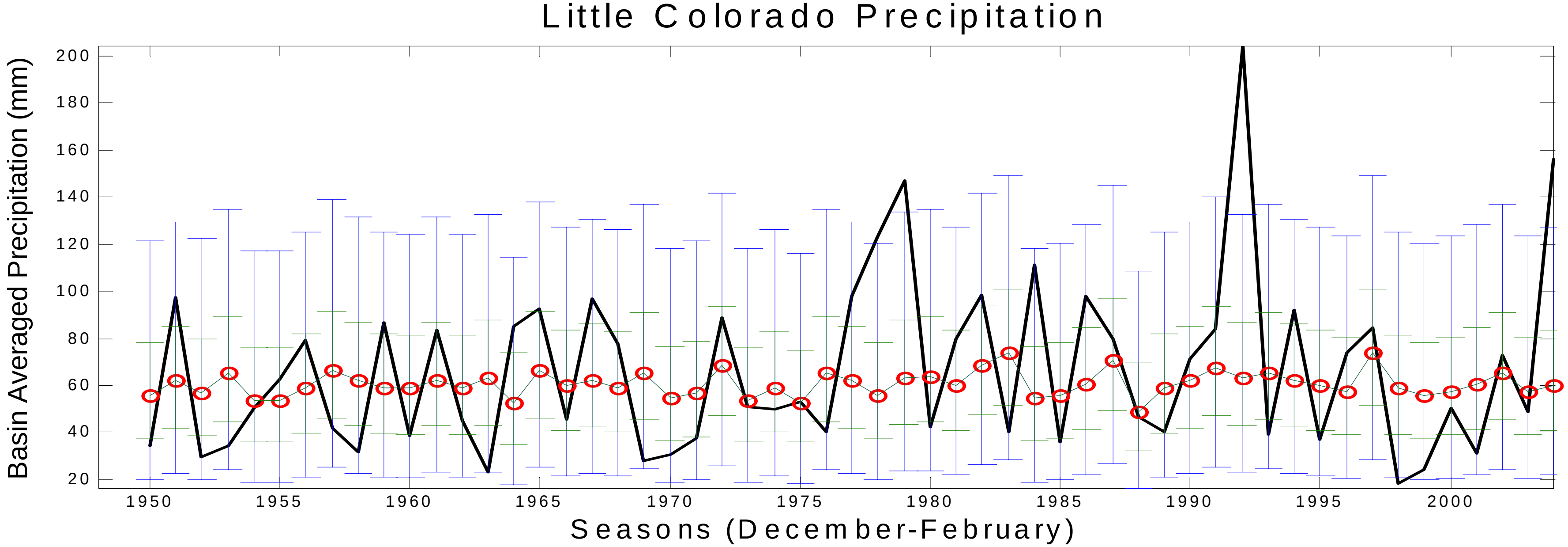
CORRCOEF = .62
RMSE = 4.44
NS = .3762



Seasonal prediction of Precipitation: NINO3

June SST anomalies to predict precipitation in Little Colorado 2 seasons ahead (December-February)

