Drought and California's Climate of Extremes

A climate history of droughts and floods

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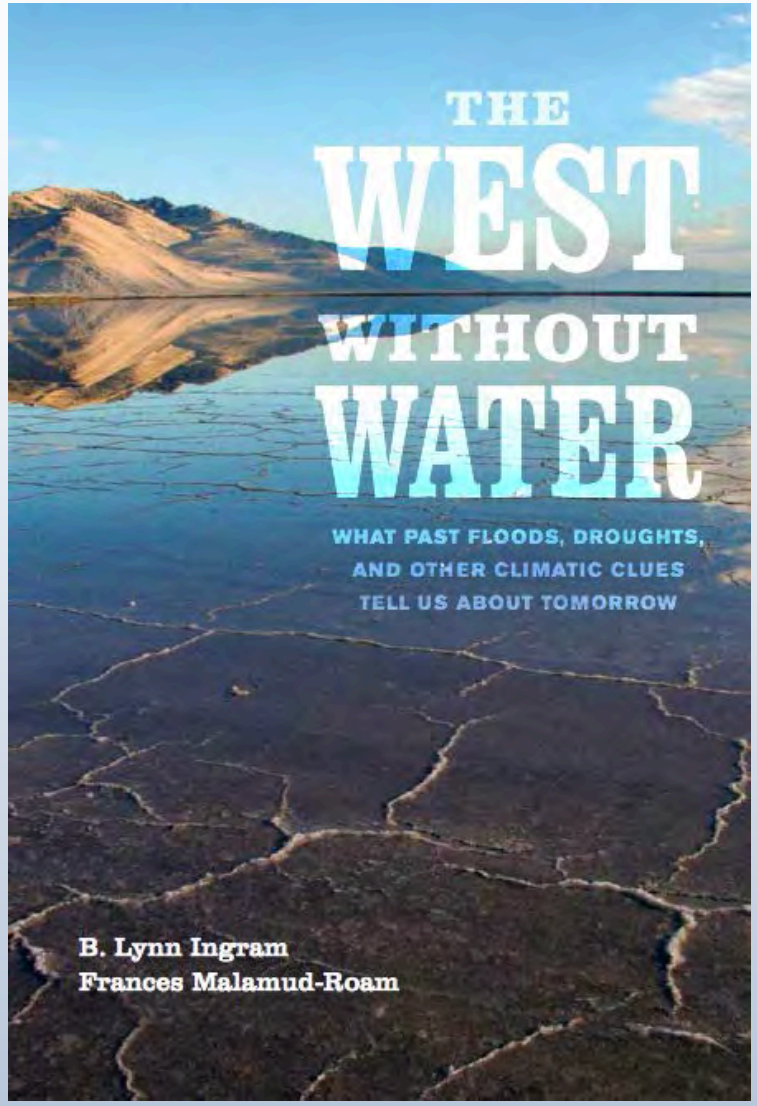


The questions that our book addresses:

- *How much does climate vary naturally?*
- *How frequent and severe were past droughts and floods and what were the impacts?*
- *Is our current way of life in the American West sustainable?*
- *How will future warming impact water resources?*

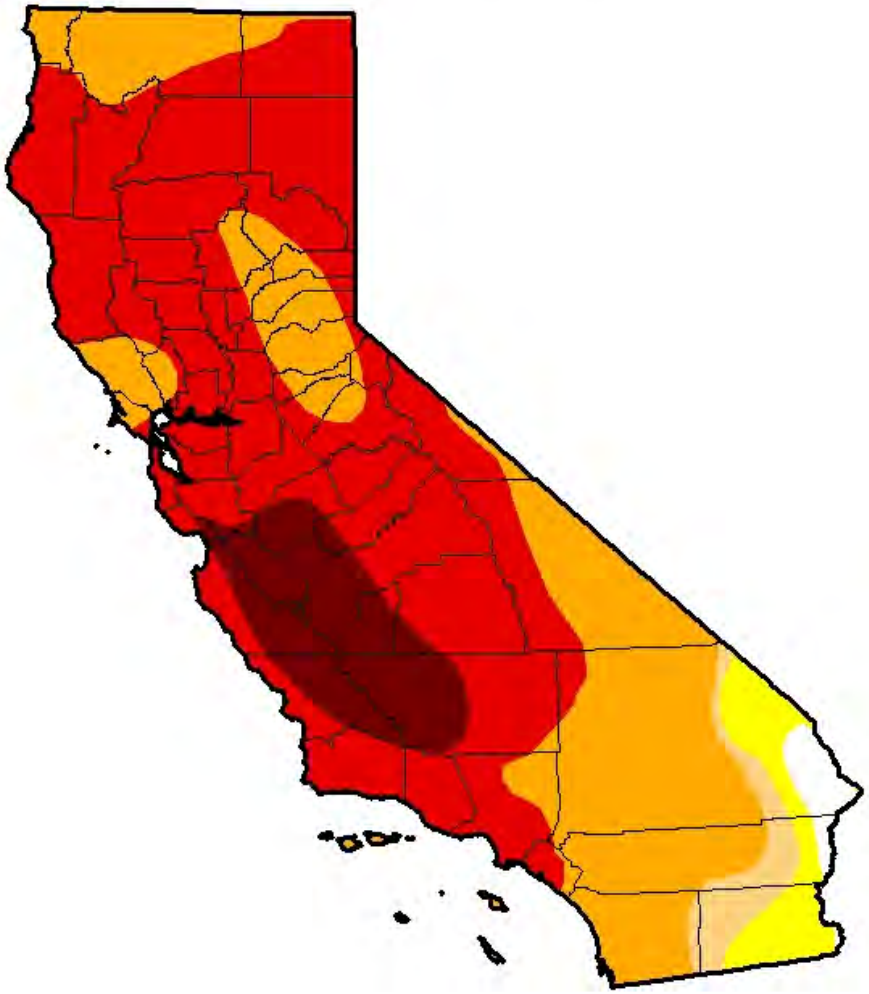
2013-14 Drought…

Precipitation ~20% average

Reservoirs ~ 30% average

"drought emergency" declared

U.S. Drought Monitor
California



February 11, 2014
(Released Thursday, Feb. 13, 2014)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	1.43	98.57	94.54	91.59	60.94	9.81
Last Week 2/4/2014	1.43	98.57	94.18	89.91	67.13	9.81
3 Months Ago 11/12/2013	2.61	97.39	96.00	84.12	11.36	0.00
Start of Calendar Year 12/31/2013	2.61	97.39	94.25	87.53	27.59	0.00
Start of Water Year 10/1/2013	2.63	97.37	95.95	84.12	11.36	0.00
One Year Ago 2/12/2013	34.53	65.47	47.18	23.72	0.00	0.00

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
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NOAA/NWS/NCEP/CPC

http://droughtmonitor.unl.edu/

Shasta Reservoir

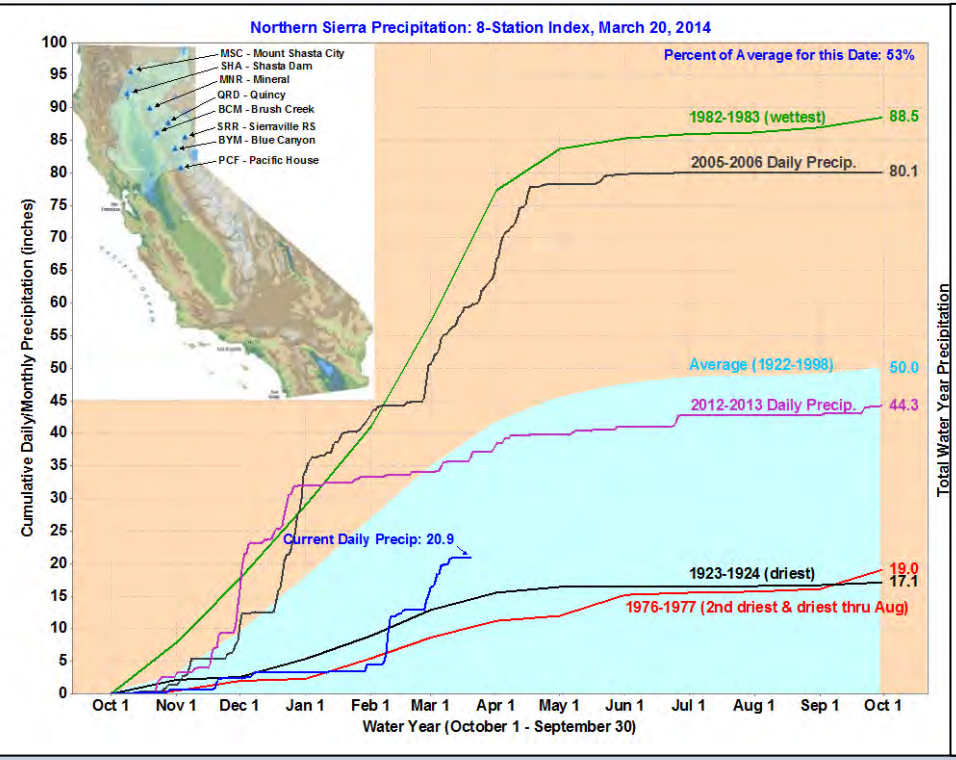
Folsom Lake

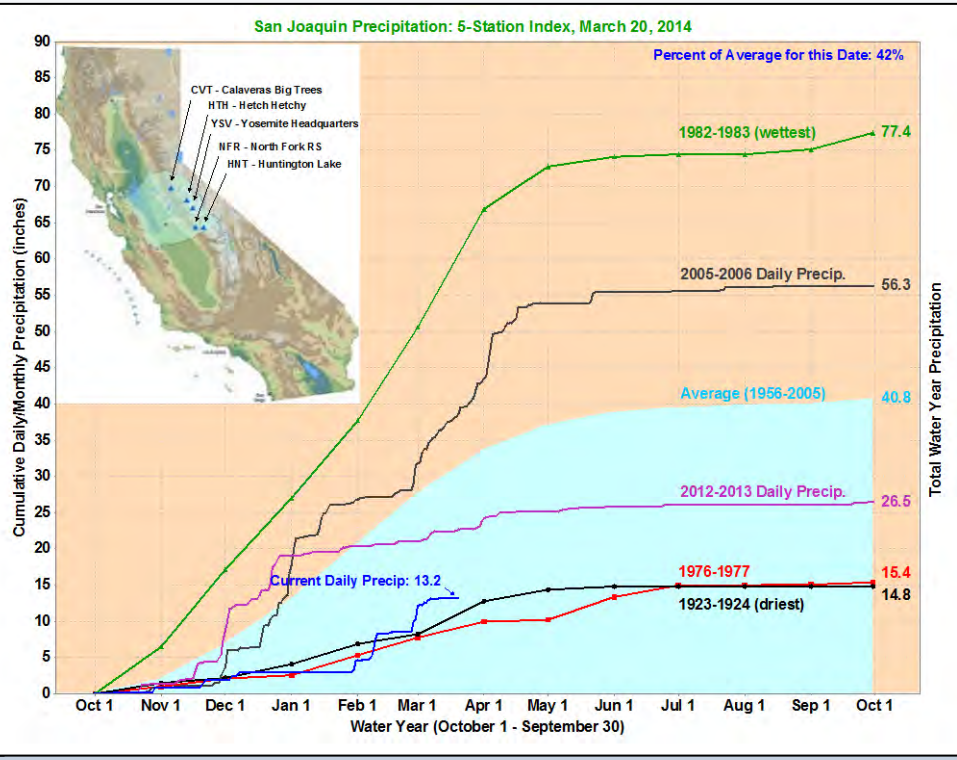
Snowpack ~25% average

Unusually long fire season

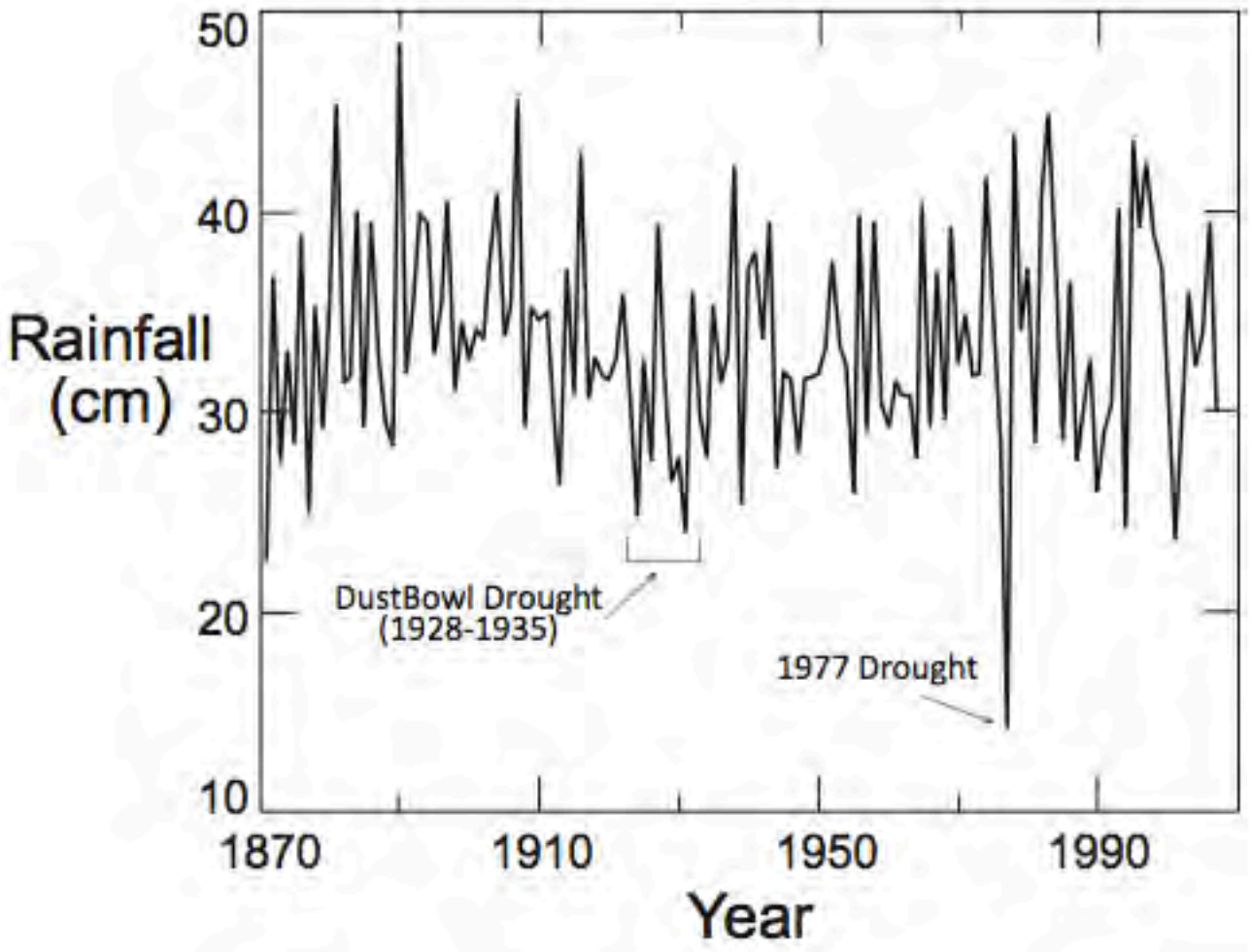
How unusual is this year?

