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***and US Geological Survey***

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***More info:***

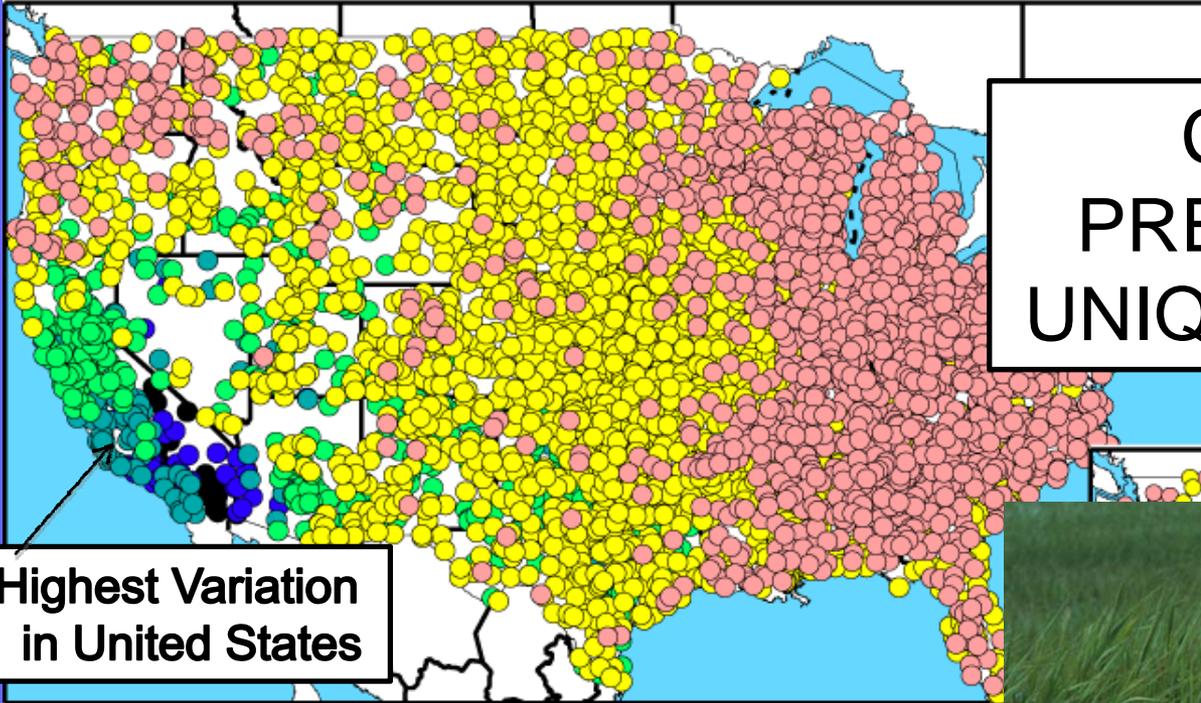
**<http://meteora.ucsd.edu/CAP/>**

California is known as a climate  
where not much happens

*but observations say otherwise*

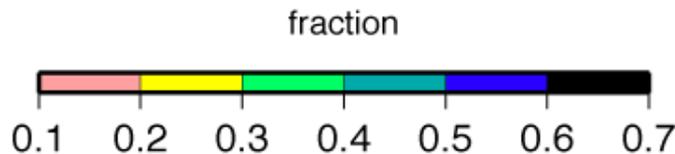
*and climate change projections  
indicate some extremes will grow*