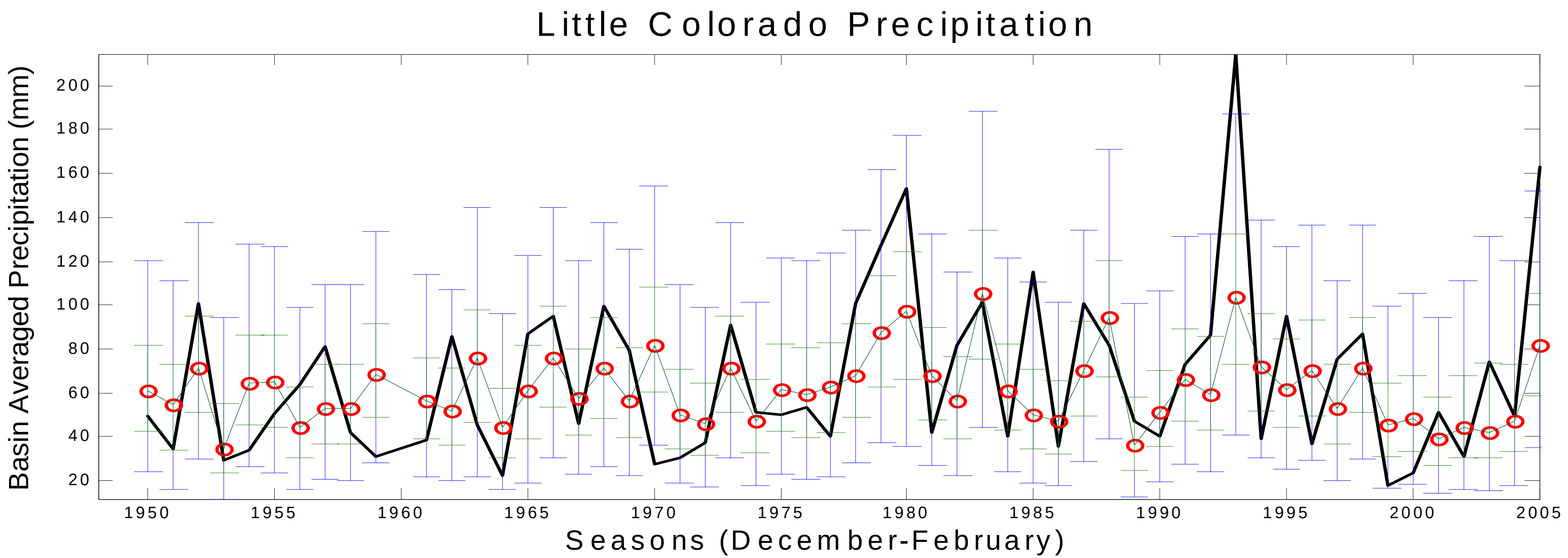
CORRCOEF = .16
RMSE = 270.1
NS = .0005



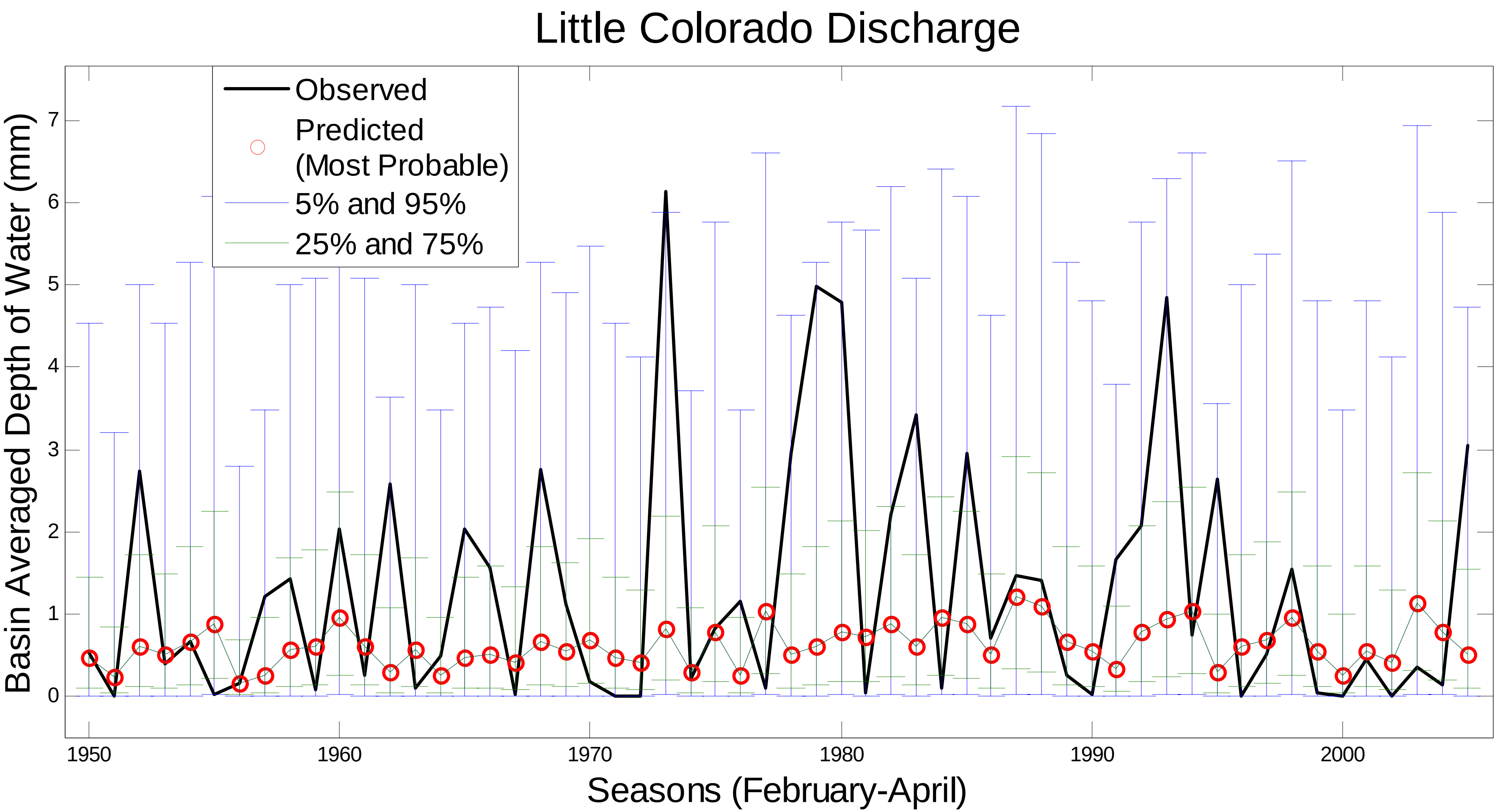
Seasonal prediction of Precipitation: SST states

