6-12-2003

SLIDES: California Water and Climate Change

Dan Cayan

Mike Dettinger

California Water and Climate Change

Dan Cayan ***(1,2)*** ***1*** **Mike Dettinger** ***(2,1)*** ***SIO 2 USGS 3***

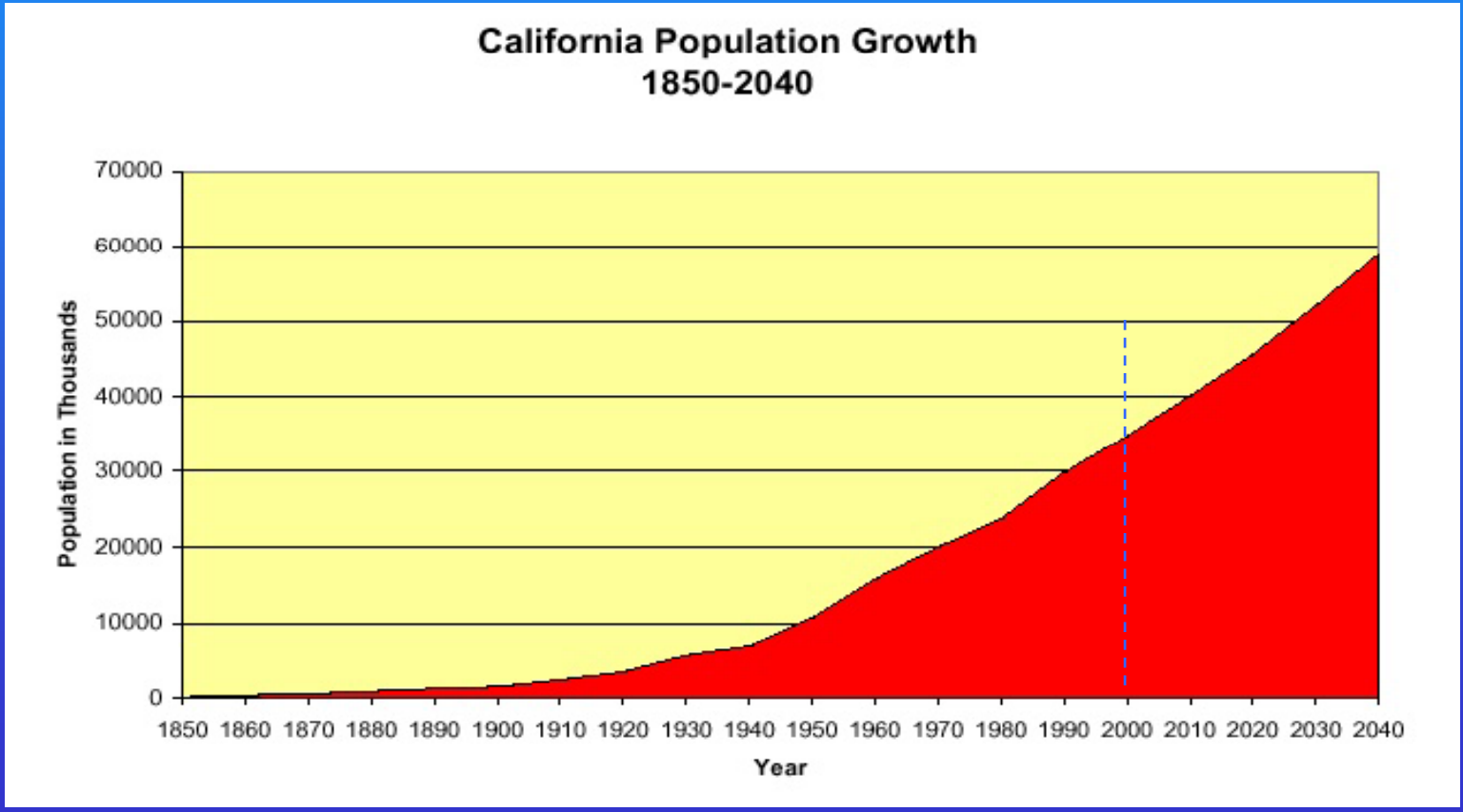
California water infrastructure

Vulnerability to climate variability and change

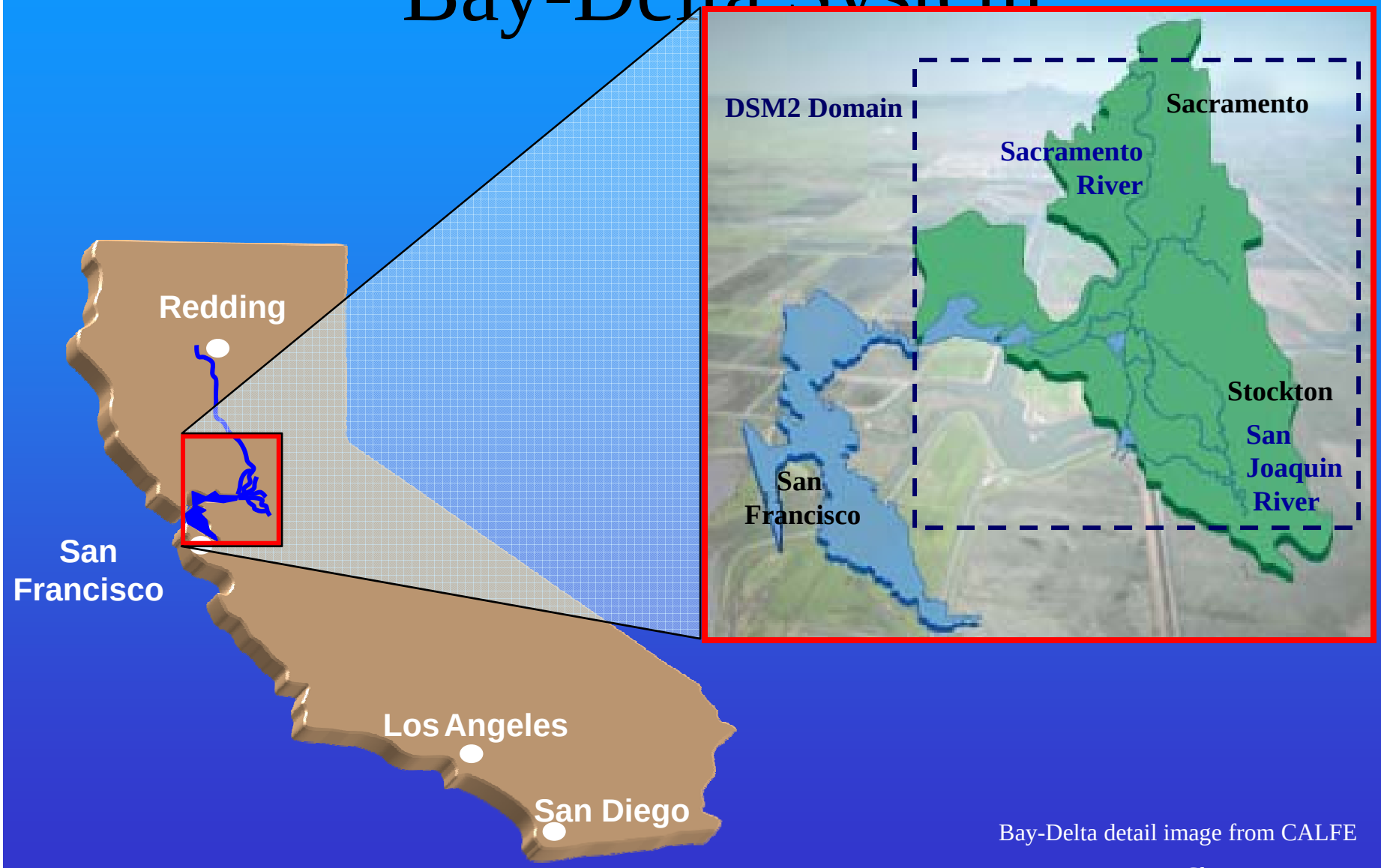
California has become concerned about climate change

California's growing Population

Nation's largest
projected to double by ~2050



Bay-Delta System



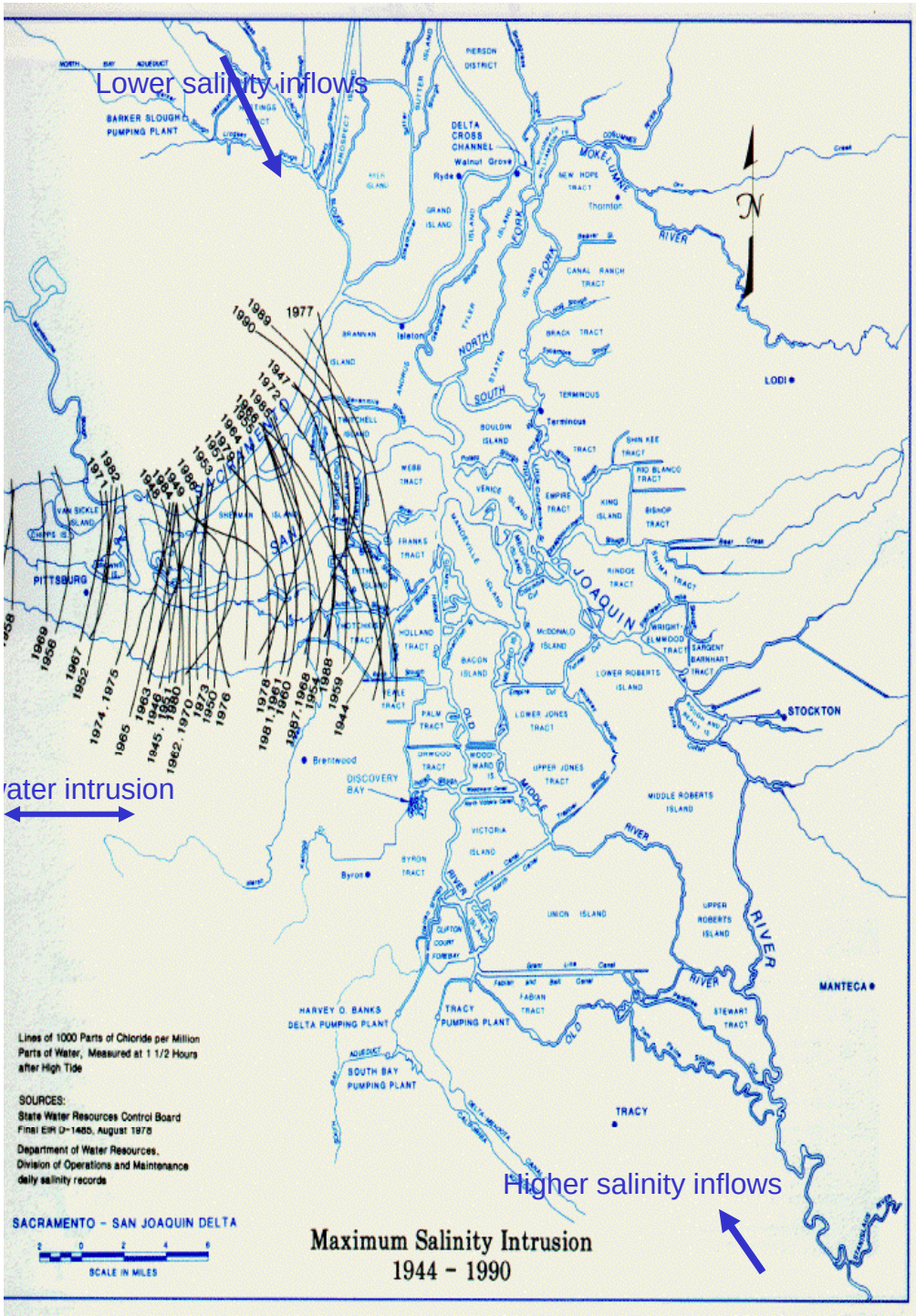
Bay-Delta detail image from CALFE

Francis Chung

CA Water Resources Supply

http://www.water.ca.gov/maps/allprojects.html

- California has an extensive plumbing system
- 75% of runoff occurs in north; 72% of consumptive use in south
- 6 km^3/yr of water is pumped from the Delta by State & Federal systems for San Joaquin Valley agriculture & Southern urban uses
- 7000+ agencies/cities have permits for water from Delta & its watershed
- About 42% of runoff exits by way of Bay/Delta



WATER QUALITY

Changes in demands on this meeting place for California's waters, changes in the channels & islands of the Delta, many many upstream land- and water uses, and growing contaminants threaten the quality of these most important waters.

