PUC/CEC San Francisco 7/27/2015

Planning for climate change on top of already high climate variability

Dan Cayan

Scripps Institution of Oceanography, UC San Diego

USGS Water Resources Discipline

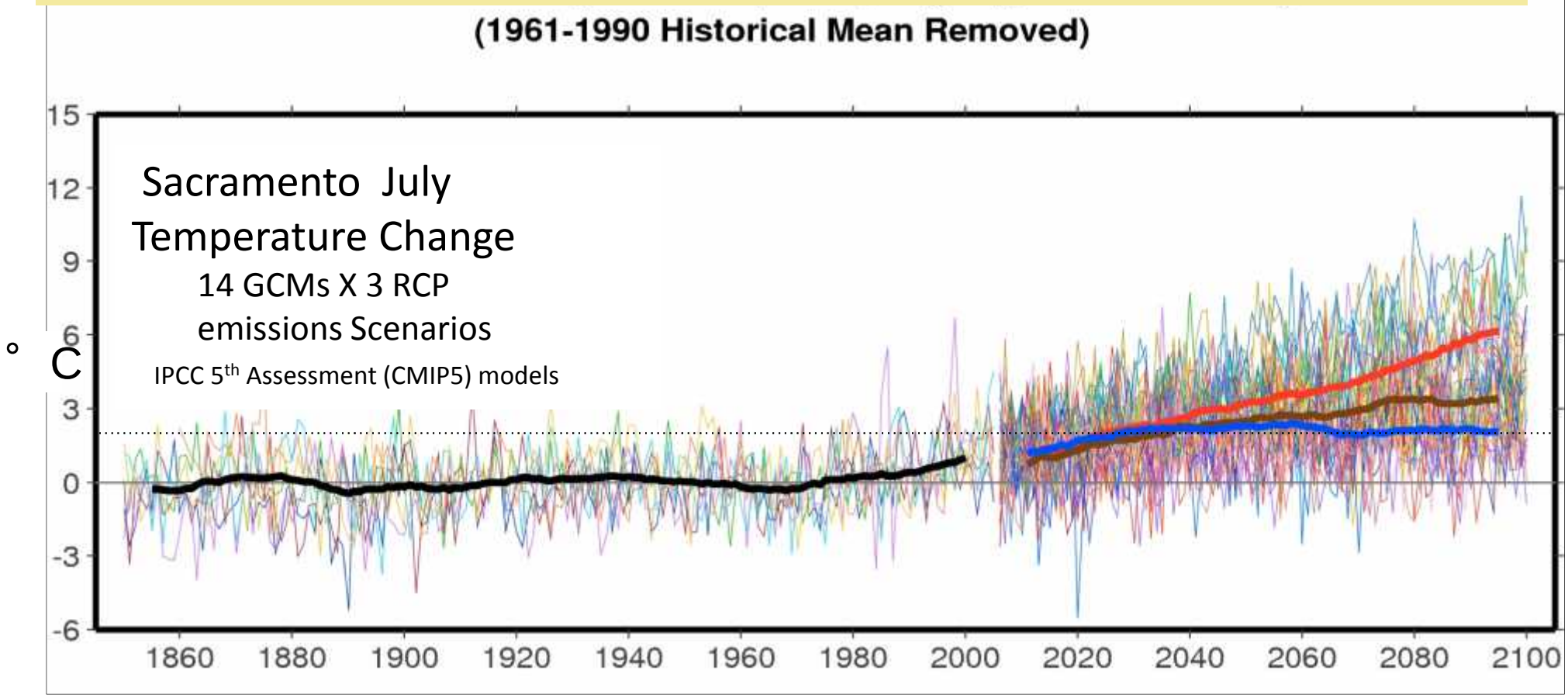
much support from David Pierce, Mary Tyree, and other colleagues

Sponsors:

California Energy Commission
NOAA RISA program
Southwest Climate Science Center
U.S. Army Corps of Engineers

Projected Climate Warming in California

near Sacramento 14 CMIP5 GCMs 3 RCPs (no downscaling)

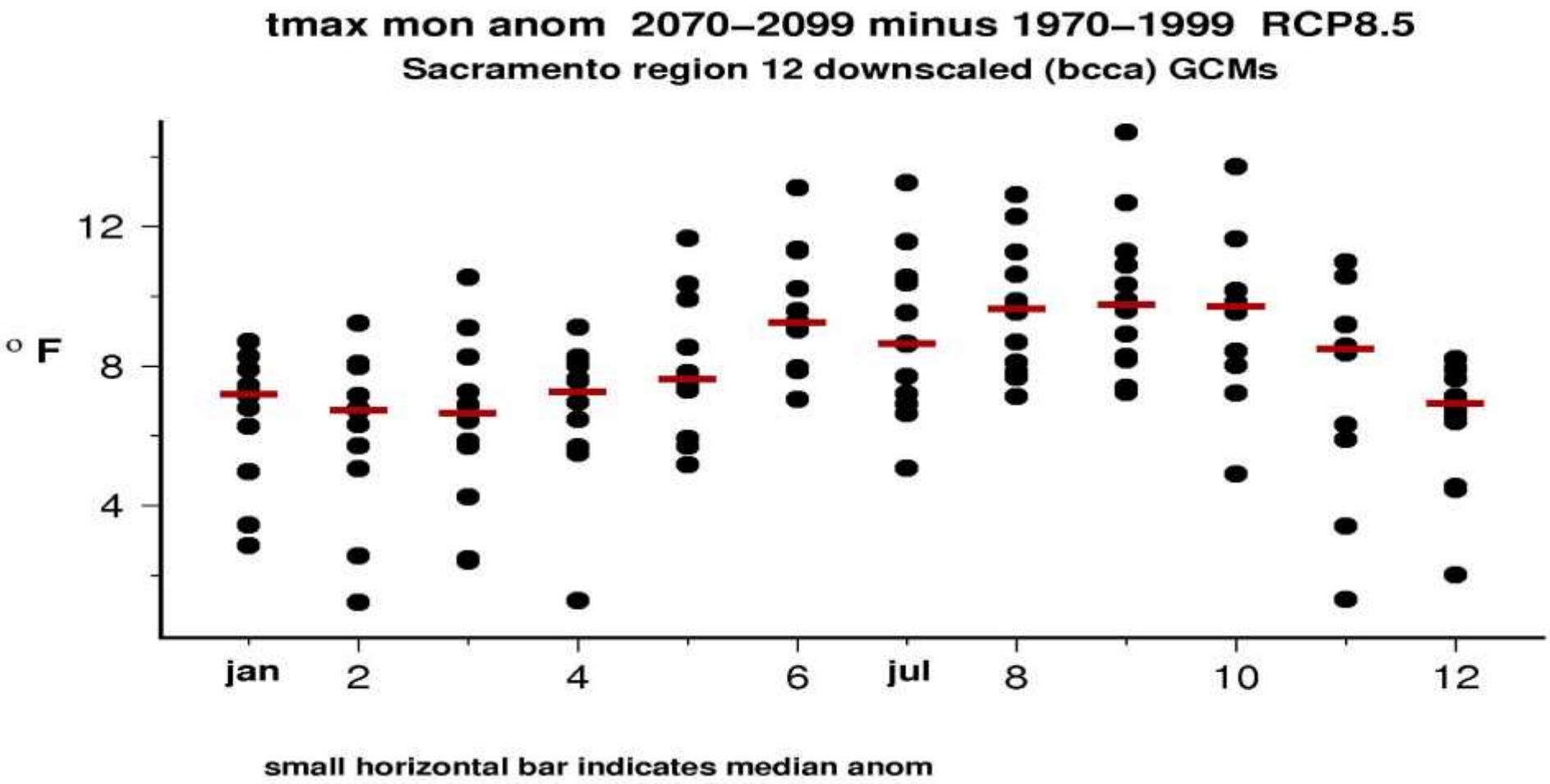


emissions pathways matter, but not much until mid-21st Century
high emissions scenario produces extraordinary amount of warming
even lowest emissions scenario reaches +2° C by ~2050
natural climate fluctuations continue to be large

Projected Warming is Intensified in Summer

12 downscaled AR5 GCMs

RCP 4.5 and RCP 8.5 emissions scenarios



Dependence of California Peak Electrical Load on Daily Tmax
2004 ISO data

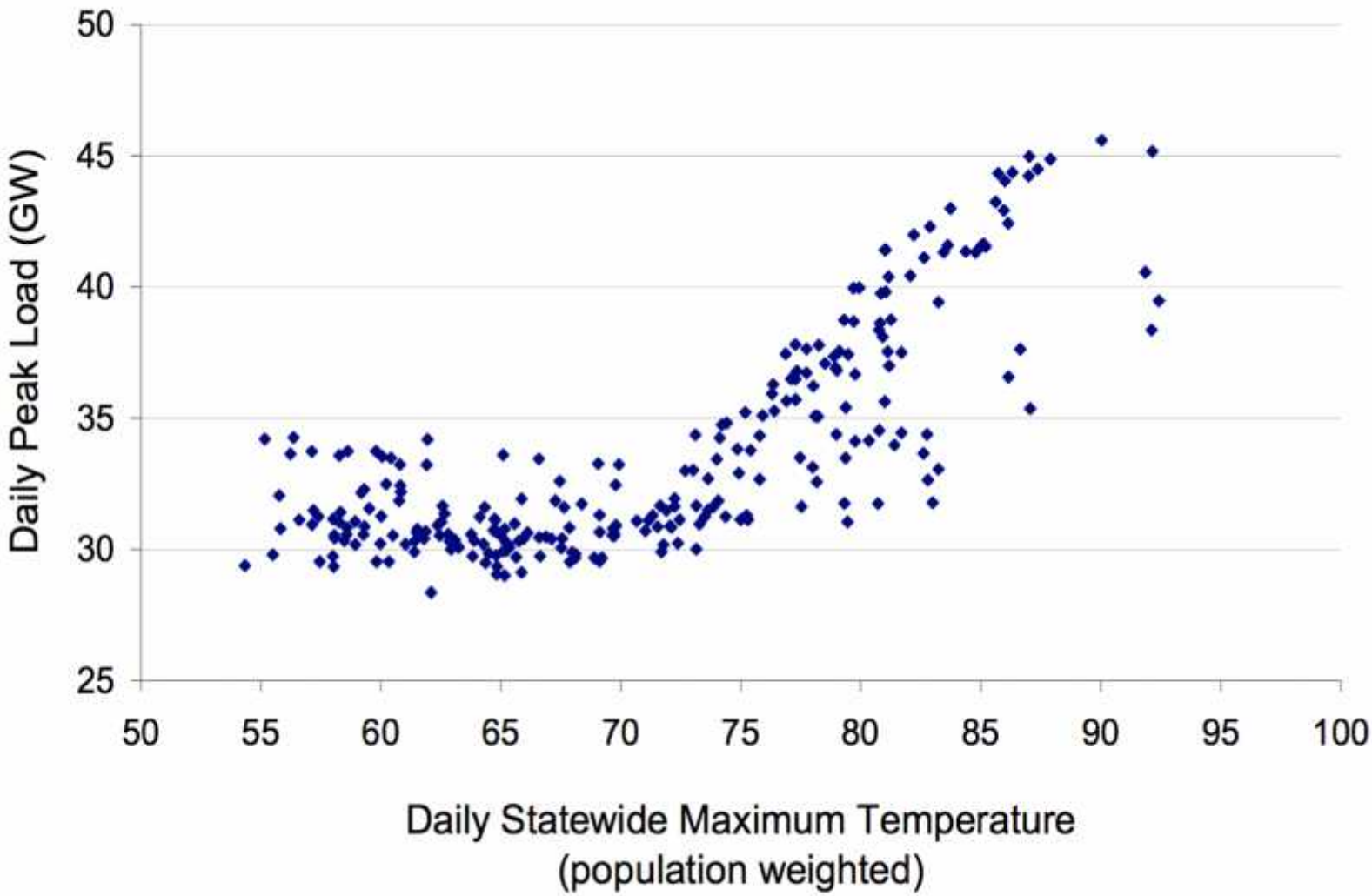
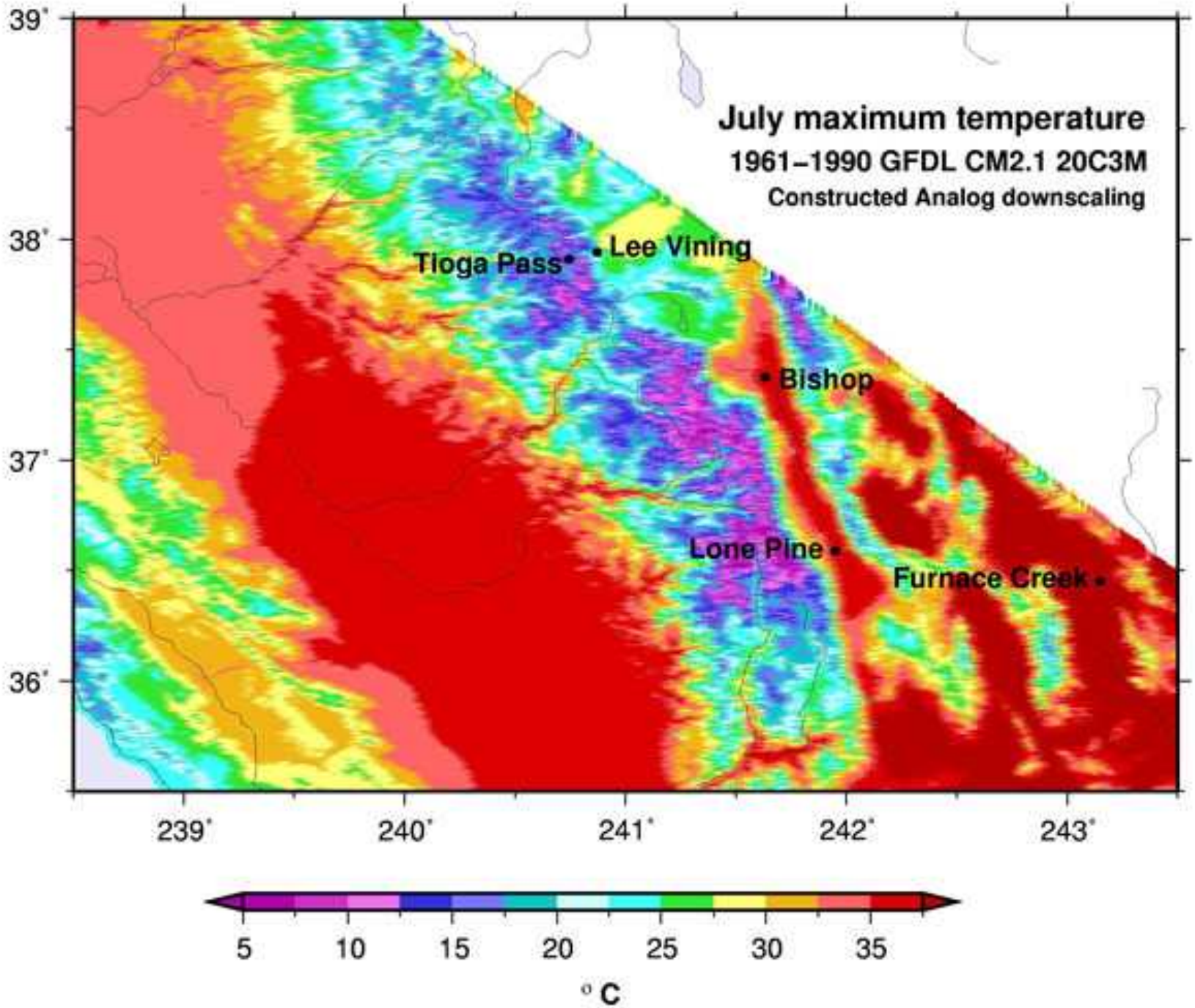
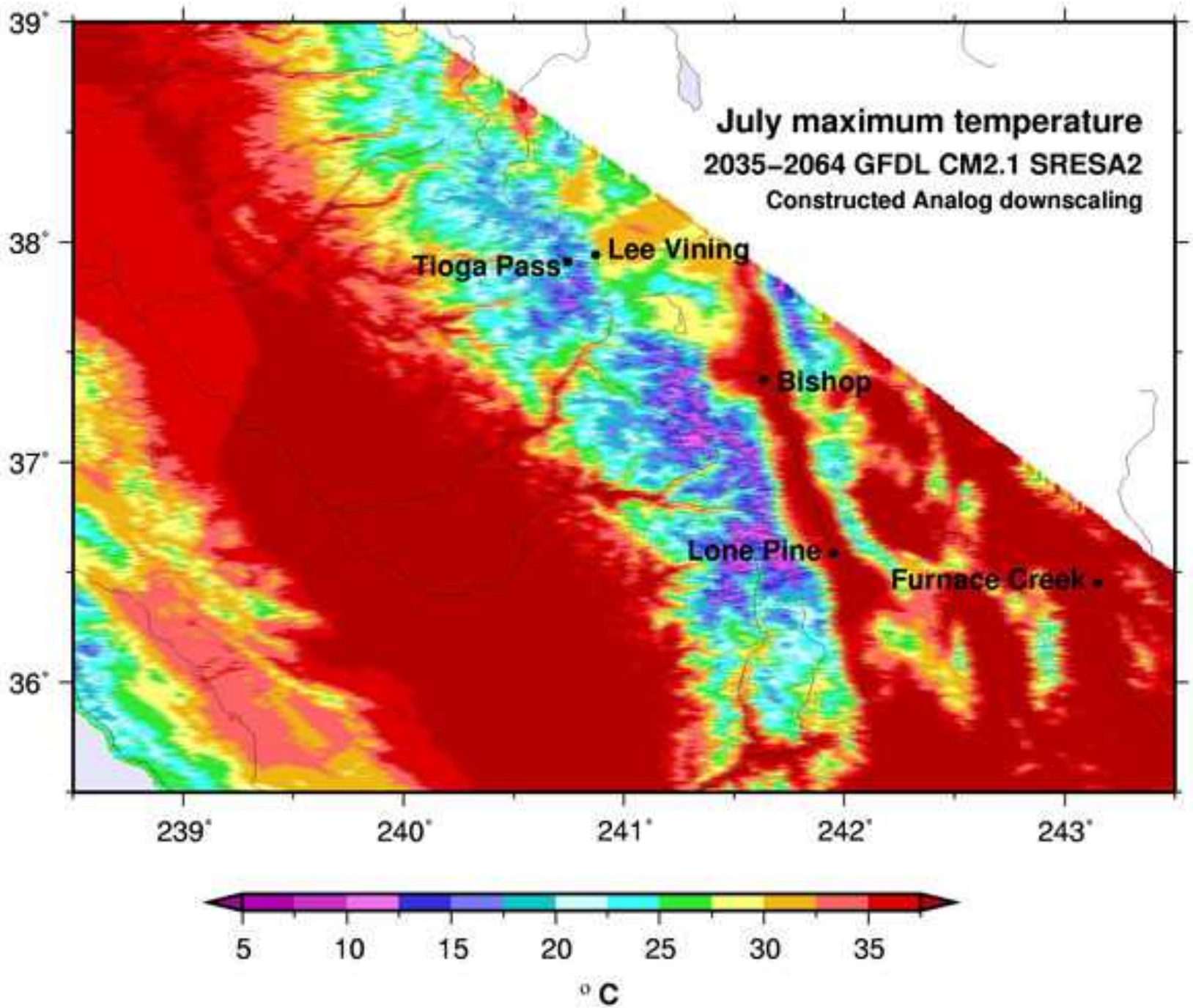
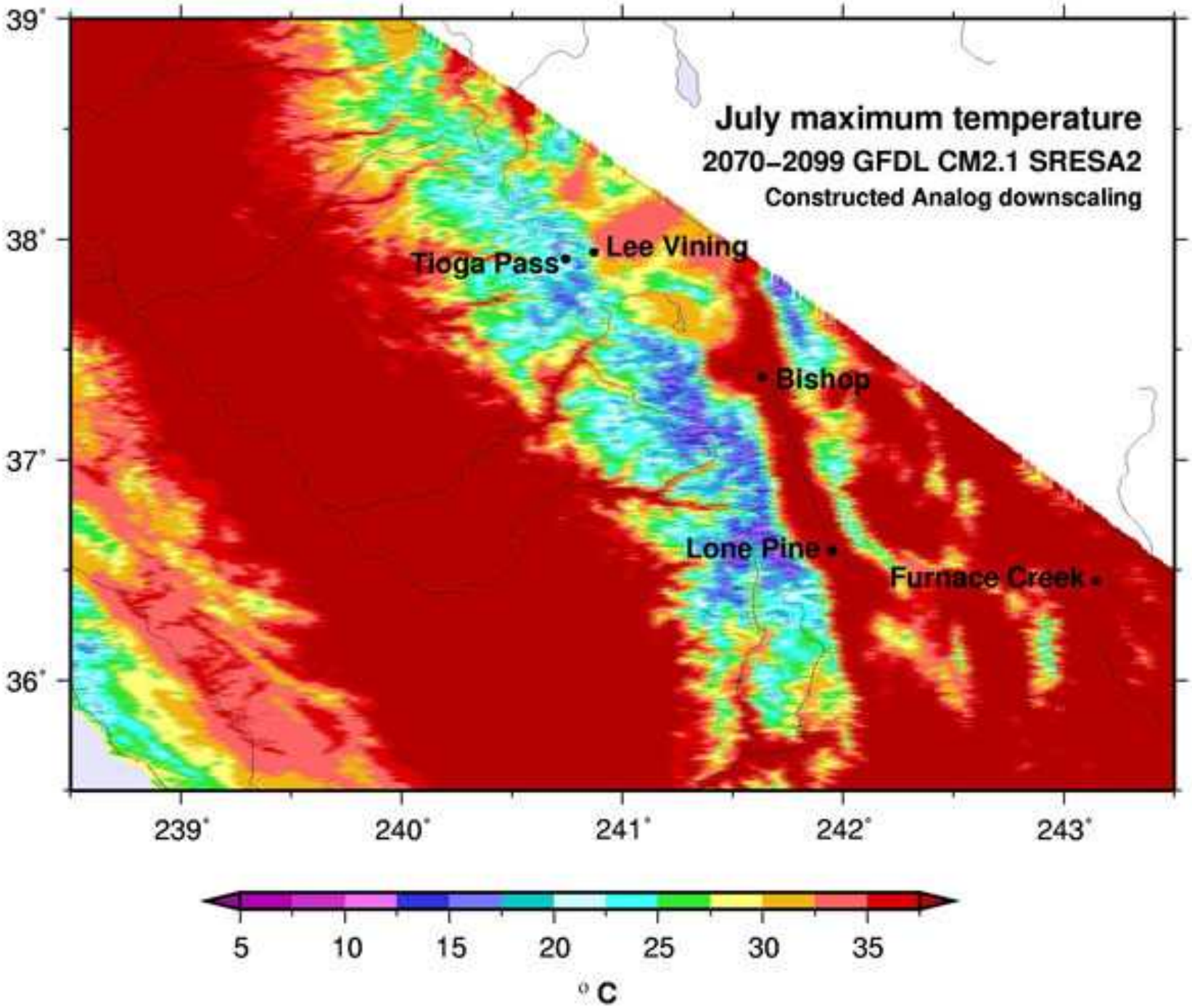


