

The State of the  
Colorado River  
Ecosystem in  
Grand Canyon

A Report of the  
Grand Canyon  
Monitoring and  
Research Center  
1991-2004

USGS Circular 1282



# CLIMATIC FLUCTUATIONS, DROUGHT, AND FLOW IN THE COLORADO RIVER

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# DECLINES IN LAKE POWELL



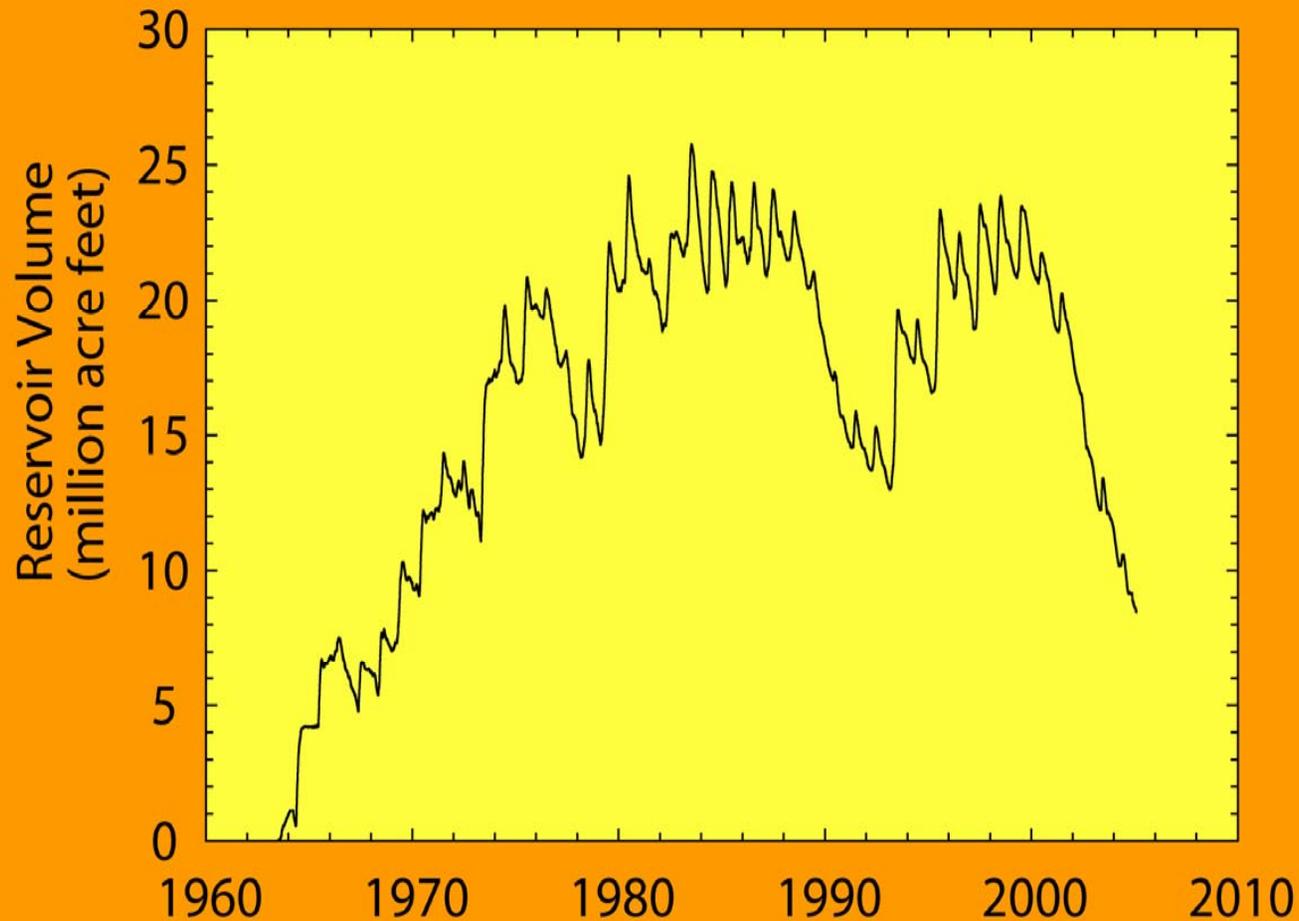
- On January 27, 2005, the level of Lake Powell was at 3,562.5 feet (full pool capacity is 3,700 feet)
- The reservoir held 8.51 maf of storage (35% of capacity)
- That reservoir capacity represents 1.03 years of normal annual flow releases
- On October 20, 2005, the reservoir was at 50% capacity.



## Lake Powell Delta

Declines in lake level created an emergent delta. Many marinas on Lake Powell are now unusable. Large amounts of deltaic sediments are either mobilized or rearranged in the emergent reaches.