a) COEFFICIENTS OF VARIATION OF  
TOTAL PRECIPITATION, WY 1951-2008

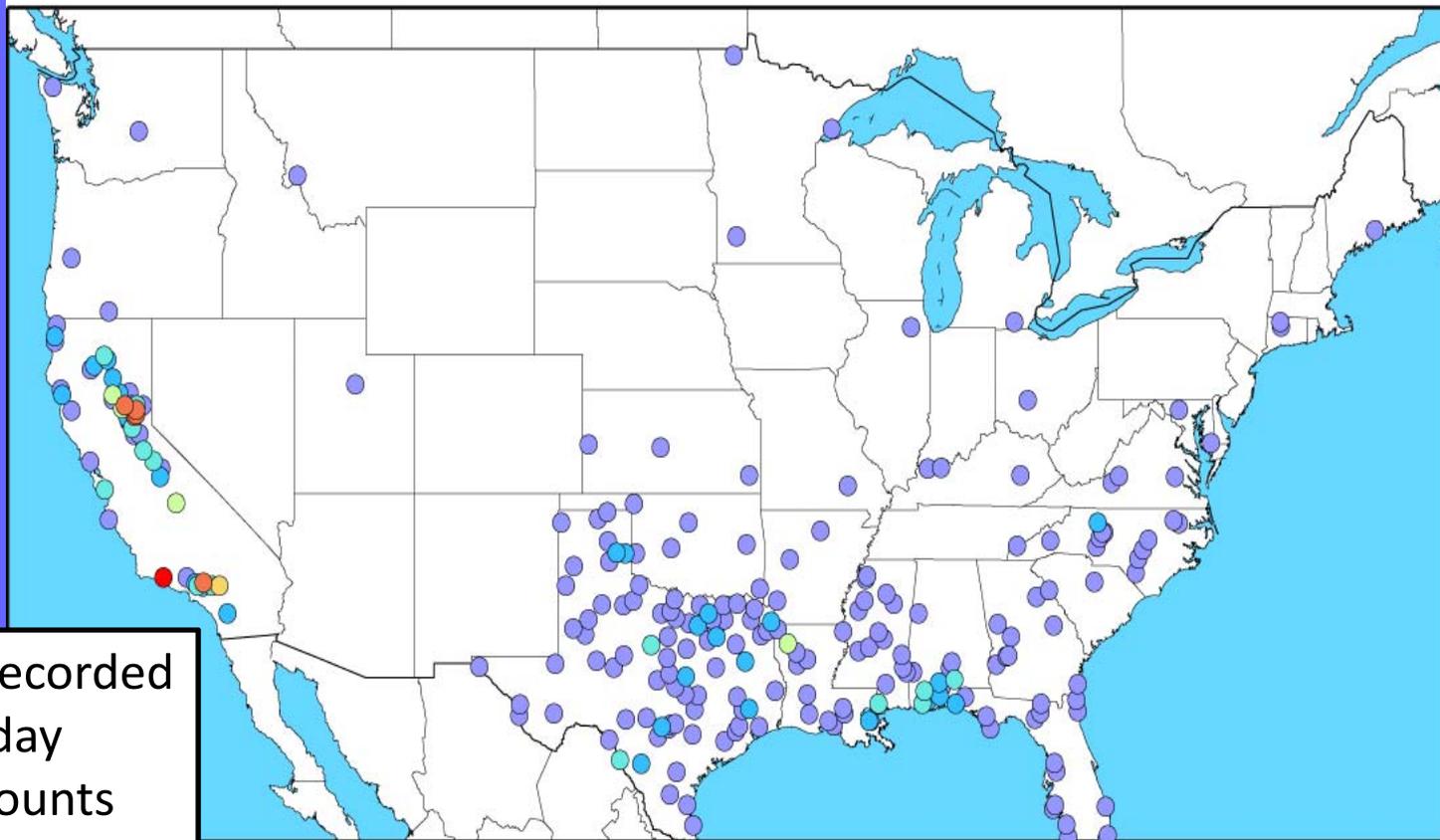


CALIFORNIA  
PRECIPITATION IS  
UNIQUELY VARIABLE

Highest Variation  
in United States



# High variability of weather and short term climate will continue

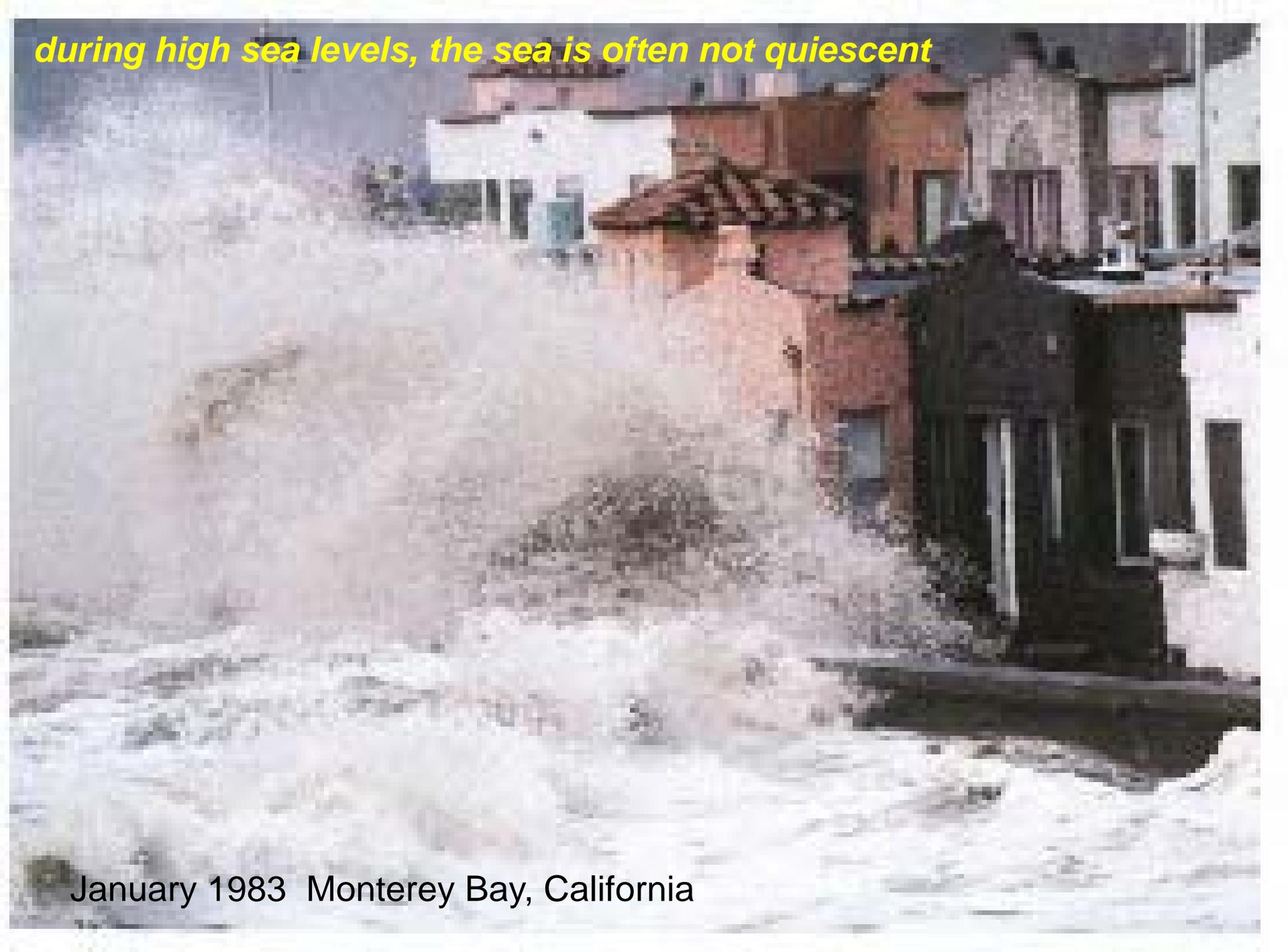


Stations that have recorded the highest 3-day precipitation amounts

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

