Southern California's vulnerability to climate change

Dan Cayan

Scripps Institution of Oceanography, CASPO, UCSD and US Geological Survey

sponsors:

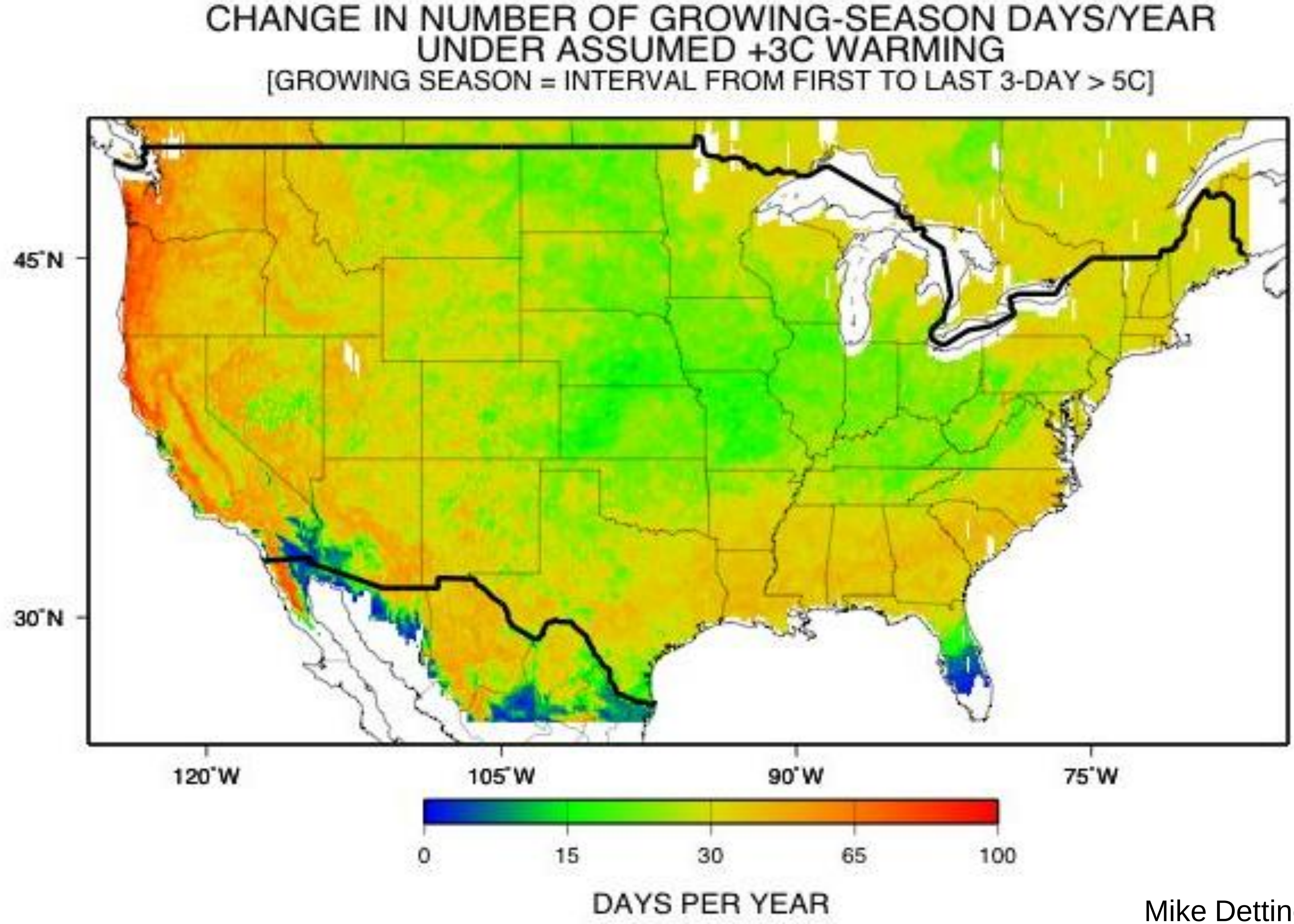
NOAA OGP RISA element

California Energy Commission PIER program

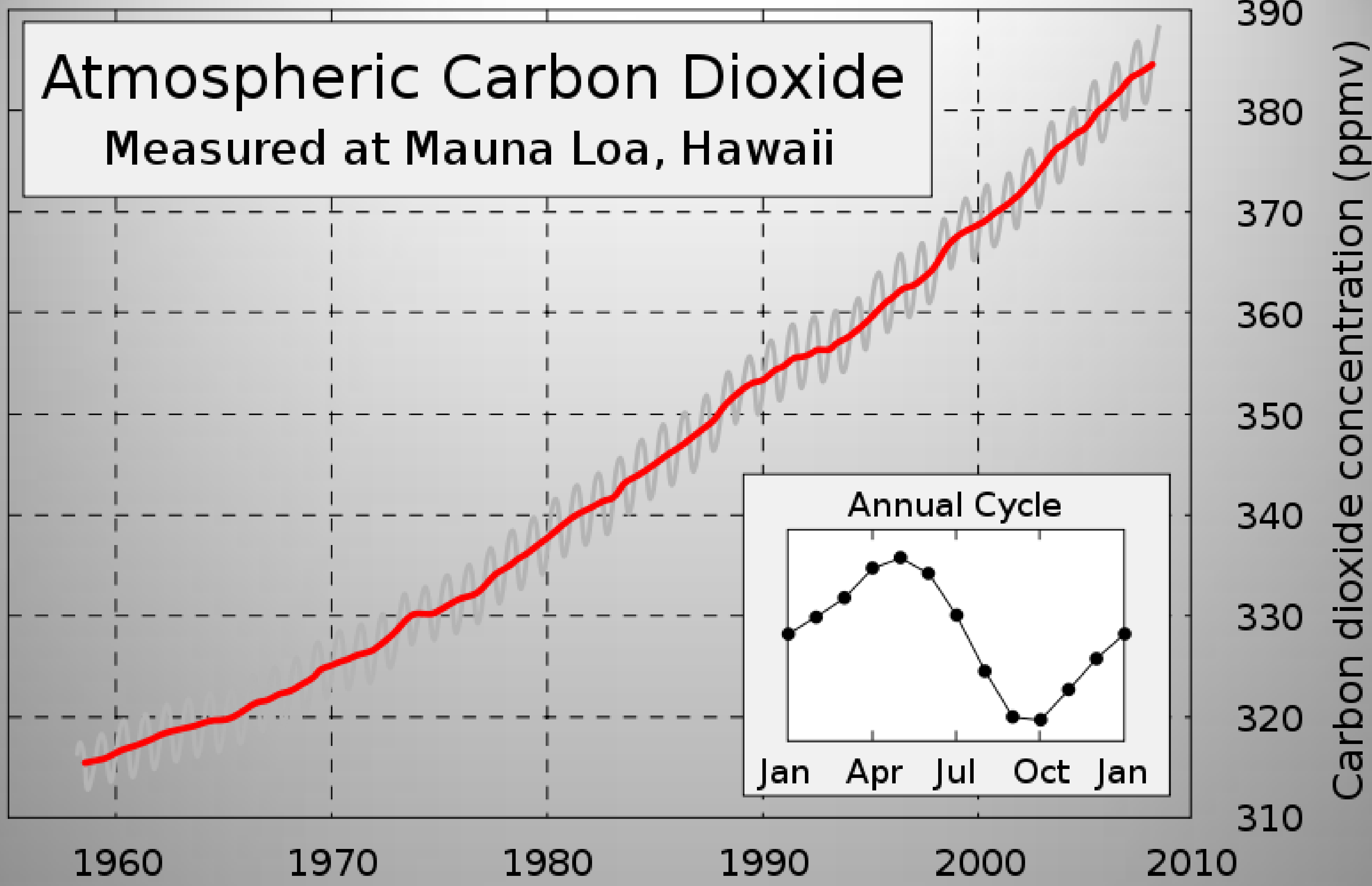
http://meteora.ucsd.edu/cap

There is a high likelihood of substantial climate change in mediterranean regions.

This places an imperative to *measure, understand and plan* for climate change impacts across the Southern California landscape.



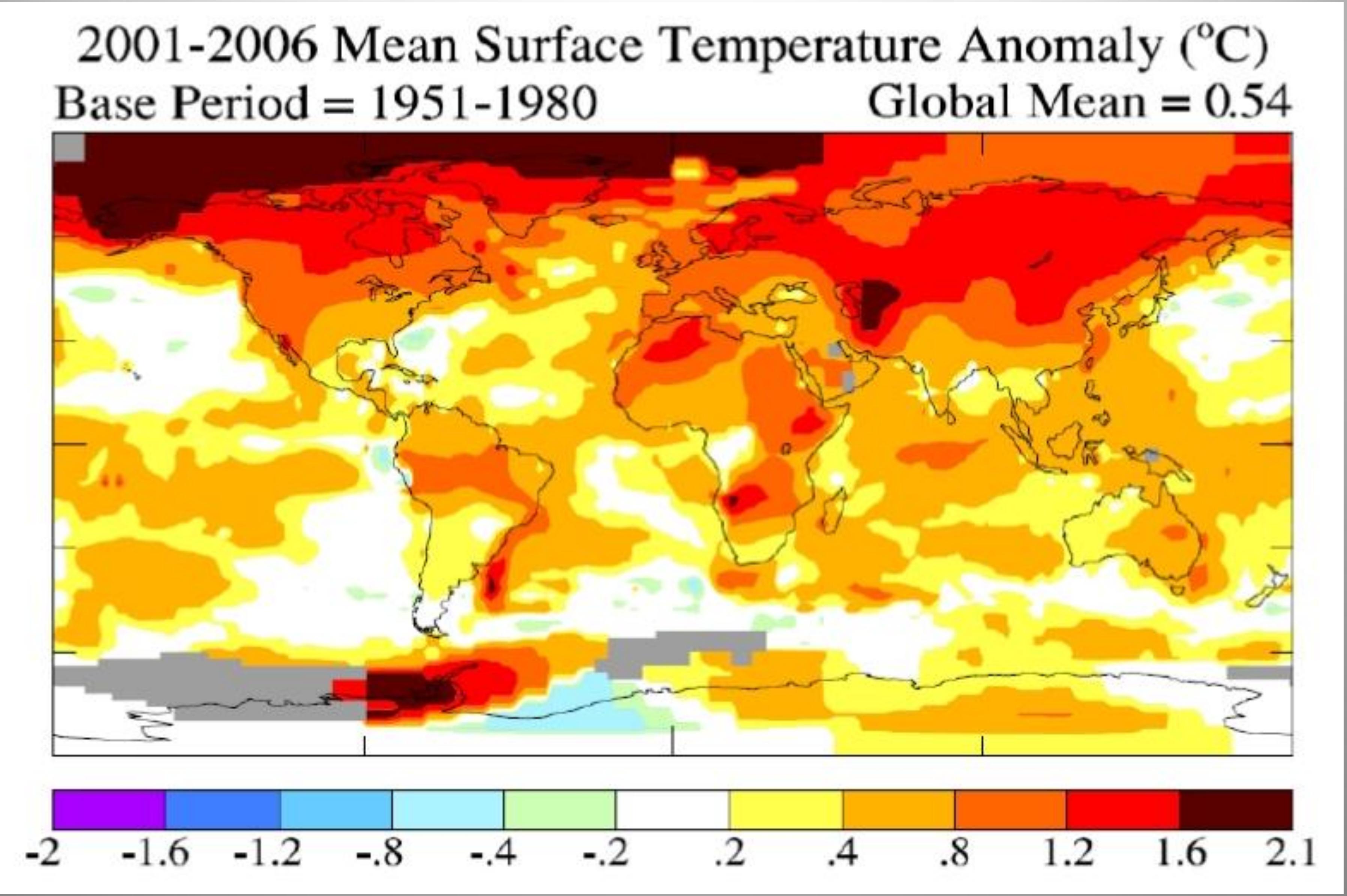
Mike Dettinger



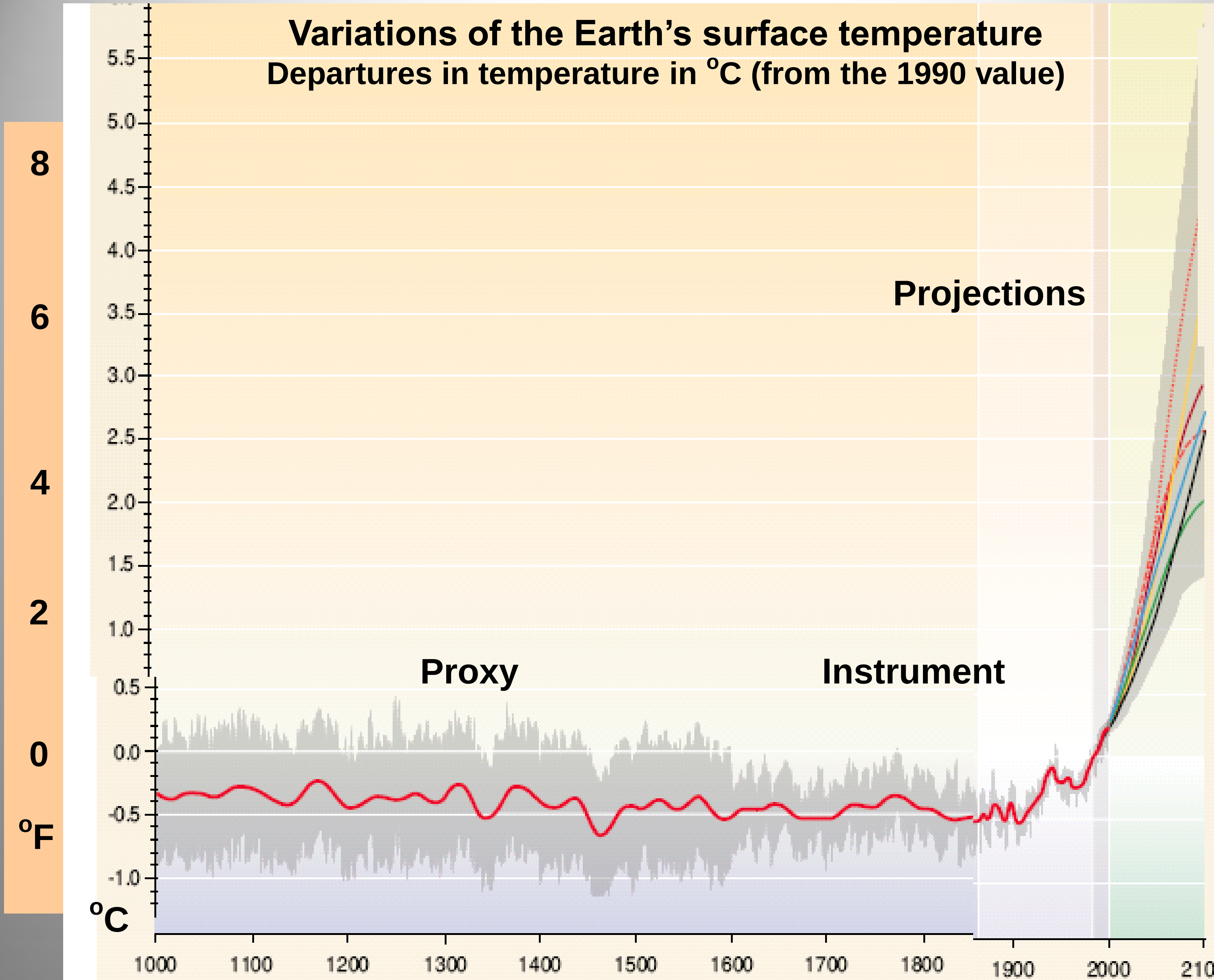
the rapid, continuing rise of CO_2 and other greenhouse gases -- a critical concern

* they "trap" terrestrial radiation and heat the earth
* they reside in the atmosphere for decades-centuries

Recent warming accentuated over No Hem land masses

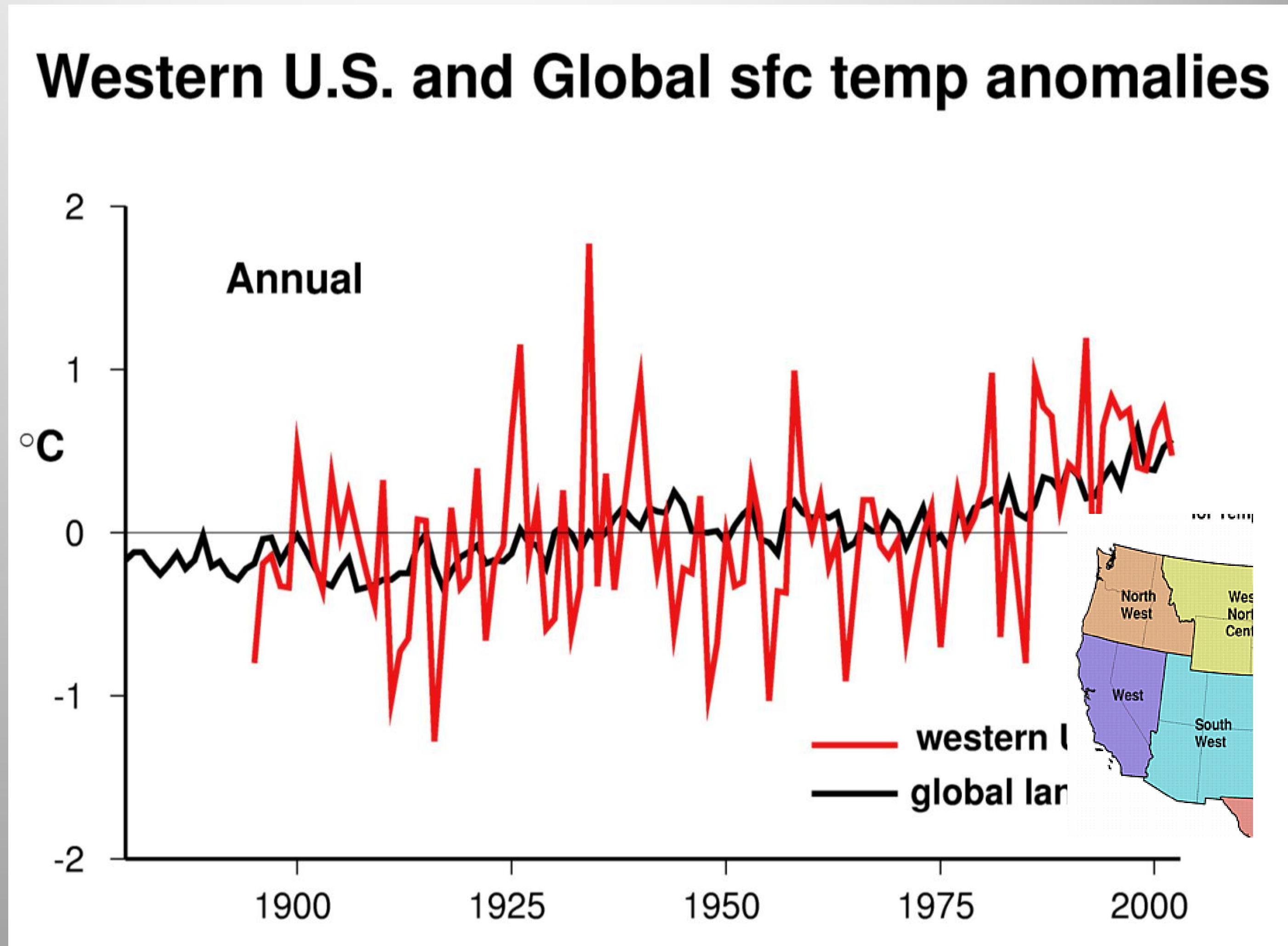


Jim Hansen et al.