# CONDITIONS IN LAKE POWELL (through January 2005)

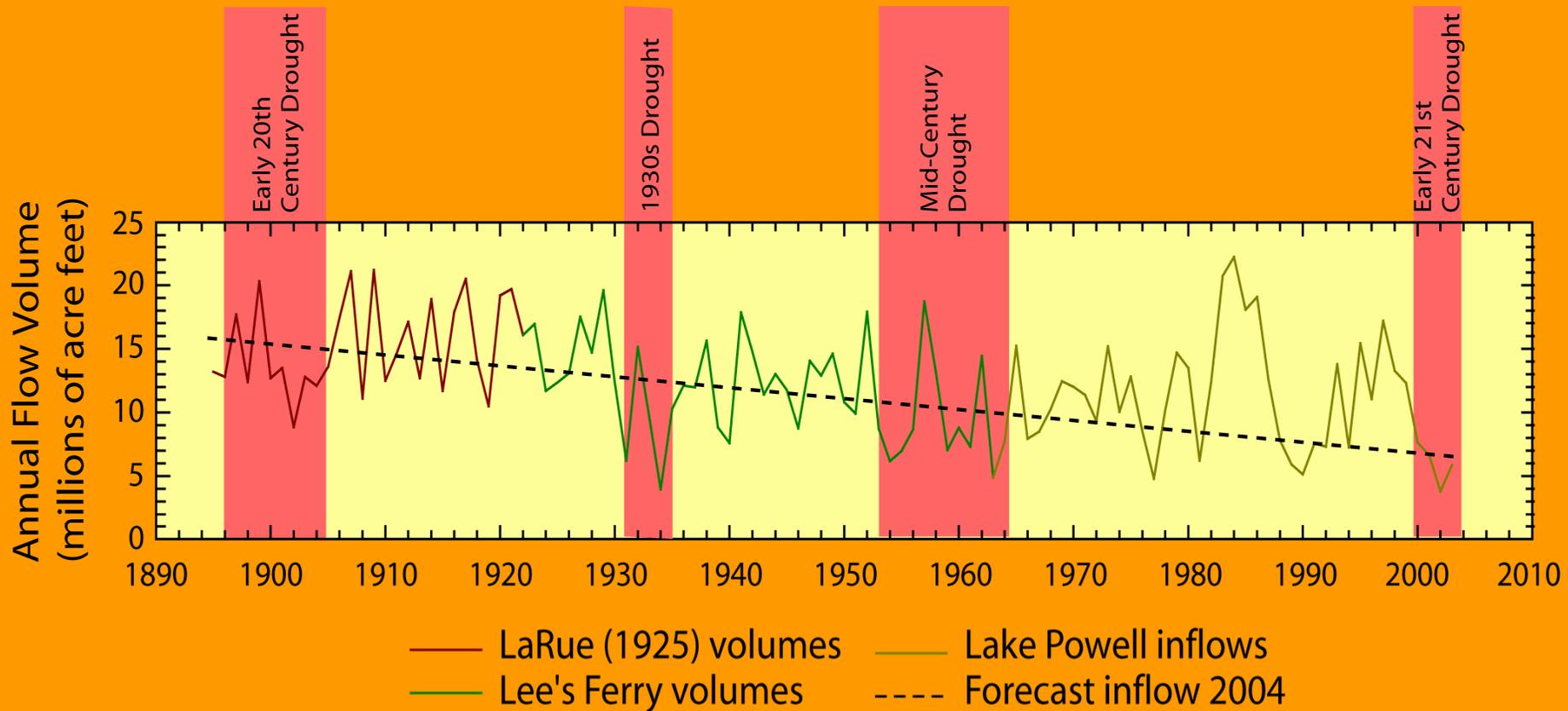


# CONDITIONS IN THE COLORADO RIVER DRAINAGE

- Inflows to Lake Powell between about 2000 and 2004 were low and unprecedented in the 20<sup>th</sup> century
- Whether “natural flow” – corrected for consumptive uses upstream – or actual flows are used, the recent drought is the most severe in the 20<sup>th</sup> century