1 2 3 4 5 6 7  
NUMBER OF 3-DAY EPISODES

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



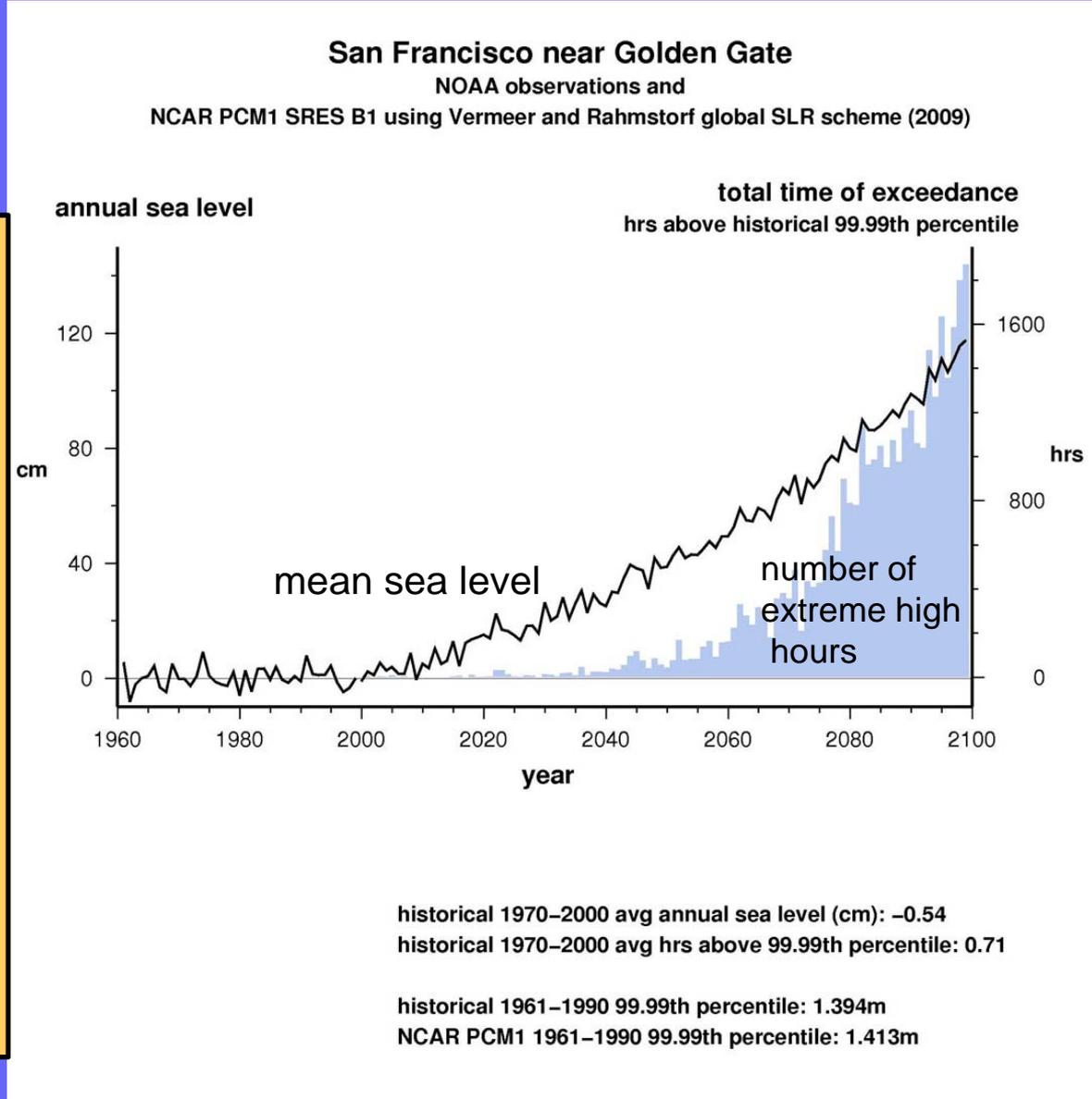
January 1983 Monterey Bay, California

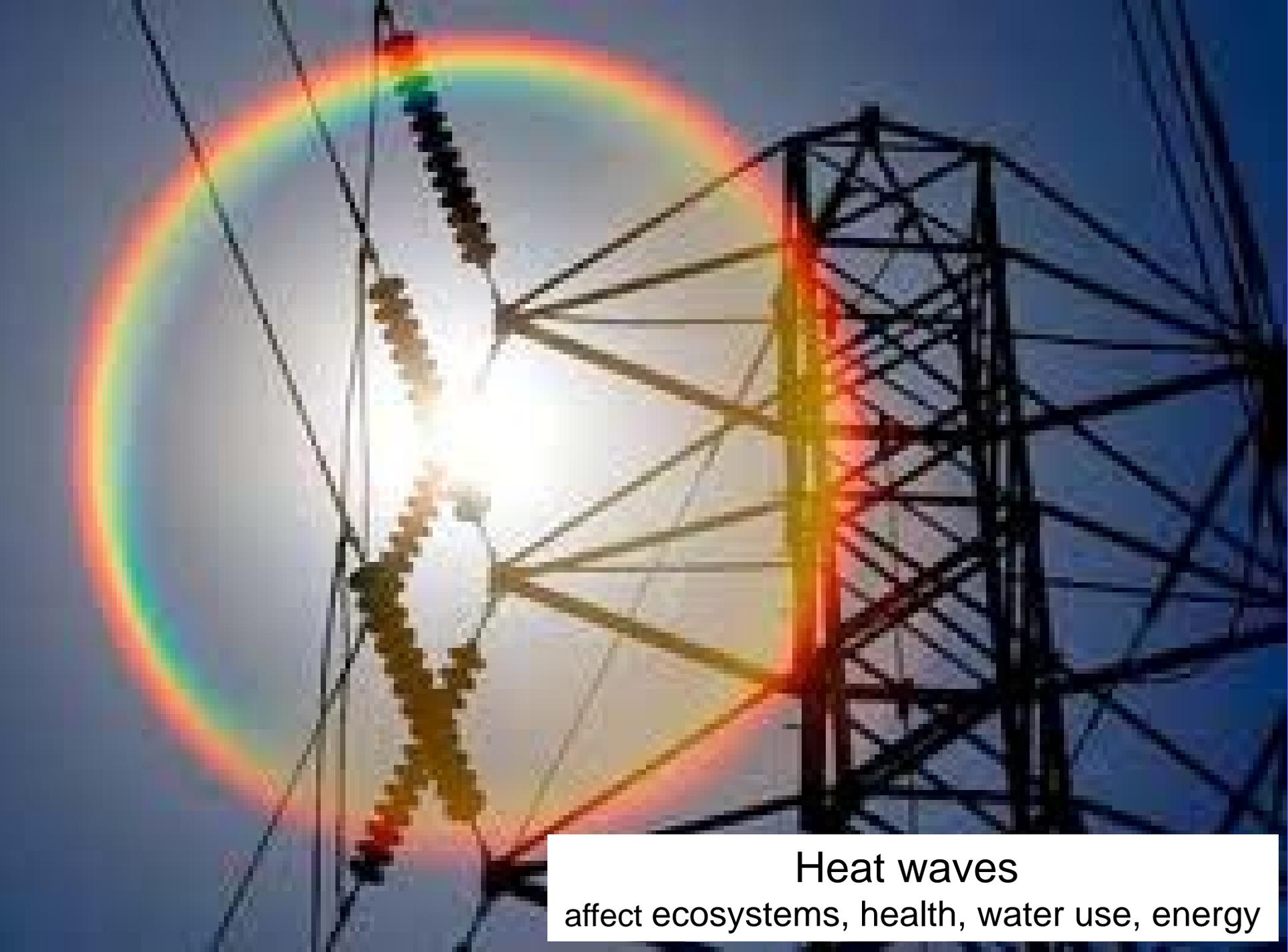
# The *pace* of climate change is projected to be rapid

## 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 21<sup>st</sup> Century and becomes commonplace by end of 21<sup>st</sup> Century.