Figure 1. Daily peak loads as a function of temperature, California ISO weekdays 2004 [6]

Karen Herter, Patrick McAuliffe, and Arthur Rosenfeld
LBNL-58956 November 2005


July maximum temperature
1961–1990 GFDL CM2.1 20C3M
Constructed Analog downscaling
Tioga Pass
Lee Vining
Bishop
Lone Pine
Furnace Creek
39°
38°
37°
36°
239°
240°
241°
242°
243°
5
10
15
20
25
30
35
°C


July maximum temperature
2035–2064 GFDL CM2.1 SRESA2
Constructed Analog downscaling
Tioga Pass
Lee Vining
Bishop
Lone Pine
Furnace Creek
39°
38°
37°
36°
239°
240°
241°
242°
243°
5
10
15
20
25
30
35
° C

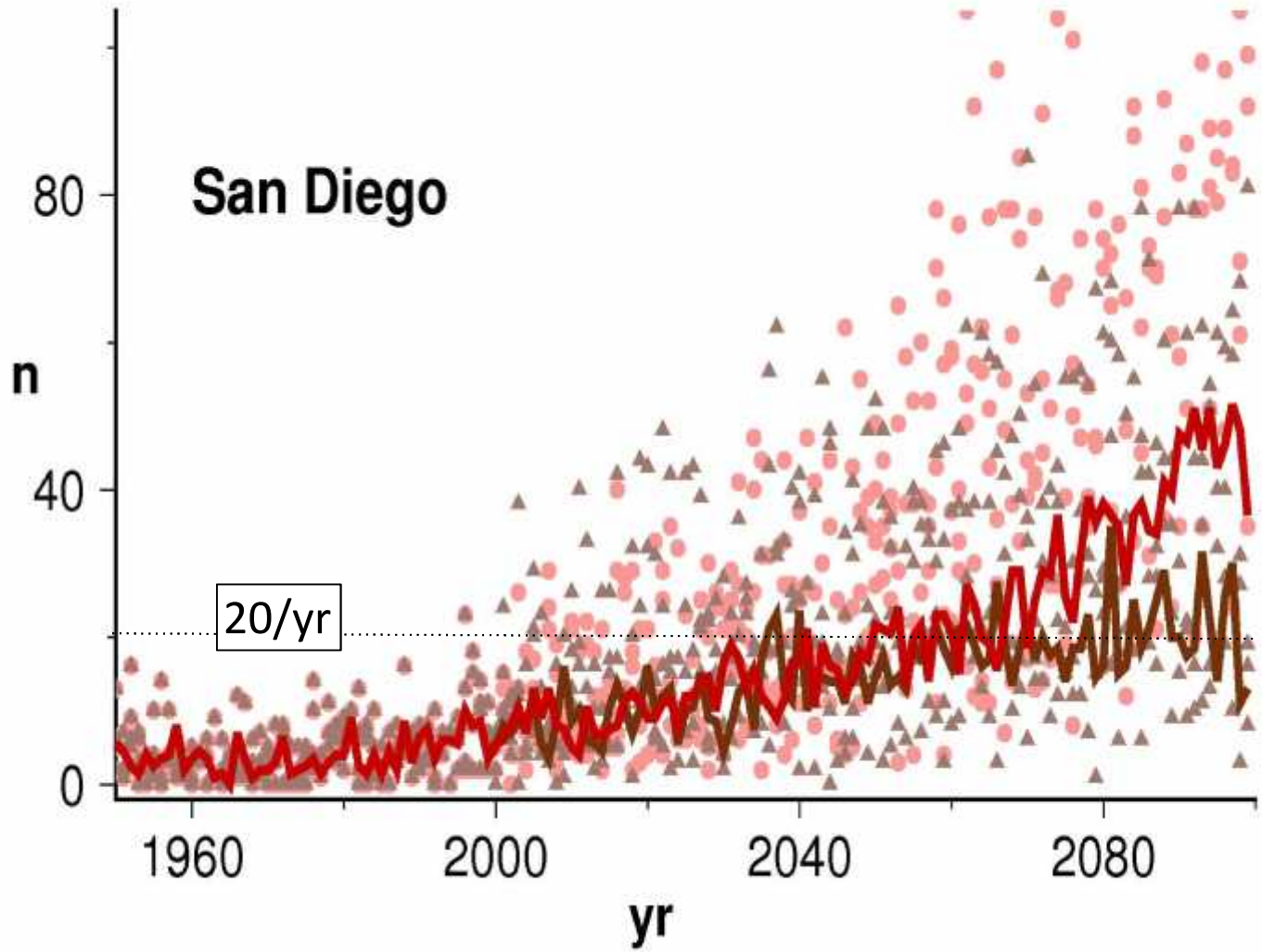

July maximum temperature
2070–2099 GFDL CM2.1 SRESA2
Constructed Analog downscaling
Tioga Pass
Lee Vining
Bishop
Lone Pine
Furnace Creek
39°
38°
37°
36°
239°
240°
241°
242°
243°
5
10
15
20
25
30
35
° C

Heat Waves

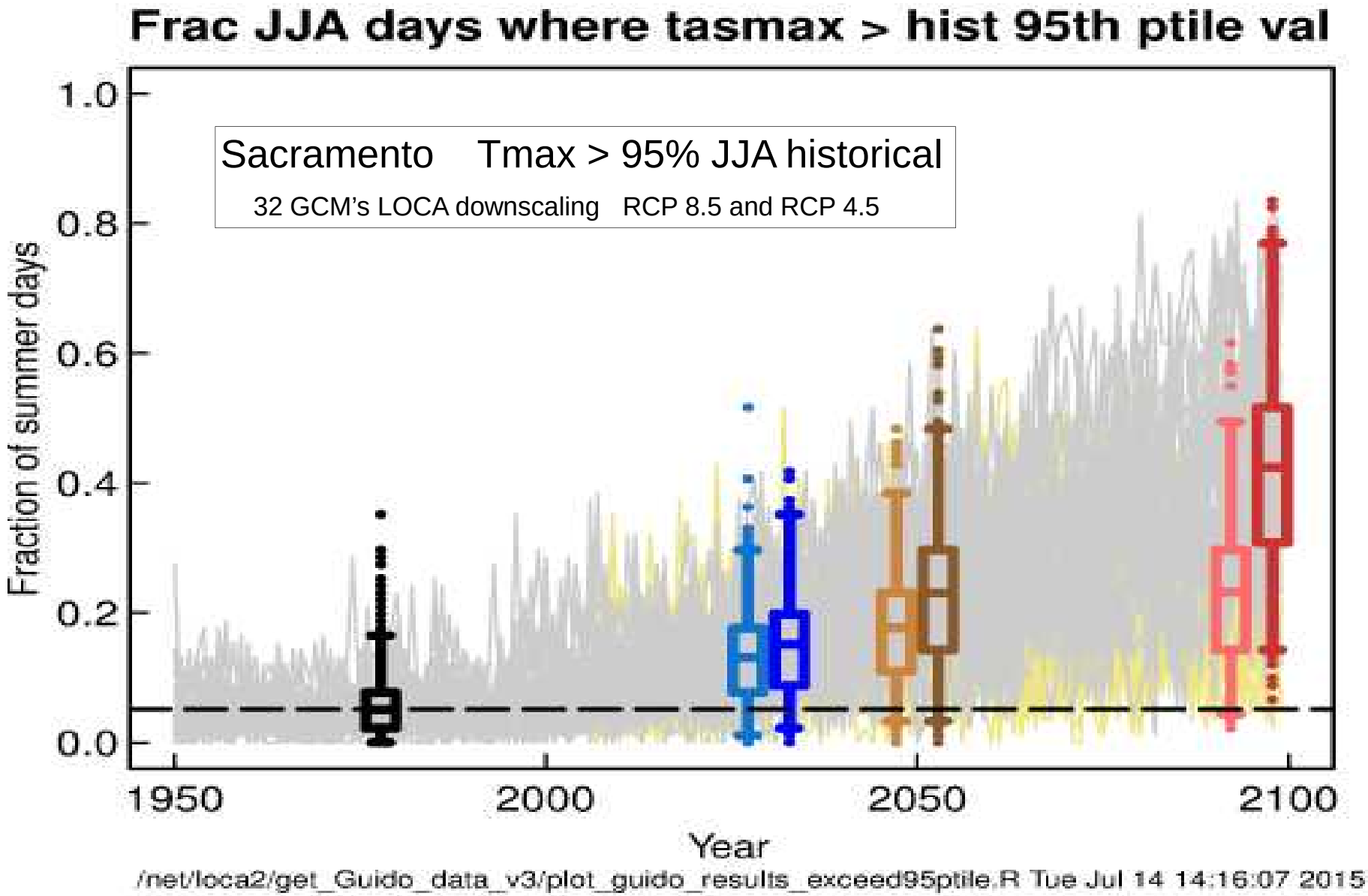
Projected in San Diego

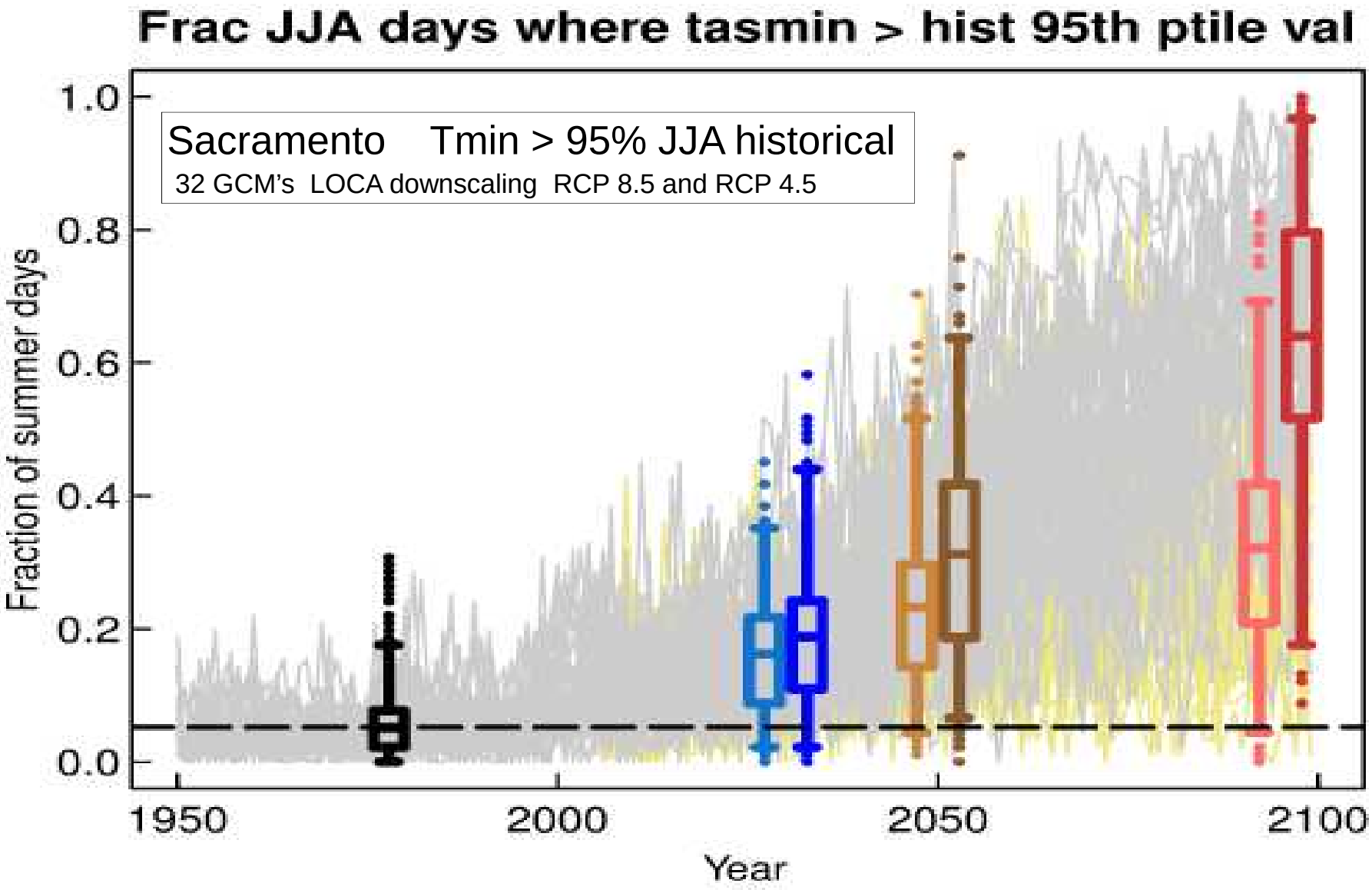
SRES A2 and SRES B1 GHG Emissions Scenarios

Number of Days (n), April–October, When Maximum Temperature (Tmax) Exceeds the 98th Percentile Historical (1961–1990) Level of 82° F at San Diego from Four BCCA Downscaled GCMs. Brown carrots and red dots shown for B1 and A2 emission scenarios, respectively. Thick brown (B1) and red (A2) lines show median value from the four simulations.