June SST anomalies to predict precipitation in Little Colorado 2 seasons ahead (December-February)

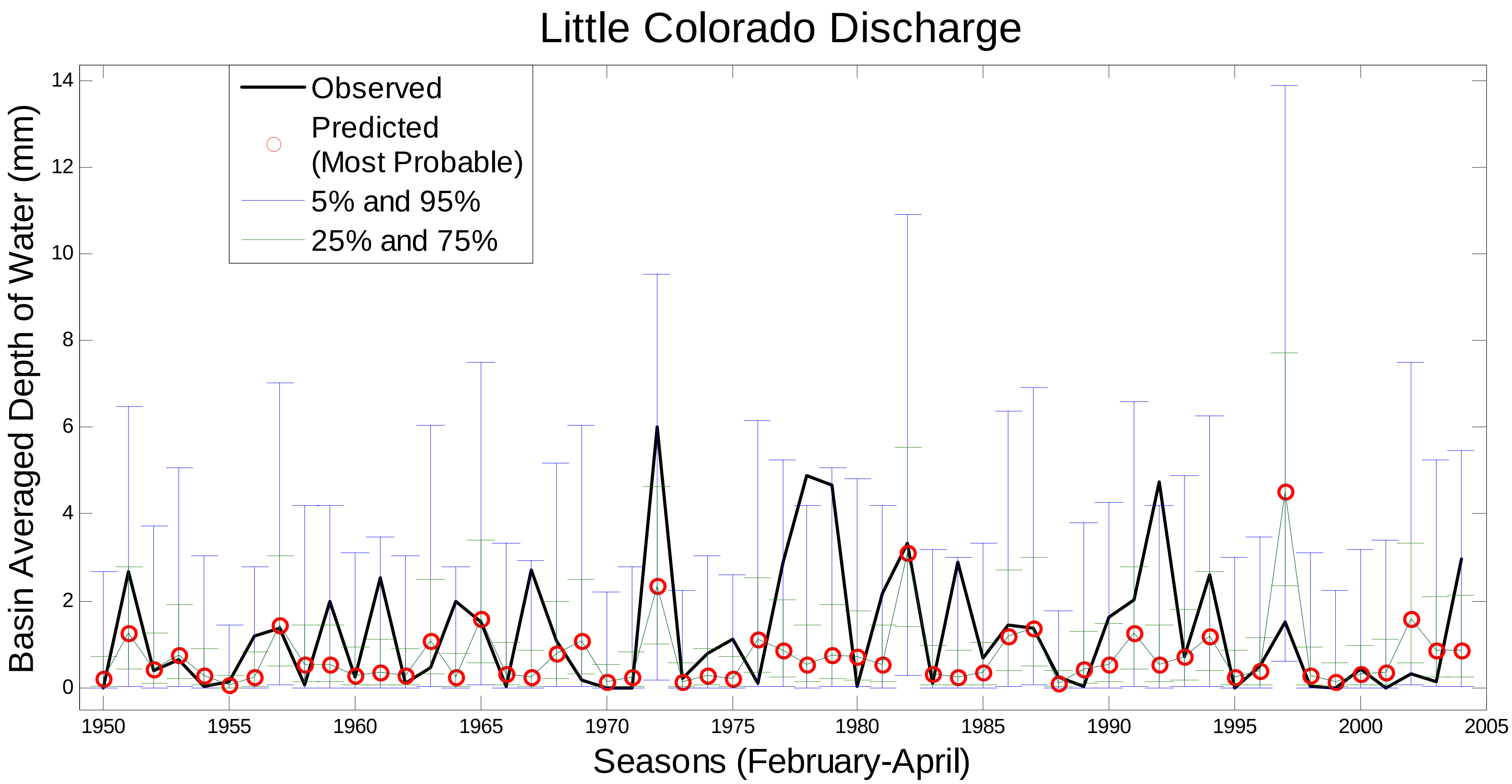
CORRCOEF = .62
RMSE = 234.4