# COLORADO RIVER FLOWS

Actual flow – not corrected for consumptive uses



Average annual flow volume: 12.34 MAF

# HOW SEVERE WERE 2001-2004 CONDITIONS? (actual flow)

## Lowest Flow Years

Year	Volume (MAF)
2002	3.80
1934	3.95
1977	4.79
1963	4.89
1990	5.14

## 3-Year Average

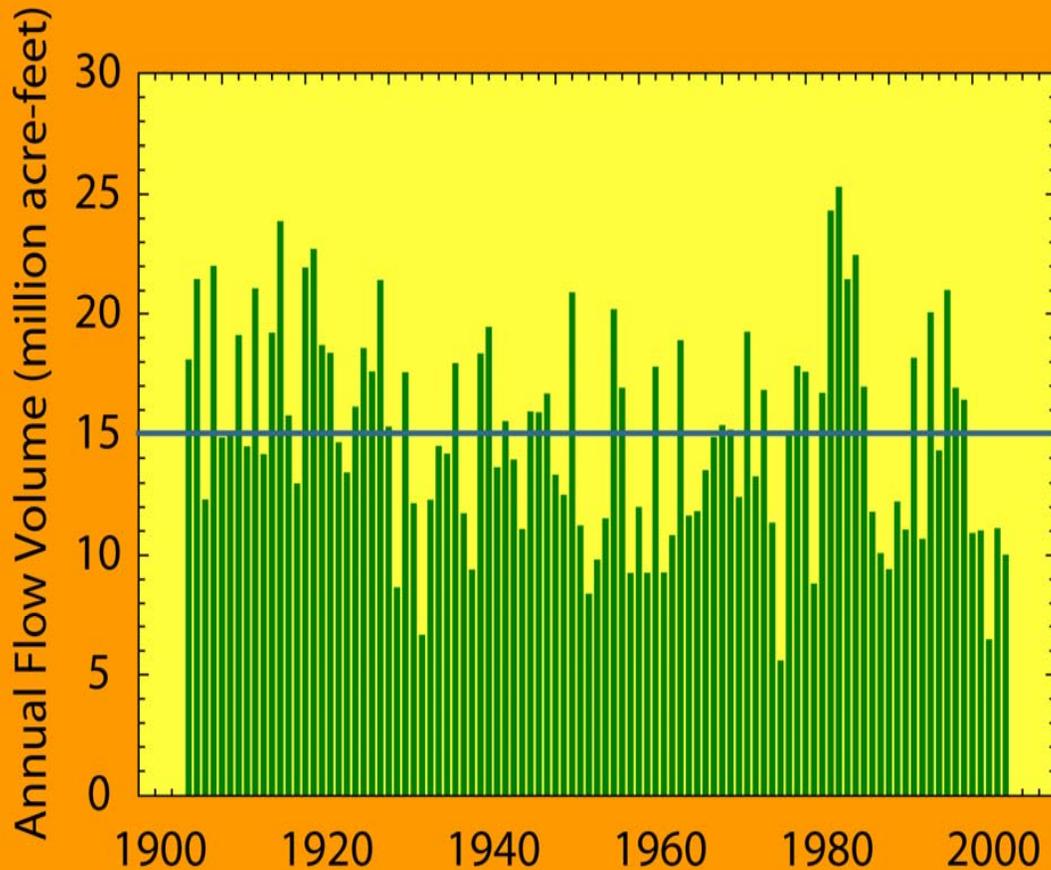
Year	Volume (MAF)
2003	5.08
2002	5.44
2001	6.03
1990	6.20
1989	6.28

## 5-Year Average

Year	Volume (MAF)
2002	5.91
1990	6.74
2001	7.25
1989	7.80
1991	7.94

# COLORADO RIVER FLOWS

“Natural” flow – corrected for consumptive uses (Reclamation)



Average  
annual  
flow  
volume:  
15.03  
MAF

# HOW SEVERE WERE 2001-2004 CONDITIONS? (Natural flow)

## Lowest-Flow Years

Year	Volume (MAF)
1977	5.57
2002	6.44
1934	6.63
1954	8.37
1931	8.63

## 3-Year Average

Year	Volume (MAF)
2003	9.18
2001	9.45
2002	9.51
1954	9.79
1955	9.89

## 5-Year Average

Year	Volume (MAF)
2002	9.89
1990	10.89
2001	11.17
1933	11.44
1961	11.50

# TRENDS IN RIVER FLOWS

- Regressions of volume versus time are poor for both natural and actual flows
- Trend in natural flow is a decrease of 0.35 MAF per decade, 1905-2004
- Trend in actual flows is a decrease of 0.5 MAF per decade, 1895-2004
- Both records are highly affected by the wet period from 1906 through 1920