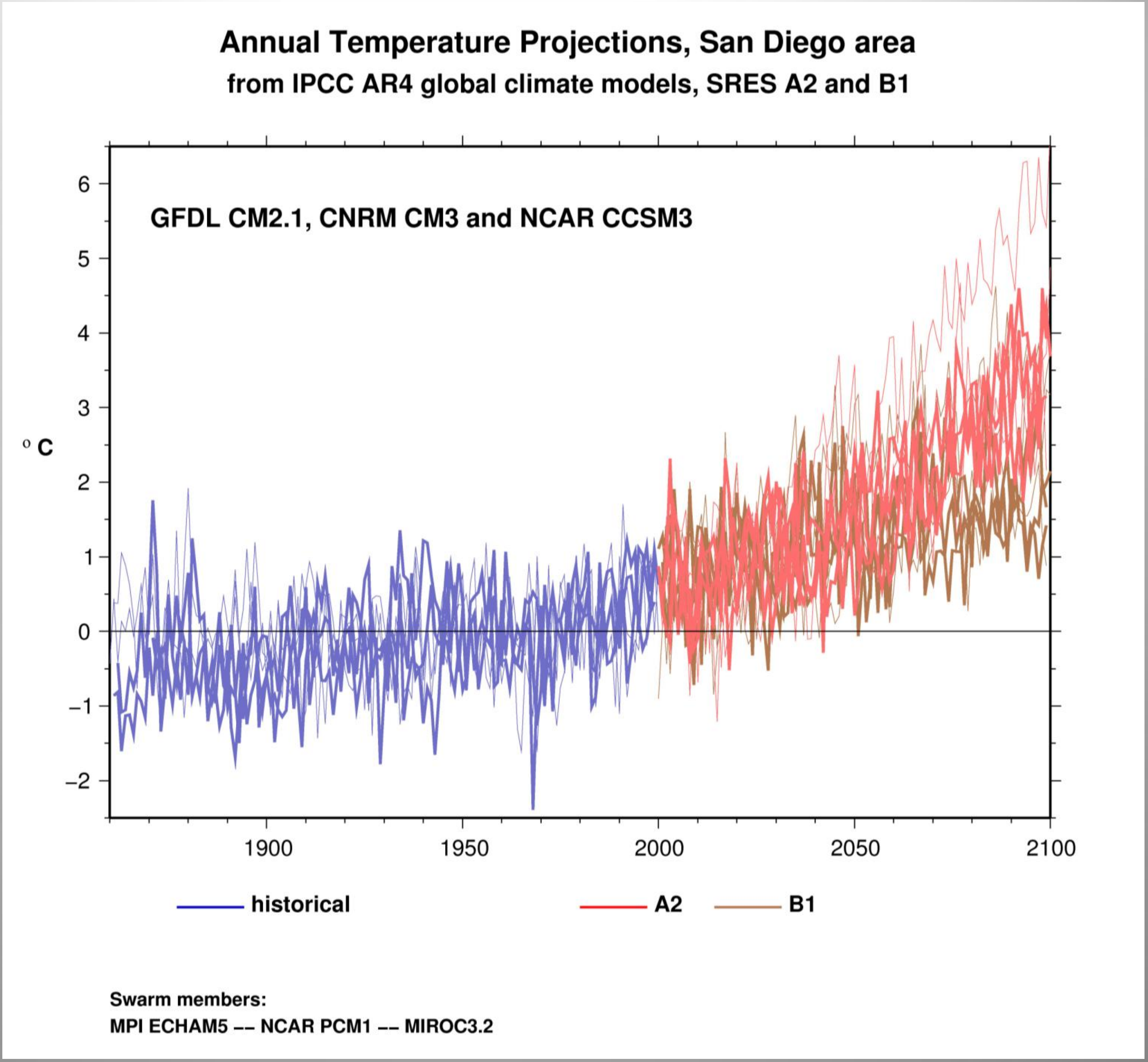
Variations of the Earth's surface temperature
Departures in temperature in °C (from the 1990 value)
Projections
Proxy
Instrument
8
6
4
2
0
°F
°C
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100

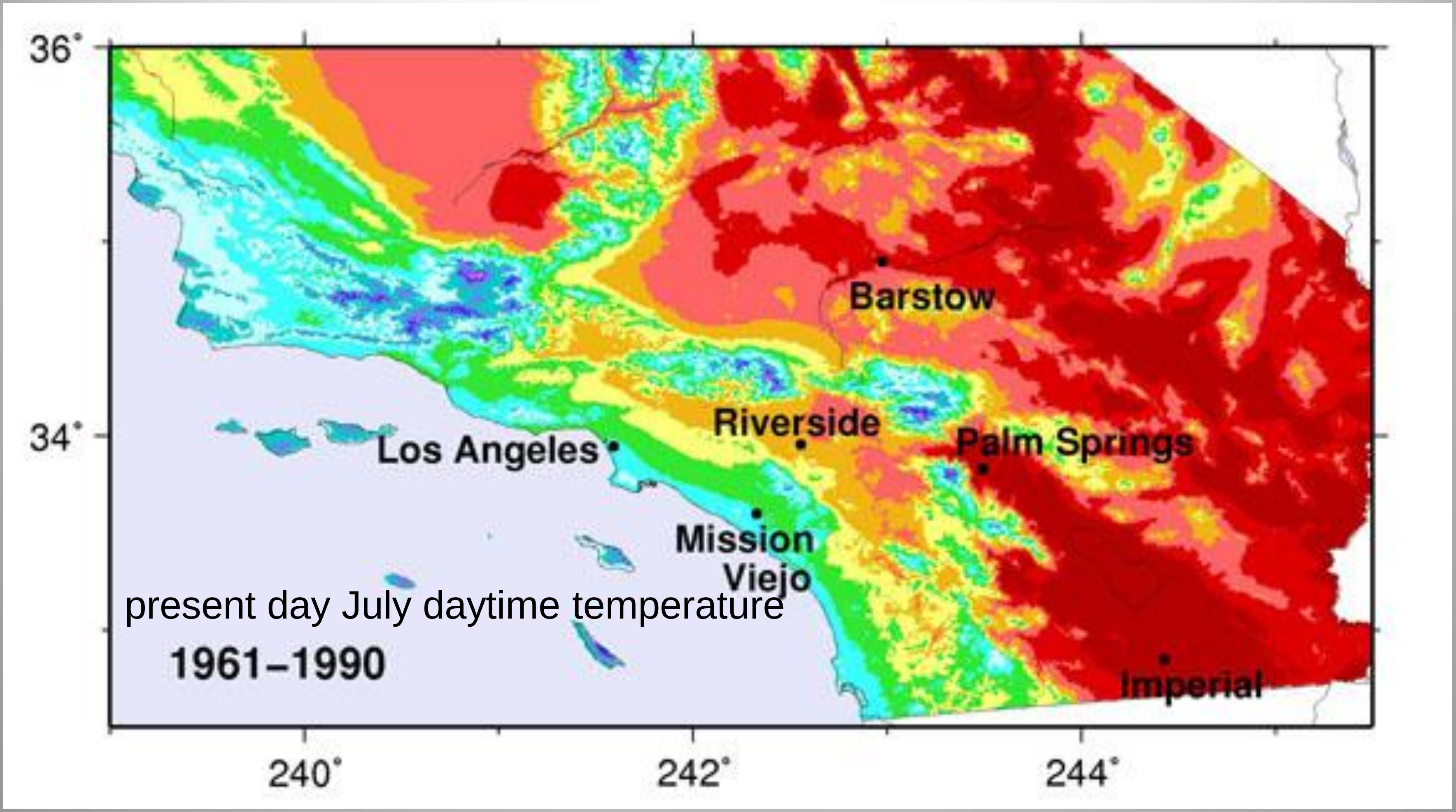
During recent history, temperature changes in west U.S. have tracked those in global temperature



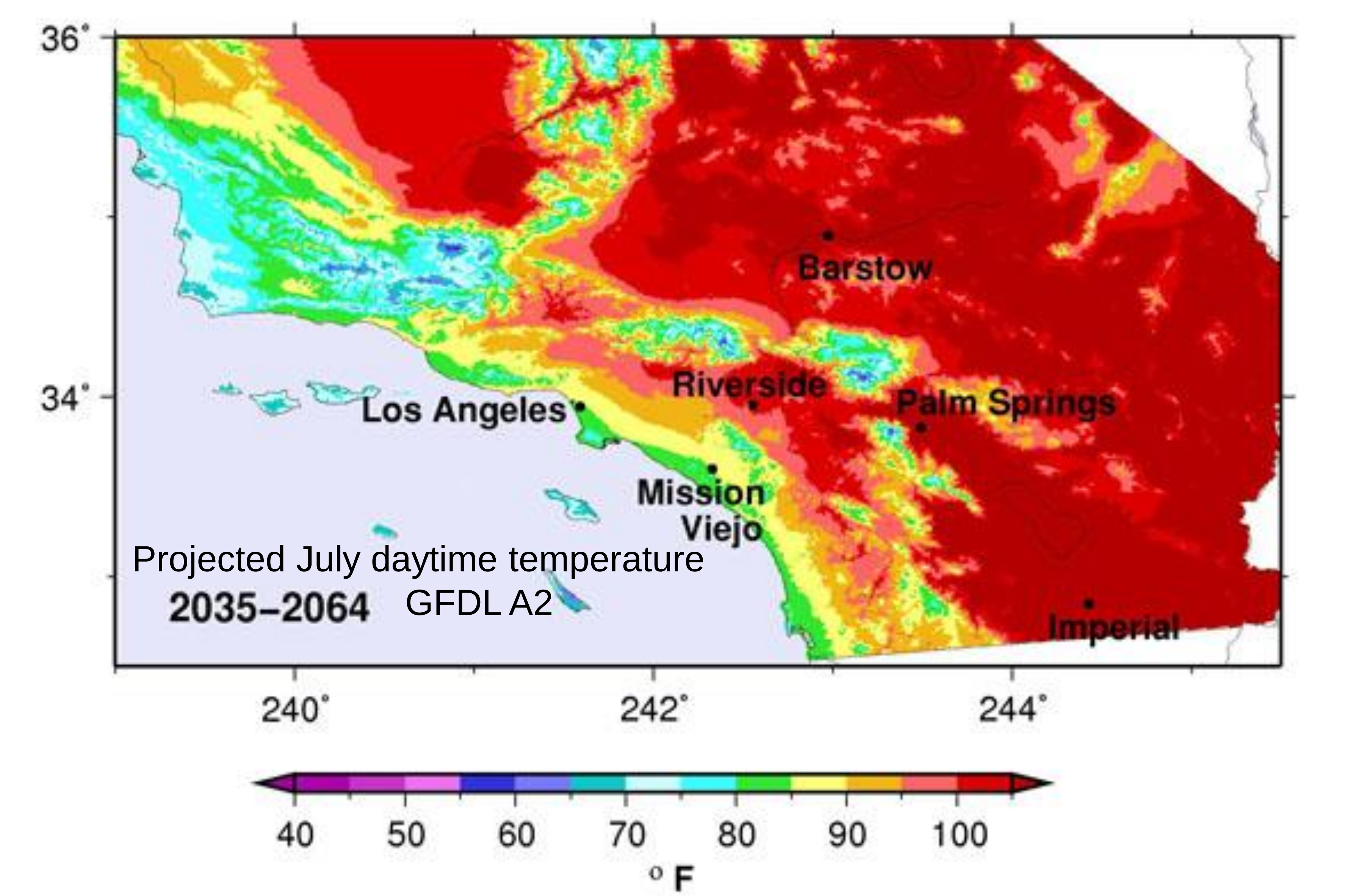
Global land data from the Global Historical Climatology Network (GHCN; Version 2) and global SST data from the UK MOHSST and NCEP OI SST (Version 2) anoms based on 1880-2002 mean

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


Annual Temperature Projections, San Diego area
from IPCC AR4 global climate models, SRES A2 and B1
GFDL CM2.1, CNRM CM3 and NCAR CCSM3
6
5
4
3
2
1
0
−1
−2
°C
1900
1950
2000
2050
2100
historical
A2
B1
Swarm members:
MPI ECHAM5 -- NCAR PCM1 -- MIROC3.2



…. and very likely climate warming will accentuate hot summer interior conditions

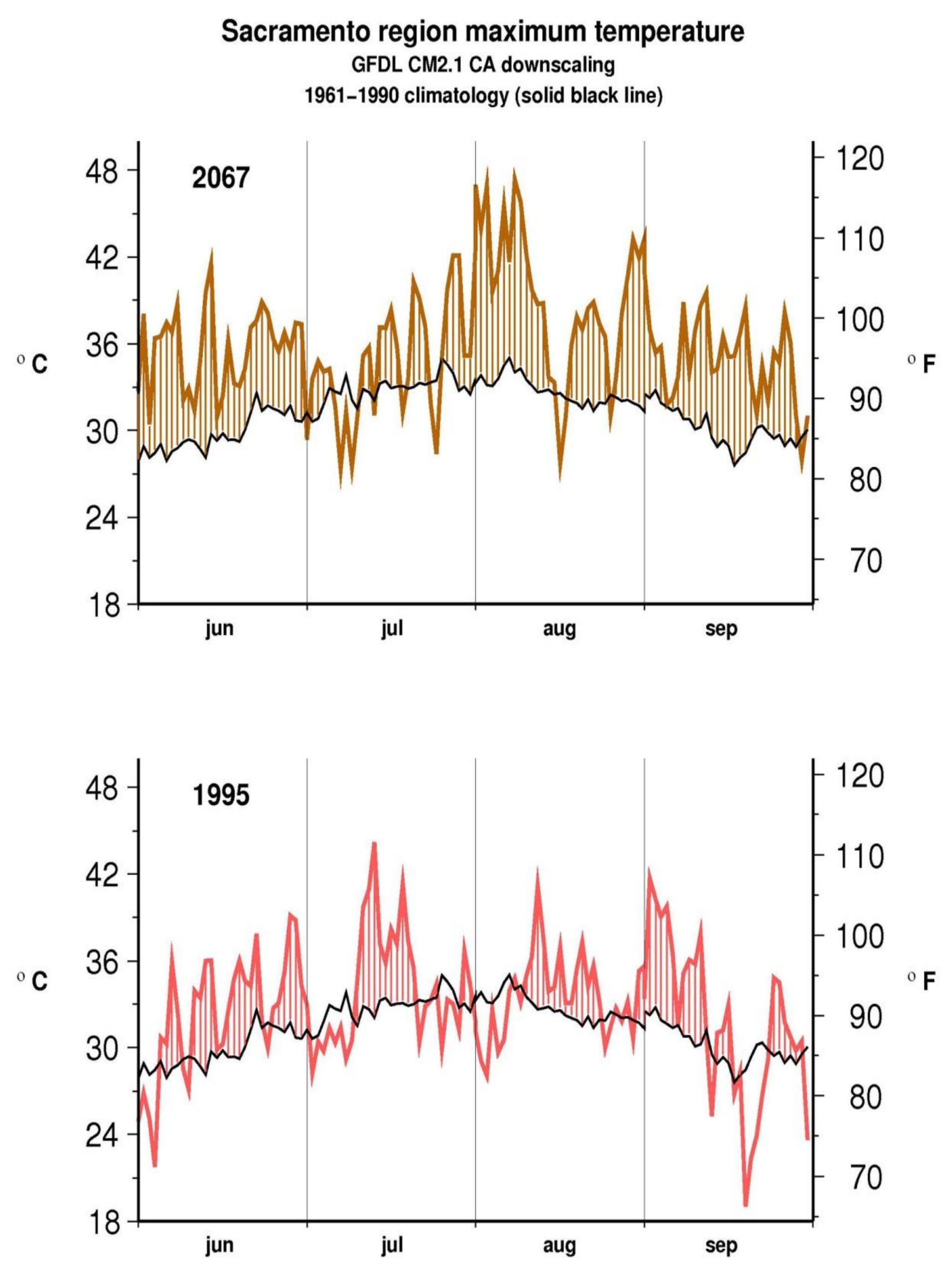


GFDL A2 1km downscaled to 1km
Hugo Hidalgo Tapash Das Mike Dettinger

daily data reveals
Intensification of heat waves

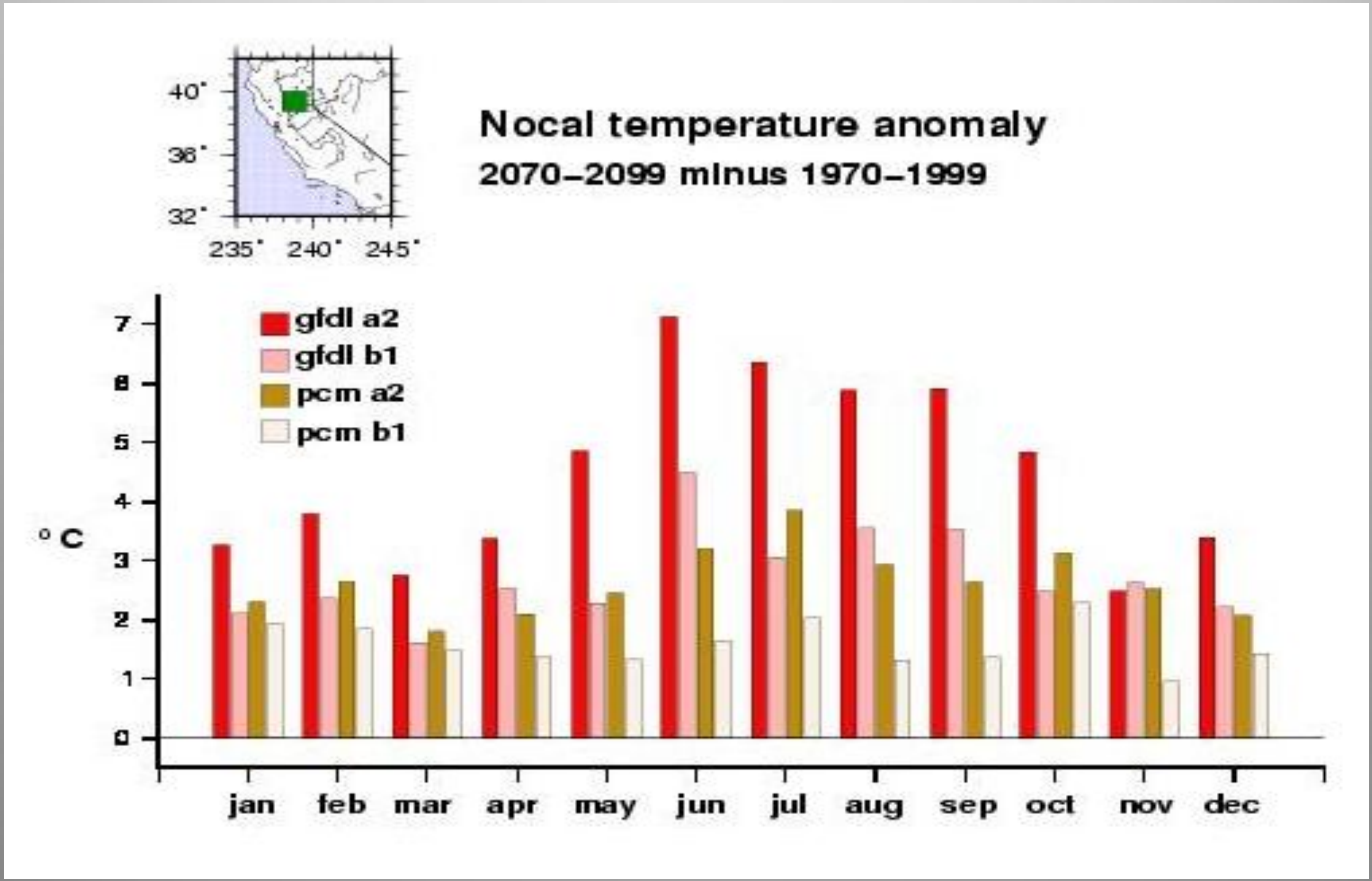
2 warm summers, Sacramento
hot days get hotter
hot spells get longer

summer daily maximum temp
CA downscaled GFDL A2 simulation
Model years 2067 and 1995

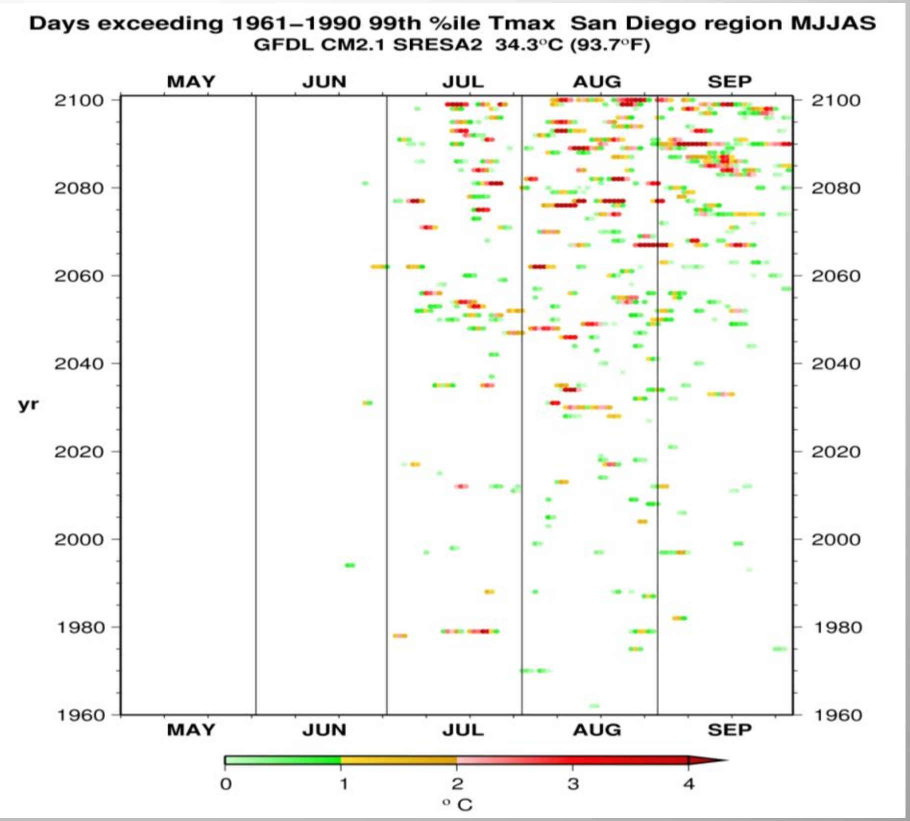


Seasonally intensified warming?