NS = .3214



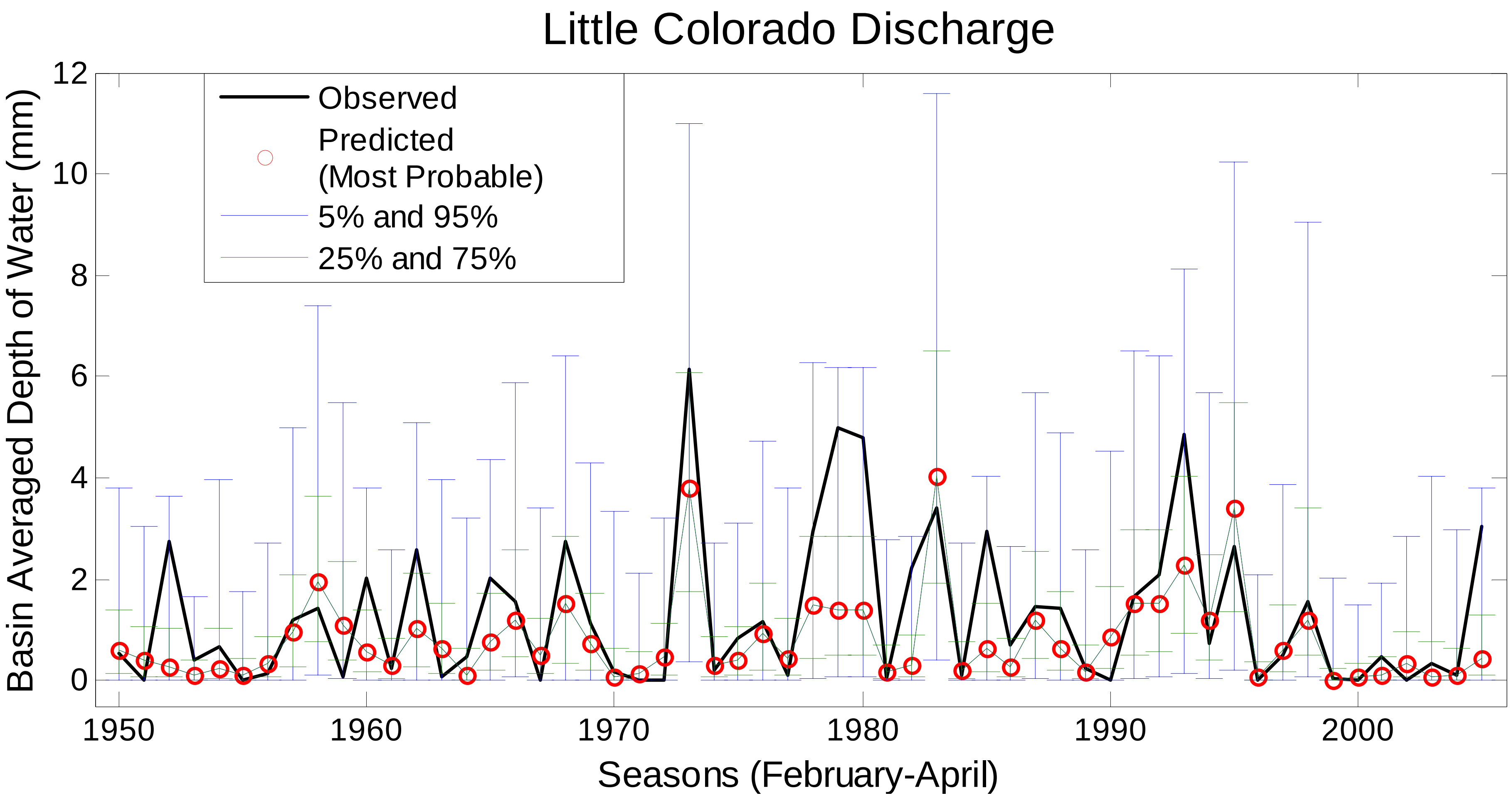
November PDO-based discharge prediction



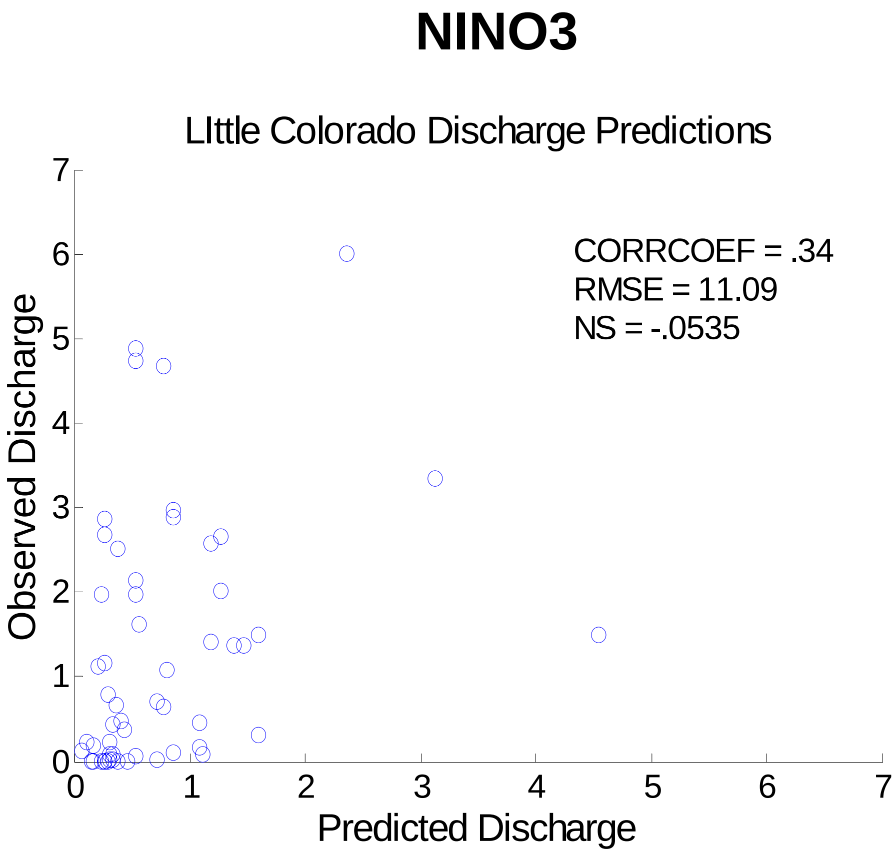
November ENSO-based discharge prediction

