Drought Spell Statistics

Colorado Water Conservation Board
Statewide Drought Conference

Building a Drought-Resilient Economy Through Innovation

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&
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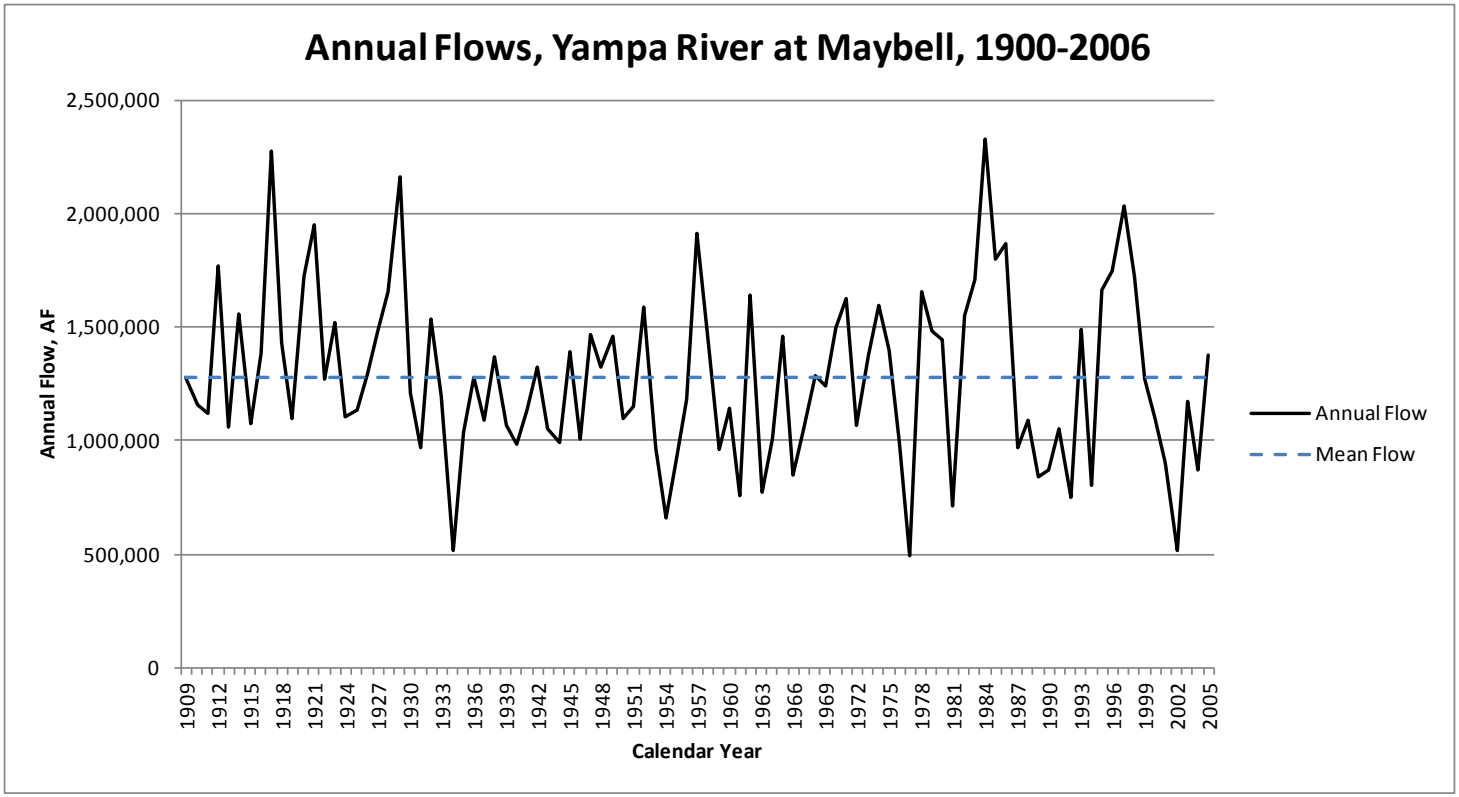
Water Resources Planning Paradigm