# MOISTURE SOURCES TO THE COLORADO RIVER DRAINAGE

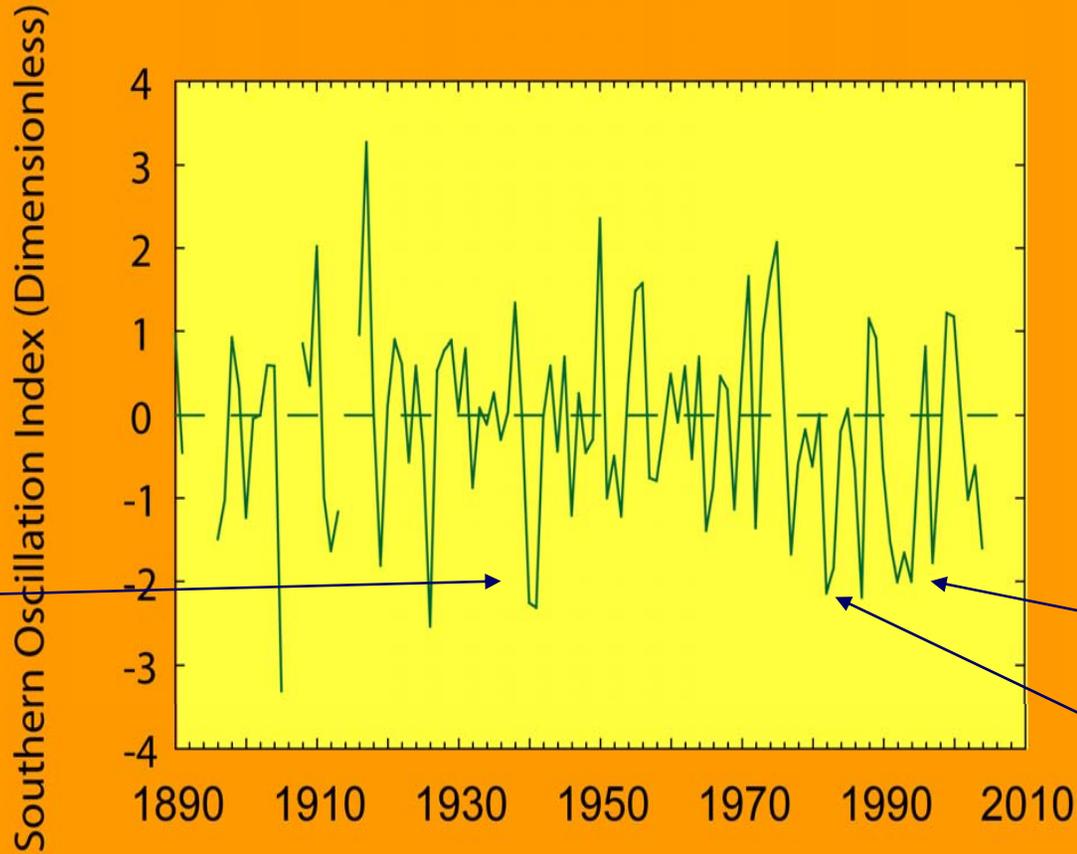


- Because of its large size and geographic position, the Colorado River defies simple hydroclimatic analysis
- This basin integrates a large variety of climatic signals

# HYDROCLIMATOLOGY OF THE COLORADO RIVER

- Interannual influences: El Nino – Southern Oscillation (ENSO)
- Corollaries: Multivariate ENSO Index (MEI)
- Interdecadal influences: Pacific Decadal Oscillation (PDO)
- Long-term: Atlantic Multidecadal Oscillation (AMO)

