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Managing Water in the West

Investigation of hydrologic variability on the Colorado River using prehistoric tree-ring data and the Reclamation CRSS long-range planning model

RiverWare User Group Meeting

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U.S. Department of the Interior
Bureau of Reclamation

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Introduction

- Recent conditions in the Colorado River Basin
  - Below normal flows into Lake Powell 2000-2004
  - 62%, 59%, 25%, 51%, 51%, respectively
    - 2002 at 25% was lowest inflow ever recorded since completion of Glen Canyon Dam
  - Lakes Powell and Mead were over 90% full in Spring 1999
  - April 2005 they were 33% and 60% full, respectively
- Some relief in 2005
  - February 2006 they were 46% and 60% full, respectively
  - Flows into Powell 105% of normal
  - Will it last?

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Motivation

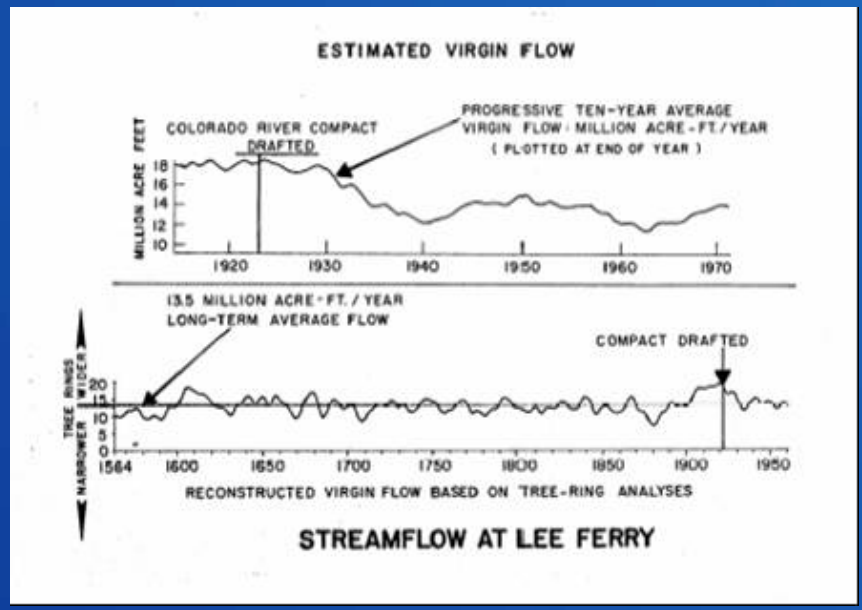
- How unusual is the current dry spell?
- How can we simulate stream flow scenarios that are consistent with the current dry spell and other realistic conditions?

Can we provide answers?

- What is done currently
  - ISM : captures natural variability of streamflow
    - Only resamples the observed record
    - Limited dataset
- What can be done?
  - Incorporate Paleoclimate information

Paleostreamflow reconstruction

- First reconstruction
  - Stockton and Jacoby, 1976
  - Colorado Rv. at Lees Ferry
- Dataset increased fivefold
- Improved frequency analysis
- Higher than normal flow during 1922 Compact



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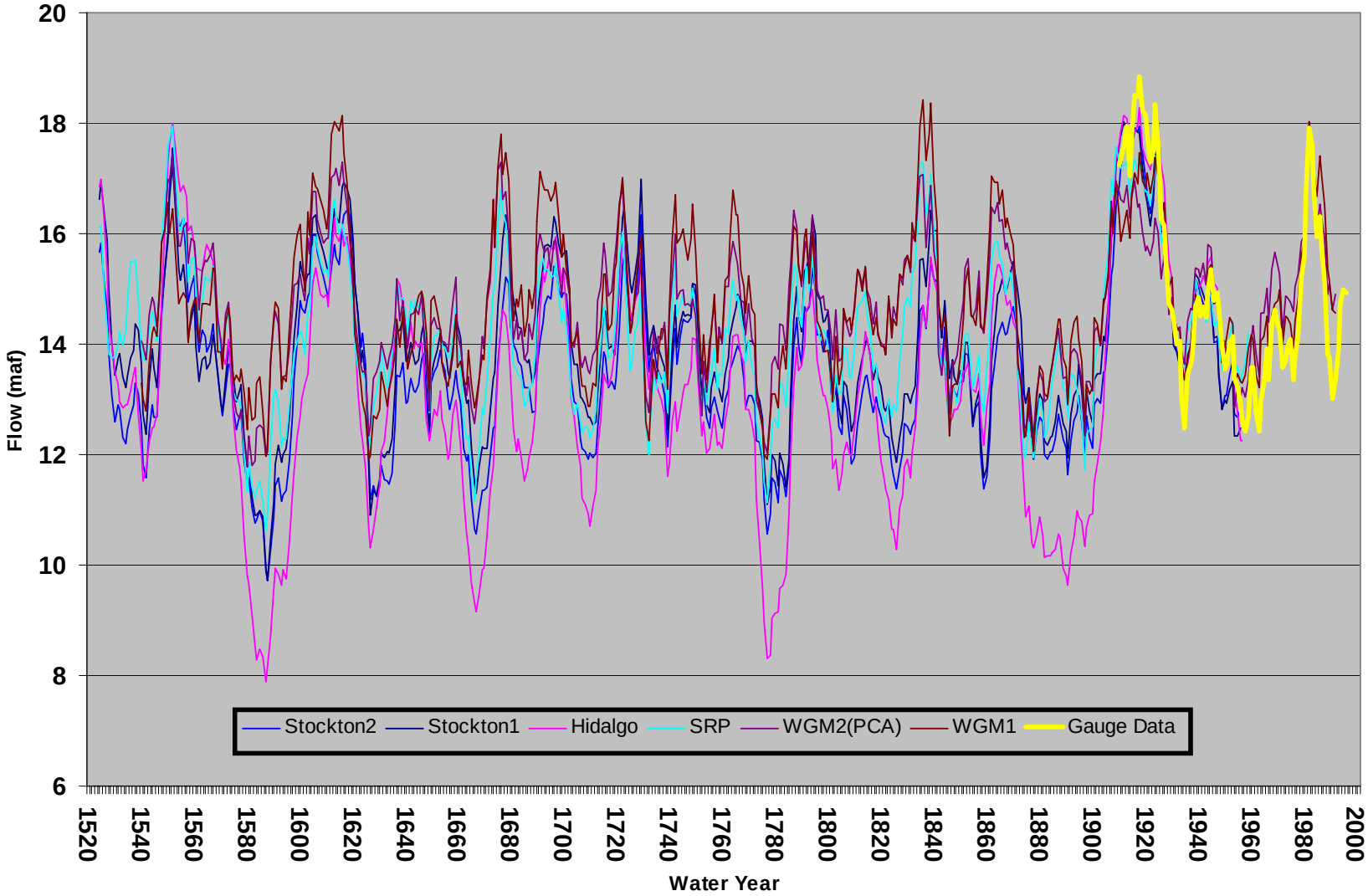
Annual Paleo-Reconstructions for Colorado River at Lees Ferry, Arizona - 10-year running average