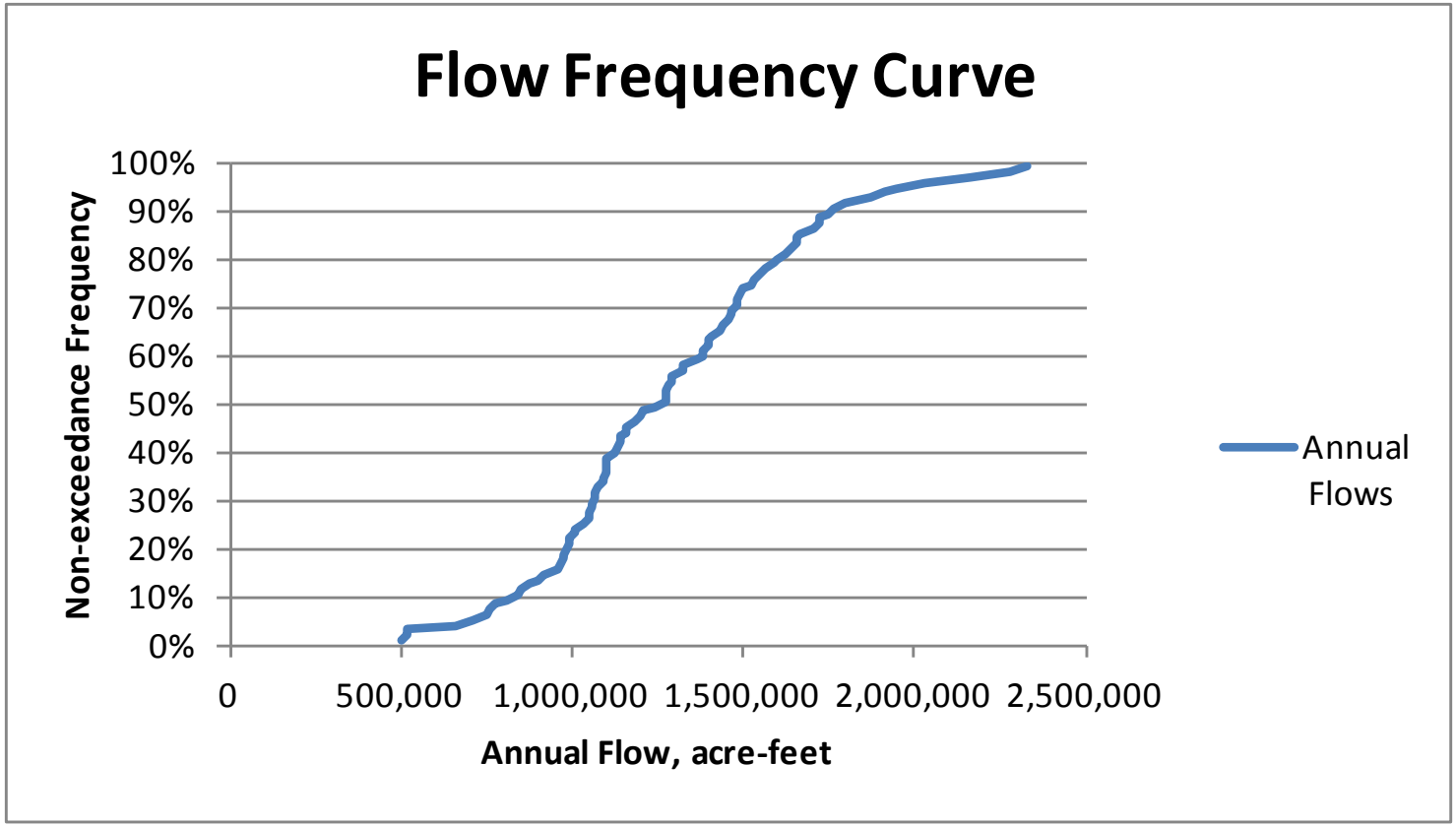
Paradigm courtesy of Lee Rozaklis.