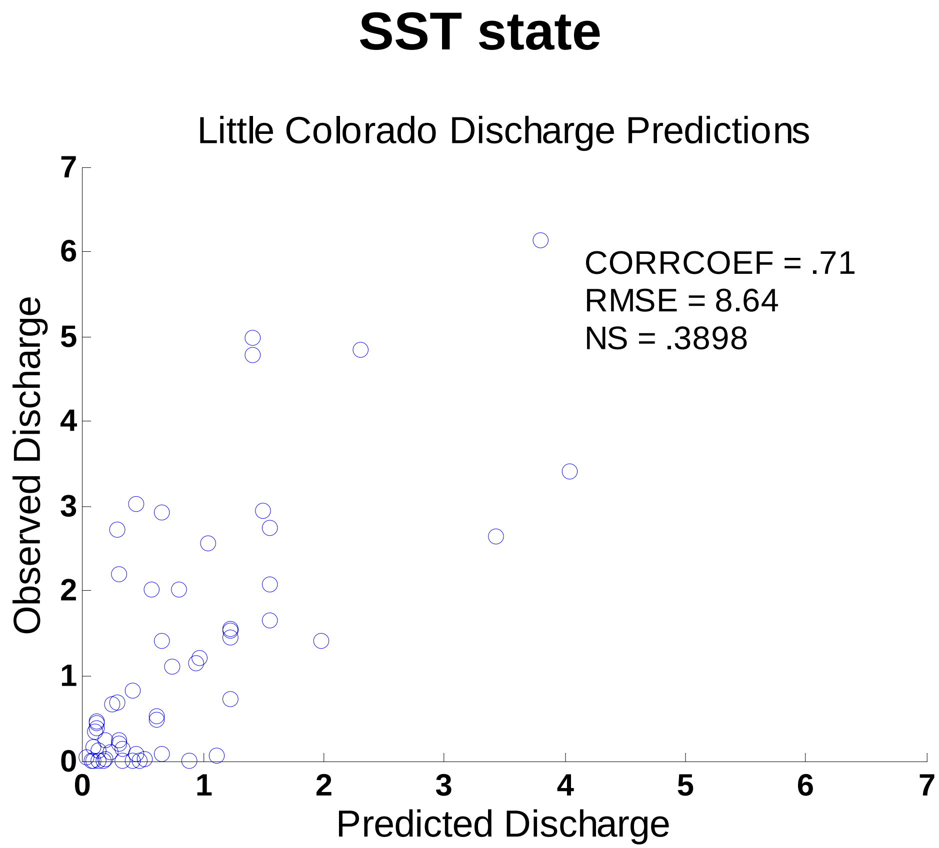


November SST-based discharge prediction

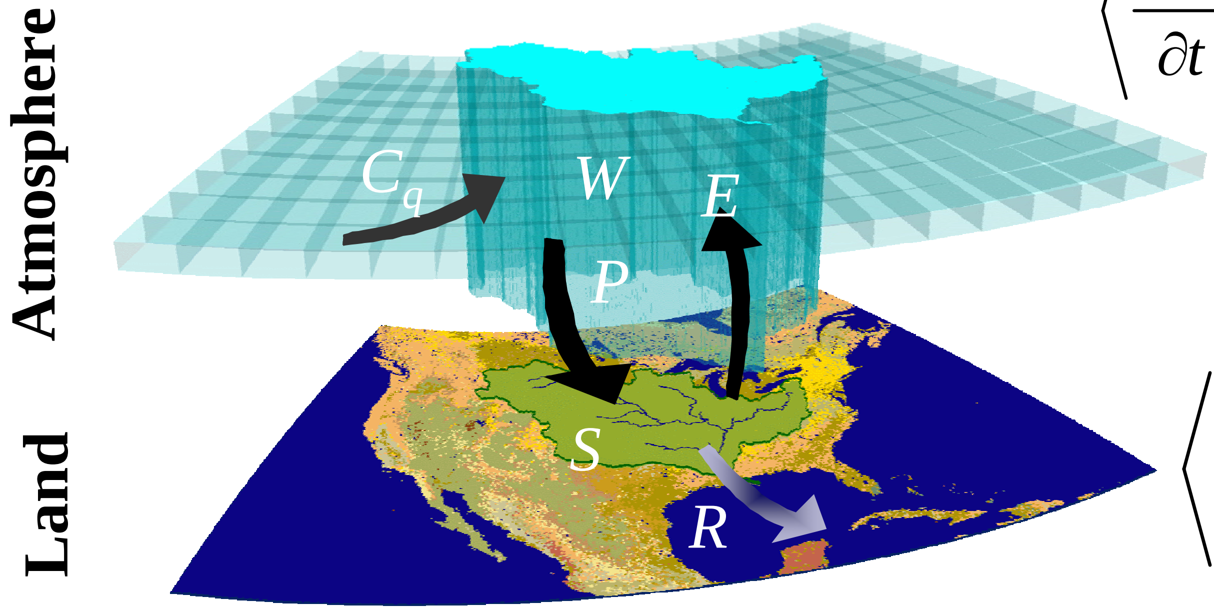


SST state-based prediction of discharge





Outlook: Land and atmosphere water balance