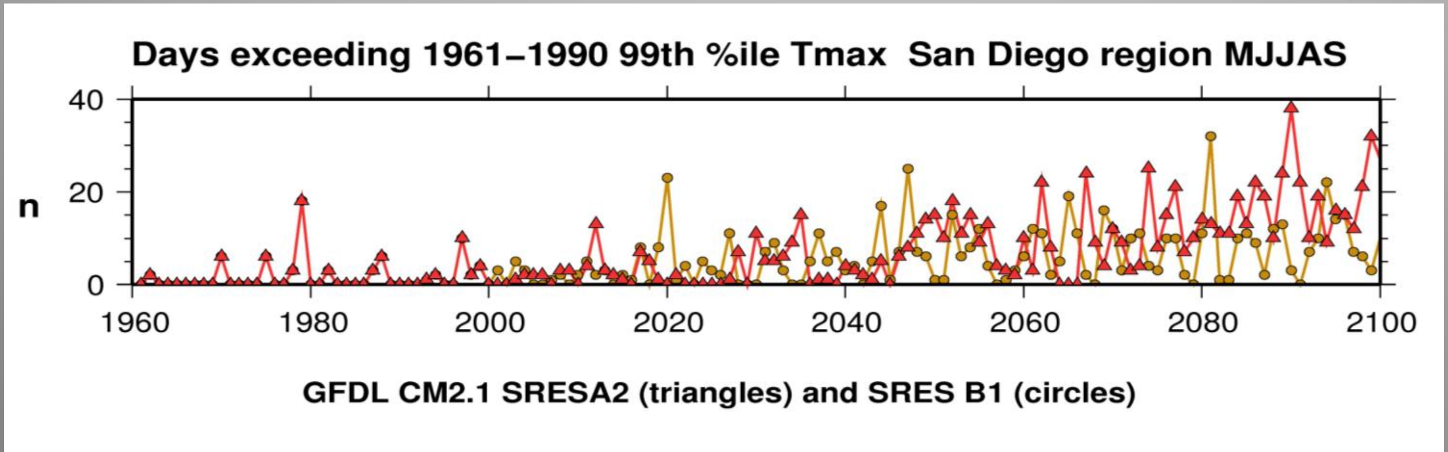
recent GCM simulations contain amplified summer warming, which could seriously impact ecosystems, energy, water and health



Southern CaliforniaHeat Waves
GFDL A2 Simulation

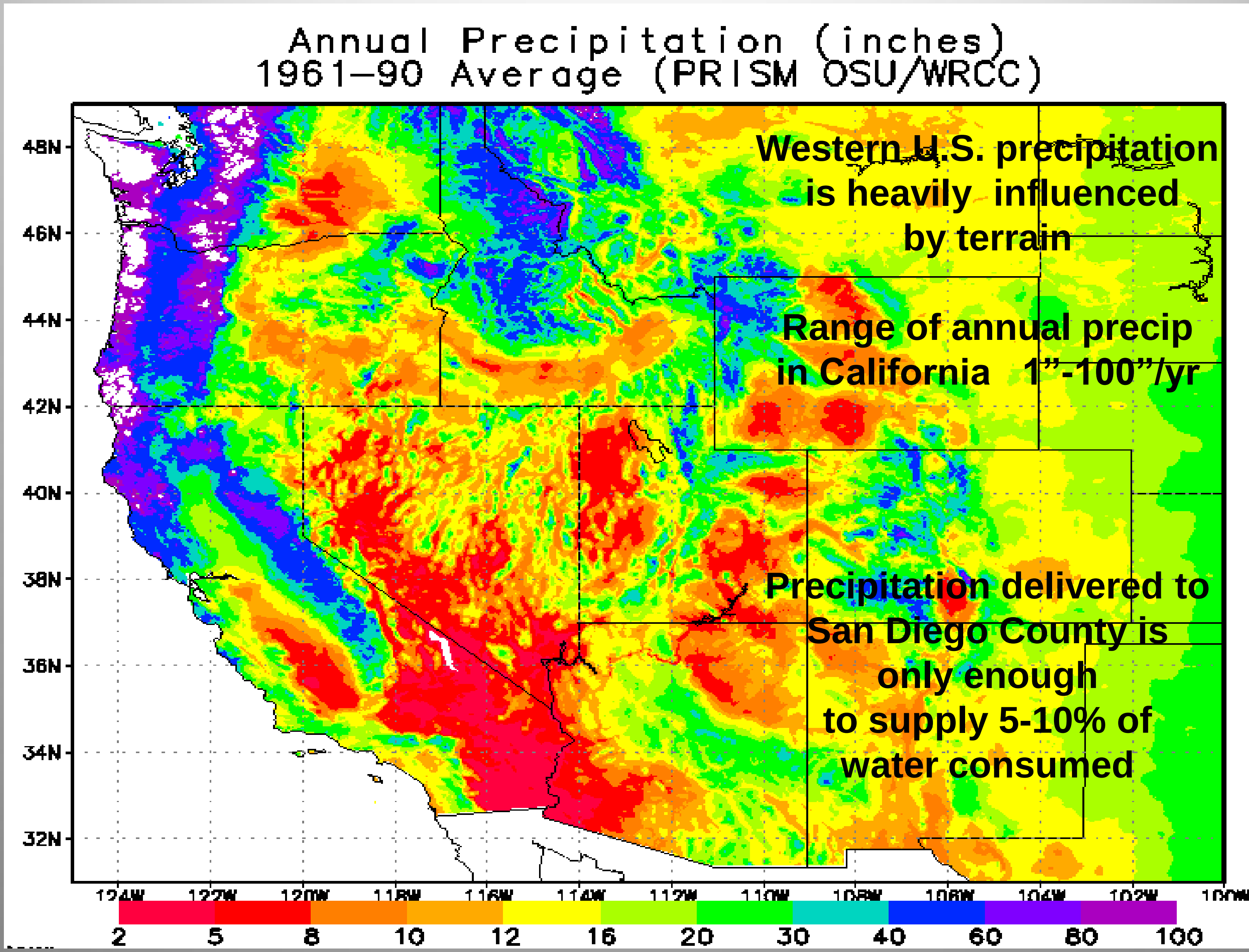


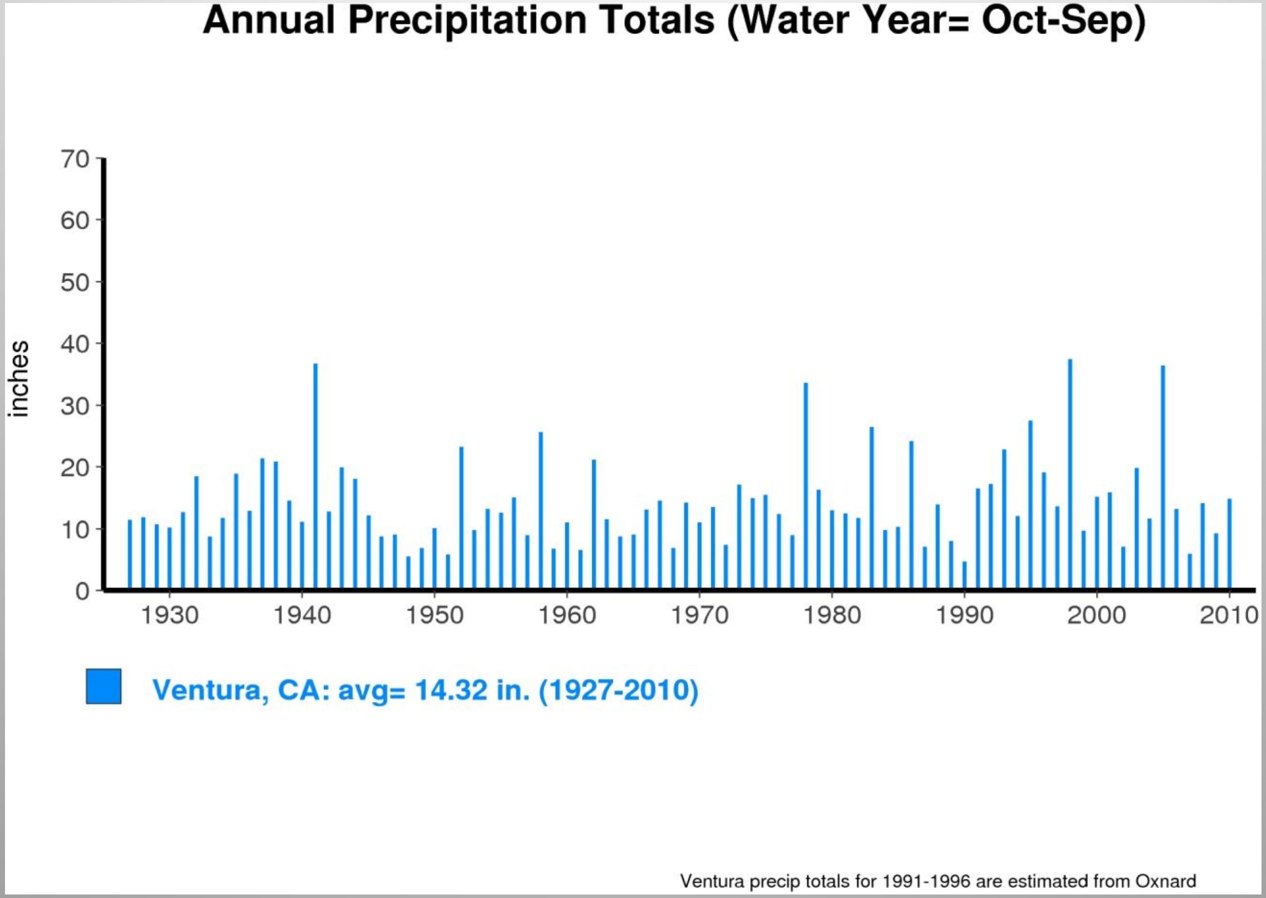
Latest generation of GCMs
Indicate that summers warm
More than winters



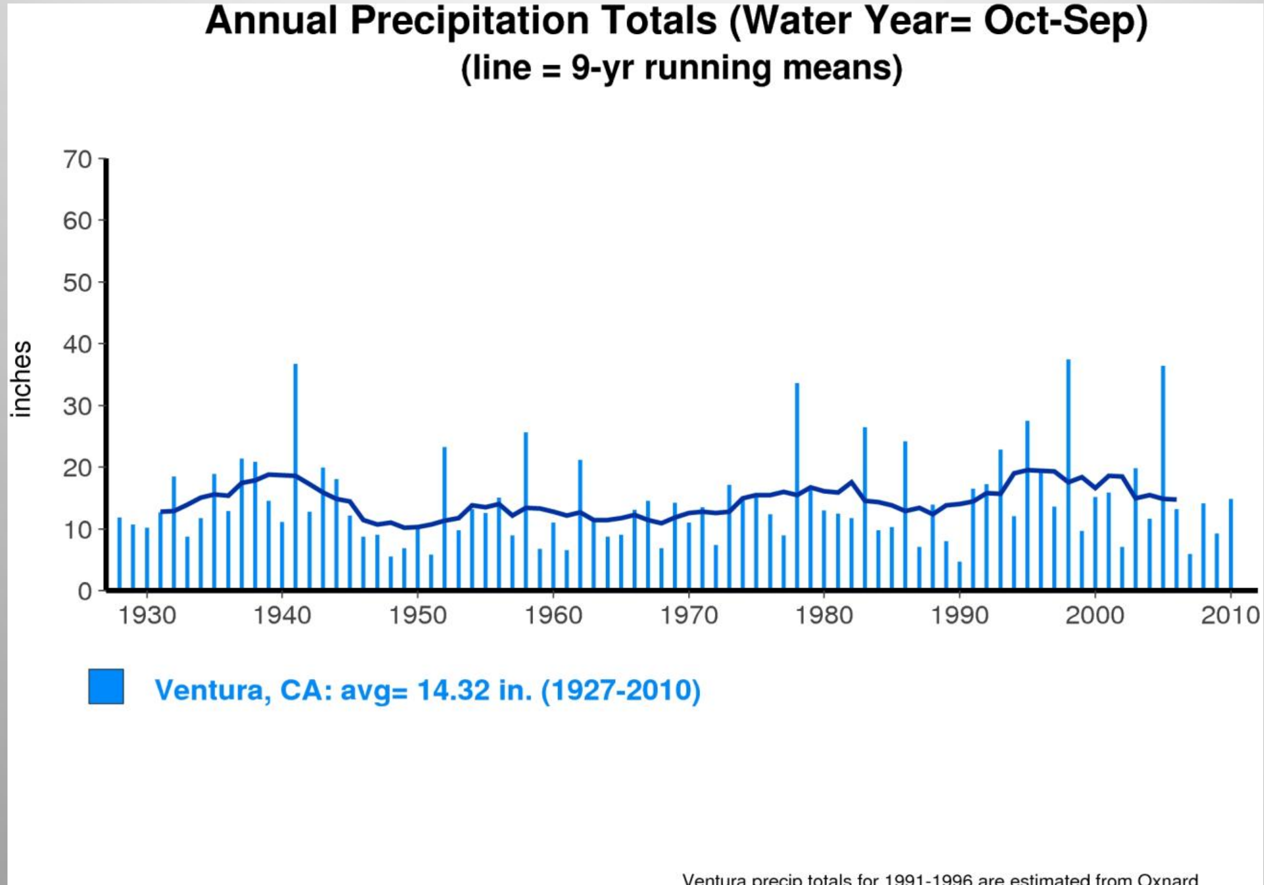
Annual Precipitation Western United States

our water is derived mainly from mountain watersheds





Annual Precipitation Totals (Water Year= Oct-Sep)
inches
70
60
50
40
30
20
10
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
Ventura, CA: avg= 14.32 in. (1927-2010)
Ventura precip totals for 1991-1996 are estimated from Oxnard


Annual Precipitation Totals (Water Year= Oct-Sep)
(line = 9-yr running means)
inches
70
60
50
40
30
20
10
0
1930
1940
1950
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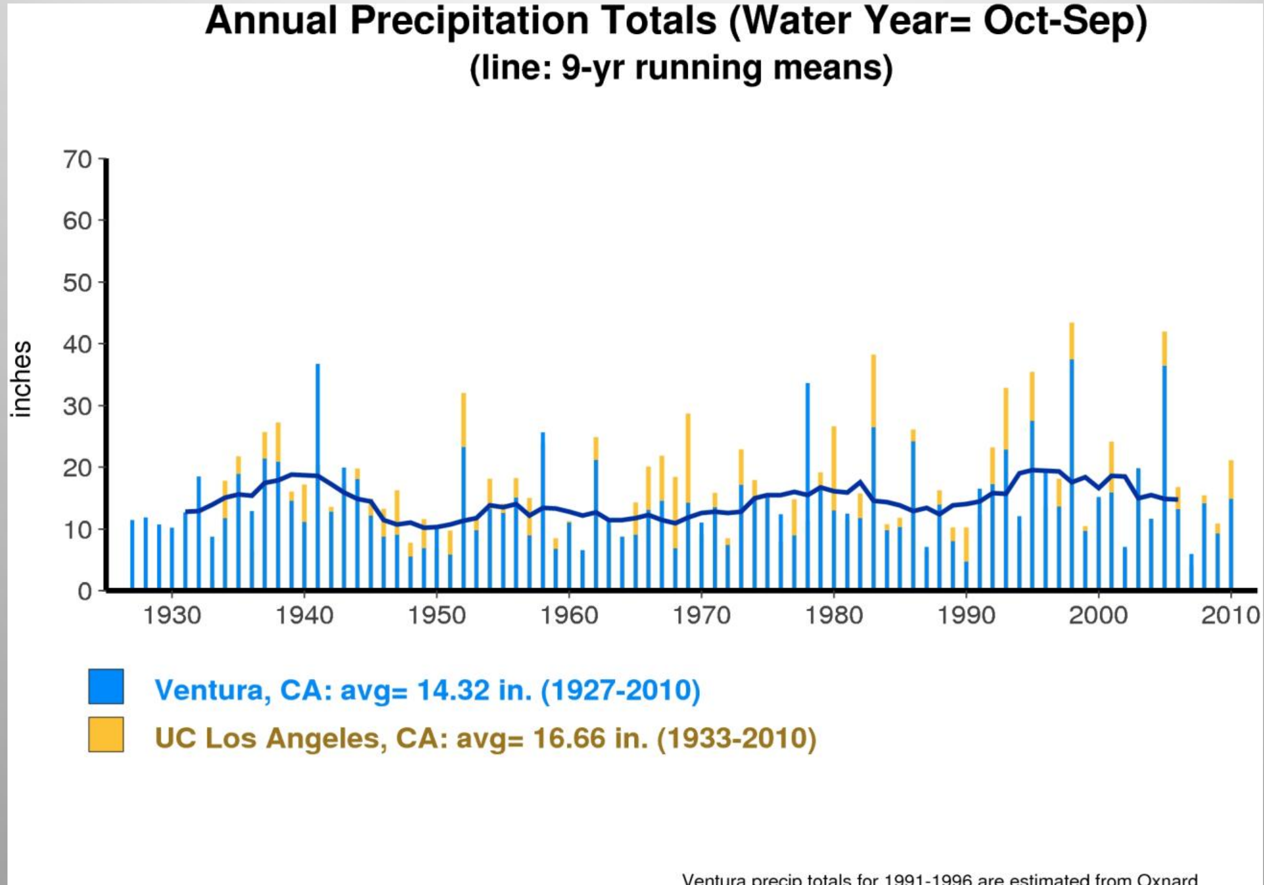
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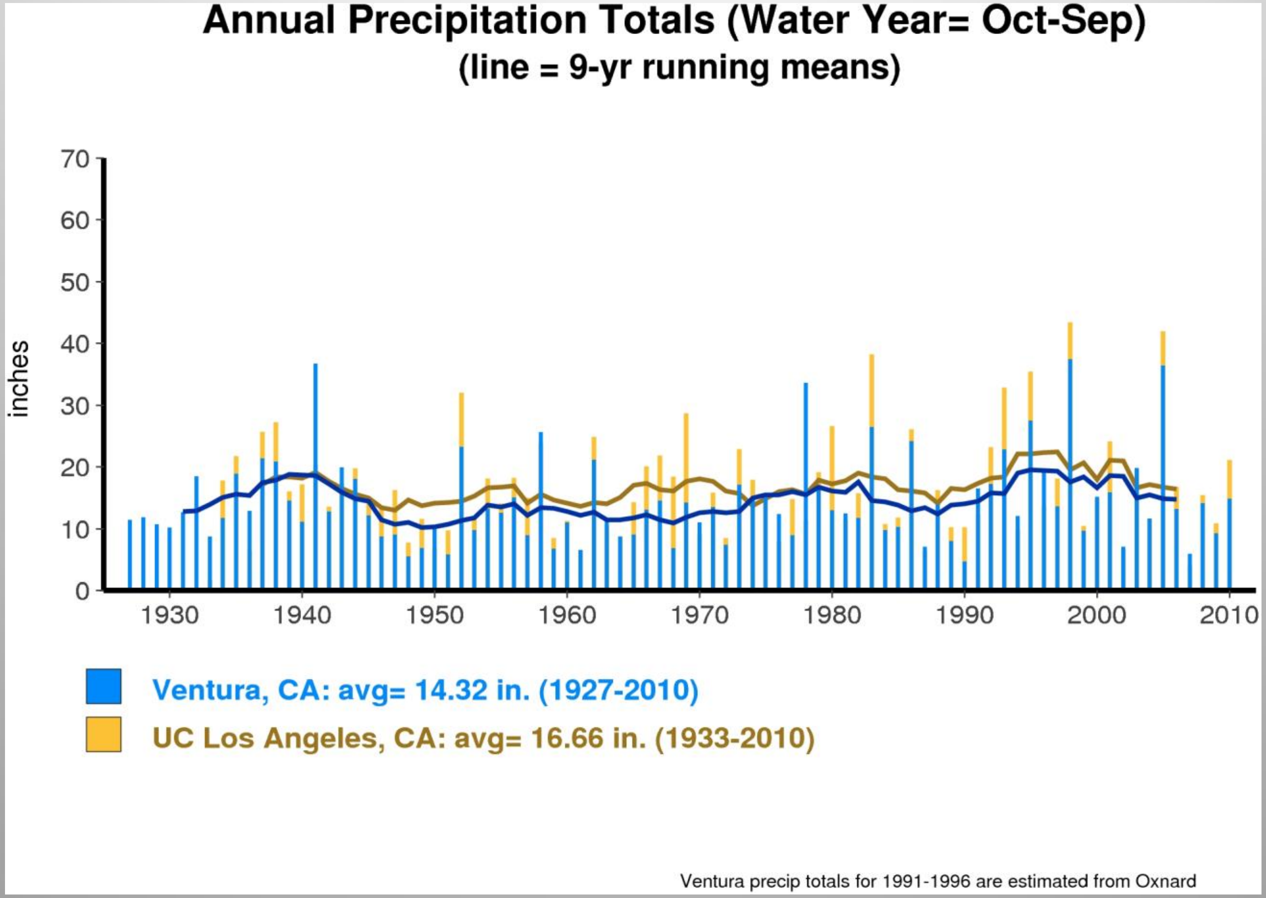