What Do We Know About the Past: The Observed Record



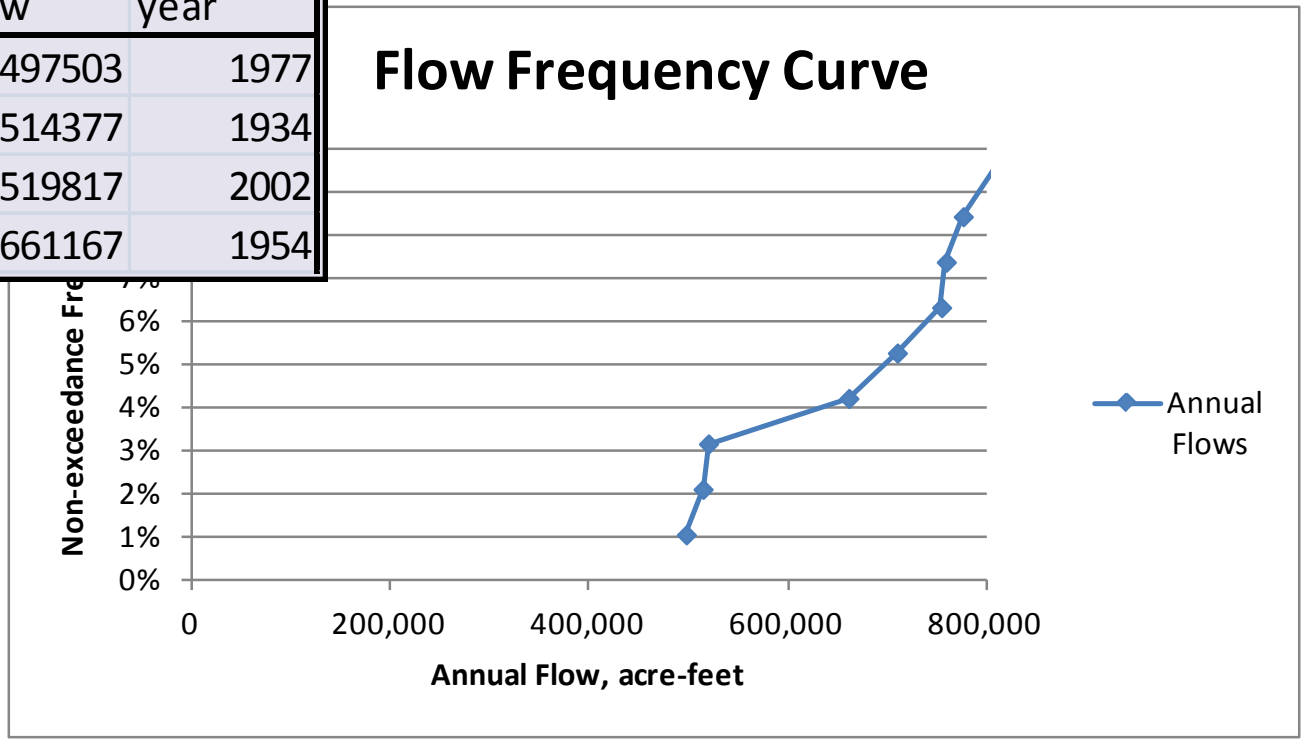
Source: CDSS Natural Flows

The Curve


Flow Frequency Curve
Non-exceedance Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Annual Flow, acre-feet
Annual Flows

The Dry End

	Historical flow	year
0.011	497503	1977
0.021	514377	1934
0.032	519817	2002
0.042	661167	1954

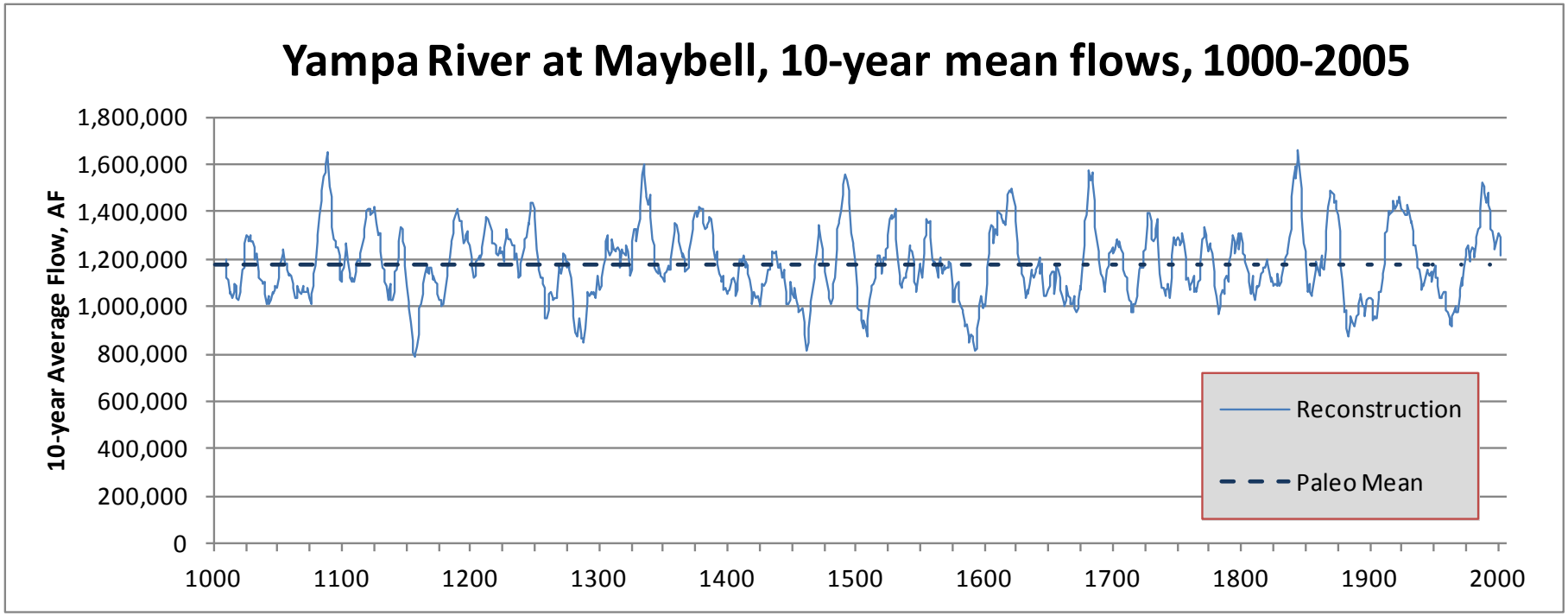


How Frequent is the Drought of Record?