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

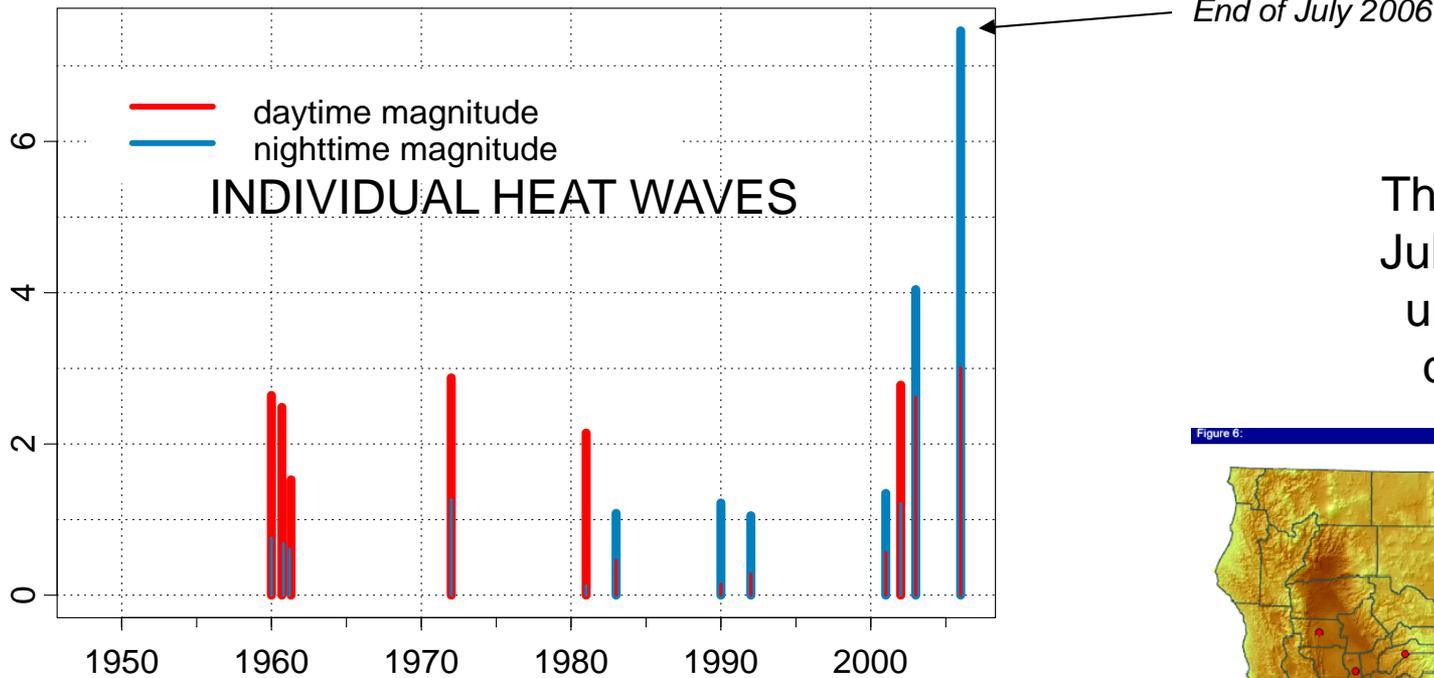




## Heat waves

affect ecosystems, health, water use, energy

# California Heat Waves might be Changing!



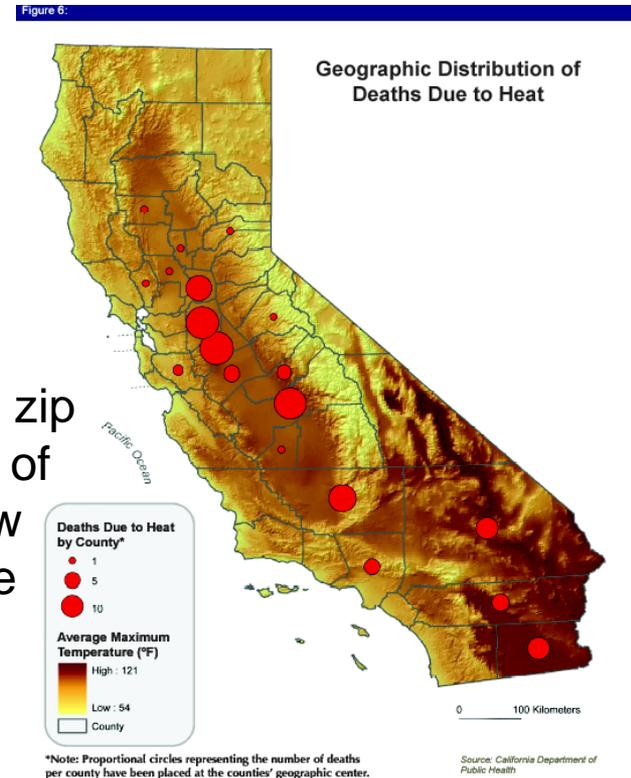
The heat wave of July 2006 was an unprecedented deadly event.

California heat wave activity increased during last decade

Specifically, **nighttime-accentuated** heat waves are on the rise...

99% of cases lived in zip codes where > 50% of residents live below Poverty Guide Line

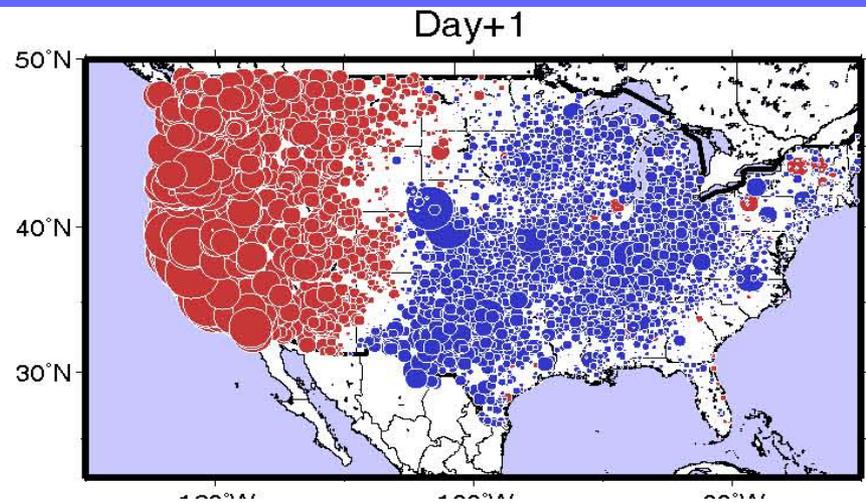
**~600 total excess deaths**



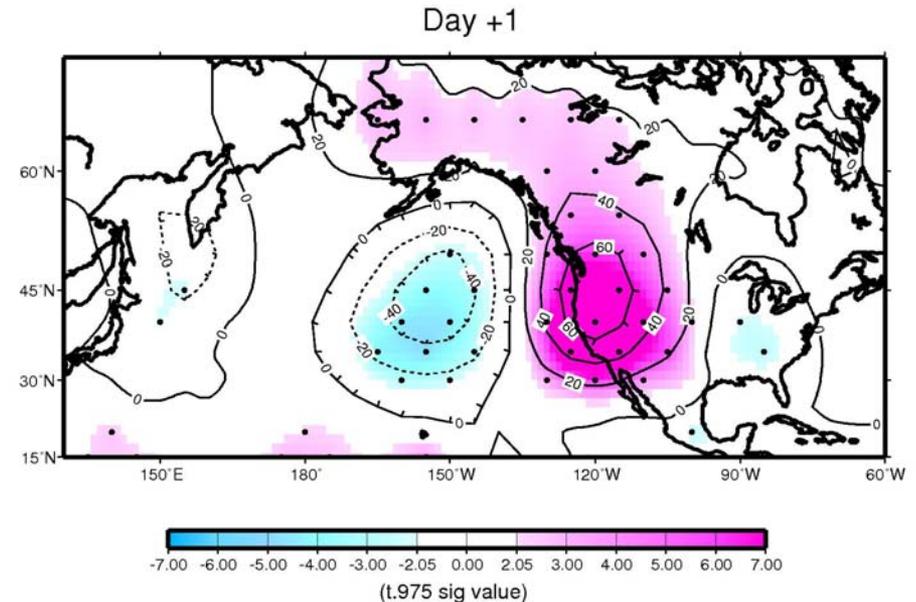
# Persistent heat waves have *broad* footprints

daily afternoon temperature (Tmax) anomalies and 700mb height anomalies

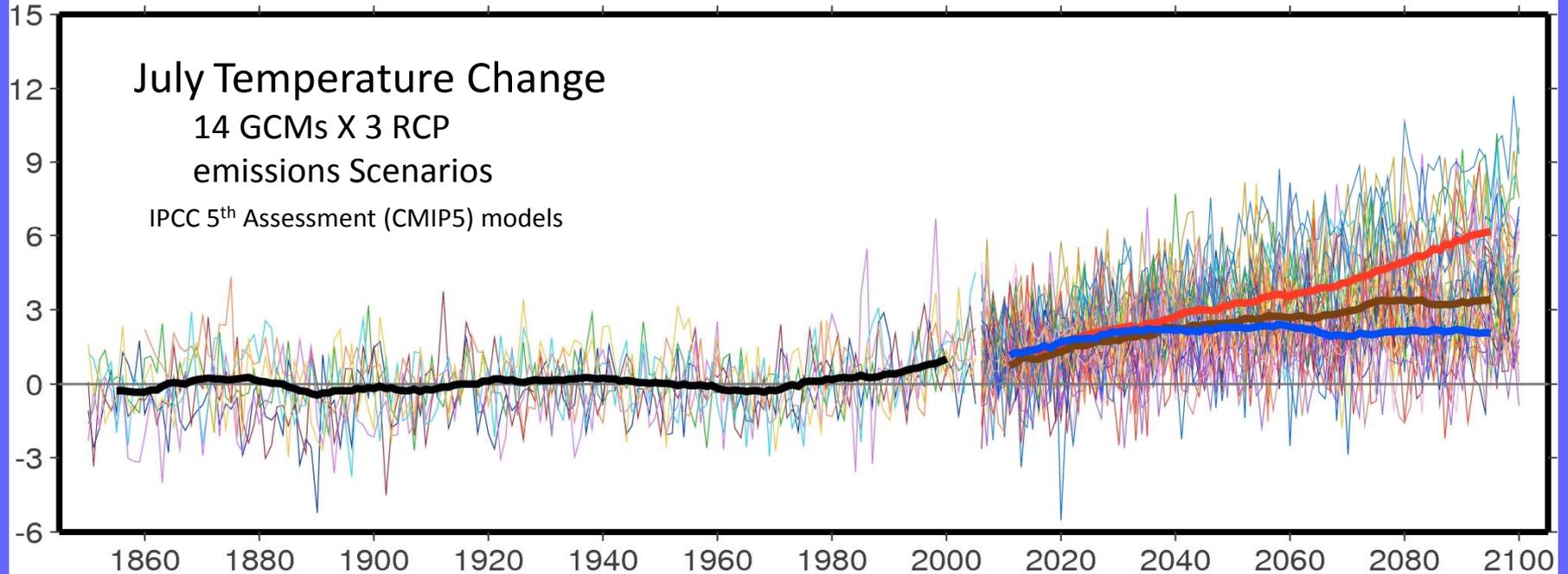
from 31 historical 3 day and longer heat waves (1948-2005)