- 50% of State's ag water drawn from Delta region
- 2/3 of State's population (22M people) drinks water from Delta

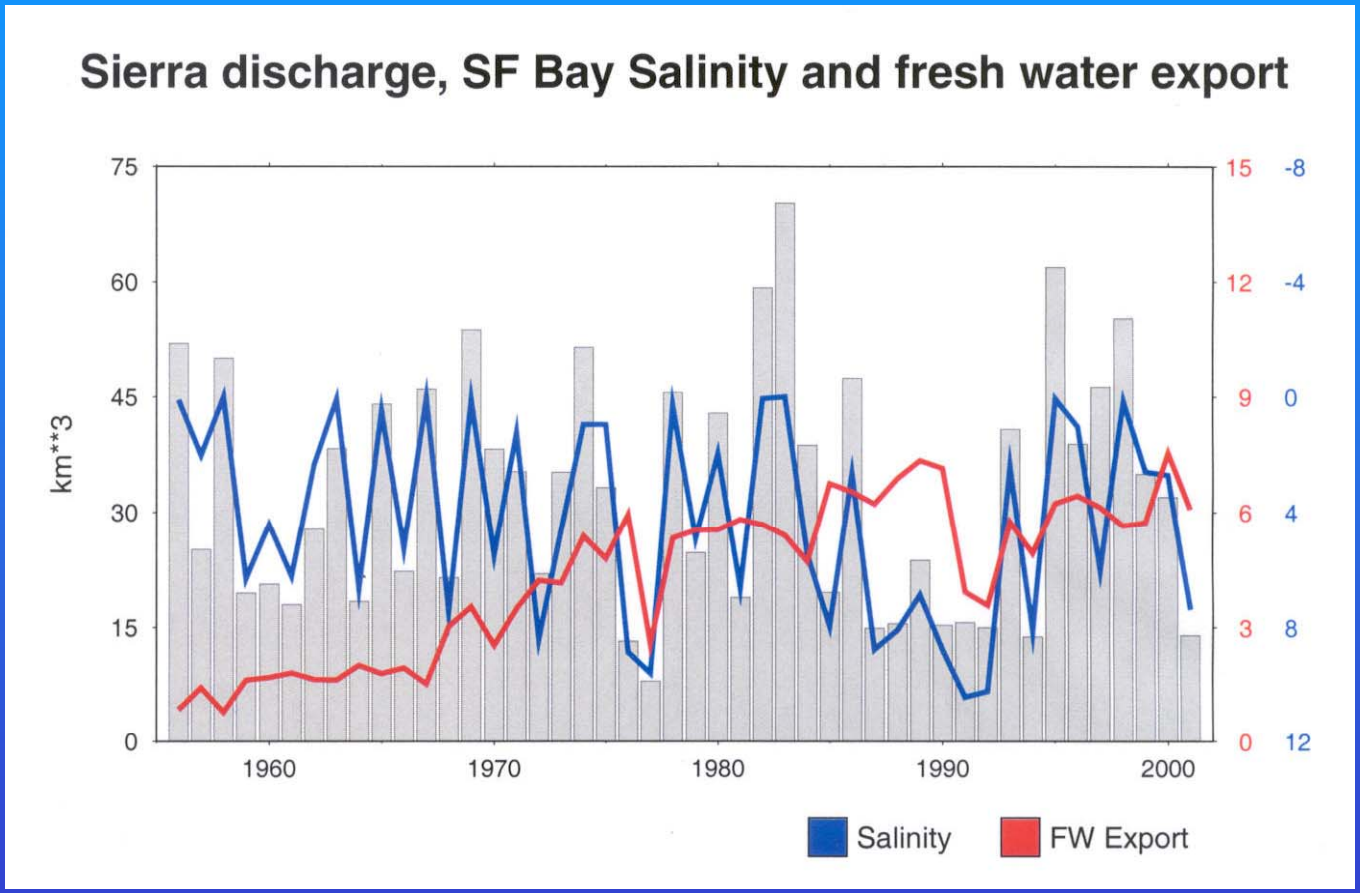
SF Bay Salinity is controlled by freshwater Discharge from Sierra watershed

Discharge varied from 15 to 70km3. May Salinity in Suisun Bay varied from 0 to 10*psu*

Freshwater exports from Bay/Delta increased markedly since 1960

Climate hasn't affected exports much, except during very dry or very wet spells

Exports are about 20% of Sierra discharge

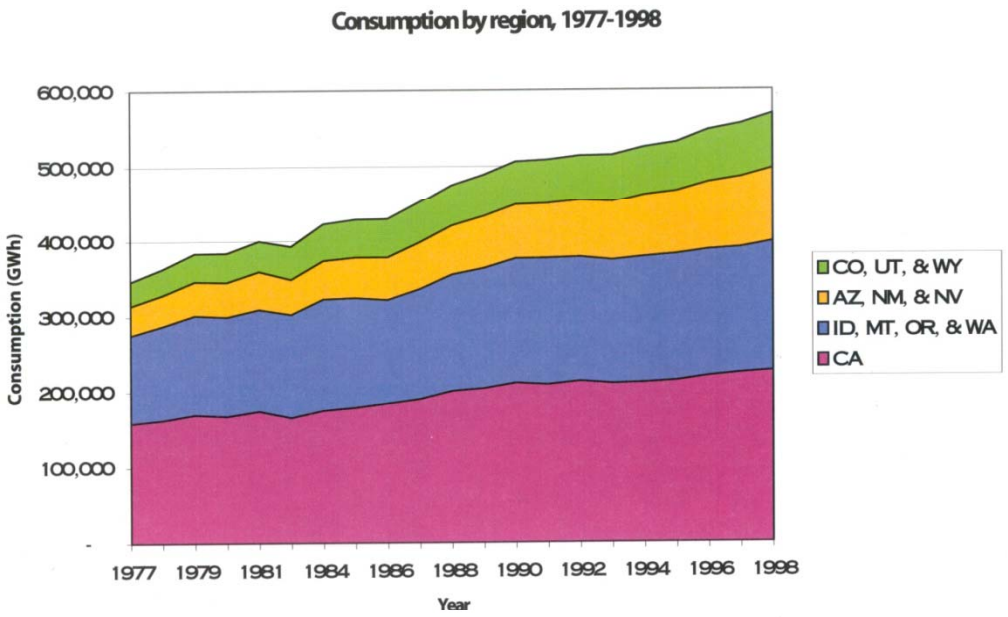


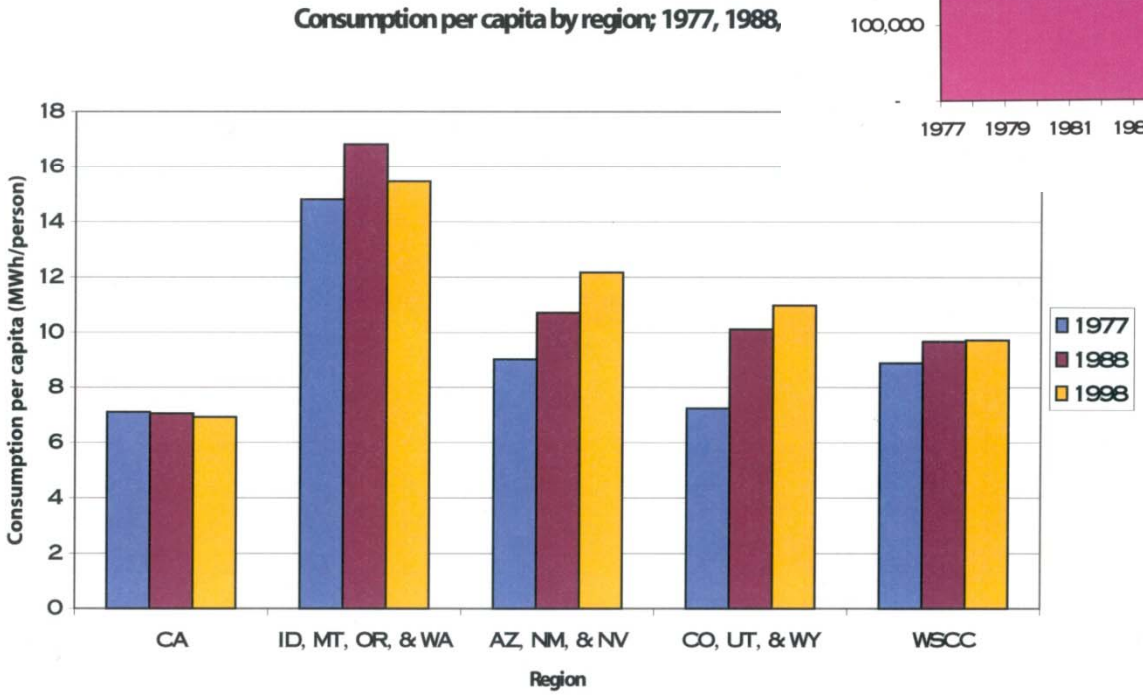
Colorado River contributes ~5MAF out of ~42MAF of State's Devlpd water. "excess" of 800,000 AF is less than 2% of State's runoff.

Western U.S. electrical consumption

California consumes 40% of total in Western 11 States

Per capita use in California is relatively low-- presumably owing to moderate climate



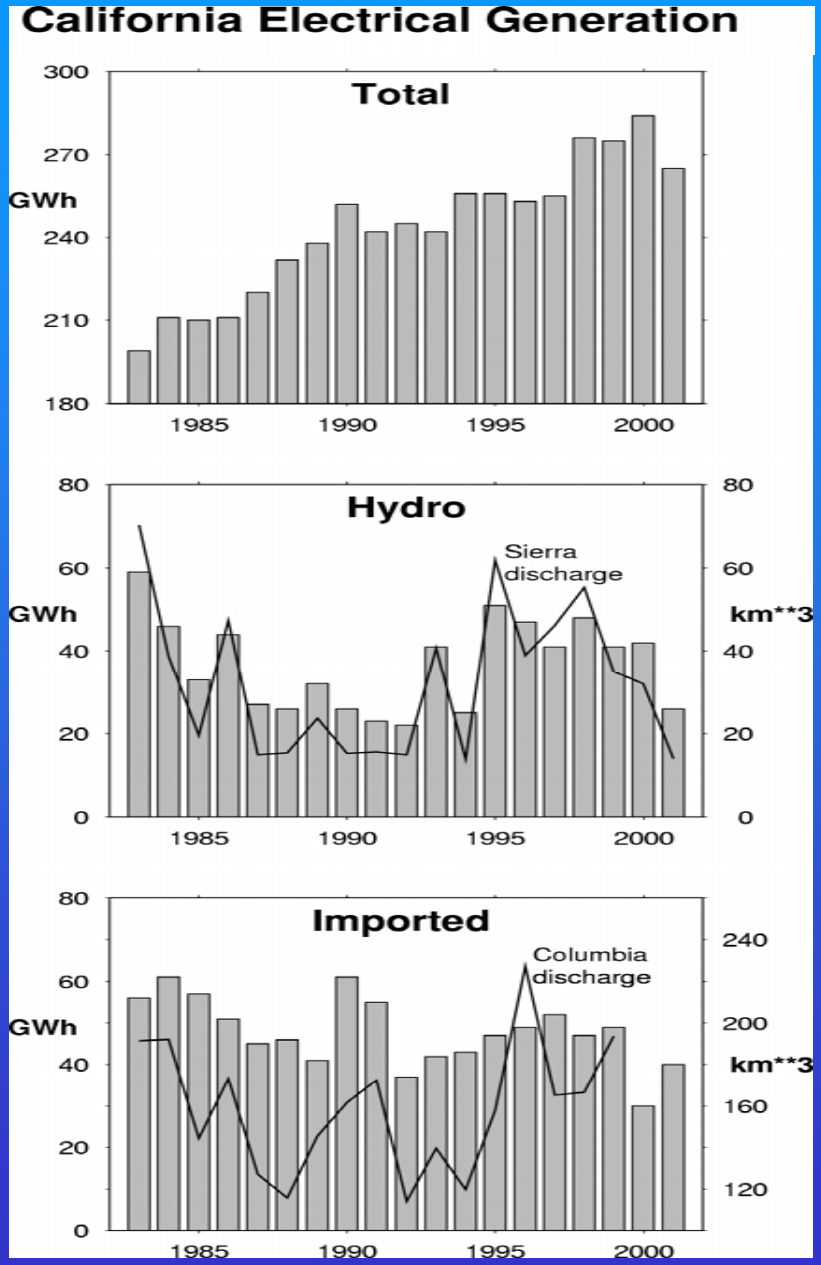


Electrical Energy in California

California's Electrical consumption is ~40% of total of all 11 western states. Peak demand in California is greatest in summer, 1.50X that in winter. (In Pacific NW demand peaks in winter.) Since 1977, consumption in California has risen ~45%.