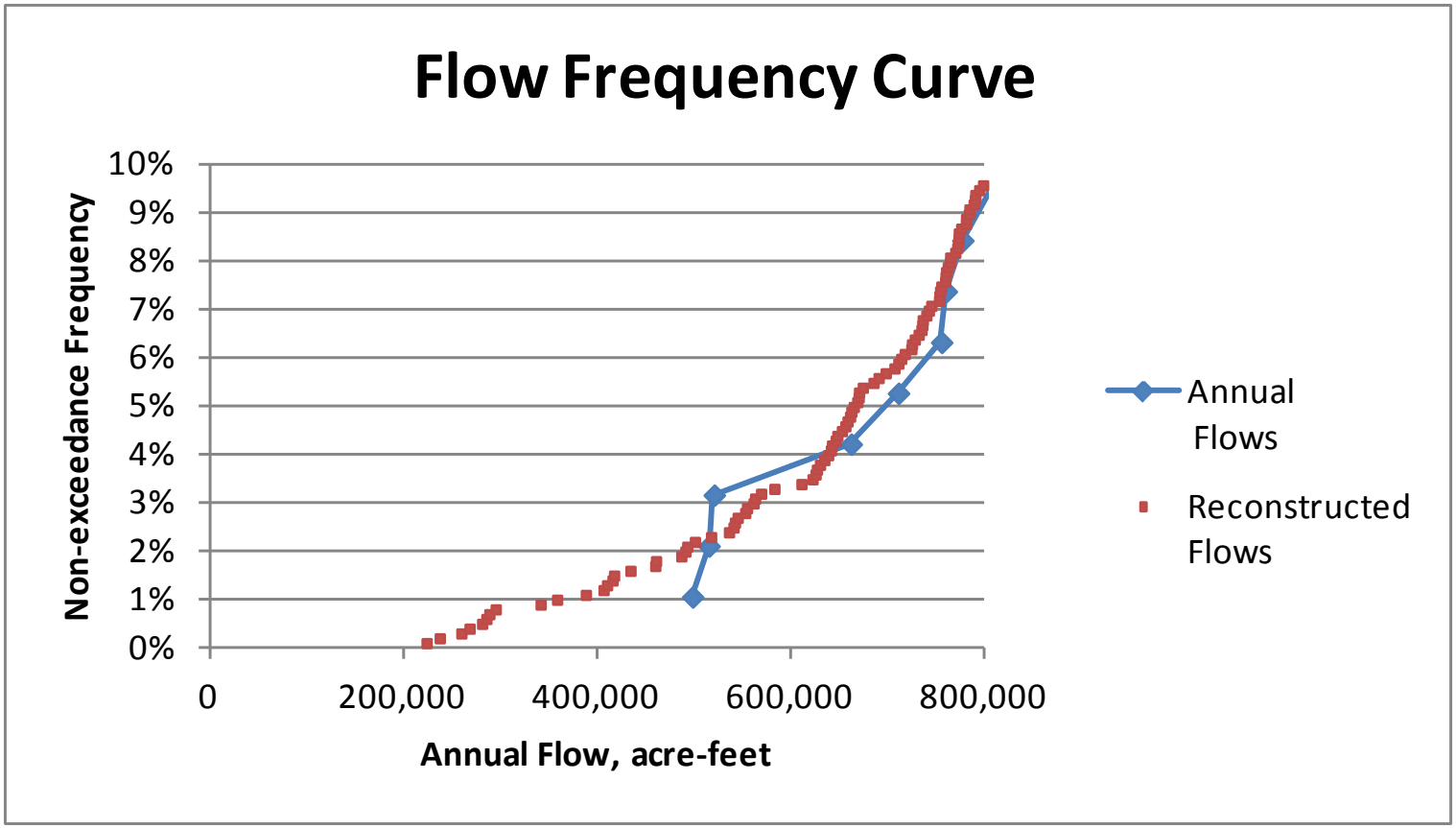
- The obvious inference:
  - The drought of record in a 100-year record is the 100-year drought.
- The truth:
  - There is about a 1 in 3 chance (37%) that a 100-year record **does not** contain a 100-year drought.
  - Said another way, there is a 37% probability that we have not yet experienced the 100-year drought.
  - There is a 95% probability that a 100-year record **does** contain the 30-year drought.
- To have a 95% probability that you have a good estimate of the 100-year drought, you need a record 300 years long.
- So…we have to turn to paleo-hydrology.

Paleo-Hydrology

- Reconstructions of prehistoric flows from tree rings
- 1000-year and longer records are possible
- We can use these to:
  - Estimate flow statistics
  - Virtually exercise our systems in models