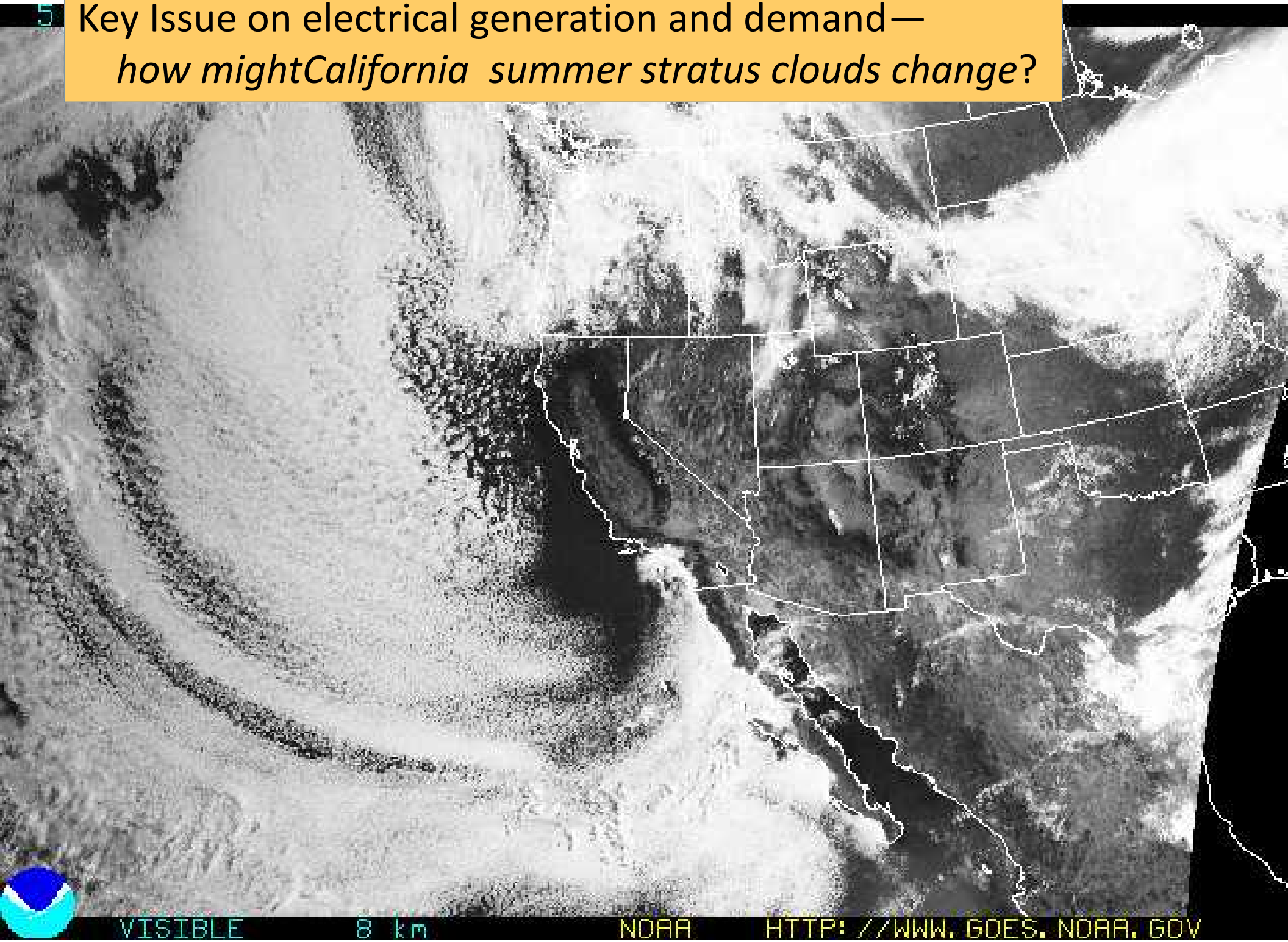


April through October number of days above the historical (1961-1990) 98th percentile maximum temperature for 4 global climate models (cnrmcm3, ncarccsm3, gfdlcm2.1, ncarpcm1) from BCCA downscaling for sresa2 (red) and sresb1 (brown). Heavy lines indicate median number of days (per year). 98th percentile values range from 81.7 °F to 82.9 °F.


Frac JJA days where tasmax > hist 95th ptile val
Sacramento Tmax > 95% JJA historical
32 GCM's LOCA downscaling RCP 8.5 and RCP 4.5
Fraction of summer days
1.0
0.8
0.6
0.4
0.2
0.0
1950
2000
2050
2100
Year
/net/loca2/get_Guido_data_v3/plot_guido_results_exceed95ptile.R Tue Jul 14 14:16:07 2015


Frac JJA days where tasmin > hist 95th ptile val
Sacramento Tmin > 95% JJA historical
32 GCM's LOCA downscaling RCP 8.5 and RCP 4.5
Fraction of summer days
1.0
0.8
0.6
0.4
0.2
0.0
1950
2000
2050
2100
Year

Key Issue on electrical generation and demand—
how mightCalifornia summer stratus clouds change?

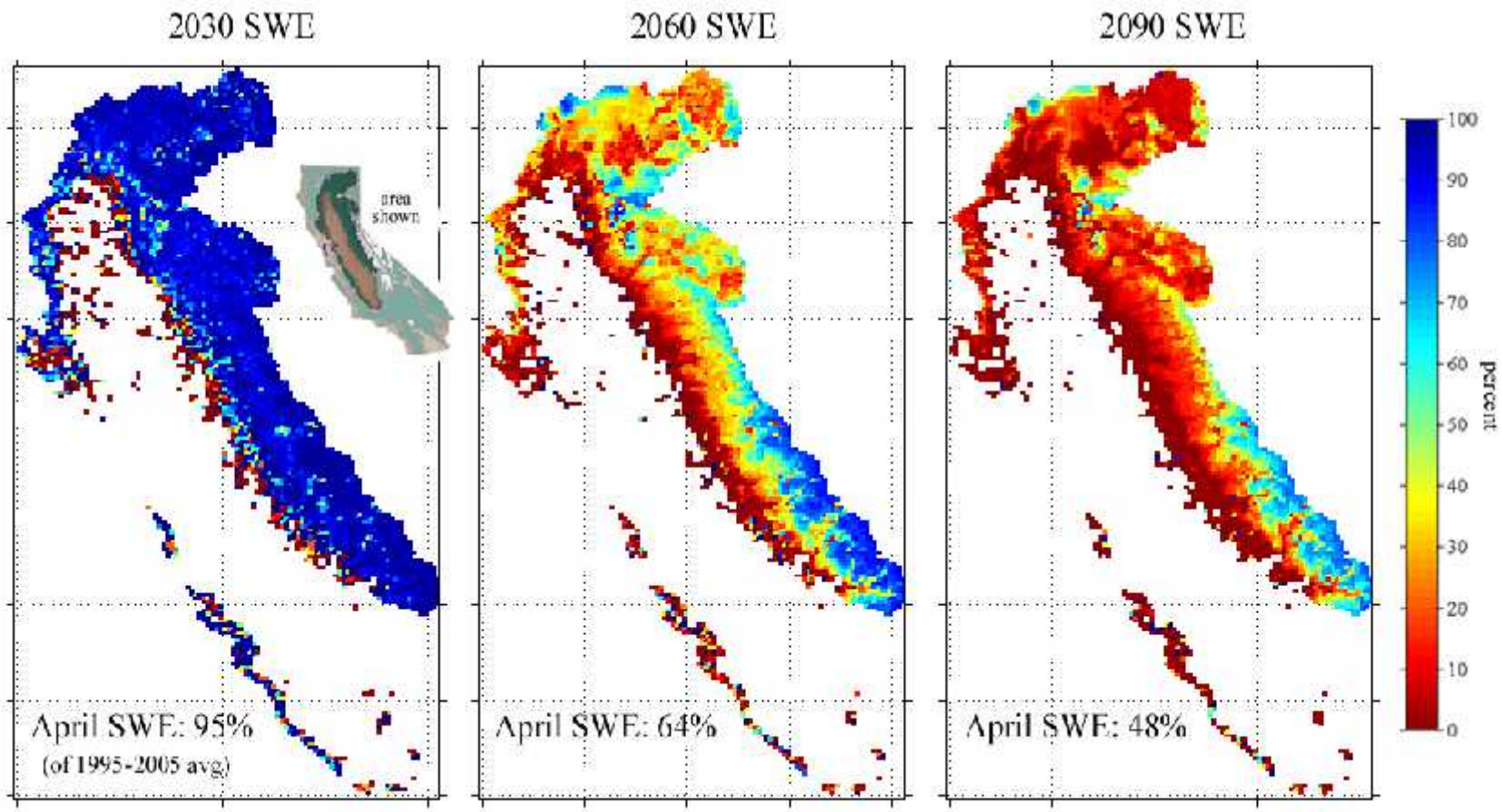


California's Sierra Nevada snowpack
How long will it remain?

Sponsors:
- California Energy Commission, California
- NOAA/NASA program
- US Geological Survey
- US Department of Energy

Douglas Alden
Scripps Institution of Oceanography
Installing met station, Lee Vining, CA

Warming drives loss of spring snowpack

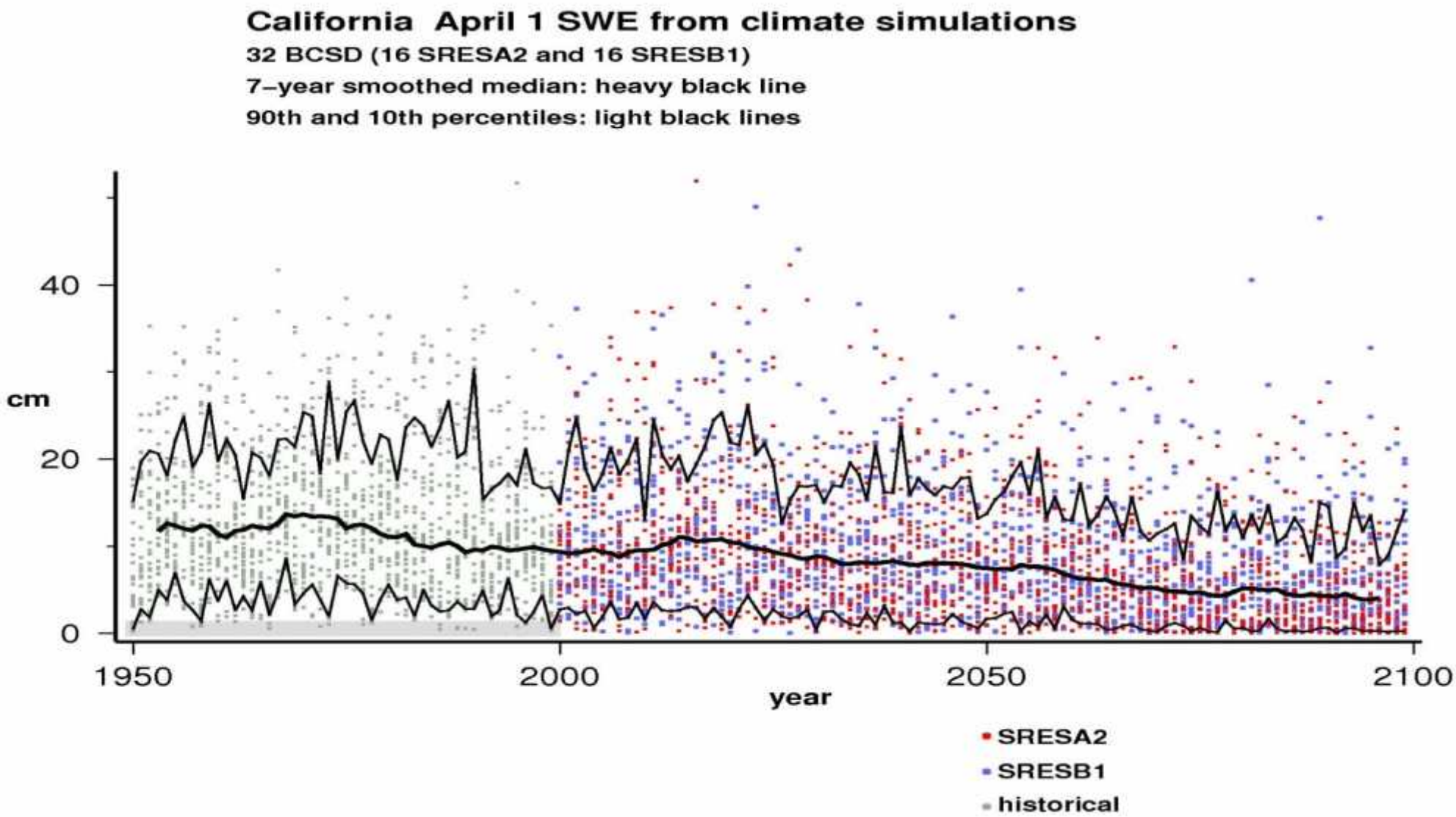


•Under this scenario, California loses half of its spring (April 1) snow pack due to climate warming. Less snow, more rain, particularly at lower elevations. The result is earlier run-off, more floods, Less stored water. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual coupled climate simulation. (this is a low-middle of the road emissions and warming scenario)

Knowles, N., and D.R. Cayan, 2002: Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. *Geophysical Research Letters*, **29**(18), 1891.

Projected decline of spring snow pack

32 GCMs, A2 and B1 simulations downscaled to 12 km grid



Sea Level Rise Issues West Coast

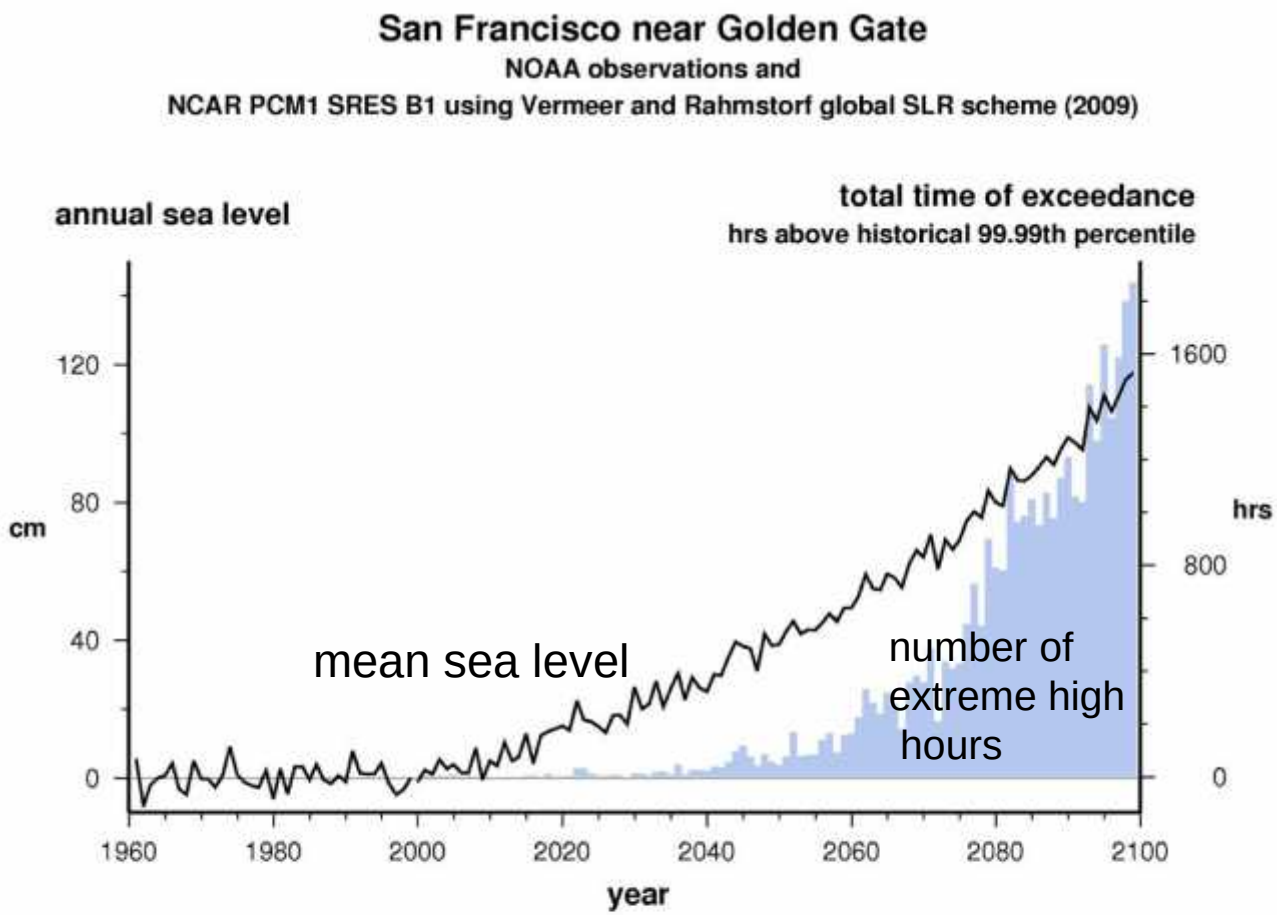
During high sea levels, the sea is often *not* quiescent
January 1983 Monterey Bay, California

The *pace* of climate change is projected to be rapid

INCREASING SEA LEVEL EXTREMES

As mean sea level rises the frequency and magnitude of extremes would increase markedly. Under plausible rates of sea level rise, an event which in present day occurs less than once per year occurs scores of times per year by mid 21st Century and becomes commonplace by end of 21st Century.

Importantly the duration of extremes becomes longer, so exposure to waves is considerably greater.