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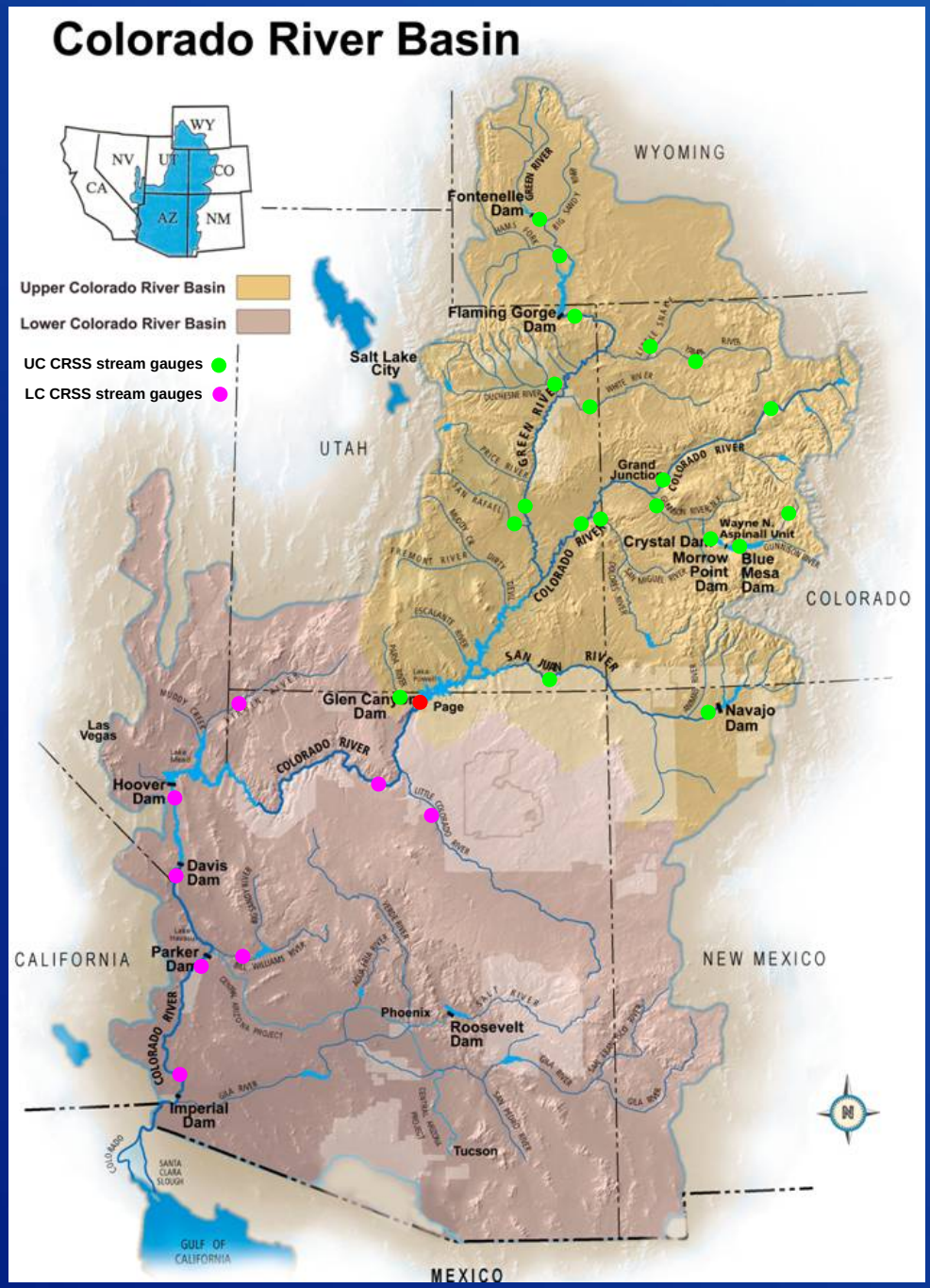

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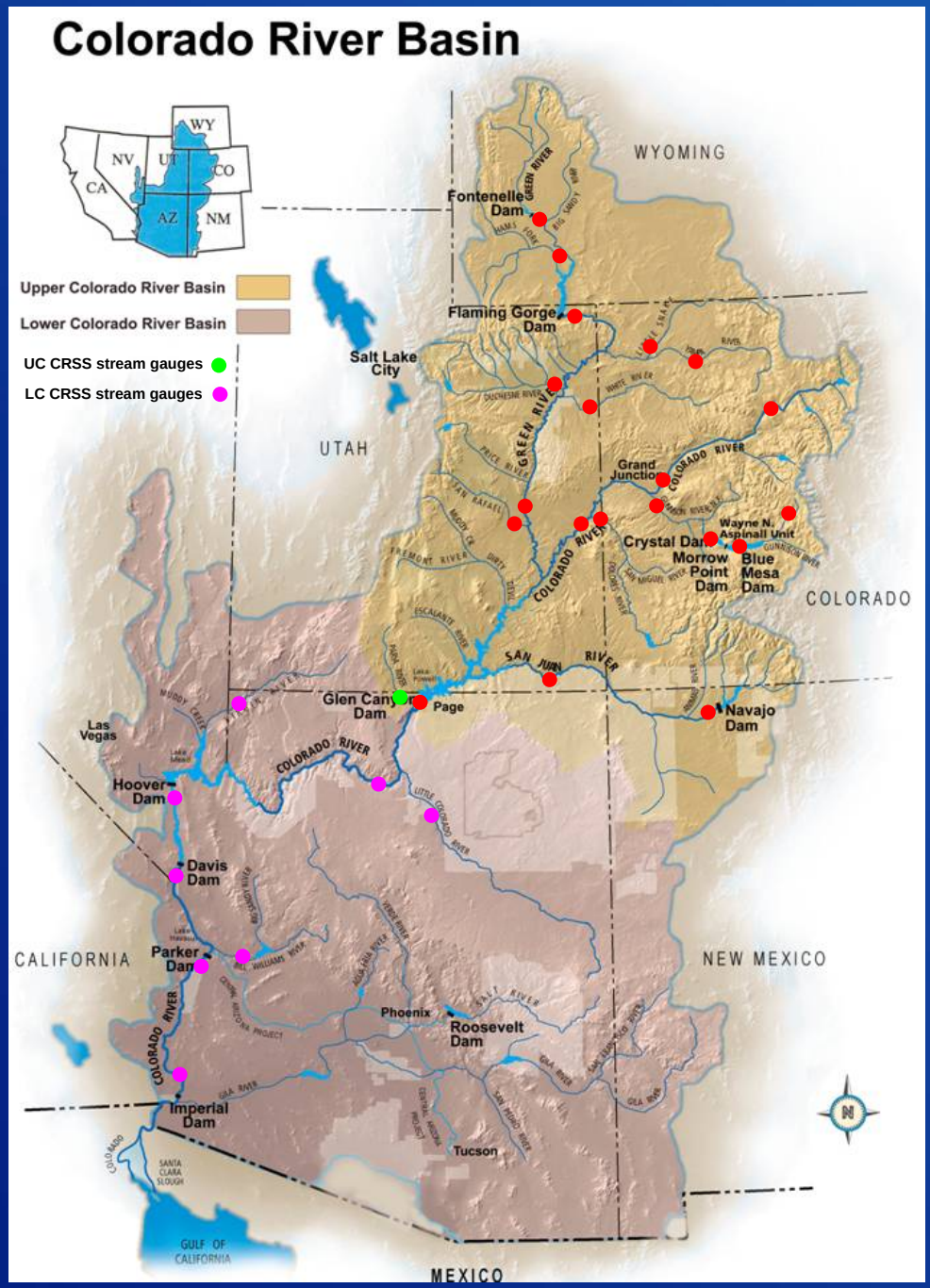