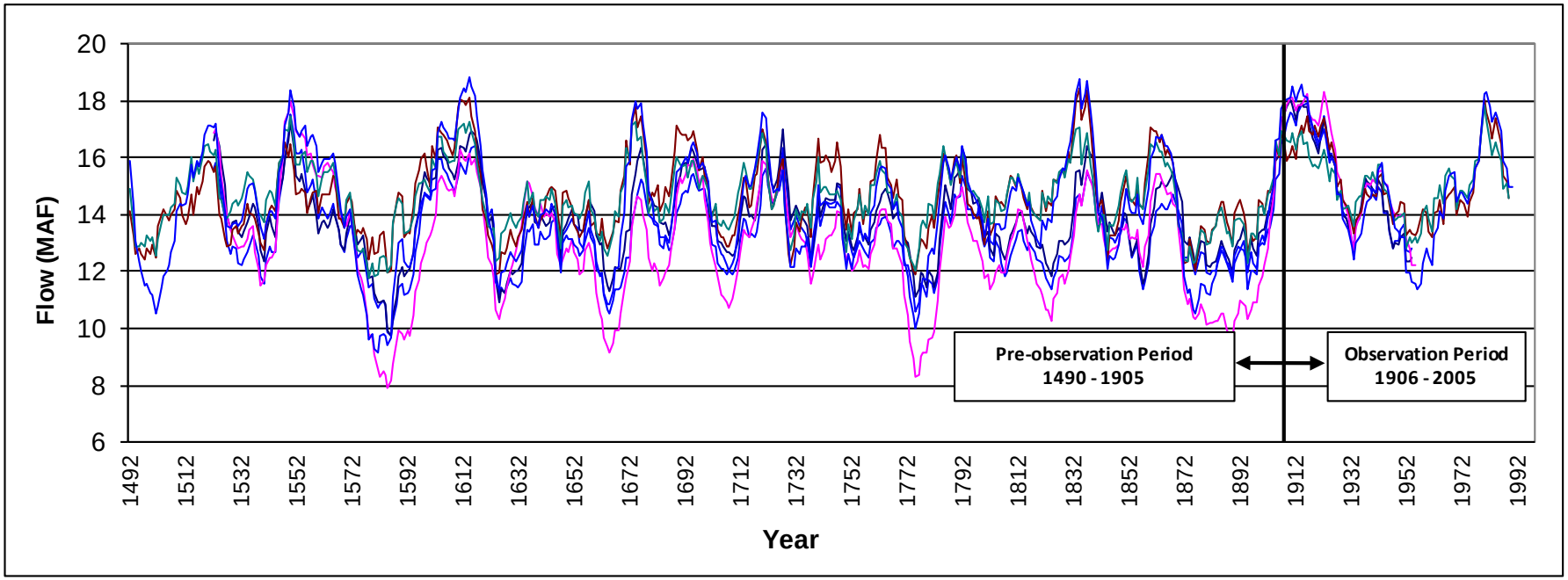
Yampa at Maybell—More information



Limitations of Paleo-Hydrology

- Based on models
- Only explain approximately 60%-80% of the variance of flows
- Different reconstructions will give different results
  - Different data (trees or flow)
  - Different model structures
  - Different model parameters

Six Reconstructions at Lees Ferry



(Smoothed to 10-year averages)