Water Year 2013-14 in historical perspective





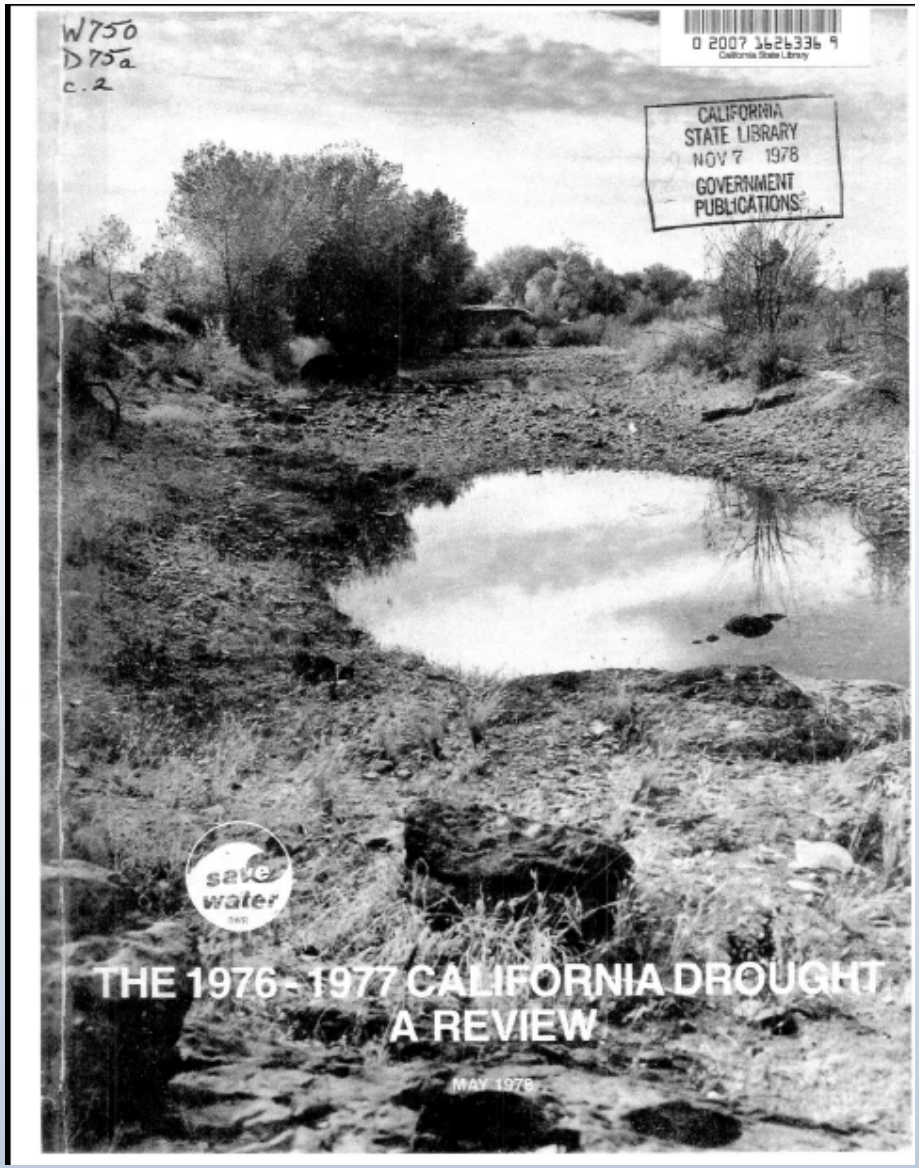
Precipitation highly variable in CA over the past century



The Dust Bowl Drought
1928-1937

(1928-1934 in California)

Worst single year drought: 1976-1977

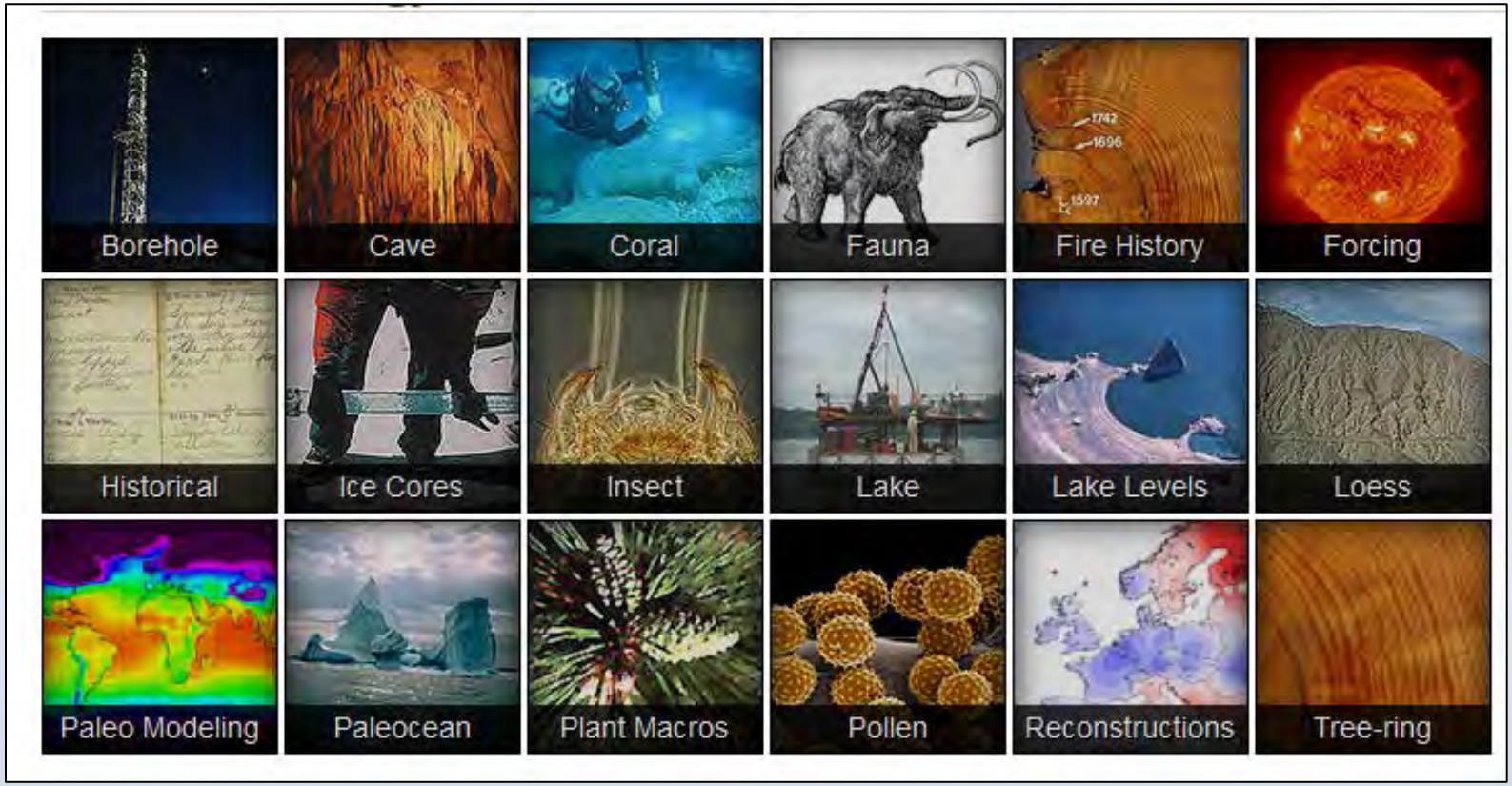


7. Low on reserves. Lake Oroville as it appeared on September 30, 1977. Storage on that date was only 1 100 cubic hectometres (915,000 acre-feet), or about one-fourth of capacity. Lake Oroville reached its lowest point on September 7.

13. One picture tells it all. Bass Lake in El Dorado County held only a small puddle when this photo was taken on March 2, 1977.

How unusual are these droughts?