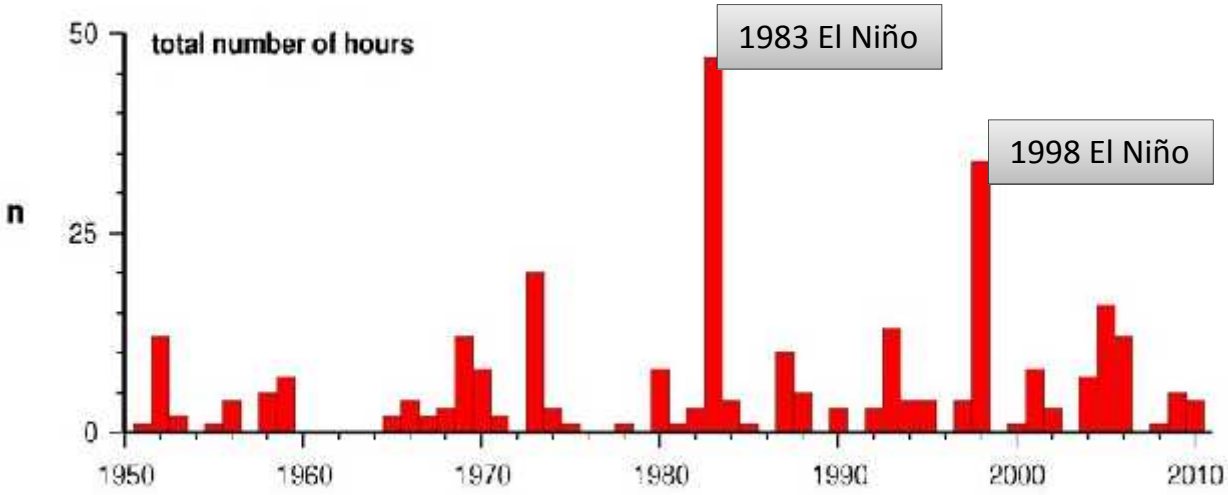


historical 1970–2000 avg annual sea level (cm): –0.54
historical 1970–2000 avg hrs above 99.99th percentile: 0.71

historical 1961–1990 99.99th percentile: 1.394m
NCAR PCM1 1961–1990 99.99th percentile: 1.413m

Extreme sea level occurrences San Francisco

observed at or above 99.99% historical hourly threshold 1.41m above mean

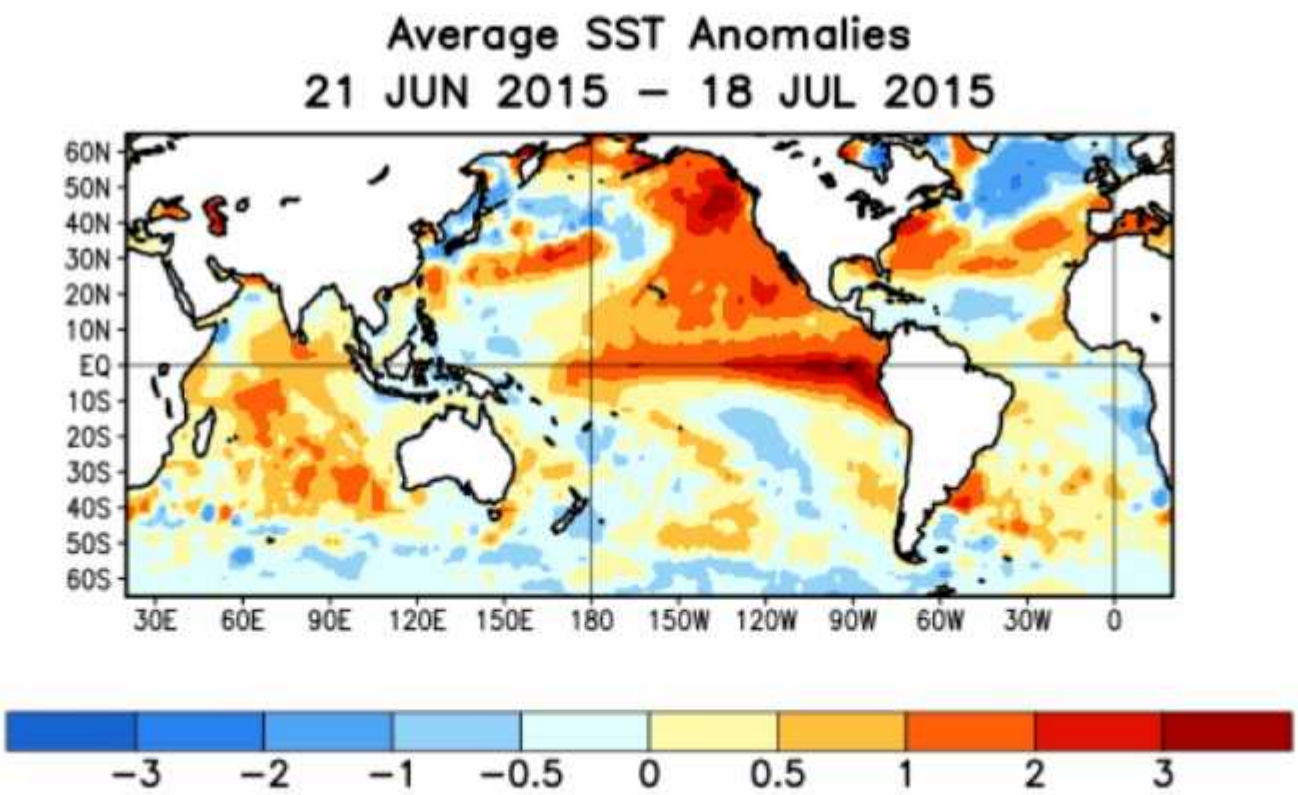


Highest California sea levels have mainly occurred in a few stormy years, especially during large El Niños (e.g., 1983 and 1998)

from hourly sea level record at Ft Point, mouth of San Francisco Bay

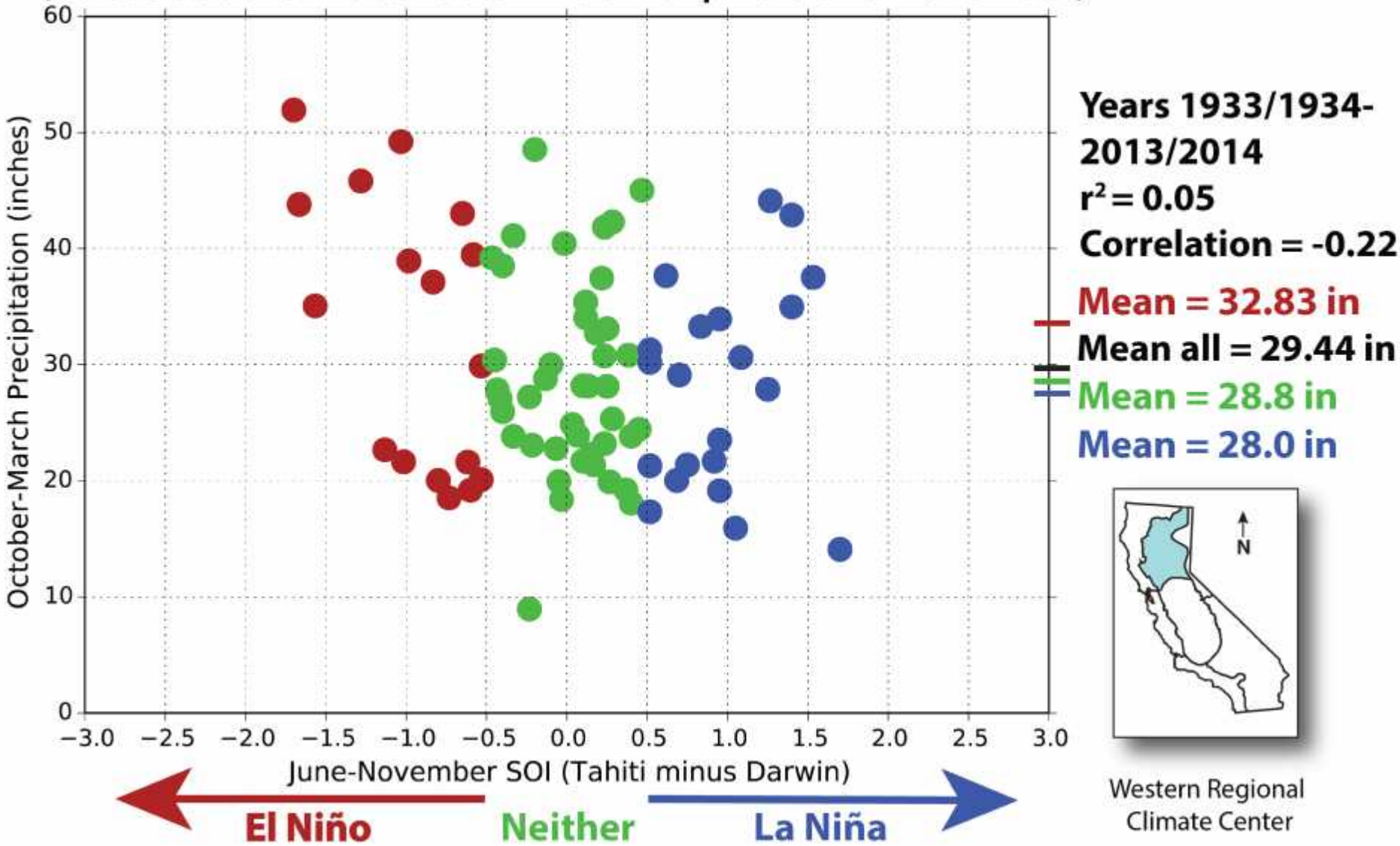
Global SST Departures (°C) During the Last Four Weeks

During the last four weeks, equatorial SSTs were above average across the central and eastern Pacific and the Indian Ocean.



CA Division 2 October-March Precipitation

(versus Southern Oscillation Index for prior June-November)



Summary

Anthropogenic global climate change is already occurring and will grow

The environment we plan for must be informed by climate projections to augment learning gained from historical experience

Summer warming may be greater than in winter. .

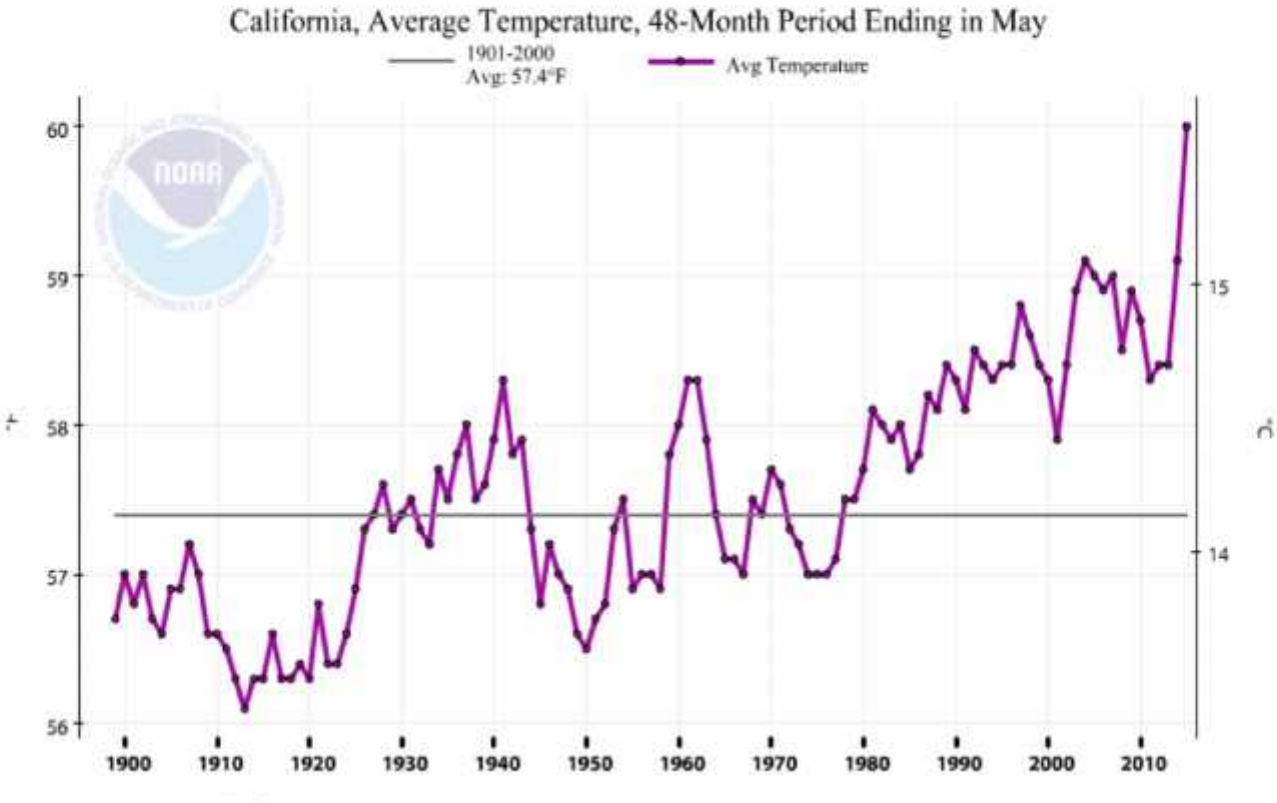
Climate warming will likely be most remarkable when coupled with natural fluctuations, such as heat waves.

Water and Energy are linked—global climate change is a change in global and regional water cycle as well as global and regional warming

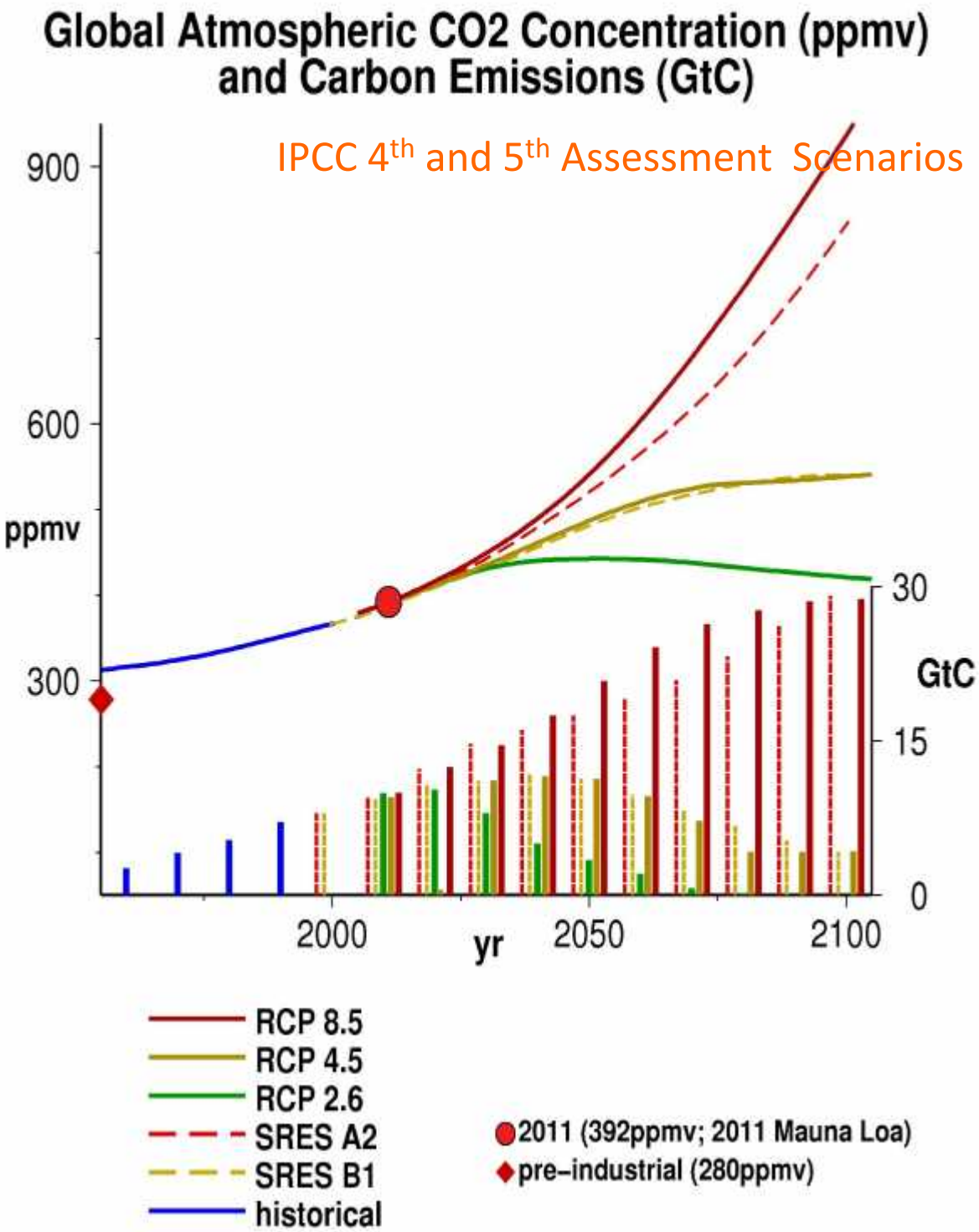
Sea level rise will exacerbate extremes in high water

Large El Niño's have produced the greatest number of extreme events

California Temperature past 48 months



California's recent dry spell has been exceptionally warm!