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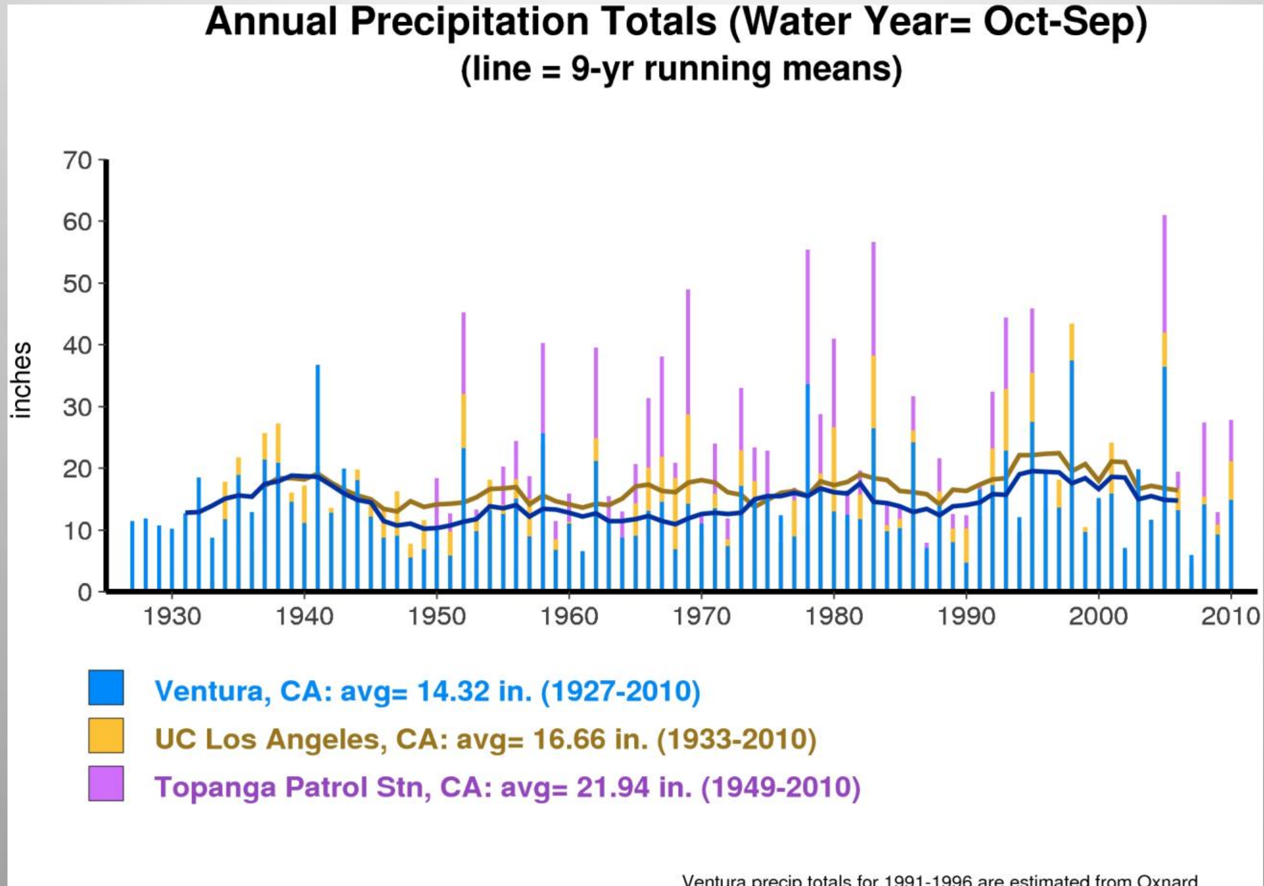
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Ventura, CA: avg= 14.32 in. (1927-2010)
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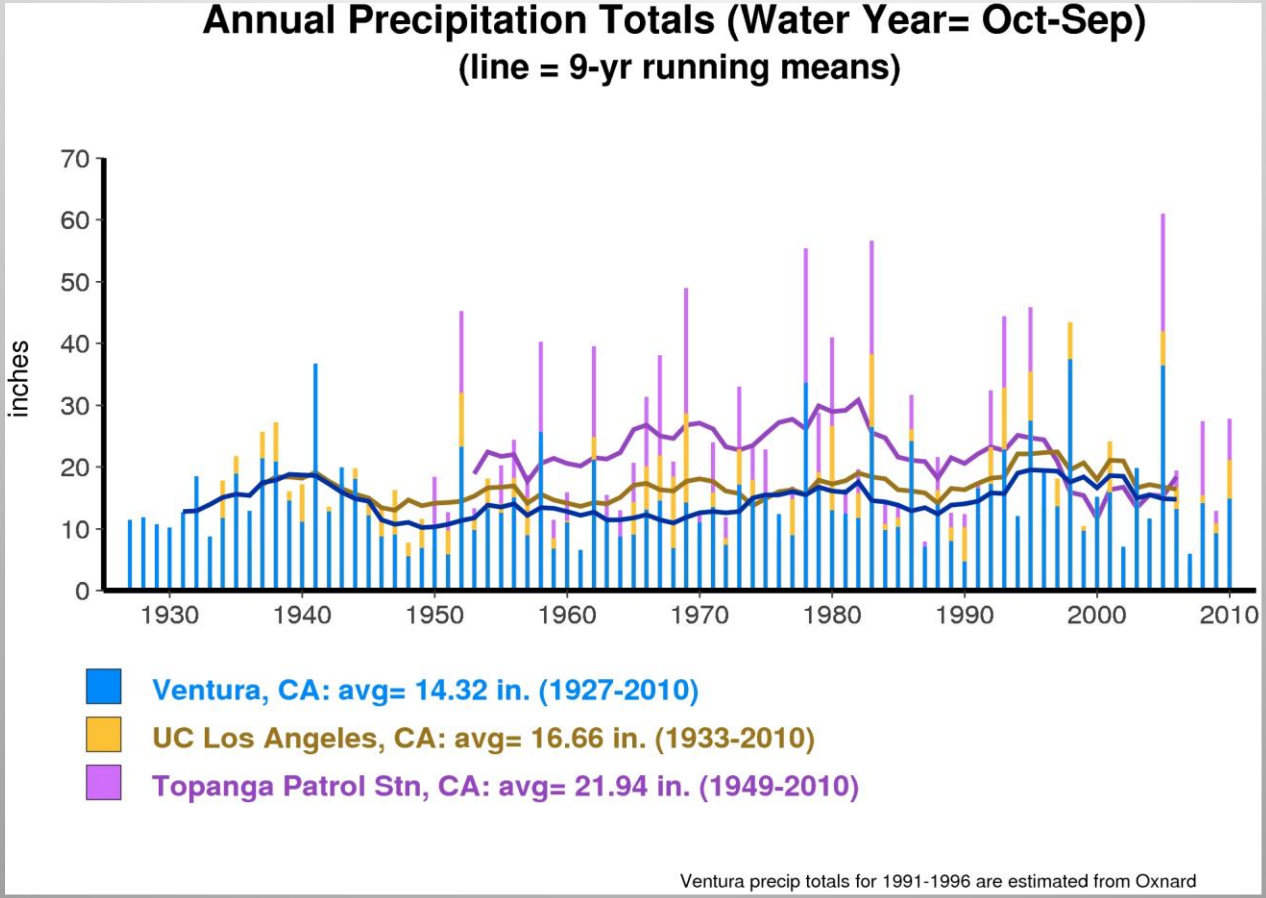
Topanga Patrol Stn, CA: avg= 21.94 in. (1949-2010)
Ventura precip totals for 1991-1996 are estimated from Oxnard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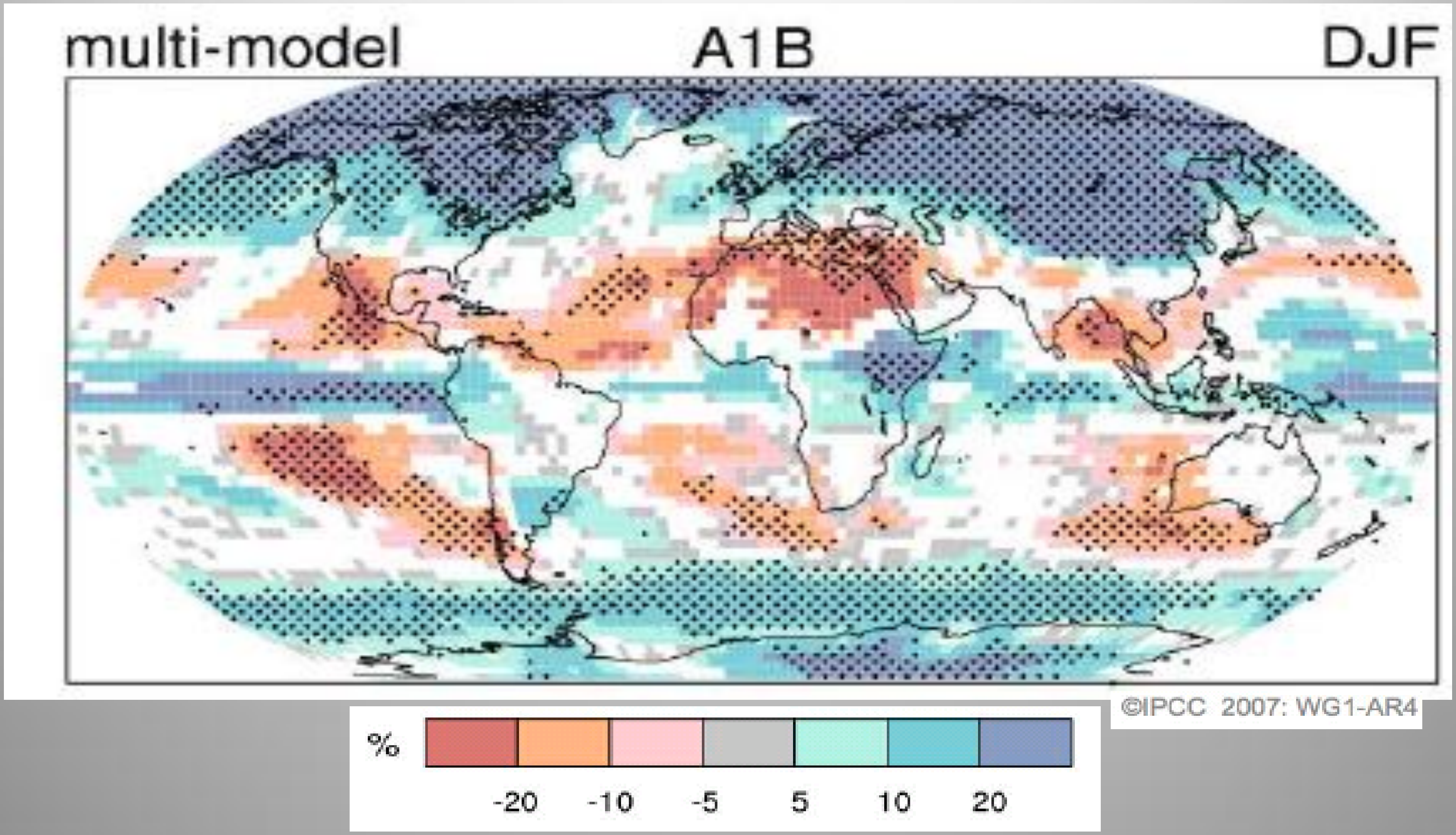
Ventura precip totals for 1991-1996 are estimated from Oxnard

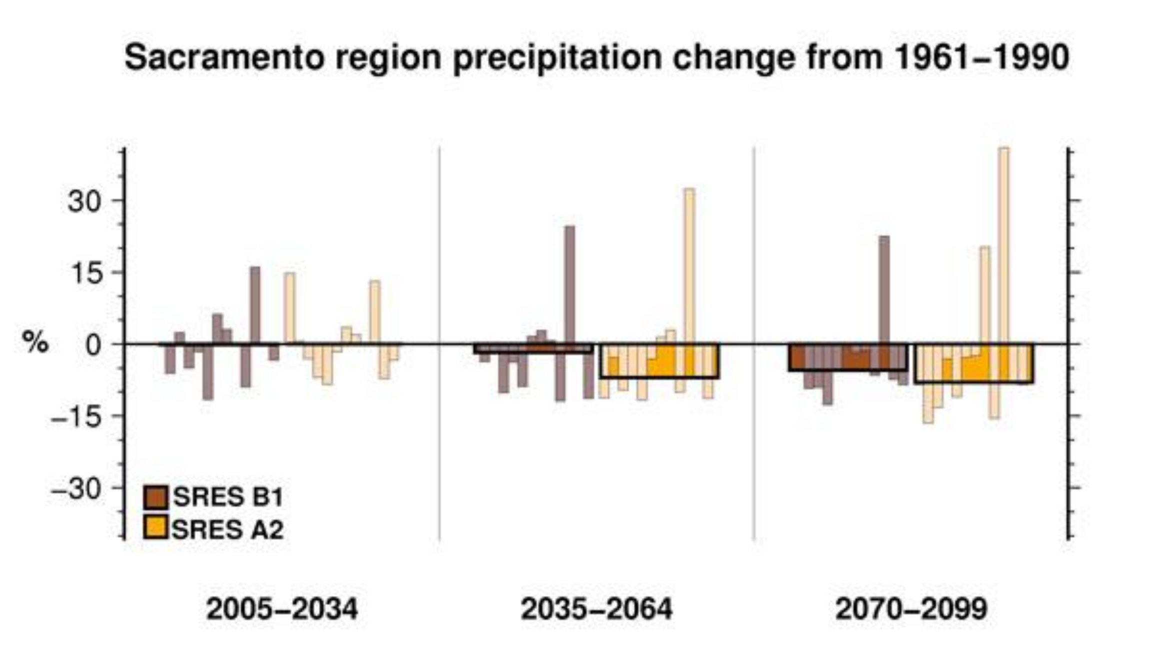
California's history is marked by extended dry spells

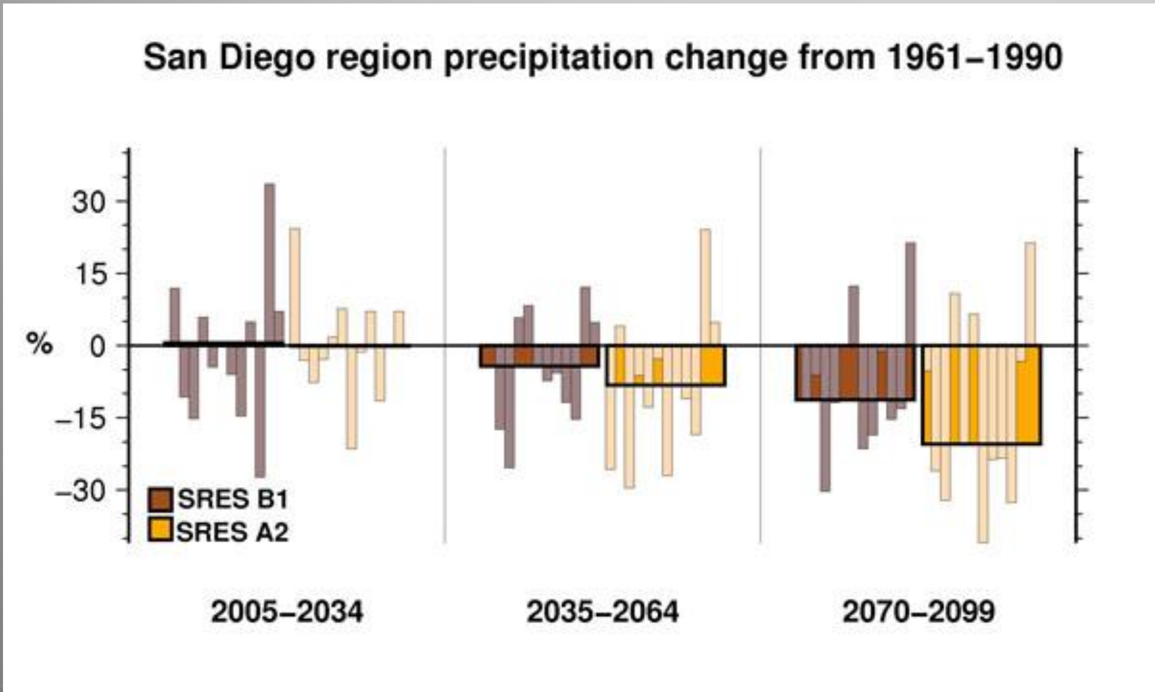
California Department of Water Resources photos

Projected patterns of precipitation changes 2090-2099 versus 1980-1999

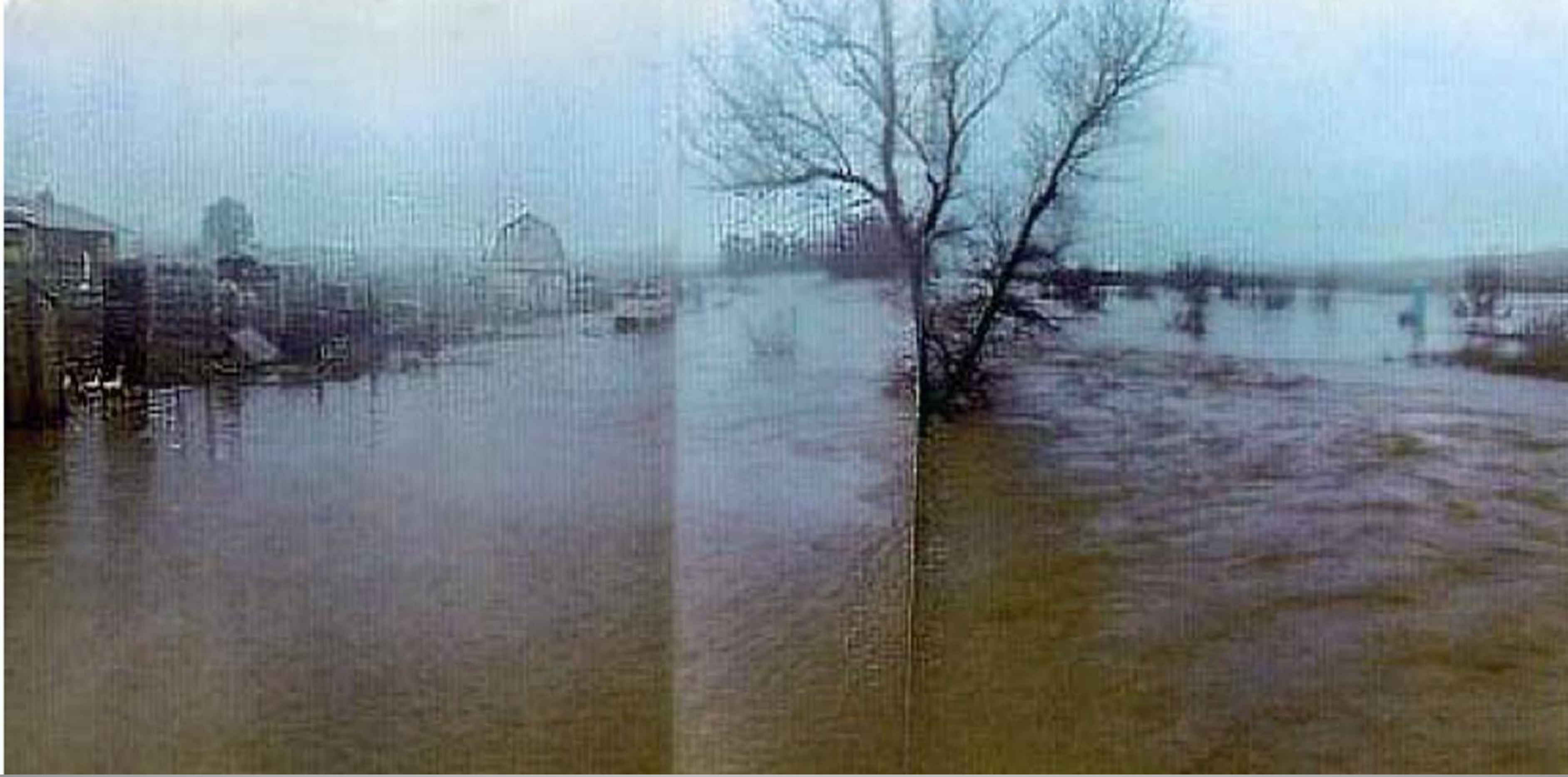


Globally, dry regions become drier?





12 AR4 GCMs,
2 emissions s
scenarios---
an uneven consensus
toward lower
California precipitation



Floods happen, even in Southern California

February 1980 after a “pineapple express” warm moist storm episode
Confluence of Etcheverry Creek and Santa Maria Creek
Westerly view from Voorhes Lane, Ramona, CA

The Atmospheric River California's primary flood generator.

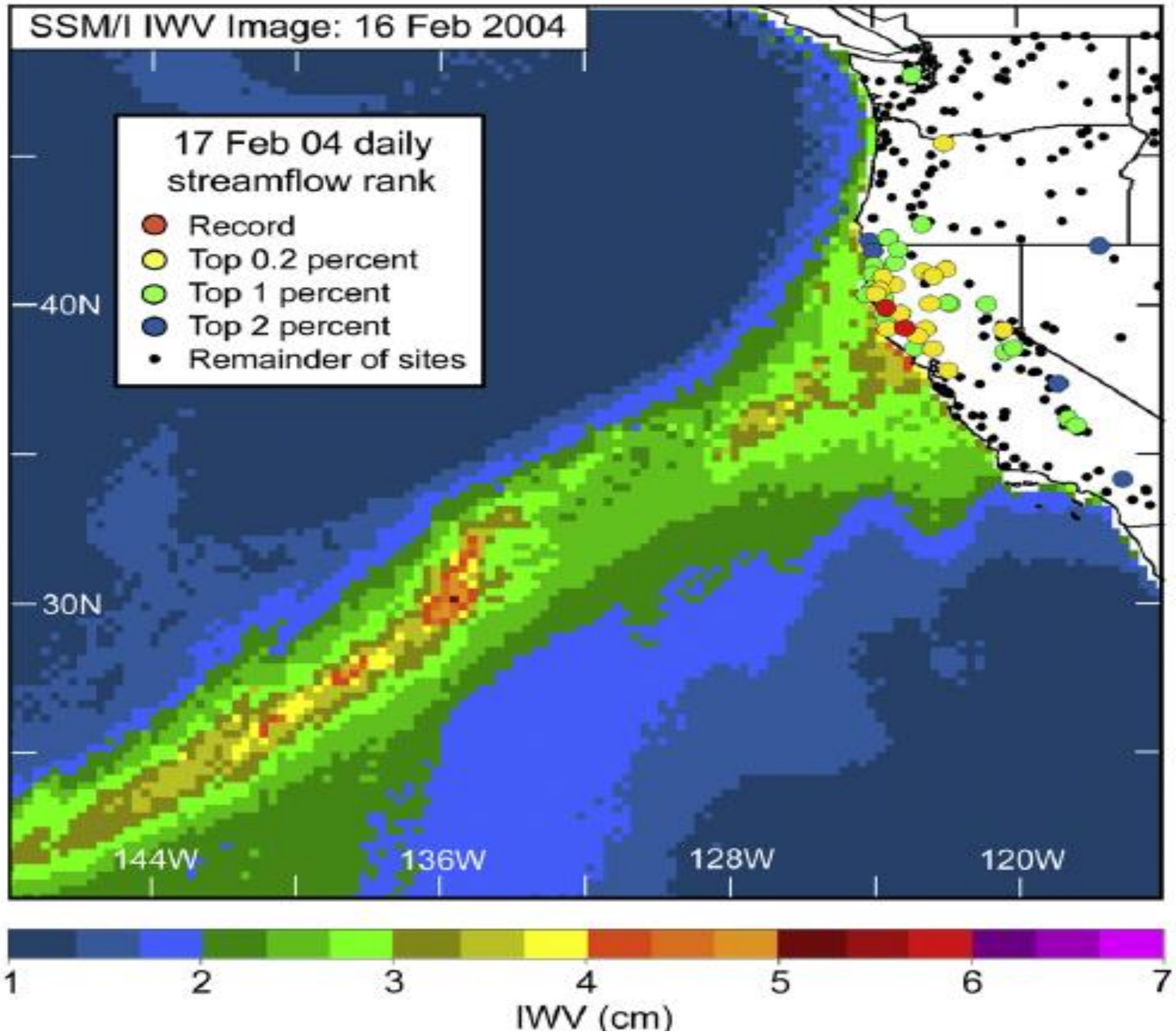


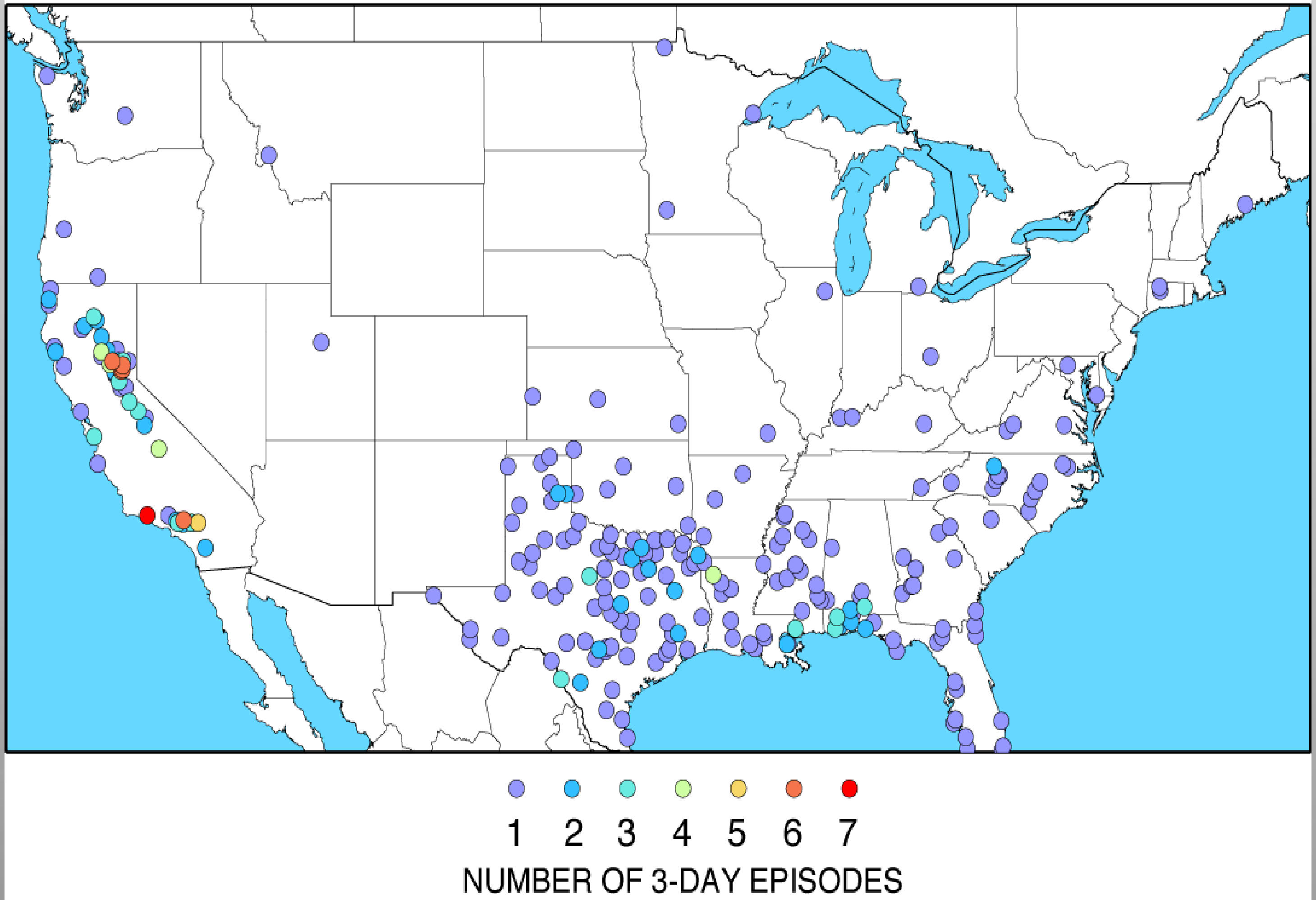
Figure 5. Composite SSM/I satellite image of IWV (cm; color bar at bottom) constructed from polar-orbiting swaths between ~1400 and 1830 UTC 16 February 2004, and ranking of daily streamflows (percent; see inset key) on 17 February 2004 for those gauges that have recorded data for ≥30 years. The streamflow data are based on local time (add 8 h to convert to UTC).