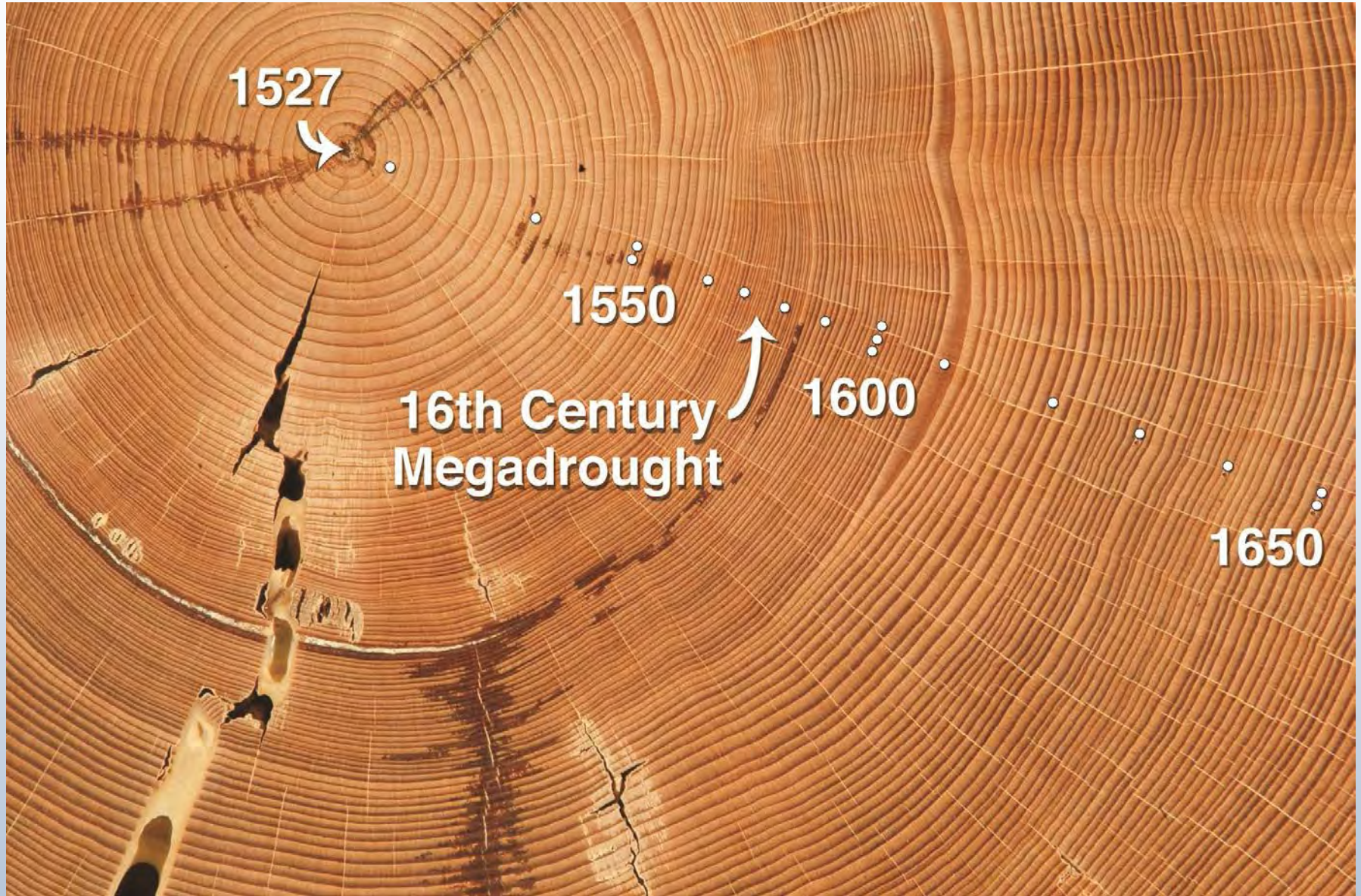
Paleoclimatology



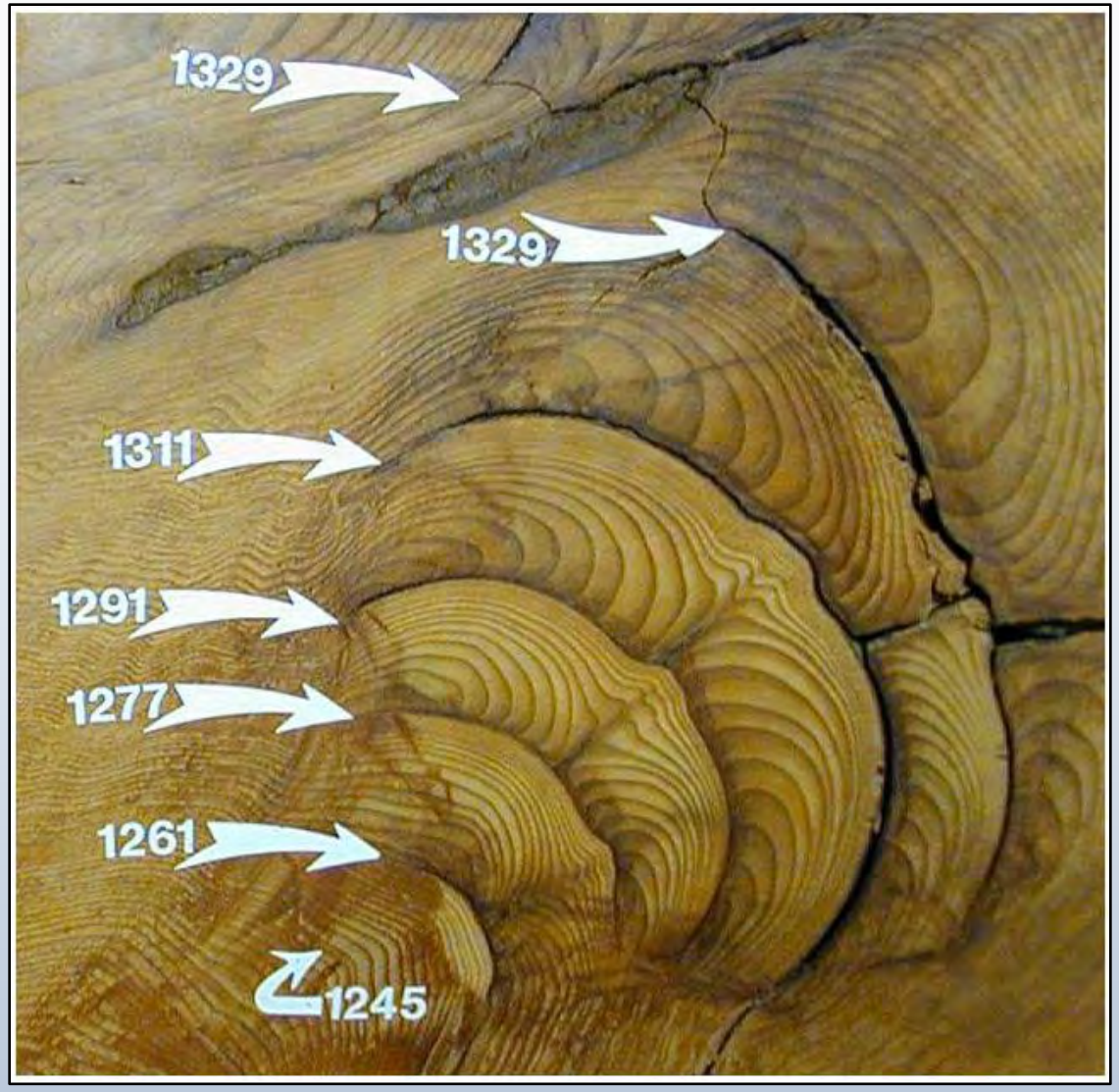
Looking at the past using environmental proxies

Proxy records

Tree ring record of past droughts: worst single year: 1580



FIRE SCARS



Provide a history of fires

Other proxy records

Ice cores

Ring widths
Air bubbles
Temperature
Sea level

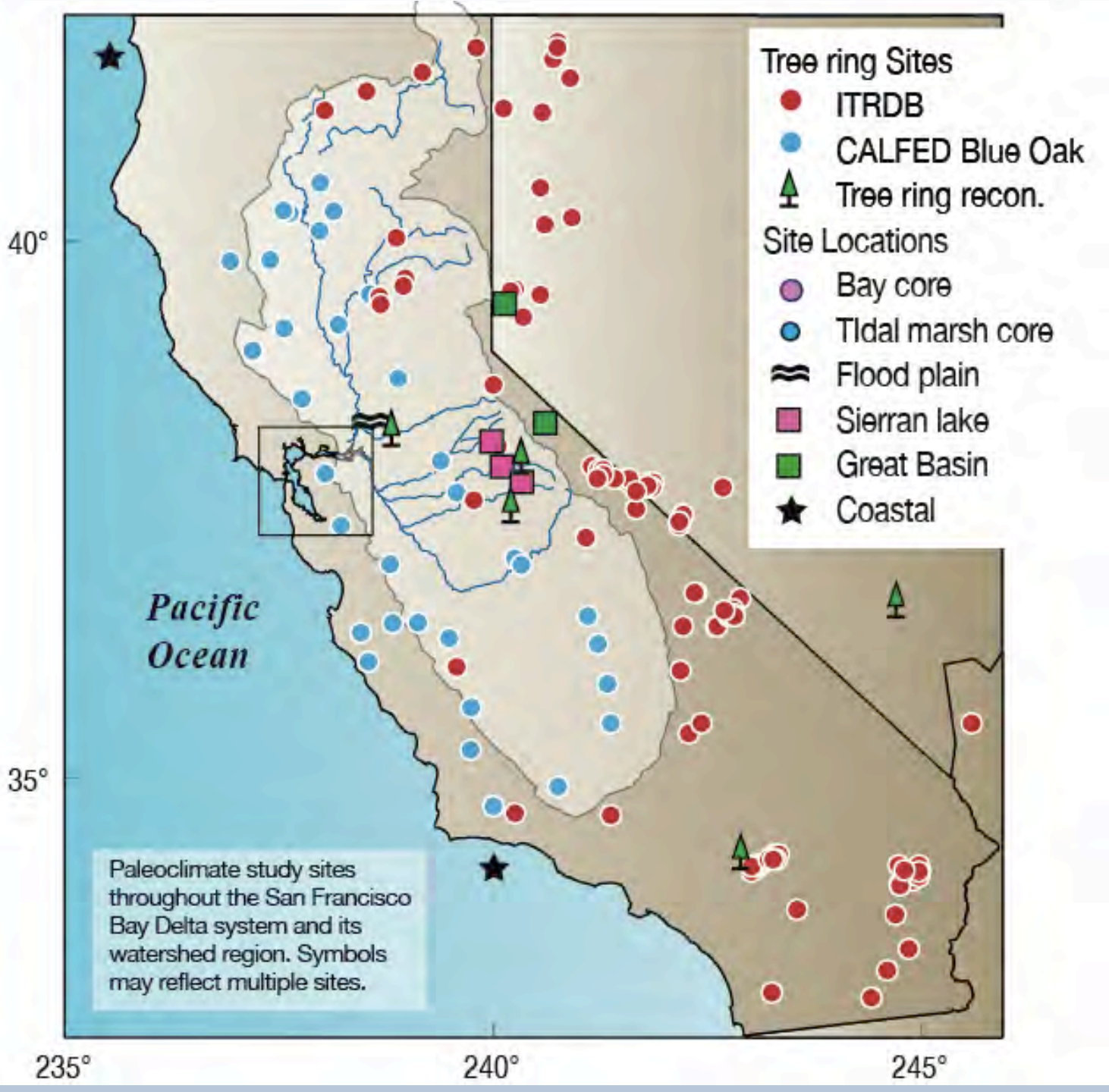
SEDIMENT CORES

Oceans; lakes; estuaries; bogs; marshes

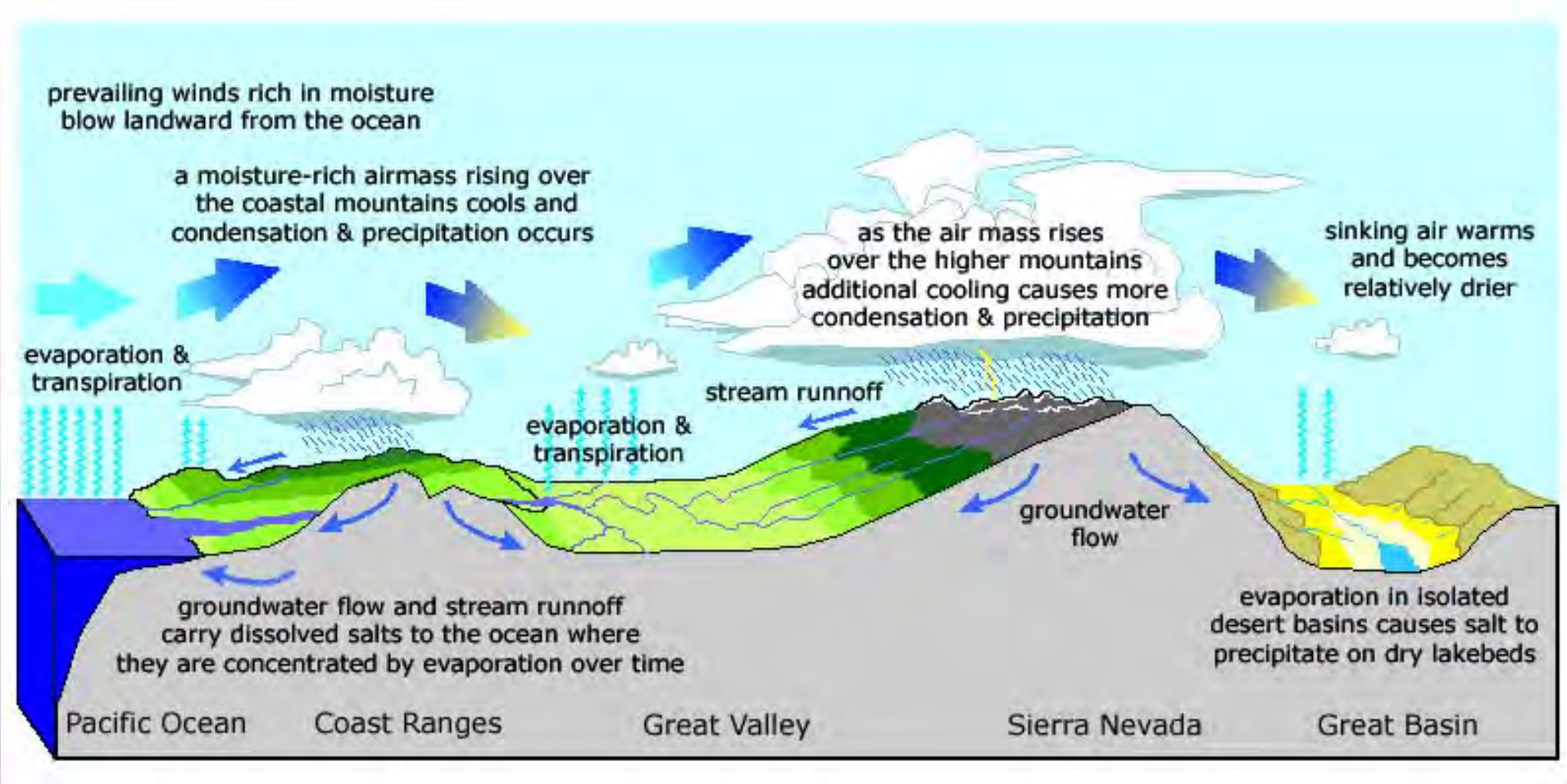
California climate archives

Tree rings
Lake sediments
Floodplain cores

San Francisco Bay Sediments – why are they so informative?