Hydroelectric is ~10-15% of Total
Strongly corr w Sierra discharge.
Droughts have strong effect

California Electrical Imports ~20% of Total . Imports about equal from Northwest and Southwest. Imports strongly linked to Columbia discharge

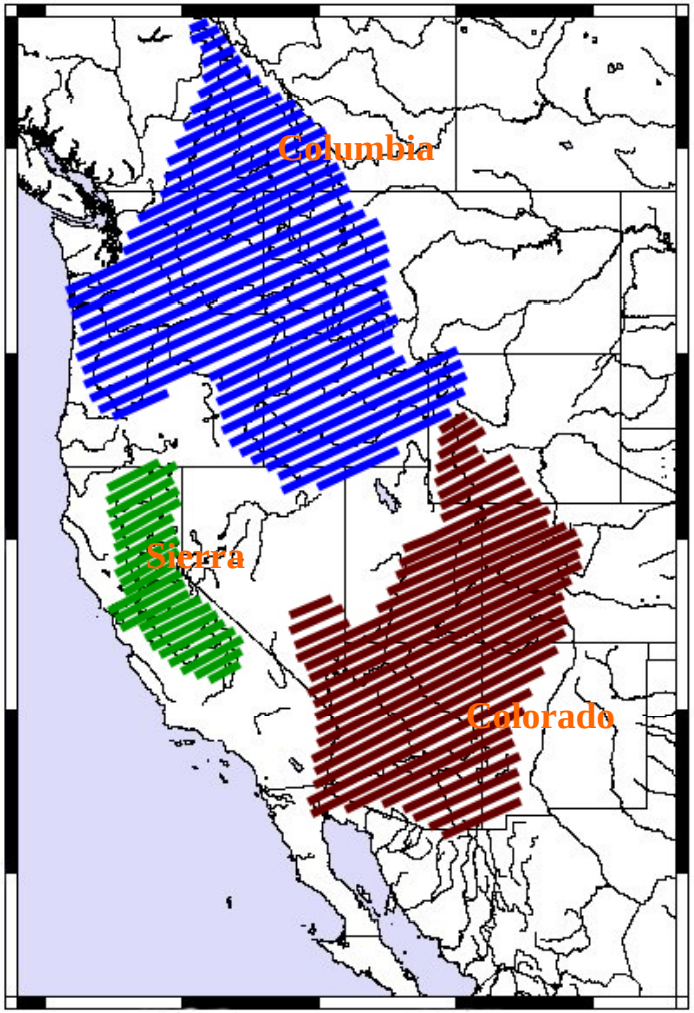


Sierra, Columbia and Colorado Watersheds
major Western U.S. drainages

Sierra drainage (140,000km2 is only about one forth of the area of the Columbia or the Colorado.

Sierra drainage generates 31.8km3 runoff only about one fifth of that in the Columbia but almost twice of that in the Colorado

Reservoir storage in California is about 49 km3. This is the equivalent of about one year's supply of the State's developed runoff. The Columbia (60km3) and the Colorado (74km3) have more reservoir storage.



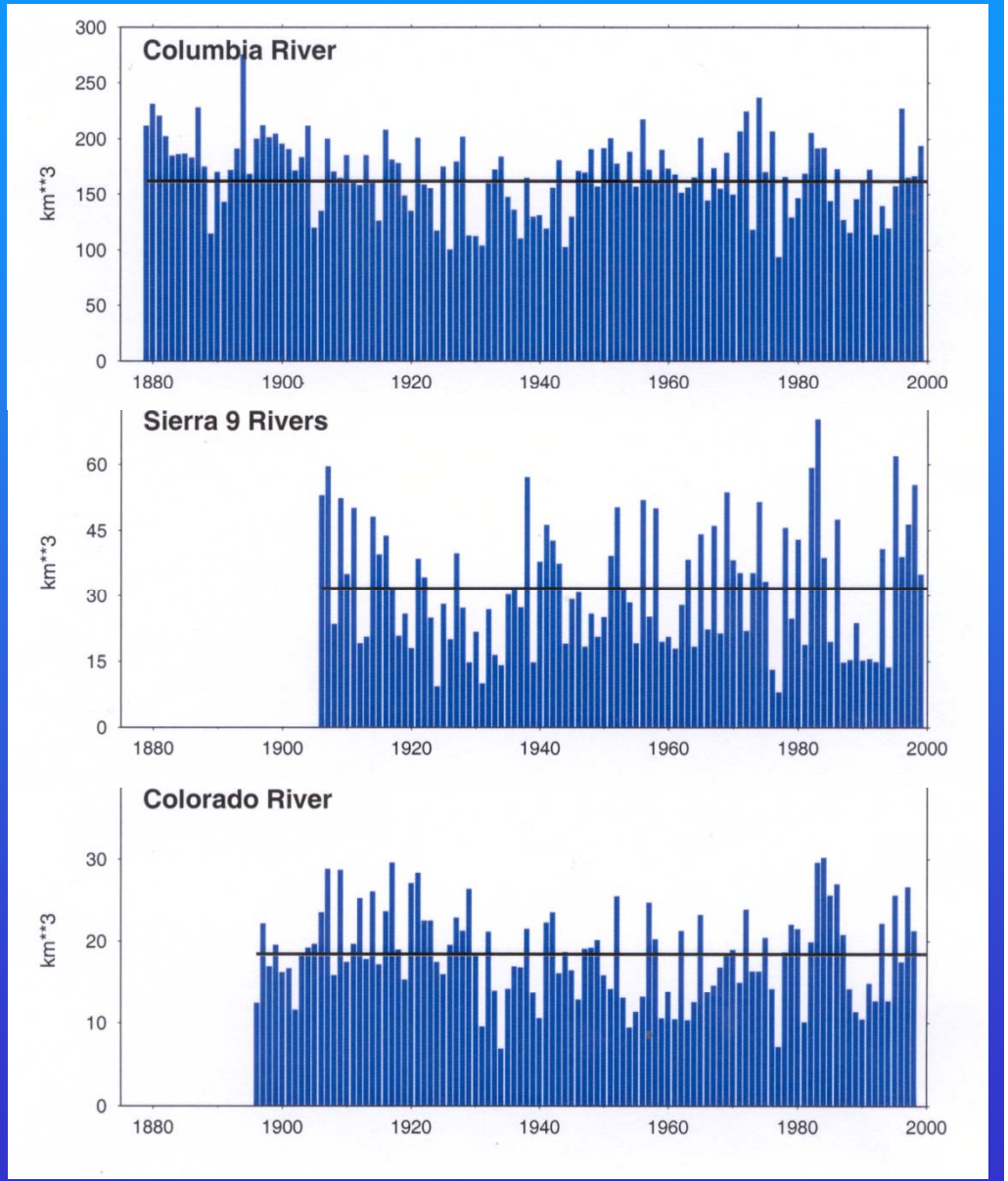
Annual Discharge Varies Considerably especially in the Sierra

In comparison,Columbia discharge is quite steady, ***stddev/mean* = 0.19**

Sierra discharge is highly variable
***stddev/mean* = 0.44**
***lowest* 1977** ***highest* 1983**

And the Colorado discharge is intermediately variable, ***stddev/mean* = 0.33**

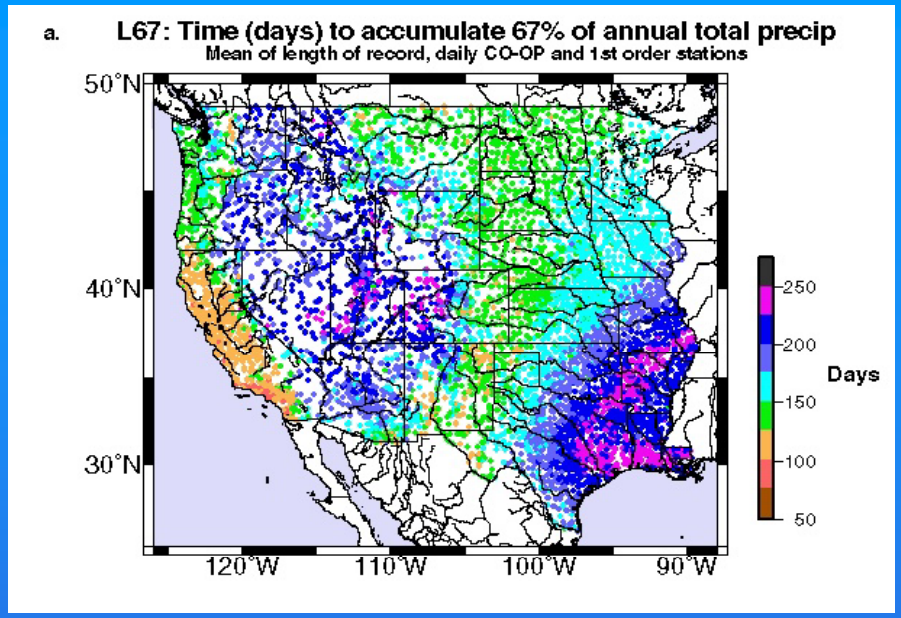
Cayan et al (in press)