Flooding on California's Russian River: Role of atmospheric rivers

F. Martin Ralph,[1] Paul J. Neiman,[1] Gary A. Wick,[1] Seth I. Gutman,[1] Michael D. Dettinger,[2] Daniel R. Cayan,[2] and Allen B. White[3]

Most frequent heavy 3-day precipitation events

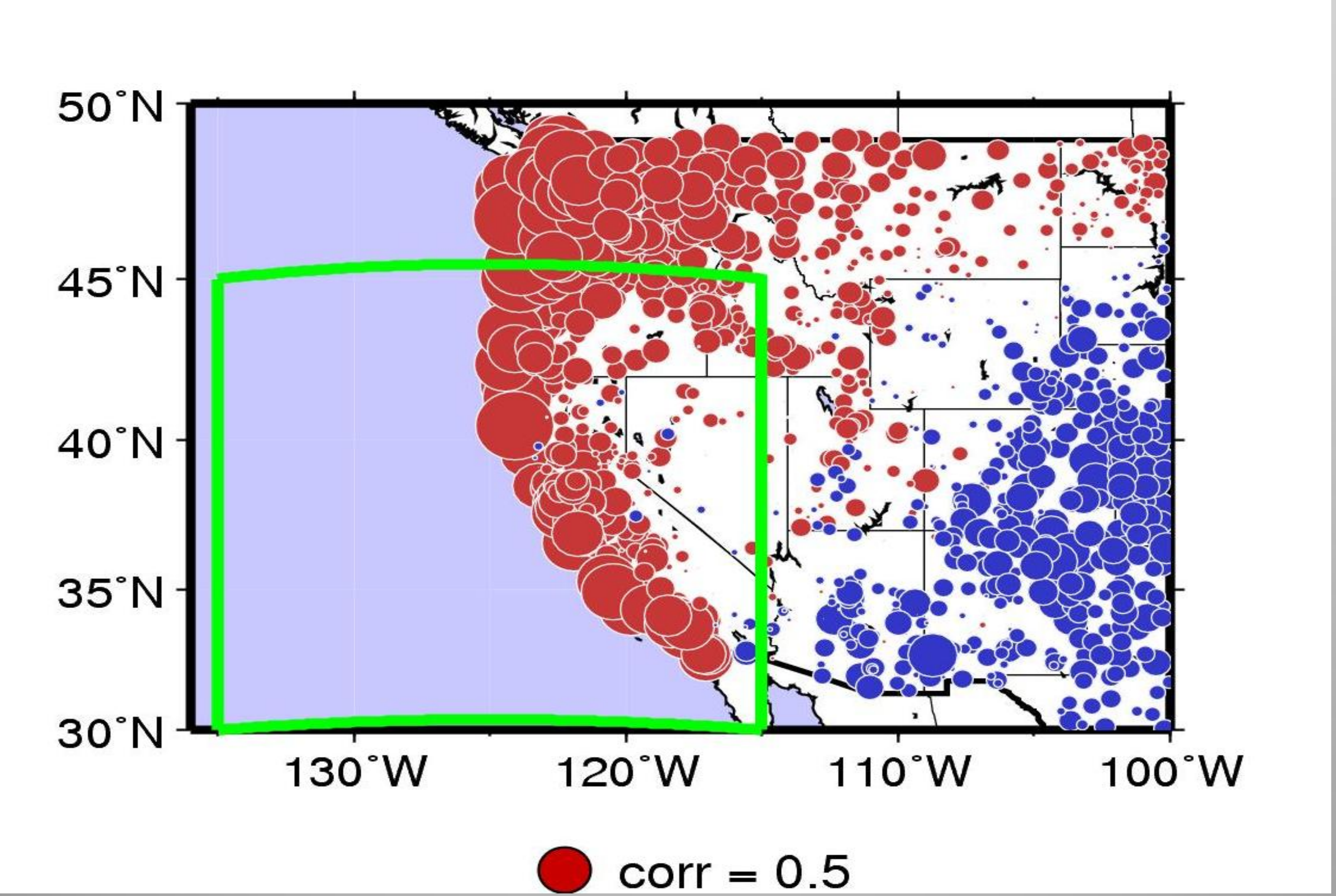
California experiences extremely heavy precipitation!



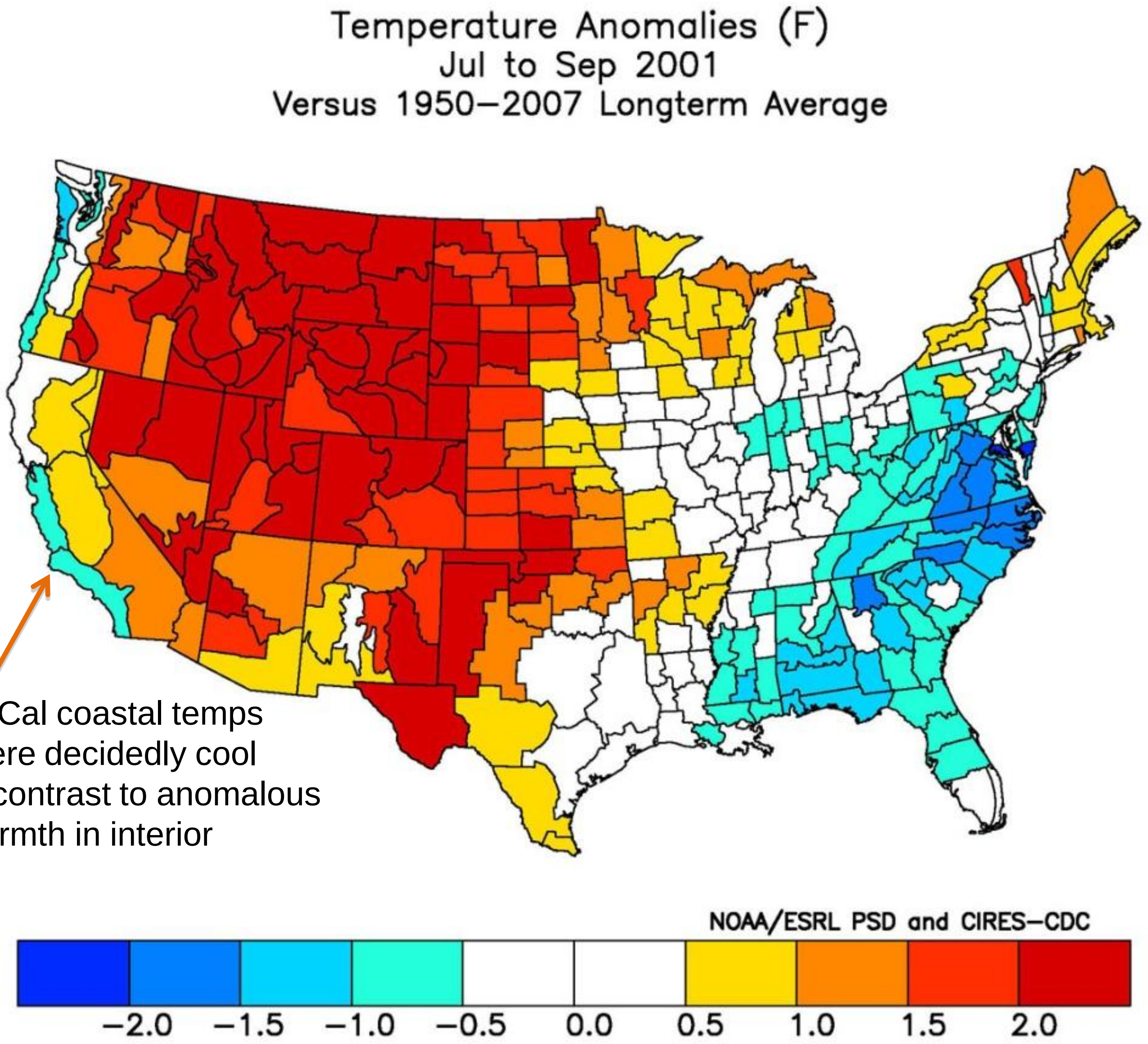
Stations that have recorded the highest 3-day precipitation amounts

Numbers of non-overlapping 3-day precipitation totals at COOP weather stations that exceeded 40 cm (15.75”) from 1950-2008.

Mike Dettinger USGS/SIO



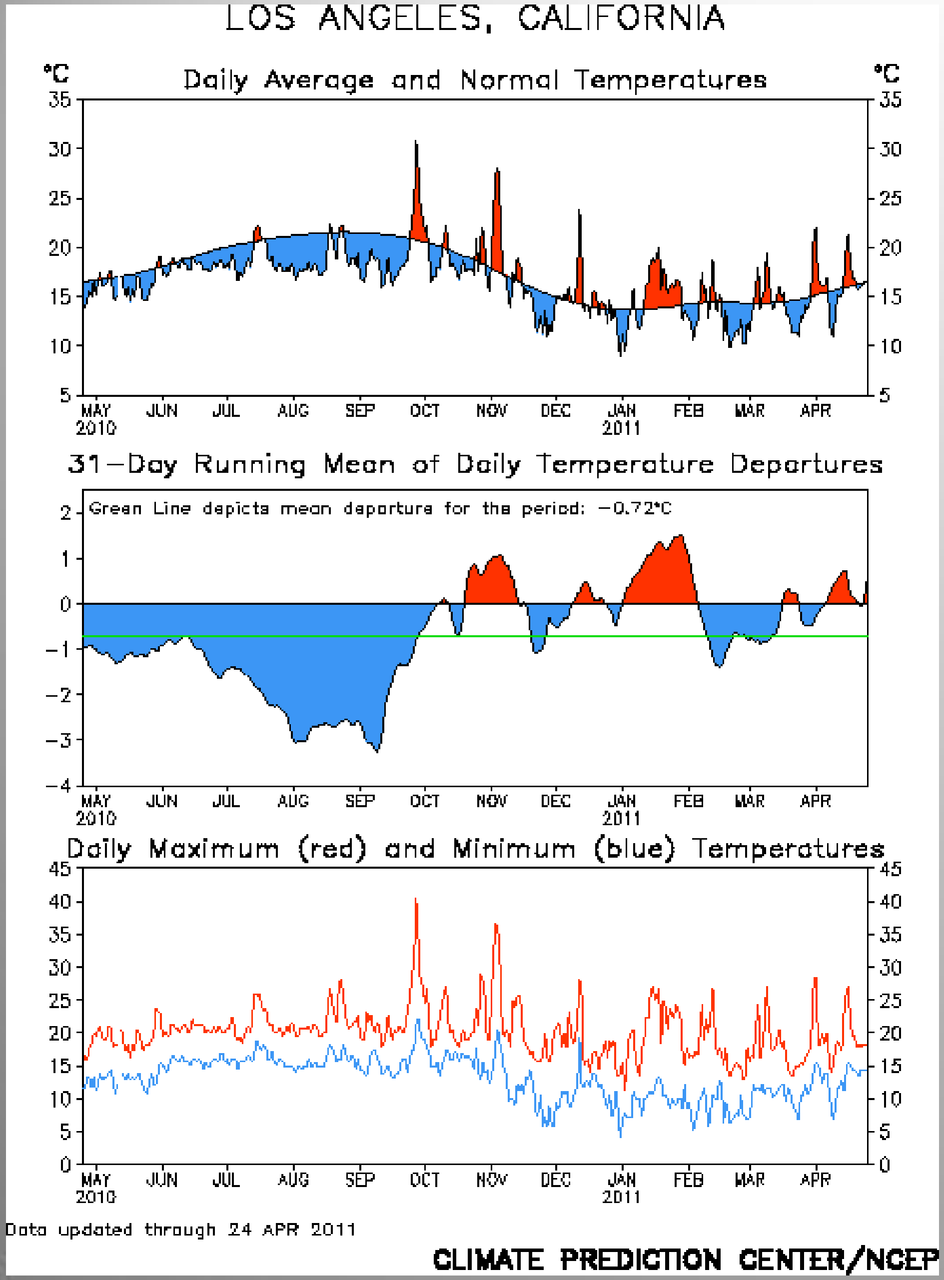
Sea Surface temperatures along California coast correlate strongly with air temperatures (August Tmin) over West Coast. Atmospheric circulation plays a strong role--correlations operate on much broader than coastal scale

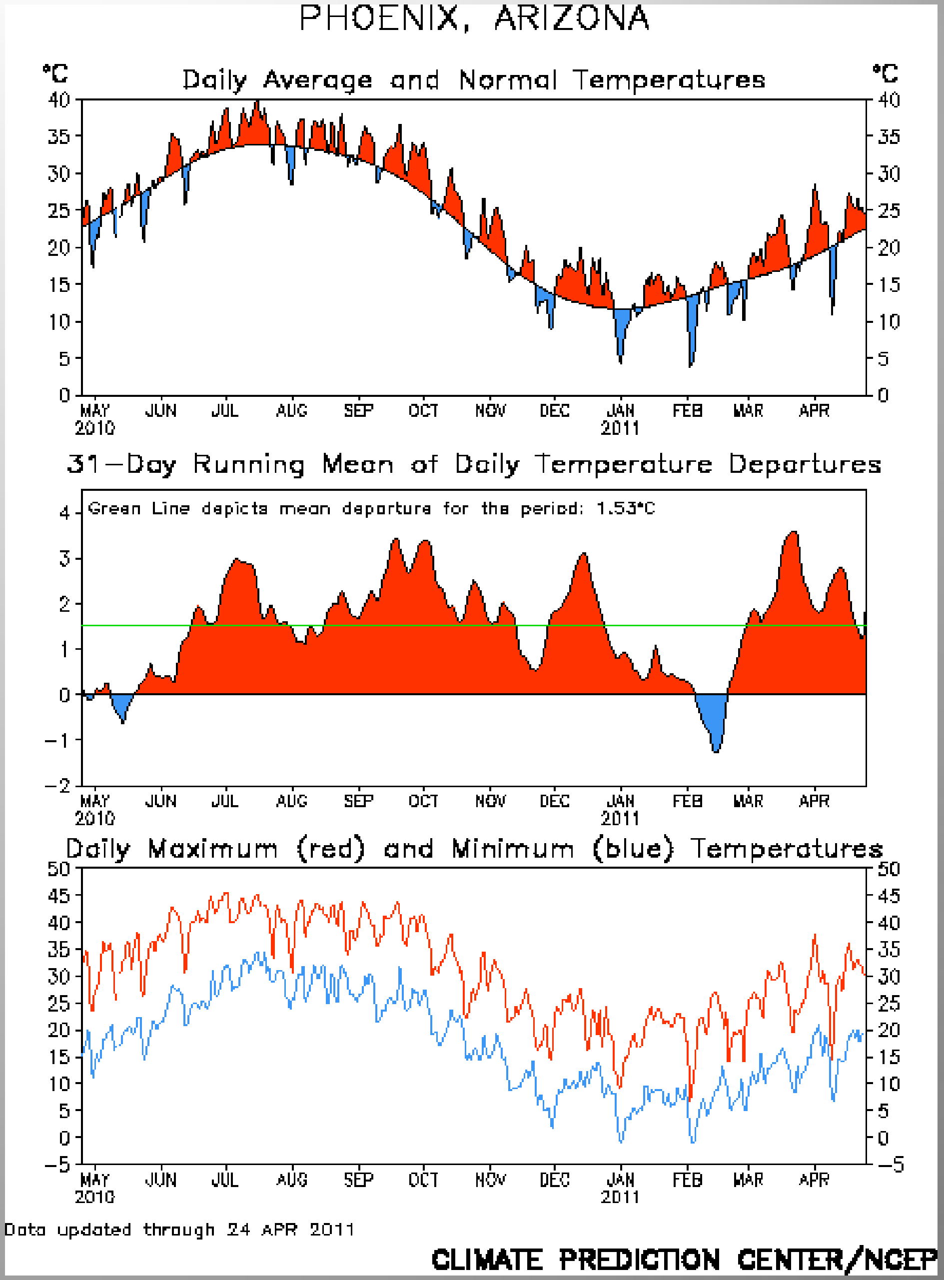


SoCal coastal temps
Were decidedly cool
in contrast to anomalous
warmth in interior

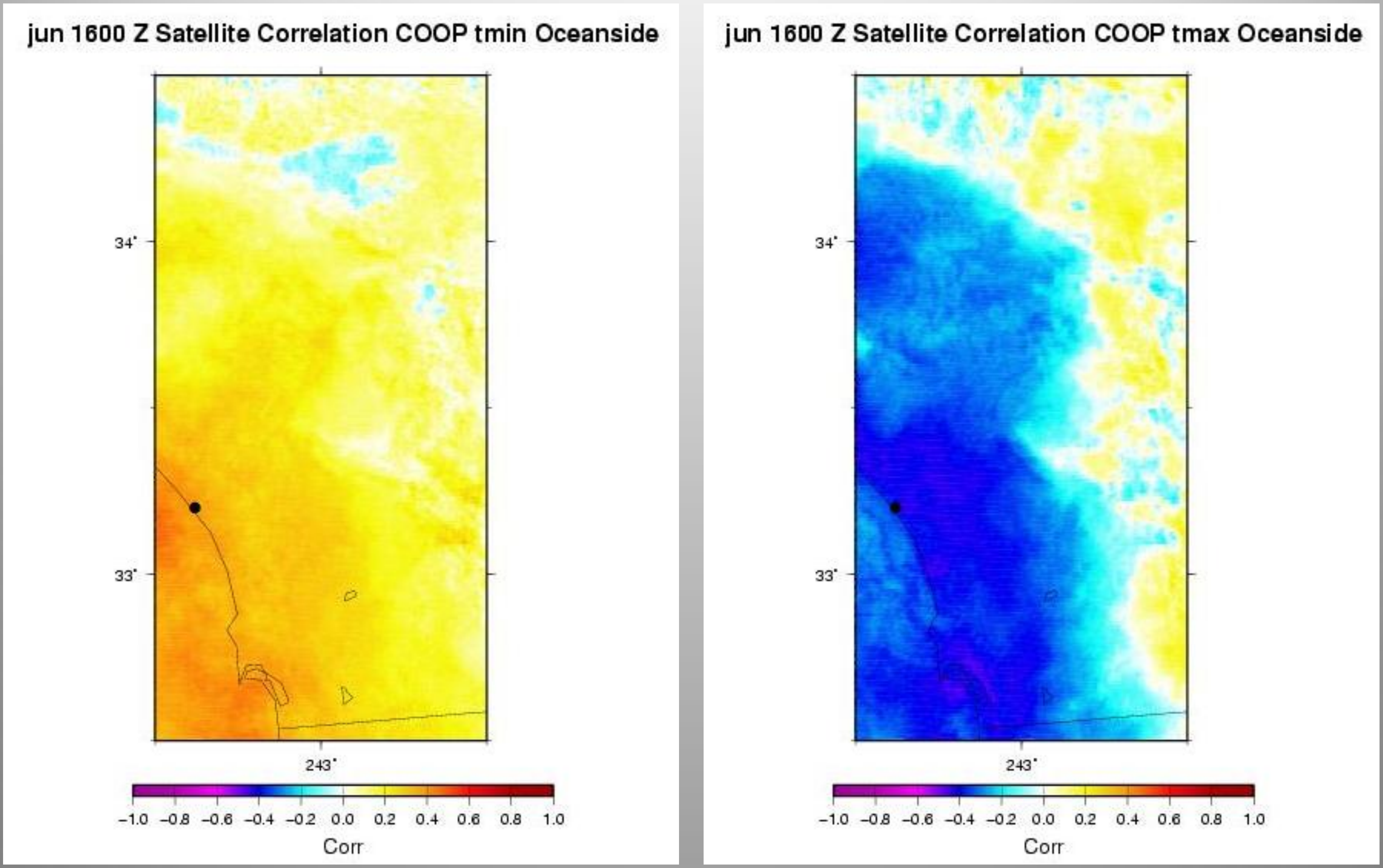
Summer 2010 exemplified an accentuated coastal influence