- Flow magnitudes differ
- Dry/Wet spells appear coherent

How “robust” are the reconstructions?
The Bar Codes

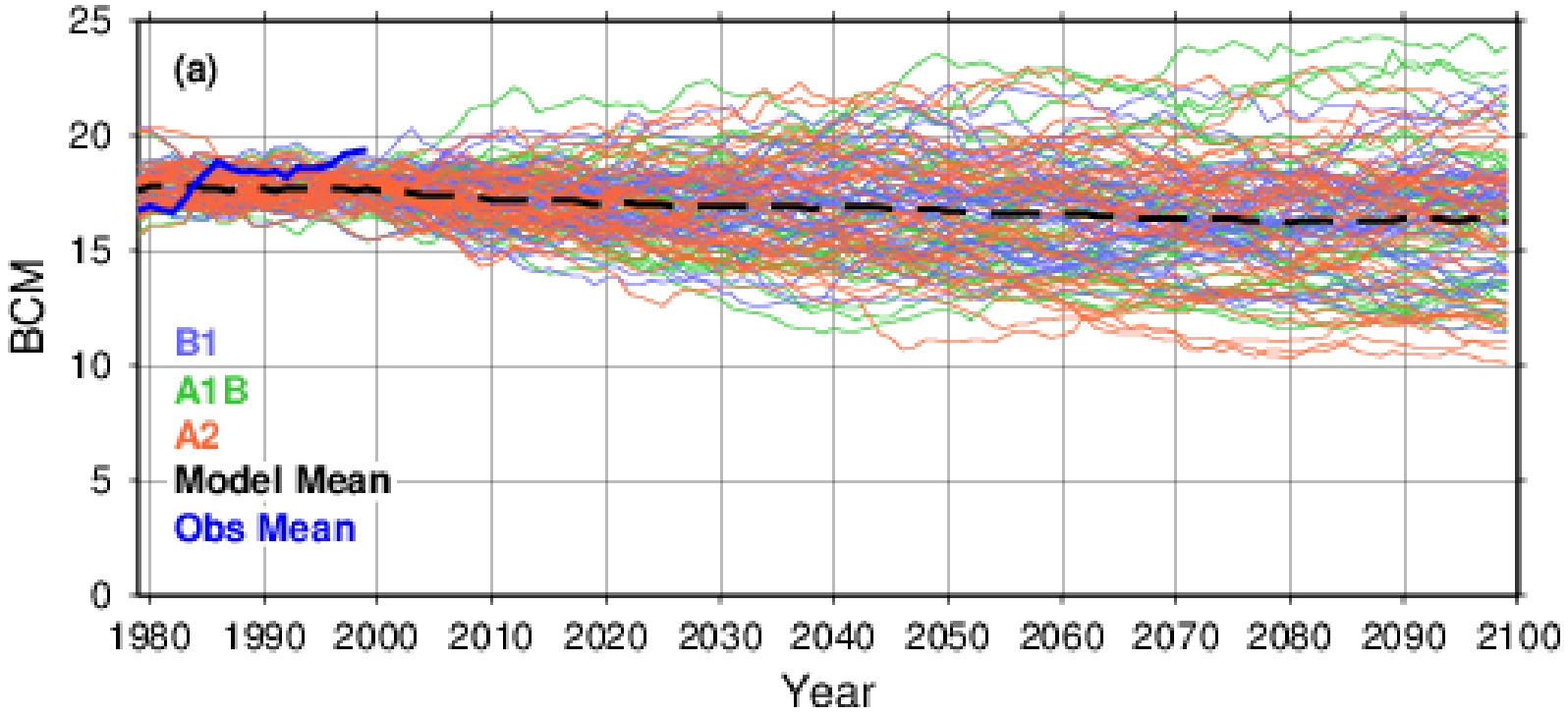
Limitations of the Paradigm

Limitations of the Paradigm

Limitations of the Paradigm

Limitations of the Paradigm

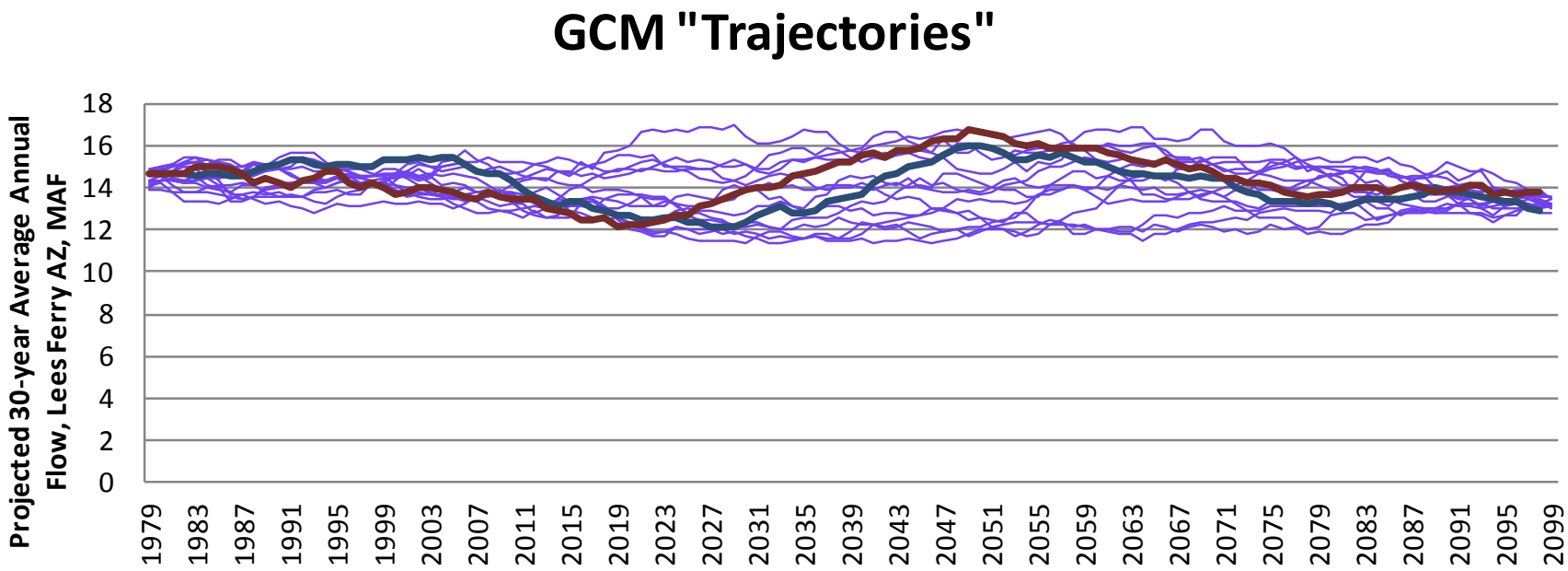
GCMs: Looking forward, into the fog



“What the *heck* do we do with that?”

Really the problem is TMN/TLI—too many numbers, too little information

Thinking in terms of “Trajectories”



- 1862-1981
- 1552-1671

"What the *heck* do we do with that?"

- Use the strongest information from each source, as we did in the CRWAS project:
  - Historical Record: Flow magnitudes
  - Prehistoric Record: Flow and spell frequencies
  - GCM Projections: Future mean conditions
- Test system performance using model studies:
  - Statistics of flows and spells are abstract measures
  - Real systems will react in complex ways
  - Models allow testing of adaptation strategies
- There is no ready answer for uncertainty—we've never done this experiment on the planet before.
  - Maybe someday the GCMs will be able to tell us at least what road we might be on
- In the meantime, drive with care and look out for road signs