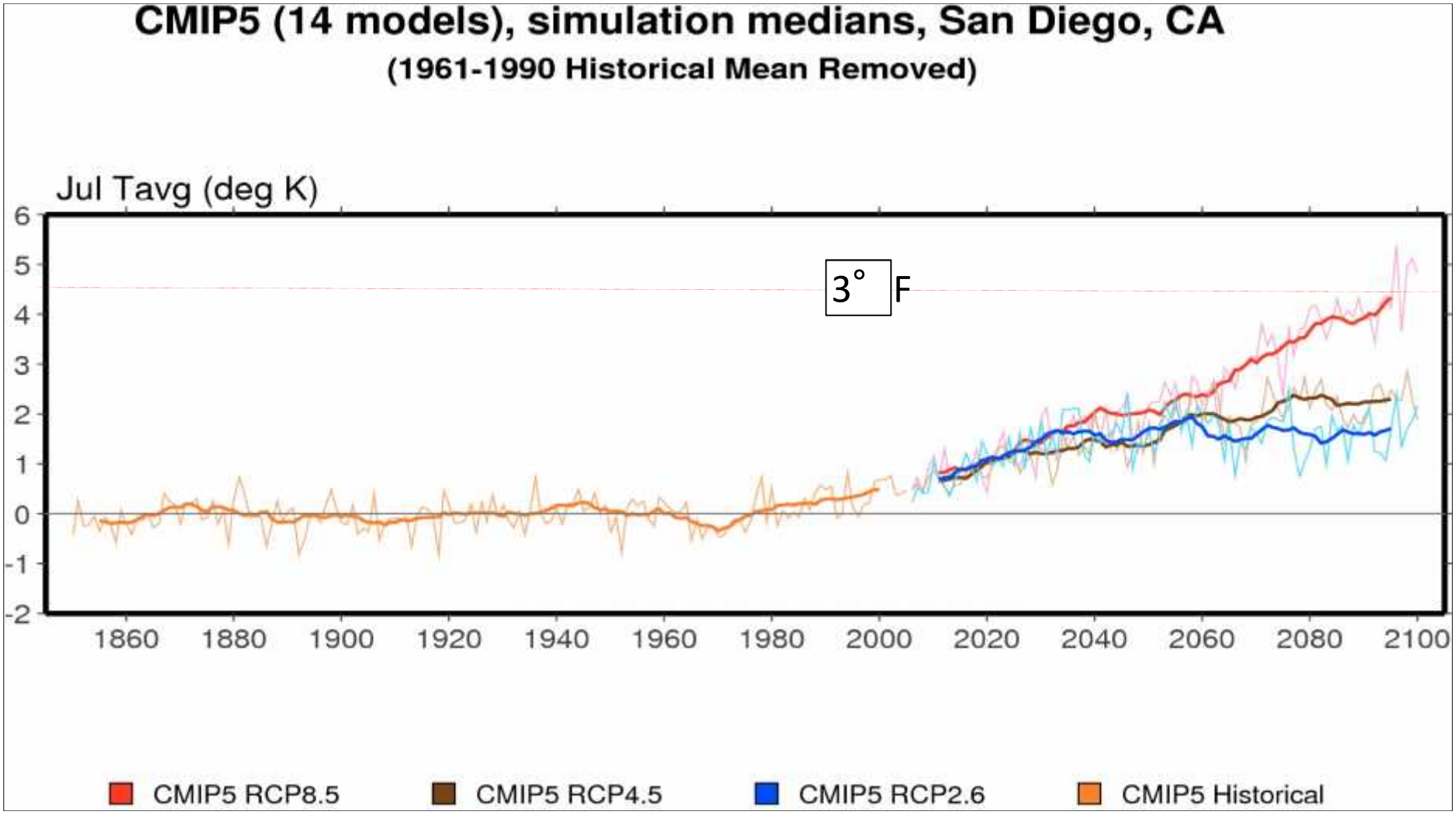


Greenhouse gas (GHG) concentrations will rise, but how much?

GHG emissions trajectories have considerable implications for global and regional climate in future decades

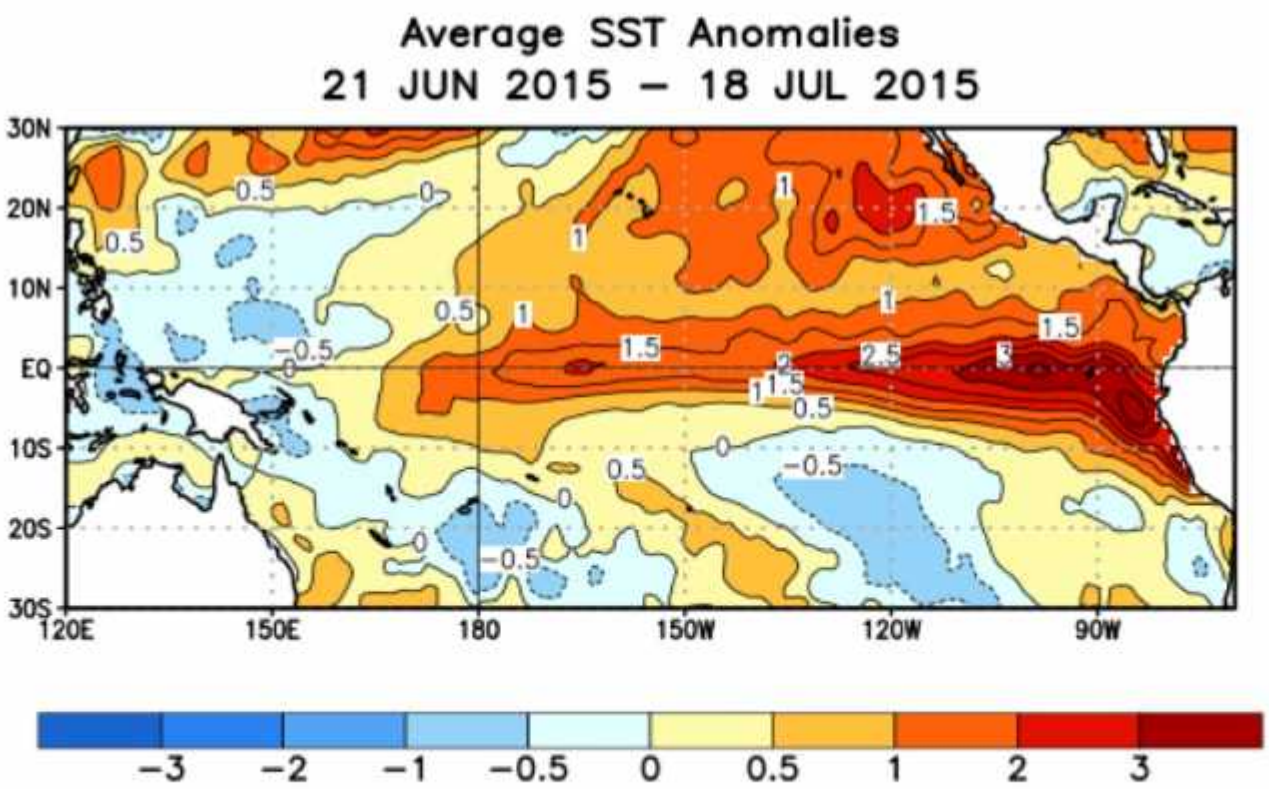
Projected Climate Warming through the 21st Century

- *because of greenhouse gas build-up we are committed and are already warming*
- *amount of warming in future decades depends on greenhouse gas emissions*



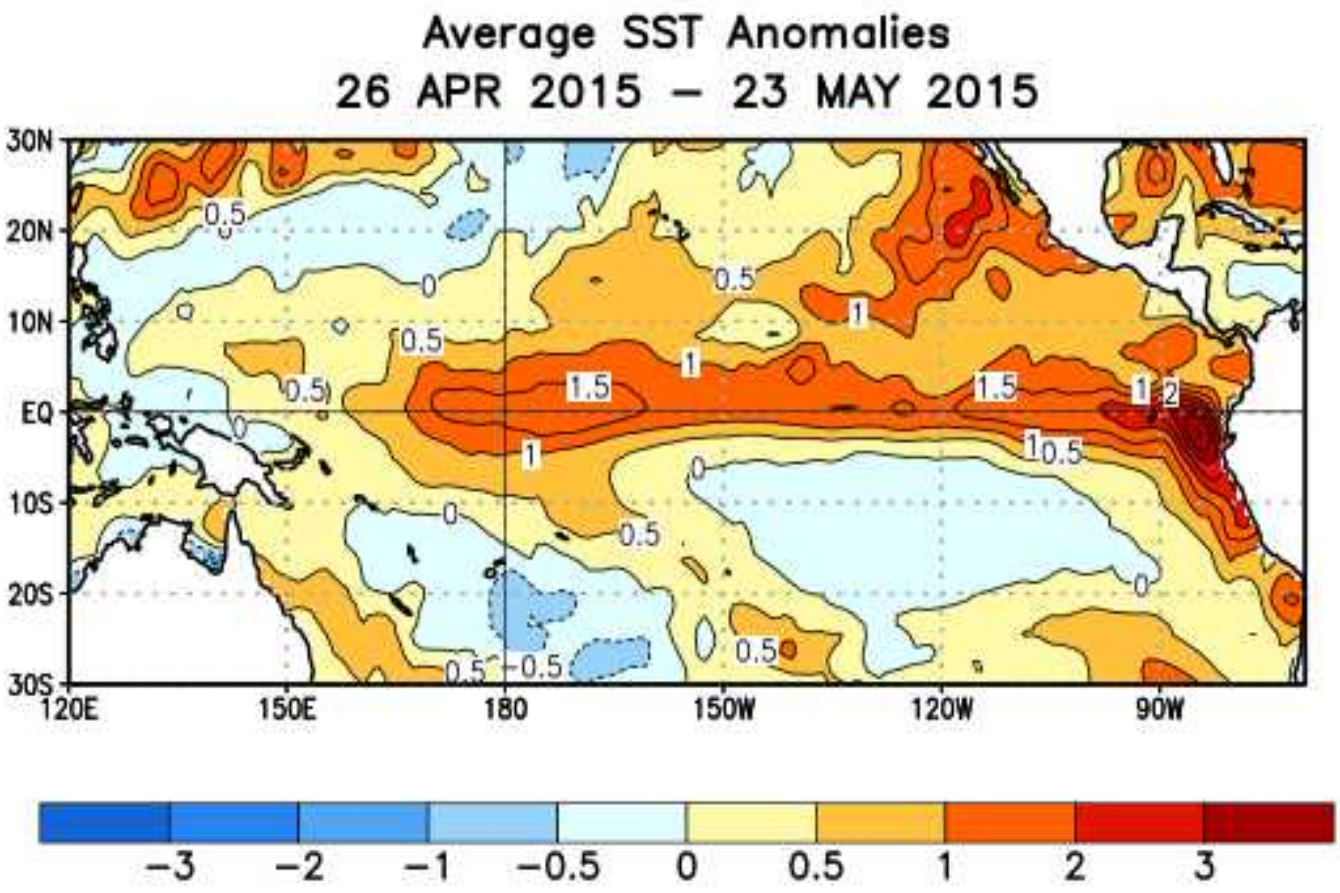
SST Departures (°C) in the Tropical Pacific During the Last Four Weeks

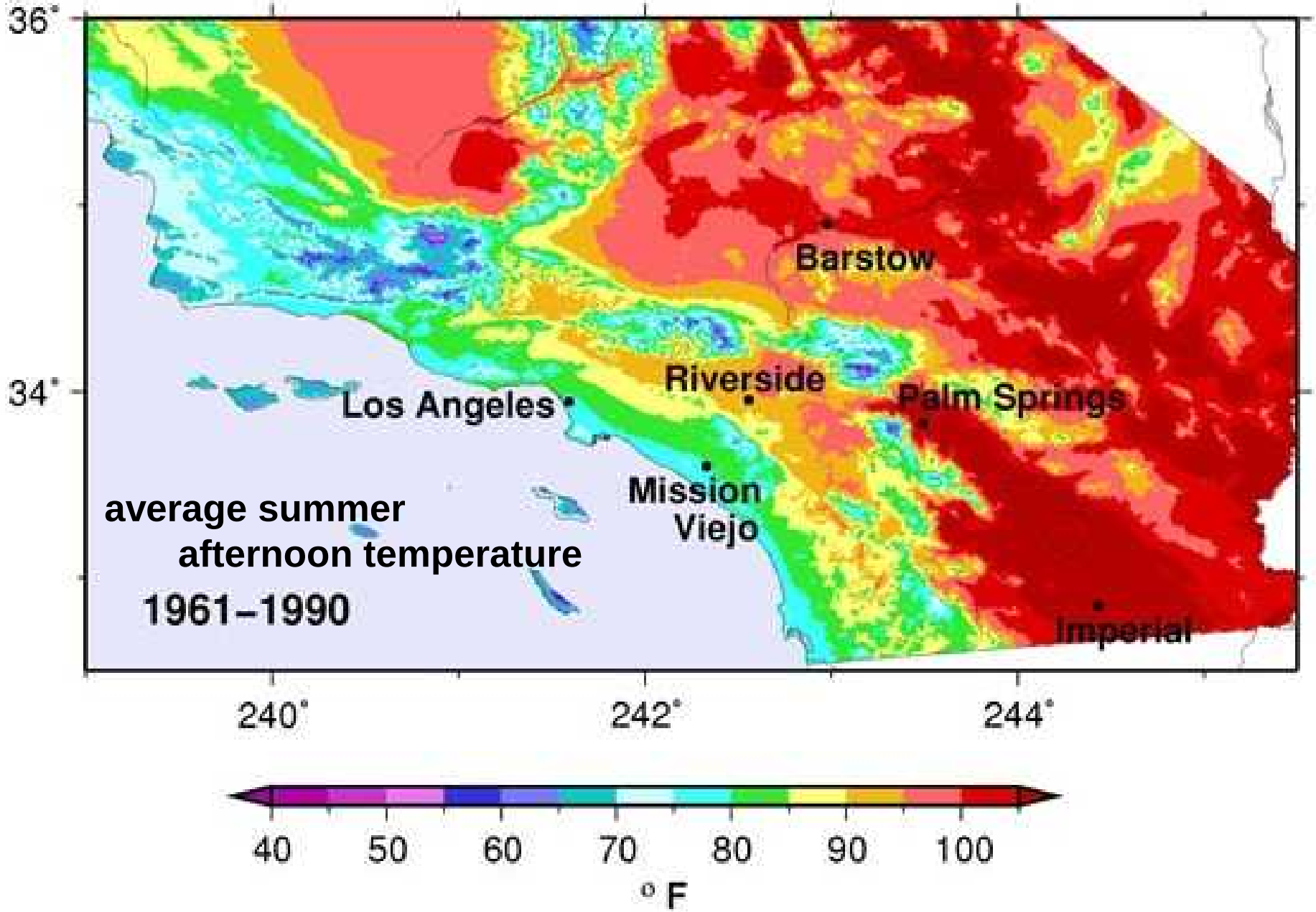
During the last four weeks, equatorial SSTs were above average across the central and eastern Pacific, with the largest anomalies off the coast of S. America.

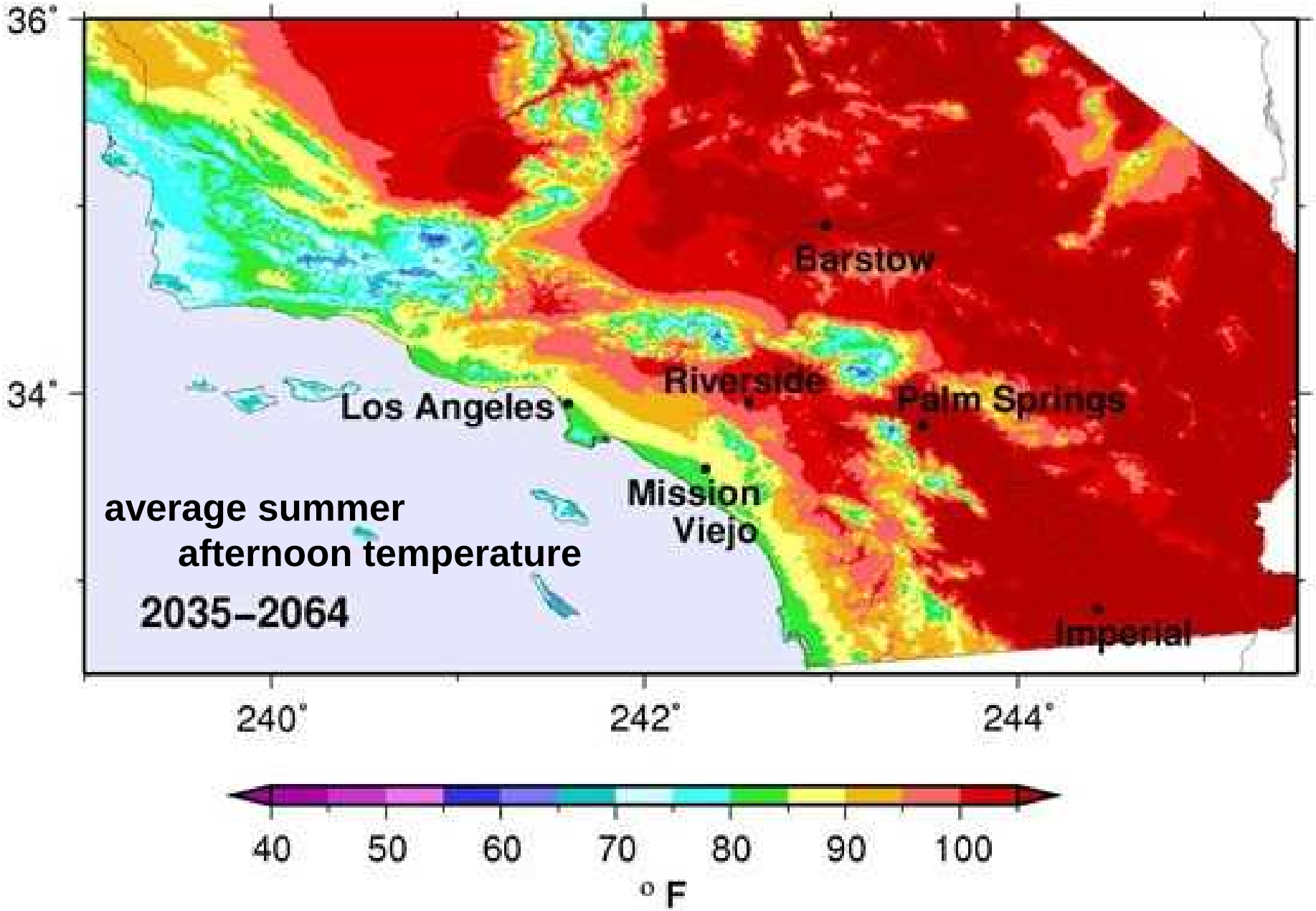


SST Departures (°C) in the Tropical Pacific During the Last Four Weeks

During the last four weeks, equatorial SSTs were above average across most of the Pacific, with the largest anomalies present near the Date Line and off the coast of S. America.