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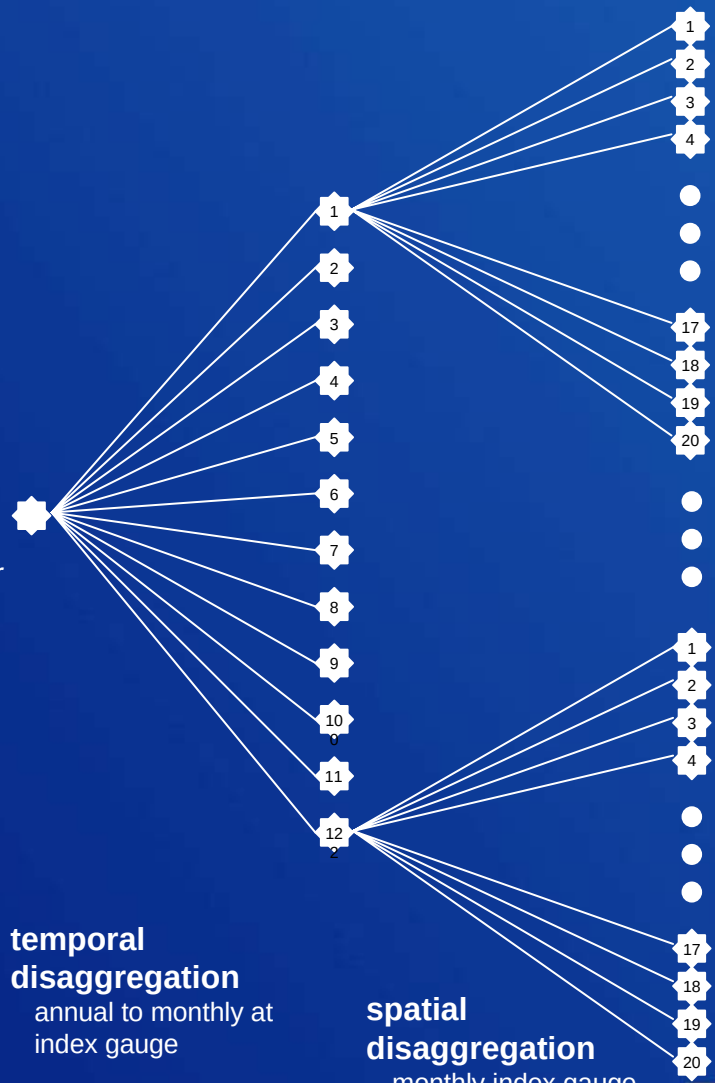
Appling Disaggregation

- Colorado River Basin
  - Upper Colorado River Basin
    - Nonparametric disaggregation
    - 20 gauges
  - Lower Colorado River Basin
    - KNN resampling of natural flows
    - 9 gauges
- Dataset
  - 5 sets of annual paleo-based reconstructed streamflows for Colorado River at Lees Ferry, Arizona
- Simulation horizon 2006-2060
- Number of traces equal to length of reconstructed streamflows

Disaggregation scheme



Index gauge

(Colorado River at Lees Ferry)