# EL NINO AND THE SOUTHERN OSCILLATION (ENSO)

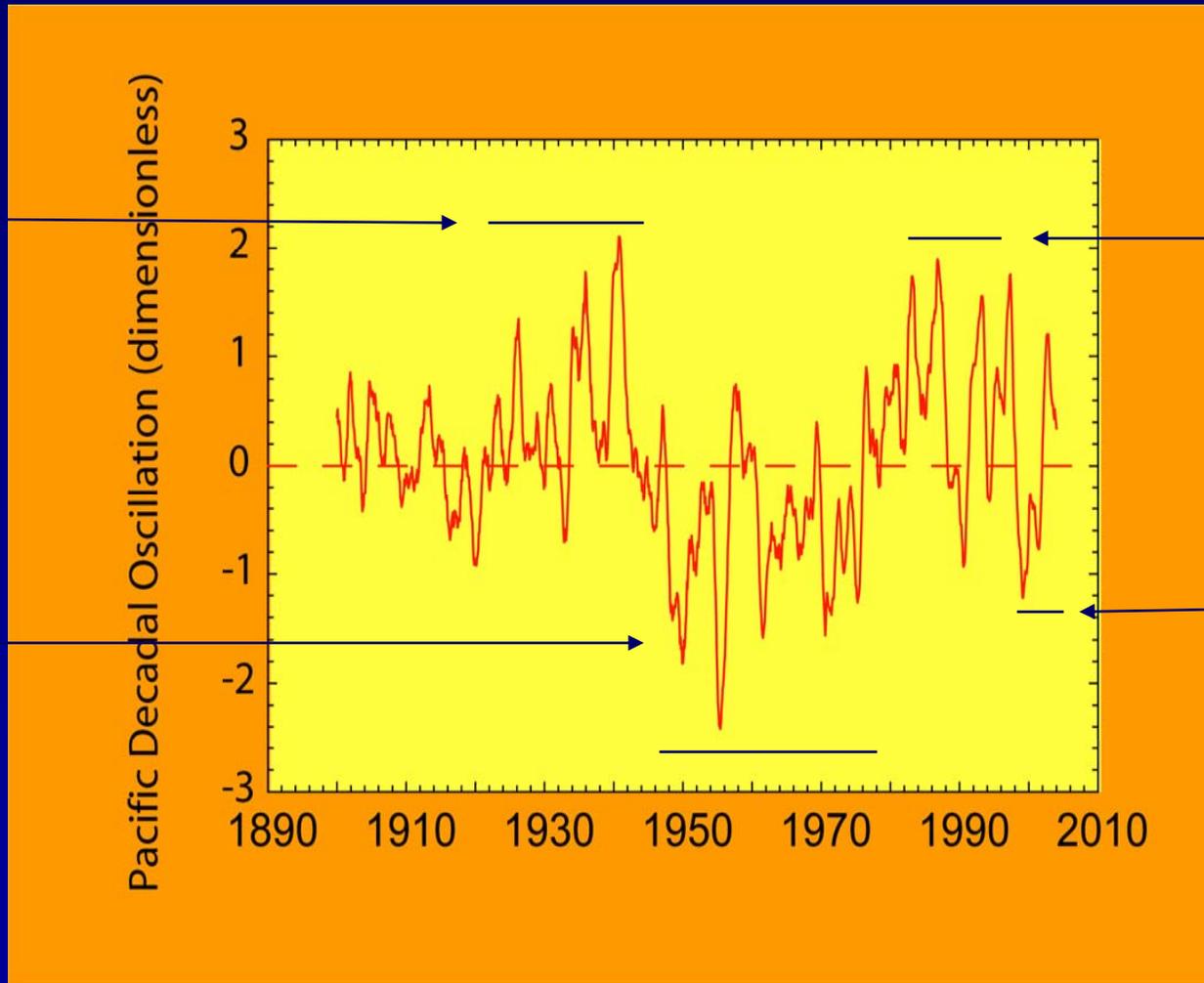


1939-1941

1991-1995

1983-1984

# PACIFIC DECADAL OSCILLATION



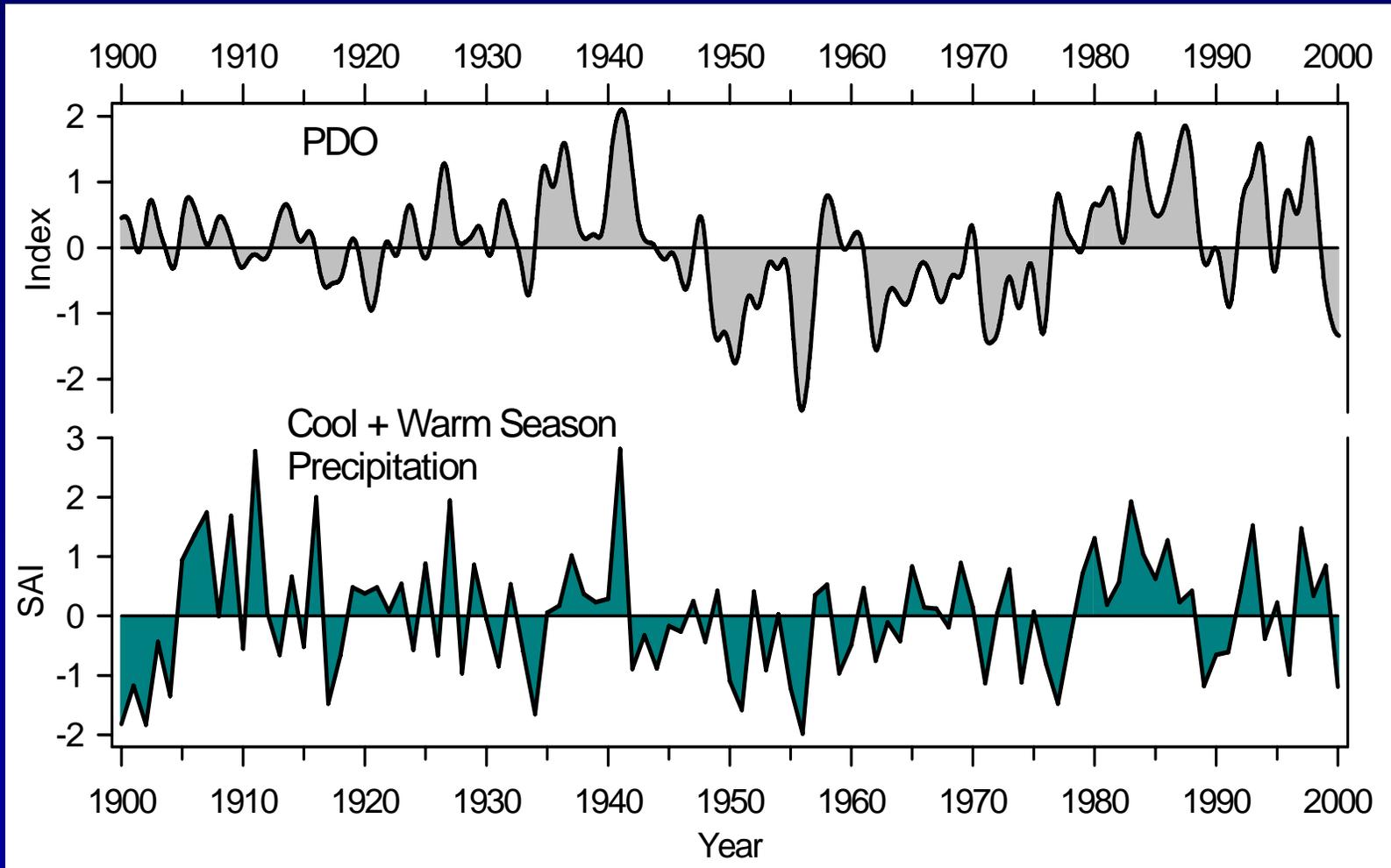
Early-20<sup>th</sup>  
century  
wet period