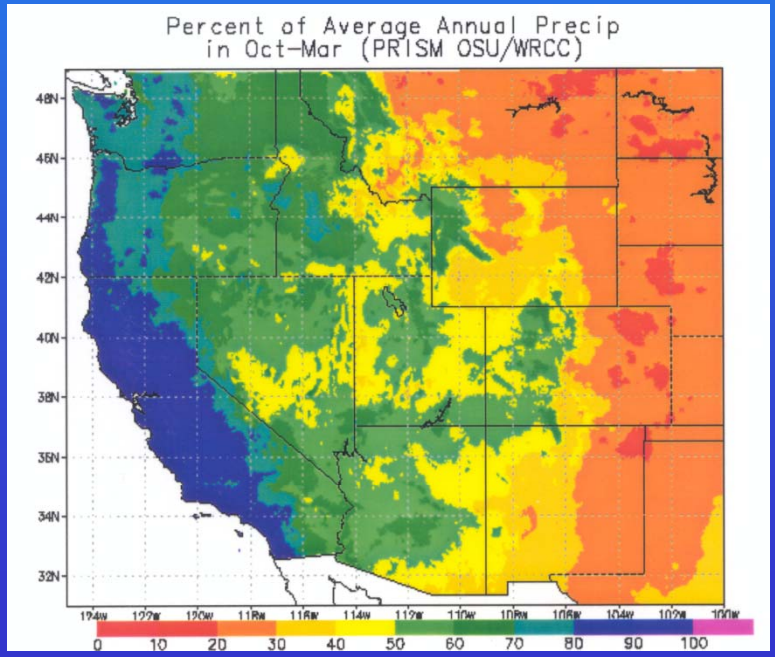


North Pacific storms are seasonal

so

California's Precipitation season is very brief





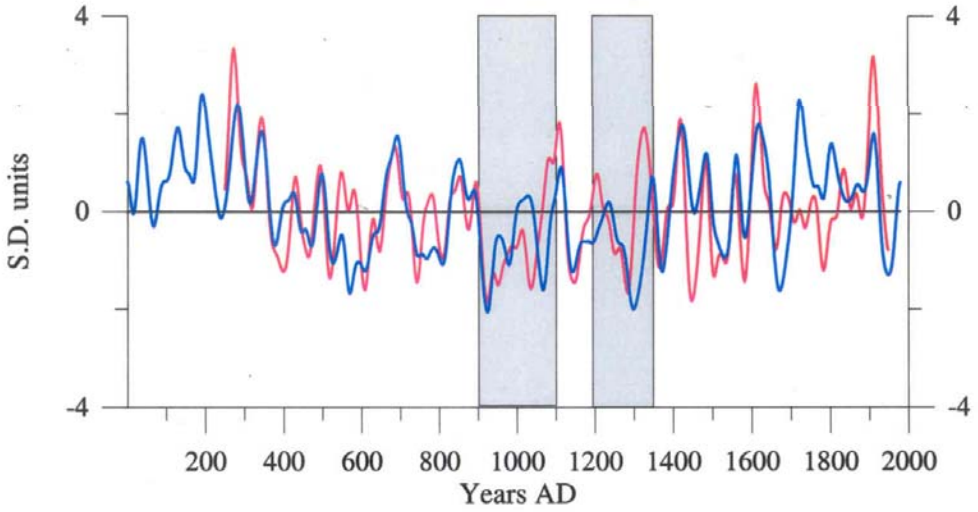
In about 120 days, California must accumulate two thirds of its annual precipitation

Our water supply comes mainly during Oct-Mar , owing to the North Pacific storm regime

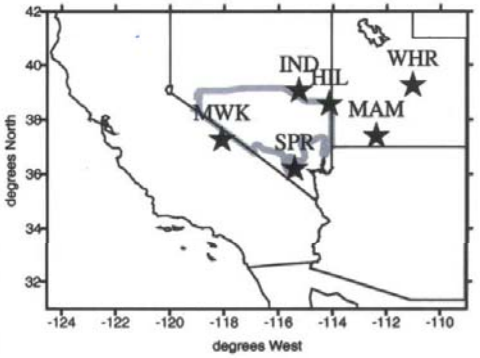
DROUGHT: A major puzzle

What causes drought and how bad can it get?

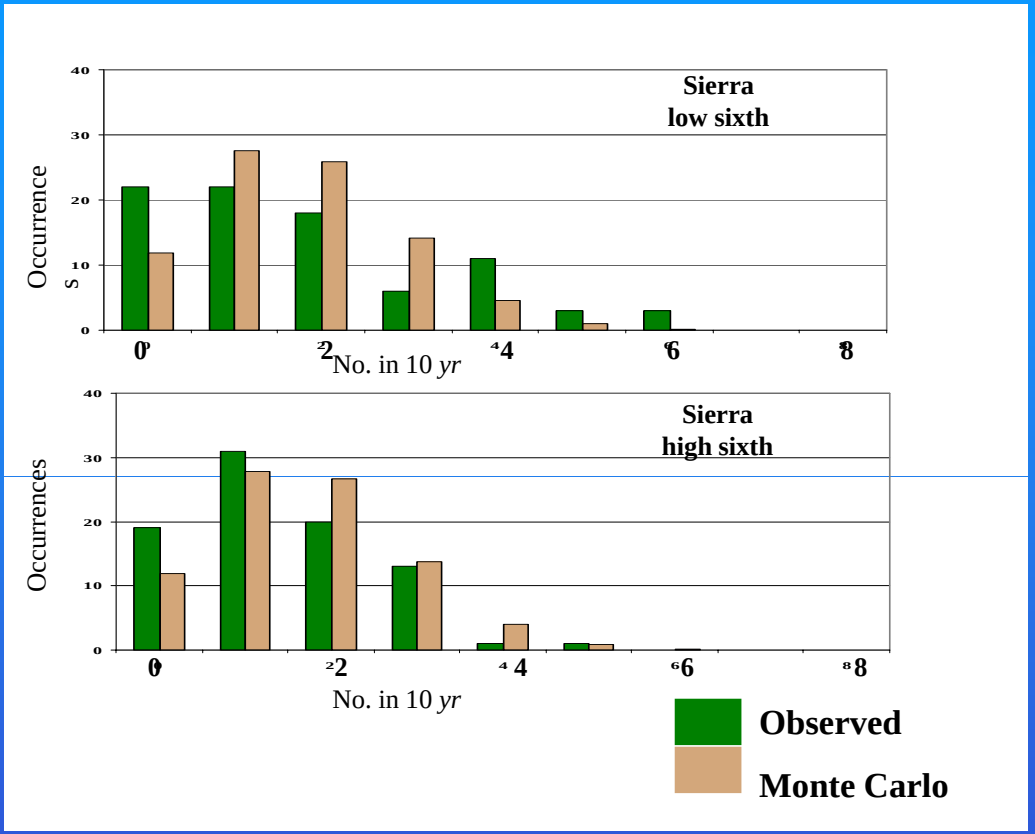
submerged tree stumps have 70+ rings!



- The blue line is the reconstruction shown in the previous slide, using only the MWK site, the red line is based on 6 sites throughout the Great Basin (see map).
- The gray areas indicate low stands of nearby Mono Lake – see photo of tree stumps tens of meters below present natural water level (Stine, 1993).



Number of dry/wet years per decade Sierra Nevada



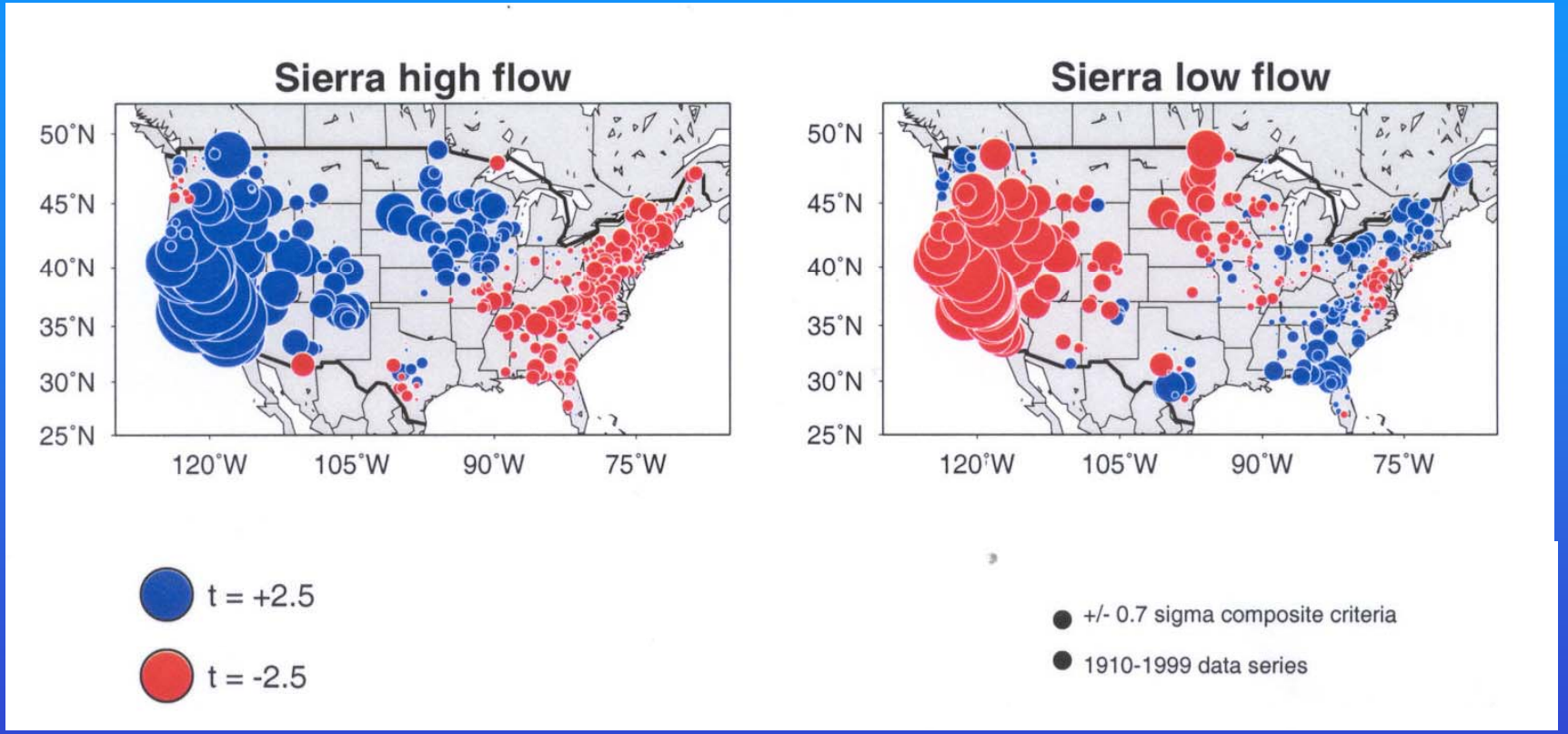
Observed 17 10yr intervals w 4 or more dry yrs

Monte Carlo Only produces 6 such intervals

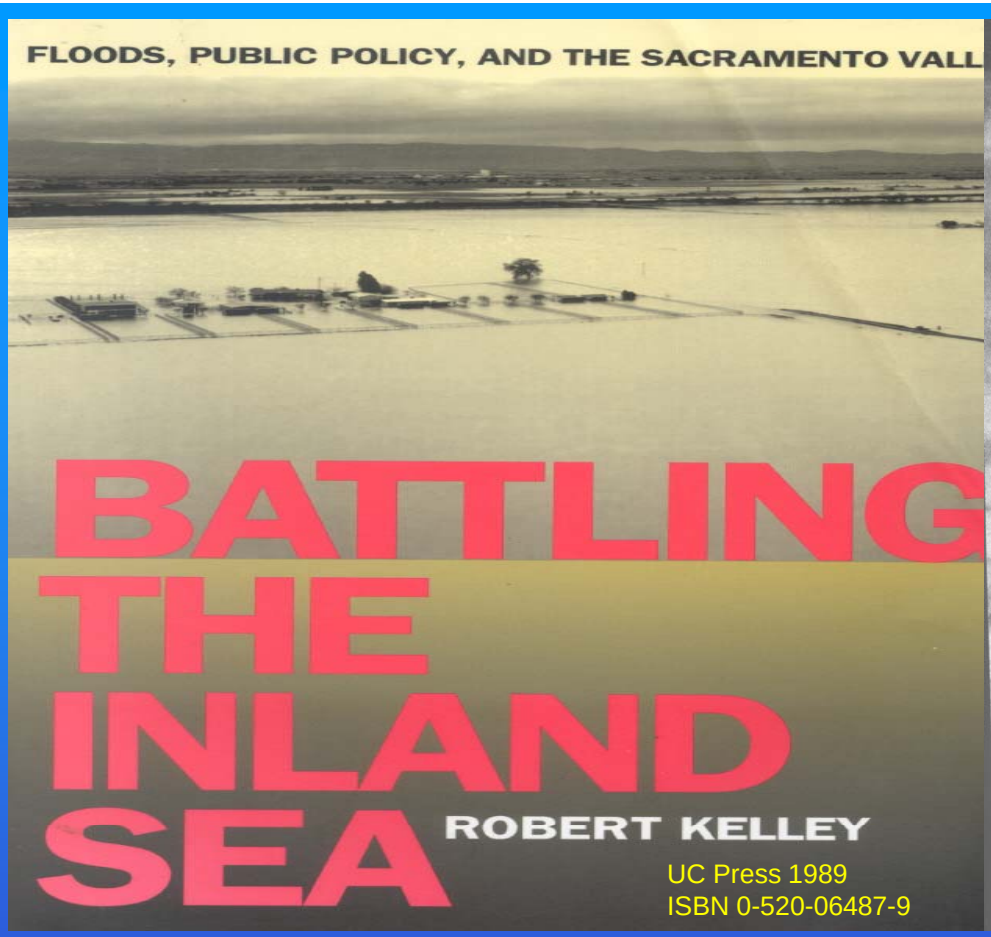
Dry years tend to cluster more than expected by chance, but *not* wet years. Also, there have been some decades with remarkably few dry or wet years.