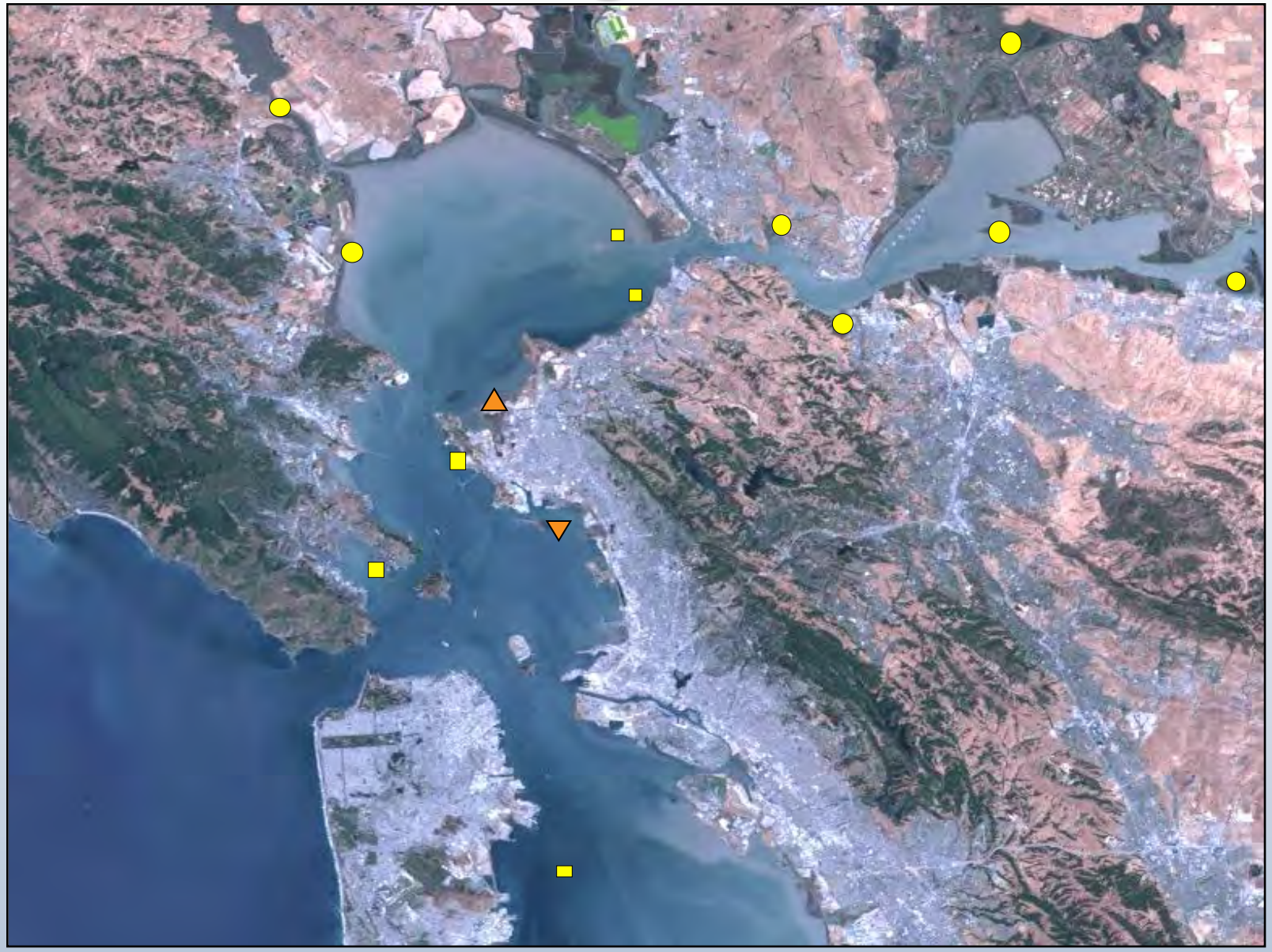
A bit about California's Water cycle



California's largest watershed

Salinity in San Francisco Bay reflects runoff over the drainage basin

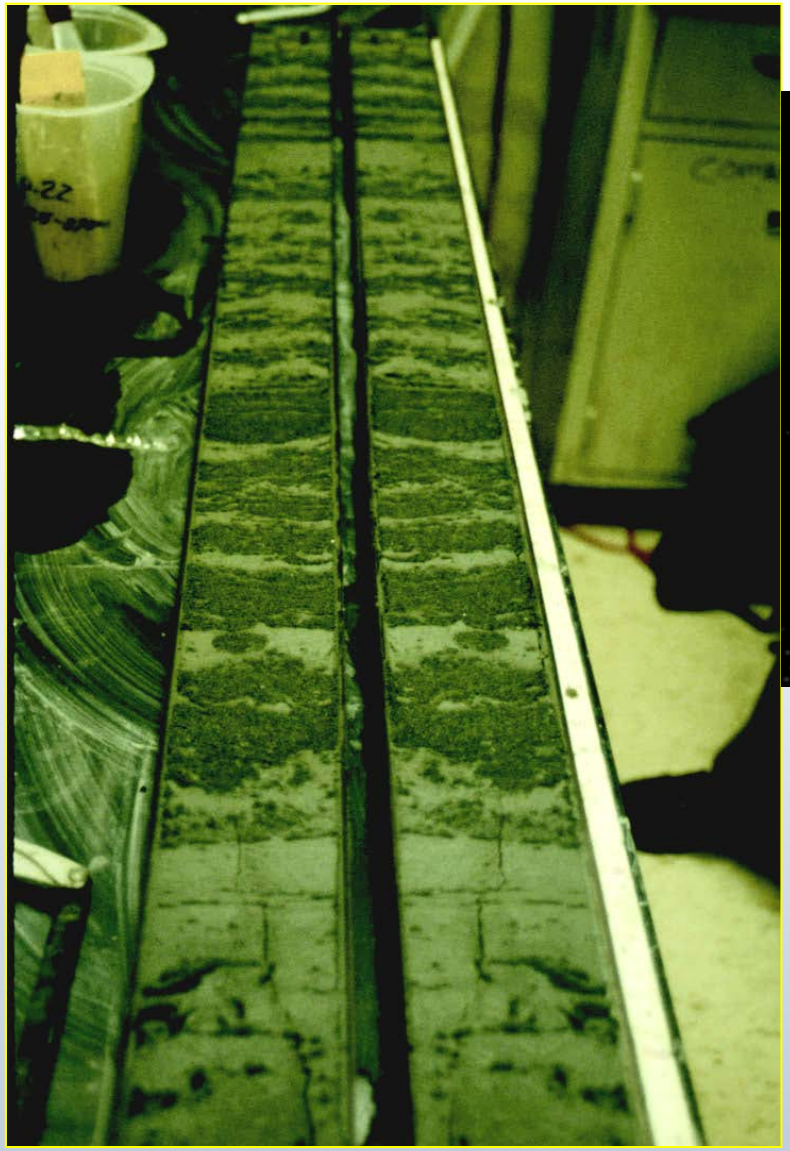
Sediment core locations (beneath bay and from surrounding tidal marshes)

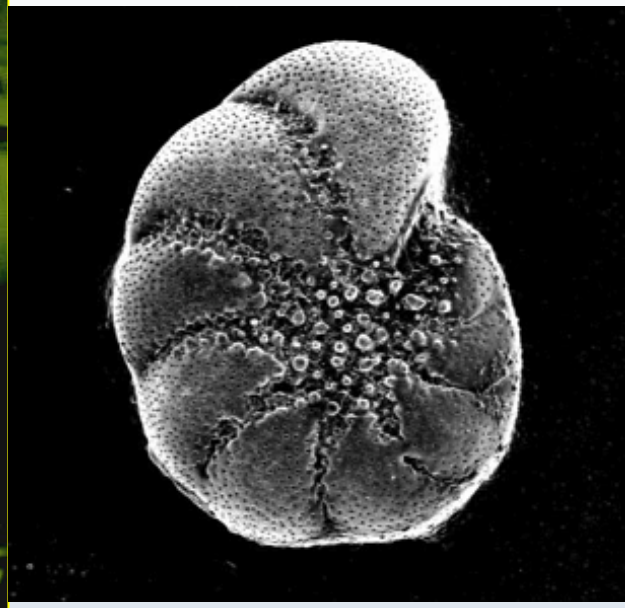


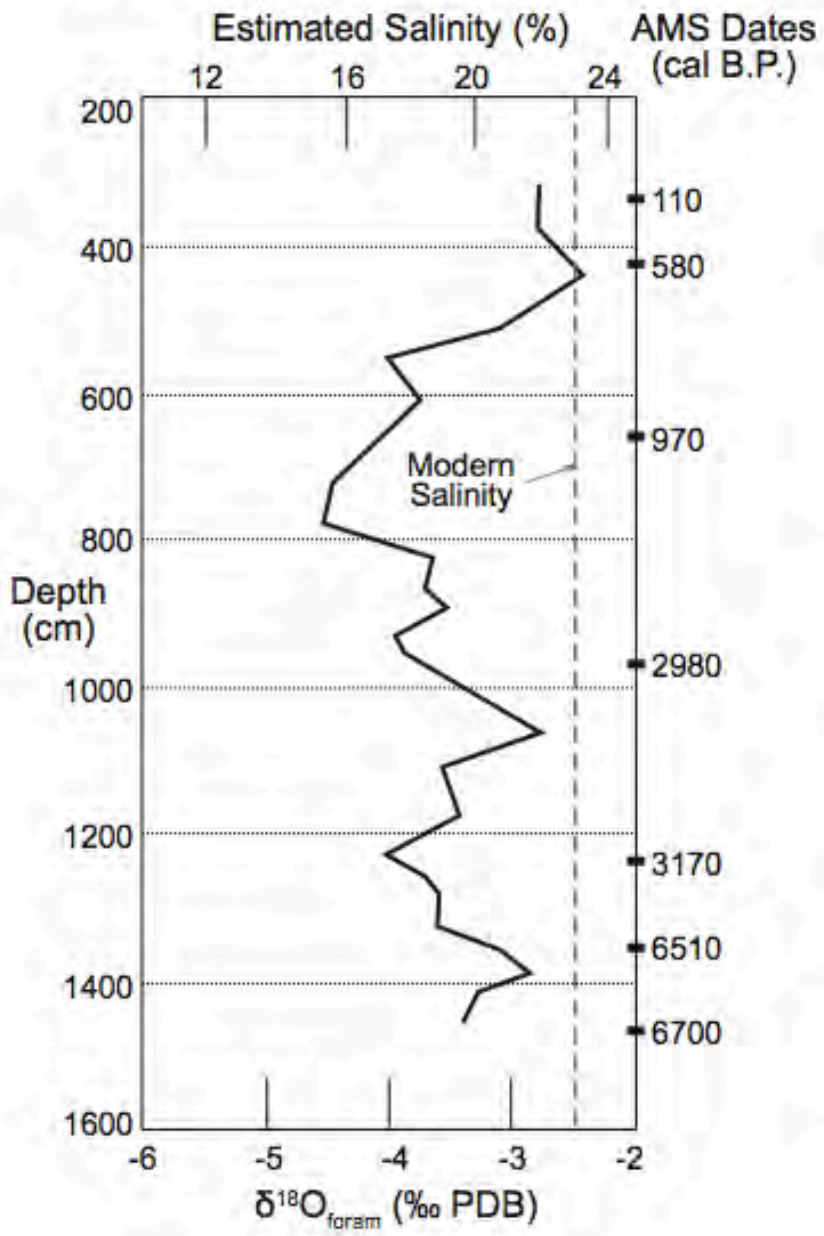
Coring - San Francisco Bay

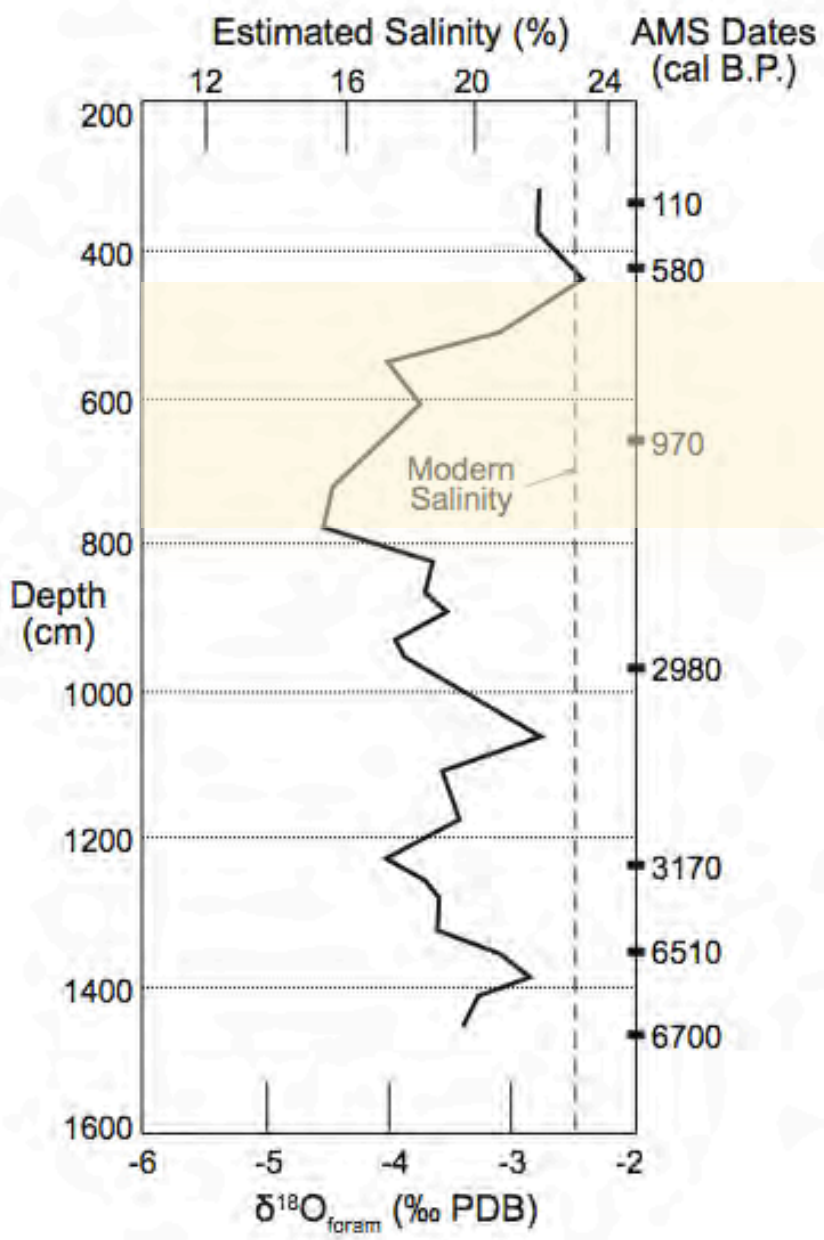
San Francisco Bay sediment core

- date with 14C
- Separate fossil shells
- Chemistry reflects salinity






Estimated Salinity (%)
AMS Dates (cal B.P.)
12
16
20
24
200
400
600
800
1000
1200
1400
1600
Depth (cm)
110
580
970
2980
3170
6510
6700
Modern Salinity
-6
-5
-4
-3
-2
δ18Oforam (‰ PDB)



Unusual period of drying

Sediment cores from tidal marshes surrounding San Francisco Bay

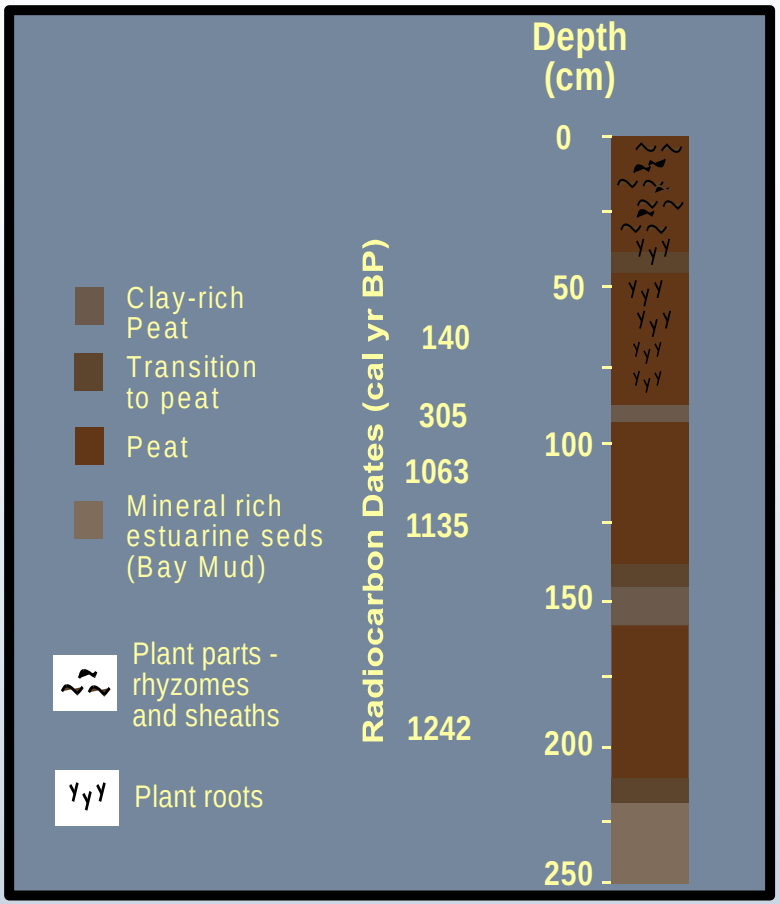
Marsh vegetation responds to salinity/inflow