Thank You

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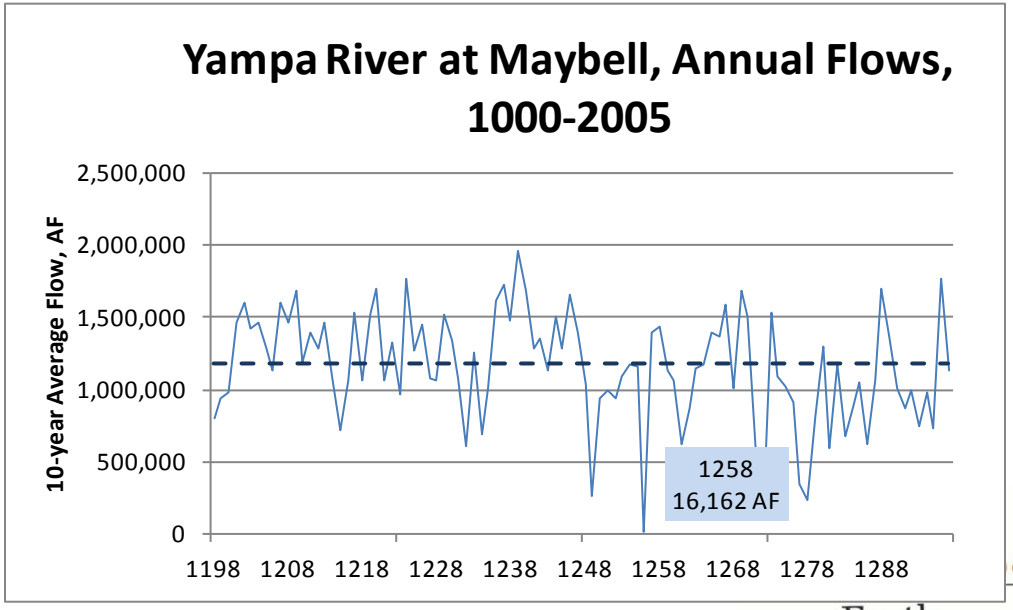
What was the bottom line?

For the Colorado River at Cameo (your mileage may vary)

- Analysis of the paleo record shows that the historical drought (length 6 years) occurred about every 30 years
- For 2040:
  - Three projections showed no significant change in drought recurrence
  - One projection showed an increase in recurrence to 6 years
  - One projection showed a decrease in recurrence to 800 years.
- For 2070:
  - Two projections showed no significant change
  - Two projections showed increases in recurrence to 6 and 12 years
  - One projection showed a decrease in recurrence to 127 years

Just for fun…



CHAPMAN CONFERENCE ON VOLCANISM AND THE ATMOSPHERE, SELFOSS, ICELAND, JUNE 11–15

Earth

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Mystery volcano site pinned down

Indonesian crater implicated in mid-13th century eruption

By Alexandra Witze

The Rinjani volcano in Indonesia may be the long-sought site of a mysterious and massive eruption known to have occurred around 1258.

One of the biggest mysteries in volcanology may finally be solved. An eruption long thought to have gone off in the year 1258 happened the year before in Indonesia, scientists report.

Until now, researchers have known a big volcano went off somewhere in the

years," Lavigne said.

Consensus in the meeting hallways was that he had shown pictures of Indonesia. Volcanologist Erik Klemetti of

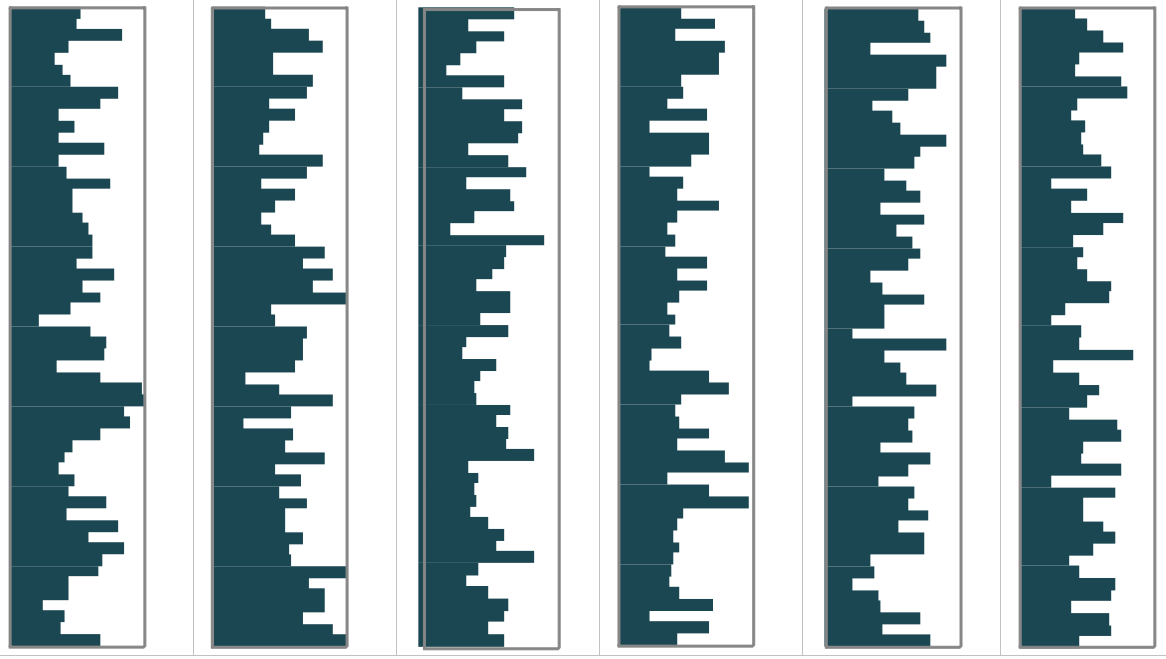
sunlight, temporarily chilling the planet.