Late-20<sup>th</sup>  
century  
wet period

Mid-20<sup>th</sup>  
century  
drought

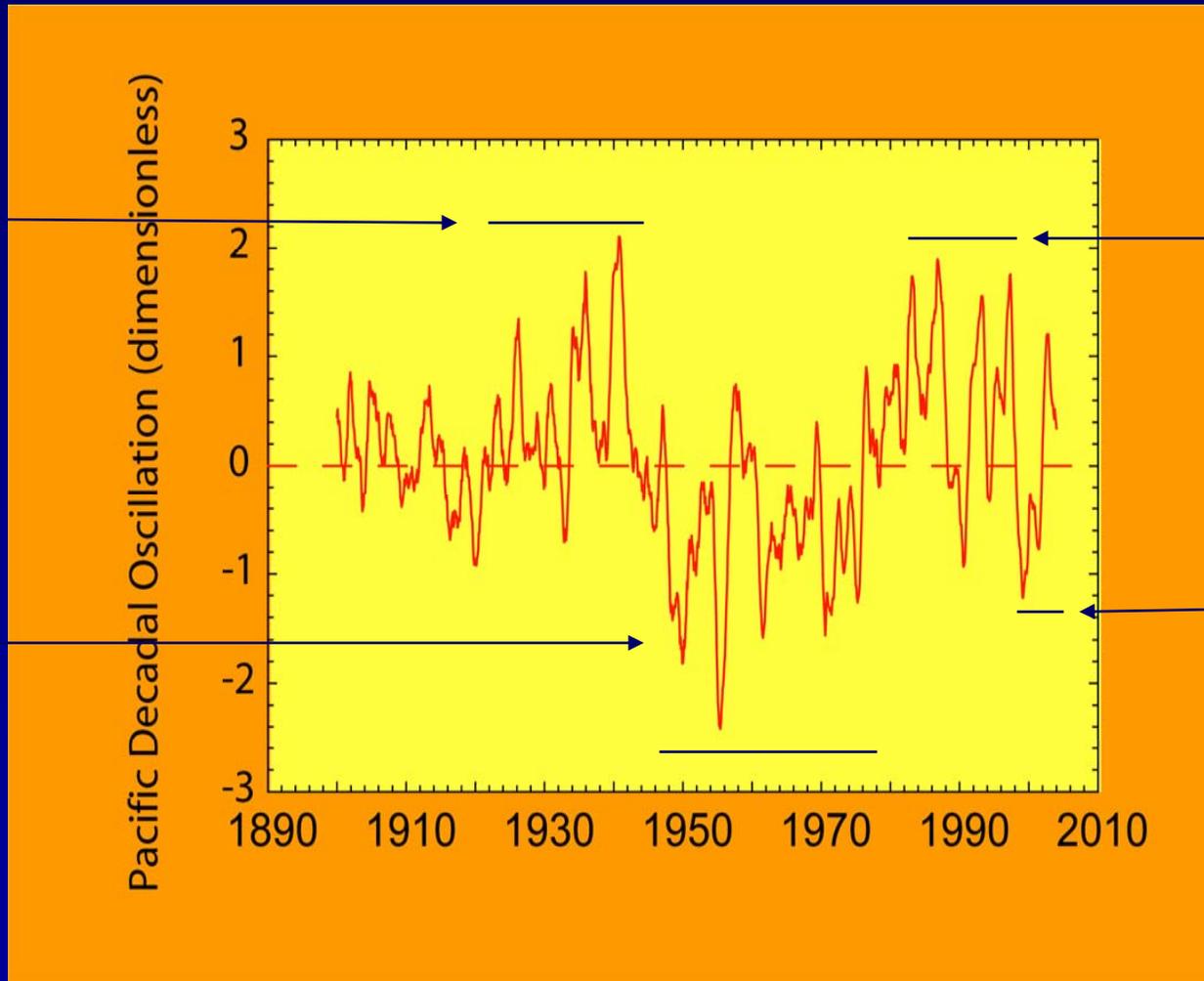
Early-21<sup>st</sup>  
century  
drought