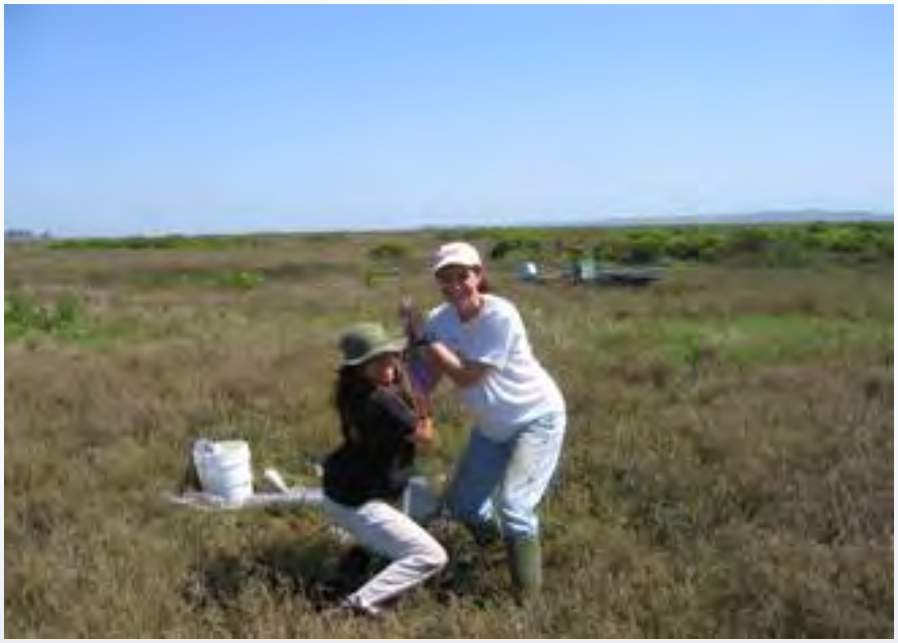
1977

Scirpus

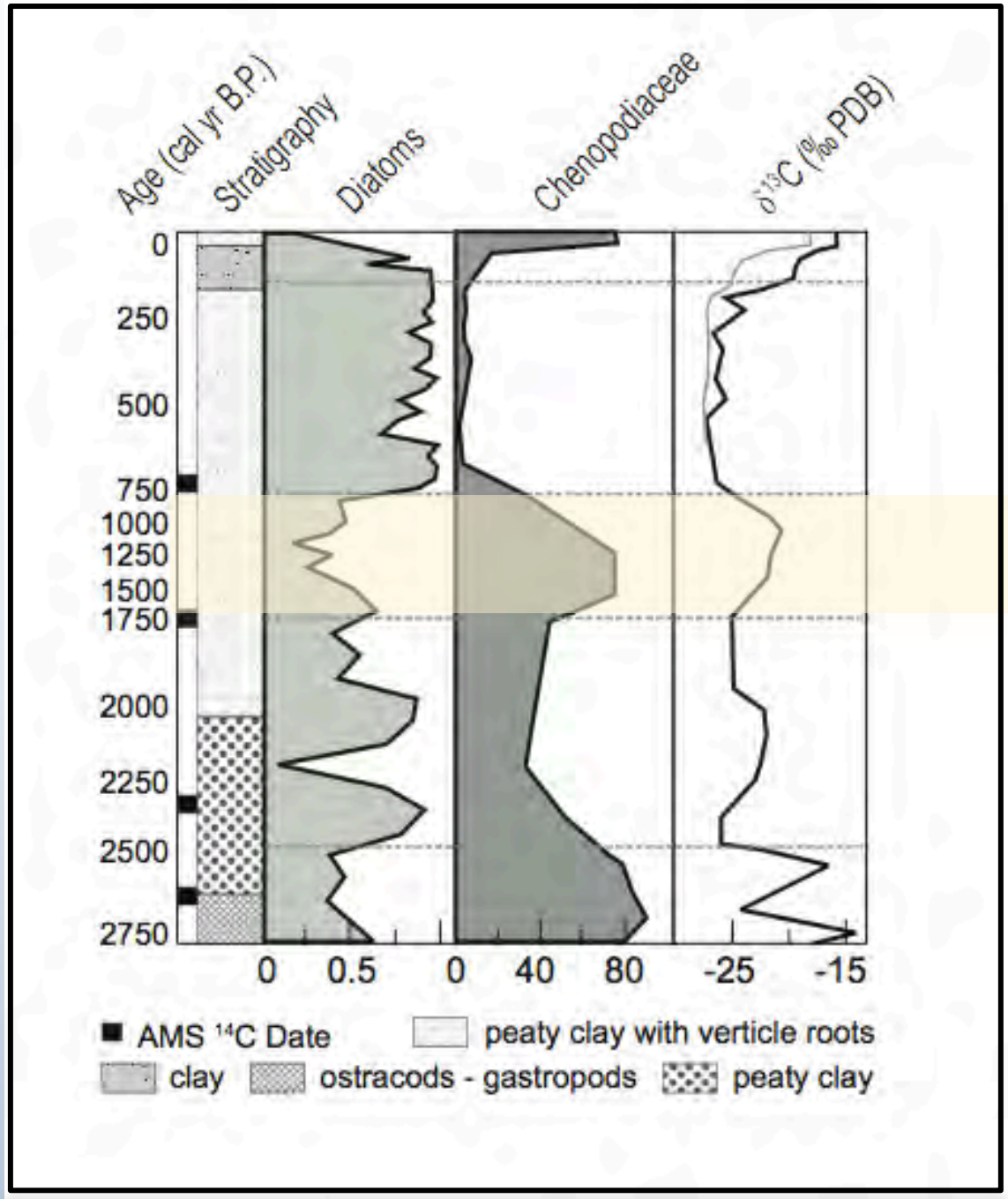
1995 - after 5 yr drought

Spartina


Depth (cm)
0
50
100
150
200
250
Radiocarbon Dates (cal yr BP)
140
305
1063
1135
1242
Clay-rich Peat
Transition to peat
Peat
Mineral rich estuarine seds (Bay Mud)
Plant parts - rhyzomes and sheaths
Plant roots

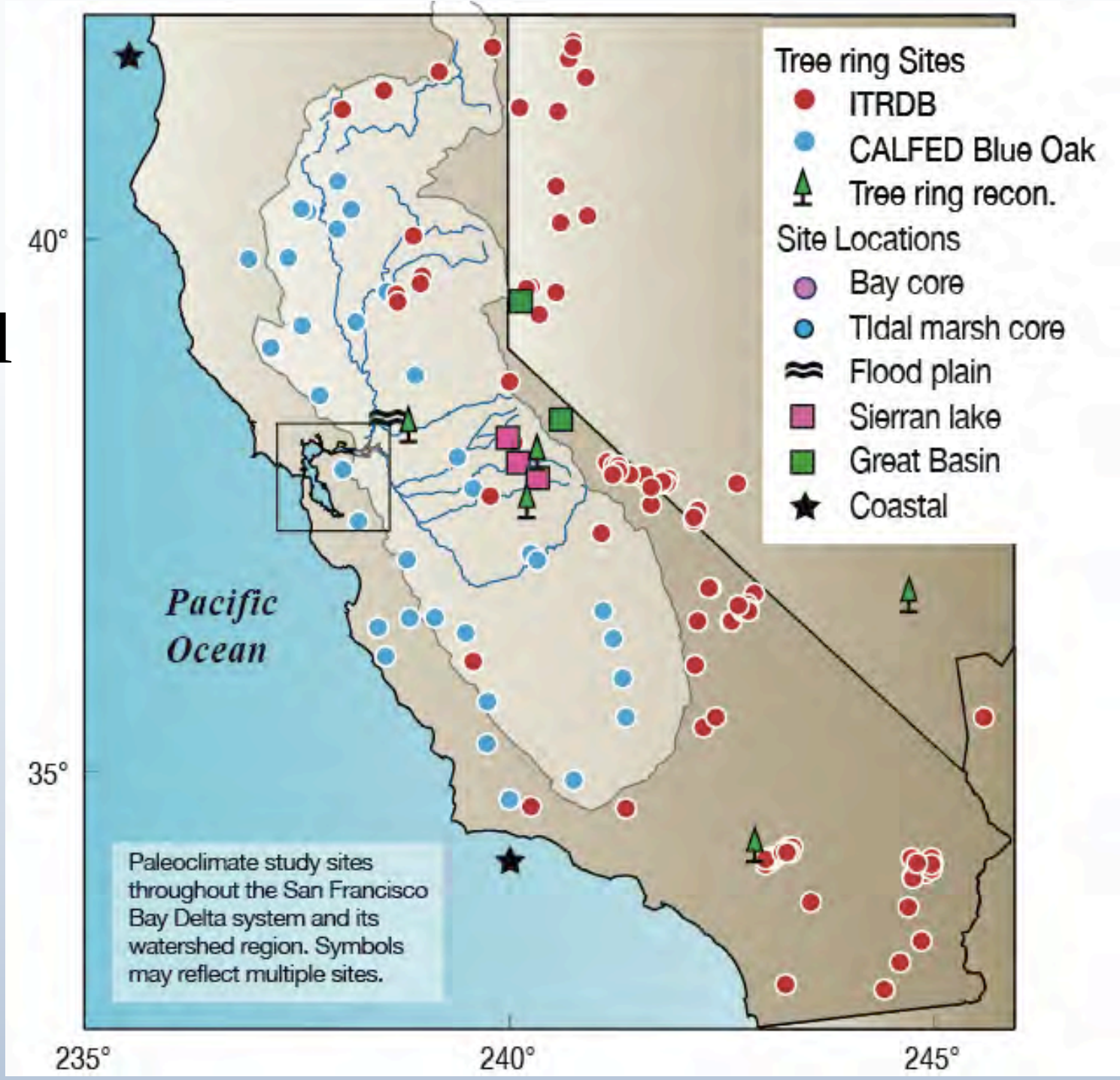



B

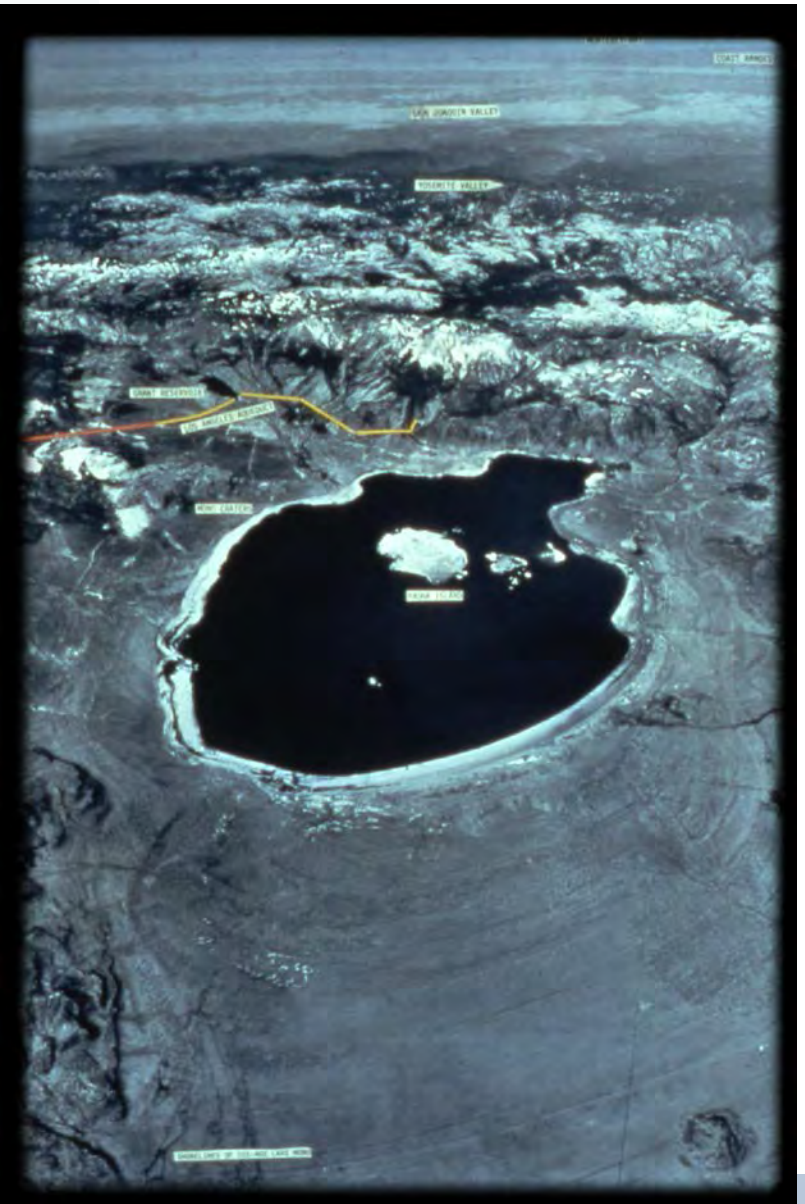

Age (cal yr B.P.)
Stratigraphy
Diatoms
Chenopodiaceae
δ13C (‰ PDB)
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
0
0.5
0
40
80
-25
-15
AMS 14C Date
peaty clay with verticle roots
clay
ostracods - gastropods
peaty clay