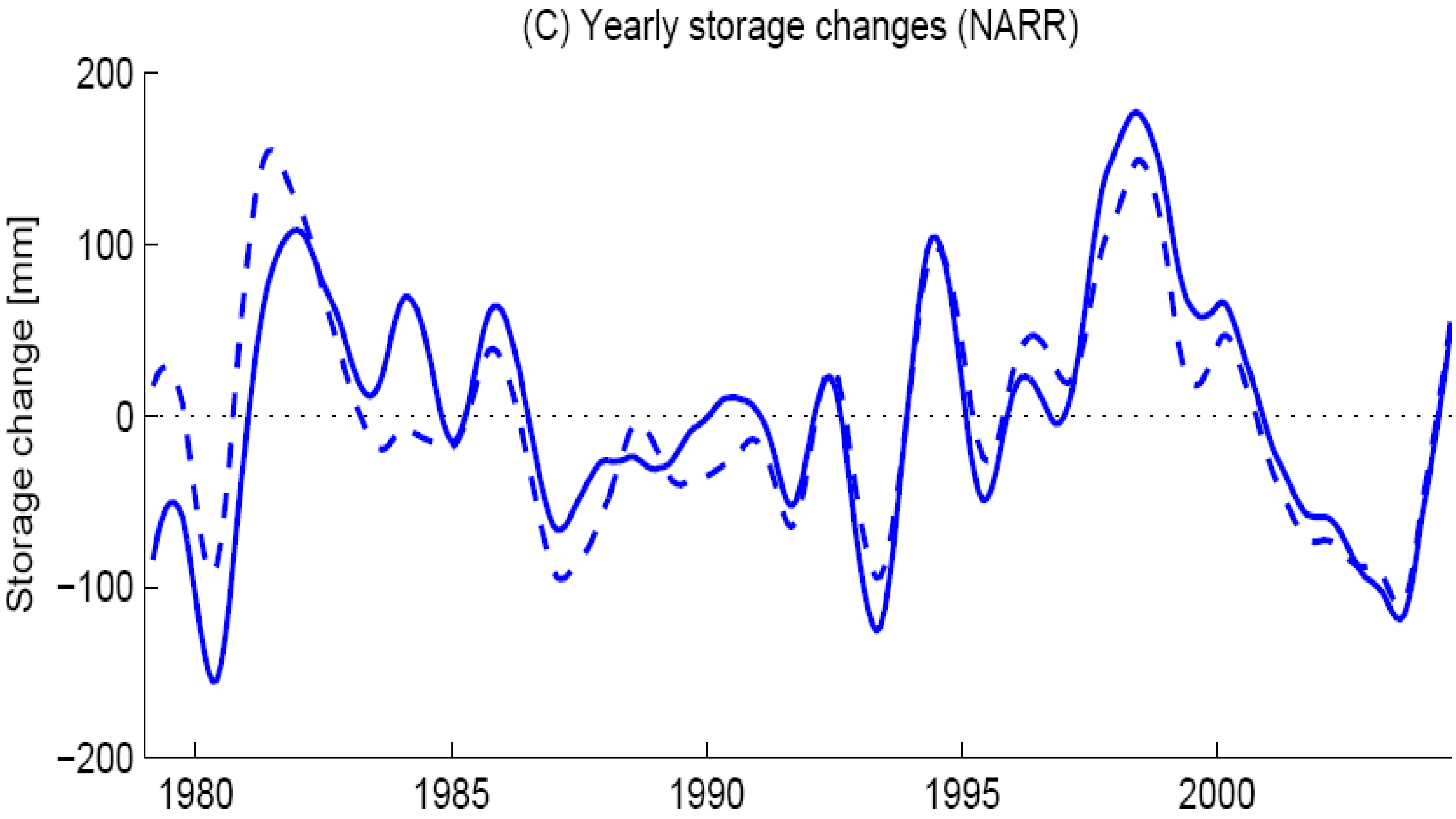
$$\left\langle \frac{\overline{\partial W}}{\partial t} \right\rangle + \left\langle \nabla_H . \vec{Q} \right\rangle = \left\langle \overline{E} - \overline{P} \right\rangle$$