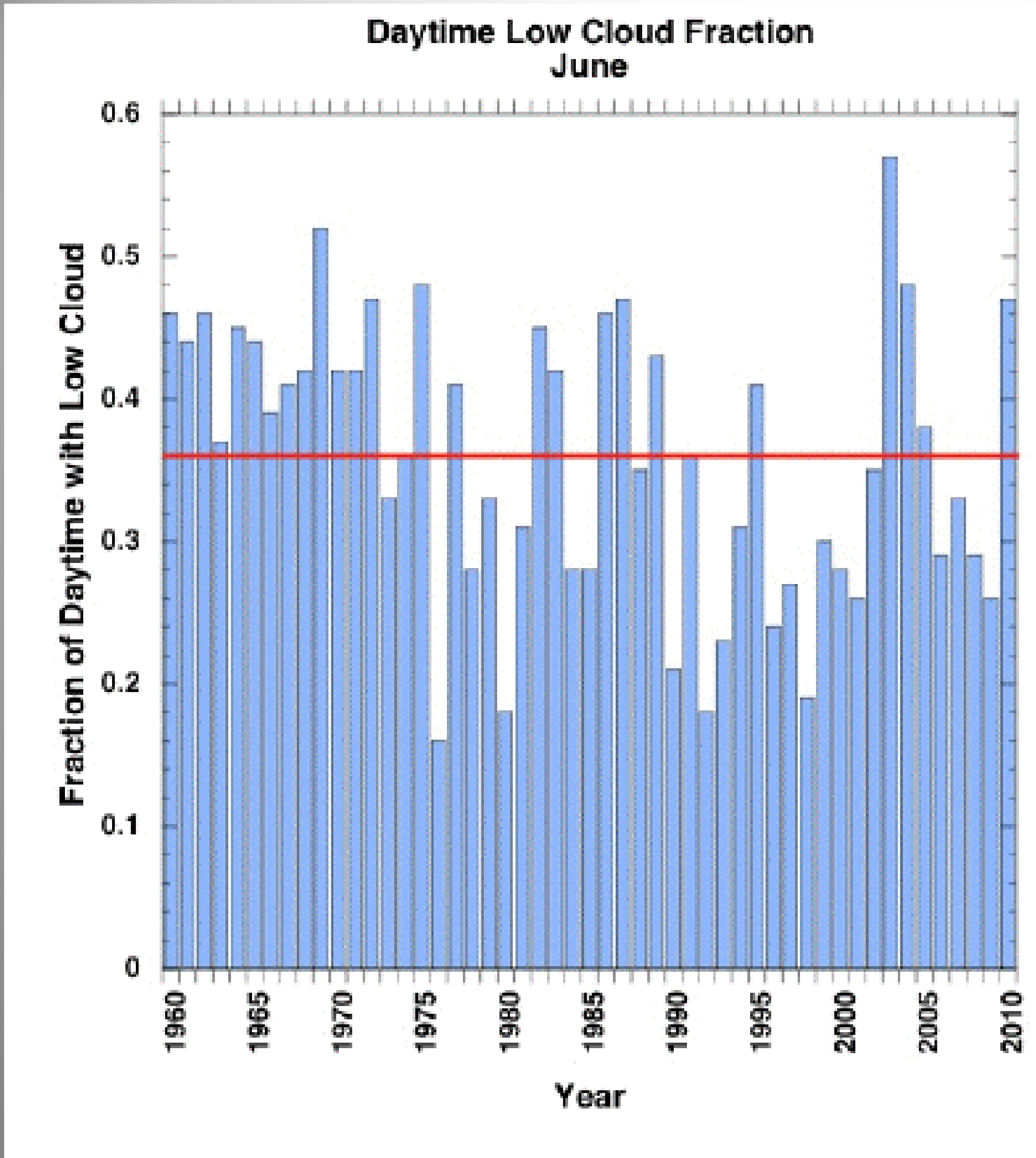
2010-2011 temperatures Los Angeles vs. Phoenix





MODIS Terra: Jun 5, 2010


jun 1600 Z Satellite Correlation COOP tmin Oceanside
34˚
33˚
243˚
−1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.8 1.0
Corr
jun 1600 Z Satellite Correlation COOP tmax Oceanside
34˚
33˚
243˚
−1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.8 1.0
Corr



Cloudiness is highly variable over yearly and decadal time scales

Monthly Low Cloud Fraction at San Diego from 1960-2010 based on KSAN Airport data

June 1949-2010

Red line = long-term monthly mean

since 1985 the number of large wildfires in western U.S. increased by 4X

Anthony Westerling et al. Science August 2006

13 major fires in CA& Mex.

> 300K hectares (750K acres)

24 lives lost

239 injured

4866 structures lost

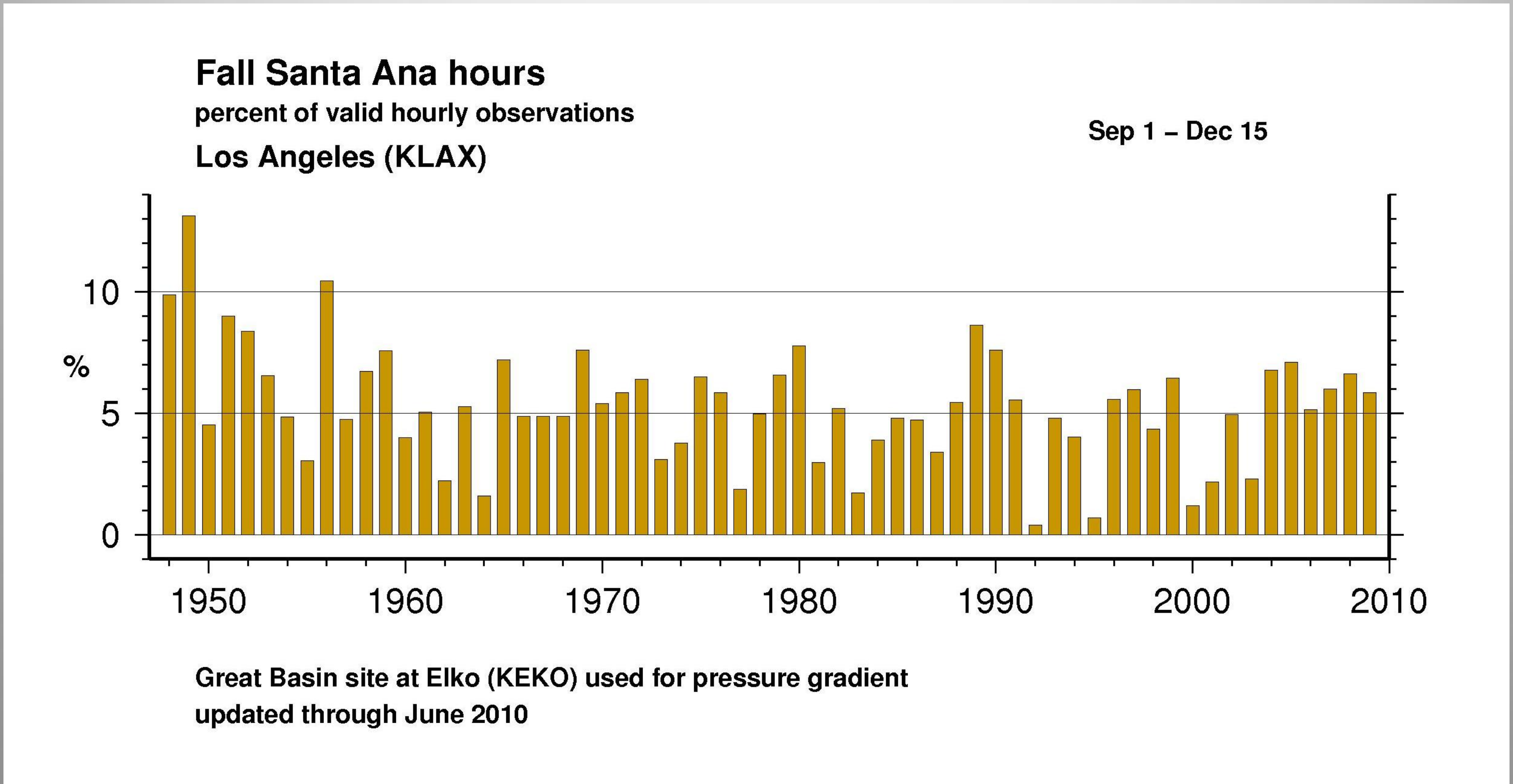
> $2 billion in insured losses

$176 million in disaster relief

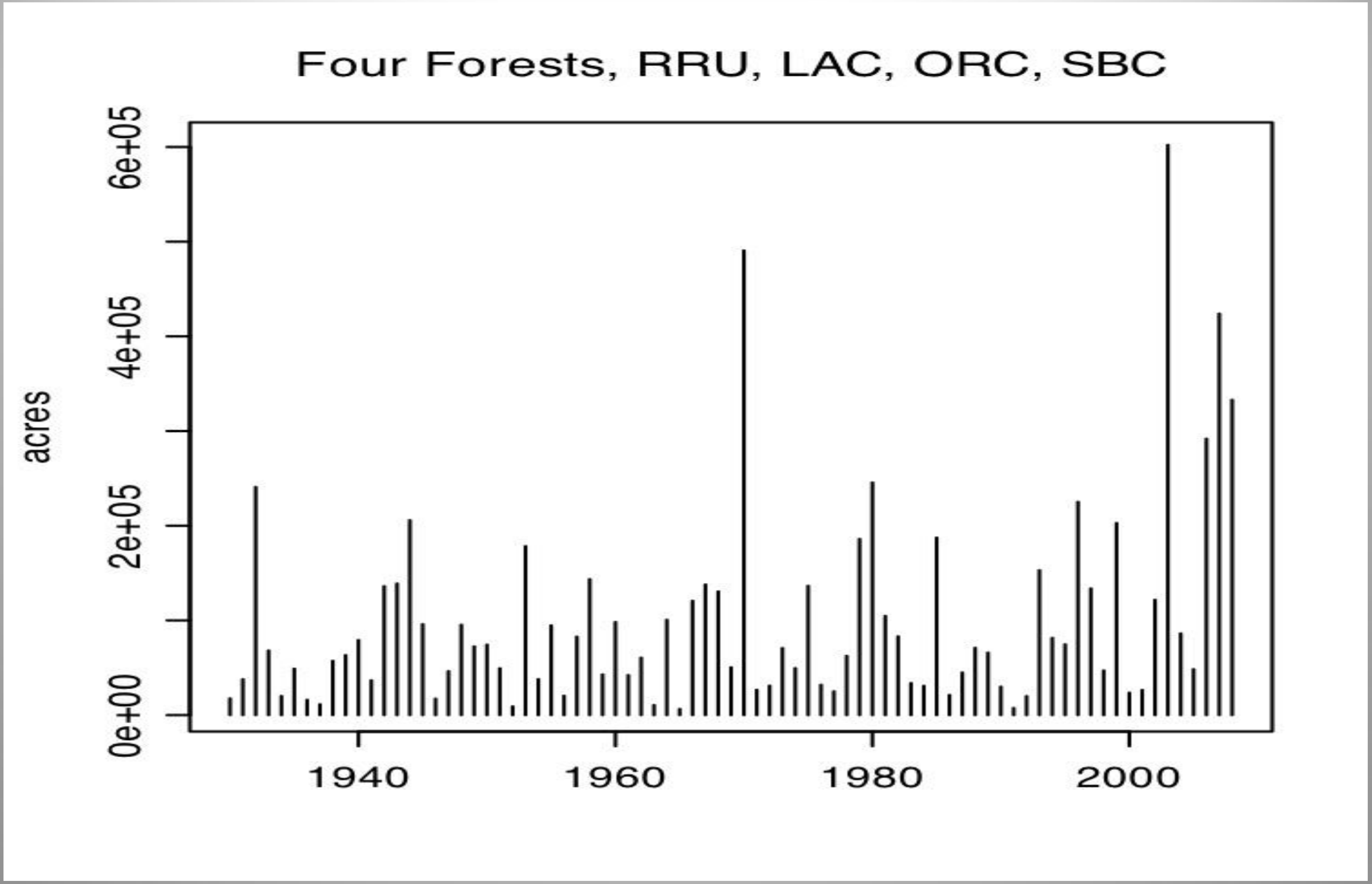
$116 million in suppression costs

Largest fire (Cedar) and largest fire siege in California history

Santa Ana occurrence varies greatly from year to year



Based upon dew point temp and wind direction at Los Angeles (LAX)
and SLP difference Elko-Los Angeles



Area Burned 1930 – 2008: an increasing trend?

four national forests, Riverside Co, Riverside Co, LA Co, Santa Barbara County

Los Padres, San Bernadino, Angeles, Cleveland

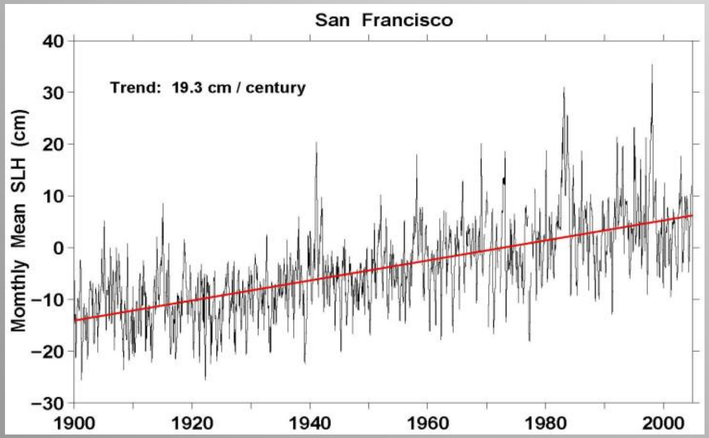
Tony Westerling, UC Merced

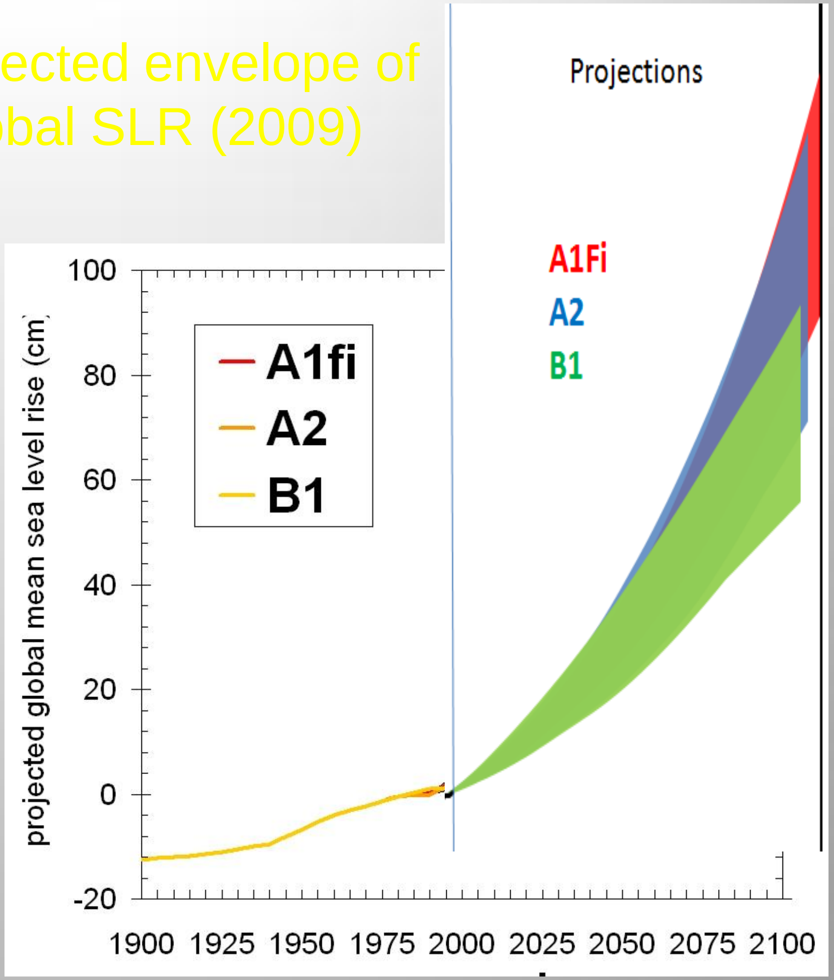
during high sea levels, the sea is often *not* quiescent

Observed SFO (left) and modeled Global (right). Sea level rise estimates based upon an envelope of output from several GHG emission scenarios

Projected envelope of global SLR (2009)

observed





Climate models only provide loose guidance on the amount of sea level rise—full physics models are still under development.

But it is quite likely that rates will increase greatly in future decades

OBSERVATIONS AND MODELS INDICATE:

Southern California's dry, volatile climate will likely present even more challenges as global climate changes ramp up during the next several decades.

Southern California's hydrology is prone to dry spells whose impacts could be exacerbated in a warmer climate. Recent climate model projections for western precipitation are scattered, but *several* show moderate drying as tends to be characteristic of Mediterranean regions globally.

Sea level rise could pose enormous challenges to California's ecosystems and society. Recent estimates are varied, but many experts think that global sea level could rise 1 meter or more above present-day levels by 2100, a rate which will be difficult for natural and human systems to adjust to

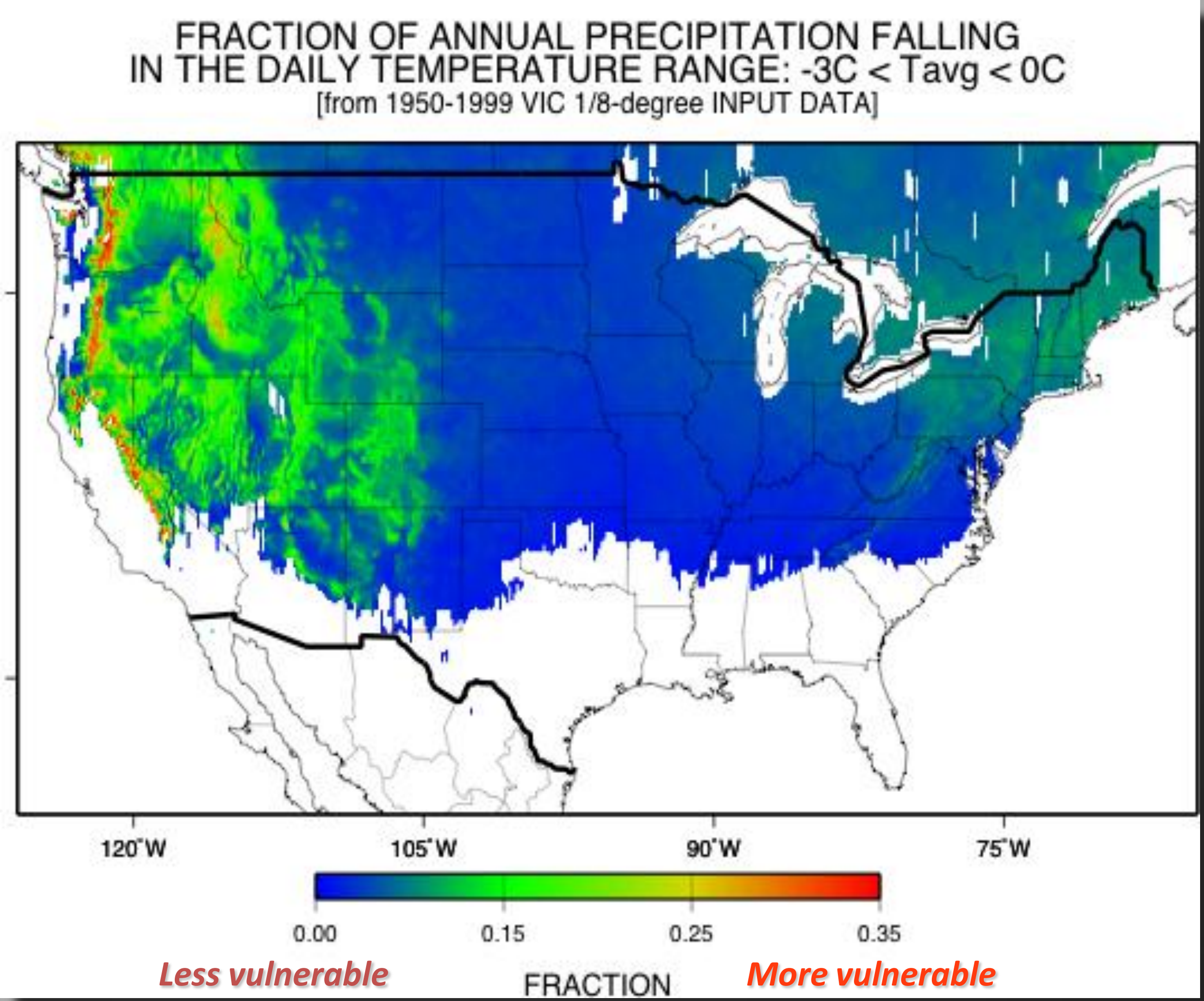
Recent climate model projections suggest that warming may be greater in summer.

Sustained monitoring of climate and climate-affected systems is critical to detect and understand changes and to plan for the future.