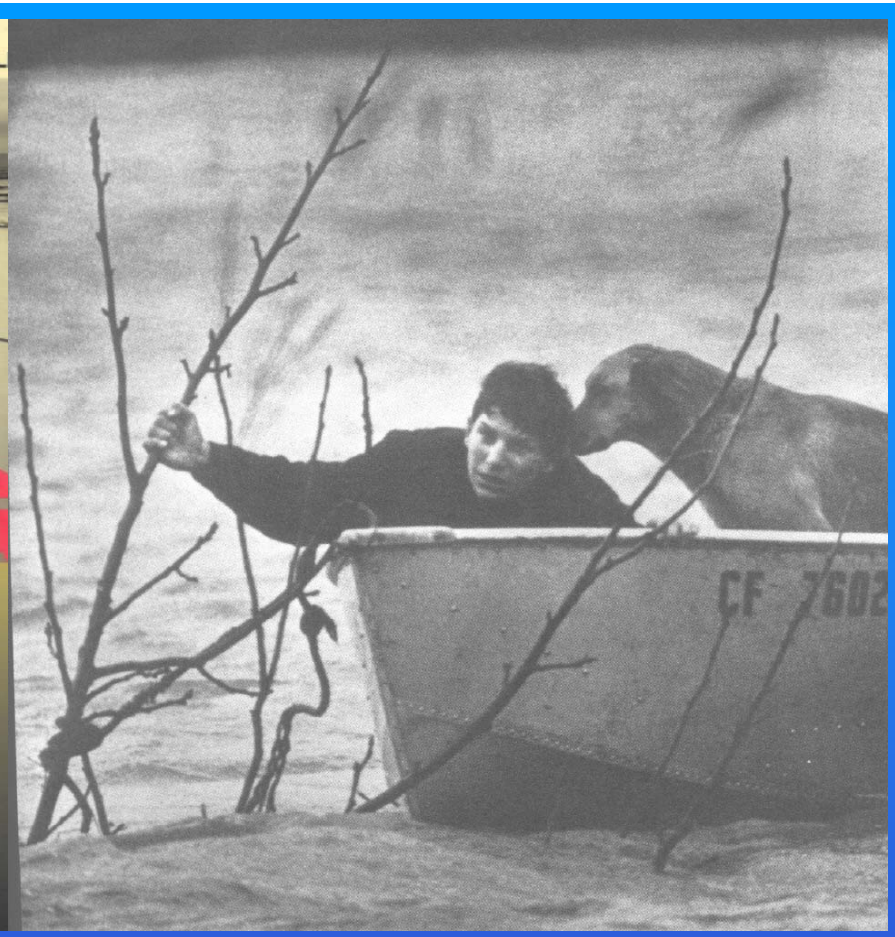
Wet/dry is sixth highest/lowest annual flow

High and low Sierra flows are Associated with large regional pattern



Thus, Sierra flows often in same phase (wet or dry) as the Columbia or the Colorado

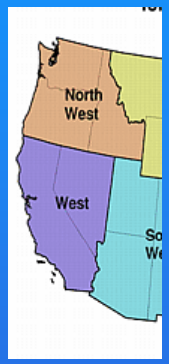


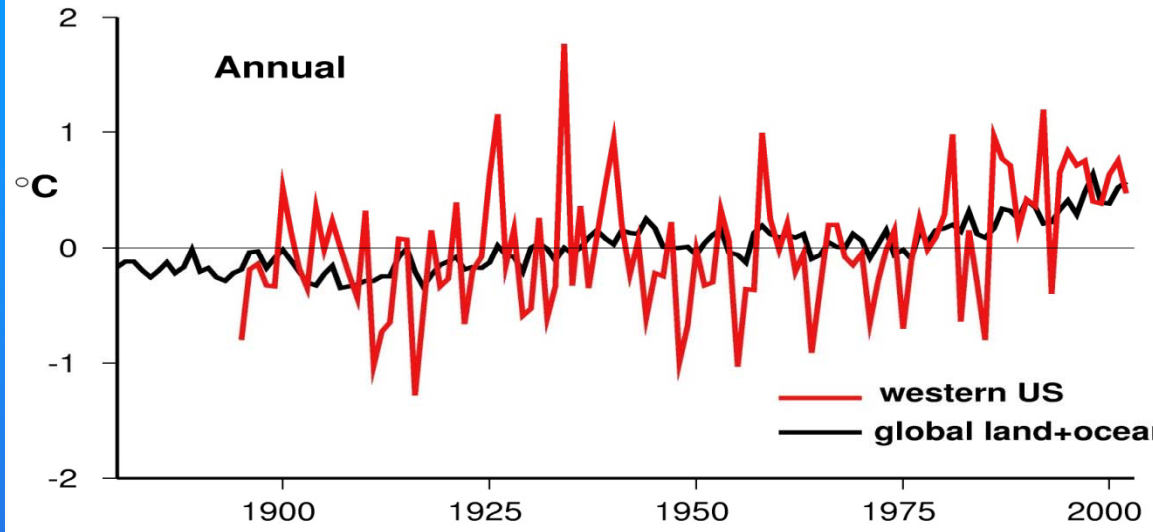


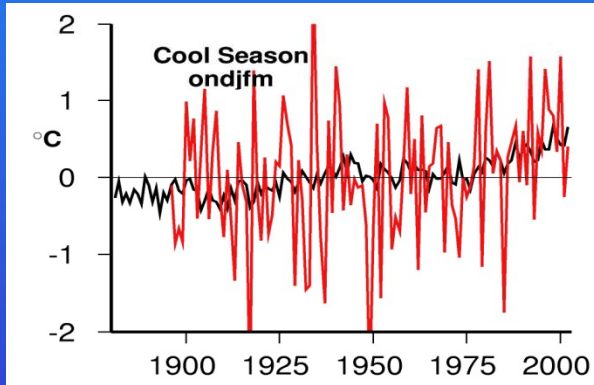
"Soon after the Gold Rush…They discovered that during the annual winter cycle of torrential storms that for millennia had swept in from the Pacific…,the Sacramento River …rose …to flow over their banks onto wide Valley floor….to produce terrifying floods."

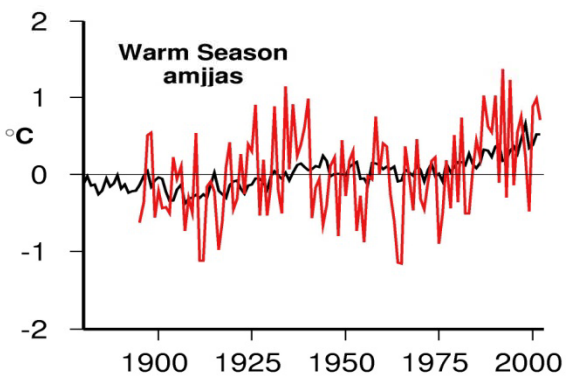
"For the better part of the next several generations, embattled farmers and townspeople struggled to get control of their great river system… In our time, after that long labor, we observe in the Sacramento Valley a literally remade environment… The Sacramento and its tributaries are hidden behind a thousand miles of high levees…which have made a Holland of the Sacramento Valley. "

Western U.S. and Global sfc temp anomalies





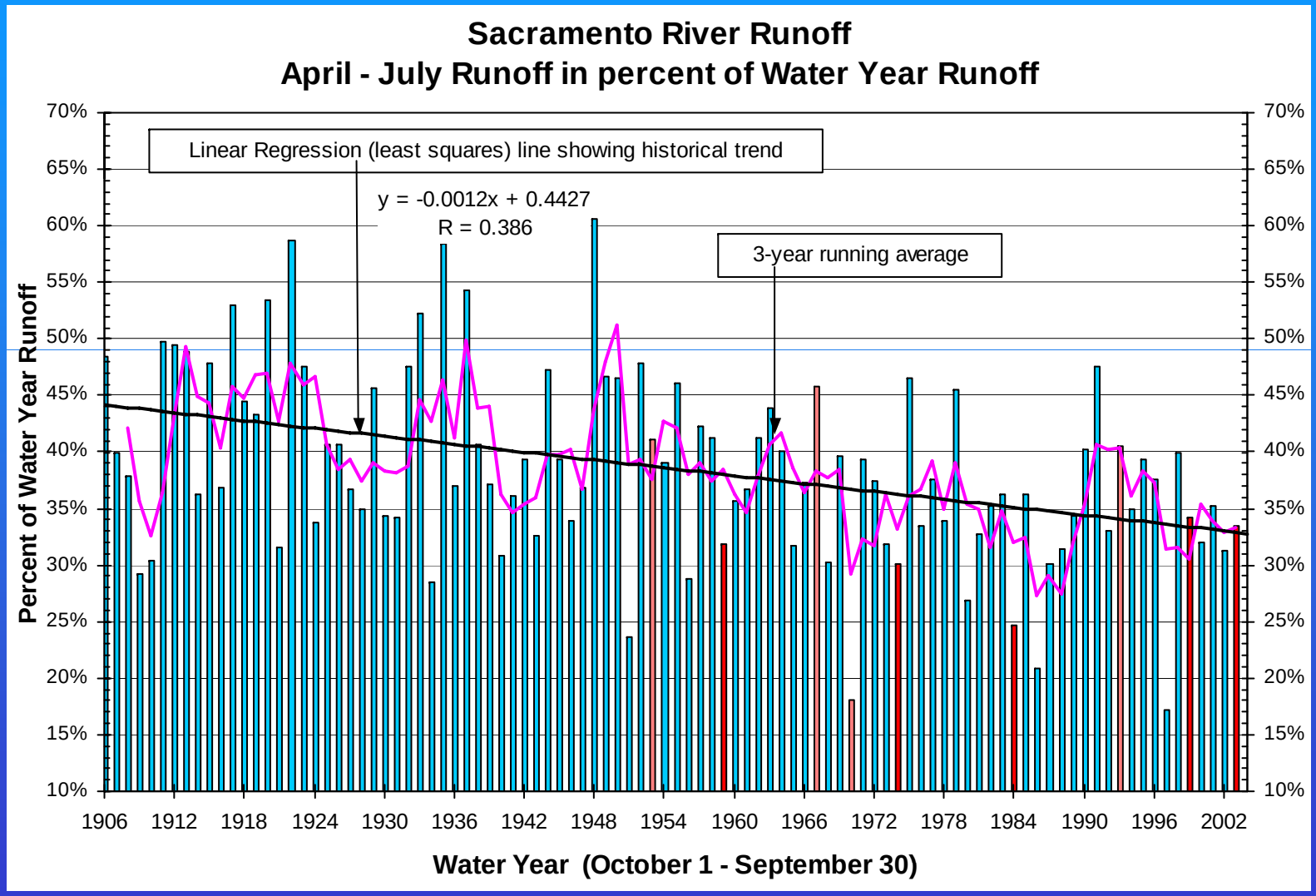




Global land data from the Global Historical Climatology Network (GHCN; Version 2) and global SST data from the UK MOHSST and NCEP OI SST (Version 2) anoms based on 1880-2002 mean