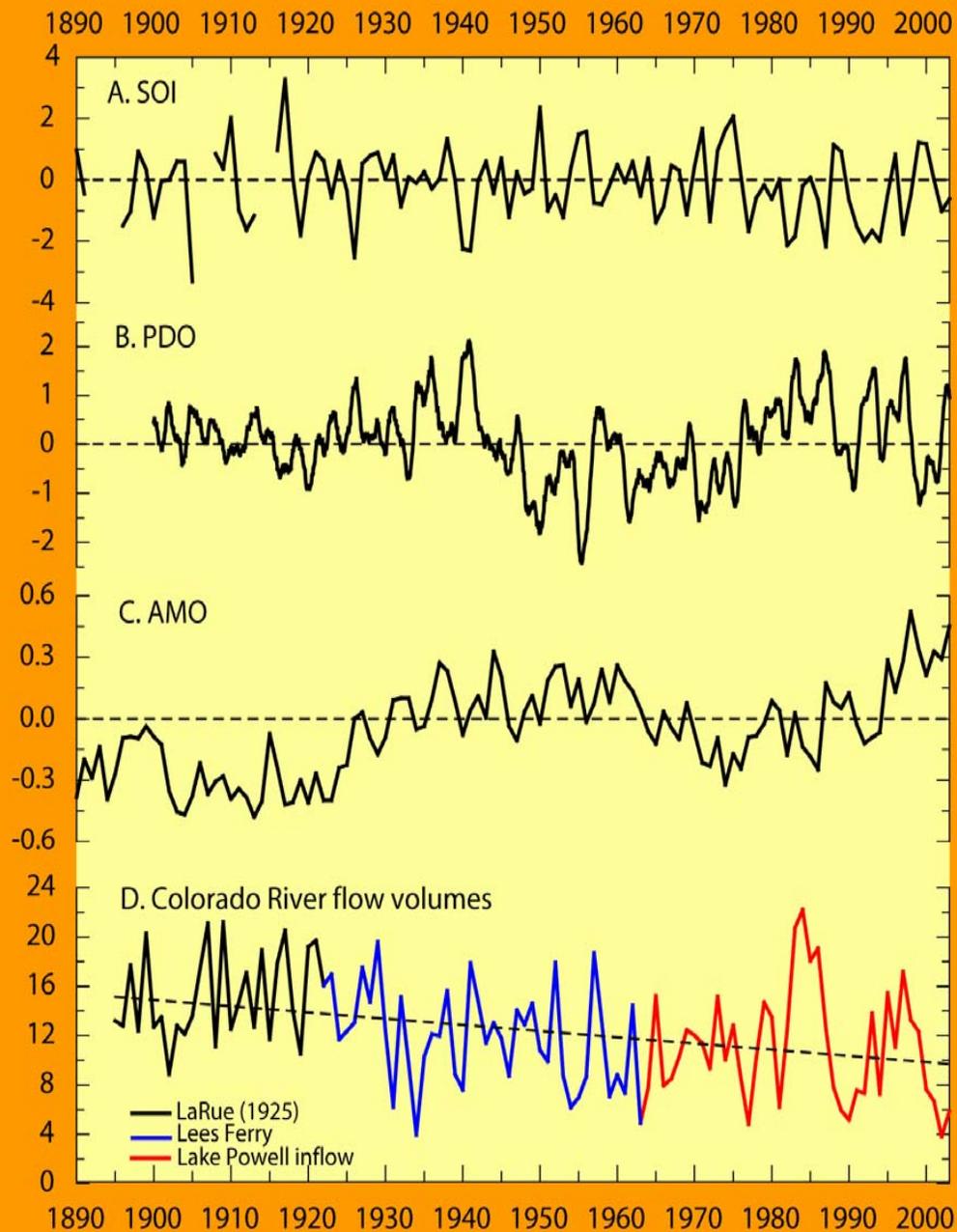
# PACIFIC DECADAL OSCILLATION



Ref: Hereford et al. (2002)