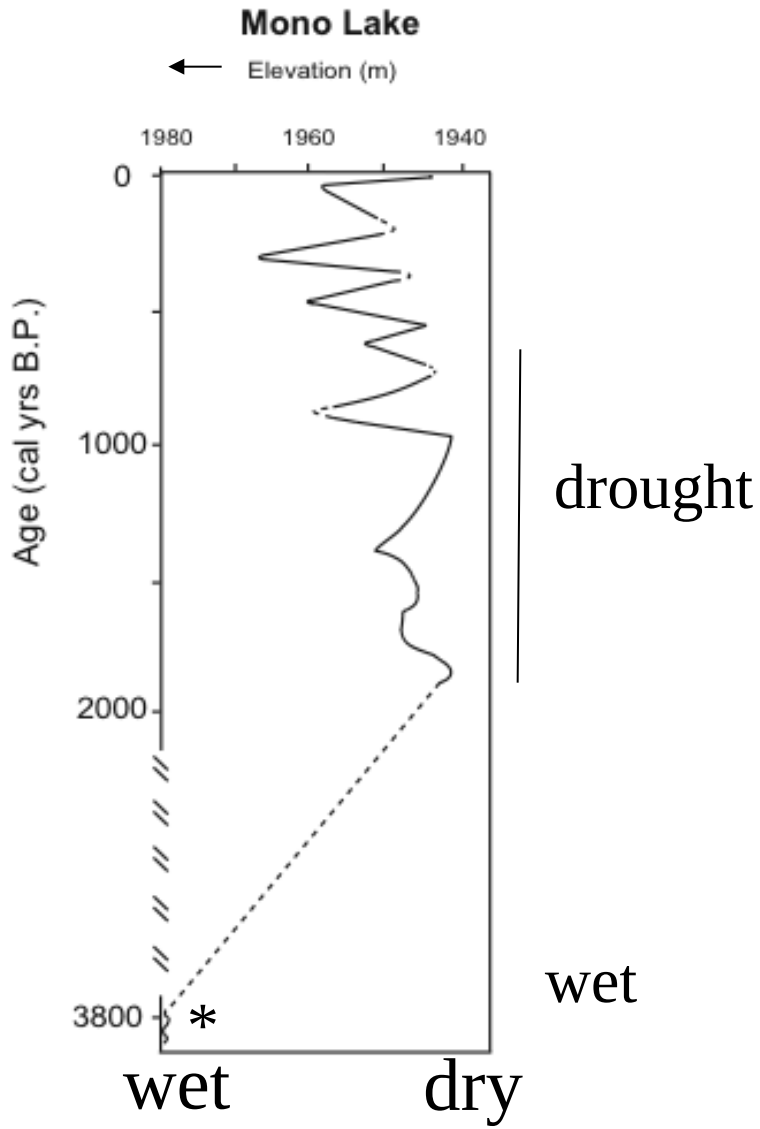
Drought

What do other records tell us about this time?



1800-600 years ago, Mono Like levels low (droughts)





(Stine, 1990)

Submerged tree-stumps

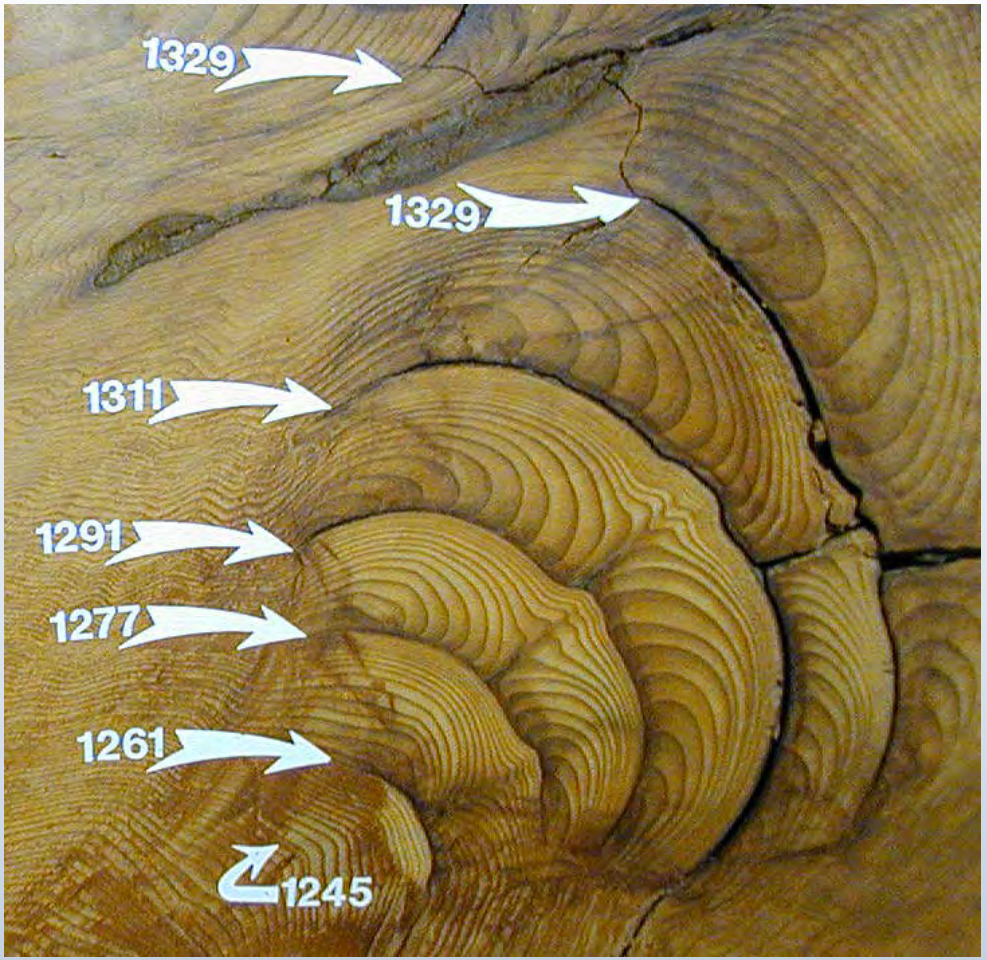
-A.D. 900-1100
-A.D. 1200-1350

“Medieval megadrought”

Stine (Nature, 1994)

The Medieval Warm Period (Climate Anomaly) in the American West

Giant Sequoia fire scars – increased fires during Medieval drought



(from Swetnam et al., 2008)

Anasazi collapse in 4 corners during Medieval drought

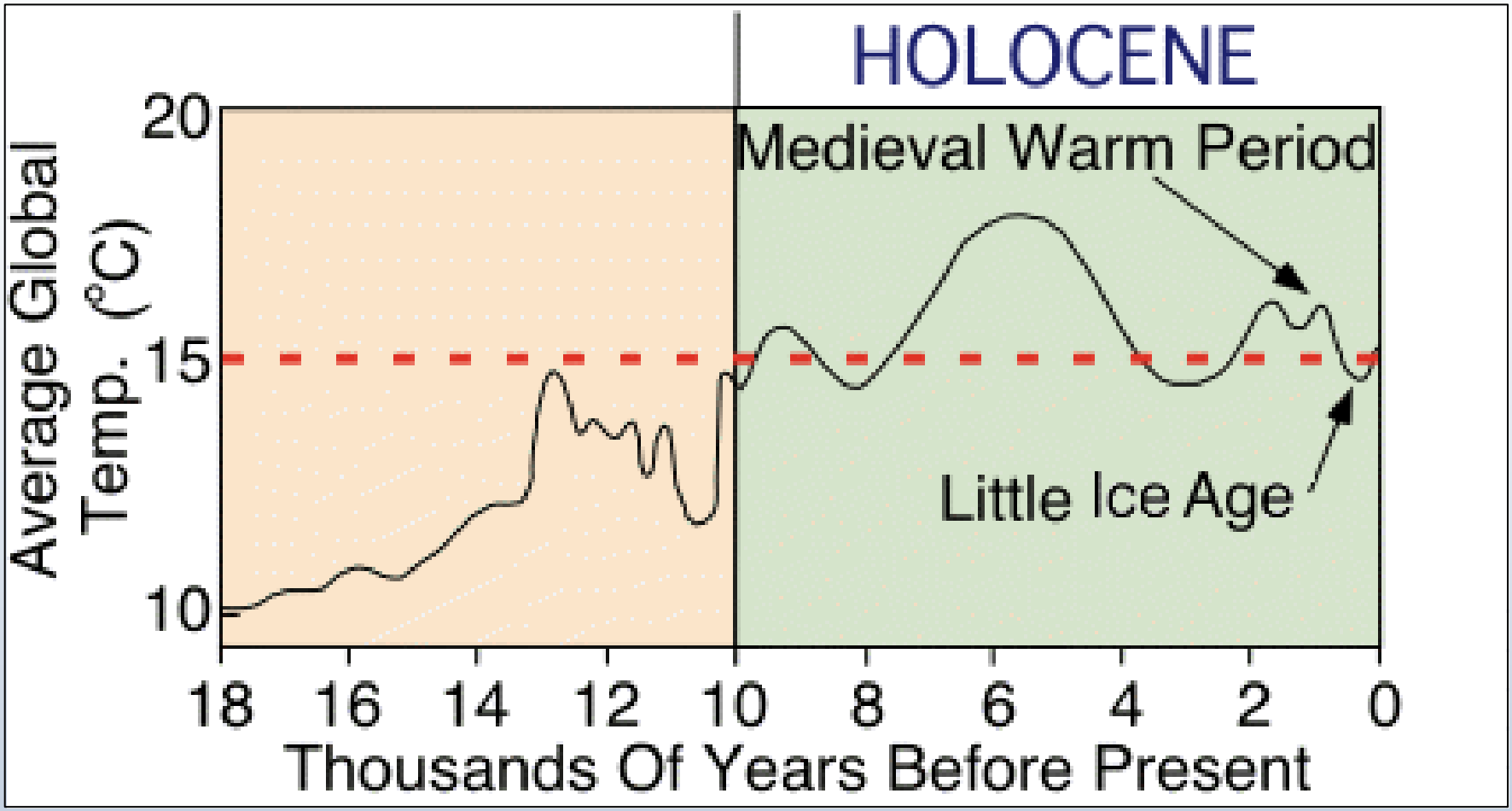
Mesa Verde, SW Colorado

Montezuma Castle, central Arizona

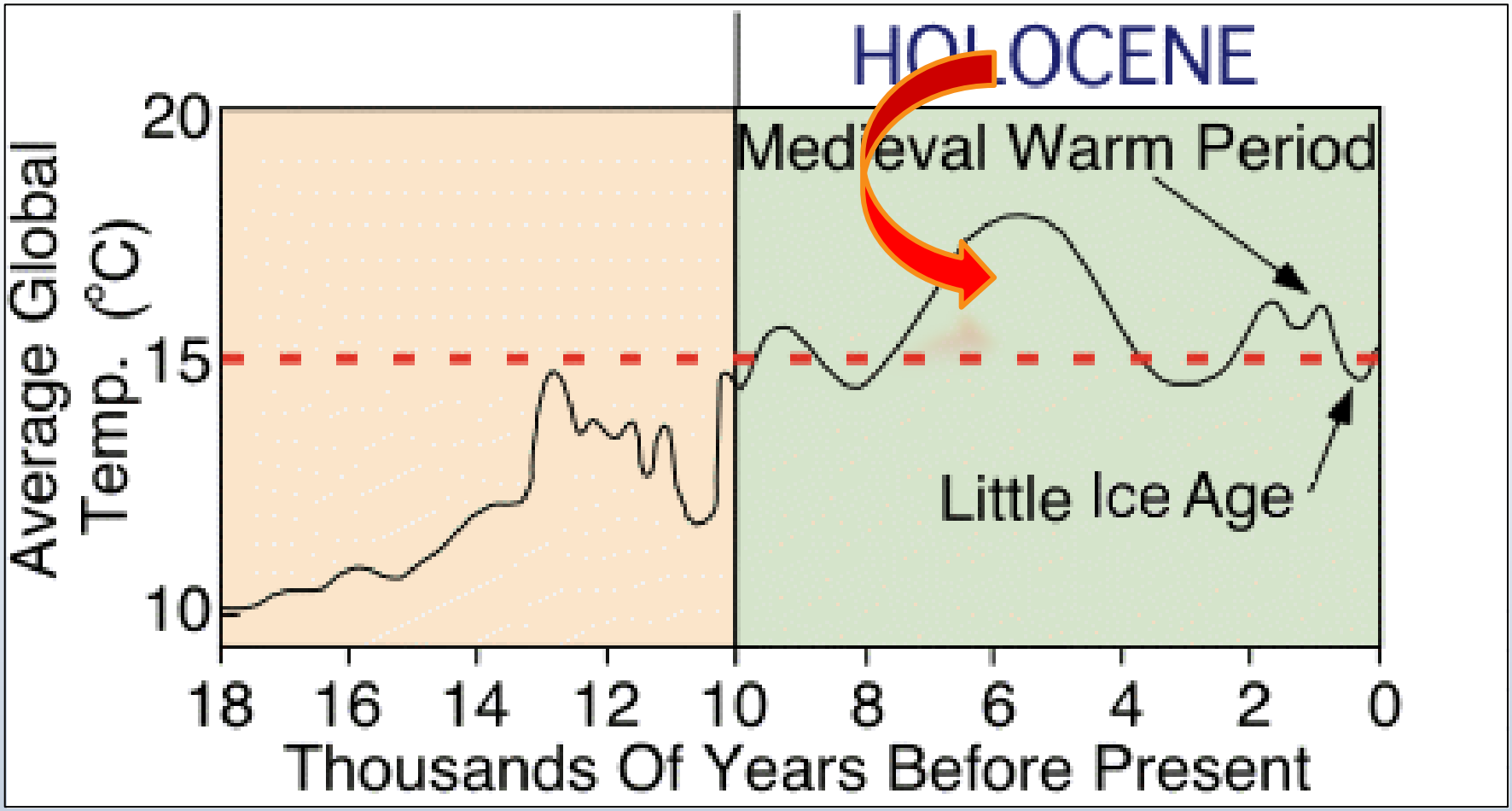
California coastal shellmound sites (including in SF Bay) abandoned at the same time