$$C_q = -\nabla_H . \vec{Q}$$

$$\left\langle \frac{\overline{\partial S}}{\partial t} \right\rangle = \left\langle \overline{P} - \overline{E} \right\rangle - \left\langle \overline{R} \right\rangle$$

$$\boxed{\left\langle \frac{\overline{\partial S}}{\partial t} \right\rangle = -\left\langle \frac{\overline{\partial W}}{\partial t} \right\rangle - \left\langle \nabla_H . \vec{Q} \right\rangle - \left\langle \overline{R} \right\rangle}$$

Outlook: water storage dynamics

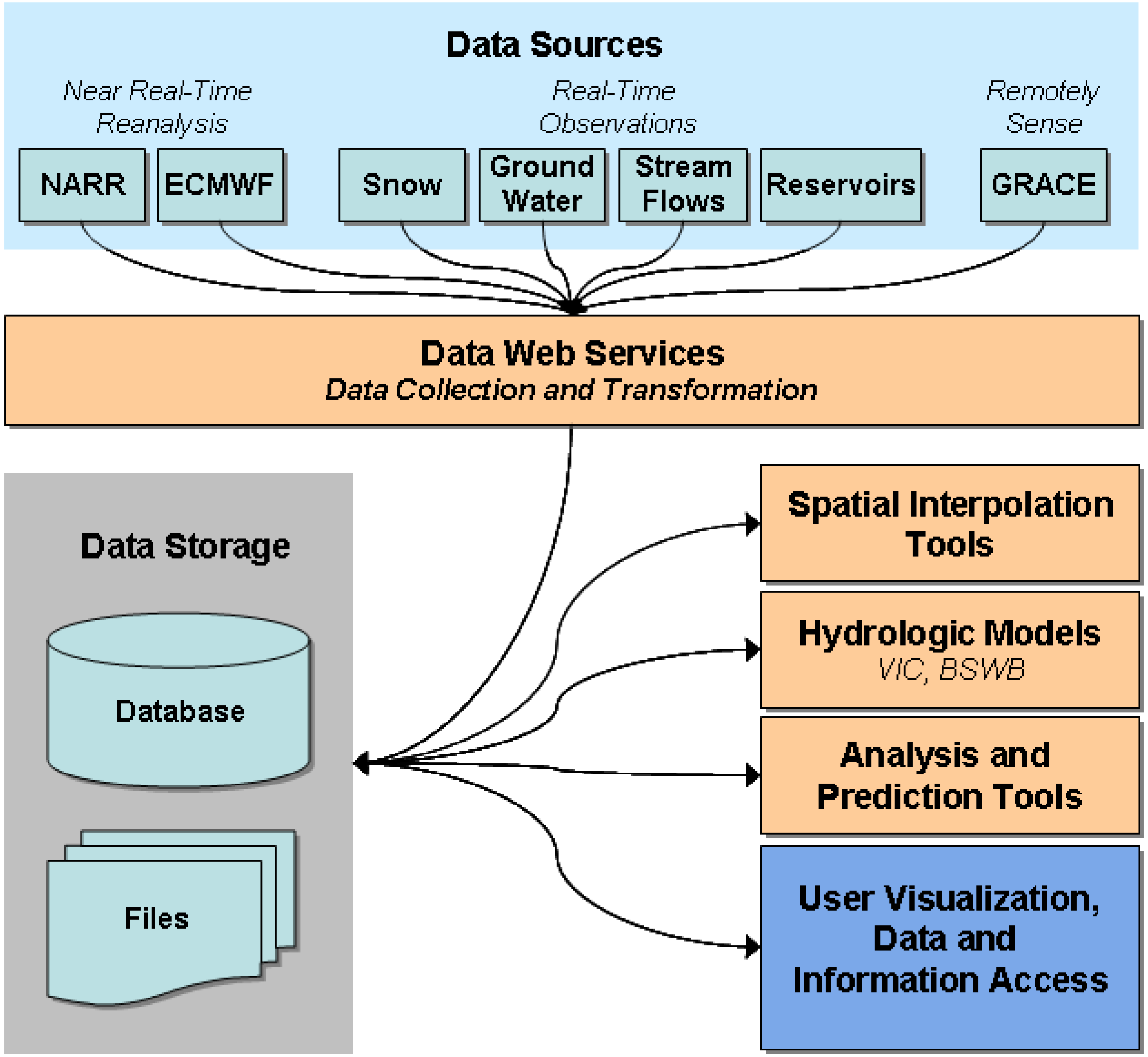


Colorado River at Imperial Dam

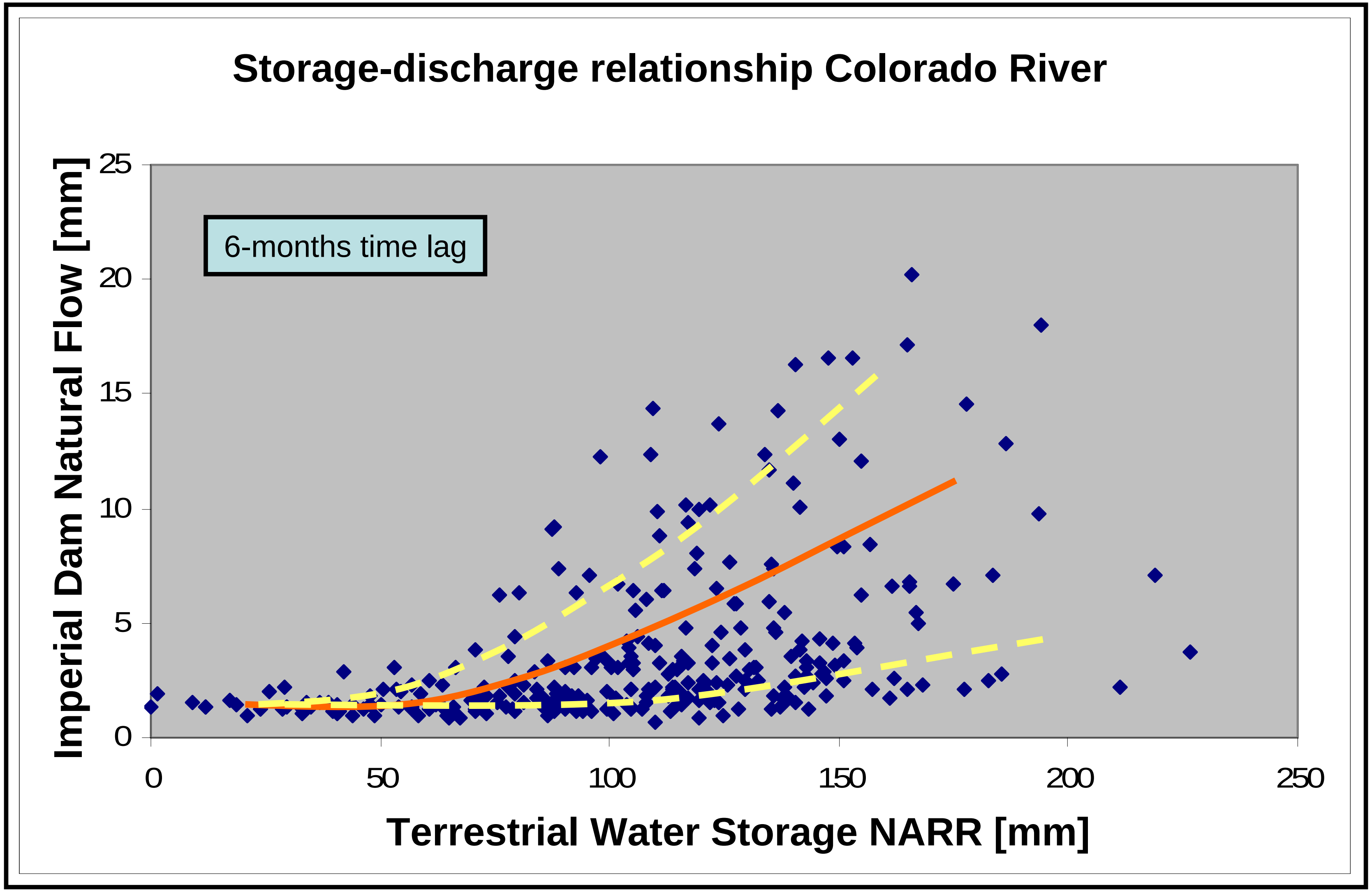
Colorado River at Lees Ferry

Troch et al. GRL (2007)

Outlook: real-time TWS monitoring



Outlook: storage-discharge relationship



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Questions?