Composite 700ht Anoms, 31 Hi Tmax dates lasting  $\geq 3$  days (days when  $\geq 9$  Sasha stns have hot days by 99%ile criteria)



# Projected Climate Warming is substantial especially during summer in interior locations



## Climate Warming:

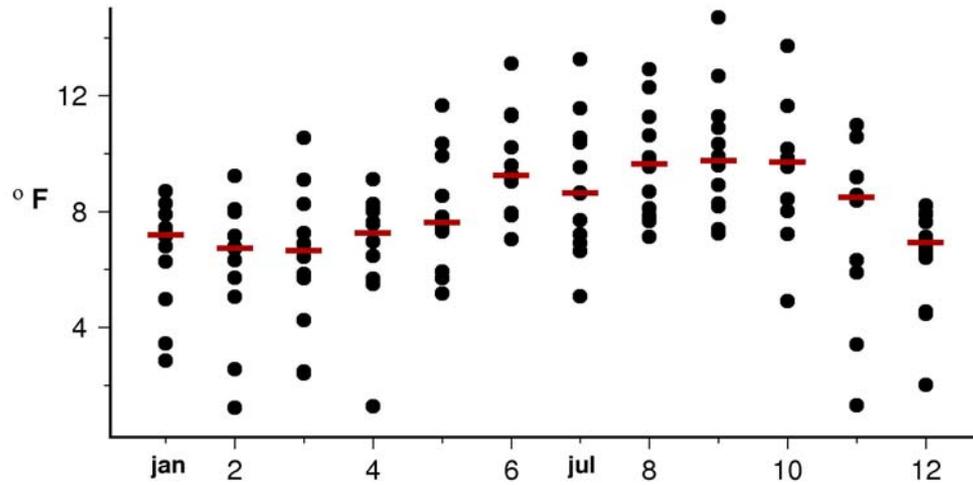
*summer warming higher than winter*

*interior warming greater than coastal/marine*

*nighttime warming has exceeded daytime warming in last few decades*

*heat wave incidence projected to become more frequent, intense, durable*

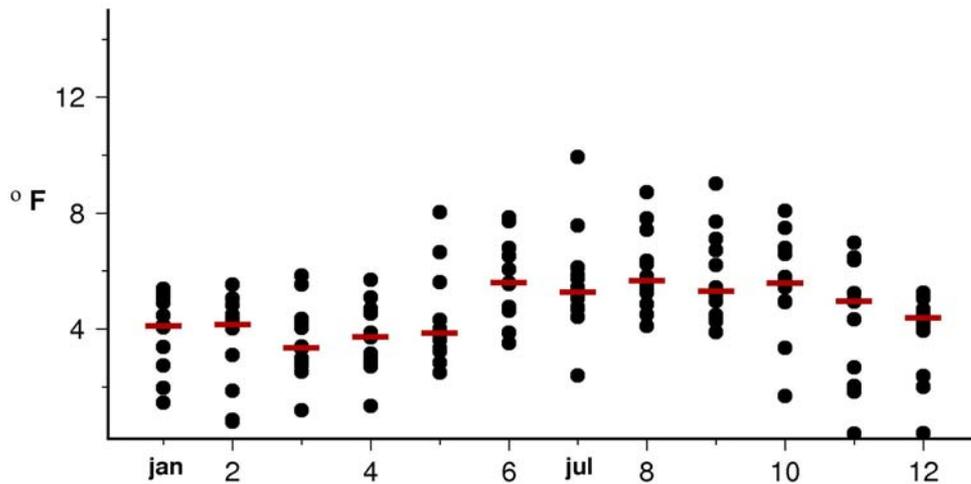
tmax mon anom 2070–2099 minus 1970–1999 RCP8.5  
Sacramento region 12 downscaled (bcc) GCMs



Projected Warming is intensified in summer

12 downscaled AR5 GCMs  
RCP 4.5 and RCP 8.5 emissions scenarios

tmax mon anom 2070–2099 minus 1970–1999 RCP4.5  
Sacramento region 12 downscaled (bcc) GCMs



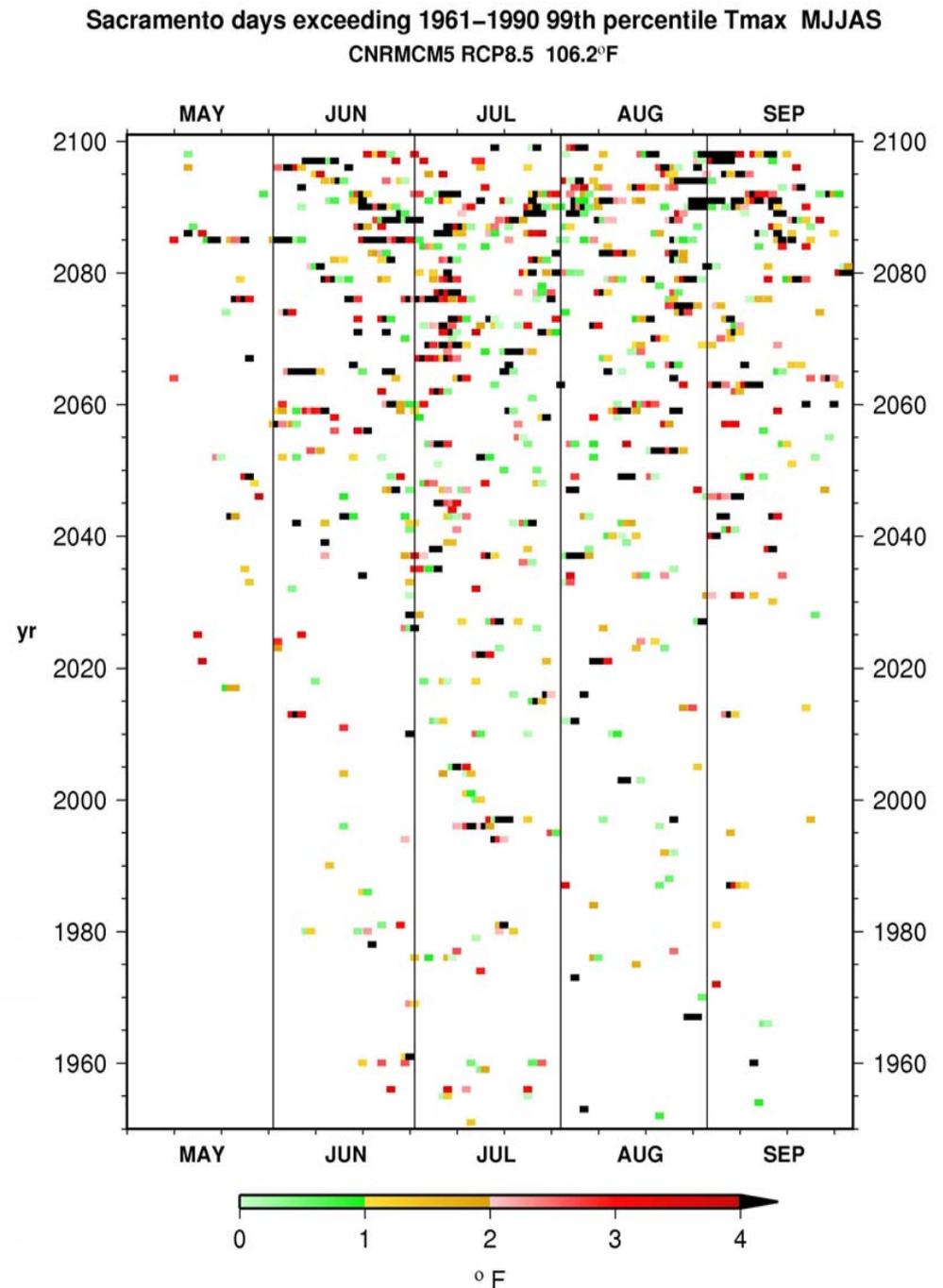
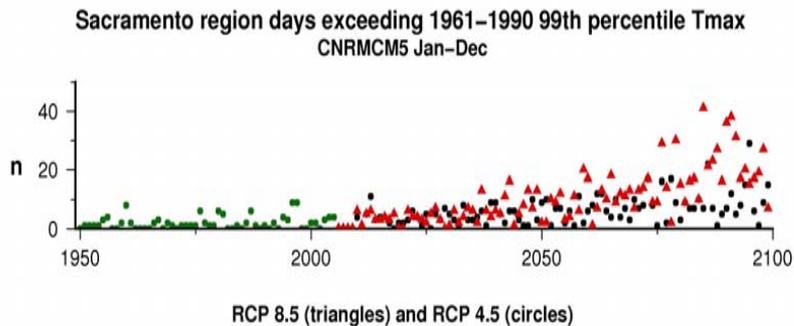
small horizontal bar indicates median anom