(Evidence of conflict and violence, infant mortality, starvation)

Other climate swings



Earlier megadrought 6000-4700 years ago



Mid-Holocene drought (6000-4700 years ago)

Lake Tahoe level was much lower
(trees grow along shores)

Some lakes dried up completely

Tulare Lake

Owens Lake

Humans migrated from interior deserts to the coast

Wet periods and floods are also a common occurrence in California

20th century floods:

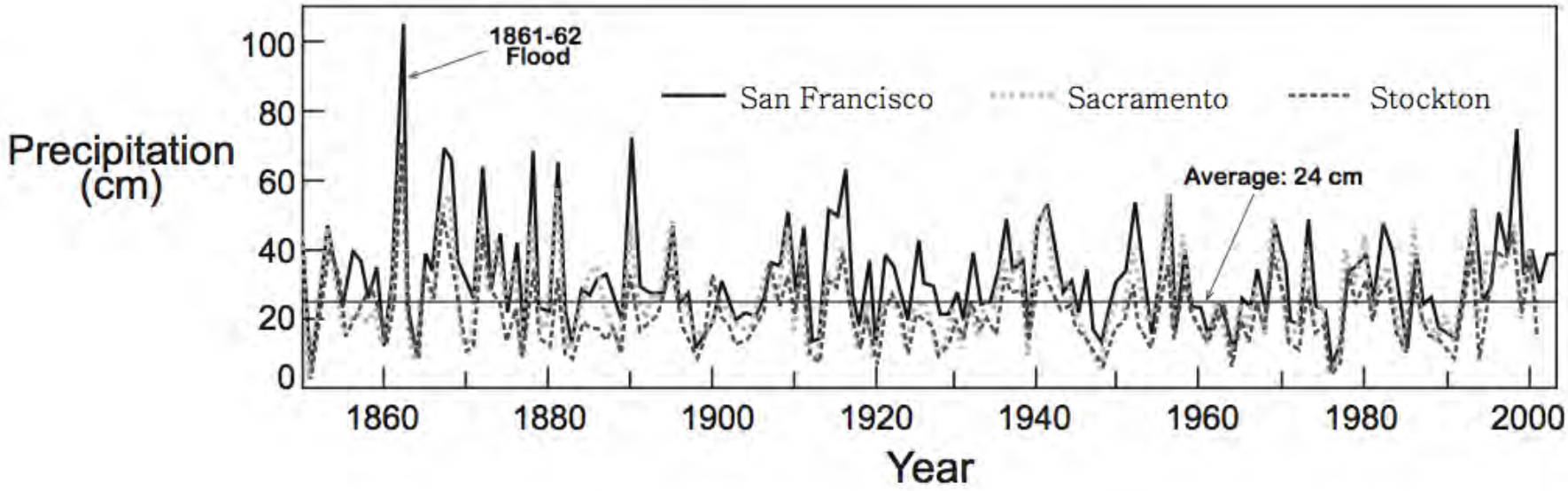
1938 Orange County
(Santa Ana River)

1955 Santa Cruz
(San Lorenzo River)

And others: 1969, 1983, 1997, 2006…

Largest historical flood: 1861-62

Precipitation was 3 to 4 times normal



(historical reconstructions from Mock, 2006)

1861-62 Flood

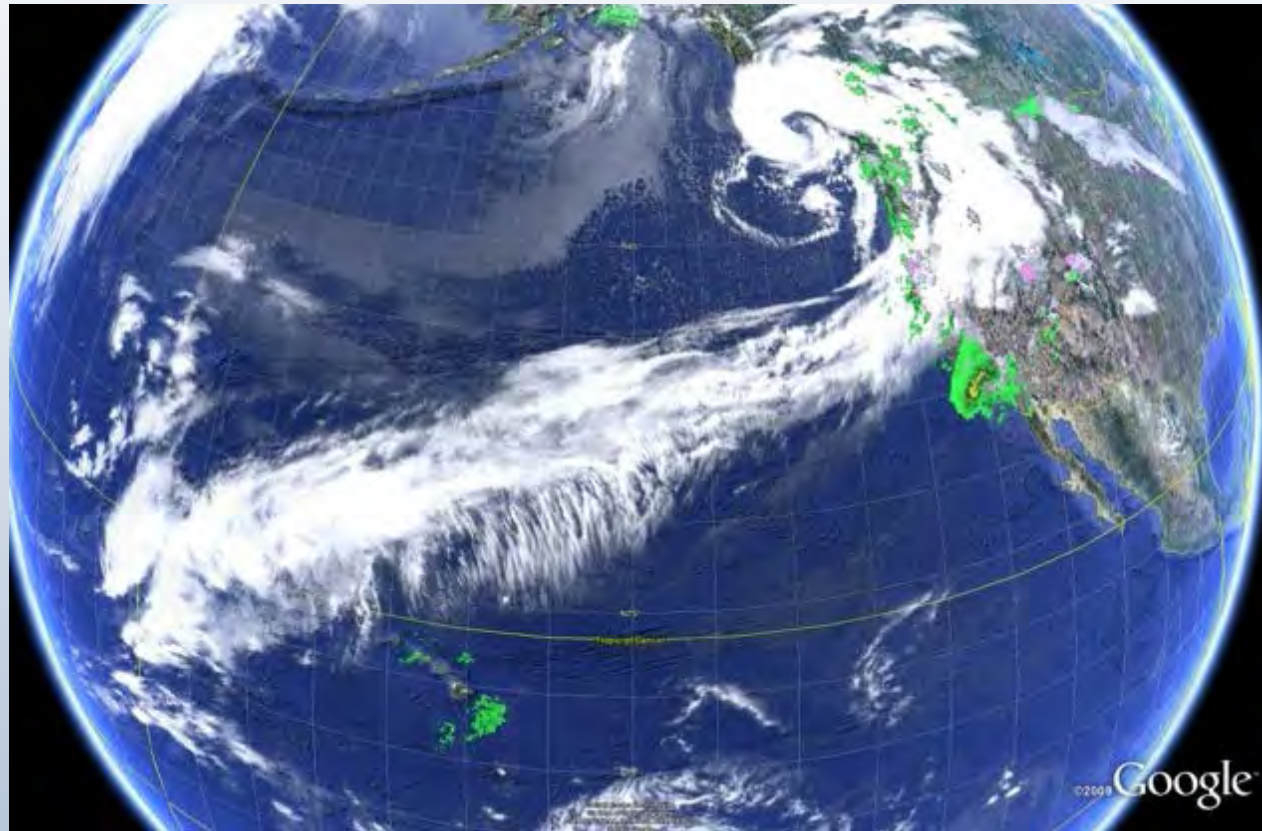
- Rained for 43 days (late December to early February)
- Filled Central Valley, flooded Sacramento
- Flooded LA to San Diego

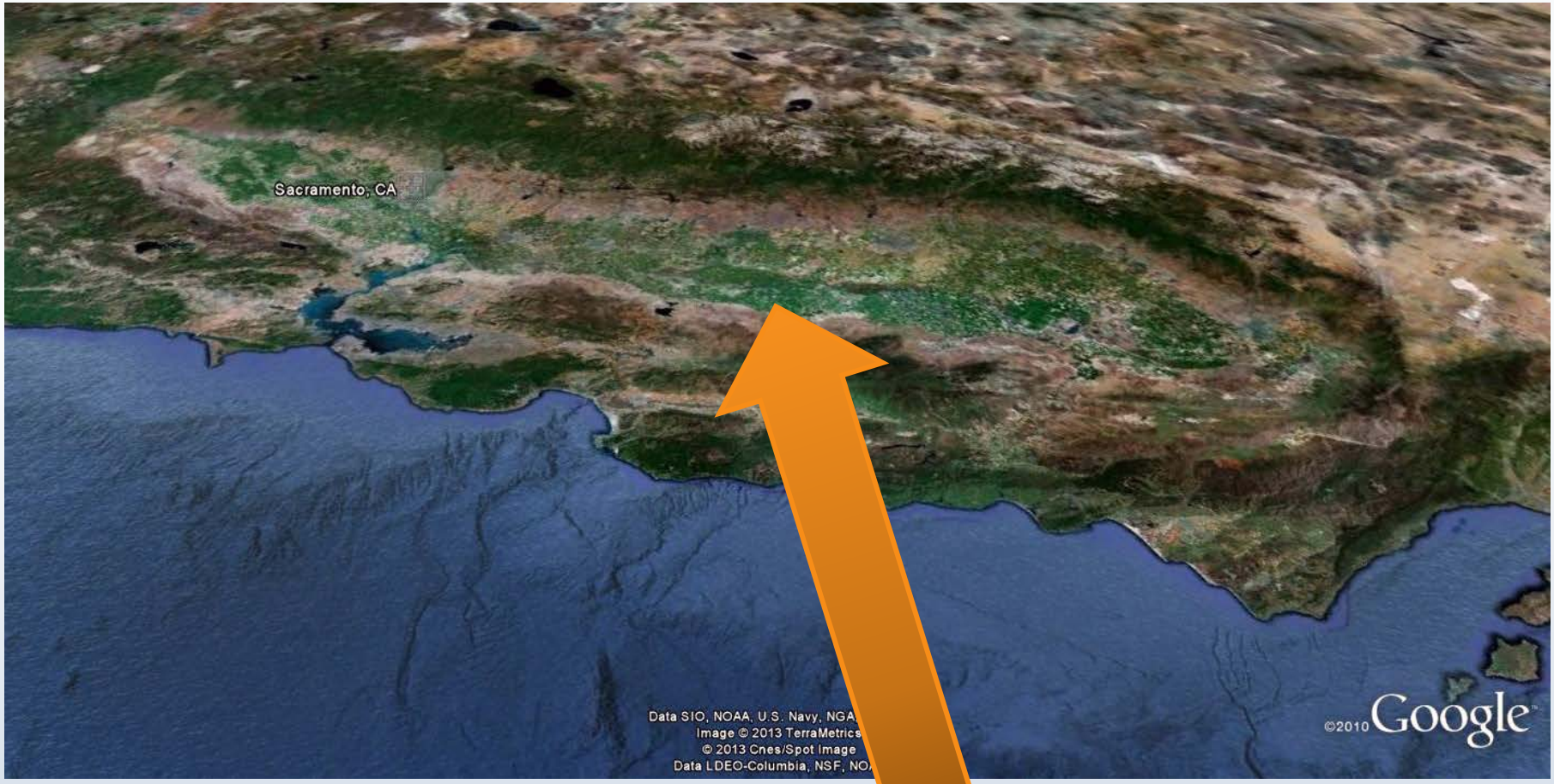
Sacramento Flooding:

- 10 ft of water flooded city: a “frontier Venice”
- houses swept away/ floating in the streets
- Legislature moved to SF for 6 months
- CA went bankrupt

Cause of flooding: Atmospheric Rivers

- 1000s of km long (across ocean basins), 100s of km wide
- Carry warm water vapor from tropics to mid-latitudes
- equivalent of up to 10 Mississippi Rivers
- We depend on them for our water supply



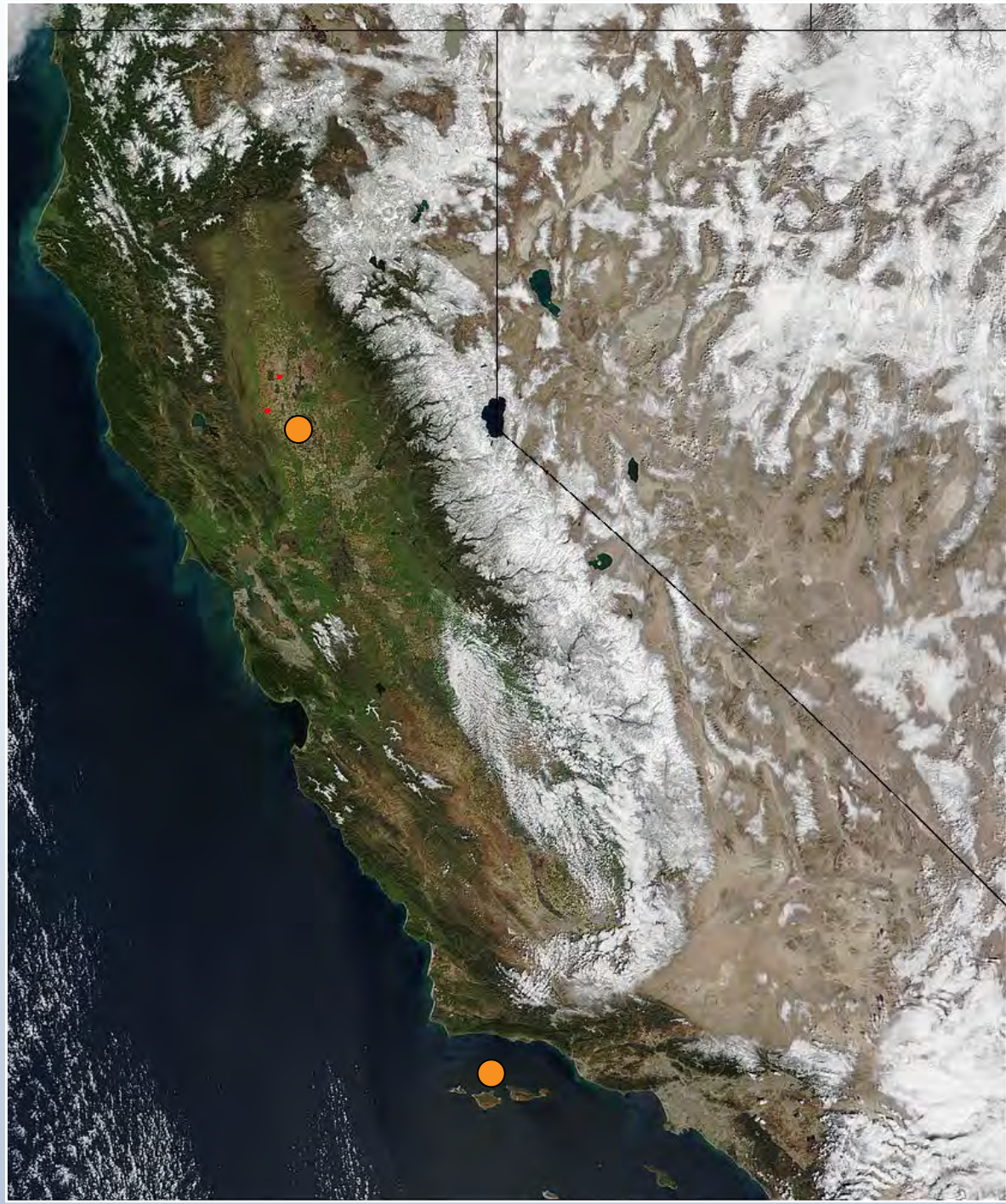


Vapor condenses as it rises over Coast Ranges and Sierra Nevada, forming rain that rapidly runs off

Have“megafloods” like 1861-62 event occurred before?