Candidates for the 1258 eruption have included Mexico's El Chichón and Quilotoa in the Ecuadorean Andes. But the

CRWAS Approach

- Combined information from the historical and prehistoric record:
  - Take flow magnitudes from historical natural flows
  - Re-order (re-sequence) historical flows based on information from the paleo record.

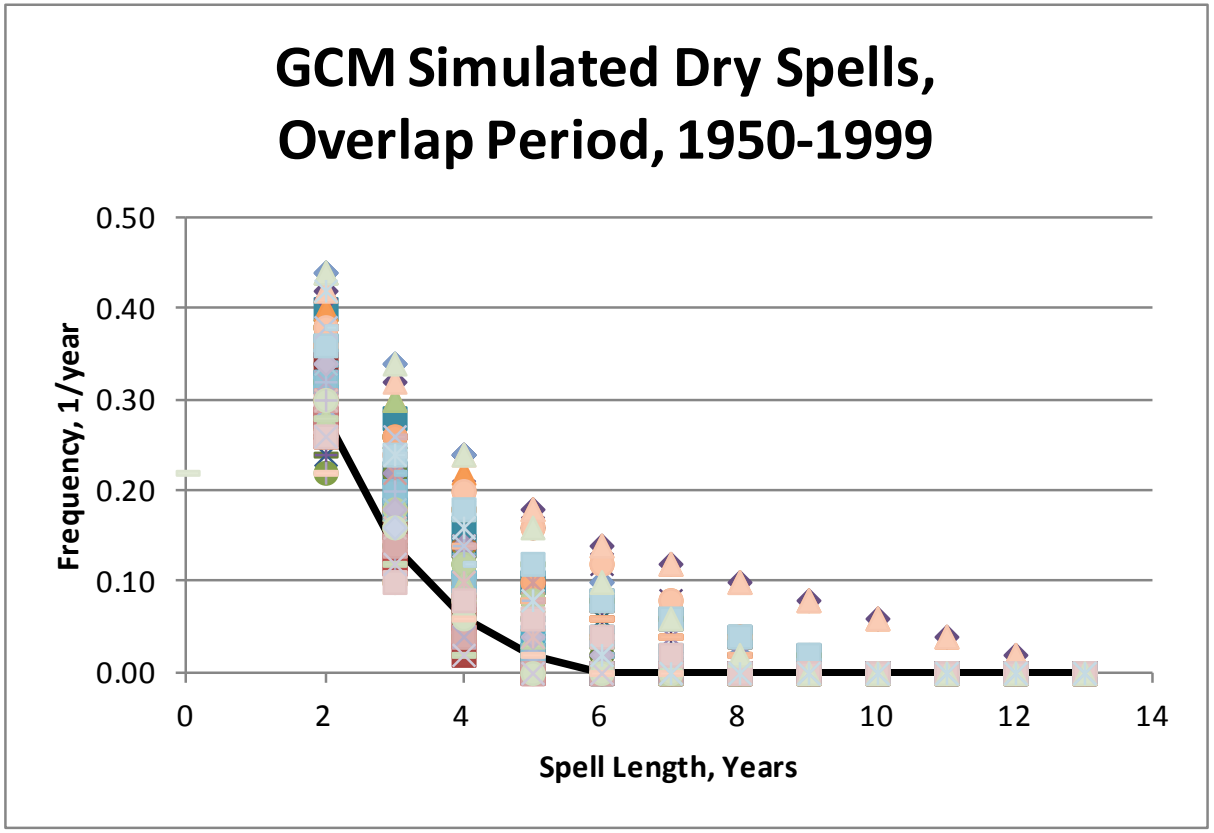
CRWAS Sequences

Trace	Historical Trace	Trace 1	Trace 2	Trace 3	Trace 4	Trace 5
Mean Flow	**14.26**	**15.62**	**14.56**	**13.01**	**16.02**	**13.16**
1950						
2005						

- 100 sequences, each 56 years long
- Used to estimate flow statistics and to run CRDSS models

GCMs on Spells

- Questions about inter-annual variability in GCM outputs



CRWAS Approach

- Use the strongest information from each source
  - Historic Record—strongest on magnitudes, weakest on frequency (due to short length) and future mean conditions.
  - Paleo Reconstructions—strongest on frequency (due to long length) weakest on magnitudes (due to limited models) and future mean conditions.
  - GCM Projections—Strongest on mean effects, weakest on magnitudes, sequences and frequency.
- Simple extension of approach to prehistoric flows
  - Re-sample from “projected” future flows rather than from historical flows