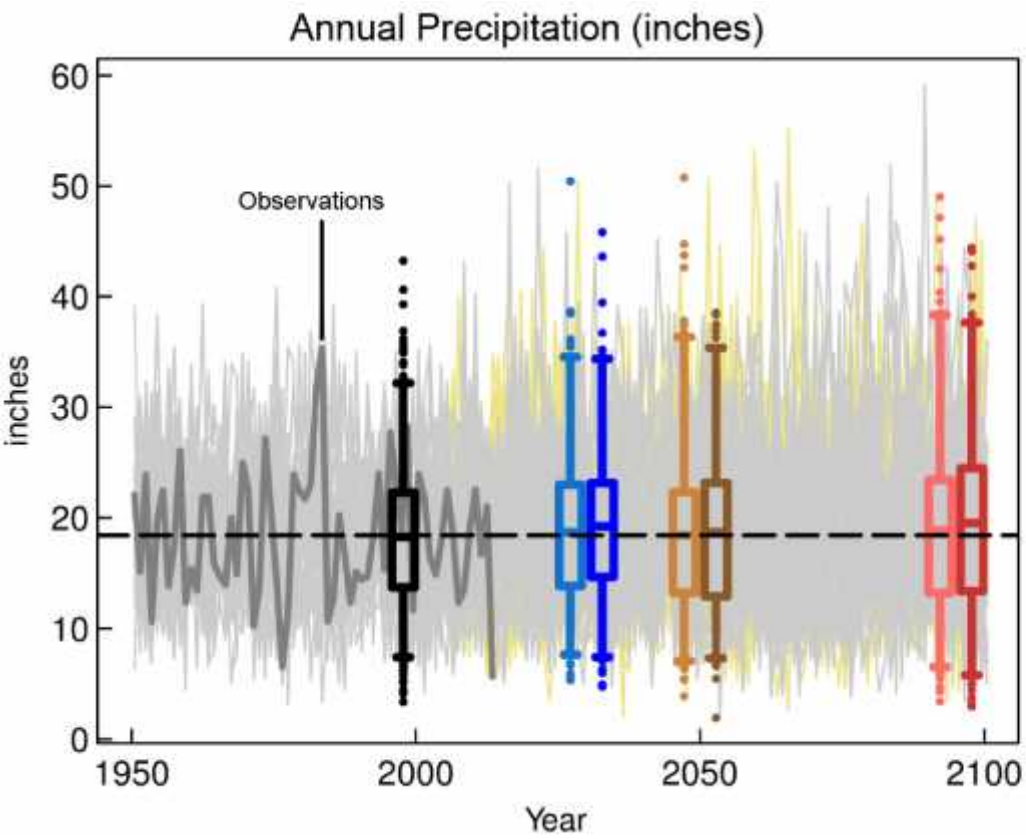


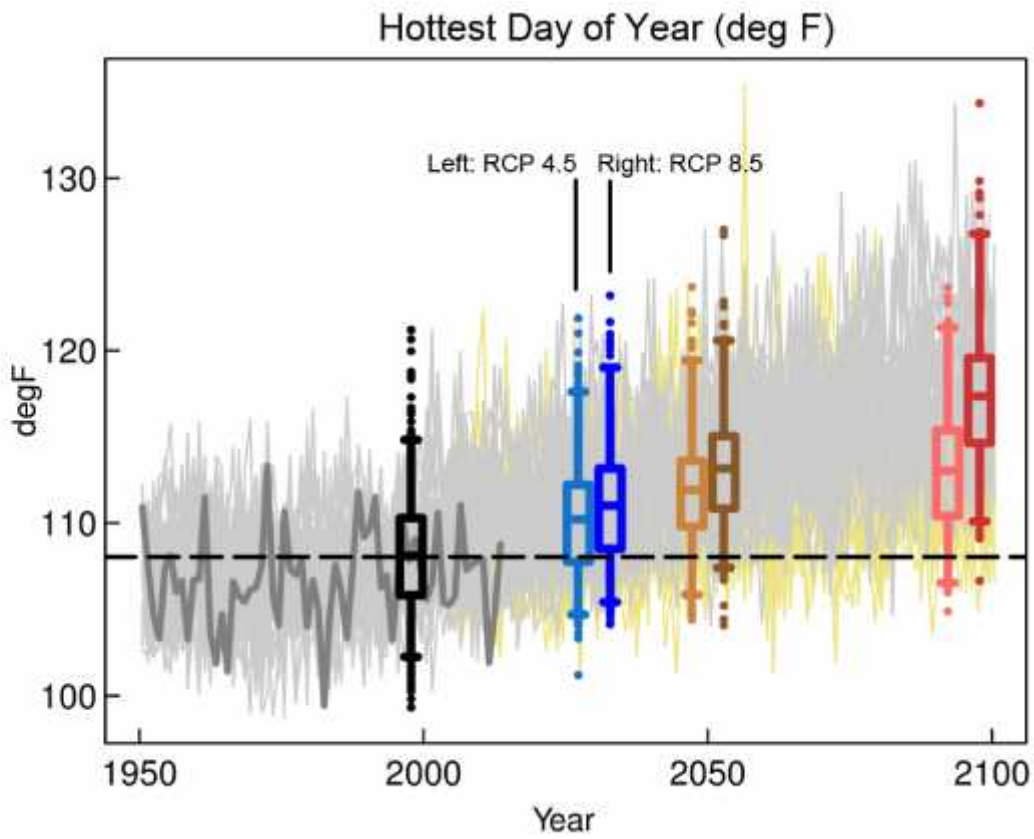

36°
34°
240°
242°
244°
Barstow
Riverside
Palm Springs
Los Angeles
Mission Viejo
Imperial
average summer afternoon temperature
1961–1990
40
50
60
70
80
90
100
° F



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

CMIP5/LOCA predicted changes at Sacramento, CA



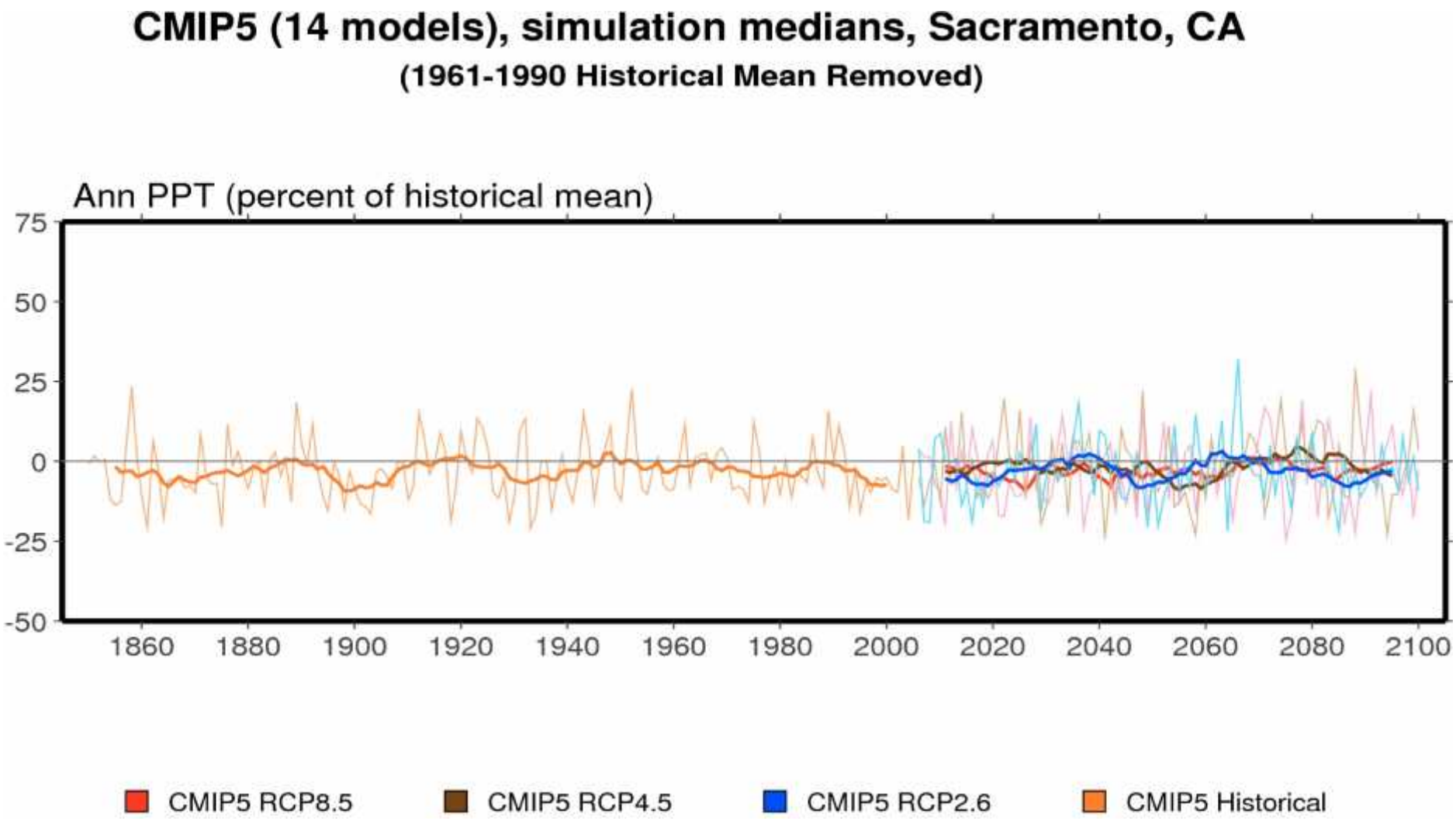


	Historical	2030	2050	2090

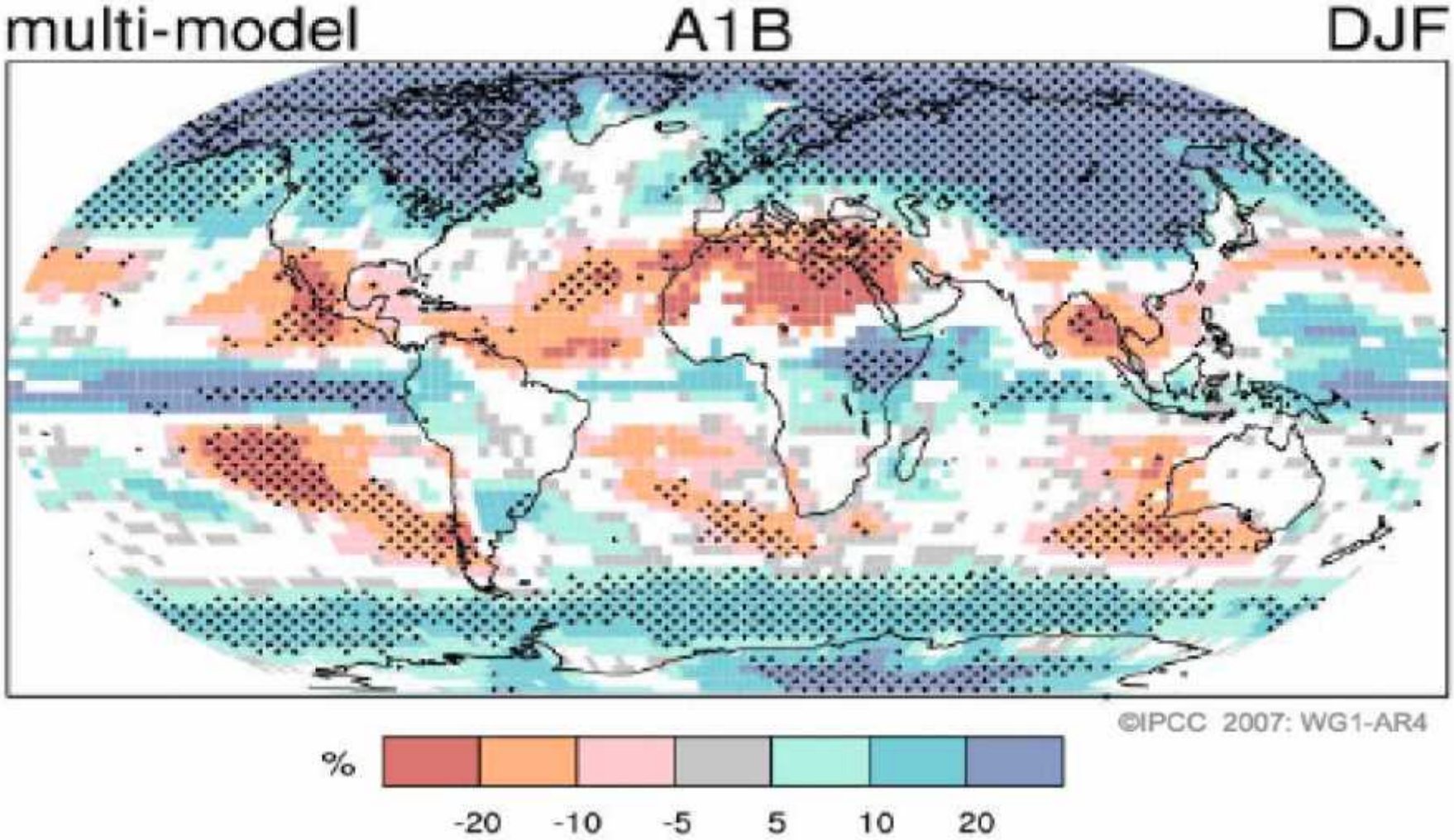
The three numbers are: typical lowest, mean, and typical highest yearly value

Little concensus Sacramento Precipitation Change

14 GCMs X 3 new Emissions Scenarios IPCC 5th Assessment models

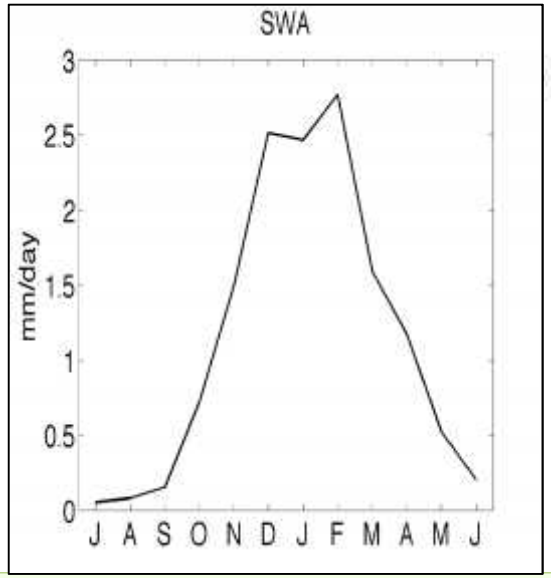


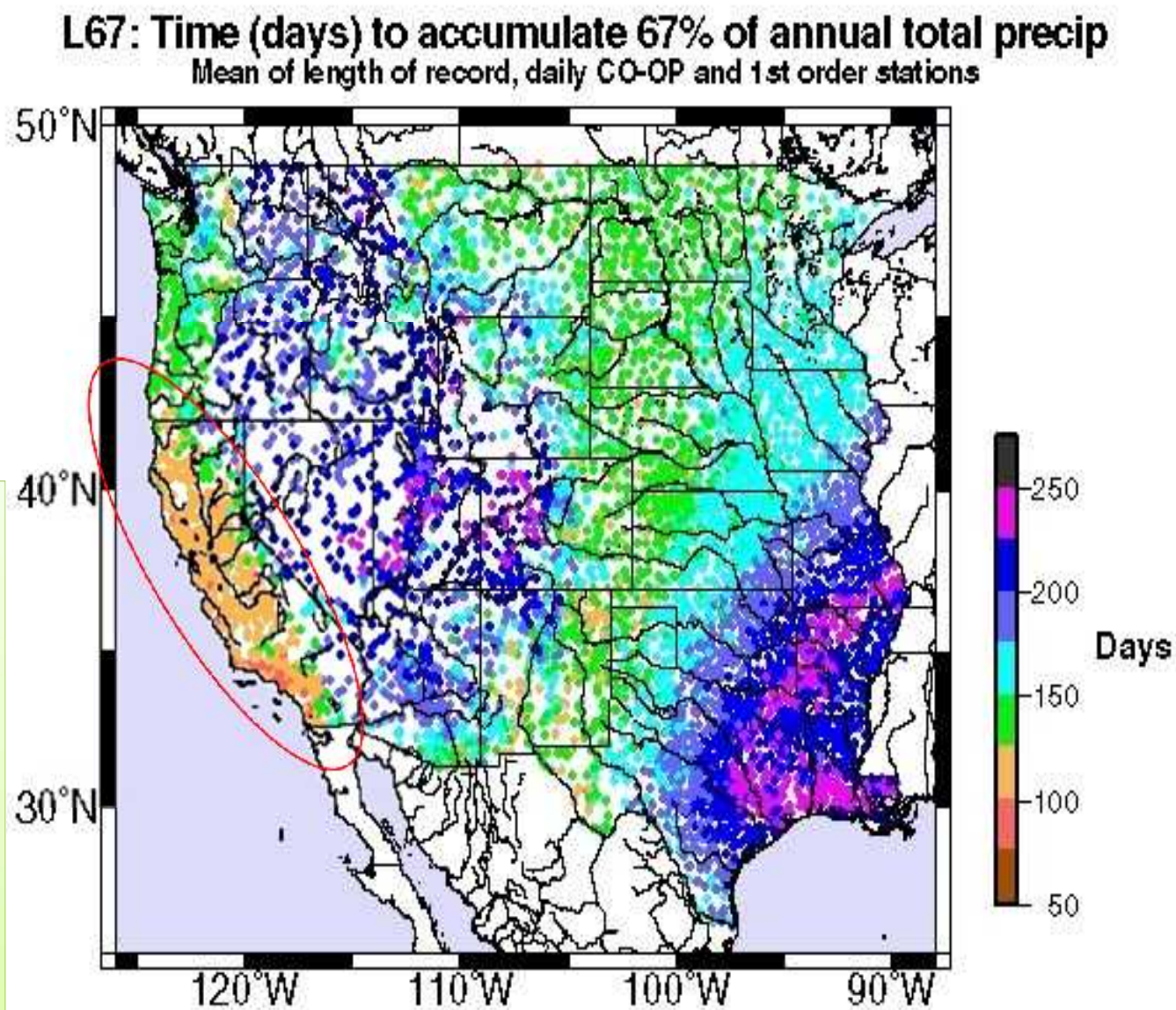
Projected patterns of precipitation changes 2090-2099 versus 1980-1999



Globally, dry regions become drier possibly including the Southwest U. S:

California's vulnerabilities to Climate Change are conditioned by our background climate setting

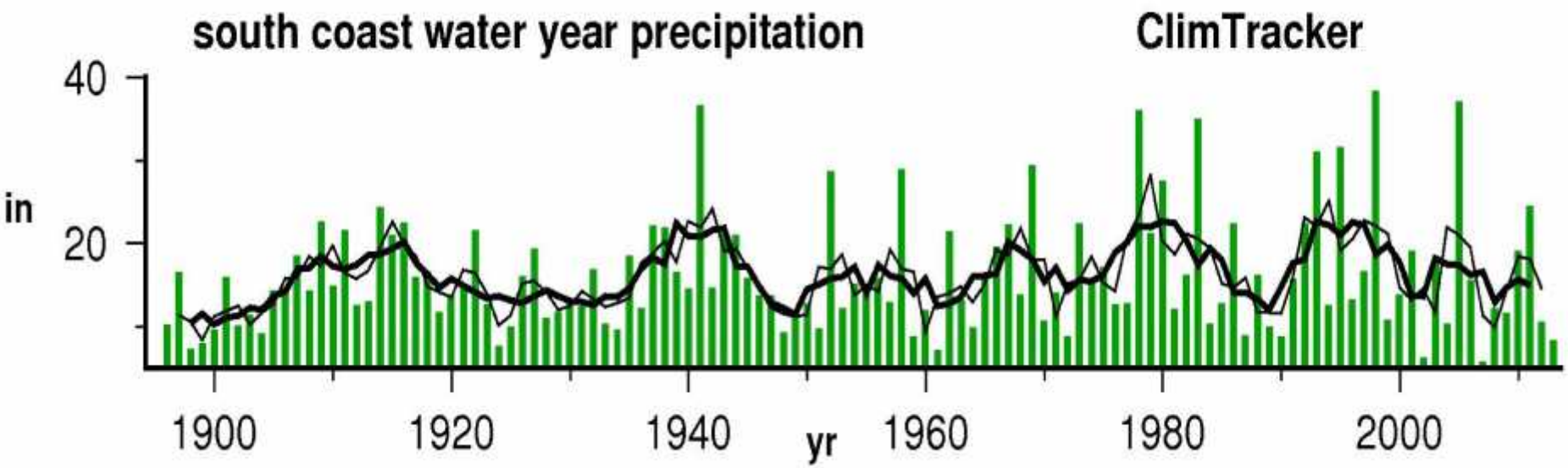




California is remarkable in having only about 120 days to accumulate two thirds of its annual precipitation. When Pacific winter storms are directed away from California during this seasonal window, unusually dry conditions result as in our current 2013-14 Winter. Of the entire U.S., the year-to-year delivery of precipitation is the most volatile!