Frank Gehrke,
California Cooperative Snow Surveys, DWR

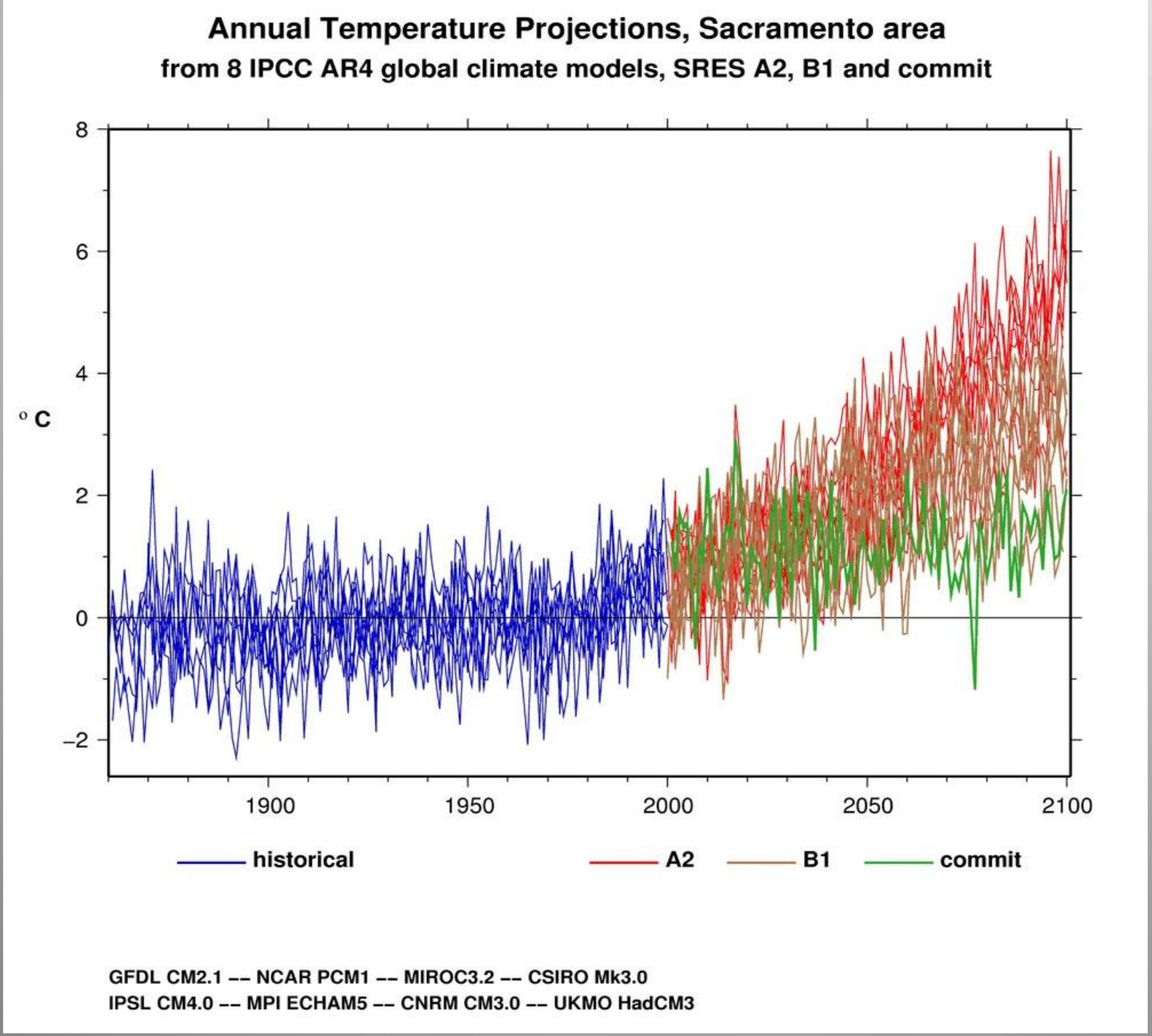
SENSITIVITY TO A +3ºC WARMING…

landscapes of the western United States, such as the west slope of the Sierra Nevada, have a significant fraction of their water budget falling in a temperature zone that is vulnerable to climate warming.



"Rain vs Snow"

Computed by Mike Dettinger from gridded historical US weather data (from Bates et al,2006 WRR)


Annual Temperature Projections, Sacramento area
from 8 IPCC AR4 global climate models, SRES A2, B1 and commit
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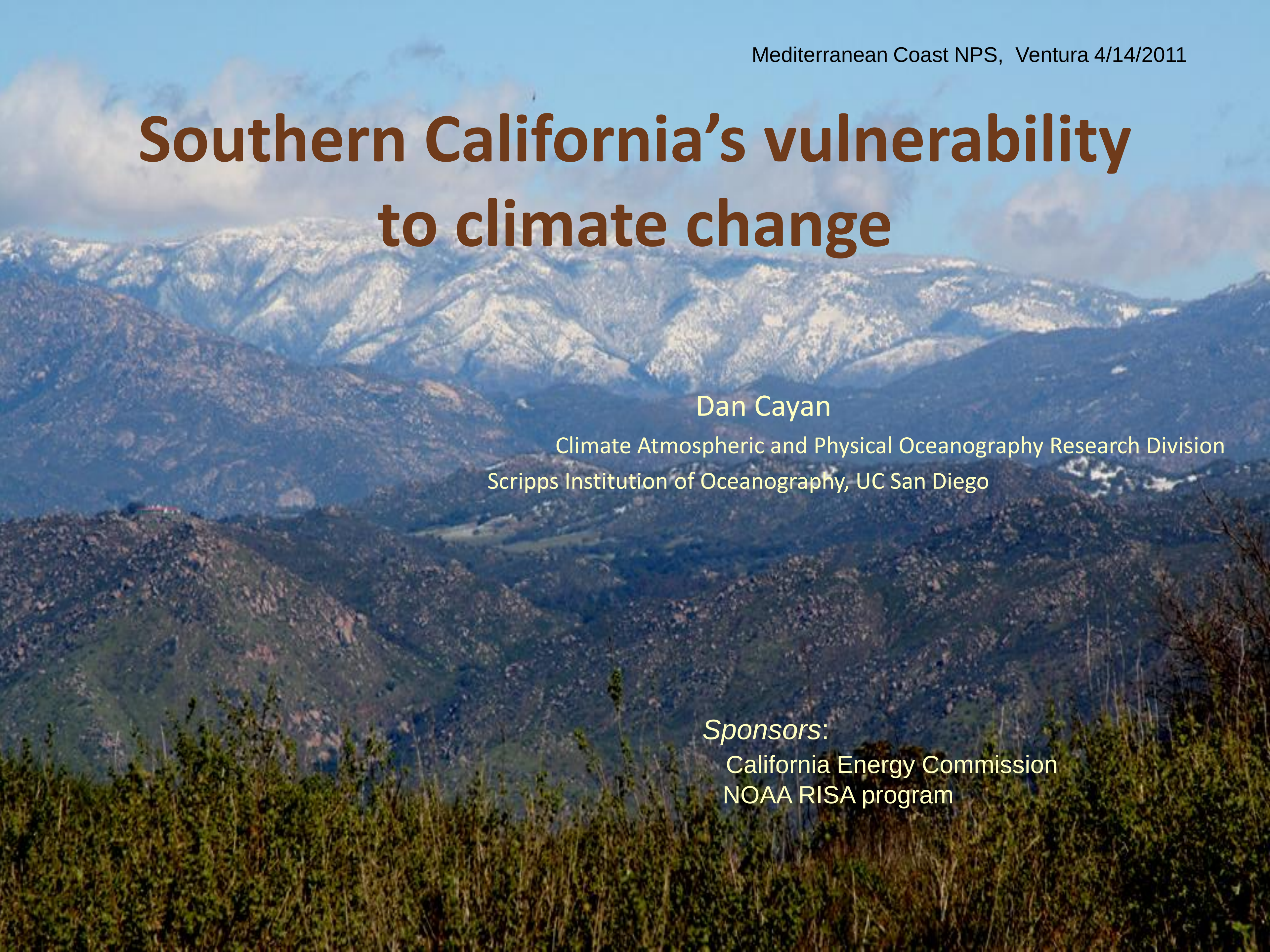
° C
1900
1950
2000
2050
2100
historical
A2
B1
commit
GFDL CM2.1 -- NCAR PCM1 -- MIROC3.2 -- CSIRO Mk3.0
IPSL CM4.0 -- MPI ECHAM5 -- CNRM CM3.0 -- UKMO HadCM3



Southern California's vulnerability to climate change

Dan Cayan

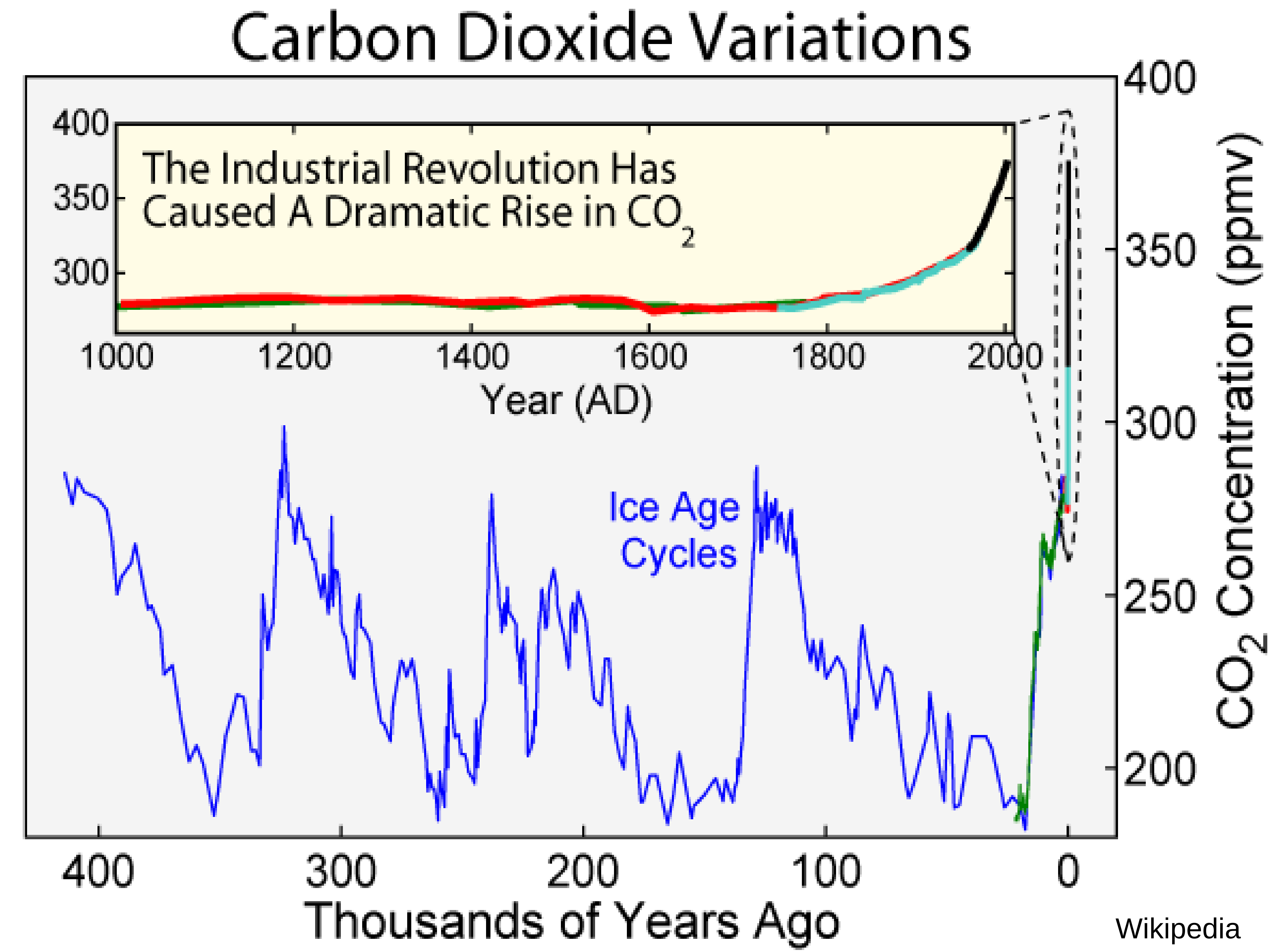
Climate Atmospheric and Physical Oceanography Research Division

Scripps Institution of Oceanography, UC San Diego

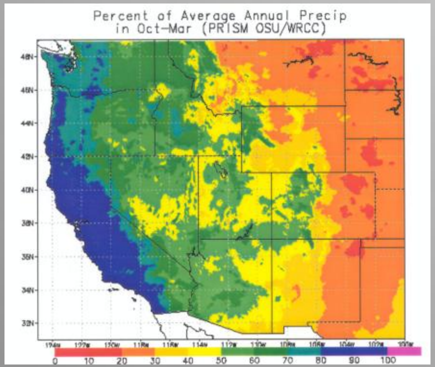
Sponsors:

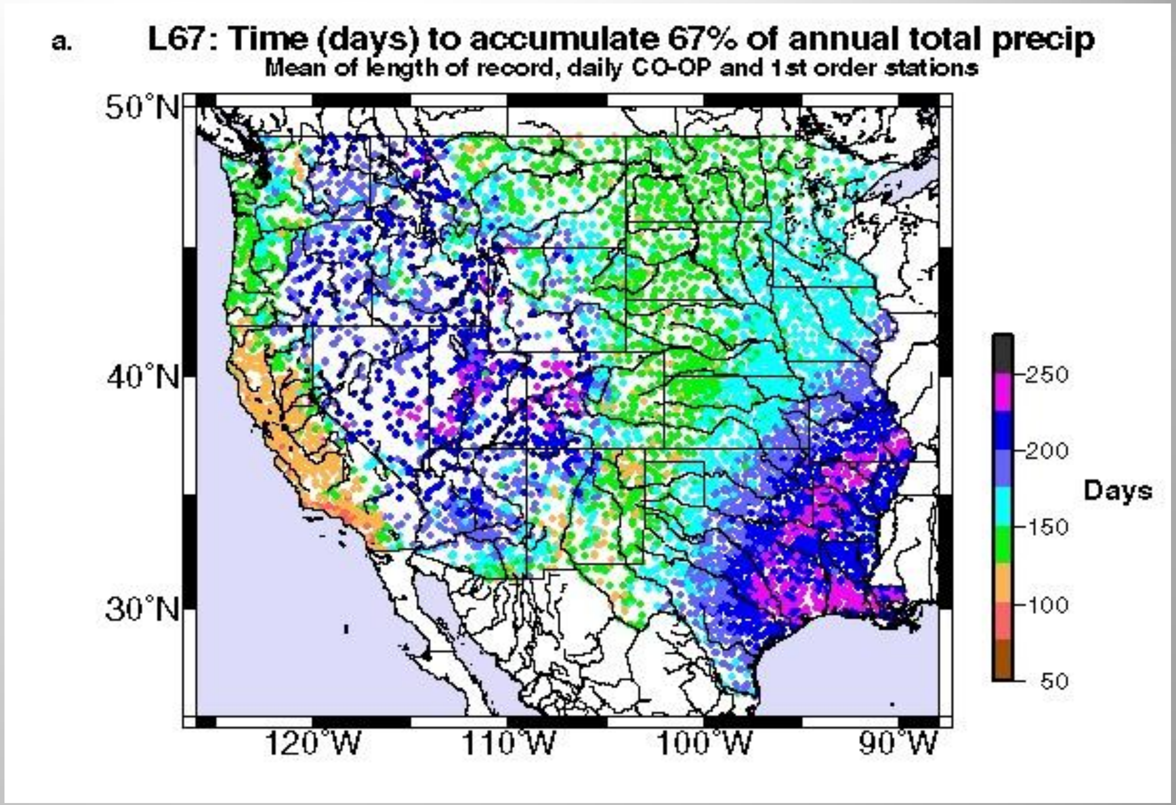
California Energy Commission

NOAA RISA program

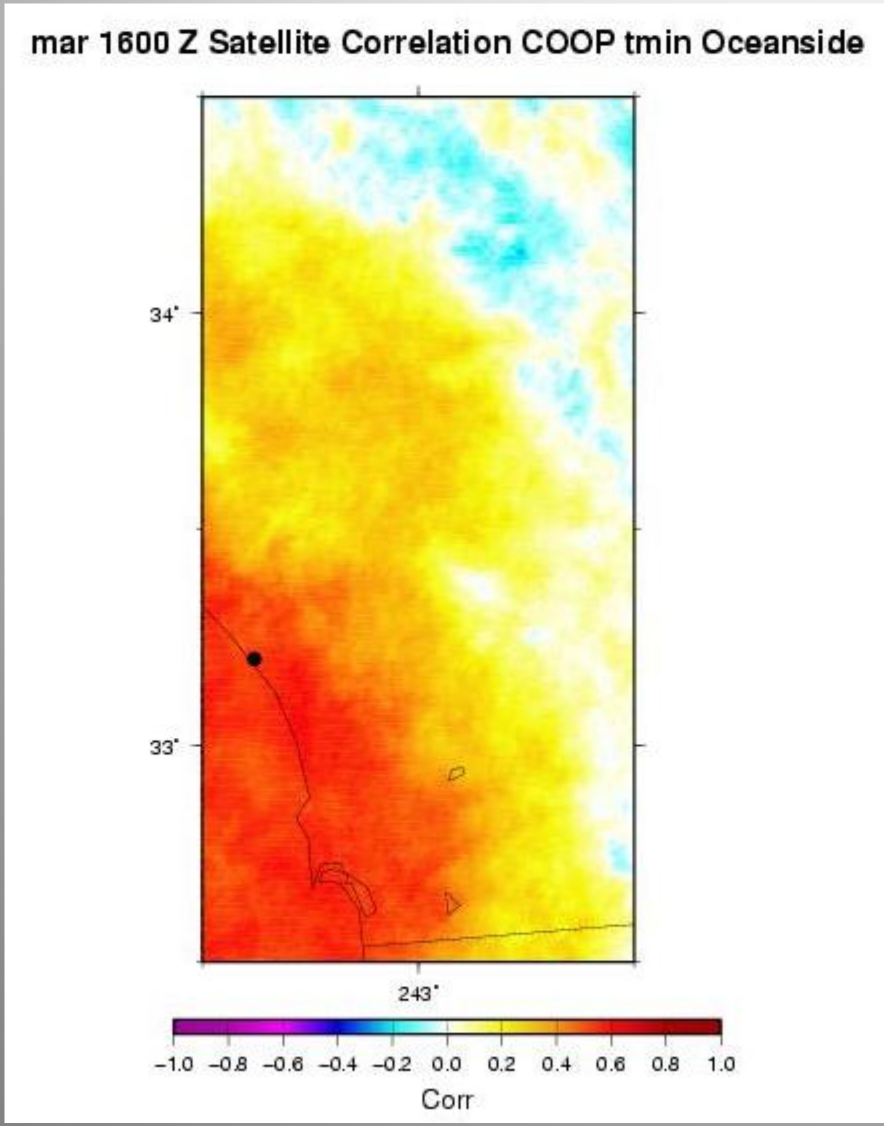

Carbon Dioxide Variations
The Industrial Revolution Has Caused A Dramatic Rise in CO_2
400
350
300
1000
1200
1400
1600
1800
2000
Year (AD)
Ice Age Cycles
400
350
300
250
200
CO_2 Concentration (ppmv)
400
300
200
100
0
Thousands of Years Ago
Wikipedia

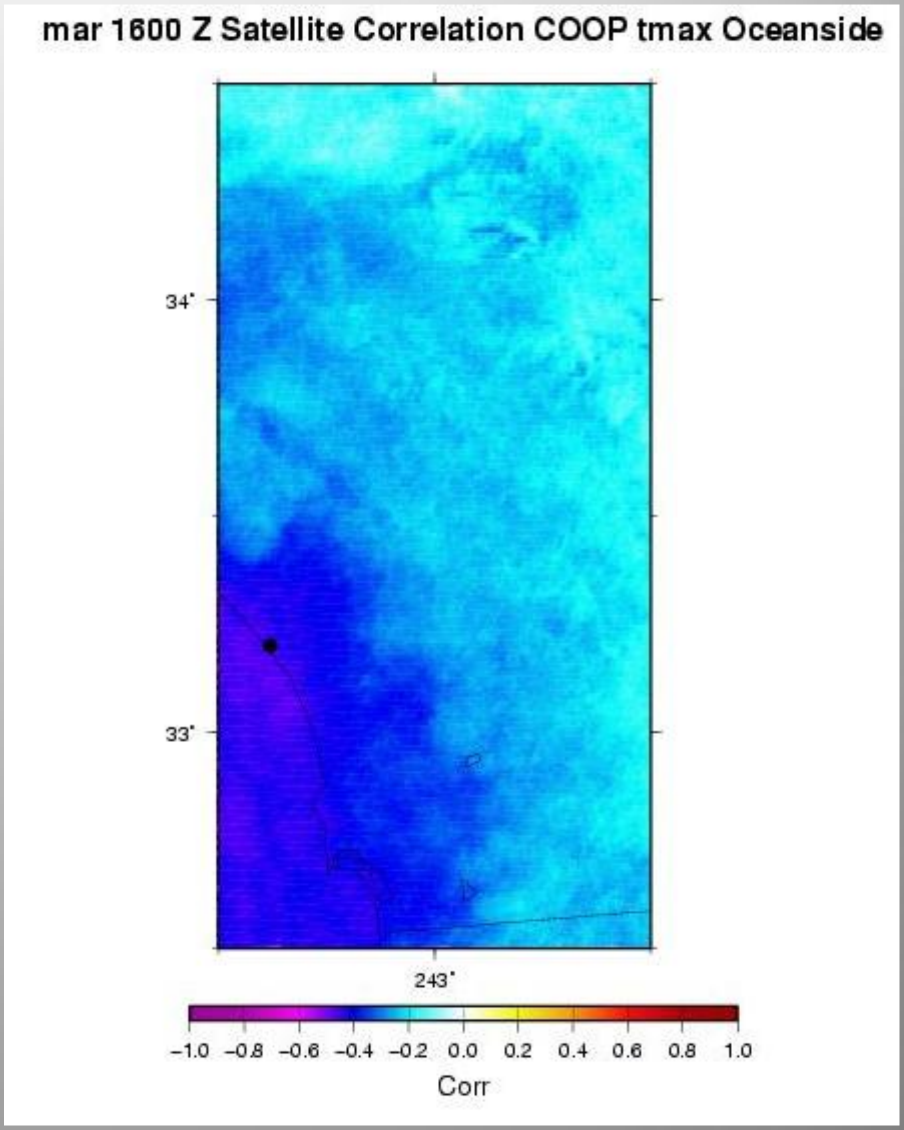
North Pacific storms are seasonal *so* California's Precipitation season is very brief