# Projected Growth of Heat Wave Occurrence

Over 21<sup>st</sup> Century, trends toward:  
Increased frequency,  
higher intensity,  
longer duration

And, trend toward  
earlier start and later end  
to heat wave season.

from BCCA downscaled CNRM RCP8.5 simulation



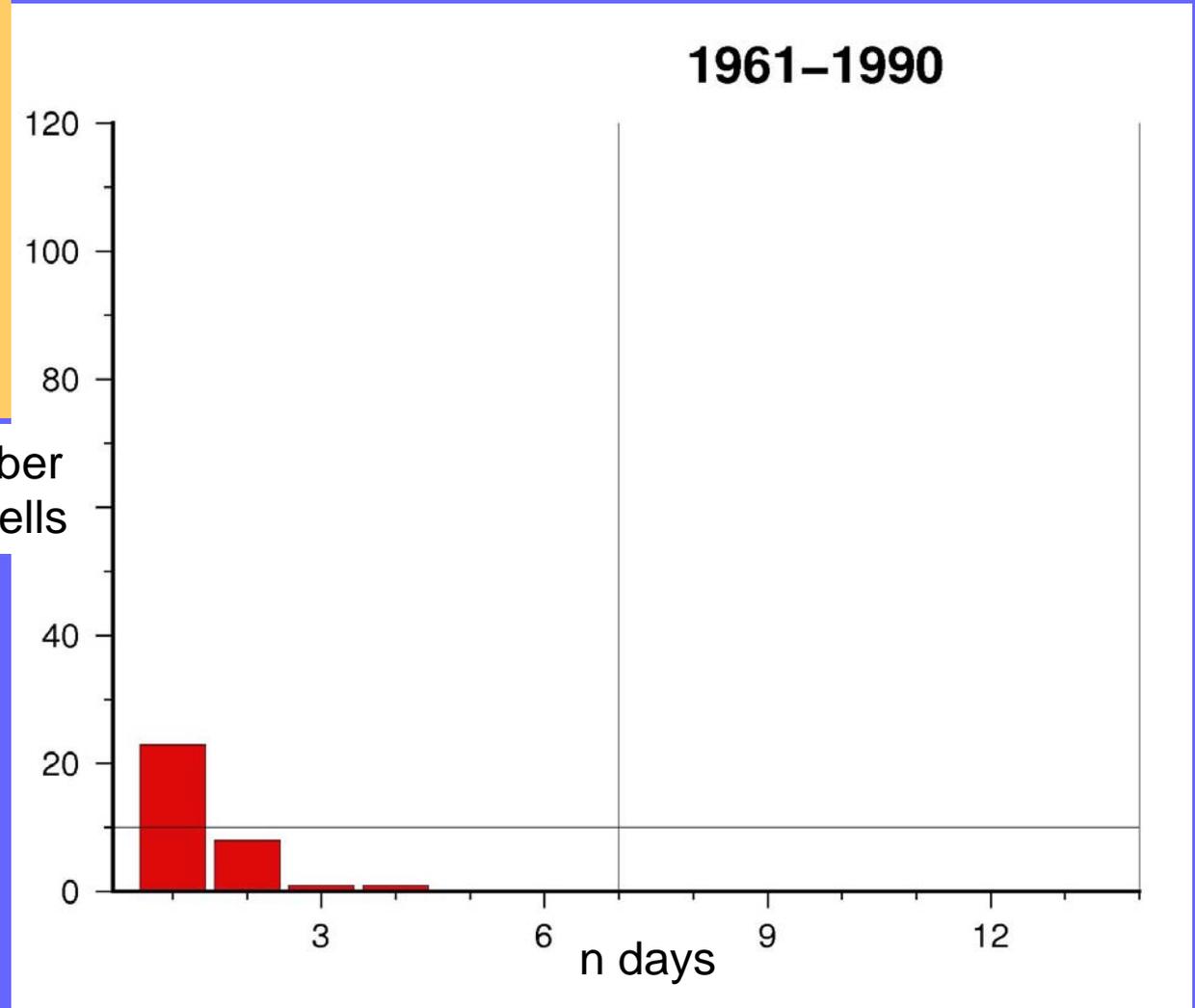
# Projected Heat spell census, Sacramento high sensitivity model, higher GHG emissions scenario

## Heat spell length Sacramento

Number of heat spells (y) of  
Length in days (x) when  
Maximum daily temperature  
Exceeds the 99.9<sup>th</sup> percentile  
Tmax 1961-1990 (102 °F)