Great year-to-year variability in California precipitation

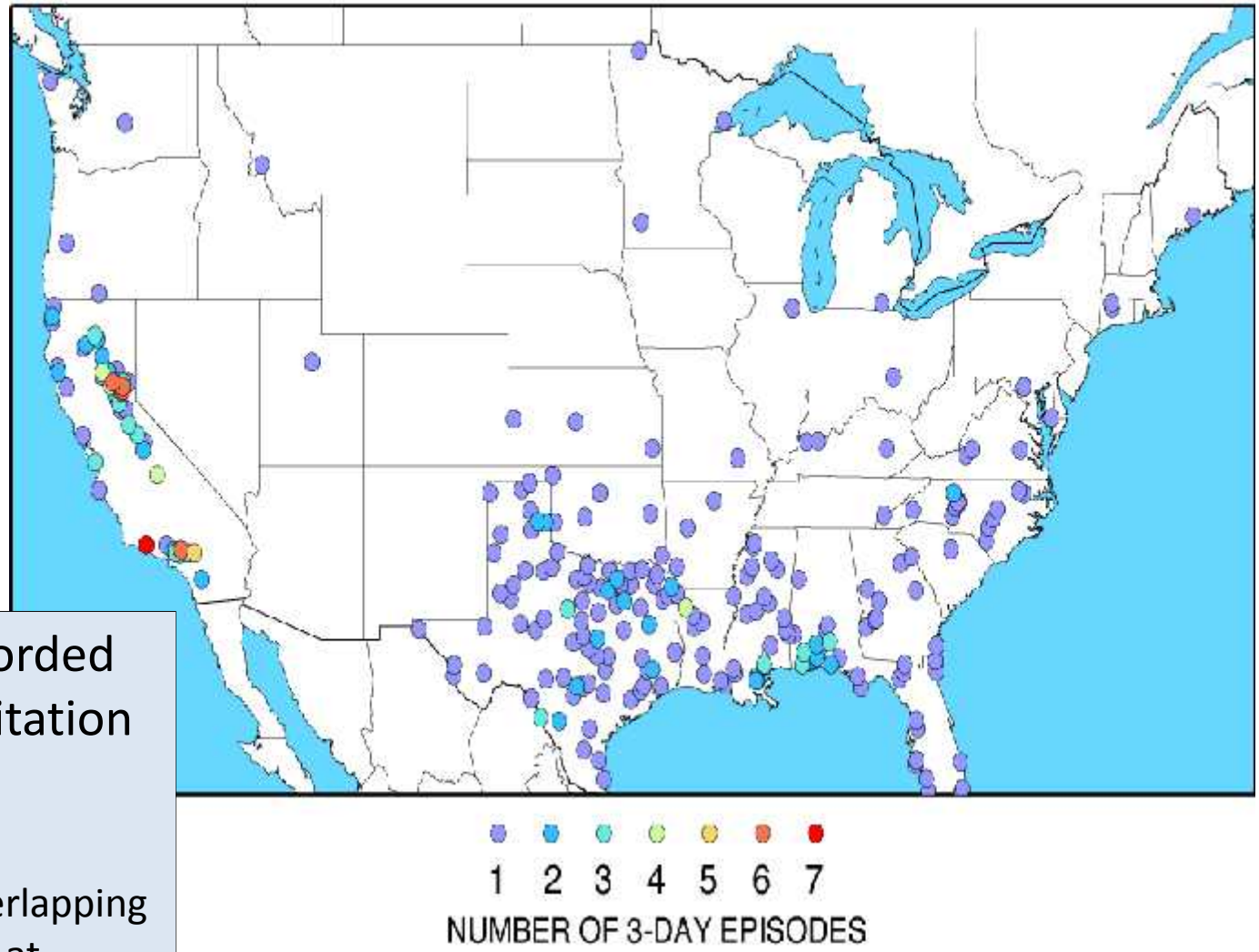
Southern California Coast area average shown here from Western Regional Climate Center
)



- Annual precipitation ranges from ~33% to 280% of average
- Intermittant very wet and very dry years
- Multi-year wet and dry spellls

High variability of weather and short term climate will continue

California records some of Nation's heaviest 3-day rainfall



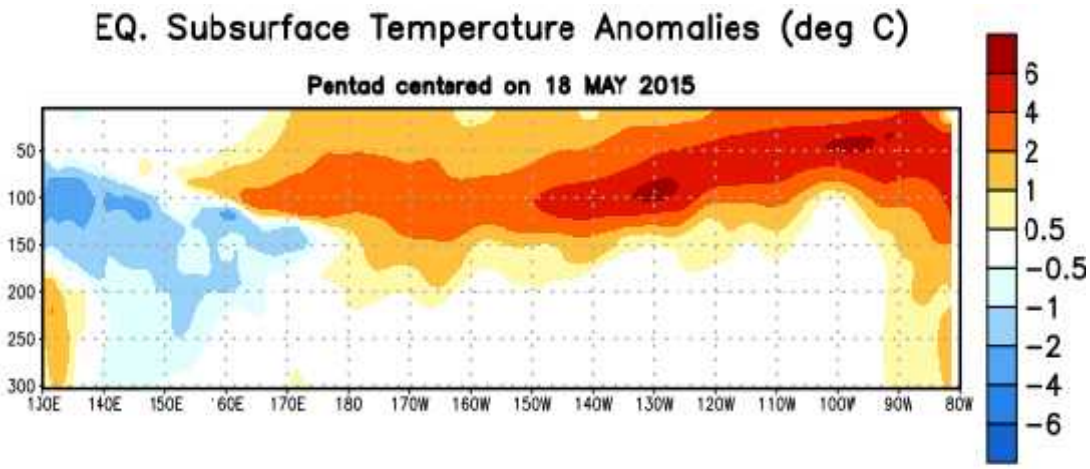
Locations that have recorded the highest 3-day precipitation amounts

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

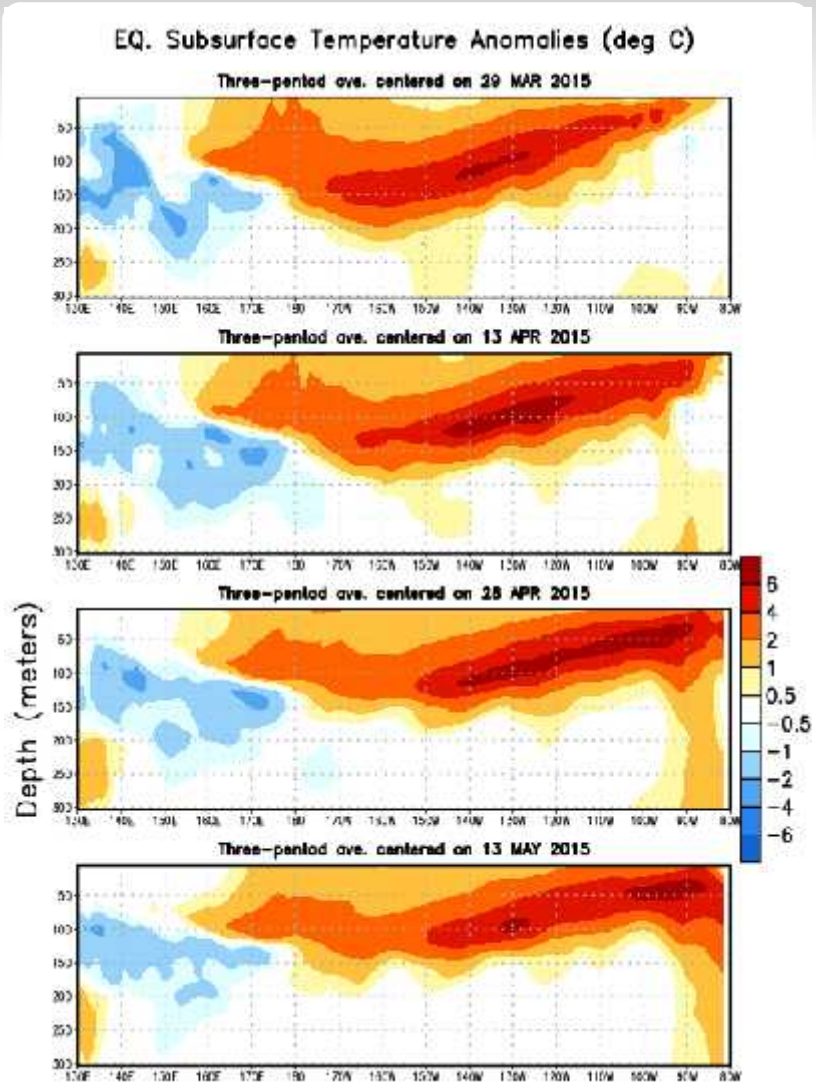
Mike Dettinger USGS/SIO

Sub-Surface Temperature Departures in the Equatorial Pacific

During the last two months, positive subsurface temperature anomalies were observed across most of the equatorial Pacific

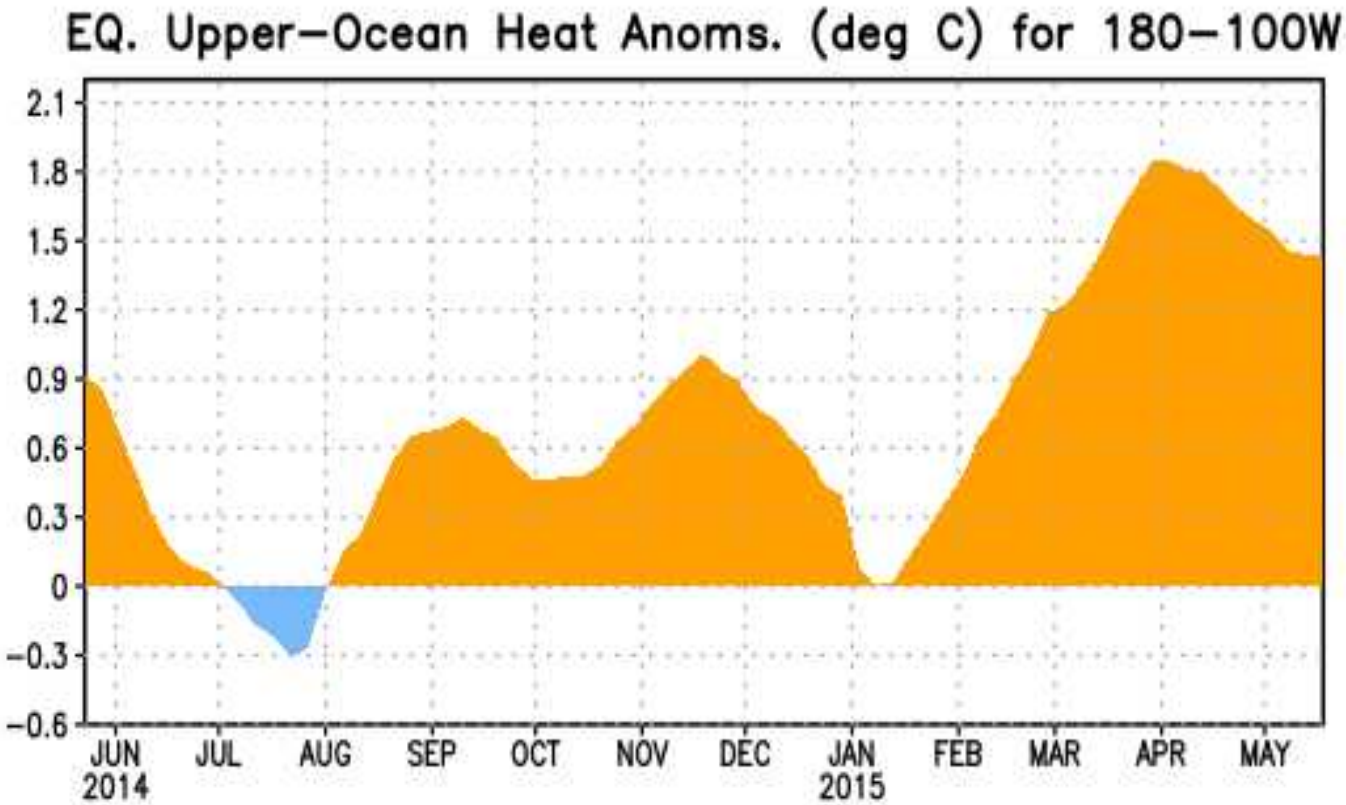


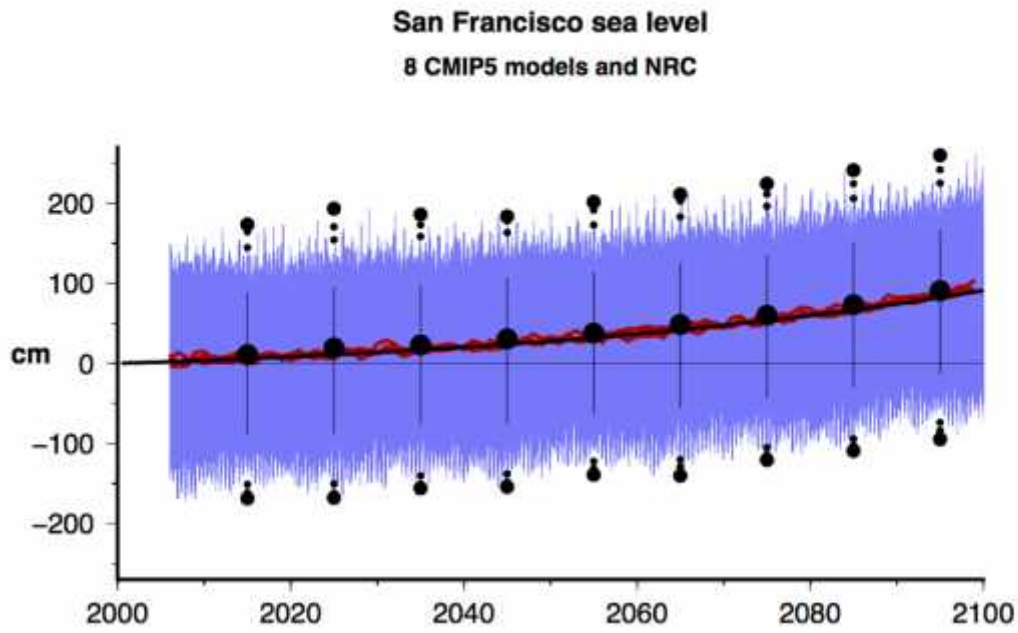
Most recent pentad analysis



Central and Eastern Pacific Upper-Ocean (0-300 m) Weekly Average Temperature Anomalies

Subsurface temperature anomalies increased from mid-October to mid-November 2014 before decreasing to near zero in early January 2015. From January to March, temperatures anomalies grew significantly. During April-early May, the positive anomalies decreased.