Colorado River at Glenwood Springs, Colorado
Colorado River near Cameo, Colorado

San Juan River near Bluff, Utah
Colorado River near Lees Ferry, Arizona

temporal disaggregation
annual to monthly at index gauge

spatial disaggregation
monthly index gauge to monthly gauge

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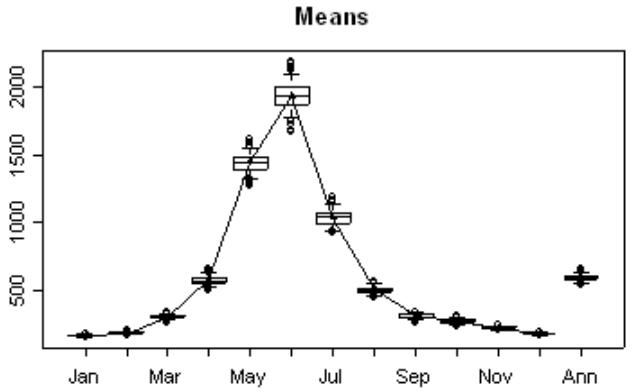
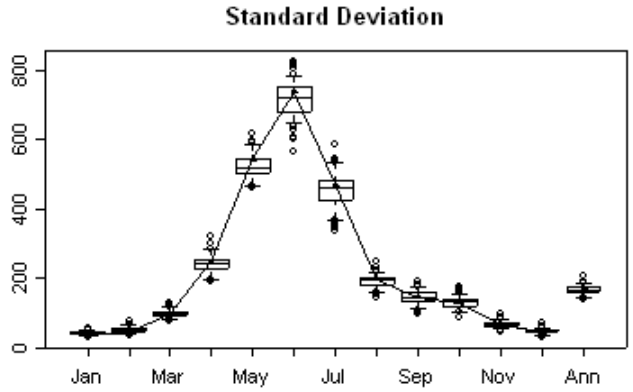
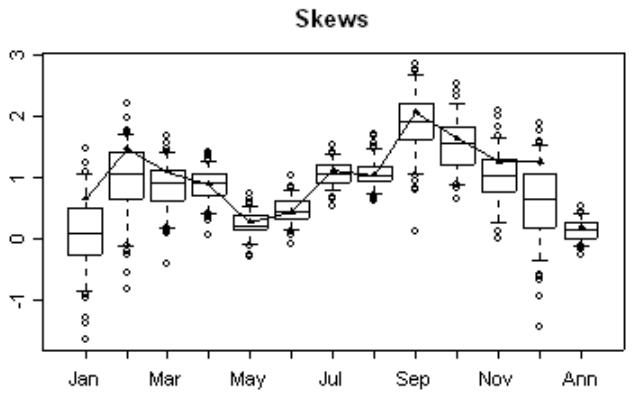
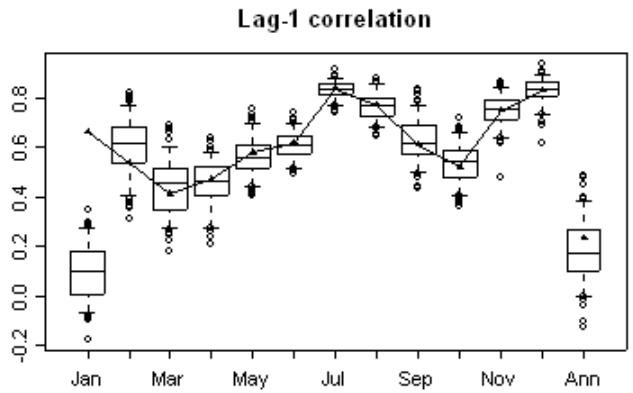
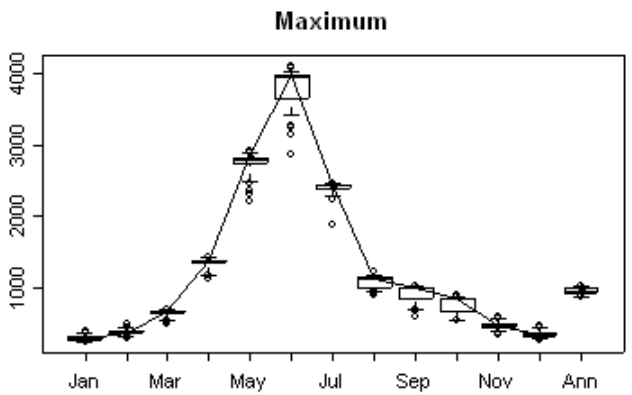
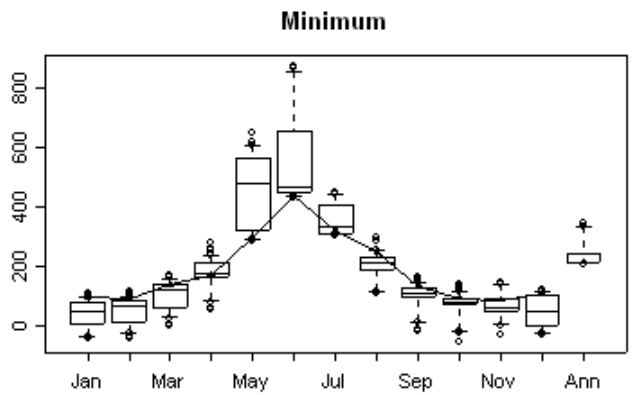












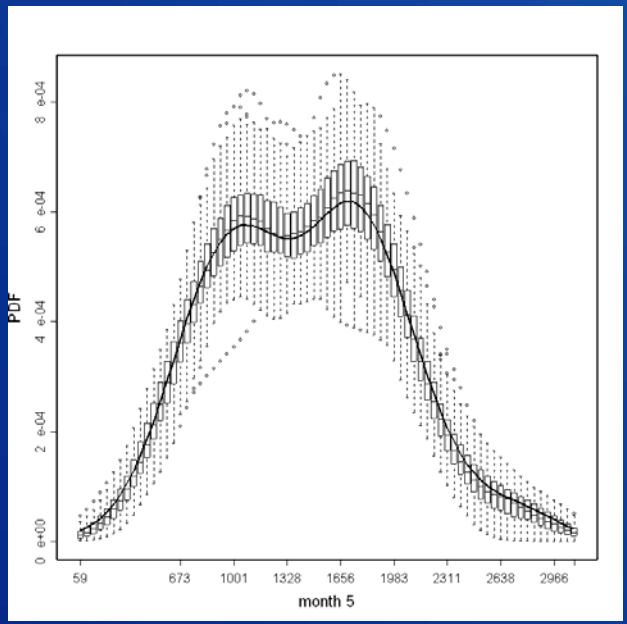
Lees Ferry

- **Total Flow**

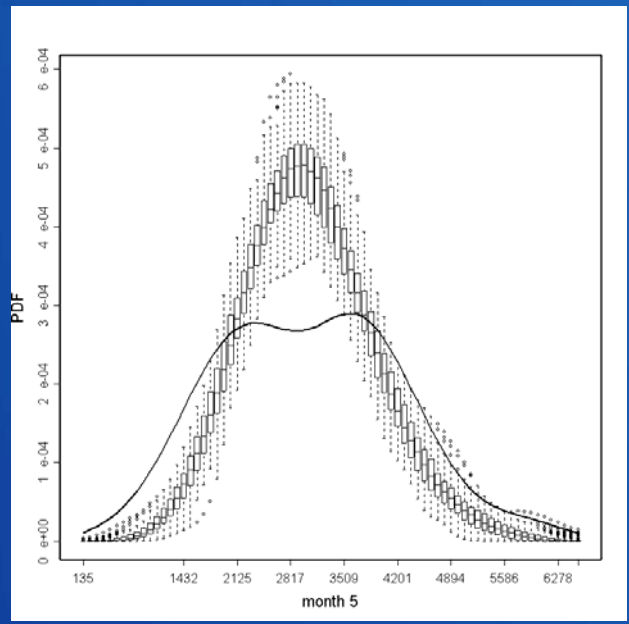
Lees Ferry

- May flows
- Total Flow

Nonparametric



Parametric



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Conclusions – Part 1

- A flexible, simple, framework for space-time disaggregation is presented
  - Obviates data transformation
  - Parsimonious
  - Ability to capture any arbitrary PDF structure
  - Preserves all the required statistics and additivity
- Easily be conditioned on large-scale climate information
- Can be developed in various scheme to fit needs

Applying Paleo Traces to CRSS

- Using monthly CRSS as of 11/01/2005
  - Before States Shortage Negotiations
- Implementing disaggregated hydrologic inflows
  - One “disaggregation” of Lee’s Ferry Flows
- Still Using Index Sequential Method (ISM) through entire paleo-trace record
- Testing the “robustness” of CRSS
  - Stress Tests - Where does it break?
    - Model Mechanics?
    - Operational Policy Assumptions?