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


mar 1600 Z Satellite Correlation COOP tmin Oceanside
34˚
33˚
243˚
−1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.8 1.0
Corr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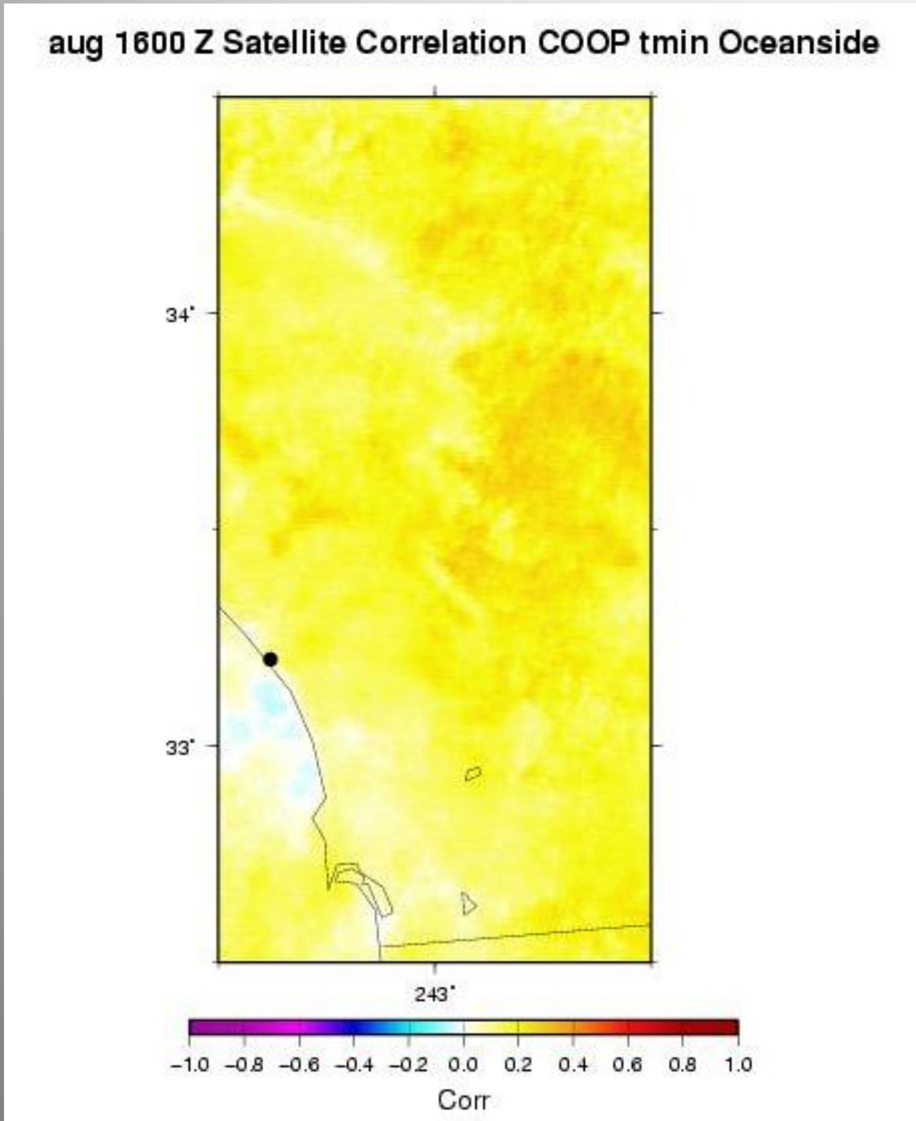
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33˚
243˚
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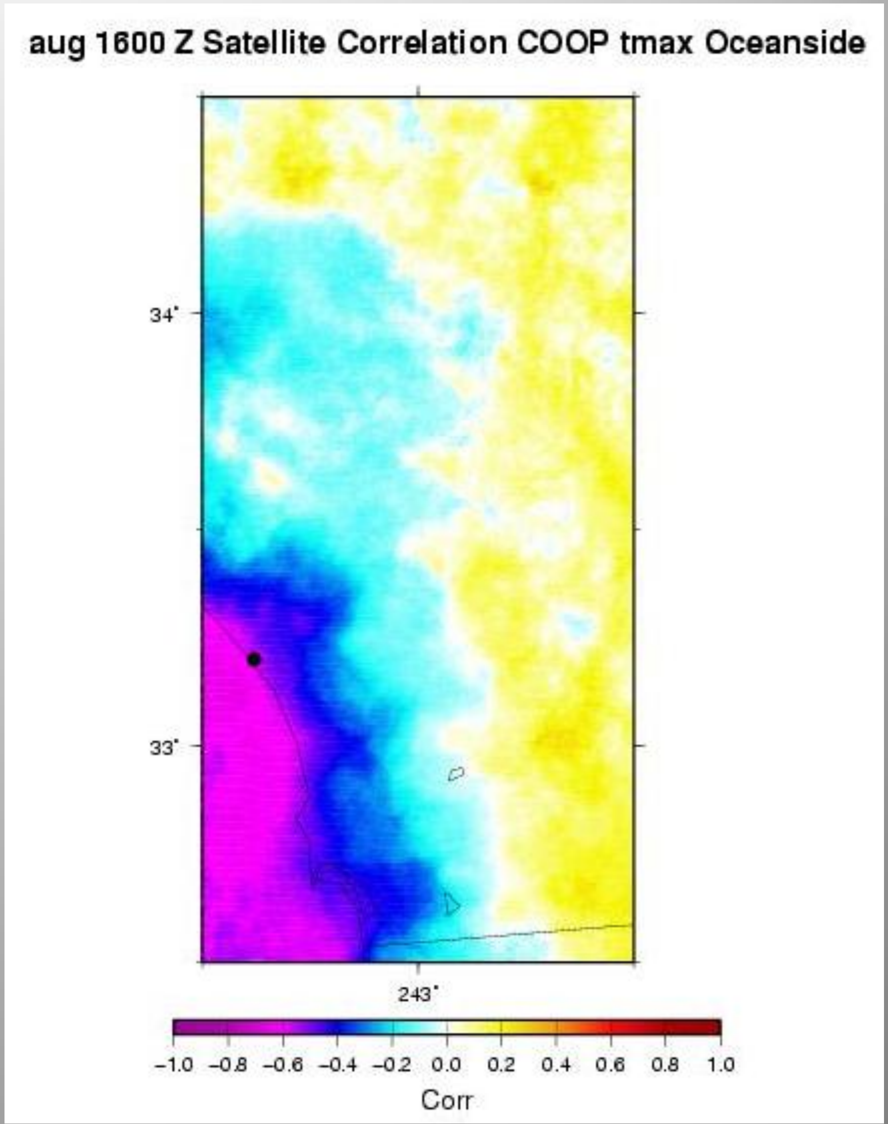
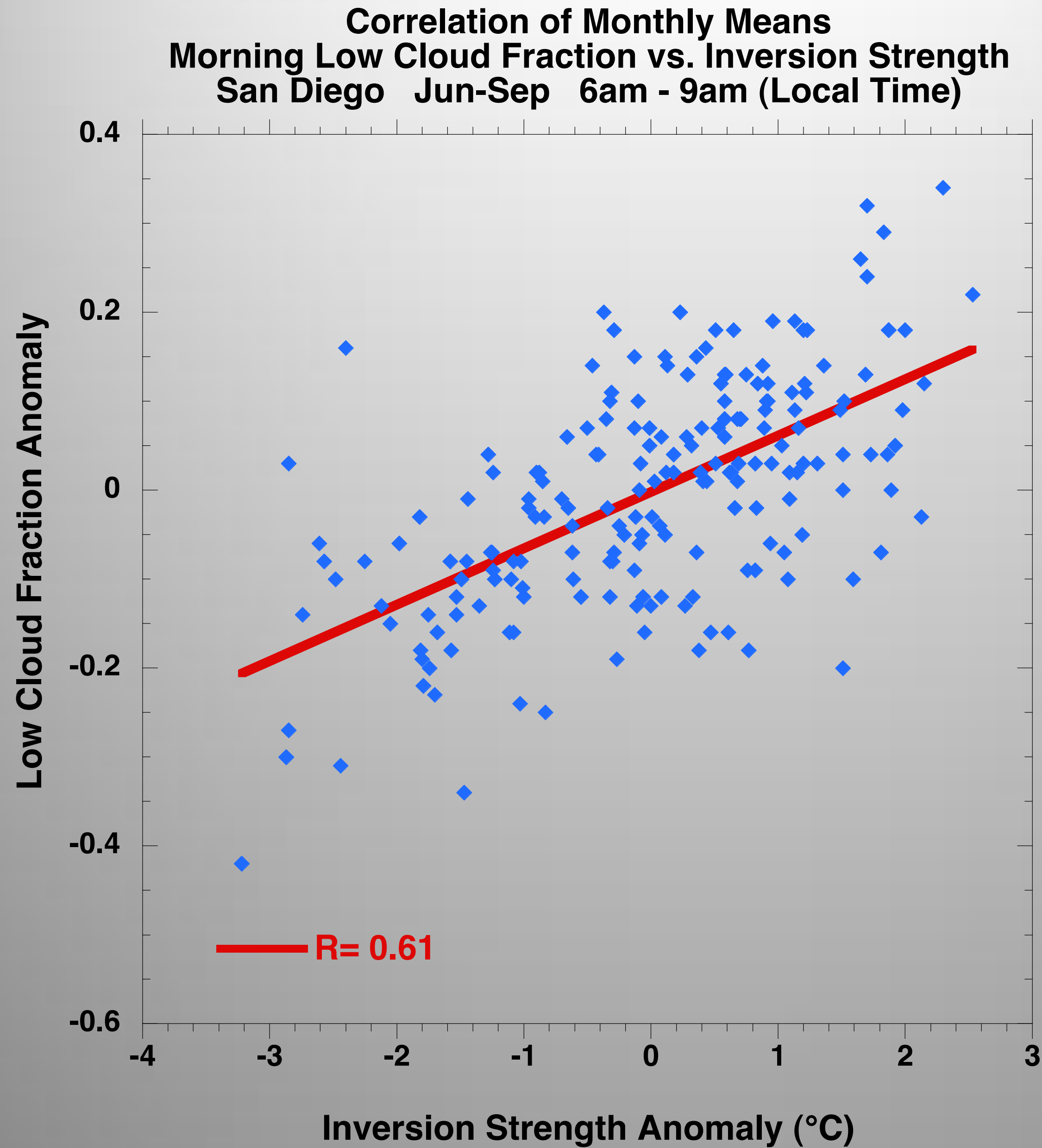
Corr


aug 1600 Z Satellite Correlation COOP tmax Oceanside
34˚
33˚
243˚
−1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.8 1.0
Corr

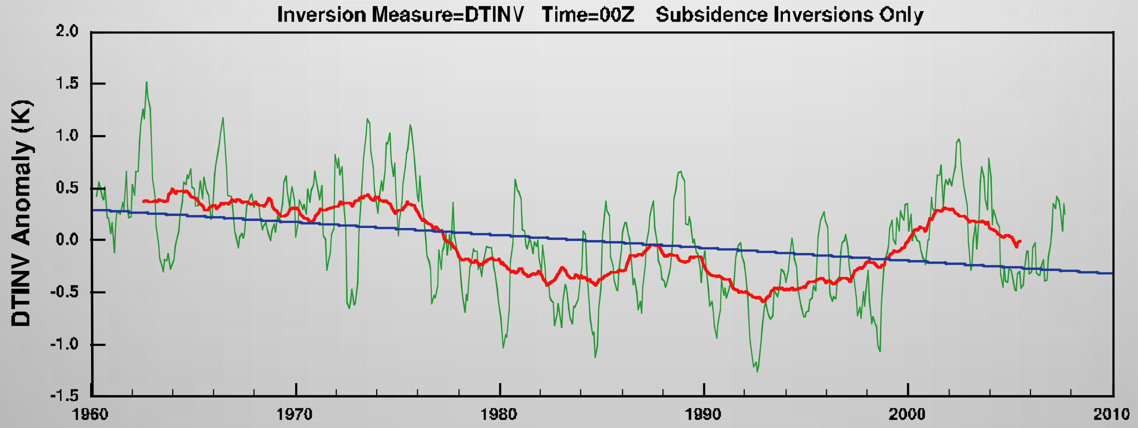


Correlation of Monthly Means
Morning Low Cloud Fraction vs. Inversion Strength
San Diego Jun-Sep 6am - 9am (Local Time)
0.4
0.2
0
-0.2
-0.4
-0.6
-4
-3
-2
-1
0
1
2
3
Low Cloud Fraction Anomaly
Inversion Strength Anomaly (°C)
R= 0.61

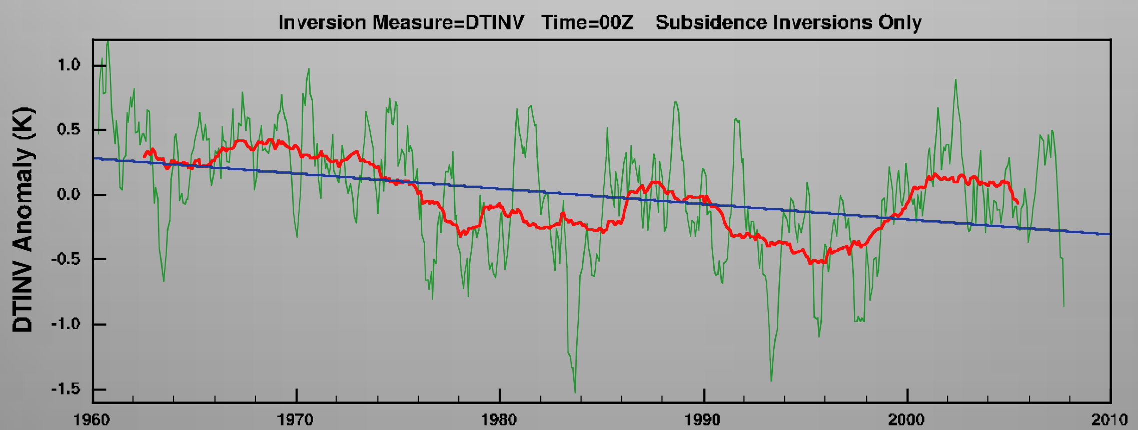
Inversion Strength from Radiosonde Measurements
Time period = 1960-2008 Subsidence Inversions Only

Green Curve = 6-month running mean
Red Curve = 5-year running mean
Blue line = long-term trend

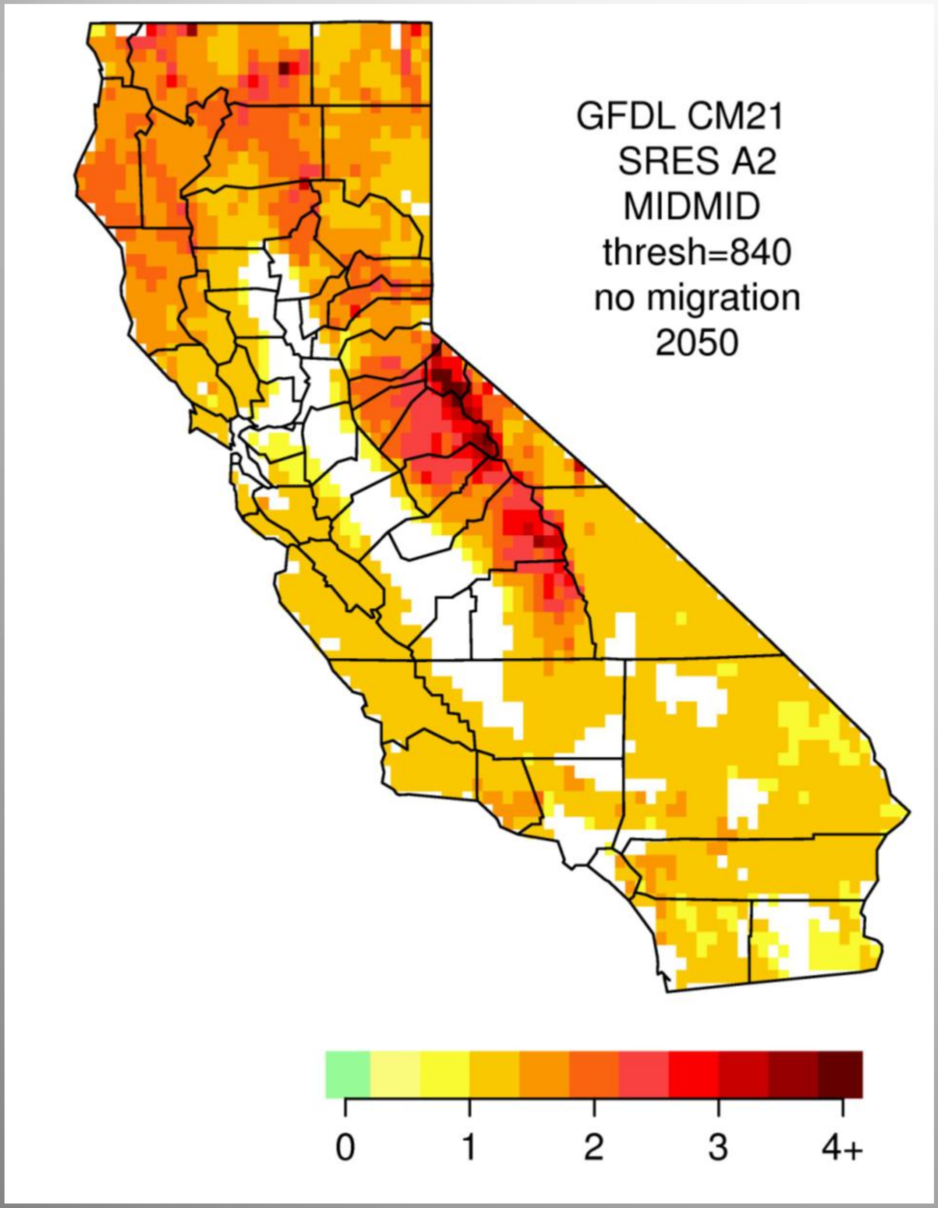
San Diego



Oakland

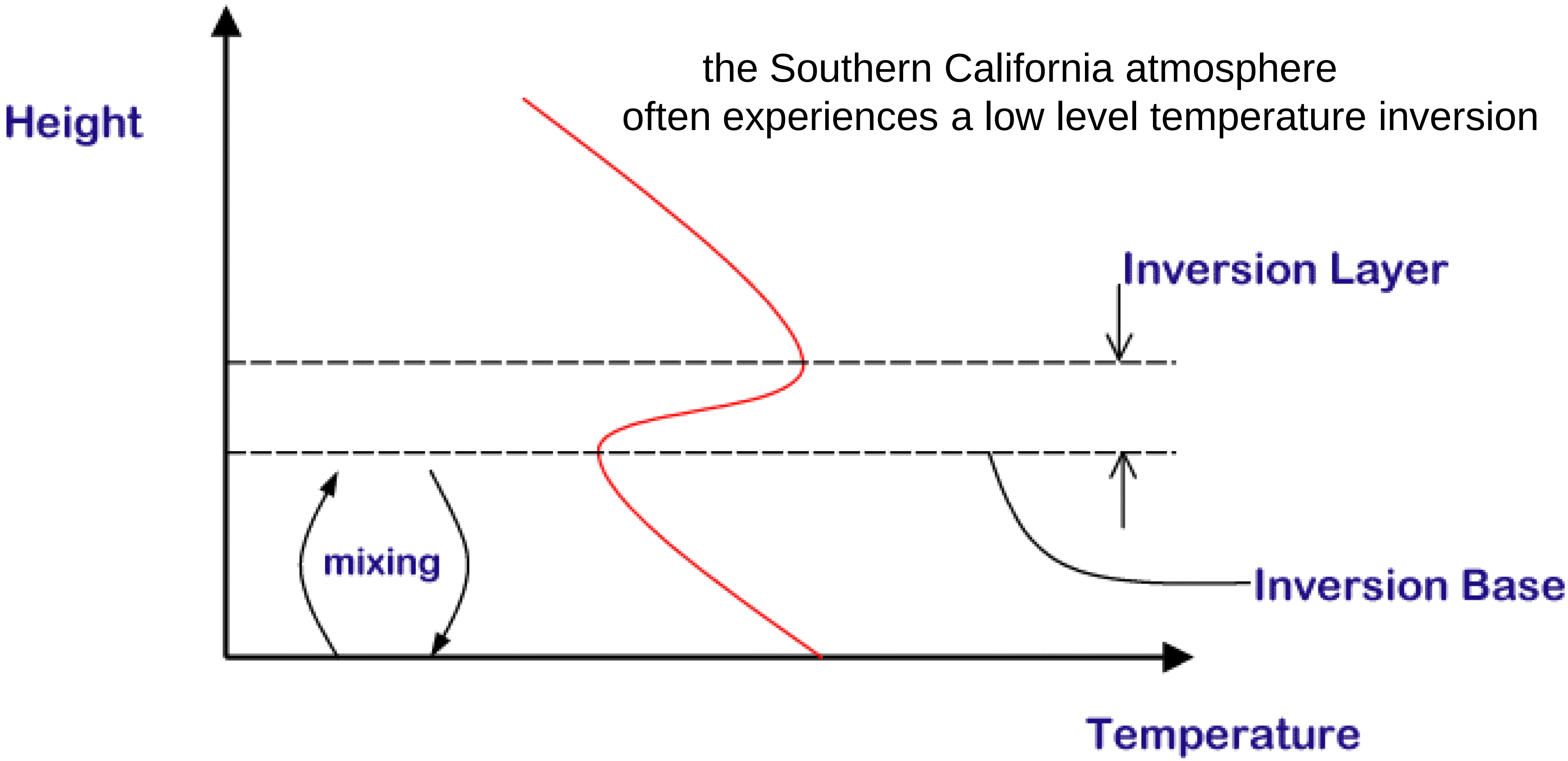


Climate warming and drying would likely exacerbate wildfire potential in California



Under warmer and somewhat
Drier climate by 2050, a
Statistical model indicates
Increases in wildfire frequencey
by 100-300% over much of California

Anthony Westerling, UC Merced


the Southern California atmosphere
often experiences a low level temperature inversion
Height
Inversion Layer
mixing
Inversion Base
Temperature

observations are essential
to track and understand climate impacts

Mosquitos!
Kern County, California—a good nights' catch, Bill Reisen UC Davis