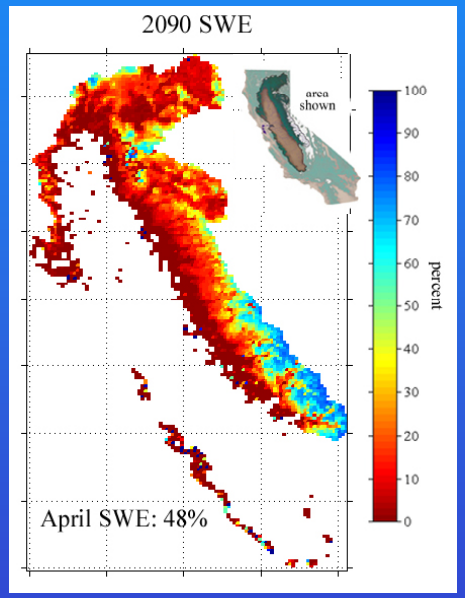
Western U.S. data from the time bias corrected NCDC statewide-regional-national dataset (Climate Division data) anoms based on 1895-2002 mean

Snowmelt flow fraction has shown marked decline

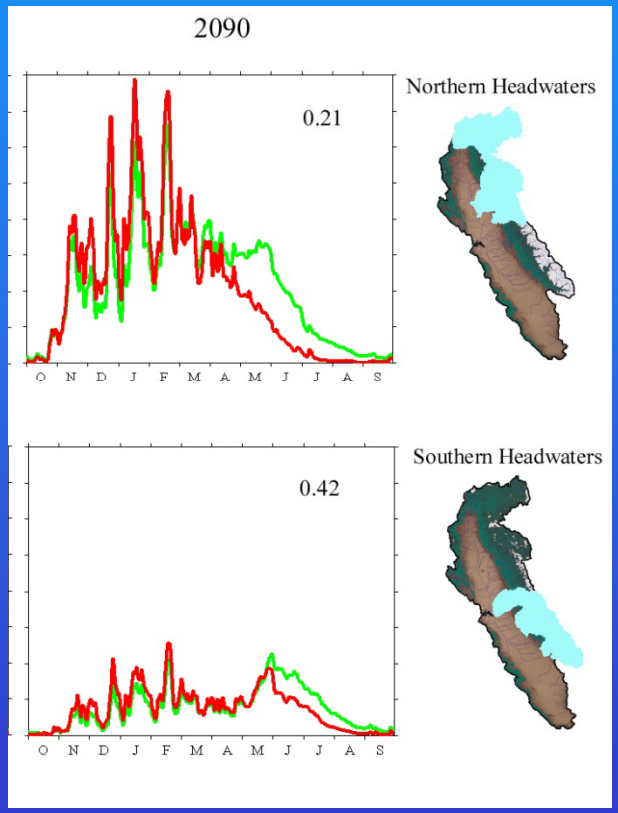


Maury Roos, Calif Dept Water Resources

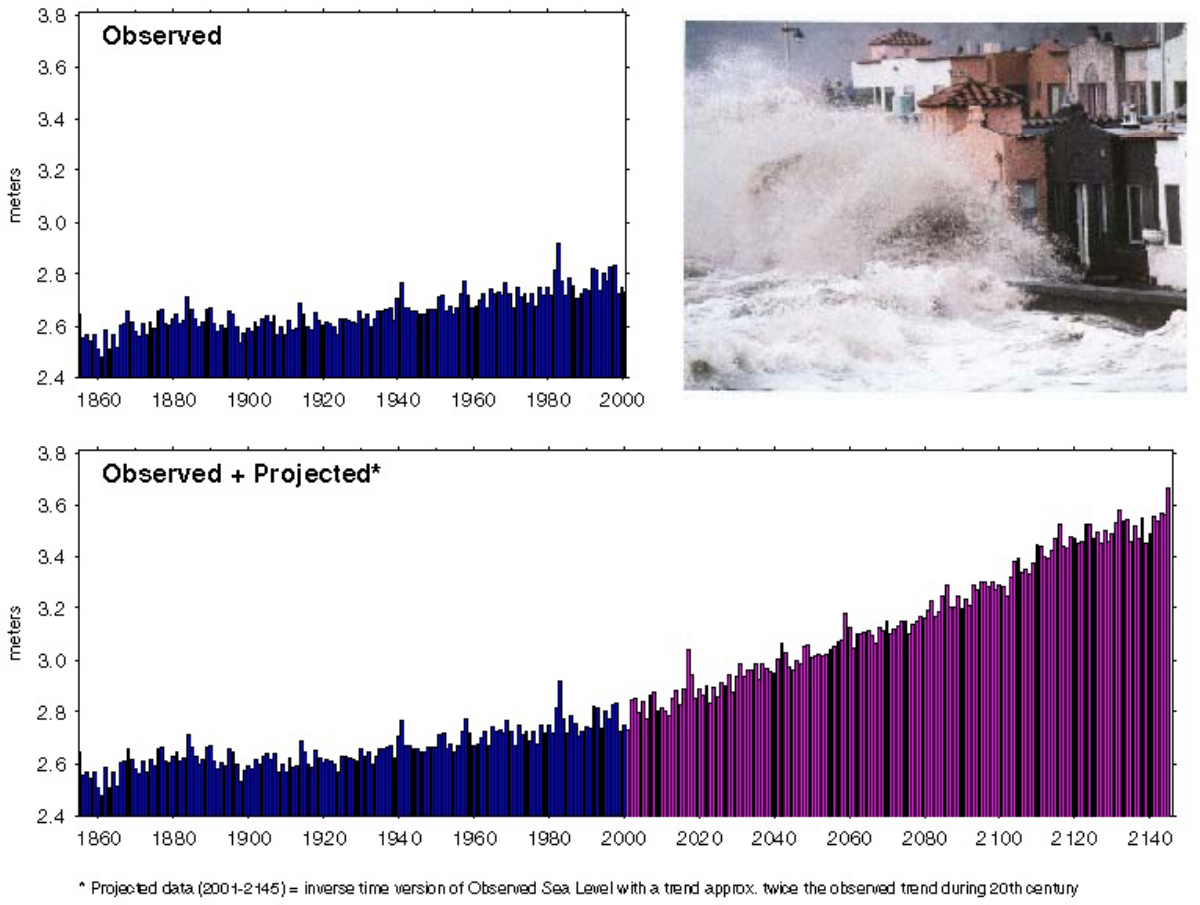
San Francisco Bay could be impacted by climate warming



Earlier snowmelt would deplete fresh water inflows to the Bay/Delta and raise summer Salinities, as shown by hydrologic simulation by Noah Knowles. The lower elevation Sacramento basin would have a greater depletion than the higher San Joaquin basin.

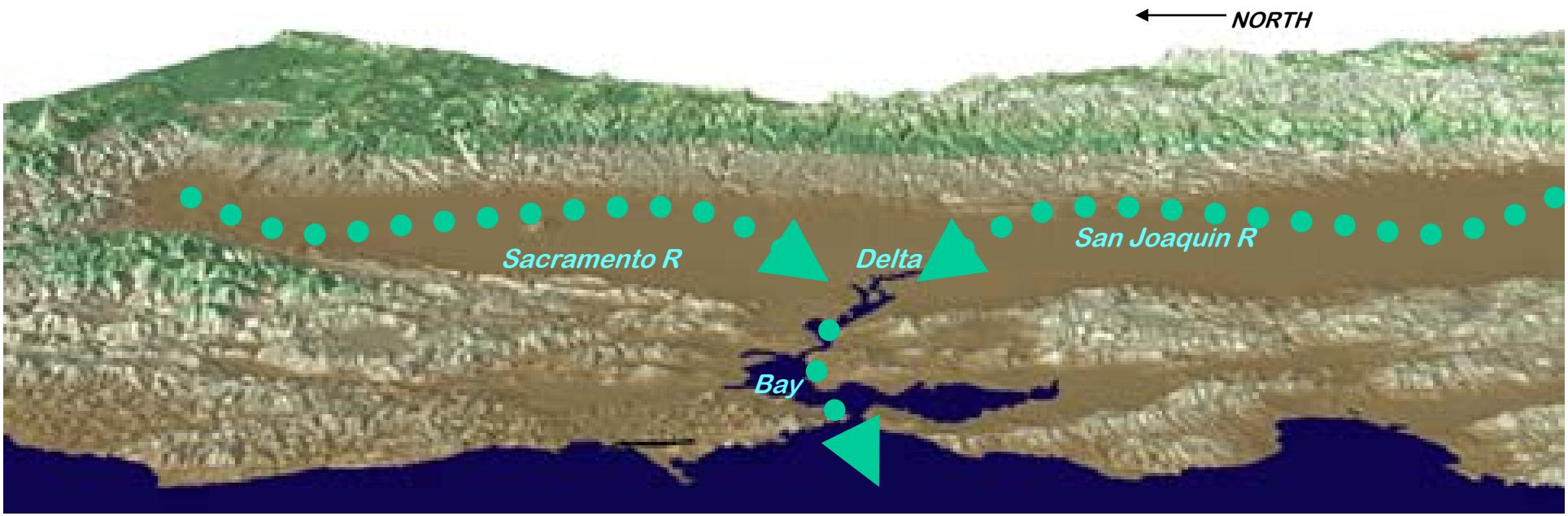


The California coast is likely to face rather dramatic sea-level rises that may threaten its shoreline and its estuaries.



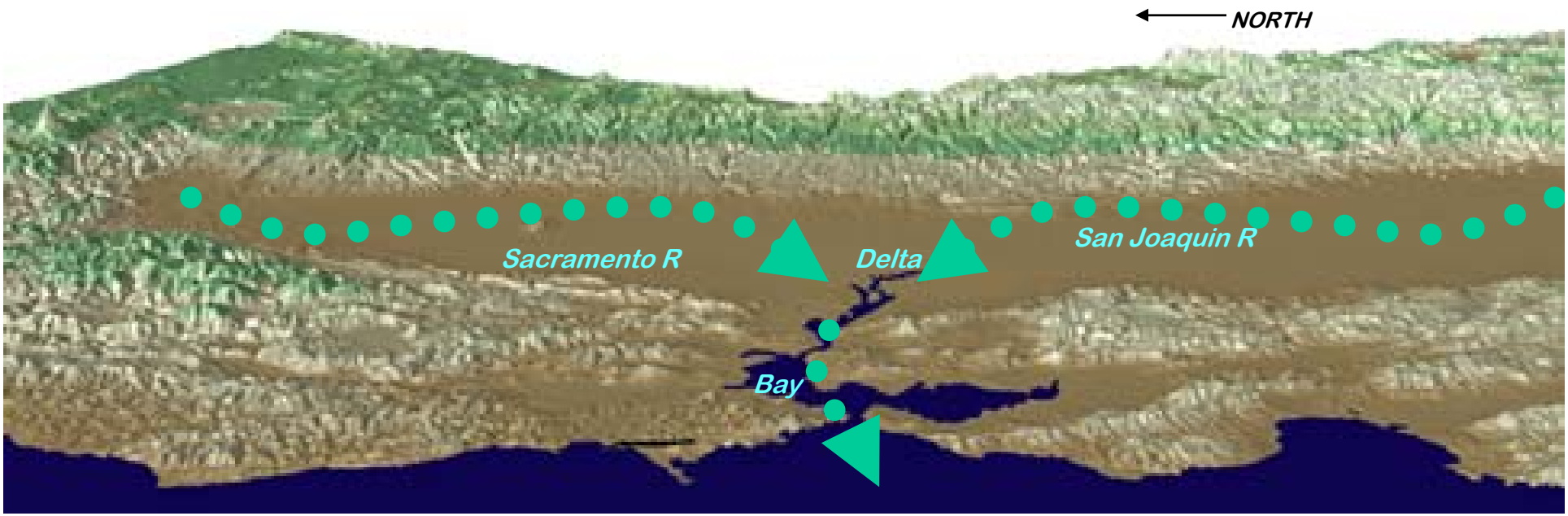
Starting in 1993, several fish species in the Sac/SJ Delta were listed as endangered *(chinook salmon, delta smelt & splittail)*, **precipitating a crisis for water/land decisionmakers in California.**

By 1998, 20+ local, State & Federal agencies combined to form the 30-yr, multibillion-$ CALFED Bay-Delta Restoration Program.