Sacramento Valley floodplain sediments

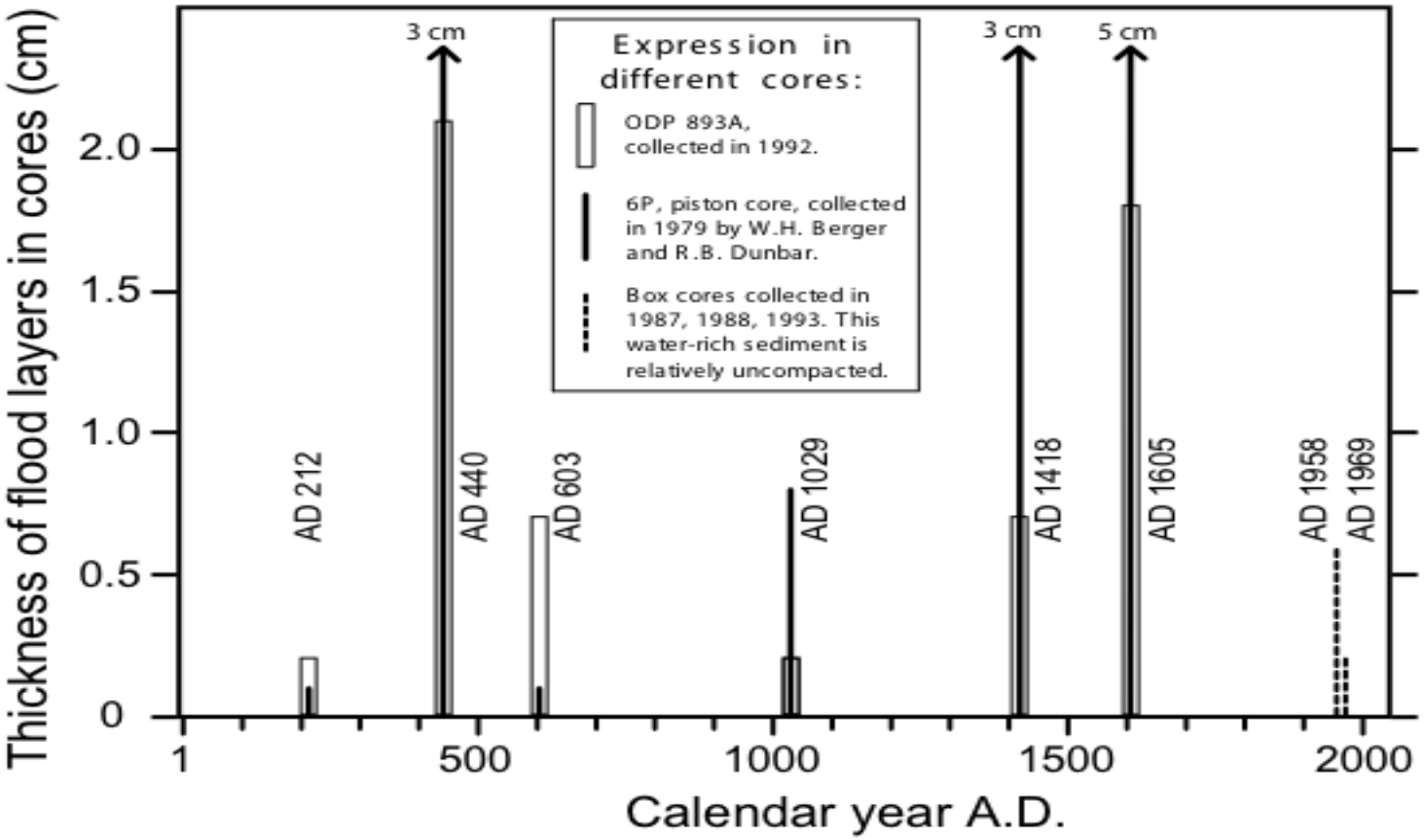
CA Coast:
Santa Barbara Basin



Sediment cores:

- Annual layers
- Unusually thick sediment layers from megafloods
- Thickness of layer proportional to size of flood

Megafloods occurred every 200 years



(Schimmelmann et al., 2003)

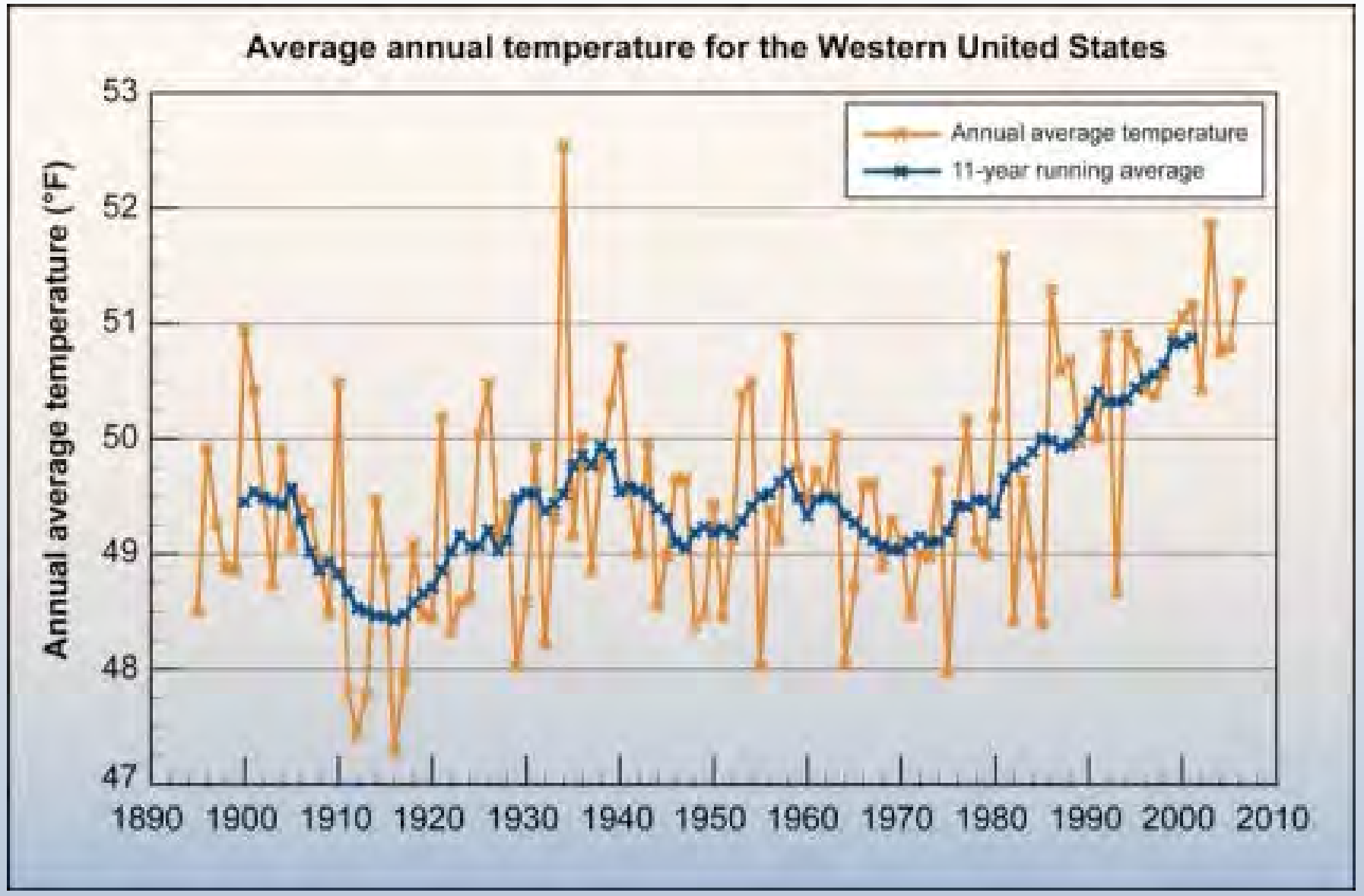
California climate periodicities

Record	Significant periods
SF Bay inflow	**90**, 150, **200** yr
SBB flood deposits	**200** yr
SBB O isotope records	55, 70, **90** yr
Mono Lake levels	**200** yr
^{14}C reservoir age	~2000 yr
Tree-ring records	150-**200** yr
Pyramid Lake (Nevada)	**200** yr

Source of climate variability in California

- El Nino (frequency, intensity)
- Pacific Decadal Oscillation (PDO)
- Solar variability (sunspot cycles)
- Changes in ocean circulation
- Volcanic eruptions

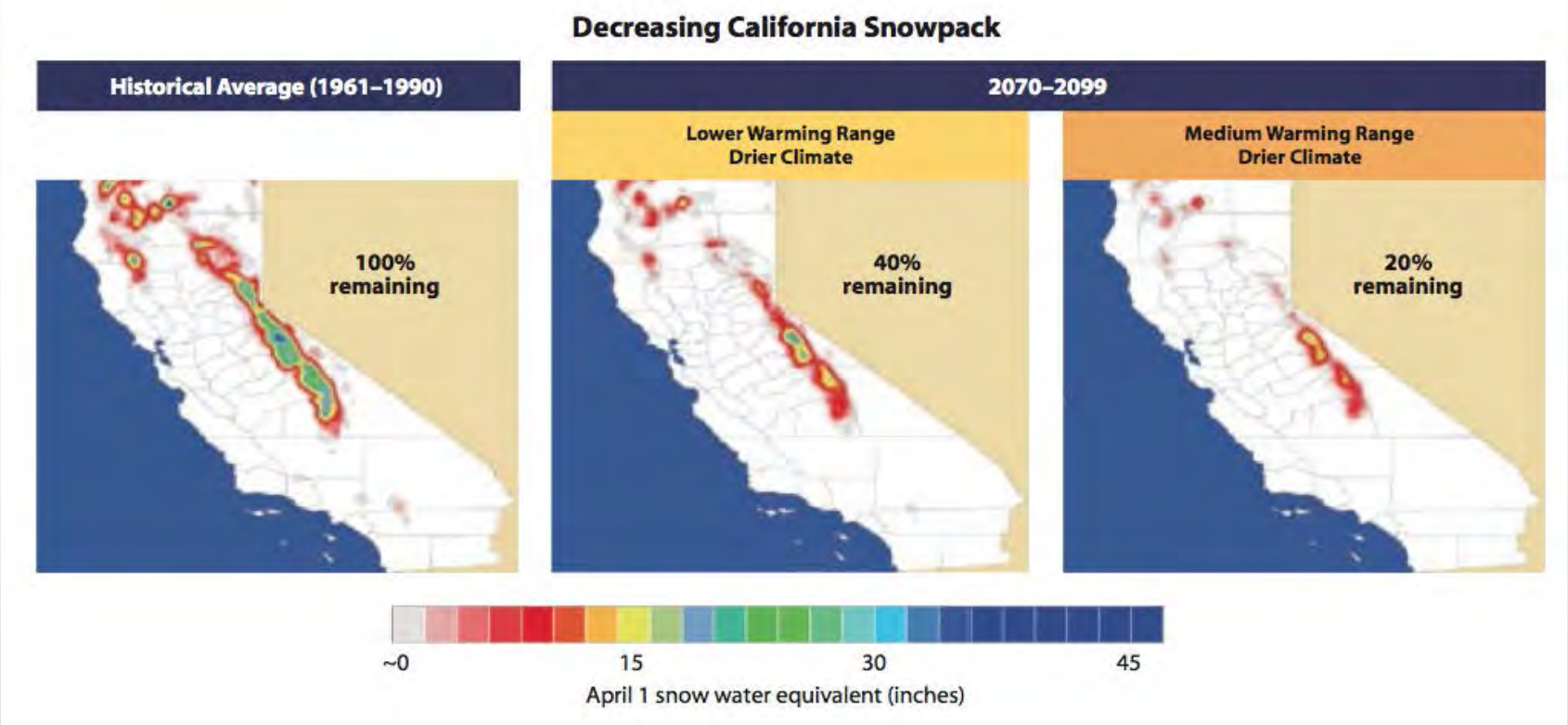
What about future warming?



Colorado River Basin

Lake Powell, 2009. Water level was down 60% from 1999 levels after a decade of drought in the West.

Warming and drying will lead to more frequent wildfires



Snowpack in Sierra Nevada will decrease in future.

More precipitation will fall as rain (instead of snow).

This will lead to larger floods in winter

With future warming as a backdrop, can California survive another megadrought?

What about the fish?

- Salmon have been here for millions of years so they have evolved within this context of extremes
- The challenges of the 20th Century were unique: water diversions, dams, pollution, invasive species
- The challenges of the 21st Century are even greater: warmer temperatures, bigger (and fewer) storms
- A warmer west means less snowpack and so possibly warmer, shallower mountain streams
- PDO may be shifting again

What can we do?

- Reduce the need for water diversions
- Remove fish barriers
- Restoration efforts
- Other ideas?

Thank you to the Salmonid Restoration Federation!