From BCCA CMRM5 RCP8.5

Number  
of spells

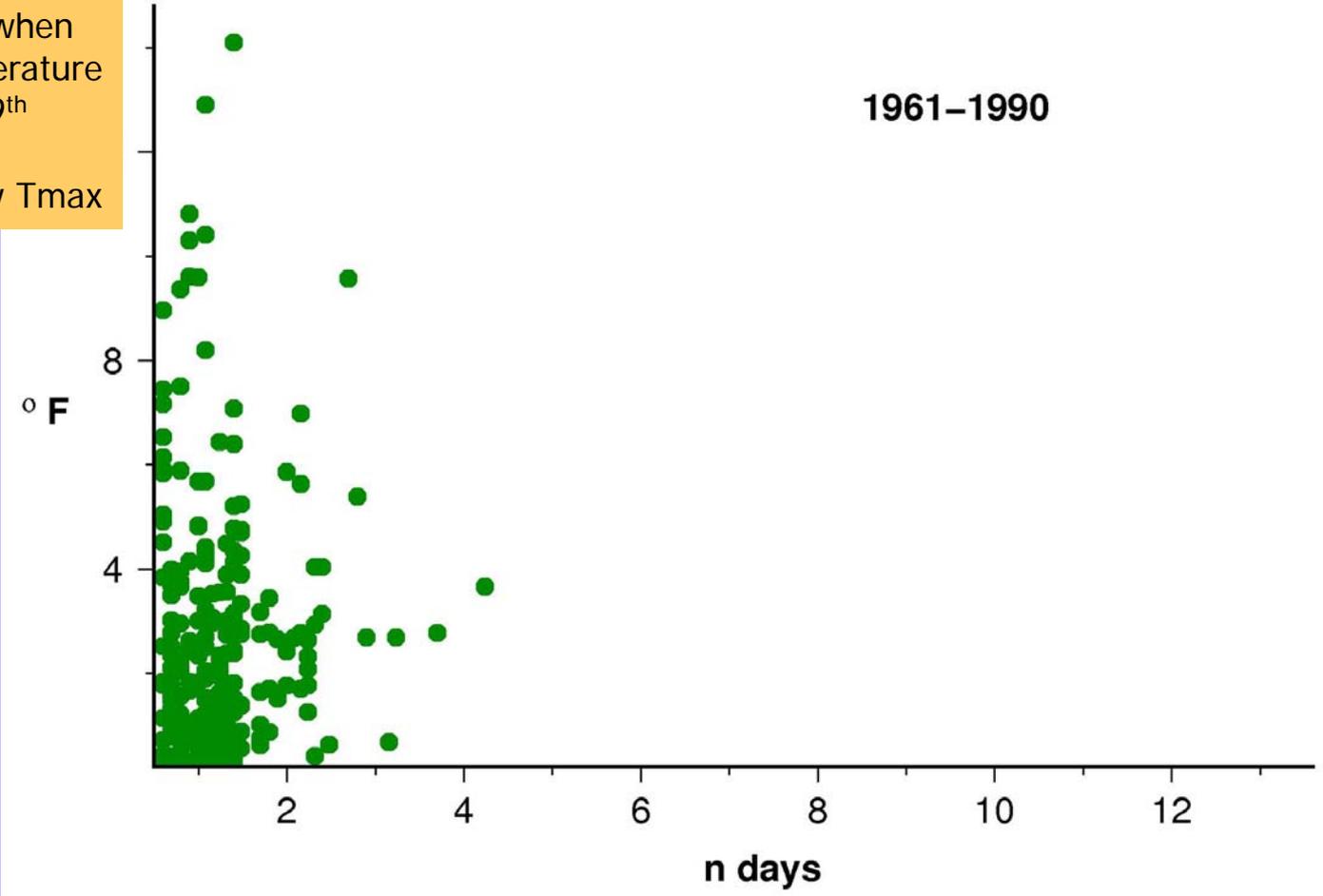


Length of heat spell

Heat spells in Sacramento  
by duration and intensity  
from 11 climate models  
Sacramento

Number of heat spells (y)  
of  
Length in days (x) when  
Maximum daily temperature  
Exceeds the 99.9<sup>th</sup>  
percentile  
Of 1961-1990 for July Tmax  
(40 °C)

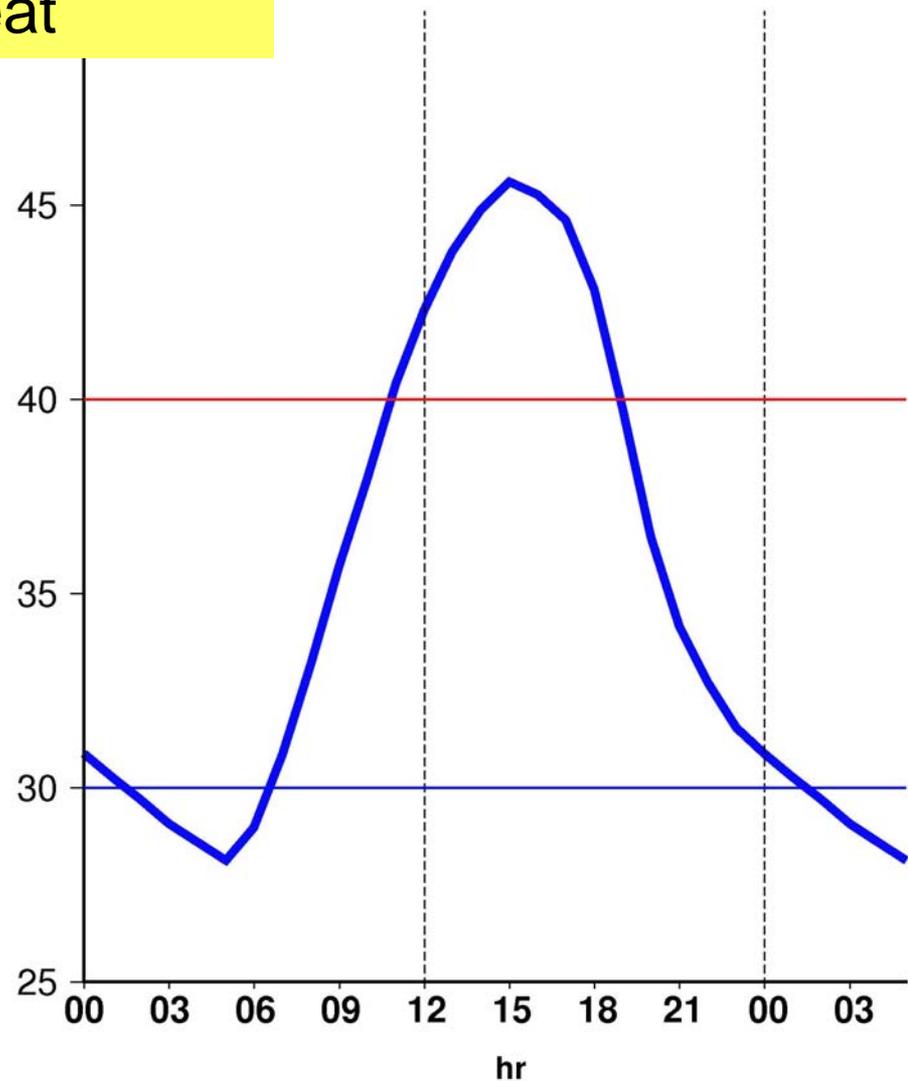
**Sacramento region heat spell duration and strength**  
ndays exceeding 1961–1990 99th ptile tmax  
avg temp above 99th ptile tmax  
11 downscaled (bcc) GCMs RCP 8.5



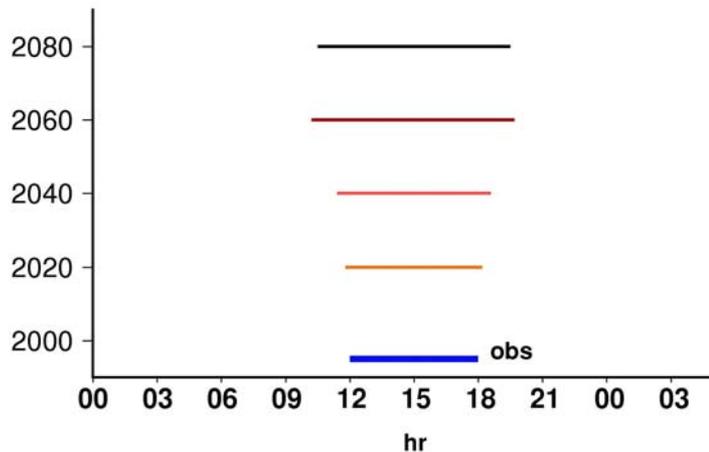
# Projected Decadal Extreme Hot Days more hours of extreme heat

model and observed hourly temp shown is an extreme Tmax during a given decade with climatological diurnal cycle attached.

Sacramento daily maximum temperature  
Model is CNRM5 BCCA downscaled  
heavy blue line is observed Tmax (45.6 °C = 114 °F)



## Hours of Day above 40°C (104°F)



*in conclusion:*

The Environment we plan for will likely not be accurately informed by 50-100 years of experience

Anthropogenic, global climate change is already occurring

Projected future warming could be moderate (less than 3C) or very large (3-6C) depending on greenhouse gas emissions

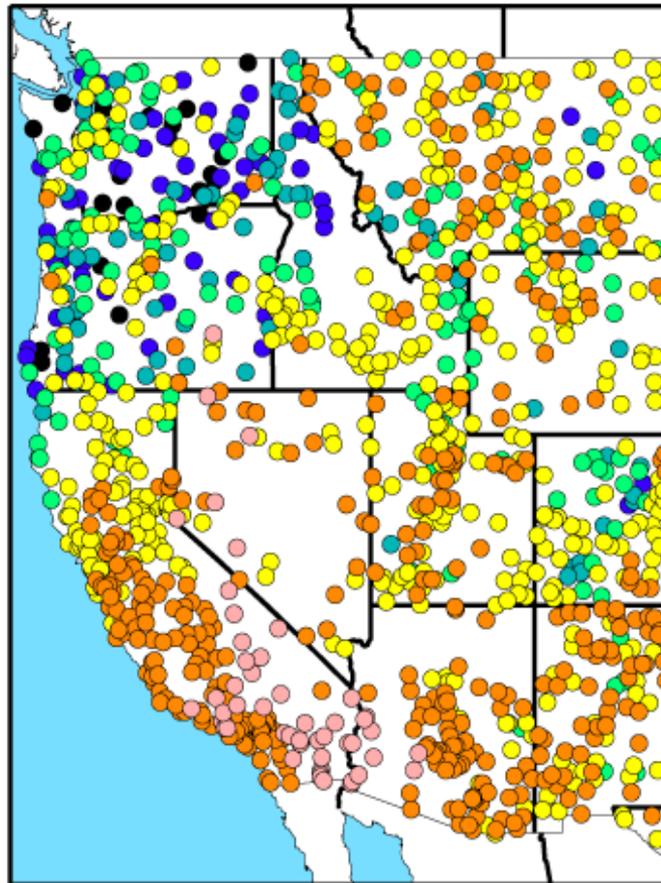
Summer warming may be greater than in winter. .