CALFED attempts to resolve 4 competing primary objectives:

1. Improve reliability of water supplies
2. Improve water quality
3. Restore ecosystems
4. Stabilize levees

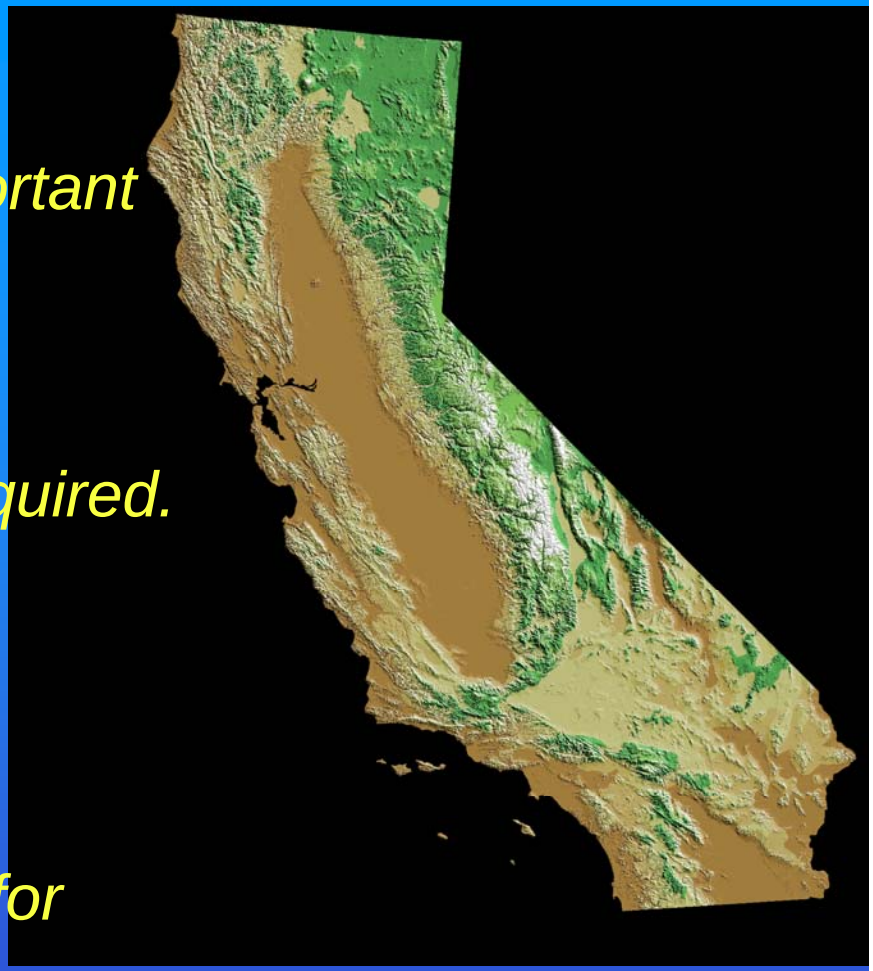


CALFED and Climate

Towards planning for climate changes in California's redesign of the Bay/Delta and its watershed

California has embarked upon a 30 year effort to redesign operations/infrastructure of the San Francisco Bay/Delta and associated upstream watershed to improve water supply and water quality, protect levees in the Delta, and to address ecosystem issues such as wetland restoration and seasonal flows necessary to support fish populations. At the onset of this effort, there was a lack of forethought about potential consequences of climate change. Current efforts are aimed at providing the information necessary to insert climate into CALFED thinking and *hopefully*, CALFED actions.

Key points for CALFED



Past climate variations are as important as is global warming!

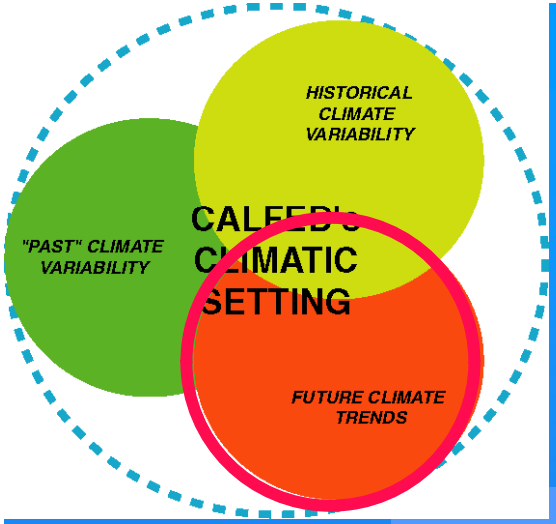
-- Megadrought
-- Changing seasonality

Integrative science emphasis is required.

-- Past, present, & future
-- Across time scales
-- California's place in large-scale climate
-- Ecosystems, society & climate
-- Geographic & disciplinary integration

Adaptive climate-science strategy for CALFED:

-- "sequential decisionmaking under general uncertainty"
-- adaptive monitoring
-- updating the science regularly
-- enhancements of State-climatologist position?
-- scenarios AND vulnerability strategies



FUTURE CLIMATE & CALFED

Two strategies for coping with uncertain projections

SCENARIO BUILDING/ANALYSIS

Knowledge of future climates → Knowledge of impacts

VULNERABILITY ASSESSMENT (Pielke, Sr, et al)

Knowledge of thresholds for impacts → Risk in future climates

USGS

Conclusions CALFED and Climate

incorporation of climate information into CALFED is imperative

implementations (restoration, new structures, etc) begin in 2005, so climate input needed soon.

climate knowledge will evolve, so input process must be flexible to adapt

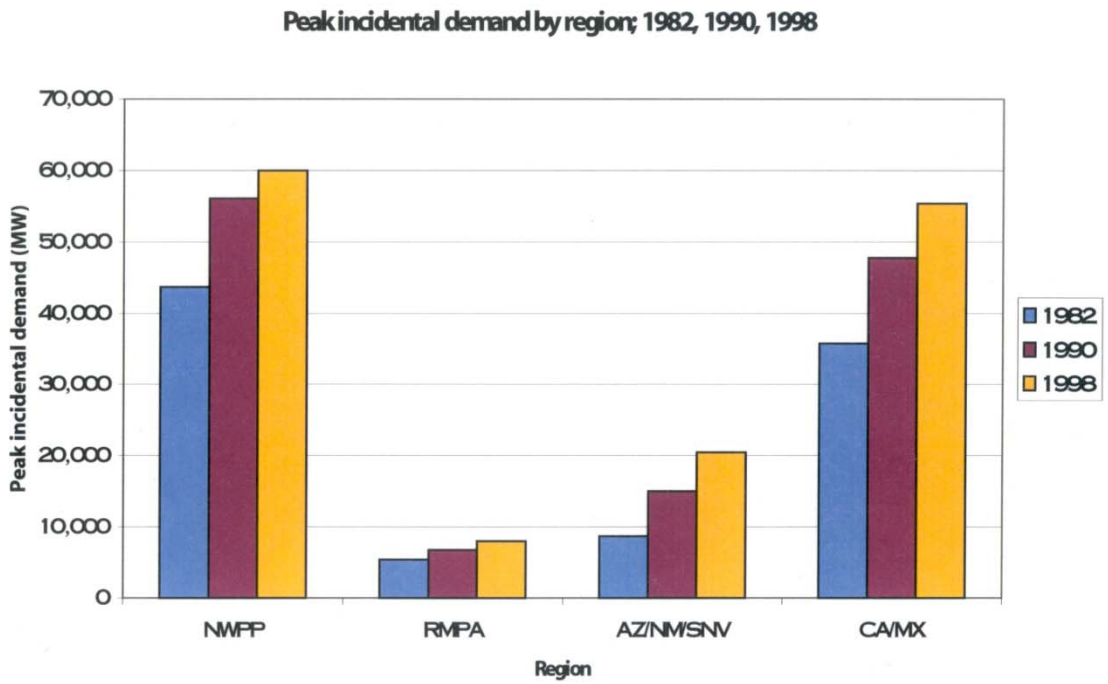
Concluding Remarks

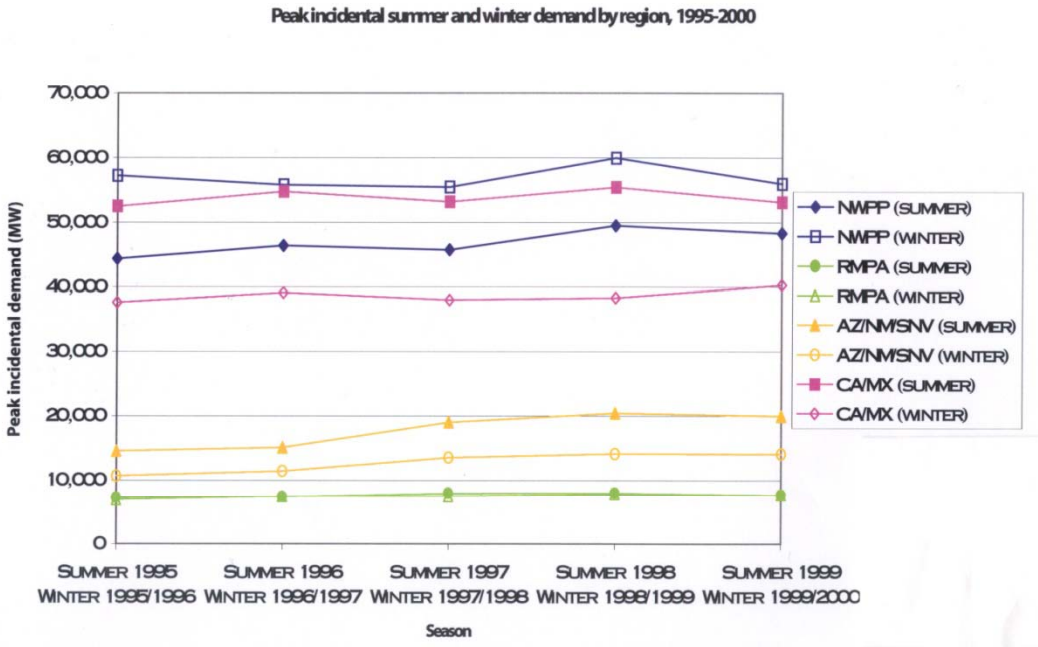
- Key Models on Water Management are available in California
- Inputs to Models are needed to account for climate change
- Scientific Uncertainties on Inputs need to be identified
- Operating rules need to be developed to account for adapted operations