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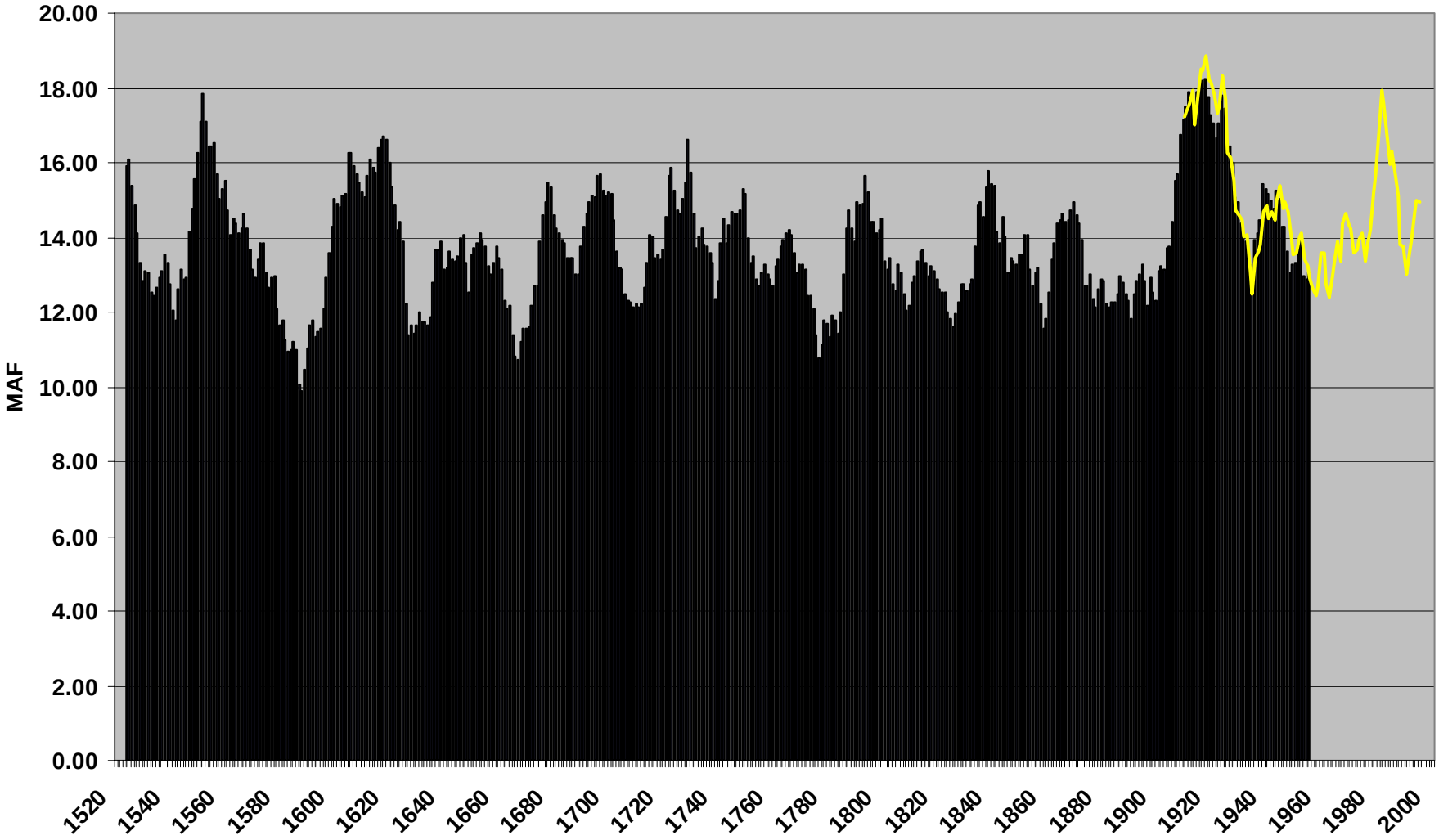
Annual Flow at Lee's Ferry (10-yr smoothing)
Stockton & Jacoby and Gauge Data



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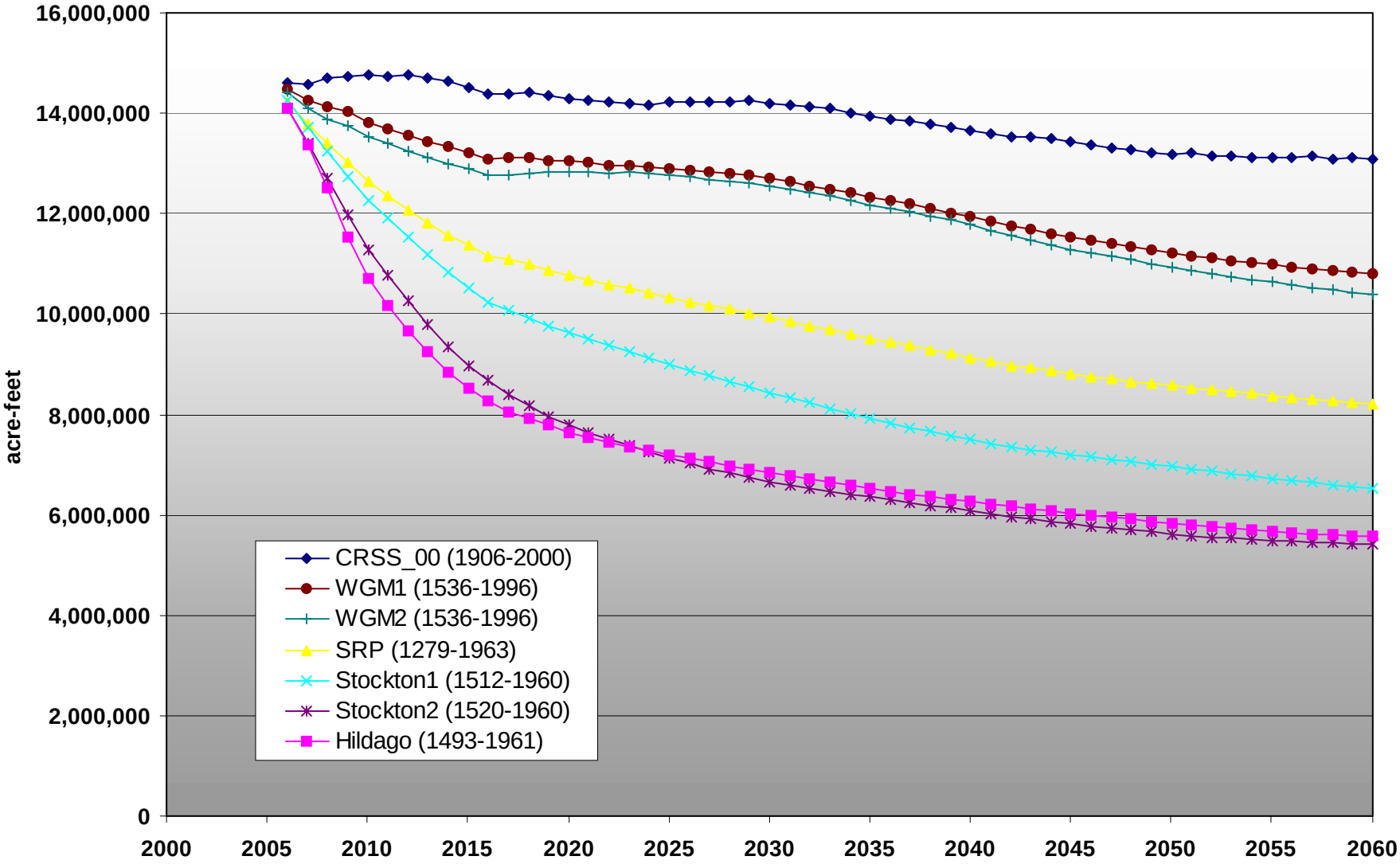
What are the Results?