Earlier, longer, more intense summers expected.

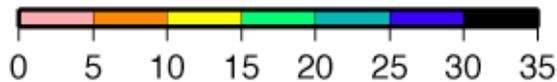
Climate warming will likely be most remarkable when coupled with natural fluctuations, such as heat waves.

Heat Wave frequency, intensity, duration increases and season lengthens.

c) AVERAGE NUMBER OF DAYS/YR TO OBTAIN HALF OF TOTAL PRECIPITATION, WY 1951-2008



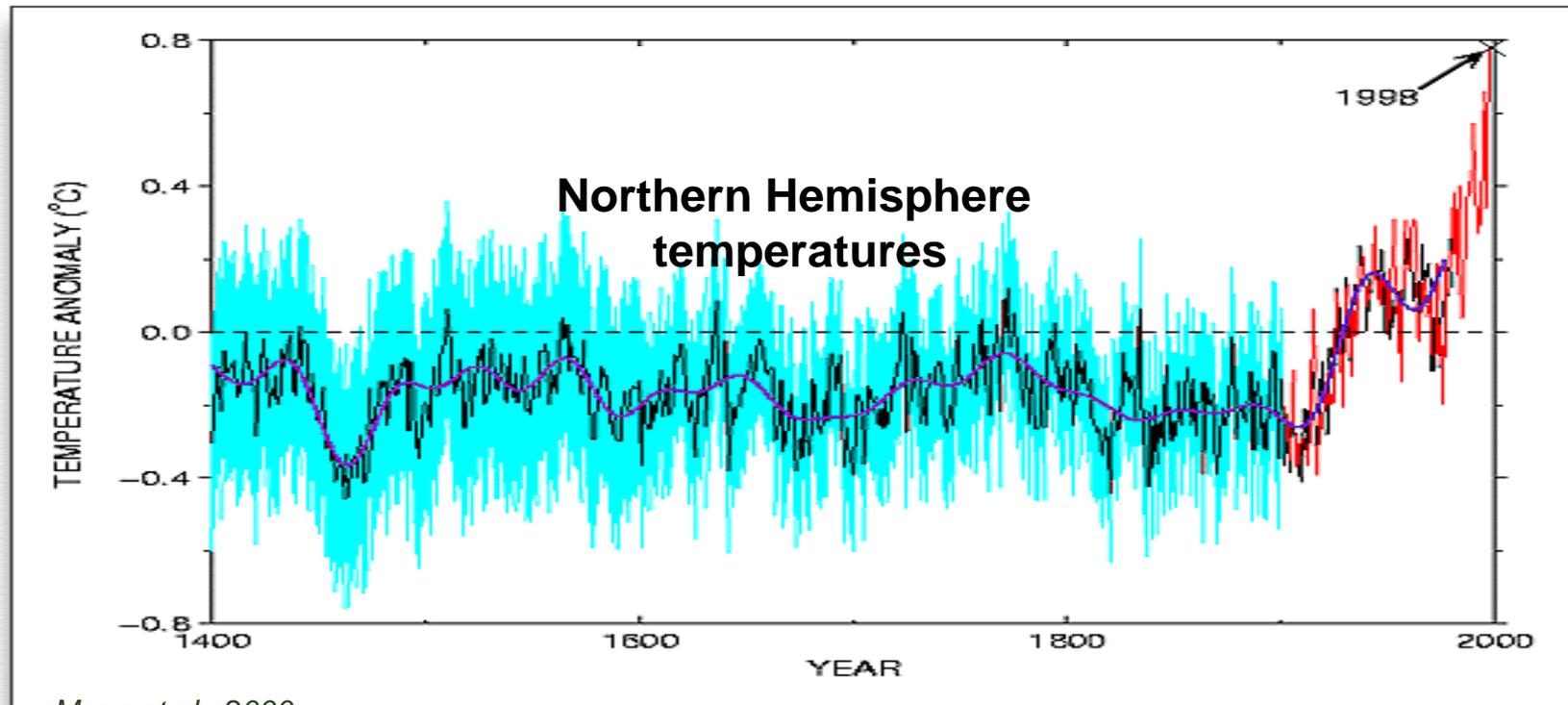
days/year



JUST A FEW  
STORMS EACH  
YEAR ARE THE  
CORE OF  
CALIFORNIA'S  
WATER SUPPLIES



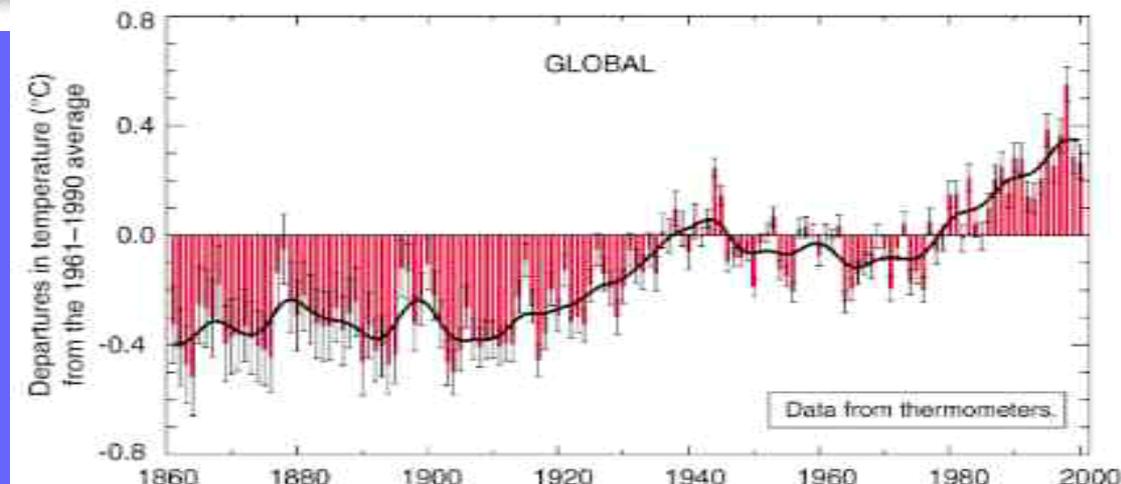
# Observations suggest that global temperatures have *already* risen at a extremely rapid pace.



1990's warmest decade in instrumental record (NASA/NOAA)

1. 1998 warmest year
2. 2002
3. 2003
4. 2004

\*\*2005 2<sup>nd</sup> (or 1<sup>st</sup>) warmest



# LARGE CALIFORNIA HEAT WAVES— regional magnitudes reflecting local intensity, duration, spatial extent

in degree days summed over the region  
for the six greatest **daytime** and six greatest **nighttime** events