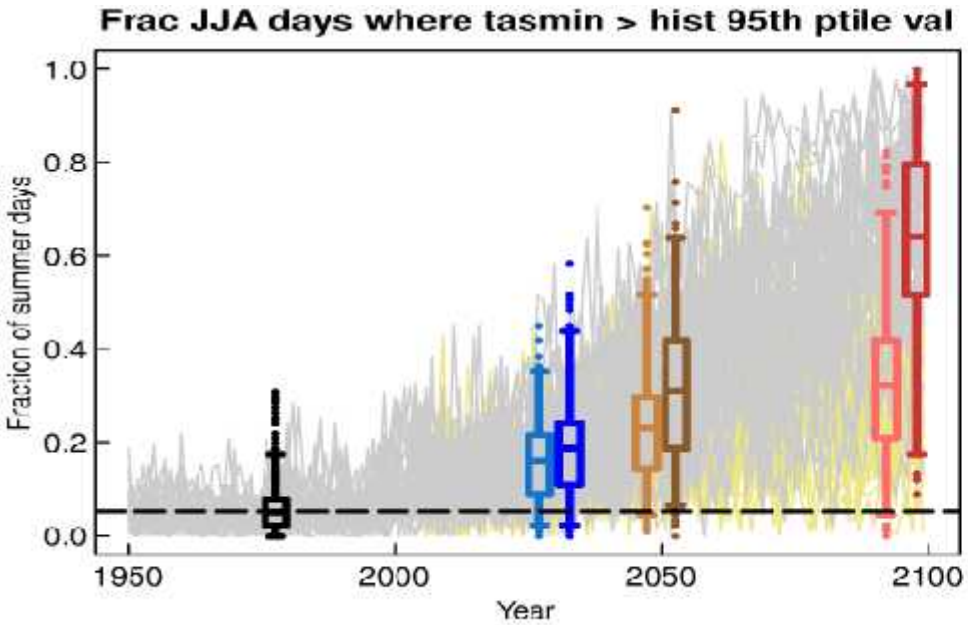




San Francisco sea level projection:

- Thick black line shows the NRC committee (mid-level) projection (annual average)
- Thick red lines show 8 RCP8.5 CMIP5 projections (annual average)
- Blue lines (background cloud) show 8 RCP8.5 CMIP5 projections based on hourly sea level model (15; maximum and minimum value for each month)
- Black circles show decadal (centered) values from 8 RCP8.5 projections (median, highest/lowest, 10th highest/lowest and 100th highest/lowest)
- All changes are relative to a 0cm mean sea level on January 1, 2000

8 CMIP5 RCP8.5 models:
1) ACCESS1-0; 2) CanESM2; 3) CMCC-CMS; 4) CNRM-CM5;
5) GFDL-CM3; 6) HadGEM2-CC; 7) HadGEM2-ES; 8) MIROC5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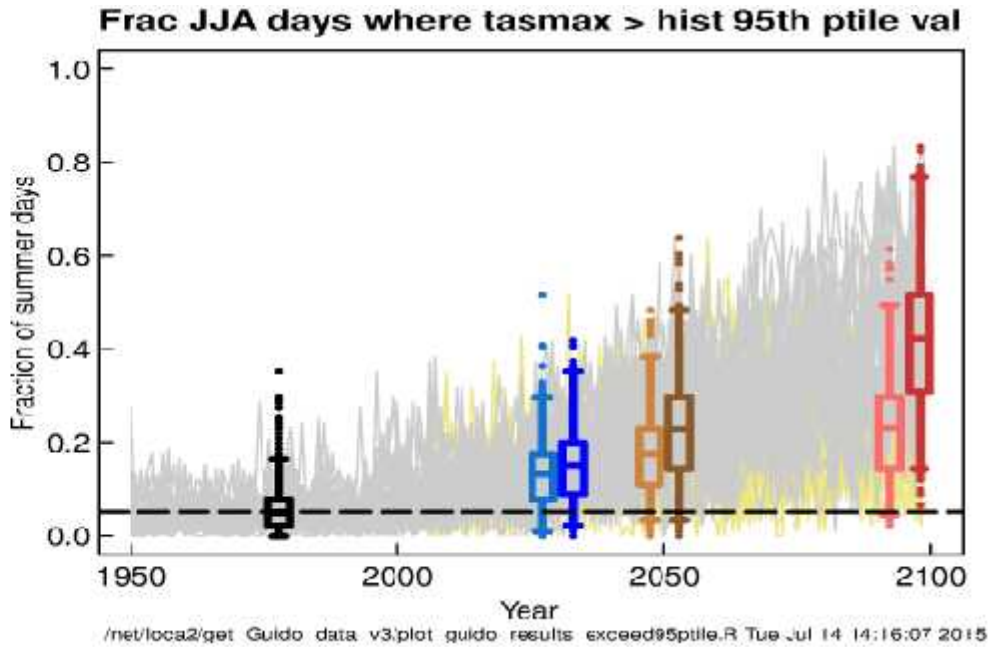
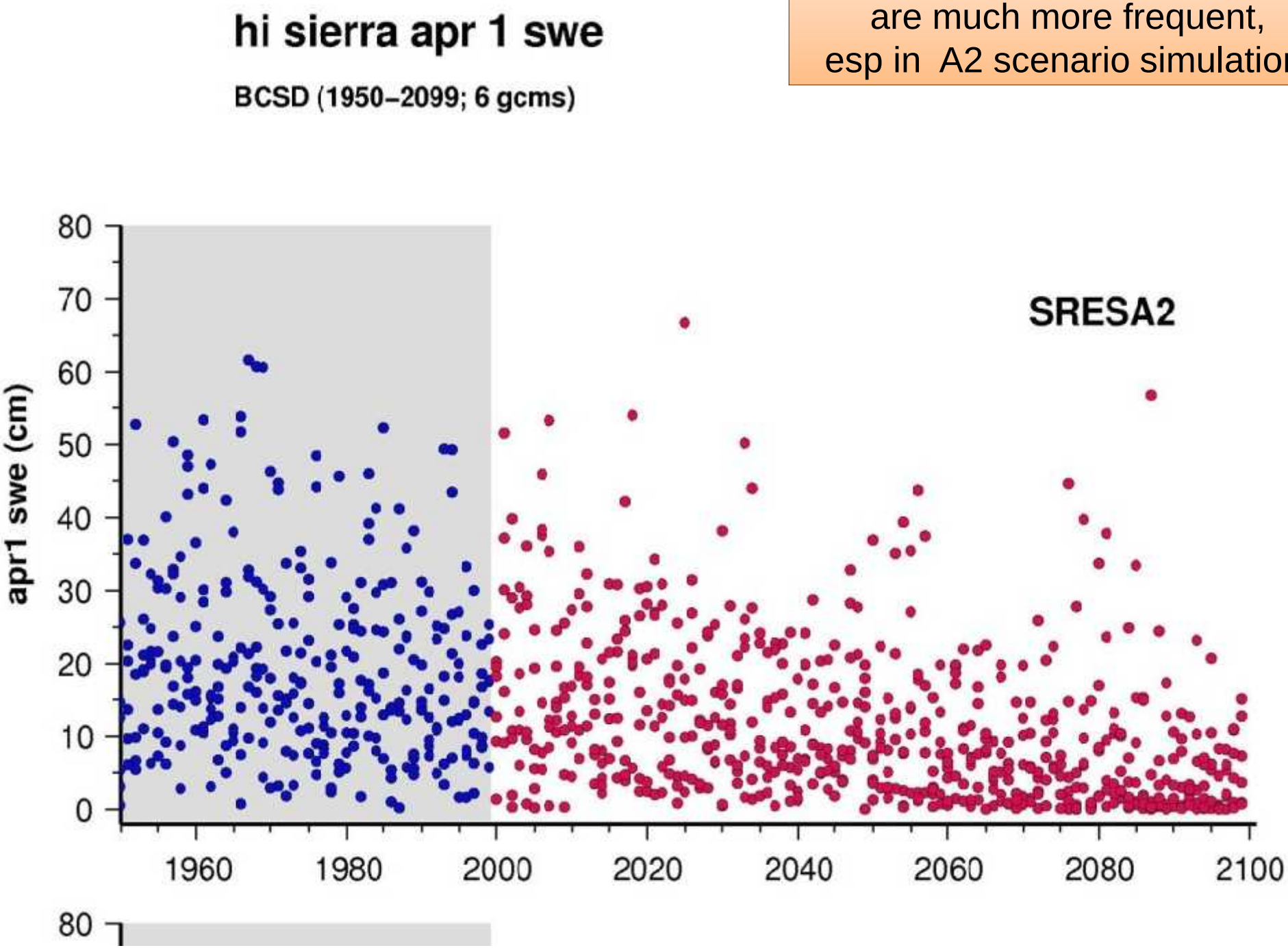
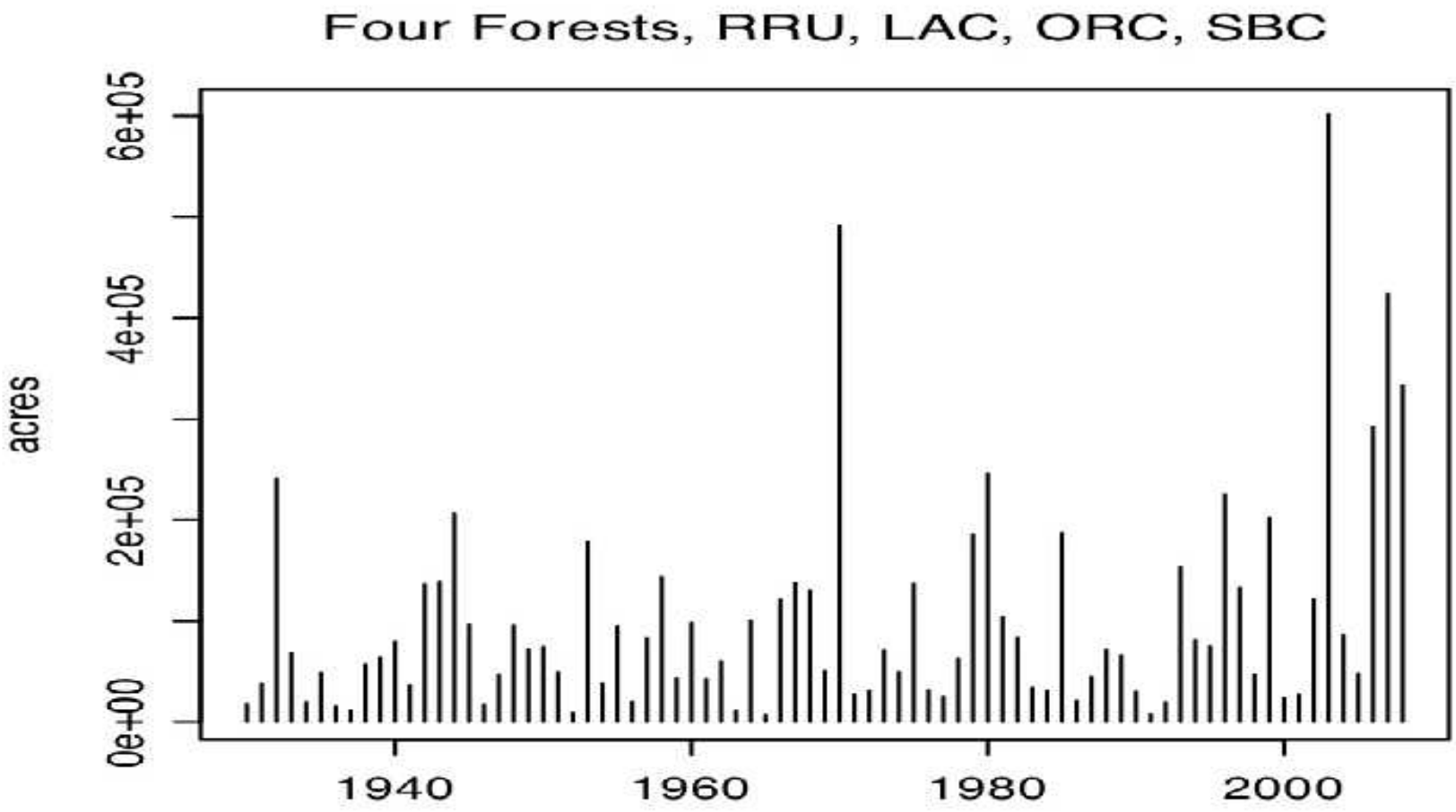

Frac JJA days where tasmax > hist 95th ptile val
Fraction of summer days
1.0
0.8
0.6
0.4
0.2
0.0
1950
2000
2050
2100
Year
/net/loca2/get Guido data v3/plot guido results exceed95ptile.R Tue Jul 14 14:16:07 2015

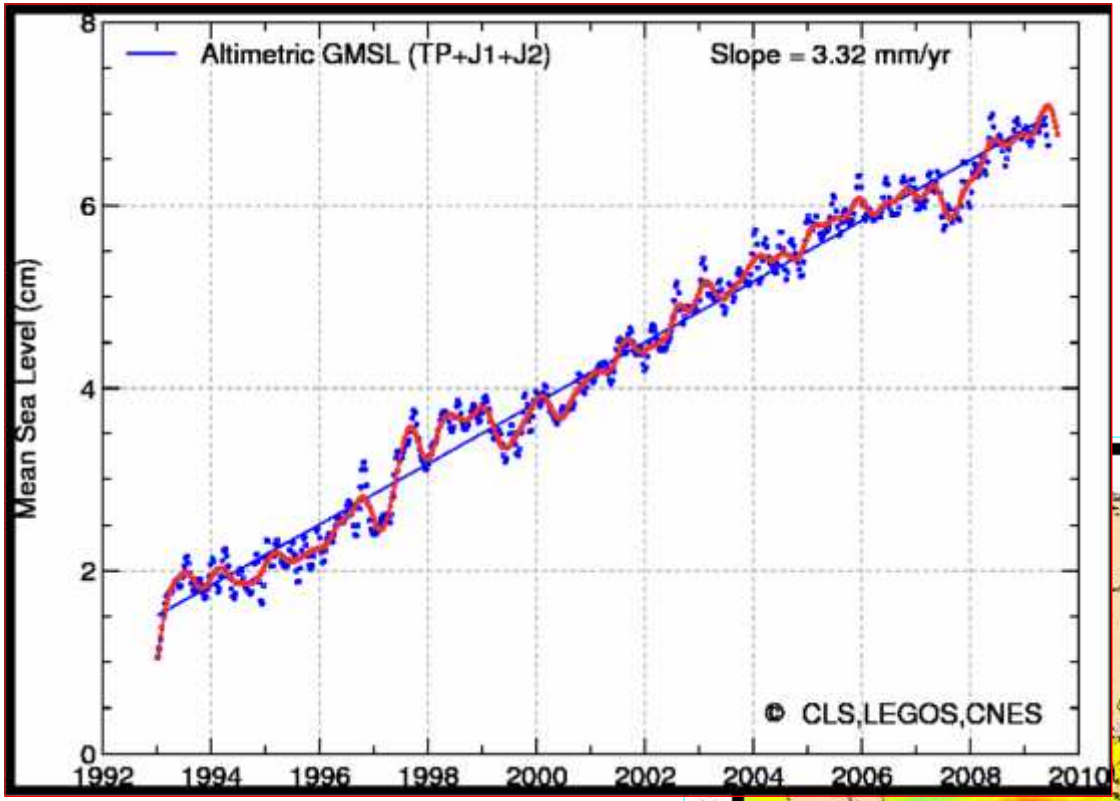
by 2050, years with minimal Sierra Nevada spring SWE are much more frequent, esp in A2 scenario simulations



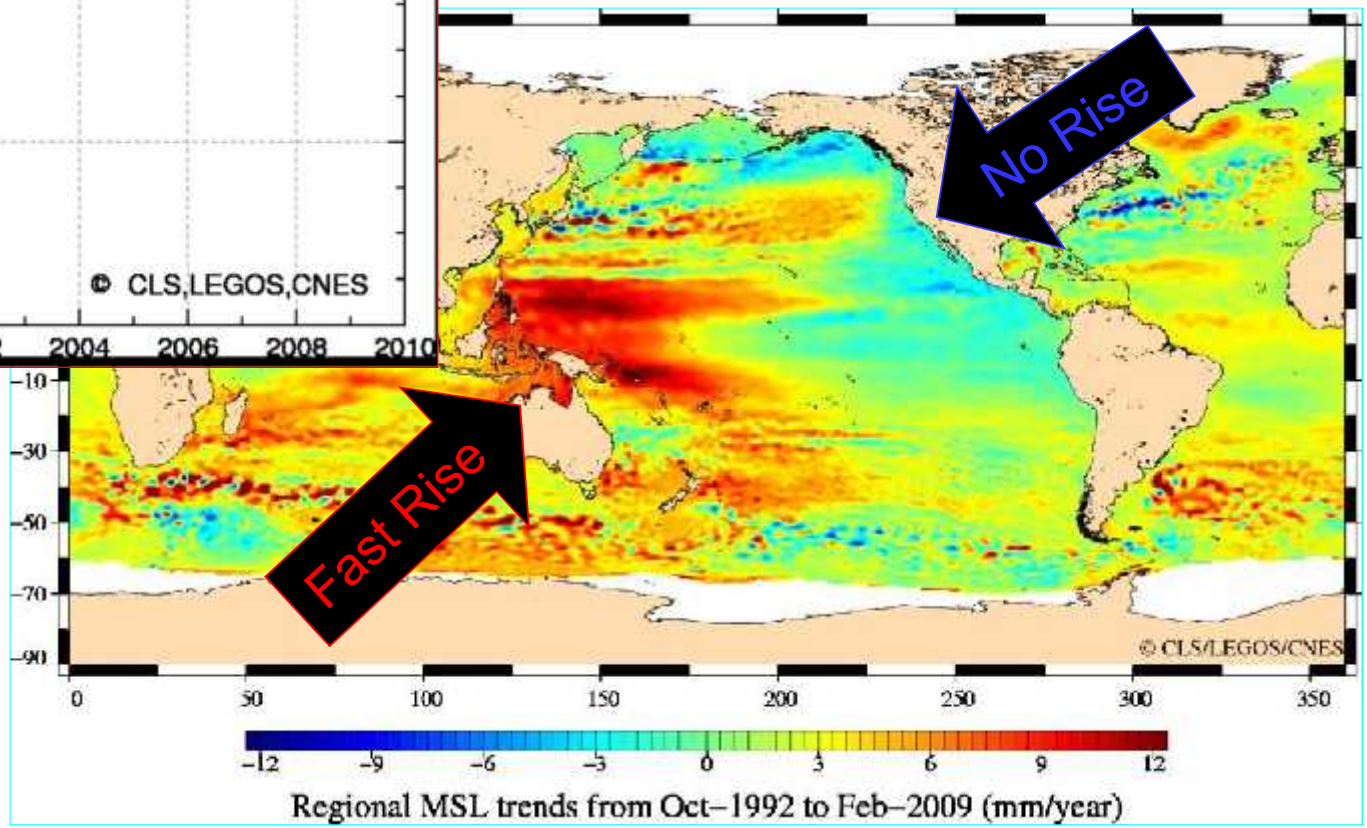
Increased SoCal fires since 2000--
a temporary rise or a trend?



The Satellite Data 1992-2009



Global MSL not evenly distributed



Summary

California has a dry, volatile climate. Southern California's water supply vulnerable to climate changes and weather extremes.

Warming is already underway and more to come +2ºF by 2050. Model projections suggest warming may be intensified in summer, especially in interior areas.

Recent IPCC climate model projections for California precipitation are scattered, but *several* show significant drying.

Hydrological model simulations indicate these drying trends, if they were to occur, would be more accentuated in runoff and soil moisture.

Sea level rise will likely occur at an increasing rate

Frank Gehrke,
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