- Made 7 minor modifications to the rule set and model file
  - Reservoir operations under near empty conditions
    - Handling evaporation
    - Meeting downstream demands with multiple reservoirs
  - Handling of reach losses / mass balance issues
  - Minimum flow criteria failures

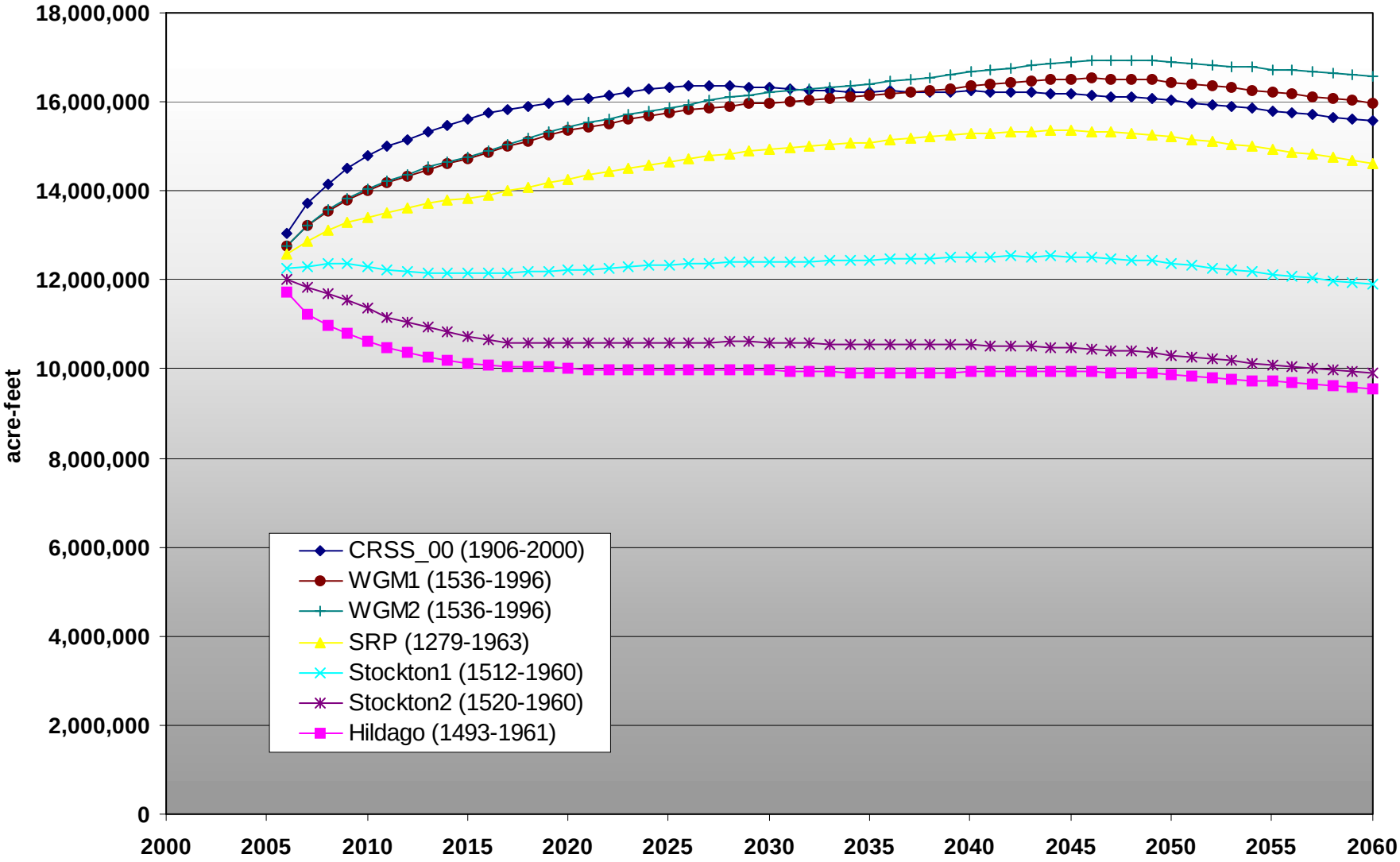
- Mead and Powell Reservoir Elevations

- Deliveries to Water Users

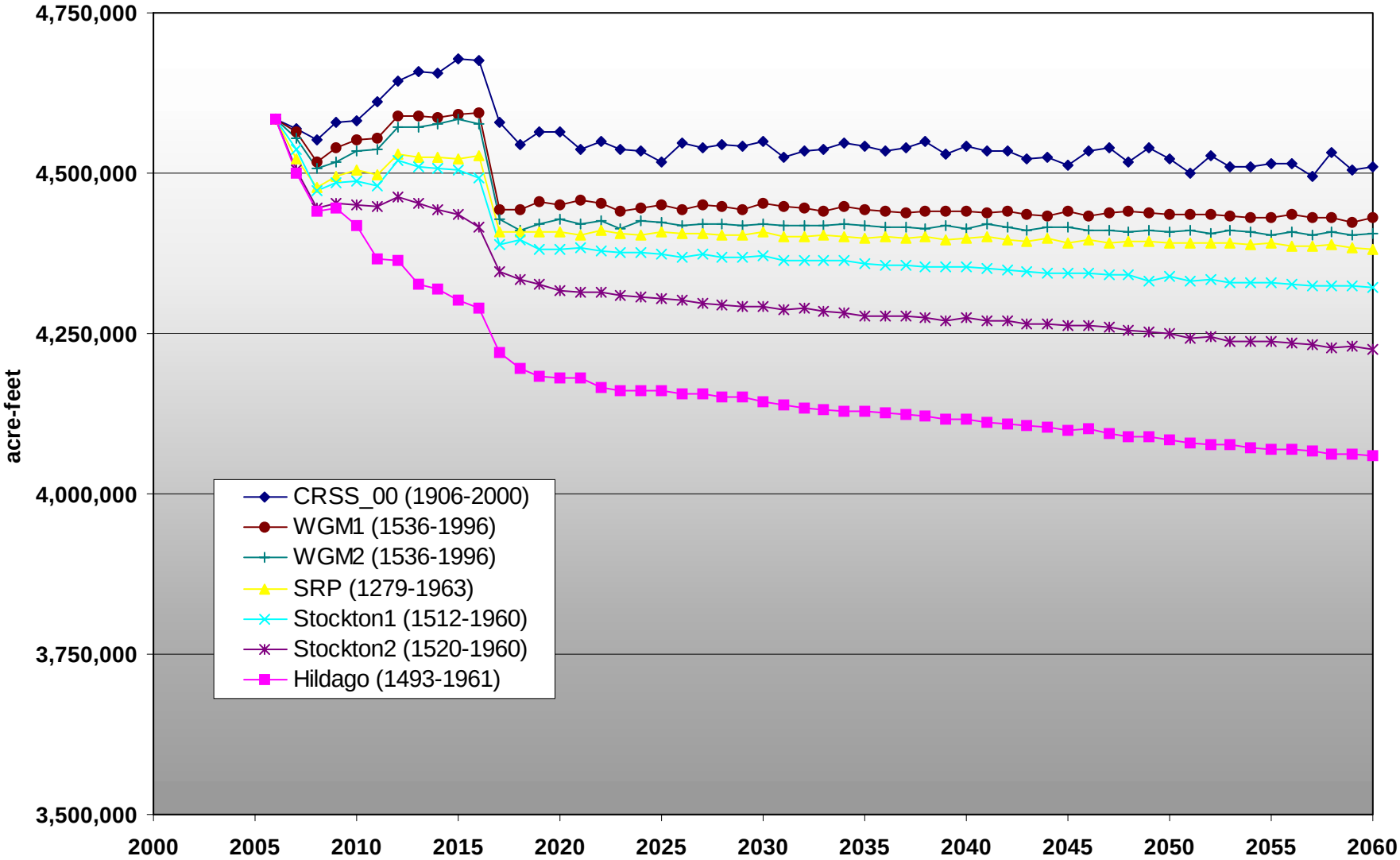