# ATLANTIC MULTIDECADAL OSCILLATION

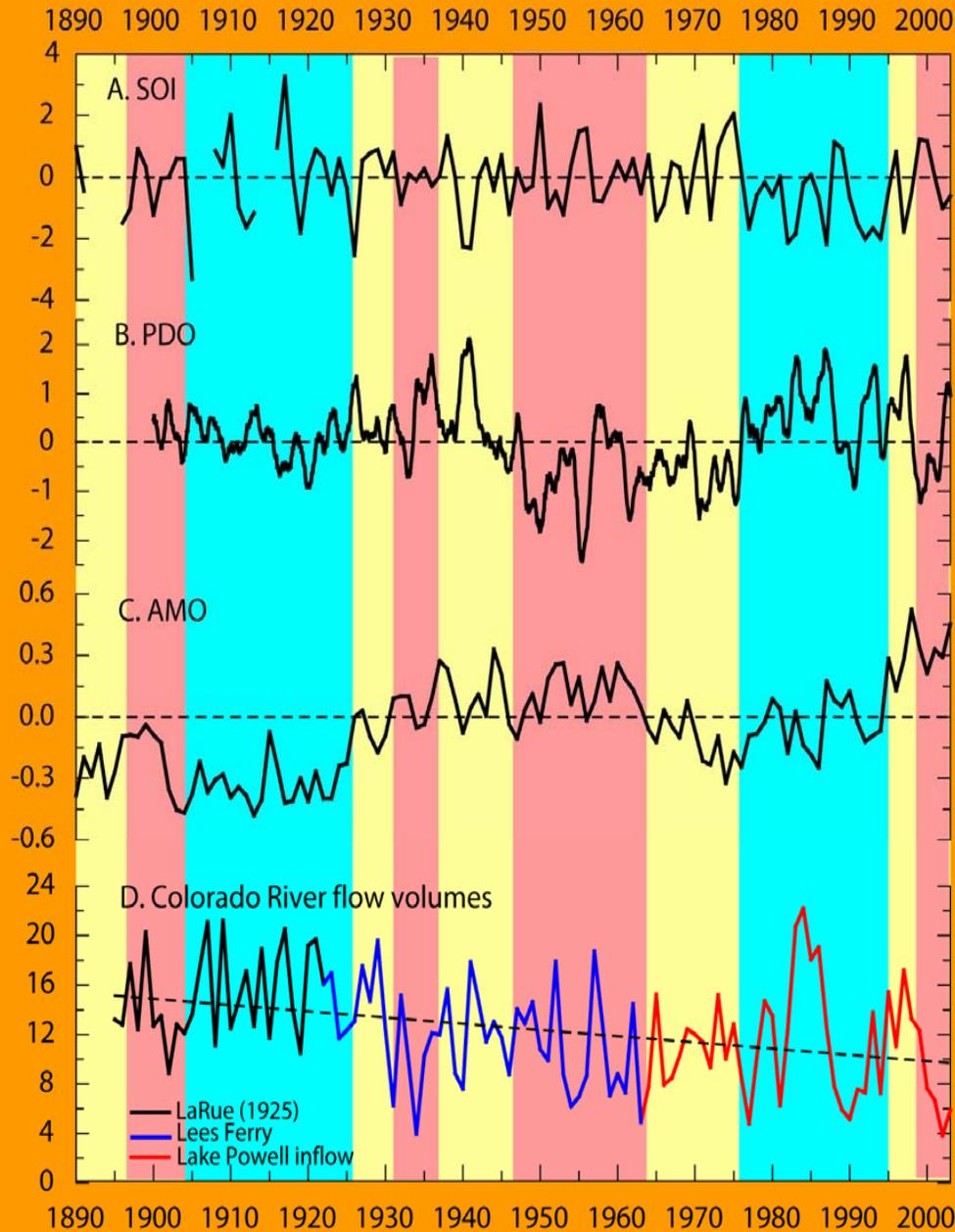




# CLIMATIC VARIABILITY AND RIVER FLOW

There is no significant statistical relation among indices of climatic variability and Colorado River at Lee's Ferry or entering Lake Powell.

# CLIMATIC VARIABILITY AND RIVER FLOW



BUT there are compelling patterns of long-term climatic variability. The lag effects and integration of climatic signal over the watershed may defy an easy statistical model.

# TREE RINGS AND DROUGHT FREQUENCY

- Dendrochronology of headwaters trees has been used to reconstruct Colorado River flow.
- Comparison of current and reconstructed conditions is an apples and oranges problem.
- Drought reconstructions indicate that the severe droughts can last 30 years. One possibility is that El Nino in 2005 merely interrupted an extended drought period.
- Tree-ring analyses indicate that the most unusual part of the 20<sup>th</sup> century was above-average conditions, not droughts.
- We're left with no long-term prognosis as to whether the early 21<sup>st</sup> century drought is over.

# CONCLUSIONS

- A drought from 2001 through 2004 caused low flow in the Colorado River and its tributaries upstream from Lake Powell from 2001 through 2004
- All available information indicates that the drought was the most severe in the period of record and (from tree-ring records) may have been the most severe in several centuries
- Although above-average conditions occurred in 2005, the longer-term climatic future is uncertain – drought conditions could resume in 2006