Peak Electrical Demand

increased by 50% since 1982

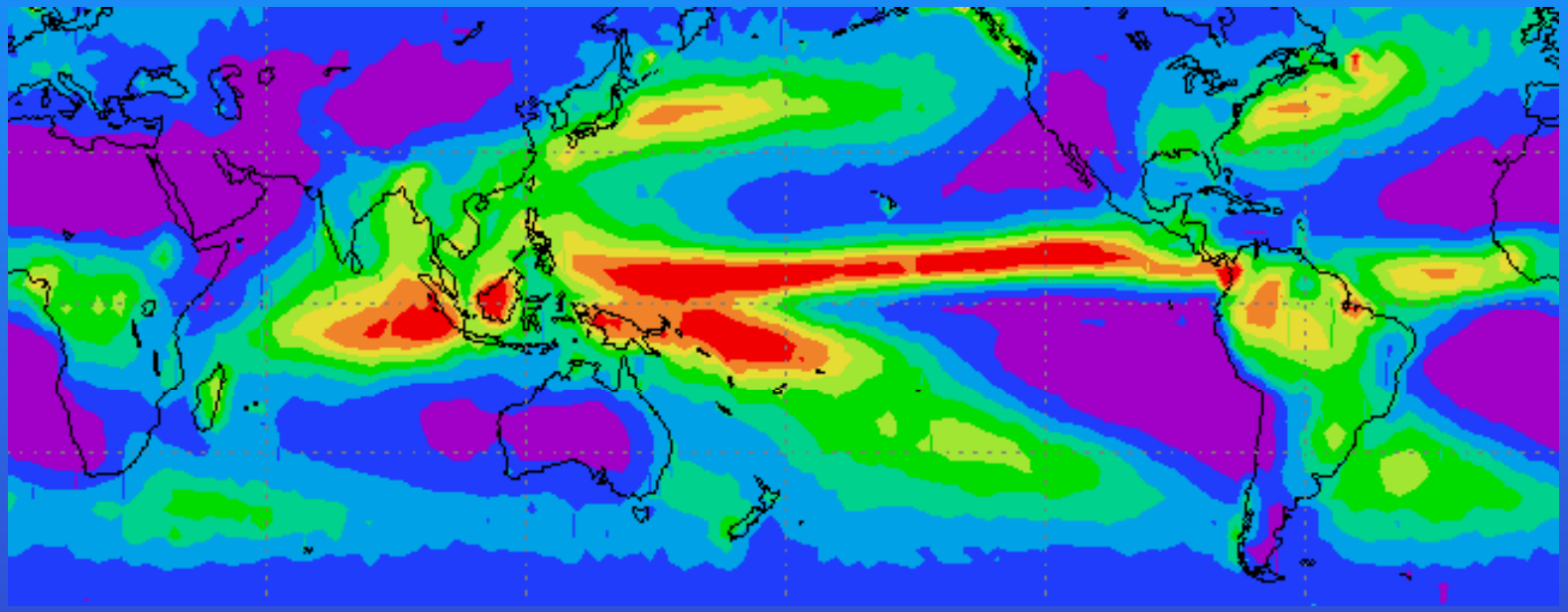
Calif has summer peak
PNW has winter peak



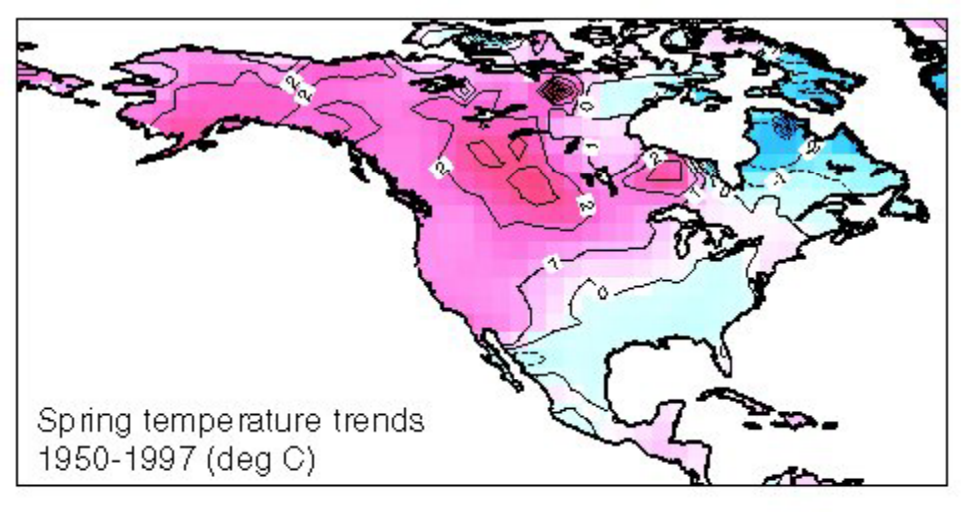


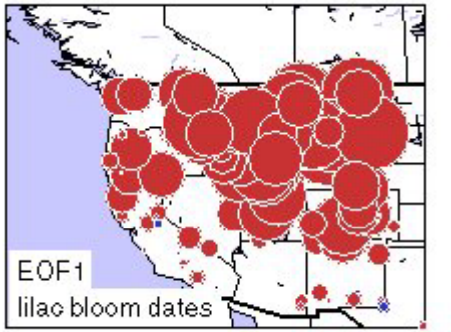
Annual Precipitation

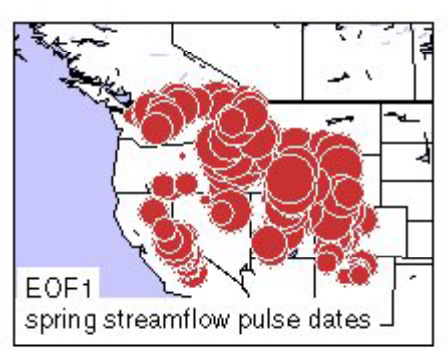
GPCP merged satellite + raingauge obs 1987-1999

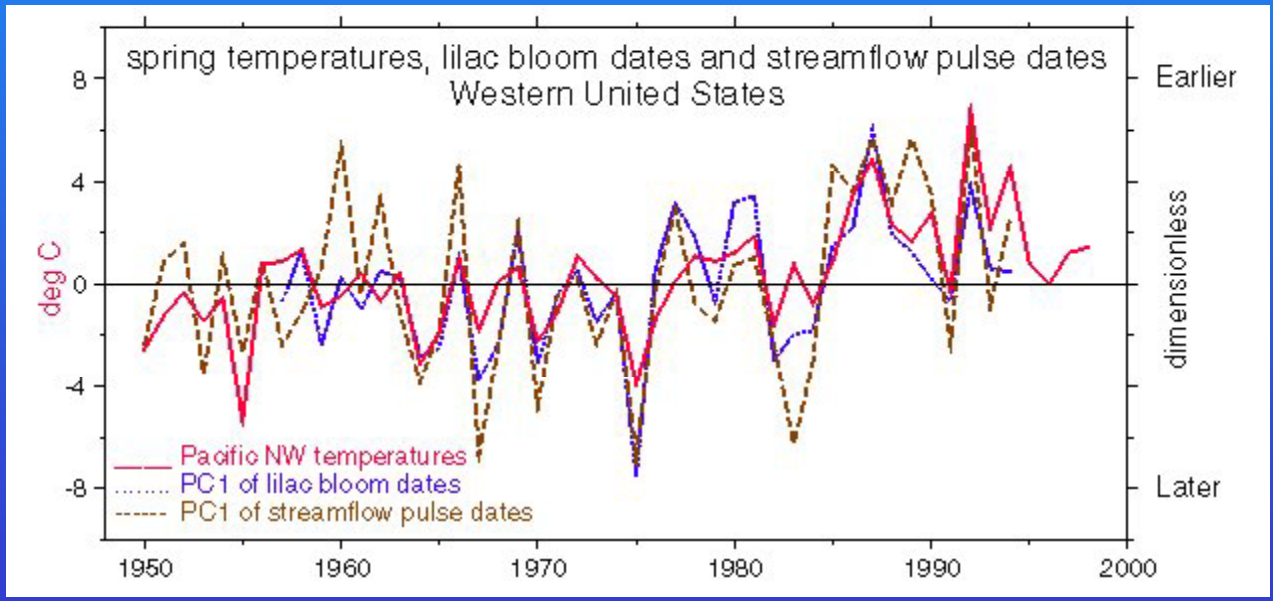


California is strongly influenced by the Pacific High
Precipitation is light compared to other global regions
Heaviest precip in red areas are several meters/yr; California region is many cm/y


Spring temperature trends
1950-1997 (deg C)


EOF1
lilac bloom dates


EOF1
spring streamflow pulse dates

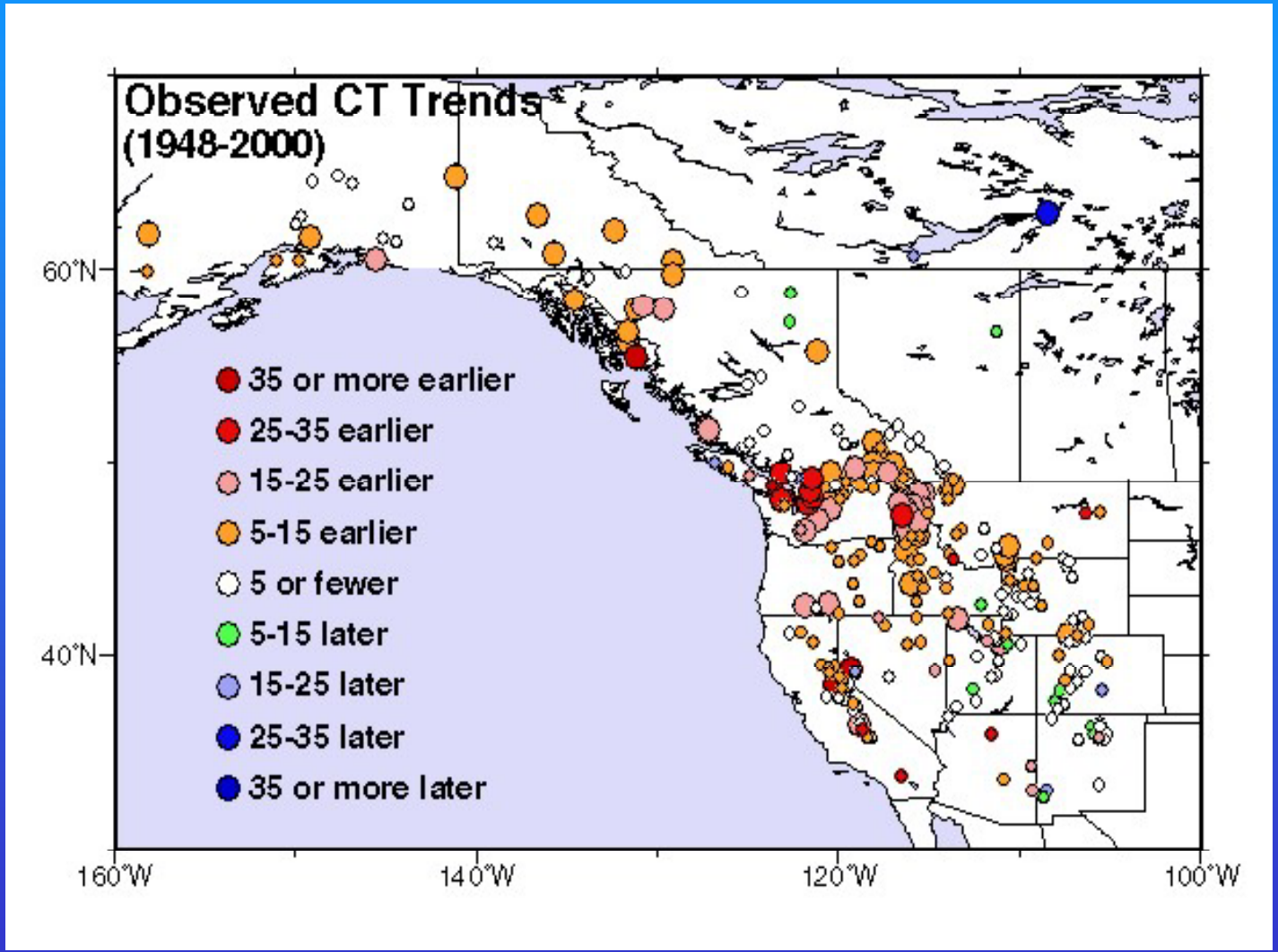

spring temperatures, lilac bloom dates and streamflow pulse dates
Western United States
deg C
8
4
0
-4
-8
Earlier
dimensionless
Later
1950
1960
1970
1980
1990
2000
Pacific NW temperatures
PC1 of lilac bloom dates
PC1 of streamflow pulse dates

California's Major Water Projects

Figure from Bulletin 160-98

Snowmelt flows have come earlier

"Center Timing" of many snowmelt watersheds has advanced by 1-4 weeks earlier across the West during last 3 decades



Iris Stewart, Dan Cayan and Mike Dettinger