Mead Storage



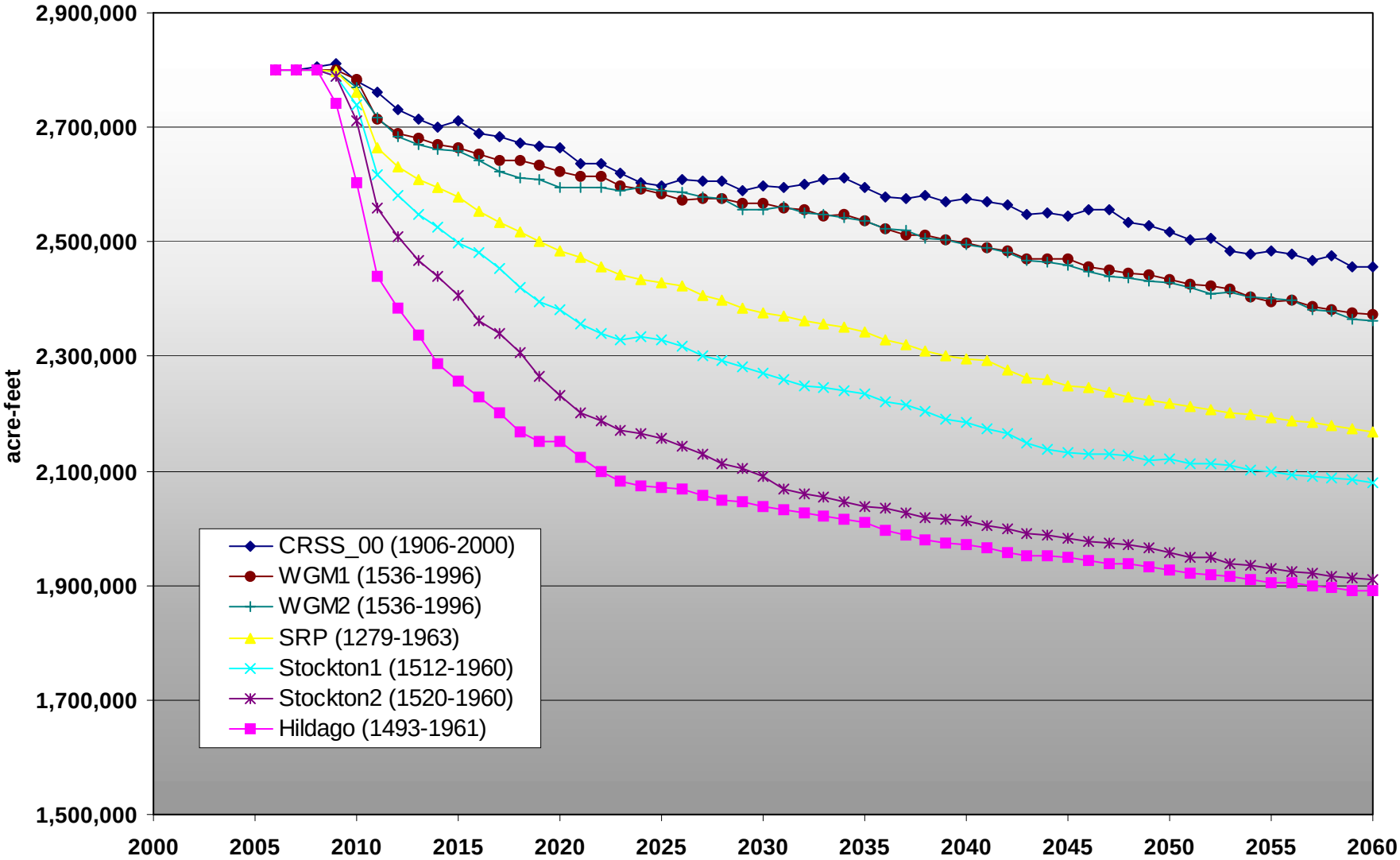
Powell Storage



Average Annual California Depletions



Average Annual Arizona Depletions



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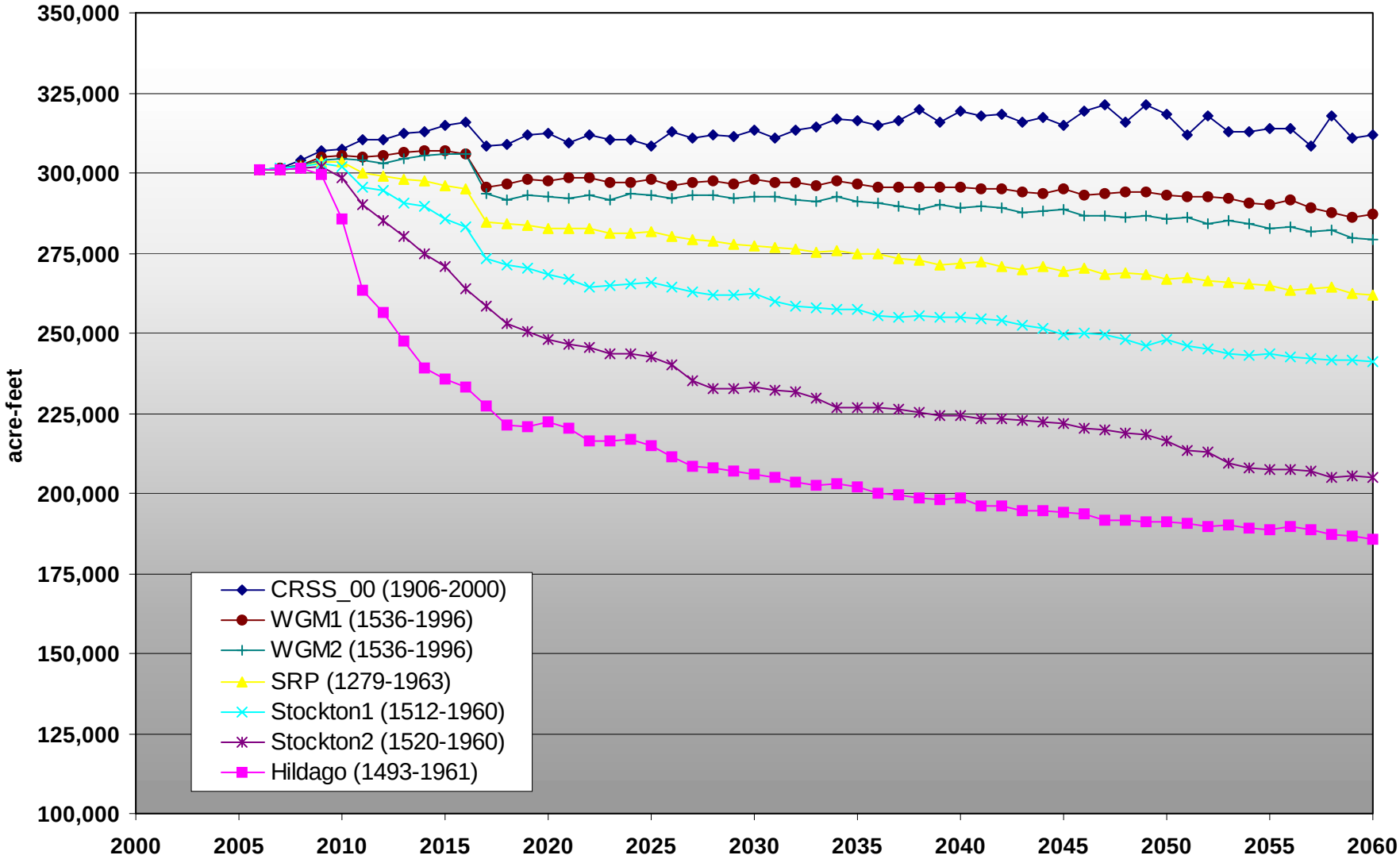
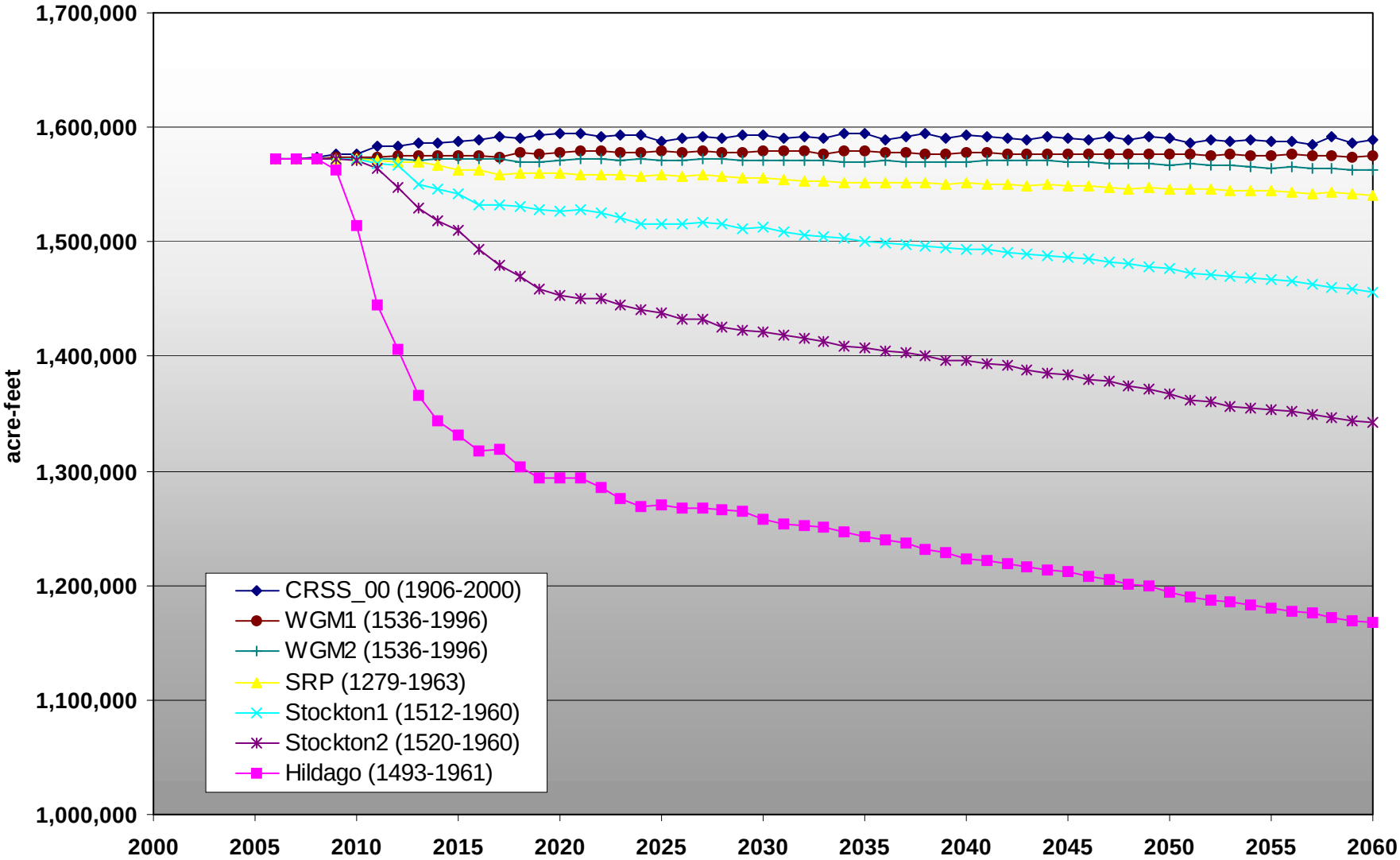
Average Annual Nevada Depletions



Average Mexico Arizona Depletions



Conclusions – Part 2
Using Paleo Traces for Decision Making

- Looking beyond the gauged record
  - An additional tool… perhaps one of the most useful
  - Magnitude vs. frequency of drought conditions

- Managing Uncertainty
  - 6 Interpretations of Paleo-record
    - All show a similar trend
  - Multiple temporal and spatial “disaggregations”
    - Once is good, 1000 times is better
  - ISM vs. Monte Carlo simulation

- Policy informed by the Best Available Science

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